ACJC P1 4
ACJC P1 ANS 31
ACJC P2 58
ACJC P2 ANS 79
ACJC P3 104
ACJC P3 ANS 120
AJC P1 136
AJC P2 165
AJC P2 ANS 184
AJC P3 205
AJC P3 ANS 219
CJC P1 234
CJC P1 ANS 258
CJC P2 285
CJC P2 ANS 307
CJC P3 338
CJC P3 ANS 352
DHS P1 374
DHS P2 403
DHS P2 ANS 425
DHS P3 439
DHS P3 ANS 455
HCI P2 466
HCI P2 ANS 489
HCI P3 500
HCI P3 ANS 514
IJC P1 520
IJC P1 ANS 542
IJC P2 565
IJC P2 ANS 583
IJC P3 603
IJC P3 ANS 619
MI P1 637

MI P1 ANS 667
MI P2 697
MI P2 ANS 725
MI P3 758
MI P3 ANS 779
MJC P1 802
MJC P1 ANS 824
MJC P2 825
MJC P2 ANS 845
MJC P3 866
MJC P3 ANS 878
NJC P1 894
NJC P1 ANS 917
NJC P2 918
NJC P2 ANS 942
NJC P3 970
NJC P3 ANS 981
NYJC P1 1005
NYJC P1 ANS 1032
NYJC P2 1059
NYJC P2 ANS 1081
NYJC P3 1102
NYJC P3 ANS 1114
PJC P1 1134
PJC P1 ANS 1162
PJC P2 1190
PJC P2 ANS 1216
PJC P3 1240
PJC P3 ANS 1258
RI P1 1273
RI P2 1302
RI P3 1323
RVHS P1 1335

RVHS P1 ANS 1360
RVHS P2 1361
RVHS P2 ANS 1384
RVHS P3 1406
RVHS P3 ANS 1422
SAJC P1 1438
SAJC P2 1465
SAJC P3 1484
SRJC P1 ANS 1497
SRJC P1 1526
SRJC P2 1555
SRJC P2 ANS 1569
SRJC P3 1588
SRJC P3 ANS 1606
VJC P1 1629
VJC P2 1655
VJC P2 ANS 1677
VJC P3 1695
VJC P3 ANS 1711
YJC P1 1728
YJC P1 ANS 1749
YJC P2 1775
YJC P3 1830
YJC P3 ANS 1845

ANGLO-CHINESE JUNIOR COLLEGE
Preliminary Examination 2016

BIOLOGY **9648/01**

HIGHER 2 **31 August 2016**

Paper 1 Multiple Choice **1 hour 15 mins**

Additional Material: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, pencil clips, highlighters, glue or correction fluid.
Write your name, centre number and index number on the Answer Sheet provided.

There are **forty** questions in this paper. Answer **all** questions. For each question there are four possible answers, **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate answer sheet.

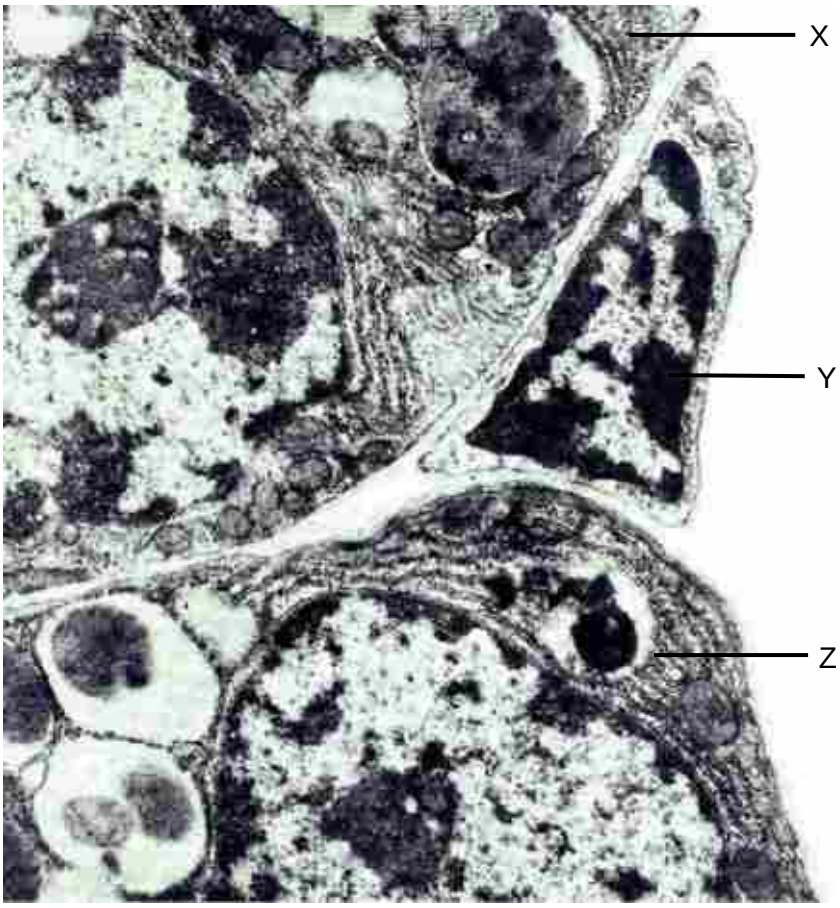
Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

Calculators may be used.

This question paper consists of **27** printed pages.

1 The following electron micrograph shows three adjacent cells, X, Y and Z.



Which of the following descriptions about these cells is **not** true?

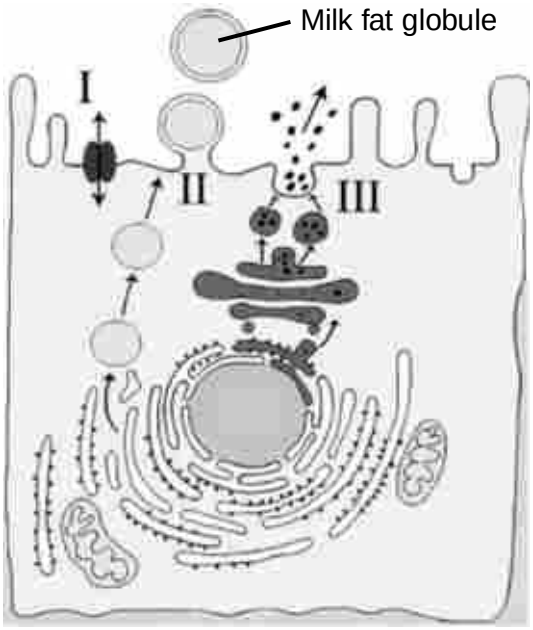
A Cell X contains both linear and circular molecules as its genetic material.

B Cell Y has a rigid cellulose cell wall which resists osmotic lysis.

C Cell Z contains 40S and 60S ribosomal subunits in its cytoplasm.

D Both cell X and cell Z possess intracellular membranes.

2 The diagram shows an epithelial cell in the mammary glands of a mammal. Such cells are responsible for the secretion of milk, an emulsion made up of lactose, lipids, proteins, ions and water. The various substances in milk are secreted through three different transport processes I, II and III.



Which of the following correctly describes the secretion of substances in milk?

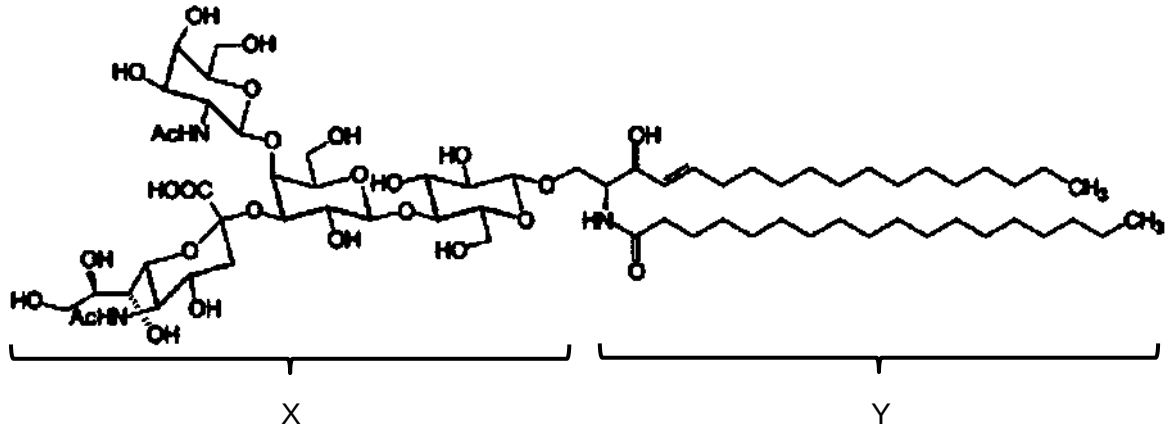
A The secretion of large fat globules occurs by exocytosis, with the expenditure of ATP.

B Lactose and ions have to be secreted through process I due to their hydrophobicity.

C Water can be transported in vesicles budding from the rough endoplasmic reticulum and secreted through process II.

D Milk proteins are transported out of the cell through process III, due to their large molecular size.

3 A ganglioside is a molecule commonly found in cell membranes, and its structure comprises two main components, X and Y.



Which of the following statements regarding a ganglioside is true?

A It comprises two fatty acid chains joined to a glycerol molecule by ester bonds.

B Component X helps to regulate the permeability of the cell membrane.

C Component X is responsible for cell-to-cell recognition and acts as a receptor for other molecules.

D Component X is embedded in the cell membrane while component Y faces the extracellular fluid.

4 The winged bean is a tropical crop that has high protein content. Winged beans have been reported to have a low level of protein digestibility. Protease inhibitors in the bean have been suggested to be responsible for the low digestibility.

In an experiment to study the effect of heat treatment on protein digestibility in winged beans, one of two winged beans was subjected to heat treatment. Trypsin was subsequently added to each reaction mixture and incubated for 30 minutes. The protein concentration of each reaction mixture at the beginning and at the end of the incubation period is shown in the table below.

Incubation period / min	Protein concentration of the reaction mixture / %	
	Trypsin + heat-treated winged bean	Trypsin + untreated winged bean
0	100	100
30	40	70

Which of the following statements is a likely explanation for the data shown?

A Heat treatment of winged bean caused the activation of trypsin inhibitors.

B Heat treatment of winged bean denatured trypsin by changing the 3-dimensional configuration of the enzyme.

C Heat treatment of winged bean disrupted cellular structure and improved accessibility of trypsin to protein.

D Heat treatment of winged bean lowered the activation energy of trypsin and increased the rate of enzyme-catalysed reaction.

5 In *Caenorhabditis elegans*, studies on the synapsis of homologous chromosomes revealed that one end of each chromosome becomes attached to protein patches on the nuclear envelope. The protein patches form a bridge between the chromosomes and the cytoskeleton outside the nucleus. The microtubules in the cytoskeleton facilitate movement of the patches and associated chromosomes, enabling encounters between chromosomes. A protein, dynein, is involved in the separation of mispaired chromosomes. It is also required in the formation of a protein complex between the correctly paired homologous chromosomes.

Which of the following statements are valid conclusions from these findings?

1 The formation of the protein complex between paired homologous chromosomes occurs spontaneously.
2 Mutations in genes coding for protein patches on the nuclear envelope that link the chromosomes to the cytoskeleton inhibit synapsis.
3 Successful formation of the protein complex between paired homologous chromosomes is required for the cell to proceed into metaphase of mitosis.
4 Dynein is necessary to ensure proper synapsis of homologous chromosomes.

A 2, 3 and 4 only

B 1, 2 and 4 only

C 1 and 3 only

D 2 and 4 only

6 The amount of DNA present in a diploid germ cell of 12 chromosomes is 6 picograms (pg). During meiosis I, non-disjunction of a pair of homologous chromosomes occurred.

Which row correctly identifies the amount of DNA and number of chromosomes at different stages of nuclear division?

	Telophase I		Telophase II	
	Amount of DNA (pg) per cell	Number of chromosomes per nucleus	Amount of DNA (pg) per cell	Number of chromosomes per nucleus
A	12	5 or 7	5 or 7	5 or 7
B	12	12	5 or 7	4 or 14
C	6	5 or 7	2.5 or 3.5	5 or 7
D	6	12	2.5 or 3.5	4 or 14

7 Which of the following statement(s) is/are **not** true of the translation process in all eukaryotes?

1 Polypeptides are only synthesised in the cytosol.
2 Amino acids are linked by the formation of peptide bonds catalysed by a ribozyme.
3 Ribosomes contain an amino-acyl tRNA site that is occupied by the initiator tRNA attached to methionine.
4 Amino-acyl tRNA synthetase attaches an amino acid to the 5' end of a tRNA molecule.

A 1, 3 and 4 only

B 2, 3 and 4 only

C 2 and 4 only

D 1 only

8 RNA is involved in the process of protein synthesis. Which of the following descriptions is true about RNA in eukaryotes?

A rRNA, which is coded for by genes found in nucleolus, associates with ribosomal proteins in the cytoplasm to form ribosomal subunits.

B Functional mRNA is formed as a result of post-transcriptional modifications of primary RNA transcript in the nucleus.

C The ribonucleotide sequence of tRNA molecules allows extensive folding and inter-strand complementarity to generate a three-dimensional structure.

D All RNAs must undergo alternative splicing.

9 The template DNA strand for a segment of polypeptide is shown below:

3' ------ GTA ACC GCA TCT CAG AGG ------ 5'

Which of the following will most likely occur if nitrous acid (a mutagenic agent) introduces mutations to this DNA strand by replacing cytosine bases with uracil bases?

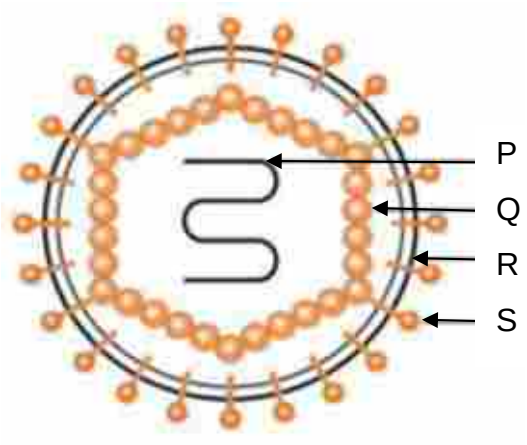
A No polypeptide will be synthesised.

B A truncated polypeptide will be synthesised.

C Four new amino acids with different chemical properties will be found in the polypeptide.

D A polypeptide of original length but with a few new amino acids of different side chains will be synthesised.

10 The diagram shows the structure of a virus.



Which of the following statements are true?

1 P determines the structure of Q and S.
2 Q assists viral entry into the host cell.
3 R and S are required for the entry of the virus into the host cell.
4 Q and R are made of the same components.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 2 and 4 only

11 How many of these statements about the Human Immunodeficiency Virus (HIV) are correct?

1 The genome is made up of deoxyribonucleotides.
2 The viral enzyme reverse transcriptase is coded for by *pol* gene.
3 Haemagglutinin on viral surface binds to CD4 receptor of helper T cell.
4 HIV enters the host cell via fusion.

A 1

B 2

C 3

D 4

12 The following statements describe the process of conjugation between two bacterial cells.

1 F plasmid replicates semi-conservatively in the donor cell.
2 Replication of F plasmid occurs to form double-stranded DNA in recipient cell.
3 Conjugation tube breaks and retracts.
4 Conjugation tube forms between two bacterial cells.
5 Single-stranded copy of F plasmid is transferred into recipient cell.

Which of the following order describes conjugation correctly?

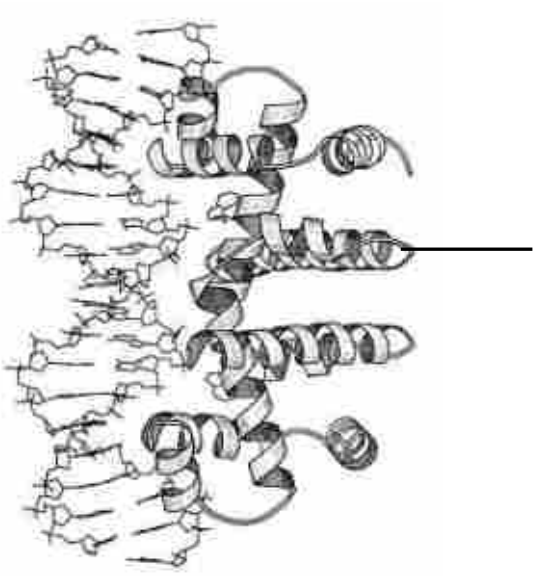
A 1 → 4 → 5 → 2 → 3

B 1 → 5 → 4 → 3 → 2

C 4 → 1 → 5 → 2 → 3

D 4 → 5 → 3 → 1 → 2

13 The diagram shows the binding of an active *trp* repressor protein to DNA.



Which of the options shows the most possible effect of a mutation of the *trp* repressor?

	Part of *trp* repressor affected by mutation	Type of mutation	State of *trp* operon in the presence of tryptophan
A	DNA binding site	Gain-of-function	Transcribed
B	DNA binding site	Loss-of-function	Not transcribed
C	Tryptophan binding site	Loss-of-function	Transcribed
D	Tryptophan binding site	Loss-of-function	Not transcribed

14 The table shows a comparison of some aspects of the genomes and protein-coding genes of eukaryotic and prokaryotic organisms.

Organism	Genome size / base pairs	Chromosome number	Estimated gene number
Human (*Homo sapiens*)	3 billion	46	About 25,000
Mouse (*Mus musculus*)	2.9 billion	40	About 25,000
Fruit fly (*Drosophila melanogaster*)	165 million	8	13,000
Plant (*Arabidopsis thaliana*)	157 million	10	25,000
Roundworm (*Caenorhabditis elegans*)	97 million	12	19,000
Yeast (*Saccharomyces cerevisiae*)	12 million	32	6,000
Bacteria (*Escherichia coli*)	4.6 million	1	3,200

Which of the following statement(s) account(s) for the differences seen in the table?

1 The greater the number of chromosomes an organism has, the larger its genome.
2 The presence of introns in the eukaryotes results in larger genomes and more chromosomes.
3 A larger number of genes would result in a significantly larger genome.
4 *Homo sapiens* and *Mus musculus* are the most closely related, hence they have similar genome size, number of chromosomes and gene number.

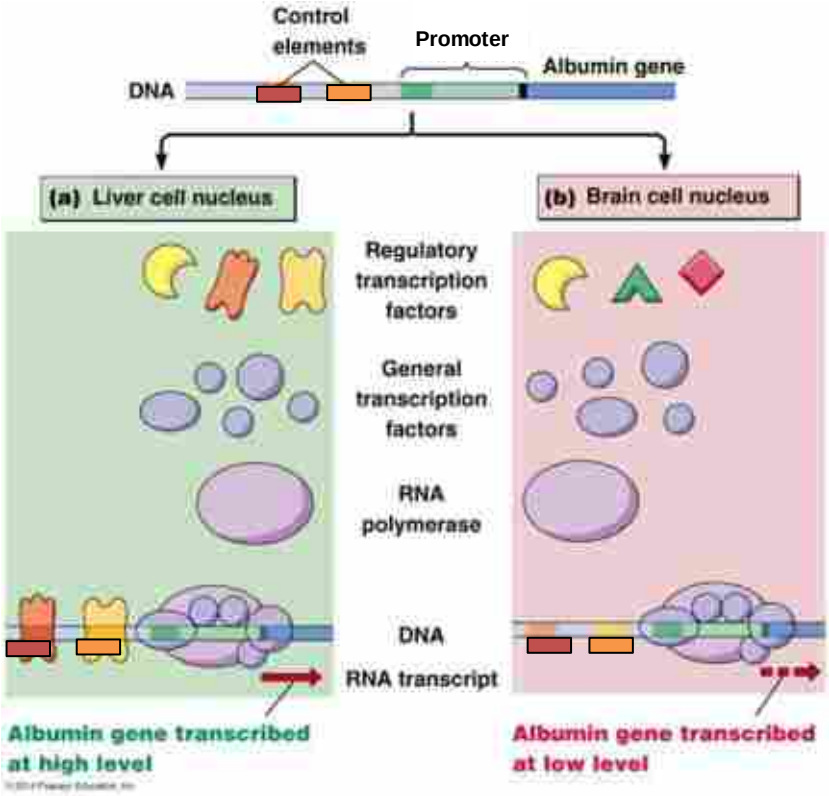
A 2, 3 and 4 only

B 1 only

C 4 only

D None of the above

15 Gene expression of albumin gene is regulated by two control elements and its promoter. These control elements are recognised by regulatory transcription factors which bind to allow for high rate of transcription of the albumin gene.



Which of the following is a result of differential albumin gene expression in liver cells and brain cells?

A Liver and brain cells are differentiated from different pluripotent stem cells, hence they contain different control elements which result in differential gene expression.

B Brain cells contain different RNA polymerases and general transcription factors resulting in low transcription of the albumin gene.

C Brain cells do not contain the regulatory transcription factors that are required to bind to the control elements of the albumin gene to promote the assembly of the transcription complex.

D Liver and brain cells contain the same regulatory control elements, RNA polymerase and transcription factors but a mutation has occurred in the regulatory control elements of the brain cells hence making them dysfunctional.

16 Which of the following is an example of translational control of gene expression?

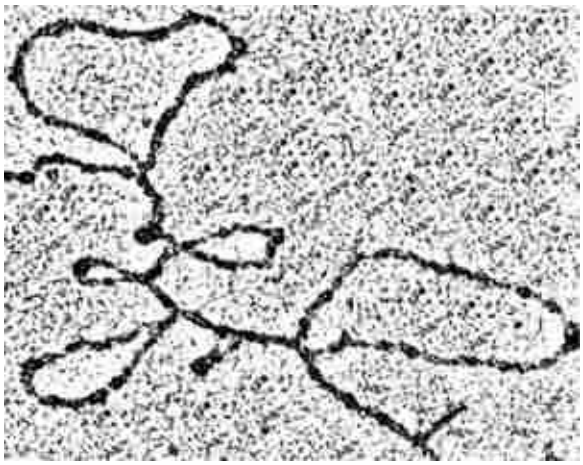
A The binding of protein factors to mRNA to prevent the binding of the small ribosomal subunit

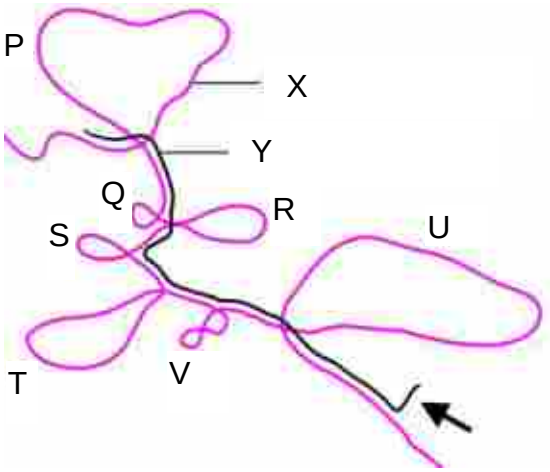
B The activation of proteins by association with other proteins

C The addition of chemical groups such as phosphates to free amino acids

D The degradation of a protein by proteasome

17 The ovalbumin gene from chicken was isolated and made single-stranded and then subsequently mixed together with its mature mRNA. The results were observed under an electron microscope. The electron micrograph and its corresponding diagrammatic representation show the binding of the mRNA to certain regions of the DNA.





Which of the following statement(s) can be concluded?

1 X is the template strand of DNA and Y is the mRNA strand transcribed from X.
2 P, Q, R, S, T, U and V correspond to the introns on the DNA that have been excised from the mRNA.
3 The arrow indicates the 3' end of the mRNA where the poly(A) tail was added during post-transcriptional modification.
4 The 3' end of the mRNA is free because there is no corresponding stretch on the template DNA where complementary base pairing can take place.

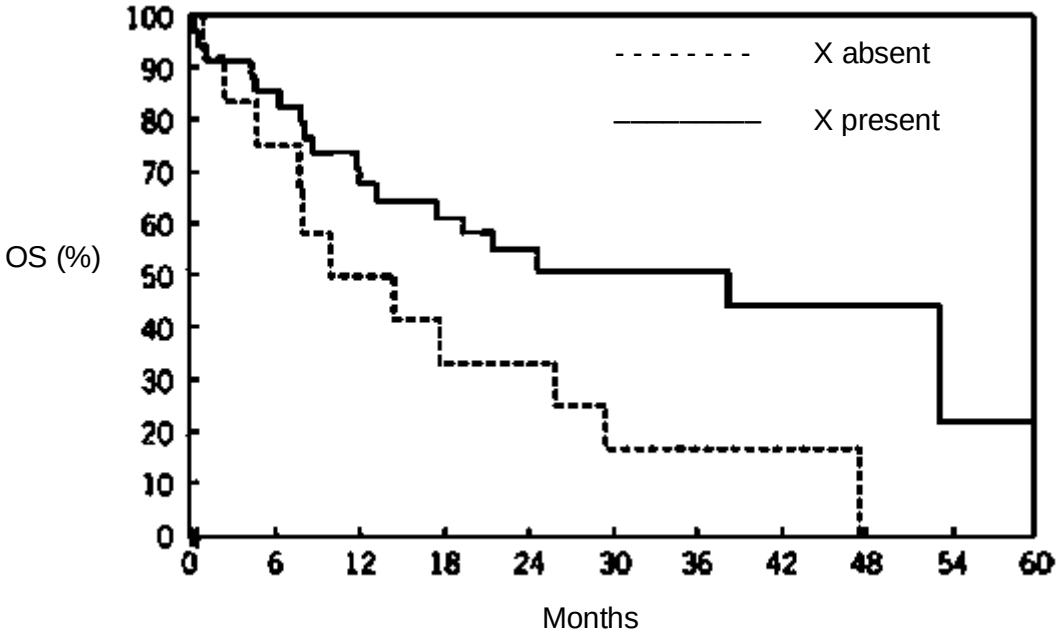
A 1, 2, 3 and 4

B 2, 3 and 4 only

C 1 and 2 only

D 1 only

18 A group of scientists discovered a novel protein and named it X. X is implicated in chromatin structure rearrangement in mammalian cells. The figure shows the overall survival (OS) percentage of cancer patients in the absence and presence of X.



Which of the following statement can best account for the increased survival rates of the cancer patients?

A X is involved in histone acetylation which results in the chromatin having a less compact structure leading to increased expression of tumour suppressor genes, hence allowing cell division to be regulated.

B X is involved in histone acetylation which results in the chromatin having a less compact structure leading leading to expression of oncogenes, hence allowing cell division to be regulated.

C X is involved in histone deacetylation which results in the chromatin having a less compact structure leading to expression of the telomerase gene, hence allowing cell division to be regulated.

D X is involved in histone deacetylation which results in chromatin having a more compact structure leading to a lack of expression of genes involved in angiogenesis, hence allowing cell division to be regulated.

19 In Shorthorn cattle, the allele for the absence of horns is dominant to the allele for the presence of horns. Coat colour can be red (genotype: $\mathbf{C^RC^R}$), roan (genotype: $\mathbf{C^RC^W}$) or white (genotype: $\mathbf{C^WC^W}$).

A roan bull, heterozygous for the hornless trait, is crossed with a cow of the same genotype. Which of the following statement(s) regarding the F_1 offspring is/are true?

1 The probability that a calf from this cross would have the same phenotype as its parents is 3/8.
2 The ratio of horned to hornless calves is 3:1.
3 The number of red and white calves is more than that of roan calves.

1

A 1 and 2 only

B 2 and 3 only

C 1 only

D 3 only

20 Wing size in *Drosophila* is controlled by a gene with three alleles. The normal wings are long while the other two traits arise as a result of mutation in the same gene locus. The order of dominance for these alleles is as follows.

Long (L) > Vestigial (L^{vg}) = Antlered (L^{a})

How many different genotypes for wing size are possible?

A 3

B 4

C 6

D 8

21 The coat colour of Norwegian cattle is mainly determined by the distribution of two pigments: red and black. Both pigments are produced by the action of the enzyme tyrosinase in cells called melanocytes. A low level of activity of the enzyme leads to the production of red pigment, whilst a high activity allows only black pigment production. The activity of the enzyme is increased by the melanocyte stimulating hormone (MSH), which binds to a MSH receptor. The receptor is coded for by the **E** gene locus, which has two alleles, **E** and **e**. No receptor is produced by the recessive allele **e**.

The dominant allele of a second gene, the **A** locus, codes for a protein which binds to and blocks the MSH receptors, thus preventing stimulation of tyrosinase activity in a melanocyte.

Which of the following statements about the two genes and their effects in the colouration of Norwegian cattle is true?

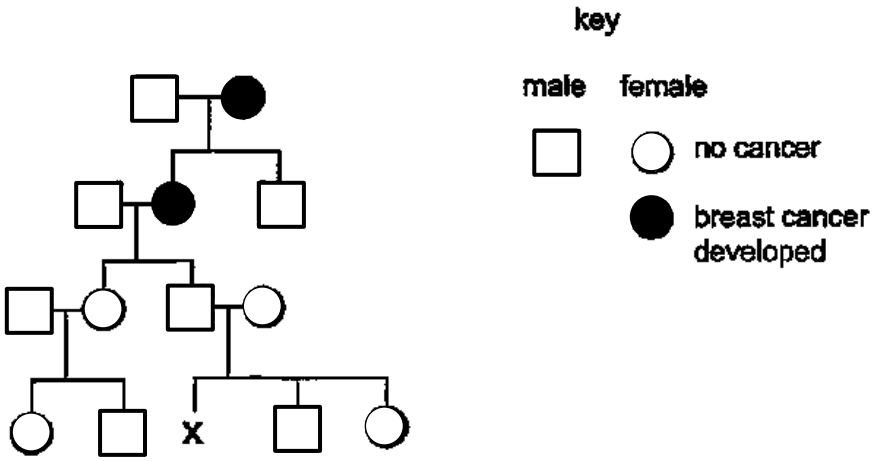
A Allele A is completely epistatic to allele a and allele E is completely epistatic to allele e.

B Cattle with the genotype AAEE have red coats.

C Cattle with black coats must have the genotype aaEe only.

D Cattle with the genotypes aaEE, aaEe and Aaee will have high tyrosinase activity.

22 The diagram below shows the inheritance of a form of breast cancer associated with the presence of just one mutant allele of an autosomal gene *BRCA1*.



What is the probability that woman X inherits the *BRCA1* mutant allele associated with breast cancer?

A 0.00

B 0.25

C 0.50

D 1.00

23 The table below shows the results of an early investigation into the genetic control of phenotypic variation. The dry masses of 5493 bean seeds collected from many plants were classified into nine categories.

Mass of bean/mg	51-150	151-250	251-350	351-450	451-550	551-650	651-750	751-850	851-950
Number of beans	5	38	370	1676	2255	928	187	32	2

Which statement correctly describes these data and could account for the variation shown?

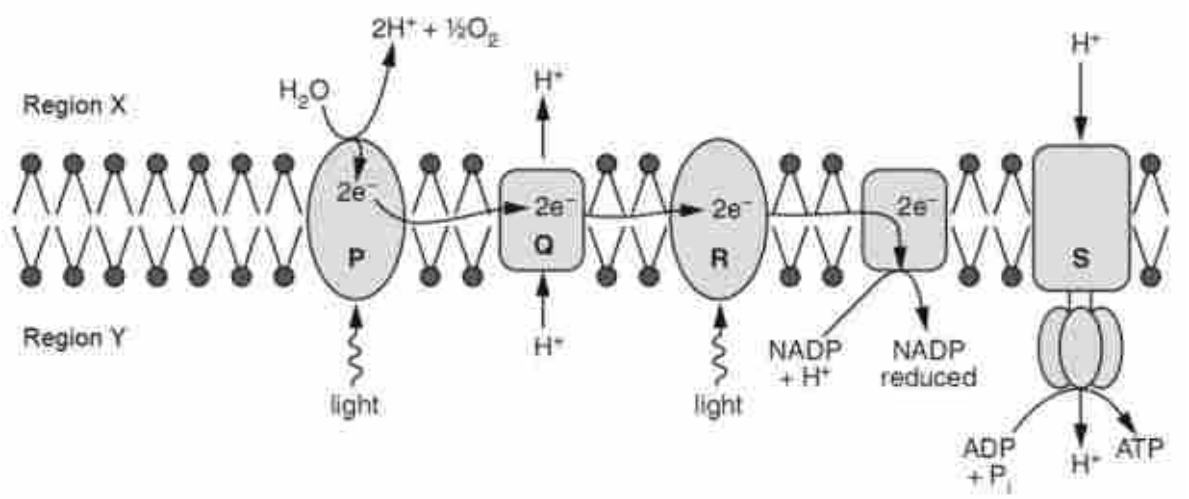
A The phenotypic variation is continuous and could be the result of two non-linked genes acting on their own.

B The phenotypic variation is continuous and could be the result of several non-linked genes acting on their own.

C The phenotypic variation is discontinuous and could be the result of two linked genes acting on their own.

D The phenotypic variation is discontinuous and could be the result of several linked genes acting on their own.

24 The diagram below represents a cross section of a thylakoid, showing some components which are involved in the light-dependent stage of photosynthesis.



Which of the following statements about the following components in the light-dependent stage is true?

A An inhibitor which blocks electron flow through R would inhibit the production of oxygen at P.

B In structures P and R, electrons are passed from one pigment molecule to another until it reaches chlorophyll *a*.

C Region X is expected to have a higher pH than Region Y.

D There is a non-cyclical flow of electrons through structures P, Q, R and S.

25 In respiration, the enzyme hexokinase uses ATP to transfer a phosphate group to glucose to form glucose-6-phosphate.

If a cell only has glucose available for energy and the activity of hexokinase is suddenly inhibited in this cell, which of the following will occur?

1 The cell will not be able to produce pyruvate through glycolysis.
2 Respiratory processes in the mitochondria would not proceed.
3 The use of oxygen by the cell will decrease.

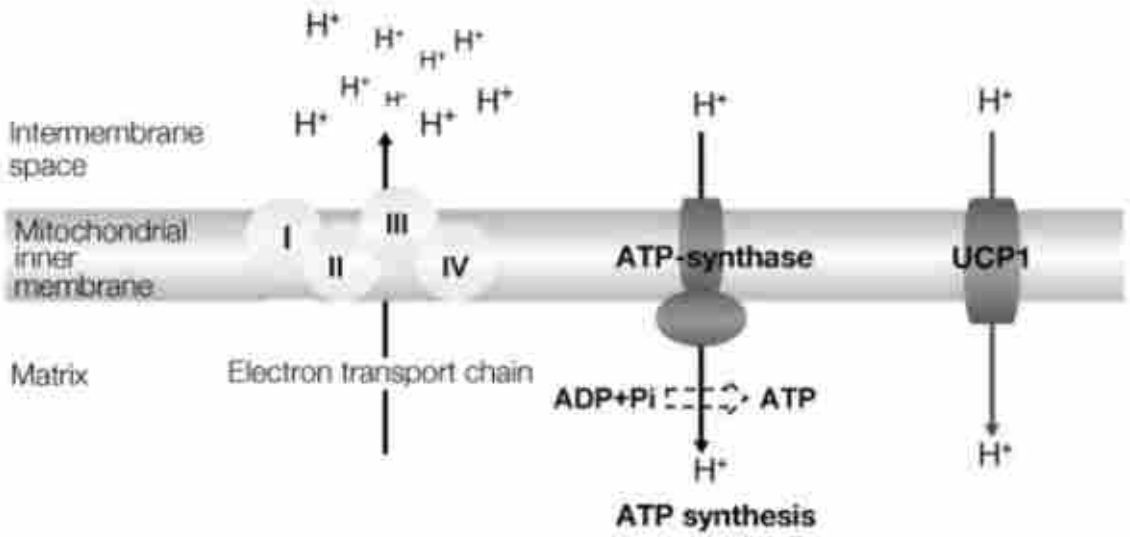
A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

26 Thermogenesis is a process that helps certain animals to maintain a constant body temperature. Such animals are found to contain a lot of mitochondria which have proton channels known as UCP1 embedded in the inner membrane as shown below.



Based on the above information, which of the following statements is a likely explanation for the role of UCP1 in thermogenesis?

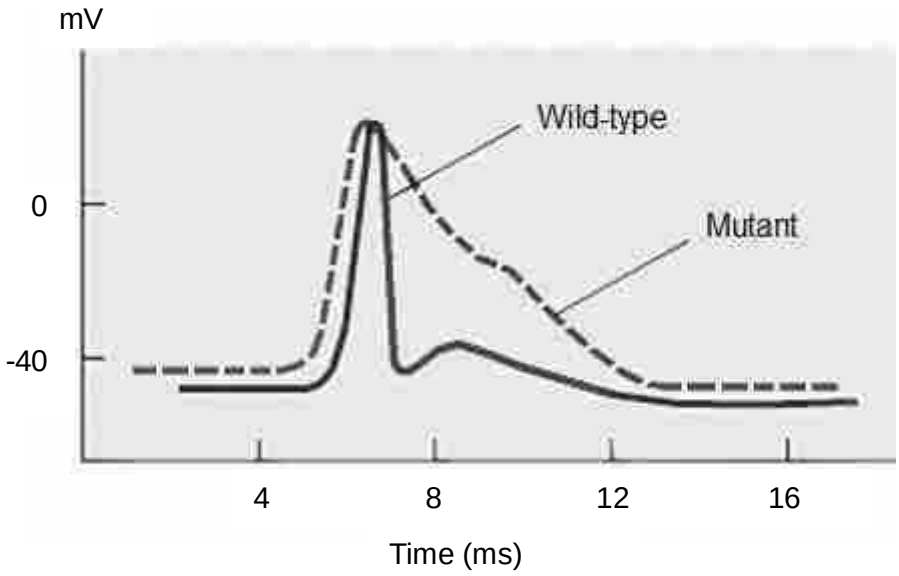
A UCP1 disrupts the flow of electrons along the electron transport chain, channelling protons through it instead of ATP synthase, thus producing heat in the process.

B A proton gradient cannot be established as UCP1 allows protons to pass through the inner membrane passively, hence the energy released from electron transfer is used for heat production.

C The proton motive force is dissipated as heat due to protons flowing through UCP1 instead of passing through ATP synthase.

D The presence of UCP1 allows more protons to diffuse into the intermembrane space so that more protons can eventually diffuse through ATP synthase for ATP production to generate heat.

27 An experiment was carried out to investigate the effect of a particular gene mutation. The action potentials of wild-type flies and mutant flies are shown below.



Which of the following can explain the shape of the action potential in the mutant flies?

A Voltage-gated sodium ion channels were unable to close

B Defective voltage-gated potassium ion channels

C Hyperactive sodium-potassium pumps

D Slow-opening ligand-gated potassium ion channels

28 Some receptors for growth factors activate a protein kinase cascade, usually with the participation of multiple enzymes which cause changes in gene expression. Which of the following statements regarding cell signalling are true?

1 Multiple steps allow the amplification of a signal.
2 External signals can lead to changes in gene expression.
3 The same signal can lead to different responses in cells due to the presence of different target proteins.
4 All cascade systems modify gene expression by activating kinases that enter the cell nucleus by phosphorylating specific transcription factors.

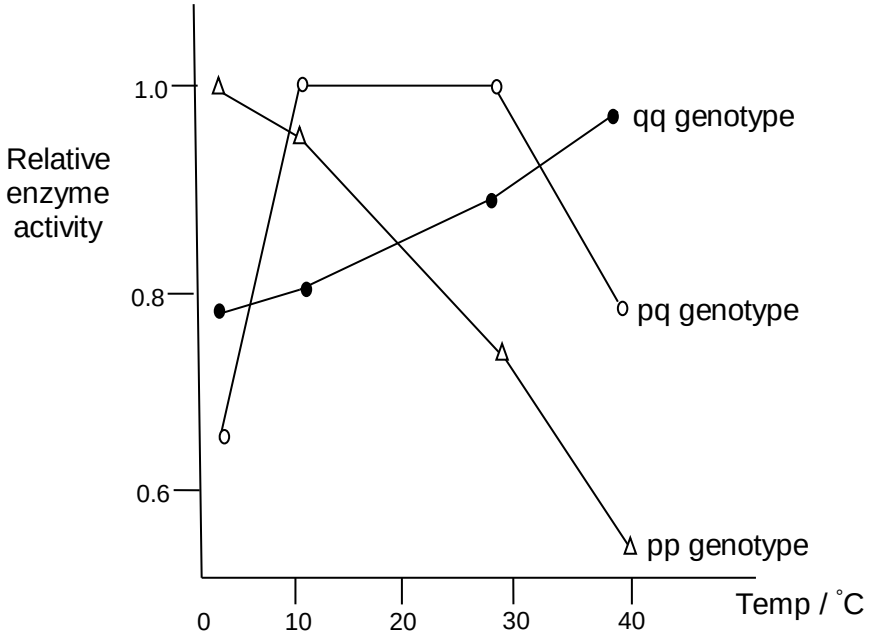
A 1, 2, 3 and 4

B 1, 2 and 3 only

C 1 and 2 only

D 3 and 4 only

29 In the North American catfish *Catostomus elarki*, two alleles represented by p and q, control the synthesis of a vital enzyme. The three possible genotypes (pp, pq, qq) lead to the synthesis of variations of the same enzyme with different temperature optima as shown in the graph below.



When the mean annual temperature is 5°C, which of the following statements are correct?

1 Allele q will be positively selected for.
2 The proportion of allele p in the gene pool will increase over time.
3 The heterozygotes will have a selective advantage over the homozygotes.
4 The catfish will develop a new enzyme variant that has a temperature optimum at 5°C.
5 Catfish with genotype pp will have a selective advantage over the others.

A 1 and 3 only

B 2 and 4 only

C 2 and 5 only

D 3 and 4 only

30 A large population of a certain species of freshwater fish lives in a South America lake. Assuming that there are no mutations, all immigration into the population is prevented and there is no change in selection pressure, which one of the following statements best expresses the probable future of the population?

A All evolution will promptly cease because without mutation, there will be no raw material for evolution.

B The population will begin to decrease in size after three to four generations because of excessive inbreeding that will result from the absence of immigration.

C The population will continue to evolve as selection acts on the different allelic combinations formed during meiosis.

D The population will cease to evolve and may survive for a long time as long as there is no selection.

31 When organochlorine insecticides such as DDT were in widespread use, mosquitoes in malarial regions developed resistance more rapidly than did houseflies in Britain. What could account for the difference in the rates of the development of resistance?

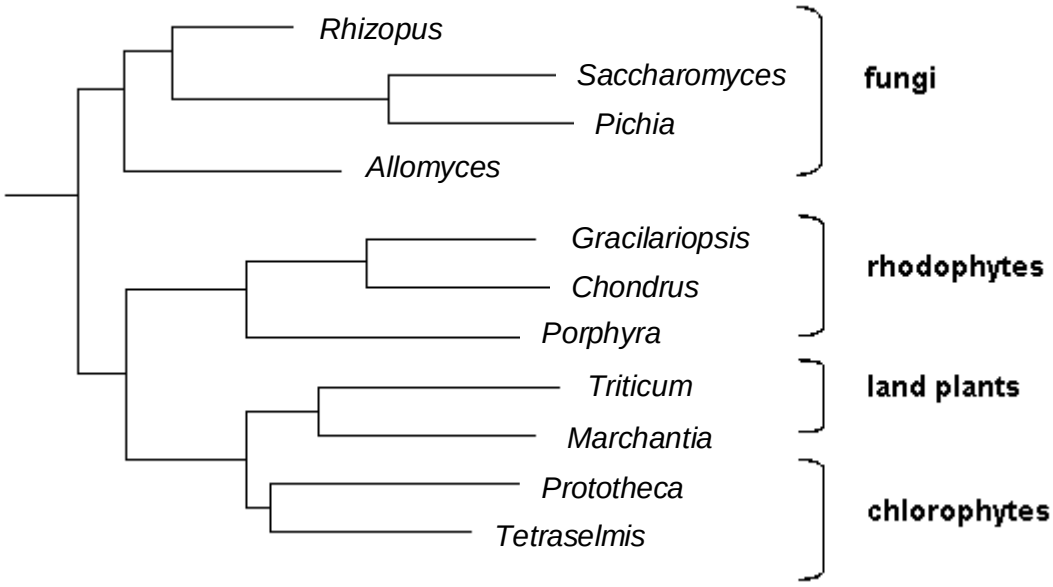
A Mosquitoes produce fewer generations a year.

B More insecticide was used in Britain.

C More insecticide was used in malarial regions.

D Mosquitoes show fewer random mutations per generation.

32 The phylogenetic tree below is derived from comparisons made with mitochondrial DNA from animals, fungi, rhodophytes (red algae) and plants.



What may be concluded from the above phylogenetic tree?

1 *Triticum* and *Marchantia* form a clade while *Allomyces* does not belong to any clade.
2 *Gracilariopsis*, *Chondrus* and *Porphyra* have evolved from the same most recent ancestor.
3 Chlorophytes and land plants are more closely related compared to chlorophytes and rhodophytes.
4 The rhodophytes share a common ancestry with chlorophytes and land plants.

A 1, 2 and 3 only

B 2, 3 and 4 only

C 2 and 4 only

D 3 and 4 only

33 In genetic engineering, which of the following are possible reasons for the limit on the size of the gene to be inserted into a plasmid vector?

1 cDNA is usually used instead of genomic DNA.
2 Probability of number of errors during replication increases as size of gene increases.
3 Number of ligases needed increases with an increase in the size of gene.
4 Efficiency of transformation of competent bacteria decreases with an increase in size of gene.

A 1, 2 and 4 only

B 2, 3 and 4 only

C 1 and 3 only

D 2 and 4 only

34 Which of the following statements regarding Restriction Fragment Length Polymorphisms (RFLP) and their analyses are correct?

1 RFLPs tightly linked to a gene coding for a disease can be used for disease detection.
2 All RFLPs exist as dominant and recessive alleles.
3 RFLPs can identify all single base pair changes in a chromosome.
4 All changes in restriction enzyme sites can be used as genetic markers.

A 1, 2, 3 and 4

B 1, 2 and 3 only

C 2, 3 and 4 only

D 1 and 4 only

35 Which of the following is an ethical concern of the Human Genome Project?

A Difficult to develop treatment for diseases involving multiple genes

B Costly procedures limit genetic testing to those who can afford them

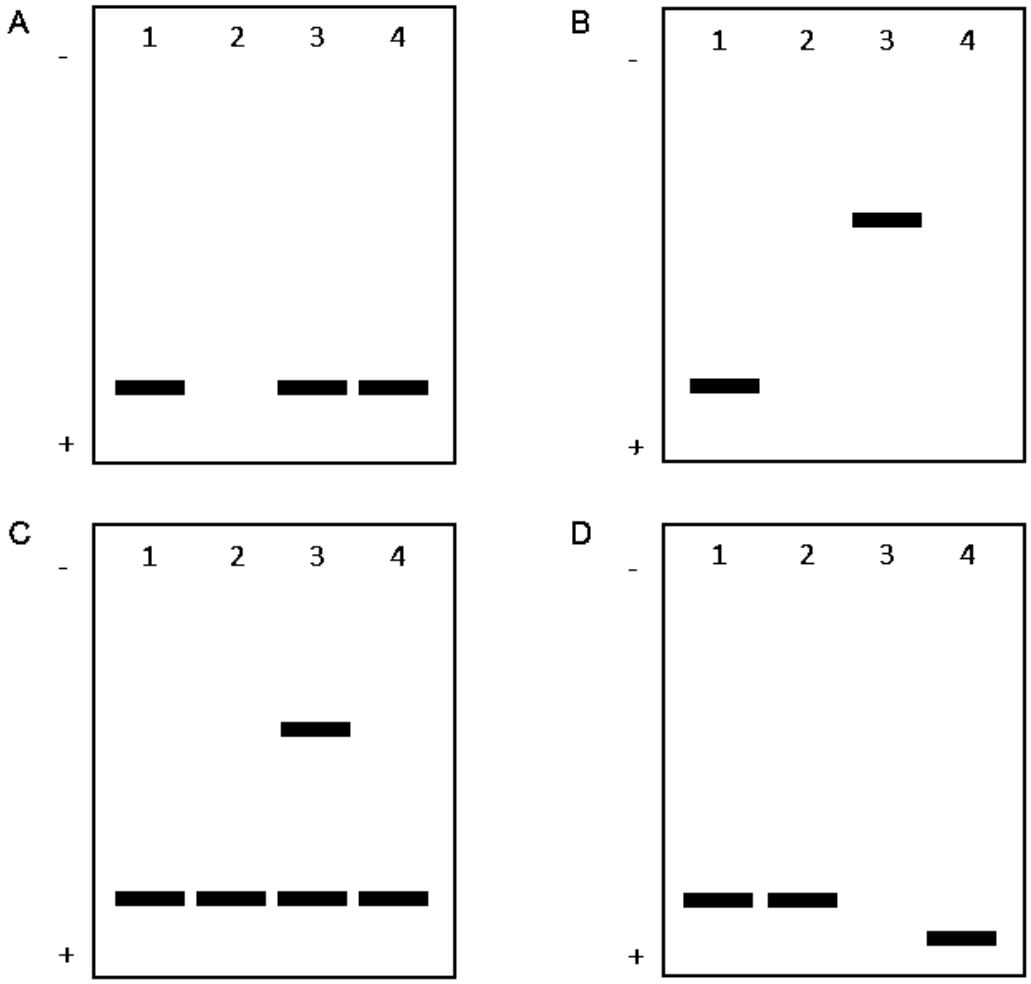
C Genetic testing may not provide reliable and accurate information

D Unborn foetuses detected with diseases may be aborted

36 Polymerase chain reactions (PCRs) were carried out on fruit fly genomic DNA. The DNA was added to four test-tubes and the treatments for the test-tubes are shown in the table below. The primers were designed to amplify a DNA section which is about 2 kb long.

Test-tube	Reagents	Temperature
1	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 72°C (for 120 s)
2	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	55°C (for 75 s) → 72°C (for 120 s)
3	Forward primers only, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 72°C (for 120s)
4	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 37°C (for 120 s)

After the above treatments were completed, gel electrophoresis was carried out on the contents of each test-tube. Which of the following electrophoregrams shows the correct results for each of the tubes?



37 Which of the following best illustrates totipotency?

A A somatic cell isolated from a root tip develops into a normal adult plant.

B Stem cells are able to divide indefinitely.

C Mesenchymal stem cells can differentiate into an extensive range of cell types, including bone cells, cartilage cells, muscle cells and fat cells.

D The replacement of the nucleus of an unfertilised egg with that of a pancreatic cell converts the egg into a pancreatic cell.

38 Which of the following are social implications for the use of gene therapy in treating genetic diseases?

1 Gene therapy might provide alternative treatments for patients where conventional treatments have failed.
2 Genetic enhancements can be costly and accessible only to the wealthy.
3 There is difficulty in determining which conditions are normal and which are considered disorders.

A 1, 2 and 3

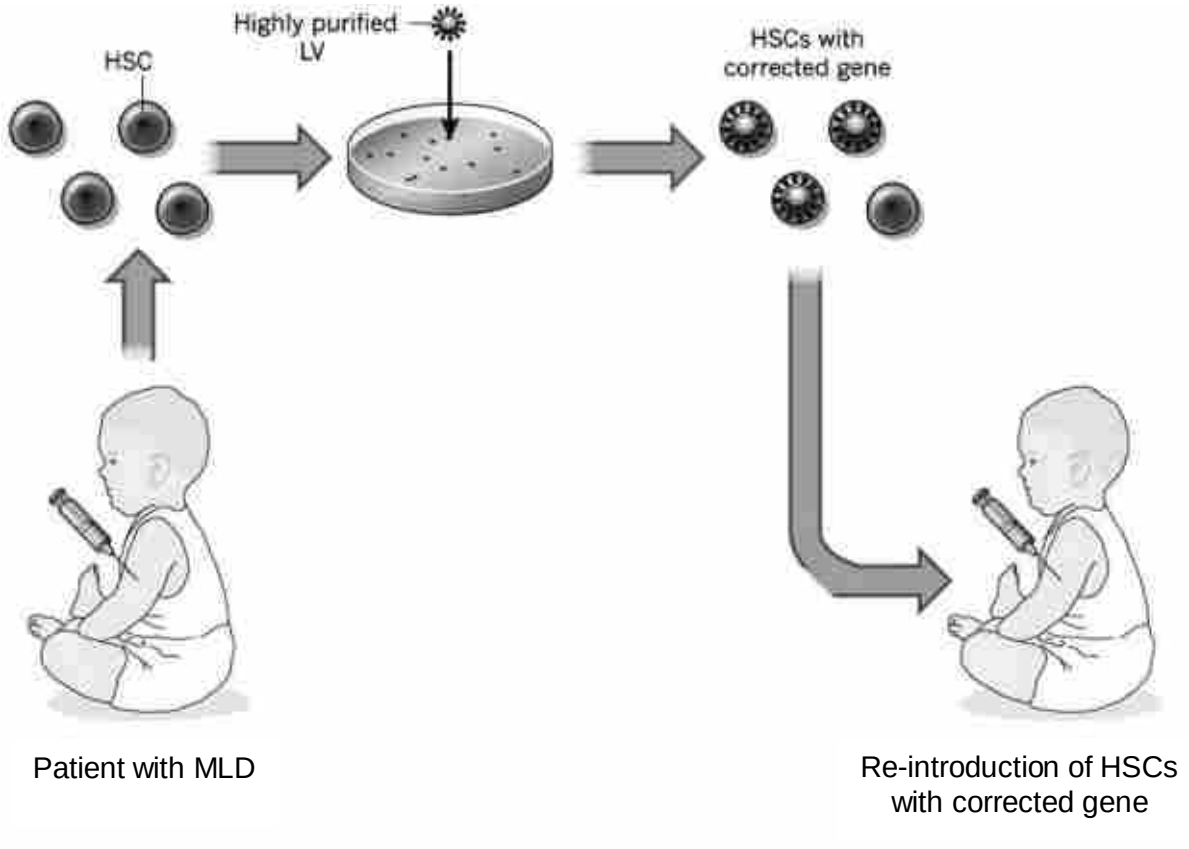
B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

39 Metachromatic leukodystrophy (MLD) is an inherited disorder caused by a deficiency in arylsulphatase A (ARSA) enzyme activity in leukocytes. Patients with MLD accumulate a toxic metabolite and die within a few years.

In a clinical trial, a team of scientists collected haematopoietic stem cells (HSCs) from the bone marrow of children with MLD and exposed them to lentiviral vectors (LV) carrying normal ARSA genes. These genes were then integrated into HSC genomic DNA. HSCs with the corrected gene were then re-introduced into the children's bone marrow.



Which of the following statement(s) regarding the treatment of MLD is/are true?

1 This method of treatment is beneficial as it reduces the risk of incompatibility of HSC transplants.
2 This method of treatment is less effective than introducing lentiviruses containing the normal ARSA genes into the patient directly.
3 Other than HSCs, it is also possible to use leukocytes as target cells for gene therapy.

A 1, 2 and 3
B 1 and 2 only
C 1 and 3 only
D 3 only

40 Transgenic crops expressing insecticidal toxins could provide an effective means of pest control. However, the widespread cultivation of such transgenic crops is expected to promote the development of toxin-resistant pests, hence eventually compromising the usefulness of the pest management strategy. Two planting strategies have thus been recommended to prevent the development of toxin-resistant pests:

Strategy 1: Separate fields of transgenic plants and non-transgenic plants are planted

Strategy 2: 'Seed mixtures' of such transgenic plants and non-transgenic plants in the same field are planted

Which of the following considerations would most likely encourage farmers to favour Strategy 1 over Strategy 2?

A Low mortality of susceptible insects on toxin-free plants

B Movement of randomly mating insects from plant to plant within a field

C Concern that 'superweeds' might emerge in fields with 'seed mixtures'

D When toxin resistance is recessive and frequency of recessive alleles is low

ANGLO-CHINESE JUNIOR COLLEGE
Preliminary Examination 2016

BIOLOGY **9648/01**

HIGHER 2 **31 August 2016**

Paper 1 Multiple Choice **1 hour 15 mins**

Additional Material: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, pencil clips, highlighters, glue or correction fluid.
Write your name, centre number and index number on the Answer Sheet provided.

There are **forty** questions in this paper. Answer **all** questions. For each question there are four possible answers, **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate answer sheet.

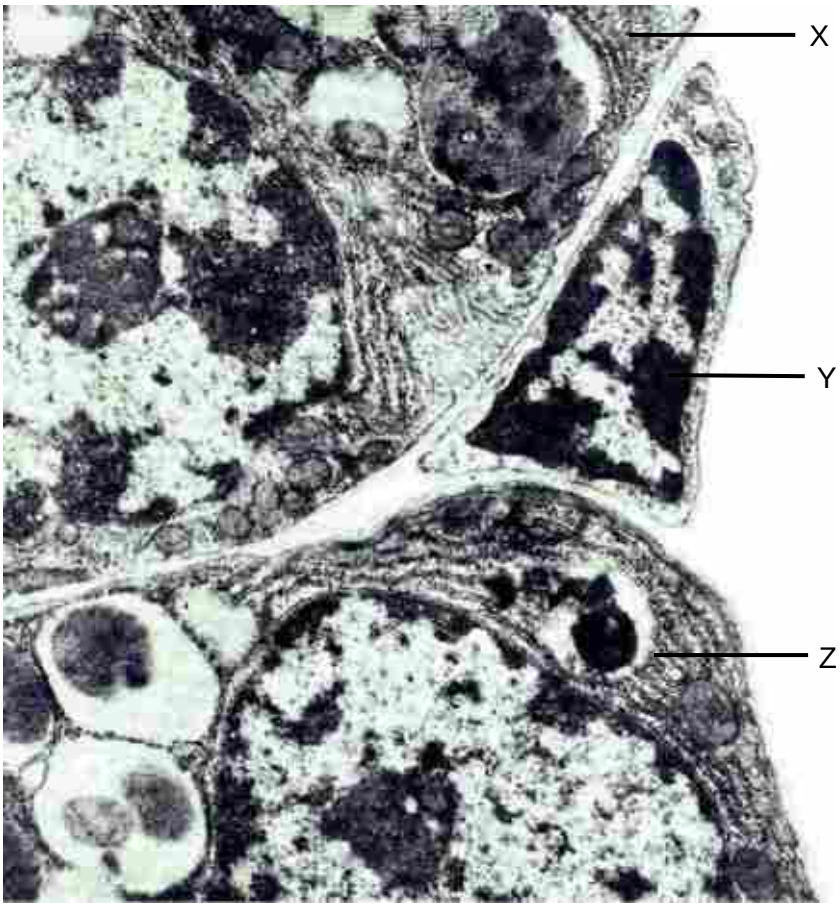
Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

Calculators may be used.

This question paper consists of **27** printed pages.

1 The following electron micrograph shows three adjacent cells, X, Y and Z.



Which of the following descriptions about these cells is **not** true?

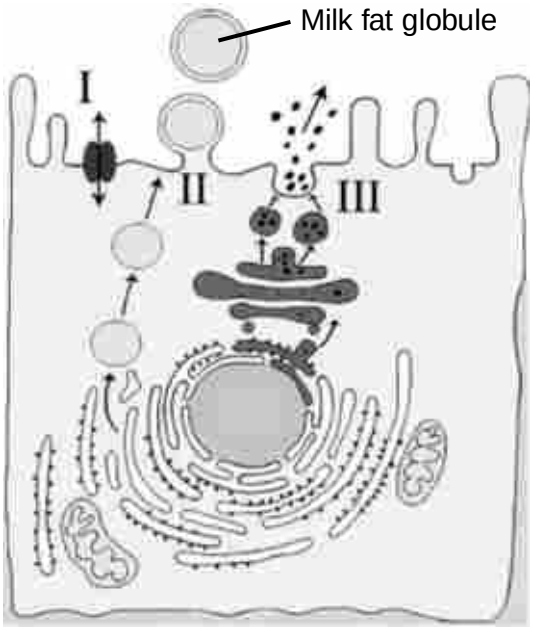
A Cell X contains both linear and circular molecules as its genetic material.

B Cell Y has a rigid cellulose cell wall which resists osmotic lysis.

C Cell Z contains 40S and 60S ribosomal subunits in its cytoplasm.

D Both cell X and cell Z possess intracellular membranes.

2 The diagram shows an epithelial cell in the mammary glands of a mammal. Such cells are responsible for the secretion of milk, an emulsion made up of lactose, lipids, proteins, ions and water. The various substances in milk are secreted through three different transport processes I, II and III.



Which of the following correctly describes the secretion of substances in milk?

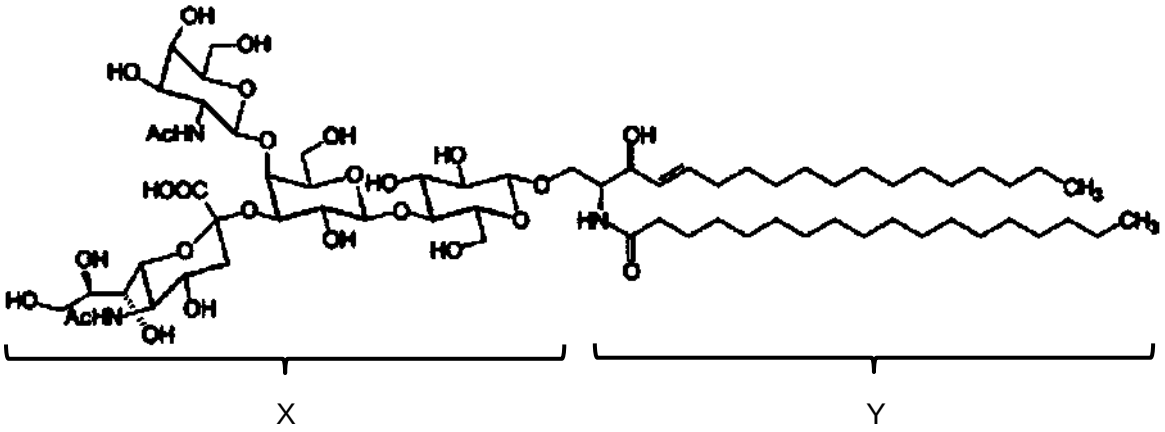
A The secretion of large fat globules occurs by exocytosis, with the expenditure of ATP.

B Lactose and ions have to be secreted through process I due to their hydrophobicity.

C Water can be transported in vesicles budding from the rough endoplasmic reticulum and secreted through process II.

D Milk proteins are transported out of the cell through process III, due to their large molecular size.

3 A ganglioside is a molecule commonly found in cell membranes, and its structure comprises two main components, X and Y.



Which of the following statements regarding a ganglioside is true?

A It comprises two fatty acid chains joined to a glycerol molecule by ester bonds.

B Component X helps to regulate the permeability of the cell membrane.

C Component X is responsible for cell-to-cell recognition and acts as a receptor for other molecules.

D Component X is embedded in the cell membrane while component Y faces the extracellular fluid.

4 The winged bean is a tropical crop that has high protein content. Winged beans have been reported to have a low level of protein digestibility. Protease inhibitors in the bean have been suggested to be responsible for the low digestibility.

In an experiment to study the effect of heat treatment on protein digestibility in winged beans, one of two winged beans was subjected to heat treatment. Trypsin was subsequently added to each reaction mixture and incubated for 30 minutes. The protein concentration of each reaction mixture at the beginning and at the end of the incubation period is shown in the table below.

Incubation period / min	Protein concentration of the reaction mixture / %	
	Trypsin + heat-treated winged bean	Trypsin + untreated winged bean
0	100	100
30	40	70

Which of the following statements is a likely explanation for the data shown?

A Heat treatment of winged bean caused the activation of trypsin inhibitors.

B Heat treatment of winged bean denatured trypsin by changing the 3-dimensional configuration of the enzyme.

C Heat treatment of winged bean disrupted cellular structure and improved accessibility of trypsin to protein.

D Heat treatment of winged bean lowered the activation energy of trypsin and increased the rate of enzyme-catalysed reaction.

5 In *Caenorhabditis elegans*, studies on the synapsis of homologous chromosomes revealed that one end of each chromosome becomes attached to protein patches on the nuclear envelope. The protein patches form a bridge between the chromosomes and the cytoskeleton outside the nucleus. The microtubules in the cytoskeleton facilitate movement of the patches and associated chromosomes, enabling encounters between chromosomes. A protein, dynein, is involved in the separation of mispaired chromosomes. It is also required in the formation of a protein complex between the correctly paired homologous chromosomes.

Which of the following statements are valid conclusions from these findings?

1 The formation of the protein complex between paired homologous chromosomes occurs spontaneously.
2 Mutations in genes coding for protein patches on the nuclear envelope that link the chromosomes to the cytoskeleton inhibit synapsis.
3 Successful formation of the protein complex between paired homologous chromosomes is required for the cell to proceed into metaphase of mitosis.
4 Dynein is necessary to ensure proper synapsis of homologous chromosomes.

A 2, 3 and 4 only

B 1, 2 and 4 only

C 1 and 3 only

D 2 and 4 only

6 The amount of DNA present in a diploid germ cell of 12 chromosomes is 6 picograms (pg). During meiosis I, non-disjunction of a pair of homologous chromosomes occurred.

Which row correctly identifies the amount of DNA and number of chromosomes at different stages of nuclear division?

	Telophase I		Telophase II	
	Amount of DNA (pg) per cell	Number of chromosomes per nucleus	Amount of DNA (pg) per cell	Number of chromosomes per nucleus
A	12	5 or 7	5 or 7	5 or 7
B	12	12	5 or 7	4 or 14
C	6	5 or 7	2.5 or 3.5	5 or 7
D	6	12	2.5 or 3.5	4 or 14

7 Which of the following statement(s) is/are **not** true of the translation process in all eukaryotes?

1 Polypeptides are only synthesised in the cytosol.
2 Amino acids are linked by the formation of peptide bonds catalysed by a ribozyme.
3 Ribosomes contain an amino-acyl tRNA site that is occupied by the initiator tRNA attached to methionine.
4 Amino-acyl tRNA synthetase attaches an amino acid to the 5' end of a tRNA molecule.

A 1, 3 and 4 only

B 2, 3 and 4 only

C 2 and 4 only

D 1 only

8 RNA is involved in the process of protein synthesis. Which of the following descriptions is true about RNA in eukaryotes?

A rRNA, which is coded for by genes found in nucleolus, associates with ribosomal proteins in the cytoplasm to form ribosomal subunits.

B Functional mRNA is formed as a result of post-transcriptional modifications of primary RNA transcript in the nucleus.

C The ribonucleotide sequence of tRNA molecules allows extensive folding and inter-strand complementarity to generate a three-dimensional structure.

D All RNAs must undergo alternative splicing.

9 The template DNA strand for a segment of polypeptide is shown below:

3' ------ GTA ACC GCA TCT CAG AGG ------ 5'

Which of the following will most likely occur if nitrous acid (a mutagenic agent) introduces mutations to this DNA strand by replacing cytosine bases with uracil bases?

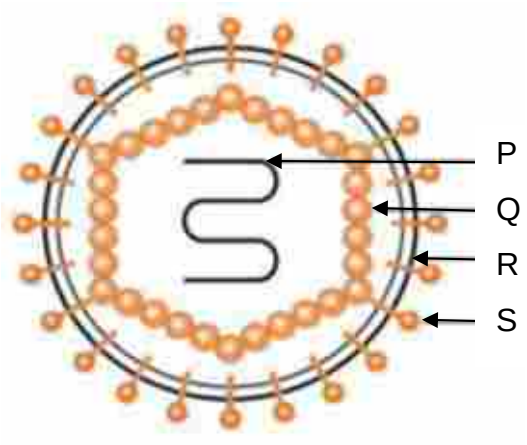
A No polypeptide will be synthesised.

B A truncated polypeptide will be synthesised.

C Four new amino acids with different chemical properties will be found in the polypeptide.

D A polypeptide of original length but with a few new amino acids of different side chains will be synthesised.

10 The diagram shows the structure of a virus.



Which of the following statements are true?

1 P determines the structure of Q and S.
2 Q assists viral entry into the host cell.
3 R and S are required for the entry of the virus into the host cell.
4 Q and R are made of the same components.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 2 and 4 only

11 How many of these statements about the Human Immunodeficiency Virus (HIV) are correct?

1 The genome is made up of deoxyribonucleotides.
2 The viral enzyme reverse transcriptase is coded for by *pol* gene.
3 Haemagglutinin on viral surface binds to CD4 receptor of helper T cell.
4 HIV enters the host cell via fusion.

A 1

B 2

C 3

D 4

12 The following statements describe the process of conjugation between two bacterial cells.

1 F plasmid replicates semi-conservatively in the donor cell.
2 Replication of F plasmid occurs to form double-stranded DNA in recipient cell.
3 Conjugation tube breaks and retracts.
4 Conjugation tube forms between two bacterial cells.
5 Single-stranded copy of F plasmid is transferred into recipient cell.

Which of the following order describes conjugation correctly?

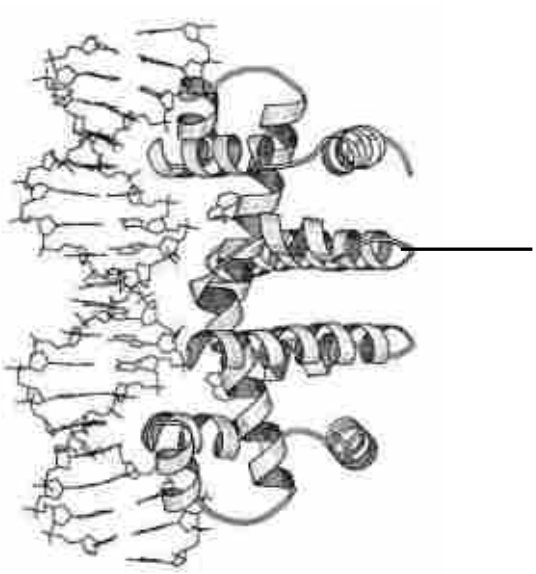
A 1 → 4 → 5 → 2 → 3

B 1 → 5 → 4 → 3 → 2

C 4 → 1 → 5 → 2 → 3

D 4 → 5 → 3 → 1 → 2

13 The diagram shows the binding of an active *trp* repressor protein to DNA.



Which of the options shows the most possible effect of a mutation of the *trp* repressor?

	Part of *trp* repressor affected by mutation	Type of mutation	State of *trp* operon in the presence of tryptophan
A	DNA binding site	Gain-of-function	Transcribed
B	DNA binding site	Loss-of-function	Not transcribed
C	Tryptophan binding site	Loss-of-function	Transcribed
D	Tryptophan binding site	Loss-of-function	Not transcribed

14 The table shows a comparison of some aspects of the genomes and protein-coding genes of eukaryotic and prokaryotic organisms.

Organism	Genome size / base pairs	Chromosome number	Estimated gene number
Human (*Homo sapiens*)	3 billion	46	About 25,000
Mouse (*Mus musculus*)	2.9 billion	40	About 25,000
Fruit fly (*Drosophila melanogaster*)	165 million	8	13,000
Plant (*Arabidopsis thaliana*)	157 million	10	25,000
Roundworm (*Caenorhabditis elegans*)	97 million	12	19,000
Yeast (*Saccharomyces cerevisiae*)	12 million	32	6,000
Bacteria (*Escherichia coli*)	4.6 million	1	3,200

Which of the following statement(s) account(s) for the differences seen in the table?

1 The greater the number of chromosomes an organism has, the larger its genome.
2 The presence of introns in the eukaryotes results in larger genomes and more chromosomes.
3 A larger number of genes would result in a significantly larger genome.
4 *Homo sapiens* and *Mus musculus* are the most closely related, hence they have similar genome size, number of chromosomes and gene number.

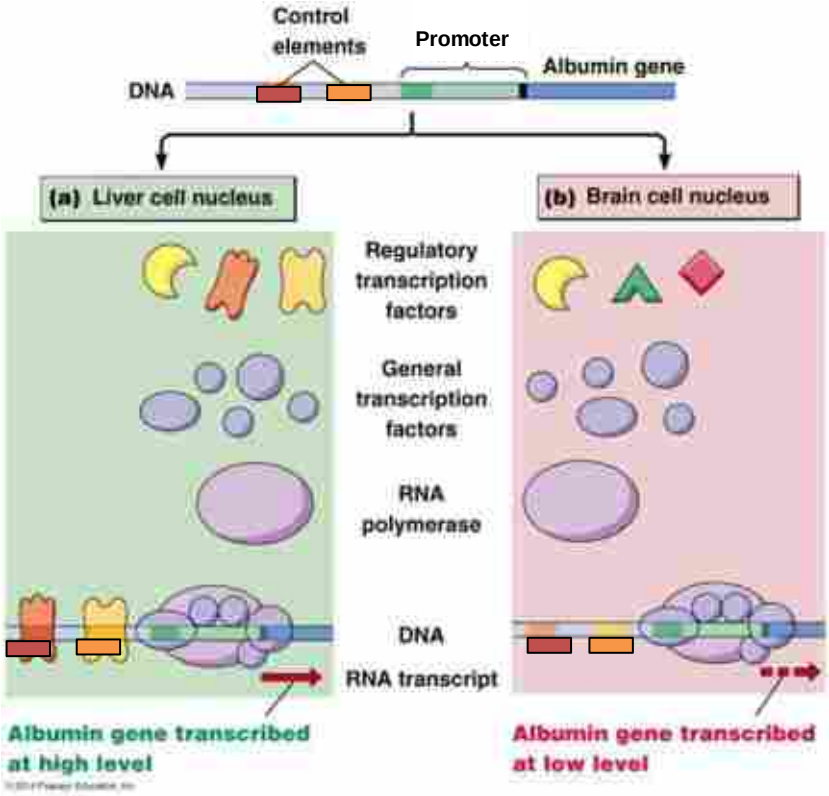
A 2, 3 and 4 only

B 1 only

C 4 only

D None of the above

15 Gene expression of albumin gene is regulated by two control elements and its promoter. These control elements are recognised by regulatory transcription factors which bind to allow for high rate of transcription of the albumin gene.



Which of the following is a result of differential albumin gene expression in liver cells and brain cells?

A Liver and brain cells are differentiated from different pluripotent stem cells, hence they contain different control elements which result in differential gene expression.

B Brain cells contain different RNA polymerases and general transcription factors resulting in low transcription of the albumin gene.

C Brain cells do not contain the regulatory transcription factors that are required to bind to the control elements of the albumin gene to promote the assembly of the transcription complex.

D Liver and brain cells contain the same regulatory control elements, RNA polymerase and transcription factors but a mutation has occurred in the regulatory control elements of the brain cells hence making them dysfunctional.

16 Which of the following is an example of translational control of gene expression?

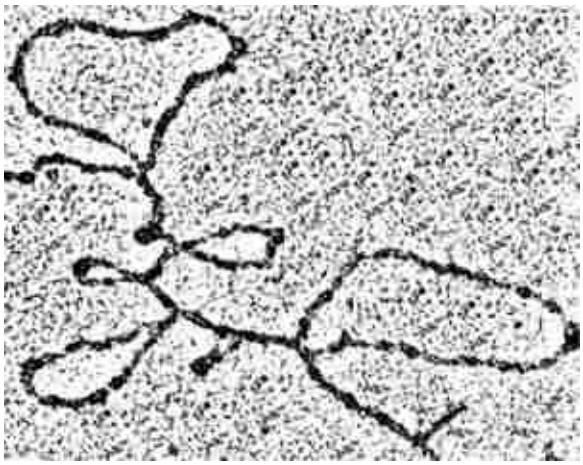
A The binding of protein factors to mRNA to prevent the binding of the small ribosomal subunit

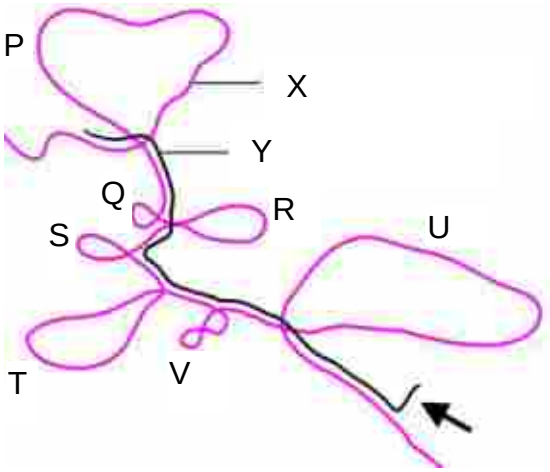
B The activation of proteins by association with other proteins

C The addition of chemical groups such as phosphates to free amino acids

D The degradation of a protein by proteasome

17 The ovalbumin gene from chicken was isolated and made single-stranded and then subsequently mixed together with its mature mRNA. The results were observed under an electron microscope. The electron micrograph and its corresponding diagrammatic representation show the binding of the mRNA to certain regions of the DNA.





Which of the following statement(s) can be concluded?

1 X is the template strand of DNA and Y is the mRNA strand transcribed from X.
2 P, Q, R, S, T, U and V correspond to the introns on the DNA that have been excised from the mRNA.
3 The arrow indicates the 3' end of the mRNA where the poly(A) tail was added during post-transcriptional modification.
4 The 3' end of the mRNA is free because there is no corresponding stretch on the template DNA where complementary base pairing can take place.

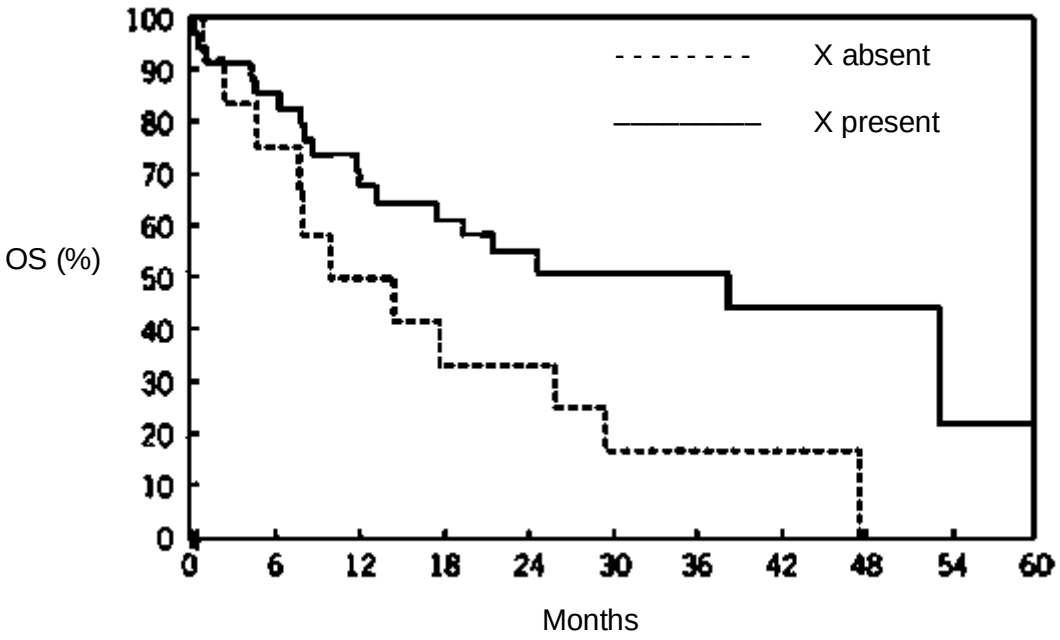
A 1, 2, 3 and 4

B 2, 3 and 4 only

C 1 and 2 only

D 1 only

18 A group of scientists discovered a novel protein and named it X. X is implicated in chromatin structure rearrangement in mammalian cells. The figure shows the overall survival (OS) percentage of cancer patients in the absence and presence of X.



Which of the following statement can best account for the increased survival rates of the cancer patients?

A X is involved in histone acetylation which results in the chromatin having a less compact structure leading to increased expression of tumour suppressor genes, hence allowing cell division to be regulated.

B X is involved in histone acetylation which results in the chromatin having a less compact structure leading leading to expression of oncogenes, hence allowing cell division to be regulated.

C X is involved in histone deacetylation which results in the chromatin having a less compact structure leading to expression of the telomerase gene, hence allowing cell division to be regulated.

D X is involved in histone deacetylation which results in chromatin having a more compact structure leading to a lack of expression of genes involved in angiogenesis, hence allowing cell division to be regulated.

19 In Shorthorn cattle, the allele for the absence of horns is dominant to the allele for the presence of horns. Coat colour can be red (genotype: $\mathbf{C^RC^R}$), roan (genotype: $\mathbf{C^RC^W}$) or white (genotype: $\mathbf{C^WC^W}$).

A roan bull, heterozygous for the hornless trait, is crossed with a cow of the same genotype. Which of the following statement(s) regarding the F_1 offspring is/are true?

1 The probability that a calf from this cross would have the same phenotype as its parents is 3/8.
2 The ratio of horned to hornless calves is 3:1.
3 The number of red and white calves is more than that of roan calves.

1

A 1 and 2 only

B 2 and 3 only

C 1 only

D 3 only

20 Wing size in *Drosophila* is controlled by a gene with three alleles. The normal wings are long while the other two traits arise as a result of mutation in the same gene locus. The order of dominance for these alleles is as follows.

Long (L) > Vestigial (L^{vg}) = Antlered (L^{a})

How many different genotypes for wing size are possible?

A 3

B 4

C 6

D 8

21 The coat colour of Norwegian cattle is mainly determined by the distribution of two pigments: red and black. Both pigments are produced by the action of the enzyme tyrosinase in cells called melanocytes. A low level of activity of the enzyme leads to the production of red pigment, whilst a high activity allows only black pigment production. The activity of the enzyme is increased by the melanocyte stimulating hormone (MSH), which binds to a MSH receptor. The receptor is coded for by the **E** gene locus, which has two alleles, **E** and **e**. No receptor is produced by the recessive allele **e**.

The dominant allele of a second gene, the **A** locus, codes for a protein which binds to and blocks the MSH receptors, thus preventing stimulation of tyrosinase activity in a melanocyte.

Which of the following statements about the two genes and their effects in the colouration of Norwegian cattle is true?

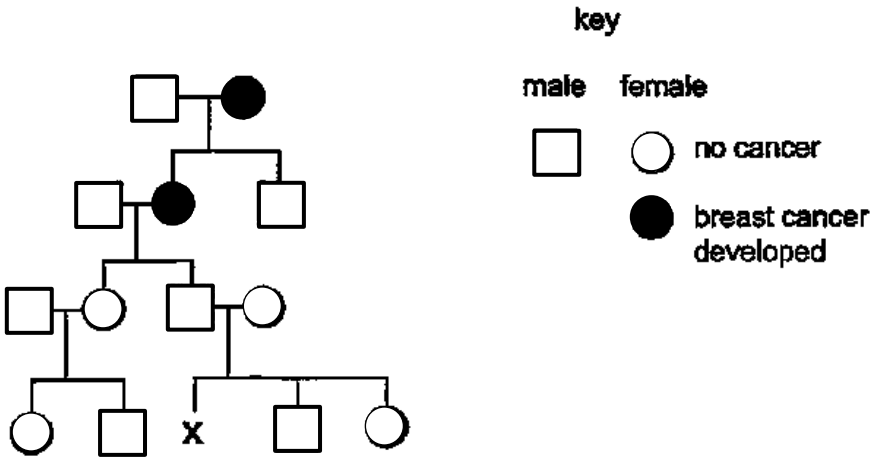
A Allele A is completely epistatic to allele a and allele E is completely epistatic to allele e.

B Cattle with the genotype AAEE have red coats.

C Cattle with black coats must have the genotype aaEe only.

D Cattle with the genotypes aaEE, aaEe and Aaee will have high tyrosinase activity.

22 The diagram below shows the inheritance of a form of breast cancer associated with the presence of just one mutant allele of an autosomal gene *BRCA1*.



What is the probability that woman X inherits the *BRCA1* mutant allele associated with breast cancer?

A 0.00

B 0.25

C 0.50

D 1.00

23 The table below shows the results of an early investigation into the genetic control of phenotypic variation. The dry masses of 5493 bean seeds collected from many plants were classified into nine categories.

Mass of bean/mg	51-150	151-250	251-350	351-450	451-550	551-650	651-750	751-850	851-950
Number of beans	5	38	370	1676	2255	928	187	32	2

Which statement correctly describes these data and could account for the variation shown?

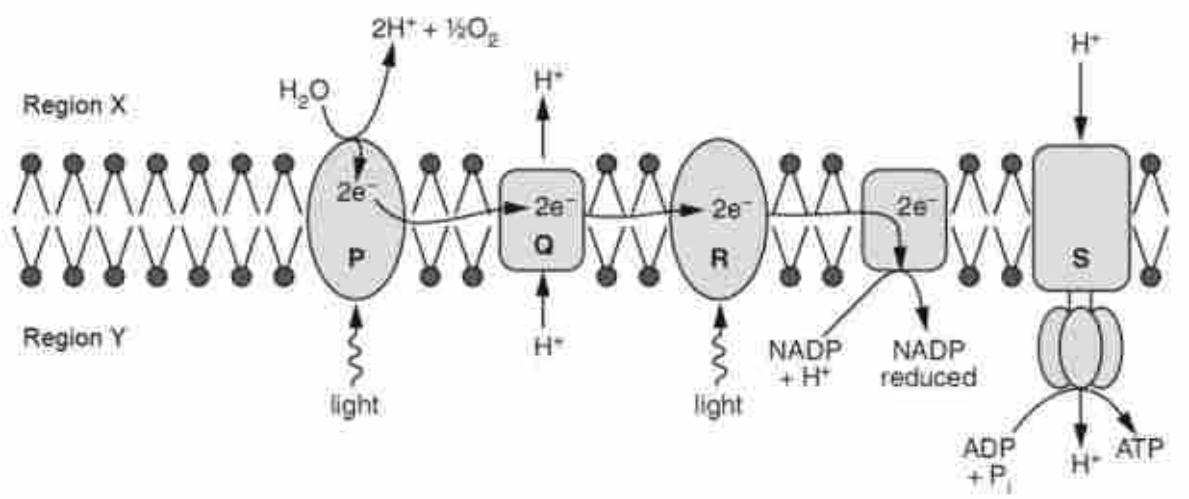
A The phenotypic variation is continuous and could be the result of two non-linked genes acting on their own.

B The phenotypic variation is continuous and could be the result of several non-linked genes acting on their own.

C The phenotypic variation is discontinuous and could be the result of two linked genes acting on their own.

D The phenotypic variation is discontinuous and could be the result of several linked genes acting on their own.

24 The diagram below represents a cross section of a thylakoid, showing some components which are involved in the light-dependent stage of photosynthesis.



Which of the following statements about the following components in the light-dependent stage is true?

A An inhibitor which blocks electron flow through R would inhibit the production of oxygen at P.

B In structures P and R, electrons are passed from one pigment molecule to another until it reaches chlorophyll *a*.

C Region X is expected to have a higher pH than Region Y.

D There is a non-cyclical flow of electrons through structures P, Q, R and S.

25 In respiration, the enzyme hexokinase uses ATP to transfer a phosphate group to glucose to form glucose-6-phosphate.

If a cell only has glucose available for energy and the activity of hexokinase is suddenly inhibited in this cell, which of the following will occur?

1 The cell will not be able to produce pyruvate through glycolysis.
2 Respiratory processes in the mitochondria would not proceed.
3 The use of oxygen by the cell will decrease.

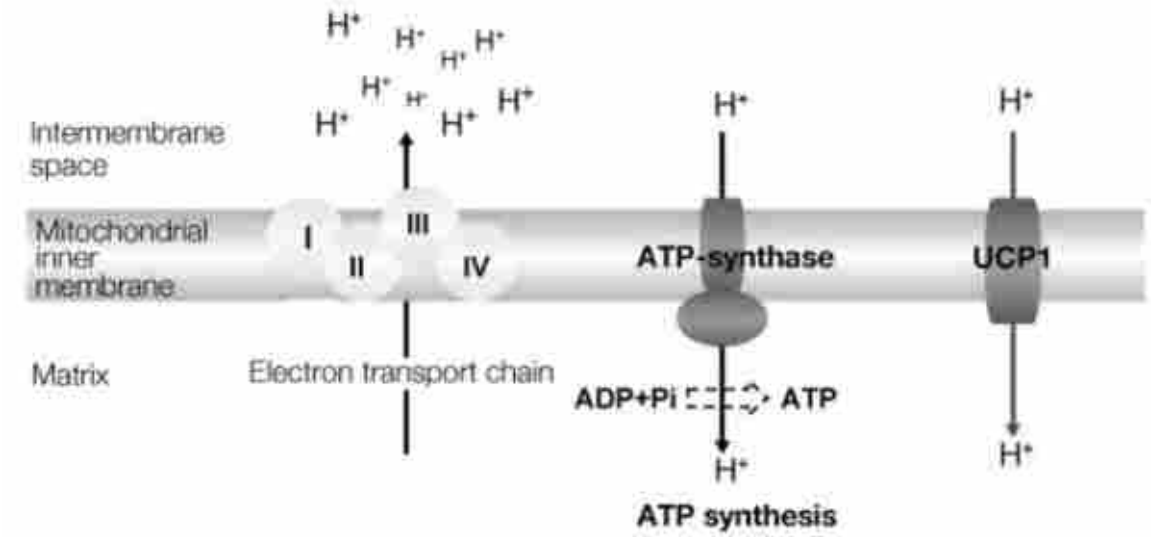
A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

26 Thermogenesis is a process that helps certain animals to maintain a constant body temperature. Such animals are found to contain a lot of mitochondria which have proton channels known as UCP1 embedded in the inner membrane as shown below.



Based on the above information, which of the following statements is a likely explanation for the role of UCP1 in thermogenesis?

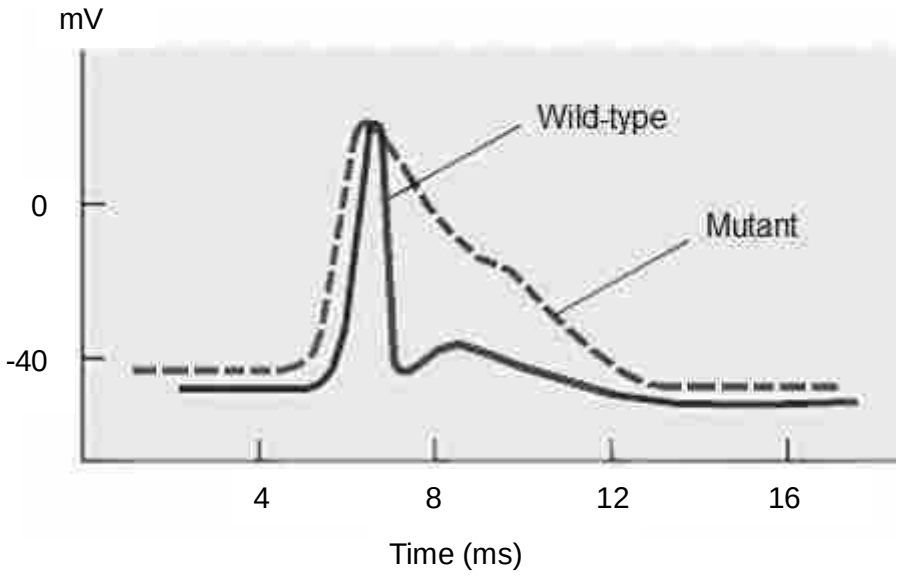
A UCP1 disrupts the flow of electrons along the electron transport chain, channelling protons through it instead of ATP synthase, thus producing heat in the process.

B A proton gradient cannot be established as UCP1 allows protons to pass through the inner membrane passively, hence the energy released from electron transfer is used for heat production.

C The proton motive force is dissipated as heat due to protons flowing through UCP1 instead of passing through ATP synthase.

D The presence of UCP1 allows more protons to diffuse into the intermembrane space so that more protons can eventually diffuse through ATP synthase for ATP production to generate heat.

27 An experiment was carried out to investigate the effect of a particular gene mutation. The action potentials of wild-type flies and mutant flies are shown below.



Which of the following can explain the shape of the action potential in the mutant flies?

A Voltage-gated sodium ion channels were unable to close

B Defective voltage-gated potassium ion channels

C Hyperactive sodium-potassium pumps

D Slow-opening ligand-gated potassium ion channels

28 Some receptors for growth factors activate a protein kinase cascade, usually with the participation of multiple enzymes which cause changes in gene expression. Which of the following statements regarding cell signalling are true?

1 Multiple steps allow the amplification of a signal.
2 External signals can lead to changes in gene expression.
3 The same signal can lead to different responses in cells due to the presence of different target proteins.
4 All cascade systems modify gene expression by activating kinases that enter the cell nucleus by phosphorylating specific transcription factors.

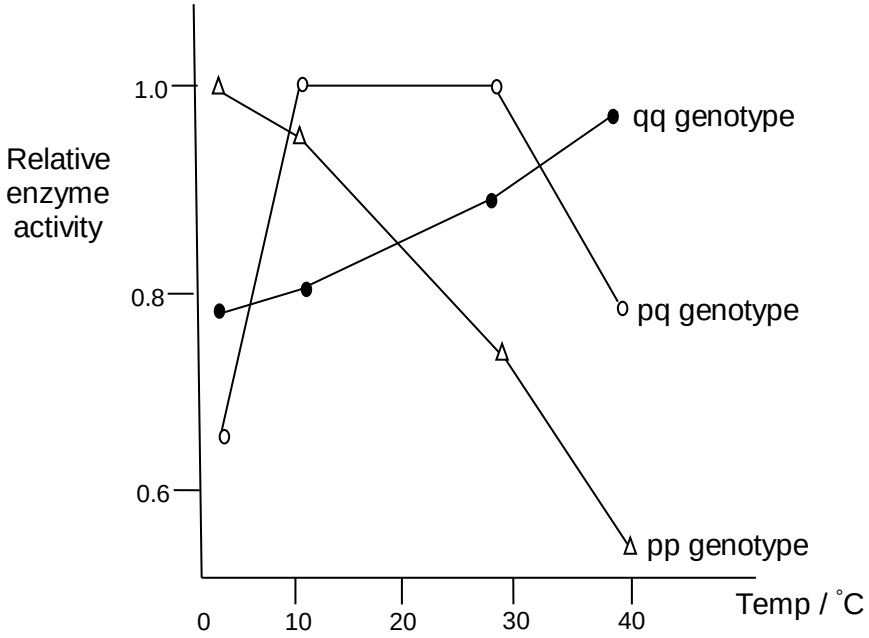
A 1, 2, 3 and 4

B 1, 2 and 3 only

C 1 and 2 only

D 3 and 4 only

29 In the North American catfish *Catostomus elarki*, two alleles represented by p and q, control the synthesis of a vital enzyme. The three possible genotypes (pp, pq, qq) lead to the synthesis of variations of the same enzyme with different temperature optima as shown in the graph below.



When the mean annual temperature is 5°C, which of the following statements are correct?

1 Allele q will be positively selected for.
2 The proportion of allele p in the gene pool will increase over time.
3 The heterozygotes will have a selective advantage over the homozygotes.
4 The catfish will develop a new enzyme variant that has a temperature optimum at 5°C.
5 Catfish with genotype pp will have a selective advantage over the others.

A 1 and 3 only
B 2 and 4 only
C 2 and 5 only
D 3 and 4 only

30 A large population of a certain species of freshwater fish lives in a South America lake. Assuming that there are no mutations, all immigration into the population is prevented and there is no change in selection pressure, which one of the following statements best expresses the probable future of the population?

A All evolution will promptly cease because without mutation, there will be no raw material for evolution.

B The population will begin to decrease in size after three to four generations because of excessive inbreeding that will result from the absence of immigration.

C The population will continue to evolve as selection acts on the different allelic combinations formed during meiosis.

D The population will cease to evolve and may survive for a long time as long as there is no selection.

31 When organochlorine insecticides such as DDT were in widespread use, mosquitoes in malarial regions developed resistance more rapidly than did houseflies in Britain. What could account for the difference in the rates of the development of resistance?

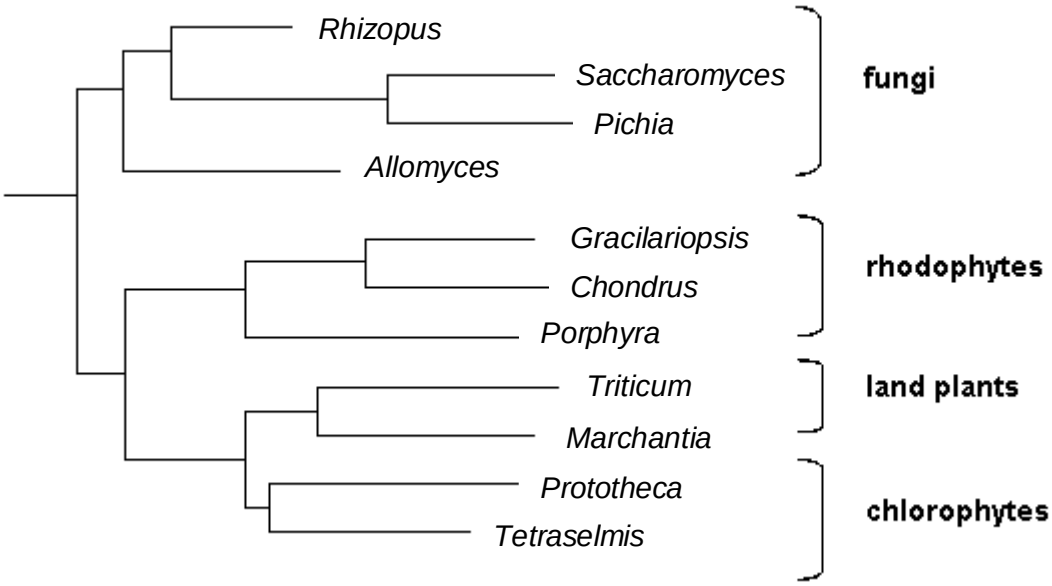
A Mosquitoes produce fewer generations a year.

B More insecticide was used in Britain.

C More insecticide was used in malarial regions.

D Mosquitoes show fewer random mutations per generation.

32 The phylogenetic tree below is derived from comparisons made with mitochondrial DNA from animals, fungi, rhodophytes (red algae) and plants.



What may be concluded from the above phylogenetic tree?

1 *Triticum* and *Marchantia* form a clade while *Allomyces* does not belong to any clade.
2 *Gracilariopsis*, *Chondrus* and *Porphyra* have evolved from the same most recent ancestor.
3 Chlorophytes and land plants are more closely related compared to chlorophytes and rhodophytes.
4 The rhodophytes share a common ancestry with chlorophytes and land plants.

A 1, 2 and 3 only

B 2, 3 and 4 only

C 2 and 4 only

D 3 and 4 only

33 In genetic engineering, which of the following are possible reasons for the limit on the size of the gene to be inserted into a plasmid vector?

1 cDNA is usually used instead of genomic DNA.
2 Probability of number of errors during replication increases as size of gene increases.
3 Number of ligases needed increases with an increase in the size of gene.
4 Efficiency of transformation of competent bacteria decreases with an increase in size of gene.

A 1, 2 and 4 only

B 2, 3 and 4 only

C 1 and 3 only

D 2 and 4 only

34 Which of the following statements regarding Restriction Fragment Length Polymorphisms (RFLP) and their analyses are correct?

1 RFLPs tightly linked to a gene coding for a disease can be used for disease detection.
2 All RFLPs exist as dominant and recessive alleles.
3 RFLPs can identify all single base pair changes in a chromosome.
4 All changes in restriction enzyme sites can be used as genetic markers.

A 1, 2, 3 and 4

B 1, 2 and 3 only

C 2, 3 and 4 only

D 1 and 4 only

35 Which of the following is an ethical concern of the Human Genome Project?

A Difficult to develop treatment for diseases involving multiple genes

B Costly procedures limit genetic testing to those who can afford them

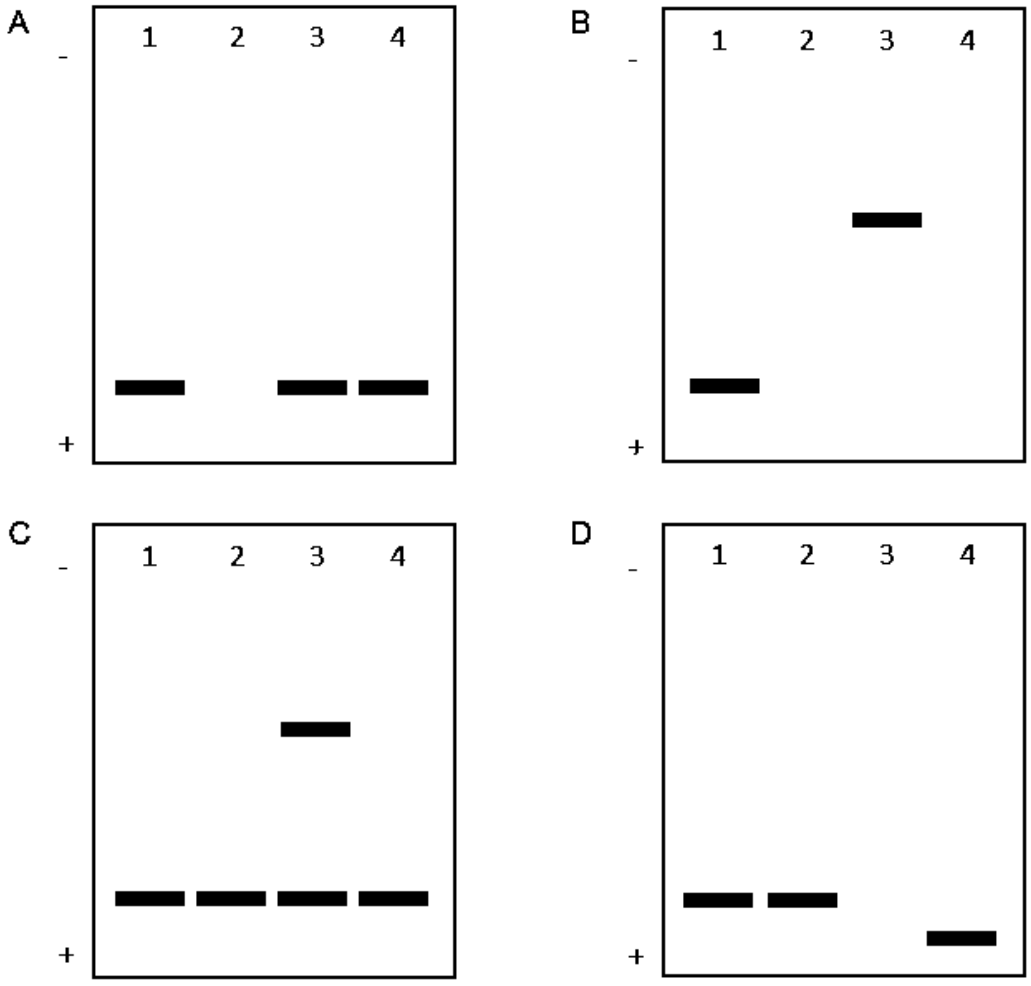
C Genetic testing may not provide reliable and accurate information

D Unborn foetuses detected with diseases may be aborted

36 Polymerase chain reactions (PCRs) were carried out on fruit fly genomic DNA. The DNA was added to four test-tubes and the treatments for the test-tubes are shown in the table below. The primers were designed to amplify a DNA section which is about 2 kb long.

Test-tube	Reagents	Temperature
1	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 72°C (for 120 s)
2	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	55°C (for 75 s) → 72°C (for 120 s)
3	Forward primers only, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 72°C (for 120s)
4	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 37°C (for 120 s)

After the above treatments were completed, gel electrophoresis was carried out on the contents of each test-tube. Which of the following electrophoregrams shows the correct results for each of the tubes? Ans B



37 Which of the following best illustrates totipotency?

A A somatic cell isolated from a root tip develops into a normal adult plant.

B Stem cells are able to divide indefinitely.

C Mesenchymal stem cells can differentiate into an extensive range of cell types, including bone cells, cartilage cells, muscle cells and fat cells.

D The replacement of the nucleus of an unfertilised egg with that of a pancreatic cell converts the egg into a pancreatic cell.

38 Which of the following are social implications for the use of gene therapy in treating genetic diseases?

1 Gene therapy might provide alternative treatments for patients where conventional treatments have failed.
2 Genetic enhancements can be costly and accessible only to the wealthy.
3 There is difficulty in determining which conditions are normal and which are considered disorders.

A 1, 2 and 3

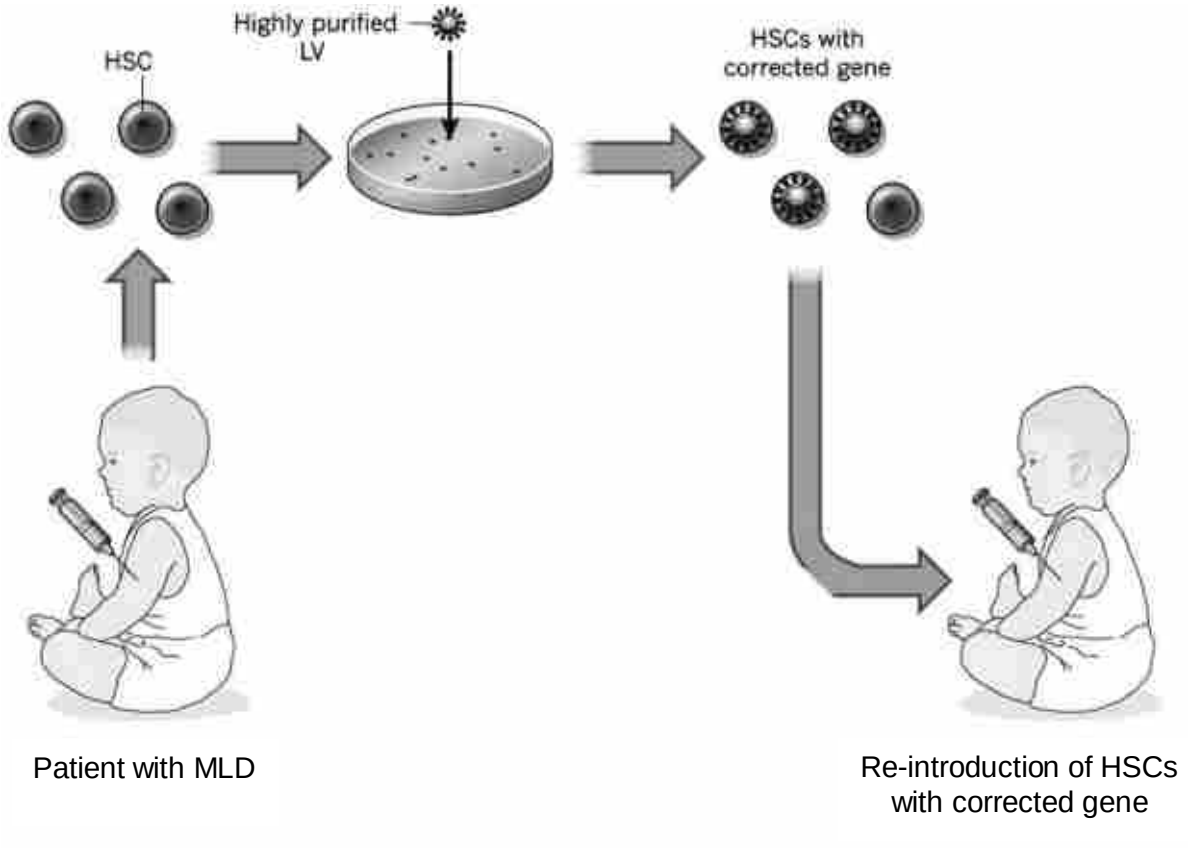
B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

39 Metachromatic leukodystrophy (MLD) is an inherited disorder caused by a deficiency in arylsulphatase A (ARSA) enzyme activity in leukocytes. Patients with MLD accumulate a toxic metabolite and die within a few years.

In a clinical trial, a team of scientists collected haematopoietic stem cells (HSCs) from the bone marrow of children with MLD and exposed them to lentiviral vectors (LV) carrying normal ARSA genes. These genes were then integrated into HSC genomic DNA. HSCs with the corrected gene were then re-introduced into the children's bone marrow.



Which of the following statement(s) regarding the treatment of MLD is/are true?

1 This method of treatment is beneficial as it reduces the risk of incompatibility of HSC transplants.
2 This method of treatment is less effective than introducing lentiviruses containing the normal ARSA genes into the patient directly.
3 Other than HSCs, it is also possible to use leukocytes as target cells for gene therapy.

A 1, 2 and 3
B 1 and 2 only
C 1 and 3 only
D 3 only

40 Transgenic crops expressing insecticidal toxins could provide an effective means of pest control. However, the widespread cultivation of such transgenic crops is expected to promote the development of toxin-resistant pests, hence eventually compromising the usefulness of the pest management strategy. Two planting strategies have thus been recommended to prevent the development of toxin-resistant pests:

Strategy 1: Separate fields of transgenic plants and non-transgenic plants are planted

Strategy 2: 'Seed mixtures' of such transgenic plants and non-transgenic plants in the same field are planted

Which of the following considerations would most likely encourage farmers to favour Strategy 1 over Strategy 2?

A Low mortality of susceptible insects on toxin-free plants

B Movement of randomly mating insects from plant to plant within a field

C Concern that 'superweeds' might emerge in fields with 'seed mixtures'

D When toxin resistance is recessive and frequency of recessive alleles is low

Name	Subject Class	Class	Candidate Number
	2BI		

ANGLO-CHINESE JUNIOR COLLEGE
Preliminary Examination 2016

BIOLOGY **9648/02**
22 AUGUST 2016
HIGHER 2 **2 hours**

Paper 2 Core Paper

Additional Material: Writing Paper

READ THESE INSTRUCTIONS FIRST
Write your name, index number and class on this answer booklet.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

At the end of the examination, circle the number of the Section B question you have answered in the grid opposite.
Fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
8	
Section B	
9 or 10	
Total	**100**

This question paper consists of **21** printed pages.

[Turn over

1 The appearance of cancer cells has been known to be different from normal cells. These differences have been used as a method of diagnosis by doctors. Prostate cells taken from wild-type mice and mice with prostate cancer were analysed.

Fig. 1.1 compares the same organelle found in these cells viewed under the electron microscope, while Fig. 1.2 shows the levels of ribosomal RNA (rRNA) measured in these two types of cells.

Part of a prostate cell from wild-type mice

Part of a prostate cell from mice with prostrate cancer

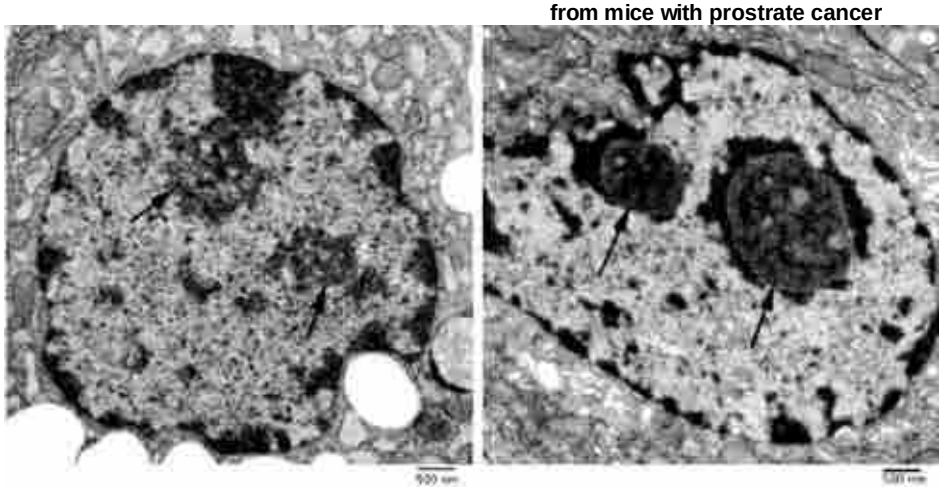


Fig. 1.1

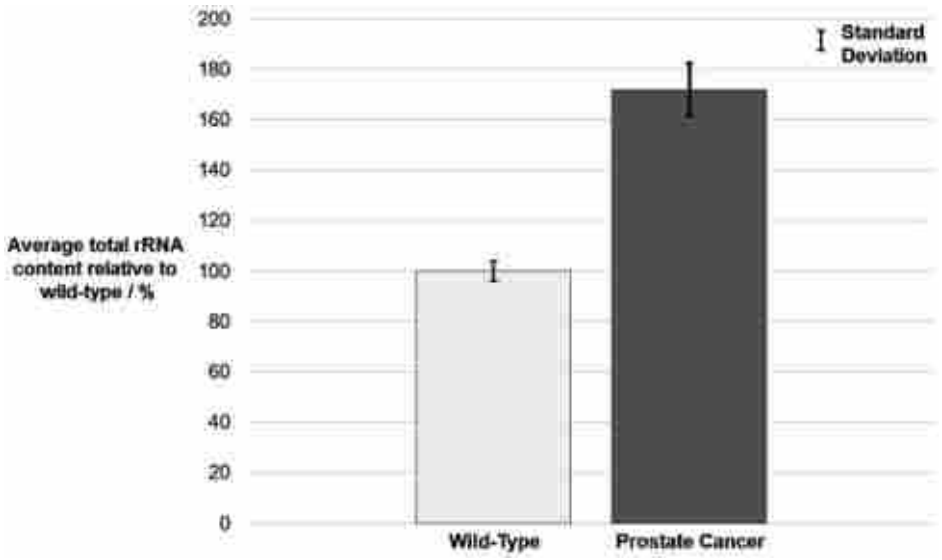


Fig. 1.2

For examiner's use

Formatted Table

(a) (i) Identify the regions indicated by the arrows in Fig. 1.1.

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..... [1]

(ii) With reference to the regions identified in Fig. 1.1 and information given in Fig. 1.2, describe the differences between wild-type prostate cells and prostate cancer cells.

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(iii) Explain the differences described in (a)(ii).

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..... [3]

For Examiner's Use

Studies on ribosomal proteins have shown that these proteins undergo a high degree of post-translational modifications, including methylation, acetylation and phosphorylation.

(b) Suggest reasons why post-translational modification of ribosomal proteins is needed.

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..... [2]

[Total: 8m]

2 The meiotic cell cycle in the diploid germ cells of an organism can be followed by measuring the number of chromosomes as well as the amount of DNA material per cell over a period of time. Fig. 2.1 shows the results of the analyses, beginning with the start of prophase.

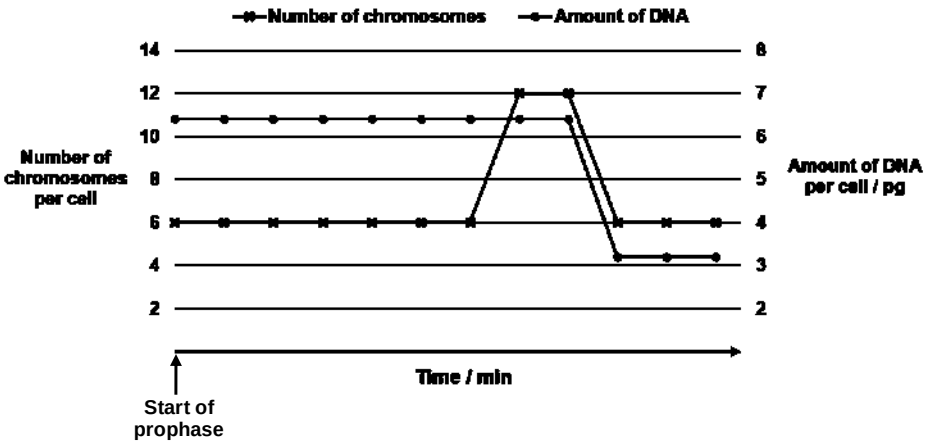

Fig. 2.1

(a) (i) On Fig. 2.1, indicate with an arrow where anaphase begins. [1]

(ii) Explain whether Fig. 2.1 shows the first or the second meiotic division.

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(iii) The centromere of a chromosome comprises non-coding tandem repeats. Suggest how the structure of the centromere allows it to carry out one of its functions in cell division.

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In normal cells, the ends of chromosomes do not normally fuse with each other. However, in senescent cells where the ends of chromosomes are eroded to a critical length due to the end-replication problem, chromosomes may undergo end-to-end fusions. Fig. 2.2 shows how the ends of two sister chromatids may fuse and subsequently break during cell division at a location other than the point of fusion.

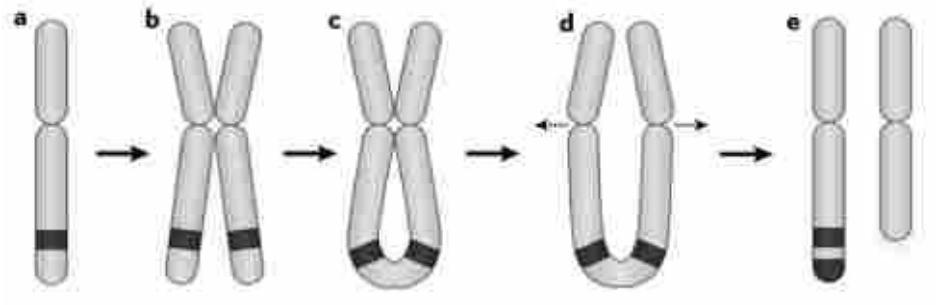

Fig. 2.2

(b) (i) Describe the result of the chromosomal mutation on the chromosomes shown in Fig. 2.2(e).

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.....[1]

(ii) Suggest how the ends of chromosomes are normally protected from end-to-end fusions.

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.....[1]

(iii) Explain how the end-replication problem will lead to the erosion of the ends of chromosomes.

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.....[3]

[Total: 11m]

For examiner's use

For Examiner's Use

3 **(a)** A new type of influenza drug has been shown to be effective against drug-resistant strains of the flu virus, according to a study led by University of British Columbia researchers in 2013. This drug works by inhibiting newly-formed influenza viruses from leaving the cell surface membrane of host cells, thus preventing the infection of other host cells.

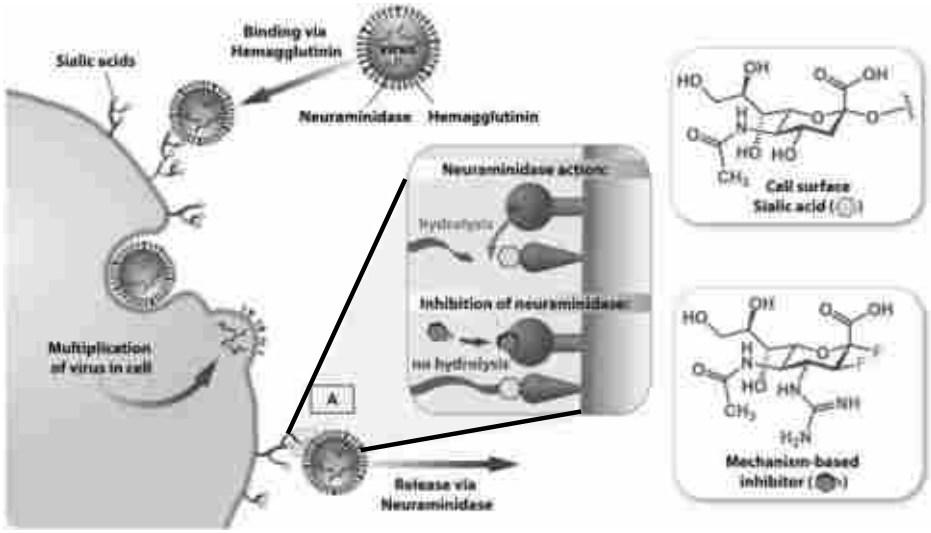

Fig. 3.1

(i) Describe the process by which influenza viruses replicate in host cells.

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For examiner's use

(ii) With reference to Fig. 3.1, describe how the drug prevents the newly formed influenza viruses from infecting other host cells in the process labelled **A**.

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(iii) Suggest a limitation of using this type of influenza drug.

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.....[1]

(b) Describe the differences between the lysogenic life cycle of a lambda phage and the life cycle of an influenza virus.

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[Total: 10m]

For examiner's use

4 The most common type of lung cancer is non-small cell lung cancer (NSCLC) which affects between 75% to 85% of all lung cancer patients. The *c-Met* gene which is located on chromosome 7 has been implicated in NSCLC.

To investigate the role of *c-Met* gene in NSCLC, researchers studied the level of expression of c-Met receptor tyrosine kinase protein in several NSCLC cancer cell lines.

cDNA was generated from mRNA samples from the cancer cell lines and subsequently sequenced. Fig. 4.1a shows the normal cDNA. The corresponding protein regions it codes for are labelled. Fig. 4.1b shows two mutant cDNAs and the corresponding protein regions they code for. The corresponding regions shown in the mutant cDNA may or may not be translated to functional protein structures.

Normal cDNA:

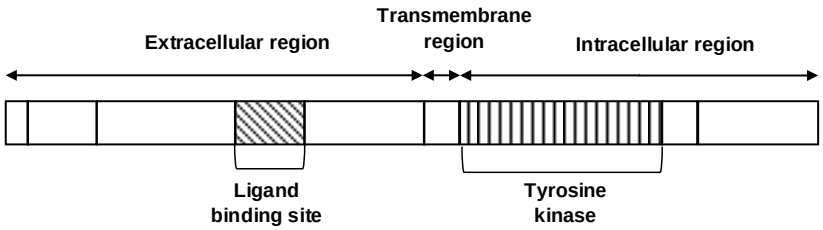

Fig. 4.1a

Mutant 1 cDNA:

Mutant 2 cDNA:

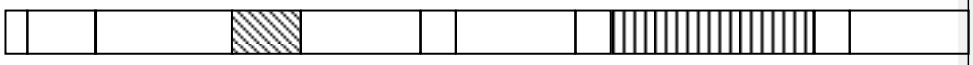

Fig. 4.1b

For Examiner's Use

With reference to Fig. 4.1a and 4.1b,

(a) (i) State and explain the types of mutation in the *c-Met* gene that could have resulted in mutant 1 and mutant 2.

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9

Fig. 4.2 shows the cell signaling pathway of the c-Met receptor tyrosine kinase protein.

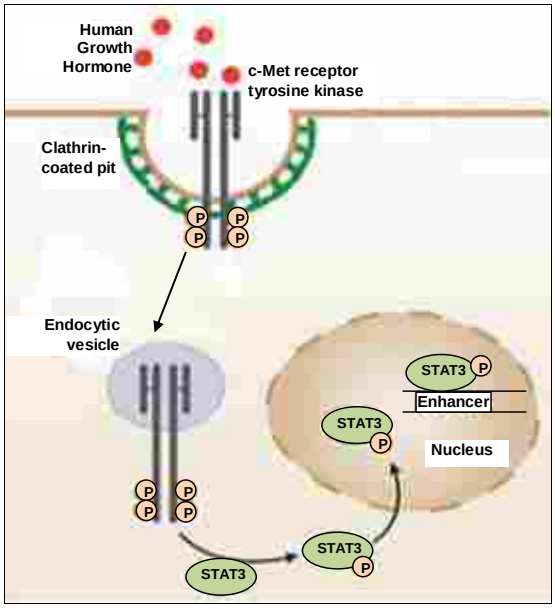

Fig. 4.2

(b) With reference to Fig. 4.2, describe the mechanism by which STAT3 controls the expression of genes involved in cell division.

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..... [4]

For examiner's use

For Examiner's Use

For examiner's use

(c) Many cells are shown to have a mutation in the *c-Met* gene resulting in a hyperactive c-Met receptor tyrosine kinase. However, not all of these cells develop into cancerous cells. Explain why.

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[Total: 12m]

For examiner's use

5 (a) A geneticist is interested in studying eye and body pigmentation in *Drosophila*. The genes for eye colour and body colour are located 11 cM apart on chromosome 3. Purple eye is produced by a dominant mutation that is lethal in a homozygous state.

Female flies with purple eyes (**E**) and ebony bodies (**b**) were mated with male flies which were true-breeding for red eyes (**e**) and yellow bodies (**B**). All the F_1 offspring of this cross had yellow bodies. F_1 female flies which had purple eyes were chosen and test-crossed with male flies. 200 flies were present in the F_2 generation. There were equal numbers between the two parental phenotypes and equal numbers between the recombinant phenotypes.

(i) Draw a genetic diagram of the F_1 cross to show the observed results, indicating clearly the number of individuals in each different phenotypic class in the F_2 offspring.

[5]

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In many other crosses, the proportion of recombinant offspring obtained is lower than the one observed in (a)(i). One possible cause is the occasional occurrence of a double cross-over in female *Drosophila*, as shown in Fig. 5.1 for a doubly heterozygous female.

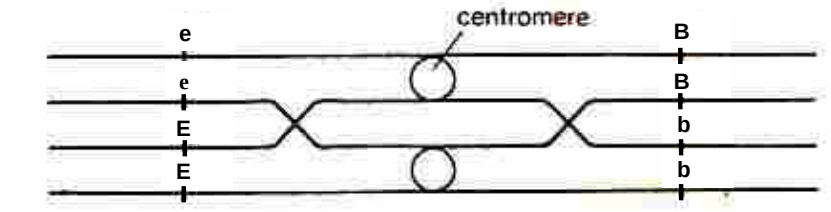

Fig. 5.1

(ii) Assuming that a double cross-over does occur between the two genes, suggest why the recombination frequency between the two loci would be lower than the predicted percentage.

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..... [1]

In a separate experiment, the geneticist decides to investigate the chromosomal positions of genes controlling body pigmentation and wing shape in *Drosophila*. The alleles for these traits are shown below.

B: Allele for grey body **b:** Allele for black body
C: Allele for straight wings **c:** Allele for curved wings

He carried out a cross between a female fly heterozygous for both loci with a homozygous recessive black-bodied, male fly with curved wings and obtained a large number of offspring. Table 5.1 shows the results.

Table 5.1

Phenotype	**Number of offspring**
Grey-bodied, straight wings	35
Black-bodied, straight wings	37
Grey-bodied, curved wings	35
Black-bodied, curved wings	33

A chi-squared test was used to find out if there is any significant difference between the observed and expected ratios.

The table of probabilities is given as follows:

degrees of freedom	probability, p				
	0.10	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

For examiner's use

For Examiner's Use

(b) The calculated χ^2 value is found to be 0.229. Using the chi-squared (χ^2) test and the information given above, state the conclusion that may be drawn from the result.

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.....[4]

[Total: 10m]

For examiner's use

For Examiner's Use

For examiner's use

6 Fig. 6.1 shows an electron micrograph of a plant cell.

Fig. 6.1

(a) (i) Name the macromolecule which makes up structure **A**.

.....[1]

For Examiner's Use

(ii) Describe how the structure of the named macromolecule in (a)(i) gives rise to its fibrous nature.

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.....[3]

Fig. 6.2 shows how a seed undergoes germination to form a seedling.

Fig. 6.2

(b) (i) State what is meant by respiratory quotient (RQ).

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.....[1]

(ii) In some pea plants, the RQ has been found to be between three and four at the start of germination. Suggest a reason to explain the high RQ obtained at the early stages of germination.

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.....[2]

(iii) Following root growth, leaves will develop and this is necessary for the seedling to harvest energy from the sun. Light intensity plays a role in determining the rate of photosynthesis. State why the rate of photosynthesis remains constant even at high light intensity.

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.....[1]

[Total: 8m]

For examiner's use

For Examiner's Use

For examiner's use

7 The Fluid Mosaic Membrane Model of biological membrane structures was proposed as a basic framework model to describe the basic structures of biological membranes.

Synapses are unique cell junctions found between a neurone and another cell that serve to conduct signals in a neural pathway. A chemical synapse is cholinergic if it uses acetylcholine as its neurotransmitter.

(a) Explain the significance of the Fluid Mosaic Model of membrane structures in the transmission of signals across a cholinergic synapse.

[4]

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Transmission at the neuromuscular junctions takes place in the same way as synapses between nerve cells. Fig. 7.1 shows a chemical synapse formed by the contact between a motor neurone and a muscle cell at the neuromuscular junction.

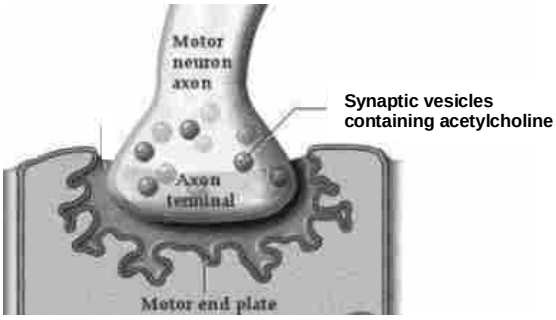

Fig. 7.1

Suxamethonium is a drug that mimics the action of acetylcholine (ACh) at acetylcholine receptors of the motor end plate. Unlike ACh, it cannot be hydrolysed by acetylcholinesterase.

(b) With reference to the above information, explain the effect of suxamethonium on the muscles.

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..... [4]

[Total: 8m]

For examiner's use

For Examiner's Use

For examiner's use

8 (a) The camelids are a group of mammals that share a large numbers of homologies. Recognisable camelids have been found fossilized in rock that are 45 million years old. Modern camelids have a discontinuous distribution. Guanacos and vicunas are found in South America together with the domesticated llamas and Alpacas. Bactrian Camels and Dromedaries are found in the Asian and South African deserts.

(i) Explain how homologies in camelids supports Darwin's theory of descent with modification.

[4]

(ii) Without considering the theory of continental drift, explain how discontinuous distribution of modern day camelids poses a problem to Darwin's theory of descent with modification.

[2]

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(b) Fig. 8.1 is a graph which shows the relationship between the number of amino acid changes of the protein haemoglobin with respect to the number of years since two organisms diverged from their common ancestor.

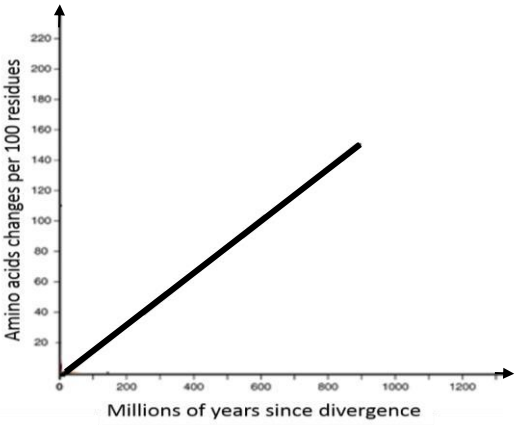

Fig. 8.1

(i) Explain the significance of the shape of the graph shown in Fig. 8.1.

For Examiner's Use

[4]

(ii) Compare neutral mutation and silent mutation.

.....

.....

.....

.....

.....

..... [3]

[Total: 13m]

For examiner's use

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Section B

Answer **EITHER 9 OR 10**.

Write your answers in the lined pages provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

EITHER

9 **(a)** Using the induced-fit hypothesis, explain the mode of action of enzymes. [6]

(b) With reference to haemoglobin, explain the significance of bonds in maintaining the protein's structure and function. [8]

(c) Compare competitive and non-competitive inhibition of enzyme action. [6]

[Total: 20m]

OR

10 **(a)** Explain the roles of the key components of the homeostatic control system. [6]

(b) With the use of named examples, describe the role of hormones in the regulation of blood glucose concentration in humans. [8]

(c) Explain the significance of cell signalling pathways in homeostasis. [6]

[Total: 20m]

Name	Subject Class	Class	Candidate Number
	2BI		

ANGLO-CHINESE JUNIOR COLLEGE
Preliminary Examination 2016

BIOLOGY **9648/02**
22 AUGUST 2016
HIGHER 2 **2 hours**

Paper 2 Core Paper

Additional Material: Writing Paper

READ THESE INSTRUCTIONS FIRST
Write your name, index number and class on this answer booklet.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

At the end of the examination, circle the number of the Section B question you have answered in the grid opposite.
Fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
8	
Section B	
9 or 10	
Total	**100**

This question paper consists of **21** printed pages.

[Turn over

For examiner's use

1 The appearance of cancer cells has been known to be different from normal cells. These differences have been used as a method of diagnosis by doctors. Prostate cells taken from wild-type mice and mice with prostate cancer were analysed.

Fig. 1.1 compares the same organelle found in these cells viewed under the electron microscope, while Fig. 1.2 shows the levels of ribosomal RNA (rRNA) measured in these two types of cells.

Part of a prostate cell from wild-type mice

Part of a prostate cell from mice with prostate cancer

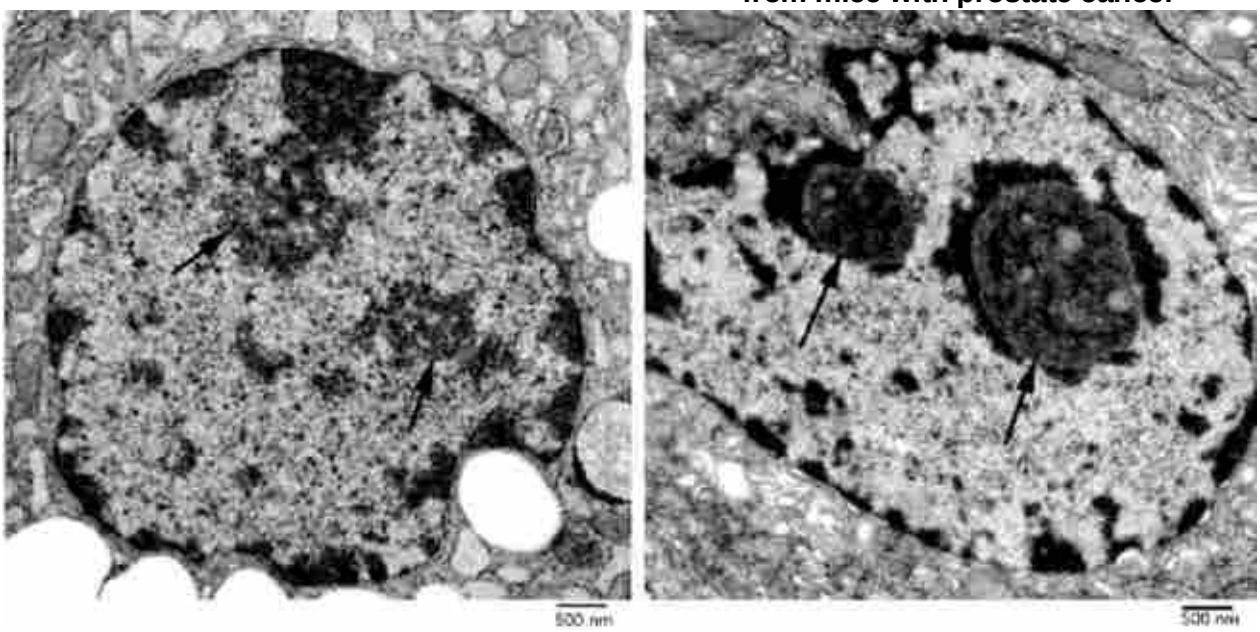

Fig. 1.1

For Examiner's Use

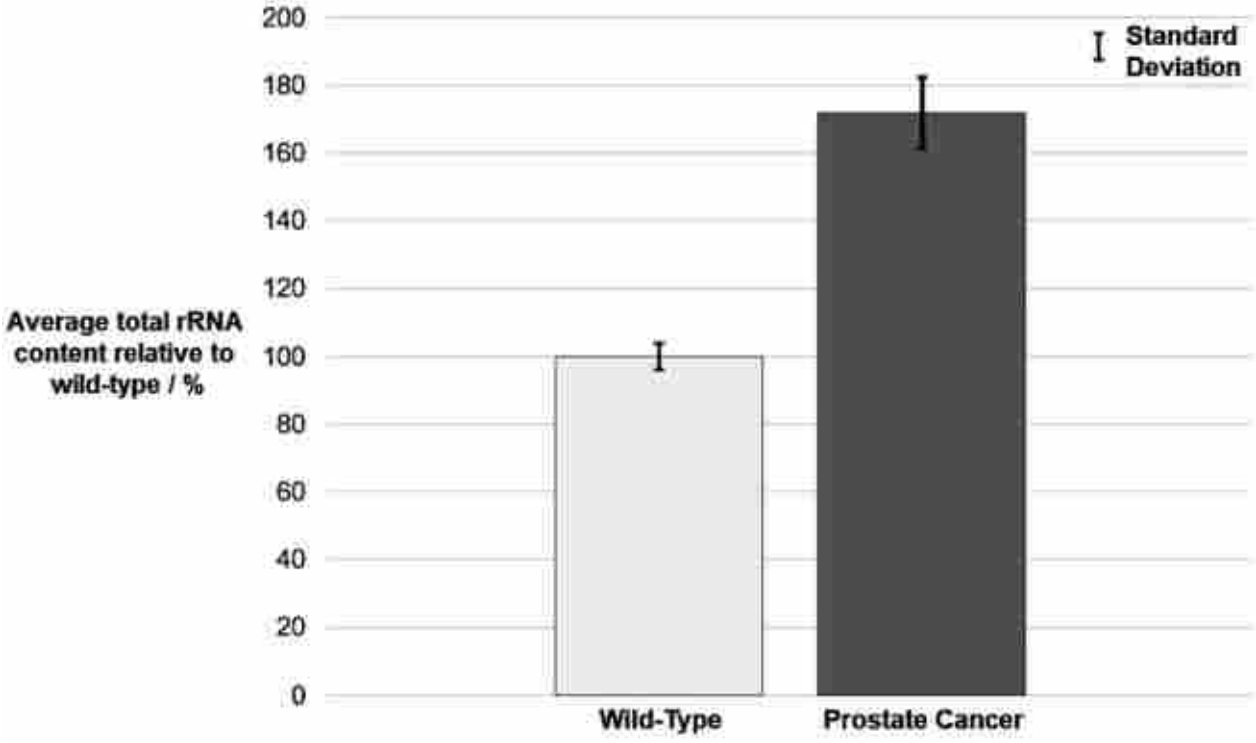

Fig. 1.2

(a) (i) Identify the regions indicated by the arrows in Fig. 1.1.

Nucleoli;

R! Nucleolus [1]

(ii) With reference to the regions identified in Fig. 1.1 and information given in Fig. 1.2, describe the differences between wild-type prostate cells and prostate cancer cells.

1. **Prostate cancer cells have denser / larger nucleoli;**
2. **Prostate cancer cells contain more rRNA / show greater variation in rRNA content compared to wild-type cells + Ref. to data from Fig. 1.2 (72% higher in average total rRNA content / higher standard deviation of 20% vs 8%);**

@ 1m

[2]

(iii) Explain the differences described in (a)(ii).

1. **Nucleoli are the sites of rRNA synthesis through transcription / sites of assembly of ribosomal subunits, hence appear denser in cancer cells;**
2. **Cancer cells undergo higher rates of protein synthesis in preparation for faster rate of cell division;**
3. **Higher rates of translation is facilitated by a greater number of ribosomes, hence the higher rRNA content in cancer cells;**
4. **(Different cancer cells have different mutations resulting in) dysregulation of gene expression in cancer cells lead to different cells having different rates of protein synthesis and greater variation in rRNA content;**

@ 1m, max 3

[3]

Studies on ribosomal proteins have shown that these proteins undergo a high degree of post-translational modifications, including methylation, acetylation and phosphorylation.

(b) Suggest reasons why post-translational modification of ribosomal proteins is needed.

1. **Plays a role in the regulation of rate of translation / rate of protein synthesis / translation accuracy;**
2. **Affects the folding / 3D configuration of ribosomal proteins, which affects their binding with rRNA / assembly of ribosomal subunits;**
3. **Contributes to the stability of ribosomal proteins, making them more resistant to degradation by proteases;**
4. **Provides for diversity in protein structure beyond that allowed by the 20 encoded amino acids;**
5. **Ref. to inactive proteins becoming active, or making proteins functional;**

@ 1m, max 2

[2]

[Total: 8m]

2 The meiotic cell cycle in the diploid germ cells of an organism can be followed by measuring the number of chromosomes as well as the amount of DNA material per cell over a period of time. Fig. 2.1 shows the results of the analyses, beginning with the start of prophase.

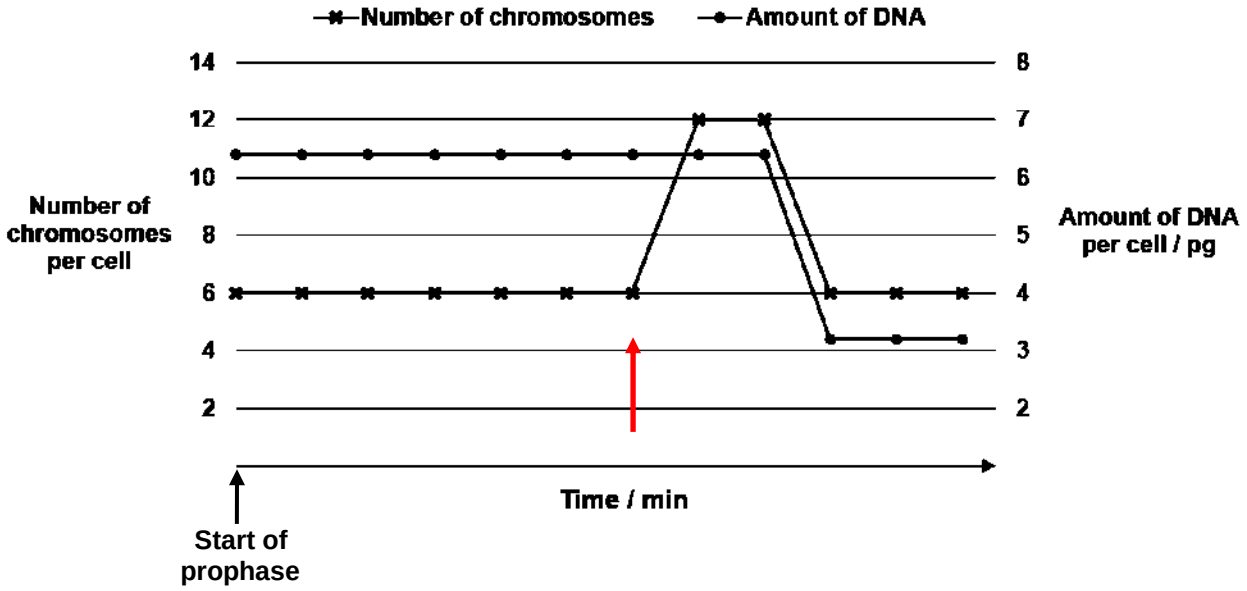

Fig. 2.1

(a) (i) On Fig. 2.1, indicate with an arrow where anaphase begins. [1]

Indicated as red arrow above;

(ii) Explain whether Fig. 2.1 shows the first or the second meiotic division.

1. **Second meiotic division / Meiosis II;**
2. **The number of chromosomes at the end of the division remained the same as that during prophase, of 6 chromosomes per cell / Cells were haploid at the start of the division and remained haploid;**
3. **During anaphase II, chromatids were separated to opposite poles and each chromatid is considered as an individual chromosome (hence no. of chromosomes / ploidy level remain unchanged); OR**
   The number of chromosomes at the end of meiosis I would have been half that of the parent cell / cells would be diploid at the start of the division but daughter cells would be haploid;

@ 1m

[3]

(iii) The centromere of a chromosome comprises non-coding tandem repeats. Suggest how the structure of the centromere allows it to carry out one of its functions in cell division.

1. **Nucleotide sequence of the centromere results in a specific 3D conformation which is complementary to (DNA-)binding site of proteins;**
2. **which facilitate adhesion of sister chromatids / which make up the kinetochore complex to allow attachment of spindle fibres;**

@ 1m

[2]

For examiner's use

In normal cells, the ends of chromosomes do not normally fuse with each other. However, in senescent cells where the ends of chromosomes are eroded to a critical length due to the end-replication problem, chromosomes may undergo end-to-end fusions. Fig. 2.2 shows how the ends of two sister chromatids may fuse and subsequently break during cell division at a location other than the point of fusion.

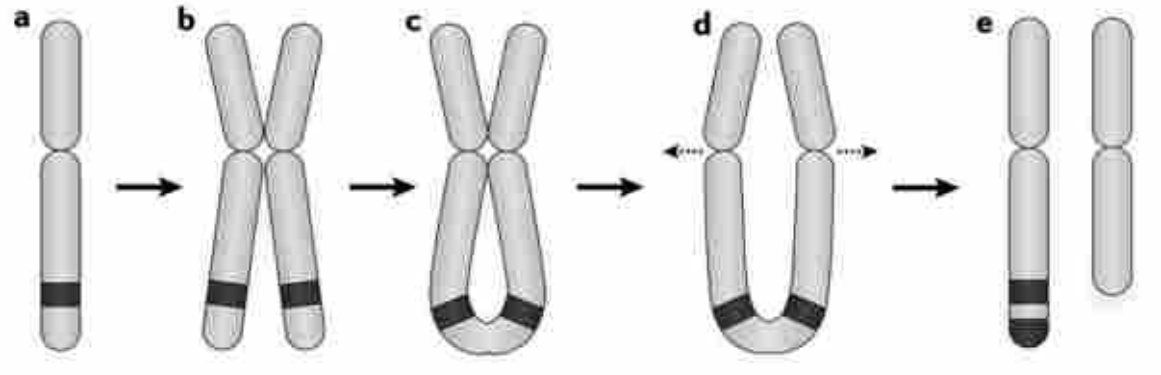

Fig. 2.2

(6) (i) Describe the result of the chromosomal mutation on the chromosomes shown in Fig. 2.2I.

A deletion on one chromosome and a duplication on the other chromosome;
R! translocation mutation **@ 1m**

[1]

(ii) Suggest how the ends of chromosomes are normally protected from end-to-end fusions.

For Examiner's Use

1. **Telomeres form loops at the ends of chromosomes, hence there are no free ends for fusion to occur;**
2. **Proteins bind to telomeres at the ends of chromosomes, preventing the fusion of these ends;**

@ 1m, max 1

[1]

(iii) Explain how the end-replication problem will lead to the erosion of the ends of chromosomes.

1. **During the replication of DNA, the RNA primer at the 5' end of the lagging strand is removed;**
2. **but the gap cannot be filled with complementary deoxyribonucleotides;**
3. **Due to the absence of an existing 3'–OH group for DNA polymerase I to add nucleotides to / DNA polymerase I can only elongate a strand in a 5' to 3' direction;**
4. **Hence, over repeated cycles of DNA replication, there will be a gradual shortening of the ends of chromosomes;**

@ 1m

[3]

[Total: 11m]

For examiner's use

3 **(a)** A new type of influenza drug has been shown to be effective against drug-resistant strains of the flu virus, according to a study led by University of British Columbia researchers in 2013. This drug works by inhibiting newly-formed influenza viruses from leaving the cell surface membrane of host cells, thus preventing the infection of other host cells.

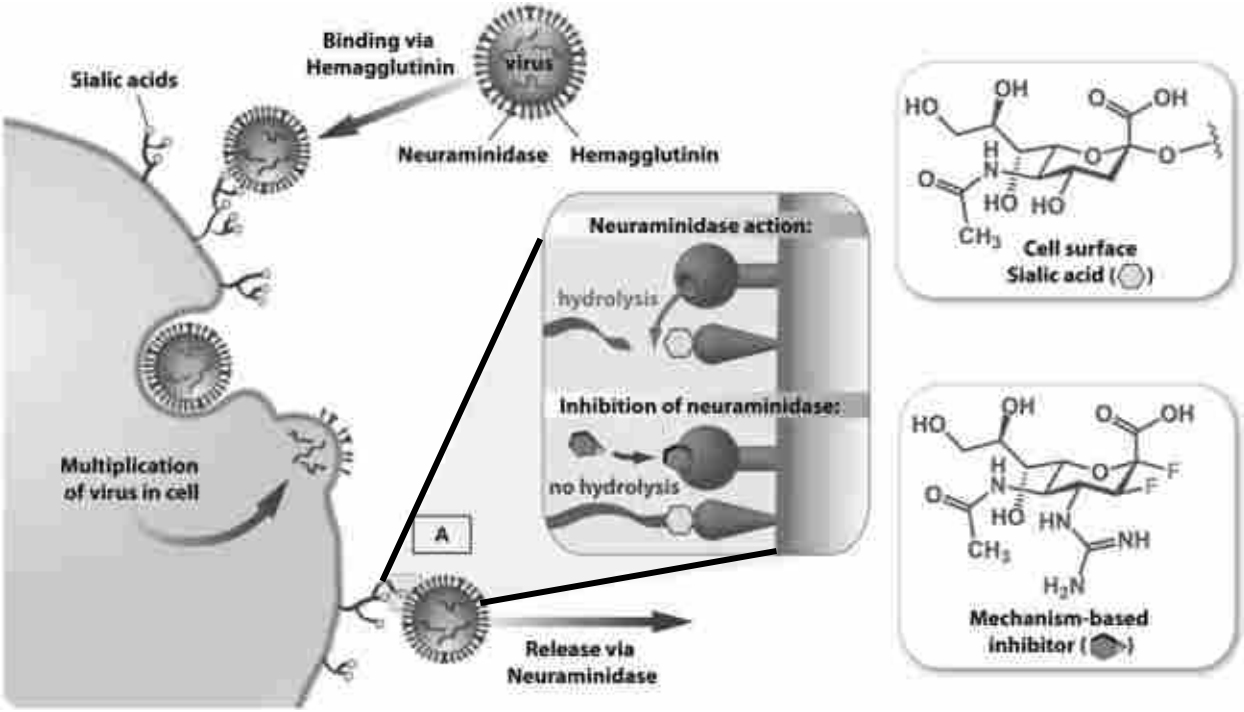

Fig. 3.1

For Examiner's Use

(i) Describe the process by which influenza viruses replicate in host cells.

1. **Viral RNA genome is transcribed to mRNA by viral RNA-dependent RNA polymerase inside nucleus;**
2. **The mRNA is transported to the cytoplasm and translated to viral structural proteins and viral enzymes by host cell ribosomes;**
3. **The mRNA in the nucleus is also used as a template to replicate new RNA genomes for new influenza viruses;**
4. **Capsid proteins are transported back to the nucleus to bind with viral RNA to form ribonucleoproteins (RNPs);**
5. **Neuraminidase and haemagglutinin are transported through the Golgi apparatus and incorporated onto the cell surface;**

@ 1m, max 4 [4]

For examiner's use

(ii) With reference to Fig. 3.1, describe how the drug prevents the newly formed influenza viruses from infecting other host cells in the process labelled **A**.

1. **The drug is a competitive inhibitor of neuraminidase as it is structurally similar to the cell surface sialic acid,;**
2. **Hence the drug binds to the complementary active site on neuraminidase instead of sialic acid;**
3. **This prevents neuraminidase from hydrolysing the sialic acid receptors which are attached to the viral haemagglutin, from the cell surface membrane and hence viruses cannot be released;**

@ 1m [3]

(iii) Suggest a limitation of using this type of influenza drug.

1. **Concentration of inhibitors may not be high enough to target all neuraminidase/ large number of host cells, difficult to ensure inhibitors reach <u>all</u> the host cells;**
2. **Antigenic drift/shift/mutation in neuraminidase gene will result in a different 3D conformation of neuraminidase, so drug needs to be continually updated;**

AVP; **@ 1m** [1]

(6) Describe the differences between the lysogenic life cycle of a lambda phage and the life cycle of an influenza virus.

For Examiner's Use

	Lysogenic life cycle	Influenza life cycle
1.	Use tail tip to bind to specific receptors on bacterial cells	Use haemaglutinin to bind to sialic acid receptors on epithelial cells;
2.	Only DNA is injected into host cell /Capsid left outside host cell	Capsid and viral RNA enters host cell;
3.	Viral DNA integrated into host cell genome directly	Viral RNA transcribed into mRNA by RNA-dependent RNA polymerase directly;
4.	Occurs in host cell bacteria	Occurs in epithelial cells;
5.	Do not result in death of the host cell	Release of influenza virus by budding may result in death of host cell;

AVP; **@1m, max 2**

[2]

[Total: 10m]

4 The most common type of lung cancer is non-small cell lung cancer (NSCLC) which affects between 75% to 85% of all lung cancer patients. The *c-Met* gene which is located on chromosome 7 has been implicated in NSCLC.

To investigate the role of *c-Met* gene in NSCLC, researchers studied the level of expression of c-Met receptor tyrosine kinase protein in several NSCLC cancer cell lines.

cDNA was generated from mRNA samples from the cancer cell lines and subsequently sequenced. Fig. 4.1a shows the normal cDNA. The corresponding protein regions it codes for are labelled. Fig. 4.1b shows two mutant cDNAs and the corresponding protein regions they code for. The corresponding regions shown in the mutant cDNA may or may not be translated to functional protein structures.

Normal cDNA:

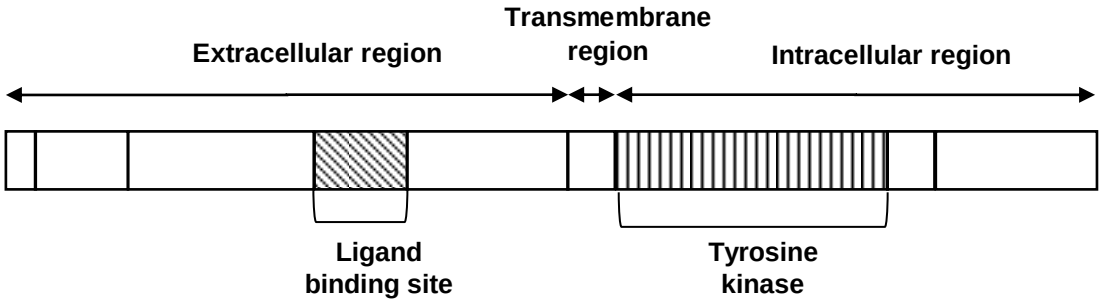

Fig. 4.1a

Mutant 1 cDNA:

Mutant 2 cDNA:

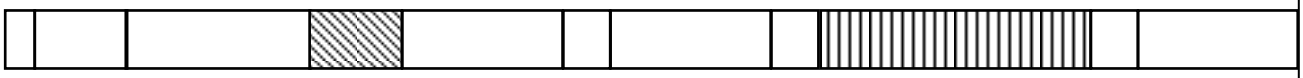

Fig. 4.1b

With reference to Fig. 4.1a and 4.1b,

(a) (i) State and explain the types of mutation in the *c-Met* gene that could have resulted in mutant 1 and mutant 2.

Mutant 1: (max 2)

1. **Insertion/deletion/substitution of nucleotide(s);**
2. **Such that there is the creation of a new splice site in the mRNA;**
3. **Spliceosome deletes one or more exons resulting in a shortened sequence coding for the extraceullar region of the protein;**

OR

4. **Deletion of several nucleotides;**
5. **In the exon;**
6. **Hence, shorter exon resulting in a shortened sequence coding for the extracellular region of the protein;**

Mutant 2: (max 2)

7. **Duplication/insertion of a part of the gene sequence;**
8. **Such that exons were duplicated/inserted;**
9. **Resulting in a lengthened sequence coding for a part of the extracellular and transmembrane region.;**
   OR
10. **Insertion/deletion/substitution of nucleotide(s);**
11. **Such that there is the deletion of a splice site in the mRNA;**
6. **Spliceosome does not delete one or more introns resulting in a lengthened sequence coding for a part of the extracellular and transmembrane region.;**

@1m, max 4

[4]

Fig. 4.2 shows the cell signaling pathway of the c-Met receptor tyrosine kinase protein.

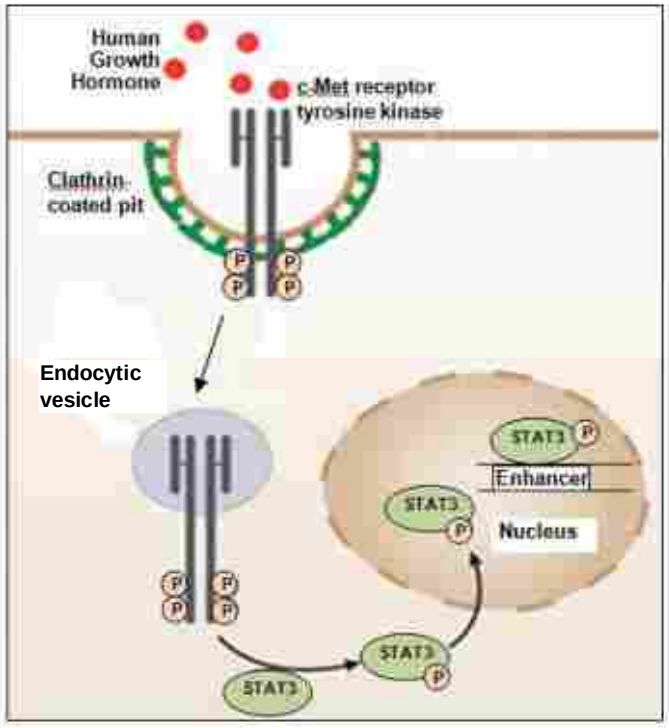

Fig. 4.2

(6) With reference to Fig. 4.2, describe the mechanism by which STAT3 controls the expression of genes involved in cell division.

1. **STAT 3 is an activator;**
2. **Upon phosphorylation, STAT3 changes its 3D conformation and is activated and travels into the nucleus via the nuclear pore;**
3. **It is complementary in conformation/configuration to the enhancer sequence and binds to it.;**
4. **A DNA-bending protein is recruited and causes DNA bending, (which brings STAT3 closer to the promoter.);**
5. **Other general transcription factors, (mediator proteins) and RNA polymerase**

are also recruited to the promoter.;

6. **STAT3 binds to the above, forming a transcription initiation complex.;**

7. **Hence, transcription of genes involved in cell division occurs at an optimal/ increased/higher rate.;**

@1m, max 4

Reference to phosphorylation of STAT3 is required for awarding of full marks.

[4]

(c) Many cells are shown to have a mutation in the *c-Met* gene resulting in a hyperactive c-Met receptor tyrosine kinase. However, not all of these cells develop into cancerous cells. Explain why.

1. **A loss of function mutation in both alleles of a tumour suppressor gene is also required.;**
2. **For the cell to divide excessively.;**
3. **Allowing for an accumulation of mutations in other genes involved in cancer development (e.g. telomerase, genes involved in angiogenesis etc.)**
4. **In a single cell lineage;**
5. **Cancer is a multistep process.;**

@1m, max 4

[4]

[Total: 12m]

For examiner's use

5 (a) A geneticist is interested in studying eye and body pigmentation in *Drosophila*. The genes for eye colour and body colour are located 11 cM apart on chromosome 3. Purple eye is produced by a dominant mutation that is lethal in a homozygous state.

Female flies with purple eyes (**E**) and ebony bodies (**b**) were mated with male flies which were true-breeding for red eyes (**e**) and yellow bodies (**B**). All the F_1 offspring of this cross had yellow bodies. F_1 female flies which had purple eyes were chosen and test-crossed with male flies. 200 flies were present in the F_2 generation. There were equal numbers between the two parental phenotypes and equal numbers between the recombinant phenotypes.

(i) Draw a genetic diagram of the F_1 cross to show the observed results, indicating clearly the numbers of individuals in each different phenotypic class in the F_2 offspring.

F_1 phenotypes	**female with purple eyes and yellow body**	**X**	**male with red eyes and ebony body**	
F_1 genotypes	**(Eb)(eB)**	**X**	**(eb)(eb)**	**;**
Gametes	**(Eb)** **(eB)** **(EB)** **(eb)**		**(eb)**	**;**

F_2 genotypes	**(Eb)(eb)**	**(eB)(eb)**	**(EB)(eb)**	**(eb)(eb)**	**;**
F_2 phenotypes	**purple eyes ebony body**	**red eyes yellow body**	**purple eyes yellow body**	**red eyes ebony body**	**;**
	89	**89**	**11**	**11**	**;**
	parental phenotypes		**recombinant phenotypes**		

For Examiner's Use

[5]

In many other crosses, the proportion of recombinant offspring obtained is lower than the one observed in (a)(i). One possible cause is the occasional occurrence of a double cross-over in female *Drosophila*, as shown in Fig. 5.1 for a doubly heterozygous female.

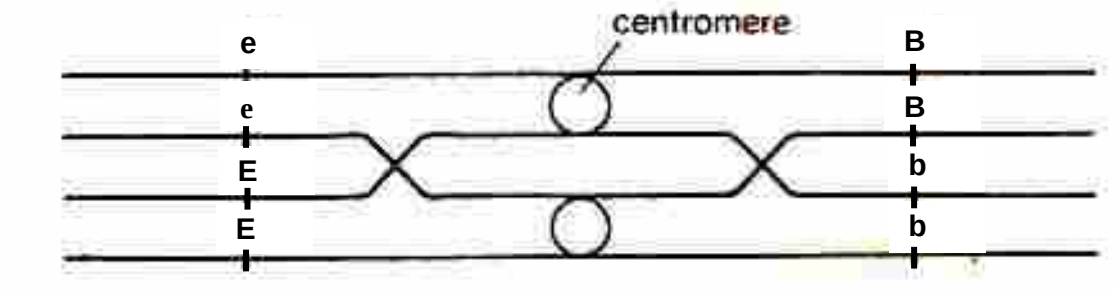

Fig. 5.1

(ii) Assuming that a double cross-over does occur between the two genes, suggest why the recombination frequency between the two loci would be lower than the predicted percentage.

A double cross-over returns / restores the grouping of the linked alleles to the parental combination; OWTTE [1]

In a separate experiment, the geneticist decides to investigate the chromosomal positions of genes controlling body pigmentation and wing shape in *Drosophila*. The alleles for these traits are shown below.

B: Allele for grey body **b:** Allele for black body
C: Allele for straight wings **c:** Allele for curved wings

He carried out a cross between a female fly heterozygous for both loci with a homozygous recessive black-bodied, male fly with curved wings and obtained a large number of offspring. Table 5.1 shows the results.

Table 5.1

Phenotype	**Number of offspring**
Grey-bodied, straight wings	35
Black-bodied, straight wings	37
Grey-bodied, curved wings	35
Black-bodied, curved wings	33

A chi-squared test was used to find out if there is any significant difference between the observed and expected ratios.

The table of probabilities is given as follows:

degrees of freedom	probability, p				
	0.10	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(b) The calculated χ^2 value is found to be 0.229. Using the chi-squared (χ^2) test and the information given above, state the conclusion that may be drawn from the result.

1. **Calculated χ^2 value of 0.229 is less than the critical χ^2 value of 7.82;**
2. **At df =3;**
3. **<u>p> 0.05</u>;**
4. **Difference between observed ratio and expected ratio is not significant and probably due to chance;**
5. ***The genes controlling body pigmentation and wing shape are not linked / are found on separate chromosomes;**

***compulsory pt @ 1m** [4]

[Total: 10m]

For examiner's use

6 Fig. 6.1 shows an electron micrograph of a plant cell.

Fig. 6.1

(6) (i) Name the macromolecule which makes up structure **A**.

Cellulose; [1]

(ii) Describe how the structure of the named macromolecule in (a)(i) gives rise to its fibrous nature.

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1. **Polymer of β glucose residues with alternate glucose residues rotated 180°;**
2. **OH groups found on both sides of the chain enables crosslinking / formation of H bonds with other chains;**
3. **Chains associate to form microfibrils which are arranged in larger bundles to form macrofibrils (idea of bundling is important);**
4. **Chains form long strands/fibres;** **@ 1m, max 3** [3]

Fig. 6.2 shows how a seed undergoes germination to form a seedling.

Fig. 6.2

(b) (i) State what is meant by respiratory quotient (RQ).

1. RQ is the ratio of carbon dioxide given out to oxygen taken in during respiration;

[1]

(ii) In some pea plants, the RQ has been found to be between three and four at the start of germination. Suggest a reason to explain the high RQ obtained at the early stages of germination.

1. The testa or seed coat still covers the seed/seed is embedded deep in the soil, making it difficult for oxygen to penetrate inside;
2. Respiration in seed is partly anaerobic (hence, the RQ > 1);

[2]

(6) Following root growth, leaves will develop and this is necessary for the seedling to harvest energy from the sun. Light intensity plays a role in determining the rate of photosynthesis. State why the rate of photosynthesis remains constant even at high light intensity.

Light is no longer limiting / another factor e.g. CO_2 or temperature is now limiting/ light saturation has been reached; **@ 1m** [1]

[Total: 8m]

7 The Fluid Mosaic Membrane Model of biological membrane structures was proposed as a basic framework model to describe the basic structures of biological membranes.

Synapses are unique cell junctions found between a neurone and another cell that serve to conduct signals in a neural pathway. A chemical synapse is cholinergic if it uses acetylcholine as its neurotransmitter.

(6) Explain the significance of the Fluid Mosaic Model of membrane structures in the transmission of signals across a cholinergic synapse.

1. Fluid: phospholipids free to move within the membrane;

2. allow synaptic vesicles containing neurotransmitters to fuse with plasma membrane of pre-synaptic neurone to be released into the synaptic cleft/ allow membrane proteins to change conformation even when embedded in membrane;

3. Mosaic: Presence of (a variety of) proteins scattered on/in the membrane;

4. Voltage-gated Ca2+ ion channels which allow Ca2+ influx across pre-synaptic membrane upon membrane depolarisation/ Chemically-gated Na+ ion channels which allow Na+ influx across post-synaptic membrane upon binding of neurotransmitters (to their specific receptors);

[4]

For examiner's use

Transmission at the neuromuscular junctions takes place in the same way as synapses between nerve cells. Fig. 7.1 shows a chemical synapse formed by the contact between a motor neurone and a muscle cell at the neuromuscular junction.

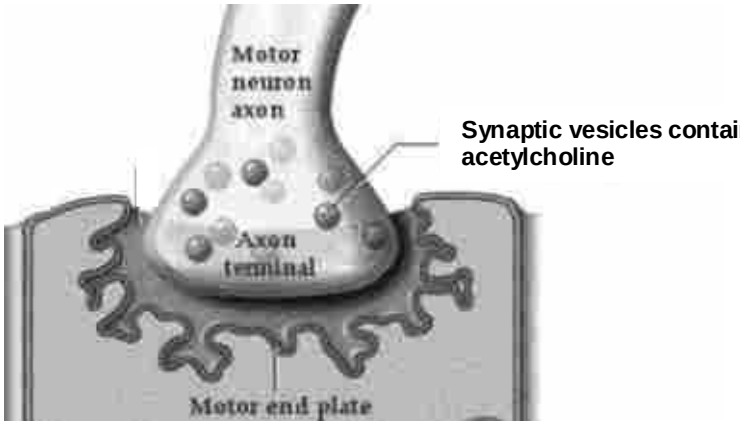


Fig. 7.1

Suxamethonium is a drug that mimics the action of acetylcholine (Ach) at acetylcholine receptors of the motor end plate. Unlike Ach, it cannot be hydrolysed by acetylcholinesterase.

(b) With reference to the above information, explain the effect of suxamethonium on the muscles.

For Examiner's Use

1. Suxamethonium is structurally similar to acetylcholine;

2. Hence, it <u>competes</u> for binding to the Ach receptors at the motor end plate; (R! Competitive inhibition)

3. Because it cannot be hydrolysed by acetylcholinesterase, this results in prolonged opening of the chemically-gated Na^+ ion channels ;

4. Influx of Na+ ions results in depolarization of the motor end-plate;

5. the end plate remains depolarised/ cannot be repolarize;

6. Muscles remained contracted/ cannot relax/ OWTTE;

[4]

[Total: 8m]

For examiner's use

8 (a) The camelids are a group of mammals that share a large numbers of homologies. Recognisable camelids have been found fossilized in rock that are 45 million years old. Modern camelids have a discontinuous distribution. Guanacos and vicunas are found in South America together with the domesticated llamas and Alpacas. Bactrian Camels and Dromedaries are found in the Asian and South African deserts.

(i) Explain how homologies in camelids supports Darwin's theory of descent with modification.

1. Presence of homologous structures in all the camelids shows that they inherited a common set of genes from common ancestor;
2. Ref to anatomical, embryological and molecular homologies;
3. (Modification arises due to) natural selection selecting for better adapted traits/ phenotypes in each population;
4. Due to different selection pressure found in different geographical location;

[4]

(ii) Without considering the theory of continental drift, explain how discontinuous distribution of modern day camelids poses a problem to Darwin's theory of descent with modification.

For Examiner's Use

1. Different species which are descendants of a common ancestors should be found close in geographical proximity;
2. As their range is limited by geographical barriers, the ocean between continents;
3. Hence being found on different continents in present day suggest modern camelids may not descended from a common ancestor;

[2]

For examiner's use

(b) Fig. 8.1 is a graph which shows the relationship between the number of amino acid changes of the protein haemoglobin with respect to the number of years since two organisms diverged from their common ancestor.

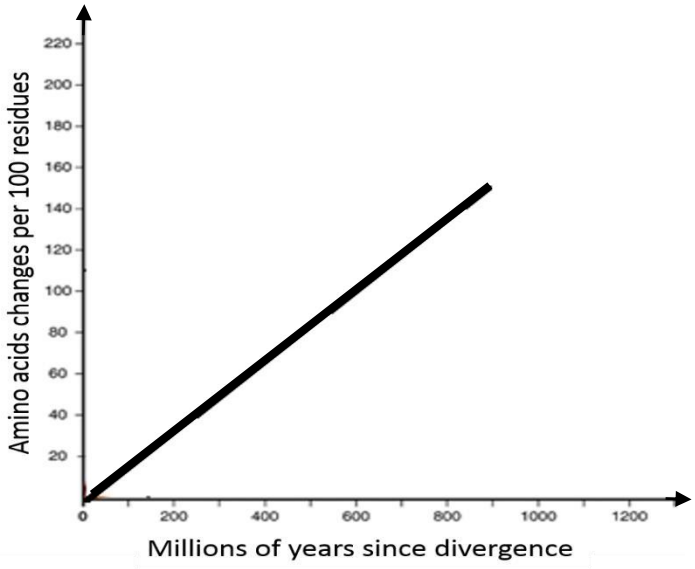


Fig. 8.1

(i) Explain the significance of the shape of the graph shown in Fig. 8.1.

1. **The linear graph shows mutation accumulates at a <u>constant rate</u> over time;**
2. **Shows that most mutation / amino acid differences between organisms are <u>neutral mutation / silent mutation</u>;**
3. **As the mutation does not come under selection pressure;**
4. **Frequency of the mutation in the population changes mainly due to <u>genetic drift</u>;**
5. **Elaborate genetic drift;**
6. **Use data as molecular clock to calculate no. of years since divergence of a species from ancestral species;**

[4]

For Examiner's Use

(ii) Compare neutral mutation and silent mutation.

1. **Both does not affect the fitness of the organism;**
2. **Both involve a change in nucleotide sequence;**
3. **However silent mutation does not involve a change to the amino acid sequence of the polypeptide;**
4. **While neutral mutation includes changes to the amino acid sequence;**
5. **Both do not change the phenotype of an organism;**

[3]

[Total: 13m]

For examiner's use

Section B

Answer **EITHER 9 OR 10**.

Write your answers in the lined pages provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

EITHER

9 **(a)** Using the induced-fit hypothesis, explain the mode of action of enzymes. [6]

1. **Enzyme lowers activation energy/ alternative pathway of lower activation energy;**
2. **Ref. to *mechanisms e.g. 'proximity effect', 'strain effect' and 'orientation surface'* (any one)**
3. **Enzyme <u>specific</u> in its action;**
4. **due to <u>complementary</u> 3D configuration/conformation of <u>active site</u> to that of substrate;**
5. **The induced fit model suggests that the enzyme and the substrate do not fit together exactly;**
6. **<u>Effective</u> collisions between enzymes and (specific) substrate molecules result in substrate binding to active site of enzyme;**
7. **The enzyme undergoes a 3D conformation change, which improves the fit between substrate and enzyme;**
8. **to form enzyme-substrate (ES) complexes;**
9. **Product formed that no longer fits into active site and is released;**
10. **Enzyme remains unchanged at the end of the reaction (and can be reused);**

For Examiner's Use

For examiner's use

(b) With reference to haemoglobin, explain the significance of bonds in maintaining the protein's structure and function. [8]

Compulsory points (must be seen for full marks):

1. **The primary structure is maintained by peptide bonds between amine groups and carboxyl groups of amino acids;**
2. **The secondary structure which refers to the α helix is maintained by hydrogen bonds between –CO and –NH groups of the polypeptide backbone;**
3. **The tertiary structure which refers to the overall 3D configuration/ globular shape of the subunit that is maintained by hydrogen bonds, ionic bonds and hydrophobic interactions (any 2) between the R groups of amino acid residues.;**
4. **The quaternary structure which refers to the association of the two polypeptide chains in each dimer and association of the two dimers are held together by mainly hydrophobic interactions and weak hydrogen and ionic bonds respectively; (give for quaternary structure if student describes either association within or between dimers)**

N.B. If there is none of the above points, max 4 marks can be awarded.

Description of tertiary structure:

5. **Globular structure allows for the packing of many haemoglobin in red blood cells;**
6. **Each globin polypeptide is folded such that the bulk of the hydrophobic amino acid residues are buried in the interior of the globular structure;**
7. **Ref. to haem binding pocket lined with hydrophobic amino acids to provide a hydrophobic environment for hydrophobic haem group to bind;**
8. **Ref. to presence of Fe^{2+} to allow for reversible binding of O_2;**
9. **Hydrophilic amino acid residues are on the outside (to form hydrogen bonds with water);**
10. **Haemoglobin is soluble in aqueous medium and hence a good transport protein for oxygen in blood;**

For Examiner's Use

Description of quaternary structure:

11. **(Association of two dimers with weak hydrogen and ionic bonds) results in the ability of the two dimers to move with respect to each other;**
12. **This allows for cooperativity;**
13. **When an oxygen molecule binds to/is released from 1 haemoglobin subunit, the binding/ release induces a conformational change in the remaining subunit;**
14. **Which increases/ lowers the affinity for oxygen of the remaining three oxygen binding sites respectively;**
15. **Hence facilitates the loading and unloading of oxygen;**

(c) Compare competitive and non-competitive inhibition of enzyme action. [6]

Similarities:

1. **At <u>low substrate concentration</u>, rate of reaction in the presence of inhibitors is slower than that in the absence of inhibitor;**

Features	Competitive	Non-competitive
Structure of inhibitor	**2. Resembles substrate;**	**Does not resemble substrate;**
Binding site of inhibitor	**3. Binds to active site of enzyme;**	**Binds to enzyme at a region other than the active site/ allosteric site;**
Mechanism of inhibition	**4. Blocks substrates from binding to active site of the enzyme;**	**Blocks substrates from binding to active site by changing the conformation of the active site;**
Effect of high substrate concentration on inhibition	**5. Inhibition can be reversed at high substrate concentration;** **6. V_{max} in the presence of inhibitor can be very close to that of reaction in the absence of inhibitor;**	**Inhibition cannot be reversed at high substrate concentration;** **V_{max} in the presence of inhibitor is less than that of reaction in the absence of inhibitor;**

[Total: 20m]

OR

10 (a) Explain the roles of the key components of the homeostatic control system. . [6]

1. **It consists of the following components: detector, control centre and effector;**
2. **The detector/ receptor senses the stimuli and the information is relayed to the control centre;**
3. **The control centre (receives the information and) compares it with the set-point of that parameter;**
4. **Which is the optimal level of that specific parameter;**
5. **When there is a deviation in the parameter from the set point, the control centre initiates an appropriate response *(to restore conditions back to the set point);**
6. **This action is conveyed to the effector through the communication systems/nervous & endocrine systems in the body;**
7. **The effector will carry out the response (initiated by the control centre to restore conditions to the set point);**
8. **Ref to negative feedback mechanism;**

*** Ref to be made at least once in answer**

@ 1m, max 6

(b) With the use of named examples, describe the role of hormones in the regulation of blood glucose concentration in humans. [8]

<u>Insulin:</u>

1. **When blood glucose concentration is higher than the set point of 80-90mg/100ml;**
2. **The change is detected by <u>β cells</u> (α and β cells of the islets of Langerhans) and are stimulated to secrete (more) insulin (and secretion of glucagon by α cells is inhibited);**
3. **Insulin binds to cell-surface insulin receptors on the plasma membrane of effector cells e.g. liver, skeletal muscles and adipose cells (at least one);**
4. **(Upon binding of insulin,) the insulin receptor, which is a receptor tyrosine kinase, phosphorylates intracellular enzymes to bring about the following effects:;**
5. **Acceleration of the rate of glucose uptake via facilitated diffusion;**
6. **By increasing the number of glucose transporters in the plasma membrane of cells (but not in liver cells);**
7. **Rate of glycolysis is increased, glycogenesis is stimulated, glycogenolysis is inhibited, stimulates amino acid absorption and protein synthesis, inhibits gluconeogenesis, stimulates lipogenesis.; (any two)**

[max 4 marks]

Glucagon:

8. **When the blood glucose concentration is lower than the set point of 80 - 90mg/100ml;**
9. **The change is detected by α cells (α and β cells of the islets of Langerhans) and are stimulated to secrete (more) glucagon (and secretion of insulin by β cells is inhibited);**
10. **Glucagon binds to the cell-surface glucagon receptors on the plasma membrane of effector cells e.g. liver;**
11. **Upon binding of glucagon to its receptor, a G-protein coupled receptor, adenylate cyclase is activated to produce cyclic AMP (cAMP) from ATP to bring about the following effects:;**
12. **Stimulates glycogenolysis, gluconeogenesis and lipolysis.; (any two)**

[max 4 marks]

13. **Hence, the opposite actions of both hormones help to maintain the blood glucose concentration about a set point;**
14. **The ratio of the amounts of both hormones determines the net effect.;**

(c) Explain the significance of cell signalling pathways in homeostasis. [6]

1. **Cell signaling pathways allows for cellular response by an extracellular signal.;**
2. **Such that a constant internal environment can be maintained.;**

3. **It allows for signal amplification;**
4. **Since at each catalytic step in the cascade, the number of activated products is much greater than in the preceding step.;**
5. **A small number of extracellular signal molecules is sufficient to elicit a large cellular response.;**
6. **Ref to a small number of glucagon molecules binding to receptors on the surface of an effector cell can lead to the release of hundreds of millions of glucose molecule from glycogen.;**

[max 2]

7. **It allows for coordination and regulation (to information coming from different sources in a body).;**
8. **A pathway that is triggered by a single kind of signal can diverge to produce two or more cellular responses.;**
9. **Ref. to receptor tyrosine kinases which can activate multiple relay proteins or second messengers which can regulate numerous proteins.;**
10. **Different signal transduction pathways can also converge to modulate a signal response;**

[max 2]

11. **It contributes to the specificity of the response;**
12. **Because of the specific constitution of proteins within target cell such as signalling proteins, receptors, relay proteins to carry out the response in a particular cell type.;**
13. **A specific signal molecule must bind to a specific receptor with a specific complementary conformation to elicit a specific reaction via a specific pathway;**
14. **Ref. to muscle cells responding to insulin but not glucagon;**
15. **Hence, two cells can respond differently to the same signal / Multiple responses in different cells to one signal molecule because 1 ligand can trigger multiple signal transduction pathways to elicit different responses;**
16. **Ref. to Insulin causes increase in glucose uptake in muscle and fat cells but not in liver cells because liver cells do not express a specific type of glucose transporter.;**

[max 2]

17. **The hormone may be carried in the blood stream and cells in all parts of the body will be exposed to the hormone;**
18. **Hence, as long as the cells have the appropriate receptor, many cells in different parts of the body can be activated and they respond simultaneously;**
19. **Ref. to Insulin causes increase in glucose uptake in muscle and fat cells in different parts of the body;**

[max 2]

N.B. Students have to discuss at least 3 of the 4 areas to be awarded the full marks.

[Total: 20m]

Name	Subject Class	Class	Candidate Number
	2BI		

ANGLO-CHINESE JUNIOR COLLEGE
Preliminary Examination 2016

BIOLOGY **9648/03**

Applications Paper and Planning Question **26 Aug 2016**

PAPER 3 **2 hours**

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your name, subject class, form class and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINER'S USE	
1	
2	
3	
4	
5	
TOTAL	**72**

This document consists of **16** printed pages.

1 The first restriction enzyme was discovered in *Escherichia coli* in the 1960s, and thousands more have been discovered since. These enzymes opened the path to powerful research tools which scientists use to sequence genomes through the process of genetic engineering.

(a) Compare the roles of restriction enzymes occurring naturally in bacteria and those used in genetic engineering.

.....

.....

.....

..... [2]

(b) A gene, *URA3*, was discovered to be a potential marker gene for genetic engineering. This gene is obtained from yeast and codes for orotidine 5'-phosphate decarboxylase, which converts 5-fluoroorotic acid (5-FOA) into the toxic compound 5-fluorouracil, so any cells carrying the *URA3* gene will not survive in the presence of 5-FOA.

In an investigation of the effectiveness of *URA3* as a marker gene, researchers created a plasmid vector shown in Fig. 1.1.

A eukaryotic gene was inserted into this plasmid and the mixture was added to competent *Escherichia coli* for transformation to take place. These bacteria were then grown on agar plates containing X-gal and 5-FOA.

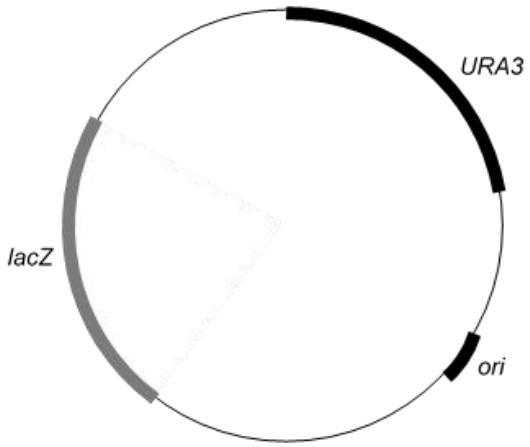


Fig. 1.1

(i) The researchers observed that recombinant bacteria appeared as blue colonies on agar plates containing X-gal and 5-FOA. Using this information, draw a cross (**X**) on the plasmid in Fig. 1.1 to indicate where the eukaryotic gene was inserted. [1]

For Examiner's Use

(ii) Account for the observations stated in **b(i)**.

[4]

(iii) State the purpose of the *lacZ* gene.

[1]

(iv) Explain why the bacteria containing the recombinant plasmid should be further subjected to gene probing.

[3]

For Examiner's Use

(c) The differences between the formation of genomic and cDNA libraries are due to the original source of genetic material used. In genomic libraries, the genetic material used is the genome of a haploid cell while in cDNA libraries, mRNA from a specialised cell is extracted.

(i) Describe two differences in the processes involved in the formation of these libraries.

.....

.....

.....

..... [2]

(ii) State two applications of cDNA libraries.

.....

.....

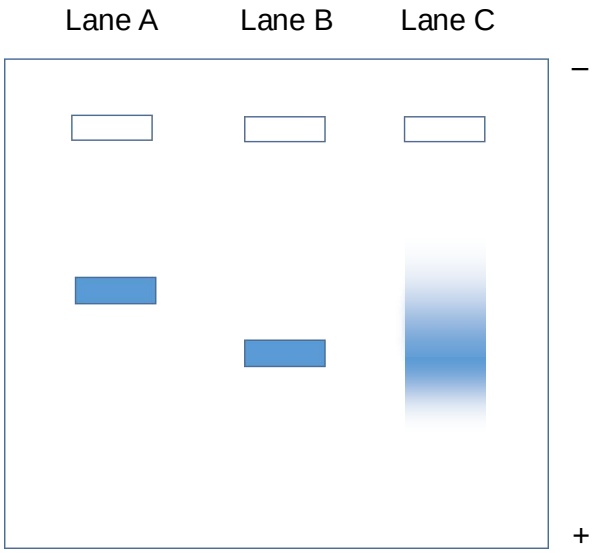
.....

..... [2]

[Total: 15m]

2 Gel electrophoresis is a technique that is widely used in molecular biology to separate DNA fragments based on molecular mass. The molecular mass of DNA fragments may differ due to the number of nucleotides present in the DNA fragment as well as chemical modifications made to the DNA.

Fig. 2.1 shows the gel electrophoregram of the DNA fragments taken from three sources. DNA fragments from all three samples are known to have equal lengths.



Key

Lane A: DNA fragments comprising insulin gene isolated from liver cells

Lane B: DNA fragments comprising insulin gene isolated from Islets of Langerhans

Lane C: Linear DNA isolated from many lambda phages

Fig. 2.1

(a) Describe the role of the buffer solution in gel electrophoresis.

.....

.....

.....

..... [2]

(b) (i) Describe and explain the position of the band in lane A with respect to the band in lane B.

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..... [3]

For Examiner's Use

(ii) Fig. 2.2 shows the DNA of a lambda phage.

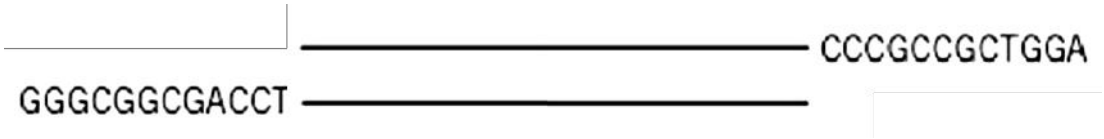


Fig. 2.2

Describe and explain the band pattern of the lambda phage DNA in lane C.

[4]

Cyclopselemia is a new genetic disease recently discovered in a small town called X-mansion. A patient suffering from cyclopselemia has red eyes and cannot control the amount of light entering his eyes. They have to constantly wear sun glasses. Scientists used information from a pedigree chart as well as RFLP analyses of the individuals in the pedigree chart to determine the allele that is responsible for this genetic disease.

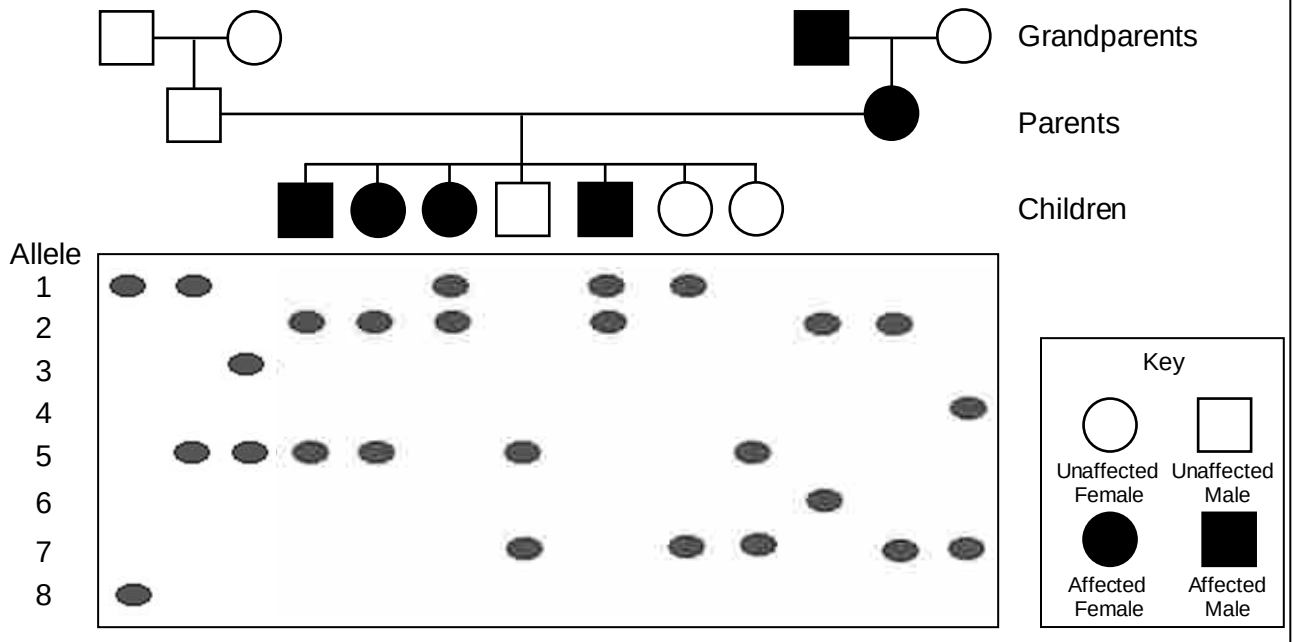


Fig. 2.3

For Examiner's Use

(c) Outline the process that can be used to determine the presence of cyclopselemia in a foetus.

[5]

[Total: 14m]

3 Embryonic stem cells, which are derived from the inner cell mass of mammalian blastocysts, are used in research to understand disease development and develop future cell-based therapies for currently untreatable diseases.

In 2006, a team of scientists led by Shinya Yamanaka discovered that differentiated cells can be isolated and modified to an embryonic-like state. These cells, subsequently known as induced pluripotent stem cells (iPSCs), have been hailed as an effective replacement for human embryonic stem cells for its usefulness in regenerative medicine. Fig. 3.1 shows a potential application of human iPSCs in gene therapy.

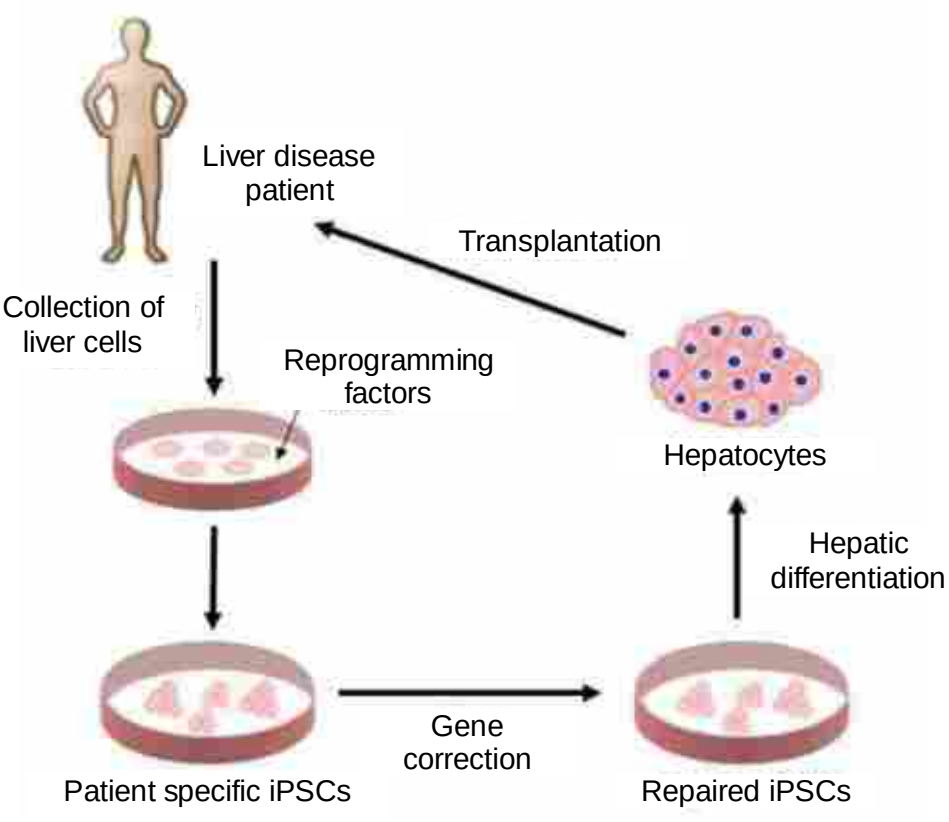


Fig. 3.1

(a) (i) State two similarities in the features of embryonic stem cells and iPSCs.

.....

.....

.....

..... [2]

For Examiner's Use

(ii) State and explain two advantages of using iPSCs over embryonic stem cells in gene therapy.

[4]

Yamanaka's research team studied 24 genes expressed by embryonic stem cells in mice to identify genes that can induce pluripotency. They discovered that four genes, notably *Oct4*, *Sox2*, *Klf4* and *c-Myc*, encode transcription factors which could be used to reprogramme differentiated cells to form iPSCs. These genes can be introduced into differentiated somatic cells via viral transduction or the introduction of non-integrating plasmids. This process is shown in Fig. 3.2.

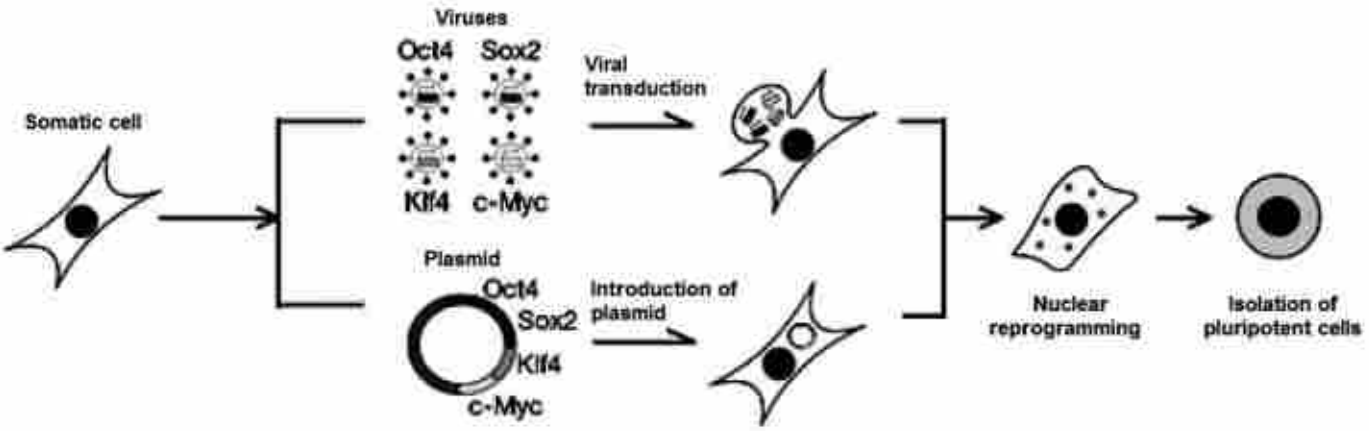


Fig. 3.2

(b) (i) Suggest why it is necessary to introduce these four genes into somatic cells in iPSC formation.

[1]

For Examiner's Use

(ii) Describe two advantages and one disadvantage of introducing the four genes via non-integrating plasmids over viral transduction using retroviruses.

[3]

(iii) Before iPSCs are stimulated to undergo cellular differentiation, the introduced genes must be removed from the cells. Suggest why this process is necessary.

[1]

[Total: 11m]

4 Planning question

The visking tubing is a semi-permeable membrane which allows smaller molecules such as water and glucose to pass through, but not larger molecules like sucrose and proteins. The tubing is to be supported in a boiling tube as shown in Fig. 4.1.

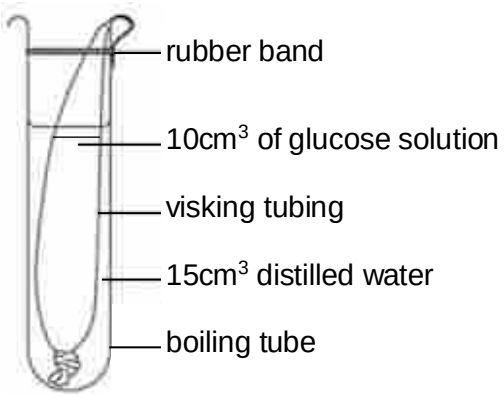


Fig. 4.1

The presence of glucose can be detected using the Benedict's test for reducing sugars.

Using this information and your own knowledge, design an experiment to investigate the effect of glucose concentration on its rate of diffusion across the visking tubing.

You must use:
- 5 pieces of visking tubing (each knotted at one end, and open at the other), soaked in a beaker of distilled water
- 5 boiling tubes and 5 rubber bands
- 2.0 moldm^{-3} glucose solution
- Benedict's solution
- weighing balance and weighing paper
- filter paper and funnel
- distilled water
- thermostatically-controlled water bath

You should select from the following apparatus:
- any normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, glass rods
- tripod stand, bunsen burner and lighter
- test-tube holder
- stopwatch
- syringes

Your plan should:
- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- include layout of results tables and graphs with clear headings and labels,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12m]

For Examiner's Use

For Examiner's Use

5 Free-response Question

Write your answers to this question on the separate writing paper provided.

Your answers:

- should be illustrated by large, clearly labelled diagrams, where appropriate.
- must be in continuous prose, where appropriate.
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

(a) Describe the steps and advantages of plant tissue culture. [8]

(b) Discuss the benefits and ethical issues related to the use of a named genetically-modified animal. [6]

(c) Discuss the goals and benefits of the human genome project. [6]

[Total: 20m]

Name	Subject Class	Class	Candidate Number
	2BI		

ANGLO-CHINESE JUNIOR COLLEGE
Preliminary Examination 2016

BIOLOGY **9648/03**

Applications Paper and Planning Question **26 Aug 2016**

PAPER 3 **2 hours**

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your name, subject class, form class and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINER'S USE	
1	
2	
3	
4	
5	
TOTAL	**72**

This document consists of **16** printed pages.

1. The first restriction enzyme was discovered in *Escherichia coli* in the 1960s, and thousands more have been discovered since. These enzymes opened the path to powerful research tools which scientists use to sequence genomes through the process of genetic engineering.

(a) Compare the roles of restriction enzymes occurring naturally in bacteria and those used in genetic engineering. [2]

1. **Similarity 1 – Both cut dsDNA at specific sites which have complementary 3D conformation to the restriction enzyme;**
2. **Similarity 2 – Cut phosphodiester bonds between adjacent nucleotides;**
3. **Difference – Restriction enzymes found naturally in bacteria cut/cleave/hydrolyse foreign/viral DNA to destroy them while those used in genetic engineering cut/cleave/hydrolyse vectors/gene of interest to allow gene of interest to be inserted into the vector;**

Note: students need to have 1 similarity and 1 difference to score full marks

(b) A gene, *URA3*, was discovered to be a potential marker gene for genetic engineering. This gene is obtained from yeast and codes for orotidine 5'-phosphate decarboxylase, which converts 5-fluoroorotic acid (5-FOA) into the toxic compound 5-fluorouracil, so any cells carrying the *URA3* gene will not survive in the presence of 5-FOA.

In an investigation of the effectiveness of *URA3* as a marker gene, researchers created a plasmid vector shown in Fig. 1.1.

A eukaryotic gene was inserted into this plasmid and the mixture was added to competent *Escherichia coli* for transformation to take place. These bacteria were then grown on agar plates containing X-gal and 5-FOA.

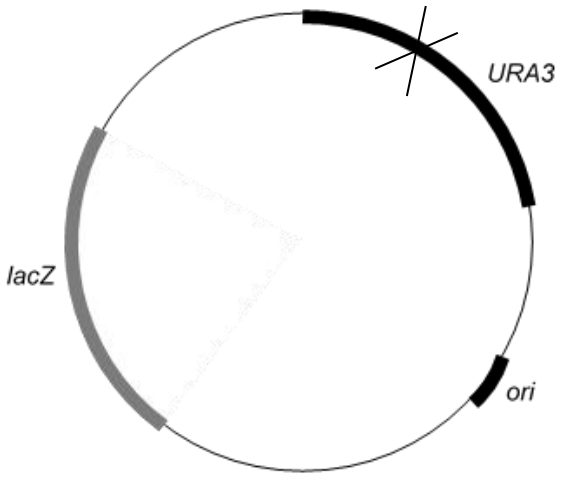


Fig. 1.1

(i) The researchers observed that the recombinant bacteria appeared as blue colonies on agar plates containing X-gal and 5-FOA. Using this information, draw a cross (**X**) on the plasmid in Fig. 1.1 to indicate where the eukaryotic gene was inserted. [1]

The cross should be within the *URA3* gene.

(ii) Account for the observations stated in **b(i)**. [4]

1. **The *URA3* gene will be disrupted because the gene of interest has been inserted into the plasmid within the *URA3* gene;**

2. **5-FOA will not be converted into the toxic compound <u>5-fluorouracil, and so there will be growth of bacteria colonies on the agar plates;</u>**
3. **Bacteria with the recombinant plasmid will express a *lacZ* gene/*lacZ* gene is intact;**
4. **X gal will be hydrolysed to form blue compound → colonies appear blue;**

(iii) State the purpose of the *lacZ* gene. [1]

Select for transformed bacteria (and not untransformed bacteria);

(iv) Explain why the bacteria containing the recombinant plasmid should be further subjected to gene probing. [3]

1. **To confirm the presence of the eukaryotic gene in the plasmid;**
2. **A gene probe, which is single-stranded radioactive DNA complementary to the gene of interest → will specifically bind to the (denatured) gene of interest;**
3. **Bacteria colonies with the gene of interest will expose photographic film (owtte);**

OR

1. **DNA other than the gene of interest could have been inserted into the vector/(for marking only: mutation could have occurred in the URA3 gene);**
2. **A gene probe, which is single-stranded radioactive DNA complementary to the gene of interest → will not bind to any DNA segment in the bacteria (which has been denatured);**
3. **Bacteria colonies will therefore not expose the photographic film (owtte);**

(c) The differences between the formation of genomic and cDNA libraries are due to the original source of genetic material used. In genomic libraries, the genetic material used is the genome of a haploid cell while in cDNA libraries, mRNA from a specialised cell is extracted.

(i) Describe two differences in the processes involved in the formation of these libraries. [2]

Basis of comparison	**Genomic library**	**cDNA library**
Addition of DNA linkers	**1. No**	**Yes;**
Use of DNA ligase	**2. Once – formation of recombinant vector/DNA**	**Twice – Add linkers to ds cDNA and formation of recombinant vector/DNA;**
Reverse transcription/ Use of enzymes involved in reverse transcription	**3. No**	**Yes – reverse transcriptase, RNase H, DNA Pol;**

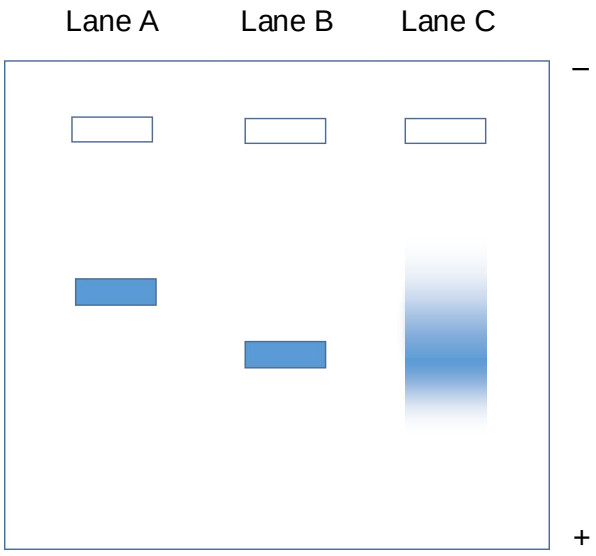
(ii) State two applications of cDNA libraries. [2]

1. **To study gene expression;**
2. **To locate a gene of interest to be inserted into a cloning vector;**
3. **To use as a gene probe;**
4. **To use as a primer for PCR;**

[Total: 15m]

2. Gel electrophoresis is a technique that is widely used in molecular biology to separate DNA fragments based on molecular mass. The molecular mass of DNA fragments may differ due to the number of nucleotides present in the DNA fragment as well as chemical modifications made to the DNA.

Fig. 2.1 shows the gel electrophoregram of the DNA fragments taken from three sources. DNA fragments from all three samples are known to have equal lengths.



Key

Lane A: DNA fragments comprising insulin gene isolated from liver cells

Lane B: DNA fragments comprising insulin gene isolated from Islets of Langerhans

Lane C: Linear DNA isolated from many lambda phages

Fig. 2.1

(a) Describe the role of the buffer solution in gel electrophoresis. [2]

1. **To maintain the pH;**
2. **So that charge on DNA will not change, affecting the migration rate of DNA;**
3. **To conduct electricity across the gel by providing ions (for the separation of DNA fragments);**

(b) (i) Describe and explain the position of the band in lane A with respect to the band in lane B. [3]

1. **DNA fragment migrated shorter distance than in lane B/ to a position of higher kilo basepair than in lane B/vice versa; (compulsory point to obtain full marks)**
2. **DNA fragment that contain insulin gene from the liver cell may be highly methylated ;**
3. **as it is not expressed in liver cell / found in heterochromatin region / region of transcriptionally inert DNA;**
4. **hence it slows down the movement of the DNA fragment due to the size of the methyl groups;**

(ii) Fig. 2.2 shows the DNA of a lambda phage.

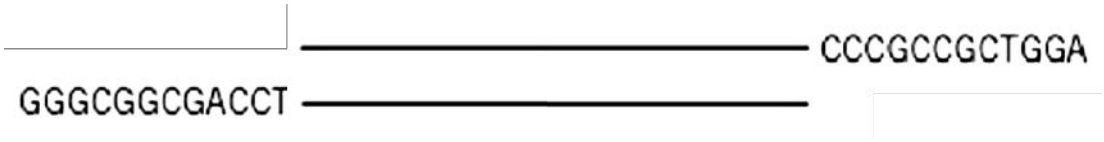


Fig 2.2

Describe and explain the band pattern of the lambda phage DNA in lane C. [4]

1. ***Lambda DNA resulted in 1 <u>smear</u> / owtte; (compulsory point to obtain full marks)**
2. **DNA of lambda phage has (long) <u>sticky ends</u>;**
3. **Hence they can <u>anneal</u> with <u>other</u> lambda DNA by <u>complementary base pairing</u>;**
4. **Ref to multiple annealing can produce <u>fragments of many different sizes/lengths</u> (resulting in the smear)/ Annealing of complementary sticky ends at both strands, forming <u>circular</u> DNA;**
5. **Small size of circular DNA migrated faster (through the pores of the agarose gel)**;

(c) Cyclopselemia is a new genetic disease recently discovered in a small town called X-mansion. A patient suffering from cyclopselemia has red eyes and cannot control the amount of light entering his eyes. They have to constantly wear sun glasses. Scientists used information from a pedigree chart as well as RFLP analyses of the individuals in the pedigree chart to determine the allele that is responsible for this genetic disease.

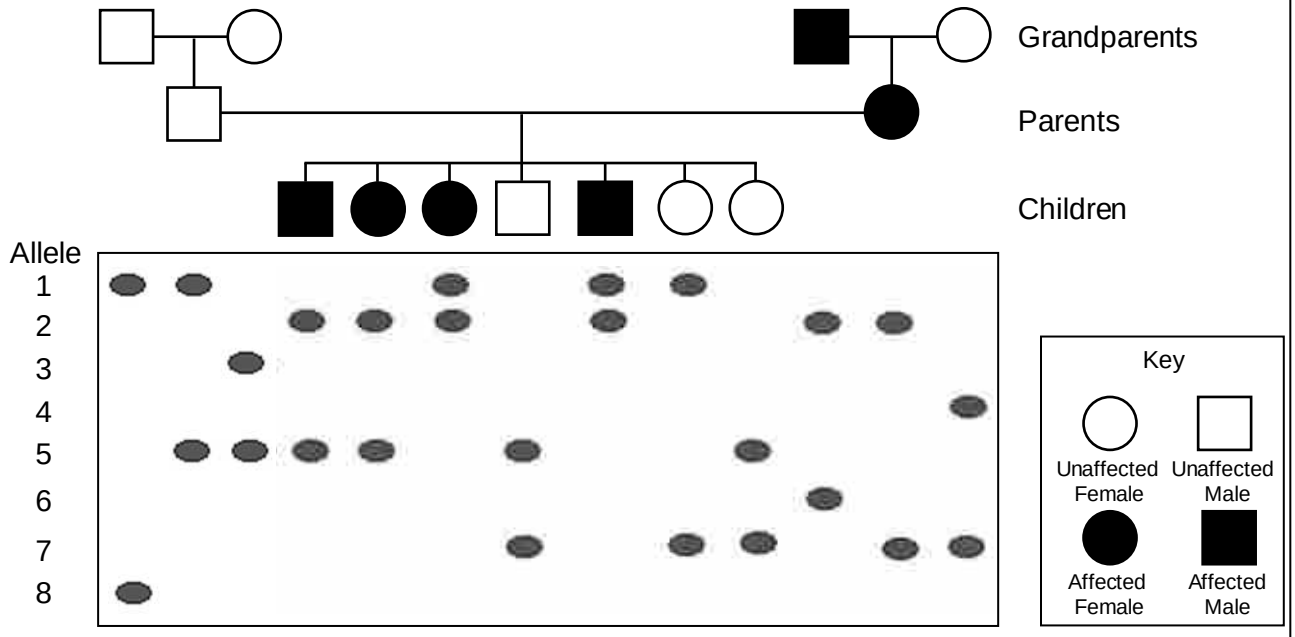


Fig. 2.3

Outline a process that can be used to determine the presence of cyclopselemia in a foetus. [5]

1. **Isolate DNA from foetus and amplify via PCR;**
2. **Subject to restriction digest with the same restriction enzyme <u>used in the RFLP analysis above</u>;**
3. **Separate restriction fragment via gel electrophoresis;**
4. **Ref to southern blotting / Transfer fragment to nitrocellulose membrane;**
5. **Single-stranded <u>radioactive</u> probe binds/anneals to region of interest (via complementary base pairing);**
6. **Bands are visualised via autoradiography;**
7. ***Presence of one RFLP allele 2 indicates presence of disease; (compulsory point to obtain full marks)**

[Total: 14m]

3. Embryonic stem cells, which are derived from the inner cell mass of mammalian blastocysts, are used in research to understand disease development and develop future cell-based therapies for currently untreatable diseases.

In 2006, a team of scientists led by Shinya Yamanaka discovered that differentiated cells can be isolated and modified to an embryonic-like state. These cells, subsequently designated as induced pluripotent stem cells (iPSCs), have been hailed as an effective replacement for human embryonic stem cells for its usefulness in regenerative medicine. Fig. 3.1 shows a potential application of human iPSCs in gene therapy.

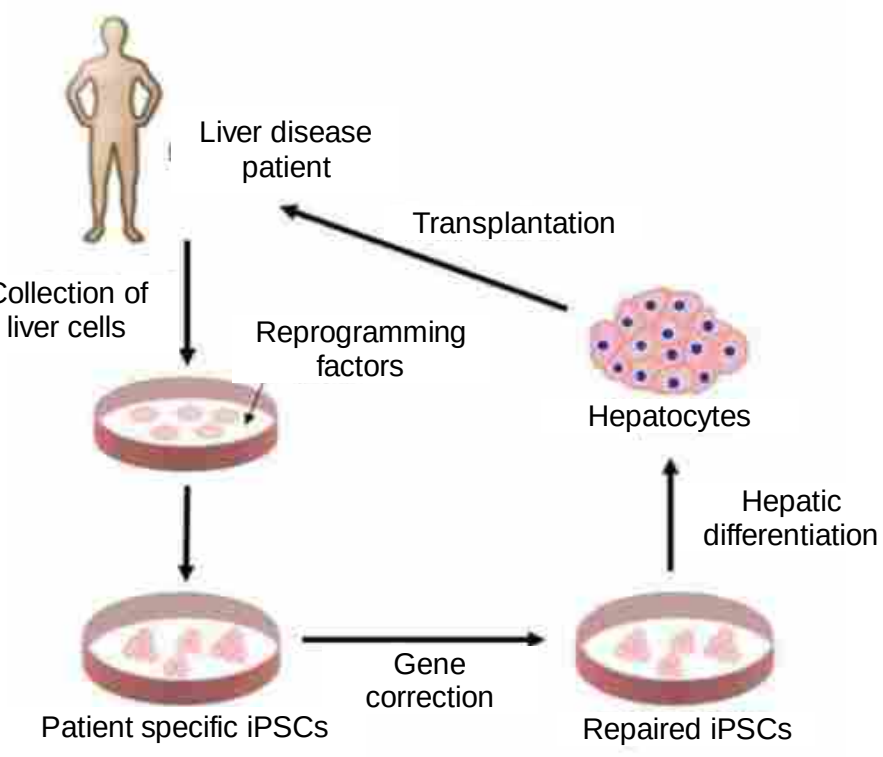


Fig. 3.1

(a) (i) State two similarities between the features of embryonic stem cells and iPSCs. [2]

1. **Both are pluripotent (and can be multipotent, but not totipotent);**
2. **Both have the potential to become any cell type in the adult body but not those of the extra-embryonic membranes;**
   R! Only stating 'both can differentiate' without elaboration
3. **Both have self-renewing capabilities / active telomerase / can divide continually via mitosis;**
4. **Both are unspecialised/undifferentiated;**
5. **Both have similar DNA methylation patterns;**

(ii) State and explain two advantages of using iPSCs over embryonic stem cells in gene therapy. [4]

1. **iPSCs can be obtained directly from transplant recipient (and will therefore be genetically identical to the patient);**
2. **Hence there is reduced immune incompatibility between donor cells and recipient / lower chance of rejection of transplanted cells;**
   R! Tissue rejection
3. **iPSCs are not derived from human embryos / does not involve isolation and subsequent death of embryos;**
4. **Hence avoiding ethical issues associated with usage of embryos in scientific research (and scientists are more likely to obtain federal funding and support);**
5. **It also has fewer ethical issues involved, as genetic makeup of patient's descendants are not altered, unlike in germ-line gene therapy;**
6. **It is easier to obtain iPSCs in greater numbers compared to embryonic stem cells;**
7. **iPSCs can be obtained from any differentiated somatic cell while embryonic stem cells can only be obtained from the inner cell mass of the blastocyst;**

Yamanaka's research team studied 24 genes expressed by embryonic stem cells in mice to track down genes that can induce pluripotency. They discovered that four genes, notably *Oct4*, *Sox2*, *Klf4* and *c-Myc*, encode transcription factors which could be used to reprogram differentiated cells to form iPSCs. These genes can be introduced into differentiated somatic cells via viral transduction or the introduction of non-integrating plasmids in Fig. 3.2.

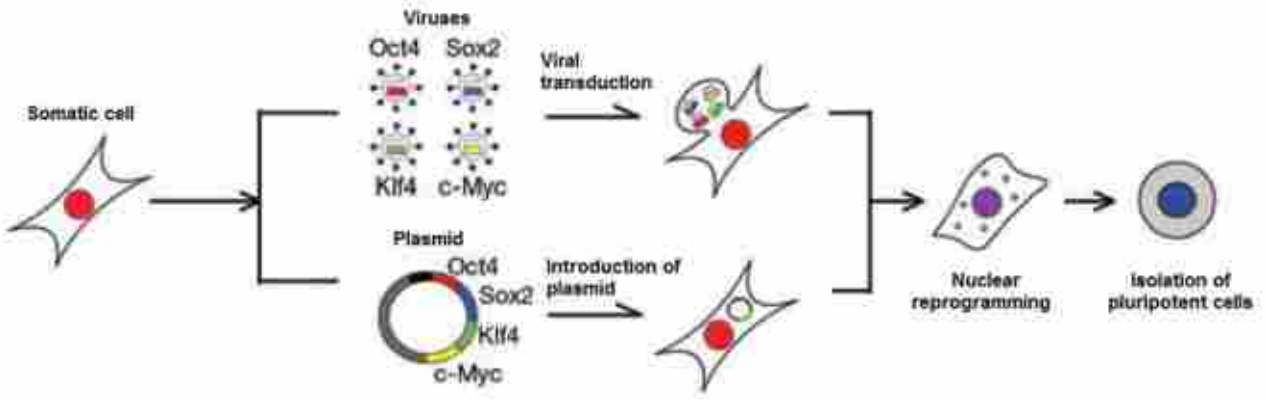


Fig 3.2

(b) (i) Suggest why it is necessary to introduce these four genes into somatic cells in iPSC formation. [1]

These four genes are not expressed / methylated in differentiated (somatic) cells;
R! Genes are not found in somatic cells

(ii) Describe two advantages and one disadvantage of introducing the four genes via non-integrating plasmids over viral transduction using retroviruses. [3]

1. **Advantage #1: Plasmids do not integrate into the genome, hence it does not cause insertional mutagenesis which can facilitate cancer development;**
2. **Advantage #2: Lower risk of stimulating immune response;**

3. **Advantage #3: Do not cause disease / lower risk of pathogenicity;**
4. **Disadvantage #1: Plasmids do not integrate into the genome, hence expression of transgenes is short-lived / cells may only achieve pluripotency temporarily / require multiple rounds of introduction of plasmid;**
   R! Gene therapy is short-lived (irrelevant context)
5. **Disadvantage #2: Lower efficiency of transferring transgenes into cells;**

Note: Students must have 2 advantages and 1 disadvantage to get full marks.

(iii) Before iPSCs are stimulated to undergo cellular differentiation, the introduced genes must be removed from the cells. Suggest why this process is necessary. [1]

1. **Transcription factors encoded by transgenes allow cells to remain pluripotent which impedes differentiation;**
2. **To remove the risk of insertional mutagenesis if transgenes are integrated into cells (via retroviral transfection);**

[Total: 11m]

4. Planning question

The visking tubing is a semi-permeable membrane which allows smaller molecules such as water and glucose to pass through, but not larger molecules like sucrose and proteins. The tubing is to be supported in a boiling tube as shown in Fig. 4.1.

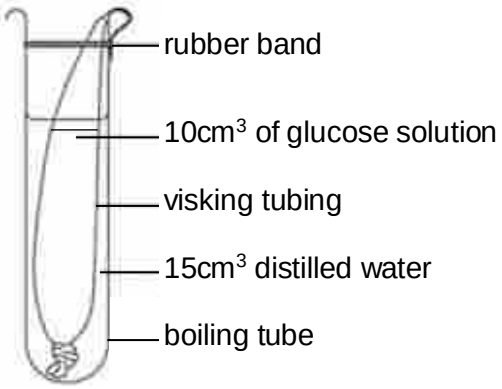


Fig. 4.1

The presence of glucose can be detected using the Benedict's test for reducing sugars.

Using this information and your own knowledge, design an experiment to investigate the effect of glucose concentration on its rate of diffusion across the visking tubing.

You must use:
- 5 pieces of visking tubing (each knotted at one end, and open at the other), soaked in a beaker of distilled water
- 5 boiling tubes and 5 rubber bands
- 2.0 moldm^{-3} glucose solution
- Benedict's solution
- weighing balance and weighing paper
- filter paper and funnel
- distilled water
- thermostatically-controlled water bath

You should select from the following apparatus:
- any normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, glass rods
- tripod stand, bunsen burner and lighter
- test-tube holder
- stopwatch
- syringes

Your plan should:
- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- include layout of results tables and graphs with clear headings and labels,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12m]

Answer Scheme

1. Theoretical consideration or rationale of the plan to justify the practical procedure (1 mark)

A. How would the independent variable (glucose concentration) affect the dependent variable (rate of diffusion)?

(a) As **concentration of glucose** in the visking tubing **increases**, the **rate of diffusion of glucose molecules across the membrane increases** (over a fixed amount of time)**;**

B. How would the dependent variable (rate of diffusion) be measured?

(b) The rate of diffusion can be **measured by weighing the amount of precipitate** formed from reacting the solution in the boiling tube with **Benedict's solution** to test for presence of reducing sugars.

(c) As a result, **mass of precipitate (g) formed will increase with an increase** in the **rate of diffusion**.

2 The correct use of technical and scientific terms (throughout the write-up, 1 mark)
(a) down/along concentration gradient,
(b) precipitate

Procedure [max 9 m]

Independent Variable	**3. Identification** of **independent variable: concentration of glucose solutions.;**
	4. At least 5 concentration of glucose solutions with **regular interval** ranging from 0.4, 0.8, 1.2, 1.6, 2.0moldm^{-3} not inclusive of 0.0moldm^{-3}
	5. Dilution table to make up different concentrations of glucose solutions (volume of water, volume of glucose solutions, concentration of glucose solutions must be indicated, total volume is the same for all concentrations) Note for markers: Precision does not need to be seen, but if incorrect units penalize.
Dependent Variable	**6. Use of filter funnel and filter paper to obtain precipitate**
	7. Determination of dependent variable: rate of diffusion **measured by measuring the mass of precipitate formed using a weighting balance** from reacting glucose with Benedict's solution
	8. Description of Benedict's test: **(a) Equal volume of Benedict's solution and test solution** **(b) Boiling water bath**
Constant Variables (Points 9 to 14, max 2)	Constant vol. of glucose solution 10cm^3 (stated in qn, no marks awarded) Constant vol of distilled water 15cm^3 (stated in qn, no marks awarded) **9. Constant vol of solution taken from boiling tube to react with Benedict's solution** e.g. 1-5cm^3 **10. Constant volume of Benedict's solution used** e.g. 1-5cm^3 **11. Fixed amount of time for diffusion to occur** e.g. 5-30min **12. Fixed amount of time for heating Benedict's solution with sample solution** e.g. 1-5min **13. Constant temperature** (suitable temperature: 25-35^{o}C) **at which diffusion takes place** (maintained thermostatically-controlled water bath)

Equilibration	**14.** Place the (visking tubing in the beaker of distilled water)**, the glucose solutions and a beaker of distilled water separately** in a **thermostatically controlled water bath** for **fixed time** e.g. 5 minutes at **fixed temperature** e.g. 25-30°C.
Control	**15.** Description of control experiment: **(a)** Replace glucose solution with **10.0cm^3** of **distilled water**. (as long as present in dilution table, award) **(b)** Subject the control tube to the same experimental conditions. **(c)** Ref to rationale of control: This shows that without glucose, red precipitate is not observed as there is **no diffusion of glucose** across the visking tubing.
Table of results	**16.** Table of results with **clear headings and units**. (**Concentration** of glucose solution/moldm^{-3}, Weight of ppt/g, **average rate of diffusion** of glucose across membrane/gmin^{-1}). Note for markers: ECF. If theory is incorrect, marks can still be awarded.
Repeats and replicates	**17.** **(a)** Repeat experiment twice to get replicate readings (at least 3 replicates) **(b)** Repeat entire experiment twice for repeat readings (at least 2 repeats)
Data Analysis & Graph	**18.** **(a)** Plot graphs of average rate of diffusion (gmin-1) against concentration of glucose (moldm-3) **(b)** Sketch expected trend, straight line positive gradient graph R: Plateau Note for markers: ECF. If theory is incorrect, marks can still be awarded. However, the y axis of the graph must follow the table seen in 16.
~~Labelled Diagram~~	Not required since it is already provided

Points 3-18 max 9 marks

19 Safety Precautions (1 mark)

a. Handle the boiling water bath with care as **hot** water can scald / Handle the lit Bunsen burner with care as it can burn/ Handle the test-tubes in the boiling water bath with test-tube holders as the test-tubes can burn
b. Wear gloves when handling the Benedict's solution as it is a possible skin irritant.
c. Use dry hands when handling the power socket/supply of the thermostatically controlled water bath/ electrical appliances to prevent electrocution.

Procedure

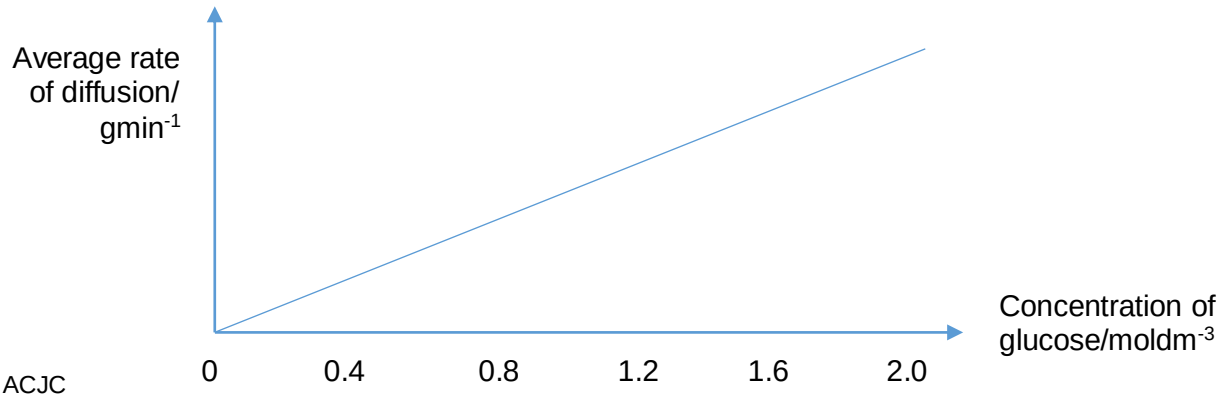
1. Label 5 test-tubes 0.4, 0.8, 1.2, 1.6 and 2.0moldm^{-3} glucose.
2. Using a 10.0cm^3 syringe, dilute the glucose solution, as shown, to obtain the following glucose concentrations:

Conc of glucose solution/moldm^{-3}	Volume of 2.0 moldm^{-3} glucose solution added/cm^3	Volume of distilled water added/cm^3	Total volume/cm^3
0.4	2.0	8.0	10.0
0.8	4.0	6.0	10.0
1.2	6.0	4.0	10.0
1.6	8.0	2.0	10.0
2.0	10.0	0.0	10.0

3. Equilibrate the visking tubing in the beaker of distilled water, the 2.0moldm^{-3} glucose solution and a beaker of distilled water separately in a thermostatically controlled water bath for 5 minutes at 30°C.
4. Remove a visking tubing from the distilled water and squeeze it to remove as much distilled water as possible.
5. Using a 10.0cm^3 syringe, place 10.0cm^3 of the 2.0moldm^{-3} glucose solution into the visking tubing and set up the experiment as shown in Fig. 4.1.
6. Start the stopwatch once you place the visking tubing into the boiling tube filled with distilled water and leave the set-up for 10 minutes.
7. After 10min, use a 10.0cm^3 syringe to transfer 2.0cm^3 of the solution in the boiling tube into test-tube labelled 2.0 moldm^{-3}.
8. Using a 10.0 cm^3 syringe, add 2.0cm^3 of Benedict's solution to the test-tube.
9. Mix the contents thoroughly and place the test-tubes in a beaker of boiling water for 3 minutes.
10. Remove the test-tube from the boiling water with a test-tube holder.
11. Let it cool before pouring the contents into a funnel lined with filter paper. Use the glass rod to remove all remaining precipitate in the test-tube onto the filter paper.
12. Let the filtrate drip into the sink. When the filtrate stops dripping, remove the filter paper from the funnel.
13. Tare the weighing balance with a clean sheet of weighing paper.
14. Using the glass rod, gently scrap as much of the precipitate from the filter paper onto the weighing boat.
15. Record the weight of the precipitate in a table as shown:

Concentration of glucose solution/moldm^{-3}	Weight of precipitate / g				Average rate of diffusion of glucose across membrane/gmin^{-1}
	Replicate 1	Replicate 2	Replicate 3	Average	
0.4					
0.8					
1.2					
1.6					
2.0					

16. Do two more replicates by repeating steps 3 to 15.
17. Repeat steps 3 to 16 for the other glucose concentrations.
18. Repeat the entire experiment twice.
19. To set up the control, repeat steps 3 to 16 using 10.0cm^3 of distilled water instead of glucose. Subject the control tube to the same experimental conditions. This shows that without glucose, red precipitate is not observed as there is no diffusion of glucose across the visking tubing.
20. Calculate the average rate of diffusion of glucose across the visking tubing membrane: average weight of precipitate divided by 10min.
21. Plot a graph to show how average rate of diffusion increases with concentration of the glucose.



Safety Precautions:

d. Handle the boiling water bath with care as hot water can scald / Handle the lit Bunsen burner with care as it can burn.
e. Wear gloves when handling the Benedict's solution as it is a possible skin irritant.

For Examiner's Use

5. Free-response Question

Write your answers to this question on the separate paper provided.

Your answers:

- should be illustrated by large, clearly labelled diagrams, where appropriate.
- must be in continuous prose, where appropriate.
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

(a) Describe the steps and advantages of plant tissue culture.

[8]

Techniques (max. 6)

1. **Plant tissue culture is performed under aseptic conditions (in a laminar flow hood to prevent bacterial and fungal contamination);**
2. **A small piece of plant tissue / explant is taken from the meristematic tissue of a stock plant that possess desirable characteristics;**
3. **Explants are sterilized with bleach / sodium hypochlorite;**
4. **Explant cells are cultured in a growth medium containing plant growth regulators such as auxin and cytokinin and other nutrients such as sucrose, amino acids, vitamins and inorganic ions (name any 2 nutrients);**
5. **To allow cells to divide by mitosis to form a callus;**
6. **Callus is subcultured into separate culture vessels to produce more plantlets;**
7. **Specific ratio of plant growth regulators such as auxin and cytokinin is then added to induce differentiation of callus into a plantlet;**
8. **Plantlet is transferred into soil and allowed to grow under controlled conditions in a greenhouse (until plant is hardy enough to survive in the field);**

Advantages (max. 4)

9. **Production is not affected by weather or environmental conditions;**
10. **Plants that are difficult to germinate from seeds (e.g., orchids) can be easily produced via tissue culture;**
11. **Less space is required to grow plants in the lab as compared to the field;**
12. **Disease-free plants can be produced;**
13. **Mass production of many copies of genetically identical plants with desirable traits is possible, hence increasing yield of crop;**
14. **Plant cultures stored in culture flasks are easier to transport (via air freight);**

@ 1m, max. 8

(b) Discuss the benefits and ethical issues related to the use of a named genetically modified animal. [6]

1. GM salmon;

Beneficial considerations:

2. GM Salmon can produce growth hormones all year round and achieve a faster growth rate to increase yield/ grow to marketable size in half the time required;
3. Make fish farming more environmentally sustainable as reduction in the time required to raise salmon means supply could be increased without proportionately increasing the use of coastal waters;
4. Increase in food conversion rates means that fewer natural resources are required to produce the fish;

Negative ethical implications:

5. Some argue that producing GMOs is tampering with nature as foreign genes are introduced into an organism's genome;
6. Concerns that human genetic modification for enhancement may one day occur;
7. Concerns that genetically modifying salmon may cause suffering or pain or distress / welfare of animals is compromised in the process;
8. There could be unexpected undesirable outcomes / side-effects in the well-being of animals due to unpredictable interaction of the transgenes with its own DNA;
9. Companies (AquaBounty Technologies) have sought to patent GM Salmon that they have developed, and some argue that it reduces animals to the level of objects;
10. Labelling of products on sale to indicate that genetic engineering was involved in their production is not mandatory in some countries;
11. Consumers may thus unknowingly consume products that could be harmful to them / consumption of GM Salmon may produce unintended harmful secondary by-products that lead to potential health risks;
12. GM salmon might upset ecological balance; if the fast-growing salmon escape into the sea, they might affect balance of wild salmon populations as GM salmon may be more aggressive and better at competing with the wild salmon populations for resources;
13. Companies monopolise the technology hence dominating the market because innovations in research are not shared;

(Max. 3)
@ 1m

R: Answers that discuss a named plant organism (awarded 0 marks).
Answers that do not give a named organism, will still be awarded marks for relevant points.

(c) Discuss the goals and benefits of the human genome project. [6]

Goals

1. **Construct a detailed genetic map (i.e. map formed using recombination frequencies and measured in terms of cM) of the entire human genome.;**
2. **Determine the nucleotide sequences of all 24 human chromosomes (i.e. the physical map of the genome as measured in base pairs) by the year 2005.;**
3. **Identify all the approximately 20,000-25,000 genes in human DNA.;**
4. **Improve technology for DNA sequencing and studying the function of DNA on a genomic scale.;**
5. **Sequence genomes of model organisms (*E. coli*, budding yeast, *C. elegans*, *Drosophila*, and mouse) in order to compare genomes.;**
6. **Develop bioinformatics support – to (a) create and operate databases for easy access to data and (b) develop and improve tools for data analysis eg. Comparing and interpreting genome information.;**
7. **Address the ethical, legal and social issues that may arise from the project.;**

Max 3

Benefits

8. **Genetic testing - Improve diagnosis of disease; predict the risk of future disease in healthy individuals or their progeny**
9. **Pharmacogenetics - Customised medication and treatment based on your unique genome;**
10. **Gene therapy - Delivering specific genes into cells to treat disease;**
11. **Risk assessment of individuals upon exposure to toxic agents - Genetic differences make some people more susceptible and others more resistant to such agents → Assess health damage and risks to individuals caused by exposure to radiation exposure and carcinogens → Evaluate if individuals are suitable to work in those areas with exposure to radiation and carcinogens;**
12. **Understanding human evolution - Study evolution through germline mutations in lineages/ Compare breakpoints in the evolution of mutations with ages of populations and historical events/ Study migration of different population groups based on female genetic inheritance (mitochondrial DNA) and male genetic inheritance (Y chromosome);**
13. **DNA forensics - Catch criminals / Identify victims of crimes, disasters / Establish family relationships / Match organ donors and recipients / Identify endangered/protected species / Determine pedigree for seed or livestock / Authenticate consumables such as caviar and wine;**

NOTE: each point requires elaboration and can be owtte

Max 3

H2

ANDERSON JUNIOR COLLEGE
HIGHER 2

BIOLOGY 9648/01

Paper 1 Multiple Choice

23 September 2016
Friday

1 hour 15 mins

Additional Materials: Multiple Choice Answer Paper

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, PDG and identification number on the Answer Sheet.

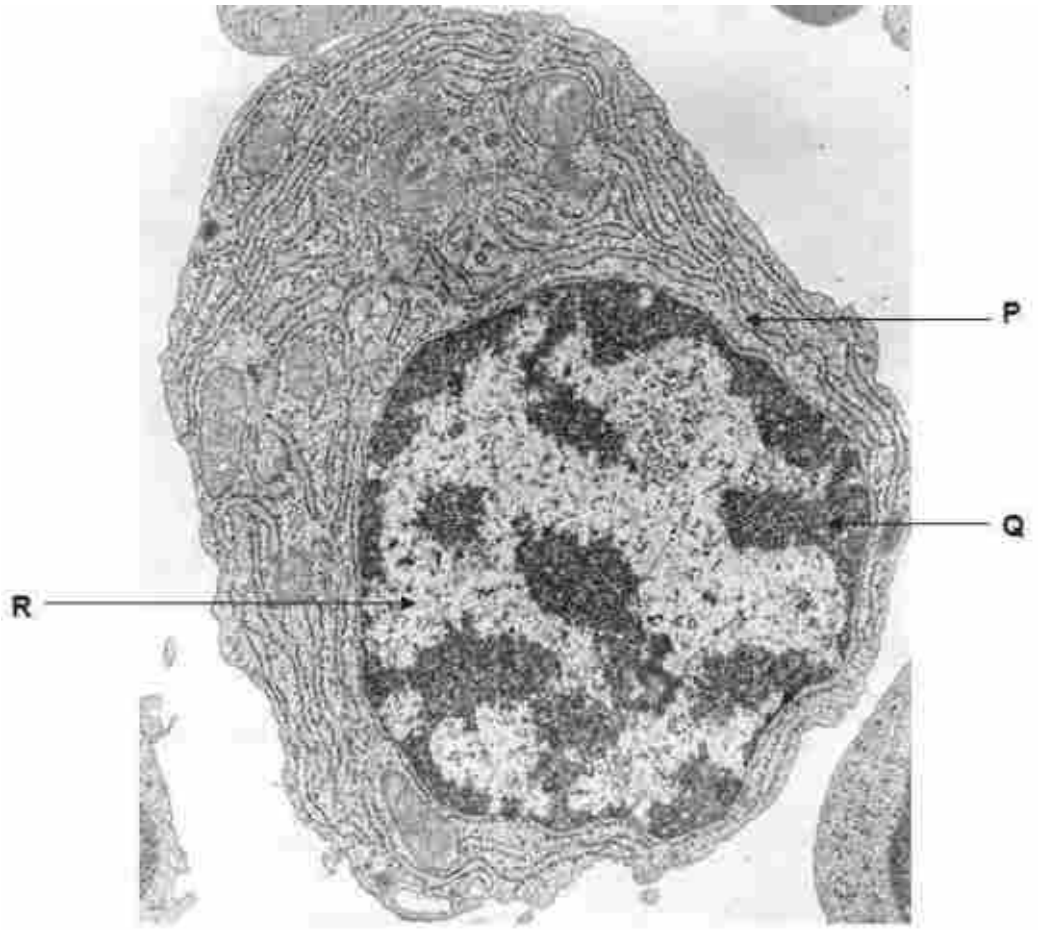
There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

Calculators may be used.

This document consists of **28** printed pages

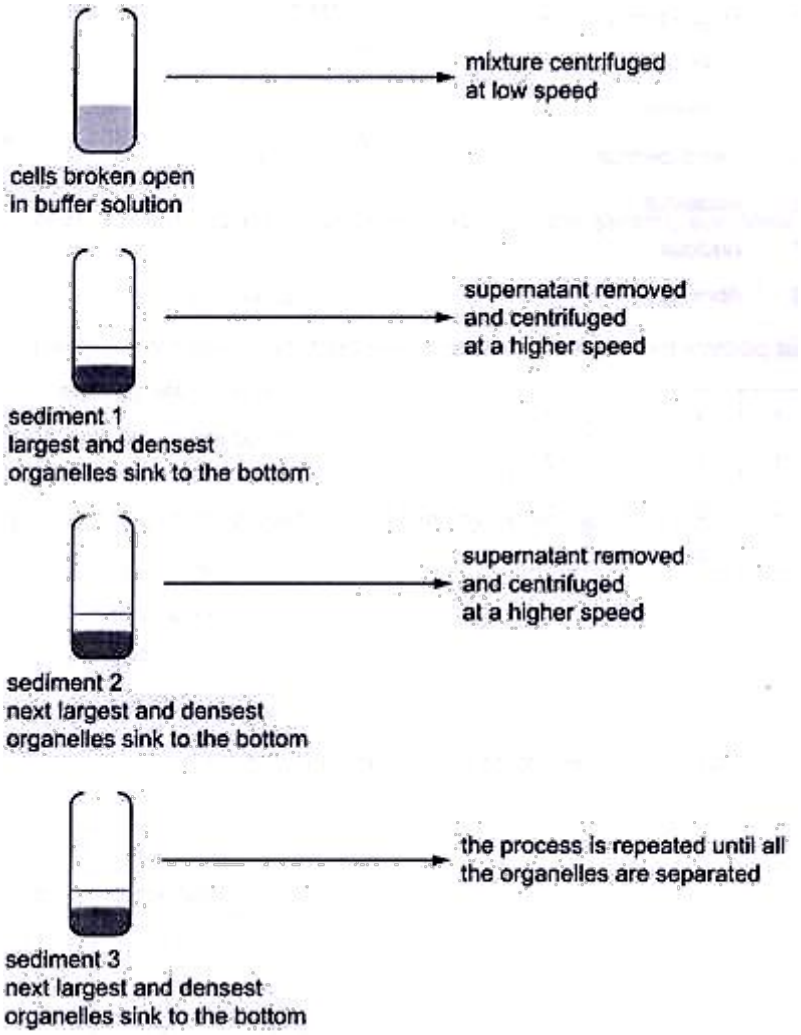
1 The figure below shows an electron micrograph of a cell.



Which of the following about structures **P**, **Q** and **R** are correct?

	P	Q	R
A	provides large surface area for attachment of ribosomes	contains demethylated DNA	contains acetylated histones
B	transport of proteins to Golgi apparatus	histones are deacetylated	active condensation of chromatin
C	synthesis and processing of membrane proteins	contains methylated DNA	active transcription of genes
D	synthesis of phospholipids and steroid hormones	transcription of genes silenced	synthesis of proteins on free ribosomes

2 Fractionation is a process used to separate cell components according to their size and density. The diagram shows the main stages in fractionation of a plant cell.



DCPIP and buffer solution (containing glucose, fructose, sodium bicarbonate) were added to each of the sediments, and the mixtures were left in the dark for fifteen minutes. Sediment 2 caused the DCPIP to be reduced.

Which organelle present in Sediment 2 caused reduction of DCPIP?

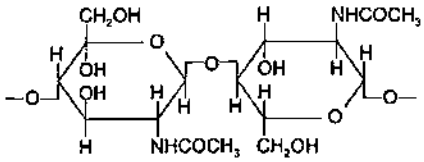
A Chloroplast

B Mitochondria

C Nuclei

D Ribosomes

3 The diagrams show short sections of some common polysaccharides and modified polysaccharides.



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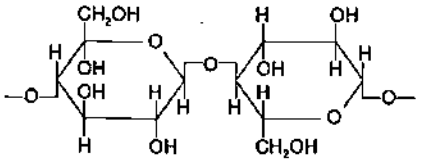
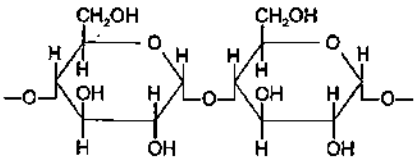
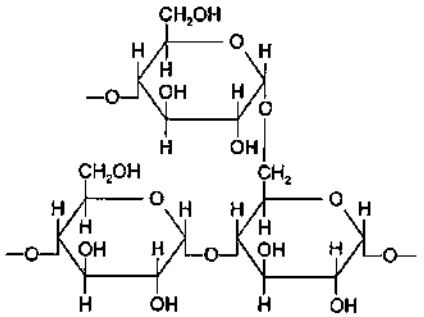


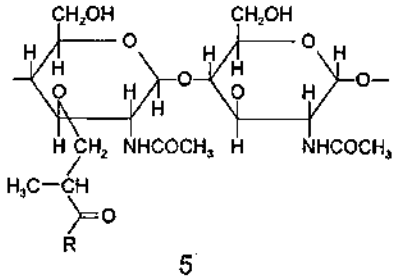
2



3



4



5

The polysaccharides can be described as below.

- polysaccharide **F** is composed of β-glucose monomers with 1,4 glycosidic bonds
- polysaccharide **G** is composed of α-glucose monomers with 1,4 and 1,6 glycosidic bonds
- polysaccharide **H** is composed of N-acetylglucosamine and N-acetylmuramic acid monomers with β-1,4 glycosidic bonds
- polysaccharide **J** is composed of α-glucose monomers with 1,4 glycosidic bonds
- polysaccharide **K** is composed of N-acetylglucosamine monomers with β-1,4 glycosidic bonds

Which shows the correct pairings of polysaccharide descriptions and diagrams?

	polysaccharide **F**	polysaccharide **G**	polysaccharide **H**	polysaccharide **J**	polysaccharide **K**
A	2	4	5	3	1
B	2	5	4	1	3
C	3	4	5	2	1
D	3	5	4	1	2

4 Which description concerning collagen is correct?

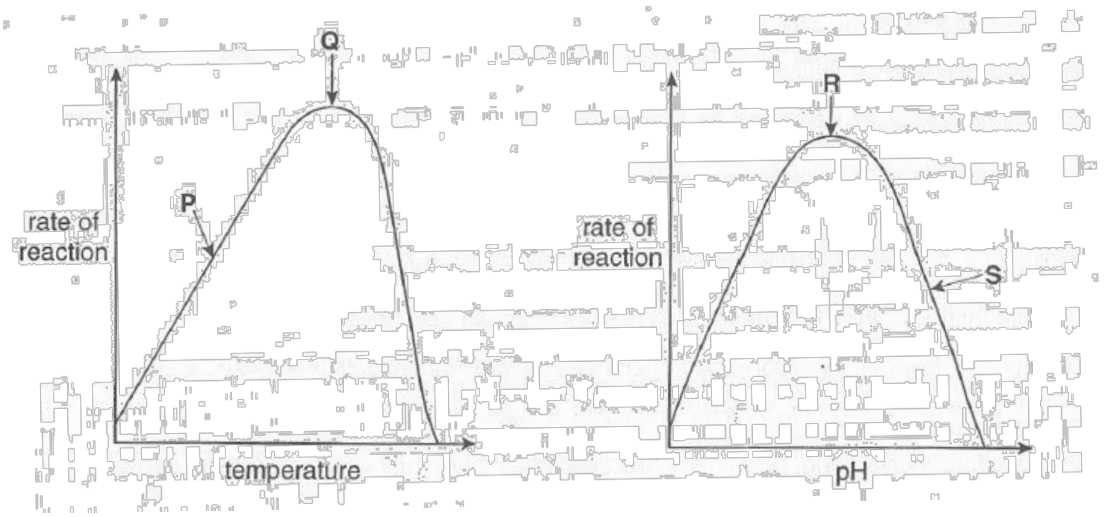
A Collagen has polypeptides arranged parallel to each other and the amino acid sequence contains a large variety of amino acids with different sized R-groups.

B Collagen has polypeptides that are arranged very closely together and the amino acid sequence has every third amino acid as glycine.

C Collagen has three polypeptides that are bounded to one another by covalent cross links and the amino acid sequence contains amino acids with hydrophobic R-groups.

D Collagen is an insoluble molecule and the amino acid sequence contains successive amino acids which are rotated to allow formation of bonds.

5 The graphs show the effects of temperature and pH on enzyme activity.



Which statement is a correct explanation of the rate of reaction at the point shown?

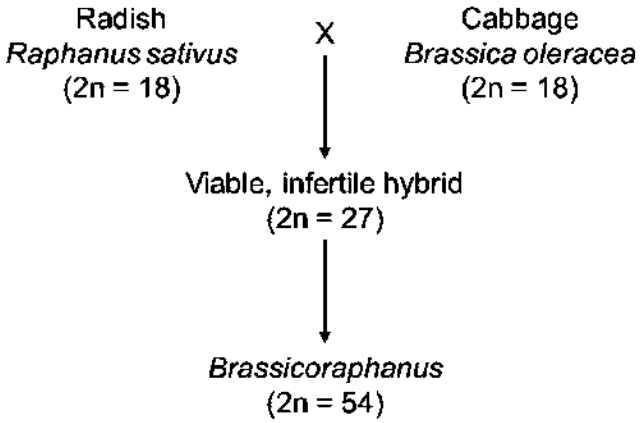
A At **P**, hydrogen bonds in the enzyme are broken.

B At **Q**, the kinetic energy of enzyme and substrate is highest.

C At **R**, covalent bonds are formed between enzyme and substrate.

D At **S**, ionic bonds in the enzyme are broken.

6 A cross between radish (*Raphanus sativus*) and cabbage (*Brassica oleracea*) produced the following results.



Which of the following statements are possible explanations for the results of the cross shown above?

1 Non-disjunction of all sister chromatids during anaphase II resulted in the production of diploid gametes in radish, which fused with a haploid gamete of cabbage to give rise to the infertile hybrid progeny.

2 The hybrid is infertile because it has a diploid number which is odd.

3 The hybrid is infertile as there are nine unpaired chromosomes during prophase I, which prevented the formation of gametes.

4 Addition of colchicine prevents the formation of spindle fibres, which enabled the infertile hybrid to form gametes. Fusion of two of these gametes gives rise to *Brassicoraphanus.*

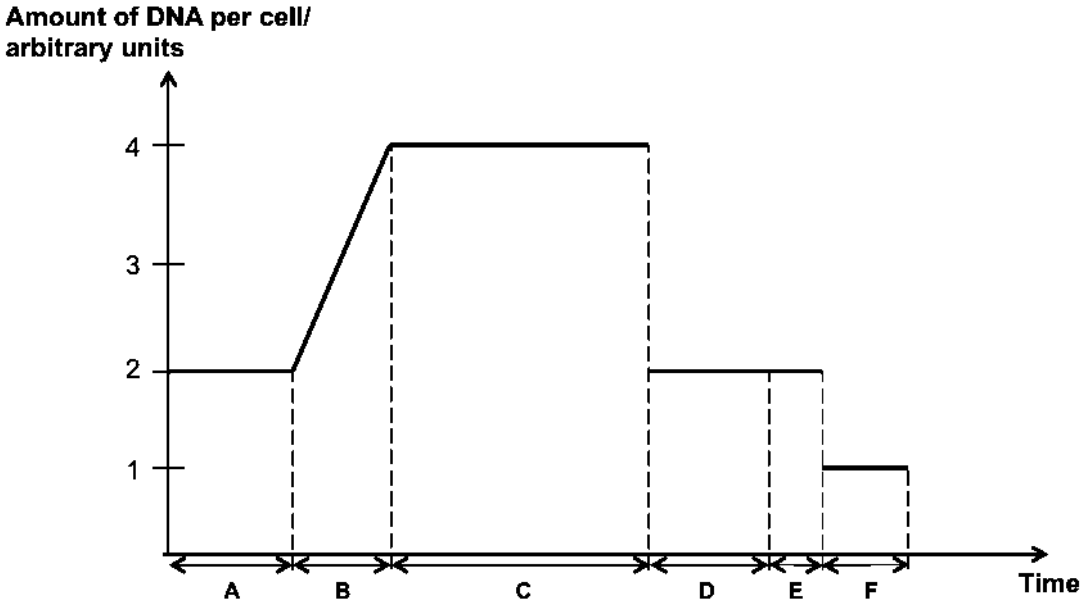
A 1 and 4

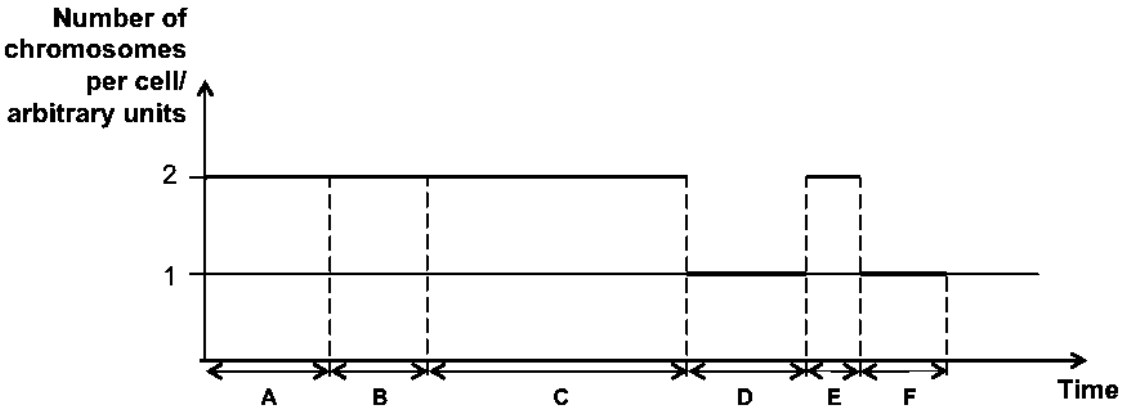
B 2 and 3

C 1, 2 and 4

D 1, 3 and 4

7 The figures below show how the amount of DNA and number of chromosomes vary in a cell of *Chrysanthemum makinoi* during meiosis.





Which of the following statement is **false**?

A Phase A and B correspond to G1 and S phase of interphase respectively.

B In phase C, the cell is undergoing prophase, metaphase, anaphase and telophase of meiosis I only.

C In phase E, the cell is undergoing telophase II only.

D In both phase D and F, the cell has completed cytokinesis.

8 The table below shows a list of characteristics displayed by mutant strains of *E. coli* during DNA replication and the possible reasons.

No.	Characteristics	Enzymes or functions affected by mutation
1	Okazaki fragments accumulate and DNA synthesis is never completed	DNA ligase activity is missing
2	Supercoils are found to remain at the regions that flank the replication bubbles	DNA helicase is hyperactive
3	Synthesis is very slow.	DNA polymerase keeps dissociating from the DNA and has to re-associate
4	No initiation of replication occurs.	The TATA box region at origin of replication is deleted

Which of the reasons correctly explain the characteristics displayed by the mutant *E. coli* strains?

A 1 and 3

B 2 and 3

C 1, 2 and 4

D 1, 3 and 4

9 Tay-Sachs disease is a fatal neurodegenerative disease which is caused by a mutation in the hexosaminidase A (Hex A) gene located on chromosome 15.

Part of the sequence of the non-template (coding) DNA strand of the normal Hex A allele and the mutated Tay-Sachs allele are shown below. The sequences are the same as the mRNA sequence of both alleles.

DNA sequences of normal Hex A allele:

Amino acid position		424	425	426	427	428	429	430	431	
Non-template DNA	5'…	CGT	ATA	TCC	TAT	GGC	CCT	GAC	TGT	…3'

DNA sequences of mutated Tay-Sachs allele:

Amino acid position		424	425	426	427	428	429	430	431	
Non-template DNA	5'…	CGT	ATA	TCT	ATC	CTA	TGG	CCC	TGA	…3'

For both alleles, 9 different amino acids are encoded for by the DNA triplets:

Amino acid	DNA triplet
Arg	CGT
Asp	GAC
Cys	TGG, TGT
Gly	GGC
Ile	ATA, ATC

Amino acid	DNA triplet
Leu	CTA
Pro	CCC, CCT
Ser	TCC, TCT
Tyr	TAT
Stop codon	TAG, TAA, TGA

Which statement is true?

A The disease is caused by the deletion of one DNA nucleotide.

B The Hex A protein encoded for by the Tay-Sachs allele is non-functional due to a frameshift mutation.

C The polypeptide encoded for by the Tay-Sachs allele has the same number of amino acids as that encoded by the normal Hex A allele.

D At amino acid position 431, there is a silent mutation.

10 Scientists were able to excise out the promoter of eukaryotic gene and attach it to the end of a gene as shown below. The gene was reintroduced back to the organism, which is homozygous at the gene loci.

Which of the following outcomes is true?

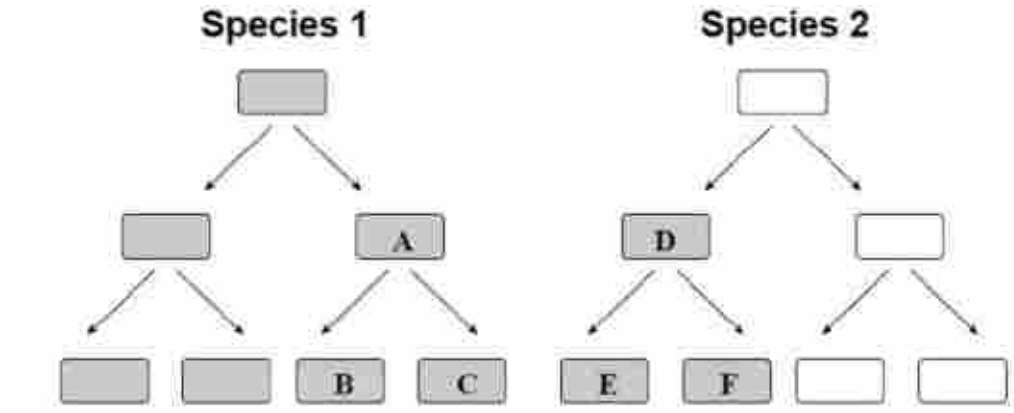
A No transcription of the gene takes place, as the promoter cannot initiate transcription of the non-template strand.

B Transcription initiates but may prematurely terminate due to a premature stop codon.

C Transcription takes place but translation cannot take place because the genetic code is no longer the original code.

D Transcription takes place but less translation occurs to obtain functional protein because the mRNA may form a duplex RNA.

11 The diagram below shows how two species of bacteria reproduce when placed together in a growth medium. The bacteria that are shaded are resistant to the antibiotic penicillin.



Which one of the following statement(s) is likely to be true?

1 Bacteria **B** and **C** are resistant to penicillin as a result of binary fission of Bacterium **A**.

2 Bacteria **C, D** and **F** are resistant to penicillin as a result of random mutation.

3 Bacterium **D** is resistant to penicillin as a result of conjugation from Bacterium **A**.

4 Bacterium **D** is resistant to penicillin through transduction from Bacterium **A** where there is transfer of the complete F plasmid.

A 3 only

B 1 and 3

C 1 and 4

D 2, 3 and 4

12 When a mutant strain of *Escherichia coli* that has lost the regulatory gene of its tryptophan operon is placed in a medium that contains all nutrients the cell need to grow except tryptophan, which of the following will occur?

A The cells will grow even though there is no tryptophan in the medium.

B The cells will grow until excessive tryptophan arrests the expression of the operon.

C The cells will not grow until enough tryptophan has been synthesised to make the repressor active.

D The cells will never grow unless tryptophan is added to the medium.

13 Temperate bacteriophages, such as the lambda phage, undergo the lysogenic cycle in their bacterial host cells.

Which of the following could prevent the temperate bacteriophages from entering the lysogenic life cycle?

1 A loss-of-function mutation in the viral gene which codes for integrase.

2 Deletion of 10 nucleotides at the site of phage integration on the bacterial chromosome.

3 Gain-of-function mutations in the viral genes which code for transcriptional repressor proteins.

4 Loss-of-function mutations in the viral genes which code for nucleases which break down bacterial chromosomal DNA.

A 1 and 2 only

B 1 and 3 only

C 2 and 4 only

D 1, 2 and 3 only

14 Which of the following occurs in the reproductive cycle of the human immunodeficiency virus (HIV) but **not** in that of the influenza virus?

A Newly synthesised viruses are released from host cells by budding from cell surface membrane.

B Host cell ribosomes are used to synthesise viral proteins.

C Viral RNA acts as a template for viral DNA synthesis.

D Viruses enter the host cell by endocytosis.

15 The percentage of the human genome that is transcribed is larger than predicted based on the range of proteins made by the cells.

Which of the following accounts for the difference?

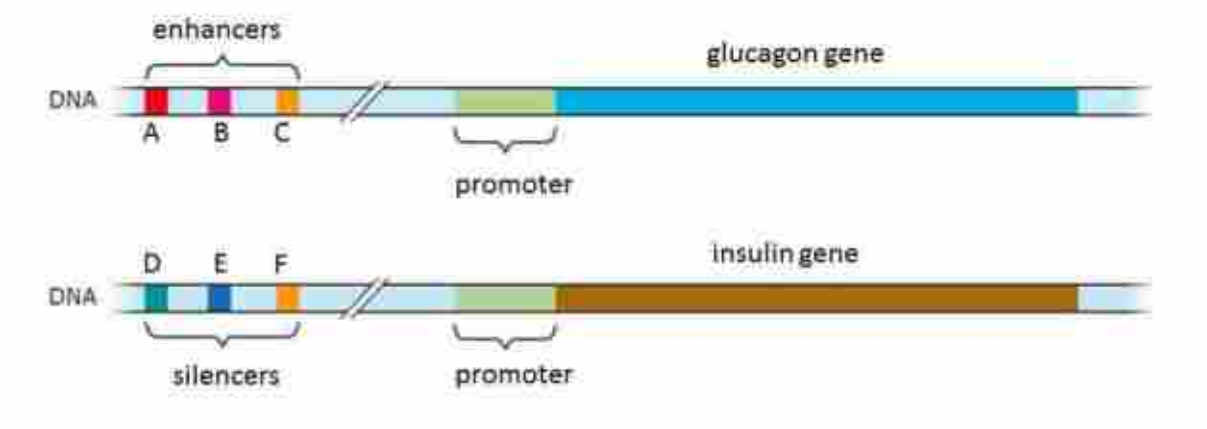
A Alternative splicing can result in more than one kind of protein produced from one gene.

B Some genes are transcribed to give RNA that is not meant to serve as a template for protein synthesis.

C The enhancers present in the human genome are also transcribed to bring about an increase in the transcription of protein-coding genes.

D The telomeric regions are also transcribed to give telomerase, which helps to maintain the telomere length.

16 The diagram below shows the control elements and two genes found in the human genome.



Which of the following statement(s) about the above genes is/are true?

1 The glucagon gene is found only in the α-cells of the Islets of Langerhans while the insulin gene is found only in the β-cells of the Islets of Langerhans.

2 Binding of control elements, specific transcription factors and RNA polymerase at the promoter initiates transcription of glucagon.

3 The glucagon gene will be transcribed at a high level when transcription factors bind to control elements A, B, and C.

4 The expression of insulin can only be suppressed when transcription factors bind to control elements D, E and F.

A 3 only

B 2 and 3 only

C 1, 2 and 4 only

D 2, 3 and 4 only

17 Which statement correctly describes introns and/or exons?

A Different combinations and numbers of exons and introns in the mature mRNA allow more than one type of protein to be coded for by a gene.

B Mutations that occur within introns have no effect on the primary structure of protein as it will not be present in the mature mRNA.

C The exons found in the DNA sequence of a gene are always translated into proteins.

D Mutation at a splice site would result in a truncated protein as the intron, which is not excised, is non-coding and cannot be translated.

18 Which of the following statements correctly describe the changes in cancer cells?

1 Limitless replicative potential often results in the accumulation of chromosomal mutations in many cancer cells.

2 Cancer cells could overproduce signal molecules so that they become self-sufficient in growth signals.

3 Angiogenesis is the result of expression of oncogenes in a cell line that produces blood vessels.

4 Loss-of-function mutations in tumour suppressor genes contribute to tissue invasion and metastasis.

A 1 and 4 only

B 2 and 3 only

C 1, 2 and 4 only

D 2, 3 and 4 only

19 The statements listed below give information on the genetic control of hair curliness in dogs.

1 Chromosome 27 contains the gene responsible for curliness of the dog hair.

2 The nucleotide sequence of the gene produces an enzyme with arginine at residue position 151 but small changes in the nucleotide sequence produces an enzyme with cysteine at this point.

3 A dog may have both nucleotide sequences in its genome.

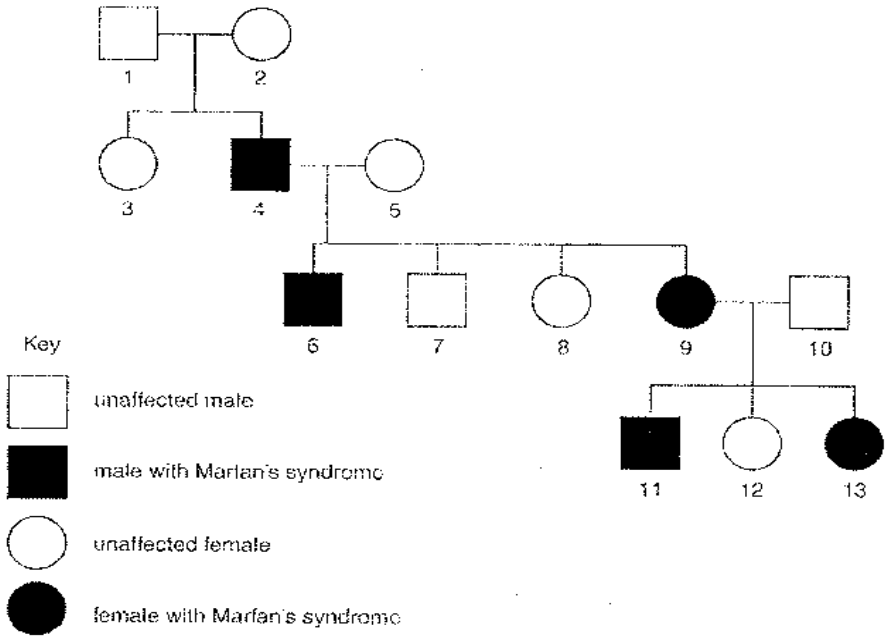
4 A dog producing both enzymes will have 'wavy' coat of hair.

5 At fertilisation, the dog inherits one set of chromosomes from each parent. Each set carries one of each form of the gene.

Which row matches each statement to the genetic term that it most closely describes?

	1	2	3	4	5
A	locus	genotype	allele	heterozygous	phenotype
B	locus	allele	heterozygous	phenotype	genotype
C	genotype	allele	heterozygous	phenotype	locus
D	locus	allele	genotype	phenotype	heterozygous

20 Marfan's syndrome is a rare genetic condition of humans, caused by a dominant allele. This condition is caused by a reduction in the quality or amount of the important protein fibrillin-1. The diagram below shows a family pedigree including some people with the condition.



Which of the following conclusions can be made based from the information provided?

A The fibrillin-1 gene locus is on the X chromosome.

B The mutation that gave rise to a non-functional fibrillin-1 allele occurred in the individual 4 during embryonic development.

C The variation in disease expression will be discontinuous.

D If individual 11 mated with a female who is heterozygous for the gene locus, the probability that they have an unaffected female child is 0.125.

21 In pigeons, the alleles of the gene controlling eye colour are co-dominant.

Two separate crosses were carried out and the results were shown below.

Cross 1

Parental generation black eye female X white eye male

F_1 generation grey eye females and black eye males

Cross 2

Parental generation white eye female X black eye male

F_1 generation grey eye females and white eye males

What phenotypic ratio would be expected in the F_2 generation in the first cross?

A 1 black-eyed male: 1 white-eyed male: 2 grey-eyed females

B 1 black-eyed male: 1 white-eyed male: 1 grey-eyed female: 1 black-eyed female

C 1 black-eyed male: 1 grey-eyed male: 1 white-eyed female: 1 black-eyed female

D 2 black-eyed males: 1 grey-eyed female: 1 white-eyed female

22 The coat colour of Labrador retrievers is controlled by two genes, **B/b** and **A/a**. Allele **B** (dominant) codes for black coat, while allele **b** (recessive) codes for brown coat. The coat colour of a Labrador retriever with genotype **aa** is yellow.

A cross between a male black Labrador retriever and a female yellow Labrador retriever produced some black puppies and some yellow ones.

What are the genotypes of the parental dogs?

	Black retriever	**Yellow retriever**
A	AaBb	aabb
B	AaBb	aaBb
C	AaBb	aaBB
D	AABb	aaBb

23 A cross was made between 2 pure breeding maize varieties, Tom Thumb and Black Mexican which differed markedly in ear length. The ear length for the parental, F_1 and F_2 generations was measured in centimetres and recorded in the table below with the number of ears in each length category (e.g.13 of the F_1 plants produced ears 12 cm in length).

Generation	Ear length (cm)														
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Black Mexican (parental)									4	11	12	32	27	10	8
Tom Thumb (parental)	4	28	19	3											
F_1					2	12	18	13	17						
F_2			2	3	15	22	33	28	19	13	2	2			

Which of the following statements correctly explains the data shown above?

1 The phenotypic variation is continuous and could be the result of multiple alleles.

2 Variation in environmental factors has a large effect on the phenotype.

3 The increase in phenotypic variation from F_1 to F_2 generation could be due to genetic mutations.

4 The increase in phenotypic variation from F_1 to F_2 generation could be due to sexual reproduction processes like crossing over, independent assortment of homologous chromosomes and random fusion of gametes.

A 1 and 3

B 2 and 4

C 1, 2 and 4

D 2, 3 and 4

24 Unaffected carriers with chromosomal inversions are likely to produce genetically abnormal progeny.

Which of the following explains this?

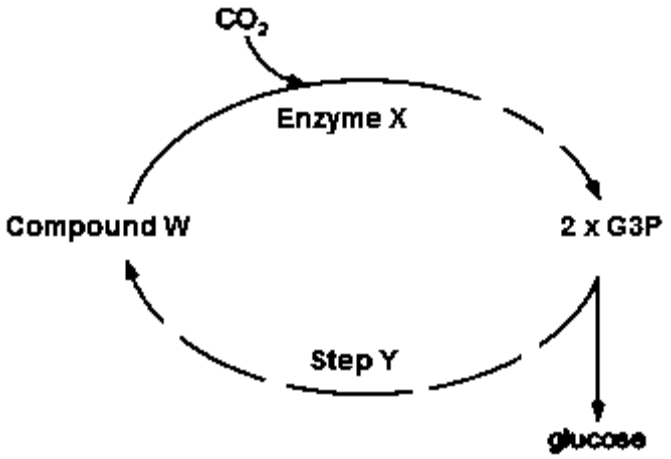
A The mutated chromosome is more likely to be placed in a gamete than the normal chromosome.

B The mutated chromosome is unable to accomplish synapsis with the normal chromosome during meiosis.

C Crossovers cannot occur between normal and mutated chromosomes.

D Crossovers between the normal and mutated chromosomes lead to chromosomes with deletions, deficiencies, or abnormal structure.

25 The figure below summaries some key reactions which occur in the Calvin cycle. The dashed lines indicate that there is more than one reaction present.



Using the figure above and your knowledge of Calvin cycle, determine which one of the following statements below is true.

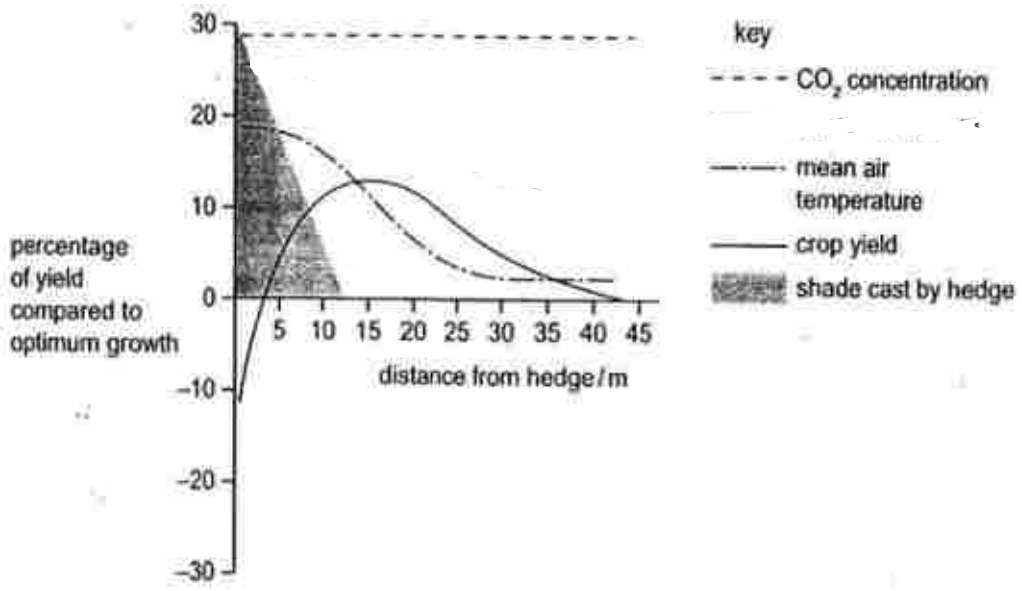
A Compound **W** is expected to accumulate if carbon dioxide concentration increases under low light intensity.

B Products released from Enzyme **X** are expected to accumulate when light intensity is low.

C G3P is expected to accumulate when light intensity is low.

D ATP from substrate level phosphorylation is required for Step **Y** to proceed and Compound **W** to be formed.

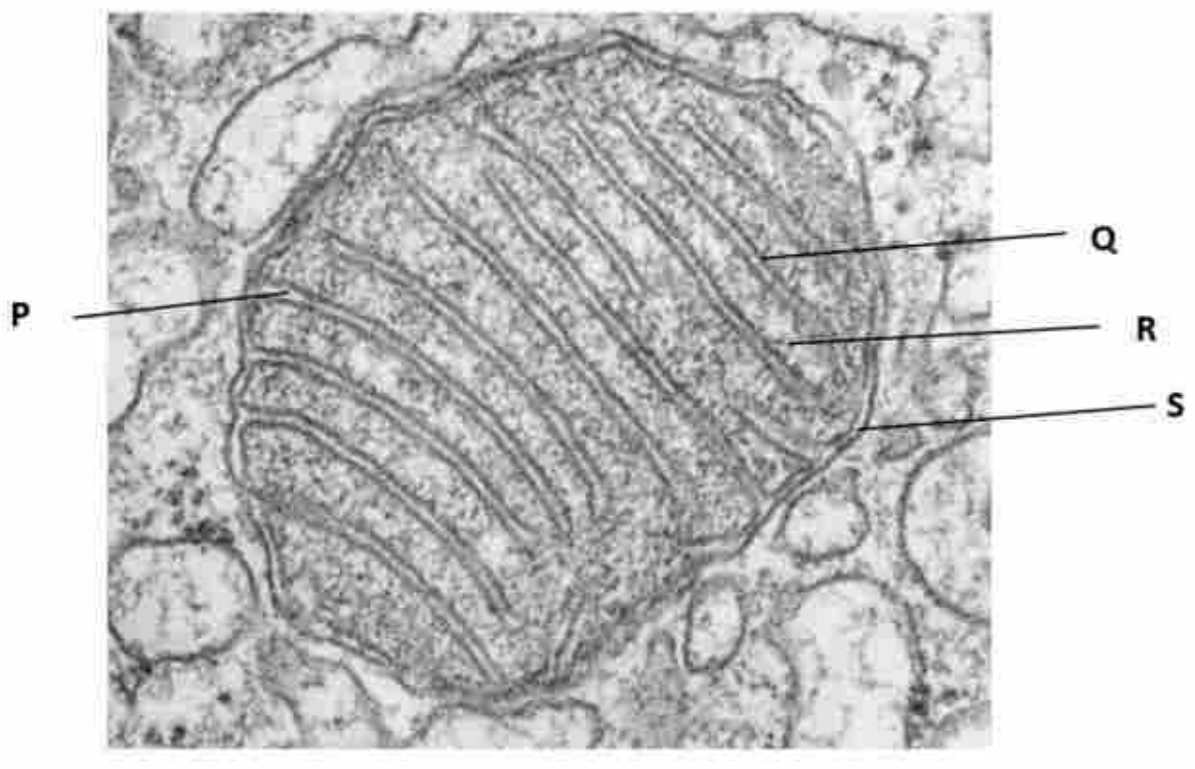
26 In the diagram, researchers superimposed the changes in four environmental factors on a graph of crop yield against distance from a hedge.



Which factor is most likely to have been the limiting factor in crops 8m and 25m from the hedge?

	Limiting Factor	
	8m from hedge	**25m from hedge**
A	CO_2 concentration	Light intensity
B	Light intensity	Mean air temperature
C	Mean air temperature	Mean air temperature
D	Light intensity	CO_2 concentration

27 The figure below shows an electron micrograph of a mitochondrion.



Match the following processes with each of the labelled sites **P – S.**

1 Oxidative decarboxylation
2 Lowering of pH
3 Protein synthesis
4 Electron flow
5 Formation of oxidised co-enzymes of dehydrogenase

	P	**Q**	**R**	**S**
A	1, 3, 5	2	4, 5	3
B	2	4, 5	1, 3	2
C	1, 5	3, 4	2	1
D	2	4	1, 3, 5	2

28 Two test tubes containing the following contents are shown below:

Tube 1:
Radioactive glucose solution + yeast cells suspension + oxygen + antimycin

Tube 2:
Radioactive glucose solution + yeast cells suspension + oxygen

Radioactive glucose has all its six carbons made of radioactive ^{14}C. The initial radioactivity measured for the glucose in each test tube is 60 arbitrary units.

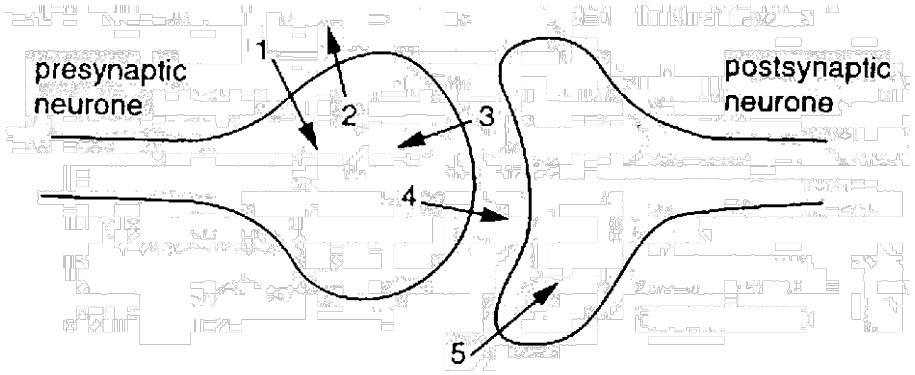
Antimycin is an electron transport chain inhibitor.

If the gaseous product and the aqueous products are tested using a radioactive meter after all the glucose has been metabolised, what would be the final observed readings?

	Tube 1 *(radioactivity measured/ arbitrary units)*		**Tube 2** *(radioactivity measured/ arbitrary units)*	
	aqueous products	**gaseous products**	**aqueous products**	**gaseous products**
A	0	60	40	20
B	20	40	0	60
C	40	20	0	60
D	40	20	60	0

29 The diagram shows the sequence of events occurring as an action potential arrives at a synapse.

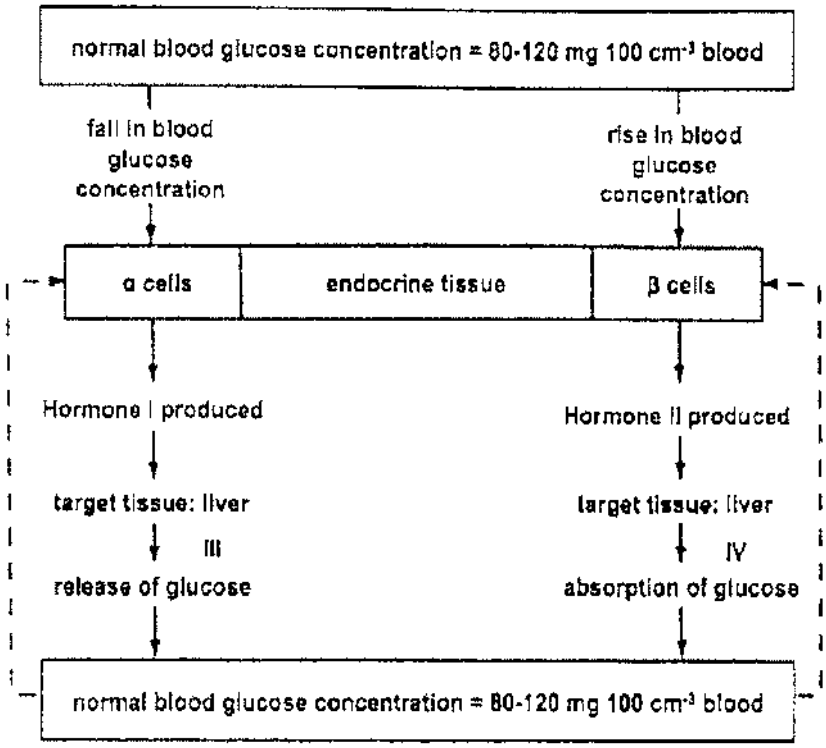
The numbered arrows represent the movement of substance across the membranes.



What are the substances moving across the membranes?

	1	**2**	**3**	**4**	**5**
A	K^+	Na^+	acetylcholine	Ca^{2+}	K^+
B	K^+	Na^+	K^+	Ca^{2+}	acetylcholine
C	Na^+	K^+	Ca^{2+}	acetylcholine	Na^+
D	Na^+	K^+	Na^+	acetylcholine	Ca^{2+}

30 The diagram below shows the role of an endocrine tissue in controlling blood glucose concentration.



Which of the following statements is/are true?

1 Small amounts of hormone I and II inducing a large response in liver tissue demonstrates positive feedback.

2 Hormones I and II inducing different responses from the same target tissue is due to the hormones binding to different receptors on the liver cell surface membrane.

3 The binding of Hormone I to receptors on liver cell surface membrane leads to the activation of second messenger cAMP.

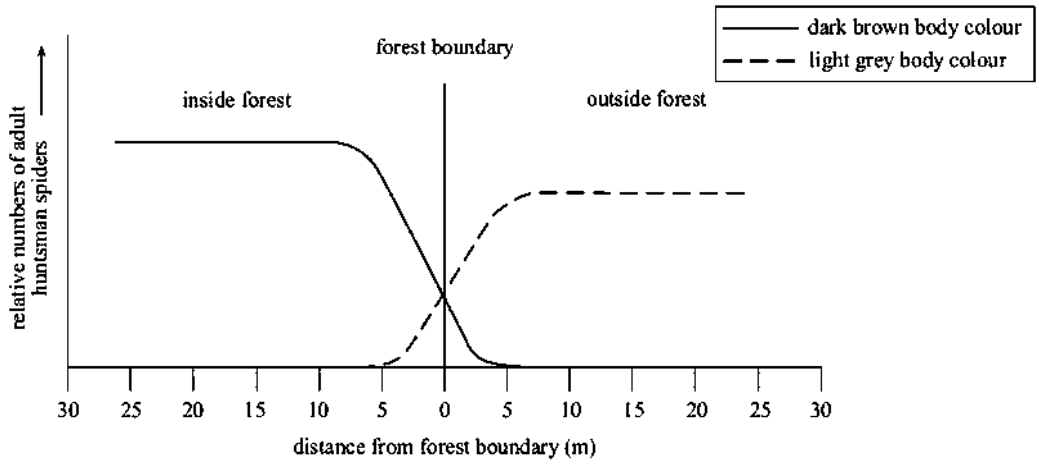
A 1 only

B 2 only

C 1 and 3

D 2 and 3

31 The graph below shows the distribution of huntsman spiders at a forest boundary:



One species of huntsman spider (*Isopeda isopedella*) varies in body colour from dark brown to light grey. In one community at the forest boundary, two populations of this species were found. Some were found living inside the forest and others were found living just outside the forest. The relative numbers of dark brown adult spiders and light grey adult spiders found at certain distances from the forest boundary are shown in the graph above.

Which of the following can be **least** inferred from the graph?

A The type of selective advantage inside the forest is different from the type of selective advantage outside the forest.

B The plateau in the population number as seen inside the forest and outside the forest is due to competition among the adult spiders for limited resources.

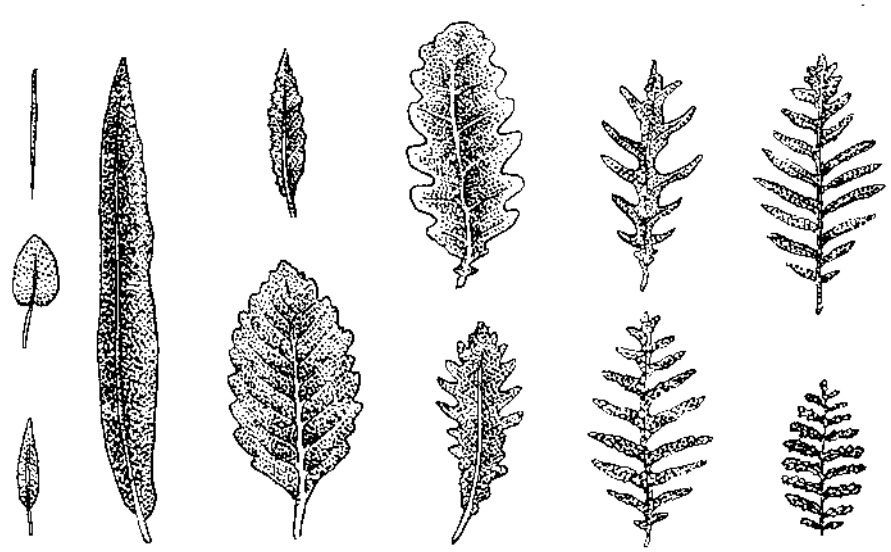
C The lower plateau of spider population outside the forest compared to that of inside the forest is due to the presence of additional selection pressure existing outside the forest.

D Dark brown huntsman spiders are not eaten by birds inside the forest as their colour allows them to camouflage and hence provides a selective advantage.

32 One of the six native genera of *Lobeliaceae, Cyanea,* contains 55 species that constitute 6% of the flora in Hawaii. They are restricted to particular islands or parts of islands. All *Cyanea* descend from a single ancestor, many have undergone striking changes in growth form, leaf size and shape.

Leaf morphology in *Cyanea* is thought to be determined by several gene loci on separate chromosomes.

The leaf morphologies of different *Cyanea* species are shown below.



Which of the following reasons explain the emergence of distinct leaf morphological differences between various species?

1 Mutation in leaf cells

2 Crossing over between non-sister chromatids of homologous chromosomes during gamete formation

3 Different humidity levels on different islands and in different parts of an island

4 The Hawaiian honeycreepers which pollinate the flowers of the plants on one island are unable to fly to other islands

A 1 and 2 only

B 3 and 4 only

C 1, 3 and 4 only

D 2, 3 and 4 only

33 Which of the following statements about the Neutral Theory of Molecular Evolution is **incorrect**?

A The neutral theory involves studying the changes in neutral allele frequencies of a gene pool in the absence of selection.

B The neutral theory involves nucleotide sequence variations that do not affect the reproductive success of organisms.

C The neutral theory contradicts Darwin's theory of natural selection as it postulates that change in allele frequency is driven by genetic drift and not natural selection.

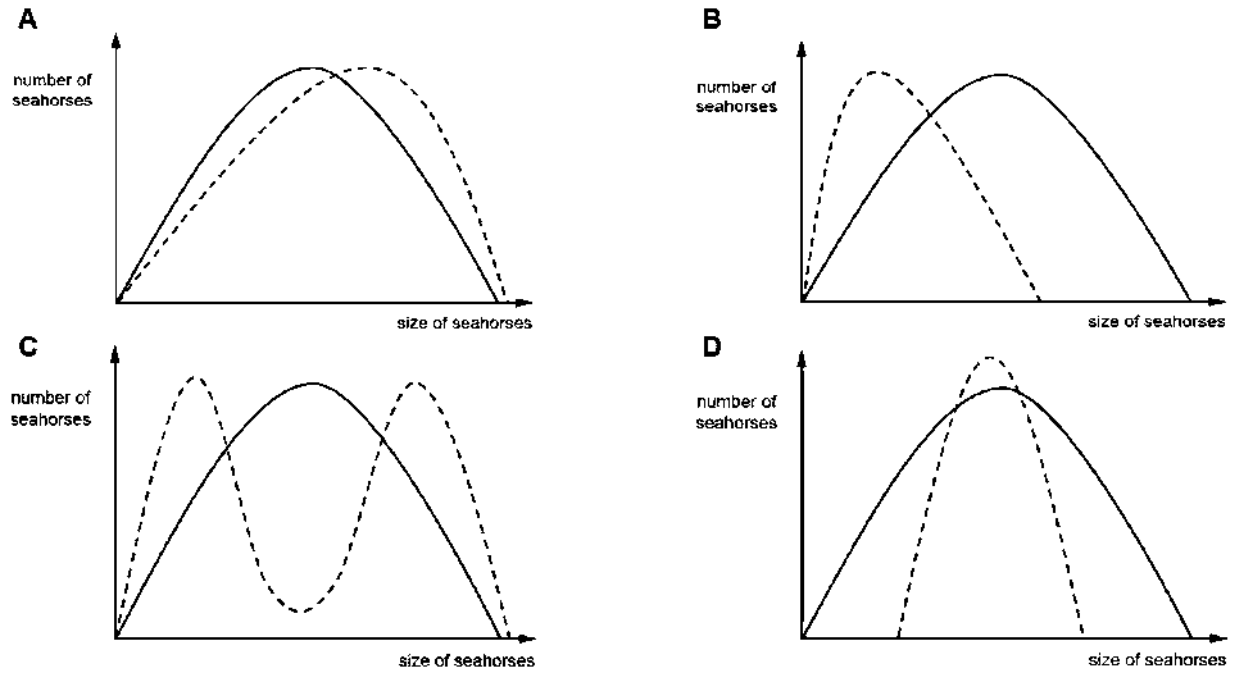
D Rate of change in gene sequence may be greater than the rate of change in amino acid sequence of the polypeptide chain coded for due to degeneracy of the genetic code.

34 The seahorse, *Hippocampus,* is an unusual small fish. It gives birth to live young and it is the male rather than the female that becomes pregnant.

In one species of seahorse, large females within a population mate with large males and small females mate small males. Few medium-sized individuals are produced and they have a low survival rate.

Which graph shows the effect of natural selection on size of seahorses after a fixed period of time?

Legend: ——— Original population - - - Population after selection



35 Which of the following statements best explains why some restriction sites are suitable to be used in genetic engineering?

A A short nucleotide sequence that can be recognised by many types of endonucleases.

B A short nucleotide sequence that occurs many times in a DNA molecule such that cutting the DNA molecule with an endonuclease will result in many fragments.

C A short nucleotide sequence that can be cut by an endonuclease to produce single-stranded ends that can bind to other single-stranded ends.

D A short nucleotide sequence that allow a fragment of DNA to be introduced into another DNA molecule via homologous recombination.

36 Which of the following factors is **not** critical for the functioning of Polymerase Chain Reaction (PCR)?

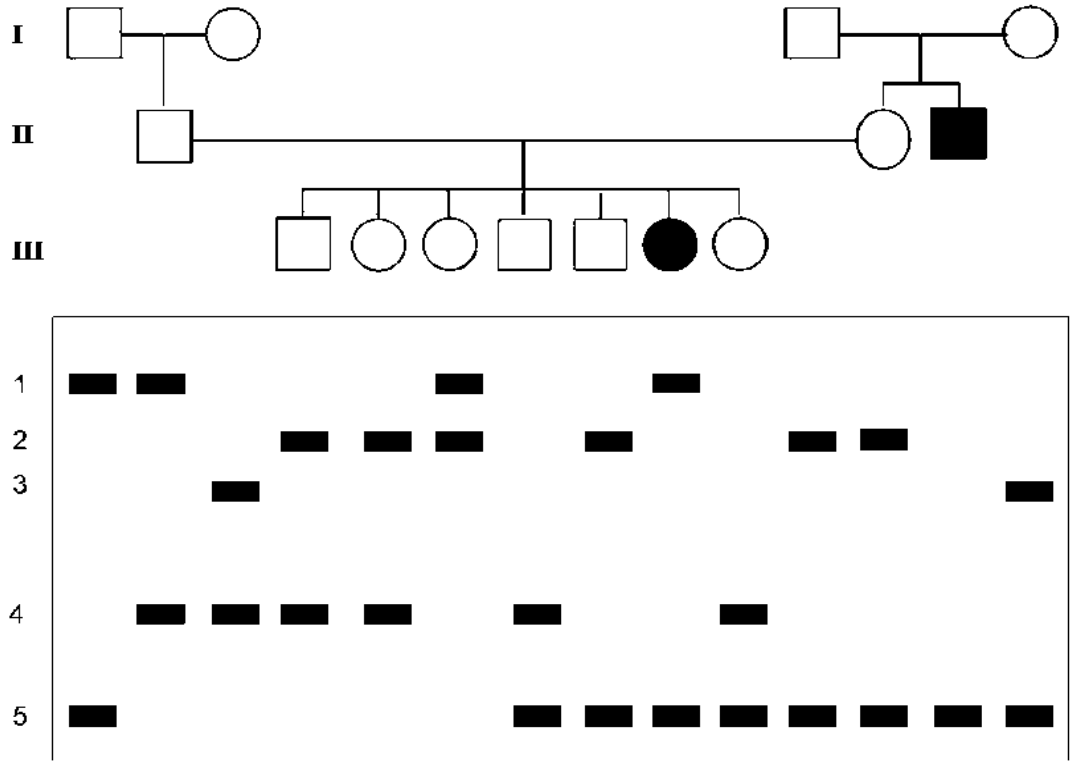
A Presence of DNA sequences other than target DNA.

B Temperatures for Stage 1 and 3 of the PCR cycle are only sustained for a short period of time (1 – 5 minutes).

C Presence of large amount of primers such that it is not the limiting reagent.

D Use of a thermostable polymerase enzyme.

37 A Restriction Fragment Length Polymorphism (RFLP) locus with 5 alleles (1-5), is linked to the gene causing Disease H.



Which of the following conclusions can be made from the information given above?

1 Crossing over occurred at a locus between the gene locus and the RFLP locus in the affected individual from generation III.

2 The disease is an autosomal recessive disease.

3 Among the unaffected individuals, all are heterozygous at the gene locus.

4 The RFLP alleles have different number of tandem repeats between 2 restriction sites.

A 1 and 3

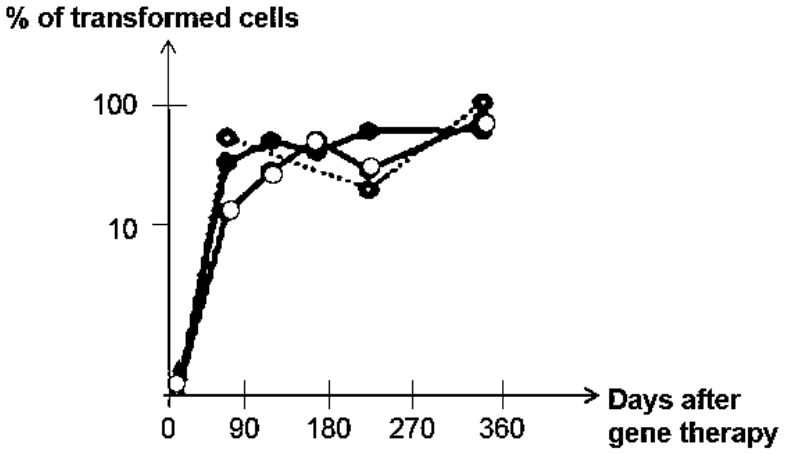
B 2 and 4

C 1, 2 and 4

D 2, 3 and 4

38 Recent research has developed a technique that combines gene therapy with stem cell therapy. This inspired a group of scientists to carry out a clinical trial with such modified stem cells in the hope of treating a neurological disease that is caused by a homozygous recessive genotype at a single gene locus.

Upon introducing stem cells with the functional dominant allele into the brains of three patients, their conditions did not improve although the following results were obtained from analysing the cell count in the target area of their brains.



What would be the most appropriate investigation to carry out in view of the unsuccessful clinical trial?

A regulation of neurone-specific genes in implanted stem cells

B in-vitro efficiency of gene delivery vector

C modification of stem cells to reduce immune reaction to implanted stem cell

D plasticity of neural stem cells to form other types of specialised cells

39 Plant physiologists attempted to produce papaya plants using tissue culture. They investigated the effects of different concentrations of plant growth factors on small pieces of the stem tip from a papaya plant. Their results are shown in the table below.

Concentration of auxin / μmol dm^{-3}	Concentration of cytokinin / μmol dm^{-3}		
	5	25	50
0	No effect	No effect	Leaves produced
1	No effect	Leaves produced	Leaves produced
5	No effect	Leaves produced	Leaves and some plantlets produced
10	Callus produced	Leaves and some plantlets produced	Plantlets produced
15	Callus produced	Callus and some leaves produced	Callus and some leaves produced

What evidence from the table supports that cells from the stem tip are totipotent?

A Under certain concentrations of cytokinin to auxin, there is production of both leaves and calluses or leaves and plantlets showing that more than one type of cells can be produced at any one time.

B Stem tip cells are able to produce calluses when the concentration of cytokinin to auxin is in the ratio of 1:2 or 1:3.

C Stem tip cells are able to produce leaves although they are supposed to differentiate into stems.

D Stem tip cells are able to give rise to plantlets.

40 What is an example of genetically modified organisms?

A Cows that grow to adult size quickly due to injection of growth hormone into the cows.

B Pigs that grow to large size via inbreeding.

C High yielding rice that are flood resistant due to intensive self-pollination over many generations.

D Durians that ripen slowly due to anti-sense RNA technology.

Paper 1 Answer Scheme

Qns	Ans
1	C
2	B
3	A
4	B
5	D
6	D
7	C
8	A
9	B
10	D
11	B
12	A
13	A
14	C
15	B
16	A
17	B
18	C
19	B
20	D

Qns	Ans
21	B
22	C
23	B
24	D
25	B
26	B
27	B
28	C
29	C
30	D
31	D
32	B
33	C
34	C
35	C
36	A
37	B
38	A
39	D
40	D

H2 ANDERSON JUNIOR COLLEGE HIGHER 2

CANDIDATE NAME

PDG

PDG INDEX NUMBER

BIOLOGY
9648/02

Paper 2 Core Paper

13 September 2016
Tuesday

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and PD group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

All working for numerical answers must be shown.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Calculators may be used

For Examiner's Use	
Section A	**80**
1	
2	
3	
4	
5	
6	
7	
8	
Section B	**20**
9 / 10	
Total	**100**

This document consists of **19** printed pages.

Section A

Answer **all** the questions in this section.

1 The enzyme human immunodeficiency virus (HIV) protease is essential for the life cycle of HIV.

Fig. 1.1 shows the structure of the HIV protease. It exists as a homodimer made up of two identical polypeptide chains, each forming a subunit. The active site lies between the subunits, with each subunit contributing an aspartic acid that functions as a catalytic residue.

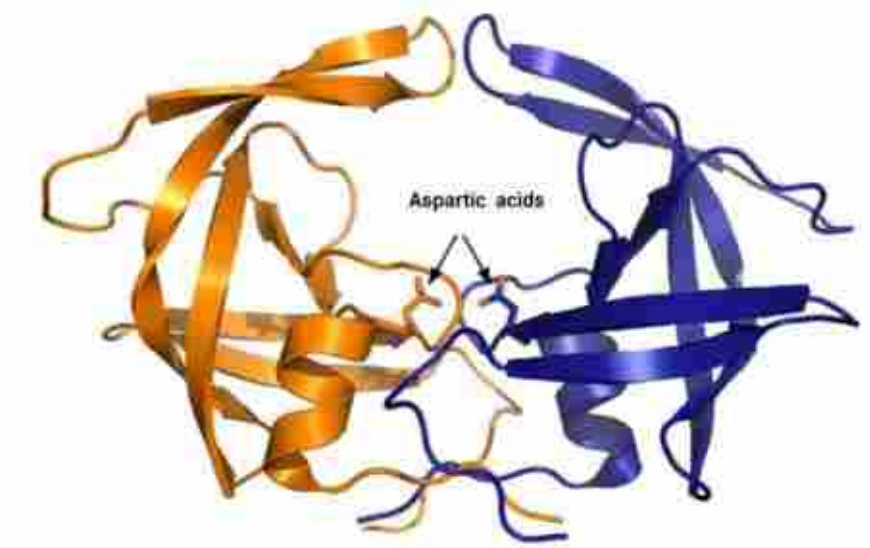


Fig. 1.1

(a) **(i)** Describe the function of aspartic acid in HIV protease.

…… [1]

(ii) With reference to Fig. 1.1, outline how the structure of HIV protease is formed.

……..

……

……

……

……

…… [4]

(iii) Suggest an advantage of protease being a homodimer.

……..

…… [1]

(b) Many HIV proteases inhibitors have been developed to treat people infected with HIV. Most inhibitors act as competitive inhibitors to HIV protease. Fig. 1.2 shows three such inhibitors.

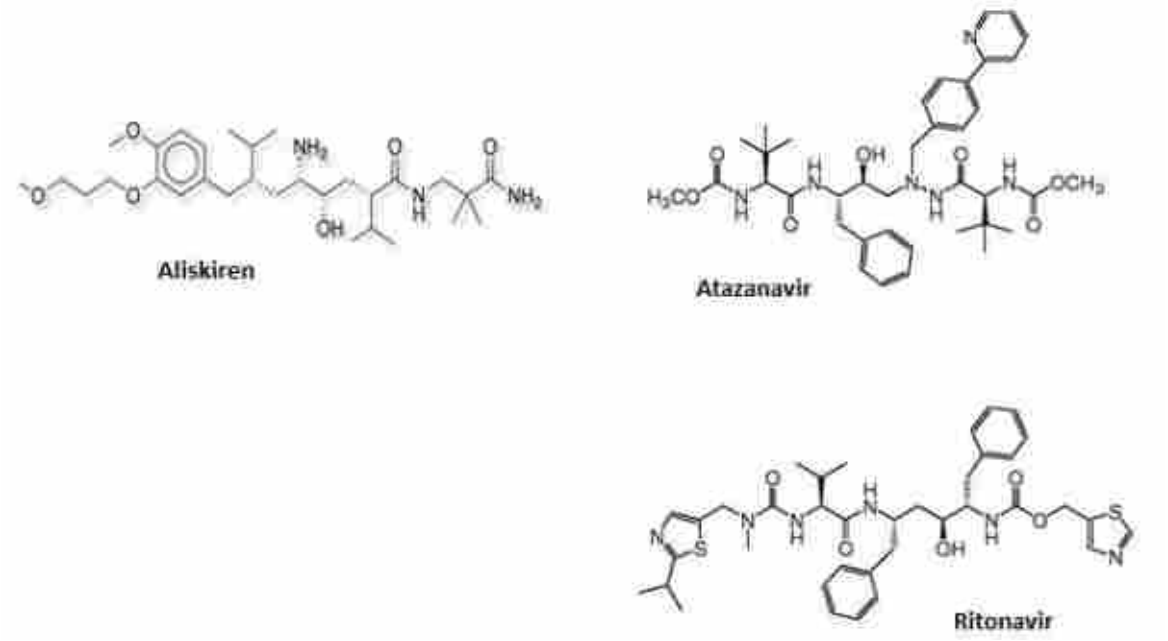


Fig. 1.2

With reference to Fig. 1.2, explain how HIV protease inhibitors work in the treatment of HIV infection.

……

……

……

……

…… [3]

[Total: 9]

2 Fig. 2.1 shows an electron micrograph of an actively dividing cell from *Bellevalia romana*, a flowering herbaceous plant.

A **B** **C**

Fig. 2.1

(a) **(i)** Identify stages **A** and **B**, and state the visible features that enabled your identification.

……..

……

…… [2]

(ii) Explain the change in distance between centromeres of a chromosome in stage **C**.

……..

……

……

……

…… [3]

(iii) Explain why it is important that replication occurs before mitosis.

……..

……

…… [2]

(iv) Explain how homologous chromosomes in stage **A** are genetically different from those in prophase II of the same plant.

……..

……

……

……

…… [3]

Prokaryotic organisms such as *Escherichia coli* do not divide by mitosis. Apart from ribosomes, prokaryotes have no organelles comparable to those found in eukaryotes and have a circular 'chromosome' with no centromere.

(b) With reference to the information given above and your knowledge of mitosis, suggest why mitosis does not occur in prokaryotes.

……..

……..

……... [2]

[Total: 12]

3 Fig. 3.1 is a diagram showing translation. Table 3.2 shows an mRNA codon table.

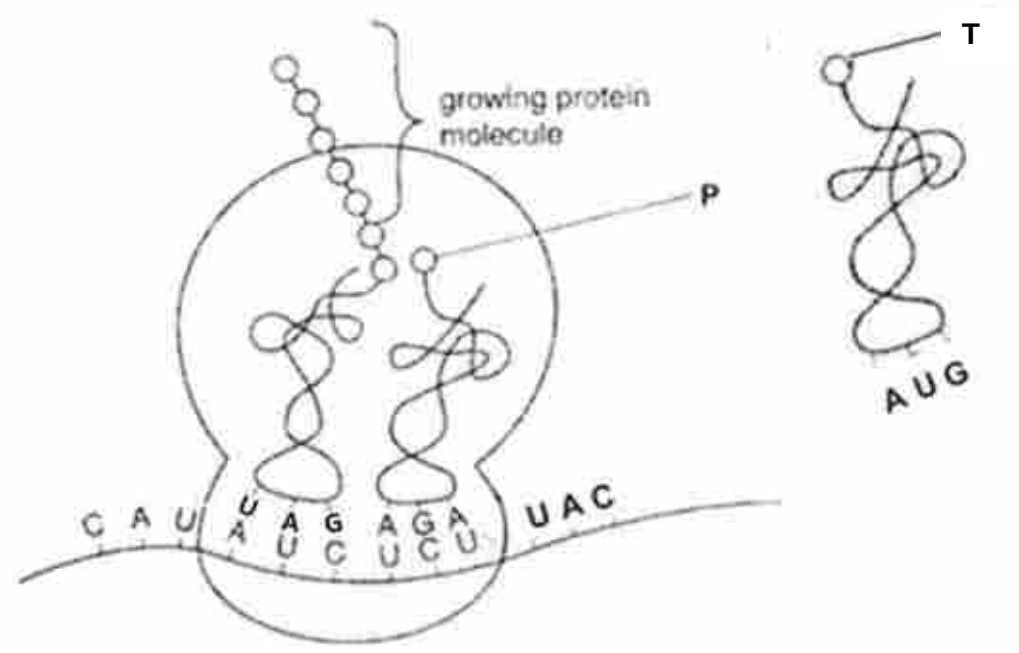


Fig. 3.1

First Base		Second Base					Third Base
		U	C	A	G		
U		phenyalanine	serine	tyrosine	cysteine	U	
		phenyalanine	serine	tyrosine	cysteine	C	
		leucine	serine	(stop)	(stop)	A	
		leucine	serine	(stop)	tryptophan	G	
C		leucine	proline	histidine	arginine	U	
		leucine	proline	histidine	arginine	C	
		leucine	proline	glutamine	arginine	A	
		leucine	proline	glutamine	arginine	G	
A		isoleucine	threonine	asparagine	serine	U	
		isoleucine	threonine	asparagine	serine	C	
		isoleucine	threonine	lysine	arginine	A	
		(start) methionine	threonine	lysine	arginine	G	
G		valine	alanine	aspartate	glycine	U	
		valine	alanine	aspartate	glycine	C	
		valine	alanine	glutamate	glycine	A	
		valine	alanine	glutamate	glycine	G	

Table 3.2

(a) **(i)** State **two** molecules required for translation that are not shown in Fig. 3.1.

……... [1]

(ii) Using Table 3.2 to identify **P** and **T**, briefly describe the process of translation as shown in Fig. 3.1.

……..

……

……

……

……

…… [4]

(b) Suggest why parts of tRNA are double stranded.

……..

……..

…….. [2]

(c) State **two** ways in which DNA replication:

(i) is similar to transcription.

……..

……

…… [2]

(ii) differs from transcription.

……..

……..

…… [2]

[Total: 11]

4

(a) Explain why viruses are obligate parasites.

……..

……..

…… [2]

Fig. 4.1 is an electron micrograph of T4 bacteriophages infecting an *Escherichia coli*.

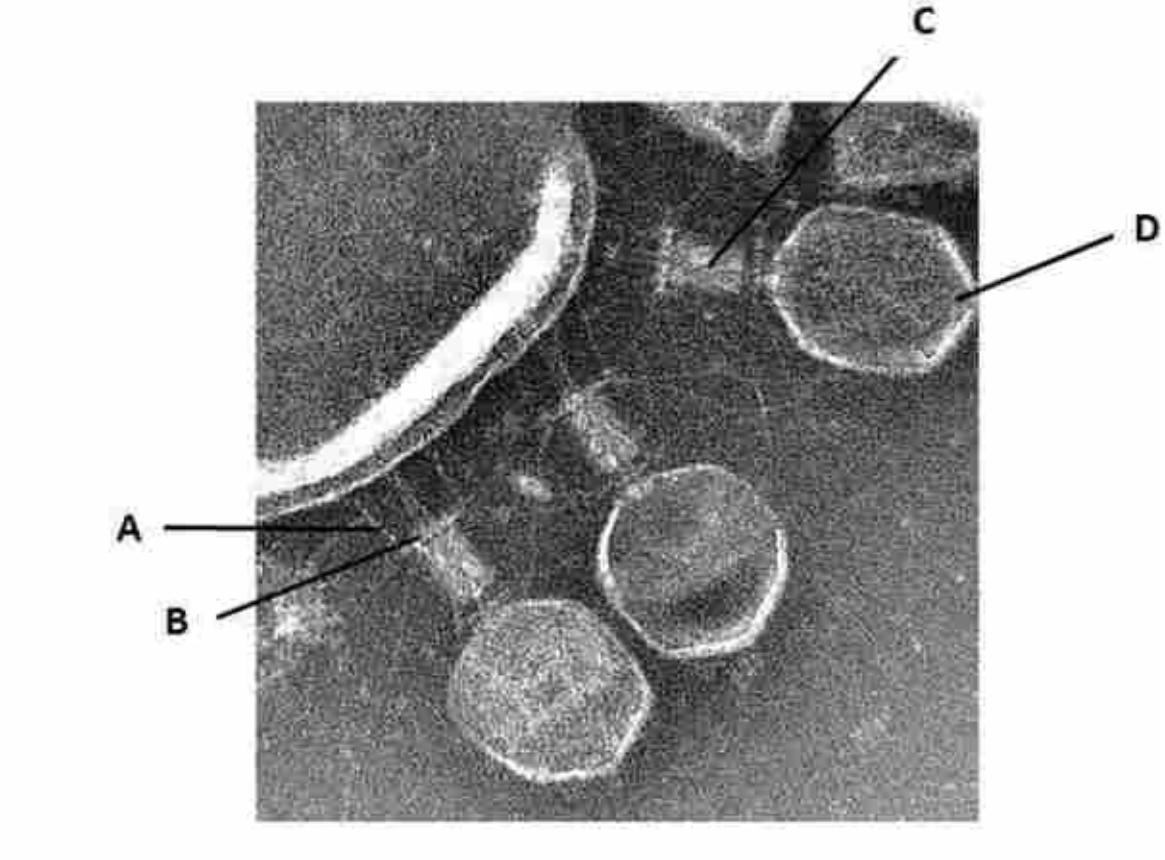


Fig. 4.1

(b) **(i)** Identify the structures labelled **A** - **D**.

A……..

B……

C……

D…… [2]

(ii) Explain why polymerase enzymes are present in human influenza virus but not in T4 bacteriophage.

……..

……

…… [2]

(c) With reference to the reproductive cycle of bacteriophages, suggest why bacteriophage infection may be beneficial to bacteria population.

……..

……..

……..

……..

…….. [3]

[Total: 9]

5 Voltage-gated sodium ion channels are integral membrane proteins that allow generation of an action potential across the axon membrane.

Fig. 5.1 shows a typical voltage-gated sodium ion channel which has two gates, the activation and inactivation gates. At different membrane potentials, the channel exists in different states depending on which gates are open or close.

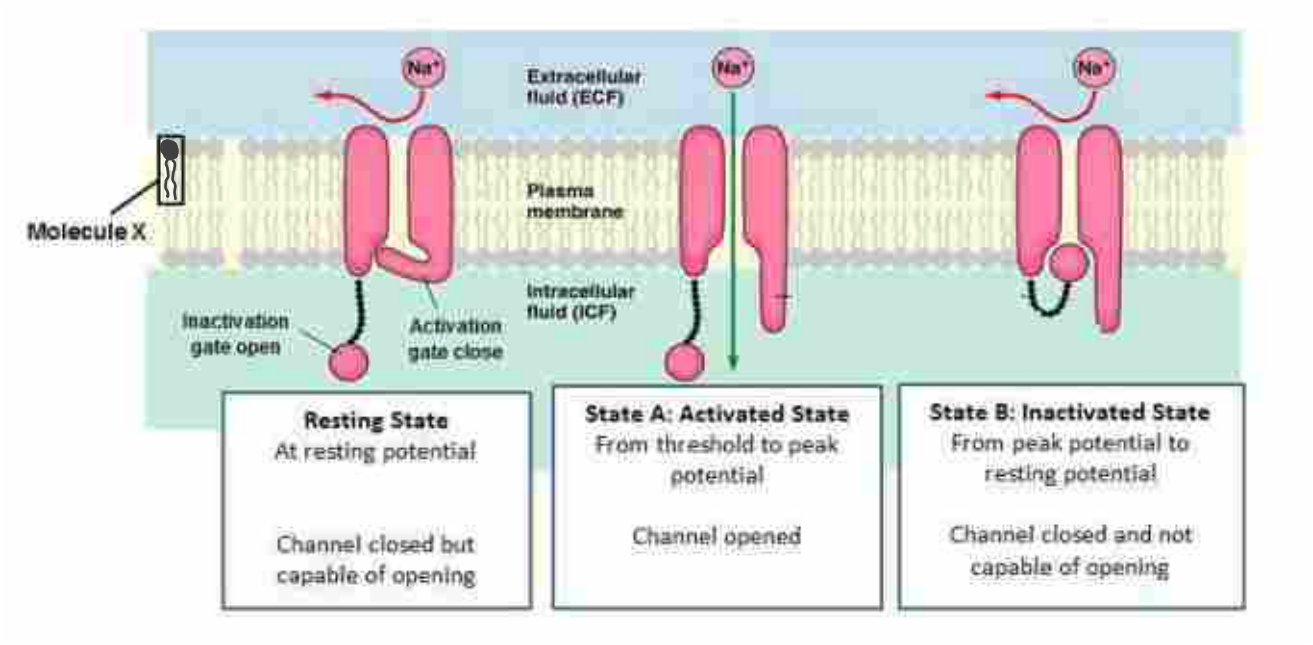


Fig. 5.1

(a) **(i)** Describe how State **A** results in depolarisation**.**

……..

……

…… [2]

(ii) Explain how State **B** ensures unidirectional movement of nerve impulse along the neurone.

……..

……

……

……

…… [3]

(iii) Describe how Molecule **X** differs from a triglyceride in terms of structure.

……..

……..

…….. [2]

(b) Explain why triglycerides are better respiratory substrates than carbohydrates.

……..

……..

…… [2]

[Total: 9]

6 In Drosophila, the characteristics of wing length and body colour are controlled by one gene each. Wild type flies have normal (long) wings and grey body colour while mutant flies have vestigial (undeveloped) wings and black body colour. Pure-breeding wild-type and mutant flies will breed to produce flies with normal wings and grey colour.

A male fly with wild phenotype was crossed with a female fly with mutant phenotype. The resulting offspring were as follows:

normal wings and black body colour	107
vestigial wings and grey body colour	92

Using the following symbols:

N	normal wings	**n**	vestigial wings
E	grey body colour	**e**	black body colour

(a) Draw a genetic diagram in the space below showing the cross described.

[4]

(b) The observed numbers are usually different from the expected numbers in any genetic cross.

(i) Suggest **two** reasons why such a difference may occur in a monohybrid cross, referring only to events after meiosis.

……

……

…… [2]

(ii) A chi-squared test was carried out on the results of the cross. A *p* value of about 0.30 is obtained.

With reference to the cross results, explain the significance of the *p* value.

……

……

…… [2]

(c) The wing length of fruit flies with normal wings varies between 70 to 85 µm.

Suggest a reason for the variation in wing length within fruit flies with normal wings.

……

…… [1]

(d) Alleles coding for mutant phenotypes in fruit flies are caused by artificially induced mutations in laboratory bred flies. Suggest why such mutants are unlikely to be found in natural populations.

……

……

…… [2]

[Total:11]

7 Giant anteaters, armadillos and Australian numbats (*Myrmecobius fasciatus*) have many similar traits. This led some to believe that they were closely related and that they should be classified into the same taxon of a lower rank under the hierarchical classification system.

Table 7.1 shows the comparison of four characteristics between the three mammals

Mammal	Characteristics			
	Diet	**Body**	**Snout**	**Tongue**
Armadillo	Feed on insects	Covered by bony keratinised plates	Pointy snout	Long tongues
Giant Anteater	Feed on ants and termites	Covered by hair	Elongated narrow snout	Long tongues
Numbats	Feed on termites	Covered by hair	Narrow snout	Long tongues

Table 7.1

DNA sequences of selected genes such as 18s rRNA are subsequently compared between some organisms, including the three mammals, when molecular experimental techniques advanced and the results helped clarified the phylogenetic relationships of the mammals.

Fig. 7.2 shows the simplified phylogenetic tree of the organisms based on nucleotide sequence comparison results.

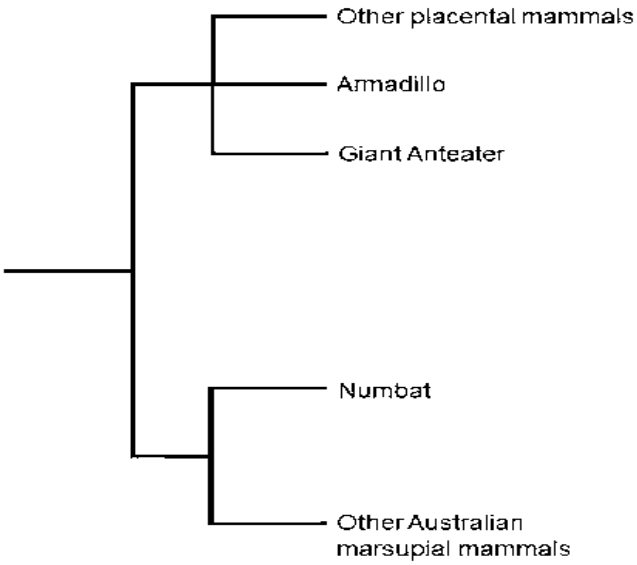


Fig. 7.2

(a) Explain the relationship between classification and phylogeny.

………..

………..

……… [2]

(b) Using the information above, explain why comparison of morphological structures led to the incorrect conclusion about the phylogenetic relationships of the three mammals.

………..

………..

………..

………...

………..

………... [4]

(c) State **one** reason why the 18s rRNA gene was chosen to compare DNA sequences between organisms.

………..

……….. [1]

Fig. 7.3 shows the geographical distribution of the various mammals.

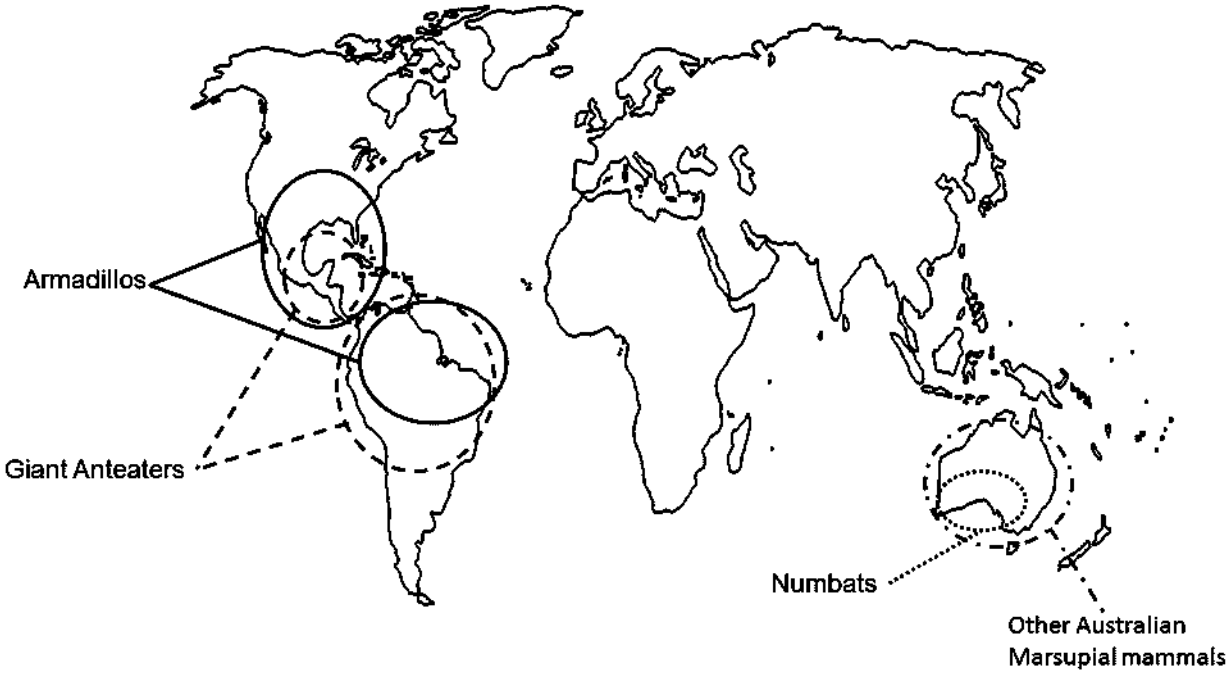


Fig. 7.3

(d) Using the information above, explain how biogeography supports the phylogenetic relationships constructed from DNA sequence comparison.

……..

……..

…… [2]

[Total: 9]

8 Epidermal growth factor receptors (EGFR), which belong to the ErbB family of receptor tyrosine kinases, have been found to be overexpressed in many cancers, such as glioblastoma, colorectal and breast cancers.

Fig. 8.1 shows the EGFR signalling pathway.

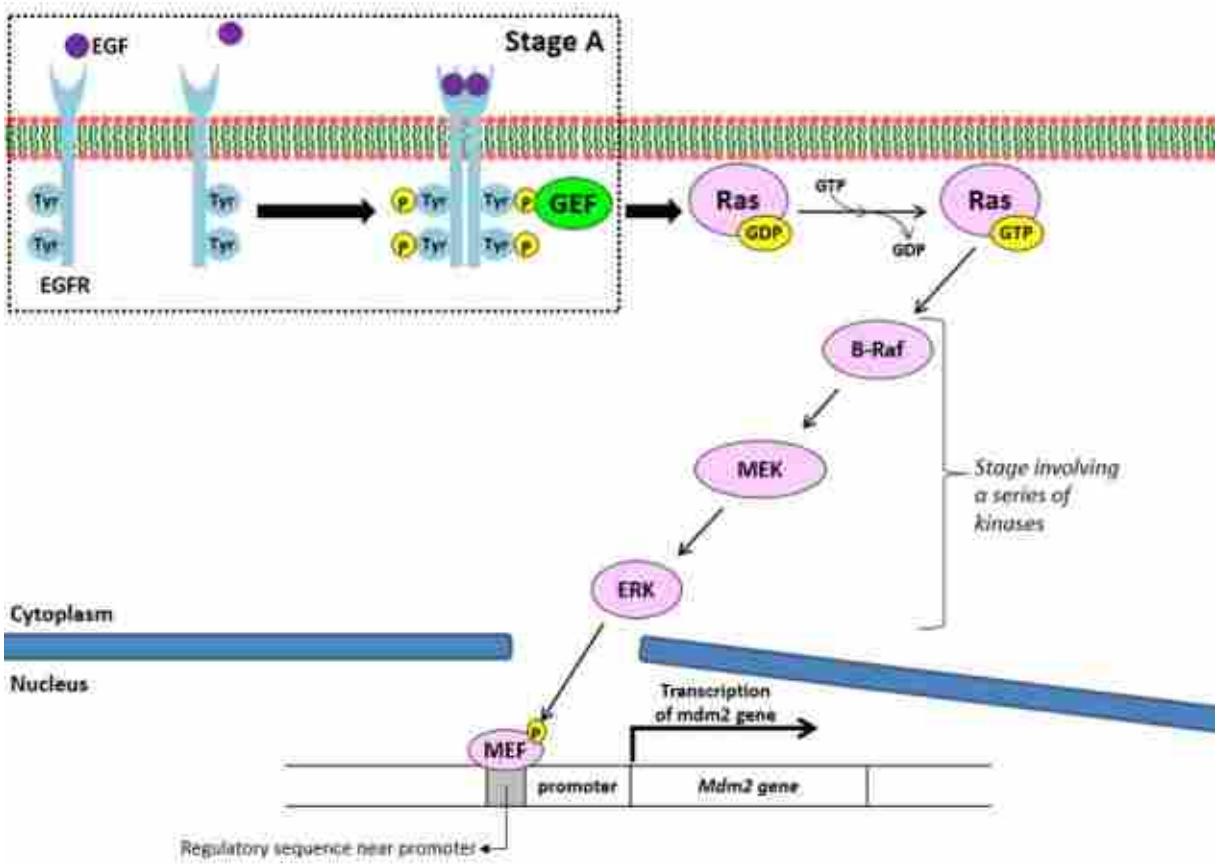


Fig. 8.1

Legend:

EGF	Epidermal growth factor
Ⓟ	Phosphate group
GEF	Guanine nucleotide exchange factor that binds to and activates Ras
B-Raf, MEK, ERK	Kinases
MEF	A specific transcription factor that binds near the promoter

With reference to Fig. 8.1,

(a) Describe the events occurring at stage A.

……

……

……

……

……

…… [4]

(b) **(i)** Suggest how a mutation in Ras GTPase that causes GTP to be permanently bound results in the overexpression of mdm2.

……

……

……

……

…… [3]

(ii) Mdm2 is an enzyme which catalyses the addition of ubiquitin to p53. Explain how high levels of mdm2 enzyme may lead to increased chances of cancerous growth.

……

……

……

……

…… [3]

[Total: 10]

Section B

Answer **EITHER 9 or 10.**

Write your answers on the separate answer paper provided.
Your answer should be illustrated by large, clearly labeled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in section (a), (b) etc., as indicated in the question.

9 **(a)** Explain how fluidity of biological membranes can be maintained and the importance of fluidity to membrane function. [8]

(b) Plant cells have a cellulose cell wall outside the cell surface membrane. Explain how the structure of cellulose is related to its function. [7]

(c) Describe how photophosphorylation differs from oxidative phosphorylation. [5]

[Total: 20]

Or

10 **(a)** Distinguish between gene mutation and chromosome structural mutation. [4]

(b) Describe how the most common CFTR gene mutation affects function of the protein and explain why other mutations vary in the extent to which they affect protein function. [8]

(c) With reference to mutation of named genes, outline the development of cancer. [8]

[Total:20]

H2 ANDERSON JUNIOR COLLEGE HIGHER 2

CANDIDATE NAME

PDG

PDG INDEX NUMBER

BIOLOGY
9648/02

Paper 2 Core Paper

13 September 2016
Tuesday

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and PD group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

All working for numerical answers must be shown.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Calculators may be used

For Examiner's Use	
Section A	**80**
1	
2	
3	
4	
5	
6	
7	
8	
Section B	**20**
8 / 9	
Total	**100**

This document consists of **20** printed pages.

Section A

Answer **all** the questions in this section.

1 The enzyme human immunodeficiency virus (HIV) protease is essential for the life cycle of HIV.

Fig. 1.1 shows the structure of the HIV protease. It exists as a homodimer made up of two identical polypeptide chains, each forming a subunit. The active site lies between the subunits, with each subunit contributing an aspartic acid that functions as a catalytic residue.

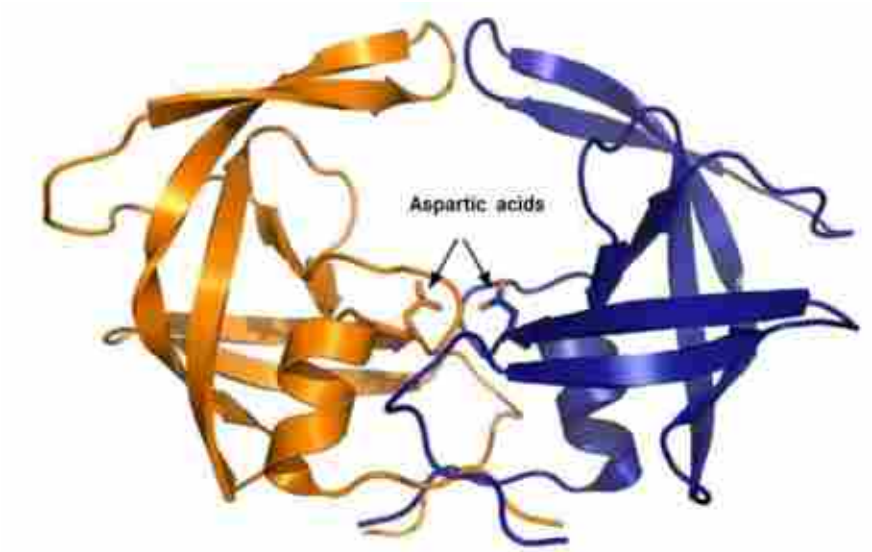


Fig. 1.1

(a) (i) State the function of aspartic acid in HIV protease.

- (R-group) is involved in the **hydrolysis** of **peptide bonds** (between amino acids) [1]

(ii) With reference to Fig. 1.1, outline how the structure of HIV protease is formed.

- **Polypeptide chain** consisting of **amino acids** joined by **peptide bonds**
- Within each subunit, a polypeptide chain is **folded** into (secondary structure) **alpha helices** and **beta-pleated sheets**
  Many cannot identify beta-pleated sheets shown in the diagram, hence only mentioned alpha helices.
- stabilised by **hydrogen bonds** formed between the **O atom of the CO** of one amino acid and **H atom of the NH group** of another amino acid in the **polypeptide backbone**
- Further folding of the polypeptide chain into a **globular shape / 3D shape/tertiary structure** *structure*
- maintained by **disulfide bonds, hydrogen bonds**, **ionic bonds** and **hydrophobic interactions** (name at least 2) formed between the **R groups** of the amino acids of the polypeptide chain

[4]

- The two subunit assemble together via **R-group interactions /** named bonds to form **active site**, exposing the **aspartic acids** (forming the quaternary structure)

Any 4

(iii) Suggest an advantage of protease being a homodimer.

- Shorter/smaller genome/ RNA for virus to package within its capsid
- Lesser types of tRNA / amino acids required from the host cell for synthesis of HIV protease [1]

(b) Many HIV proteases inhibitors have been developed to treat people infected with HIV. Most inhibitors act as competitive inhibitors to HIV protease. Fig. 1.2 shows three such inhibitors.

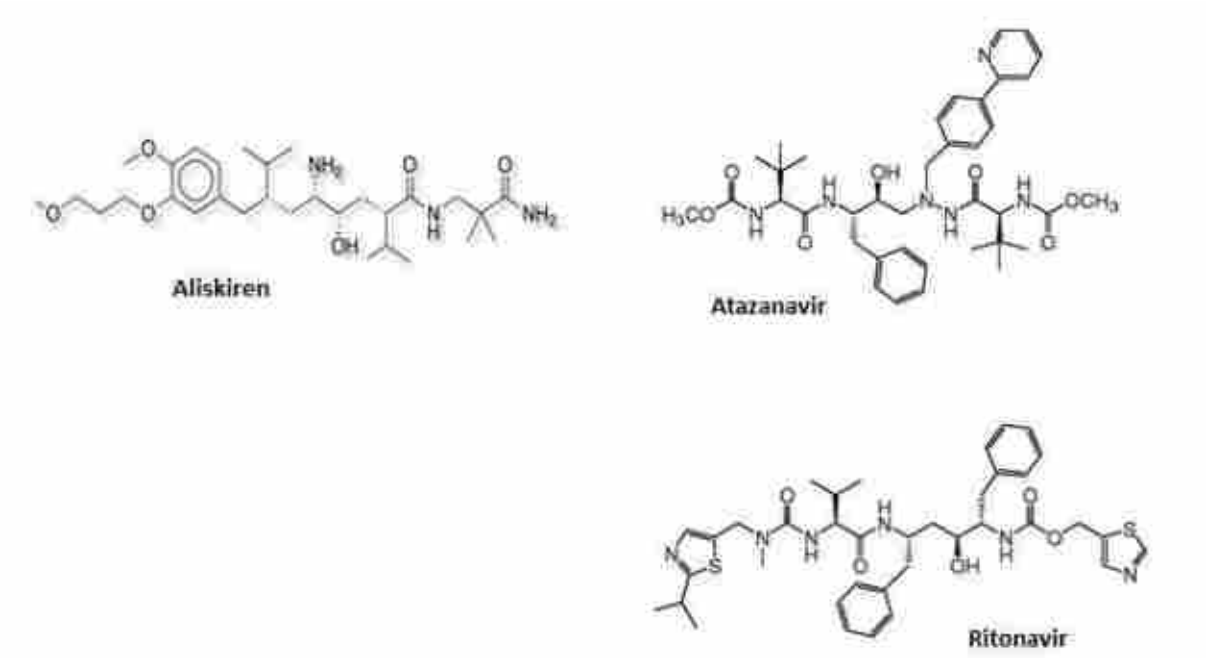


Fig. 1.2

With reference to Fig. 1.2, explain how HIV protease inhibitors work in the treatment of HIV infection.

- HIV protease inhibitors have similar structure/ shape to **polyprotein/proteins/polypeptide chain** as seen in the presence of **peptide bonds / polypeptide backbone**
- Compete with polyprotein for **binding** to **active site** of HIV protease
- Viral **polyprotein** not cleaved
  → functional viral(structural/ enzymatic) proteins not formed / newly formed virus **not** infective/ mature/ **functional** hence unable to infect other cells. [3]

[Total: 9]

2 Fig. 2.1 shows an electron micrograph of an actively dividing cell from *Bellevalia romana*, a flowering herbaceous plant.

A **B** **C**

Fig. 2.1

(a) **(i)** Identify stages **A** and **B**, and state the visible features that enabled your identification.

- Stage A → chromatin fibres (coil and) **condense** to become (discrete) **chromosomes** → thus (early) **prophase;**
- Stage B → chromosomes (starting to) **align singly** at **metaphase plate** → thus (early) **metaphase**; [2]

(ii) Explain the change in distance between centromeres of a chromosome in stage **C**.

- Distance between centromeres of sister chromatids **increase** in stage C;
- Because during stage C, which is anaphase, **centromere divide**;
- **Chromosomes** pulled to opposite **poles** by shortening of kinetochore microtubules/spindle fibres (with centromeres leading); [3]

(iii) Explain why it is important that replication occurs before mitosis.

- So that each **chromosome** consists of **2 genetically identical** sister chromatids (joined at centromere during prophase and metaphase);
- Each (of the two) **daughter cells** receive a copy of exact/same DNA molecule/same number and type of chromosomes → **genetically identical**; [2]

(iv) Explain how homologous chromosomes in stage **A** are genetically different from those in prophase II of the same plant.

- **Sister chromatids** of homologous chromosomes in prophase II have different alleles of the same gene as compared to those in **stage A, prophase**;

OR

- **Sister chromatids** of homologous chromosomes in prophase II are **not genetically identical** while the sister chromatids of homologous chromosomes in prophase are **genetically identical**;

- This is because in **prophase I**, (chiasmata formation and) **crossing over between non-sister chromatids of homologous chromosomes occurred**;
- Exchange of DNA segments with different alleles of the same gene/formation of new linkage [3]

groups/formation of new combinations of alleles;

Prokaryotic organisms such as *Escherichia coli* do not divide by mitosis. Apart from ribosomes, prokaryotes have no organelles comparable to those found in eukaryotes and have a circular 'chromosome' with no centromere.

(b) With reference to the information given above and your knowledge of mitosis, suggest why mitosis does not occur in prokaryotes.

- Prokaryotes do not have centrioles to form/ organise spindle fibres/ form mitotic spindles;
- Prokaryotes do not have centromeres for attachment of spindle fibres/ kinetochore microtubules (via kinetochore proteins) to separate sister chromatids; [2]

[Total: 12]

3 Fig. 3.1 is a diagram showing translation. Table 3.2 shows an mRNA codon table.

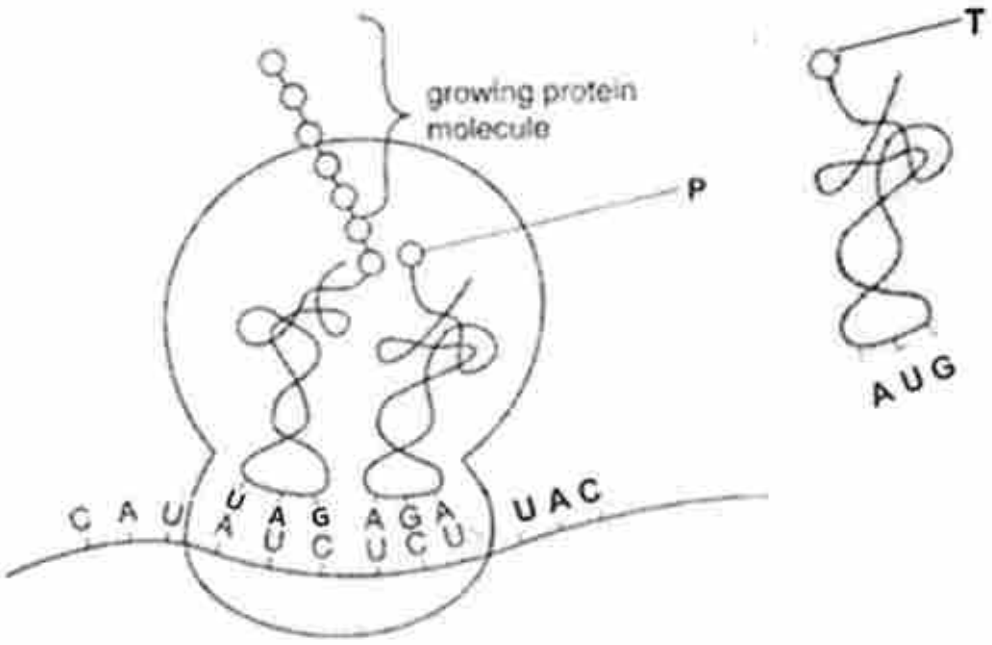


Fig. 3.1

First Base	Second Base U	Second Base C	Second Base A	Second Base G	Third Base
U	phenyalanine	serine	tyrosine	cysteine	U
	phenyalanine	serine	tyrosine	cysteine	C
	leucine	serine	(stop)	(stop)	A
	leucine	serine	(stop)	tryptophan	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	threonine	asparagine	serine	U
	isoleucine	threonine	asparagine	serine	C
	isoleucine	threonine	lysine	arginine	A
	(start) methionine	threonine	lysine	arginine	G
G	valine	alanine	aspartate	glycine	U
	valine	alanine	aspartate	glycine	C
	valine	alanine	glutamate	glycine	A
	valine	alanine	glutamate	glycine	G

Table 3.2

(a) (i) State **two** molecules required for translation that are not shown in Fig. 3.1.

- Translation **initiation** factors
- Translation **elongation** factors
- Release factors
- GTP
- ATP
- Initiator tRNA (carrying methionine)
- Aminoacyl-tRNA **synthetase**
- Peptidyltransferase

[Any 2, 0.5 marks each] [1]

(ii) Using Table 3.2 to identify **P** and **T**, briefly describe the process of translation as shown in Fig. 3.1.

- **Peptide bond formation** occurs between growing protein molecule/ last amino acid of the growing protein molecule/ isoleucine and **serine** (identify amino acid P).
- **catalysed** by **peptidyl transferase**
- ribosome translocates **1 codon/3 bases** down mRNA in **5' to 3' direction**
- tRNA carrying **tyrosine**(identify amino acid T) enters A site of ribosome
- anticodon **AUG** binds with codon **UAC**
- via (hydrogen bonds) between **complementary** base pairs/complementary base pairing.

[0.5 m each] [4]

(b) Suggest why parts of tRNA are double stranded.

rRNA is doube-stranded due to

- **Complementary base pairing** between different parts of a signle stranded tRNA.
- This contributes to the **stability** of the tRNA molecule
- allow tRNA to have a **shape** that fits into /is complementary into the E,P,A sites of ribosome/active sites of aminoacyl-tRNA sythetase. [2]

(c) State **two** ways in which DNA replication:

(i) is similar to transcription.

- Both occur in the **nucleus**;
- Both require DNA as template strand;
- Formation of **phosphodiester bonds** between **nucleotides** in DNA replication and transcription;
- **Reading** of DNA template strand is 3' to 5' direction for both DNA replication and transcription **OR Elongation** of the newly synthesis occur from 5' to 3' direction

[max 2m] [2]

(ii) differs from transcription.

- Synthesis of **a RNA strand** in transcription but synthesis of **DNA molecule** in DNA replication;
- Transcription uses **one DNA strand** as a **template** to synthesise mRNA while DNA replication uses **two DNA strands** as **template** to synthesise DNA;
- **RNA nucleotides** used as **monomers** to form polynucleotide chain in transcription while **DNA nucleotides** are used in DNA replication
- Phosphodiester bond formation/addition of monomers catalysed by DNA polymerase in DNA replication while it is catalysed by **RNA polymerase** in transcription;
- DNA replication requires a pre-existing strand known as a primer to provide a 3'OH group for polymerase to add nucleotides to while transcription can be initiated without the pre-existing strand.
- In DNA Replication, the whole DNA molecule is replicated in a single process, but in transcription only certain region/gene is being transcribed in a single process. (the phrase "in a single process" is crucial as it provides a basis of comparison)

[max 2m]

[2]

[Total: 11]

4

(a) Explain why viruses are obligate parasites.

- Related organelles/ enzymes to function: e.g lacks ribosomes for protein synthesis/ lack mitochondria for ATP generation / DNA polymerase for DNA replication

- Contains only 1 type of nucleic acid either DNA or RNA as genome but not both

any 1

AND

- hence need to takes over/ takes control/hijacks host cell metabolic machinery for the production/replication of progeny viruses [2]

Fig. 4.1 is an electron micrograph of T4 bacteriophages infecting an *Escherichia coli*.

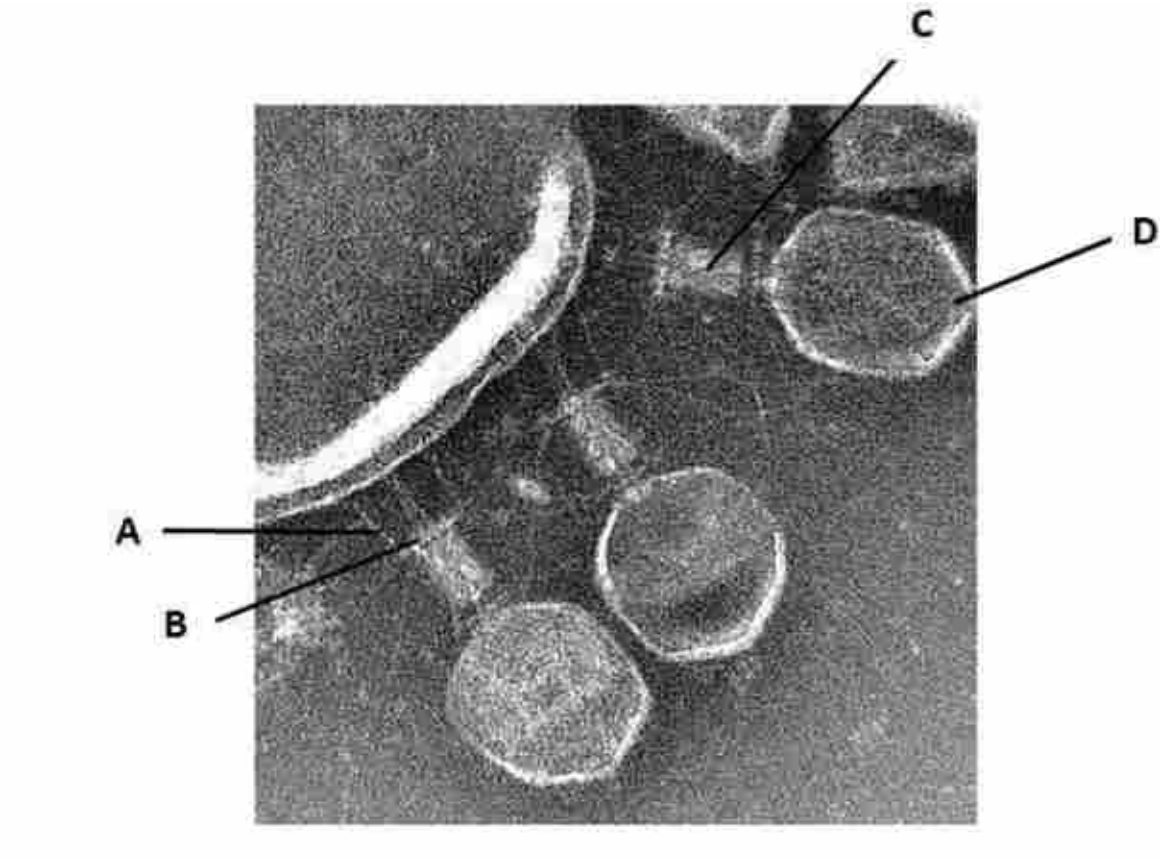


Fig. 4.1

(b) **(i)** Identify the structures labelled **A** - **D**.

A Tail fibre
B Base plate
C Tail/tail sheath
D Capsid head / capsid / nucleocapsid [2]

(ii) Explain why polymerase enzymes are present in human influenza virus but not in T4 bacteriophage.

- T4 phage genome is **DNA** while influenza virus genome is **RNA**
- T4 uses **host cell DNA polymerase** to replicate its genome / host cell **RNA polymerase** for transcription
  while influenza virus uses **RNA-dependent RNA polymerase** for transcription / replication which is <u>not present</u> in the host cell [2]

(c) With reference to the reproductive cycle of bacteriophages, suggest why bacteriophage infection may be beneficial to bacteria population.

- A **small piece** of a **bacteria DNA** can be incorporated into the **phage capsid** due to mistakes during viral assembly / a small region of bacterial DNA may be **excised** together with the prophage (and packaged)

- The resulting transducing phages **infect other / recipient bacteria** and newly infected cell **acquires** [3]

the original bacterial DNA

- Idea of allows **genetic recombination**/ increase **genetic variation** → increase adaptability of the bacteria to changes in environment

[Total: 9]

5 Voltage-gated sodium ion channels are integral membrane proteins that allow generation of an action potential across the axon membrane.

Fig. 5.1 shows a typical voltage-gated sodium ion channel which has two gates, the activation and inactivation gates. At different membrane potentials, the channel exists in different states depending on which gates are open or close.

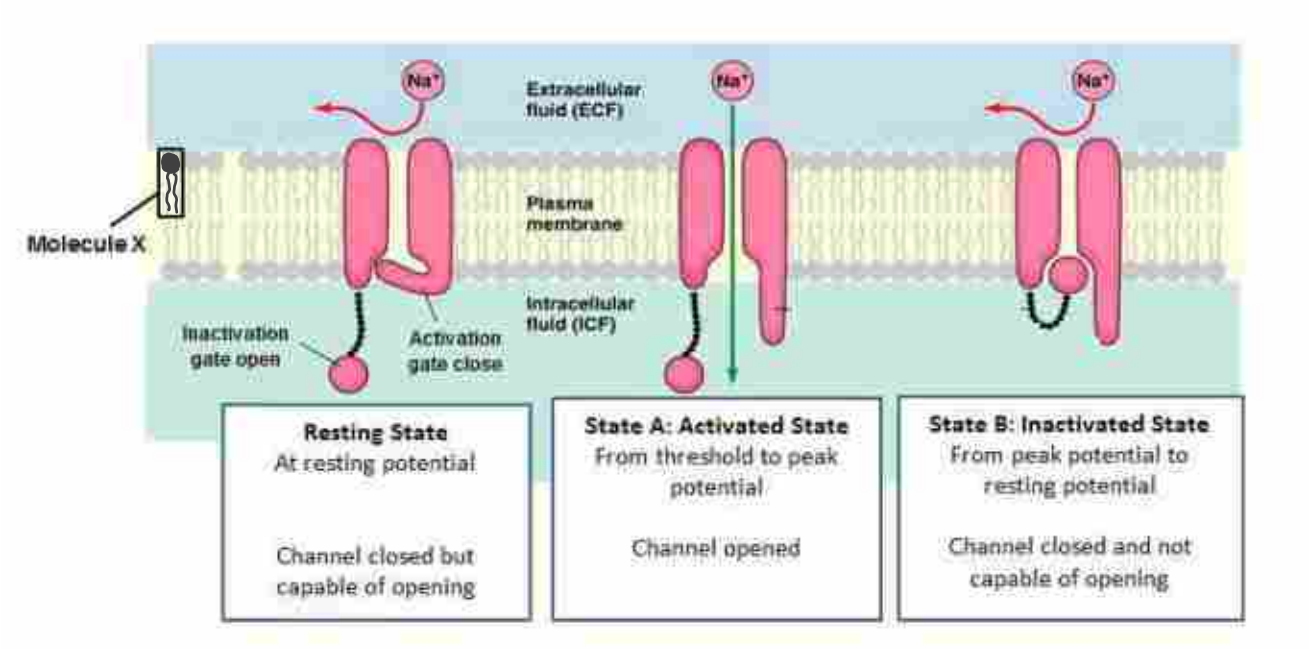


Fig. 5.1

(a) (i) Describe how State **A** results in depolarisation**.**

- In the activated state, (inactivation and) **activation gates open**
- **Na+ influx/** diffuse into the axon **through the opened ion channel** , increasing **membrane potential**

[2]

(ii) Explain how State **B** ensures unidirectional movement of nerve impulse along the neurone.

- In the inactivated state, (activation gate is open) but **inactivation gate is closed**
- this results in absolute **refractory period**
- No stimulus, can initiate another action potential / No depolarisation occurs at this part of the membrane (,resulting in the unidirectional movement of the impulse)

[3]

(iii) Describe how Molecule **X** differs from a triglyceride in terms of structure.

Molecule A (phospholipid)	Triglyceride
2 fatty acid/ hydrocarbon tails / chains	3 fatty acid/ hydrocarbon tails / chains
A phosphate group present	No phosphate group
2 ester bonds and 1 phosphoester bond	3 ester bonds

[2]

(b) Explain why triglycerides are better respiratory substrates than carbohydrates.

- release **twice as much/more** energy on oxidation/ during respiration per unit mass compared carbohydrate / compared with an **same mass** of carbohydrate

- due to two times **more hydrogen atoms** per gram/ **greater ratio of hydrogen to oxygen** atoms/ **more C-H bonds** (compared to the same mass of carbohydrate)

- Only award one mark if both answers are given but didn't mention that basis of comparison "per unit mass" at all.

[2]

[Total: 9]

6 In Drosophila, the characteristics of wing length and body colour are controlled by one gene each. Wild type flies have normal (long) wings and grey body colour while mutant flies have vestigial (undeveloped) wings and black body colour. Pure-breeding wild-type and mutant flies will breed to produce flies with normal wings and grey colour.

A male fly with wild phenotype was crossed with a female fly with mutant phenotype. The resulting offspring were as follows:

normal wings and black body colour	107
vestigial wings and grey body colour	92

Using the following symbols:

N	normal wings	**n**	vestigial wings
E	grey body colour	**e**	black body colour

(a) Draw a genetic diagram in the space below showing the cross described.

- Correct parental genotypes linked to phenotypes;
- Correct gametes;
- Correct F1 genotypes;
- Correct F1 phenotypes linked to genotypes; [4]

(b) The observed numbers are usually different from the expected numbers in any genetic cross.

(i) Suggest **two** reasons why such a difference may occur in a monohybrid cross, referring only to events after meiosis.

- sample size too small;
- chance variation / variation statistically insignificant;
- difference in survival rate of sperm / ova with particular genotypes;
- difference in survival rates of zygotes with particular genotypes; [2]

(ii) A chi-squared test was carried out on the results of the cross. A *p* value of about 0.30 is obtained.

With reference to the cross results, explain the significance of the *p* value.

- *p* value is the probability that the difference between observed and expected ratio is due to chance alone;
- since *p* is more than 0.05 / probability is more than 5%, there is no significant difference between the observed and expected ratio of 1:1;

[2]

(c) The wing length of fruit flies with normal wings varies between 70 to 85 µm.

Suggest a reason for the variation in wing length within fruit flies with normal wings.

- environmental factors such as nutrition affected the expression of allele coding for normal wings / environmental factors such as nutrition has a small effect on wing length; [1]

(d) Alleles coding for mutant phenotypes in fruit flies are caused by artificially induced mutations in laboratory bred flies. Suggest why such mutants are unlikely to be found in natural populations.

- Mutation rate is low;
- Mutant alleles may **confer selective disadvantage**, resulting in alleles being removed by **natural selection** / ref. to **decrease in frequency** of mutant alleles / unable to survive, **reproduce to pass on the alleles**;
- Mutant alleles are **recessive** and their effect on the phenotype can be **masked** by the normal dominant allele;

[max 2m] [2]

[Total:11]

7 Giant anteaters, armadillos and Australian numbats (*Myrmecobius fasciatus*) have many similar traits. This led some to believe that they were closely related and that they should be classified into the same taxon of a lower rank under the hierarchical classification system.

Table 7.1 shows the comparison of four characteristics between the three mammals

Mammal	Characteristics			
	Diet	Body	Snout	Tongue
Armadillo	Feed on insects	Covered by bony keratinised plates	Pointy snout	Long tongues
Giant Anteater	Feed on ants and termites	Covered by hair	Elongated narrow snout	Long tongues
Numbats	Feed on termites	Covered by hair	Narrow snout	Long tongues

Table 7.1

DNA sequences of selected genes such as 18s rRNA are subsequently compared between some organisms, including the three mammals, when molecular experimental techniques advanced and the results helped clarified the phylogenetic relationships of the mammals.

Fig. 7.2 shows the simplified phylogenetic tree of the organisms based on nucleotide sequence comparison results.

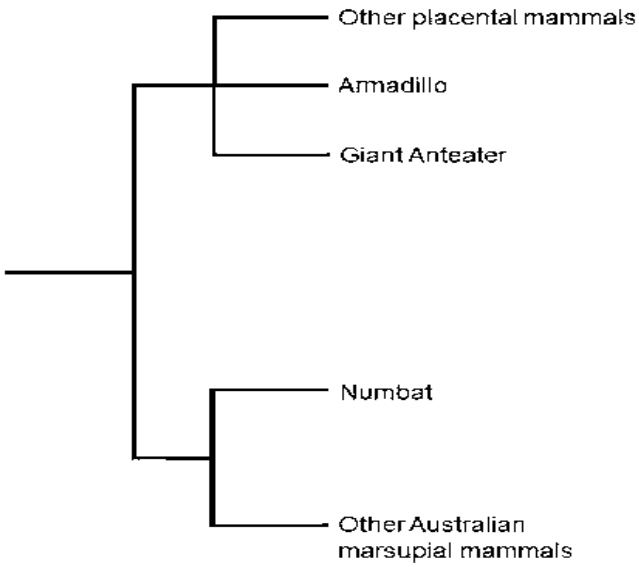


Fig. 7.2

(a) Explain the relationship between classification and phylogeny.

- Classification is organisation of species according to particular characteristics, may not take into consideration evolutionary relationship between the species;
- Phylogeny is organisation of species according to particular characteristics which takes into consideration evolutionary relationship between the species;

[2]

(b) Using the information above, explain why comparison of morphological structures led to the incorrect conclusion about the phylogenetic relationships of the three mammals.

- Structures were **analogous structures** arising from **convergent evolution**;
- All are subjected to **similar selection pressures**, e.g. same type of food (insects);
- Similar **structures** were **inherited** from **different ancestors** but selected for;
- E.g. of selective advantage: strong digging limbs to dig for insects / long tongue probe into insect nest;

[4]

(c) State **one** reason why the 18s rRNA gene was chosen to compare DNA sequences between organisms.

- 18s rRNA gene is **ubiquitous** / will be present in all organisms which serves as a good basis of comparison between organisms;
- **Essential gene** which changes very **slowly,** useful for estimating time of divergence that occurred [1]

long time ago;
- accumulates mutations at a constant rate and therefore can be used to calibrate a molecular clock for the estimation of time of divergence between species;

[max 1m]

Fig. 7.3 shows the geographical distribution of the various mammals.

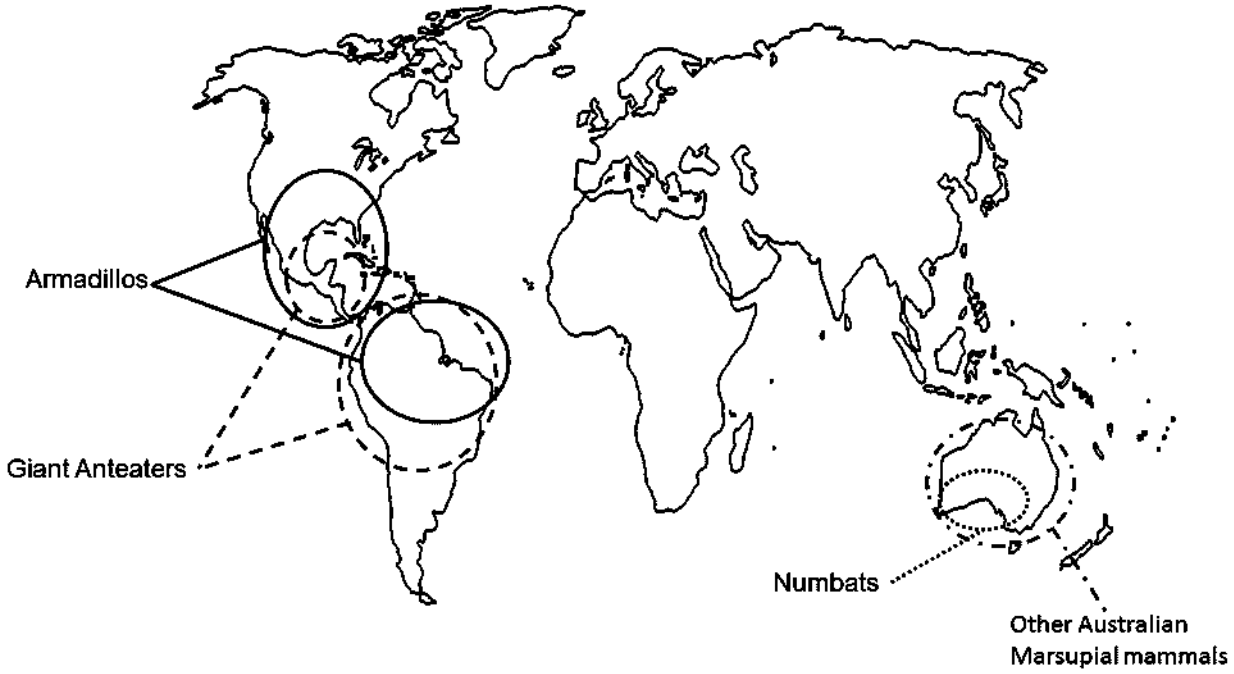


Fig. 7.3

(d) Using the information above, explain how biogeography supports the phylogenetic relationships constructed from DNA sequence comparison.

- Numbats are **more closely located** to other Australian marsupial mammals than to giant anteaters and armadillos / giant anteaters and armadillos are **more closely located**;
- Supports the phylogenetic relationship that numbats are **more closely related** to other Australian marsupial mammals than to giant anteaters and armadillos / giant anteaters and armadillos are **more closely related** / diverge from a **more recent** common ancestor;

[2]

[Total: 9]

8 Epidermal growth factor receptors (EGFR), which belong to the ErbB family of receptor tyrosine kinases, have been found to be overexpressed in many cancers, such as glioblastoma, colorectal and breast cancers.

Fig. 8.1 shows the EGFR signalling pathway.

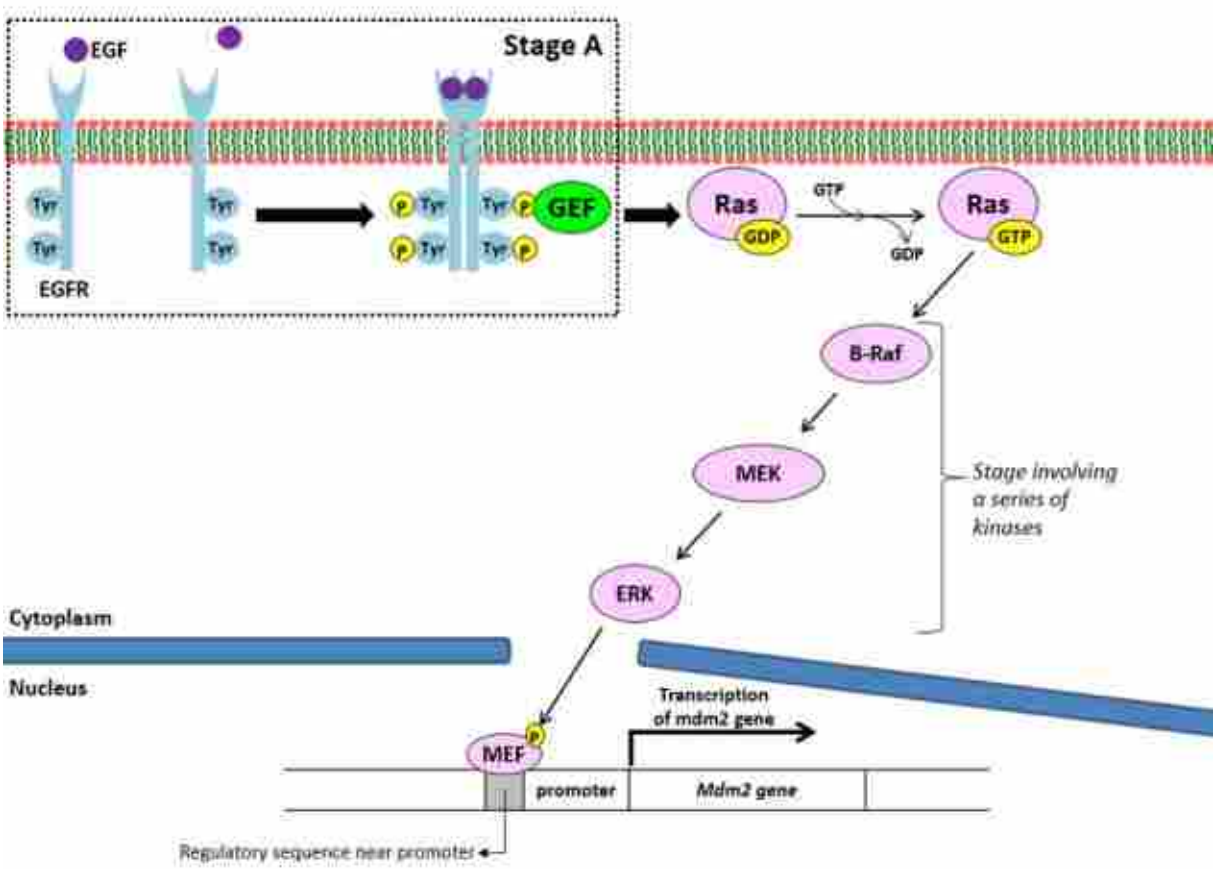


Fig. 8.1

Legend:

EGF	Epidermal growth factor
P	Phosphate group
GEF	Guanine nucleotide exchange factor that binds to and activates Ras
B-Raf, MEK, ERK	Kinases
MEF	A specific transcription factor that binds near the promoter

With reference to Fig. 8.1,

(a) Describe the events occurring at stage A.

- Epidermal growth factor (EGF) binds to **extracellular ligand-binding site** of epidermal growth factor receptor (EGFR) via complementary shape;
- leads to **dimerisation** of EGFR subunits occur/EGFR subunits aggregate to **form dimer**, causing the tyrosine kinase region on each EGFR subunit to be (exposed and) **activated**;
- **Autophosphorylation** occurs, each activated tyrosine kinase region **cross-phosphorylates** the other receptor at the tyrosine residues on their cytoplasmic/intracellular domain;
- (GEF binds to phosphorylated tyrosine kinase residues of fully-activated EGFR and) GEF is **activated** by phosphorylation;

[4]

(b) **(i)** Suggest how a mutation in Ras GTPase that causes GTP to be permanently bound results in the overexpression of mdm2.

- Mutation of (intrinsic) GTPase of Ras → GTP bound to Ras cannot be hydrolysed to GDP (→ Ras remains/always active/hyperactive);
- Kinase B-Raf is **always activated** by Ras, and kinases MEK and ERK are always phosphorylated and active/resulting in **continuous** trigger of **phosphorylation cascade**;
- (Specific) transcription factor MEF is always phosphorylated and thus is able to bind to the proximal control element (via complementary shape)
- accelerating and stabilising formation of transcription initiation complex and hence a high rate of transcription of mdm2;

[Any 3] [3]

(ii) Mdm2 is an enzyme which catalyses the addition of ubiquitin to p53. Explain how high levels of mdm2 enzyme may lead to increased chances of cancerous growth.

- Ubiquitinated p53 degraded/hydrolysed/broken down (by proteasome into short peptides);
- Absence of p53 (transcription factor binding to DNA/control elements) to **trigger transcription of genes** that code for proteins involved in cell cycle arrest/DNA repair/apoptosis;
- (Fail to inhibit the cell cycle /no DNA repair mechanism / allow evasion of mutated cells from apoptosis → accumulation of mutations in other proto-oncogene/ tumour suppressor genes to occur) → uncontrolled cell division.

[3]

[Total: 10]

Section B

Answer **EITHER 9 or 10.**

Write your answers on the separate answer paper provided.
Your answer should be illustrated by large, clearly labeled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in section (a), (b) etc., as indicated in the question.

9 (a) Explain how fluidity of biological membranes can be maintained and the importance of fluidity to membrane function. [8]

How fluidity is maintained (max 4)

- Definition of fluidity: phospholipids and proteins free to move laterally within membrane/ transversely (phospholipids only)
- Unsaturated hydrocarbon/ fatty acid tails / C=C in hydrocarbon tails have **kinks** which keep the phospholipid molecules in the membrane from **packing close together** (enhancing membrane fluidity) (Accept reverse argument)
- **Cholesterol** found in between phospholipids/ embedded in membrane prevents / disrupts close/ regular packing of phospholipids in the membrane at low temperature
- **Hydrophobic interactions** between cholesterol and phospholipid tails restrict phospholipid movement at high temperature
- Hence cholesterol preventing membrane from freezing at lower temperatures and membrane prevented from being overly fluid / integrity of the membrane is maintained at high temperature
- Membranes freeze at a lower temperature/ has more fluidity if it has a higher proportion of phospholipids with unsaturated hydrocarbon tails and cholesterol (accept converse) reject unsaturated phospholipids
- Accept longer length of saturated fatty acid chains ensures more hydrophobic interactions between them → membrane less fluid

Importance of fluidity to membrane function (max 4) :

- ref. to need for **invagination / pinching in** of the cell surface membrane during cytokinesis
- ref. to need for **invagination / pinching in** of the cell surface membrane during endocytosis/ pinocytosis
- ref to need forformation of **pseudopodia** in cell surface membrane to engulf substances phagocytosis
- ref. to **budding/ pinching off vesicles** for the
  - transport / trafficking of proteins from rough ER to Golgi apparatus
  - from *trans* face of the Golgi apparatus during protein sorting to outside of the cell / / other membrane-bound organelles

- ref. to **fusion of vesicles membrane**
  - from endoplasmic reticulum / containing proteins to (cis-face)Golgi apparatus for protein modification;
  - with cell surface membrane to release secretory molecules from the cell / exocytosis;
  - fusion of endocytotic vesicles with lysosomes for digestion

- ref. to membrane fluidity allowing **movement of protein molecules embedded** on the cell surface membrane for dimerisation of receptors;

- ref. diffusion of small or non-polar molecules through the **gaps/transient pores** (between the phospholipids) in membrane, e.g. water / oxygen / carbon dioxide

- ref. to fluidity important for transmembrane transport **proteins changing conformation,** such as sodium-potassium pump / ligand-gated sodium ion channel / voltage-gated sodium ion channel (at least one named example);

- accept fluidity required for **embedment of protein molecules** such as ETC in thylakoid membrane / channel proteins on cell surface membrane for transport.

(b) Plant cells have a cellulose cell wall outside the cell surface membrane. Explain how the structure of cellulose is related to its function. [7]

- Each cellulose **chain/molecule** is made up of **large number** of **β-glucose** monomers
- giving a **long/ large** molecule which is **insoluble** in water
- **Alternate/ successive/neighboring** glucose monomers are being **inverted/rotated 180°** relative to one another to allow the formation of **β(1, 4) glycosidic bonds**,
- resulting in a **straight / linear** cellulose chain.
- **Straight parallel chains with OH-groups projecting in all directions** from each chain, allowing large number of **hydrogen bonds** to **cross -links** neighboring chains.
- allowing **bundling of cellulose chains** into microfibrils, macrofibrils and fibres
- resulting in **high tensile strength**
- in plant cell wall, this prevents plant cells from bursting when placed in solutions of high water potential.
- Maintain the **shape** of the cell/protect cells from physical and mechanical injury
- Cellulose has **large intermolecular spaces between macrofibrils**
- allows the passage of water and solute molecules through the plant cell walls (fully permeable)

(c) Describe how photophosphorylation differs from oxidative phosphorylation. [5]

Features	Oxidative phosphorylation	Photophosphorylation
Location	inner mitochondrial membrane	thylakoid membrane of chloroplast
Functions in the presence of	oxygen	light
Source of energy	(from oxidation of) glucose	light

No. of electron transport chain	one	two
Electron flow	linear - one-way	linear or cyclic
Final electron acceptor	oxygen	NADP (non-cyclic) P700 (cyclic)
Involvement of water	water produced	photolysis of water
Establishment of proton gradient	protons pumped outwards from matrix across inner mitochondrial membrane into intermembrane space	protons pumped inwards from stroma across thylakoid membrane into thylakoid space
Products	ATP, water	ATP (cyclic) ATP, NADPH and oxygen (non-cyclic)

[Total: 20]

Or

10 (a) Distinguish between gene mutation and chromosome structural mutation. [4]

Gene mutation	Chromosomal mutation
Change in structure of DNA or nucleotide / DNA sequence of a gene / a single locus on a chromosome	Change in chromosome structure / DNA / nucleotide sequence of gene (mostly) unchanged
Caused by deletion, insertion, substitution or inversion of one / several bases / nucleotides	Deletion, inversion, translocation or duplication of chromosomal fragments / several gene loci
Give rise to new alleles	Rearrangement of loci of genes / alleles / reshuffling / recombination / new combination of alleles
More frequent than chromosomal mutations because genes outnumber chromosomes by several thousand to one	Less frequent
Play more important role in evolution than chromosomal mutations because new alleles increases gene pool for natural selection to operate	Play a less important role in evolution than gene mutations because chromosomal mutations involve only reshuffling of alleles that already exist in gene pool.

(b) Describe how the most common CFTR gene mutation affects function of the protein and explain why other mutations vary in the extent to which they affect protein function. [8]

How the most common CFTR gene mutation affects function of protein

- **Deletion** of 3 bases **GAA** from CFTR gene on **chromosome 7**
- Net effect: results in **loss** of amino acid **phenylalanine** (position 508) in the polypeptide chain;
- Altering / affecting **R-group interactions** of protein→ **tertiary structure** of CFTR changed
- Mutant CFTR cannot allow chloride ions to diffuse out of the cells / degraded therefore cannot (serve as channel protein to) allow diffusion of chloride ions out of the cell;

Why other mutations vary in the extent to which they affect protein function (max 5)

Non-function proteins

- **Base addition / deletion** (not in multiple of threes) results in **frameshift mutation**
- All nucleotides downstream of mutation will be improperly wronged into codons
  Accept frameshift mutation leading to nonsense mutation
- Drastic change in tertiary structure→ non-functional proteins

- **Base substitution/ addition / deletion** resulting in **nonsense mutation**
- resulting in codon coding for amino acid changing to **stop codon** → translation terminated
- resulting in **truncated protein** → non-functional proteins

Little effect / some change in function

- **Base substitution/ addition / deletion** results in **missense mutation**

Either

- Codon encode for a **different amino acid** of **different R-group property** as original amino acid or amino acid change occur at essential region
- **change** in **tertiary structure** of CFTR protein→ less functional CFTR

OR

- Codon encode for a **different amino acid** of **similar R-group property** as original amino acid or Amino acid changed at a **non-essential region** of the protein
- **Little/small change** in **tertiary structure** of CFTR protein → little change/ small effect in function

No change in function

- **Base substitution** on the **wobble base** of a codon results in **silent** mutation
- will lead to altered codon coding for the **same amino acid**
- **Tertiary structure** of CFTR protein not changed, function not changed

OR

- Mutation that occurs in CFTR gene occurs in **non-coding introns**
- Does not change the DNA sequence that is eventually expressed / mRNA sequence that is eventually translated
- No change in tertiary structure → function not changed

(c) With reference to mutation of named genes, outline the development of cancer. [8]

Max 6 for outlining the development of cancer.

- Cancer involves **uncontrolled cell division**;
- Mutation first occurs to **single cell**, leading to **abnormal proliferation of single cell** into (clonally derived / **genetically identical tumour cells;)**
- Normal cells are converted to cancer cells by **accumulation of several mutations**;
- **Daughter cells** of a cell bearing such mutations will **become dominant within tumour cell population;**
- **Gain of function mutations** of **proto-oncogenes**, converted to **oncogenes**;
- Proteins encoded in oncogenes **produced in excessive amounts / high expression of oncogenes** producing high levels of proteins or **Hyperactive proteins** may be produced (which are constitutively active or resistant to degradation)
- **Loss of function mutations** of **tumour suppressor genes**;
- **No functional/inactive tumour suppressor proteins**
- **Deactivation** of genes involved in **cell-to-cell adhesion**, resulting in loss of anchorage dependence / tissue invasion and **metastasis**;
- **Activation** of genes involved in **angiogenesis,** resulting in formation of blood vessels that provide cancer cells with nutrients and oxygen;

Max 2 for named genes.

- E.g. of proto-oncogene: mutataion of Ras gene, involved in **signalling pathway / signal transduction** that results in **stimulation of cell cycle → cell division.**
- E.g. of proto-oncogene: mutation of c-myc, **transcription factor** that regulates expression of genes involved in cell division;
- E.g. of tumour suppressor gene: mutation of p53 gene, which encodes for a **transcription factor** which stimulation transcription of genes involved in **cell cycle arrest**, **DNA repair** and **initiation of apoptosis** when there is **DNA damage**.
- Activation of **telomerase gene**, allowing telomerase to **maintain length of telomeres** → Preventing the cell from entering **replicative senescence/ divide unlimited number of times**;

[Total:20]

H2 ANDERSON JUNIOR COLLEGE
HIGHER 2

CANDIDATE NAME

PDG

PDG INDEX NUMBER

BIOLOGY 9648/03

Applications Paper and Planning Question Paper 3

20 September 2016 Tuesday

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and PD group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

All working for numerical answers must be shown.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Calculators may be used

For Examiner's Use	
1	
2	
3	
4	
5	
Total	72

This document consists of **14** printed pages.

Answer **all** the questions.

1

(a) State **three** differences between a genomic DNA library and a cDNA library.

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Many countries are trying to increase their production of bioethanol in order to fuel a range of vehicles. Most bioethanol is produced from the cellulose cell walls of plants. The cellulose synthase gene have been identified and sequenced.

In initial experiments to increase cellulose production, DNA containing the cellulose synthase gene were inserted into plasmid vectors and subsequently introduced into bacteria cells through transformation. Fig. 1.1 is a diagram of the pUC 19 plasmid map used in the experiments.

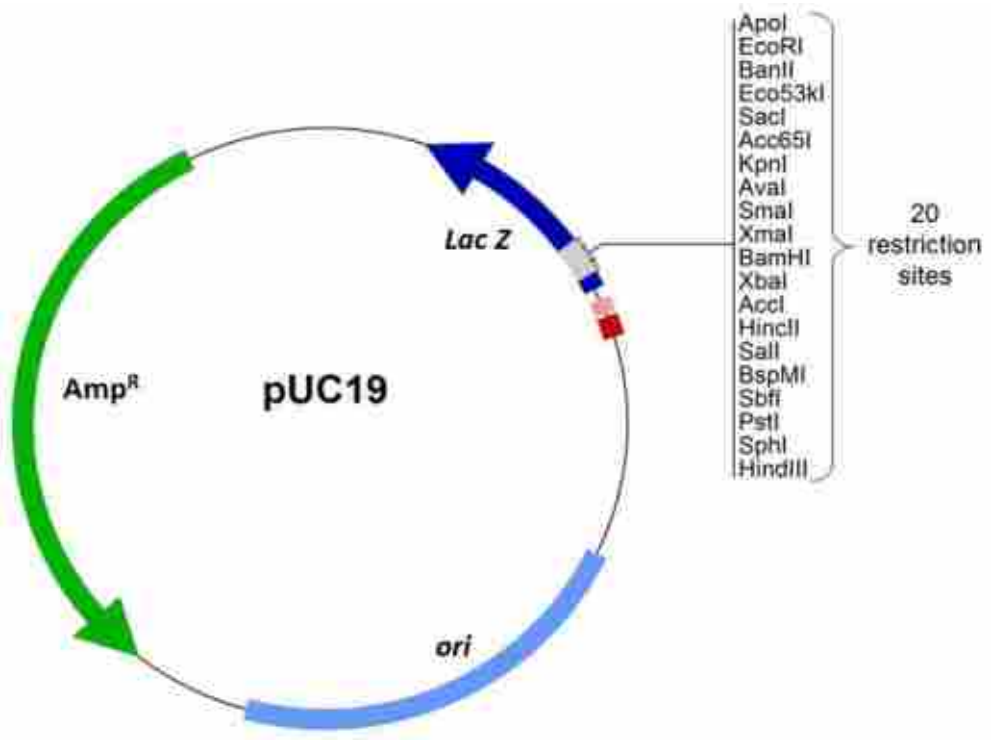

Fig. 1.1

(b) **(i)** State and explain **two** visible properties of the pUC 19 plasmid that allow it to be used as a DNA cloning vector.

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…… [4]

(ii) Explain how successfully transformed bacterial cells containing recombinant plasmids can be selected for.

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(c) The cellulose synthase gene obtained from a plant species has approximately 5000 base pairs (bp). However the length of the gene sequence inserted into bacterial cells was shortened to only approximately 3300bp.

Explain why the length of the gene inserted into bacterial cells was shortened.

…… ....

…… [2]

(d) Using bacteriophages to introduce the cellulose synthase gene into bacterial cells was thought to improve transformation efficiency. However, a lower than expected proportion of bacterial cells was found to contain the gene after bacterial transduction using bacteriophages.

Explain why using bacteriophages to introduce DNA into bacterial cells was not successful.

…… ....

…… [2]

[Total: 14]

2 Antithrombin (AT) is a protein required for the prevention of blood clots in the blood plasma. Patients with hereditary AT deficiency requires AT injection before they undergo any surgery to prevent the formation of blood clot in the veins.

ATryn, a recombinant AT (rAT) is the first medicine produced using genetically engineered animals. rAT is made from the mammary glands of goats that have been genetically modified (GM). The DNA construct introduced into goats comprises of the cDNA of human AT and regulatory elements of the goat beta casein gene, an essential milk protein produced in goat mammary glands. Microinjection was used to insert the DNA construct into a goat zygote which is then transplanted into the uterus of a female goat. GM progeny goat will produce large amounts of AT into its milk which are then isolated and purified.

(a) Explain why the DNA construct used is a recombinant DNA.

……. ....

……. [1]

(b) Suggest why the DNA construct used must include regulatory elements of the goat beta casein gene.

……. ....

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……... [2]

The effectiveness of rAT can be measured in terms of percentage activity compared with normal human blood plasma AT (hpAT). rAT was injected into four patients with AT deficiency (AT activity ≤ 60%) and their AT activities were measured every two days after the injection. Fig. 2.1 shows the results of the study.

Table 2.1 shows a comparison between the structure of rAT and hpAT.

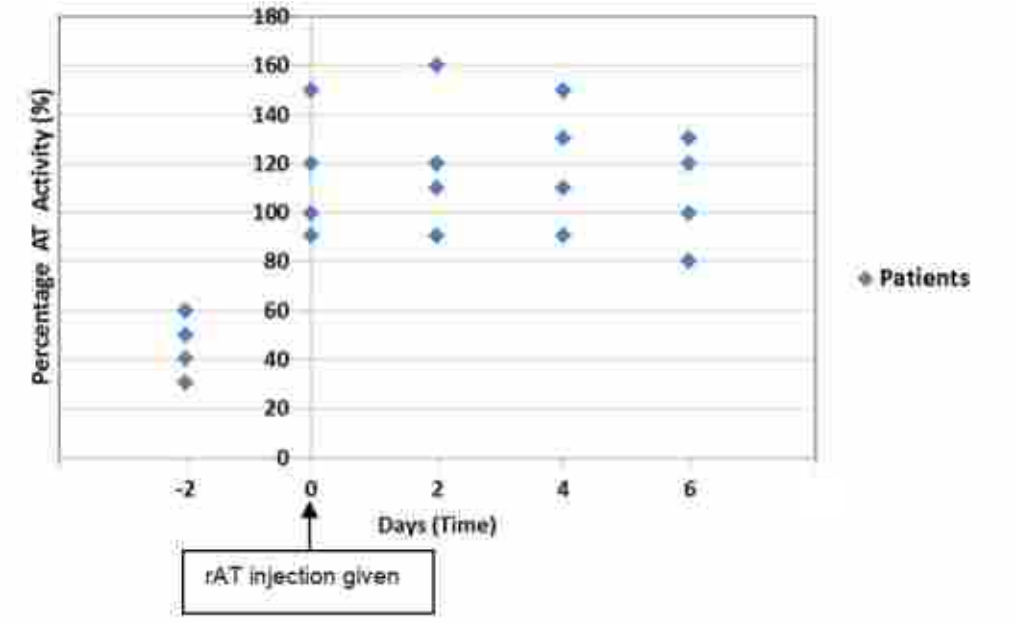

Fig. 2.1

	rAT	hpAT
Primary structure	Single chain of 432 amino acids	Single chain of 432 amino acids
Glycosylation	Glycosylation at 3 asparagine amino acid residues (Asn 96, 155, 192)	Glycosylation at 4 asparagine amino acid residues (Asn 96, 135, 155, 192)
Analysis of carbohydrate chains on the protein	Mainly N-acetyl neuraminic acid	Mainly N-glycolyl neuraminic acid

Table 2.1

(c) Using the information above,

(i) describe the effect of injecting rAT on the patients .

……

…….. [1]

(ii) describe a difference between the structures of rAT and hpAT and the effect of the difference on the patients.

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(iii) suggest what resulted in the differences in the structures of rAT and hpAT.

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Polymerase chain reaction (PCR) and gel electrophoresis can be used to distinguish between a DNA construct containing both cDNA of human AT and regulatory elements and one which contains only the regulatory elements.

Fig. 2.2 shows the DNA construct used in forming rAT.

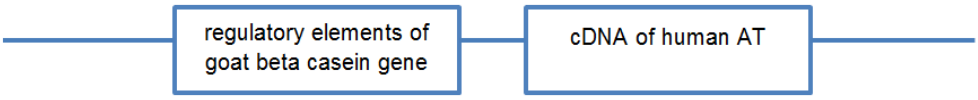

Fig. 2.2

(d) **(i)** On Fig. 2.2, indicate with ***5'*** ⟶ ***3'*** where the primers will bind in the PCR reaction.

5' and ***3'*** represents the 5' and 3' ends of the primers respectively. [1]

(ii) Explain how gel electrophoresis can be used to distinguish between a DNA construct with both cDNA of human AT and regulatory elements and one which contains only regulatory elements.

……

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…… [2]

(e) A new project, GenomeAsia 100K, aims to sequence the genomes of 100,000 Asians across Asia to tailor-made drugs for Asians, an approach known as precision medicine.

(i) State **one** benefit of precision medicine.

……

…… [1]

(ii) While there are many benefits of precision medicine, some people are apprehensive that the project will unravel genetic differences in ethnicity "making some people a lesser man and others a better man"

Explain why the project may result in the ethical issue of "making some people a lesser man and others a better man".

……

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…… [2]

[Total: 13]

3 In 2006, scientists Takahashi and Yamanaka stimulated mouse tail-tip cells, which are fully differentiated cells, to change back into stem cells in tissue culture. Such stem cells obtained from the de-differentiation of somatic cells are known as induced pluripotent stem cells (iPS cells). In the last decade, iPS cells have been generated from humans cells isolated from different tissues by introduction of various growth factors that affects the expression of many genes, such as the gene coding for human telomerase reverse transcriptase (hTERT).

(a) Explain how the expression of hTERT may help the cells regain stem cell properties.

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…… [3]

(b) X-linked Severe Combined Immunodeficiency (SCID) is a rare congenital disorder characterised by improper development of immune cells which has been treated by gene therapy.

Explain why X-linked SCID can be treated by gene therapy.

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…… [2]

The ability to generate iPS cells that have characteristics that are similar to embryonic stem cells has provided a promising alternative to the use of haematopoietic stem cells for gene therapy to treat X-linked SCID. Fig 3.1 shows a possible process of using iPS cells for gene therapy.

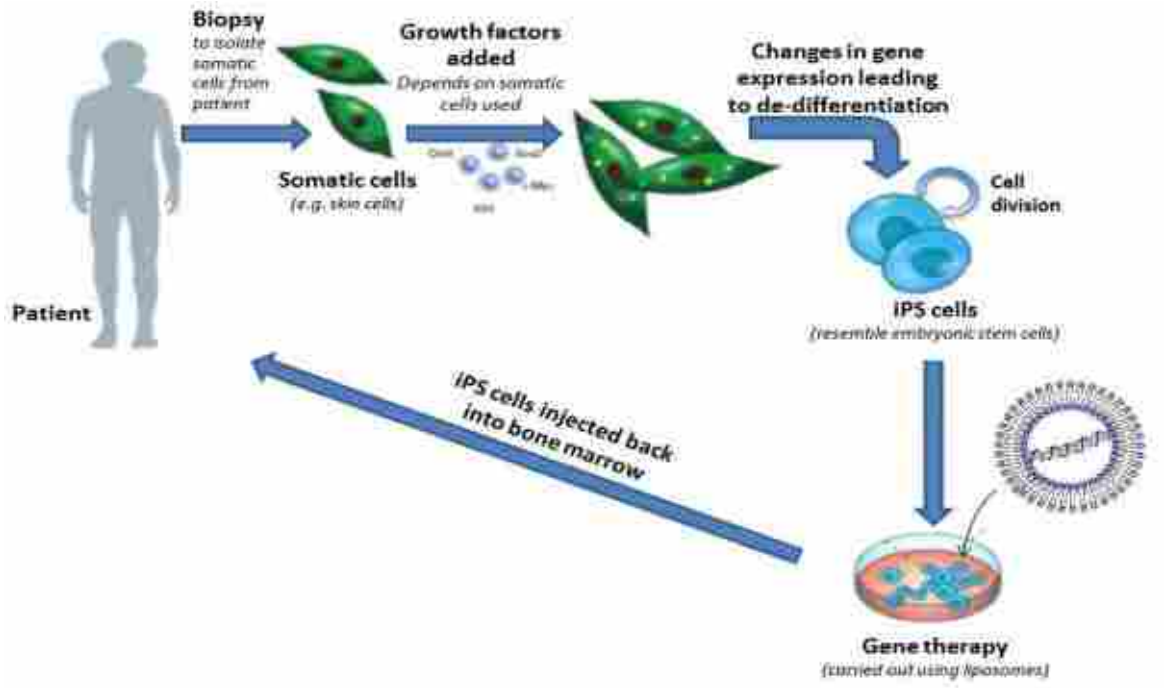

Fig. 3.1

(c) Describe and explain **two** factors that prevent this method of gene therapy for X-linked SCID from becoming an effective treatment.

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(d) Although the use of retroviral vectors for gene therapy has been highly successful in treating SCID, many patients who received treatment also developed immune responses against the virus and leukaemia.

Suggest another challenge of using viral vectors in the process shown in Fig. 3.1.

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……... [1]

(e) **(i)** Discuss the arguments for and against the use of human embryonic stem cells for therapy.

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(ii) Explain whether you agree or disagree that use of iPS cells resolve the issues discussed above.

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…… [1]

[Total: 13]

4 Planning question

Diffusion of molecules can be observed using the Visking tubing.

The Visking (dialysis) tubing is a selectively permeable membrane that allows small molecules to diffuse through. The tubing can be tightly knotted at one end and a solution can be contained within the tubing. The filled tubing can then be placed in distilled water for the diffusion of the solute molecules out of the tubing into the distilled water. Fig. 4.1 shows the Visking tubing set-up as described.

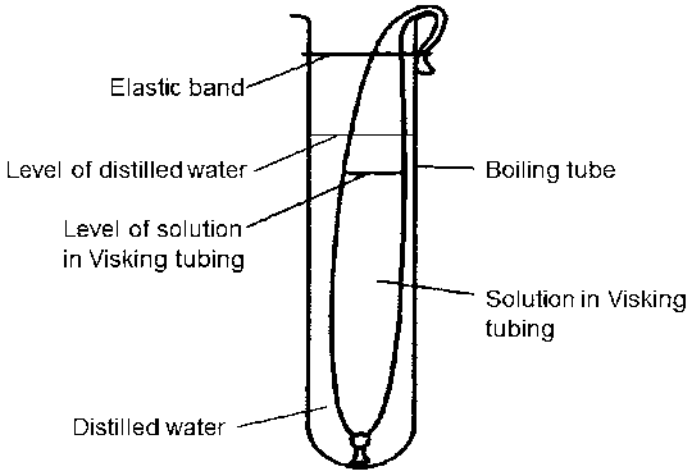

Fig. 4.1

The presence of solutes in distilled water surrounding the tubing can then be tested using quantitative / qualitative analysis.

Presence of glucose in solution can be tested using Benedict's test. The concentration of glucose in a solution can be estimated using a colour standard made with solutions with known glucose concentrations.

Using this information and your own knowledge, design an experiment to investigate the effect of temperature on the diffusion of glucose.

You must use:

- 100 cm^3 of 10g / 100 cm^3 glucose solution,
- 10 cm^3 of 5g / 100 cm^3 glucose solution for colour standard,
- Distilled water,
- Thermostatically-controlled water bath and thermometer,
- Benedict's solution,
- Boiling tubes,
- Stopwatch.

You may select from the following apparatus and chemicals:

- Normal laboratory glassware, e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods etc.,
- Syringes.

Your plan should:

- Have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

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Free-response question

Write your answers to this question on the separate answer paper provided.

Your answer:

- should be illustrated by large, clearly labelled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5 **(a)** Outline nucleic acid hybridisation and explain how it can be used in the detection of DNA sequences. [9]

(b) Explain the advantages and disadvantages of tissue culture over more traditional methods of cloning plants, such as taking cuttings or grafting. [5]

(c) Describe the goals of the Human Genome Project, and with a named example, explain how the findings of the HGP may benefit the genetic modification of crops. [6]

[Total:20]

H2 ANDERSON JUNIOR COLLEGE
HIGHER 2

CANDIDATE NAME

PDG

PDG INDEX NUMBER

BIOLOGY 9648/03

Applications Paper and Planning Question Paper 3

20 September 2016
Tuesday

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and PD group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

All working for numerical answers must be shown.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Calculators may be used

For Examiner's Use	
1	
2	
3	
4	
5	
Total	72

This document consists of **13** printed pages and **1** blank page.

Answer **all** the questions.

1

(a) State **three** differences between a genomic DNA library and a cDNA library.

Genomic Library	cDNA Library
A collection of clones containing fragments of genomic DNA representing the entire genome of a species;	A collection of clones containing cDNA copies of all the mRNAs (expressed genes) in a cell type at a particular time;
Library size is larger;	Library size is smaller and more compact;
A Genomic library is derived from the DNA of the entire genome of an organism;	A cDNA library is derived from the mRNA isolated from a cell of the organism;
DNA sequences contained include exons, introns and regulatory sequences;	cDNA sequences contain only exons / lack intron and regulatory sequences;
Gene sequences are not intact because they are cut by restriction enzymes at restriction sites;	Gene sequences are intact because cDNA are reverse-transcribed from mRNA;
More difficult to find desired gene sequence;	Easier to find desired gene sequence;
Vectors include bacteriophage lambda, cosmid, bacteriophage P1, bacterial artificial chromosome and yeast artificial chromosome;	Vectors used include plasmid or bacteriophage lambda;

[3]

Many countries are trying to increase their production of bioethanol in order to fuel a range of vehicles. Most bioethanol is produced from the cellulose cell walls of plants. The cellulose synthase gene have been identified and sequenced.

In initial experiments to increase cellulose production, DNA containing the cellulose synthase gene were inserted into plasmid vectors and subsequently introduced into bacteria cells through transformation. Fig. 1.1 is a diagram of the pUC 19 plasmid map used in the experiments.

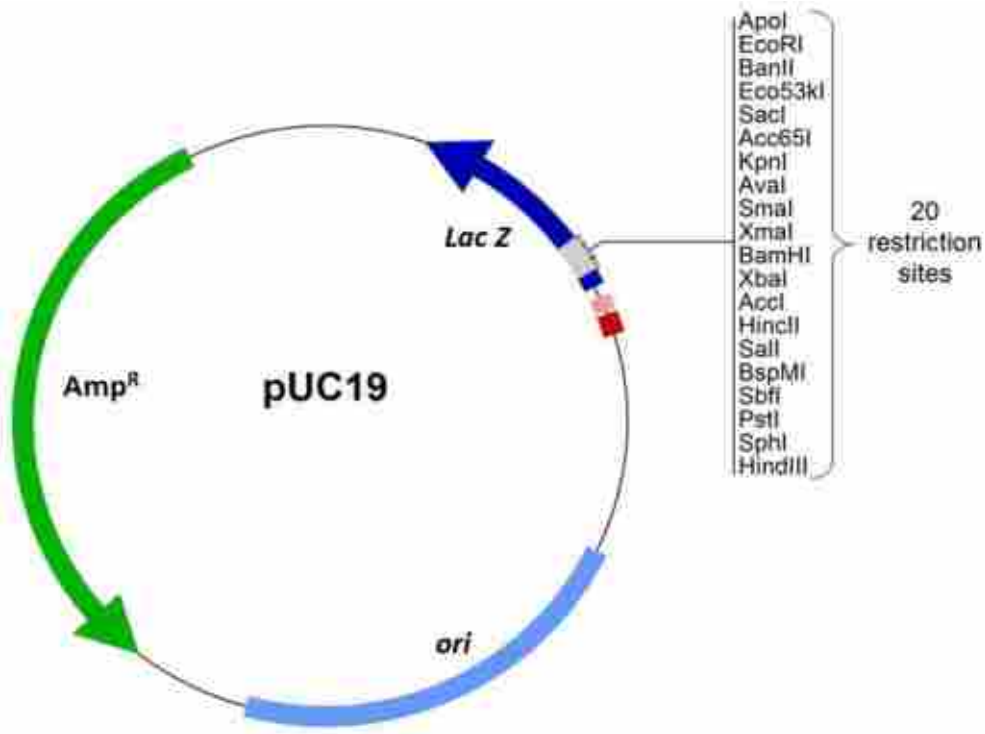


Fig. 1.1

(b) **(i)** State and explain **two** visible properties of the pUC 19 plasmid that allow it to be used as a DNA cloning vector.

- Contain **two selectable marker genes** (need to cite amp and LacZ);
- Expression of genes confer well-defined phenotype on the host cell, allowing for selection of transformed cells which have taken up vector or recombinant DNA molecules;

- contains **multiple cloning site / polylinker**;
- allow **20 different restriction enzymes** to cleave the plasmid DNA to insert some / many genes;

- have **origin of replication**;
- plasmid can be **replicated independently** of bacteria chromosome, to give **multiple copies** of the plasmid and gene of interest within **one bacterium**, ensures gene of interest can be passed onto daughter cells;

[max 4m] [4]

(ii) Explain how successfully transformed bacterial cells containing recombinant plasmids can be selected for.

- Bacterial cells grown on **medium** containing **ampicillin** and **X-gal**;
- Bacterial cells that **survive** and **form white colonies** are successfully transformed cells containing recombinant plasmids;
- Bacterial cells that survive **contain ampicillin gene** which is **transcribed and translated** to produce **ampicillin resistance proteins**;
- Cells that contain recombinant plasmids will have where there is **insertional inactivation of lacZ gene**, **no functional β-galactosidase enzymes** produced through transcription and translation and **X-gal not hydrolysed** to form blue products;

[max 3m] [3]

(c) The cellulose synthase gene obtained from a plant species has approximately 5000 base pairs (bp). However the length of the gene sequence inserted into bacterial cells was shortened to only approximately 3300bp.

Explain why the length of the gene inserted into bacterial cells was shortened.

- **Introns** from the gene sequence removed / gene **only** contain **exons**;
- **Lack of splicing mechanism** in bacterial cells;
- Translation of mRNA would produce a polypeptide chain with correct amino acid sequence;

[max 2m] [2]

(d) Using bacteriophages to introduce the cellulose synthase gene into bacterial cells was thought to improve transformation efficiency. However, a lower than expected proportion of bacterial cells was found to contain the gene after bacterial transduction using bacteriophages.

Explain why using bacteriophages to introduce DNA into bacterial cells was not successful.

- Bacterial cells have **restriction enzymes / endonucleases**;
- **Cleave / hydrolyse the DNA** containing the gene of interest to **protect bacterial cells from viral / bacteriophage infections**; [2]

[Total: 14]

2 Antithrombin (AT) is a protein required for the prevention of blood clots in the blood plasma. Patients with hereditary AT deficiency requires AT injection before they undergo any surgery to prevent the formation of blood clot in the veins.

ATryn, a recombinant AT (rAT) is the first medicine produced using genetically engineered animals. rAT is made from the mammary glands of goats that have been genetically modified (GM). The DNA construct introduced into goats comprises of the cDNA of human AT and regulatory elements of the goat beta casein gene, an essential milk protein produced in goat mammary glands. Microinjection was used to insert the DNA construct into a goat zygote which is then transplanted into the uterus of a female goat. GM progeny goat will produce large amounts of AT into its milk which are then isolated and purified.

(a) Explain why the DNA construct used is a recombinant DNA.

- Comprises of DNA from **2 different species / sources:** human and goat [1]

(b) Suggest why the DNA construct used must include regulatory elements of the goat beta casein gene.

[2]

- Regulatory elements of the goat casein gene can be bounded by transcription factors present in (cells of) mammary gland
- To allow expression/ transcription and translation of the human AT gene only in the goat mammary gland

The effectiveness of rAT can be measured in terms of percentage activity compared with normal human blood plasma AT (hpAT). rAT was injected into four patients with AT deficiency (AT activity ≤ 60%) and their AT activities were measured every two days after the injection. Fig. 2.1 shows the results of the study.

Table 2.1 shows a comparison between the structure of rAT and hpAT.

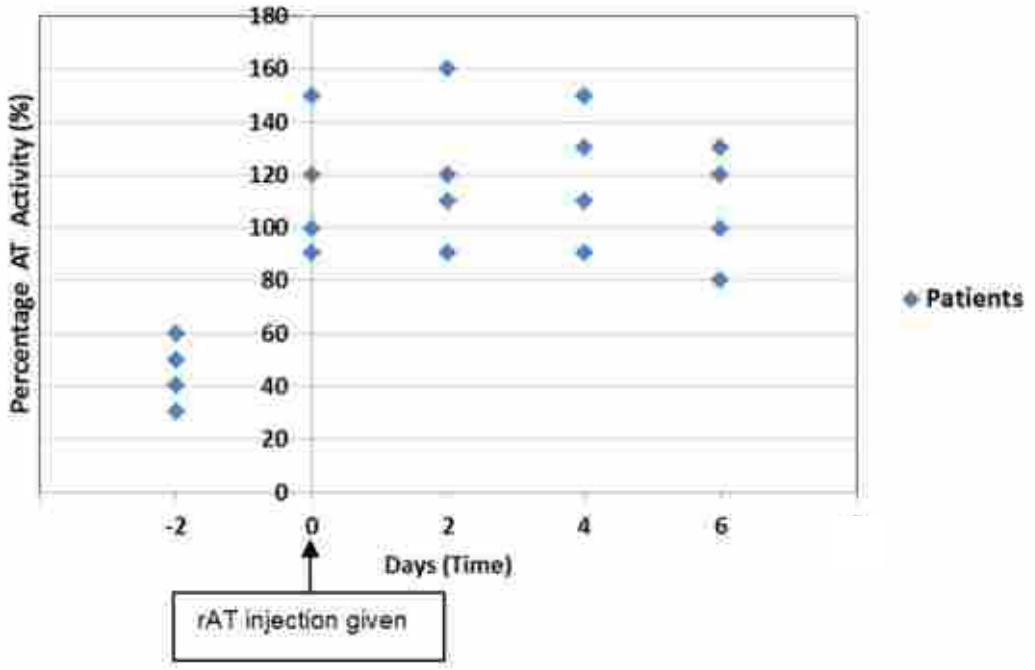


Fig. 2.1

	rAT	hpAT
Primary structure	Single chain of 432 amino acids	Single chain of 432 amino acids
Glycosylation	Glycosylation at 3 asparagine amino acid residues (Asn 96, 155, 192)	Glycosylation at 4 asparagine amino acid residues (Asn 96, 135, 155, 192)
Analysis of carbohydrate chains on the protein	Mainly N-acetyl neuraminic acid	Mainly N-glycolyl neuraminic acid

Table 2.1

(c) Using the information above,

(i) describe the effect of injecting rAT on the patients .

- AT activity in all patients increased from a range of 30-60% AT activity before treatment to 80-160% AT after treatment

[1]

(ii) describe a difference between the structures of rAT and hpAT and the effect of the difference on the patients.

Describe the difference (any 1)

- Glycosylation at 4 asparagine amino acid residues while rAT had glycosylation at 3 asparagine amino acid residues/ Asn 135 in rAT is not glycosylated

- rAT has mainly N-acetyl neuraminic acid attached while hpAT has mainly N-glycolyl-neuraminic acid

Effects on patients

rAT has different tertiary structure from hpAT → Patients have AT activity (up to 160% which is 60%) more than normal human AT [2]

(iii) suggest what resulted in the differences in the structures of rAT and hpAT.

- different enzymes carrying out glycosylation in goat and human
- N-glycolyl neuraminic acid not synthesised / found in goat cells and vice versa
- AVP

[1]

Polymerase chain reaction (PCR) and gel electrophoresis can be used to distinguish between a DNA construct containing both cDNA of human AT and regulatory elements and one which contains only the regulatory elements.

Fig. 2.2 shows the DNA construct used in forming rAT.

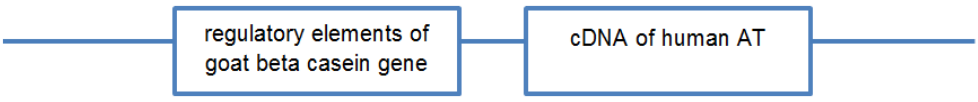


Fig. 2.2

(d) **(i)** On Fig. 2.2, indicate with ***5'*** ⟶ ***3'*** where the primers will bind in the PCR reaction.

5' and ***3'*** represents the 5' and 3' ends of the primers respectively. [1]

- 2 arrows either flanking the region containing both regulatory elements and cDNA or flanking/ on the cDNA of human AT

(ii) Explain how gel electrophoresis can be used to distinguish between a DNA construct with both cDNA of human AT and regulatory elements and one which contains only regulatory elements.

- gel electrophoresis to separate the PCR products by **size** under a **direct current**

- DNA containing AT and regulatory elements are bigger/larger, hence travel slower across the gel / DNA band appear nearer to the cathode *accept converse* [2]

OR

- A (1296 bp) band will be observed for DNA containing AT and promoter while no bands observed for DNA containing only regulatory elements

(e) A new project, GenomeAsia 100K, aims to sequence the genomes of 100,000 Asians across Asia to tailor-made drugs for Asians, an approach known as precision medicine.

(i) State **one** benefit of precision medicine.

- greater drug efficacy
- prevents dangerous side effects
- AVP [1]

(ii) While there are many benefits of precision medicine, some people are apprehensive that the project will unravel genetic differences in ethnicity "making some people a lesser man and others a better man"

Explain why the project may result in the ethical issue of "making some people a lesser man and others a better man".

- Discrimination/labelling/stereotyping of certain ethnic group based on **genetic profile/ genome**
- Idea of genetic influence on behaviour, character traits, susceptibility to diseases e.g. People will be tempted to draw connections between genes and propensity to violence, intelligence, creativity etc [2]

[Total: 13]

3 In 2006, scientists Takahashi and Yamanaka stimulated mouse tail-tip cells, which are fully differentiated cells, to change back into stem cells in tissue culture. Such stem cells obtained from the de-differentiation of somatic cells are known as induced pluripotent stem cells (iPS cells). In the last decade, iPS cells have been generated from humans cells isolated from different tissues by introduction of various growth factors that affects the expression of many genes, such as the gene coding for human telomerase reverse transcriptase (hTERT).

(a) Explain how the expression of hTERT may help the cells regain stem cell properties.

- hTERT catalyses the formation of phosphodiester bonds between DNA nucleotides which are added to the 3' end of parental DNA strands (via complementary base pairing with telomerase RNA) during DNA replication;
- Increases length of telomeres/prevents telomeres from shortening → prevents telomeres from reaching critical length after few rounds of DNA replication;
- iPS cells are able to self-renew and divide by mitosis continuously/repeatedly (must have idea of many rounds of cell division);

[3]

(b) X-linked Severe Combined Immunodeficiency (SCID) is a rare congenital disorder characterised by improper development of immune cells which has been treated by gene therapy.

Explain why X-linked SCID can be treated by gene therapy.

- X-linked-SCID is a single gene disorder/idea of only one gene mutated OR sequence of the IL2RG gene is well characterised
- Introduction/ insertion of only one normal interleukin 2 receptor gamma (IL2RG) allele into target cells is sufficient to mask the phenotypic effect of recessive mutation;

OR

- Normal IL2RG dominant allele introduced into the targeted blood stem cell codes for sufficient common gamma chain of (several) cytokine receptors (via transcription and translation of the normal IL2RG allele); [2]

The ability to generate iPS cells that have characteristics that are similar to embryonic stem cells has provided a promising alternative to the use of haematopoietic stem cells for gene therapy to treat X-linked SCID. Fig 3.1 shows a possible process of using iPS cells for gene therapy.

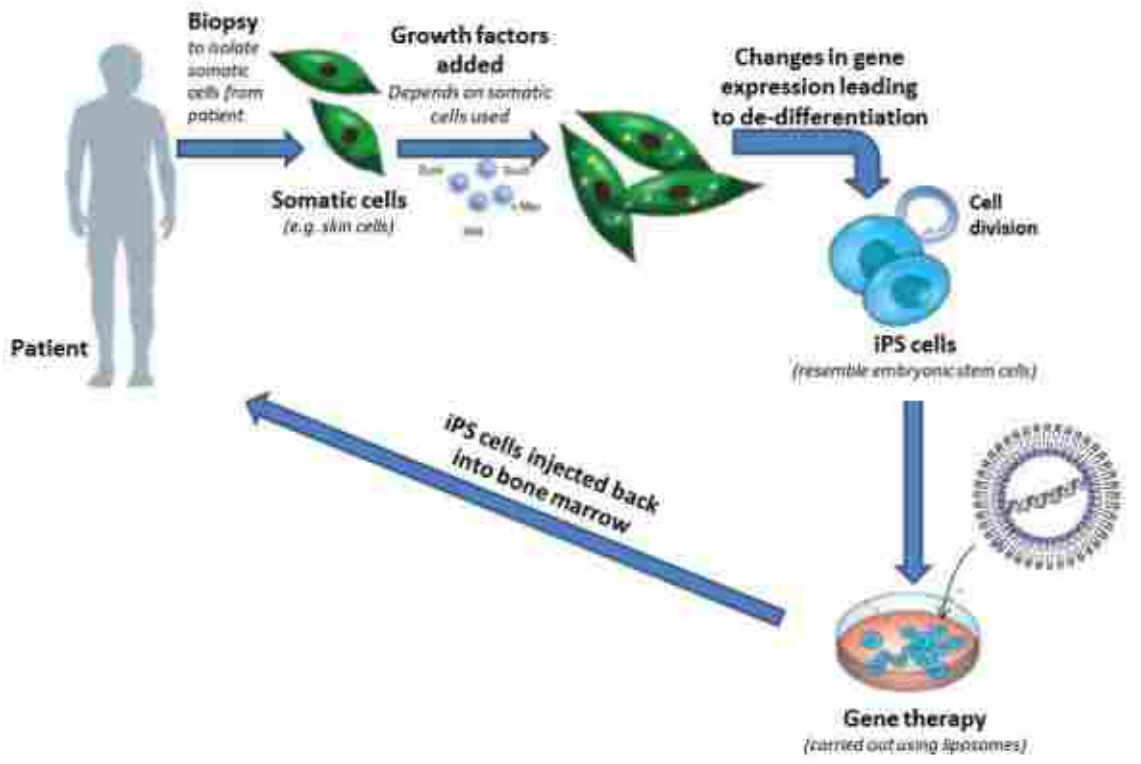


Fig. 3.1

(c) Describe and explain **two** factors that prevent this method of gene therapy for X-linked SCID from becoming an effective treatment.

Difficulties in de-differentiating somatic cells to iPS cells

- Difficult to ensure that specialised/completely differentiated somatic cells become pluripotent (completely) as it is difficult to determine the growth factors to be used;
- Treatment may not be effective as the iPS cells obtained are unable to differentiate into blood stem cells in the bone marrow;

Use of liposome as vector

- Lower probability of liposomes binding to cell surface membrane of iPS cells and membrane fusion occurring to release DNA into target cells;
- therefore not all target cells receive normal IL2RG allele, some still express non-functional IL2RG protein;

OR

- Normal IL2RG allele not integrated into the iPS cell's DNA, unless retroviral vector is used; [4]

- this leads to transient expression of normal functional proteins and multiple treatments are required;
  N2011 Examiner's report: Candidates should take care not to suggest that genes die or do not live for very long. Also note that retroviral vectors may not be suitable for treatment of all genetic diseases as they may not be able to infect certain target cells

Gene therapy does not offer complete cure

- Difficult to control the expression of the normal IL2RG alleles
- Expression of proteins may be unstable – there may be too much or too little proteins being expressed → immune cells may have insufficient cytokine receptors/are abnormal, cannot carry functions;

(d) Although the use of retroviral vectors for gene therapy has been highly successful in treating SCID, many patients who received treatment also developed immune responses against the virus and leukaemia.

Suggest another challenge of using viral vectors in the process shown in Fig. 3.1.

- Difficult to find viral vectors which have surface glycoproteins that are complementary in shape/can bind to the cell surface receptors of the target iPS cells; [1]

(e) **(i)** Discuss the arguments for and against the use of human embryonic stem cells for therapy.

- Against use of ES cells
  - involves removal of inner cell mass from blastocyst → destruction of embryo which has the potential/ability to develop into a foetus/a human being → akin to murder/killing of a life for own benefit/to treat own disease;
  - ES cells are able to divide continuously via mitosis → potential of developing tumours, causing more harm to the patient.
- For use of ES cells
  - unclear whether ES cells are considered human life → (it does not have any interests to be protected) and thus should be used to benefit/treat/save patients with life-threatening diseases;
  - ES cells are pluripotent → able to differentiate into any other cell types of the 3 germ layer → potential to treat diseases where harvesting of adult stem cells are difficult; [2]

(ii) Explain whether you agree or disagree that use of iPS cells resolve the issues discussed above.

- Agree → iPS cells were not harvested from embryos but were obtained from de-differentiation of somatic cells → no destruction of human life so it is acceptable;

OR

- Disagree → iPS cells have characteristics of ES cells and hence have the potential of developing into a develop into a foetus/a human being;

(Student must state a clear stand to gain mark) [1]

[Total: 13]

4 Planning question

Diffusion of molecules can be observed using the Visking tubing.

The Visking (dialysis) tubing is a selectively permeable membrane that allows small molecules to diffuse through. The tubing can be tightly knotted at one end and a solution can be contained within the tubing. The filled tubing can then be placed in distilled water for the diffusion of the solute molecules out of the tubing into the distilled water. Fig. 4.1 shows the Visking tubing set-up as described.

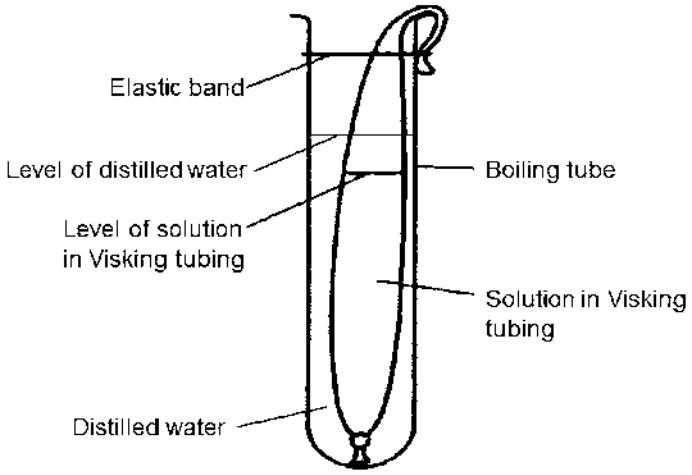


Fig. 4.1

The presence of solutes in distilled water surrounding the tubing can then be tested using quantitative / qualitative analysis.

Presence of glucose in solution can be tested using Benedict's test. The concentration of glucose in a solution can be estimated using a colour standard made with solutions with known glucose concentrations.

Using this information and your own knowledge, design an experiment to investigate the effect of temperature on the diffusion of glucose.

You must use:

- 100 cm^3 of 10g / 100 cm^3 glucose solution,
- 10 cm^3 of 5g / 100 cm^3 glucose solution for colour standard,
- Distilled water,
- Thermostatically-controlled water bath and thermometer,
- Benedict's solution,
- Boiling tubes,
- Stopwatch.

You may select from the following apparatus and chemicals:

- Normal laboratory glassware, e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods etc.,
- Syringes.

Your plan should:

- Have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

Theory of Explanation [0.5m each, 1m]

Effect of Temperature on diffusion of Glucose
- The higher the temperature, the higher the **kinetic energy** of glucose molecules;

Benedict's Test
- Producing brick red precipitate from reduction of copper (II) ions;

Hypothesis [0.5m each, 1m]
- The **higher the temperature**, the **faster the diffusion of glucose / more glucose diffuse** into the surrounding distilled water / out of the Visking tubing;
- The greater the concentration of glucose in distilled water, the **greater the amount of brick-red precipitate** produced in the reducing sugar test;

Step-by-step experimental procedure [0.5m each, max 5m]

Making of glucose standard solutions [0.5m each, max 1m]
- Using serial dilution / simple dilution, concentration stated 0.1 g – 5 g per 100 cm^3 (any reasonable range);
- Description of dilution process / drawing of dilution table;

Diffusion of glucose at different temperatures [0.5m each, max 2.5m]
- Tie one end of the Visking tubing;
- Use syringe to add 10 cm^3 of 10 g per 100 cm^3 glucose solution into Visking tubing (accept any reasonable volume of solution);
- Use syringe to add 20cm^3 of distilled water into a boiling tube (accept any reasonable volume of solution);
- Place the boiling tube into the **thermostatically controlled water bath** set at 30°C;
- Time 1 minute using a stopwatch for **equilibration**;
- Measure the temperature of the water bath water using a **thermometer**;

- Place Visking tubing into the boiling tube and time for **2 minutes** using **stopwatch** (accept any fixed period of time);
- After 2 minutes, remove the boiling tube from the water bath and remove the Visking tubing from the boiling tube;
- Repeat the experiment at different temperatures, (Accept any temperature range from 30°C to 100°C, five stated temperatures required, reject any temperatures below 25°C);
- Dependent variable: Rate of glucose diffusion;
- Independent variable: Temperature;

Reducing sugar test [0.5m each, max 1.5m]
- Add 2cm^3 of solution from one boiling tube and 1cm^3 of Benedict's solution into a test tube using 5cm^3 syringe;
- Place test tubes into a thermostatic water bath set at 90°C / boiling water bath for 2 minutes (accept reasonable time);
- Repeat with the solutions from four boiling tubes and the glucose solutions of known concentration;
- **Compare** the **colour of the precipitates** from the solutions of the boiling tubes with the colour of the precipitates from the glucose solutions of known glucose concentration to **determine the glucose concentration of solutions from the boiling tubes**;

Reliability and Reproducibility [0.5m each, max 1m]
- Carry out 3 replicates at each diffusion temperature to obtain an average rate of glucose diffusion to ensure reliability of the experiment;
- Repeat the entire experiment twice to ensure the reproducibility of the results;

Control [0.5m each, max 1m]
- Repeat the entire experiment, replacing the solution in the Visking tubing with an **equal volume of distilled water**;
- No brick red precipitate produced from the solution;
- Presence of glucose in the distilled water in the boiling tube is due to the presence of glucose solution in the Visking tubing;

Results [0.5m each, max 2m]
- **Tabulation** of data with **headings and units** (temperature / °C, average glucose concentration in boiling tube solution in 2 minutes / g 100 cm^3);
- Processing of data, includes average rate of glucose diffusion (g 100$cm^{-3}s^{-1}$);
- Graph showing trend of average glucose diffusion vs. temperature;
- Correct labeling of x and y-axis with units;

Risk assessment [0.5m each, max 1m]
- Risk: Benedict's solution is an irritant to skin and the eyes;
- Precaution: Wear gloves and goggles to avoid contact with skin and eyes respectively;

Free-response question

Write your answers to this question on the separate answer paper provided.

Your answer:

- should be illustrated by large, clearly labelled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5 **(a)** Outline nucleic acid hybridisation and explain how it can be used in the detection of DNA sequences. [9]

- The formation of a double-stranded nucleic acid molecule by binding of one single stranded nucleic acid to another;
- Via **complementary base-pairing** / formation of hydrogen bonds between complementary bases;
- Possible hybrid nucleic acid molecules, two strands of DNA, two strands of RNA or DNA-RNA hybrid molecules;

[max 2m]

- **Southern blotting** is a method that uses nucleic acid hybridisation to detect specific DNA sequences;
- DNA fragments of different sizes separated by **gel electrophoresis**
- Double-stranded DNA are **denatured** into single strands by adding alkali to the gel;
- The denatured DNA is transferred to a piece of nitrocellulose membrane by **capillary action**;

[max 2m]

- **Colony hybridisation** is a method that uses nucleic acid hybridisation to identify which bacteria colonies on an agar plant contains a specific DNA sequence of interest / target DNA sequence;
- Colonies on an agar plate is pressed against a nitrocellulose membrane
- Treated with alkali to lyse cells and denature DNA;

[max 2m]

- membrane then **incubated with a labelled single-stranded** DNA or RNA **probe**;
- Probe has **complementary sequence** to the target DNA sequence / sequence of interest;
- If target DNA sequence is present, probe will hybridise with the target DNA and indicate its presence;
- Hybridised probe is detected via autoradiography, colour development or development of fluorescence on membrane;
- Nitrocellulose membrane will show a visual band where the probe hybridised with the complementary target DNA;

[max 3m]

(b) Explain the advantages and disadvantages of tissue culture over more traditional methods of cloning plants, such as taking cuttings or grafting. [5]

Advantages:

- **Less space** is required to grow the plants in the lab, as compared to the field.
- Plant cultures (stored in culture flasks) are **easier and cheaper to transport** (via air freight) compared to adult plants

- **Disease-free** plants can be produced
- **Genetic modification** of plant cells is possible during tissue culture.
- Production is **not affected by weather / environmental conditions**.
- Plants that are difficult to germinate from seeds (e.g. orchids) can be easily produced via tissue culture.

[max 2m/3m]

Disadvantages:

- **Expensive** because of labour intensive/equipment/ requirement to maintain a sterile environment via e.g. use of laminar flow hoods which are expensive.
- An infected stock plant (with fungi) can produce many infected progeny/some plants are very difficult to disinfect of fungal organisms.
- Not all plants can be successfully tissue-cultured, often because the growth medium (for that plant species) is not known.
- Monocultures / (genetically identical plants) are susceptible to new diseases or pests.

[max 2m/3m]

Accept converse if student talked about advantages/disadvantages of traditional methods of plant cloning.

(c) Describe the goals of the Human Genome Project, and with a named example, explain how the findings of the HGP may benefit the genetic modification of crops. [6]

Goal of HGP **[max 4m]**	Possible benefit to plant cloning **[max 2m]**
• Knowledge of plant genomics: To **determine the sequence** of the coded information contained in the DNA of the various genomes studied; OR • **Completing the sequences of several other organisms** (such as bacteria, yeast, *Drosophila melanogaster* and the mouse) to be used as models for research → Knowledge gained by the study of genomes of other organisms would assist in the analysis of the human genome;	• Give example: determine sequence of ○ *psy* gene (from daffodil) *crtI* gene (from soil bacterium); OR ○ *Bt* gene (from soil bacterium/ *Bacillus thuringiensis*) • (In the process of sequencing and mapping of human genome), **genetic engineering/ techniques of cloning** were developed (which could be applied to create genetically modified crops);
• Functional genomics: **studying genes' normal functions**;	• Idea of allowing the isolation of gene(s) of interest from other organisms which code for traits which are desirable to have in GM crop; • Give example: ○ Golden rice: *psy* gene and *crtI* gene code for enzymes (phytoene synthase and carotene desaturase) that convert phytoene to β-carotene (in rice endosperm) (→ improve nutritious value/increase quality of rice); OR ○ Bt corn: *Bt* gene codes for toxin which causes the death of corn borer (→ increase crop yield without use of chemical insecticides/pesticides)

	• to improve the yield and quality of crop plants to solve world demand for food (don't double award if benefits are explained with the examples);
• Storing all sequence information in databases that are accessible by all;	• Idea of: easy access of shared data enables different groups of researchers to search for information about e.g. gene sequences and functions without having to do extensive/time-consuming research on their own to create new GM crops with novel traits;
• Studying and addressing the ethical, legal and social implications (ELSI) of genome research;	
• Improving tools for analysis such as sequencing technology development, developing technology for functional genomics, developing technology in bioinformatics;	

[Total:20]

NAME: _____ CLASS: _____ INDEX: _____

CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
Higher 2

BIOLOGY
9648/01

Paper 1 Multiple Choice
29th August 2016
1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write and/or shade your name, NRIC / FIN number and HT group on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** questions on this paper. Answer **all** questions. For each question, there are four possible answers, **A, B, C** and **D**.
Choose the **one** you consider correct and record your choice in **soft 2B pencil** on the separate Answer Sheet.

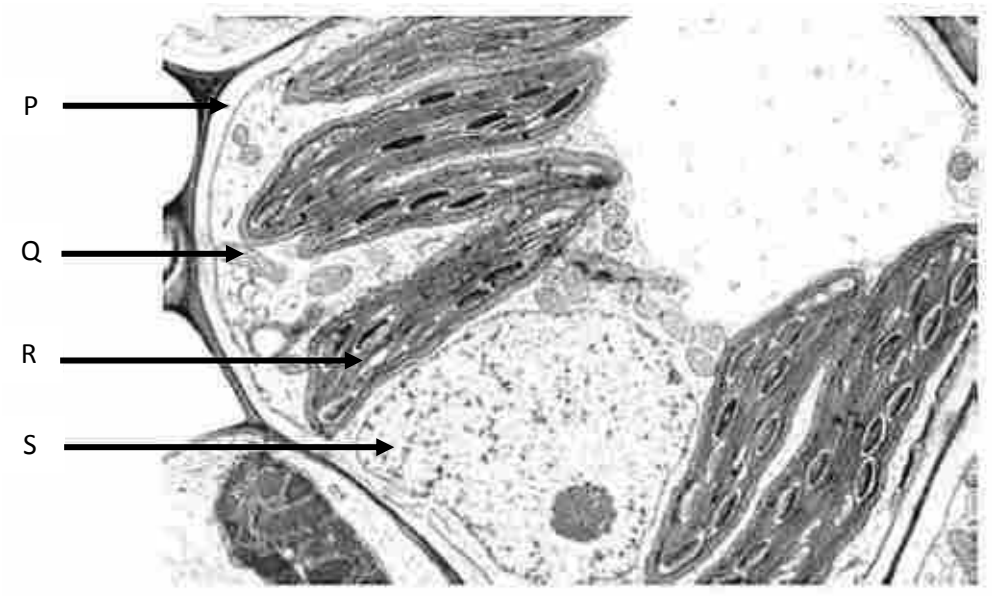
Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of 24 printed pages and **0** blank page.

[Turn over

1 The electron micrograph of a cell is shown below.



The electron micrograph of a cell is shown below.

Which of the following statements are true?

1 Structure P is found in all eukaryotic cells.
2 Organelle Q contains hydrolytic enzymes.
3 Organelle R contains starch.
4 Organelle S contains heterochromatin but not euchromatin.
5 Organelles Q, R and S contain RNA polymerase.

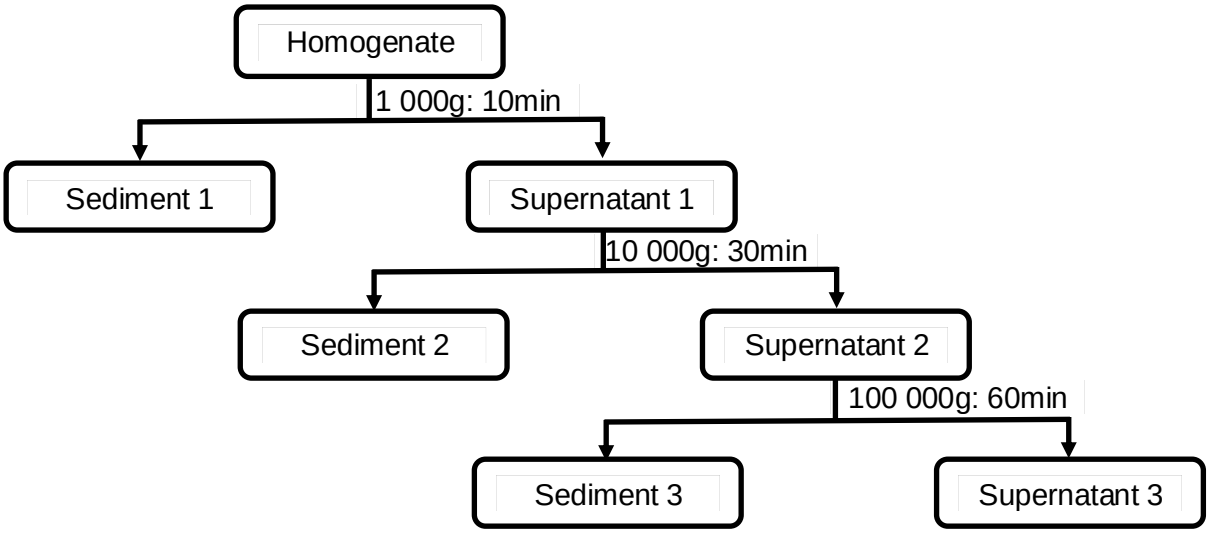
A 1 and 3 only

B 3 and 5 only

C 1, 3 and 5 only

D 2, 3 and 5 only

2 The figure below shows a centrifugation schematic of a rat liver cell.



Which of the following statements is incorrect?

A Sediment 1 contains organelles which are nucleic acid rich.

B Sediment 2 contains organelles with carbohydrate and nucleic acid.

C Supernatant 2 contains organelles that are the most dense amongst all other organelles.

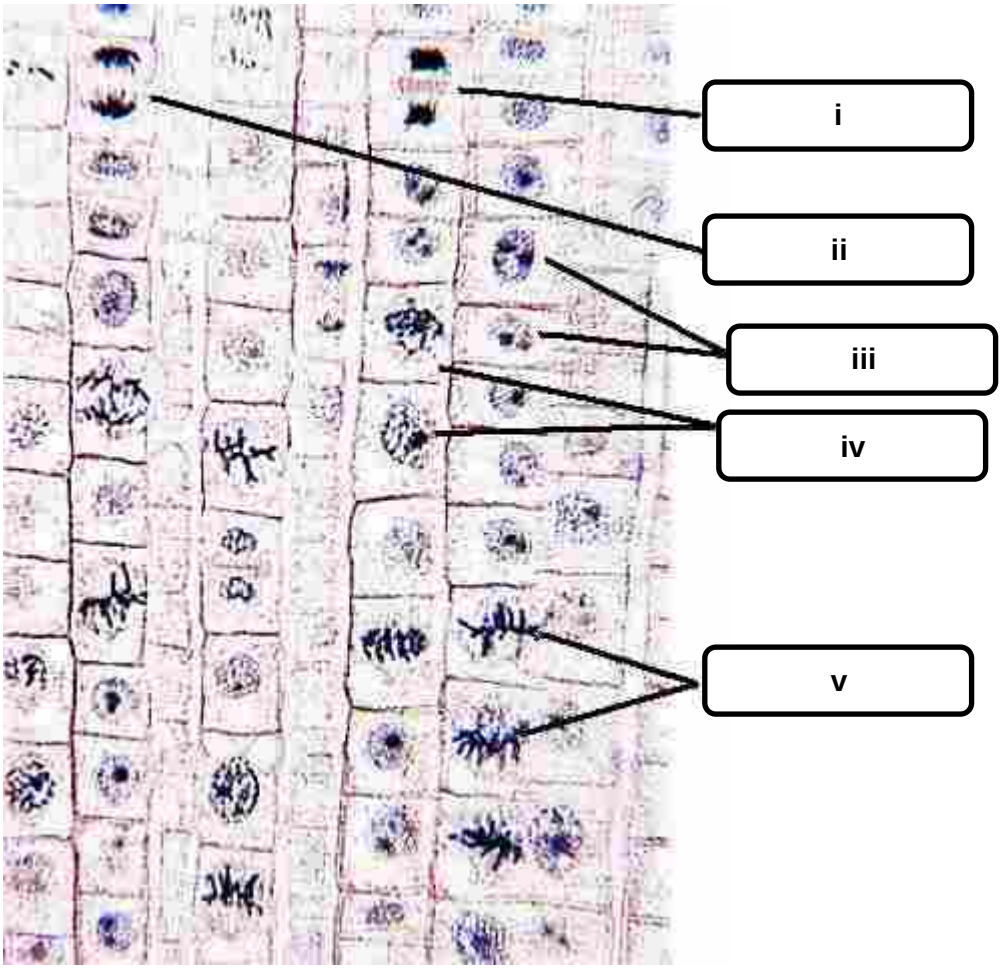
D Supernatant 3 contains organelles that are involved in protein synthesis.

3 Which features of collagen result in it having high tensile strength?

1 covalent bonds form between adjacent molecules
2 each three-stranded molecule is held together by intramolecular hydrogen bonds
3 every third amino acid in the polypeptide is small
4 the primary structure is held together by peptide bonds

A 1 and 2
B 1, 2 and 3
C 1, 3 and 4
D All of the above

4 The diagram below shows the longitudinal section of a root tip.



Which of the following correctly outlines the sequence in the stages of cell division in the root tip

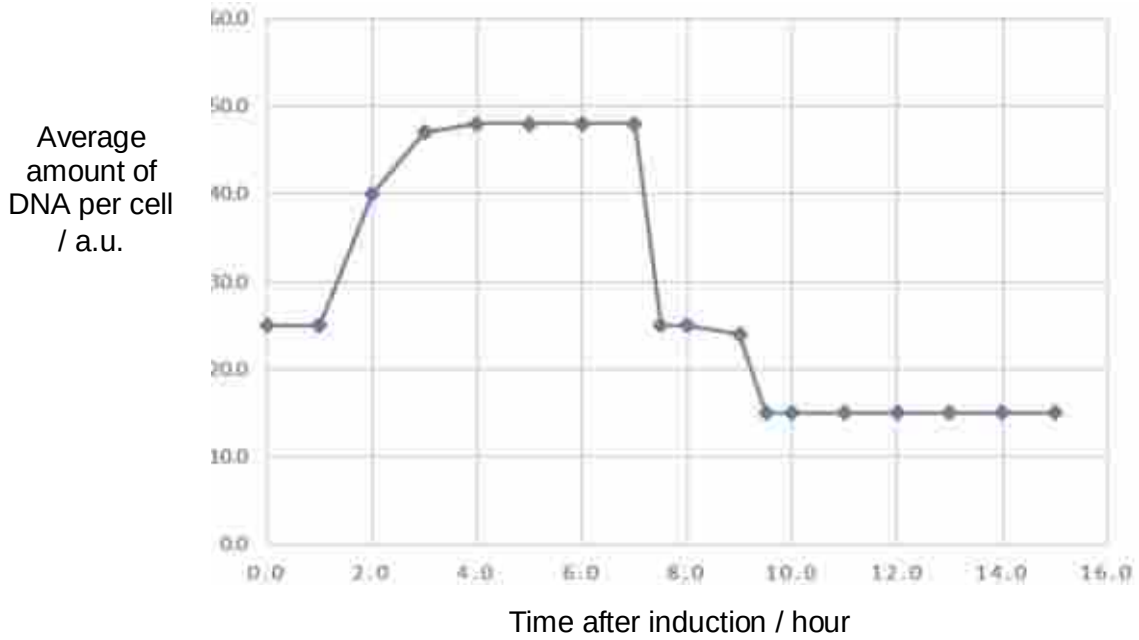
A iii > iv > v > ii > i

B iii > iv > i > v > ii

C iv > iii > v > ii > i

D iv > v > iii > i > ii

5 The figure below shows the average amount of DNA in a cell after induction.



Which of the following correctly accounts for the trends seen?

	Time Frame after induction / hours	Ploidy level at the end of timeframe	Stage in Cell growth
A	0.0 to 1.0	2n	G2
B	1.0 to 3.0	4n	S
C	3.0 to 8.0	n	G2-Meiosis I
D	8.0 to 9.0	2n	Meiosis II

6 Which of the following is not required for transcription?

A Ribonucleoside triphosphates

B RNA polymerase

C RNA primer

D TATA box

7 A mutation had occurred on the template DNA strand which resulted in the polypeptide having the following sequence:

Met – Ser – Cys – Gly – Glu – Gln – His – Phe – Arg – Gly – Stop

The mRNA codon table is shown below.

First Letter	Second Letter				Third Letter
	U	C	A	G	
U	phenylalanine	serine	tyrosine	cysteine	U
	phenylalanine	serine	tyrosine	cysteine	C
	leucine	serine	stop	stop	A
	leucine	serine	stop	tryptophan	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	threonine	asparagine	serine	U
	isoleucine	threonine	asparagine	serine	C
	isoleucine	threonine	lysine	arginine	A
	methionine	threonine	lysine	arginine	G
G	valine	alanine	aspartate	glycine	U
	valine	alanine	aspartate	glycine	C
	valine	alanine	glutamate	glycine	A
	valine	alanine	glutamate	glycine	G

If the normal non-mutated template DNA strand has the following sequence,

3’ – TAC – TCA – ACA – ACC – TCT – TGT – CGT – GAA – GGC – CCA – ACT – 5’

Identify the mutation(s) that had occurred.

A Single base pair substitution

B Deletion

C Addition

D Deletion and addition

8 The bacterium, Pneumococcus pneumoniae, forms two types of colonies whose cells are structurally different. Smooth (S) cells have thick outer capsules, but rough (R) cells lack this capsule. S cells cause the disease pneumonia.

In 1928, Frederick Griffith found that:

- when R cells were mixed with heat-killed S cells and the mixture injected into mice, some of the mice became infected and died.
- living S cells with capsules could be isolated from these dead mice.
- injection of heat-killed S cells alone or of living R cells alone did not cause disease in mice.

What can be concluded from these three observations to explain what happened when R cells were mixed with heat-killed S cells?

A A heritable genetic change occurred in the R cells.

B R and S cells conjugated when mixed.

C R cells were changed into S cells by transduction.

D R cells were transformed by DNA from heat-killed S cells.

9 Which statements about bacterial conjugation are correct?

1. The F-plasmid is transferred to the recipient bacterial cell via the rolling circle mechanism.

2. An F plasmid carries genes controlling the process of conjugation.

3. Only one DNA strands of an F plasmid in the donor cell break at the origin of replication.

4. An F plasmid DNA strand enters the recipient cell beginning at its 5' end.

5. After transfer of F plasmid DNA, complementary strands of F plasmid DNA are synthesised in both donor and recipient cells.

6. Exonucleases cleave the donor DNA to create a nick.

A 1, 2, 3 and 5 only

B 1, 2, 3, 5 and 6 only

C 1, 2, 3, 4 and 5 only

D All of the above

10 Which of the following is not part of the Trp operon?

A Structural genes (*trp A* to *E*)

B *trp R*

C *trp* operator

D *trp* promoter

11 Which statements about inducible and repressible systems are correct?

1. Repressible systems code for the synthesis of enzymes involved in anabolic pathways.
2. An inducible system is one where the operon is switched on under normal conditions.
3. An repressible system is one where the operon is switched off under normal conditions.
4. Inducible systems functions in catabolic pathways, digesting nutrients to simpler molecules.
5. An example of a inducible system is the Trp operon.

A All of the above

B 1 and 4 only

C 2, 3 and 4 only

D 1, 2, 3 and 4 only

12 Viruses are considered obligate parasites because

A they reproduce using host cell DNA polymerase.

B they lack RNA-dependent RNA polymerases and ribosomes hence must depend on the host cell to carry out gene expression.

C they are unable to generate or store energy in the form of ATP and thus derive their energy for all metabolic functions from the host cell.

D they make use of the host cell's inorganic molecules such as amino acids, nucleotide and tRNA.

13 Which of the following proposed methods would be most viable in treating influenza?

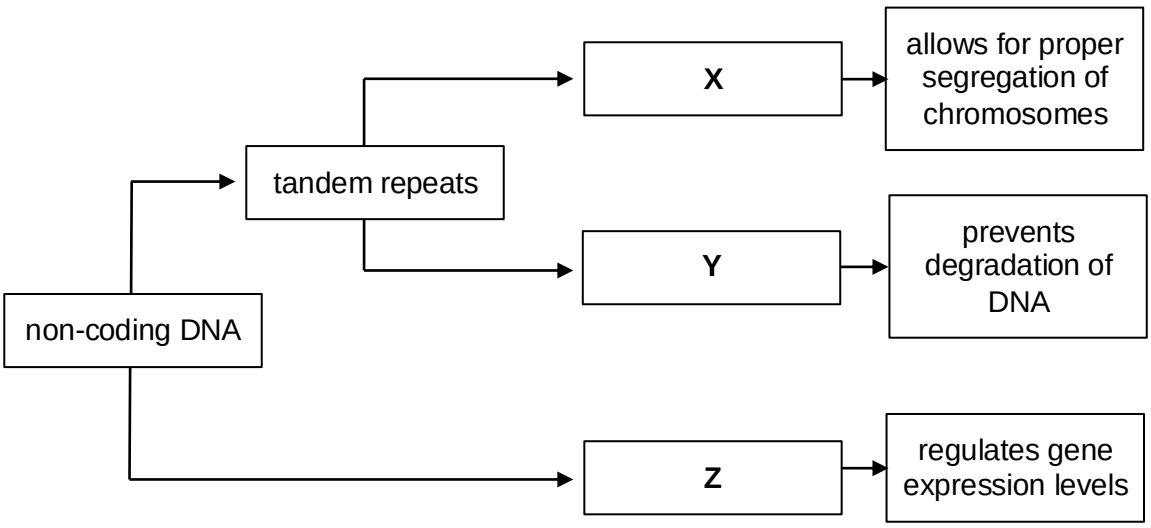
A Introducing a ribosome inhibitor so that translation of viral proteins cannot take place.

B Introducing a ribonucleotide analog that would cause chain termination upon addition to an RNA polymer.

C Inhibit the attachment and thereby entry of the virus into its host cell by developing inhibitors that bind to the sialic acid on host cells.

D Inhibit the attachment and thereby entry of the virus into its host cell by developing antibodies that bind to the haemagglutinin on the viruses.

14 The flowchart shows the classification of several regions of non-coding eukaryotic DNA, **X**, **Y** and **Z**.



Which statement(s) correctly describes **X**, **Y** and **Z**?

1 Regions **X** and **Y** are made up of transcriptionally active tandem repeats.

2 Regions **X** and **Y** are always associated with proteins, but DNA at region **Z** is only associated with proteins during gene expression.

3 Region **Z** may involve DNA bending but region **Y** shortens during DNA replication.

4 Regions **X**, **Y** and **Z** are conserved throughout the life of the organism.

A 2 only

B 3 only

C 1 and 4 only

D 2 and 3 only

15 Which one of the following statements correctly describes the role of enhancers.

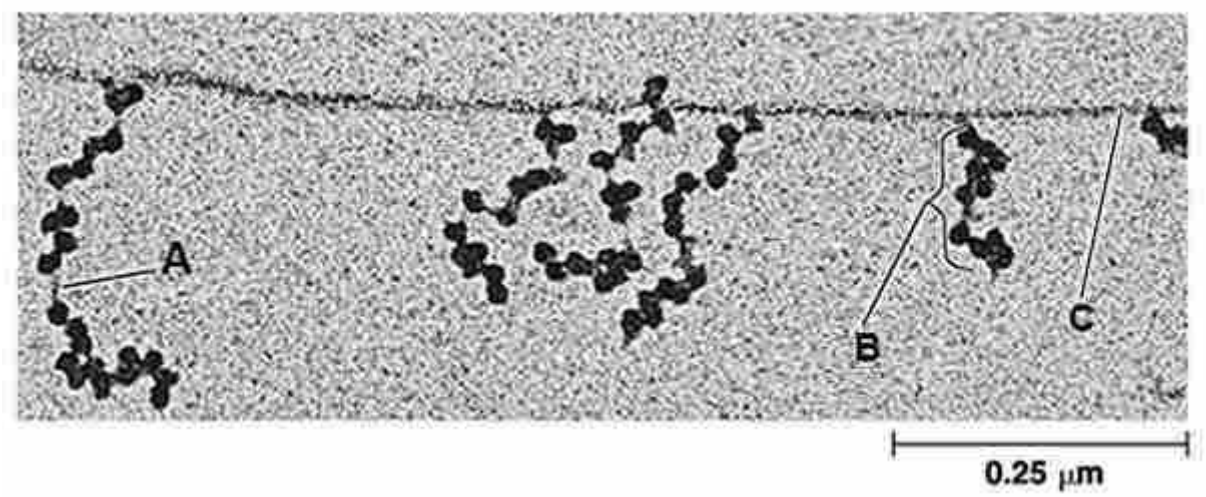
A DNA sequences that are bound by general transcription factors.

B DNA sequences that directly induces the bending of DNA.

C DNA sequences that are involved in stabilisation of the transcriptional initiation complex.

D DNA sequences are proximal control elements that are non-coding.

16 The electron micrograph below shows several labelled structures present in a mitochondrion.



Which of the statements below correctly describe the labelled structures?

1 The structure labelled **A** is the polypeptide chain.

2 The structures labelled **B** are polyribosomes which consist of many 70S ribosomes.

3 The structure labelled **C** is the 3' end of template DNA strand.

4 The structure labelled **C** is the 5' end of the mRNA strand.

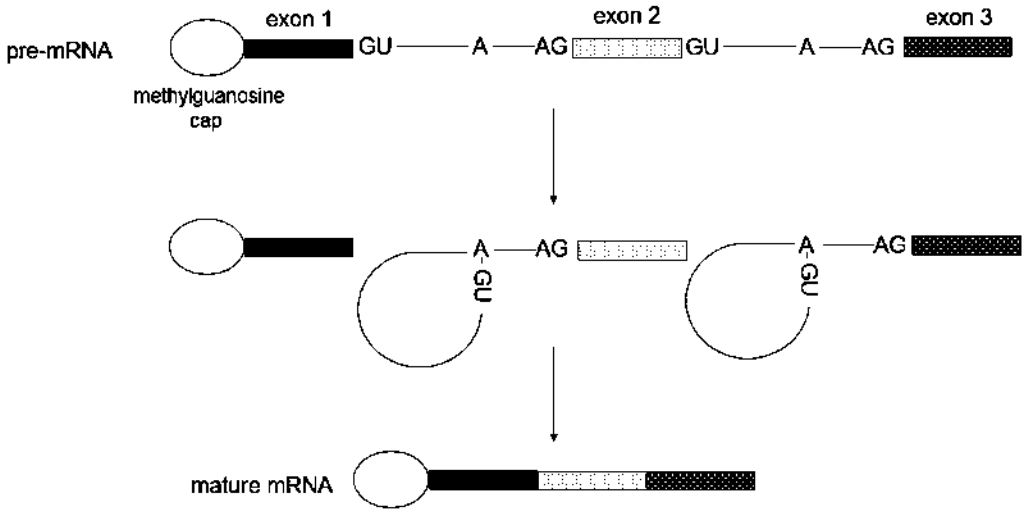
A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 1, 2 and 4 only

17 The diagram shows part of an mRNA undergoing the process of splicing.



With reference to the diagram above, which statement(s) is / are related to the process shown?

1 RNA splicing occurs after the release of pre-mRNA from RNA polymerase.

2 Spliceosome binds to the 3' splice site GU and the 5' splice site AG on the pre-mRNA.

3 A RNA loop is formed on the pre-mRNA where the intron is excised.

4 There can be more than one type of product formed from a single pre-mRNA.

A 1 and 2

B 3 and 4

C 2, 3 and 4

D 1, 3 and 4

18 Gene expression is similar in prokaryotes and eukaryotes in that both:

A have post-transcriptional modifications.

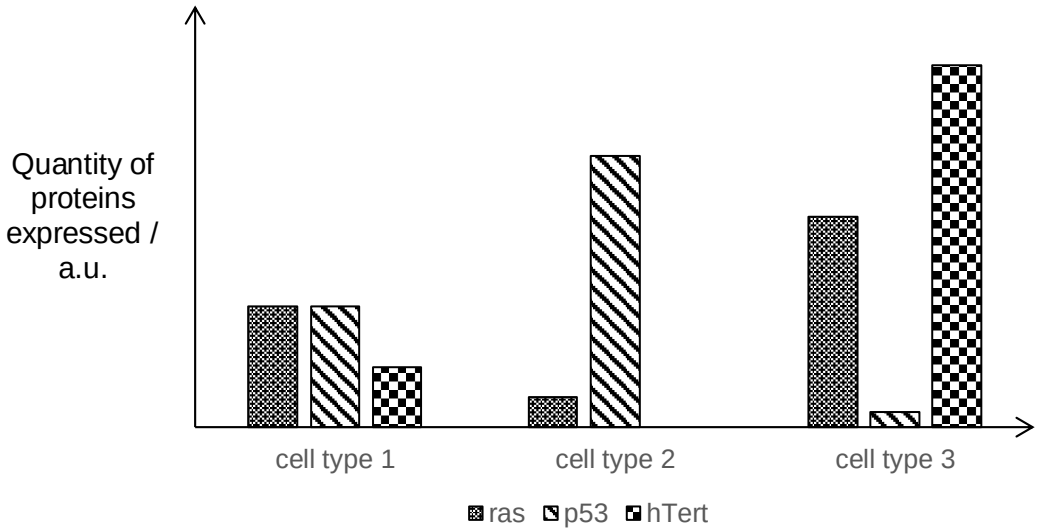
B require helicase to separate the DNA so that transcription can take place.

C have spliceosomes to intron splicing.

D involve attachment of proteins to DNA adjacent to the gene being transcribed.

19 Cancer critical genes include ras, p53 and hTert. hTert codes for human telomerase.

The levels of proteins expressed by each gene in three different cell types of a patient are shown in the graph. Only one cell type was taken from a malignant tumour.



Which statement is true?

A Cell type 1 is not from the malignant tumour since balanced expression of *ras* and *p53* halts cell cycle progression.

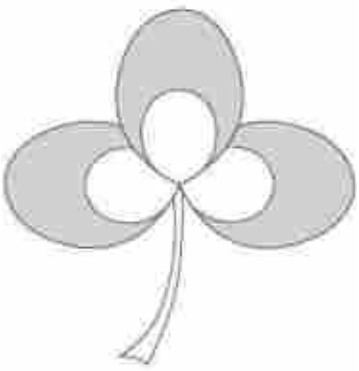
B Activation of telomerase will result in cell type 2 gaining immortality and becoming cancerous.

C Cell type 3 is obtained from the malignant tumour as the cells will divide uncontrollably.

D Gain-of-function mutation of *hTert* in cell type 1 will result in malignant tumour formation.

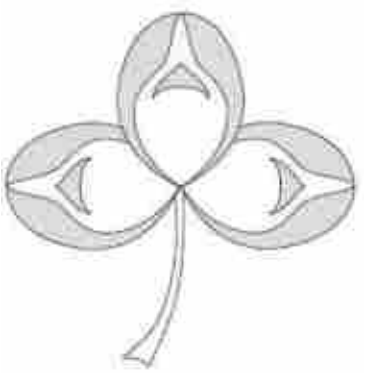
20 The white clover, *Trifolium repens*, is one of the plants found growing as a weed in many lawns. Leaves of the white clover are divided into three leaflets, which often have characteristic white patterns visible on their surface. The two basic forms of the pattern are a chevron and patch. The diagram below shows these two patterns.

chevron pattern



patch pattern

If a pure-breeding clover plant with the chevron pattern is crossed with a pure-breeding plant with the patch pattern, the offspring have leaflets with a mixed chevron and patch pattern, as shown in the diagram below.



mixed pattern

Which row correctly describes the inheritance of leaflet patterns in white clover?

	number of alleles that determines the white patterns in the leaflets	mode of inheritance
A	2	codominance
B	2	epistasis
C	> 2	codominance
D	> 2	epistasis

21 In a cross involving polygenic inheritance, 3 genes control the height of a tulip plant. The shortest and tallest plants are 12 cm and 24 cm respectively.

Assuming all other environmental factors are kept constant, what is the height of the F1 offspring obtained from a cross between a homozygous 12 cm and a homozygous 24 cm plant?

A 6 cm

B 12 cm

C 14 cm

D 18 cm

22 A plant with orange-spotted flowers was grown in a greenhouse from a seed collected in the wild. The plant was self-pollinated and gave rise to the following progeny: 129 plants with orange-spotted flowers, 22 plants with yellow-spotted flowers, 26 plants with solid orange flowers, and 15 plants with solid yellow flowers.

The formula for the chi-squared (χ^2) test is given as follows:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

degrees of freedom	probability			
	0.10	0.05	0.01	0.001
1	2.71	3.84	6.64	10.83
2	4.69	5.99	9.21	13.82
3	6.25	7.82	11.35	16.27
4	7.78	9.49	13.28	18.47

Which statement is true about the inheritance of flower colour and flower pattern at 99% confidence level?

A Since p < 0.05, the difference between the observed and expected results is not significant. The inheritance of flower colour and flower pattern is following Mendel's law of independent assortment.

B Since p > 0.05, the difference between the observed and expected results is not significant. The inheritance of flower colour and flower pattern is not following Mendel's law of independent assortment.

C Since p > 0.01, the difference between the observed and expected results is not significant. The inheritance of flower colour and flower pattern is following Mendel's law of independent assortment.

D Since p < 0.01, the difference between the observed and expected results is significant. The inheritance of flower colour and flower pattern is not following Mendel's law of independent assortment.

23 Which of the following statements about transport in the cell is incorrect?

A Active transport is the movement of substances across the cell membrane against a concentration gradient.
B Diffusion is the mechanism by which movement of hydrophobic particles through a cell membrane down a concentration gradient.
C Receptor mediated endocytosis involves the binding of the substance to specific receptors and their subsequent passive entry into the cell.
D Bulk transport is a process which requires energy.

24 Which of the following statements is false about cell signalling involving tyrosine kinase receptors.

A Ligand molecules are mostly hydrophilic in nature.

B Different activated relay proteins serve to directly amplify the effects of the ligand.

C Dimerisation serves to initiate auto-phosphorylation.

D Receptors are transmembrane proteins that are anchored within the cell surface membrane.

25 Phosphorylation cascade is an important component in cell signaling, which of the following statements is incorrect about this cell signaling mechanism.

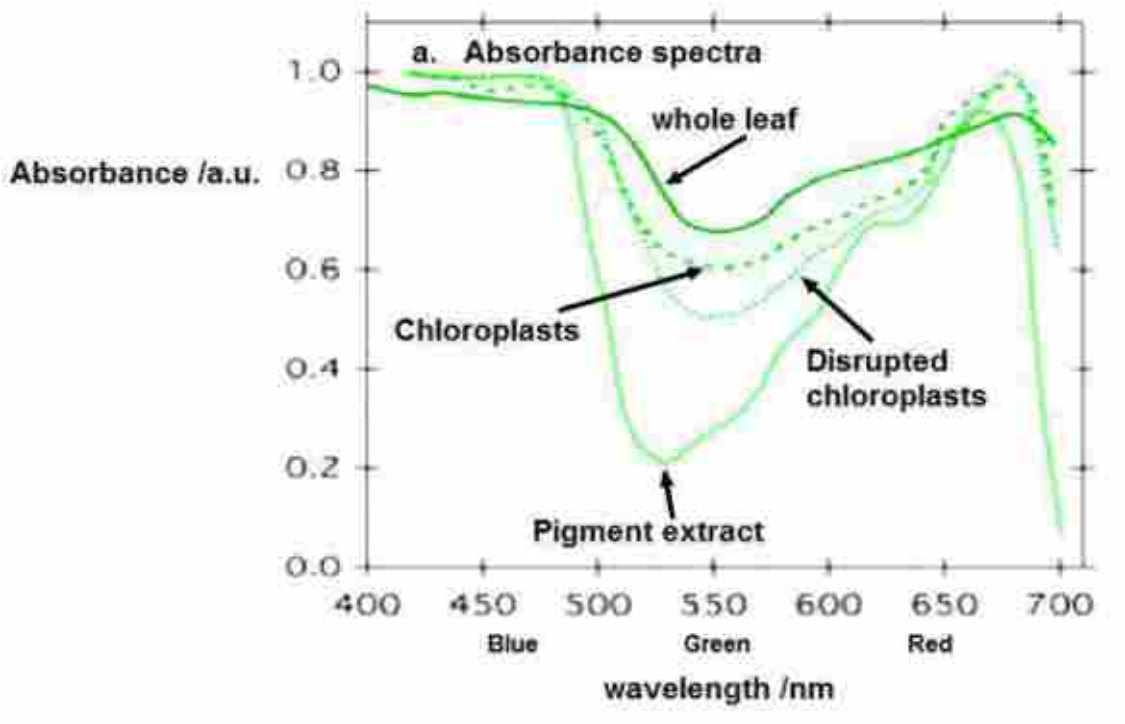
A The signal is passed via a series of phosphorylation involving protein kinases.

B The mechanism allows for greater control and speed in transmission of the signal.

C Phosphorylation cascade mechanism is initiated by a second messenger.

D Inactivation of the signal mechanism involves phosphatases which deactivate protein kinases.

26 The figure shows the absorptance spectra of various components of a leaf.



What can be inferred from the data shown?

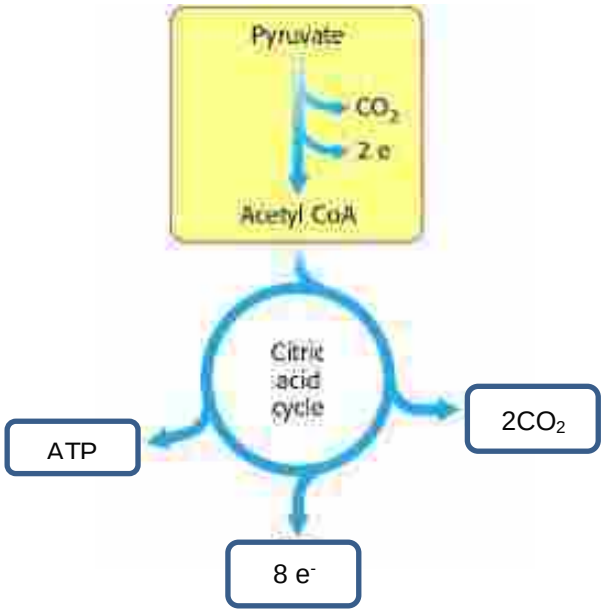
A Absorptance is highest in 650-700 nm in all leaf components due to light harvesting complexes.

B Whole leaf samples experience the least absorptance at 550 nm due to all green light being reflected.

C Disrupted chloroplast samples have higher absorptance compared to chloroplasts due to a larger surface area for light capture.

D Pigment extracts are the main agents of light harvesting due to the presence of carotenoids.

27 The figure below shows the part of the process of aerobic respiration.



Which of the following statements is true of the significance of acetyl CoA?

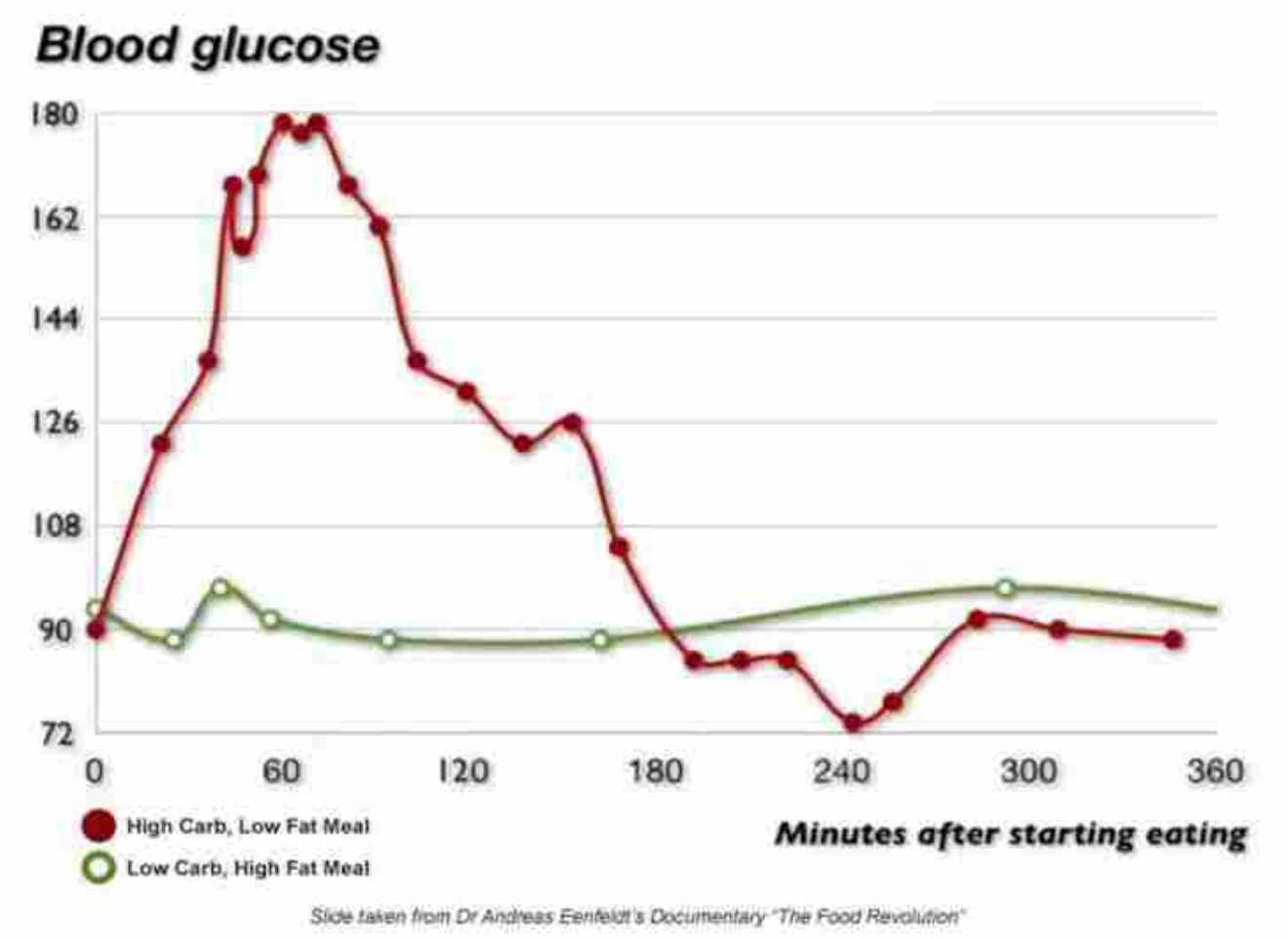
A Acetyl CoA is the product of the link reaction and is subsequently brought into the mitochondria to enter the Krebs cycle

B Acetyl CoA is the entry point into the metabolic pathway of both carbohydrates and fats.

C Acetyl CoA is an energised molecule combined with Oxaloacetate, to yield 4 molecules of citric acid per molecule of Glucose.

D Electrons released in the formation of Acetyl CoA are used in the production of NADPH.

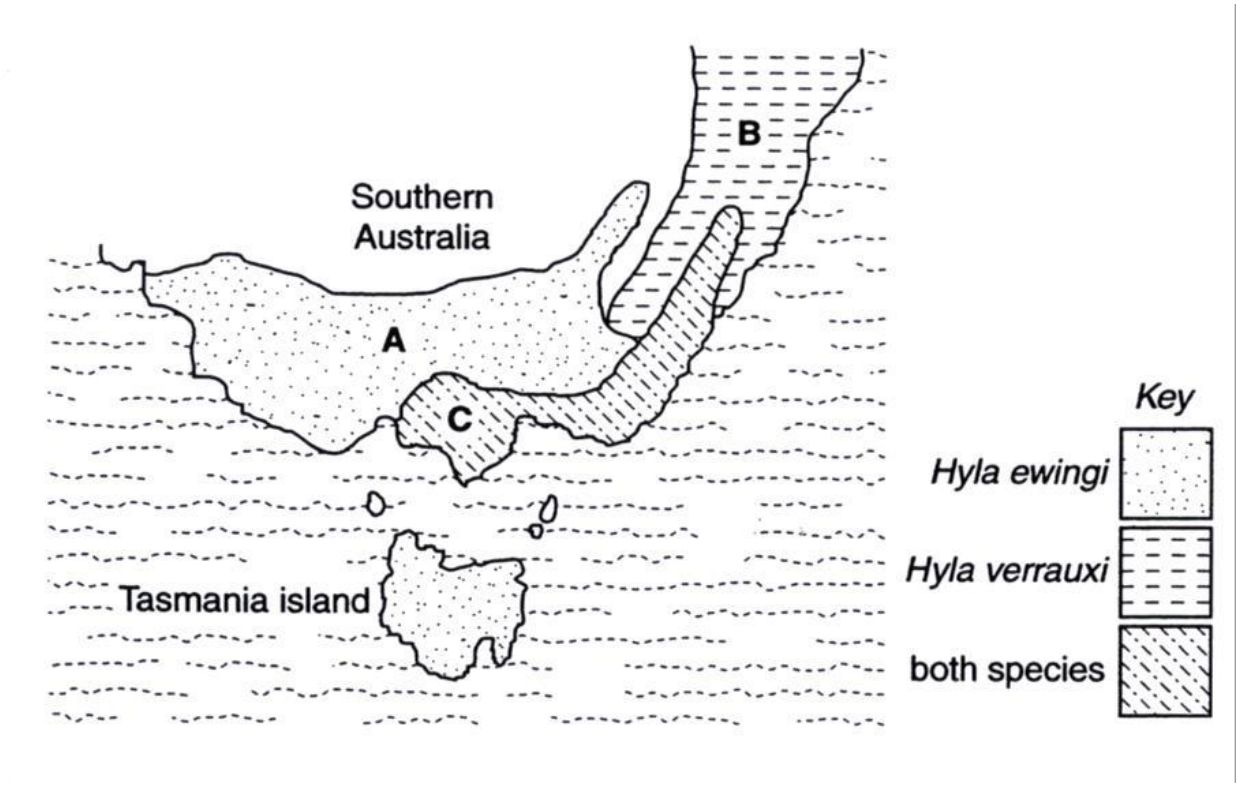
28 The figure below represents the blood glucose levels of a normal person after a meal.



At which time do the beta cells of the islets of Langerhans detect and effect the secretion of insulin to manage blood glucose levels?

	Detection by beta cells	Secretion of insulin
A	0 to 5 minutes	61 to 180 minutes
B	0 to 5 minutes	0 to 10 minutes
C	180 to 200 minutes	240 to 300 minutes
D	180 to 200 minutes	180 to 200 minutes

29 Two closely related species of frog, *Hyla ewingi* and *Hyla verrauxi* live in South Australia. The figure below shows the distribution of the tree frogs in Southern Australia.



Hyla ewingi and *Hyla verrauxi* are two closely related species of tree frogs from southern Australia. Research from breeding studies and DNA sequence data has shown that they have weak genetic incompatibility.

Male frogs attract females of the same species for mating by their pulsing call. The pulse rate of the male calls of the two species is almost identical. However, when both species coexist within the same region, the calls of *H. ewingi* are quite different than those of *H. verrauxi*.

Which of the following can be correctly inferred from the data given?

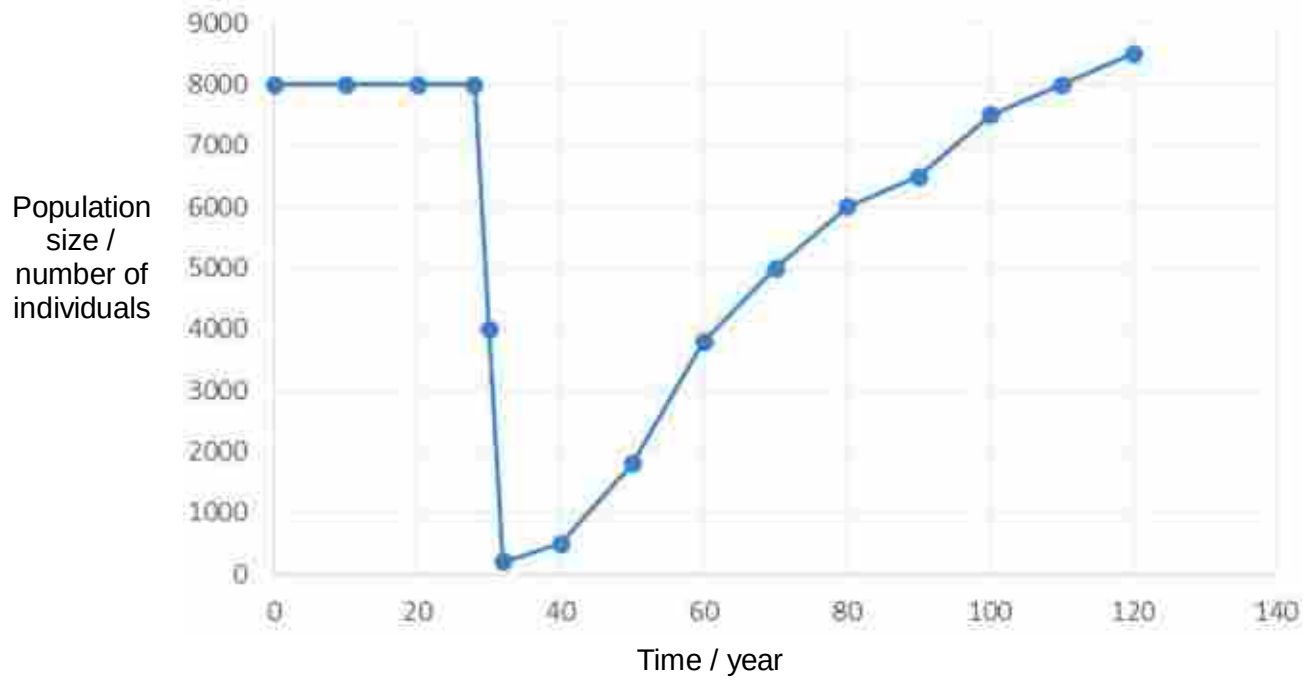
A Complete speciation has taken place between the two groups of frogs.

B Allopatric speciation was probably the evolutionary mechanism at work.

C Convergent evolution has seen the frogs in Tasmania similar to those in region A in Australia.

D Sympatric speciation was probably the evolutionary mechanism at work.

30 The figure shows the population of a group of organisms in a fixed region over time.



The following statements are derived from the data shown.

i. Bottleneck event has taken place Year 30 to 35
ii. Genetic variation has been fully restored by Year 110
iii. Allele frequency steadily increases due to genetic drift
iv. Founder effect has taken place from Year 28 onward

Which statements can be concluded as true?

A i only

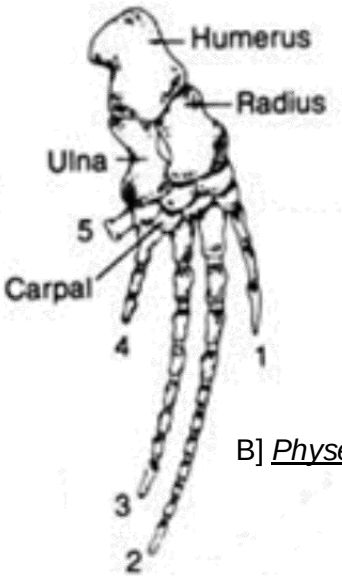
B ii only

C i, ii & iii only

D i, iii & iv only

31 The following figure shows the anatomy of the left front appendages of the two vertebrates.

A] *Javan surili*



B] *Physeter macrocephalus*

Which one of the following correctly describes the type of structures seen and their evolutionary connection?

	Type of structures	Ancestry	Type of evolution
A	Homologous	Different ancestor	Convergent Evolution
B	Homologous	Common ancestor	Divergent Evolution
C	Analogous	Different ancestor	Convergent Evolution
D	Analogous	Common ancestor	Divergent Evolution

32 All the characteristics below support the use of plasmids in cloning and expression in bacteria **except**

A More than one plasmid can be taken up by each bacterium.

B Plasmids are able to control their own replication through their origin of replication

C Plasmids contain a wide range of restriction sites for various restriction enzymes.

D Linker DNA / artificial sticky ends are not required to express eukaryotic genes of interest derived from cDNA.

33 *lacZ* gene is a genetic marker found in the plasmid which can be used in genetic engineering.

What is the function of *lacZ* gene in a cloning vector?

A Express *lac* repressor

B Distinguish between introns and exons

C Break down lactose to galactose and glucose

D Screen for cells with the recombinant plasmid

34 Which correctly describe the difference between genomic and cDNA libraries and the corresponding reason for the difference?

	Difference	Reason
A	Genomic library may contain distant control elements and centromere while cDNA library contains only expressed genes.	Due to mRNA splicing which removes exons and splice introns together.
B	Genomic library is larger in size than cDNA library.	Due to genomic library containing total DNA extract from a cell while cDNA library containing the total mRNA extract from a particular cell type.
C	Genomic library from an individual is always the same, while cDNA library may differ, depending on the cell type from which it is constructed.	Due to differential gene expression in the different cell types.
D	Genes from genomic library are more suited than those from cDNA library for expression in bacterial cells.	Due to the action of restriction endonucleases in the construction of genomic library and that of reverse transcriptase in the construction of cDNA library.

35 Genes P, Q, R and S occur on the same chromosome. The table shows the recombination frequencies.

	recombination frequency (%)
between P and Q	46
between P and R	8
between R and Q	54
between Q and S	13
between R and S	41

Which of the following represents the correct order of genes on the chromosome?

A P – Q – R – S

B P – R – S – Q

C R – P – S – Q

D R – S – Q – P .

36 The Human Genome Project facilitated genetic testing of individuals and renewed emphasis on ethical and social implications.

Which of the following statements correctly describe unintended consequences of genetic testing?

1 discovery of wrongly attributed paternity

2 unauthorised publication of genetic test results

3 psychological stress after receiving genetic test results

4 social stigmatisation of genetically predisposed individuals

A 1 and 2

B 3 and 4

C 1, 2 and 3

D All of the above .

37 Which of the following shows the correct developmental potency of the following stem cells.

	Haematopoietic stem cells	Zygotic stem cells	Embryonic stem cells	Neural stem cells
A	Multipotent	Pluripotent	Totipotent	Unipotent
B	Multipotent	Totipotent	Pluripotent	Unipotent
C	Multipotent	Pluripotent	Totipotent	Multipotent
D	Multipotent	Totipotent	Pluripotent	Multipotent

.

38 Which problem is associated with gene therapy?

A Target cells do not have suitable receptors on their cell surface membranes.

B The nuclear pores do not allow the vector into the nucleus.

C The viral vector cannot trigger cyclic AMP to activate appropriate genes.

D Viral vectors insert therapeutic genes at random points in the genome. .

39 Some plant tissue culture techniques involve the production of protoplasts using leaf tissue. Preparation of protoplasts involves incubation in a solution that contains enzymes such as cellulase and pectinase.

Which statement about protoplast is not correct?

A Protoplasts are pluripotent and regenerate into whole plants when provided with the correct growth factors.

B Protoplasts are more susceptible to microbial contamination.

C Protoplasts are used for the production of genetically engineered plants as they take up naked DNA easily.

D Protoplasts need to be maintained in the solution of the same water potential to prevent lysis. .

40 Which statement supports the view that genetically engineered animals could help to solve the demand for food in the world?

A Transgenic pigs and sheep are produced to express higher levels of growth hormone.

B Biomedical applications of genetically engineered animals have also become routine within the pharmaceutical industry, for drug discovery, drug development and risk assessment.

C Cloning of either extinct or endangered species such as thylacine and woolly mammoth helps to retain genetic diversity in small populations.

D By inserting genes from sea anemone and jellyfish, zebrafish have been genetically engineered to express fluorescent proteins.

END OF PAPER

NAME: _____ CLASS: _____ INDEX: _____

CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
Higher 2

Answers

BIOLOGY

9648/01

Paper 1 Multiple Choice

29th August 2016
1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write and/or shade your name, NRIC / FIN number and HT group on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** questions on this paper. Answer **all** questions. For each question, there are four possible answers, **A, B, C** and **D**.
Choose the **one** you consider correct and record your choice in **soft 2B pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

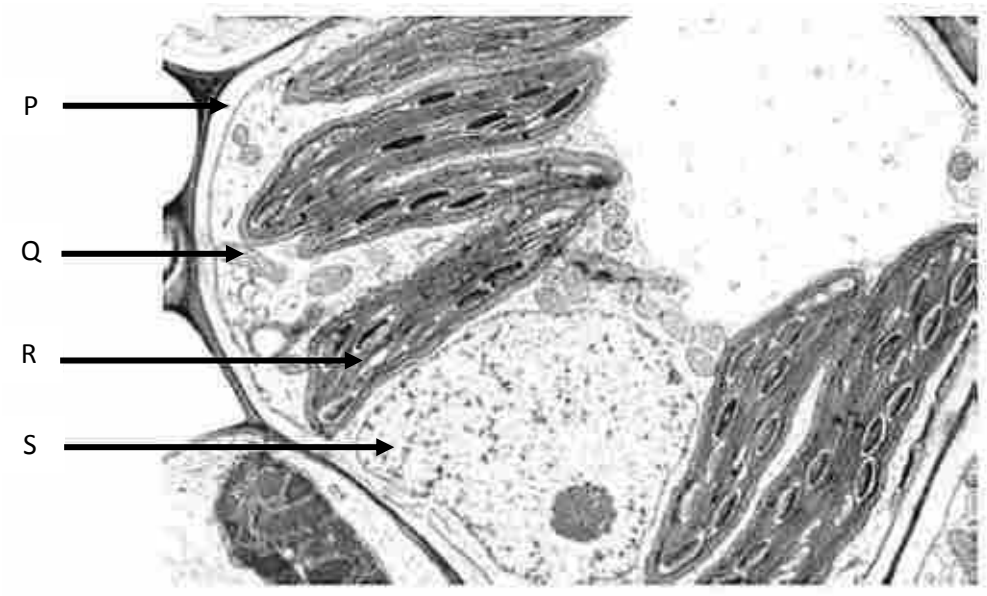
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

1	B	2	C	3	C	4	A	5	C
6	C	7	D	8	A	9	C	10	B
11	B	12	C	13	D	14	B	15	C
16	C	17	D	18	D	19	C	20	A
21	D	22	C	23	C	24	B	25	B
26	D	27	B	28	B	29	D	30	A
31	B	32	D	33	D	34	C	35	C
36	D	37	D	38	D	39	A	40	A

This document consists of 27 printed pages and **0** blank page.

[Turn over

1 The electron micrograph of a cell is shown below.



The electron micrograph of a cell is shown below.

Which of the following statements are true?

1 Structure P is found in all eukaryotic cells.
2 Organelle Q contains hydrolytic enzymes.
3 Organelle R contains starch.
4 Organelle S contains heterochromatin but not euchromatin.
5 Organelles Q, R and S contain RNA polymerase.

A 1 and 3 only

B 3 and 5 only

C 1, 3 and 5 only

D 2, 3 and 5 only

Ans: B

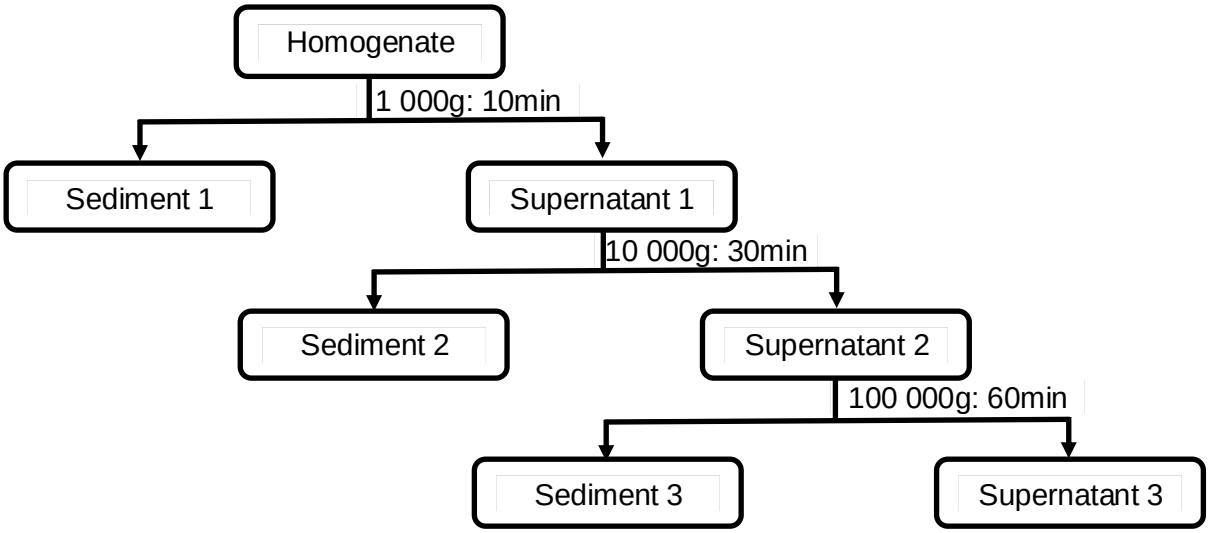
1.1] Cell structure and Organisation – EM

SC: P- Cell Wall Q-Mitochondria R- Chloroplast S- Nucleus

OR:
1 Structure P is found in all eukaryotic cells. × Only Plant Cells
2 Organelle Q contains hydrolytic enzymes. × Q is not a lysosome
3 Organelle R contains starch. ✓
4 Organelle S contains heterochromatin but not euchromatin. × Contains both
5 Organelles Q, R and S contain RNA polymerase. ✓

[L1] (ACJC H1 PRELIM 2015 P1.Q1)

2 The figure below shows a centrifugation schematic of a rat liver cell.



Which of the following statements is incorrect?

A Sediment 1 contains organelles which are nucleic acid rich.

B Sediment 2 contains organelles with carbohydrate and nucleic acid.

C Supernatant 2 contains organelles that are the most dense amongst all other organelles.

D Supernatant 3 contains organelles that are involved in protein synthesis.

SC: Sed1: Nucleus Sed2: Mitochondria and Chloroplast Sed3: ER, Golgi

OR:
A Sediment 1 contains organelles which are nucleic acid rich — True

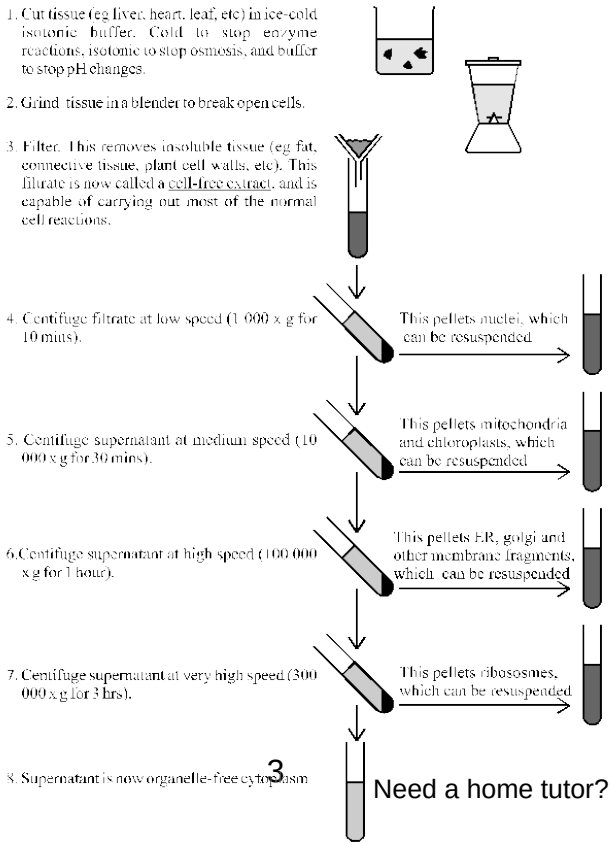
B Sediment 2 contains organelles which produce carbohydrate and nucleic acid — True
ATP is a nucleic acid

C Supernatant 2 contains organelles that are the most dense amongst all other organelles. — False
nuclei are in Sediment 1

D Supernatant 3 contains organelles that are involved in protein synthesis - True-
ribosomes

Ans: C

[L2] Novel



3 Which features of collagen result in it having high tensile strength?

1 covalent bonds form between adjacent molecules
2 each three-stranded molecule is held together by intramolecular hydrogen bonds
3 every third amino acid in the polypeptide is small
4 the primary structure is held together by peptide bonds

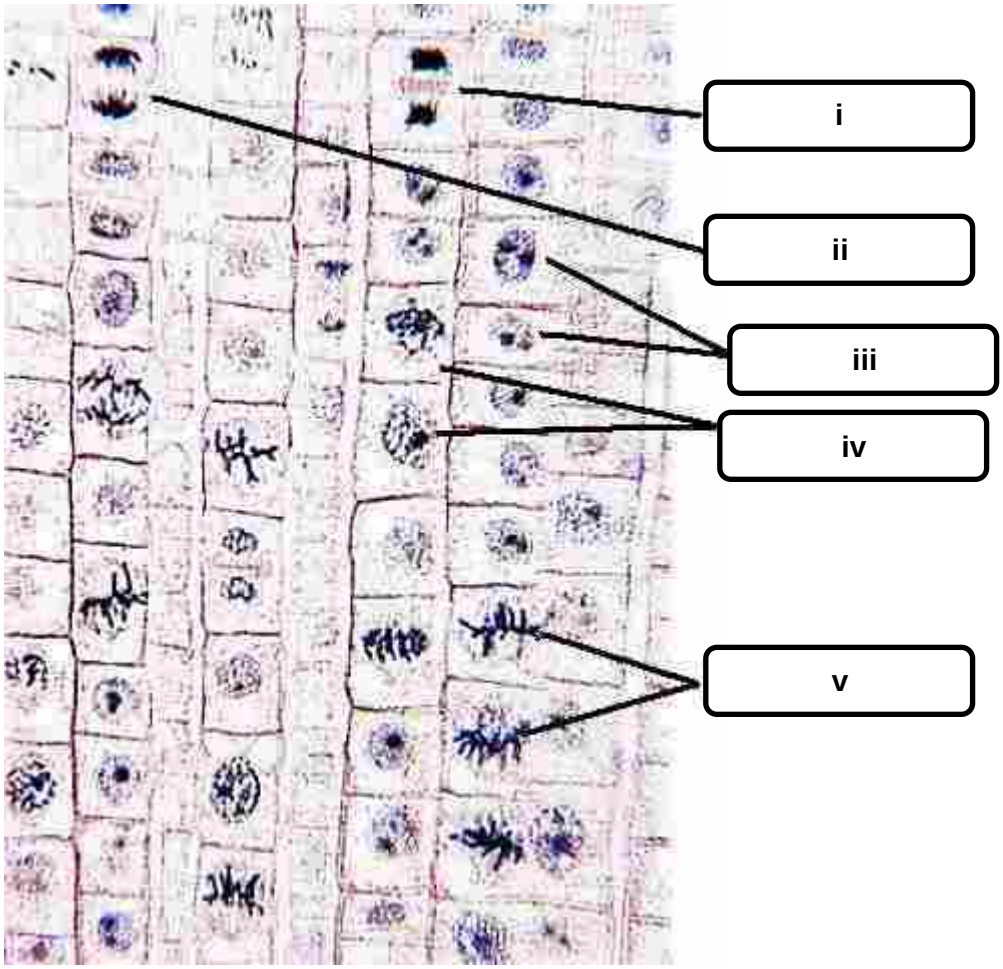
A 1 and 2
B 1, 2 and 3
C 1, 3 and 4
D All of the above

SC: features / collagen / high tensile strength
OR: Option 1 ✓ parallel strands bring cyctine groups together forming Disulphide cross bridges
Option 2 × No hydrogen bonds across molecules
(where present will more likely be intramolecular)
Option 3✓ X,Y,Glycine the third being small allows a tight coil in each fibril
Option 4✓ Primary structure is a polypeptide chain comprising of peptide bonds.

Ans: **C**

[L2] (2015 IJC Prelim P1Q5)

4 The diagram below shows the longitudinal section of a root tip.



Which of the following correctly outlines the sequence in the stages of cell division in the root tip

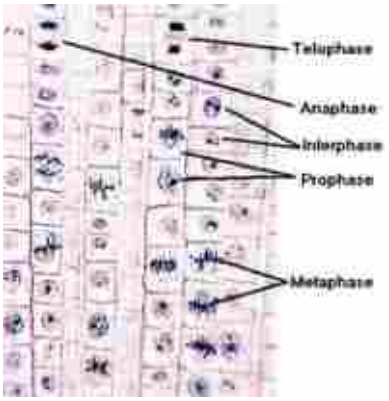
A iii > iv > v > ii > i

B iii > iv > i > v > ii

C iv > iii > v > ii > i

D iv > v > iii > i > ii

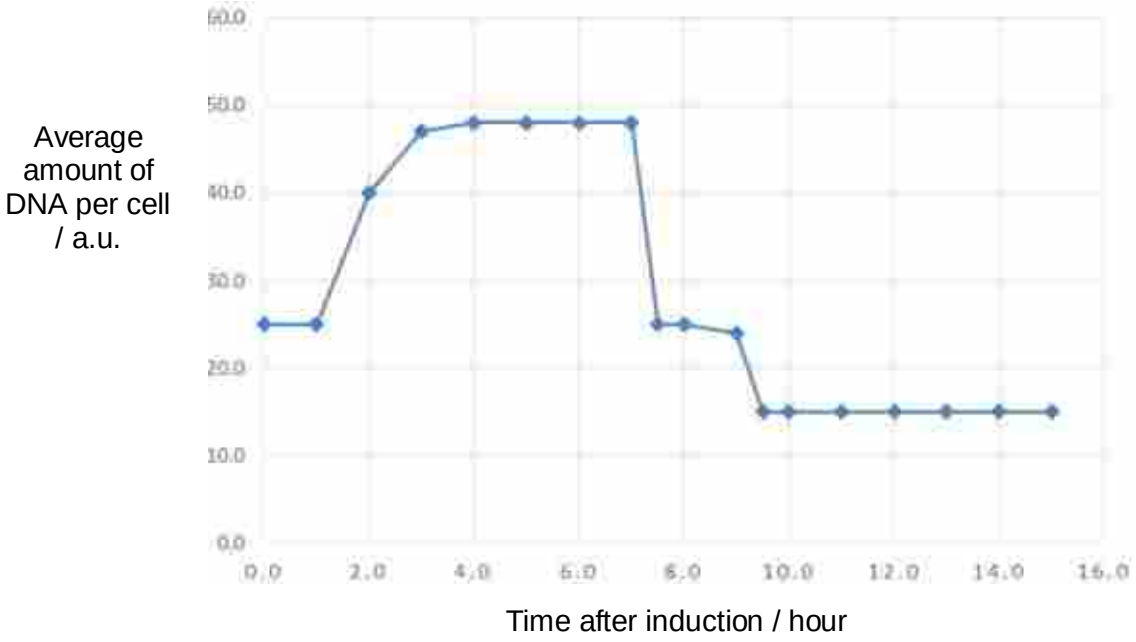
SC: correctly outlines seq in cell division
OR: Interphase (iii) >> Prophase (iv) >> Metaphase (v) >> Anaphase (ii) >> Telomerase (i)



Ans: **A**

[L2] Novel

5 The figure below shows the average amount of DNA in a cell after induction.



Which of the following correctly accounts for the trends seen?

	Time Frame after induction / hours	Ploidy level at the end of timeframe	Stage in Cell growth
A	0.0 to 1.0	2n	G2
B	1.0 to 3.0	4n	S
C	3.0 to 8.0	n	G2-Meiosis I
D	8.0 to 9.0	2n	Meiosis II

SC: cell after induction / correctly accounts
OR: A ✗ Ploidy 2n ✓ stage is G1 not G2
B ✗ Ploidy 4n ✗ stage S ✓ slow rise in DNA as replication increases DNA 2 fold
C✓ Ploidy n✓ since after cytokinesis time 7 hrs Stage G2-MI✓

D✗ Ploidy 2n✗ sice it is after cytokinesis time 7 hrs Stage MII. ✓

Ans: C
[L2] Novel

6 Which of the following is not required for transcription?

A Ribonucleoside triphosphates

B RNA polymerase

C RNA primer

D TATA box

SC: Need to know which factors play a role in transcription and which does not.
OR:
- ✓ A: Ribonucleoside triphosphates are the incoming monomers of transcription.
- ✓ B: RNA polymerase catalyses the process of transcription.
- ✗ C: RNA primer is not required. It is required only for DNA replication.
- ✓ D: TATA box is where RNA polymerase and general transcription factors will bind to during initiation of transcription.

Ans: C

[L1] Novel

7 A mutation had occurred on the template DNA strand which resulted in the polypeptide having the following sequence:

Met – Ser – Cys – Gly – Glu – Gln – His – Phe – Arg – Gly – Stop

The mRNA codon table is shown below.

First Letter	Second Letter				Third Letter
	U	C	A	G	
U	phenylalanine	serine	tyrosine	cysteine	U
	phenylalanine	serine	tyrosine	cysteine	C
	leucine	serine	stop	stop	A
	leucine	serine	stop	tryptophan	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	threonine	asparagine	serine	U
	isoleucine	threonine	asparagine	serine	C
	isoleucine	threonine	lysine	arginine	A
	methionine	threonine	lysine	arginine	G
G	valine	alanine	aspartate	glycine	U
	valine	alanine	aspartate	glycine	C
	valine	alanine	glutamate	glycine	A
	valine	alanine	glutamate	glycine	G

If the normal non-mutated template DNA strand has the following sequence,

3' – TAC – TCA – ACA – ACC – TCT – TGT – CGT – GAA – GGC – CCA – ACT – 5'

Identify the mutation(s) that had occurred.

A Single base pair substitution

B Deletion

C Addition

D Deletion and addition

SC:
Template: 3' –TAC–TCA–ACA–ACC–TCT–TGT–CGT–GAA–GGC–CCA--ACT–5'
mRNA: 5'- AUG--AGU-UGU-UGG-AGA-ACA-GCA-CUU-CCG-GGU -UGA-3'
Protein: Met – Ser – Cys -Trp-Arg-Thr-Ala-Leu-Pro-Gly-Stop
Mutated protein: Met– Ser– Cys– Gly– Glu– Gln– His– Phe– Arg– Gly– Stop

OR:
- A: If it is a single base pair substitution, there will only be one amino acid changing.
- B & C: If is is addition of deletion the frame will not be reinstated at the back.
- D: Most likely an addition occurred which caused a frameshift mutation. This is followed by a deletion which caused a resotring of the frame towards the end of the amino acid sequence.

Ans: D

[L3] Novel

8 The bacterium, Pneumococcus pneumoniae, forms two types of colonies whose cells are structurally different. Smooth (S) cells have thick outer capsules, but rough (R) cells lack this capsule. S cells cause the disease pneumonia.

In 1928, Frederick Griffith found that:

- when R cells were mixed with heat-killed S cells and the mixture injected into mice, some of the mice became infected and died.
- living S cells with capsules could be isolated from these dead mice.
- injection of heat-killed S cells alone or of living R cells alone did not cause disease in mice.

What can be concluded from these three observations to explain what happened when R cells were mixed with heat-killed S cells?

A A heritable genetic change occurred in the R cells.

B R and S cells conjugated when mixed.

C R cells were changed into S cells by transduction.

D R cells were transformed by DNA from heat-killed S cells.

SC: Process here is transformation.
OR:
- A: It is not mutation here and furthermore this does not explain what happened to the R cells.
- B: S cells were heat killed so it is not alive and conjugation requires sex pillus to form between two live bacterial cels.
- C: No virues were cited in the preamble and therefore transduction is possible.
- D: R cells underwent genetic recombination when it was transformed by a naked DNA that came from heat-killed S cells.

Ans: D

[L2] ('13 A-level/P1/Q13)

9 Which statements about bacterial conjugation are correct?

1 The F-plasmid is transferred to the recipient bacterial cell via the rolling circle mechanism.

2 An F plasmid carries genes controlling the process of conjugation.

3 Only one DNA strands of an F plasmid in the donor cell break at the origin of replication.

4 An F plasmid DNA strand enters the recipient cell beginning at its 5' end.

5 After transfer of F plasmid DNA, complementary strands of F plasmid DNA are synthesised in both donor and recipient cells.

6 Exonucleases cleave the donor DNA to create a nick.

A 1, 2, 3 and 5 only

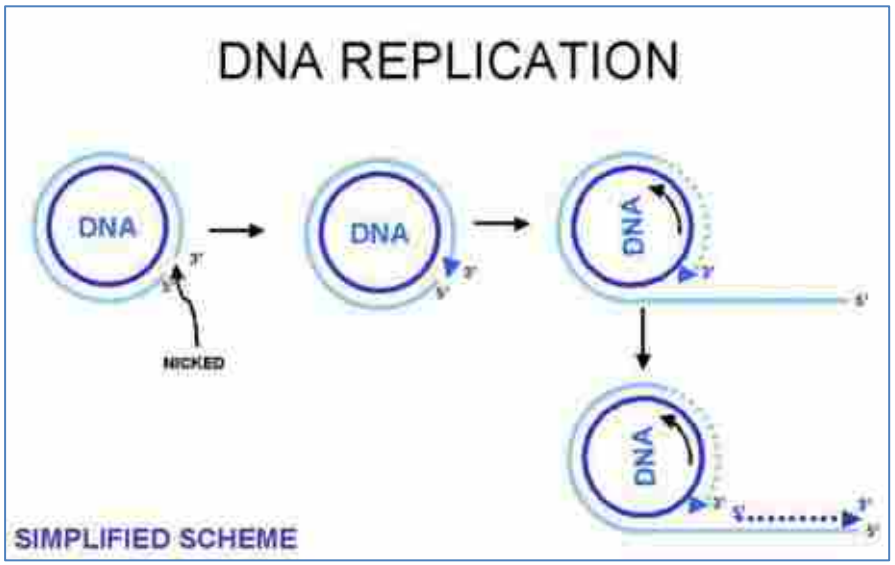
B 1, 2, 3, 5 and 6 only

C 1, 2, 3, 4 and 5 only

D All of the above

SC: Process here is conjugation. (Question was scaffolded in MYE & June holiday assignment)
OR:
- ✓1: Yes, the F-plasmid is transferred to recipient bacterial cell via rolling circle mechanism.

- ✓2: Yes, the F-plasmid carries the genes responsible for conjugation to take place.
- ✓3: Yes, only 1 strand break.
- ✓4: Yes, the F-plasmid enters the recipient cells from the 5' end onward.



- ✓5: Yes, the single-stranded DNA serves as a template for the second strand to be complementarily synthesized for the molecule to become double-stranded.
- ✓6: Yes, that is correct.
- ✗7: No. It is supposed to be endonucleases.
-

Ans: C

[L2] (Adapted from '14 A-level/P1/Q13)

10 Which of the following is not part of the Trp operon?

A Structural genes (*trp A* to *E*)

B *trp R*

C *trp* operator

D *trp* promoter

SC: *Trp* operon knowledge.
OR:
- *trp R* codes for the regulatory protein (Trp repressor) and it is not part of the Trp operon.

Ans: B

[L1] (novel)

11 Which statements about inducible and repressible systems are correct?

1. Repressible systems code for the synthesis of enzymes involved in anabolic pathways.
2. An inducible system is one where the operon is switched on under normal conditions.
3. An repressible system is one where the operon is switched off under normal conditions.
4. Inducible systems functions in catabolic pathways, digesting nutrients to simpler molecules.
5. An example of a inducible system is the Trp operon.

A All of the above

B 1 and 4 only

C 2, 3 and 4 only

D 1, 2, 3 and 4 only

SC: Inducible and repressible systems
OR:
- ✓1. Repressible genes code for the synthesis of enzymes involved in anabolic pathways.
- ✗2: An inducible system is one where the operon is switched off under normal conditions.
- ✗3: An repressible system is one where the operon is switched on under normal conditions.
- ✓4: True.
- ✗5: An example of a inducible system is the Lac operon.

Ans: B

[L2] (novel)

12 Viruses are considered obligate parasites because

A they reproduce using host cell DNA polymerase.

B they lack RNA-dependent RNA polymerases and ribosomes hence must depend on the host cell to carry out gene expression.

C they are unable to generate or store energy in the form of ATP and thus derive their energy for all metabolic functions from the host cell.

D they make use of the host cell's inorganic molecules such as amino acids, nucleotide and tRNA.

SC: Inducible and repressible systems
OR:
- ✗A. Reproduction does not occur on host cell ribosome.
- ✗B: Should be DNA-dependent RNA polymerases.
- ✓C: Correct.
- ✗D: Should be organic instead of inorganic.

Ans: C

[L1] (novel)

13 Which of the following proposed methods would be most viable in treating influenza?

A Introducing a ribosome inhibitor so that translation of viral proteins cannot take place.

B Introducing a ribonucleotide analog that would cause chain termination upon addition to an RNA polymer.

C Inhibit the attachment and thereby entry of the virus into its host cell by developing inhibitors that bind to the sialic acid on host cells.

D Inhibit the attachment and thereby entry of the virus into its host cell by developing antibodies

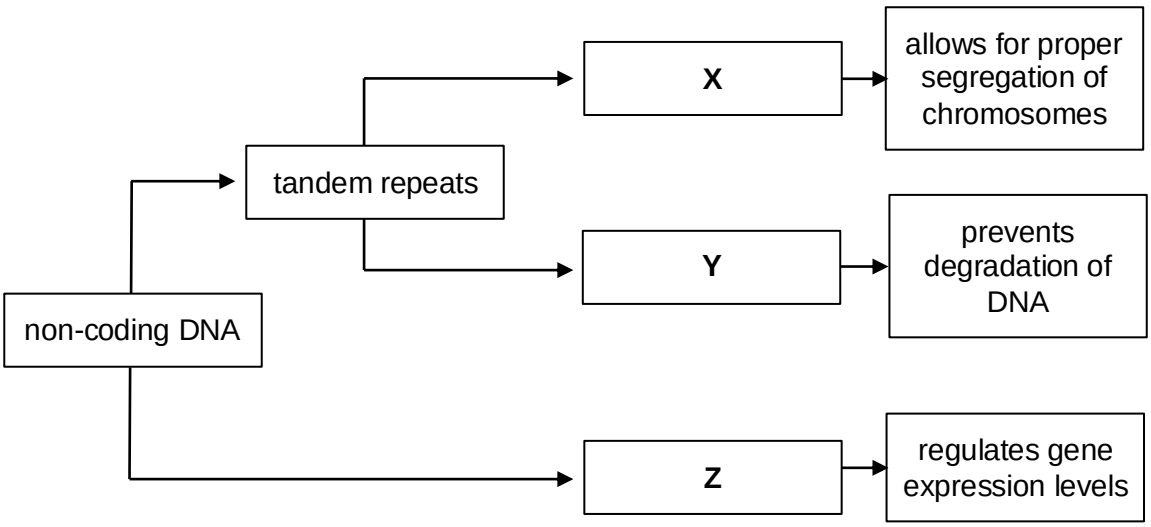
that bind to the haemagglutinin on the viruses.

SC: Influenza viral reproductive cycle
OR:
- ✗A.Translation to produce normal host cell proteins will also be affected.
- ✗B: Transcription to produce normal host cell RNA will also be affected.
- ✗C: By binding to host cell sialic acid is not an option as sialic acid is ubiquitous and blocking all sialic acid is not practical.
- ✓D: Yes, by targeting HA, virus cannot adsorb on host cell and thus cannot enter host cell.

Ans: D

[L3] (novel)

14 The flowchart shows the classification of several regions of non-coding eukaryotic DNA, **X**, **Y** and **Z**.



Which statement(s) correctly describes **X**, **Y** and **Z**?

1 Regions **X** and **Y** are made up of transcriptionally active tandem repeats.

2 Regions **X** and **Y** are always associated with proteins, but DNA at region **Z** is only associated with proteins during gene expression.

3 Region **Z** may involve DNA bending but region **Y** shortens during DNA replication.

4 Regions **X**, **Y** and **Z** are conserved throughout the life of the organism.

A 2 only

B 3 only

C 1 and 4 only

D 2 and 3 only

SC: X - centromeres, Y – telomeres and Z – control elements (non-coding)
OR: Statement 1 False (all non-coding), Statement 2 False (all associated with protein, Z is associated with proteins during chromatin packaging), Statement 3 True, Statement 4 False (not all conserved).

Ans: **B**

[L3] (HCI 2015 Prelim P1 Q14 modified)

15 Which one of the following statements correctly describes the role of enhancers.

A DNA sequences that are bound by general transcription factors.

B DNA sequences that directly induces the bending of DNA.

C DNA sequences that are involved in stabilisation of the transcriptional initiation complex.

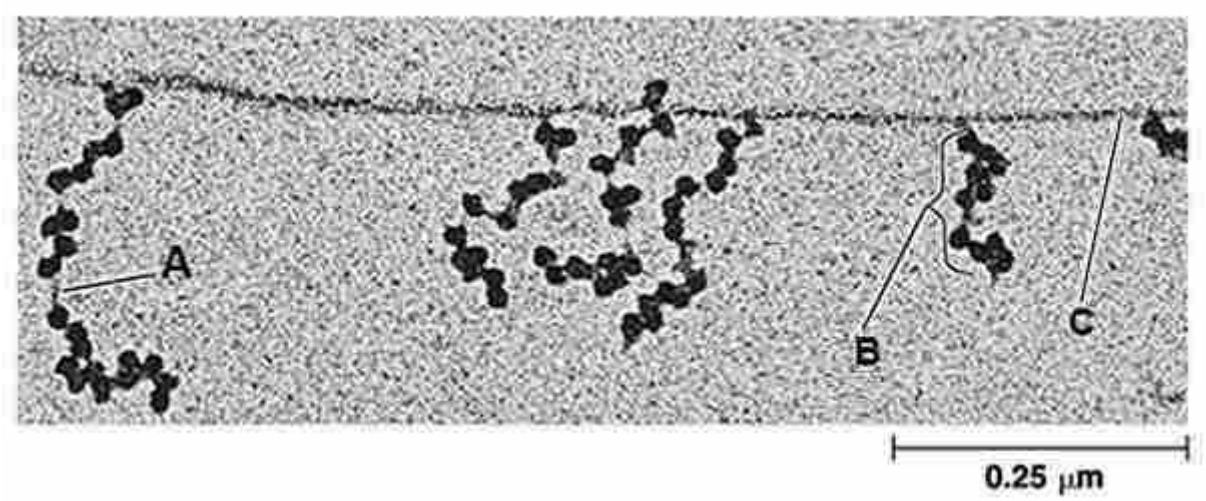
D DNA sequences are proximal control elements that are non-coding.

SC: Factual recall
OR:
- A is wrong because it should not be general transcription factors.
- B is wrong because it does not directly induce bending but bending occurs only after an activator binds to it.
- C is correct.
- D is wrong because it is not a proximal control element.

Ans: **C**

[L1]

16 The electron micrograph below shows several labelled structures present in a mitochondrion.



Which of the statements below correctly describe the labelled structures?

1 The structure labelled **A** is the polypeptide chain.

2 The structures labelled **B** are polyribosomes which consist of many 70S ribosomes.

3 The structure labelled **C** is the 3' end of template DNA strand.

4 The structure labelled **C** is the 5' end of the mRNA strand.

A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

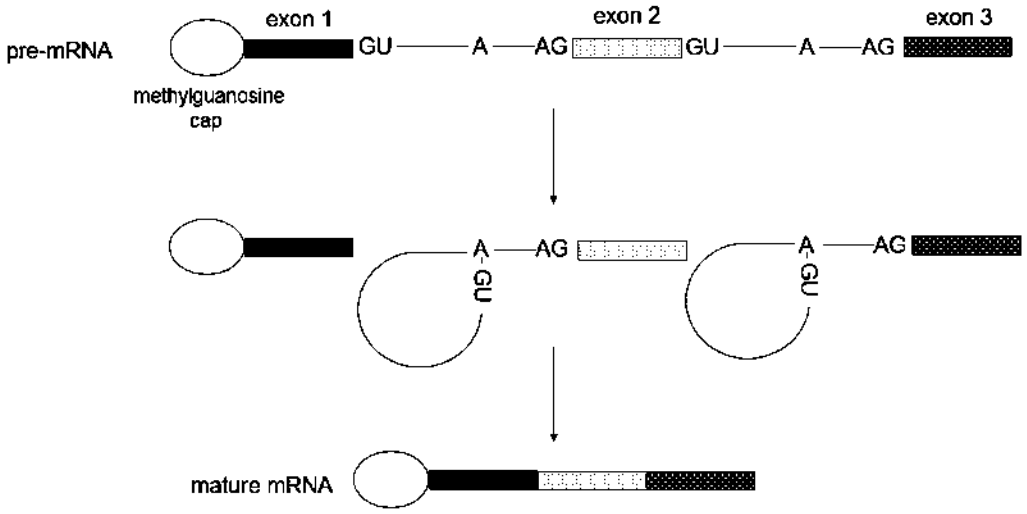
D 1, 2 and 4 only

SC: Labelled structure in EM is polyribosomes (structure B), ribosomes binds to mRNA template for translation (hence structure A is mRNA), Structure C must be DNA template strand. 70S ribosome because context is mitochondrion.
OR: Statement 1 false; Statement 2 true; Statement 3 true; Statement 4 false → accept Option C

Ans: **C**

[L3] AJC 2015 Prelim P1 Q16

17 The diagram shows part of an mRNA undergoing the process of splicing.



With reference to the diagram above, which statement(s) is / are related to the process shown?

1 RNA splicing occurs after the release of pre-mRNA from RNA polymerase.

2 Spliceosome binds to the 3' splice site GU and the 5' splice site AG on the pre-mRNA.

3 A RNA loop is formed on the pre-mRNA where the intron is excised.

4 There can be more than one type of product formed from a single pre-mRNA.

A 1 and 2

B 3 and 4

C 2, 3 and 4

D 1, 3 and 4

SC: Diagram shows RNA looping, splicing (alternative splicing possible)
OR: Statement 1, 3 and 4 possible (even if not shown explicitly as qns ask for related process)
Statement 2 is wrong (should be 5'GU and 3'AG)

Ans: D

[L3] (HCI 2015 Prelim P1 Q15)

18 Gene expression is similar in prokaryotes and eukaryotes in that both:

A have post-transcriptional modifications.

B require helicase to separate the DNA so that transcription can take place.

C have spliceosomes to intron splicing.

D involve attachment of proteins to DNA adjacent to the gene being transcribed.

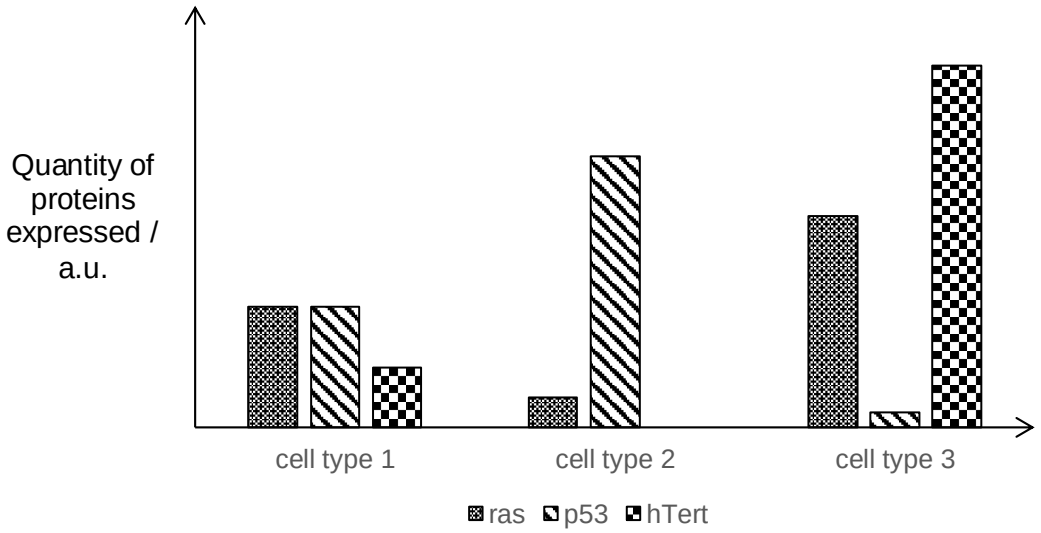
SC: Transcription and translation are common to both prokaryotes and eukaryotes. Among options given, points on transcription are given.
OR: Statement A false (prokaryotes do not have), Statement B false (RNA polymerase not helicase), Statement C (Prokaryotes do not utilise spliceosome). Accept D.

Ans: **D**

[L2]

19 Cancer critical genes include ras, p53 and hTert. hTert codes for human telomerase.

The levels of proteins expressed by each gene in three different cell types of a patient are shown in the graph. Only one cell type was taken from a malignant tumour.



Which statement is true?

A Cell type 1 is not from the malignant tumour since balanced expression of *ras* and *p53* halts cell cycle progression.

B Activation of telomerase will result in cell type 2 gaining immortality and becoming cancerous.

C Cell type 3 is obtained from the malignant tumour as the cells will divide uncontrollably.

D Gain-of-function mutation of *hTert* in cell type 1 will result in malignant tumour formation.

SC: ras – oncogene, p53 – Tumour suppressor gene, hTert – Telomerase gene (activated in cancer)

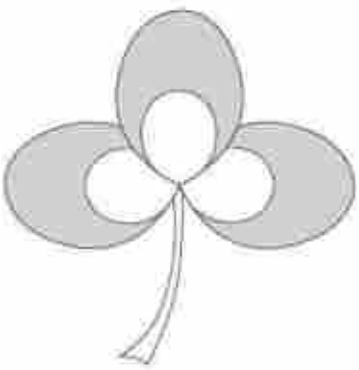
OR: Statement A false (insufficient info from data), Statement B false (no expression of telomerase), Statement D false (insufficient info from data to conclude gain-of-function mutation). State C true as it fulfils 3 conditions for cancer development (overexpression of ras oncogene, underexpression of p53 tumour suppressor gene and high expression of telomerase).

Ans: **C**

[L2] (HCI 2015 Prelim P1 Q17 modified)

20 The white clover, *Trifolium repens*, is one of the plants found growing as a weed in many lawns. Leaves of the white clover are divided into three leaflets, which often have characteristic white patterns visible on their surface. The two basic forms of the pattern are a chevron and patch. The diagram below shows these two patterns.

chevron pattern



patch pattern

If a pure-breeding clover plant with the chevron pattern is crossed with a pure-breeding plant with the patch pattern, the offspring have leaflets with a mixed chevron and patch pattern, as shown in the diagram below.

mixed pattern

Which row correctly describes the inheritance of leaflet patterns in white clover?

	number of alleles that determines the white patterns in the leaflets	mode of inheritance
A	2	codominance
B	2	epistasis
C	> 2	codominance
D	> 2	epistasis

SC: only 2 alleles (one for chevron and other for patch). Offspring shows mixed pattern (both expressed hence codominace)

OR: Accept A, Reject B (not epistasis), C (not sufficient information provided to infer 3 or more alleles) and D (not epistasis)

Ans: **A**

[L2] (HCI 2015 Prelim P1 Q19)

21 In a cross involving polygenic inheritance, 3 genes control the height of a tulip plant. The shortest and tallest plants are 12 cm and 24 cm respectively.

Assuming all other environmental factors are kept constant, what is the height of the F1 offspring obtained from a cross between a homozygous 12 cm and a homozygous 24 cm plant?

A 6 cm

B 12 cm

C 14 cm

D 18 cm

SC: polgenic inheritance involving 3 gene A,B,C. shortest homozygous (aabbcc – 12cm → every recessive allele contribute 2 cm) tallest homozygous (AABBCC - 24cm → every dominant allele contribute 4 cm)

OR: Cross between homozygous recessive (aabbcc) and homozygous dominant (AABBCC) result in heterozygous (AaBbCc) which will result in 18 cm tall plants.

Ans: D

[L3] (VJC 2015 Prelim P1 Q20 modified)

22 A plant with orange-spotted flowers was grown in a greenhouse from a seed collected in the wild. The plant was self-pollinated and gave rise to the following progeny: 129 plants with orange-spotted flowers, 22 plants with yellow-spotted flowers, 26 plants with solid orange flowers, and 15 plants with solid yellow flowers.

The formula for the chi-squared (χ^2) test is given as follows:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

degrees of freedom	probability			
	0.10	0.05	0.01	0.001
1	2.71	3.84	6.64	10.83
2	4.69	5.99	9.21	13.82
3	6.25	7.82	11.35	16.27
4	7.78	9.49	13.28	18.47

Which statement is true about the inheritance of flower colour and flower pattern at 99% confidence level?

A Since p < 0.05, the difference between the observed and expected results is not significant. The inheritance of flower colour and flower pattern is following Mendel's law of independent assortment.

B Since p > 0.05, the difference between the observed and expected results is not significant. The inheritance of flower colour and flower pattern is not following Mendel's law of independent assortment.

C Since p > 0.01, the difference between the observed and expected results is not significant. The inheritance of flower colour and flower pattern is following Mendel's law of independent assortment.

D Since p < 0.01, the difference between the observed and expected results is significant. The inheritance of flower colour and flower pattern is not following Mendel's law of independent assortment.

SC: Observed no. compared against dihybrid ratio of 9:3:3:1, chi square calculated for df=3 is 6.91.

OR: p>0.05 (random chance of difference high), not statistically significant, inheritance follows Mendel's law of independent assortment.

Ans: C

[L2] (HCI 2015 Prelim P1 Q 23 modified)

23 Which of the following statements about transport in the cell is incorrect?

A Active transport is the movement of substances across the cell membrane against a concentration gradient.

B Diffusion is the mechanism by which movement of hydrophobic particles through a cell membrane down a concentration gradient.

C Receptor mediated endocytosis involves the binding of the substance to specific receptors and their subsequent passive entry into the cell.

D Bulk transport is a process which requires energy.

SC: transport / false / transport / correct
OR: A True

B True

C False (Receptor mediated endocytosis is an active process.)

D True

Ans: C

[L1]

24 Which of the following statements is false about cell signalling involving tyrosine kinase receptors.

A Ligand molecules are mostly hydrophilic in nature.

B Different activated relay proteins serve to directly amplify the effects of the ligand.

C Dimerisation serves to initiate auto-phosphorylation.

D Receptors are transmembrane proteins that are anchored within the cell surface membrane.

SC: statement / false / TKR
OR: A True (are extracellular within an aqueous medium) True

B Different activated relay protein affect different processes and therefore are not seen to directly amplify
(ie there is more of the same effect) False

C Correct True

D both hydrophobic tails and hydrophilic head form anchor points with the respective portions of the receptor True

Ans: B

[L2] Novel

25 Phosphorylation cascade is an important component in cell signaling, which of the following statements is incorrect about this cell signaling mechanism.

A The signal is passed via a series of phosphorylation involving protein kinases.

B The mechanism allows for greater control and speed in transmission of the signal.

C Phosphorylation cascade mechanism is initiated by a second messenger.

D Inactivation of the signal mechanism involves phosphatases which deactivate protein kinases.

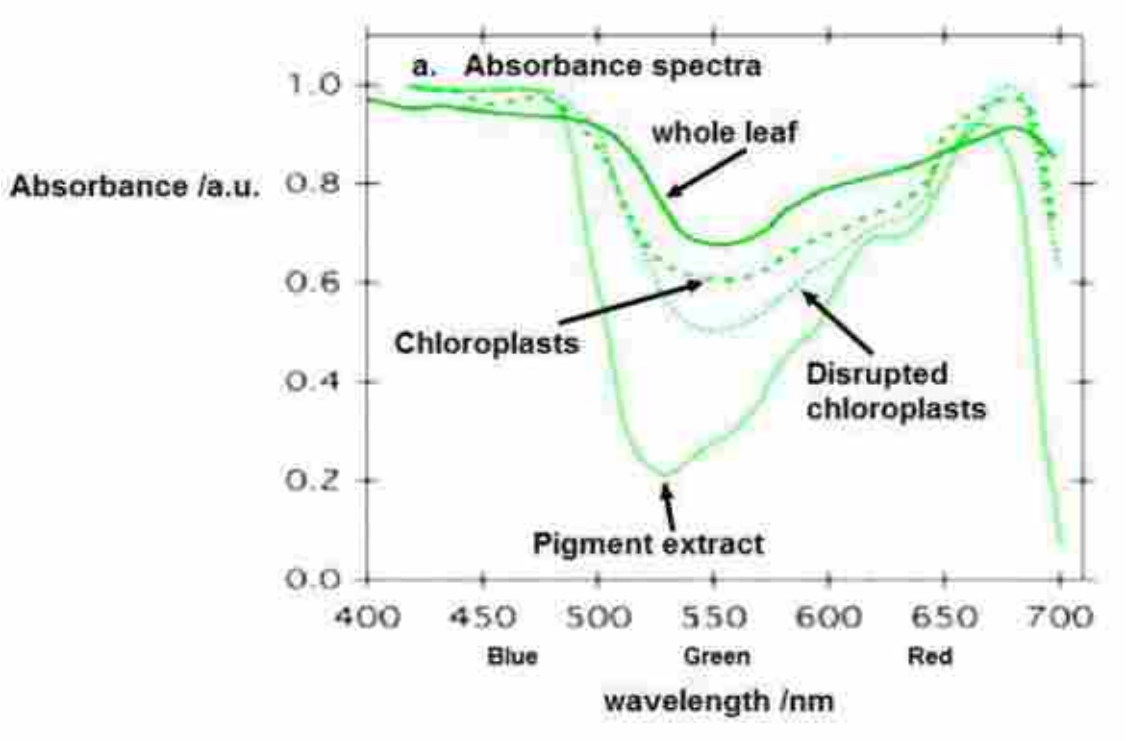
SC: statement / false / phosphorylation cascade
OR: A True
B False -Phosphorylation cascade does not speed up the transmission of the signal.
C True
D True

Ans: **B**

[L1]

21

26 The figure shows the absorptance spectra of various components of a leaf.



What can be inferred from the data shown?

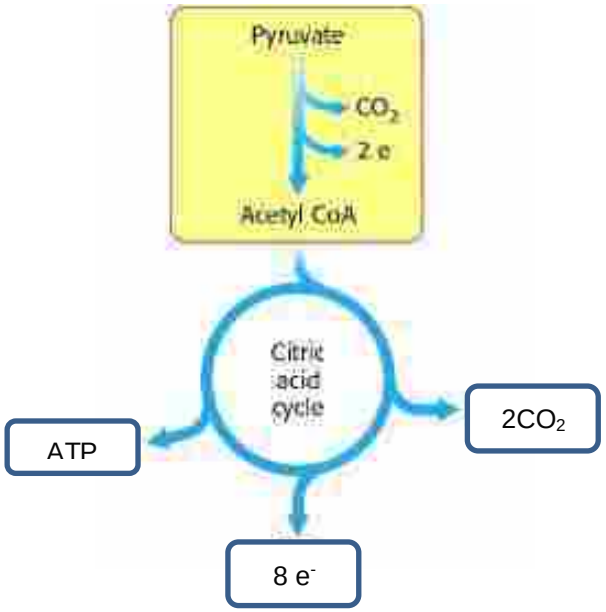
A Absorptance is highest in 650-700 nm in all leaf components due to light harvesting complexes.
B Whole leaf samples experience the least absorptance at 550 nm due to all green light being reflected.
C Disrupted chloroplast samples have higher absorptance compared to chloroplasts due to a larger surface area for light capture.
D Pigment extracts are the main agents of light harvesting due to the presence of carotenoids.

SC: inferred from data
OR: A × except in whole leaf where at 475nm, absorption is higher compared to 650-700nm.
B × not all green light is reflected, there is still absorption of 0.2 a.u.
C × Disrupted chloroplasts lack the organization compared to chlorophyll.
D ✓ Carotenoids make up the main light harvesting components of the leaf.

Ans: **D**

[L3]

27 The figure below shows the part of the process of aerobic respiration.



Which of the following statements is true of the significance of acetyl CoA?

A Acetyl CoA is the product of the link reaction and is subsequently brought into the mitochondria to enter the Krebs cycle

B Acetyl CoA is the entry point into the metabolic pathway of both carbohydrates and fats.

C Acetyl CoA is an energised molecule combined with Oxaloacetate, to yield 4 molecules of citric acid per molecule of Glucose.

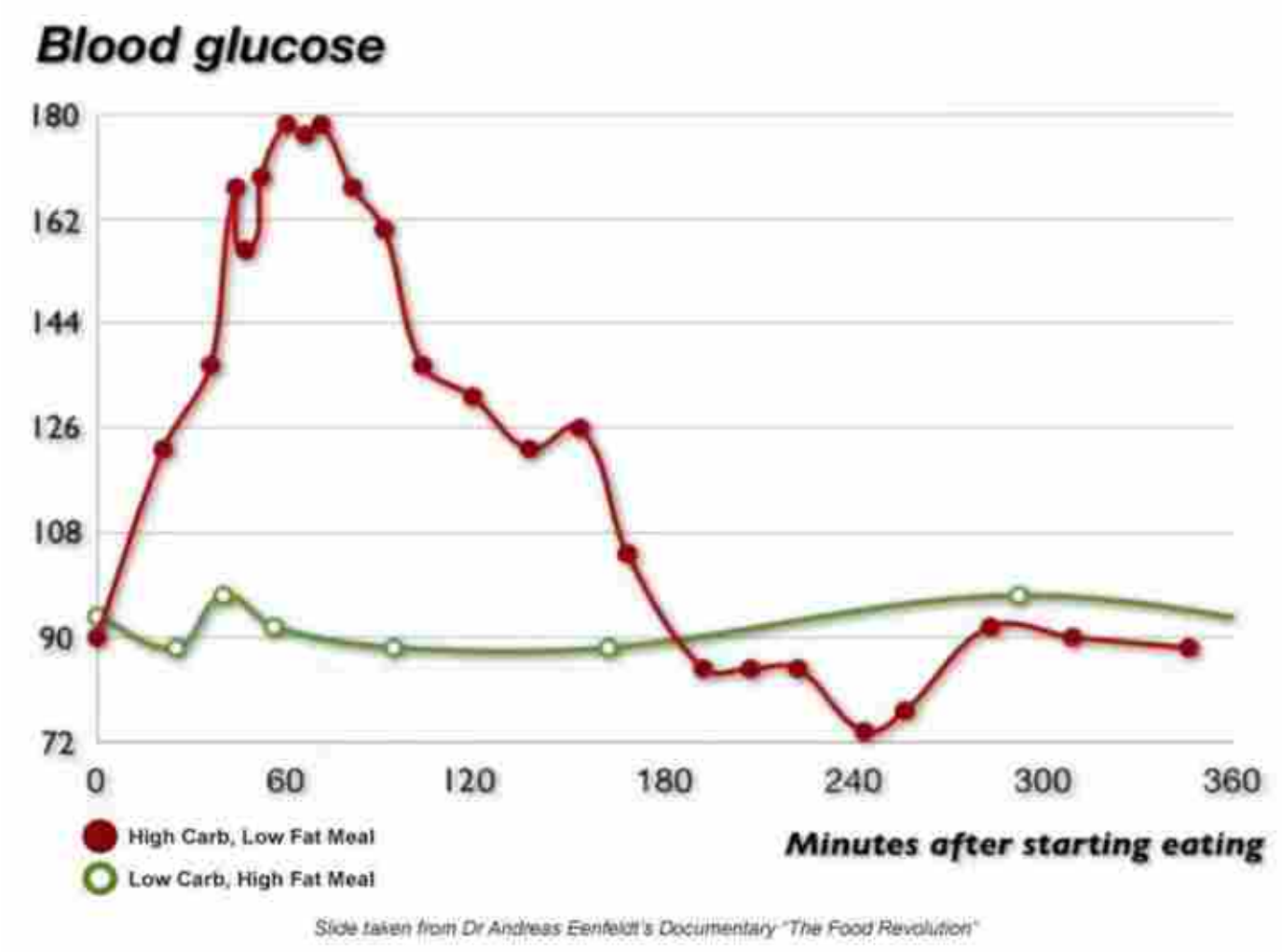
D Electrons released in the formation of Acetyl CoA are used in the production of NADPH.

SC: true significance / acetyl CoA
OR: A × link reaction occurs in the mitochondrial matrix.
B ✓ lipid metabolism enters here.
C × only 2 molecules of citric acid are produced for every 1 molecule of glucose.
D × electrons released is used in the production of NADH not NADPH.

Ans: **B**

[L2]

28 The figure below represents the blood glucose levels of a normal person after a meal.



At which time do the beta cells of the islets of Langerhans detect and effect the secretion of insulin to manage blood glucose levels?

	Detection by beta cells	Secretion of insulin
A	0 to 5 minutes	61 to 180 minutes
B	0 to 5 minutes	0 to 10 minutes
C	180 to 200 minutes	240 to 300 minutes
D	180 to 200 minutes	180 to 200 minutes

SC: time / beta cells Islets Langerhans / detect and secrete insulin

OR: A × detection and secretion are close together –detection immediately followed by secretion of insulin

B ✓ as explained in A.

C × detection is by Alpha cells of islets of Langerhans and for hypoglycaemic conditions..

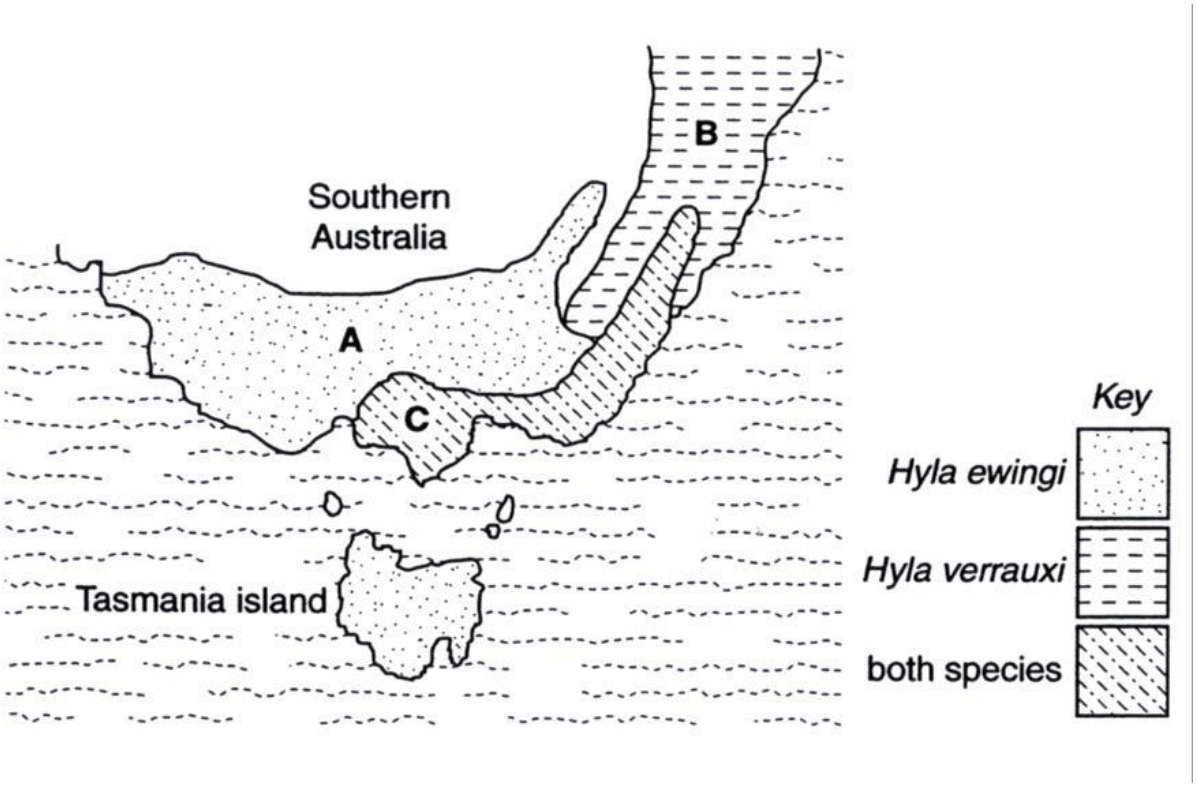
D × detection and secretion are close together- detection immediately followed by secretion of glucagon.

Ans: **B**

[L1 high/ L2]

23

29 Two closely related species of frog, *Hyla ewingi* and *Hyla verrauxi* live in South Australia. The figure below shows the distribution of the tree frogs in Southern Australia.



Hyla ewingi and *Hyla verrauxi* are two closely related species of tree frogs from southern Australia. Research from breeding studies and DNA sequence data has shown that they have weak genetic incompatibility.

Male frogs attract females of the same species for mating by their pulsing call. The pulse rate of the male calls of the two species is almost identical. However, when both species coexist within the same region, the calls of *H. ewingi* are quite different than those of *H. verrauxi*.

Which of the following can be correctly inferred from the data given?

A Complete speciation has taken place between the two groups of frogs.

B Allopatric speciation was probably the evolutionary mechanism at work.

C Convergent evolution has seen the frogs in Tasmania similar to those in region A in Australia.

D Sympatric speciation was probably the evolutionary mechanism at work.

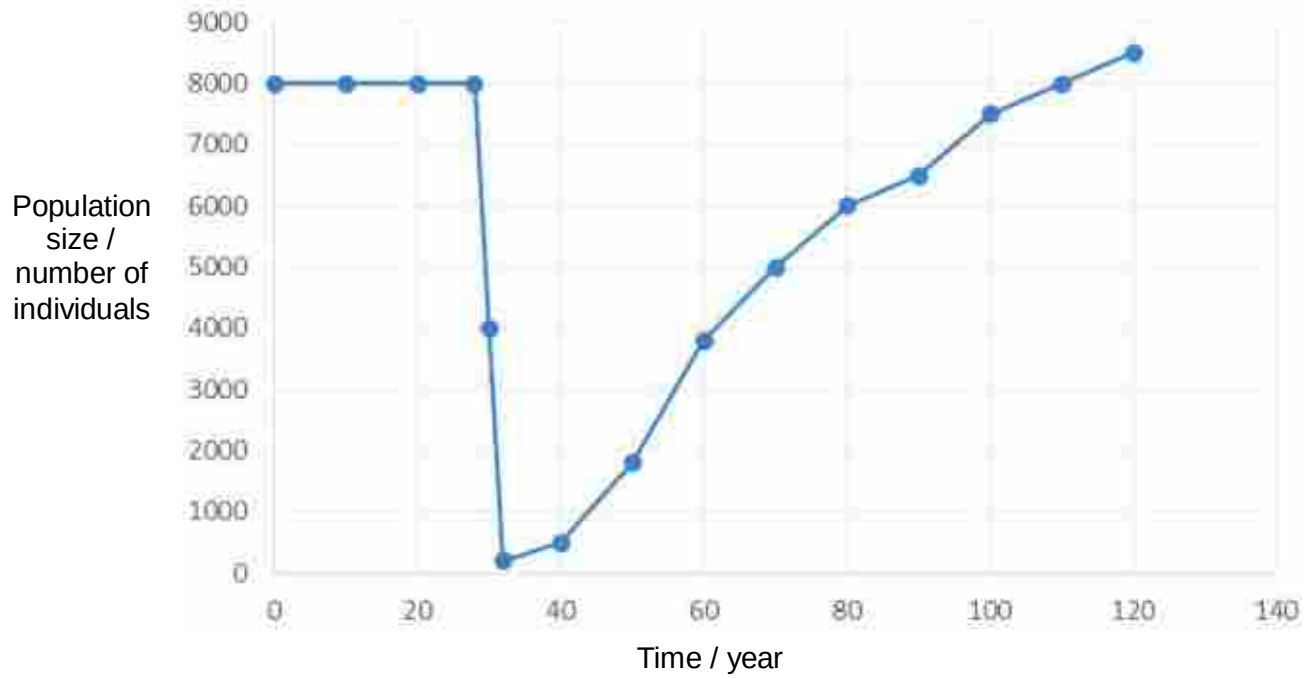
SC: 1. P2L1 weak genetic incompatibility – ie genetically similar
2. P3L1 Male attract females for mating – ie are not reproductively isolated- same species
3. P3L1 different behaviours- behavioural isolation beginning but not led yet to reproductive isolation.
4. P3L2 coexist in same region, no geographical isolation- Sympatric speciation occurring over time.
-correctly inferred / data given

OR: A × reasons from point 2.
B × reasons from point 4.
C × plate tectonics in biogeography would explain H. ewingi present in both regions not convergent evolution. Besides they are exactly the same species so cannot be Convergent evolution.
D ✓reasons from point 4.

Ans: **D**

[L2]

30 The figure shows the population of a group of organisms in a fixed region over time.



The following statements are derived from the data shown.

i. Bottleneck event has taken place Year 30 to 35
ii. Genetic variation has been fully restored by Year 110
iii. Allele frequency steadily increases due to genetic drift
iv. Founder effect has taken place from Year 28 onward

Which statements can be concluded as true?

A i only

B ii only

C i, ii & iii only

D i, iii & iv only

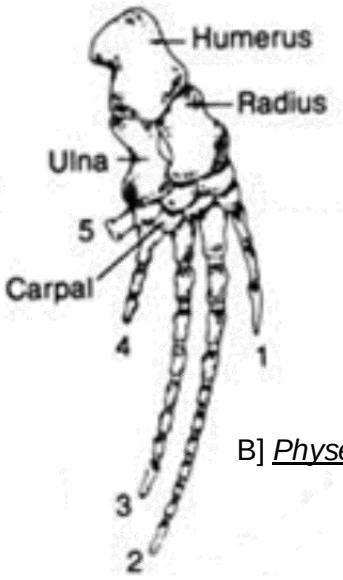
SC: 1. P1L1 Populatio .. fixed region ie no founder effect
OR: 2. i ✓ Bottle neck possible drastic reduction in population
3. ii × genetic variation is reduced after bottleneck and is only increased by mutation over time but would not have been regained by year 150.
4. iii × Not conclusive from the table.
5. iv × Founder Effect is not considered in the original population see point 1.

Ans: **A**

[L2 high]

31 The following figure shows the anatomy of the left front appendages of the two vertebrates.

A] *Javan surili*



B] *Physeter macrocephalus*

Which one of the following correctly describes the type of structures seen and their evolutionary connection?

	Type of structures	Ancestry	Type of evolution
A	Homologous	Different ancestor	Convergent Evolution
B	Homologous	Common ancestor	Divergent Evolution
C	Analogous	Different ancestor	Convergent Evolution
D	Analogous	Common ancestor	Divergent Evolution

SC: correct type structure / evo connection
OR: Homologous (same pentadactyle plan) / divergent evo / common ancester
A × same ancestor / not convergent
B ✓ correct.
C × not analogous / same ancestor / not convergent.
D × not analogous / not divergent evo.
Ans: **B**

[L2]

32 All the characteristics below support the use of plasmids in cloning and expression in bacteria **except**

A More than one plasmid can be taken up by each bacterium.

B Plasmids are able to control their own replication through their origin of replication

C Plasmids contain a wide range of restriction sites for various restriction enzymes.

D Linker DNA / artificial sticky ends are not required to express eukaryotic genes of interest derived from cDNA.

SC: factual recall
OR: Statement A, B and C are true. Only Statement D false. Accept option D.

Ans: **D**

[L1] (VJC 2015 Prelim P1 Q33 modified)

33 *lacZ* gene is a genetic marker found in the plasmid which can be used in genetic engineering.

What is the function of *lacZ* gene in a cloning vector?

A Express *lac* repressor

B Distinguish between introns and exons

C Break down lactose to galactose and glucose

D Screen for cells with the recombinant plasmid .

SC: factual recall
OR: Statement A wrong, B (wrong) and C (true but not align to qn context. Also, the gene does not do the breakdown of lactose, it is the enzyme that is encoded for). Only Statement D relevant. Accept option D.

Ans: **D**

[L1] (TJC 2015 Prelim P1 Q33)

34 Which correctly describe the difference between genomic and cDNA libraries and the corresponding reason for the difference?

	Difference	Reason
A	Genomic library may contain distant control elements and centromere while cDNA library contains only expressed genes.	Due to mRNA splicing which removes exons and splice introns together.
B	Genomic library is larger in size than cDNA library.	Due to genomic library containing total DNA extract from a cell while cDNA library containing the total mRNA extract from a particular cell type.
C	Genomic library from an individual is always the same, while cDNA library may differ, depending on the cell type from which it is constructed.	Due to differential gene expression in the different cell types.
D	Genes from genomic library are more suited than those from cDNA library for expression in bacterial cells.	Due to the action of restriction endonucleases in the construction of genomic library and that of reverse transcriptase in the construction of cDNA library.

SC: Statement Evaluation of DNA libraries

OR: Statement A wrong (introns are excised and exons spliced), B (cDNA library does not contain total mRNA extract) and D (genes from genomic library are not more suitable for expression in bacterial cells due to presence of introns). Only Statement C True. Accept option C.

Ans: **C**

[L2] (MJC 2015 Prelim P1 Q37)

35 Genes P, Q, R and S occur on the same chromosome. The table shows the recombination frequencies.

	recombination frequency (%)
between P and Q	46
between P and R	8
between R and Q	54
between Q and S	13
between R and S	41

Which of the following represents the correct order of genes on the chromosome?

A P – Q – R – S

B P – R – S – Q

C R – P – S – Q

D R – S – Q – P .

SC: Distance between gene loci can be inferred from recombination frequencies; the closer the gene loci → smaller recombination frequency, the more distant gene loci → higher recombination frequency.
OR: R and Q has the highest recombination frequency so should be furthest from each other → Option C

Ans: **C**

[L2] (IJC 2015 Prelim P1 Q35)

36 The Human Genome Project facilitated genetic testing of individuals and renewed emphasis on ethical and social implications.

Which of the following statements correctly describe unintended consequences of genetic testing?

1 discovery of wrongly attributed paternity

2 unauthorised publication of genetic test results

3 psychological stress after receiving genetic test results

4 social stigmatisation of genetically predisposed individuals

A 1 and 2

B 3 and 4

C 1, 2 and 3

D All of the above .

SC: For HGP genetic testing, all are unintended.
OR: Statement 1, 2, 3 and 4 are unintended consequences. Accept Option C.

Ans: **D**

[Low L2]

37 Which of the following shows the correct developmental potency of the following stem cells.

	Haematopoietic stem cells	Zygotic stem cells	Embryonic stem cells	Neural stem cells
A	Multipotent	Pluripotent	Totipotent	Unipotent
B	Multipotent	Totipotent	Pluripotent	Unipotent
C	Multipotent	Pluripotent	Totipotent	Multipotent
D	Multipotent	Totipotent	Pluripotent	Multipotent

SC: Stem cells' developmental potency
OR:
- HSCs & NSCs are multipotent
- Zygotic stem cells are totipotent
- ESCs are pluripotent

Ans: D

[L1] (novel)

38 Which problem is associated with gene therapy?

A Target cells do not have suitable receptors on their cell surface membranes.

B The nuclear pores do not allow the vector into the nucleus.

C The viral vector cannot trigger cyclic AMP to activate appropriate genes.

D Viral vectors insert therapeutic genes at random points in the genome.

SC: Stem cells' developmental potency
OR:
- A: Receptors are not necessarily required. Non-viral methods do not require receptors.
- B: They usually do.
- C: cAMP not necessarily triggered.
- D: Yes, this will cause insertional mutagenesis and hence cancer.

Ans: D

[L2] ('13 A-level/P1/Q39)

39 Some plant tissue culture techniques involve the production of protoplasts using leaf tissue. Preparation of protoplasts involves incubation in a solution that contains enzymes such as cellulase and pectinase.

Which statement about protoplast is not correct?

A Protoplasts are pluripotent and regenerate into whole plants when provided with the correct growth factors.

B Protoplasts are more susceptible to microbial contamination.

C Protoplasts are used for the production of genetically engineered plants as they take up naked DNA easily.

D Protoplasts need to be maintained in the solution of the same water potential to prevent lysis.

SC: Plant cloning
OR:
- A: They are not pluripotent. They can be totipotent.
- B: Yes they are.
- C: Yes they take up naked DNA easily as they lack cell wall.
- D: Yes.

Ans: A

[L2] ('15 HCI/P1/Q40)

40 Which statement supports the view that genetically engineered animals could help to solve the demand for food in the world?

A Transgenic pigs and sheep are produced to express higher levels of growth hormone.

B Biomedical applications of genetically engineered animals have also become routine within the pharmaceutical industry, for drug discovery, drug development and risk assessment.

C Cloning of either extinct or endangered species such as thylacine and woolly mammoth helps to retain genetic diversity in small populations.

D By inserting genes from sea anemone and jellyfish, zebrafish have been genetically engineered to express fluorescent proteins.

SC: GMO animals
OR:
- A: Correct.
- B: Does not solve the demand for food.
- C: Does not solve the demand for food.
- D: Does not solve the demand for food.

Ans: A

[L2] ('15 HCI/P1/Q40)

END OF PAPER

CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME			
CLASS	**2T**	**INDEX NUMBER**	

BIOLOGY

9648/02
23rd August 2016
2 hours

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

There are two sections in this paper.

Section A]
Answer all questions

Section B]
Answer all questions. Answer each part on a **separate** piece of paper.

At the end of the examination, fasten all work securely together.
The number of marks is given in brackets [ ] at the end of each question or part of the question.

For Examiner's Use	
Section A	**80**
1 [10]	
2 [10]	
3 [10]	
4 [10]	
5 [10]	
6 [10]	
7 [10]	
8 [10]	
Section B	**20**
9a/10a	
9b/10b	
9c/10c	
TOTAL	**100**

This document consists of **21** printed pages and **1** blank page.

[Turn over

Section A

Answer **all** questions in this section.

1 The figure below shows three structural components of the membrane system in a pancreatic cell.

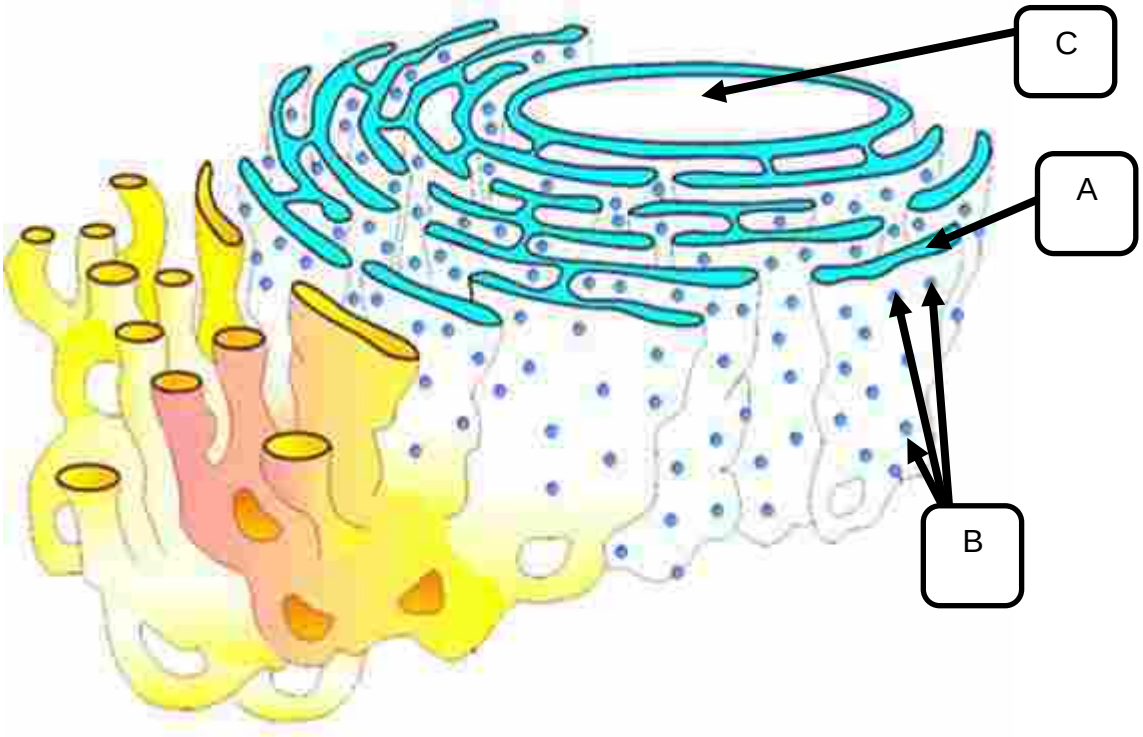


Fig. 1.1

(a) State the name and function of the structures in Fig. 1.1.

Structure A

Name: ……

Function: …… [1]

Structure B

Name: ……

Function: …… [1]

(b) State what is **structure C** and explain how **structure A** remains in close proximity to **C.**

……

……[2]

Fig. 1.2 shows a hormone essential for regulation of high blood glucose levels.

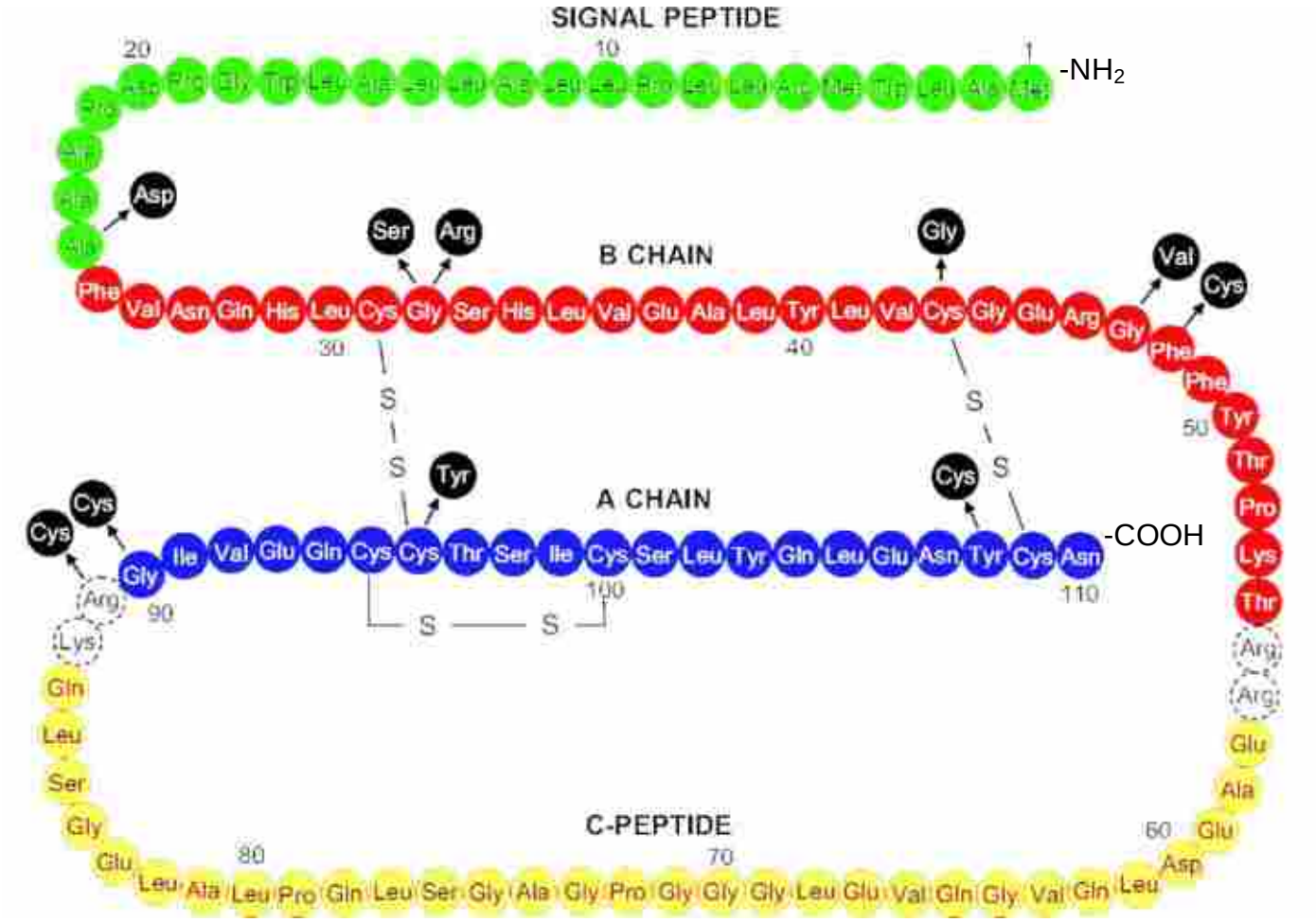


Fig. 1.2 Unit sequences of wild type (WT) and the mutant hormone. The mutations are noted in black circles together with location in the B (25 to 5) or A chain (90-110). The dashed circles indicate the basic residues that are activation cleavage sites.

(c) With reference to Fig. 1.2, draw out the bond (ensure correct orientation) formed between units 109 and 110 of the A-chain.

[2]

(d) With reference to Fig 1.2, suggest how amino acid substitutions between 90 and 109 could occur and what would be the corresponding effect on the resultant mutant hormone.

……

……

……

……[4]

[Total: 10]

2 The figure shows the molecular configuration of chymotrypsin. Chymotrypsin is one of the major proteases in the human digestive tract, in which its role is to hydrolyse large protein molecules into smaller peptides that are then further processed by peptidases. Fig. 2.1a shows a blown up representation of a portion of chymotrypsin shown in Fig. 2.1b.

Fig. 2.1a

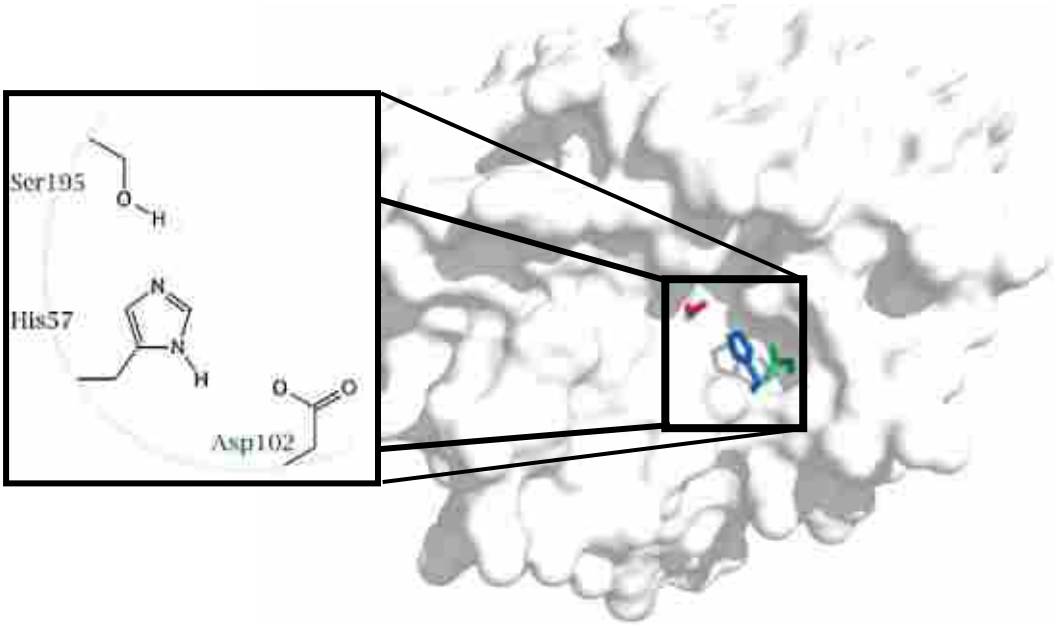


Fig. 2.1b

(a) Using the 'induced-fit hypothesis', explain the mechanism in which chymotrypsin carries out its function.

……

……[2]

Fig. 2.2 shows the energy exchange in a chemical reaction without the enzyme present.

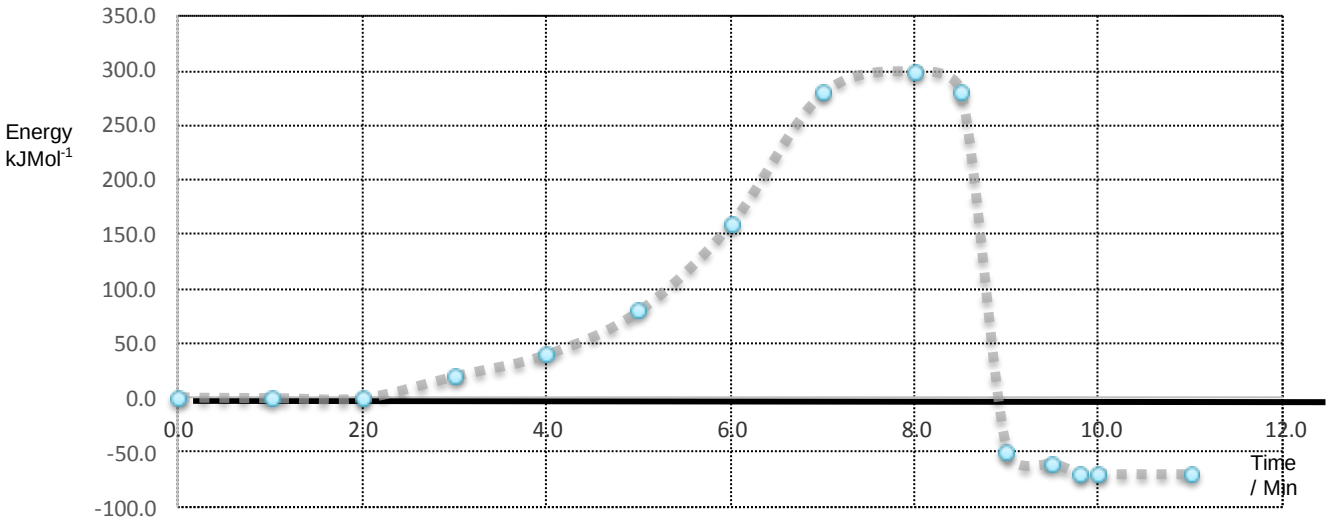


Fig. 2.2

(b) On the graph above draw out the plot tracing the effect of enzyme action and label the effect of enzyme on activation energy. [2]

Fig. 2.3 shows the effects of substrate on enzyme reaction.

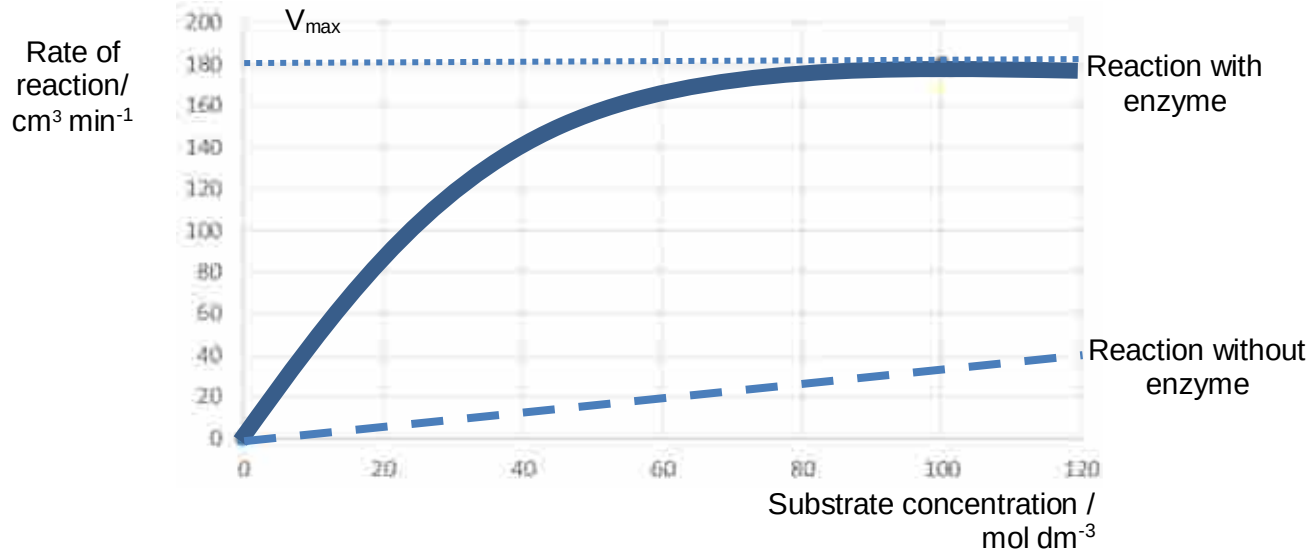


Fig. 2.3

(c) Explain what can be inferred from the graph in Fig. 2.3, with reference to substrate concentration and limiting factors.

……

……

……[2]

(d) On Fig. 2.3 draw a curve representing the effect of a non-competitive inhibitor on rate of reaction with no change in the affinity of the enzyme.

[2]

(e) Account for why the Michaelis constant for both the non-competitive inhibitor and the reaction without inhibitor is the same.

……

……

……[2]

[Total: 10]

3 Cells were transferred and grown in ^{15}N medium for many generations before they were transferred to ^{14}N medium again and allowed to divide.

DNA was extracted periodically from the culture and subjected to density gradient centrifugation using caesium chloride.

Fig. 3.1 shows the density gradient results across three generations.

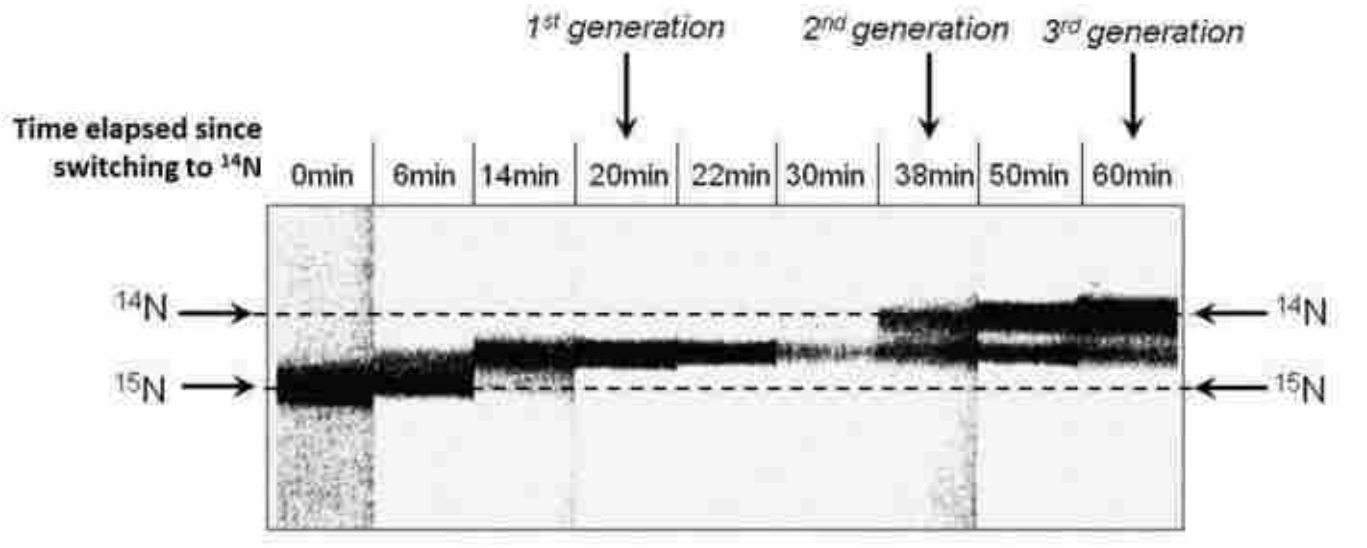


Fig. 3.1

(a) With reference to Fig. 3.1, account for the model of DNA replication which these cells undergo.

……

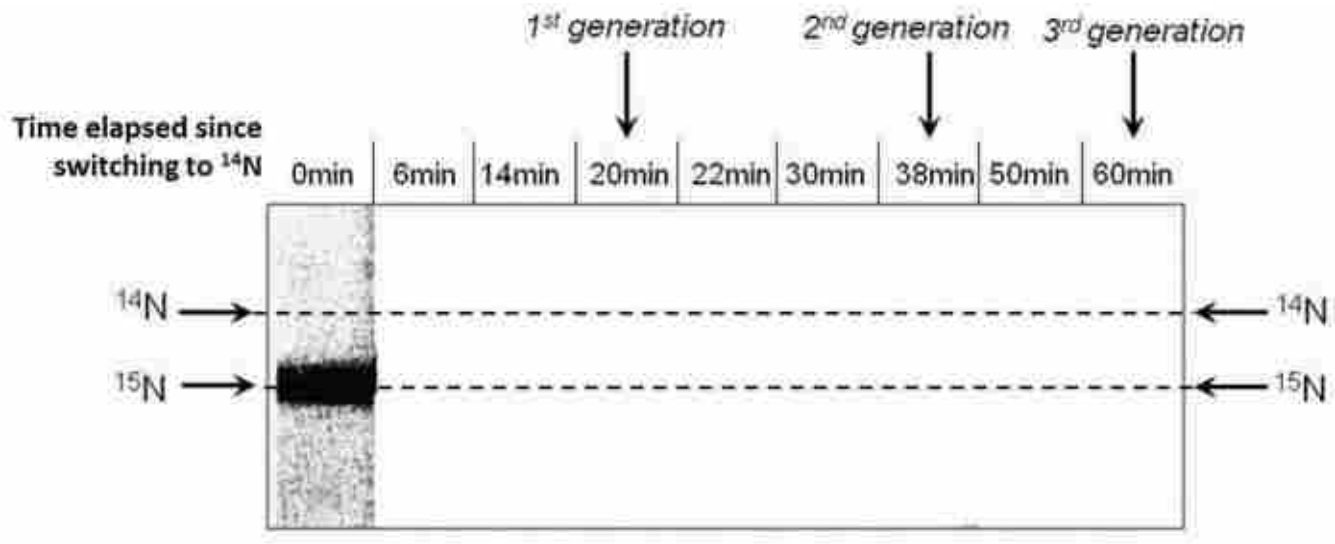
……

……

……[3]

(b) State another model of DNA replication not shown in Fig. 3.1 draw only its band patterns for the 1st, 2nd and 3rd generations in the Figure below.

Model of DNA replication: ……



[2]

Fig. 3.2 shows a simplified representation of DNA replication occurring on a linear chromosome.

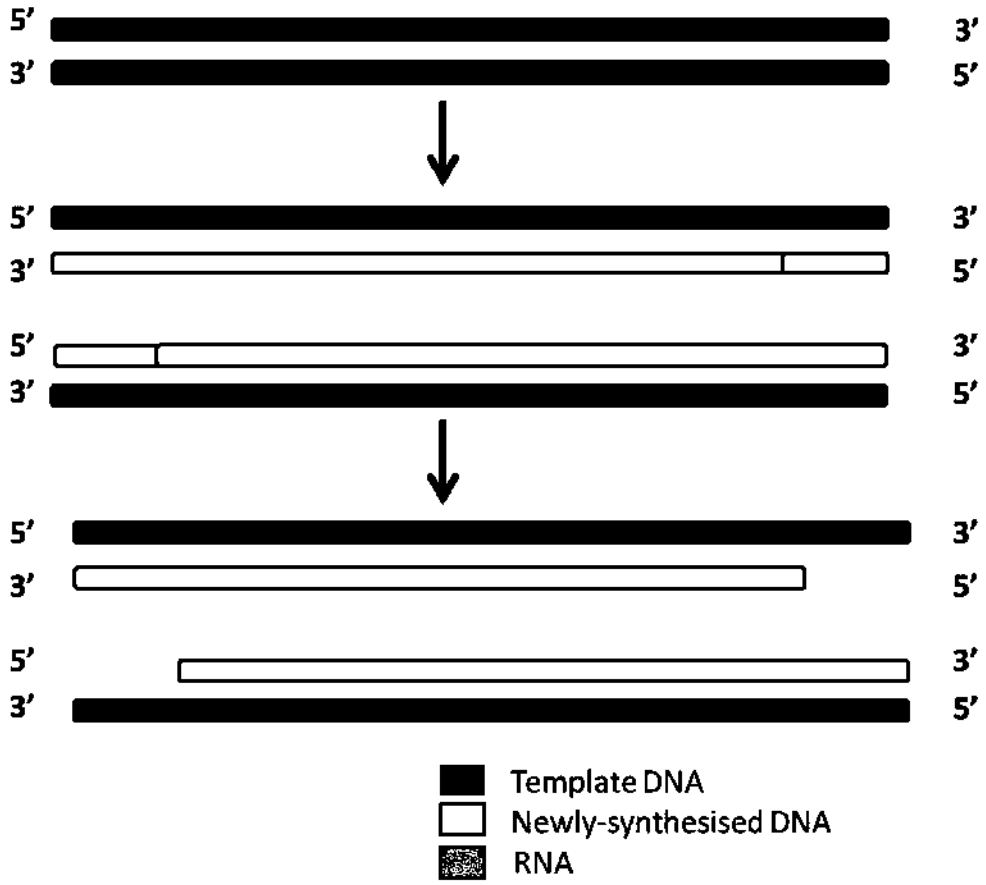


Fig. 3.2

(c) Explain how certain cells address the molecular issue reflected in Fig. 3.2.

……

……

……[2]

The cellular process shown in Fig. 3.2 has many similarities with translation even though the products formed are different. Some of the similarities are that they both take place in 3 different stages (initiation, elongation, termination), both require energy, monomers for extension, a template for product synthesis as well as bond formation involving the removal of a water molecule.

(d) State three other similarities between the cellular process shown in Fig. 3.2 and translation.

……

……

……

…… [3]

[Total: 10]

4 Fig. 4.1 shows two different stages, A and B (as shown by arrow) of the HIV reproductive cycle.

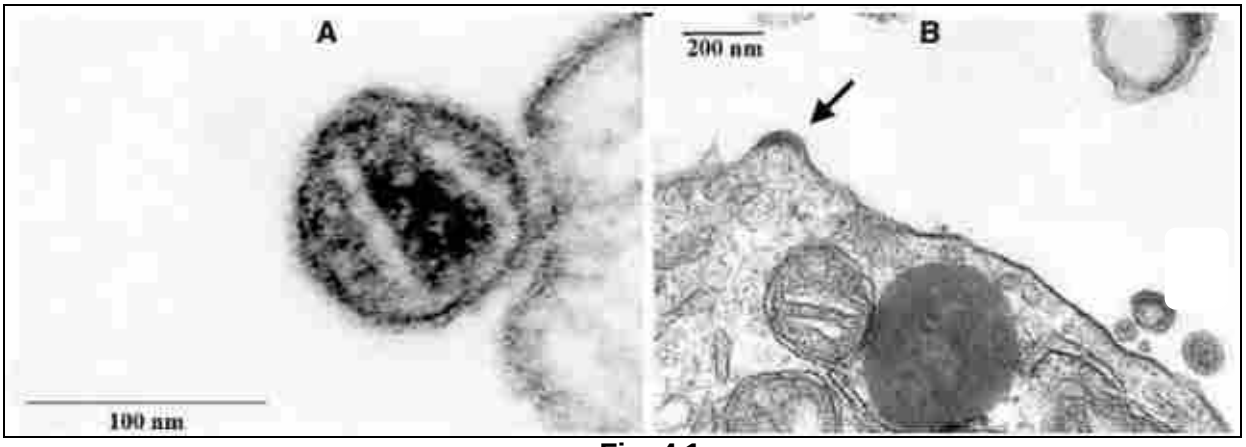


Fig. 4.1

(a) Describe the events occurring in stage A of the HIV reproductive cycle.

……

……

……[2]

(b) Compare the stage immediately following stage A with stage B.

……

……

……[2]

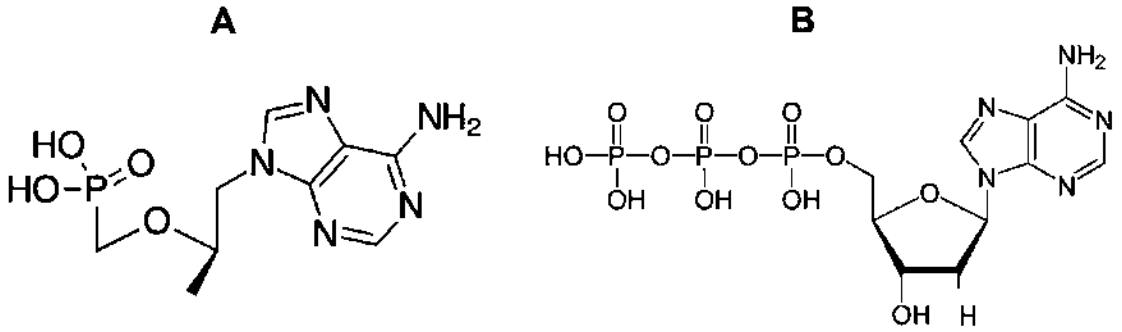
(c) Contrast the final stage of the reproductive cycle of HIV and T4 phage.

……

……[1]

For treatment, HIV-infected patients can receive HIV antiviral drugs such as Tenofovir (Fig. 4.2A).

Fig 4.1B shows an adenosine triphosphate (dATP) molecule, which shares similar chemical groups to Tenofovir.



Tenofovir **dATP**

Fig. 4.2

(d) With reference to Fig. 4.2, suggest how Tenofovir acts as a drug that interferes with the HIV reproductive cycle.

……

……

……[2]

HIV entry into cells requires involvement of at least one type of co-receptor. CCR5 is required for HIV virus entry. CCR5 Δ32 is a 32-base-pair deletion that introduces a premature stop codon into the CCR5 receptor locus, resulting in a non-functional receptor.

Timothy Ray Brown was an AIDS patient who received a hematopoietic stem cell transplant from a donor with homozygous CCR5 Δ32 on the CCR5 gene. After the transplant, he stopped his antiretroviral treatment. Following that, it was found that Timothy's HIV viral levels steadily decreased and his CD4 T- cell count increased. Eventually, he was found to be cured from HIV.

(e) Suggest why not all HIV-infected patients can be cured with this therapeutic method.

……

……[1]

(f) Explain how HIV infection may result in the death of infected CD4 cells.

……

……

……[2]

[Total: 10]

5 Fig. 5.1 shows the formation of a eukaryotic transcription initiation complex.

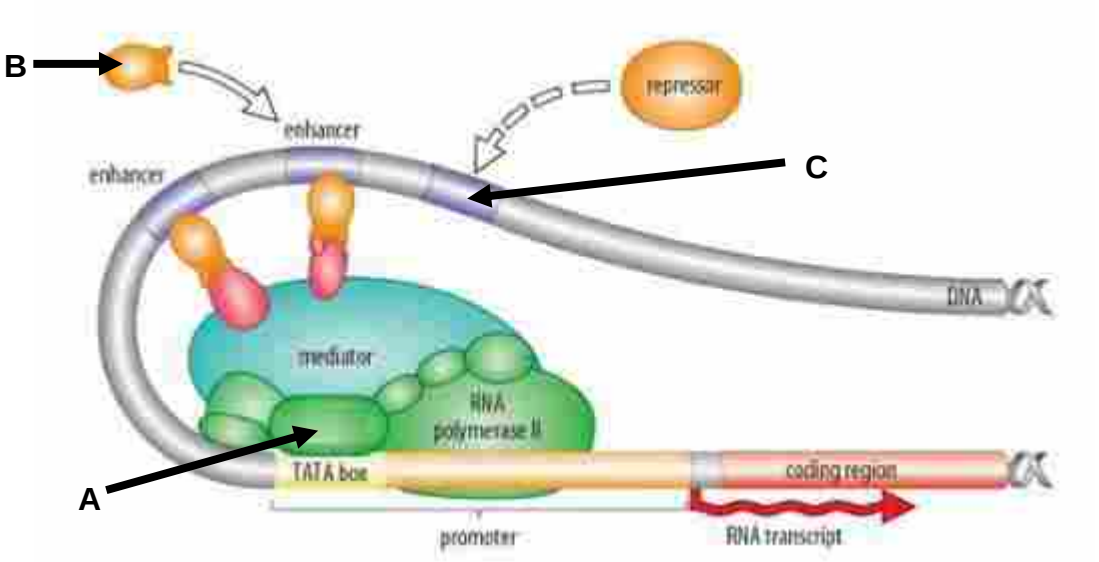


Fig. 5.1

(a) Identify the following proteins.

A: _____

B: _____

C: _____

[3]

(b) Explain how the eukaryotic transcription initiation complex for high rate of transcription can be formed.

……

……

……

……

……[4]

High rate of transcription caused by mutations in cancer critical genes may result in dysregulation of cell cycle control and subsequently lead to uncontrolled cell division.

c-myc is a regulator gene that codes for a transcription factor. A mutated version of c-myc that is highly expressed is found in many cancers. Fig 5.2 shows the relative level of expression of c-myc in normal and cancer prostate tissue.

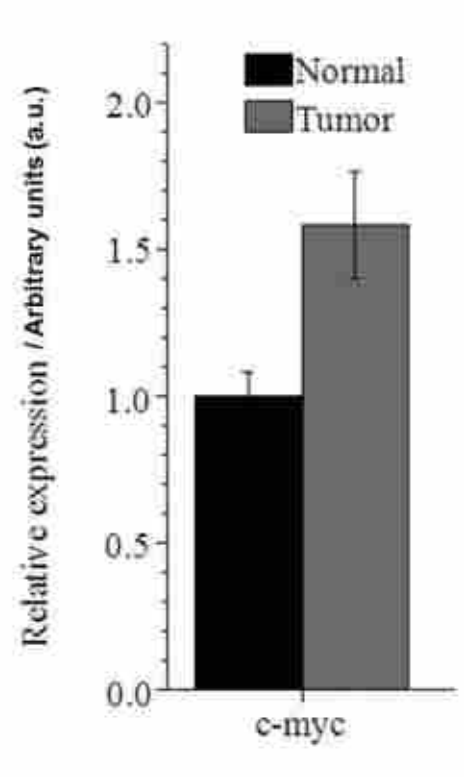


Fig 5.2

(c) With reference to Fig.5.2, explain how mutation in the c-myc gene led to increased expression in cancer prostate tissue.

……

……

……

……[3]

[Total: 10]

6 Fig. 6.1 shows a Calico cat with a mosaic coat with patches of orange and black. It is known that fur coat colour in cats is determined by a single gene. Only female cats can develop calico fur coat. Male cats usually have only orange or black fur coat.

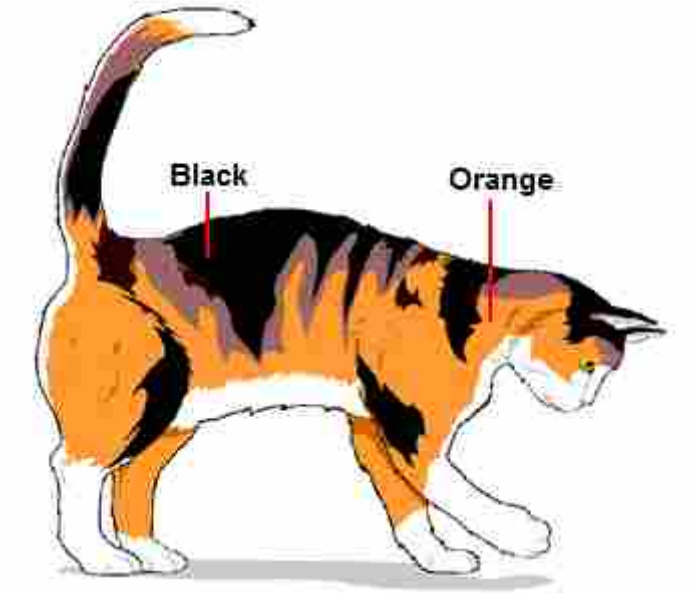


Fig. 6.1

(a) Identify the type(s) of inheritance determining Calico fur coat colour in cats.

……

……[1]

(b) Using B to represent allele for black coat and R to represent allele for orange coat, draw a genetic diagram to show how a cat-breeder can obtain Calico cat from a cross between a pure-breeding black male and an orange female cat.

[4]

Coat colour inheritance in horses is different from cats. Two unlinked genes *E* and *G* control coloured coat in horses. The two genes are thought to be involved in the same metabolic pathway for pigment formation.

- Horses may be bay, black or chestnut in colour.
- Horses may be bay / black when at least one dominant allele *E* is present.
- Chestnut coat colour is always produced in the presence of two copies of the e allele.

Horses coat colour goes through a natural graying process. Horses born with bay, black or chestnut coat colour will steadily turn gray. This process is mediated by a single copy of the dominant allele G regardless of the genotype of the gene E controlling coat colour.

(c) Draw a genetic diagram in the space below to show the result of the cross between two gray horses that were heterozygous at both gene loci G/g and E/e and the resultant phenotypic ratio of the offspring.

[5]

[Total: 10]

7 Fig. 7.1 shows the different modes of signal conduction in a non-myelinated neuron.

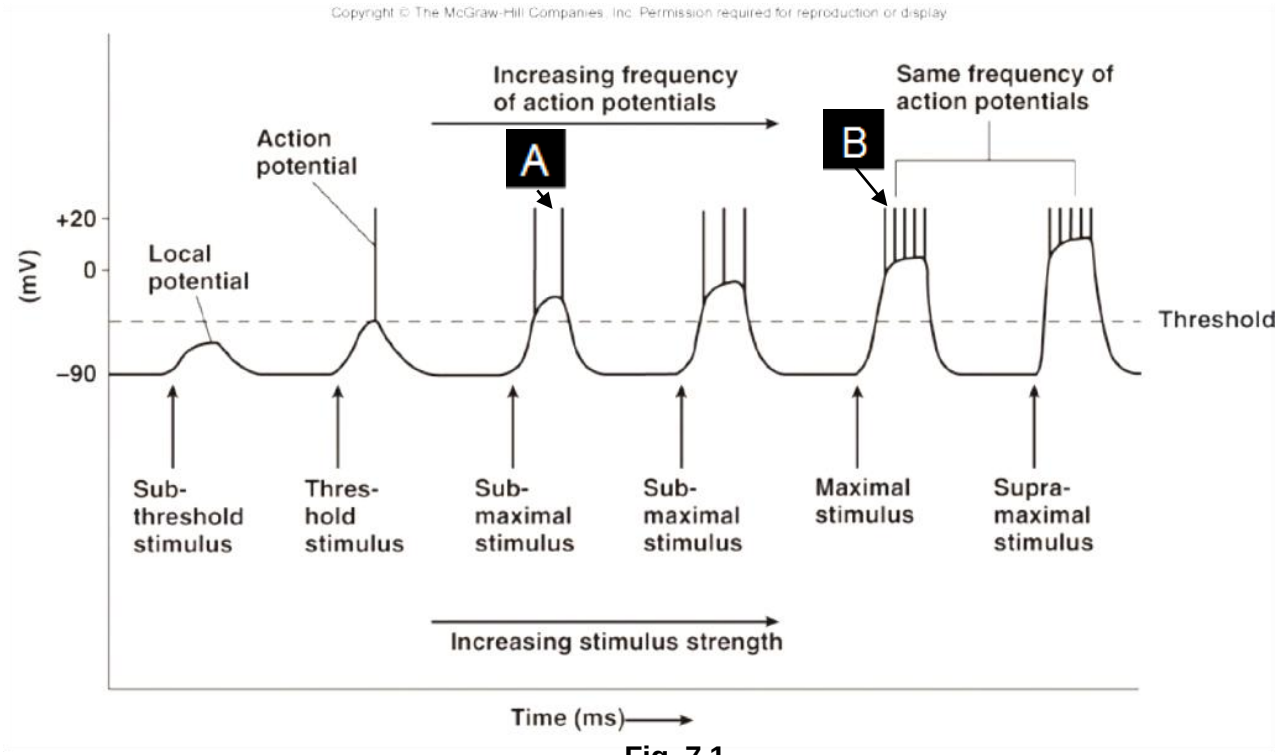


Fig. 7.1

(a) State one factor that contributes to unidirectional conduction of impulses down an axon.

……..[1]

With reference to Fig. 7.1 for all questions following,

(b) explain why there is no action potential generated with a sub-threshold stimulus.

……

……

……..[2]

(c) explain how the time interval between action potentials seen in label **B** is shorter than the time interval between action potentials seen in label **A**.

……

……

……

……..[3]

(d) state the advantages in the ability of neurons to display these characteristics shown in Fig. 7.1.

……

……

……..[2]

(e) explain what would increase the speed of the signal conduction down the neuron.

……

……

……..[2]

[Total: 10]

8 The Grand Canyon National Park is home to two groups of squirrels. The Albert squirrels *Sciurus aberti* live generally on the south rim of the canyon and the Kaibab squirrels *Sciurus kaibabensis* live on the north rim of the canyon (Fig. 8.1 and Fig. 8.2).

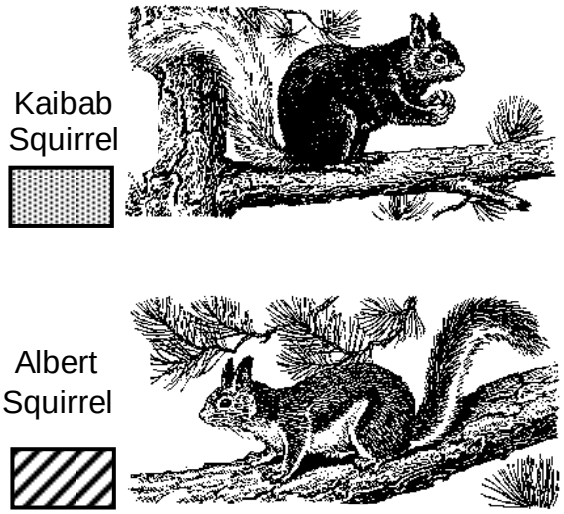


Fig. 8.1

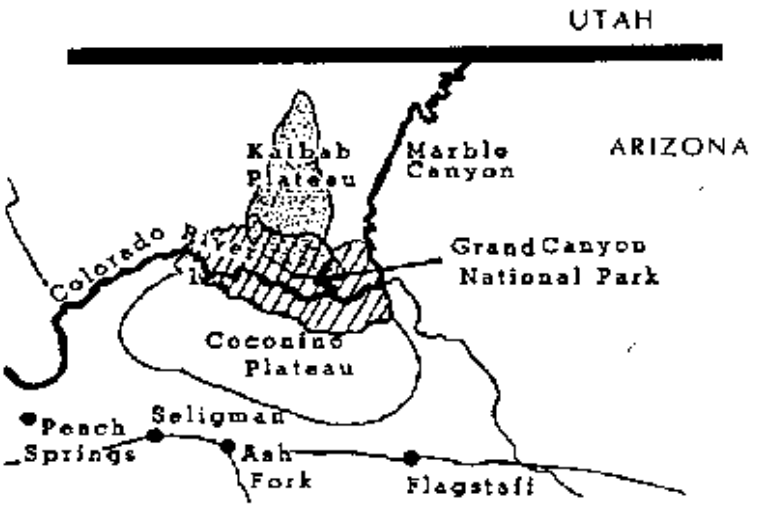


Fig. 8.2

The north rim is about 370 m higher than the south rim. Almost twice as much precipitation falls on the north rim than on the south rim every year. The two groups share many characteristics, but they do not look the same, both groups have tasselled ears, but each group has a unique fur colour pattern.

(a) Explain which Darwinian principles can be applied from the above information on *S. alberti* and *S. kaibabensis*.

……

……

……

……

……[4]

Several studies have been done on the phylogenetic relationship of the squirrels in and around the Grand Canyon region. Fig. 8.3 is one such study based on cytochrome b DNA sequences.

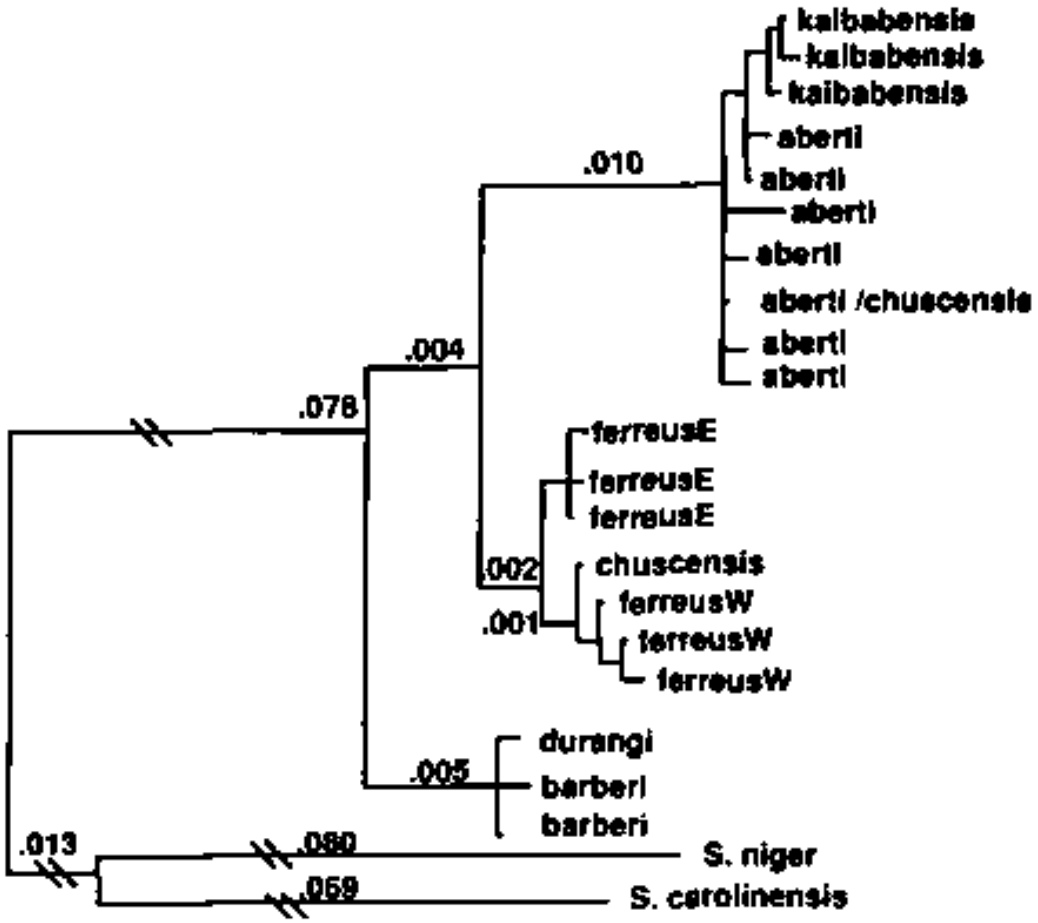


Fig.8.3 Phylogenetic relationship between six *sciurus* subspecies base on cytochrome b sequences constructed by the neighbour-joining method of Saitou and Nei (1987) using the *S. niger* and *S. carolinesis* (Thomas and Martin 1993) sequences as outgroups. Branch lengths and confidence probabilities are noted above and below the branches respectively.

(b) With reference to information already given and also to Fig. 8.3, it is clear that divergent evolution or adaptive radiation is occurring in the evolution of *S. alberti* and *S. kaibabensis*

Explain why it is not convergent evolution.

……

……

……..[2]

(c) (i) With reference to information already given and also to Fig. 8.3, suggest with reasons what kind of speciation *S. Alberti* is undergoing.

……

……

……..[2]

(ii) With a known species concept, explain what would be the determining factor confirming *S. alberti* and *S. kaibabensis* as two separate species.

……

……

……[2]

[Total: 10]

Section B

Answer **one** question. Answer each part on a **separate** piece of paper.

Write your answers on separate answer paper provided.
Your answer should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answer must be in continuous prose, where appropriate.
Your answer must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

9 **(a)** Describe cell signaling with the G-protein coupled receptor with a named ligand and its corresponding cellular response. [8]

(b) Explain the advantages and disadvantages of a phosphorylation cascade. [6]

(c) Contrast with elaboration, anaerobic respiration with light independent reaction (Calvin cycle). [6]

[Total: 20]

10 **(a)** Contrast binary fission and mitosis. [6]

(b) Describe generalised and specialised transduction. [8]

(c) In an experiment using T4 bacteriophage, different component molecules were labelled.

- T4 bacteriophages with protein coats labelled with radioactive sulfur.
- T4 bacteriophages with DNA labelled with radioactive phosphorus.

The differently-labelled bacteriophages were allowed to infect host bacteria.
The inside and outside of infected bacteria before lysis were tested for radioactive sulfur and radioactive phosphorus.

Describe and explain the expected results of the experiment. [6]

[Total: 20]

END OF PAPER

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CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

Answers

CANDIDATE NAME			
CLASS	**2T**	**INDEX NUMBER**	

BIOLOGY

9648/02
23rd August 2016
2 hours

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

There are two sections in this paper.

Section A]
Answer all questions

Section B]
Answer all questions. Answer each part on a **separate** piece of paper.

At the end of the examination, fasten all work securely together.
The number of marks is given in brackets [ ] at the end of each question or part of the question.

For Examiner's Use	
Section A	**80**
1 [10]	
2 [10]	
3 [10]	
4 [10]	
5 [10]	
6 [10]	
7 [10]	
8 [10]	
Section B	**20**
9a/10a	
9b/10b	
9c/10c	
TOTAL	**45**

This document consists of **31** printed pages and **0** blank page.

[Turn over

Section A

Answer **all** questions in this section.

1 The figure below shows three structural components of the membrane system in a pancreatic cell.

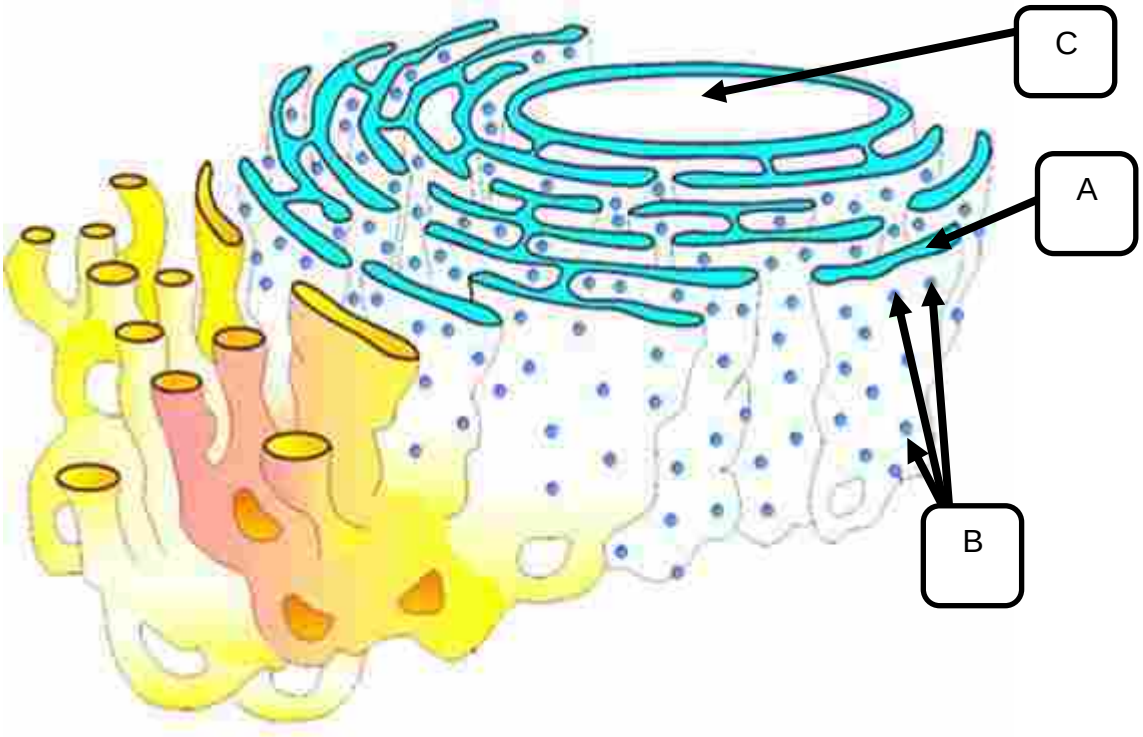


Fig. 1.1

(a) State the name and function of the structures in Fig. 1.1.

Structure A

Name: ……

Function: …… [1]

1. **Cisternae** of rough endoplasmic reticulum / rER, involved in structural **folding** of primary **polypeptide.**

[L1]

Structure B

Name: ……

Function: …… [1]

2. **Bound ribosomes** of rough ER, involved in the **synthesis of polypeptide** chain which enters the rER.

[L1]

(b) State what is **structure C** and explain how **structure A** remains in close proximity to **C.**

……

……[2]

SC: Structure C / How Structure A remains close to structure C
OR: Nucleus / continuous membrane with nucleus

1. **Nucleus,**
2. The **nuclear envelope / membrane** / **double membrane** of the nucleus is **continuous with** the **membrane** system of the **rough ER.**

[L2]

Fig. 1.2 shows a hormone essential for regulation of high blood glucose levels.

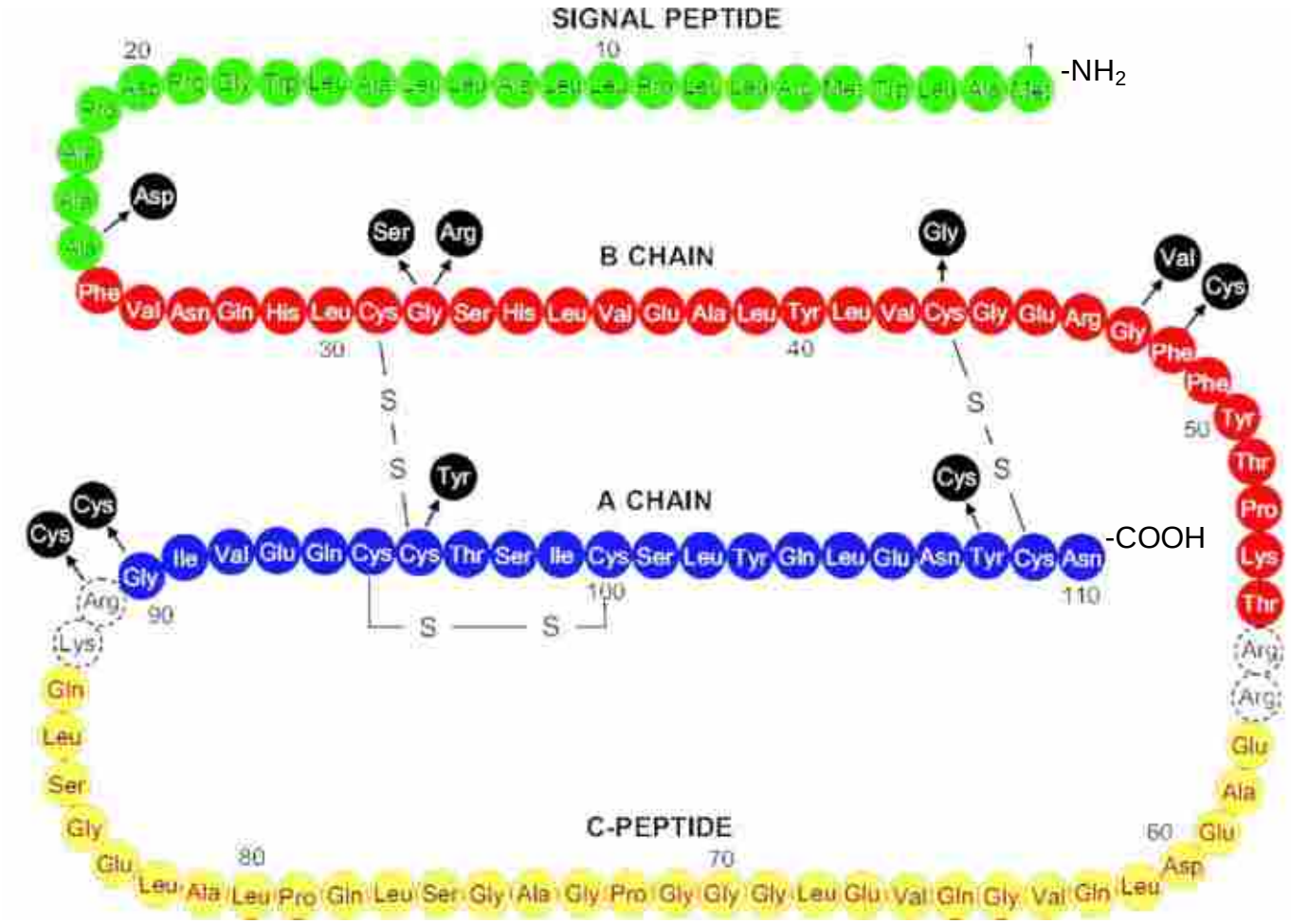


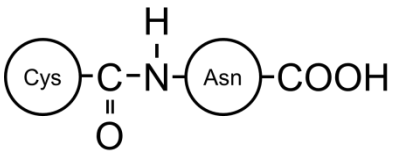
Fig. 1.2 Unit sequences of wild type (WT) and the mutant hormone. The mutations are noted in black circles together with location in the B (25 to 5) or A chain (90-110). The dashed circles indicate the basic residues that are activation cleavage sites.

(c) With reference to Fig. 1.2, draw out the bond (ensure correct orientation) formed between units 109 and 110 of the A-chain.

[2]

SC: Draw / Bond / orientation
OR: Peptide bond / COOH on right same as in aa 110

1. Peptide bond
2. Correct orientation



[L2]

(d) With reference to Fig 1.2, suggest how amino acid substitutions between 90 and 109 could occur and what would be the corresponding effect on the resultant mutant hormone.

……

……

……

……[4]

SC: how aa substitution occur / effect on hormone
OR: base pair substitutions on template strand
– change amino acid Example 96 Cytosine / Cys to Tyrosine / Tys
- Affects the disulphide bond between 31 Cys and 96 Cys
- Changing the quaternary structure [chain A and B >2 molecules]
- Change in overall configuration of hormone

1. **Base pair substitution** on the **non coding strand of DNA**.

Any pair 2 & 3 or 4 & 5
2. results in a change in **codon** for a specific amino acid **96 Cys to Tys**.
3. resulting in **the loss of a disulphide bond** between **96 Cys and 31 Cys**.

Any 1 of the following:
4. results in a change in **codon** for a specific amino acid **108 Tyr to Cys**.
5. resulting in **the gain of a disulphide bond** between **43 Cys and 108 Cys**.

6. **changing** the **quaternary structure** of the hormone and its **overall specific configuration**.

(Max 4)

[L3]

[Total: 10]

2 The figure shows the molecular configuration of chymotrypsin. Chymotrypsin is one of the major proteases in the human digestive tract, in which its role is to hydrolyse large protein molecules into smaller peptides that are then further processed by peptidases. Fig. 2.1a shows a blown up representation of a portion of chymotrypsin shown in Fig. 2.1b.

Fig. 2.1a

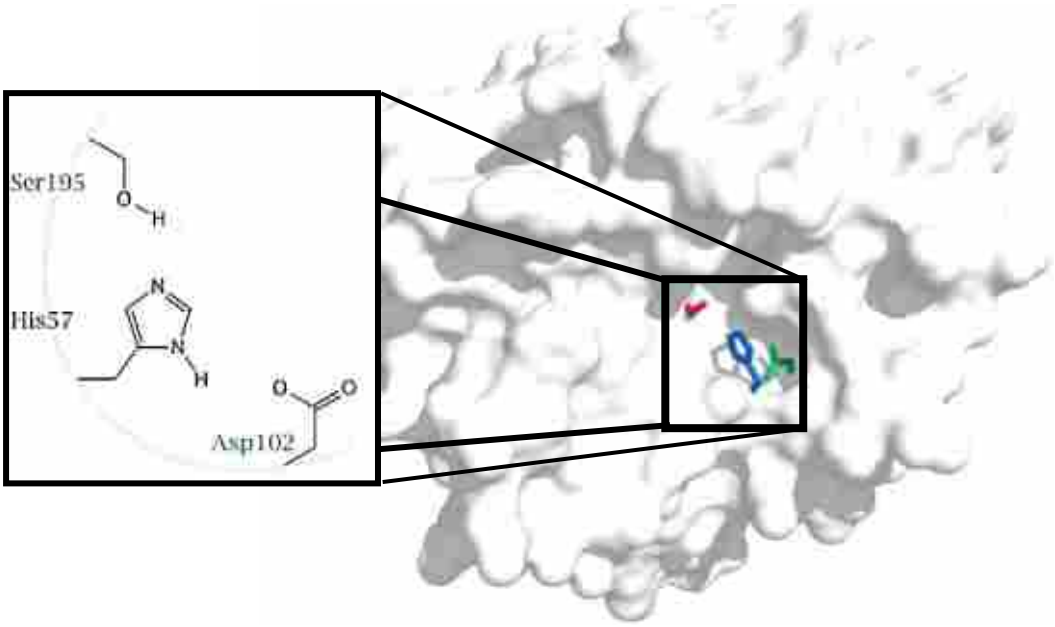


Fig. 2.1b

(a) Using the 'induced-fit hypothesis', explain the mechanism in which chymotrypsin carries out its function.

……..

……

……[2]

SC: Induced fit / mechanism / chymotrypsin / function.
OR: 1. In the induced-fit hypothesis, catalytic R groups of the active site come into correct orientation and bind.
2. The binding causes conformational change that fits the enzyme more closely with the substrate and in so doing a strain on the substrate bond to be broken.

1. In the 'induce fit' hypothesis, **catalytic R groups** of the **active site** come into correct orientation and **bind to the protein**.
2. The bind causes **conformational change** that **fits the enzyme more closely** with the substrate.
3. and in so doing **causes a strain** in the structural bond **lowering the activation energy** of the reaction.

(Max 2)

[L2]

Fig. 2.2 shows the energy exchange in a chemical reaction without the enzyme present.

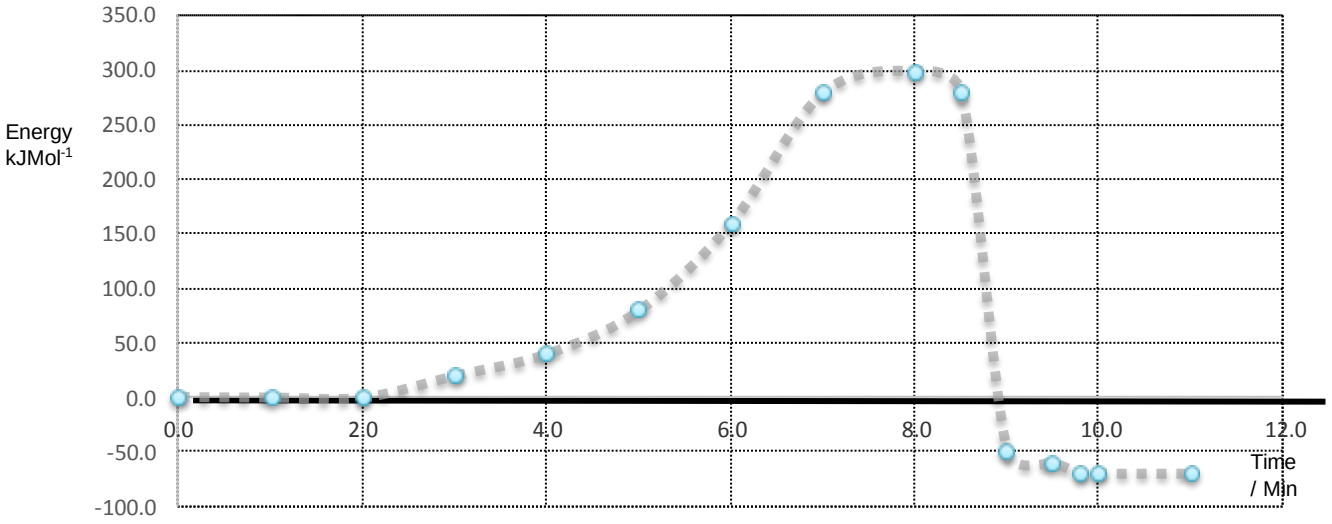
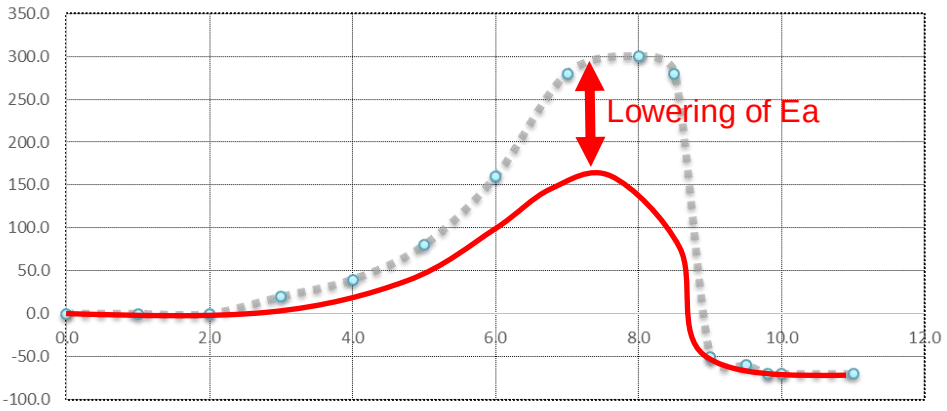


Fig. 2.2

(b) On the graph above draw out the plot tracing the effect of enzyme action and label the effect of enzyme on activation energy. [2]



Correct drawing of the enzyme reaction graph [1 mark]
Lowering of Ea. [1 mark]

[L2]

Fig. 2.3 shows the effects of substrate on enzyme reaction.

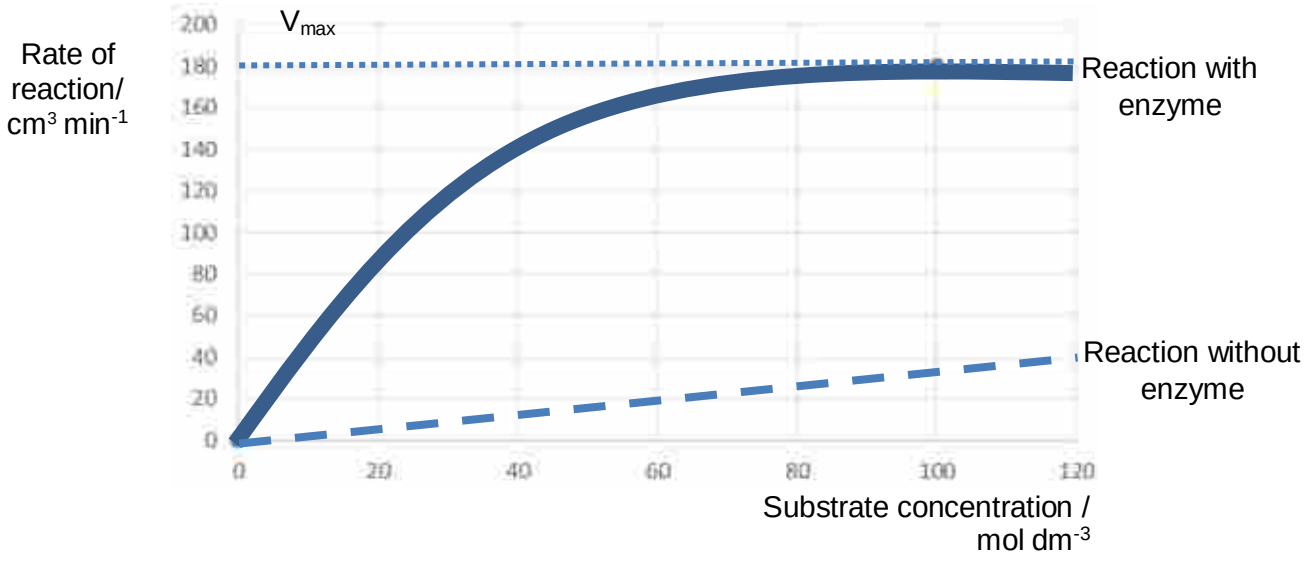


Fig. 2.3

(c) Explain what can be inferred from the graph in Fig. 2.3, with reference to substrate concentration and limiting factors.

……

……[2]

SC: inferred from graph / ref Sub con. & limiting factors..
OR: 1. DRUM substrate con below 80 mol dm^{-3} / limiting factor / adding more rate of reaction increases.
2. From 80 mol dm^{-3} onward, substrate concentration no longer is the limiting factor

.

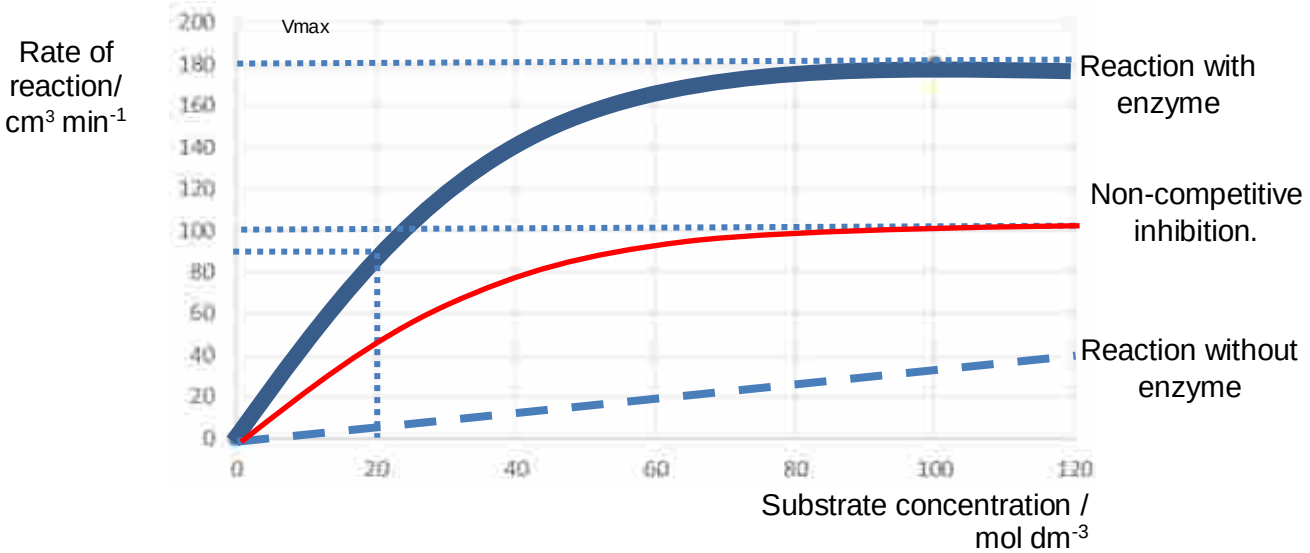
1. From **0 to 80 mol dm^{-3} substrate** is the **limiting factor** since **upon adding more substrate** sees the **rate of reaction increasing**.
2. From **80 mol dm^{-3} onward**, **substrate concentration is no longer the limiting factor.**
3. **Citation of Data**.

(Max 2)

[L2]

(d) On Fig. 2.3 draw a curve representing the effect of a non-competitive inhibitor on rate of reaction with no change in the affinity of the enzyme.

[2]



Non-competitive inhibitor graph plateaus and does not reach V_{max}. [1 mark]
K_m values of Reaction with enzyme and that of the Non-competitive are the same. [1 mark]

[L2]

(e) Account for why the Michaelis constant for both the non-competitive inhibitor and the reaction without inhibitor is the same.

……

……[2]

SC: Michaelis Const / both rxn SAME
OR: 1. **Michaelis constant (Km) / ½ Vmax**

2. Since **binding of the inhibitor** / **a site other than the active site** / **allosteric site** there is **no change in affinity** / **Km** value **remains the same**.

1. **Michaelis constant (K_m)** is derived by **measuring ½ V_{max} of each respective graph..**
2. Since **binding of the inhibitor** is at **a site other than the active site** / allosteric site there is **no change in affinity** of the active site of the enzyme to its substrate and Km value remains the same.
3. The **3D configuration of the active site is changed** with the binding of the inhibitor.

(Max 2)

[L2]

[Total: 10]

3 Cells were transferred and grown in ^{15}N medium for many generations before they were transferred to ^{14}N medium again and allowed to divide.

DNA was extracted periodically from the culture and subjected to density gradient centrifugation using caesium chloride.

Fig. 3.1 shows the density gradient results across three generations.

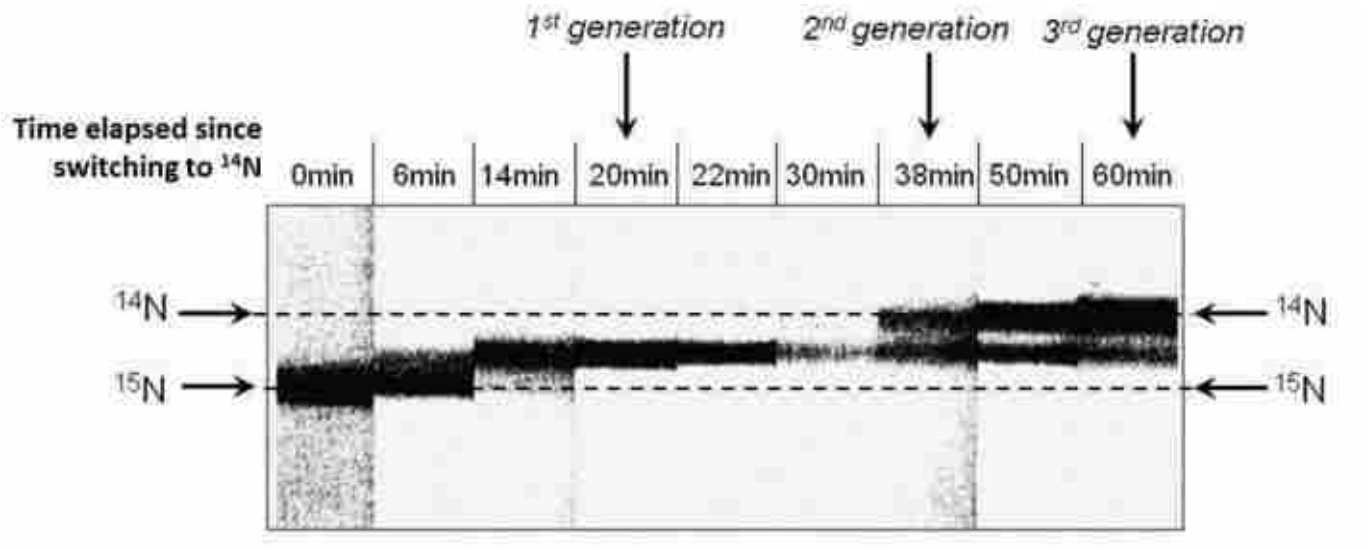


Fig. 3.1

(a) With reference to Fig. 3.1, account for the model of DNA replication which these cells undergo.

……

……

……

……[3]

S: Account (CW), with reference..Fig. 3.1, model..DNA replication, cells…undergo,

C:
- With reference Fig. 3.1 → Must cite information from Fig. 3.1 in answers
- There are 3 models of DNA replication: Semi-conservative, conservative, dispersive
- Model here is semi-conservative
  - 1 intermediate band at 1st generation
  - 2 intermediate band, 2 bands at 2nd generation, 2 bands at 3rd generation with intermediate band becoming thinner and light band becoming thicker.

ORE:

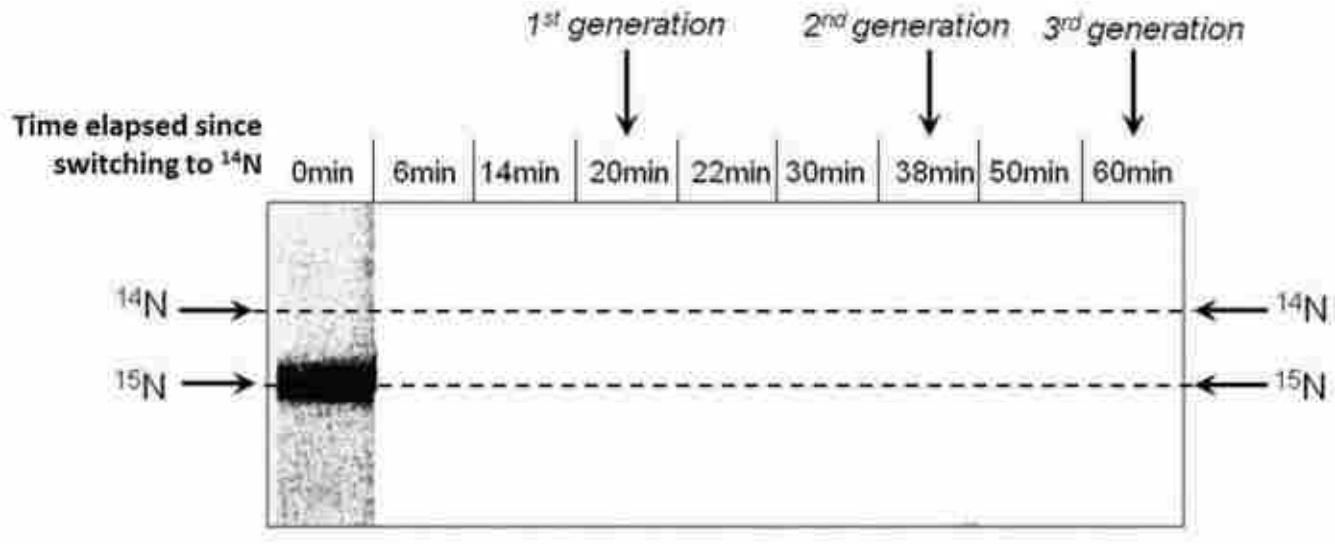
1. The model of DNA replication is **semi-conservative.**
2. At the **first generation**, there is only **one $^{14}N/^{15}N$** / hybrid **band**, which suggests the **parental strands**, that **contain ^{15}N separate** to serve as **template** for the synthesis of the **newly synthesised strand,** which **contains ^{14}N**.
3. At the **second generation**, there is **one $^{14}N/^{15}N$** / hybrid **band** and **1 light band** which align with the semi-conservative model of replication as the former contains DNA with **1 strand containing ^{15}N and another containing ^{14}N**, whereas the latter contains DNA with **both strands containing ^{14}N**.
4. For the **third generation**, there is still **one $^{14}N/^{15}N$** / hybrid **band** and **1 $^{14}N/^{14}N$ band** and the intermediate band becomes thinner whereas the light band becomes thicker due to **more DNA** molecules containing **^{14}N on both strands**.

(Max 3)

[L2]

(b) State another model of DNA replication not shown in Fig. 3.1 draw only its band patterns for the 1st, 2nd and 3rd generations in the Figure below.

Model of DNA replication: ……



[2]

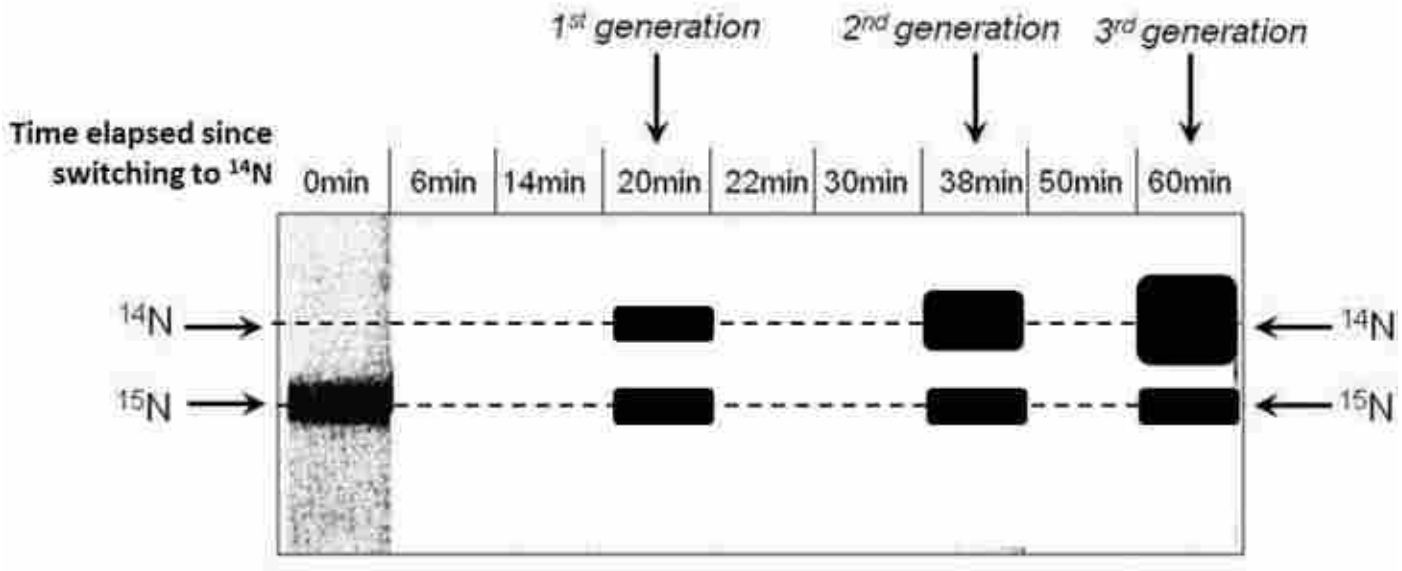
S: State….Draw (CW), model of DNA replication, not shown in Fig. 3.1, draw..band patterns..1st,2nd,3rd,

C:

- Model of DNA replication shown in Fig. 3.1: Semi-conservative
- Other models: Conservative & Dispersive

ORE:

- Model of DNA replication: **Conservative** replication

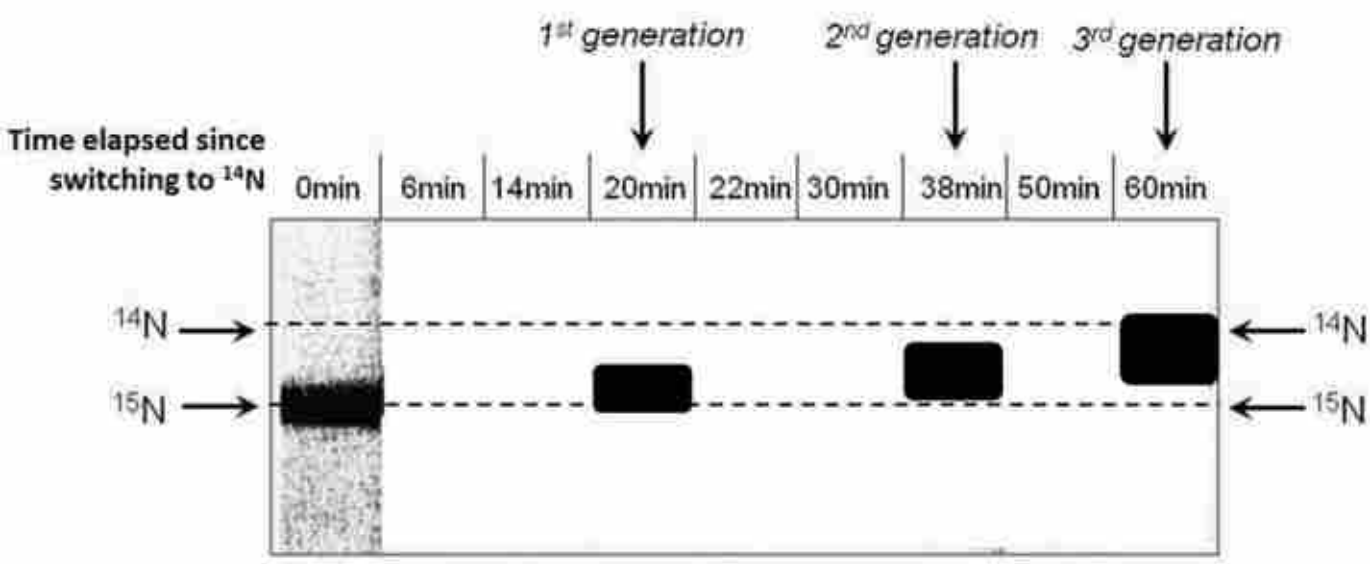


Correct positioning of the bands. [1 mark]

Correct amount of DNA as shown by thickness of band or shade of band. [1 mark]

OR

ORE:
- Model of DNA replication: **Dispersive** replication [1 mark]



Correct positioning of the bands. [1 mark]
Correct amount of DNA as shown by thickness of band or shade of band. [1 mark]

[L2]

Fig. 3.2 shows a simplified representation of DNA replication occurring on a linear chromosome.

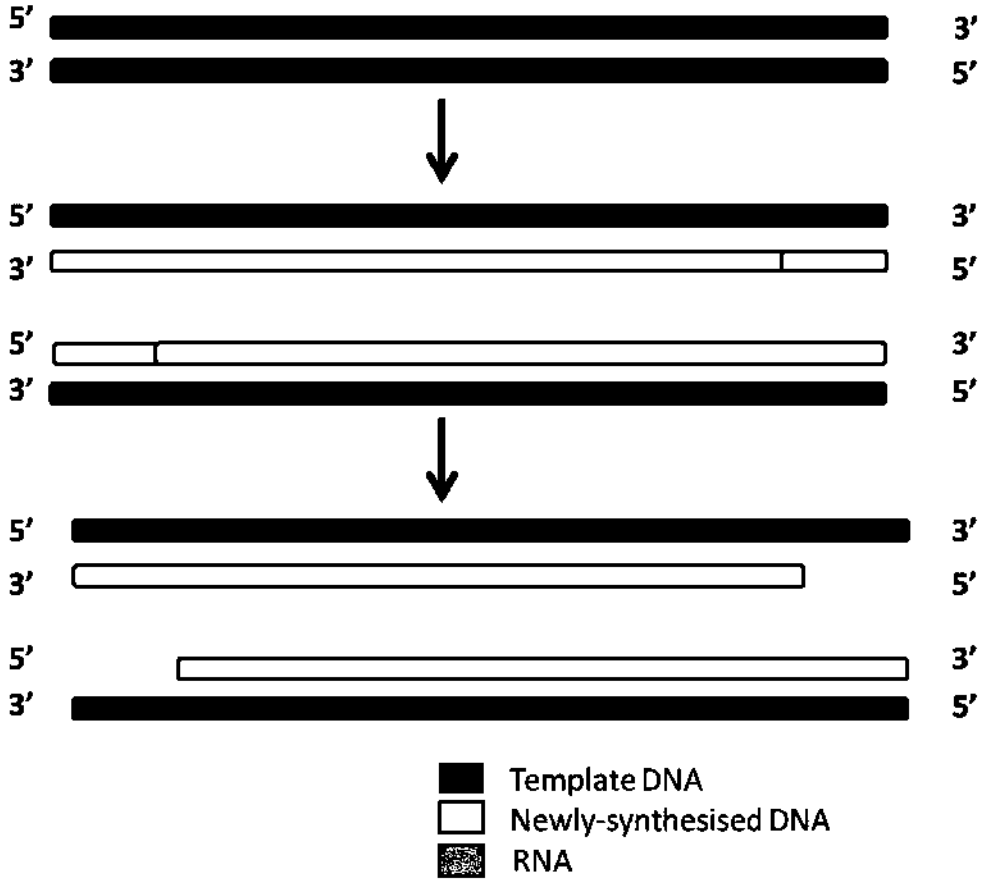


Fig. 3.2

(c) Explain how certain cells address the molecular issue reflected in Fig. 3.2.

……

……

……[2]

S: Explain how (CWs), certain cells, address, molecular issues, reflected..Fig. 3.2

C:

- Molecular issue reflected in Fig. 3.2: End replication problem
- Certain cells: Stem cells and cancer cells
- How:
  - Telomerase lengthen the telomeres
  - They have an RNA template which adds the DNA sequence.

ORE:

1. An enzyme, **telomerase** is an enzyme that **adds telomere** repeat **sequences** to the **3' end** of **DNA** strands to act as a **buffer** for the **end-replication problem**. (Reject: prevent / resolve)
2. Telomerase has a short molecule of **RNA** that serves as a **template** (AAUCCC)
3. which is **complementary** to the **non-coding** **telomere repeat** (TTAGGG).

(Max 2)

[L2]

The cellular process shown in Fig. 3.2 has many similarities with translation even though the products formed are different. Some of the similarities are that they both take place in 3 different stages (initiation, elongation, termination), both require energy, monomers for extension, a template for product synthesis as well as bond formation involving the removal of a water molecule.

(d) State three other similarities between the cellular process shown in Fig. 3.2 and translation.

……

……

……

…… [3]

S: State (CW), cellular process…Fig. 3.2, translation, other similarities

C:

- Cellular process in Fig. 3.2: DNA replication
- Similarities between DNA replication & Translation
- Other similarities: Cannot mention both require energy, monomers for extension, a template for product synthesis as well as bond formation involving the removal of a water molecule

ORE:

1. Both processes require **enzymes** (DNA replication: DNA polymerase &and Translation: Peptidyl transferase).
2. Both processes involve **complementary base pairing**.
3. Both processes are **regulated** by regulatory **factors** (DNA replication: cyclins, CDKs, Helicase & Translation: translational regulatory proteins).
4. Both processes are **compartmentalised** in the **cell** (DNA replication: nucleus, Translation: ribosome).
5. **Errors** can occur for both processes.
6. Both processes **only occur** when **required** by the cell.

[L3]

[Total: 10]

4 Fig. 4.1 shows two different stages, A and B (as shown by arrow) of the HIV reproductive cycle.

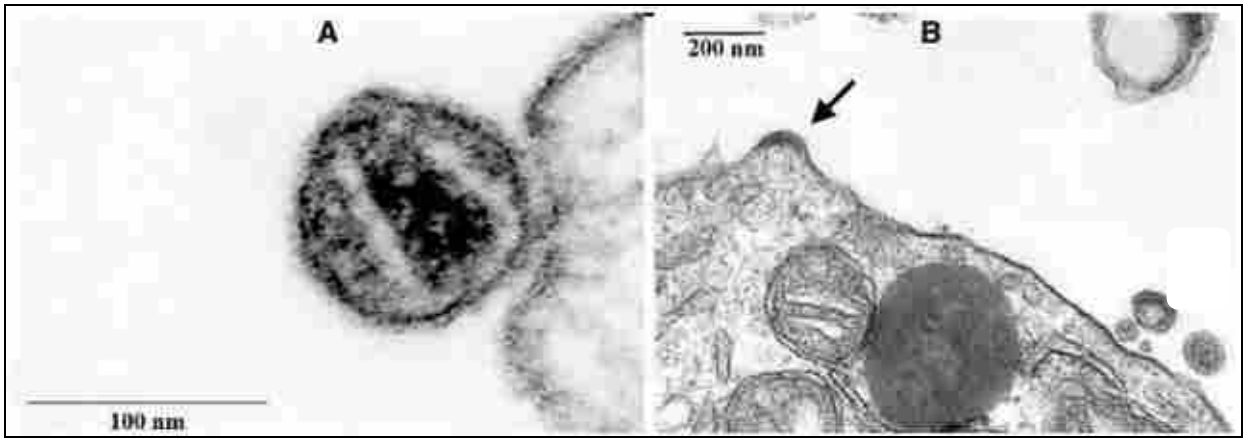


Fig. 4.1

(a) Describe the events occurring in stage A of the HIV reproductive cycle.

……

……

……..[2]

S: Describe (CW), events, occurring, stage A, HIV reproductive cycle

C:
- Stage shown: Adsorption
- GP120 binds CD4 receptor and co-receptor CCR5/CXCR4.

ORE:

1. **GP120** on **viral envelope** binds to **CD4 receptor** on **host cell surface membrane**.
2. **GP120** also **binds** to **co-receptor CCR5/CXCR4** on host cell surface membrane.

Reject: Fusion (as fusion is yet to occur as seen in Fig. 4.1)

[L2]

(b) Compare the stage immediately following stage A with stage B.

……

……

……..[2]

S: Compare(CW), stage immediately following A, with B

C:
- Compare→ Cite one difference and one similarity
- Stage immediately following stage A → Fusion
- Stage B → Budding
- Fusion vs Budding

ORE:

	Basis of comparison	Stage immediately following stage A (Fusion)	Stage B (Budding)
Difference	1. Virus entry/exit	Virus is **entering** the **host cell** during **fusion**.	Virus is **leaving** the **cell** via **budding**.
Difference	2. Membrane interaction	During fusion, **viral envelope fuses** with **cell surface membrane**. (Reject: Endocytosis)	During budding, virus **acquires host cell surface membrane** as **viral envelope**.
Similarity	3. Cytoskeleton involvement	Both processes involve **rearrangement** of the **cytoskeleton** at the cell surface membrane.	
Similarity	4. Location of capsid	For both processes, the viral **capsid** is not totally surrounded by the viral envelope and is partly **in** the host cell **cytoplasm**.	
Similarity	5. Requirement of energy	Both processes **require energy / ATP**.	
Similarity	6. Rearrangement of phospholipid	Both processes involve the **rearrangement of phospholipid**.	

(1 similarity and 1 difference, Max 2)

[L3]

(c) Contrast the final stage of the reproductive cycle of HIV and T4 phage.

……

……....[1]

S: Contrast (CW), stage B, release stage, T4 phage

C:
- Contrast → Only cite difference (reject similarities)
- T4 phage undergoes lytic cycle
- Budding (of HIV) vs. Release via osmotic lysis (of T4 phage)

ORE:

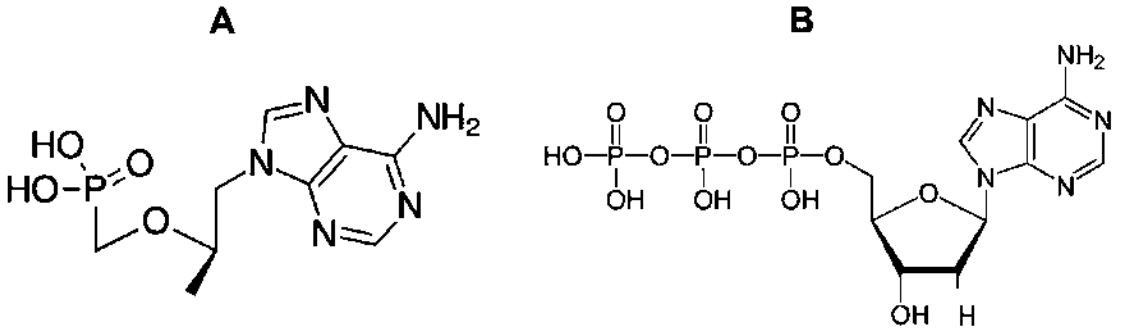
1. Release of **HIV** via **budding** will **not** directly **kill** the **host cell** but release of **T4 phages** via osmotic **lysis** will **kill** the host cell.
2. For the release of T4 phages, a phage-encoded **enzyme, lysozyme** will break down the bacterial peptidoglycan causing osmotic lysis and release of the intact new bacteriophages whereas for the release of HIV **no enzymes** are involved.

(Max 1)

[L3]

For treatment, HIV-infected patients can receive HIV antiviral drugs such as Tenofovir (Fig. 4.2A).

Fig 4.1B shows an adenosine triphosphate (dATP) molecule, which shares similar chemical groups to Tenofovir.



Tenofovir **dATP**

Fig. 4.2

(d) With reference to Fig. 4.2, suggest how Tenofovir acts as a drug that interferes with the HIV reproductive cycle.

……

……

……[2]

S: Suggest how (CW), with reference to Fig. 4.2, Tenofovir, act..drug, interferes HIV cycle

C:
- With reference to Fig. 4.2 → Need to refer to structures of A & B
- A does not have 3' OH but B has.
- Enzyme competing for is reverse transcriptase
- A is competitive inhibitor
- But it causes chain termination → New incoming nucleotides cannot be added.

ORE:
Either 1 or 2
1. Tenofovir is an **analog** of **adenosine triphosphate**. / Tenofovir has a similar shape/conformation to adenosine monophosphate
   OR
2. It is a **competitive inhibitor** for the **reverse transcriptase** enzyme. / It **competes** with **adenosine triphosphate** for the active site of **reverse transcriptase**.

Plus 3 or 4
3. which **lacks** an **3' OH group**,
   - and hence results in **chain termination** (when incorporated into the existing DNA strand.
   OR
4. which **lacks** an **3' OH group**,
   - / and **incoming nucleotide** **cannot form phosphodiester bond** with the DNA molecule.

5. **Reverse transcription** **cannot** be **complete**d (OWTTE) resulting in a **not complete**/ **truncated** **viral DNA** molecule to form.

(Max 2)

[L3]

HIV entry into cells requires involvement of at least one type of co-receptor. CCR5 is required for HIV virus entry. CCR5 Δ32 is a 32-base-pair deletion that introduces a premature stop codon into the CCR5 receptor locus, resulting in a non-functional receptor.

Timothy Ray Brown was an AIDS patient who received a hematopoietic stem cell transplant from a donor with homozygous CCR5 Δ32 on the CCR5 gene. After the transplant, he stopped his antiretroviral treatment. Following that, it was found that Timothy's HIV viral levels steadily decreased and his CD4 T- cell count increased. Eventually, he was found to be cured from HIV.

(e) Suggest why not all HIV-infected patients can be cured with this therapeutic method.

……

……[1]

S: Suggest why (CWs), not all HIV-infected patients, cured, this therapeutic method
C:
- There are different strains of HIV
- Some strains use a different co-receptor for adsorption and then entry (e.g. CXCR4)

ORE:

1. There are different strains of HIV which use a **different co-receptor**, such as CXCR4 for adsorption and **entry**.

[L2]

(f) Explain how HIV infection may result in the death of infected CD4 cells.

……

……

……[2]

S: Suggest how (CWs), HIV infection, death, non-infected CD4 cells
C:
- HIV-infected cells release cytokines
- Syncytium form

ORE:

1. HIV-infected cells may undergo **apoptosis.**

2. Multiple bound cells may fuse, forming a giant multinucleated cell or syncytium. The syncytium may rupture / is **destroyed by** the body's **immune system**.

[L2]

[Total: 10]

5 Fig. 5.1 shows the formation of a eukaryotic transcription initiation complex.

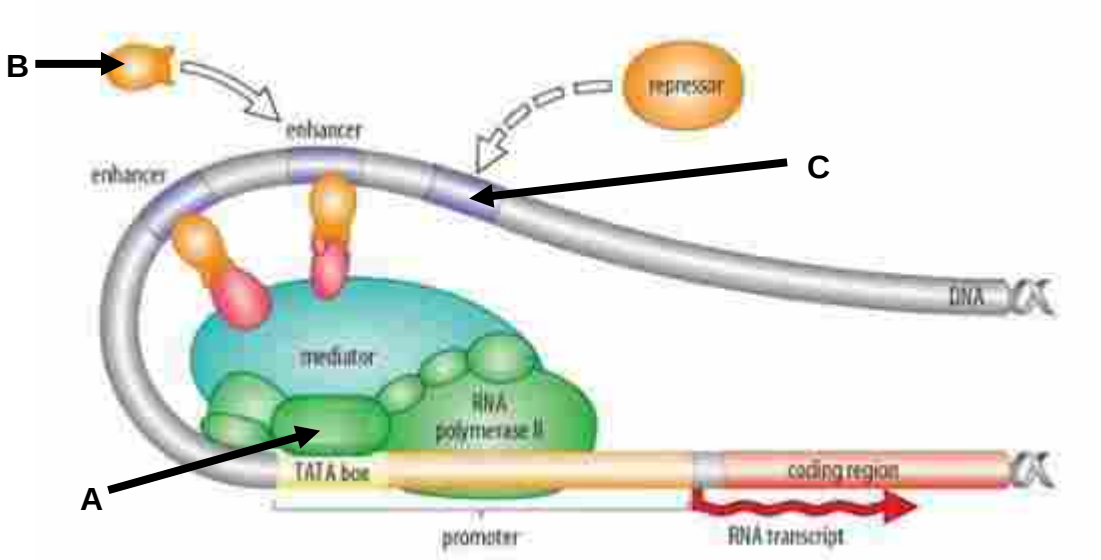


Fig. 5.1

(a) Identify the following proteins.

A: _____ **General transcription factor**

B: _____ Transcriptional **activator** protein

C: _____ **Silencer** sequence

[3]

[L1]

(b) Explain how the eukaryotic transcription initiation complex for high rate of transcription can be formed.

……

……

……

……

……[4]

1. **General transcription factors** must **assemble at the promoter** to **position RNA polymerase** II correctly at the promoter and release it from the promoter into elongation mode for transcription.
2. **Binding to transcriptional activator proteins to enhancer**,
3. resulting in **protein mediated bending of DNA / OWTTE**
4. to **bring bound activators in contact with other proteins of the transcription initiation complex** / Accept **mediator protein action**
5. **Stabilizing RNA polymerase** for **high rate of transcription**.

(Max 4)

[L2]

High rate of transcription caused by mutations in cancer critical genes may result in dysregulation of cell cycle control and subsequently lead to uncontrolled cell division.

c-myc is a regulator gene that codes for a transcription factor. A mutated version of c-myc that is highly expressed is found in many cancers. Fig 5.2 shows the relative level of expression of c-myc in normal and cancer prostate tissue.

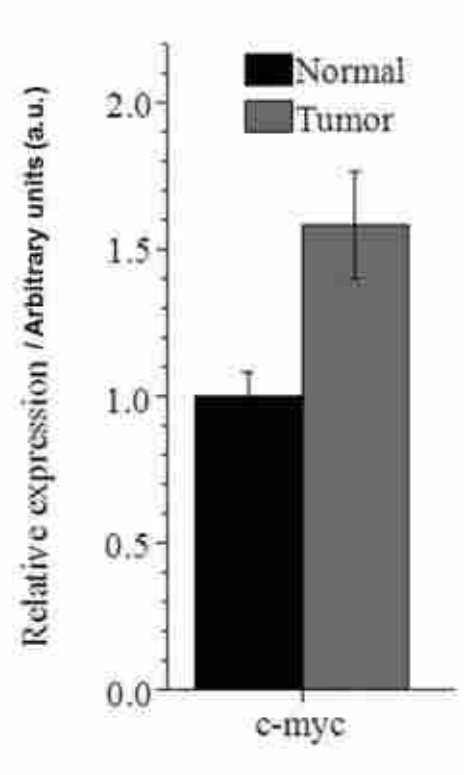


Fig 5.2

(c) With reference to Fig.5.2, explain how mutation in the c-myc gene led to increased expression in cancer prostate tissue.

……

……

……

……[3]

1. c-myc expression in **normal prostate tissue is 1.0 a.u.** as compared to **1.6 a.u in cancer prostate tissue**.
2. c-myc **proto-oncogene** undergoes **gain-of-function mutation** to become **oncogene**.
3. **Translocation beside active promoter / Gene amplification** resulted in increased expression of c-myc.

[L3]

[Total: 10]

6 Fig. 6.1 shows a Calico cat with a mosaic coat with patches of orange and black. It is known that fur coat colour in cats is determined by a single gene. Only female cats can develop calico fur coat. Male cats usually have only orange or black fur coat.

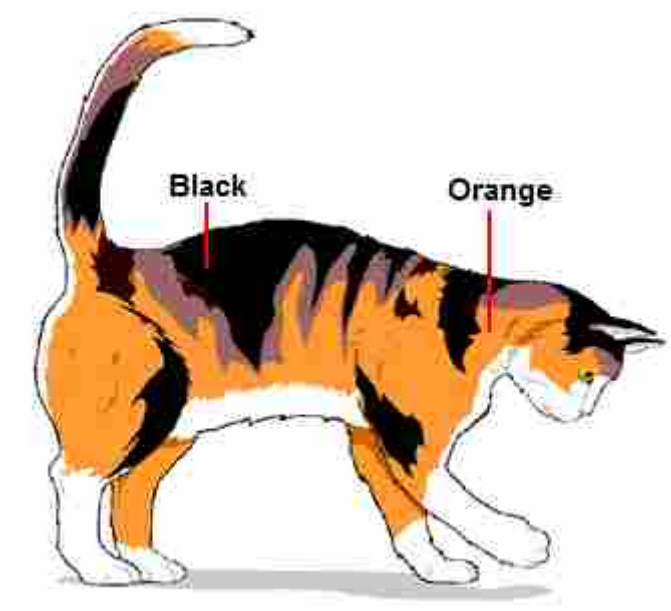


Fig. 6.1

(a) Identify the type(s) of inheritance determining Calico fur coat colour in cats.

……

……[1]

S: State (CWs), type of inheritance, fur coat colour
C:
- Calico (patches of black and orange) → both equally expressed → codominance/epistasis.
- Difference between male and female → possible sex-linked.
- Inheritance determined by single gene → confirm codominance (cannot be epistasis)

ORE:

1. **Co-dominance**
2. **Sex-linked / X-linked**

[L2]

(b) Using B to represent allele for black coat and R to represent allele for orange coat, draw a genetic diagram to show how a cat-breeder can obtain Calico cat from a cross between a pure-breeding black male and an orange female cat.

S: Draw (CWs), genetic diagram, orange female x black male,
C:
- Sex-linked & codominant (X^B & X^R alleles)
- Orange female X^RX^R
- Black male X^BY

ORE:

Let **X^B represent the allele for black coat colour**.
Let **X^R represent the allele for orange coat colour**, where **X^B and X^R** are **codominant**.

Parental phenotypes : Orange Female x Black Male

Parental genotypes (2n): $X^R X^R$ x $X^B Y$ **[1]**

Parental gametes (n): X^R R x X^B R, Y **[1]**

F_1 genotypes and phenotypes (2n):

♀ \ ♂	X^B R	Y
X^R R	$X^B X^R$ Calico coat	X^R Y Orange coat

[1]

F_1 phenotypic ratio: **1 Calico female: 1 Orange male** **[1]**

[L2]

[4]

Coat colour inheritance in horses is different from cats. Two unlinked genes *E* and *G* control coloured coat in horses. The two genes are thought to be involved in the same metabolic pathway for pigment formation.

- Horses may be bay, black or chestnut in colour.
- Horses may be bay / black when at least one dominant allele *E* is present.
- Chestnut coat colour is always produced in the presence of two copies of the e allele.

Horses coat colour goes through a natural graying process. Horses born with bay, black or chestnut coat colour will steadily turn gray. This process is mediated by a single copy of the dominant allele G regardless of the genotype of the gene E controlling coat colour.

(c) Draw a genetic diagram in the space below to show the result of the cross between two gray horses that were heterozygous at both gene loci G/g and E/e and the resultant phenotypic ratio of the offspring.

S: Draw (CWs), genetic diagram, GgEe (Gray) x GgEe (Gray) Dominant epistasis
C:
- Epistatic gene locus G (result in gray coat regardless of genotype of gene E)
- Hypostatic gene locus E
- Single copy of E allele will result in horses with black/bay coat
- Homozygous recessive (ee) will result in horses with chestnut coat

ORE:

Let G represent the dominant allele for Gray coat colour and g represent the recessive allele for other colour coat.

Let E represent the dominant allele for black/bay coat colour, where e represent the recessive allele for chestnut coat.

Gene locus G is epistatic over Gene locus E **[1]**

P phenotypes : Gray Horse x Gray Horse **[1]**

P genotypes (2n) : GgEe x GgEe

P gametes (n): GE Ge gE ge x GE Ge gE ge **[1]**

Punnett square: **[1]**

♂ gametes / ♀ gametes	*GE*	*Ge*	*gE*	*ge*
GE	*GGEE Gray*	*GGEe Gray*	*GgEE Gray*	*GgEe Gray*
Ge	*GGEe Gray*	*GGee Gray*	*GgEe Gray*	*Ggee Gray*
gE	*GgEE Gray*	*GgEe Gray*	*ggEE Black/Bay*	*ggEe Black/Bay*
ge	*GgEe Gray*	*Ggee Gray*	*ggEe Black/Bay*	*ggee Chestnut*

Offspring phenotypic ratio : **12** Gray: **3** Black/Bay: **1** Chestnut **[1]**

[L3]

[5]

[Total: 10]

7 Fig. 7.1 shows the different modes of signal conduction in a non-myelinated neuron.

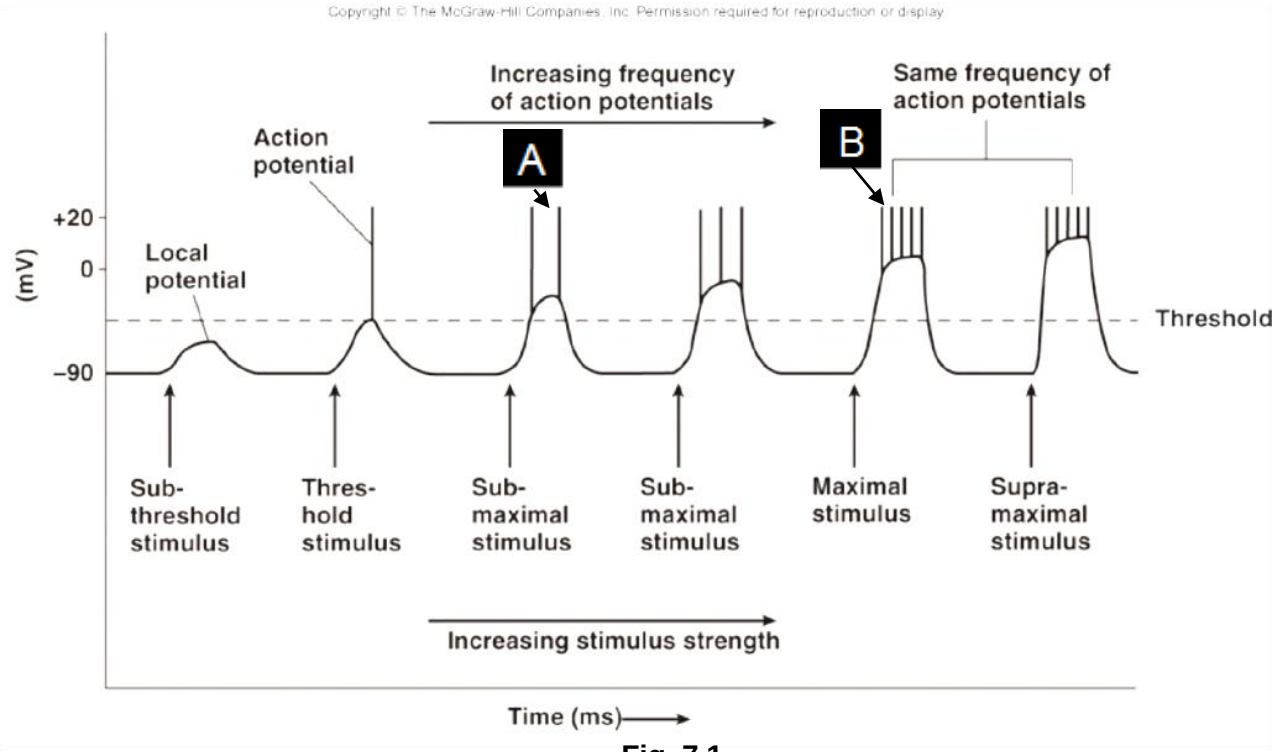


Fig. 7.1

(a) State one factor that contributes to unidirectional conduction of impulses down an axon.

……..[1]

SC: one factor / contributes / unidirectional conduction / neuron.
OR: refractory period

1. **Refractory period** (accept absolute and relative refractory periods)

[L1]

With reference to Fig. 7.1 for all questions following,

(b) explain why there is no action potential generated with a sub-threshold stimulus.

……

……

……..[2]

SC: no AP / sub threshold stimulus.
OR: 1. Sub-threshold stimulus **does not reach threshold**.
2. No opening of VG Na^+ Channels, no influx of Na^+ and subsequently no AP created. .

1. Sub-threshold stimulus **does not reach threshold** therefore **no opening of all voltage-gated Na^+ Channels**,
2. **no influx of Na^+** and subsequently **no AP** created.

[L2]

(c) explain how the time interval between action potentials seen in label **B** is shorter than the time interval between action potentials seen in label **A**.

……

……

……

……[3]

SC: time interval / B / shorter than / A.
OR: 1. Refractory period
2. dependent on strength of signal
3. B maximal stimulus - A sub maximal stimulus.

1. Time interval between action potentials is **dependent** on the **refractory period**
2. and on the **strength** of the **incoming signal**.
3. **B has maximal stimulus** compared to **A which has sub maximal stimulus**.

[L3]

(d) state the advantages in the ability of neurons to display these characteristics shown in Fig. 7.1.

……

……

……[2]

SC: advantage / neuron ability / display characteristics .
OR: 1. **Variation** / **differentiation** of **signal frequency**.
3. determines the **sensitivity** of the neuron / OWTTE.

[L2]

(e) explain what would increase the speed of the signal conduction down the neuron.

……

……

……[2]

SC: increase speed/ down neuron.
OR: 1. Myelin sheath
2. Saltatory conduction

1. With the presence of the **myelin sheath**
2. Signal conductance down the neuron is even **faster** due to **saltatory conduction**.
3. at the **nodes of Ranvier**.

(Max 2)

[L2]

[Total: 10]

10 The Grand Canyon National Park is home to two groups of squirrels. The Albert squirrels *Sciurus aberti* live generally on the south rim of the canyon and the Kaibab squirrels *Sciurus kaibabensis* live on the north rim of the canyon (Fig. 8.1 and Fig. 8.2).

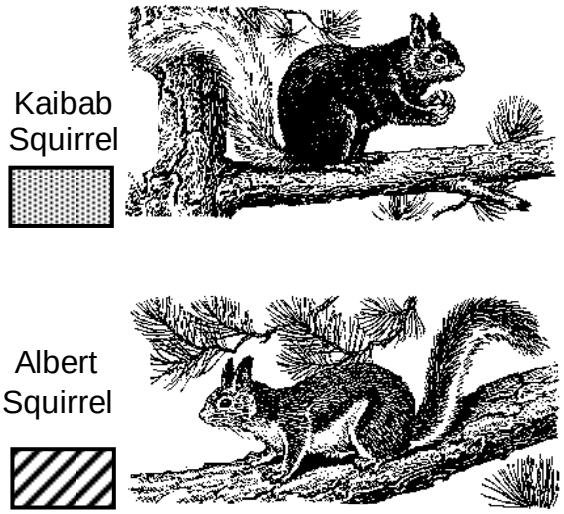


Fig. 8.1

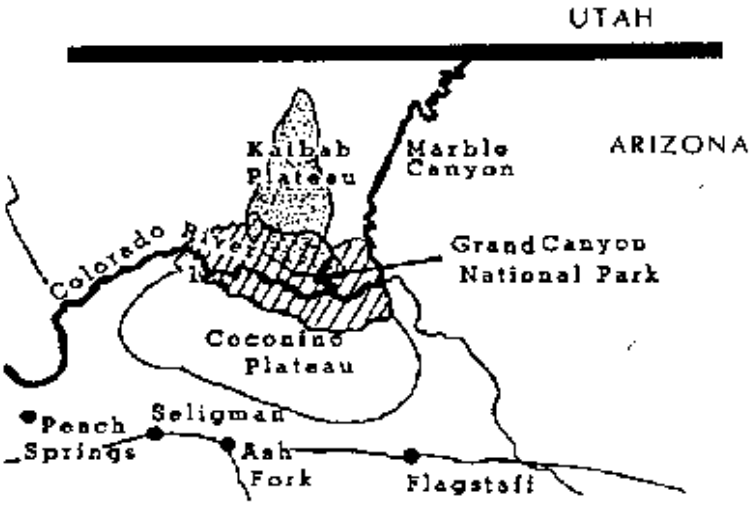


Fig. 8.2

The north rim is about 370 m higher than the south rim. Almost twice as much precipitation falls on the north rim than on the south rim every year. The two groups share many characteristics, but they do not look the same, both groups have tasselled ears, but each group has a unique fur colour pattern.

(a) Explain which Darwinian principles can be applied from the above information on *S. alberti* and *S. kaibabensis*.

……

……

……

……

……[4]

SC: which Darwin Principles / squirrels
OR: 1. High reproductive potential- great range
2. Competition / struggle to survive – no information
3. Constant population- great range seen in both groups.
4. Variation- Seen from the different phenotypic characteristics.
5. Selection pressure – environment on either side of canyon.precipitation
6. Passed down to next generation- phenotypical characteristics.

1. **High reproductive potential** inferred from the wide distribution of both groups in Fig. 8.2
2. **Constant population** inferred from the wide distribution of both groups in Fig. 8.2
3. **Variation** can be inferred from the **different phenotypic characteristics of the squirrels.**
4. **Selection Pressure** inferred from the environmental conditions on either side of the canyon, reference to precipitation being twice greater in the north compared to the south.
5. **Passed down to the next generation**- phenotypical characteristics of each group.

[L2]

Several studies have been done on the phylogenetic relationship of the squirrels in and around the Grand Canyon region. Fig. 8.3 is one such study based on cytochrome b DNA sequences.

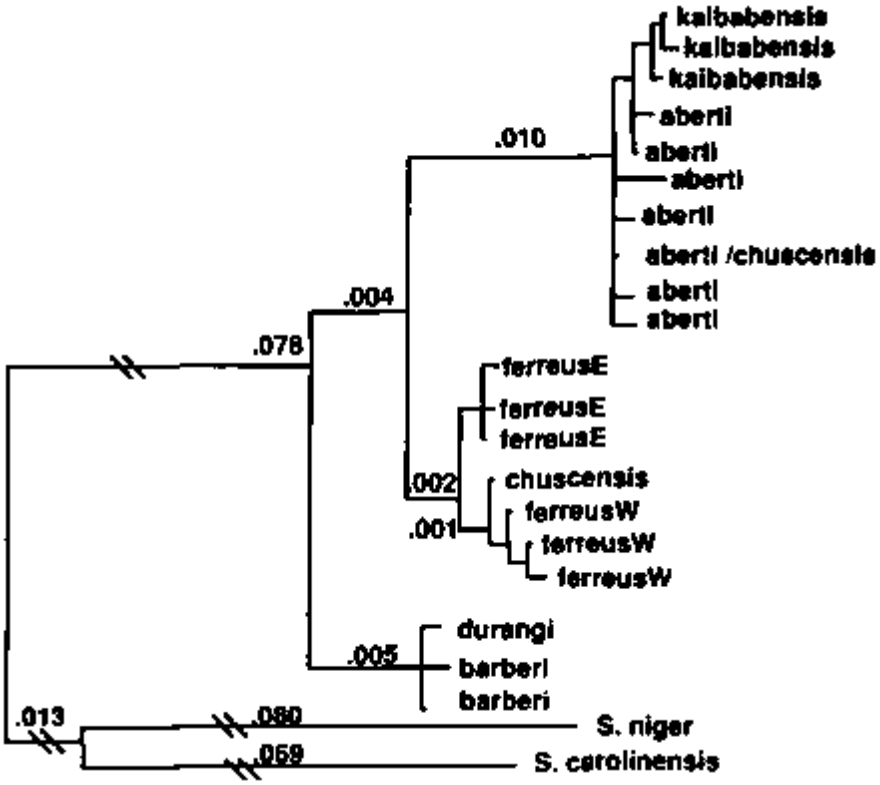


Fig.8.3 Phylogenetic relationship between six *sciurus* subspecies base on cytochrome b sequences constructed by the neighbour-joining method of Saitou and Nei (1987) using the *S. niger* and *S. carolinesis* (Thomas and Martin 1993) sequences as outgroups. Branch lengths and confidence probabilities are noted above and below the branches respectively.

(b) With reference to information already given and also to Fig. 8.3, it is clear that divergent evolution or adaptive radiation is occurring in the evolution of *S. alberti* and *S. kaibabensis*

Explain why it is not convergent evolution.

……

……

……..[2]

SC: kind of evo- not divergent / adaptive rad. / why not convergent evo
OR: 1. common ancestor
2. subspecies
Reject morphological homology

1. share a recent **common ancestor**
2. **convergent evolution** involves **two phylogenetically different groups** with no recent common ancestor.

Or any one of the following-

3. **homology of DNA** sequence for cytochrome b shows **high relation 0.01**
4. **they are subspecies**

(Max 2)

[L2]

(c) (i) With reference to information already given and also to Fig. 8.3, suggest with reasons what kind of speciation *S. Alberti* is undergoing.

……

……

……[2]

SC: kind of speciation
OR: 1. Probably **allopatric speciation**.

2. Due to the presence of a **physical barrier** (a river).

OR

3. Probably **sympatric speciation**.

4. Due to presence of **overlapping geographical regions**.

(Points 1 and 2 are awarded together, points 3 and 4 are awarded together)

[L2]

(ii) With a known species concept, explain what would be the determining factor confirming *S. alberti* and *S. kaibabensis* as two separate species.

……

……

……[2]

SC: determining factor / confirming separate species
OR: 1. Random mating between *S. alberti* and *S. kaibabensis* to confirm no fertile offspring
2. Reproductive isolation

1. Probably **no fertile offspring** can be derived between the two species.
2. **Confirming reproductive isolation** as a definitive indication via **biological species concept**.
3. **Phylogenetic - Molecular evidence** (**DNA** + **RNA** or **amino acid** sequence comparison).

Reject: Ecological (insufficient information), Morphological (insufficient information from just comparing phenotype).

[L3]

[Total: 10]

Section B

Answer **one** question. Answer each part on a **separate** piece of paper.

Write your answers on separate answer paper provided.
Your answer should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answer must be in continuous prose, where appropriate.
Your answer must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

9 **(a)** Describe cell signaling with the G-protein coupled receptor with a named ligand and its corresponding cellular response. [8]

1. The **ligand**, **glucagon** **binds** to the **G-protein coupled receptor** (GPCR).This causes a **conformational change** in the GPCR.
2. **G-protein** will be **activated** and undergo a **conformational change** causing **GDP** on G-protein will be **substituted** for **GTP**.
3. **Alpha subunit of the G-protein** will translocated to membrane-bound enzyme, **adenylyl cyclase** and **activate** so that it **catalyse** the conversion of **ATP** to **cAMP**.
4. **cAMP** will act as a **second messenger** and **activate** **protein kinase A**.
5. **Protein kinase A** will **catalyse** the **phosphorylation** of **another protein kinase** resulting in its subsequent activation.
6. A **phosphorylation cascade** will occur.
7. Eventually the a specific **hydrolytic enzyme / glycogen phosphorylase** will be **activated**,
8. which will **hydrolyse glycogen** to **glucose** monomers (glucose-1-phosphate).

[L1]

(b) Explain the advantages and disadvantages of a phosphorylation cascade. [6]

Advantages	Great degree of control – can be stopped at any stage.	1
	Sensitive- can be reset very easily via phosphatases.	2
	Acts as a buffer before the final cellular response.	3
	Is triggered by 2nd messengers which affect more than one metabolic process.	4
	Amplification	5
Disadvantage	Energy consuming ATP needed for each activation of PKA / OWTTE	6
	Will be susceptible to temperature/pH etc.	7
	A mutation that renders a protein kinase non-functional may terminate the cascade.	8
	A mutation that renders a phosphatase non-functional may cause the cascade to continue.	9

[L3]

(c) Contrast with elaboration, anaerobic respiration with light independent reaction (Calvin cycle).[6]

	Anaerobic respiration	Light independent reaction
Reduced co-enzymes	1. Uses **NADH** in the	2. Use of **NADPH** in the conversion
Reduction process	3. **reduction of pyruvate to ethanol.**	4. conversion of **glycerate-3 phosphate** to **glyceraldehyde-3 phosphate**.
ATP	5. **ATP synthesized** via **substrate level phosphorylation**.	6. **ATP used** in the **conversion of glycerate 3 phosphate to glyceraldehyde 3 phosphate**
CO_2	7. **CO_2 produced** in the **conversion of pyruvate to ethanol / lactic**.	8. **CO_2 incorporated** with **RuBP to form citric acid**.

	acid	
Location	9. Occurs in **cytoplasm**.	10. Occurs in the **stroma**.
Molecule regenerated	10. **NAD^+**	11. **RuBP** & **$NADP^+$**

[L3]

[Total: 20]

10 (a) Contrast binary fission and mitosis. [6]

S: Contrast (CW), binary fission, mitosis

C:
- Contrast → Cite differences
- Binary fission vs mitosis (must have clear basis of comparison)
  - Type of cell that process occurs in
  - Location of cell that process occurs in
  - etc……

ORE:

Basis of comparison	Binary fission	Mitosis
Type of cells that process occurs in	1. Binary fission occurs in **prokaryotes**.	1. Mitosis occurs in **eukaryotes**.
Location of cell that process occurs in	2. Binary fission occurs in the **nucleoid / cytoplasmic** region of prokaryotic cell / OWTTE	2. Mitosis occurs in the **nucleus** of eukaryotic cell./ OWTTE
Type of DNA involved	3. Binary fission occurs on **circular** double-stranded **DNA**.	3. Mitosis occurs on **linear** double stranded **DNA**.
Number of chromosomes involved	4. Only **1 chromosome** is involved in binary fission.	4. **More than 1 chromosome** is involved in mitosis.
Separation of daughter cells	5. There is **division** of **parental cell** to give rise to **2 daughter cells** during binary fission.	5. There is **no division** of **parental cell** to give rise to 2 daughter cells during mitosis. This occurs during cytokinesis.
Type of division	6. Involves **cell division**.	6. Involves **nuclear division**.
Origin of replication	7. DNA replication occurs at **1 point of origin**.	7. DNA occurs at **multiple points** of the genome.
Utilisation of spindle fibres	8. There is **no spindle fibre formation** during binary fission.	8. **Spindle fibre formation** occurs during mitosis.
Presence/absence of end replication problem	9. There is **no End replication problem** during binary fission.	9. **End replication problem occurs** during mitosis.

Reject: Citation of interphase and cytokinesis as these stages occur prior and after mitosis.

[L3]

(b) Describe generalised and specialised transduction. [8]

S: Describe (CW), specialised transduction

C:
- Content knowledge recall

ORE:
Generalised transduction:
1. A **virulent phage** **infects** a **bacteria** cell and **hydrolytic enzymes** **degrade** the host bacteria **chromosome** into **fragments**.
2. A **small fragment** of the **host cell's degraded DNA** is **improperly packaged** within a **capsid**,
3. rather than the phage genome due to an **error** during the viral particle **assembly** process.
4. When this **phage** **attaches**/**infects** to **another bacteria cell**, it will **inject** this foreign **bacterial DNA** into its new host.
5. and may be **integrate**d into new host **bacteria chromsome** under the proper circumstances
6. via **homologous recombination**.
   (Max 4)

Specialised transduction:
7. A **temperate phage** **infects** a **bacteria** cell and has its **viral DNA** genome **integrated** into the bacterial **chromosome**.
8. When the **prophage** viral DNA is **excised** from the **chromosome**,
9. it sometimes takes with it a small region of **adjacent bacterial DNA** due to improper excision.
10. These **bacterial DNA** are **injected**, along with the **phage's genome**, into the **next host bacteria cell** and
11. may be **integrate**d into new host **bacteria chromsome** under the proper circumstances.
12. via **homologous recombination**.
    (Max 4)

(Max 4 marks for generalised, Max 4 marks for specialised)

[L1]

(c) In an experiment using T4 bacteriophage, different component molecules were labelled.

- T4 bacteriophages with protein coats labelled with radioactive sulfur.
- T4 bacteriophages with DNA labelled with radioactive phosphorus.

The differently-labelled bacteriophages were allowed to infect host bacteria.
The inside and outside of infected bacteria before lysis were tested for radioactive sulfur and radioactive phosphorus.

Describe and explain the expected results of the experiment. [6]

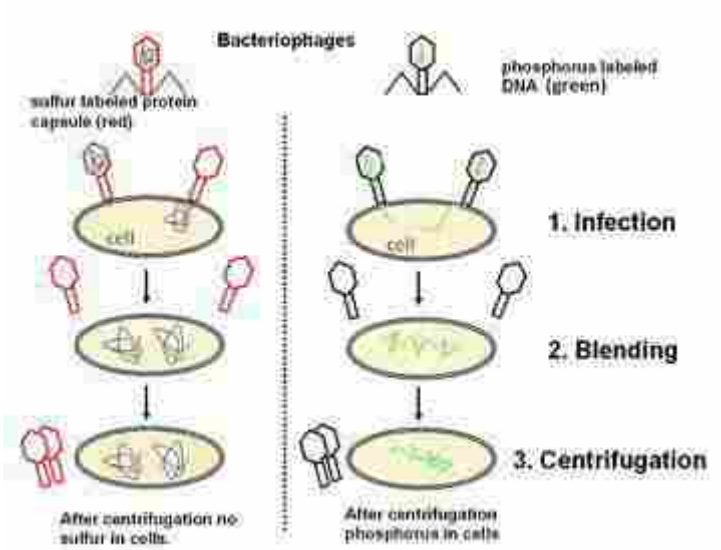
S: Describe..Explain (CWs), expected results, Protein coats…labelled..radioactive sulphur, DNA..labelled..radioactive phosphorus**,** inside…outside..bacteria…before lysis…tested for radioactive

C:
- Description
  - Bacterial cells infected with radioactive sulfur-labelled bacteriophages:
    - Radioactivity will be detected outside

- No radioactivity will be detected inside

- Explanation
  - Protein capsid does not enter the bacteriophage, hence only outside will have radioactivity

- Description
  - Bacterial cells infected with radioactive phosphorus-labelled bacteriophages:
    - No radioactivity will be detected outside
    - Radioactivity will be detected inside
- Explanation
  - DNA will be injected into the bacterial cell during transduction, hence DNA that is radioactive phosphorus-labelled will be detected inside the bacterial cells.



ORE:

Bacteria infected with **radioactive sulfur-labelled bacteriophages:**

Description:
1. There will be **radioactivity detected** **outside** the **bacteria**.
2. There will be no **radioactivity detected inside** the **bacteria**.

Explanation:
3. Protein **capsid**s **do not enter** the **bacteria** cells during **transduction** / but instead **remain** on the **bacteria** cell **surface** membrane after **transduction**.

Bacteria infected with **radioactive phosphorus-labelled bacteriophages:**

Description:
4. There will be **radioactivity detected** **outside** the **bacteria**.
5. There will be no **radioactivity detected inside** the **bacteria**.

Explanation:
6. Bacteriophage DNA **enter /is injected into** the **bacteria** cells during **transduction**.

[Total: 20]

END OF PAPER

CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME					
CLASS	**2T**	**INDEX NUMBER**			

BIOLOGY
9648/03

25th August 2016
2 hours

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

There are two sections in this paper.

Section A]
Answer all questions

Section B]
Answer all questions. Answer each part on a **separate** piece of paper.

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For Examiner's Use	
Section A	**52**
1 [13]	
2 [13]	
3 [14]	
4 [12]	
Section B	**20**
5a [6]	
5b [6]	
5c [8]	
TOTAL	**72**

This document consists of **13** printed pages and **1** blank page.

[Turn over

Section A

Answer **all** questions in this section.

1 Human Growth Hormone is important to augment normal growth and development in the treatment of individuals with dwarfism. Fig. 1.1 shows how human growth hormone can be produced via expression of recombinant DNA in *Escherichia coli* host cells.

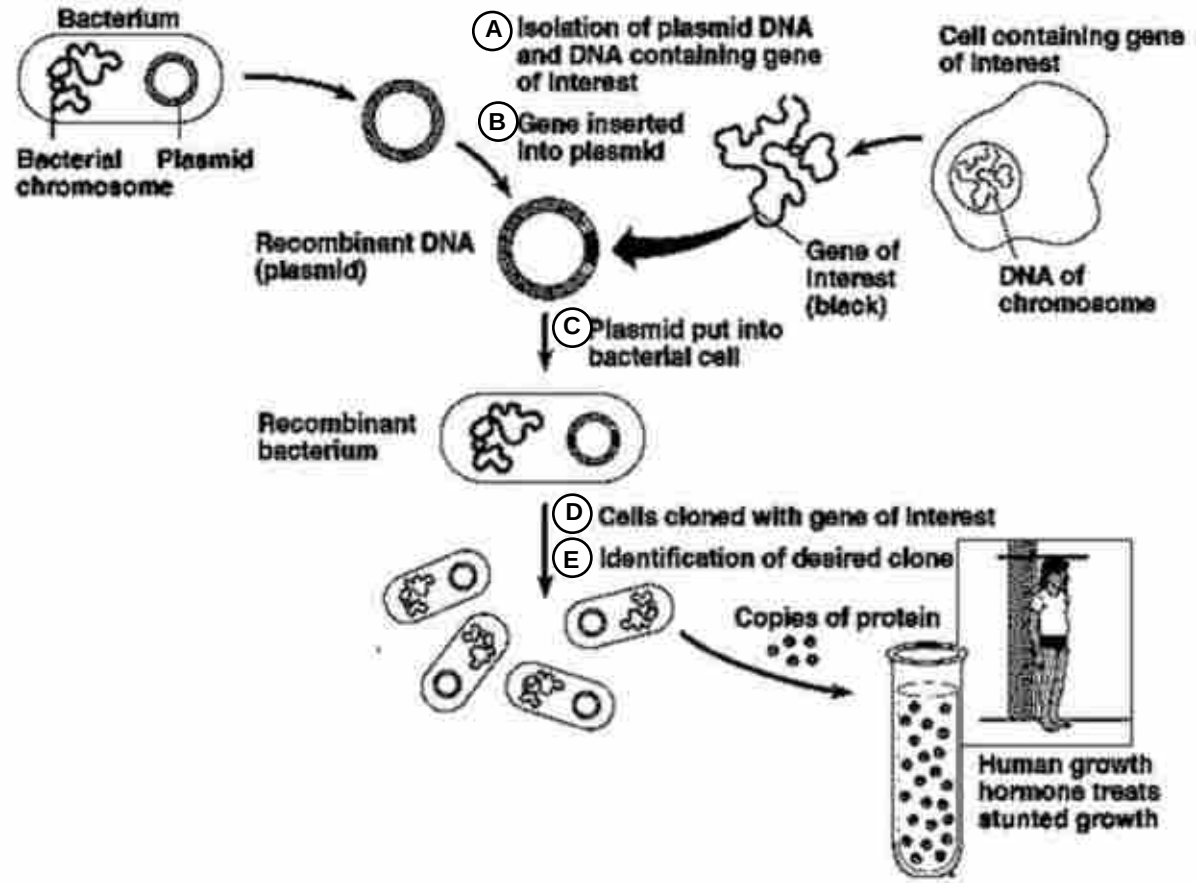


Fig. 1.1

(a) Explain what is meant by recombinant DNA.

……

……[1]

(b) Name the process required in the following procedure in Fig 1.1.

C : ……..

E : ……

[1]

(c) The gene of interest cannot be taken directly from DNA of chromosome but require additional processing in order to produce functional protein.

(i) With reference to Fig. 1.1, explain why the gene of interest cannot be taken directly from chromosomal DNA.

……

……

……[2]

(ii) Outline the additional processing required to yield the gene of interest prior to insertion into the plasmid.

……

……

……

……[3]

(d) State one possible pair of gene markers present on the cloning site of the plasmid for the identification of desired clone in Fig. 1.1.

……

……

……[1]

(e) Outline the process for Stage E in Fig 1.1 using one of the gene markers in (d).

……

……

……

……[3]

Fig 1.2 shows details of how stage A and B are carried out.

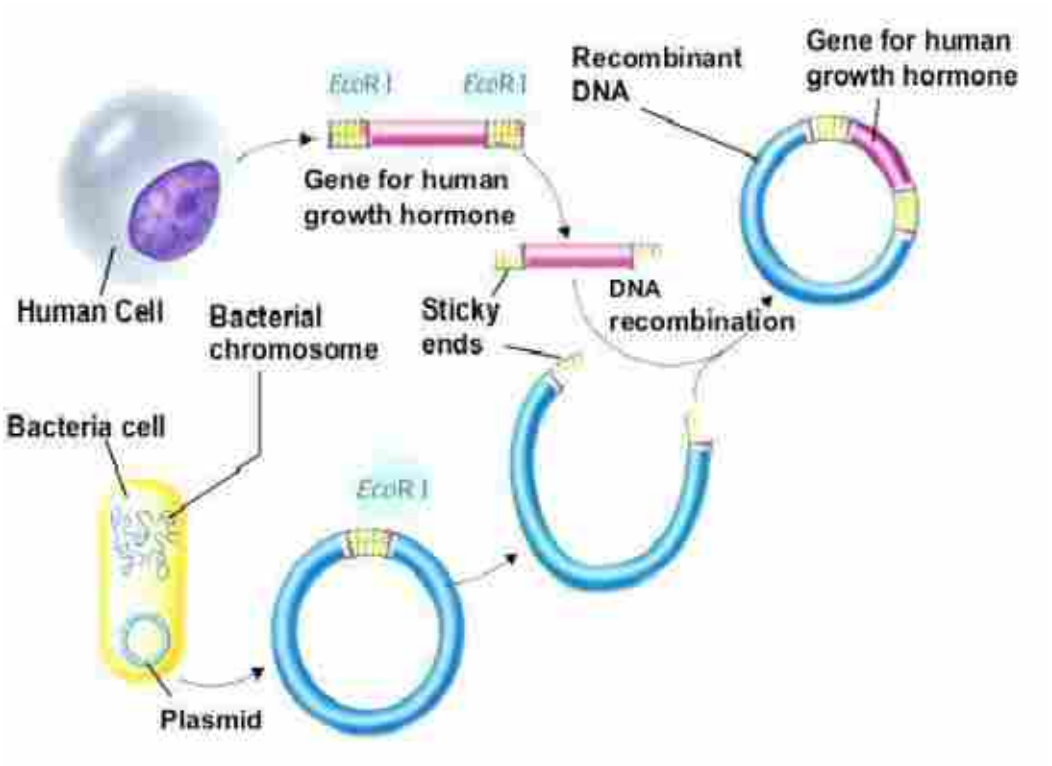


Fig 1.2

(f) A scientist commented that two different restriction enzymes should be used to isolate the gene for human growth hormone instead of using only *EcoRI* restriction enzyme. Explain the rationale behind his comment.

……

……

……[2]

[Total: 13]

2 Restriction Fragment Length Polymorphism (RFLP) is an important application for comparative genetic analysis of normal and diseased individuals.

(a) Outline the key techniques used for RFLP analysis.

……

……

……

……

……[4]

Fig. 2.1 shows the pedigree and southern blots of an RFLP locus that is closely linked with a disease phenotype. Affected individuals are shaded in the pedigree.

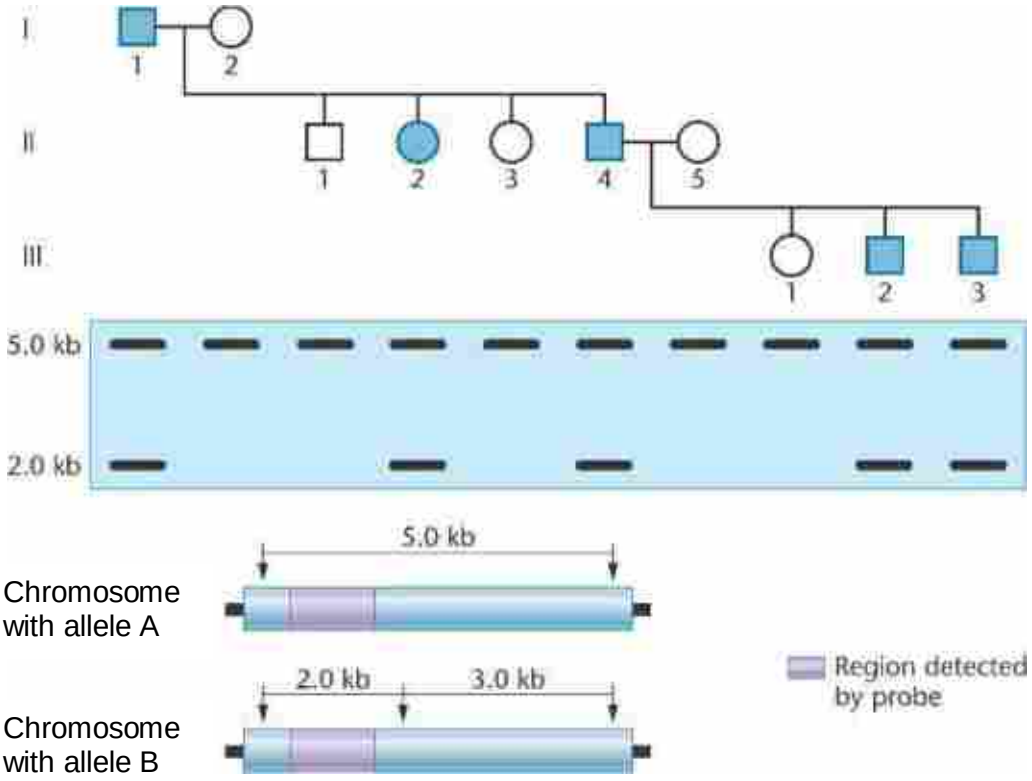


Fig. 2.1

(b) Explain the genetic basis of RFLP in comparative analysis in disease study.

……

……

…… [2]

(c) With reference to Fig. 2.1,

(i) Identify the allele responsible for the disease.

……[1]

(ii) State the considerations for target region of the probe.

……..

……..

……[2]

(iii) Explain if the disease allele is dominant or recessive.

……..

……..

……[2]

(d) Briefly describe two other applications of RFLP.

……..

……..

……[2]

[Total: 13]

3 Fig. 3.1 shows how gene therapy using modified viruses can be carried out.

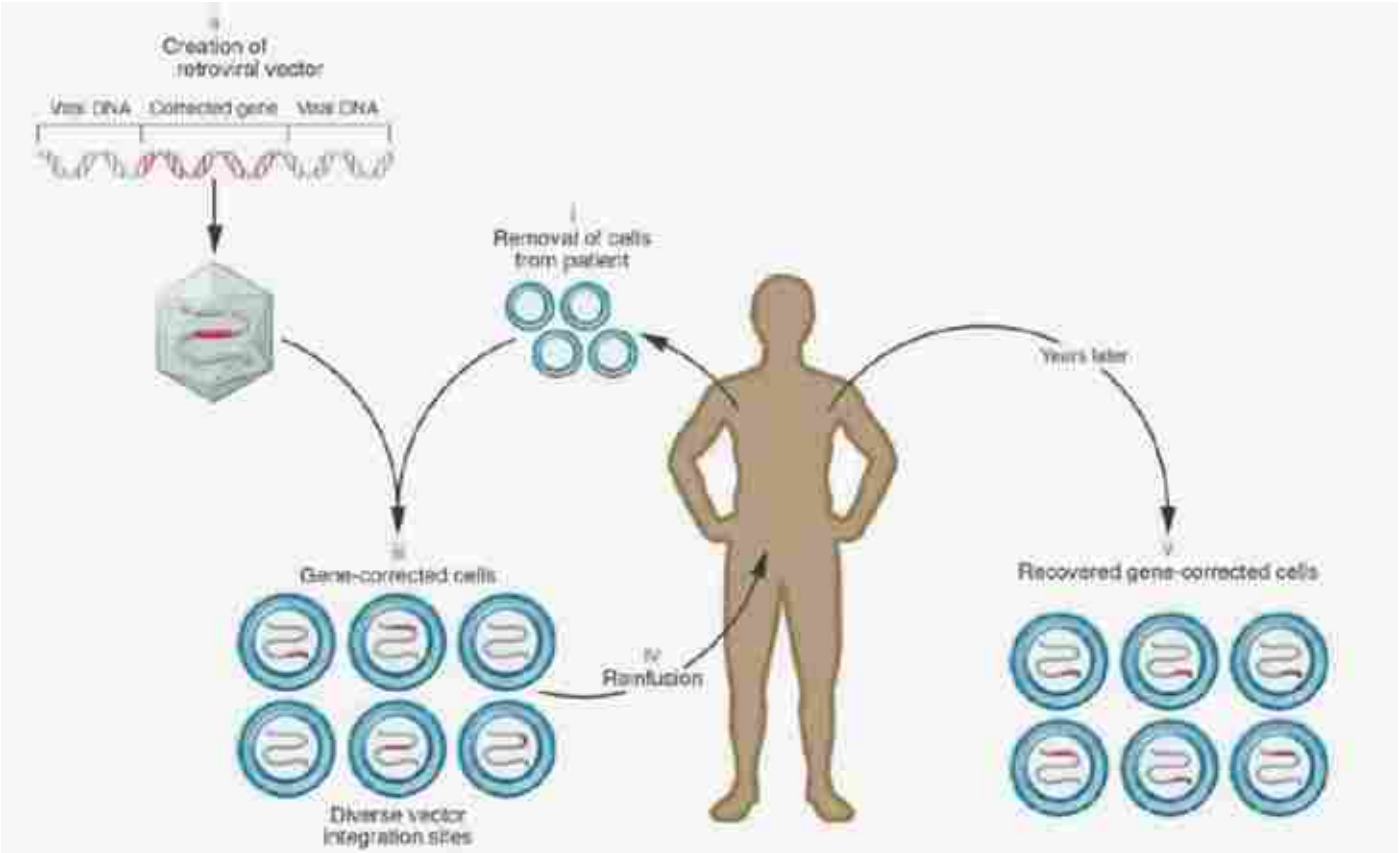


Figure obtained from Retroviral integration and human gene therapy The Journal of Clinical Investigation, Volume 117, Number 8

Fig. 3.1

Severe combined immunodeficiency (SCID) and X-linked SCID are two genetic diseases that can be treated by the gene therapy method shown in Fig. 3.1.

(a) State the genes that can be corrected for SCID and X-linked SCID.

SCID: ……..

X-linked SCID: ……..

[2]

(b) Explain how mutation in one of the genes cited in **(a)** would give rise to immunodeficiency.

……

……

……..[2]

Excerpt from the *The Journal of Clinical Investigation* review titled *Retroviral integration and human gene therapy*:

> "However, with these successes came the first serious adverse events in retrovirus based gene therapy. Three of the SCID-X1 patients treated by the French team developed a leukemia-like lymphoproliferative disease."

(c) Suggest why these patients developed leukemia-like lymphoproliferative diseases.

……

……

……[2]

In 1999, 18-year old Jesse Gelsinger died after suffering from a massive immune response following a clinical trial that administered adenoviral-based gene therapy.

(d) Besides adenovirus' ability to elicit a strong immune response, explain why adenovirus is also not favoured in the treatment of the genetic diseases cited in **(a)**.

……

……

……[2]

(e) Explain why scientists prefer to isolate hematopoietic stem cells rather than T-cells from the patient for the gene therapy treatment shown in Fig. 3.1.

……

……

……

……[3]

Viruses are not the only vectors that are utilised to deliver genes into patients' host cells.

(f) State one other type of vector that is not viral.

……

……[1]

(g) Discuss two ethical implications of gene therapy.

……

……

……

……[2]

[Total: 14]

4 Planning question

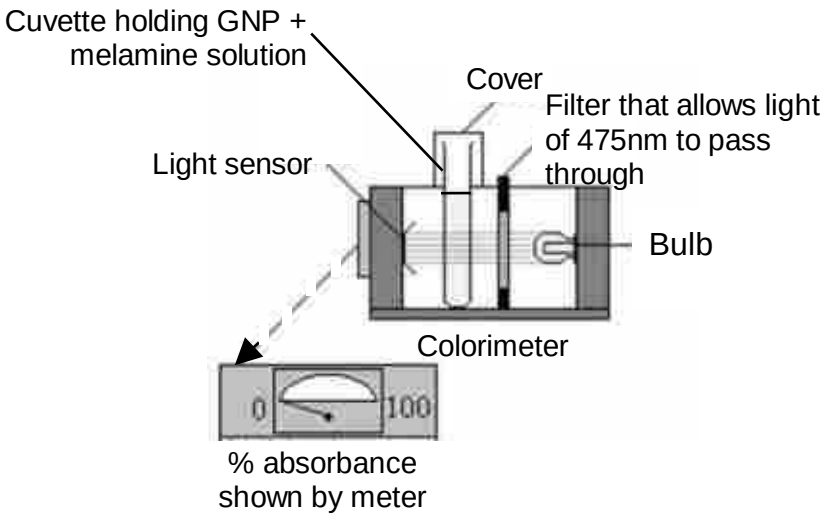
In 2008, contaminated milk and infant formula with melamine in China resulted in over a thousand babies hospitalised and caused several deaths. Melamine with its large number of nitrogen atoms, was unethically added to foods to mimic proteins detected through conventional measurements for nitrogen.

A research group found a way to detect the presence of melamine via a colour indicator. They attached cyanuric acid to gold nanoparticles to produce functionalized gold nanoparticles (GNP) that are red, the cyanuric acid component of GNP detects the melamine through hydrogen-bonding. Upon binding to melamine, the GNP changes from red to blue, giving a clear signal that there is contamination.

GNP (red) + Melamine → GNP-Melamine complex (blue)

The intensity of the blue colour after a set time interval of 5 minutes is a measure of the concentration of the melamine present in a specimen.

The test involves addition of 1 cm^3 of solution (to be tested) to 0.1 cm^3 of GNP in a cuvette (glass container), followed by colourimetric measurement of absorbance (% absorbance) at a specified wavelength. It is known that the blue wavelength is 475 nm.



You are required to plan, but not carry out, an investigation to determine the lowest concentration of melamine detectable by GNP indicator.

Your planning must be based on the assumption that you have been provided with the following equipment and materials which you **must** use:

- 1 % GNP
- Colourimeter
- 6 x Cuvettes (container for colourimeter measurement)
- 6 x Test-tubes
- Test-tube rack
- 2 x 10 cm^3 syringes
- 2 x 1 cm^3 syringes
- Micropipette
- 15 cm^3 of 1% melamine solution labelled M
- 50 cm^3 of buffer solution
- Marker pen
- Stopwatch
- Safety googles

- Disposable gloves

Your plan should have a clear and helpful structure to include:

- an explanation of theory to support your practical procedure
- a description of the method used including the scientific reasoning behind the method
- proposed layout of results tables with clear headings and labels
- the correct use of technical and scientific terms

[Total: 12]

Section B: Free-response question

Answer **all** questions. Answer each part on a **separate** piece of paper.

Write your answers on separate answer paper provided.
Your answer should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answer must be in continuous prose, where appropriate.
Your answer must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5 **(a)** Compare between Genomic and cDNA libraries used in protein production. [6]

(b) Explain the advantages and limitations of PCR. [6]

(c) Discuss the pros and cons of genetically-modified crop plants. [8]

[Total: 20]

END OF PAPER

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CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

Answers

CANDIDATE NAME			
CLASS	**2T**	**INDEX NUMBER**	

BIOLOGY

9648/03
25th August 2016
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Additional Materials: Writing Paper

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[Turn over

Section A

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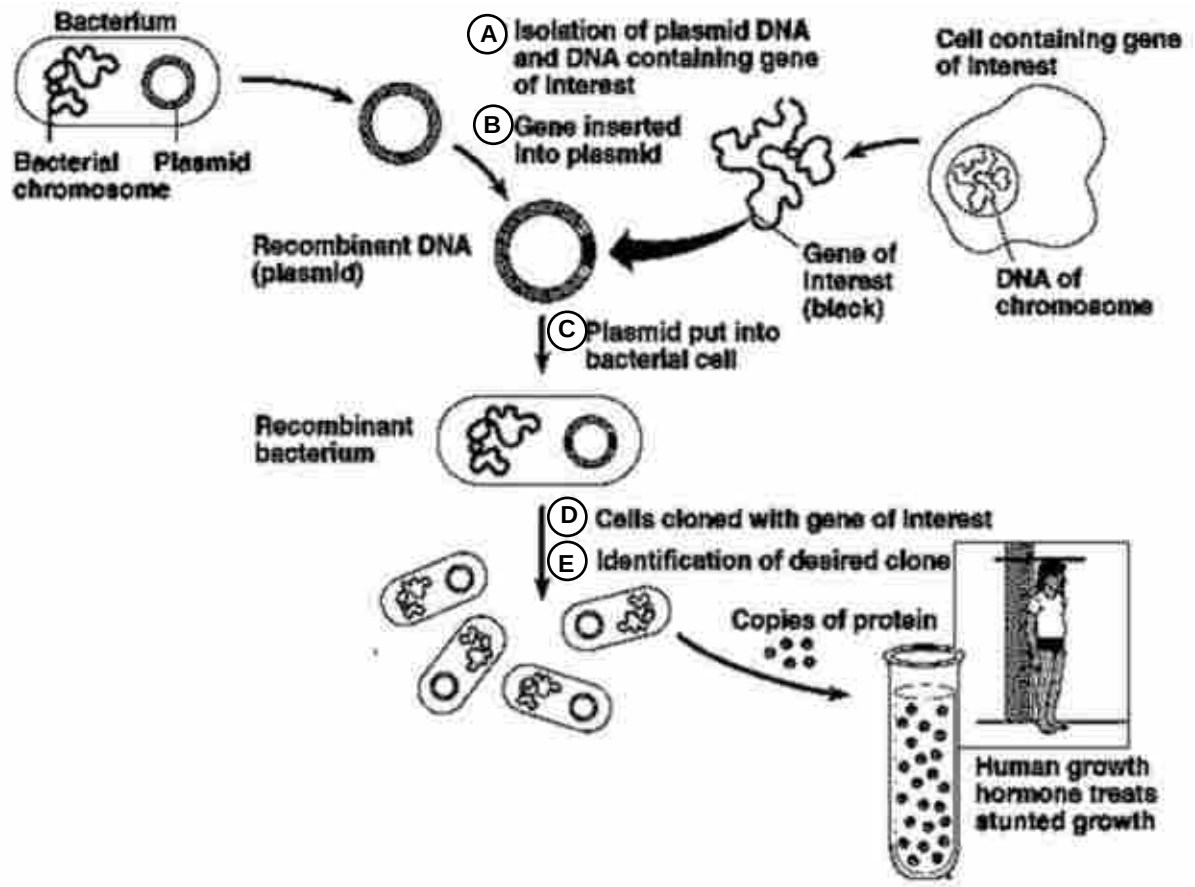


Fig. 1.1

(a) Explain what is meant by recombinant DNA.

……

……[1]

1. **Genes from two different sources / organisms** are **combined** *in vitro* into a single plasmid **/ OWTTE** (accept contextual answers).

[L1]

(b) Name the process required in the following procedure in Fig 1.1.

C : ……**Transformation**

E : ……**Selection / Screening**

[1]

(Both correct – 1 mark)

[L1]

(c) The gene of interest cannot be taken directly from DNA of chromosome but require additional processing in order to produce functional protein.

(i) With reference to Fig. 1.1, explain why the gene of interest cannot be taken directly from chromosomal DNA.

……

……

……[2]

1. **Eukaryotic DNA** contains **introns** and
2. **bacterial** / **prokaryotic** host cells **do not have post-transcriptional modification / splicing to remove introns.**
3. **Non-functional protein may be synthesized** if introns are not removed.

(Max 2)

[L1]

(ii) Outline the additional processing required to yield the gene of interest prior to insertion into the plasmid.

……

……

……

……[3]

1. **Isolate the processed / mature mRNA** coding for human Growth Hormone
2. Use **reverse transcriptase** to **synthesize single-stranded cDNA** using the processed mRNA as template **(Reject: conversion)**
3. Use **DNA polymerase** to replicate the **single-stranded cDNA into double-stranded cDNA**.
4. **Addition of linker DNA** to the **ends** of the double stranded cDNA / Gene of interest.

(Max 3)

[L2]

(d) State one possible pair of gene markers present on the cloning site of the plasmid for the identification of desired clone in Fig. 1.1.

……

……

……[1]

1. **Ampicillin resistance gene** & **Tetracycline resistance gene**

OR

2. **LacZ gene / β-galactosidase gene** & **Ampicillin resistance gene**

(Max 1)

[L2]

(e) Outline the process for Stage E in Fig 1.1 using one of the gene markers in (d).

……

……

……

……[3]

1. **Replica-plate** the **master plate containing the bacterial clones** on two separate **agar plates containing ampicillin and tetracycline**.
2. **Bacterial clones / colonies** that grow on both antibiotic plates are **resistant to both antibiotics are non-recombinant**.
3. **Select for bacterial clones sensitive to the antibiotic of the gene marker in (d)** but **resistant to the other antibiotic** from the **master plate**.
4. Correct reference to **insertional inactivation**.

(Max 3)

OR

1. **Culture the bacterial clones / colonies** on **X-gal** medium with ampicllin.
2. **Bacterial clones / colonies** that appear **blue** are **non-recombinant** as LacZ gene is intact.
3. **Select for white bacterial clones** that are **recombinant**.
4. **LacZ gene is disrupted** due to **insertional inactivation**.

(Max 3)

[L2]

Fig 1.2 shows details of how stage A and B are carried out.

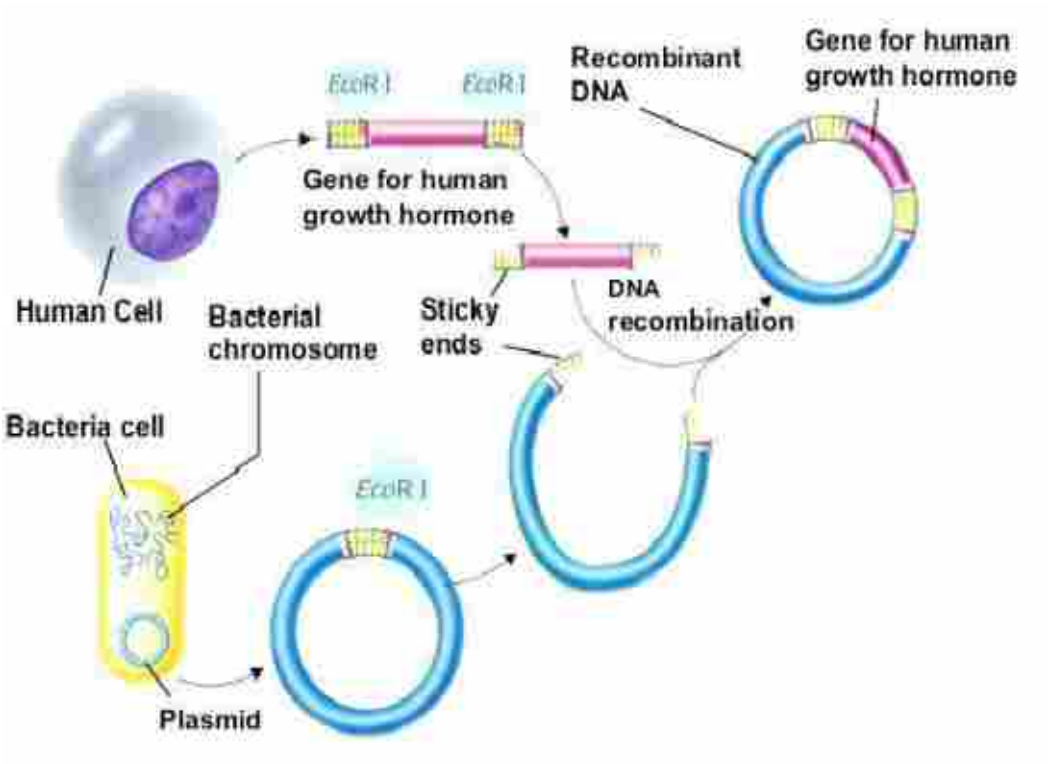


Fig 1.2

(f) A scientist commented that two different restriction enzymes should be used to isolate the gene for human growth hormone instead of using only *EcoRI* restriction enzyme. Explain the rationale behind his comment.

……

……

……[2]

1. The **gene** for human growth hormone **may insert into the plasmid in more than one orientation** / **OWTTE**
2. This may lead to **non-functional protein being synthesized** if the gene is inserted in the wrong orientation
3. Having two different restriction enzymes produces **two different sticky ends** to isolate the gene at the ends will ensure **uni-directional insertion** of the gene into the plasmid.

(Max 2)

[L3]

[Total: 13]

2 Restriction Fragment Length Polymorphism (RFLP) is an important application for comparative genetic analysis of normal and diseased individuals.

(a) Outline the key techniques used for RFLP analysis.

……

……

……

……

……[4]

1. **Same** set of **restriction enzyme(s) to digest DNA** samples.
2. **Gel electrophoresis** to **separate DNA fragments** of different **length**.
3. **Southern Blotting**
4. to **transfer DNA fragments to nitrocellulose membrane**.
5. **Nucleic acid hybridization** with **labelled probes complementary to target sequences**.
6. **UV transillumination / Autoradiography** (relevant to point 4 on type of probes) to **visualized DNA fragment** containing target sequences.

(Max 4)

[L1]

Fig. 2.1 shows the pedigree and southern blots of an RFLP locus that is closely linked with a disease phenotype. Affected individuals are shaded in the pedigree.

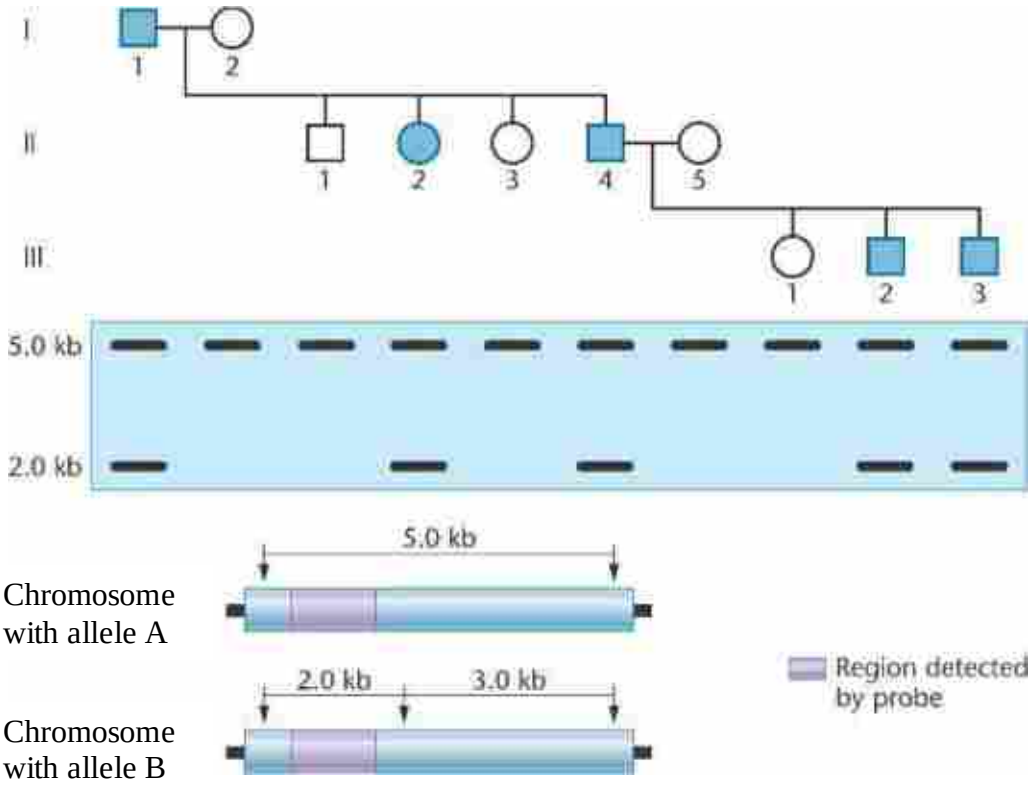


Fig. 2.1

(b) Explain the genetic basis of RFLP in comparative analysis in disease study.

……

……

…… [2]

1. **Normal and disease individual** have **difference(s) in genetic sequence**.
2. Upon **digestion with same set of restriction enzyme(s), different number and length of DNA fragment** will be produced.
3. Gel electrophoresis and nucleic acid hybridization with labelled probes will result in **different RFLP profile / band patterns** for normal and diseased individual.

[L2]

(c) With reference to Fig. 2.1,

(i) Identify the allele responsible for the disease.

……[1]

1. **Allele B**

[L2]

(ii) State the considerations for target region of the probe.

……..

……..

……[2]

1. **Same target sequence for allele A and B**.
2. **Disease allele** is **closely linked/associated** with **polymorphic RFLP locus**.
3. **Probe binds to different fragment lengths** for **normal and disease allele** / **OWTTE**.

[L3]

(iii) Explain if the disease allele is dominant or recessive.

……..

……..

……[2]

1. **Dominant**
2. **2kb fragment** associated with allele B is always present in **affected individuals** (I-1, II-2, II-4, III-2 and III-3).
3. In the **absence of allele B**, **individuals are normal**.

[L2]

(d) Briefly describe two other applications of RFLP.

……..

……..

……[2]

1. RFLP as **genetic markers in genomic/linkage/physical mapping**.
2. **DNA fingerprinting** for **paternity testing / forensic investigation / verification of poaching**.

[L1]

[Total: 13]

3 Fig. 3.1 shows how gene therapy using modified viruses can be carried out.

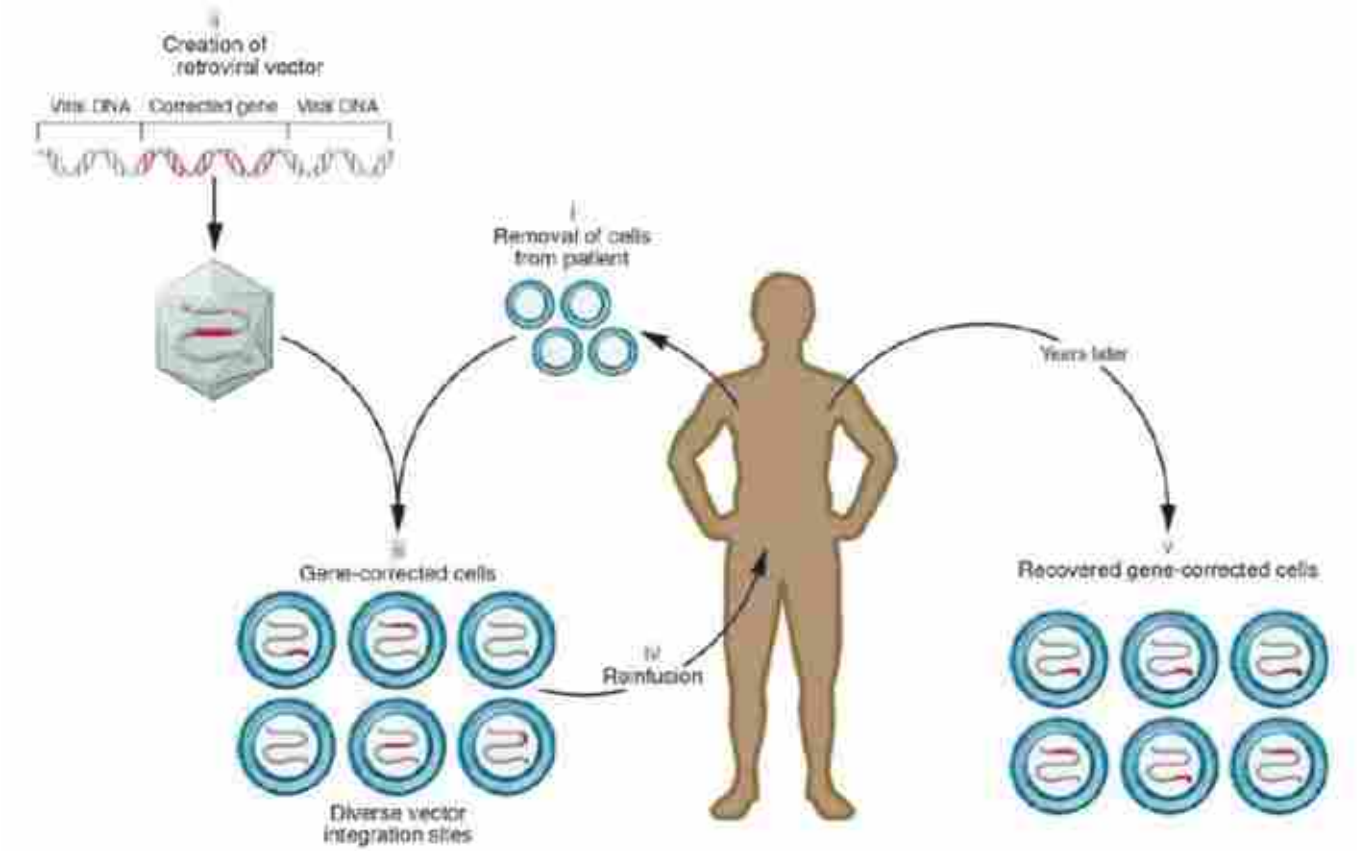


Figure obtained from Retroviral integration and human gene therapy The Journal of Clinical Investigation, Volume 117, Number 8

Fig. 3.1

Severe combined immunodeficiency (SCID) and X-linked SCID are two genetic diseases that can be treated by the gene therapy method shown in Fig. 3.1.

(a) State the genes that can be corrected for SCID and X-linked SCID.

SCID: ……..

X-linked SCID: ……..

[2]

S: State (CW), gene, corrected, X-linked SCID

C: Factual recall

ORE:

1. SCID: **Adenosine deaminase** gene Reject: ADA gene
2. X-linked SCID: Gene coding for a subunit **gamma c** (γc) of an **interleukin receptor**.

[L1]

(b) Explain how mutation in one of the genes cited in **(a)** would give rise to immunodeficiency.

……

……

……[2]

S: Explain why(CWs), mutations genes, (a), immuodeficiency

C:
- Cause and effect
- Adenosine deaminase gene mutation → Purines cannot be broken down → Toxic to cells
- Mutation in gene coding for a subunit gamma c (γc) of an interleukin receptor → HSC cannot convert to T-cells

ORE:
1. Adenosine deaminase (ADA) **breaks down purine**
2. hence without ADA, purines which **accumulate** is **toxic** to **T** and **B cells**, causing them to **die**.

OR
3. γc subunit of IL receptors is needed to convert **hematopoietic stem cells to progenitors of T cells**,
4. hence without the the progenitors there will be **no derivation / generation** of **T-cells.**

(Points 1 & 2 have to be together & Points 3 & 4 have to be together.)

[L2]

Excerpt from the *The Journal of Clinical Investigation* review titled *Retroviral integration and human gene therapy*:

> "However, with these successes came the first serious adverse events in retrovirus based gene therapy. Three of the SCID-X1 patients treated by the French team developed a leukemia-like lymphoproliferative disease."

(c) Suggest why these patients developed leukemia-like lymphoproliferative diseases.

……

……

……..[2]

S: Suggest why(CWs), patients, developed, leukemia-like lymphoproliferative diseases, retrovirus

C:
- Retroviruses integrate in the genome
- Protooncogene converted to oncogene
- Not tumour suppressor gene as two alleles need to be inactivated.

ORE:

1. **DNA** of modified **retroviruses integrate** into **host** cell **genome** / **insertional mutagenesis**.
2. Integration may cause **gain of function mutation** resulting in **protooncogene** converted to **oncogene**.
3. Integration may cause **loss of function mutation** in **2 alleles** of the **tumour suppressor gene**.

[L3]

In 1999, 18-year old Jesse Gelsinger died after suffering from a massive immune response following a clinical trial that administered adenoviral-based gene therapy.

(d) Besides adenovirus' ability to elicit a strong immune response, explain why adenovirus is also not favoured in the treatment of the genetic diseases cited in **(a)**.

……

……

……..[2]

S: Explain why (CWs), besides, adenovirus, immune response, not favoured, treatment..genetic diseases..(a)

C:
- Cannot mention adenovirus' high immunogenicity
- Adenovirus does not integrate into host genome
- Limited duration of in vivo gene expression

ORE:
1. **Adenovirus does not integrate** into **host** cell **genome** after infection.
2. There is therefore **limited duration** of ***in vivo*** **gene expression / OWTTE**.

[L2]

(e) Explain why scientists prefer to isolate hematopoietic stem cells rather than T-cells from the patient for the gene therapy treatment shown in Fig. 3.1.

……

……

……

……..[3]

S: Explain why (CWs), scientists, prefer, isolate, HSCs vs T-cells, gene therapy, Fig. 3.1

C:
- HSCs

ORE:
1. Gene targeting T-cells does **not** result in **long-term expression** of the corrected **genes**, since most of these cells **die** rather than self-renew.
2. Gene targeting haematopoietic stem cells result long-term expression of the corrected genes as these cells have the capability to **self-renew**
3. and **differentiate** to give rise to more **T-cells** /
4. and are **multipotent stem cells**.

[L2]

Viruses are not the only vectors that are utilised to deliver genes into patients' host cells.

(f) State one other type of vector that is not viral.

……

……..[1]

S: State (CW), one, other type, vector, not viral

C:
- Factual recall

ORE:

1. **Liposomes**
2. **Gene gun**

(Max 1)

[L1]

(g) Discuss two ethical implications of gene therapy.

……

……

……

……..[2]

S: Discuss (CW), two, ethical implications, gene therapy

C:
- Discursive question

ORE:

1. Philosophical perspective on **morality** of changing genetics / OWTTE.
2. **Germ-line gene therapy** will alter offspring genetics, we may not have the **right to alter** our **children's genes** / OWTTE.
3. Those involved in the research related to **germ-line gene therapy** regularly **create and destroy embryos** as a part of their research. There are objections to killing embryos used for research in gene therapy as **human life** may be considered to have begun at conception.
4. **Genetic determinism / Definition of 'normal' and 'disability'**. The decision of what is normal and what is a disability should not rest on just a small group of individuals or medical professionals. The question of whether disabilities are considered disease and whether these need to be cured or prevented requires thorough consideration.
5. **Patenting** to **develop drug/process at the expense of human life** / OWTTE.
   Reject all social/religious points.
   (Max 2)

[L2]

[Total: 14]

4 Planning question

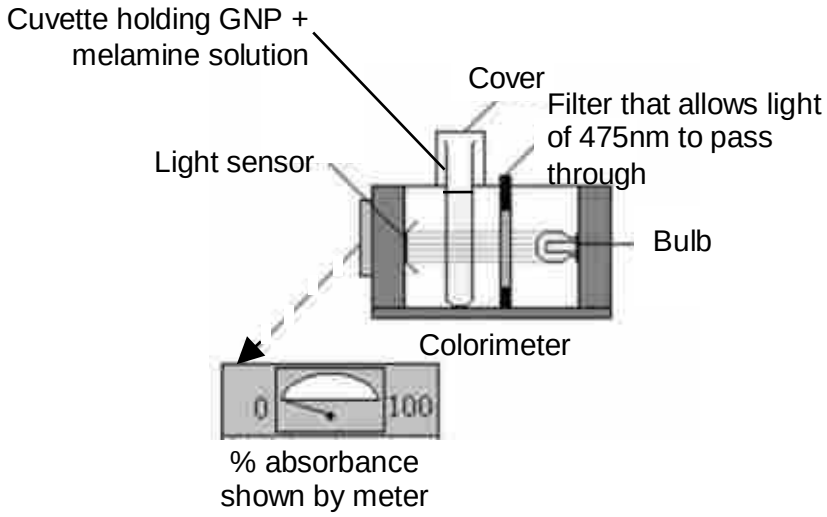
In 2008, contaminated milk and infant formula with melamine in China resulted in over a thousand babies hospitalised and caused several deaths. Melamine with its large number of nitrogen atoms, was unethically added to foods to mimic proteins detected through conventional measurements for nitrogen.

A research group found a way to detect the presence of melamine via a colour indicator. They attached cyanuric acid to gold nanoparticles to produce functionalized gold nanoparticles (GNP) that are red, the cyanuric acid component of GNP detects the melamine through hydrogen-bonding. Upon binding to melamine, the GNP changes from red to blue, giving a clear signal that there is contamination.

GNP (red) + Melamine → GNP-Melamine complex (blue)

The intensity of the blue colour after a set time interval of 5 minutes is a measure of the concentration of the melamine present in a specimen.

The test involves addition of 1 cm^3 of solution (to be tested) to 0.1 cm^3 of GNP in a cuvette (glass container), followed by colourimetric measurement of absorbance (% absorbance) at a specified wavelength. It is known that the blue wavelength is 475 nm.



You are required to plan, but not carry out, an investigation to determine the lowest concentration of melamine detectable by GNP indicator.

Your planning must be based on the assumption that you have been provided with the following equipment and materials which you **must** use:

- 1 % GNP
- Colourimeter
- 6 x Cuvettes (container for colourimeter measurement)
- 6 x Test-tubes
- Test-tube rack
- 2 x 10 cm^3 syringes
- 2 x 1 cm^3 syringes
- Micropipette
- 15 cm^3 of 1% melamine solution labelled M
- 50 cm^3 of buffer solution
- Marker pen
- Stopwatch
- Safety googles
- Disposable gloves

Your plan should have a clear and helpful structure to include:

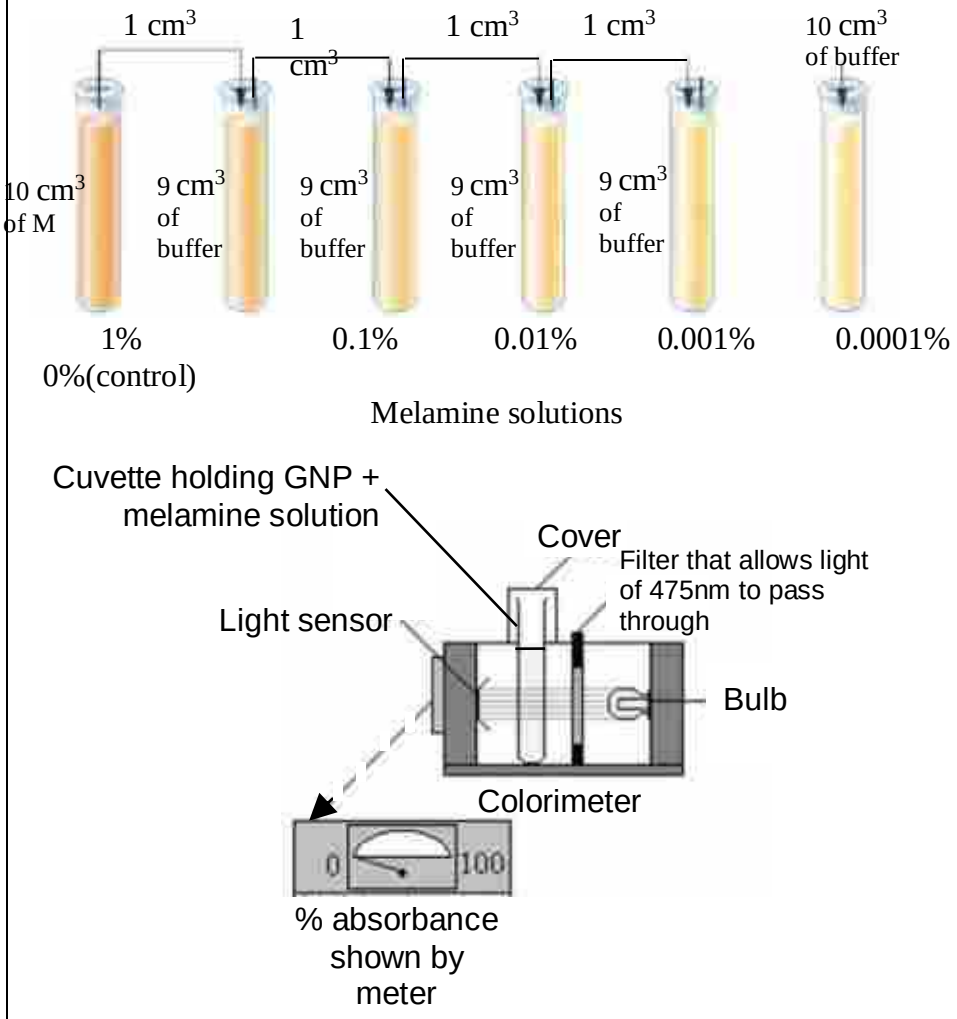
- an explanation of theory to support your practical procedure
- a description of the method used including the scientific reasoning behind the method
- proposed layout of results tables with clear headings and labels
- the correct use of technical and scientific terms

[Total: 12]

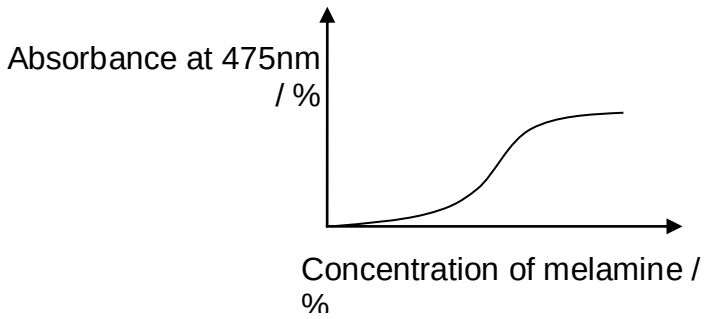
……

……

Section	Marking Points	
Aim, Hypothesis, Introduction [Max 2]	1. **Melamine may mimic protein in infant formula**.	**1**
	2. **Presence of melamine can be detected by a colour change of GNP from red to blue**	**1**
	3. **Melamine binds to cyanuric acid component of GNP through hydrogen-bonding**, is the basis for detection.	**1**
	4. The presence of melamine contaminant could be **measured by a colorimeter** that measure **% absorbance at specifc wavelength**	**1**

	(475nm),	
Variables [1] Both Independent & Dependent variable must be correct.	**5. Independent variable: Concentration of melamine / % (1%, 0.1%, 0.01%, 0.001%, 0.0001%)**	**1**
	6. Dependent variable: % absorbance of solution at specific wavelength (475nm) after **5 mins**	
Apparatus & Procedures [Max 4] **Note: rationale must be included for award of marks.**	**7. Carry out serial dilution of 1% melamine solution using the buffer** to reduce the concentration of melamine solution by a factor of 10 between each of the four successive dilutions, to give **0.1%, 0.01%, 0.001% and 0.0001% (Description / Table of dilution accepted)**	**1**
	8. Clear labelled diagram of experimental setup  	**1**
	9. **Negative Control contains buffer only.** All other conditions remain the same. This shows that colour change of GNP indicator to blue only occurs in the presence of melamine.	**1**
	10. **Data points [Five melamine concentration]: Table of preparation must be shown**	**1**

Concentration of melamine/% (no need to consider s.f.)	**1.0000**	**0.1000**	**0.0100**	**0.0010**	**0.0001**	**0.0000**
Melamine solution to be diluted		**1.0000**	**0.1000**	**0.0100**	**0.0010**	
Volume of melamine solution to be diluted / cm^3	**10.0**	**1.0**	**1.0**	**1.0**	**1.0**	**0.0**
Volume of buffer to be added / cm^3	**0.0**	**9.0**	**9.0**	**9.0**	**9.0**	**10.0**

<table>
<tr><td></td><td>11. Controlled variable: Volume of melamine solution tested kept constant to 1cm^3</td><td>1</td></tr>
<tr><td></td><td>12. Controlled variable: Volume of GNP indicator used kept constant to 0.1 cm^3</td><td>1</td></tr>
<tr><td></td><td>13. Controlled variable: Solution reaction time to GNP indicator kept constant to 5 mins.</td><td>1</td></tr>
<tr><td></td><td>14. After 1 cm^3 of melamine solution is added to 0,1 cm^3 of GNP indicator and stand for 5 mins in the cuvette.</td><td>1</td></tr>
<tr><td></td><td>15. [Colorimeter Calibration] Fill another cuvette with buffer/control to calibrate the colorimeter zero absorbance reading.</td><td>1</td></tr>
<tr><td></td><td>16. Measure the % absorbance of solution using colorimeter.</td><td>1</td></tr>
<tr><td></td><td>17. Repeat Step 11-16 for other concentrations of melamine solutions.</td><td>1</td></tr>
<tr><td></td><td>18. [Data collection]: Record the % absorbance of the solutions in a table.</td><td>1</td></tr>
<tr><td></td><td>19. [Reliability]: Perform 2 repeats to obtain 3 replicates → ensure reliability [See point 23-24]</td><td>1</td></tr>
<tr><td>Safety & Precautions [1]</td><td>20. Specify at least <u>ONE</u> valid risk and corresponding precaution:
• [Risk] Use of glassware during preparation of melamine serial dilution, exercise caution + [Precaution] prevent breakage of glassware to avoid cut injuries.
• [Risk] Wet hands could risk electrocution when switching on colorimeter + [Precaution] Dry hands before switching on colorimeter.
• [Risk] Melamine is poisonous + [Precaution] wear gloves and protective googles to prevent exposure.
• AVP</td><td>1</td></tr>
<tr><td>Results [Max 2]</td><td>19. [Table of results] must include:
• Independent variable with unit
• Dependent variable with unit
• Processed data with unit
• Correct trend (in agreement with hypothesis – lower absorbance at lower concentration of melamine)
[T] <u>Table showing intensity of colour of extract</u>
<table>
<tr><td rowspan="2">Concentration of melamine solution / %</td><td colspan="4">Absorbance at 475nm / %</td></tr>
<tr><td>Replicate 1</td><td>Replicate 2</td><td>Replicate 3</td><td>Average</td></tr>
<tr><td>1.0000</td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.1000</td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.0100</td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.0010</td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.0001</td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.00 (control)</td><td></td><td></td><td></td><td></td></tr>
</table></td><td>1</td></tr>
<tr><td></td><td>20. [Graph] must include:
• Independent variable on x-axis labelled with unit
• Dependent variable on y-axis labelled with unit
• Line graph (Increased % absorbance with increasing melamine concentration)
 
</td><td>1</td></tr>
<tr><td>Interpretation [1]</td><td>21. [Correlate with graph and hypothesis]:
• As shown by the graph, as the concentration of melamine increases, average % absorbance at 475nm increases, given a</td><td>1</td></tr>
</table>

	fixed amount of time of exposure / Vice versa	
	22. **Lowest concentration of melamine that could be detected can be determined based on the graph / comparison against control (same result).**	
	23. Further serial dilutions may be required to determine lowest concentration of melamine that could be detected.	
Correct scientific terms + Reasoning [1]	24. Use **appropriate terms** within answer (e.g. **hydrogen bonding, sensitivity, absorbance** etc.)	**1**

- **Note: Reference to SPA Planning Qn on Membrane structure (SPA Planning Booklet pg)**

Section B: Free-response question

Answer **all** questions. Answer each part on a **separate** piece of paper.

Write your answers on separate answer paper provided.
Your answer should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answer must be in continuous prose, where appropriate.
Your answer must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5 **(a)** Compare between Genomic and cDNA libraries used in protein production. [6]

Basis of Comparison	Genomic Library	cDNA libraries
Similarities [Max 3]	1. Both store genetic information	
	2. Both requires the use of vectors	
	3. Both require ligation of genetic sequence to vector using DNA ligase	
	4. Both requires storage in host cells.	
Difference [Max 3]		
5. Scope of genetic information	Entire genome inclusive of introns and exons	Expressed part of the genome
6. Starting material for library construction	Genomic DNA	Processed mRNA
7. Cloning Vector	Bacteriophage, Cosmid, BAC, YAC,	Plasmid and λ phage
8. Enzymes involved	Restriction enzymes, DNA ligase, DNA polymerase	Restriction enzymes, DNA ligase, DNA polymerase and reverse transcriptase
9. Ease of library screening	Difficult to locate gene of interest as single gene may be dispersed over several clones.	Easier as gene are isolated whole.
10. Expression of eukaryotic gene in prokaryotic system	Unlikely to produce functional protein due to the presence of introns.	Functional protein can be produced

11. Nature of genetic information stored	Same throughout the life of the cell / regardless on the type of cell	May differ at different time in the life of the cell / dependent on the type of cell
12. Presence of introns	Present	Absent
13. Presence of regulatory sequences	Present	Absent

[L3]

(b) Explain the advantages and limitations of PCR. [6]

Advantages (Max 3]:

1. PCR is **highly specific**, only sequenced flanked by **forward and reverse primers** are replicated.
2. PCR can be performed **in vitro** without the use of cells.
3. PCR is a **cheaper technique as compared to cloning** because no need to culture and maintain large quantities of host cells.
4. PCR is **faster than cloning** in replication of DNA.
5. Only **minute amounts of DNA** is required as **starting material/ for amplification**.

Limitations (Max 3):

6. Process is **not error-free** due to **absence of proofreading activity** in **Taq polymerase**.
7. Possible **contamination from non-template DNA** if primers sequence are not specific.
8. DNA sequences **flanking target sequences** to be amplified **must be known** to enable **synthesis of primers**.
9. **PCR cannot substitute gene cloning** in cells for **longer DNA sequences**.

(c) Discuss the pros and cons of genetically-modified crop plants. [8]

SC	OR	E
CW: Discuss QKW: pros & cons, genetically-modified crop plants PRO	• Crop yield increase	1. Genetic engineering on plants can **enhance crop yields**.
PRO	• May bypass seasonal restrictions	2. Genetic engineering may permit crops to **grow outside** their **usual location** / **season** so that people have **more food**.

PRO	• Enhance nutritional content	3. Genetically modified crop plants can also be **enhanced** with a certain **nutritional content** (e.g. Golden rice) so that people are **better fed/OWTTE**.
PRO	• Pest-resistant crops	4. Genetically modified crop plants can be more **pest-resistant** (e.g BT corn),
PRO	• Lower cost	5. and this will **lower cost** as **pesticide** usage will be **reduced/avoided**.
PRO	• Less pollution	6. As pesticide usage is reduced/avoided, there will be **less damage/pollution** to the **environment**.
PRO	• Drought-resistance	7. Genetically modified crop plants can be more **drought-resistant**, and this will increase crop yield for farmers.
PRO	• Avoid costly irrigation	8. Drought-resistant crops can also help farmers **avoid** installing **costly irrigation** systems to ensure sufficient water is provided.
PRO	• Profits increase → consumer cost drops	9. As farmers' cost is reduced, their **profits increase** / **consumer cost** may also **reduce**.
PRO	• Increased shelf-life	10. **Shelf-life** of **crops** can be **increased** **Flavor Savr PG gene** example must be given
CON	• More invasive plants • Superweeds	11. The introduced gene(s) may be **transferred by pollen** to **wild relatives** whose hybrid offspring will become more **invasive** and hence become **'superweeds'**.
CON	• Cost involved in removing superweeds	12. This may lead to **additional cost for** the **removal** of such **'superweeds'.**
CON	• Plant diversity compromised	13. 'Superweeds' may also **reduce plant biodiversity** by **out-competing** natural plants
CON	• Organic farms may be compromised	14. The introduced gene(s) may be **transferred by pollen** to **unmodified plants** growing on a farm with **'organic'** certification, hence losing organic certification.
CON	• Toxic components	15. The modified plants will be a direct hazard to humans, domestic **animals** or other beneficial animals by being **toxic.** OR For instance, the herbicides that can now be used on the crop will itself **leave toxic residues** in the crop, which will be toxic to humans who consume them.

		OR **Disrupt ecological systems** e.g. Monarch Butterflies affected by BT.
	• Damage environment	16. The toxic residues/ overused pesticide may also affect and cause **unintended damage** to the **environment** by causing pollution to the surroundings.
	• Allergies	17. The modified plants will be a direct hazard to humans, domestic animals or other beneficial animals by being **producing allergies** upon consumption.
	• Farmers pay royalties	18. Farmers may have to **pay royalties** to sow the crops. OR 18. Some companies have extended their **patents on genetically engineered seeds** to prevent farmers from re-sowing the seed from these genetically engineered crops.
	• Higher consumer cost	19. The cost that farmers have to pay for the royalties may be passed on the **consumers** who may have to **pay higher prices** for them.
	• Vulnerability to diseases	20. **Genetically identical** and would be **equally vulnerable to disease.**

(Max 8, Maximum 4 pros and 4 cons)

[L2]

[Total: 20]

END OF PAPER

Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

Paper 1 Multiple Choice Questions **28 September 2016**
1 hour 15 min

Additional Material: OTAS sheet

INSTRUCTIONS TO CANDIDATES:

DO NOT TURN THIS PAGE OVER UNTIL YOU ARE TOLD TO DO SO.

READ THESE NOTES CAREFULLY.

Section A MCQ [40 marks]

There are **forty** questions in this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

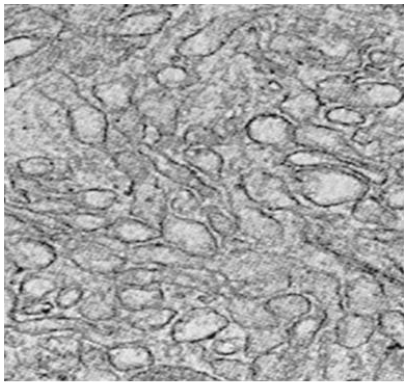
Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet.

This document consists of **27** printed pages and **1** blank page.

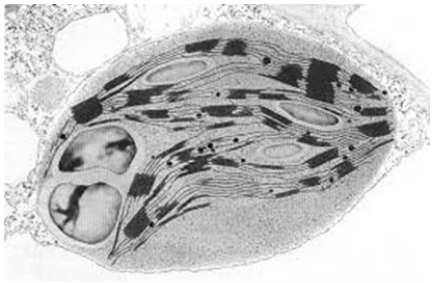
[Turn over

Answer **all** questions in this section.

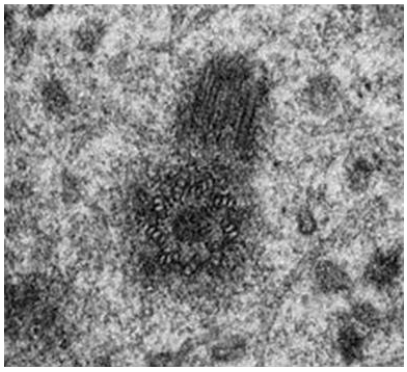
1 The figure below shows electron micrographs of 4 different organelles **P**, **Q**, **R** and **S**.



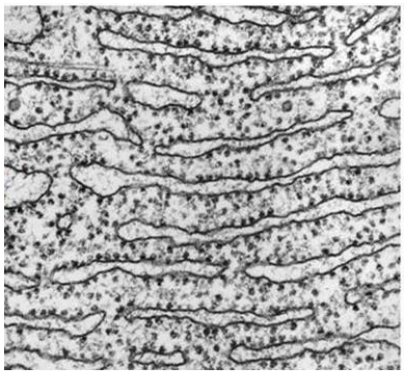
P



Q



R



S

Which of the following matches the organelle to its function?

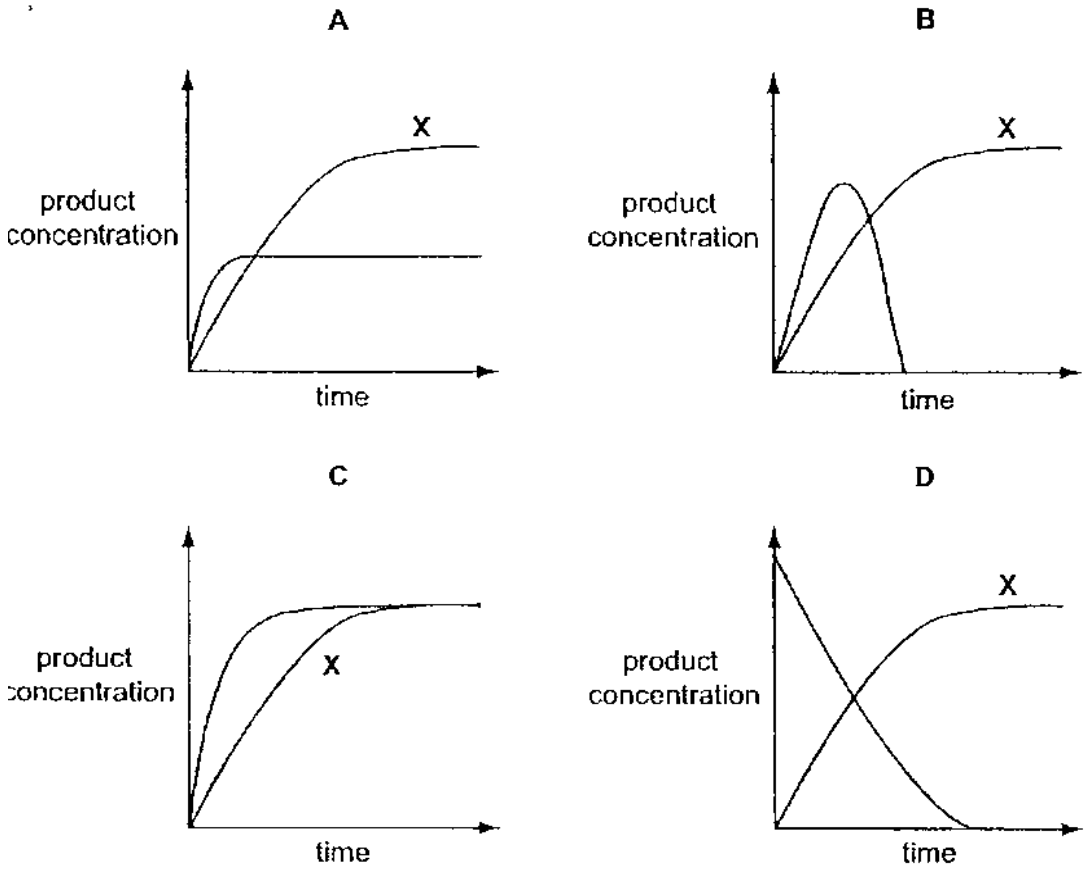
	Organelle	**Function**
A	**P**	phospholipid synthesis
B	**Q**	enzyme secretion
C	**R**	protein synthesis
D	**S**	glycosylation of proteins

2 Which pair shows the ***CORRECT*** classification?

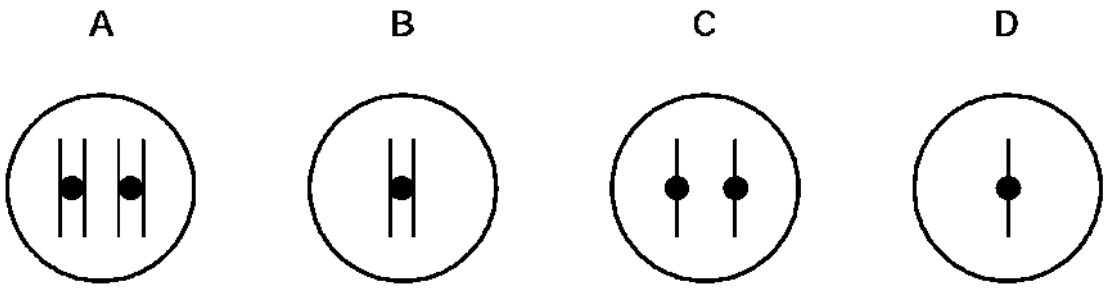
	Branched structure	**Unbranched structure**
A	amylose	glycogen
B	amylopectin	cellulose
C	cellulose	amylopectin
D	glycogen	amylopectin

3 Two enzyme experiments were carried out. The first, experiment **X**, was carried out at a constant temperature of 37°C. During the second experiment, the temperature was increased from 37°C to 80°C.

Which graph shows the results?



4 A cell with one pair of chromosomes (2n = 2) undergoes meiosis. Which nucleus is formed at the end of meiosis I?



5 In an attempt to synthesise DNA molecules *in vitro*, a student isolated and purified various molecules needed for DNA replication. She added some DNA to the mixture, and replication occurred. However, the DNA molecules formed were defective. Each molecule consists of a normal DNA strand paired with numerous segments of DNA, each about hundreds of nucleotides long.

What might she have left out in the mixture?

A DNA primer

B RNA primer

C DNA ligase

D DNA polymerase III

6 The mechanism of action of four drugs that inhibit DNA replication is stated below.

- **Aphidicholine** inhibits DNA polymerase III.
- **Cytarabine** is converted into a molecule that can substitute for a DNA nucleotide and also inhibits DNA repair mechanisms.
- **Epirubicin** inhibits an enzyme involved in the unwinding and separation of DNA strands.
- **Hydroxycarbamide** inhibits an enzyme involved in the production of deoxyribonucleotides.

Which row ***CORRECTLY*** matches the effects of these drugs on DNA replication?

	Effects of Drug on DNA Replication			
	Inhibition of chain elongation	**DNA damaged during replication**	**DNA strands not available as templates for replication**	**Exposed DNA template strands unable to be copied**
A	aphidicholine	hydroxycarbamide	epirubicin	cytarabine
B	cytarabine	epirubicin	aphidicholine	hydroxycarbamide
C	epirubicin	hydroxycarbamide	cytarabine	aphidicholine
D	hydroxycarbamide	cytarabine	epirubicin	aphidicholine

7 The diagram shows part of the normal sequence of an mRNA molecule.

CCAAGUGGUCCGCUAAGAAGGC

A mutation in the DNA resulted in a polypeptide beginning with the following sequence.

glycine - serine - proline - glycine - isoleucine - leucine

The DNA triplets for some amino acids are

Glycine	Isoleucine	Leucine	Proline	Serine
CGA	ATA	TTA	CCA	TCA
GGT	ATT	CTT	CCG	TCG
GGC		CTC		

Which mutation has occurred in the DNA molecule?

A The replacement of one nucleotide by a different nucleotide.

B A reversal in the order of nucleotides.

C An addition of an extra nucleotide.

D The loss of a nucleotide.

8 All of the following statements about viruses are true ***EXCEPT*** _____.

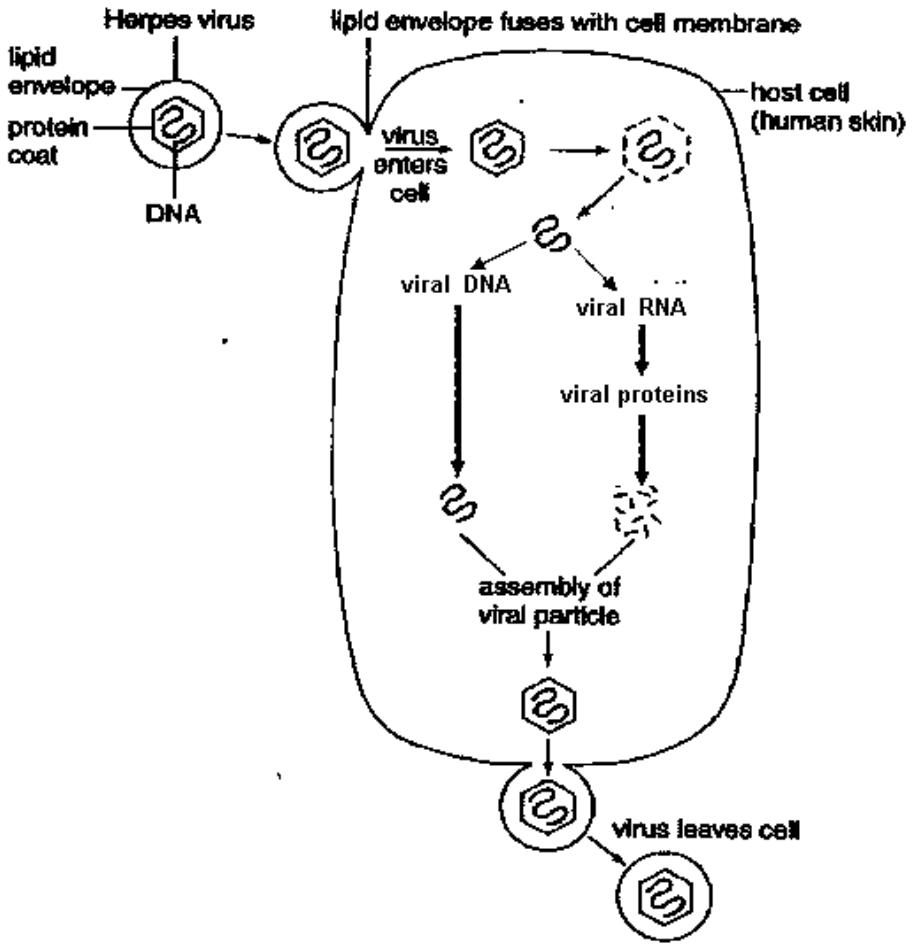
A The genome of RNA viruses are more likely to mutate than those of DNA viruses.

B All viruses produce RNA as an intermediate molecule during the production of new viruses.

C All RNA viruses produce DNA as an intermediate molecule during the production of new RNA viruses.

D Before entering a host cell, specific proteins of viruses bind to receptors on specific host cells.

9 The diagram below shows the reproductive cycle of the herpes virus which causes cold sores on the mouth.



With reference to the diagram below, which of the following statements ***BEST*** describes the herpes virus?

A It is not a retrovirus as it does not contain RNA as its genetic material.

B Its mode of replication is similar to that of influenza virus.

C Its replication cycle includes a lysogenic phase.

D Death of the host cell is necessary for the release of the viral progeny.

10 In a repressible operon under negative control, a mutation that alters the product of the operon's regulatory gene such that it is unable to bind to the co-repressor occurred.

This mutation will result in _____.

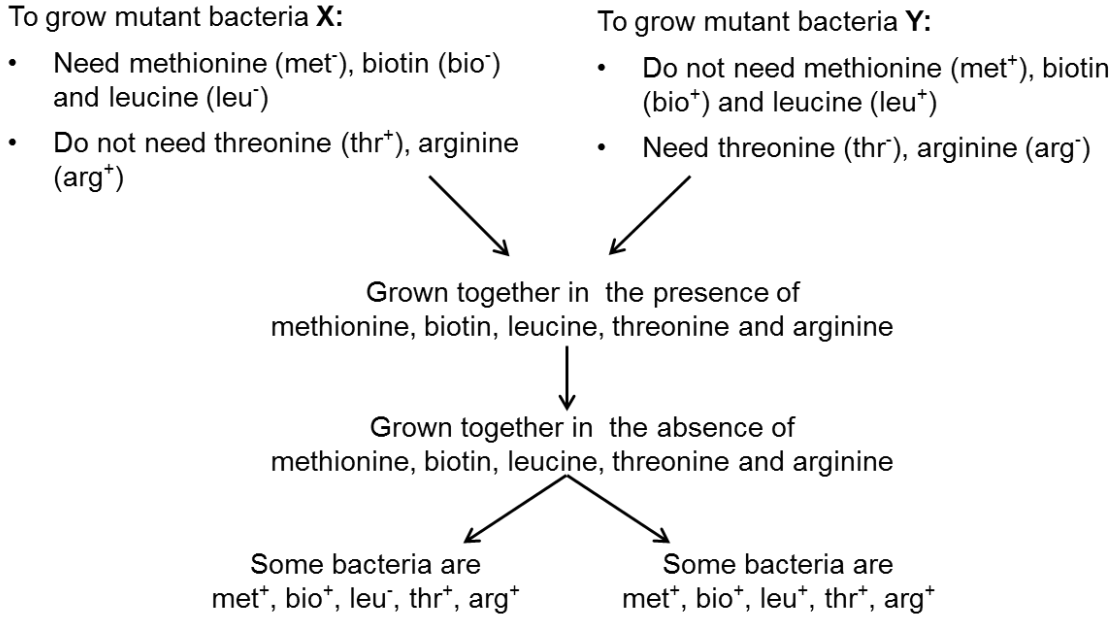
A irreversible binding of the repressor to the operon

B no transcription of genes of the operon

C continuous transcription of genes of the operon

D no difference in the transcription rate

11 The diagram shows an investigation into bacterial genetics.



Which process or processes could explain these results?

I conjugation

II transduction

III transformation

A **I** only

B **III** only

C **I** and **II**

D **I** and **III**

12 Which of the following is ***TRUE*** of cancers?

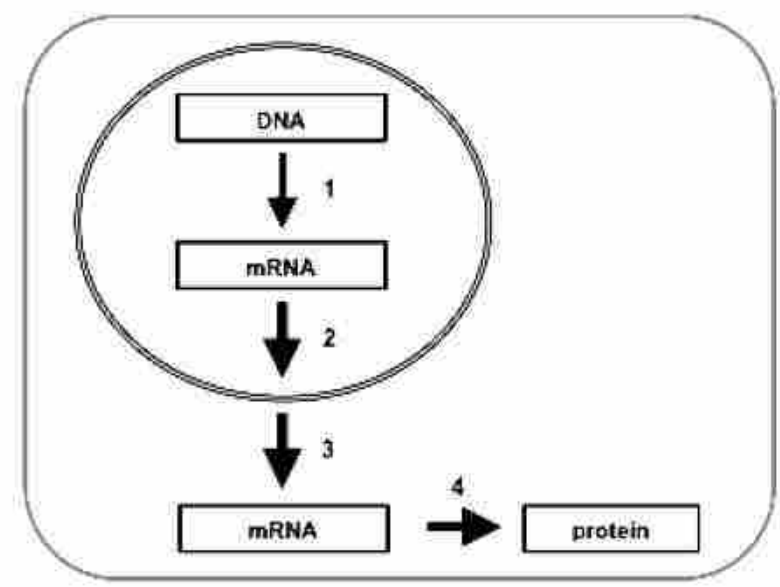
A Anchorage dependence is lost in cancer cells.

B Cancer cells are likely to have longer-than-usual telomeres despite having inactivated telomerases.

C A cell that has a copy of the p53 tumour suppressor gene inactivated can be considered to be cancerous.

D When a copy of the ras proto-oncogene is activated into an oncogene in a normal cell, cancer immediately develops.

13 The following diagram shows the expression of a particular gene to its protein product in a eukaryotic cell. Which of the following combination correctly describes steps **1** – **4**?



	1	2	3	4
A	DNA is demethylated	5' capping occurs	RNase does not degrade 5' capped mRNA	Initiation factors bind to ribosome
B	DNA is demethylated	Alternative splicing occurs	Activators bind to enhancers	Ribosome binds to 5' UTR
C	DNA is methylated	Poly(A) tail is added to 3' end	poly-A tail is extended	Phosphorylation of protein
D	DNA is methylated	5' capping occurs	Removal of 5' cap	Activators bind to enhancers

14 Which statement best explains how related genes involved in the same metabolic pathway are expressed together in eukaryotic cells?

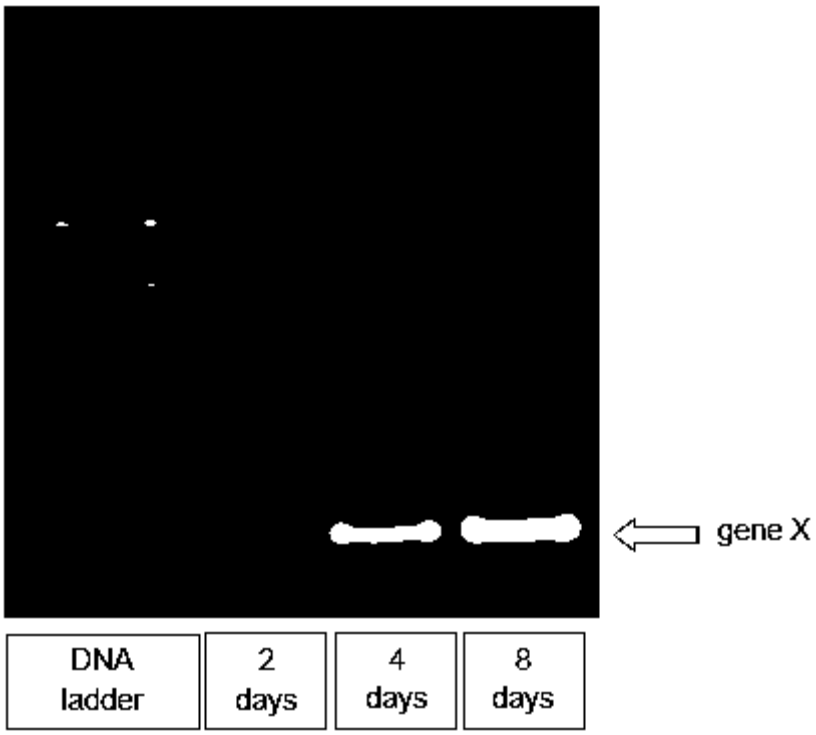
A Related genes are usually located on the same chromosome so that they can be controlled by the same set of control elements.

B The same set of general transcription factors may be capable of recognising the same promoter site of related genes.

C There are specific sets of control elements associated with related genes, recognised by specific sets of transcription factors.

D Within the control element of related genes, the specific numbers of transcription factors binding to the control element will enable related genes to be expressed.

15 Gel electrophoresis was performed using DNA samples of gene X isolated from equal number of cells from a human embryo after 2 days, 4 days and 8 days of development.



What kind of gene regulation is illustrated by the results of this gel electrophoresis?

A DNA demethylation

B Histone deacetylation

C Transcriptional activation

D Gene amplification

16 Fruit flies (*Drosophila*), homozygous for long wings, were crossed with flies homozygous for vestigial wings. The F_1 and F_2 generations were raised at three different temperatures.

At each temperature, the F_1 generation all had long wings.

The table shows the results in the F_2 generation.

Temperature / °C	Result
21	¾ long wings, ¼ vestigial wings
26	¾ long wings, ¼ intermediate wing length
31	all long wings

Which statement explains these results?

A Heterozygous flies have vestigial wings only at 21°C or below but have long wings at 31°C or above.

B Long wing and vestigial wing illustrate codominance at 26°C.

C Long wing is dominant at higher temperatures but vestigial wing is dominant at lower temperatures.

D Vestigial wing is recessive but causes a vestigial wing phenotype only at lower temperatures.

17 In mice, the gene for “dappled” coat (D) and its recessive allele for “plain” coat (d), are located on the X chromosome. The gene for “straight” whiskers (W) and its recessive allele for “bent” whiskers (w), are autosomal.

A male mouse with plain coat and bent whiskers was mated on several occasions to the same female and the large number of offspring consisted of males and females in equal numbers in all possible combinations of phenotypes,

What is the genotype of the female parent?

A X^DX^DWW

B X^DX^dWW

C X^DX^DWw

D X^DX^dWw

18 Three gene loci in mice are shown below.

Locus 1 Coat colour	**Locus 2** Tail appearance	**Locus 3** Coat appearance
agouti albino	kinky straight	non-frizzy frizzy

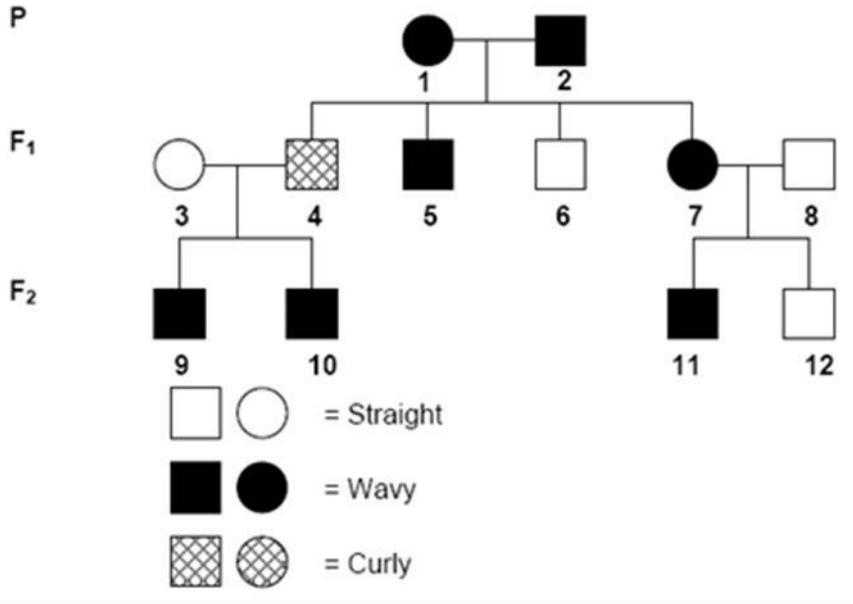
Crosses involving two loci at a time were set up and their outcomes are shown in the table below.

Parents (pure breeding)	**F1**	**Offspring of a test cross of the F1**
cross 1 agouti, non-frizzy coat x albino, frizzy coat	agouti, non-frizzy coat	agouti, non-frizzy coat 44 albino, frizzy coat 46 agouti, frizzy coat 5 albino, non-frizzy coat 5
cross 2 agouti, straight tail x albino, kinky tail	agouti, kinky tail	agouti, straight tail 23 albino, kinky tail 27 agouti, kinky tail 24 albino, straight tail 26

Which of the following statement is ***TRUE*** about **cross 1** and **cross 2**?

	Cross 1	**Cross 2**
A	The frequency of crossing over between locus 1 and locus 3 is 10%.	The agouti coat and kinky-tailed offspring of the test cross of the F1 are heterozygous at both loci.
B	Locus 1 and locus 3 undergo independent assortment.	The albino coat and straight-tailed offspring of the test cross are pure breeding.
C	Locus 1 and locus 3 are located on the same chromosome.	The F1 mice were test crossed with agouti coat and straight-tailed mice.
D	The interaction between locus 1 and locus 3 is an example of epistasis.	Locus 1 and locus 2 undergo independent assortment.

19 The pedigree below shows the inheritance of type of hair.



Which of the following statements are ***TRUE***?

I One of the parents of individual 2 may not always have the same phenotype as individual 2.

II If individual 10 married someone with wavy hair, the first child would have wavy hair.

III If individual 6 married a woman with straight hair, all of the offspring would have straight hair.

IV If individual 7 married a man with curly hair, the first child would have curly hair.

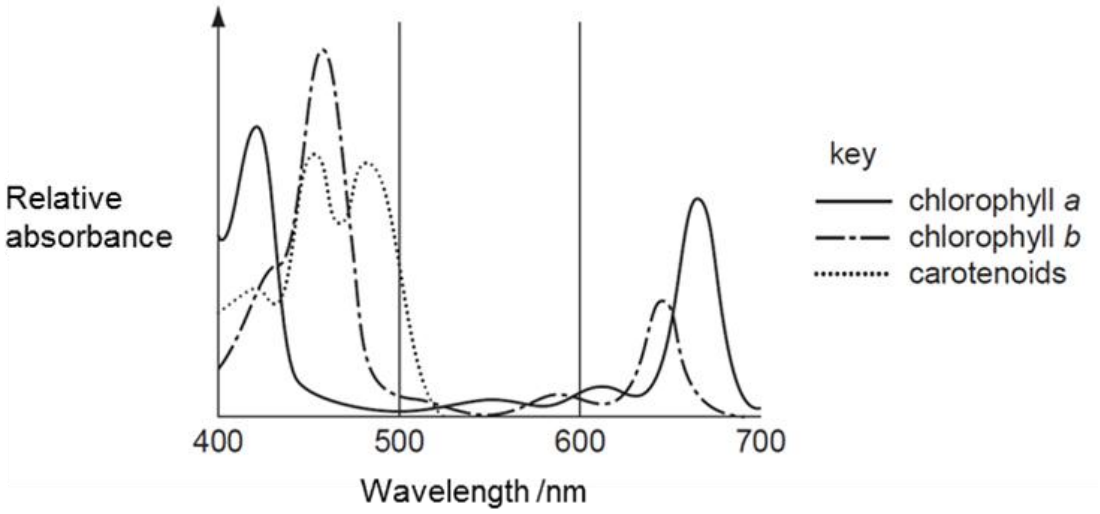
A **I** and **III** only

B **I** and **IV** only

C **II** and **III** only

D **II** and **IV** only

20 The graph shows the absorption spectra of some pigments found in chloroplasts.



Which statement is ***NOT*** correct?

A Having several pigments rather than one increases the efficiency of photosynthesis.

B Photosynthesis will be fastest when exposed to red light as red light has higher energy than blue light.

C Prior to leaf fall, chlorophyll is broken down, leaving carotenoids which makes leaves look yellow or red.

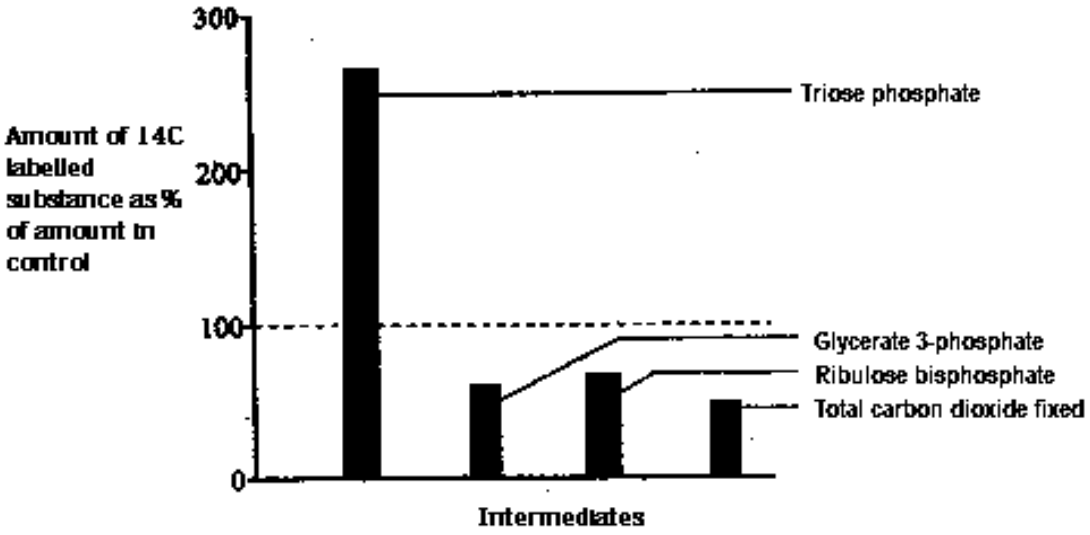
D Most leaves are green as chlorophyll absorbs light in the blue and red regions of the spectrum.

21 Removal of the source of carbon dioxide from photosynthesising chloroplasts results in rapid changes in the concentration of certain chemicals. Which one of the following represents the correct combination of concentration changes?

	ATP	***ribulose bisphosphate***	***glycerate-3-phosphate***
A	increases	increases	decreases
B	increases	decreases	increases
C	decreases	increases	decreases
D	decreases	decreases	increases

22 An experiment was conducted to test the properties of a chemical G on the photosynthetic capabilities of a unicellular agar, *Chlorella*. An illuminated suspension of the alga was treated with carbon dioxide labelled with ^{14}C in the presence of an unknown chemical G. The light was switched off and the amount of radioactivity present in some intermediates was determined after 10 minutes in the dark.

A control suspension of alga without chemical G being added was treated in exactly the same manner. The bar chart below shows the amount of radioactivity in these intermediates in the alga with chemical G added as a percentage of the intermediates in the control alga.



Which option ***CORRECTLY*** describes the action of chemical G?

A G binds to NADPH produced in light reactions and prevent its oxidation process.

B G competes with triose phosphate for the active site of the enzyme that converts triose phosphate into hexose phosphate.

C G inhibits the ribulose bisphosphate carboxylase enzyme, preventing carbon fixation from taking place efficiently.

D G prevents the regeneration of ribulose bisphosphate at the stage after triose phosphate was formed.

23 Which one of the following substances, when added, would directly result in a decline in ATP production in glycolysis?

I A chemical that would bind to NAD^+ irreversibly and induces its reduction to NADH.

II An inhibitor that has a similar structure to glucose but cannot be broken down by respiratory enzymes.

III A chemical that creates an anaerobic environment by combusting in oxygen

IV A reagent that binds to the active site of ATPase permanently

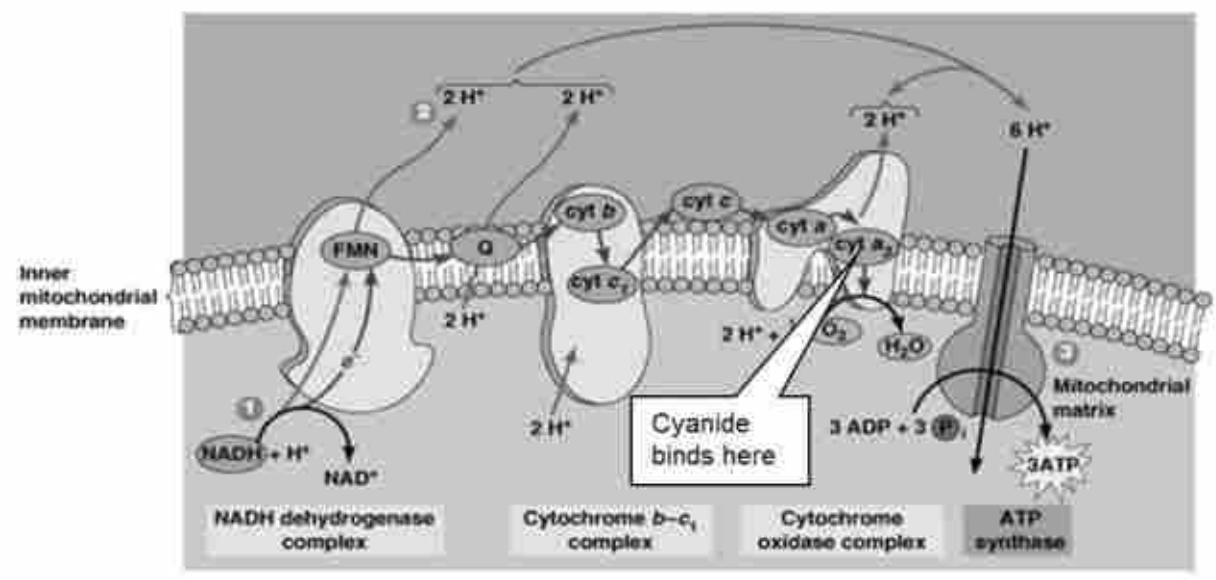
A **I** and **II** only

B **III** and **IV** only

C **I**, **II** and **IV** only

D All of the above

24 Cyanide is an inhibitor that binds irreversibly with the enzyme cytochrome oxidase in the electron transport chain. The diagram below shows the position where cyanide binds.



Which statement is ***TRUE*** of its effect on cellular respiration?

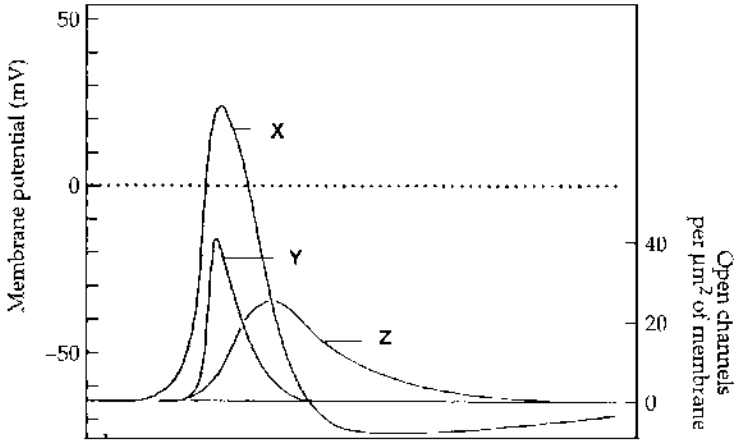
A It prevents cells from breaking down glucose.

B It prevents all synthesis of ATP in the cell.

C The cell's demand for oxygen would decrease.

D NAD+ would still be regenerated at the electron transport chain.

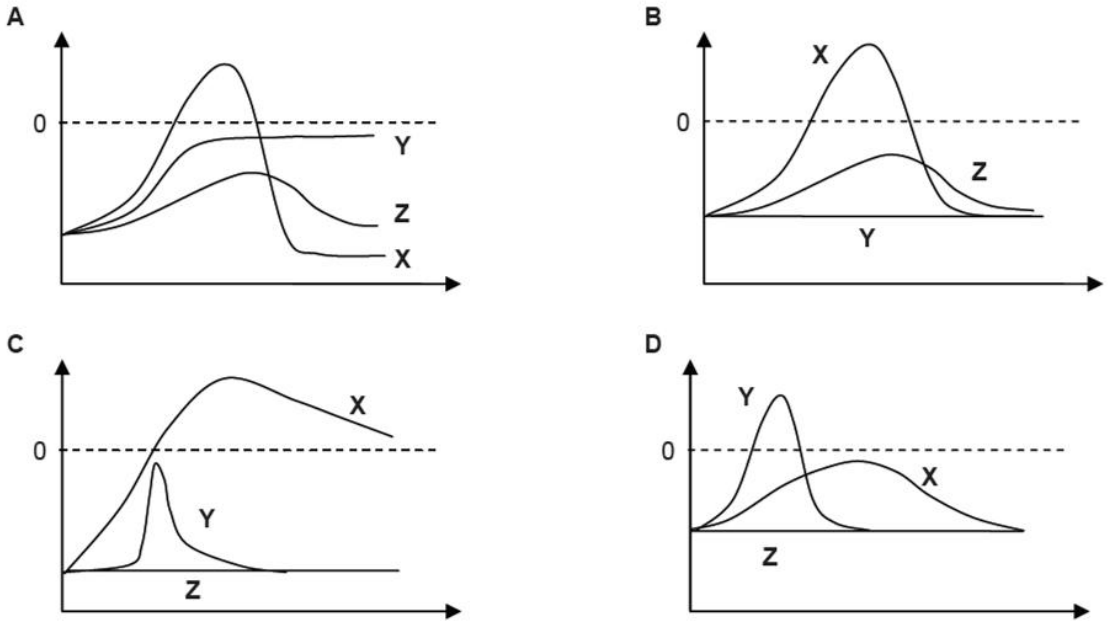
For Questions 25 and 26 refer to the figure below.



25 The values of Y and Z affect the value of X in an action potential. What do X, Y and Z in the above figure represent?

	X	Y	Z
A	Change in membrane potential	Sodium ion permeability	Calcium ion permeability
B	Sodium ion permeability	Potassium ion permeability	Calcium ion permeability
C	Change in membrane potential	Sodium ion permeability	Potassium ion permeability
D	Sodium ion permeability	Calcium ion permeability	Potassium ion permeability

26 Maurotoxin is a neurotoxin released by scorpions that blocks the pore of the voltage-gated K^+ channel in neurons. Choose from the following graphs to represent how the above diagram will change upon addition of maurotoxin to a neuron.



27 Which of the following statements about diabetes is ***FALSE***?

A In Type 1 diabetes, insulin receptors are absent.

B In Type 2 diabetes, beta cells of the islets of Langerhans are normal.

C In Type 1 diabetes, beta cells of the islets of Langerhans are not functional.

D In Type 2 diabetes, insulin receptors are defective.

28 Which of the following ***CORRECTLY*** describes the action of a trimeric G-protein?

A G-protein is phosphorylated and activated by receptor tyrosine kinase.

B G-protein has GTPase activity, hydrolysing GDP to GTP.

C Presence of an intracellular signal molecule activates the G-protein coupled receptor, leading to activation of G-protein.

D Activated subunits of the G-protein travel along the cell surface membrane to activate adenylyl cyclase.

29 A scientist is investigating the effects of Poison **T** on the cell signalling pathway of glucagon. It is found that Poison **T** is lipid soluble and diminishes the effect of glucagon. The levels of cAMP were also low in the cell.

Which of the following are possible statements that explain the effects of Poison **T**?

I Poison **T** binds directly to proteins in the cytoplasm.

II Poison **T** prevents G protein from hydrolysing GTP.

III Poison **T** inactivates the enzyme adenylyl cyclase.

IV Poison **T** prevents signal amplification by binding competitively to protein kinase A.

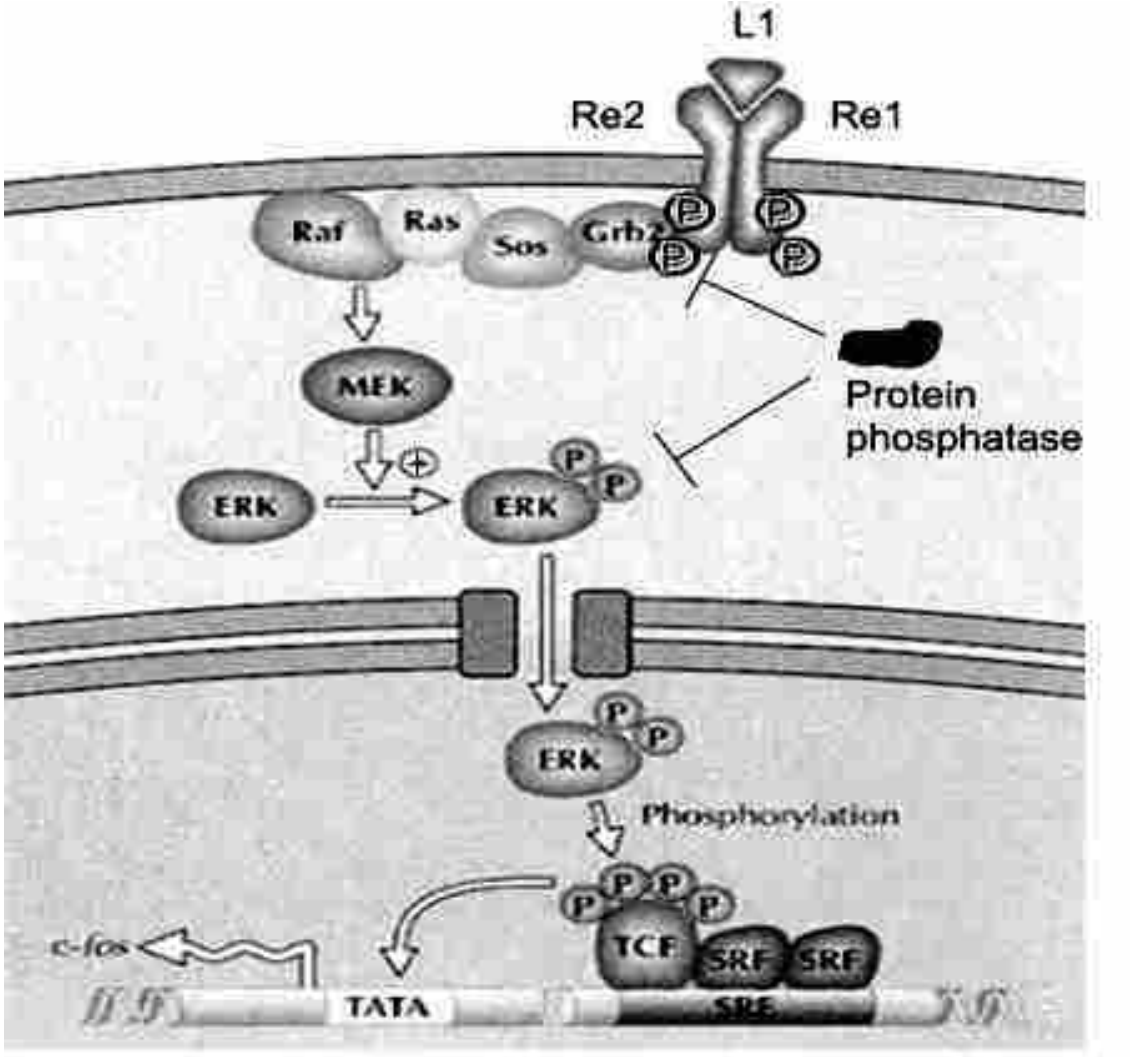
A **I** and **III** only

B **II** and **IV** only

C **I**, **II** and **IV**

D **I**, **III** and **IV**

30 The diagram below shows the cell signalling pathway involving a growth factor receptor.



From the given diagram, which step is involved in the role of signal amplification?

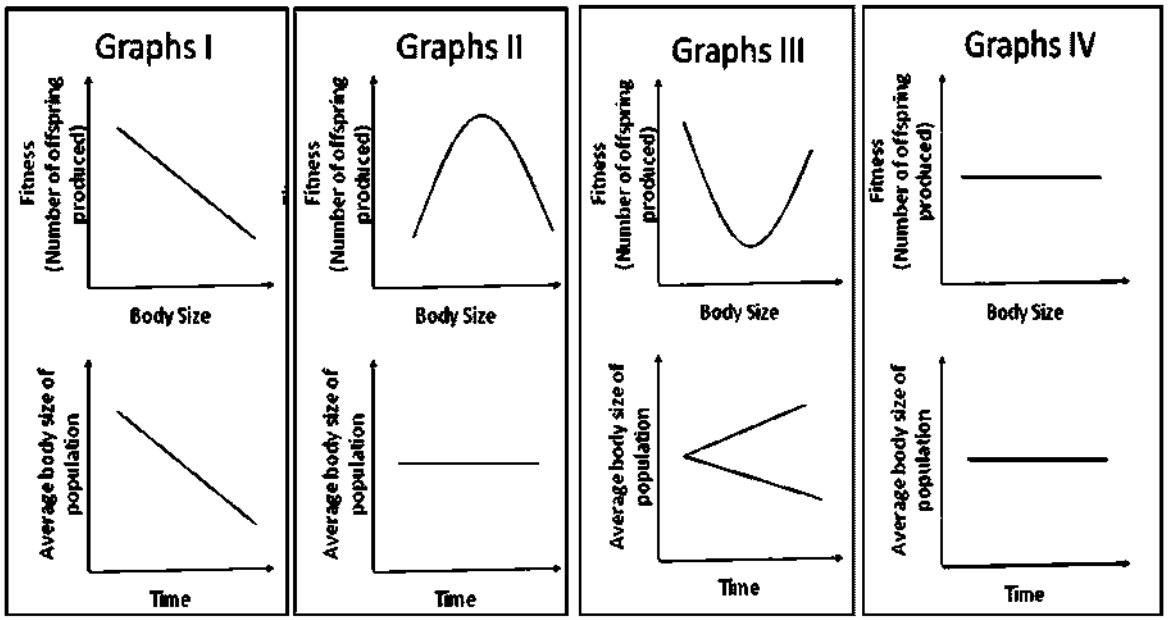
A Binding of L1 to Re1 and Re2.

B Auto-phosphorylation of Re1 and Re2.

C Phosphorylation of ERK by MEK.

D Dephosphorylation by protein phosphatase.

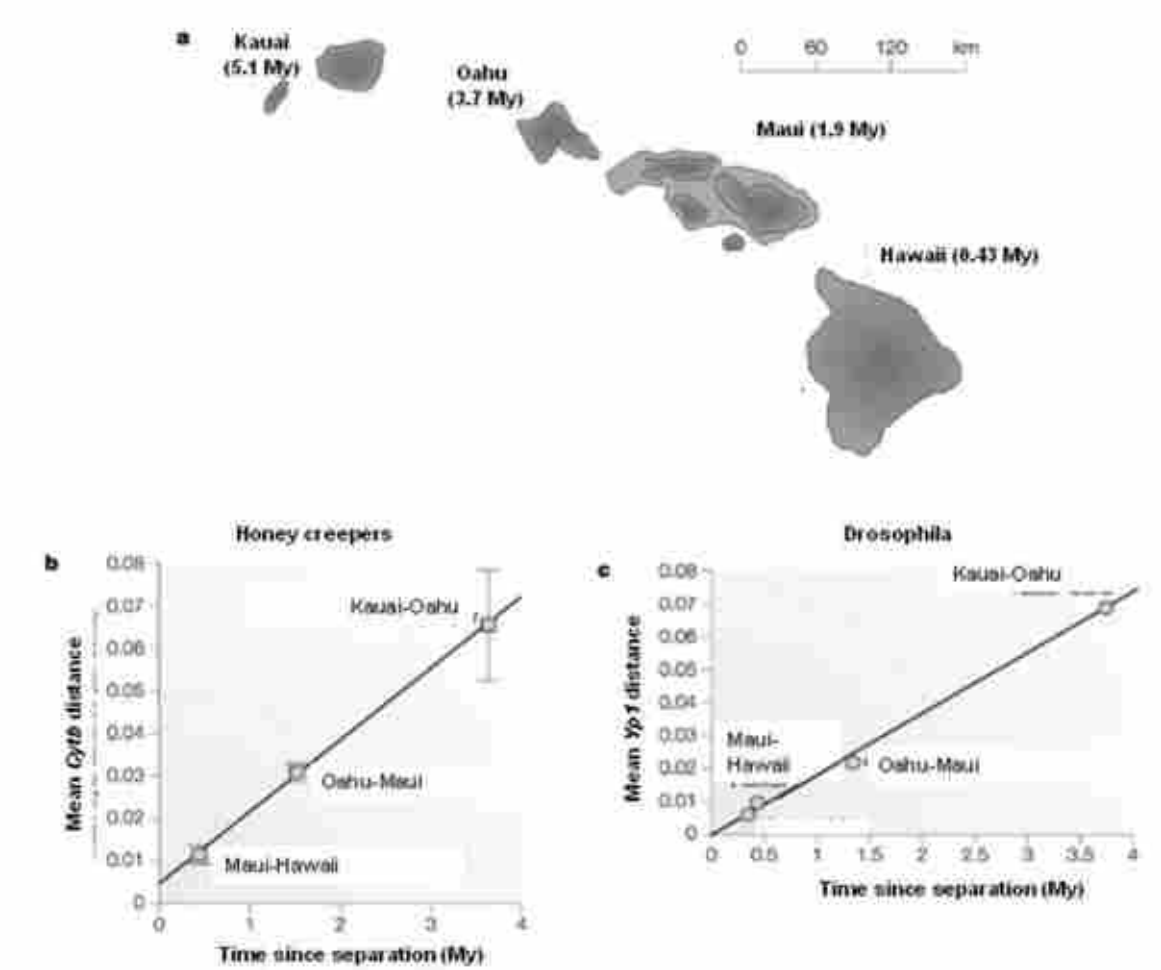
31 The different forms of natural selection can be distinguished according to their effect on the body size of the pink salmon (*Onchorhynchus gorbuscha*).



Which of the following describes the ***CORRECT*** form of natural selection for each of the following sets of graphs?

	Graphs I	**Graphs II**	**Graphs III**	**Graphs IV**
A	Disruptive selection	Directional selection	Stabilizing selection	No selection
B	No selection	Stabilizing selection	Directional selection	Disruptive selection
C	Directional selection	Stabilizing selection	Disruptive selection	No selection
D	Directional selection	Disruptive selection	No selection	Stabilizing selection

32 The volcanic islands that were formed millions of years ago, range from Kauai (the oldest) to Hawaii (the youngest). *Cytb* gene from honey creepers and *Yp1* gene from *Drosophila* were analysed for divergence.



Which of the following statement is ***INCORRECT***?

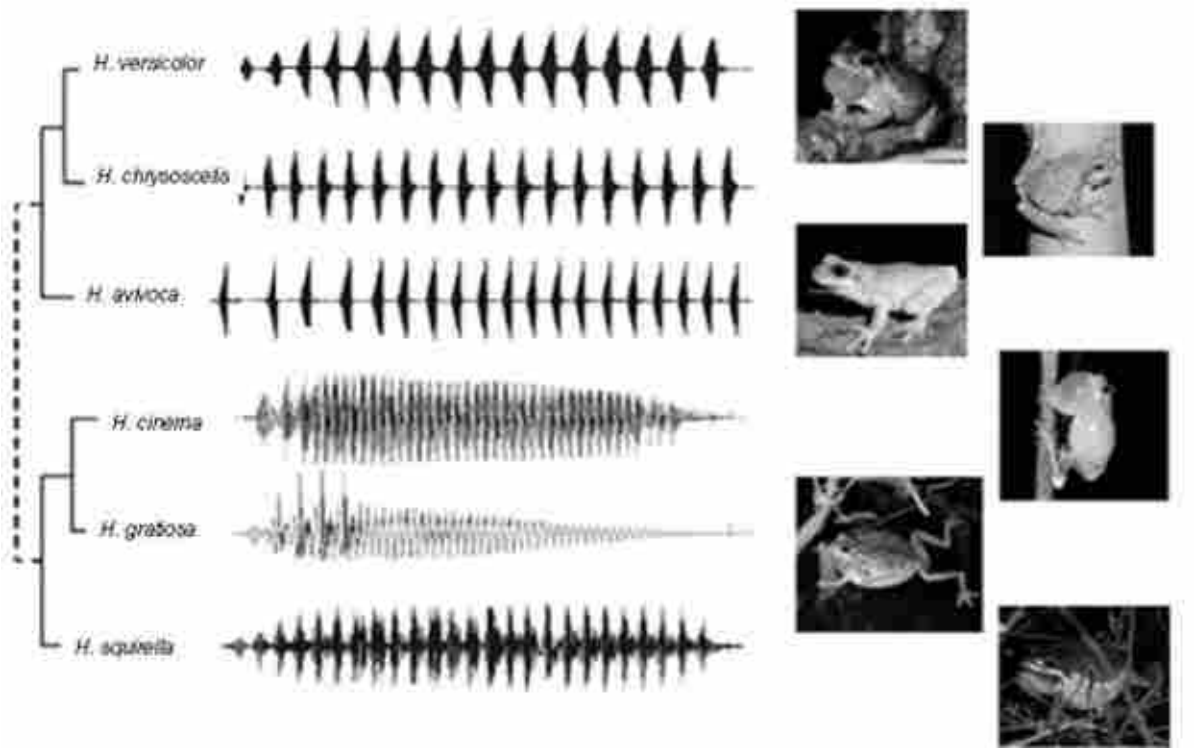
A Geographical isolation prevented colonization of newly formed islands.

B There is a positive linear correlation between genetic distance and island age.

C *Cytb* gene and *Yp1* gene are chosen because they are essential genes.

D Genetic drift is a factor that contributes to the increase in the mean genetic distance.

33 The calls of six different species of frogs belonging to the *Hyla* genus are recorded and shown.



Which of the following can be inferred from the chart?

I Frogs with more similar call patterns are more closely related.

II A frog species can be identified by looking at the duration, intensity, and frequency of the call.

III The call of each species of frog affects their survivability.

IV These calls are a form of isolation mechanism.

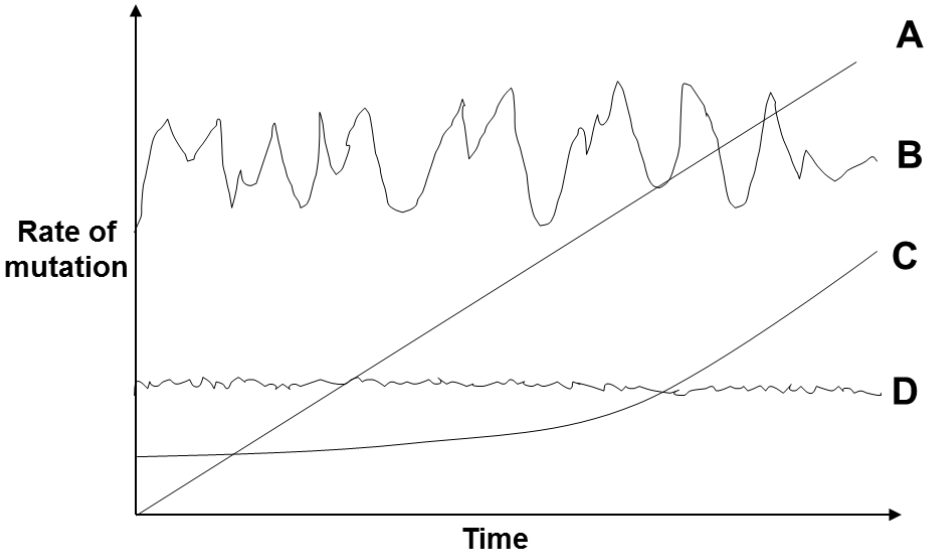
A **I** and **II** only

B **I**, **II** and **IV** only

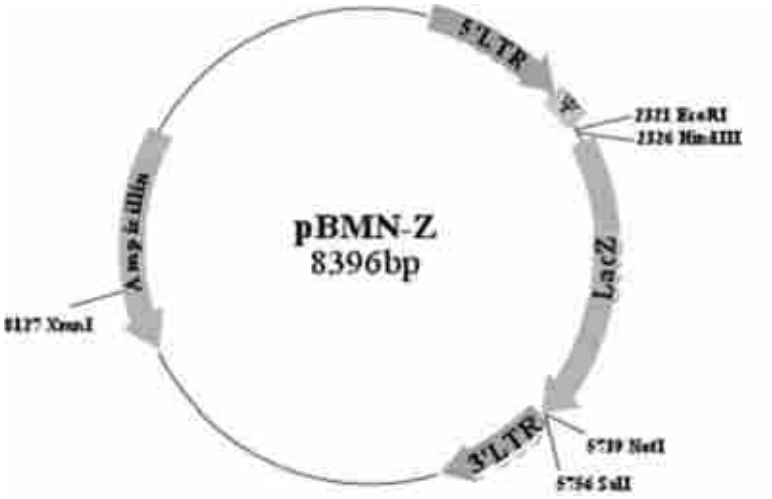
C **I** and **III** only

D All of the above

34 Which pattern of mutation rate would be most helpful if one desires to use a gene as a molecular clock to determine evolutionary relatedness of species that are closely related to each other?



35 As part of the procedure to produce recombinant proteins in *E. coli*, you are asked to insert the gene encoding for the MAL protein into the pBN-Z vector. The restriction sites and selectable markers on the vector are shown below.



If the gene for MAL protein were to be inserted into Lac Z site, what should be added to the agar plate in order to screen for recombinant clones and how would the recombinant clones appear?

	Chemicals to be added		**Colour of colonies**
A	Ampicilin	X-gal	Blue
B	β-galactosidase	X-gal	Blue
C	Ampicilin	X-gal	White
D	β-galactosidase	lactose	White

36 What is the key reason for using a greater range of probes and restriction enzymes in DNA fingerprinting?

A It permits more regions of the DNA to be analysed so as to reduce the possibility that two individuals' DNA would produce the same banding pattern.

B It is necessary for the creation of unique DNA fingerprints from two individuals' DNA that are significantly different in sequence.

C It increases the likelihood that one of the probes will bind to the polymorphic region of the DNA after the latter is cut by the restriction enzymes.

D It allows all the DNA bands produced via restriction enzymes cutting to be detected so as to give a more accurate DNA fingerprint.

37 Some of the goals of the Human Genome Project are:

- To determine the sequence of the entire human genome
- To identify all the genes in the human genome
- To find the locus of all the genes on the 46 human chromosomes

Which of the following are ethical concerns arising from the goals stated?

I Anthropologist tracing the ancestry of human populations.

II Parents choosing embryos for implantation only after tests for acceptable genes.

III Insurance company offering cheaper rates to people with genetic disposition to fewer diseases.

IV Scientists developing tests for only some disease causing genes.

V Genetic counsellors giving advice to people who are genetically pre-disposed to risks.

A **II** and **III**

B **III** and **IV**

C **I** and **V**

D **IV** and **V**

38 Totipotency is demonstrated when _____.

A cancer cells give rise to heterogeneous cell types.

B an isolated plant cell develops into a normal adult plant.

C a hematopoietic stem cell differentiates into a lymphocyte.

D an embryonic stem cell divides and differentiates.

39 Which of the following genetic modifications would ***NOT*** decrease the quantity of chemicals sprayed onto crop plants by farmers?

A Fungal resistance

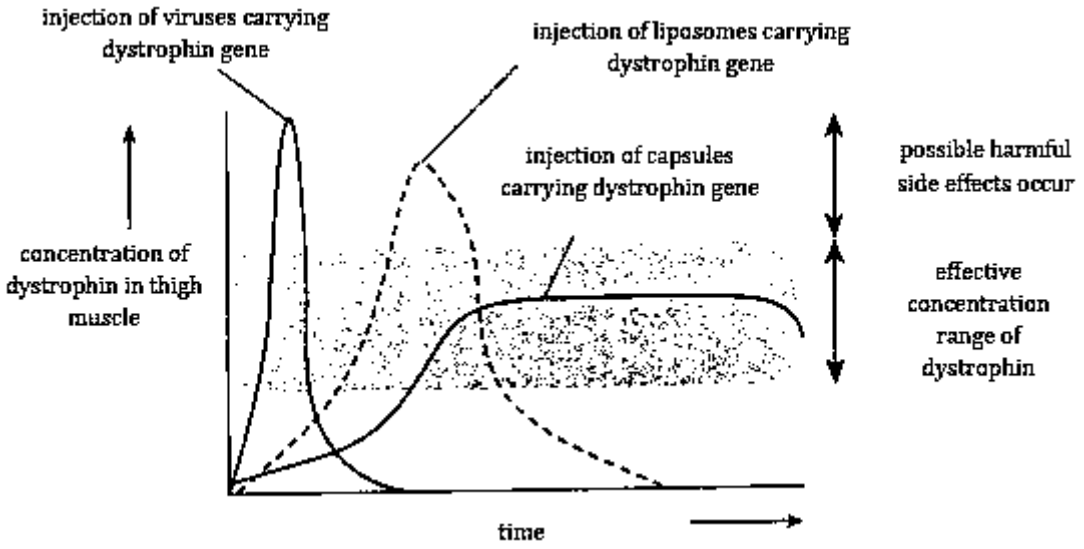
B Herbicide resistance

C Insect resistance

D Viral resistance

40 Duchenne muscular dystrophy (DMD) is a lethal X-linked human genetic disease caused by the absence of the protein dystrophin in muscle fibres.

Gene therapy experiments were conducted to compare the effectiveness of three different vectors for introducing a corrective gene coding for dystrophin. Each of the three vectors, virus, liposome and capsule, carrying normal copies of the dystrophin gene was injected into the thigh muscle tissue of DMD patients. The results are shown in the graph.



Which is a viable advantage of the capsule vector over the viral and liposome vectors?

A It produces more dystrophin.

B It takes effect in more target cells.

C It takes a shorter time to take effect.

D It requires less frequent treatments.

END OF PAPER

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2016 Y6 Preliminary Exam H2

MCQ Answer Scheme

1	**A**	21	**A**
2	**B**	22	**D**
3	**A**	23	**A**
4	**B**	24	**C**
5	**C**	25	**C**
6	**D**	26	**C**
7	**D**	27	**A**
8	**C**	28	**D**
9	**A**	29	**D**
10	**C**	30	**C**
11	**D**	31	**C**
12	**A**	32	**A**
13	**A**	33	**B**
14	**C**	34	**D**
15	**D**	35	**C**
16	**D**	36	**A**
17	**D**	37	**A**
18	**A**	38	**B**
19	**A**	39	**B**
20	**B**	40	**D**

Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

Paper 2 Structured and Free-Response Questions **19 September 2016**
2 hours

Additional Materials: Writing paper

INSTRUCTIONS TO CANDIDATES:

DO NOT TURN THIS PAGE OVER UNTIL YOU ARE TOLD TO DO SO.

READ THESE NOTES CAREFULLY.

Section B Structured Questions

Answer **all** questions.

Write your answers on space provided in the Question Paper.

Section C Free-Response Questions

Answer **one** question. Your answer to Section C must be in continuous prose, where appropriate. Write your answers on the writing paper provided.

Submit your answers to Sections B and Section C separately.

INFORMATION FOR CANDIDATES

Essential working must be shown.

The intended marks for questions or parts of questions are given in brackets [ ].

For Examiner's Use	
Section A [40]	
Section B [80]	
1	/ 10
2	/12
3	/ 10
4	/ 12
5	/ 11
6	/ 9
7	/ 7
8	/ 9
Section C [20]	
1 / 2	
Total [140]	

This document consists of **22** printed pages.

[Turn over

Section B: Structured Questions (80 marks)
Answer **all** questions in this section.

For Examiner's use

Question 1

Triglycerides are not transported in the blood on their own as they are insoluble in water. Instead they are transported within lipoproteins such as LDL. Lipoproteins are made up of proteins and lipids. Their function is to carry cholesterol, triglycerides and other lipids through the blood. Lipoproteins such as LDL are then taken up by target cells via receptor mediated endocytosis.

Fig. 1.1 illustrates the structure of a LDL.

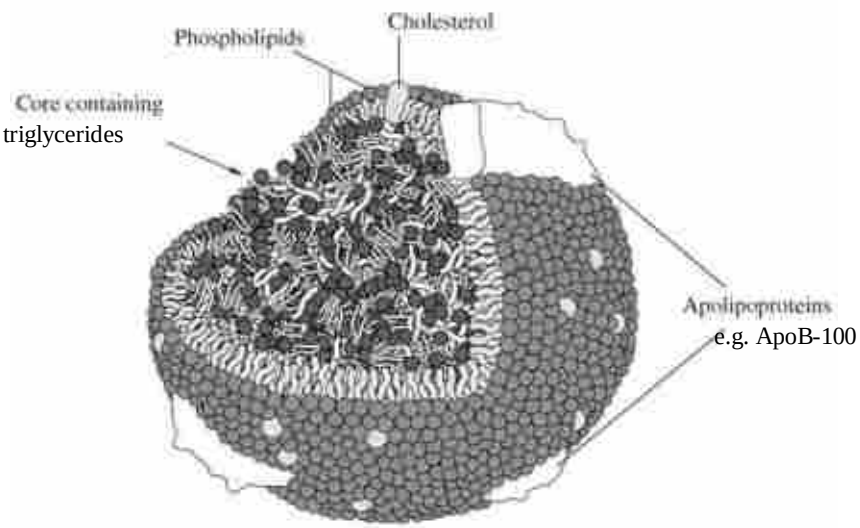


Fig. 1.1

Fig. 1.2 below shows the uptake of an LDL particle into a cell.

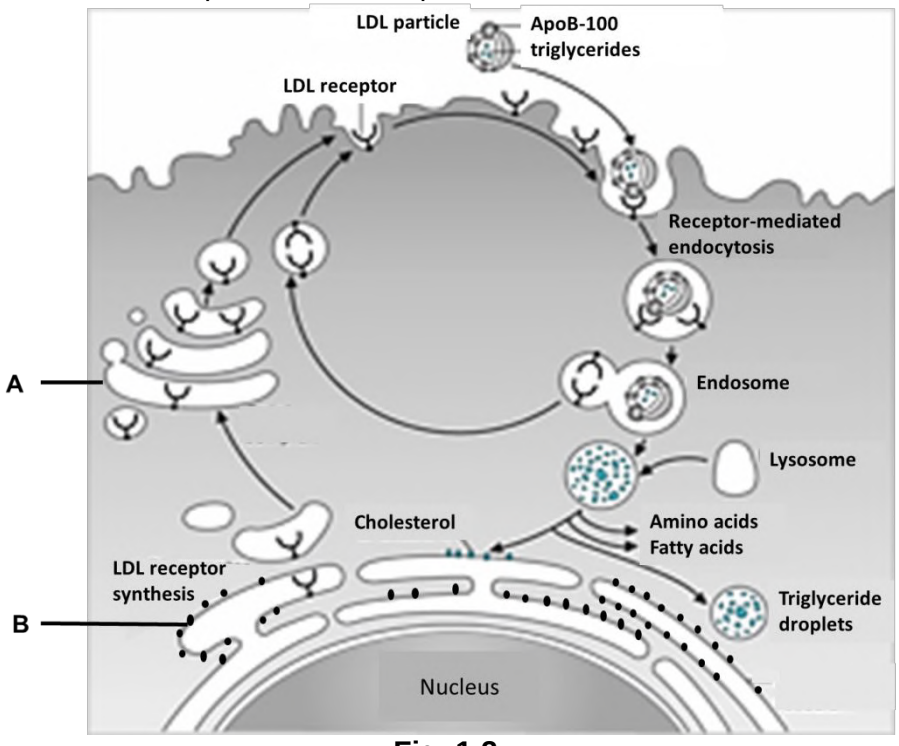


Fig. 1.2

For Examiner's use

(a) With reference to **Fig. 1.1**, explain the role of phospholipids in lipoproteins such as LDL. [2]

(b) With reference to **Fig 1.2**,

(i) Name the organelles labelled **A** and **B**. [2]

A :

B :

(ii) Explain the roles of organelles **A** and **B** in expression of the LDL receptor on the cell surface. [4]

A :

B :

(c) Using the fluid mosaic model, explain how the properties of the cell surface membrane enable the uptake of LDL by a cell. [2]

Total:[10]

Question 2

For Examiner's use

(a) **Fig. 2.1** shows the sequence of bases in a section of a single-stranded RNA virus. The bases code for the **first few amino acids** of a polypeptide chain.

5' UACAUGGAUUACCCCGUUGUACAU 3'

Fig. 2.1

Each codon codes for a specific amino acid as shown in **Table 2**.

Table 2

UUU	phe	UCU	ser	UAU	tyr	UGU	cys
UUC	phe	UCC	ser	UAC	tyr	UGC	cys
UUA	leu	UCA	ser	UAA	STOP	UGA	STOP
UUG	leu	UCG	ser	UAG	STOP	UGG	trp
CUU	leu	CCU	pro	CAU	his	CGU	arg
CUC	leu	CCC	pro	CAC	his	CGC	arg
CUA	leu	CCA	pro	CAA	gln	CGA	arg
CUG	leu	CCG	pro	CAG	gln	CGG	arg
AUU	ile	ACU	thr	AAU	asn	AGU	ser
AUC	ile	ACC	thr	AAC	asn	AGC	ser
AUA	ile	ACA	thr	AAA	lys	AGA	arg
AUG	met	ACG	thr	AAG	lys	AGG	arg
GUU	val	GCU	ala	GAU	asp	GGU	gly
GUC	val	GCC	ala	GAC	asp	GGC	gly
GUA	val	GCA	ala	GAA	glu	GGA	gly
GUG	val	GCG	ala	GAG	glu	GGG	gly

Using information from **Fig. 2.1** and **Table 2**,

(i) State the **third** amino acid coded by the section shown in **Fig. 2.1** if the virus was a **positive-sense** RNA virus. [1]

.....

(ii) State the **fourth** amino acid coded by the section shown in **Fig. 2.1** if the virus was a **negative-sense** RNA virus. [1]

.....

For Examiner's use

(b) **(i)** Termination of protein synthesis is not 100% efficient. A number of natural mechanisms that suppress translation termination exist. One of them is the 'STOP codon readthrough'. This process enables the ribosome to pass through the STOP codon in mRNA and continue translation to the next STOP codon. STOP codon readthrough is commonly observed in viruses.

Suggest an advantage of STOP codon readthrough for viruses. [1]

(ii) 'Nonstop' mutations are single base-pair substitutions that occur within translational termination (stop) codons.

State the immediate events that would occur when the ribosome reaches one such 'nonstop' mutation during translation of an mRNA in yeast. [2]

(iii) Contrast 'nonstop' mutation with 'nonsense' mutation. [1]

For Examiner's use

(c) Cystic fibrosis is a genetic disorder that affects the respiratory and digestive systems. People with cystic fibrosis inherit a defective gene on chromosome 7 called CFTR (cystic fibrosis transmembrane conductance regulator) gene.

Well over one thousand mutations have been described that can affect the CFTR gene. Two of such mutations are shown in **Fig. 2.2**.

Amino acid position	*506*	*507*	*508*	*509*	*510*		*522*	*523*	*524*
Normal CFTR gene	ATC	ATC	TTT	GGT	GTT	.....	GCA	TGC	CAA
Mutation 1	ATC	ATT	GGT	GTT	GCC	.....	GCA	TGC	CAA
Mutation 2	ATC	ATC	TTT	GGT	GTT	.....	GCA	TGA	CAA

Fig. 2.2 (showing part of the base sequence on the non-template DNA strand)

Table 2

UUU	phe	UCU	ser	UAU	tyr	UGU	cys
UUC	phe	UCC	ser	UAC	tyr	UGC	cys
UUA	leu	UCA	ser	UAA	STOP	UGA	STOP
UUG	leu	UCG	ser	UAG	STOP	UGG	trp
CUU	leu	CCU	pro	CAU	his	CGU	arg
CUC	leu	CCC	pro	CAC	his	CGC	arg
CUA	leu	CCA	pro	CAA	gln	CGA	arg
CUG	leu	CCG	pro	CAG	gln	CGG	arg
AUU	ile	ACU	thr	AAU	asn	AGU	ser
AUC	ile	ACC	thr	AAC	asn	AGC	ser
AUA	ile	ACA	thr	AAA	lys	AGA	arg
AUG	met	ACG	thr	AAG	lys	AGG	arg
GUU	val	GCU	ala	GAU	asp	GGU	gly
GUC	val	GCC	ala	GAC	asp	GGC	gly
GUA	val	GCA	ala	GAA	glu	GGA	gly
GUG	val	GCG	ala	GAG	glu	GGG	gly

Using information from **Fig. 2.2** and **Table 2**,

(i) Explain the effect of mutation 1 on the structure of the protein formed. [4]

(ii) Explain the effect of mutation 2 on the amino acid sequence in the protein. [2]

For Examiner's use

Total: [12]

Question 3

For Examiner's use

Fig. 3.1 shows the first step in T4 infection of its host.

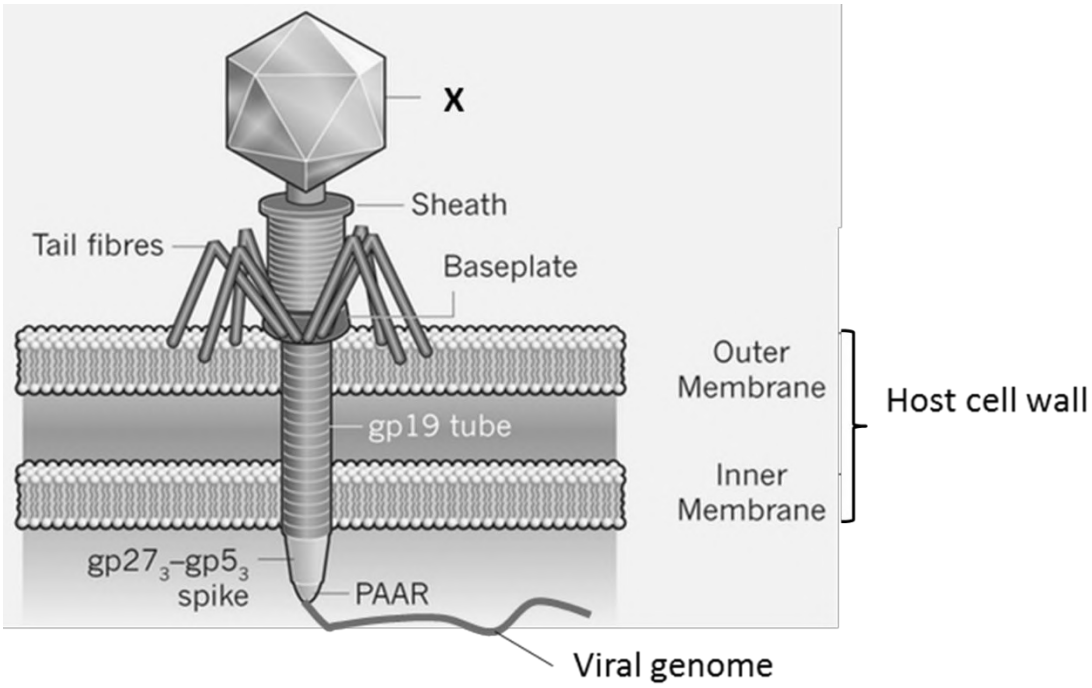


Fig. 3.1

(a) Name structure **X** and explain its function. [2]

(b) Explain the role of the contractile sheath and as shown in **Fig. 3.1**. [2]

(c) Describe what occurs after the stage shown in **Fig. 3.1** to complete the virus life cycle. [4]

For Examiner's use

(d) Explain how the T4 phage can result in horizontal gene transfer between bacteria. [2]

Total: [10]

Question 4

For Examiner's use

(a) **Fig. 4.1** shows the different phases of the cell cycle. The arrows indicate the checkpoints of the cell cycle.

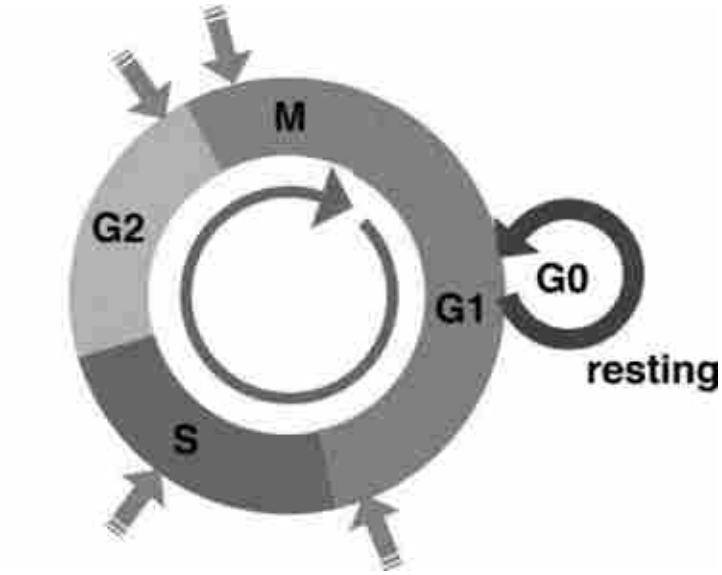


Fig. 4.1

(i) Outline how the normal mitotic cell cycle is regulated at the G_1 and M checkpoints. [4]

(ii) G_2 is part of a stage that takes place during the cell cycle. Describe what happens during this stage. [2]

For Examiner's use

(iii) Upon maturity, nerve and heart muscle cells enter into a G_0 phase that can last indefinitely. Such cells are said to be quiescent. On the other hand, cells such as fibroblasts can reach a maximum of 50 cell divisions before becoming senescent.

State two differences between cellular quiescence and senescence. [2]

(b) **Fig. 4.2** below shows a cell at a certain stage of nuclear division in *Drosophila*.

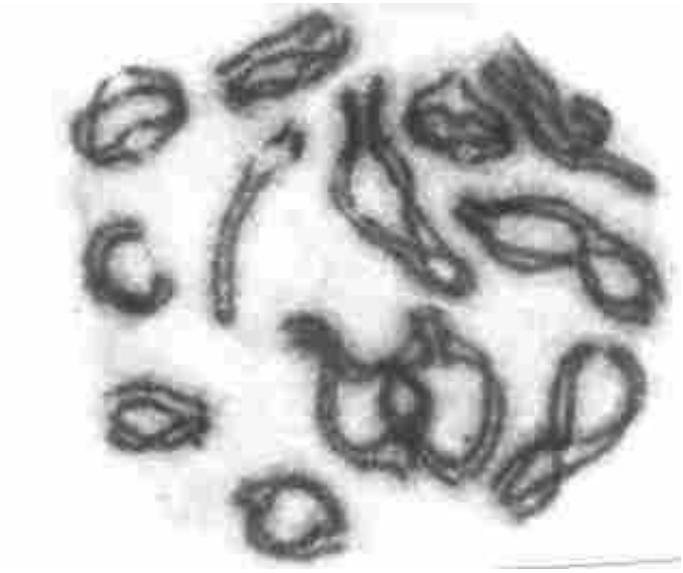


Fig. 4.2

(i) State the number of telomeres present in the cell. Explain your answer. [2]

(ii) Explain the role centromeres play in mitosis. [2]

Total: [12]

Question 5

For Examiner's use

(a) Malvidin is a plant pigment responsible for the colours of red grapes, cranberries and blueberries which may have anticancer properties. The dominant allele, K, codes for an enzyme involved in the biosynthesis of malvidin. The presence of dominant allele, D, of another unlinked gene, results in the absence of malvidin production in plants, even when the enzyme is present whilst the recessive allele, d, does not affect malvidin production.

(i) Draw a genetic diagram to show the gametes and the genotypes and phenotypes of the F1 and F2 generations of a cross between a pure-breeding malvidin-producing plant and a non-producing plant of genotype k'k'DD. Give the ratio of the phenotypes in the resulting F2 generation. [4]

For Examiner's use

(ii) Explain how the two genes interact. [2]

.....

.....

.....

.....

(b) The dominant allele, S, of another gene results in the fruits having smooth skin, whilst the recessive allele, s', results in the fruits having wrinkled skin. A cross was made between a malvidin-producing plant with smooth-skinned fruits (KKSS) and a non-producing plant with wrinkled-skinned fruits (k'k's's'). The F_1 generation were all malvidin-producing plants with smooth-skinned fruits. The F_1 plants were test crossed and gave offspring with the following numbers of plants in each of the four phenotypes:

Malvidin-producing plants with smooth-skinned fruits	40
Non-producing plants with wrinkled-skinned fruits	42
Malvidin-producing plants with wrinkled-skinned fruits	20
Non-producing plants with smooth-skinned fruits	18

Distribution of χ^2

Degrees of freedom	Probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

χ^2 test: $\chi^2 = \Sigma \frac{(O-E)^2}{E}$ $\nu = c - 1$

Key to symbols: Σ = sum of …
ν = degrees of freedom
c = number of classes
O = observed value
E = expected value

(i) Calculate the χ^2 value for the given data. Show your working below. [2]

For Examiner's use

(ii) Using the information from the table provided, explain the conclusion drawn from the calculated χ^2 value above. [3]

Total:[11]

Question 6

For Examiner's use

(a) The Korean rice beer *takju* is prepared by mixing a yeast fermentation starter powder (*nuruk*) with cooked rice and incubating at approximately 20°C for 2-3 days, following which it is filtered through a fine mesh. **Fig. 6.1** shows the summary of this process.

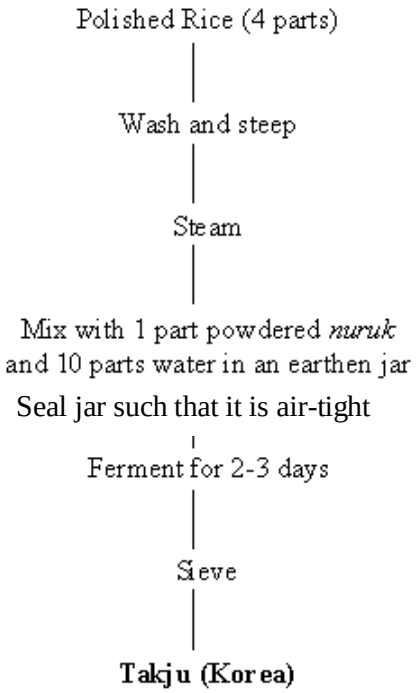


Fig. 6.1

Biochemical changes occurring during the fermentation of *takju* are summarised in **Fig. 6.2**.

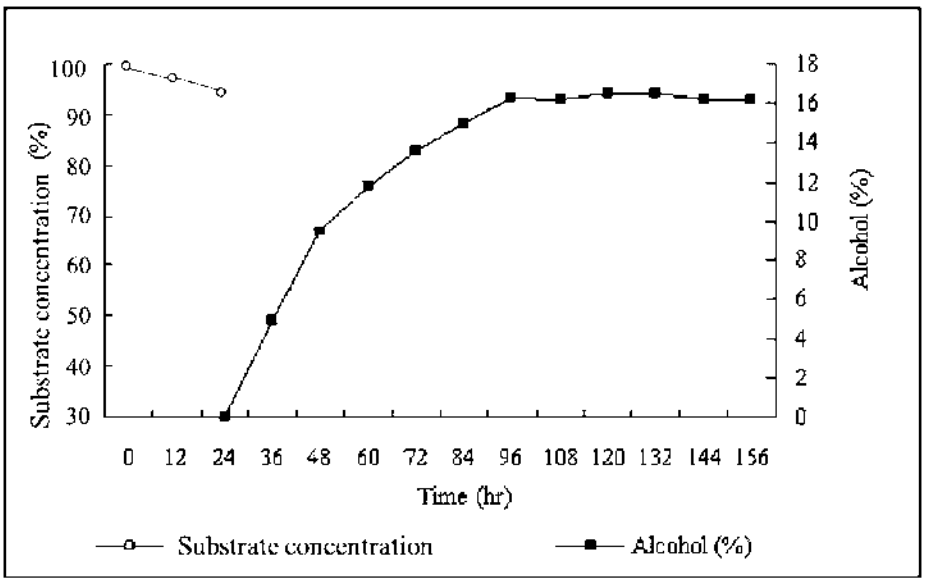


Fig. 6.2

For Examiner's use

(a) With reference to **Fig. 6.1** and **Fig. 6.2**,

(i) Explain why there was a lag time of 24h before any alcohol was produced. [1]

(ii) Explain the mode of respiration of the yeast between 24-96h and relate it to the production of alcohol in the brewing of *takju*. [5]

(iii) Explain why there is no further increase of alcohol concentration after 96h. [2]

(b) **Fig. 6.2** shows the changes in substrate concentration in the brewing of *takju* from 0-24h.

Complete the graph on **Fig. 6.2** to show the predicted changes in substrate concentration from 24-96h. [1]

Total: [9]

Question 7

For Examiner's use

(a) GABA is a neurotransmitter present in some parts of the nervous system. **Fig. 7.1** shows how the release of GABA from a presynaptic membrane affects the ion channels of a postsynaptic membrane.

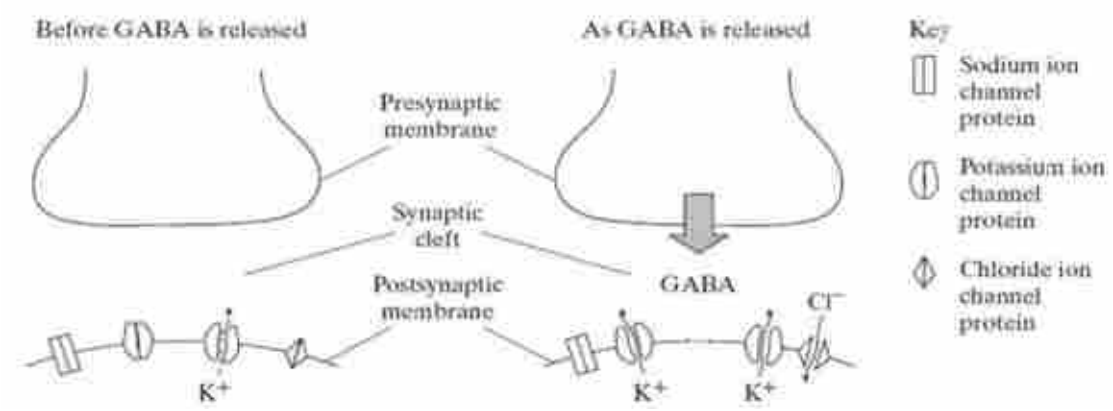


Fig. 7.1

(i) With reference to **Fig. 7.1**, explain what would happen to the membrane potential on the postsynaptic membrane when GABA is released. [2]

Fig. 7.2 shows the synapses of neurone **B** with two other neurones, **P** and **Q**.

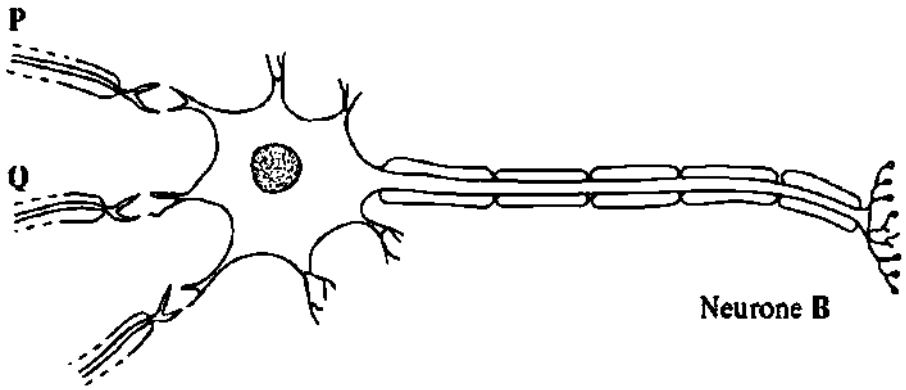


Fig. 7.2

Neurone **P** releases acetylcholine whereas neurone **Q** releases GABA.

For Examiner's use

(ii) Explain why neurone **B** is less likely to respond if both neurones **P** and **Q** are stimulated at the same time. [2]

(iii) Barbiturates act as depressants with effects similar to anesthetics. They act mainly by enhancing the activity of the GABA neurotransmitter. Suggest how barbiturates enhance the activity of the GABA neurotransmitter. [1]

(b) Explain how the temporal summation of various stimuli can result in a coordinated response at the postsynaptic neurone through post synaptic potentials. [2]

Total:[7]

Question 8

For Examiner's use

(a) Fishes in the genus *Anisotremus* comprise of ten described species which occur predominantly on coral reefs and subtropical rocky reefs in the Neotropics.

Bernardi *et.al.* did a molecular phylogenetic study on such fishes in that area. Results are shown in **Fig. 8.1**.

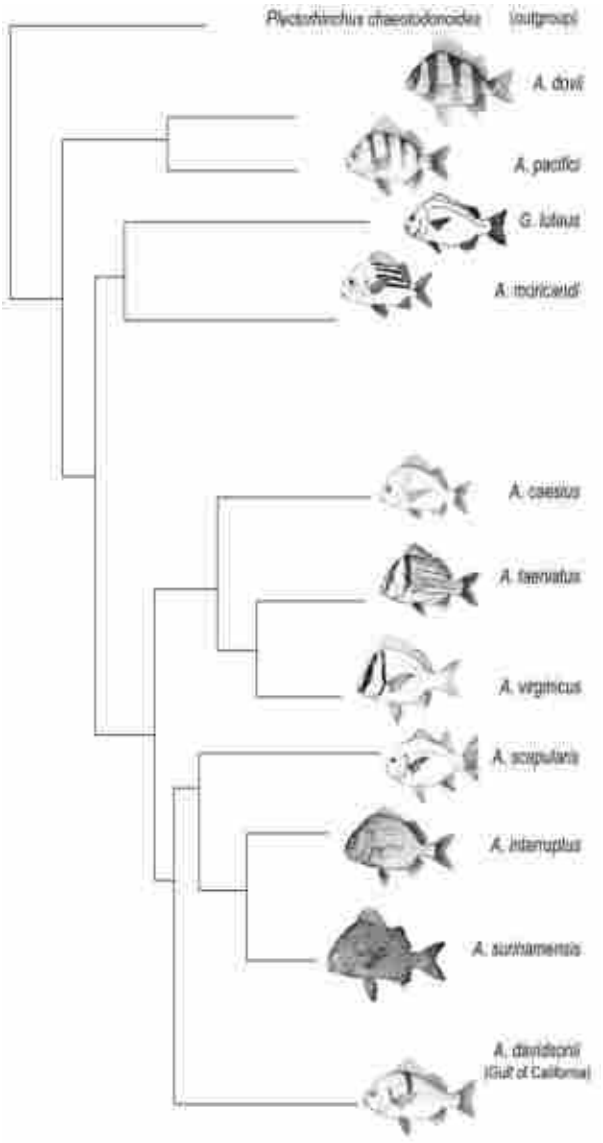


Fig. 8.1

(i) Explain how molecular methods can be used to elucidate the evolutionary relationships of the different species of *Anisotremus* fishes. [2]

(ii) Explain why it may be more reliable to construct a phylogenetic tree of the ten species of *Anisotremus* using molecular data instead of morphological comparisons. [2]

For Examiner's use

(iii) With reference to **Fig. 8.1** and molecular homology, comment on the evolutionary relationship between *A. taeniatus* and *A. virginicus*. [1]

For Examiner's use

(b) *A. taeniatus* is found in the Pacific Ocean, whereas *A. virginicus* is found in the Caribbean Sea. These two species were derived due to the formation of the Isthmus of Panama about 3.5 million years ago. Before that event, the waters of the Pacific Ocean and Caribbean Sea mixed freely.

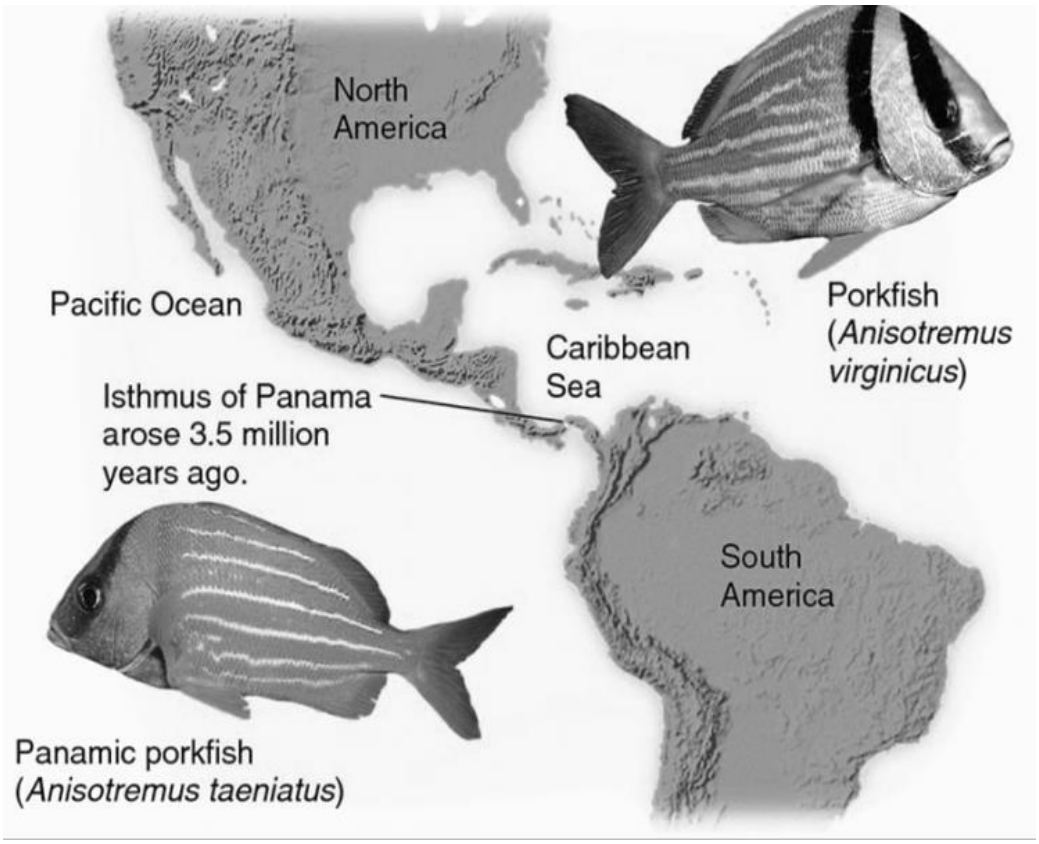


Fig. 8.2

Explain how the formation of the Isthmus of Panama results in the emergence of *A. taeniatus* and *A. virginicus*. [4]

Total:[9]

Section C: Free-Response Question (20 marks)

Answer only **one** question.
Write your answers on the writing paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.
A **NIL RETURN** is required.

Question 1

(a) Describe the protein folding of an enzyme and relate its structure to its function. [10]

(b) Describe the effect of pH on enzymes and their activity. [4]

(c) Compare and contrast competitive and non-competitive inhibitors and their effects on the rate of enzyme activity. [6]

OR

Question 2

(a) Distinguish between the processes of Krebs Cycle and Calvin Cycle. [8]

(b) State the similarities between ATP production in mitochondria and chloroplasts and suggest why these similarities exist. [6]

(c) Discuss the effects of varying carbon dioxide and oxygen levels on photosynthesis. [6]

Total: [20]

END OF PAPER

DUNMAN HIGH SCHOOL
PRELIMINARY EXAMINATION 2016
YEAR SIX
H2 BIOLOGY (9648)
PAPER 2

Structured Questions Answers

Question 1

(a)
Phospholipids arranged in a **monolayer** with **hydrophobic hydrocarbon tails face inward** to interact with triglycerides in interior and **hydrophilic phosphate heads face outwards** to interact with the aqueous medium;

Makes hydrophobic lipids soluble for transport in the blood;

(b)(i)
A: Golgi apparatus;
B: Rough endoplasmic reticulum; (A: ribosome, R: ribosomes)

(b)(ii)
A:
chemically modifies the LDL receptors (e.g. glycosylates);
packages LDL receptors the into transport vesicles to be **targeted** to the plasma membrane for insertion into membrane;

B: RER
Ref to **translation** of LDL receptor mRNA at bound **ribosome**s to from LDL receptor polypeptide;
folding of polypeptide into native configuration inside cisternal space;
transport of newly synthesized LDL receptor to the cis face of the golgi apparatus within transport vesicles;
2 max

OR
B: ribosome
Ref to **translation** of LDL receptor **mRNA** to from LDL receptor **polypeptide**;
Ref to **peptidyl transferase** in large ribosomal subunit catalyzing the formation of **peptide bonds** between amino acids;

(c)
Fluid nature of phospholipids moving in the membrane allows invagination of plasma membrane/ fusion of two ends of plasma membrane to form endocytic vesicle;
Mosiac – membrane has proteins embedded such as the LDL receptor. Binding of LDL to receptor triggers invagination of the membrane;

Question 2

(a)(i) **Tyrosine (tyr);**

(a)(ii) **Glycine (gly);**

(b)(i) Increase coding capacity; AVP

(b)(ii)

Ribosomes will continue translation as **STOP codon now codes for an amino acid**;

Translation of the mRNA continues into the **3'-untranslated region**;

Translation continues until the **next in-frame stop codon downstream**;

2 max

(b)(iii)

Nonstop mutations differ from nonsense mutations in that they **do not create a stop codon but, instead, delete one**;

(c)(i)

Deletion of CTT (or TCT), at corresponding amino acid positions 507 and 508;

Change of codon from ATC to ATT results in **same amino acid encoded at position 507, isoleucine**;

Change of codon from TTT to GGT results in a **different amino acid at position 508 - glycine instead of phenylalanine** (OR **deletion of phenylalanine at position 508**);

Overall **primary structure of the polypeptide / amino acid sequence is changed;**

Ref. to change **affecting folding of the polypeptide / incorrect folding** of the polypeptide;

4 max

(c)(ii)

Single base substitution, at corresponding **amino acid position 523**, where the third base, **C is replaced by A**, changing the codon UGC to a **stop codon** UGA;

Results in **premature termination of translation**, producing a **truncated / shortened polypeptide chain**;

Question 3

(a)
Icosahedral capsid head;
protects the viral ds DNA when virus is outside its host;

(b)
Contractile sheath punctures a hole through bacterial host cell wall to allow entry of viral DNA into the host cell;
Ref to gp19 tube / gp27 – gp5 spike;
As viral DNA too large and charged to cross bacterial cell wall and cell membrane on its own;
2 max

(c)
Phage uses host cell DNA polymerase to synthesize new copies of phage DNA;
And host RNA polymerase and ribosomes to synthesize new phage proteins;
new phage particles then assemble from newly synthesized components;
Phage coded lysozyme breaks down peptidoglycan cell wall resulting in osmotic lysis of host and release of phage particles;
4 max

(d)
During T4 phage replication, a phage enzyme degrades bacterium host cell's DNA;
During assembly of the virus, a fragment of the host's genome may be packaged inside the virus capsid by mistake;
The resultant defective phage then injects this bacterial gene into another bacterium, thus resulting in horizontal gene transfer between bacteria;
2 max

Question 4

(a)(i)

G_1 checkpoint (**2 max**): checks that

- sufficient nutrients present;
- environment is favourable / need for new cells for replacement;
- sufficient growth of the cell / cell reach a minimum size;
- sufficient organelles;
- DNA not damaged and can be replicated;
- growth factors are present;

M checkpoint (**2 max**):

- Checks for attachment of spindle fibers to the kinetochores (centromeres) of the chromosomes;
- Ensures correct alignment of chromosomes at metaphase plate;
- Allows separation of sister chromatids equally at anaphase;

(a)(ii)

Synthesis of proteins/RNA/enzymes;

Formation of new organelles;

ATP production;

(a)(iii)

Quiescence is **reversible** while senescence is **irreversible**;

Quiescence occurs when cells are **neither dividing nor preparing to divide** (e.g. when they 'exit' from the cell cycle) while senescence occurs **in response to DNA damage or degradation** that would make a cell's progeny nonviable / when cells reach the **Hayflick limit** (i.e. reproductive limit);

(b)(i)

96 telomeres;

There are 11 tetrads/ bivalents and 1 pair of unpaired chromosomes (**A!** any suitable number based on clarity of diagram). Each chromosome consists of two sister chromatids, hence total number of sister chromatids is 48. Both ends of each sister chromatid is flanked by telomeres, hence the total number of telomeres is 96;

(b)(ii)

- Centromeres **hold genetically identical sister chromatids together** as the chromosomes align themselves at the metaphase plate;
- **Kinetochore proteins** bind to the centromeres;
- During metaphase spindle fibres from both poles attach to the kinetochore proteins;
- During anaphase, shortening of the spindle fibres and the duplication of the centromeres results in sister chromatids being separated to opposite poles;
- Such that at the end of mitosis, each daughter nuclei contains the identical genetic material.

2 max

Question 5

(a)(i)

Parental phenotypes malvidin producing plant X non-producing plant
Parental genotypes KKdd X k'k'DD

Gametes (Kd) X (k'D) [1]

F_1 phenotype Non-producing plant X Non-producing plant
F_1 genotype Kk'Dd X Kk'Dd

F_1 gametes (KD) (k'D) (Kd) (k'd) X (KD) (k'D) (Kd) (k'd)
[1]

F2 genotype

	(KD)	(k'D)	(Kd)	(k'd)
(KD)	KKDD Non-producing	Kk'DD Non-producing	KKDd Non-producing	Kk'Dd Non-producing
(k'D)	Kk'DD Non-producing	k'k'DD Non-producing	Kk'Dd Non-producing	k'k'Dd Non-producing
(Kd)	KKDd Non-producing	Kk'Dd Non-producing	KKdd Malvidin producing	Kk'dd Malvidin producing
(k'd)	Kk'Dd Non-producing	k'k'Dd Non-producing	Kk'dd Malvidin producing	k'k'dd Non-producing

[1]

F2 genotype:	**KKDD, Kk'DD, KKDd, Kk'Dd, k'k'Dd, k'k'DD, k'k'dd**	**KKdd, Kk'dd**
F2 phenotype:	**non-producing**	**malvidin producing plant**
F2 phenotypic ratio:	**13**	**: 3**

[1]

(a)(ii)
Allele D is epistatic over the K and k' locus where it prevents the formation of malvidin;
By synthesizing a gene product which suppresses the action of the enzyme encoded by K / D codes for an inhibitor which binds to and prevents the action of the enzyme encoded by K;

(b)(i)

$$\chi^2 = \frac{(40-30)^2}{30} + \frac{(42-30)^2}{30} + \frac{(20-30)^2}{30} + \frac{(18-30)^2}{30}$$

$= 16.27$; (2dp);

(b)(ii)

At n=3 where the calculated value of χ^2 (16.27), the corresponding probability is 0.001;

Critical χ^2 value (7.82) < calculated χ^2 value (16.27), therefore there is a significant difference between observed and expected values;

The cross does not follow ratio of 1:1:1:1. Any difference is not due to chance alone but other factors must be at operation (eg. linked genes);

Question 6

(a)(i)

Yeast are still respiring aerobically, using up oxygen in jar after it was sealed;

(a)(ii)

Anaerobic respiration - Ref. to incomplete/partial oxidation of glucose during glycolysis in the absence of oxygen;

1 molecule of glucose is broken down to 2 molecules of pyruvate with the net yield of 2 ATP by substrate level phosphorylation and 2 reduced NAD/ 2NADH;

Alcoholic fermentation occurs to regenerate NAD^+ for glycolysis to continue;

Pyruvate is decarboxylated to form acetaldehyde with the removal of carbon dioxide;

Acetaldehyde is then reduced to ethanol by accepting H atoms from NADH to regenerate NAD^+;

Resulting in an increase in concentration of alcohol from 0 to 16% from 24 to 96 hr;

(a)(iii)

Yeast is killed at 16% ethanol;

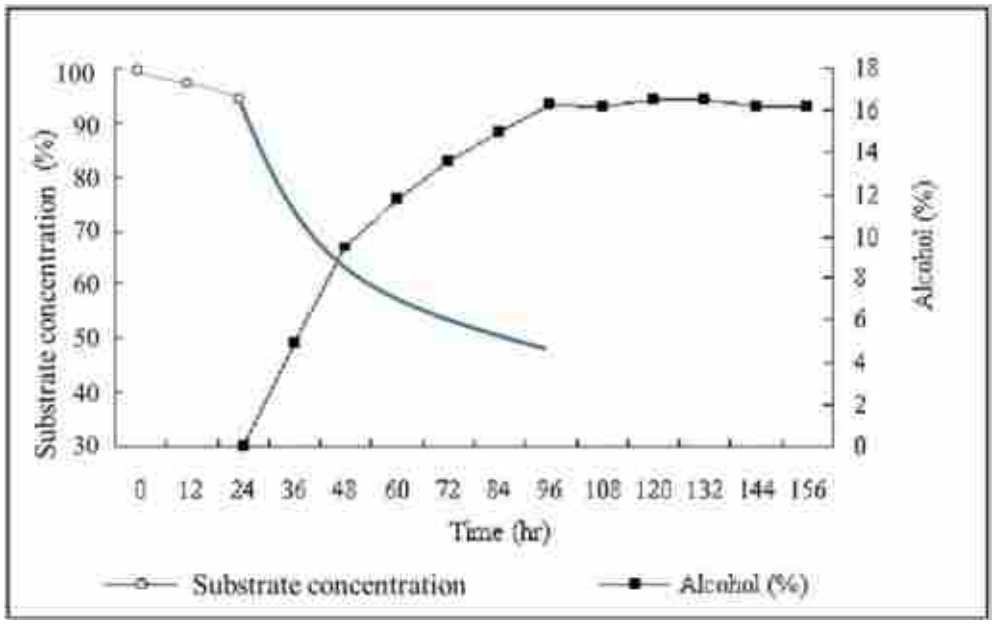
ethanol is organic and thus dissolves and disrupts phospholipid bilayer of the cell membranes in yeast;

enzymes in yeast are also denatured by the high ethanol concentration;

2 max

(b)

Curve with sharper initial decrease in substrate concentration than original gradient from 0-24h;



Question 7

(a)(i)
GABA binds to receptors and thus leads to the opening of K+ / Cl- gated channels;
This results in more Cl- diffusing into / more K+ diffusing out of postsynaptic membrane, thus membrane potential becomes more negative / hyperpolarized;

(ii)
Acetylchloline from P will cause depolarisation while GABA from Q will cause hyperpolarisation / ref. to acetylcholine causing influx of Na+ & GABA causing influx of Cl- and efflux of K+;
Ref. to spatial summation of these potentials counteracts each other resulting in a weak stimulus in neurone B;

(iii)
Barbiturates bind to GABA receptor and cause more influx of Cl- ions and efflux of K+ ions;
Prevents enzyme from degrading GABA;
Prevents GABA from unbinding from GABA receptor;
Ref. to binds to GABA and helps GABA bind to the GABA receptor;
Ref. to barbiturates causes increased secretion of GABA;

1 Max.

(b)
Ref. to the summation of EPSPs produced by repeated stimulation of only ONE presynaptic neurone (at high frequency);
If more neurotransmitters are released into the cleft before the first EPSP is destroyed;
Additive effects of several EPSPs may exceed threshold potential to result in an action potential in the post synaptic neurone;

2 Max.

Question 8

(a)(i)
Compare DNA sequence of a particular common gene between different species of fish / comparison/alignment of homologous genetic sequences;
% sequence homology indicates degree of evolutionary closeness / number of mutation in genetic sequence is used to calculate the length of time since divergence;
Neutral mutations are accumulated at a relatively constant rate and use as a molecular clock;

2 Max.

(a)(ii)
Quantifiable where protein, nucleic acid sequence data are precise and accurate and easy to quantify / convertible to numerical form for mathematical and statistical analysis**;**
Based on the idea of molecular clock, that the rate of mutation is constant, species can be arranged in order of time of evolution;
Objective where data is based strictly on heritable material / can be easily described in an unambiguous manner / some morphological similiarities may be analogous / ref. convergent evolution**;**
Use of phenotypically non-visible characteristics / considers changes caused by silent mutation which is not shown on the phenotype;

2 Max.

(a)(iii)
A. taeniatus and *A. virginicus* are closely related where they share a (recent) common ancestor. They have a high percentage homology in DNA sequence alignment;

(b)
Geographical isolation /Isthmus of Panama is a physical barrier / ref. allopatric speciation;
Disruption to gene flow in the ancestral population where there is no interbreeding between the organisms in the Pacific Ocean and Caribbean Sea;
Genetic variations exist within each sub-population due to mutation or genetic recombination;
Different selection pressures in Pacific Ocean and Caribbean Sea. List 1 eg. food availability/ salinity /temperature/ different predators;
Individuals with traits that are selectively advantageous in the particular environment survive, reproduce and pass on their alleles to offspring;
There will be changes in allele frequency of gene pool and accumulation of genetic changes takes place over many generations;
Speciation into *A. taeniatus* and *A. virginicus* takes place when the two populations ultimately cannot interbreed to produce viable, fertile offspring;

4 Max.

Essay Answers

Essay Question 1

(a) Describe the protein folding of an enzyme and relate its structure to its function. [10]

1. Enzymes are globular proteins with unique three-dimensional conformation / tertiary / quaternary structure;
2. Ref to primary structure being the unique sequence and number of amino acids in a polypeptide linked by peptide bonds;
3. Ref to secondary structure being the regular coiling and folding/pleating of the polypeptide held by *hydrogen bonds** between CO and NH groups of the peptide bonds / polypeptide backbone;
4. In *alpha helix**, *hydrogen bonds** form between CO and NH groups 4 a.a. apart, forming a 3D helical structure
5. In *beta pleated sheet**, *hydrogen bonds** form between CO (or NH) group of one region/segment and NH (or CO) group of an adjacent region/segment of a single polypeptide chain, forming a flat/pleated sheet;
6. Tertiary structure refers to the folding of polypeptide into a specific conformation, held by bonds between *R-groups** of structural amino acids within same polypeptide, maintained by *hydrophobic interaction, hydrogen bonds, ionic bonds, disulfide bridges;*
7. Ref to quaternary structure: more than 1 polypeptide chain to form functional protein held by *hydrophobic interaction, hydrogen bonds, ionic bonds, disulfide bridges* between R groups between polypeptide chains;
8. Folding gives rise to a specific cleft / groove - *active site* that is *complementary in shape and charge* to its *substrate*.
9. Folding brings catalytic amino acids and binding amino acids far apart in the primary structure / polypeptide close together in the active site
10. R groups of binding residues bind reversibly with substrate to position it in the correct orientation for catalysis to occur.
11. R groups of catalytic residues present within active site catalyze conversion of substrate to product.
12. The rest of the amino acids in the protein molecule are structural residues - provides a framework to maintain active site configuration
13. Active site may not be a rigid receptacle → ref to induced fit model – entrance of substrate induces enzyme to change its shape slightly to 'wrap around' substrate, bringing R group of active site into positions that enhance their ability to catalyze the chemical reaction;
14. Some enzymes contain another site (apart from active site) for another molecule to bind to (cofactors/allosteric molecules) allowing for regulation of enzyme activity;
15. Enzymes are soluble due to arrangement of hydrophilic residues on the surface and hydrophobic residues in the interior, allowing them to catalyse reactions in the aqueous environment of the cell;

(b) Describe the effect of pH on enzymes and their activity. [4]

1. Reference of influence of pH to the effect on ionic bonds, hydrogen bonds;
2. Change in charges of catalytic residues in active site affects catalytic function of enzyme;
3. Changes in shape / conformation and configuration of the tertiary structure affecting the fit and binding of the substrate to the active site;
4. Optimum pH / show graph of narrow pH range / named example;
5. Denaturation results in loss of structure and activity;
6. Denaturation is often reversible, restoring pH to optimum restores enzyme activity;

(c) Compare and contrast competitive and non-competitive inhibitors and their effects on the rate of enzyme activity. [6]

1 Both serve to lower rate of enzyme activity by preventing substrate from binding to active site
2 Both involve reversible binding of inhibitor to enzyme

	Competitive	Non-competitive
3 Structure	Structural similarity to substrate	No structural similarity to substrate
4 Binding site	Binds to active site	Binds to site other than active site – allosteric site
5 Competing for active site	Competes with substrate for active site	Does not compete with substrate for active site
6 Conformation of Enzyme	Does not change conformation of enzyme upon binding	Changes conformation of enzyme upon binding such that substrate can no longer bind to active site
7 Effect of increasing [S]	Increasing [S] concentration alleviates effect of inhibitor	Increasing [S] concentration does not alleviate effect of inhibitor
8 V_{max}	Max rate of reaction can be reached (with increased S concentration) / V_{max} unchanged	Max rate of reaction cannot be reached (with increased S concentration) / V_{max} reduced
If points 5 and 6 not awarded, can award point 9		
9 Mode of action	Competes with substrate for active site	Changes conformation of enzyme upon binding such that substrate can no longer bind to active site

Essay Question 2

(a)

Marking Point		Krebs cycle	Calvin cycle
1	**Location**	Mitochondrial matrix	Chloroplast stroma
2	**Substrate**	Acetyl-CoA and oxaloacetate combines to form citrate	CO_2 and Ribulose bisphosphate (RuBP)
3	**Products**	Each glucose molecule gives rise to: 6 NADH 2 $FADH_2$ 2 ATP 4 CO_2	For every 3 molecules of CO_2 that enter the cycle, one triose phosphate / Glyceraldehyde 3 phosphate is made
4	**Regenerated / Starting material**	Oxaloacetate is the starting material that is eventually regenerated	Ribulose bisphosphate (RuBP) is the starting material that is eventually regenerated
5	**ATP**	Produced via substrate level phosphorylation	Used in reduction of glycerate-3-phosphate where energy Is required through hydrolysis of ATP
6	**Electron carriers / donors**	Use NAD^+ and FAD for the oxidation of the intermediates of the cycle by serving as electron acceptors	Uses NADPH / reduced $NADP^+$ to reduce glycerate-3-phosphate to triose phosphate by serving as electron donors
7	**Overall**	Catabolic	Anabolic
8	**Role of CO_2**	CO_2 is released as a result of decarboxylation reactions	Required for carbon fixation. CO_2 is used to convert Ribulose bisphosphate (RuBP) to form an unstable 6C compound that breaks down to form glycerate-3-phosphate
9	**Role of O_2**	Occurs only when O_2 is present	Does not require O_2

8 Max.

(b)

Similarities

1. Both have electron carriers embedded in membranes - inner membrane of mitochondrion and thylakoid membrane of chloroplast;
2. Both involve electrons being passed down a series of electron carriers with increasing electronegativity and in order of decreasing energy levels;
3. Energy released from electron transport chain is used to generate a proton gradient / proton motive force;
4. Both involves diffusion of protons down a concentration gradient through ATP synthase / ref. chemiosmosis;
5. Potential energy of the proton gradient is used for the synthesis of ATP from ADP and Pi;

Why these similarities exist

6. Both processes of ATP production are similar in the organelles because of the endosymbiont theory / endosymbiosis;
7. Mitochondria and chloroplasts originated as prokaryotic organisms which were taken inside a eukaryotic cell;

6 Max.

(c)

1. Under normal field conditions, carbon dioxide is the major limiting factor in photosynthesis, since its concentration in the atmosphere is about 0.03%.
2. Increasing carbon dioxide concentration leads to a linear increase until limited by other factors.
3. Ribulose bisphosphate carboxylase oxygenase (Rubisco), the enzyme that captures carbon dioxide in the light-independent reactions, has a binding affinity for both carbon dioxide and oxygen.
4. When the concentration of carbon dioxide is high, Rubisco will fix carbon dioxide in Calvin Cycle which increases the rate of photosynthesis.
5. If the carbon dioxide concentration is low and oxygen concentration is high, oxygen will out-compete carbon dioxide for the active site of the enzyme Rubisco during the dark stage of the reaction.
6. Therefore, a high concentration of oxygen lowers the rate of photosynthesis.

Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

Paper 3 Applications Paper and SPA Planning Task **23 September 2016**
2 hours

Additional Materials: Writing paper

INSTRUCTIONS TO CANDIDATES:

DO NOT TURN THIS PAGE OVER UNTIL YOU ARE TOLD TO DO SO.

READ THESE NOTES CAREFULLY.

Section A:
Consists of 3 Structured Questions
Answer **all** questions.
Write your answers in the **space provided** on the question paper.

Section B:
Consists of 1 SPA Planning Task
Write your answers on the separate **writing papers** provided. At the end of the examination, fasten all your work securely together.

Section C:
Consists of 1 Free-Response Question.
Write your answers on the separate **writing papers** provided. At the end of the examination, fasten all your work securely together.

Sections A, B and C are to be submitted **separately**.

INFORMATION FOR CANDIDATES

Essential working must be shown.

The intended marks for questions or parts of questions are given in brackets [ ].

For Examiner's Use	
Section A [40]	
1	/ 13
2	/ 12
3	/ 15
Section B[12]	
Section C [20]	
Total [72]	

This document consists of **16** printed pages.

[Turn over

Section A: Structured Questions (40 marks)
Answer **all** questions in this section.

For Examiner's use

Question 1

(a) **Fig. 1.1** shows two types of plasmids, pAMP and pKAN. pAMP carries an ampicillin-resistant (amp^r) gene and pKAN carries a kanamycin-resistant (kan^r) gene. Restriction sites for BamHI and HindIII are found in both plasmids.

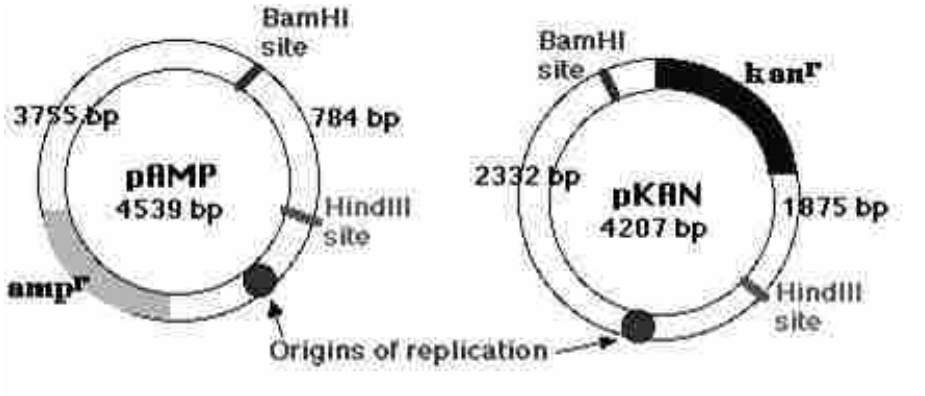


Fig. 1.1

A ligation solution of these two plasmids is mixed together with the enzymes BamHI and HindIII. The pAMP and pKAN fragments were then allowed to anneal, resulting in the plasmid shown in **Fig. 1.2**.

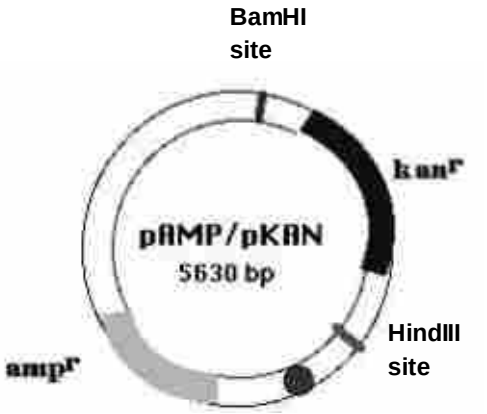


Fig. 1.2

For Examiner's use

(i) In addition to the recombinant plasmid shown in **Fig. 1.2**, three other recombinant plasmids are also formed. Draw and label clearly these three recombinant plasmids in the space provided below. [3]

(ii) *E. coli* is mixed with the ligation solution in (a). Describe and explain how *E. coli* carrying plasmid shown in **Fig. 1.2** can be selected. [2]

For Examiner's use

(iii) With reference to **Fig. 1.2**, in addition to the restriction sites for BamHI and HindIII, a single restriction site for EcoR1 was found within the sequence of the kan^r gene. To clone a human gene with a molecular size of 600 bp into bacterial cells, EcoR1 was used to cut the human gene and the plasmid in **Fig. 1.2**. The cut human gene and plasmid are then mixed together with DNA ligase. The ligated DNA mixture is then used for the transformation of *E. coli*. The bacteria is then grown on a nutrient agar plate.

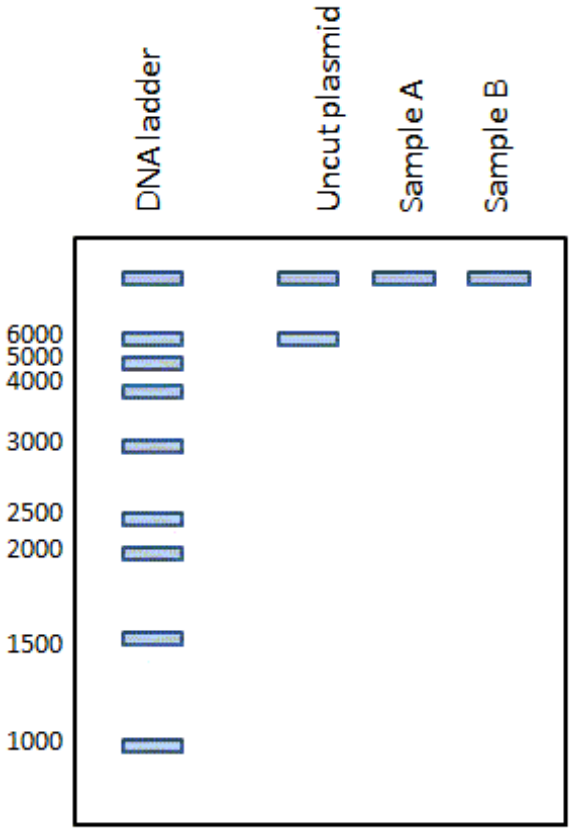
To identify *E. coli* cells that have taken up the recombinant plasmid with the human DNA, a scientist isolates two types of plasmids from 2 bacteria colonies repectively. He then subjects the two DNA samples to restriction digestion using enzymes BamHI and HindIII, producing DNA fragments of the following sizes.

Sample	Fragments (kb)
A	3755, 1875
B	3755, 2475

Suggest which sample of transformed bacterial cells is able to survive on an agar plate containing ampicillin but ***NOT*** on an agar plate containing kanamycin. Explain your answer. [3]

(iv) On the diagram below, complete the banding patterns in lanes Sample A and Sample B that the scientist will observe when he conducts gel electrophoresis using uncut plasmid, sample A and sample B. [1]

For Examiner's use



For Examiner's use

(b) DNA of organisms may be stored in genomic DNA libraries or cDNA libraries.

(i) Outline the roles of one enzyme used in the formation of the cDNA in a cDNA library. [1]

(ii) Explain why cDNA libraries made from the same type of cell at different times in the life of the cell may vary, whilst a genomic library for that organism will always be the same. [3]

Total: [13]

For Examiner's use

Question 2

(a) Although the DNA from different individuals is more alike than different, there are many chromosomal regions that exhibit a great deal of diversity. Such variable sequences are termed polymorphic and provide the basis for disease diagnosis, forensic identification and paternity testing.

One class of polymorphism results from repeated copies of a DNA sequence that lie next to each other on the chromosome. Two common types of repeat polymorphisms are short tandem repeats (STRs) and variable number of tandem repeats (VNTRs). In each type, different numbers of repeats create alleles that differ in size.

(i) Many repeat polymorphisms are highly polymorphic, having tens of different alleles. Repeat polymorphisms also exhibit high level of heterozygosity. Explain what you understand by the term "heterozygosity". [1]

(ii) Repeat polymorphisms used in forensic biology are neutral mutations, which do not affect protein functions. Suggest one location where such mutations are primarily found. [1]

For Examiner's use

(b) An experiment examines a VNTR on human chromosome 1 known as D1S80. Each repeat unit in this VNTR is 16 base-pairs (bp) long. Most individuals have between 14 and 40 copies of the repeat at the D1S80 locus.

In this experiment, polymerase chain reaction (PCR) is used to determine the number of repeated DNA sequences at the D1S80 locus. Each DNA sample is obtained from a single swab of cheek cells from a volunteer. Primers (see arrows) were used for the PCR as shown in **Fig. 2.1**.

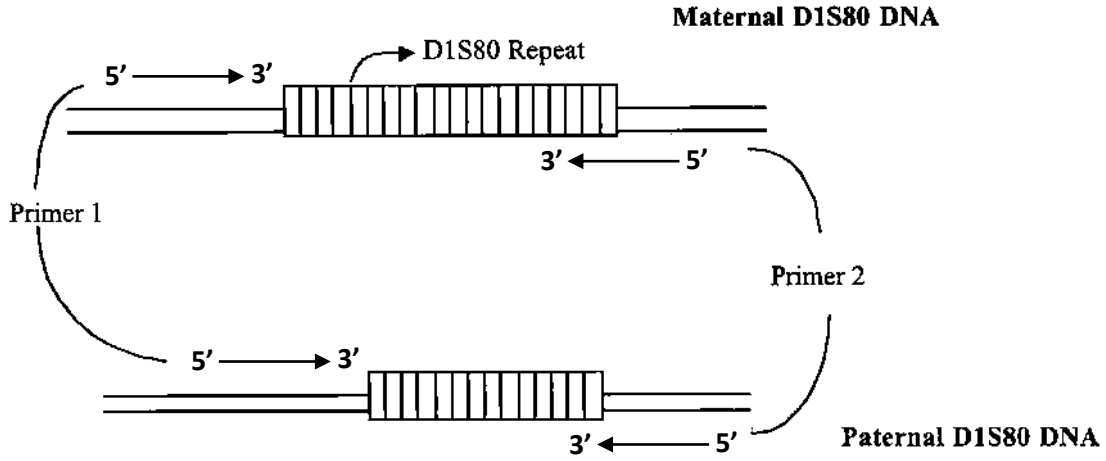


Fig. 2.1

Note:
Primer 1 : 5'-GAA ACT GGC CTC CAA-3' (15-mer)
Primer 2: 5'-GTC TTG TTG GAG ATG-3' (15-mer)

To compare the genotypes from a number of volunteers, aliquots of the respective PCR products and a DNA molecular marker are loaded onto the wells of a DNA chip. Microfluidic electrophoresis is carried out. Following computer analysis, the PCR products of one of the volunteers appear as distinct peaks with assigned base-pair sizes on an electropherogram, as shown in **Fig. 2.2**. The sizes of the PCR products can then be used to determine the specific number of repeats within each VNTR allele.

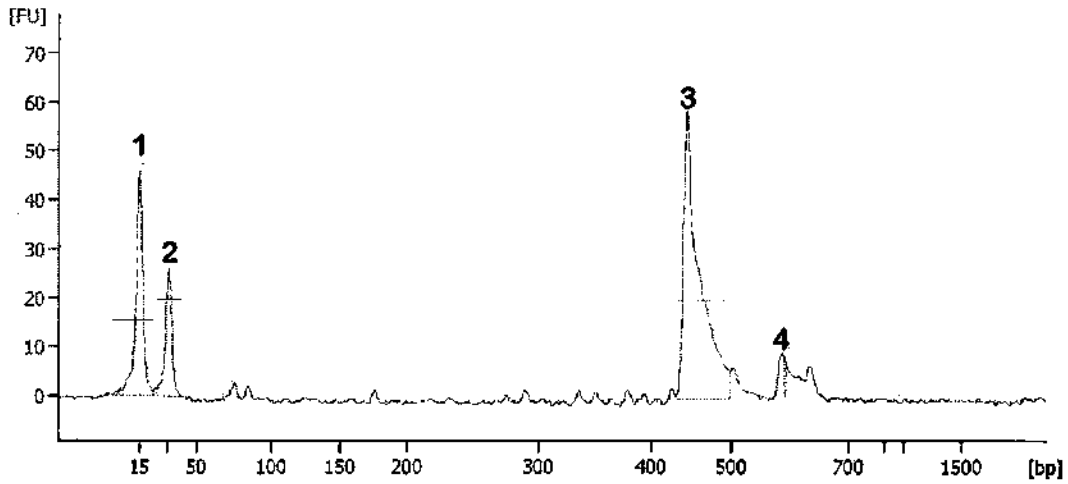


Fig. 2.2

For Examiner's use

The size of DNA corresponding to each of the peak is shown in **Table 2.1**.

Table 2.1

Peak	**Size / bp**
1	15
2	30
3	443
4	590

(i) Explain why peaks **1** and **2** appear in the electropherogram. [2]

(ii) Based on the DNA sizes corresponding to peaks **3** and **4**, calculate the number of repeats present in each VNTR allele of the volunteer. [3]

(iii) Suggest why there is an anomaly in the number of repeats found in one of the VNTRs, besides instrumental error. [2]

(iv) Discuss the benefits of using PCR analysis in place of RFLP analysis for this experiment. [3]

For Examiner's use

Total: [12]

Question 3

For Examiner's use

(a) The first gene therapy trial for an inherited disorder was initiated on 14 September 1990. The patient, Ashanti DeSilva, suffered from a very rare recessively inherited disorder, adenosine deaminase (ADA) deficiency.

An inherited deficiency of ADA has particularly severe consequences in the case of T lymphocytes. As a result, ADA-deficient patients suffer from severe combined immunodeficiency (SCID).

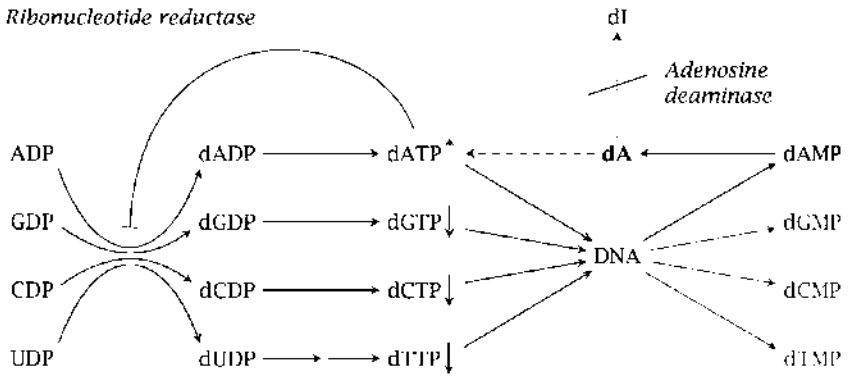


Fig. 3.1

(i) Using the information provided, explain how ADA deficiency can lead to SCID. [3]

The novel ADA gene therapy approach conducted on Ashanti DeSilva involved the following steps:

For Examiner's use

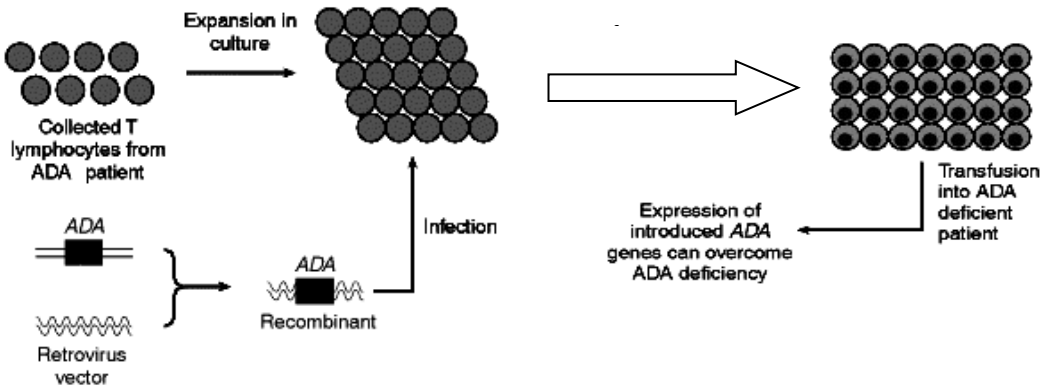


Fig. 3.2

The protocol was reviewed a dozen times by seven regulatory committees before it was finally approved by the RAC in July 1990, and by the FDA two months later. The gene therapy was considered to be a success for Ashanti but the response was far more limited in the second patient.

(ii) Suggest an improvement to the procedure shown in **Fig. 3.2** that will increase the success rate of the treatment. Explain your answer. [2]

(b) (i) ADA-SCID, cystic fibrosis and sickle cell anaemia are examples of autosomal recessive disorders. Such disorders are often prime candidates to be treated by gene therapy.

Explain why it is easier to perform gene therapy when a mutant allele is recessive instead of dominant. [2]

For Examiner's use

(ii) Although the use of gene therapy for treatment of genetic disorders in humans seems promising, there are still many concerns to be addressed.

Explain the factors that may keep gene therapy from becoming an effective treatment for genetic disorders. [3]

(c) Scientists have come up with an alternative method of generating pluripotent cells, which is to genetically reprogramme adult cells to an embryonic stem cell-like state. Genetic reprogramming is carried out by using deactivated retroviruses to introduce the genes of four transcription factors into adult cells from a patient (**Fig. 3.3**).The reprogrammed cells, called induced pluripotent stem (iPS) cells, are specific to the patient from which the adult cells were taken

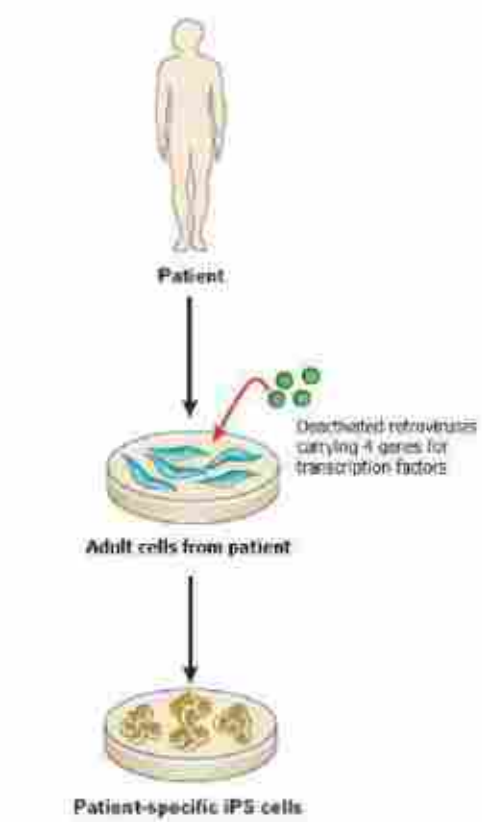


Fig. 3.3

For Examiner's use

(i) State two advantages of using iPS cells instead of embryonic stem cells for research and clinical trials. [2]

(ii) Suggest how the expression of such a small number of transcription factors in adult cells could genetically reprogramme these adult cells to an embryonic stem cell-like state. [3]

Total: [15]

Section B: SPA Planning Task (12 marks)
Write your answers on the writing paper provided.
A **NIL RETURN** is required.

Question 4

Beetroots are plants that have storage roots that are 5 to 10cm in diameter. The storage tissues of these plants have cells that contain betacyanin (red pigment) in the cell vacuole. The betacyanin pigment cannot pass through membranes, but can pass through the cellulose cell walls if the membrane integrity is disrupted.

Physical damage to the storage roots of beetroot, for example by cutting, causes large loss of pigment.

Using this information and your own knowledge, design an experiment to determine the effect of temperature on beetroot membrane integrity.

You must use:

- Beetroot
- Distilled water

You may select from the following apparatus and use appropriate additional apparatus:

- Normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, syringes, glass rods etc.
- White card
- White tile
- Knife, scapel, cork borers
- Ruler
- Blunt forceps
- Stopwatch
- Thermometer
- Access to a kettle to boil water and ice
- Marker pen
- 5% betacyanin
- colorimeter

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variables,
- describe the method with scientific reasoning used to decide the method so that the results are as accurate and reliable as possible;
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimize any risks associated with the proposed experiment.

Total: [12]

Section C: Free-Response Question (20 marks)

Write your answers on the writing paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.
A **NIL RETURN** is required.

Question 5

(a) Biofuels can be obtained from the conversion of cellulosic biomass, which is both abundant and renewable. However, the enzymes and pretreatment processes involved are very expensive. One approach is to genetically engineer plants to produce cellulase so as to enhance the conversion of cellulose into fermentable sugars and reduce the need for pretreatment processes.

Describe how one can mass produce more plants that has already been genetically modified to synthesize cellulase. [7]

(b) Explain the significance of genetic engineering in GM salmon and Bt corn in solving the demand for food in the world. [7]

(c) Discuss the social and ethical implications of Bt corn. [6]

Total: [20]

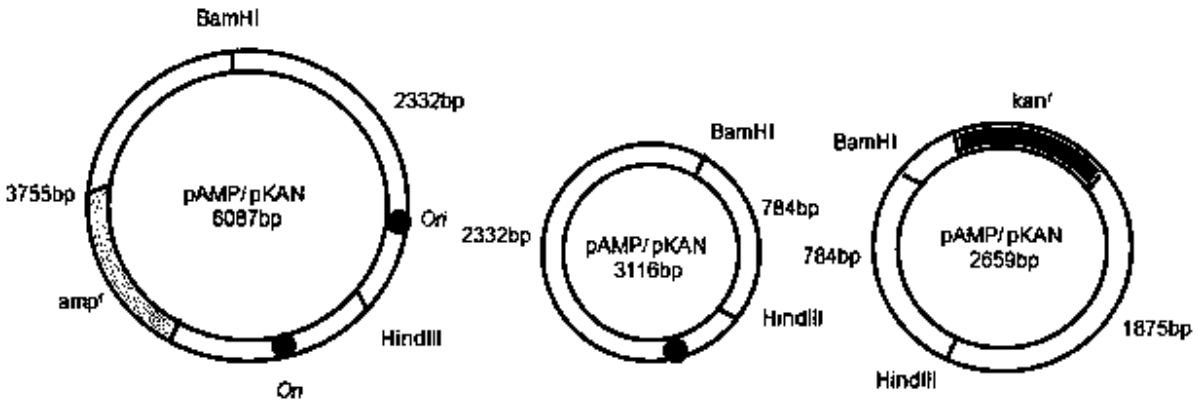
END OF PAPER

DUNMAN HIGH SCHOOL
PRELIMINARY EXAMINATION 2016
YEAR SIX
H2 BIOLOGY (9648)
PAPER 3

Structured Questions Answers

Question 1

(a)(i)

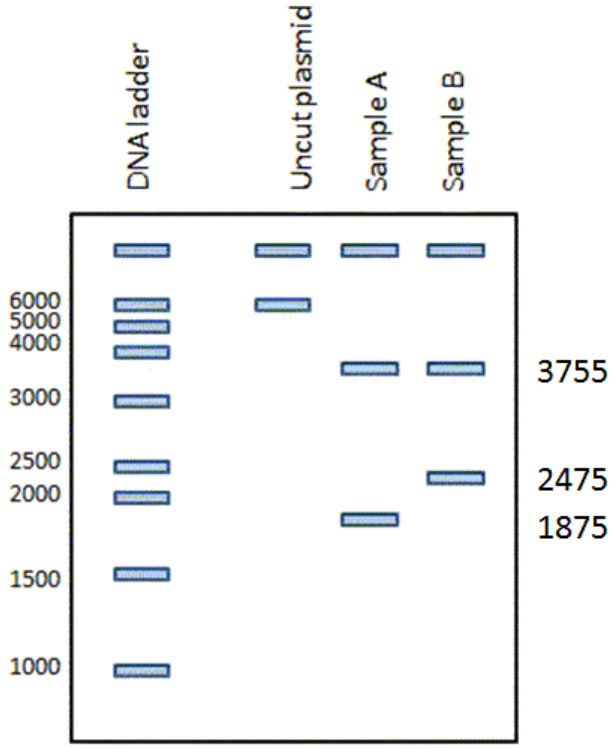


1M for each drawing of recombinant plasmid showing size of plasmid, correct labels, position of antibiotic resistance gene and *ori*
Comment: many students draw without showing complete labeling. The relative size of plasmids and segments should also be accurately represented.

(ii)
Culture *E.coli* on a nutrient plate containing ampicillin and kanamycin;
Plasmid shown in **Fig 1.2** contains ampicillin and kanamycin resistant genes and hence *E.coli* carrying this type of plasmid will survive and grow into colonies;
Or
E.coli carrying the other three types of plasmid does not contain <u>both</u> ampicillin and kanamycin resistant genes) and thus will not survive and grow into colonies;
Note: Plasmids DO NOT survive and grow on nutrient plates.

(iii)
<u>Sample B</u> is able to survive in an agar plate containing ampicillin but not kanamycin;
Sample B bacteria <u>carry plasmid with human gene</u>. 3755 kb and 2475 kb fragments. This 2475 kb fragment is the 1875 kb with an addition of the <u>600kb human gene</u>;
Thus <u>kan^r gene is disrupted by the insertion of the human gene</u> and that the bacteria cannot product protein that confer resistance to kanamycin and thus not able to grow on the plate with kanamycin;

(iv)



(b)(i)
Reverse transcriptase – synthesizes single stranded cDNA from mRNA template;

RNAse- partially degrades mRNA template after single stranded cDNA is synthesized, remaining short RNA segments serve as primers for synthesis of second strand;

DNA polymerase – synthesizes second strand of cDNA using first strand of cDNA as a template through the formation of phosphodiester bond;

DNA ligase – joins cDNA fragments of second strand to get a complete double-stranded cDNA molecule through the formation of phosphodiester bond;

1 Max.

(ii)
The starting material / template for the synthesis of cDNA is mature mRNA expressed from certain genes at that particular time;
The expression of genes varies at different times in the life of the cell / can also change in response to different stimuli;
For genomic library, the set of DNA remains the same throughout the life of the cell;

Question 2

(a)(i)
Human beings are diploid organisms where 2 different alleles are inherited, one from each parent;
(ii)
Centromere, telomere, introns;

1 Max.

(b)(i)
Excess primers are used where peak 1 corresponds to the primers;
And peak 2 corresponds to the primer dimers;

(ii)
For PCR products corresponding to each peak, there is a need to consider the length of the 2 flanking primers, i.e.
15 bp x 2 = 30 bp;

Since primers are not repeats, there is a need to subtract the length of the flanking primers from the total length of the PCR products, i.e.
For peak 3: 443 bp – 30 bp = 413 bp
For peak 4: 590 bp – 30 bp = 560 bp;

Since each repeat is 16 bp in length, divide length of PCR products in step 2 by 16 to obtain number of repeats present in each VNTR allele:
Number of repeats present in VNTR allele in peak 3 = 413/16 =25.8 (correct to 3 s.f.) = 26
Number of repeats present in VNTR allele in peak 4 = 560/16 =35;

(iii)
Identify as the 443 bp fragment where it has 25.8 repeats, i.e. not whole repeats;
This could be due to deletion mutation;

(iv)
Small amounts of DNA collected from volunteers, therefore need amplification for differences to be detected;
No restriction sites flanking the locus, thus restriction enzymes cannot cut out the marker / locus for RFLP analysis;
Specific primers used, thus can home in on a single marker / locus;
No need for Southern blot, thus it is less tedious / safer because radioactive probes are not used;

3 Max.

Question 3

(a)(i)

- Deficiency of ADA results in accumulation of the substrate deoxyadenosine (dA) in cells. This leads to the buildup of dATP in cells;
- dATP inhibits ribonucleotide reductase and prevents DNA synthesis / formation of deoxyribonucleoside diphosphates (dNDP);
- As a result, T lymphocytes are unable to divide. Consequently, the immune system is severely compromised and this leads to SCID;

(a)(ii)

- Use hematopoietic stem cells from the bone marrow of the patient instead of T-lymphocytes;
  R! Bone marrow cells / bone marrow stem cells
- since hematopoietic stem cells are able to self renew and differentiate into B- and T-lymphocytes. This will provide a more long term / permanent cure;

(b)(i)

When mutant allele is recessive, addition of functional / normal dominant allele by gene therapy will produce sufficient amounts of gene product to mask the effect of recessive allele;

If mutant allele is dominant, both alleles must be removed / repaired / inactivated to block production of defective gene product;

(b)(ii)

- Transient expression of therapeutic gene / difficult to ensure that therapeutic gene is integrated into genome of host cells;
- Incorrect insertion of therapeutic gene into genome of host cell results in cancer / insertional mutagenesis, as the insertion is random;
- Immune response may be triggered resulting in rejection because a foreign vector is introduced;
- Difficult to control expression of normal functional gene to give a fully functional protein;
- Unable to treat multigene disorders;

3 Max.

(c)(i)

- iPS cells can be generated from skin cells/adult cells, so there are **fewer <u>ethical issues</u>** involved as compared to using embryonic stem cells obtained from an embryo;

- iPS cells can be generated from skin cells/adult cells of the patient/sufferer, so there might be **less risk of tissue rejection** after gene therapy and transplantation;

- iPS cells are more **readily available** than embryonic stem cells; OWTTE

(c)(ii)

1. Each transcription factor can **activate the transcription of multiple genes**. Each gene in turn could code for a transcription factor which **activates/inactivate other genes**;

2. Transcription factors **switch on genes that are expressed in ES cells,** resulting in the synthesis of proteins which are found in ES cell;

3. **Give example of activated genes:** e.g. telomerase gene/ genes which promote cell division/ genes which cause the cell to revert to undifferentiated state;

4. Transcription factors could also **inhibit gene expression / repress genes not expressed in ES cells;**

5. **Give example of inactivated genes:** e.g. genes that result in differentiation / specialisation;

<u>3 Max.</u>

Planning Answer

<table>
<tr>
<td>Theory</td>
<td>The hydrophobic core of the phospholipid bilayer of the cell membrane prevents any large, polar, hydrophilic molecules like betacyanin to freely exit the plant cell.

Cell membrane follows fluid mosaic model - composed of membrane proteins embedded in a phospholipid bilayer. Increase in temperature increases kinetic energy, resulting in increased movement of phospholipids, increasing fluidity of membrane, making membrane slightly leaky. Too high a temperature can cause movement of phospholipids to be too great, disrupting membrane integrity, causing betacyanin to leak out of the cell.

Too high a temperature can also cause denaturation of membrane proteins by disrupting hydrophobic interactions, hydrogen bonds and ionic bonds, also disrupting membrane integrity, causing betacyanin to leak out of the cell.

As temperature increases, the cell surface membrane will become more fluid and leak a small amount of pigment, beyond a certain temperature the membrane integrity would become significantly disrupted and a large amount of pigment would leak out of the cell into the bathing solution. Beyond a certain temperature, membrane integrity is completely disrupted and further increase in temperature will not result in significant increase in amount of betacyanin released.</td>
<td>1. Theory on why betacyanin cannot pass through membrane

2. theory of how temperature affects membrane phospholipids OR theory of how temperature denatures membrane proteins

3. hypothesis:</td>
</tr>
<tr>
<td>Variables</td>
<td>Independent variables: 5 temperature water baths, evenly distributed (10, 30, 50, 70, 90^{o}C).

Dependent variables: intensity of red colouration of bathing solution after a fixed time interval in waterbath (as measured using colorimeter / as compared against colour standard)

Controlled variables: Fixed amount of time given for soaking in bathing solution,

Number/size of discs of beetroot used,</td>
<td>4. independent and dependent variables</td>
</tr>
<tr>
<td>Procedure</td>
<td>1. Use the cork borer to obtain a uniform cylinder of beetroot.
2. Use a ruler to measure 1cm to ensure uniform thickness and a scapel to cut the beetroot into discs. Obtain 3x 5 discs.

3. Wash the discs and ensure that any red pigment leakage caused by cutting is washed away before start of experiment.

4. Carryout dilution of the 5% betacyanin to have a colour standard for comparison according to the table below.

<table>
<tr><th>Percentage of betacyanin / %</th><th>Volume of 5% betacyanin stock / cm^3</th><th>Volume of distilled water / cm^3</th><th>Final volume / cm^3</th></tr>
<tr><td>5</td><td>10</td><td>0</td><td>10</td></tr>
<tr><td>4</td><td>8</td><td>2</td><td>10</td></tr>
<tr><td>3</td><td>6</td><td>4</td><td>10</td></tr>
<tr><td>2</td><td>4</td><td>6</td><td>10</td></tr>
<tr><td>1</td><td>2</td><td>8</td><td>10</td></tr>
<tr><td>0</td><td>0</td><td>10</td><td>10</td></tr>
</table>
</td>
<td>5. how to ensure uniform size of discs

6. wash

7. dilution of betacyanin for color standard</td>
</tr>
</table>

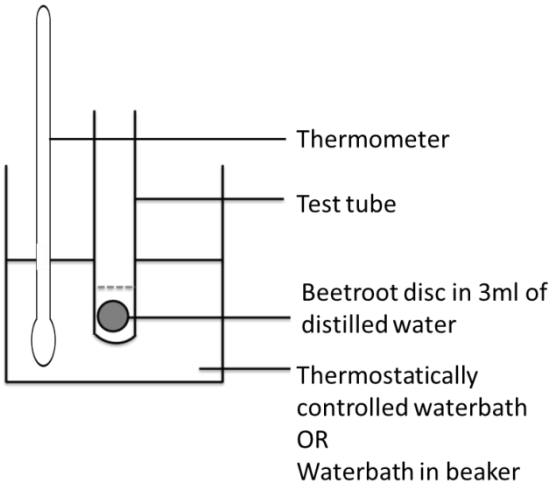
	5. Label 5 large beakers (10, 30, 50, 70, 90°C) and prepare the 5 different water bath temperatures by mixing hot water and tap water or ice provided. Use a thermometer to check and monitor water bath temperatures. Add ice or hot water as necessary to maintain these temperatures. OR Prepare the 5 different thermostatically controlled water baths at 10, 30, 50, 70, 90°C. Use a thermometer to check and adjust settings to achieve and maintain water bath temperatures. 6. Label 3x 5 test tubes (10, 30, 50, 70, 90°C) and add 3cm^3 of distilled water into each tube using a clean syringe. 7. Place the test tubes in each of their respective water baths and incubate for 5 minutes to allow distilled water in each test tube to reach water bath temperature. Use thermometer to check that test tube distilled water has reached desired temperature.  8. Use the forceps to transfer a beetroot disc into first test tube at 10°C. Immediately start the stop watch and allow the discs to incubate for 5 minutes. 9. After 5 minutes of incubation time, remove beetroot disc from test tube using forceps / decant bathing solution from test tube into clean test tube. 10. Observing the test tube against a white card as background, compare with prepared colour standard to determine concentration of betacyanin present. OR fill a cuvette with 1ml (A:1ml-1.5ml) distilled water and place in colorimeter. Press tare button. Fill a second cuvette with 1ml (A:1ml-1.5ml) of beetroot bathing solution. Place the cuvette in the colorimeter, press the test button and take the absorbance reading. 11. Record results in the table below. 12. Repeat steps 8-9 to obtain 3 replicates for each temperature to ensure reliability of results. Repeat experiment 2 more times to ensure reproducibility of results. 13. Plot a graph as shown below.	8.how to prepare & maintain water baths 9. equilibrate temperate 10. relevant figure 11. how to ensure uniform incubation time 12a. comparison with colour standard OR 12b1. tare colorimeter with water 12b2. 1ml in cuvette to take absorbance reading w/o beetroot. 13. 3 replicates, 2 repeats

Table showing effect of temperature / °C on percentage of betacynin found in bathing solution /%

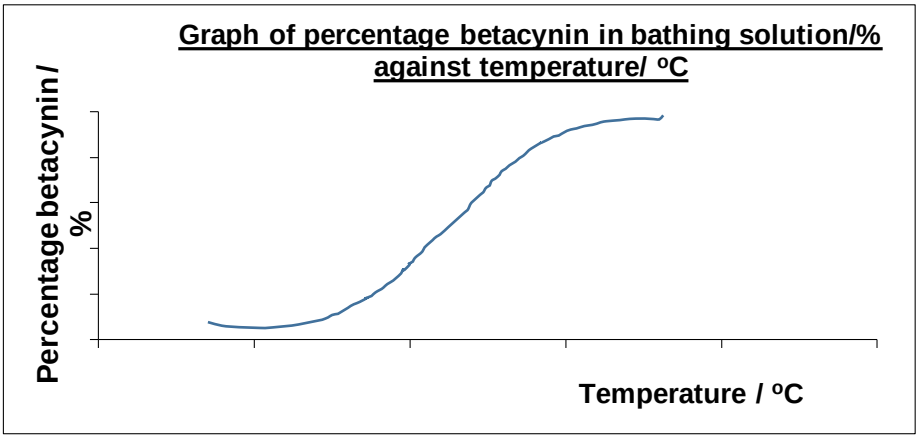
Temperature / °C	percentage of betacynin / %			
	Reading 1	Reading 2	Reading 3	Average
10				
30				
50				
70				
90				

OR

Table showing absorbance readings of bathing solutions after 5min incubation at varying temperatures / °C

Temperature / °C	Absorbance			
	Reading 1	Reading 2	Reading 3	Average
10				
30				
50				
70				
90				

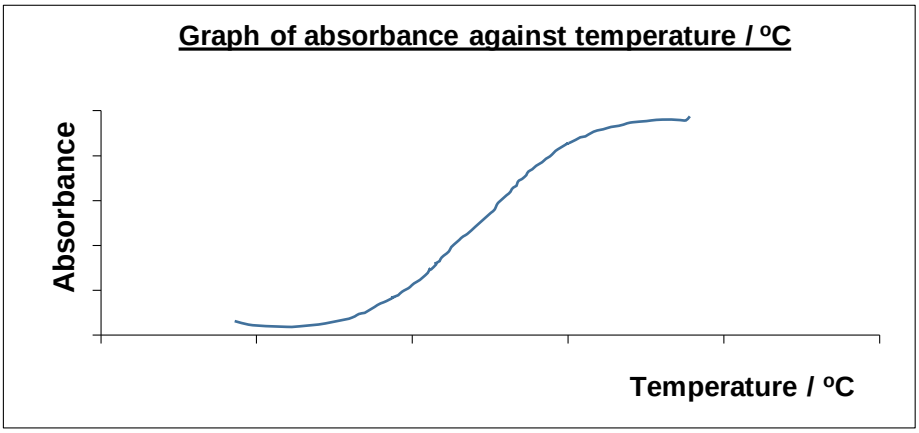
14. appropriate table with correct headings with units for recording observation of red colouration



15. graph with correct headings / units

16. Predicted trend

OR



Risk and precaution	Cut beetroot using scalpel against a white tile in a direction away from your body (side-ways or downwards) and others to prevent injury. Use oven mittens when handling beaker with hot water to prevent getting scalded.	17. Safety

Essay Answers

5(a) Biofuels can be obtained from the conversion of cellulosic biomass, which is both abundant and renewable. However, the enzymes and pretreatment processes involved are very expensive. One approach is to genetically engineer plants to produce cellulase so as to enhance the conversion of cellulose into fermentable sugars and reduce the need for pretreatment processes.

Describe how one can mass produce more plants that has already been genetically modified to synthesize cellulase. [7]

1. Obtain an **explant from plant meristematic tissue** (e.g. shoot tip) from plant that has already been genetically modified to synthesize cellulase;
2. **Culture in a medium** (with mineral nutrients, carbohydrate source, and plant growth regulators);
3. under **aseptic conditions** (e.g. surface sterilization, use of laminar flow cabinet);
4. Formation of **mass of undifferentiated cells** known as **callus**;
5. **Subculture** to increase number of callus with desired gene;
6. **Increase cytokinin to auxin ratio for shoot formation**;
7. **Increase auxin to cytokinin ratio for root formation**;
8. **Acclimatize plantlets** by growing in **sterile soil** in a greenhouse;

7 Max.

5(b) Explain the significance of genetic engineering in GM salmon and Bt corn in solving the demand for food in the world. [7]

Inability to cope with demand for food in the world

1. Food production must increase in order to cope with the **increase in human population** as **traditional methods for growing food may not be sufficient** to meet the demands**;**

GM salmon

2. In normal salmon, the gene that controls the production of growth hormone is activated by light, so the **fish usually grow only during the warm summer months**;
3. Genetically engineer GM salmon by the insertion of a **growth hormone gene** from a Pacific Chinook salmon and an **active promoter** from an ocean pout placed upstream of the growth hormone gene;
4. The active promoter allows the **growth hormone to be expressed all year round / GM salmon can grow all year round**;
5. This results in the GM salmon **reaching market size in a shorter time**, thereby **increasing the supply of salmon**;

Bt corn

6. **Insects can cause damage to crops** both in the field and during storage in silos;
7. Genetically engineer **maize/potato** by insertion of a **Bt-toxin gene** from the bacteria ***Bacillus thuringiensis*** that codes for the production of a crystalline Bt-toxin protein;
8. When insects eat Bt toxins, **toxin is broken down by the digestive enzymes into toxic proteins** that paralyzes the insect's digestive system and forms holes in the gut wall, **killing the insect**;
9. This results in **increased crop yield and quality**;

7 Max.

5(c) Discuss the social and ethical implications of Bt corn. [6]

1. **Bt toxic effects on non-target organisms**;
    - Organisms that are predators and parasites of pests are of benefit to agriculture, helping to regulate the population of the pests. However, unforeseen effects of the accumulation of Bt toxins on these organisms could cause them to die instead.
2. **Religious / Dietary restrictions** in food choices;
    - Some religious and ethnic groups have restrictions in the food that they can consume due to their religious/personal beliefs. GM food may further complicate their food choices.
3. **Allergies** to new proteins synthesised;
    - The Bt protein may lead to unexpected allergic reactions that consumers may not be aware of.
4. **Monopolization / Concentration of economic power** into a few large multinational companies;
    - As GM research is heavily funded by private companies, there is a fear that there might be **monopolization of agriculture by certain companies** since research and production of GM food is impeded by the protection of intellectual property.
    - There may also be possible **conflicts of interest** between the need for a private company to make money and the application of privately owned technology to solving food and economic problems in poor countries.
5. **Erosion of rural communities;**
    - Increased usage of GM food may lead to increased dependence on industrialized nations by developing countries. Thus, Bt corn can be as a power grab that threatens the sustainability of rural communities.
    - Alternatively, increased cultivation of Bt corn may lead to increased deforestation for farming and transport infrastructure, forcing smaller farmers out of their jobs.
    - Cultivation of other crops may also decrease, increasing the income divide due to the reliance on foreign imports.
6. **Tampering with nature / "Playing God"**;
    - Some religious groups have strong moral objections to scientists moving DNA from one species to another, breaking the natural species barrier.
7. **Labeling of GM food**;
    - Some members of the public may be fearful of eating 'weird' food and refuse to eat Bt corn. These people would like GM food to be labeled for transparency.
    - However, proponents of GM foods feel that there is "no difference" between GM crops and traditionally-bred crops and thus there is no need for labeling.

AVP (1 mark per implication with elaboration);

<u>6 Max.</u>

HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	**15S ___**

CENTRE NUMBER					**INDEX NUMBER**			

BIOLOGY

9648 / 02

Paper 2 Core Paper

13 September 2016

Additional Materials: Writing Paper

2 hours

INSTRUCTIONS TO CANDIDATES

Write your **name**, **CT group**, **Centre number** and **index number** in the spaces provided at the top of this cover page.

SECTION A

This section contains **eight** questions. Answer **all** questions.
Write your answers on the lines / in the spaces provided.

SECTION B

This section contains **two** questions. Answer any **one** question.
Your answers must be in continuous prose, where appropriate.
Write your answers on the writing paper provided.

BEGIN EACH PART ON A FRESH SHEET OF WRITING PAPER.

A **NIL RETURN** is required for parts not answered.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.

You are reminded of the need for good English and clear presentation in your answers.

For Examiners' Use	
Question	**Marks**
1	**/ 8**
2	**/ 8**
3	**/ 11**
4	**/ 8**
5	**/ 10**
6	**/ 9**
7	**/ 12**
8	**/ 14**
9 / 10	**/ 20**
Total	**/ 100**

This document consists of **23** printed pages.

BOOKLET 1

SECTION A: STRUCTURED QUESTIONS

QUESTION 1

Proteins play an important role in many biological processes.

(a) **(i)** State **two** secondary structures commonly found in proteins.

.....[1]

(ii) Compare the secondary structures stated in **(a)(i)**.

.....

.....

.....

.....[2]

Fig. 1.1 shows a mammalian DNA polymerase interacting with a DNA molecule. The catalytic and binding amino acid residues of the DNA polymerase are located at different positions on a single polypeptide chain. These residues are brought close together in the active site.

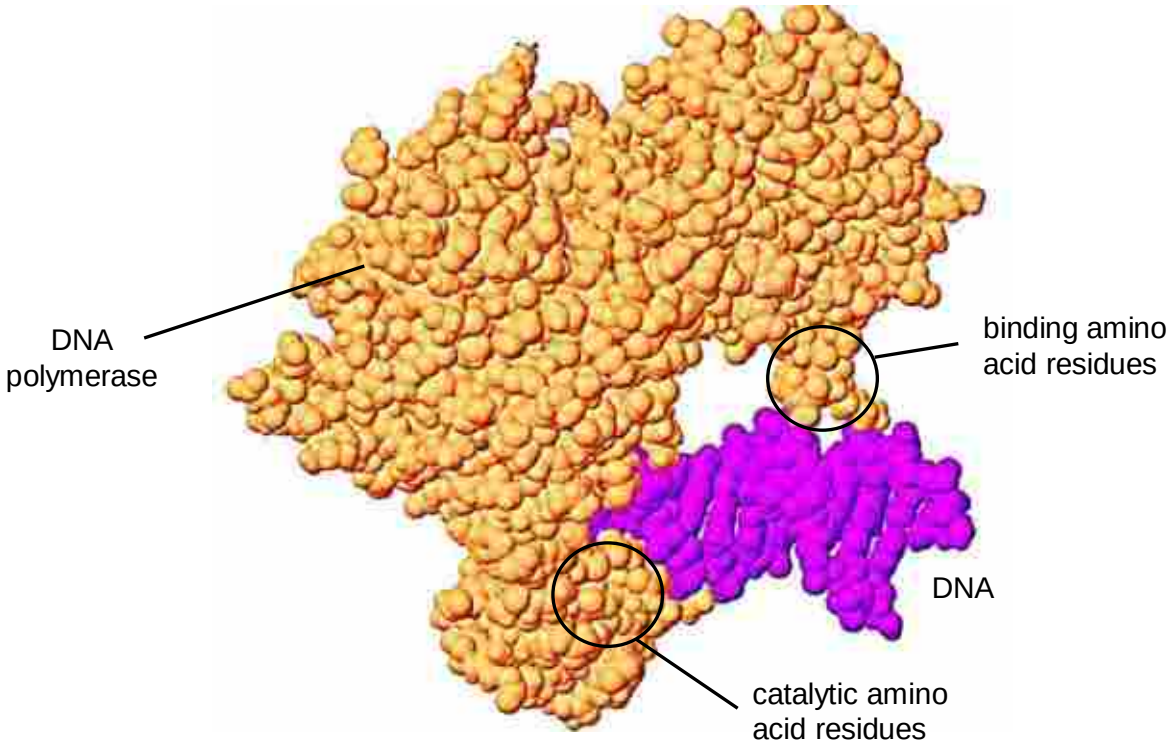


Fig. 1.1

(b) Describe how the catalytic and binding amino acid residues of DNA polymerase located at different positions are brought close together in the active site.

.....

.....

.....

.....

.....

..... [3]

Taq DNA polymerase has a similar function to the mammalian DNA polymerase. It is involved in polymerase chain reaction (PCR) in the presence of a pH 8.4 buffer.

(c) Explain the significance of the pH 8.4 buffer in PCR.

.....

.....

.....

..... [2]

[Total: 8]

QUESTION 2

Fig. 2.1 shows information about the movement of chromatids in a cell that has just started metaphase of mitosis.

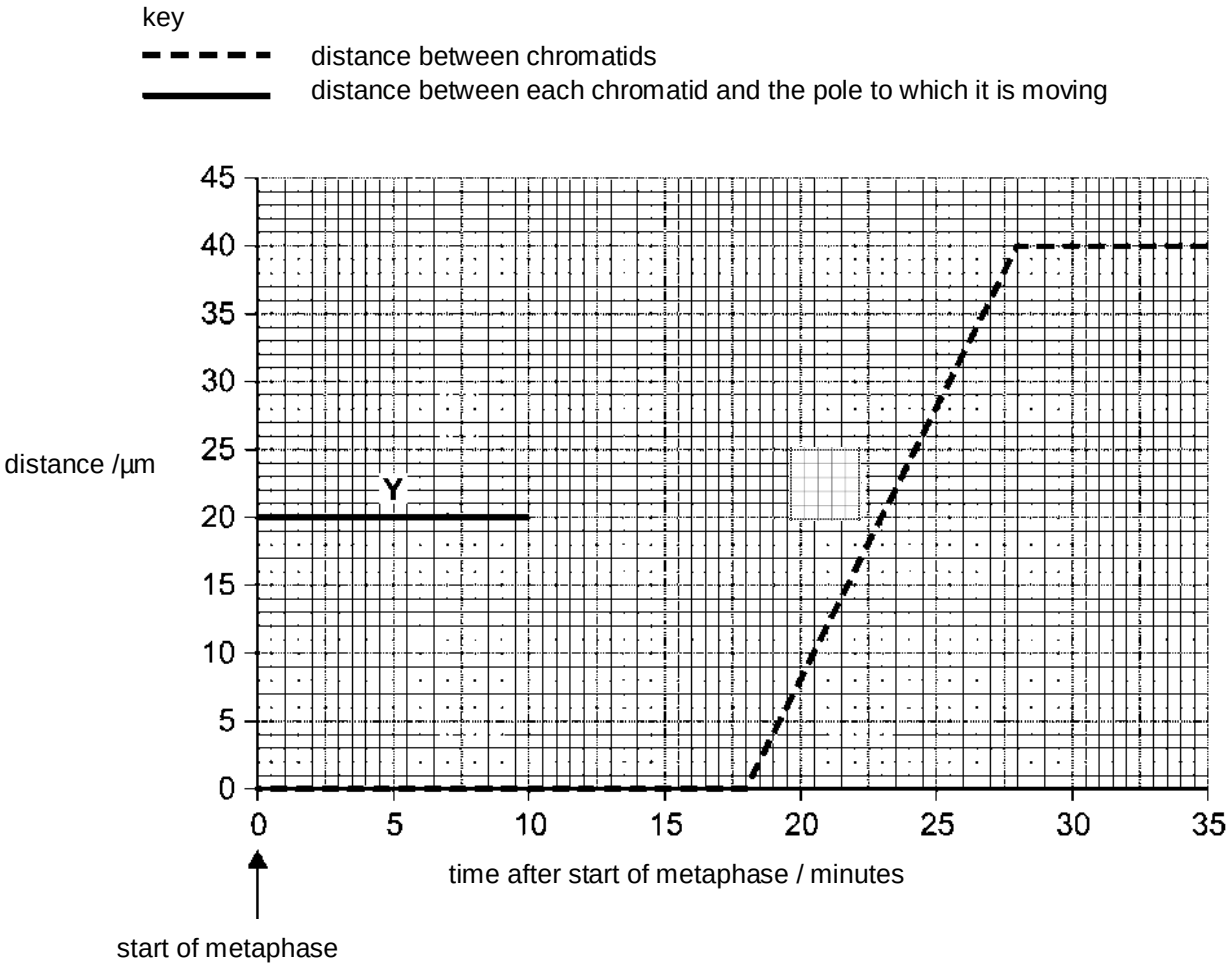


Fig. 2.1

With reference to Fig. 2.1,

(a) **(i)** state the duration of metaphase in the cell.

.....[1]

(ii) complete line **Y** on the graph. [1]

(iii) account for your answer in **(a)(ii)**.

.....

.....

.....

.....

.....

..... [3]

The movement of chromatids is dependent on spindle fibres, which are made up of many tubulin subunits. Spindle fibres are lengthened at one end during mitosis by the polymerisation of tubulin subunits through GTP hydrolysis.

A drug, eribulin, is known to prevent the polymerisation of the tubulin subunits.

(b) Suggest and explain the effect of eribulin on the behaviour of chromosomes in mitosis.

.....

.....

.....

.....

.....

..... [3]

[Total: 8]

QUESTION 3

p53 protein is a transcriptional activator that regulates the expression of *Mdm2* gene. Mdm2 protein in turn regulates the activity of p53 protein on genes involved in growth arrest, DNA repair and apoptosis.

Fig. 3.1 shows how p53 protein activates *Mdm2* gene expression.

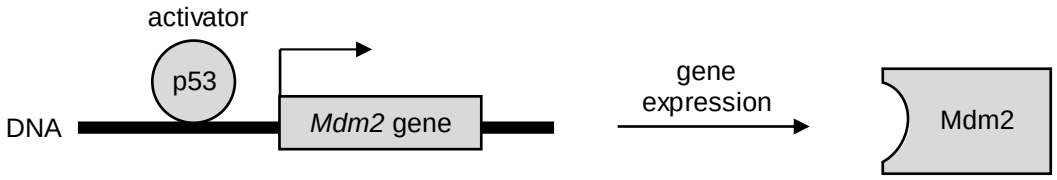


Fig. 3.1

(a) Explain the significance of p53 protein in the regulation of *Mdm2* gene expression.

.....

.....

.....

.....

.....

..... [3]

The cellular level of p53 protein is tightly regulated by Mdm2 protein.

When no DNA damage is detected in a cell, unphosphorylated p53 protein can bind to Mdm2 protein to trigger degradation of p53 protein via the ubiquitin system as shown in Fig. 3.2a.

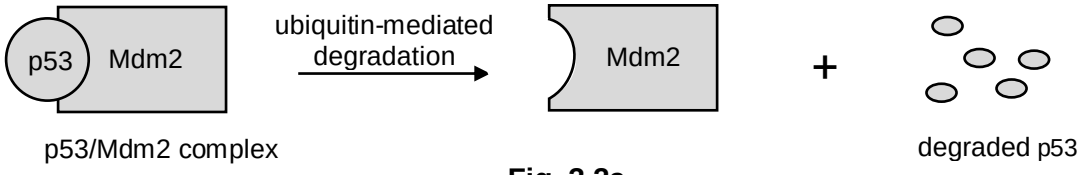


Fig. 3.2a

When DNA damage is detected in a cell, p53 protein will be phosphorylated at Serine15, Threonine18 or Serine20 amino acid residues as shown in Fig. 3.2b. In normal cells, these three amino acid residues are not phosphorylated, and p53 protein is maintained at low levels by Mdm2 protein.

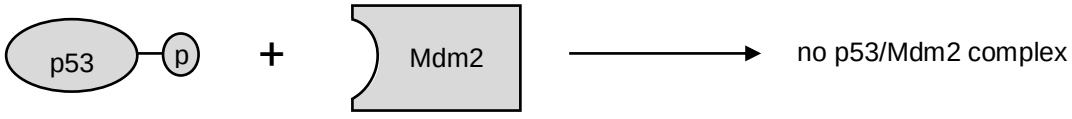


Fig. 3.2b

(b) Account for the high levels of p53 protein when DNA damage is detected in the cell.

.....

.....

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.....

.....

..... [4]

(c) Suggest the need for ubiquitin-mediated degradation of p53 protein to occur.

.....

..... [1]

(d) Homozygous deletion of *Mdm2* gene in mouse germline cells results in lethality at the blastocyst stage, due to inappropriate apoptosis.

With reference to Fig. 3.2a and Fig. 3.2b, suggest how inappropriate apoptosis occurs.

.....

.....

.....

.....

.....

..... [3]

[11 marks]

QUESTION 4

The retrovirus, human immunodeficiency virus (HIV), and the influenza virus are two types of enveloped viruses. Both enter the human host cells by adsorption and penetration. Fig. 4.1 shows the entry process of a HIV into a macrophage, which is a type of white blood cell.

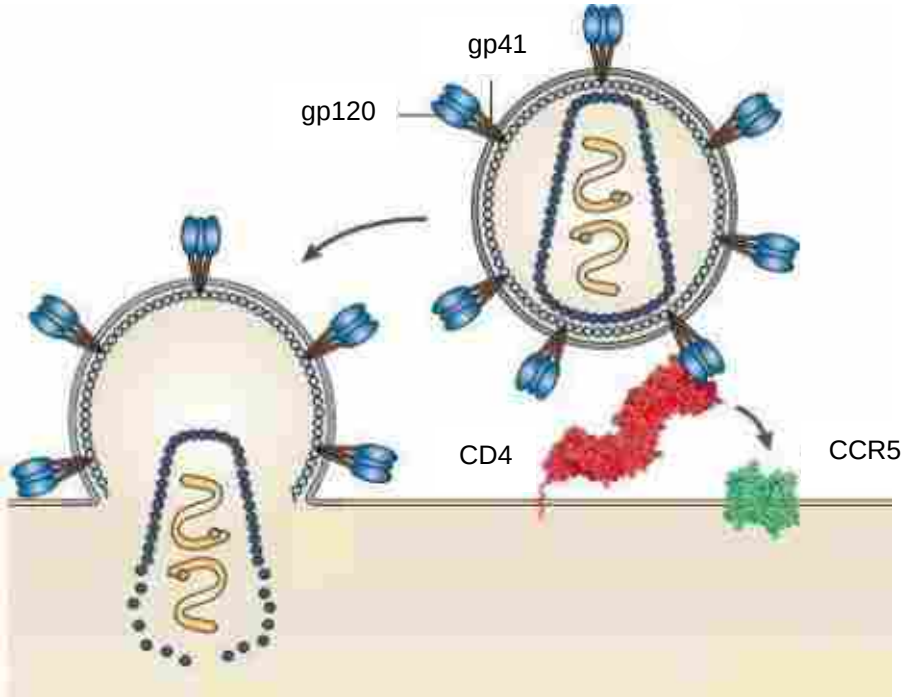

Fig. 4.1

(a) (i) State what is meant by *retrovirus*.

.....

.....

.....

..... [2]

(ii) Compare the entry processes of the HIV and influenza virus into human host cells.

.....

.....

.....

.....

.....

..... [3]

(b) Upon completion of the entry process, describe how the genome of HIV is inherited.

.....

.....

.....

.....

.....

..... [3]

[Total: 8]

QUESTION 5

George Schull, a botanist at Princeton University, conducted a genetic study of a common weed known as shepherd's purse, *Capsella bursa-pastoris*. He studied the shape of its fruit, which could be heart-shaped or narrow respectively, as shown in Fig. 5.1.

Fig. 5.1

When he crossed a pure-breeding plant with heart-shaped fruit to a pure-breeding plant with narrow fruit, the F1 generation all had heart-shaped fruit. When the F1 generation was self-fertilised, the numbers of F2 generation with the respective shaped fruit were recorded as follows:

heart-shaped fruit	2251
narrow fruit	150

Fig. 5.2 shows the possible biochemical pathway that results in the observation made in the F2 generation.

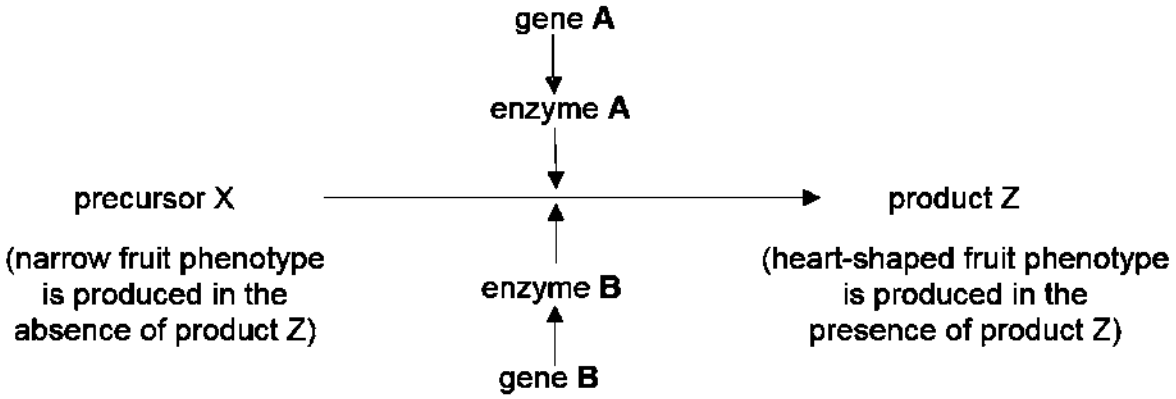

Fig. 5.2

(a) Explain the type of gene interaction observed in this context.

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..... [3]

(b) Using the symbols **A**, **a**, **B** and **b**, draw a genetic diagram to explain the results of the F2 generation in the space provided. [5]

(c) Describe how you could identify *Capsella* sp. plants with heart-shaped fruits, which are homozygous dominant in at least one gene locus.

.....

.....

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..... [2]

[Total: 10]

QUESTION 6

The unicellular green alga, *Chlorella*, a photosynthetic eukaryote is mass produced and harvested by commercial suppliers for use as a health food supplement.

Fig. 6.1 shows the effect of carbon dioxide concentration on the light-independent stage of photosynthesis in *Chlorella*. The following steps were carried out in a study:

- a cell suspension of *Chlorella* was illuminated using a bench lamp.
- the suspension was supplied with carbon dioxide at a concentration of 1% for 200 seconds.
- the concentration of carbon dioxide was then reduced to 0.03% for a further 200 seconds.
- the concentration of RuBP and glycerate-3-phosphate (GP) were measured at regular intervals.
- the temperature of the suspension was maintained at 25 ^{o}C throughout the investigation.

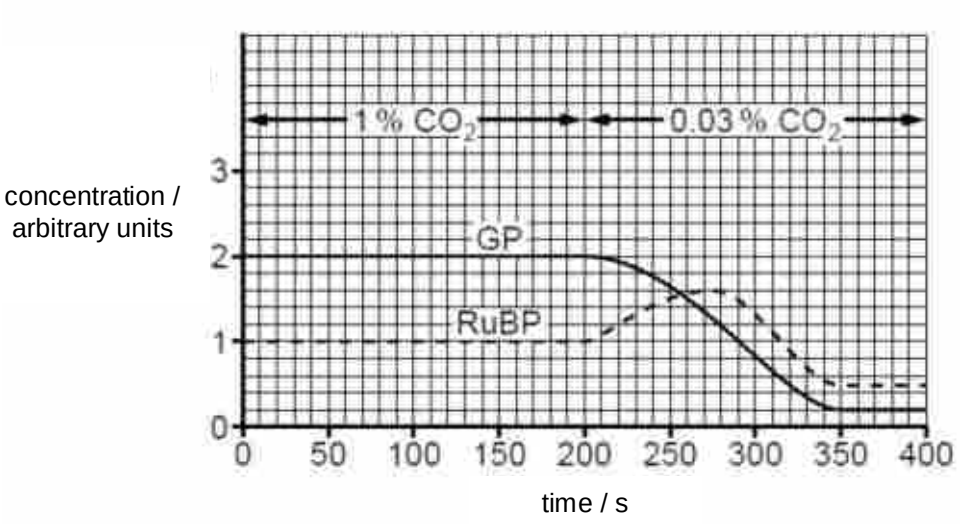

Fig. 6.1

(a) **(i)** State precisely where RuBP and GP are produced in the chloroplast.

.....[1]

(ii) Explain why the concentration of RuBP changed between 200 and 275 seconds.

.....

.....

.....

.....[2]

(b) Suggest how the decrease in the concentration of GP leads to a decrease in harvest for commercial suppliers of *Chlorella*.

.....

.....

.....

..... [2]

(c) In the light dependent stage, illumination of chloroplasts is important for maintaining the high pH in the stroma.

Explain how the illumination of chloroplasts maintains the high pH in the stroma.

.....

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.....

..... [3]

(d) The endosymbiotic theory postulates that the chloroplasts of *Chlorella* evolved from bacteria living within an eukaryotic host cell.

Suggest **one** structural similarity between the chloroplasts and the bacteria that supports this theory.

.....

..... [1]

[Total: 9]

QUESTION 7

Fig. 7.1 shows part of a myelinated motor neurone. The numbers show the membrane potential, in millivolts (mV), at various points along the axon of the myelinated neurone.

(a)(i)

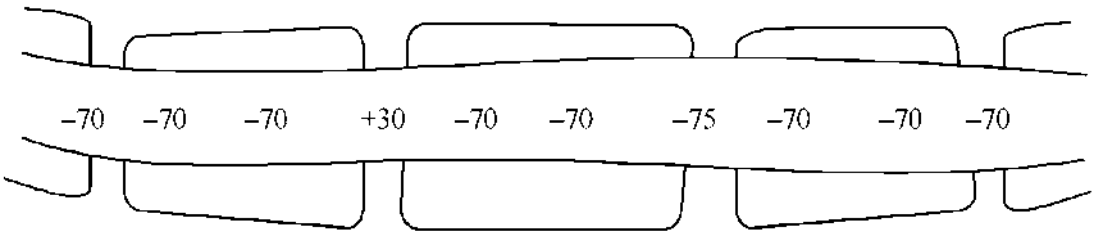

Fig. 7.1

(a) **(i)** Draw an arrow in the box provided on Fig. 7.1 to indicate the direction in which one nerve impulse is being conducted. [1]

(ii) Explain your answer in **(a)(i)**.

.....

.....

.....

..... [2]

(b) Suggest why transmission of nerve impulses along a myelinated neurone uses less energy in the form of ATP than transmission along an unmyelinated neurone.

.....

.....

.....

..... [2]

Fig. 7.2 shows the changes in the concentration of sodium ions inside a segment of an axon. The neurone was stimulated at the points indicated on the graph. The neurone was treated with dinitrophenol (DNP) in region **Y**.

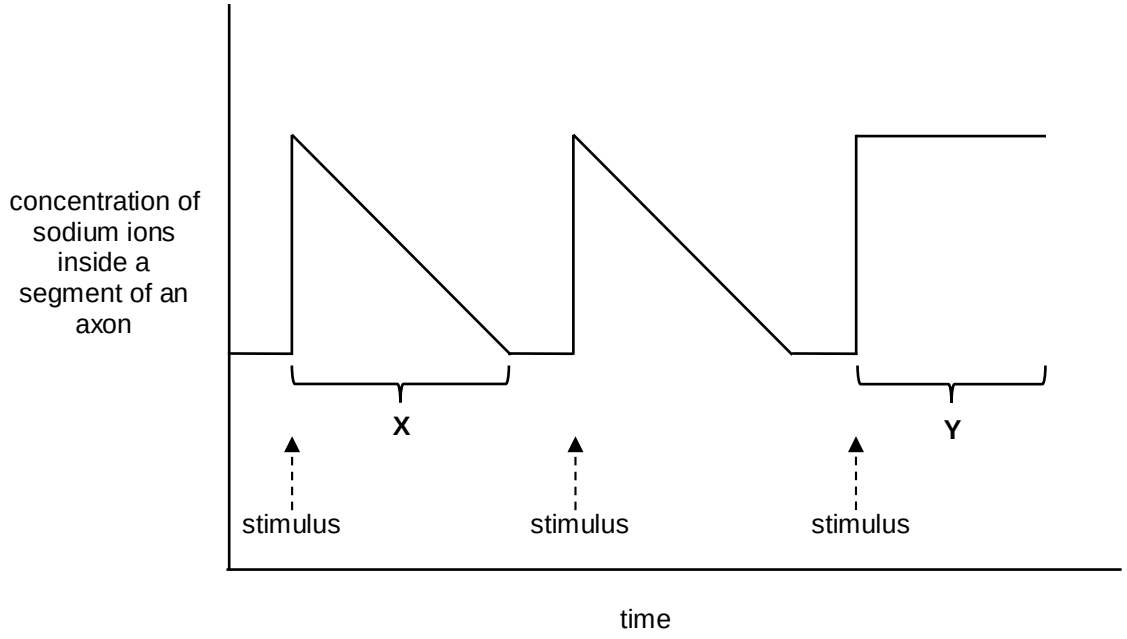

Fig. 7.2

(c) Account for the changes in the concentration of sodium ions at region **X** upon the stimulation of the neurone.

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..... [4]

DNP, a metabolic poison, makes the inner mitochondrial membrane leaky to protons during aerobic respiration.

(d) Suggest and explain why the concentration of sodium ions remain constant at region **Y**.

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.....

..... [3]

[Total: 12]

QUESTION 8

Whales are marine mammals that belong to the order Cetartiodactyla. For a long time, scientists believed that whales are related to pigs and hippopotamuses. To reconstruct the evolutionary relationships between whales, pigs and hippopotamuses, scientists studied their limb and inner-ear bones as shown in Table 8.1.

Table 8.1

type of animal	limb bones	inner ear bones
whales	thick	thick
pigs	thin	thin
hippopotamuses	thick	thin

(a) Explain how the anatomical similarities among the whales, pigs and hippopotamuses support Darwin's theory of natural selection.

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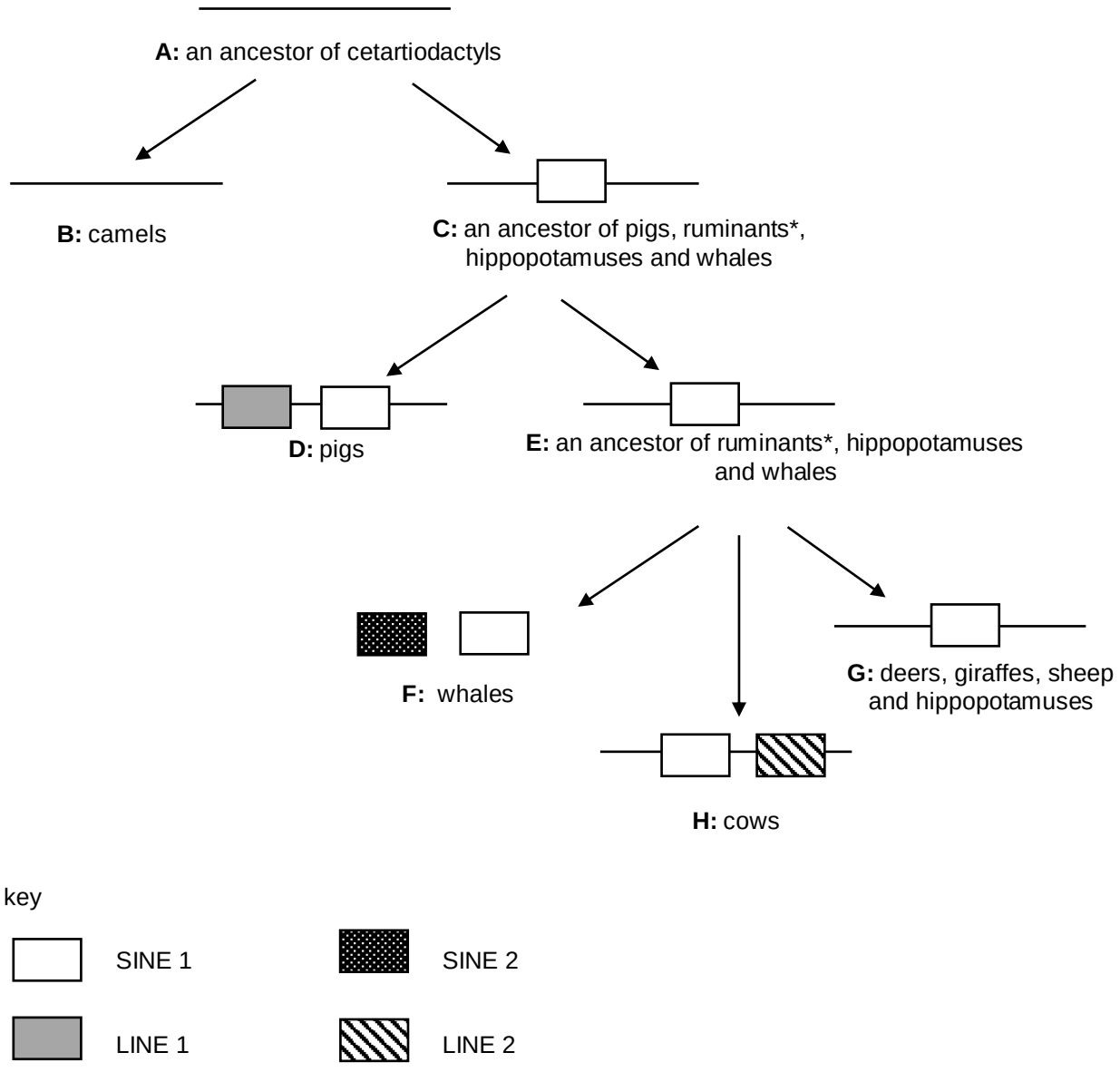
..... [3]

Phylogenetic relationships can be elucidated using molecular data. An important method of analysis involves the study of both Short Interspersed Elements (SINEs) and Long Interspersed Elements (LINEs). SINEs and LINEs are non-coding DNA sequences that have been amplified and inserted into different genomic regions.

Fig 8.1 is a schematic representation of SINEs and LINEs insertions at homologous genomic regions among the subgroups of cetartiodactyls.



*ruminants include deers, giraffes, sheep and cows

Fig. 8.1

(b) **(i)** Explain why camels and whales are of different species according to the phylogenetic species concept.

.....

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.....

..... [3]

(ii) A phylogenetic tree is constructed based on the results of SINEs and LINEs analysis in Fig 8.1. Fill in the blanks at the nodes and end points of the phylogenetic tree with the corresponding letters, **A** to **H** as represented in Fig. 8.1. [2]

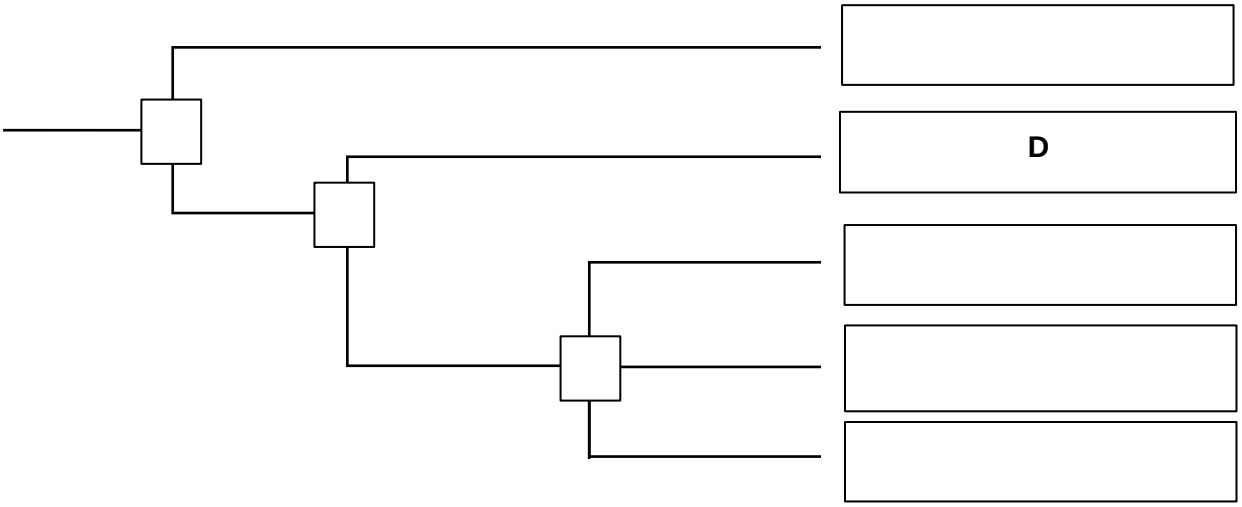

Fig. 8.2

(c) Molecular changes in SINEs and LINEs occur over time due to mutations and these are hypothesised to follow the neutral theory of evolution.

Briefly describe the neutral theory of molecular evolution and suggest how it may be used to study the subgroups of cetartiodactyls.

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..... [4]

(d) The presence of SINEs and LINEs increase the genome size over time. However, this does not contribute to a significant increase in nuclear size.

Outline how the organisation of the genome allows for DNA packaging in a non-dividing cell.

.....

.....

.....

..... [2]

[Total: 14]

--- End of Section A ---

SECTION B: FREE RESPONSE QUESTION

Answer **one** question.

BEGIN EACH PART ON A FRESH SHEET OF WRITING PAPER.

Your answer should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answer must be in continuous prose, where appropriate.

You answer must be set out in parts **(a)**, **(b)** etc., as indicated in the question

A **NIL RETURN** is required for any parts not answered.

QUESTION 9

(a) Describe how the molecular structure of cellulose is related to its function. [6]

(b) Outline the basis of the selective permeability of the cell membrane with reference to phospholipids, cholesterol and proteins. [8]

(c) Explain why animal cells mainly store lipids instead of carbohydrates. [6]

[Total: 20]

QUESTION 10

(a) Describe how the molecular structure of the G-protein coupled receptor is suited for its role in glucagon-mediated cell signalling. [8]

(b) Outline the concept of negative feedback in regulating glucagon levels in the body. [6]

(c) Explain how signal amplification is illustrated upon the binding of insulin to its receptor. [6]

[Total: 20]

--- End of Section B ---

--- End of Paper ---

MULTIPLE CHOICE QUESTIONS

QN	CORRECT ANSWER	QN	CORRECT ANSWER
1	**B**	21	**D**
2	**B**	22	**A**
3	**C**	23	**D**
4	**D**	24	**D**
5	**C**	25	**C**
6	**D**	26	**C**
7	**A**	27	**C**
8	**B**	28	**B**
9	**B**	29	**D**
10	**B**	30	**C**
11	**B**	31	**B**
12	**A**	32	**A**
13	**A**	33	**A**
14	**C**	34	**C**
15	**C**	35	**D**
16	**D**	36	**D**
17	**A**	37	**D**
18	**D**	38	**B**
19	**A**	39	**D**
20	**A**	40	**C**

STRUCTURED QUESTIONS

QUESTION 1

(a) (i) State **two** secondary structures commonly found in proteins. [1]

α-helix and β-pleated sheet ;;

(ii) Compare the secondary structures stated in **(a)(i)**. [2]

- Structures are formed as a result of regular/ repetitive, coiling / folding, of the polypeptide chain ;;
- The α-helix and β-pleated sheet are stabilised by intrachain hydrogen bonds between carbonyl (C=O) and amine (–NH) polypeptide backbone ;;
- The α-helix takes the form of an extended spiral spring/ coiled conformation whereas the β-pleated sheet has an extended sheet-like / pleated / zigzag conformation ;;

(b) Describe how the catalytic and binding amino acid residues of DNA polymerase located at different positions are brought close together in the active site. [3]

- Polypeptide chain is first folded and coiled into its secondary structures α-helix and β-pleated sheet ;;
- into specific 3D conformation of active site formed by catalytic and binding amino acid residues;;
- involving various interactions between the R groups of the structural amino acid residues *via* hydrophobic interactions, ionic bonds, hydrogen bonds and disulfide bonds/ covalent bonds (any two);;

(c) Explain the significance of the pH 8.4 buffer in PCR. [2]

- optimum pH ;;
- the rate of reaction is at a maximum/ highest amount of products formed per unit time ;;

QUESTION 2

(a)(i) state the duration of metaphase in the cell. [1]

18min

(ii) complete line Y on the graph. [1]

Horizontal until 18 minutes, then decreases as straight line to 0 μm at 28 minutes

(iii) explain your answer in **(a)(ii)**. [3]

- Chromosomes align singly at the metaphase plate during metaphase of mitosis.
- Sister chromatids separate at the centromere to become daughter chromosomes and migrate towards the opposite poles in anaphase.
- Each chromatid / daughter chromosome did not move / remain at the pole in telophase.

**quoting of data is necessary to support the answers above.*

(b) Suggest and explain the effect of eribulin on the behavior of chromosomes in mitosis. [3]

- Kinetochore microtubules cannot attach to the kinetochores at the centromeres of the chromosomes.
- Cells cannot progress through metaphase, so that chromosomes cannot align singly at the metaphase plate.
- Sister chromatids could not separate / remain attached in anaphase.

QUESTION 3

(a) Explain the significance of p53 protein in the regulation of Mdm2 gene expression. [3]

- As an activator, p53, binds to the enhancer;;
- May interact with mediator proteins;
- To improve recruitment of general transcription factors and RNA polymerase to the promoter;
- to form a stable transcription initiation complex (TIC) at the promoter;
- Ref. to upregulation of transcription of *Mdm 2* gene/ increase rate of transcription of *Mdm2* gene;

(b) Account for the high levels of p53 protein when DNA damage is detected in the cell. [4]

- During DNA damage, p53 protein is activated by phosphorylation of p53 at Ser15, Thr18 or Ser20 amino acid residues;;
- resulting in the 3D conformation of p53 protein to be no longer complementary to the 3D conformation of Mdm2 protein;;
- Hence p53 cannot bind to Mdm2 protein and p53/Mdm2 complex is not formed;;
- Thus, p53 is not degraded via ubiquitin system/ avoiding ubiquitin-mediated degradation to increase levels of p53 protein;;

(c) Suggest the need for ubiquitin-mediated degradation of p53 to occur. [1]

- To remove unwanted p53 protein/ maintain low levels of p53 when no DNA damage is detected;;

(d) Homozygous deletion of *Mdm2* gene in mouse germline cells results in lethality at the blastocyst stage, due to inappropriate apoptosis.
With reference to Fig. 3.2a and Fig. 3.2b, suggest how inappropriate apoptosis occurs. [3]

- With the homozygous deletion of the Mdm2 gene, no functional Mdm2 protein can be produced;;
- In normal cells without DNA damage, p53 has no Mdm2 protein to bind to/ p53/Mdm2 protein complex not formed;
- Resulting in no ubiquitin-mediated degradation of p53/Mdm2 complex/ p53 is not degraded via the ubiquitin system;
- Hence, leading to high levels of unbound p53 which activates apoptosis in cells;;

- despite having no DNA damage;

QUESTION 4

(a) (i) State what is meant by retrovirus. [2]

- Retroviruses are viruses with two identical copies of single stranded RNA;;
- and two molecules of reverse transcriptase ;;

(ii) Compare the entry process between the HIV and influenza virus. [3]

- Adsorption/ attachment of both viruses are by binding to specific cell surface receptors. ;;
- Glycoprotein gp120 on the surface of the HIV binds to CD4, a cell-surface receptor found on white blood cells/ T helper cells / macrophages of the host immune system ;
- Haemagglutinin on the influenza viral membrane binds to sialic acid-containing receptors on the host cell membrane ;
- The influenza virus enters the host cell by receptor-mediated endocytosis;
- The HIV envelope does not enter via receptor-mediated endocytosis. Instead, the HIV envelope fuses with the host cell membrane;
- Upon entry, the influenza virus forms an endosome / endocytic vesicle ;
- whereas the HIV virus does not form an endosome/ endocytic vesicle, the HIV releases the viral contents into the host cell cytoplasm.;

(b) Upon completion of the entry process, describe how the genome of HIV is inherited. [3]

- RNA is reverse transcribed to complementary DNA strand by the enzyme reverse transcriptase ;;
- The enzyme integrase catalyses the integration of the viral DNA into the host chromosome.;;
- The provirus genome is also replicated along with the host cell genome and all daughter cells inherit the HIV genome/ AW ;

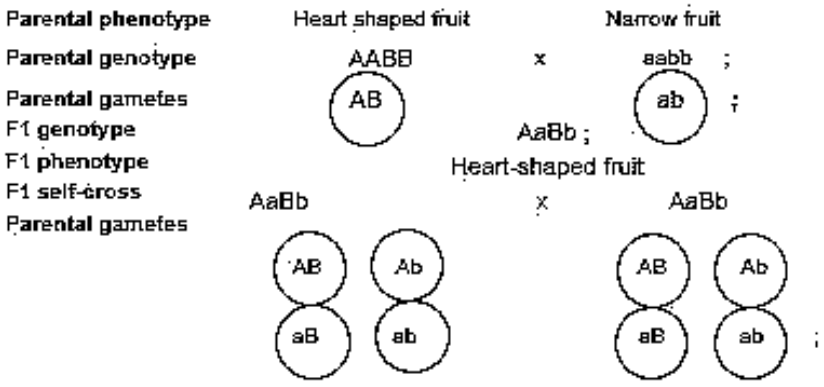
QUESTION 5

(a) Explain the type of gene interaction observed in this context. [3]

- The type of gene interaction is (duplicate dominant) epistasis;;.
- Allele A is epistatic to alleles B and b , allele B is epistatic to alleles A and a;;
- The presence of at least 1 dominant allele of either gene A or B causes the conversion of precursor X to product Z hence, allowing the formation of heart-shaped fruits;;.
- If the genotypes at both loci are homozygous, the conversion of precursor X to product Z does not occur. ;;

(c) Using the symbols **A**, **a**, **B** and **b**, draw a genetic diagram to explain the result of the F2 generation in the space provided. [5]

Let A be the dominant allele for the production of heart-shaped fruit
Let a be the recessive allele for the production of narrow fruit;
Let B be the dominant allele for the production of heart-shaped fruit
Let b be the recessive allele for the production of narrow fruit;



Random fertilization

Male gametes	Female gametes: AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

;;

F2 genotypic ratio: 9 A_B_ : 3 A_bb: : 3 aaB_ : 1 aabb ;

F2 phenotypic ratio: 15 Heart-shaped fruit : 1 Narrow fruit ;

F2 observed no: 2251 : 150

(d) Describe how you could identify *Capsella* sp. plants with heart-shaped fruits, which are homozygous dominant in at least one gene locus. [2]

- Perform a testcross;;
- If the plants with heart-shaped fruits are homozygous dominant in at least one gene locus, all offspring produced will only have heart-shaped fruits;;.

QUESTION 6

(a) (i) State precisely where RuBP and GP are produced in the chloroplast. [1]

stroma

(ii) Explain why the concentration of RuBP changed between 200 and 275 seconds. [2]

- lower CO_2 concentration
- concentration of RuBP increases from 1 au to 1.6 au
- less CO_2 fixed by RuBP

(b) Suggest how the decrease in the concentration of GP leads to a decrease in harvest for commercial suppliers of *Chlorella*. [2]

- less triose phosphate / glyceraldehyde-3-phosphate will be produced
- so less conversion to carbohydrates / lipids / amino acids / proteins

(c) In the light dependent stage, illumination of chloroplasts is important for maintaining the high pH in the stroma. Explain how the illumination of chloroplasts maintains the high pH in the stroma. [3]

- excited electrons leave, special chlorophyll *a*
- electron passed down the electron transport chain
- protons pumped into thylakoid lumen from the stroma
- protons present from photolysis of water

(d) The endosymbiotic theory postulates that the chloroplasts of *Chlorella* evolved from bacteria living within an eukaryotic host cell. Suggest **one** structural similarity between the chloroplasts and the bacteria that supports this theory. [1]

- ref. to chloroplasts having a double membrane / 70S ribosomes

QUESTION 7

(a) (i) Draw an arrow in the box provided on Fig. 7.1 to indicate the direction in which one nerve impulse is being conducted and explain your answer. [1]

Arrow pointing to the left ;;

(ii) Explain you answer in (a)(i). [2]

- Hyperpolarisation occurs during the refractory period;;
- Hence the nerve impulse can only travel towards the left where depolarisation occurs. ;;

(b) Suggest why transmission of nerve impulses along a myelinated neurone uses less energy in the form of ATP than transmission along an unmyelinated neurone. [2]

- For myelinated neurone, charges can only be leaked through the nodes of Ranvier, compared to myelinated neurone, where charges can be leaked throughout the neurone ;;
- Hence, less energy in the form of ATP is required by active transport pumps, Na^+/K^+ pumps to restore the resting membrane potential ;;

(c) Account for the changes in the concentration of sodium ion at region X upon the stimulation of the neurone. [4]

- Upon the stimulation of the neurone above threshold potential, depolarisation occurs at the axon hillock and voltage-gated Na^+ channels open ;
- Na^+ influx / Na^+ enters the neurone ;;
- resulting in sudden increase/ spike in concentration of sodium inside the neurone ;
- subsequently, repolarisation occurs and voltage-gated Na^+ channel close / membrane becomes less permeable to Na^+ ;
- Na^+/K^+ pumps will restore concentration of sodium in the neurone ;;
- leading to gradual decrease in concentration of Na^+ until resting membrane potential is achieved ;

(d) Suggest and explain why the concentration of sodium ions did remain constant at region Y. [3]

- Proton gradient cannot be maintained ;;
- ATP cannot be generated via chemiosmosis ;;
- Ref. to sodium ions entering the neurone but cannot be transported out of the cell;;

QUESTION 8

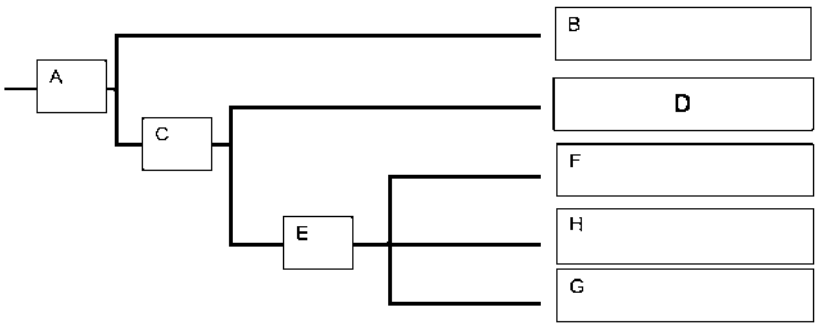
(a) Explain how the anatomical similarities among the whales, pigs and hippopotamuses support Darwin's theory of natural selection. [3]

- Limb and inner ear bones were both present in the ancestor / Cetartiodactyls;
- The presence of homologous structures / anatomical homologies between the pigs, hippopotamus and the whales signify shared / common ancestry / evolutionary relatedness;
- These animals will survive to sexual maturity / survival of the fittest / differential reproduction to pass on the favourable genes / alleles to their offspring;.
- leading to genetic variation that brings about differences in limb and inner ear bone thickness;.
- Hence showing decent with modification;

(b)(i) Explain why camels and whales are of different species according to the phylogenetic species concept. [3]

- In the phylogenetic species concept, a species is defined as the smallest group of individuals that share a common ancestor;;
- Camels and whales do not share a most recent common ancestor;
- The camels are the earliest to diverge from the ancestor of cetartiodactyls ;
- as they do not possess sequences of SINE 1 in their genome / ref made to shared derived characteristics with quotation;
- Because they possess SINE1 / SINE 1 & 2 in their genome / ref made to shared derived characteristics with quotation;

(ii) A phylogenetic tree is constructed based on the results of SINE analysis in Fig 8.1. Fill in the blanks at the branch points and end points of the phylogenetic tree with the corresponding letters, **A** to **H** as represented in Fig. 8.1. [2]



(c) Briefly describe the neutral theory of molecular evolution and suggest how it may be used to study the subgroups of Cetartiodactyls. [4]

- The neutral theory states that vast majority of evolutionary change at the molecular level are caused by random genetic drift of selectively neutral mutations;;
- which do not affect the phenotype / fitness of the organism / not subjected to natural selection / has neither selective advantage or disadvantage.;;
- Since SINE sequences are non-coding, mutations in them are not affected by natural selection;
- The greater the difference in number of mutations;
- the longer time of divergence.;;

(d) Outline how the organization of the genome allows for DNA packing in a non-dividing cell. [2]

- DNA molecule is wound around histone proteins to form the **nucleosome;;**
- Nucleosomes are linked by liner DNA to form **10nm fibers chromatin**;
- nucleosomes are further packed into **30-nm fibres / solenoids;**

FREE RESPONSE QUESTION

QUESTION 9

(a) Describe how the molecular structure of cellulose is related to its support function. [6]

- Alternate inverted β-glucose units linked by β(1,4) glycosidic bonds allow cellulose to form long, unbranched and straight chains;;
- Allow formation of linear chains of polysaccharides that can be packed tightly;;
- Many chains run parallel to each other and their hydroxyl group (OH) project outwards from each chain;;
- Extensive hydrogen bonds form between parallel chains/ Extensive hydrogen bonds form between the protruding OH groups of neighbouring chains;;
- Cross-linked cellulose chains associate in groups to form microfibrils;;
- Microfibrils associate with other, non-cellulose polysaccharides, and are arranged in large bundles to form macrofibrils;;
- Allows formation of a large molecule, resulting in an insoluble material that can be used as structural support;;

(b) Outline the basis of the selective permeability of the cell membrane with reference to phospholipids, cholesterol and proteins. [8]

Phospholipids

- cell membrane is a phospholipid bilayer ;
- it acts as a hydrophobic barrier / ref. to hydrophobic core ;;
- which prevents the diffusion of hydrophilic solutes / polar molecules, charged ions across it ;;
- weak hydrophobic interactions exist between phospholipids / ref. to lateral movement of phospholipids ;
- for small, non-polar, hydrophobic solutes to diffuse across ;;

Cholesterol

- presence of cholesterol in the membrane decreases the permeability of membrane ;;
- it does so by filling in spaces between hydrocarbon chains of phospholipids / plugging transient gaps ;;
- cholesterol regulates membrane fluidity / ref. to higher temperature, cholesterol decreases membrane fluidity / lower temperature, cholesterol increases membrane fluidity ;;

Proteins

- hydrophilic solutes / polar molecules, charged ions can be transported across the membrane ;;
- through transport proteins ;;
- ref. to solute binding and change its 3D conformation ;
- via facilitated diffusion / ref. to down a concentration gradient ;;
- via active transport / ref. to against a concentration gradient ;;
- presence of channel proteins ;;
- ref. to water-filled central pore / hydrophilic channel ;
- via facilitated diffusion / ref. to down a concentration gradient ;;

(c) Explain why animal cells mainly store lipids instead of carbohydrates. [6]

- Triglycerides are a good thermal insulator and hence a layer of fat beneath the skin (subcutaneous fat) insulates the body. This subcutaneous layer is especially thick in whales, seals and most other marine animals living in cold climates and is known as blubber;;
- Upon oxidation, triglycerides release a larger amount of energy per unit / ref. to one gram of fat releases more than twice as much energy (38 kJ / g) as a gram of carbohydrates (17 kJ / g);;
- Being highly reduced molecules, triglycerides release more metabolic water when they are oxidised during cellular respiration compared to carbohydrates, which is extremely important to desert animals like camels;;
- Triglyceride can slide under pressure hence adipose tissue (which contains fats) around the vital organs helps to cushion and protect vital organs against physical impacts;;
- Being less dense than water, fats aid buoyancy of aquatic animals ;;

QUESTION 10

(a) Describe how the molecular structure of the GPCR is suited for its role in glucagon- mediated cell signaling. [8]

- The GPCR is a transmembrane protein comprising an extracellular domain, a transmembrane region and a intracellular domain ;;
- It relays an extracellular signal to a cellular response ;;
- The extracellular domain of GPCR has a ligand binding site that is complementary to the 3D conformation of glucagon;;
- This allows glucagon to bind to its specific GPCR on the target cells in signal reception ;;
- GPCR consists of a single polypeptide chain that has seven α- helices spanning the membrane;;
- The hydrophobic interactions between the non-polar R-groups with the fatty acid tails of phospholipid bilayer allows the GPCR to be embedded in the membrane ;;
- The intracellular domain of GPCR is complementary to the 3D conformation of a G protein;;
- The activated GPCR binds and activates the G protein for signal transduction ;;

(b) Outline the concept of negative feedback in controlling glucagon levels in the body. [6]

- When blood glucose levels falls below set point of 90mg/100ml, the receptor, alpha cells in the islets of Langerhans of the pancreas, detects the change / deviation;;
- This information is integrated at the integrating centre, to initiate a response in the form of signals to act upon target / effector cells;;
- the alpha cells of the islets of Langerhans of the pancreas are then stimulated to release more glucagon;;
- Glucagon binds to GPCR receptors to activate the GPCR receptors;;
- Cellular responses are stimulated when adenylyl cyclase is activated to produce cAMP to activate ;;
- When blood glucose levels are detected by the receptor to return to the set point, negative feedback mechanism is activated to prevent further increase in blood glucose beyond setpoint;;.
- There is decreased stimulation of alpha cells resulting in decreased release of glucagon;;

(c) Explain how signal amplification is illustrated by the binding of insulin to its receptor. [6]

- The binding of small number of insulin to its receptors can lead to the activation of many glycogen synthase / AW ;; to facilitate glucose uptake and storage.
- Cytoplasmic relay proteins specific to the insulin receptor binds to a specific phosphorylated tyrosine on the receptor and undergo conformational changes;.
- These bound relay proteins becomes activated;;.
- The activated relay proteins triggers a signal transduction pathway;;
- whereby activated relay proteins (Accept: protein kinases) activate other protein kinases in phosphorylation cascade;.
- Many activated downstream protein also leads to the activation of glycogen synthase which facilitates glycogenesis / AW;.

HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		**CT GROUP**	**15S ___**
CENTRE NUMBER		**INDEX NUMBER**	

BIOLOGY

9648 / 03

Paper 3 Applications Paper and Planning Question — **16 September 2016**

Additional Materials: Writing Paper — **2 hours**

INSTRUCTIONS TO CANDIDATES

Write your **name**, **CT group**, **Centre number** and **index number** in the spaces provided at the top of this cover page.

STRUCTURED QUESTIONS

Answer **all** three questions.

Write your answers on the lines / in the spaces provided.

PLANNING QUESTION

Answer the question in booklet **4**.

Write your answers on the lines / in the spaces provided.

FREE RESPONSE QUESTION

Answer the question.

Your answers must be in continuous prose, where appropriate.

Write your answers on the writing paper provided.

BEGIN EACH PART ON A FRESH SHEET OF WRITING PAPER.

A **NIL RETURN** is required for parts not answered.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.

You are reminded of the need for good English and clear presentation in your answers.

For Examiners' Use	
Question	**Marks**
1	**/ 13**
2	**/ 12**
3	**/ 15**
4	**/ 12**
5	**/ 20**
Total	**/ 72**

This document consists of **15** printed pages

BOOKLET 1

STRUCTURED QUESTIONS

QUESTION 1

Bacteria can be genetically modified to produce insulin for human use. To achieve this, human insulin genes are transferred into bacteria. Plasmids containing two antibiotic resistance genes, one coding for resistance to tetracycline and one for resistance to ampicillin, are used to carry out this transfer.

A restriction enzyme was used to cut the human DNA and plasmids. Fig. 1.1 shows the different human DNA fragments and the linearised plasmid that was produced.

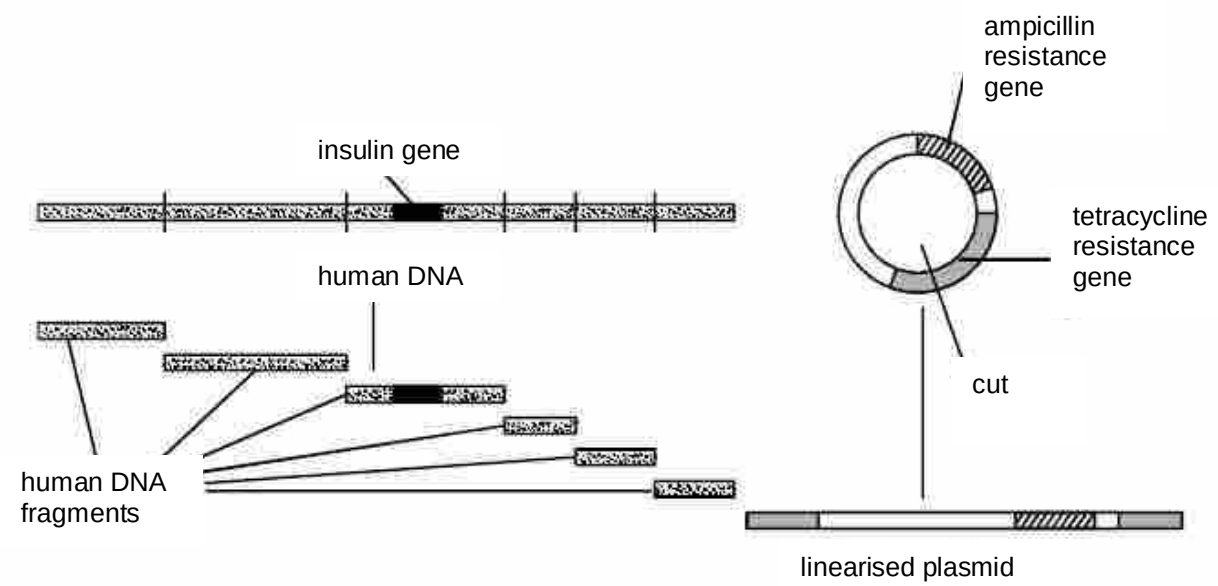


Fig. 1.1

(a) Describe how the restriction enzyme cuts the human DNA and plasmid.

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..... [2]

The human DNA fragments and linearised plasmids were mixed together with DNA ligase. The linearised plasmids are then mixed with bacteria. Some of the bacteria take up the plasmids.

(b) **(i)** Explain how it is possible to distinguish between bacteria which have taken up a plasmid containing a human DNA fragment and those which have taken a plasmid without any extra DNA.

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..... [4]

(ii) Suggest why genes for antibiotic resistance are now rarely used as selectable markers in genetic engineering.

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..... [2]

Unlike diabetes, Huntington's disease (HD), an autosomal dominant disorder, has a clear genetic basis. The gene involved contains a section of DNA with many repeats of the base sequence CAG. The number of repeats found in an allele of this gene may determine how early an individual develops HD. In genetic testing for HD, fragments of DNA are cut from an individual's alleles and separated by gel electrophoresis to determine their length.

Four members of a family affected by HD were tested:

- **A** is the father of **B** and developed symptoms of HD in old age.
- **B** is the mother of **D** and developed symptoms of HD in middle age.
- **C** is the **unaffected** father of **D**.
- **D** is the son of **B** and **C** and developed symptoms of HD as a child.

The results of the genetic test are shown in Fig. 1.2.

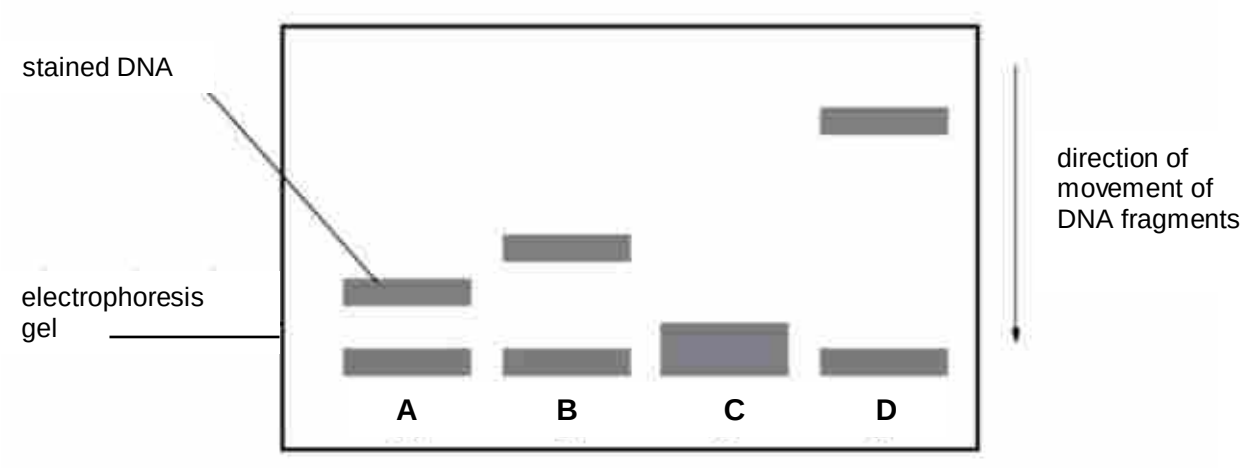

Fig. 1.2

(c) With reference to Fig. 1.2,

(i) describe the relationship between length of DNA fragment and age of onset of HD.

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..... [2]

(ii) explain the difference in positions of DNA fragments from the different members of the family in the test.

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..... [3]

[Total: 13]

QUESTION 2

Duchenne Muscular Dystrophy (DMD) is a progressive muscle wasting disease caused by mutation in the *dmd* gene. The *dmd* gene is the largest gene in humans and it encodes for the dystrophin protein. Mutations in the *dmd* gene result in a nonfunctional dystrophin protein, hence resulting in the disease.

Since the discovery of the *dmd* gene, investigations have been made to exploit gene therapy as a possible cure for DMD. In past studies, DNA library was produced by splicing together essential exons. This reduces the size of the *dmd* gene, allowing viral vectors to carry it.

(a) Identify the type DNA library and outline how the DNA library is produced.

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..... [3]

(b) Explain the limitations of using viruses in the gene transfer of the *dmd* gene.

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..... [2]

(c) Normal muscle fibres can be generated if adult mesenchymal stem cells, without the genetic defect that causes DMD, is delivered into the patients' muscles. Mesenchymal stem cells can give rise to many types of cells including bone, cartilage, lung and muscle cells.

Describe the unique features of adult stem cells.

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..... [2]

Fig. 2.1 shows a possible approach for DMD gene therapy in humans.
The following were used in the study:

- fibroblasts, which are differentiated cells.
- induced Pluripotent Stem (iPS) cells, which are cells that have been genetically reprogrammed from fibroblast cells.
- an artificial vector that carries the normal *dmd* gene (ART). Using an artificial vector overcomes the size limitations encountered with viral vectors and consequently, allows for the expression of full-length dystrophin protein.

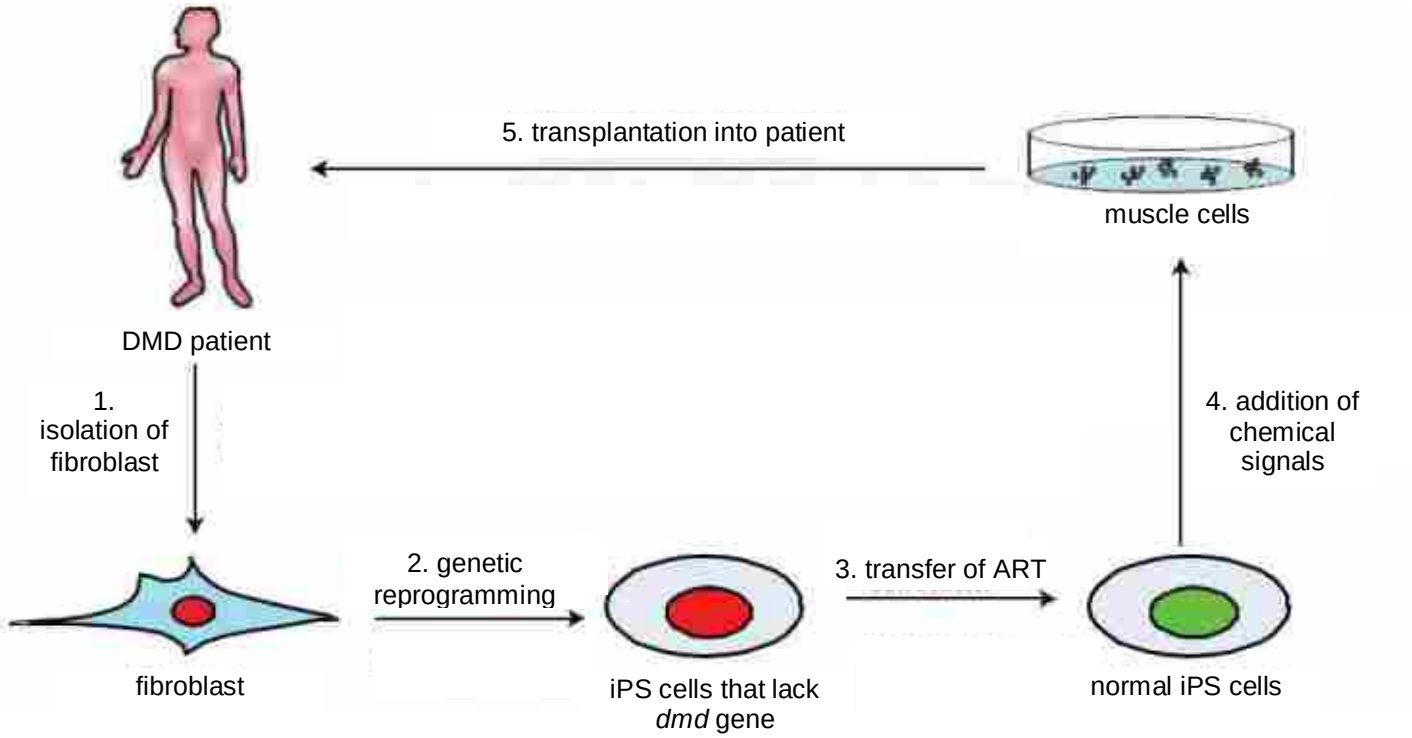

Fig. 2.1

(d) Explain why it is preferable to isolate fibroblast from the the DMD patient.

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..... [2]

(e) Suggest the purpose of adding chemical signals (step 4).

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..... [1]

(f) Upon transplantation into the patient, suggest two disadvantages of this approach that is similar to conventional gene therapy.

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..... [2]

[Total: 12]

QUESTION 3

Many of the original genetically modified crops contained only one modification. An example is Bt Corn A, which produces only one type of Bt protein. To delay Bt resistance in pest populations, such as corn rootworm, modern crops such as Bt Corn B produces two types of Bt proteins against the same pest. Fig. 3.1 shows the survival of corn rootworm larvae on the two types of Bt corn.

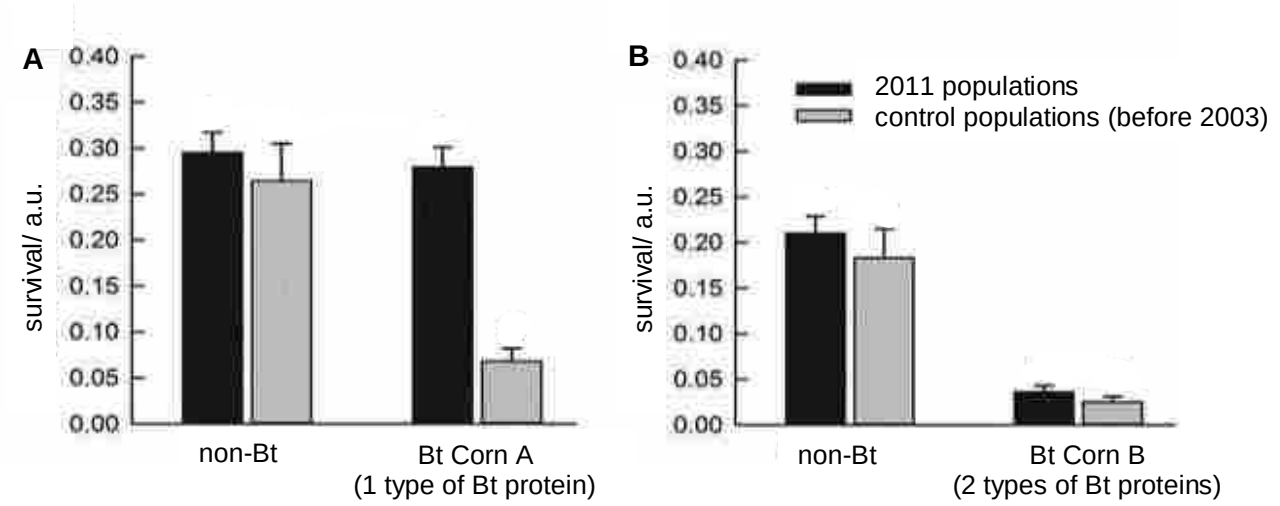

Fig. 3.1

(a) **(i)** With reference to Fig. 3.1A, suggest if there is any significant difference between the 2011 and control populations (before 2003) for non-Bt corn.

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..... [2]

(ii) With reference to Fig. 3.1B, suggest why two types of controls were used.

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..... [2]

(iii) Explain whether expressing one type or two types of Bt proteins is more effective in delaying Bt resistance in corn rootworm.

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Different Bt proteins have varying effects on particular pests. Some Bt proteins are toxic to caterpillars, such as the European corn borer, while other Bt proteins are toxic to rootworms, such as the corn rootworm. Bt genes coding for Bt proteins could be introduced in various combinations, with or without herbicide tolerance genes.

Table 2.1

type of Bt Corn	type of Bt protein	target pest	herbicide tolerance gene
A	Cry1Ab	European corn borer	-
B	Cry3Bb	corn rootworm	-
C	Cry1Ab Cry3Bb	European corn borer corn rootworm	-
D	Cry1Ab Cry3Bb	European corn borer corn rootworm	present

(b) Explain which type of Bt Corn will best increase crop yield.

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..... [2]

Glufosinate ammonium, is a broad-spectrum herbicide, effective in killing a wide range of weed species. Researchers isolated a gene (*bar* gene) derived from soil bacterium *Streptomyces hygroscopicus*, encoding for a herbicide tolerant protein. This gene is introduced to Corn **D** via a plasmid (pCIB3064), resulting in the herbicide tolerant corn.

(c) Outline how herbicide tolerant Corn **D** can be cultured by using calli of Corn **C**.

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..... [5]

(d) Suggest one social issue related to an increase in the use of Corn **D**.

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..... [1]

[Total: 15]

QUESTION 4

Enzymes, such as proteases, are key components found in contact lens cleaning solution. Proteases remove protein deposits from the surfaces of contact lenses.

Two essential contents of such contact lens cleaning solution are:

- pH 7 buffer containing disodium EDTA, a preservative and
- subtilisin A, a protease.

A student researched online and found that there is a range of concentrations of subtilisin A in different commercially available contact lens cleaning solutions. This range of concentration of subtilisin A was between 20 μg cm^{-3} and 100 μg cm^{-3}.

Fig. 4.1 shows how the student simulated a dirty contact lens using protein gelatin and a thin transparent plastic sheet. One side of the plastic sheet was dipped into melted gelatin containing a red dye. The gelatin was then allowed to set and solidify on the plastic sheet, which acts as a support for the gelatin. Subsequently, this simulated dirty contact lens was added to the cleaning solution.

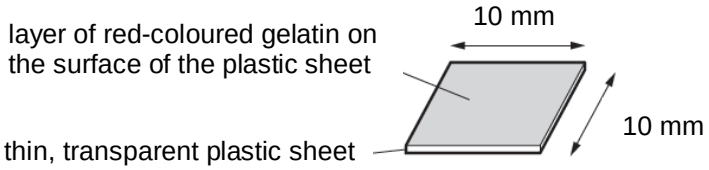


Fig. 4.1

The student tested the activity of subtilisin A by recording the intensity of the red dye in the cleaning solution as shown in Fig. 4.2. This was possible because the cleaning solution was able to remove the red-coloured gelatin from the surface of the transparent plastic sheet.

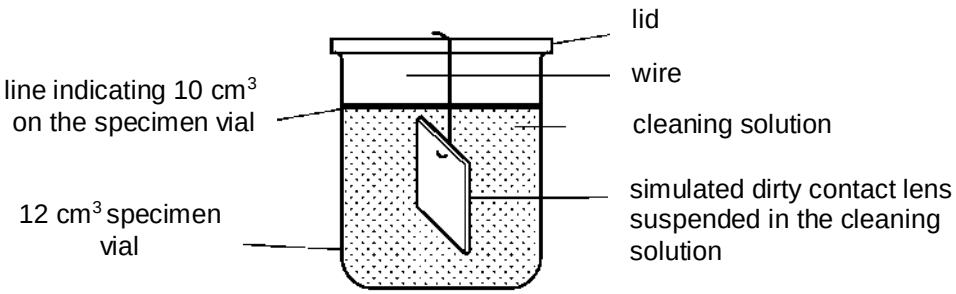


Fig. 4.2

Using this information and your own knowledge, design an experiment to investigate the effect of different concentrations of subtilisin A in commercially available contact lens cleaning solutions on the removal of protein deposits from the simulated dirty contact lenses.

You must use:

- 100 μg cm^{-3} subtilisin A 

- pH 7 buffer containing disodium EDTA, for dilution purpose
- 12 cm^3 specimen vials, with a wire attached to its lid
- 50 mm x 50 mm thin, transparent plastic sheet coated with red-coloured gelatin
- thermostatically-controlled water bath
- colourimeter and cuvettes

You may select from the following apparatus:

- any normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods etc
- syringes
- white tile
- scalpel
- 15 cm ruler
- timer e.g. stopwatch or stopclock

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

FREE RESPONSE QUESTION

Your answers must be in continuous prose, where appropriate.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Write your answers in the writing paper provided.
BEGIN EACH PART ON A FRESH SHEET OF WRITING PAPER.
A **NIL RETURN** is required.

QUESTION 5

(a) Describe the process of polymerase chain reaction. [6]

(b) Explain the advantages and limitations of polymerase chain reaction. [6]

(c) Explain the principles of restriction fragment length polymorphism analysis and how it can be used to study genetic variation within a species of organism. [8]

[Total: 20]

--- END OF PAPER---

HWA CHONG INSTITUTION (COLLEGE SECTION)
2016 JC2 H2 BIOLOGY
PRELIMINARY EXAMINTION PAPER 1 & PAPER 3 MARK SCHEME

MULTIPLE CHOICE QUESTIONS

QN	CORRECT ANSWER	QN	CORRECT ANSWER
1	**B**	21	**D**
2	**B**	22	**A**
3	**C**	23	**D**
4	**D**	24	**D**
5	**C**	25	**C**
6	**D**	26	**C**
7	**A**	27	**C**
8	**B**	28	**B**
9	**B**	29	**D**
10	**B**	30	**C**
11	**B**	31	**B**
12	**A**	32	**A**
13	**A**	33	**A**
14	**C**	34	**C**
15	**C**	35	**D**
16	**D**	36	**D**
17	**A**	37	**D**
18	**D**	38	**B**
19	**A**	39	**D**
20	**A**	40	**C**

Question 1

(a) Describe how the restriction enzyme cuts the human DNA and plasmid. [2]

- restriction enzyme cuts at restriction site
- by cleaving phosphodiester bond
- human DNA five restriction sites
- only one restriction site in plasmid

(b)(i) Explain how it is possible to distinguish between bacteria which have taken up a plasmid with human DNA and those which have taken a plasmid without any extra DNA. [4]

- use of sterile velvet to transfer bacteria from master plate of nutrient agar containing ampicillin press velvet onto replica plate of nutrient agar containing tetracycline
- bacteria carrying plasmid with human DNA, the tetracycline resistance gene is disrupted
- bacteria carrying plasmid with human DNA will be killed
- while bacteria with no extra DNA in plasmid will have intact tetracycline resistance gene
- bacteria carrying plasmid with no extra DNA will not killed

(ii) Suggest why genes for antibiotic resistance are now rarely used as markers in genetic engineering. [2]

- risk spread of resistance to other bacteria / ref. to being resistant to antibiotics
- spread of resistance via, conjugation / transformation / incorporation into the genome of bacteria

(c) With reference to Fig. 3.2,

(i) describe the relationship between length of DNA fragment and age of onset of HD. [2]

- the longer the fragment length the earlier the onset
- ref. to shorter fragments moving further / longer fragments moving slower

(ii) explain the difference in positions of DNA fragments from the different members of the family in the test. [3]

- C has recessive, alleles / ref. to homozygote
- A, B and D have one normal and dominant allele / ref. to heterozygotes
- dominant allele gets longer / ref. to increasing CAG repeats from A to B to D

Question 2

a. Identify the type DNA library and outline how the DNA library is produced. [3]

- cDNA library ;;
- Reverse transcriptase catalyses the synthesis of single stranded cDNA using the mature mRNA template of the *dmd* gene;
- DNA polymerase uses the single stranded cDNA as a template to synthesise the complementary/ second DNA strand ;
- Formation of recombinant plasmid/ vector containing the double stranded cDNA and plasmid ;
- The recombinant plasmid/ vector is transformed into bacteria cells ;

b. Explain the limitations of using viruses in the gene transfer of the *dmd* gene. [2]

- There is a limit on the size of the dystrophin gene that can be inserted into a viral vector that results in unsuccessful *dmd* gene expression / AW ;;
- The viral vector may regain virulence and trigger an immune response / AW;;
- There is a possibility of triggering the immune system leading to the host rejecting the *dmd* transgene ;;
- There is random insertion of the *dmd* transgene within the host cells' genome that may induce oncogene activation / AW ;;

c. Describe the unique features of adult mesenchymal stem cells. [2]

- Multipotent stem cells ;
- Mesenchymal stem cells are unspecialised cells ;
- capable of long term self-renewal via mitosis reproducing itself for long periods of time;
- Mesenchymal stem cells can differentiate into specialised cell types under appropriate conditions ;

d. Explain why it is preferable to isolate fibroblast from the the DMD patient. [2]

- Cells are obtained from the same individual and hence ;;
- it will not induce immune rejection when transplanted back into patients ;;

.

e. Suggest the purpose of adding chemical signals (step 4). [1]

1 Differential gene expression to induce the differentiation of iPS to muscle cells ;;

f. Upon transplantation into the patient, suggest two disadvantages of this approach that is similar to conventional gene therapy. [2]

1. Efficiency of transfer of muscle cells into patient maybe low ;;
2. Cells may not produce enough DMD protein ;;
3. The risk of stimulating the immune system leads to rejection by the host ;;

QUESTION 3

(a) (i) With reference to Fig. 3.1A, suggest if there is any significant difference between the 2011 and control populations (before 2003) for non-Bt corn. [2]

1. No significance difference between the control and 2011 populations
2. As the error bars overlap with each other

(ii) With reference to Fig. 3.1B, suggest why two types of controls were used. [2]

1. Non-Bt corn is used to determine the effectiveness of Bt protein in decreasing the survival of corn rootworm larvae
2. Control population (before 2003) is used to determine the effectiveness in delaying resistance of Bt protein over the years

(iii) Explain whether expressing one type or two types of Bt proteins is more effective in delaying Bt resistance in corn rootworm.

1. Expressing two types of Bt proteins is more effective
2. In Bt Corn A, survival of larvae increase greatly from 0.075 a.u to 0.275 a.u from control to 2011 populations
3. While in Bt corn B, survival of larvae increase very slightly, almost insignificant**;;**
4. AVP

(b) Explain which type of Bt Corn will best increase crop yield.

1. Corn D
2. Not only can Corn D protect against both the European Corn borer and the corn rootworm;
3. It is also resistant to herbicide

(c) Outline how herbicide tolerant Corn D can be cultured by using calli of Corn C.

1. Cut the region flanking the *bar* gene and the plasmid (pCIB3064) with a restriction enzyme to form a recombinant plasmid
2. Which contains the transgene, the promoter and a genetic marker, such as an antibiotic resistance gene

3. a.The callus culture of Corn C can be treated to produce a protoplast culture
   b. The recombinant plasmid can be introduced to the protoplast culture/ ref. to electroporation/heat shock/gene/ virus-mediated delivery

4. Calli grown in a medium containing the antibiotic
5. Cells who have successfully taken up the recombinant plasmid will be resistant to the antibiotic and will survive, while those who did not take up the recombinant plasmid will die
6. Surviving colonies can be transferred to an agar medium to induce shoot development/ ref. to cytokinin
7. Then transfer to another agar medium after 2-4 weeks to induce root development/ ref. to auxin
8. Ref. to acclimatization of the plantlet

d) Suggest one social issue related to an increase in the use of Corn **D**.

1. After long usage of Corn D, weeds may gain resistance to herbicide
2. Ref. to concerns associated with Bt corn/ pests gain resistance to Bt proteins

Question 4

- Enzyme subtilisin A is a protease that can be used to digest proteins (gelatin) coated on the simulated dirty contact lenses.
- The higher the concentration of subtilisin A in the cleaning solution, higher the rate of gelatin digestion.
- Cut transparent plastic sheet coated with red-coloured gelatin into squares of constant dimensions.
- Place these plastic squares coated with red-coloured gelatin into the specimen vial containing the cleaning solution.
- Start reaction in a thermostatically-controlled water bath for fixed period of time.
- Pour a fixed volume of the cleaning solution into a cuvette.
- Measure the absorbance of the cleaning solution using a colourimeter.
- Carry out a control.
- Perform replicates, repeats and statistical test.
- Calculate the average absorbance of the cleaning solution and obtain rate of gelatin digestion.
- Tabulate data in an appropriate manner.
- Draw sketch of expected trend.

Question 5

(a) Describe the process of polymerase chain reaction. [6]

- DNA denatures when hydrogen bonds are broken, resulting in separation of DNA strands;;
- by heating to 95^{0}C;;. (accept: 90-100 ^{0}C)

- A pair of primers anneal via complementary base pairing to the 3'ends of the single-stranded DNA template;;
- by cooling to 54 ^{0}C;;. (accept: 50-65 ^{0}C)

- New strands of DNA are synthesised from the position of the primers in the 5' to 3' direction;;
- by *Taq* DNA polymerase;; and
- by heating to 72 ^{0}C;;. (accept: 60-75 ^{0}C)

(b) Explain the advantages and limitations of polymerase chain reaction. [6]

Advantages

- The PCR method is extremely sensitive
- it can amplify sequences from trace amounts of DNA

- PCR is rapid
- A single PCR cycle takes less than 5 minutes / 20 – 30 cycles typically required takes only 2 – 3 hours

- PCR is robust
- PCR can permit amplification of specific sequences from material in which the DNA is badly degraded or embedded in a medium from which conventional DNA isolation is difficult

Limitations

- PCR is prone to contamination
- Due to the extreme sensitivity of PCR, any contamination of the reaction by non-template nucleic acids in the environment could be easily amplified

- PCR may result in infidelity of DNA replication
- *Taq* polymerase used in PCR lacks 3' to 5' exonuclease activity

- Prior knowledge on the DNA sequence is required for the PCR
- Designing specific oligonucleotide primers is required for selective amplification of a particular DNA sequence

(c) Explain the principles of restriction fragment length polymorphism analysis and how it can be used to study genetic variation within a species of organism. [8]

- RFLP are variations in the number / length of restriction fragments generated upon digestion with restriction enzymes;;.
- VNTR resulting in changes in the distance between two restriction sites;;.
- DNA samples of different individuals within a species are isolated and cut/cleaved with the same restriction enzyme for RFLP analysis. ;;
- The digested DNA fragments are subjected to gel electrophoresis, the DNA fragments separate by size ;;.
- Subsequently, Southern blotting was performed to transfer the size-fractionated DNA fragments from the gel onto nitrocellulose membrane ;;.
- Use of radioactively-labelled, single stranded probes complementary to the VNTR / DNA sequence of interest that hybridize to the probes by complementary base-pairing ;;
- Carry out autoradiography to visualise the DNA bands ;;.
- When cut with the same restriction enzyme, genetic variation within a species can be shown by the unique/different DNA fingerprint / banding patterns generated. ;;

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

BIOLOGY 9648/01

Paper 1 Multiple Choice **30 August 2016**

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **22** printed pages.

1 The picture shows starch grains as seen with an optical microscope. The actual length of the starch grain A is 50 µm.

Calculate the magnification.

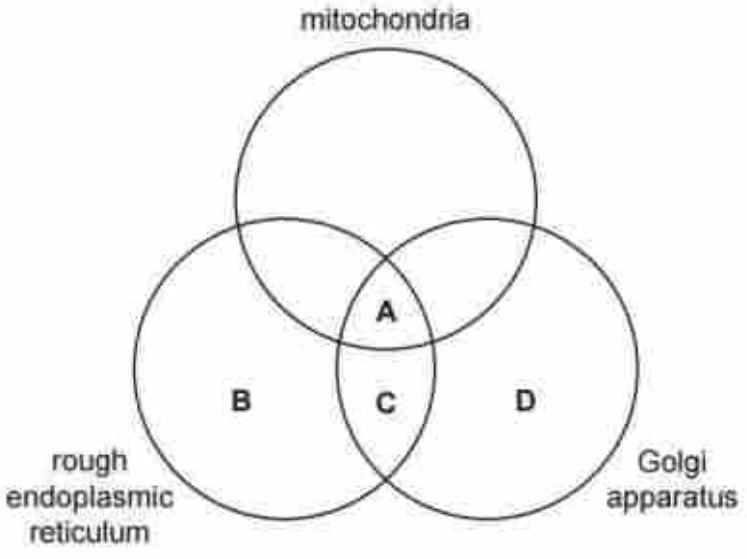
A x 5

B x 50

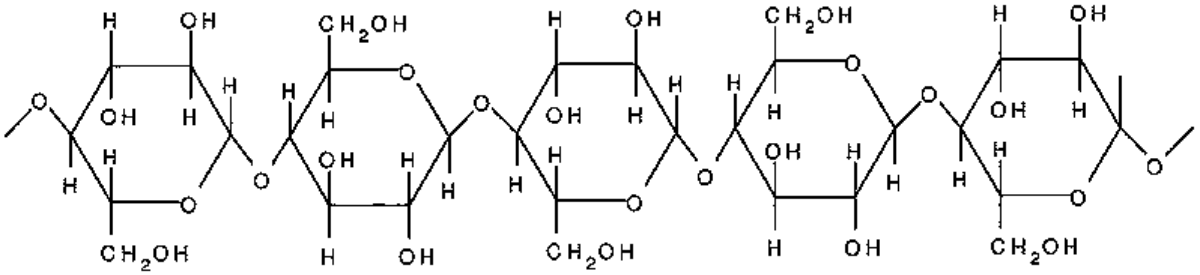
C x 500

D x 5000

2 Which of the following organelle(s) is/are directly required for the formation of the hydrolytic enzymes found in lysosomes?



3 The figure below shows a portion of a polymer.



Which statement is **true** about the polymer?

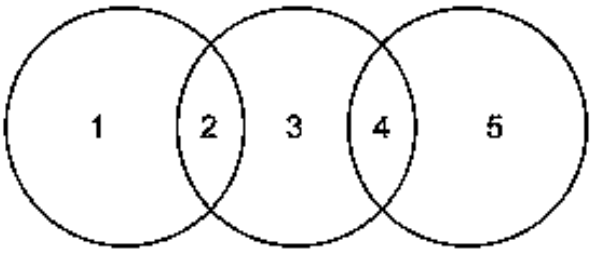
A The polymer will assume a helical structure.

B The polymer can exist in both branched and unbranched forms.

C The orientation of the monomer will result in a straight chain polymer.

D The monomers are able to form α (1-6) glycosidic bonds with one another.

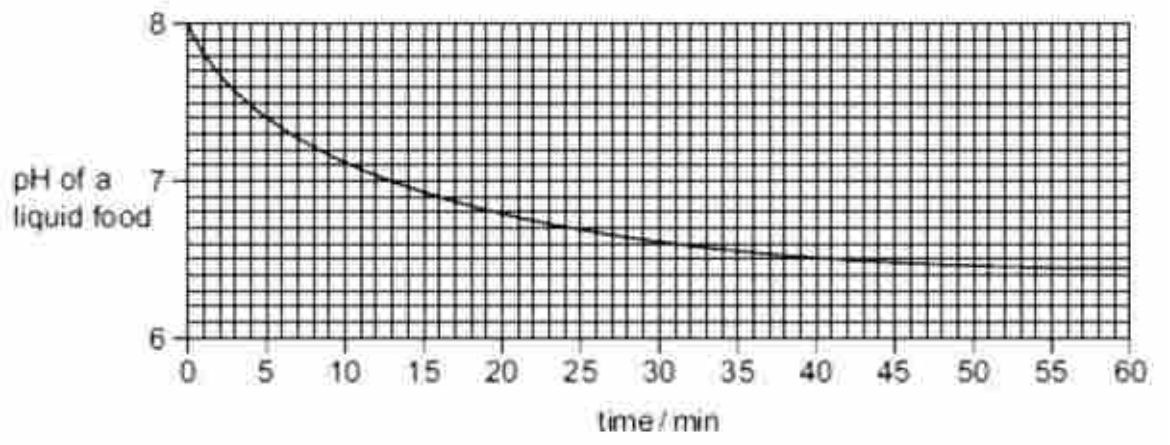
4 The diagram shows the relationship between the levels of protein structure and bonds.



Which row is **correct**?

	1	2	3	4	5
A	primary	peptide	secondary	ionic	tertiary
B	secondary	hydrogen	tertiary	peptide	primary
C	tertiary	ionic	primary	peptide	quaternary
D	quaternary	ionic	tertiary	ionic	secondary

5 Lipase is a digestive enzyme produced by the pancreas that catalyses the hydrolysis of dietary lipids. The table shows how the pH of a liquid food containing a high proportion of lipids decreases over time.



Which of the following statements are possible explanations of the results of the experiment between 50 and 60 minutes?

1 Enzyme concentration becomes the limiting factor.
2 Substrate concentration becomes the limiting factor.
3 All the enzyme active sites are saturated.
4 Denaturation of the enzyme by the products.
5 Products are acting as inhibitors.

A 1, 2 and 3
B 1, 4 and 5
C 2, 3 and 4
D 2, 4 and 5

6 Specific enzyme inhibitors inhibit only one enzyme.

The drug disulfiram, which is used as a treatment for alcoholism, is a specific inhibitor of acetaldehyde dehydrogenase. Acetaldehyde dehydrogenase is involved in the detoxification of ethanol. As a result of inhibition by disulfiram, any ethanol that is present in the system can only be partly broken down, resulting in nausea and vomiting.

Why is it important that the enzyme inhibitor disulfiram is specific?

1 It cannot disrupt other metabolic pathways.
2 It prevents ethanol from binding to the active site.
3 It is unlikely to cause unwanted side effects.
4 It inhibits aldehyde oxidase.

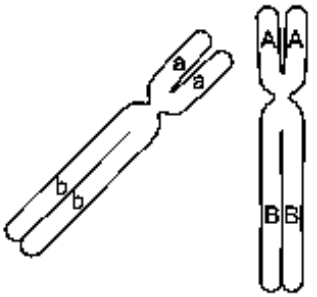
A 1, 2, 3 and 4
B 1, 2 and 3 only
C 1 and 3 only
D 2 and 4 only

7 In a multicellular organism, which of these statements about mitosis can help to explain the control of the mitotic cell cycle?

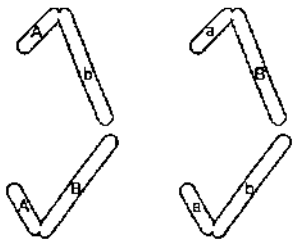
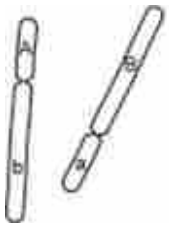
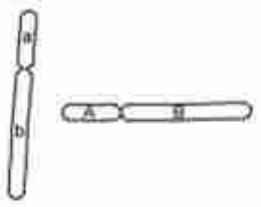
1 In most cells the genes initiating mitosis are not switched on.
2 Mitosis produces cells to replace damaged cells that cannot be repaired.
3 Mitosis transmits a complete copy of all the alleles in a cell to new cells.
4 Daughter cells formed by asexual reproduction develop from unspecialised cells.

A 1 only
B 3 only
C 1 and 4
D 2 and 4

8 The diagram shows two homologous chromosomes in early prophase I of meiosis in an animal cell. Two genes, A/a and B/b, whose loci occur on the homologous chromosomes are also shown.



Which row of diagrams is a possible representation of these chromosomes as they progress from anaphase I to prophase II?

	anaphase I	prophase II
A		
B		
C		
D		

9 The nucleic acids present in a cell of the bacterium *Escherichia coli* were analysed. Some of the results are shown in the table.

type of nucleic acid	number of different variants	number of molecules per cell	percentage of dry mass of cell
1	600	2500	2
2	60	160 000	3
3	2	20 000	21

Which row identifies each type of nucleic acid 1, 2 and 3?

	1	2	3
A	DNA	mRNA	tRNA
B	mRNA	tRNA	rRNA
C	rRNA	DNA	mRNA
D	tRNA	rRNA	DNA

10 How many of these statements about DNA polymerases are **correct**?

1 They transcribe DNA.
2 They synthesise DNA in the 3' to 5' direction.
3 They require a primer to function.
4 They require activated nucleotides.

A 1
B 2
C 3
D 4

11 What is the function of the enzyme RNA polymerase?

A to form a polypeptide using mRNA as a template
B to form a strand of DNA using mRNA as a template
C to form a strand of mRNA using DNA as a template
D to form a strand of mRNA using tRNA as a template

12 The following sequence of bases shows a short section of linear DNA from which mRNA is transcribed.

TACTCACATTAG…

The table shows a number of mRNA codons and their corresponding amino acids.

codon	AGU	AUC	AUG	CAU	GUA	UAC	UAG	UCA
amino acid	serine	iso-leucine	methionine	histidine	valine	tyrosine	'stop'	serine

Which row shows how this short section of linear DNA would be translated into part of a polypeptide chain?

	tRNA anti-codon order	amino acid sequence
A	AUGAGUGUAAUC	methionine, serine, valine, iso-leucine
B	AUGAGUGUAAUC	tyrosine, serine, histidine, stop
C	UACUCACAUUAG	methionine, serine, valine, iso-leucine
D	UACUCACAUUAG	tyrosine, serine, histidine, stop

13 About 20% of all human pregnancies are estimated to be lost by spontaneous abortion (miscarriage). About half of these spontaneous abortions are associated with chromosome aberrations.

The table shows the percentage incidence of each type of chromosome aberration that was detected in spontaneous abortions associated with chromosome aberrations.

chromosome aberration	percentage incidence
trisomy (2n+1)	62
monosomy (2n–1)	18
triploidy (3n)	17
translocations	3

What may be concluded from these data?

1 Numerical aberrations are much more likely to be associated with spontaneous abortions than are structural aberrations.

2 The occurrence of three sets of chromosomes has a similar percentage incidence as monosomy.

3 The presence of an extra chromosome is more likely to be associated with spontaneous abortion than is the lack of one chromosome.

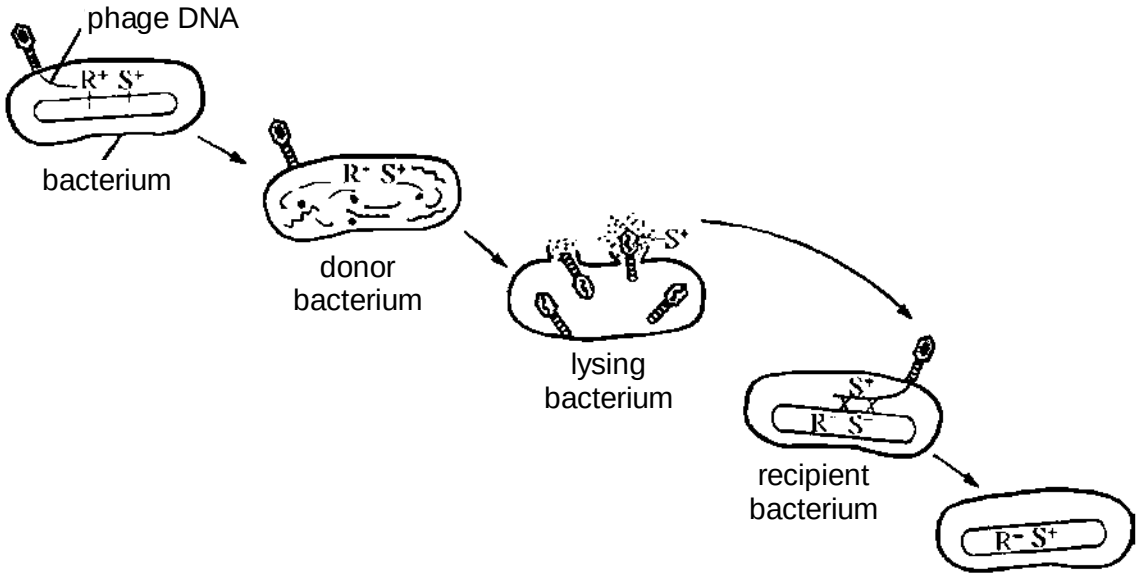
A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

14 The diagram below shows several steps in the gene transfer process between bacteria.



Which of the following statements explains how genetic variation in a population of bacteria may result from this process?

A Bacterial proteins are transferred from the donor bacterium to the recipient bacterium and recombine with the chromosome.

B The recipient bacterium incorporates the transduced genetic material into its own chromosome and synthesizes the corresponding proteins.

C The phage infection of the recipient bacterium and the introduction of the donor's DNA caused random mutations in the recipient's chromosome.

D DNA of the recipient's chromosome undergoes recombination with the donor's DNA, leading to a change in its genotype.

15 The only cells that an enveloped virus can infect are those whose cell surface membranes have specific receptors complementary to proteins in the virus envelope. The virus enters the cell by a type of endocytosis involving the protein clathrin, which is produced in the host cell.

The following are some of the events that follow attachment of an enveloped virus to a cell surface membrane.

1 A vesicle containing a virus fuses with an endosome (cytoplasmic vesicle).

2 The virus is surrounded by its envelope, a membrane and a layer of clathrin.

3 An acid pH causes the viral envelope to fuse with the membrane of an endosome.

4 The protein clathrin produces a depression in a cell surface membrane.

5 Clathrin is removed and recycled.

What is the correct sequence of these events in order to leave the virus free of its envelope in the cytoplasm of an infected cell?

A 2 → 3 → 1 → 4 → 5

B 2 → 4 → 5 → 3 → 1

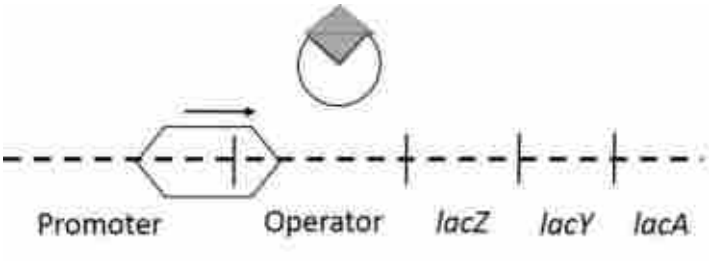
C 4 → 1 → 3 → 2 → 5

D 4 → 2 → 5 → 1 → 3

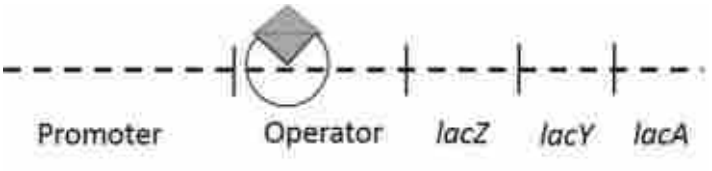
16 Using the legend provided, which of the following correctly depicts the interactions of the components at the *lac* operon when lactose is absent from the medium?

Legend:

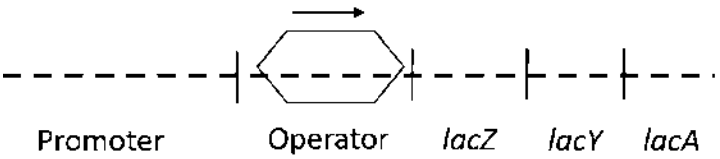
A



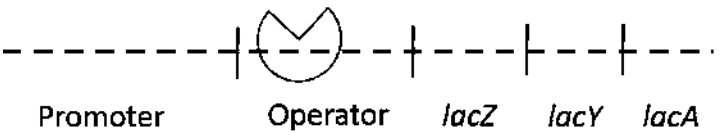
B



C



D



17 A type of bacteria caused fatalities in human. These strains of bacteria possess genes for a toxin not found in the other harmless strains.

In an attempt to find out how these genes can be transferred between bacteria, several experimental set-ups were carried out. The results are shown in the table below.

conditions	results
DNA isolated from virulent strain and incubated with harmless strain.	Some virulent strains observed.
Virulent and harmless strains of bacteria incubated in a container with no barrier.	Some virulent strains observed.
Virulent and harmless strains of bacteria incubated in a container but separated by physical membrane barrier.	No virulent strain found in the side with harmless bacteria.

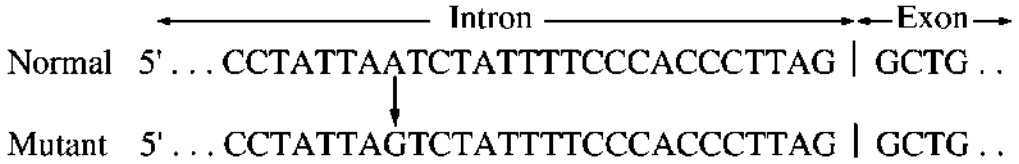
From the information provided only, which of the following gene transfer processes could have taken place?

1 transformation
2 conjugation
3 transduction

A 1 only
B 2 only
C 1 and 2
D 1 and 3

18 Portions of the DNA sequences and mutant *β*-globin genes are shown below.

The arrow (↓) indicates the single base substitution that occurred to result in the disease *β*-thalassemia.



The most plausible explanation for the effects of the mutation is that

A there was a change in the codon that affected the amino acid coded for.
B a recognition site for an restriction enzyme was generated, resulting in a DNA break.
C a nonsense mutation occurred to result in a truncated polypeptide.
D a new splice site was created, such that a portion of the intron was not removed.

19 One form of post-translational modification of a protein is the

A methylation of the CpG islands.

B shuffling of exons to produce many types of mRNA from a single gene.

C removal of introns from the pre-mRNA.

D removal or modification of amino acids in the polypeptide.

20 Laboratory mice whose *p53* genes had been switched off developed tumours.

When their *p53* genes were switched on again, the tumour cells stopped dividing and died within a few days. Healthy cells in the mice were unaffected.

What do these observations suggest?

A p53 protein speeds up the mitotic cell cycle

B p53 protein causes all cells to die

C the *p53* gene acts as a tumour suppressor gene

D the *p53* gene encourages the growth of tumours

21 In the breeding season, male Anole lizards court females by bobbing their heads up and down while displaying a colourful throat patch. Both characteristics are controlled by genes found on separate chromosomes. Anoles prefer to mate with lizards, which bob their heads fast and have red throat patches. These two alleles are dominant over their counterparts, slow bobbing and yellow throats.

A male lizard heterozygous for head bobbing and homozygous dominant for the red throat patch mates with a female that is also heterozygous for head bobbing but has yellow throat patch.

What percentage of the offspring has fast bobbing and red throat phenotype?

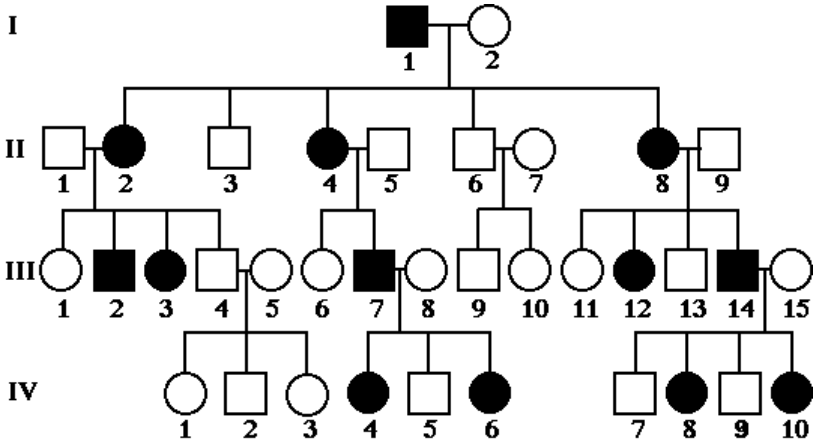
A 25%

B 50%

C 75%

D 100%

22 The inheritance of a genetic disease in a family is presented in a pedigree tree below.



What is the **most likely** type of inheritance shown?

A autosomal dominant

B autosomal recessive

C sex-linked dominant

D sex-linked recessive

23 In a plant, three genes are known to be linked. The table below gives the recombination frequencies obtained from crosses involving pairs of these genes.

pair of linked genes	recombination frequency
colour of flowers (P) x appearance of fruit (Q)	0.43
appearance of fruit (Q) x presence of prickles (R)	0.17
presence of prickles (R) x colour of flowers (P)	0.26

1 The chance of crossing over occurring between genes P and R will be lower than that of Q and R.

2 Genes Q and R are 17 map units apart on the same chromosome.

3 The order of the genes on the chromosome is P – R – Q.

4 The recombination frequencies are obtained based on the proportion of recombinant offspring.

Based on the information, which of the above statement(s) is/are **false**?

A 1 only

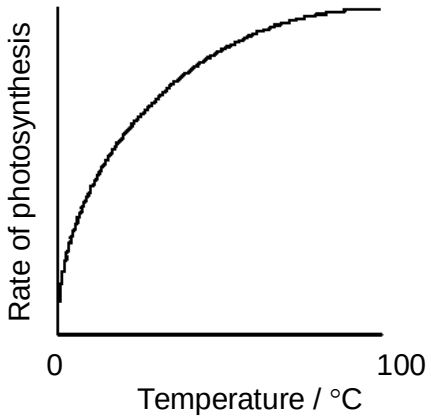
B 1 and 2

C 2 and 3

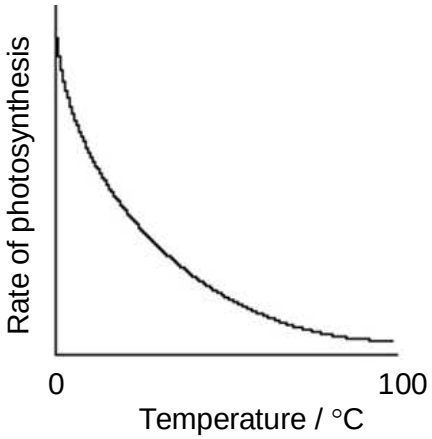
D 2 and 4

24 Which graph best represents the effect of temperature on the rate of photosynthesis of a plant?

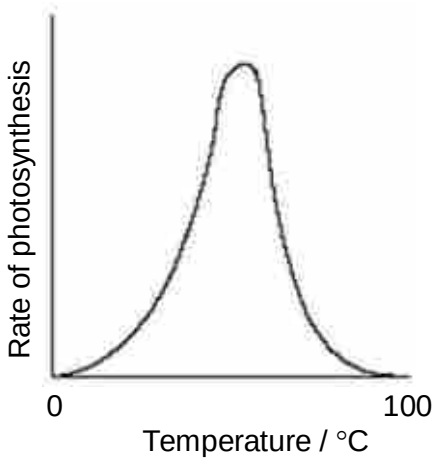
A



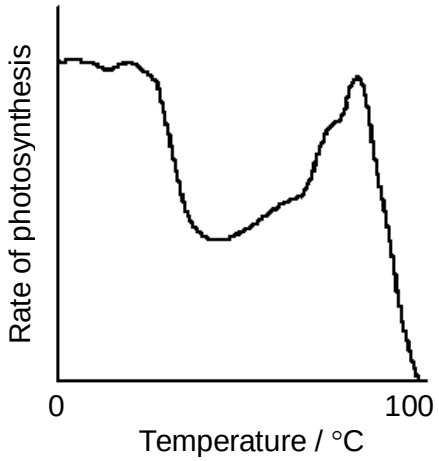
B



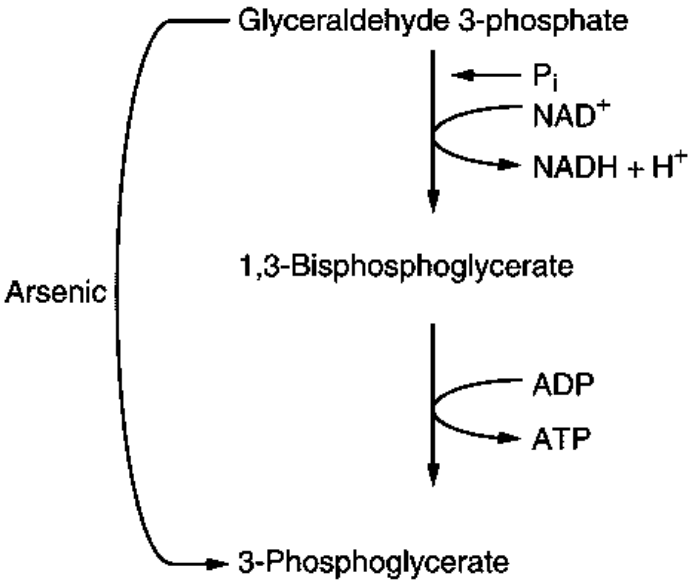
C



D



25 The diagram shows the effect of arsenic on the metabolism of glyceraldehyde-3-phosphate.



What is the net yield of ATP molecules from the glycolysis process involving 2 molecules of glucose in the presence of arsenic?

A 0

B 1

C 2

D 4

26 For an action potential to occur,

A Na^+ influx must exceed K^+ efflux.

B the membrane must not be in the relative refractory period.

C the stimulus must result in the exocytosis of neurotransmitters.

D voltage-gated potassium channels must be closed.

27 Caffeine is an inhibitor of phosphodiesterase. Therefore, the cells of a person who has recently consumed coffee would have increased levels of

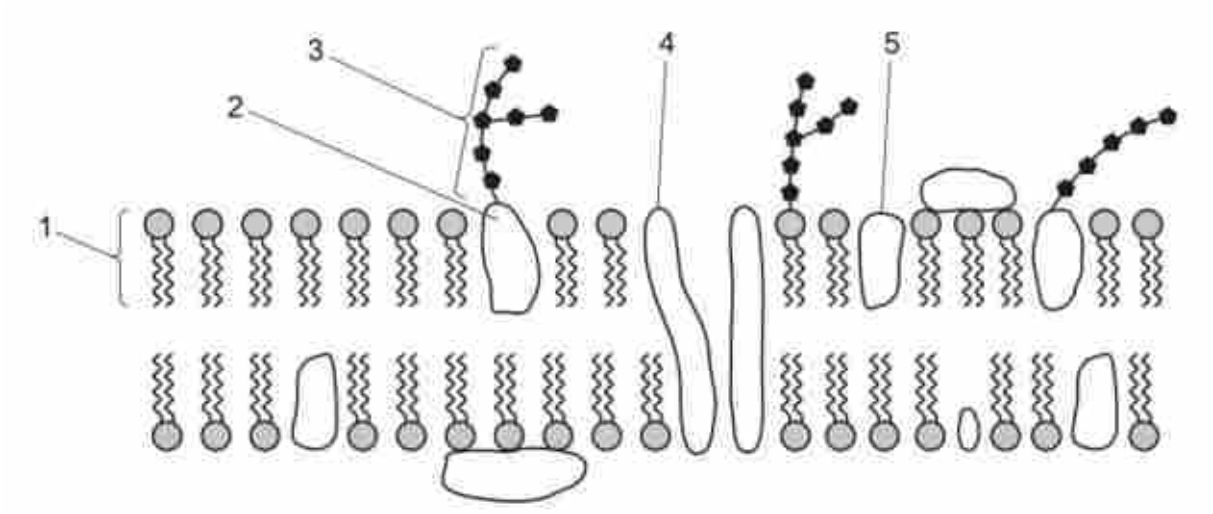
A ATP

B GTP

C AMP

D cAMP

28 The diagram shows part of a cell surface membrane.



Which molecule(s) allow(s) the movement of hydrophilic substances across the membrane?

A 1 only

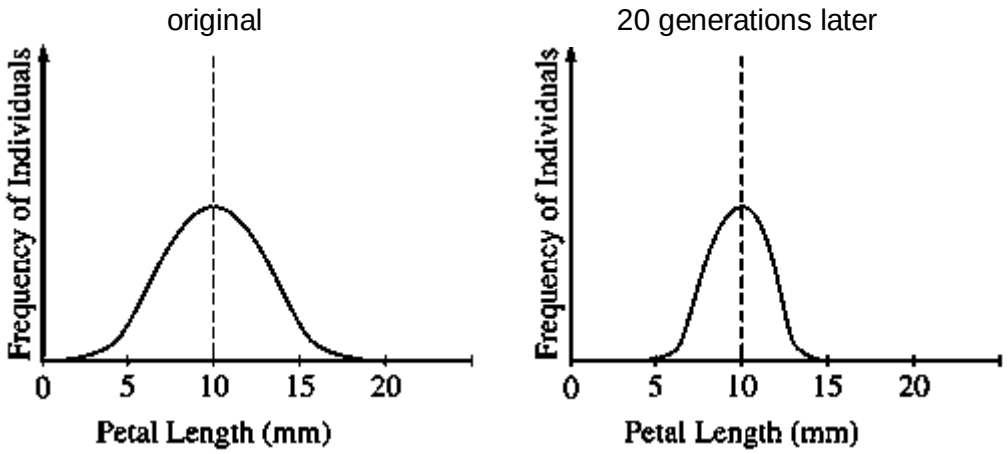
B 4 only

C 2 and 5

D 4 and 5

29 A plant species arrives at a new island and are exposed to a new set of pollinators.

The diagram below shows the frequency distribution of petal length in the original colonising population and 20 generations later.



Which type of selection is shown in this example?

A directional selection

B disruptive selection

C neutral selection

D stabilising selection

30 Q, P, R and S are related species of organisms.

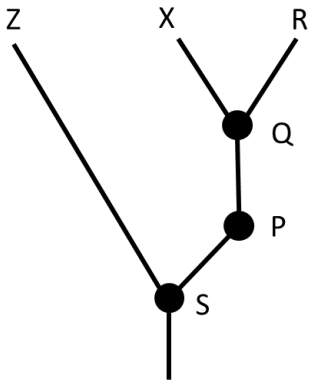
Species X is an extinct recent common ancestor of species Q and R.

X, Q and R all evolved from species P.

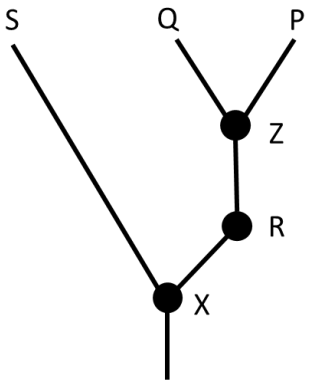
Species S is the least related to the others, with extinct species Z being its most recent phylogenetic link to the other species.

Which of the following phylogenetic trees correctly represents the relationships described above?

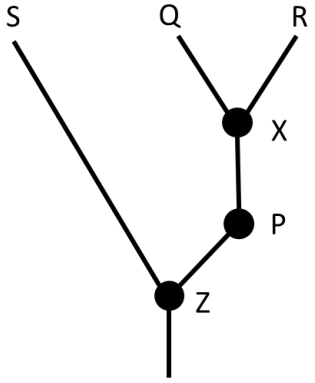
A



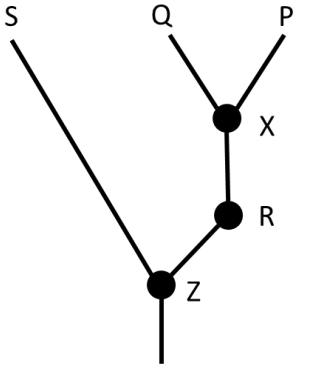
B



C



D



31 When considering the neutral theory of molecular evolution, which of the following is a correct assumption of this model?

A New alleles that confer a higher fitness level tend to increase in frequency over time in the population.

B New alleles that confer a lower fitness level tend to decrease in frequency over time in the population.

C New alleles that confer an advantage to the heterozygotes are maintained in the population.

D New alleles that do not confer any effects on the fitness level tend to fluctuate in the population randomly.

32 The human protein hormone somatotrophin can be produced by genetic engineering using plasmid vectors.

Which of the following statements describe the advantages of using such plasmids?

1 A gene coding for somatotrophin from a cDNA library can be inserted into the plasmid.

2 The plasmid carrying the gene coding for somatotrophin could contain the promoter sequence of DNA that is found in human cells expressing the hormone.

3 A synthetic gene produced from knowledge of the amino acid sequence of somatotrophin can be inserted into the plasmid.

A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 3 only

33 A polymerase chain reaction (PCR) amplification was performed on human genomic DNA.

Multiple products of varying sizes were obtained, including one of the expected size.

Which of the following modifications to the protocol is the most likely to eliminate the extra PCR products?

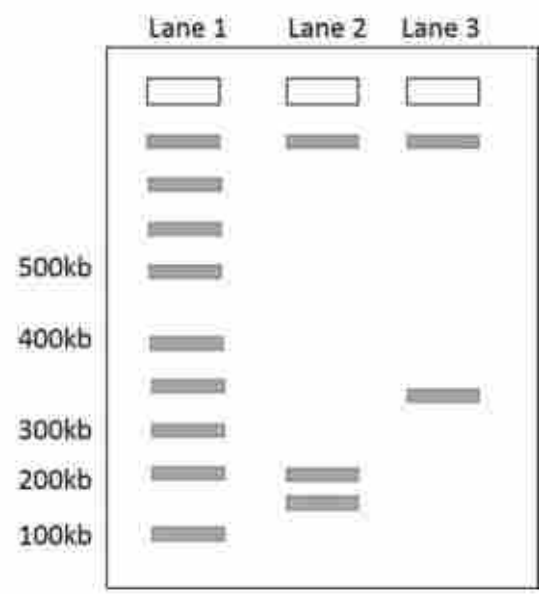
A increasing length of the primer

B increasing the denaturation temperature from 94°C to 96°C

C decreasing the annealing temperature from 56°C to 52°C

D increasing the elongation temperature from 70°C to 74°C

34 The diagram below shows the results from a restriction digestion of a normal *CFTR* allele (lane 2) and a mutant *CFTR* allele (lane 3). Lane 1 contains the DNA ladder.



Based on the results shown, which of the following statements best describes the mutation that resulted in the mutant *CFTR* allele?

A An additional restriction site was generated.

B One restriction site was lost.

C Two restriction sites were lost.

D The number of restriction sites remained unchanged.

35 Within its own environment, a particular cell line cannot be induced to produce a cell from a different cell line.

Which statement explains this?

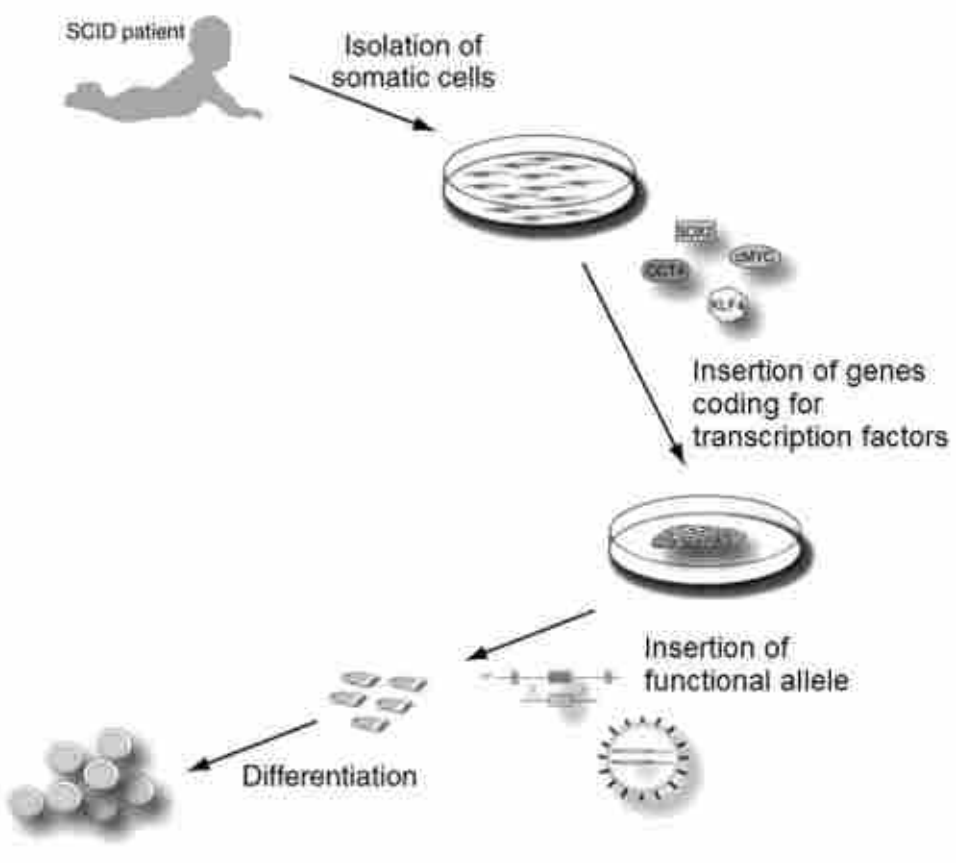
A Genes not required for a particular cell line are methylated.

B Genes not required for a particular cell line are removed by enzymes.

C Only pre-mRNA that is required for a particular cell line is processed.

D Stem cells have only the genes required for their particular cell line.

36 In 2006, scientists have discovered a means to convert somatic cells, such as skin cells, into pluripotent stem cells. By inserting four specific genes which code for transcription factors, somatic cells are able to de-differentiate and achieve pluripotency. Such pluripotent stem cells may one day be used for gene therapy to treat diseases such as severe combined immunodeficiency (SCID), as shown in the following diagram.



Which statement shows one benefit of using these novel pluripotent stem cells over embryonic stem cells?

A A functional copy of the allele could be inserted into these novel stem cells using a retroviral vector during gene therapy.

B These novel stem cells have the potential to differentiate into more types of cells, hence they can be used to treat a greater variety of diseases.

C These novel stem cells will not be rejected by the host after being transplanted back into the body.

D These novel stem cells are able to maintain the undifferentiated state for long periods of time due to the insertion of additional genes.

37 Research into gene therapy that targets germ cells (sperm and ova) has raised some concerns.

1 The inserted gene may interfere with fetal development in unexpected ways.
2 Developing babies cannot choose to have gene therapy.
3 The inserted gene could prevent the inheritance of genetic diseases.

Which concerns are ethical reasons against the use of germ cell gene therapy?

A 1, 2 and 3
B 1 and 2 only
C 1 and 3 only
D 2 and 3 only

38 In a callus culture,

A a high cytokinin to auxin ratio results in root formation.
B a low cytokinin to auxin ratio results in root formation.
C only auxin is required to induce shoot and root formation.
D only cytokinin is required to induce shoot and root formation.

39 Why can improved varieties of plants and animals, used as human food, be developed more quickly by genetic engineering than by traditional selective breeding methods?

A Genetically engineered organisms mature more quickly and breed sooner.
B The existing desirable features of the plants or animals are mostly unchanged.
C The introduced genes can improve the quality of the food produced.
D The organisms used for genetic engineering are already used for food.

40 Which statement supports the view that genetically engineered animals could help to solve the demand for food in the world?

A Transgenic pigs and sheep are produced to express higher levels of growth hormone.

B Biomedical applications of genetically engineered animals have also become routine within the pharmaceutical industry, for drug discovery, drug development and risk assessment.

C Cloning of either extinct or endangered species such as thylacine and woolly mammoth helps to retain genetic diversity in small populations.

D By inserting genes from sea anemone and jellyfish, zebrafish have been genetically engineered to express fluorescent proteins.

INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	**MARK SCHEME**
CLASS	
INDEX NUMBER	

BIOLOGY

9648/01

Paper 1 Multiple Choice

30 August 2016

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

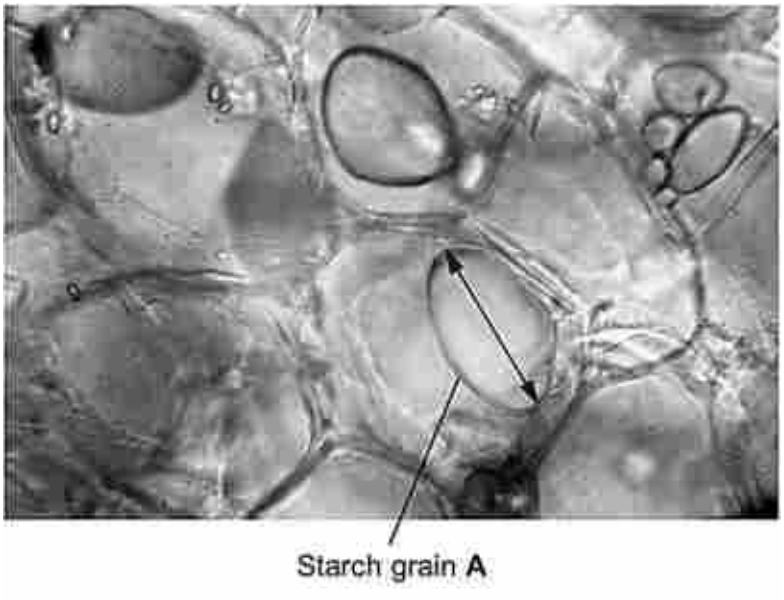
Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **22** printed pages.

1 The picture shows starch grains as seen with an optical microscope. The actual length of the starch grain A is 50 µm.



Calculate the magnification.

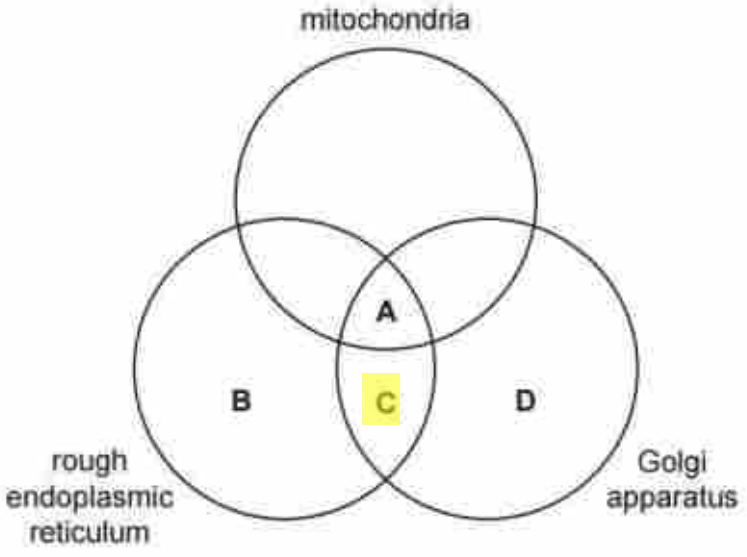
A x 5

B x 50

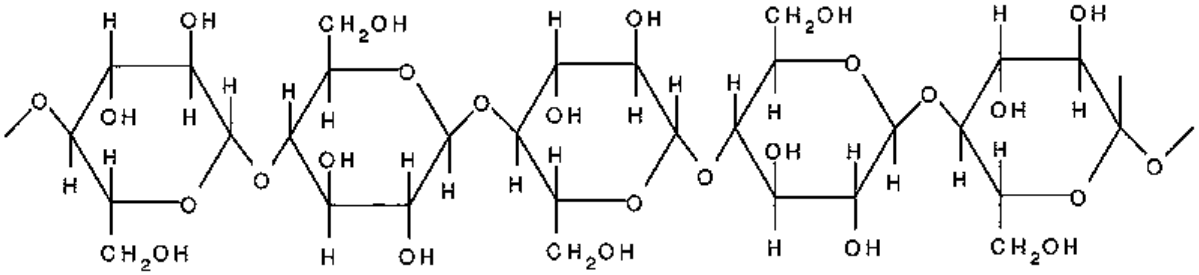
C x 500

D x 5000

2 Which of the following organelle(s) is/are directly required for the formation of the hydrolytic enzymes found in lysosomes?



3 The figure below shows a portion of a polymer.



Which statement is **true** about the polymer?

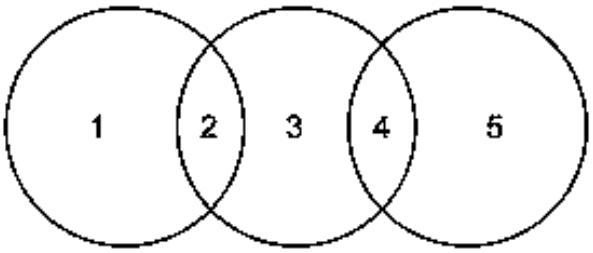
A The polymer will assume a helical structure.

B The polymer can exist in both branched and unbranched forms.

C The orientation of the monomer will result in a straight chain polymer.

D The monomers are able to form α (1-6) glycosidic bonds with one another.

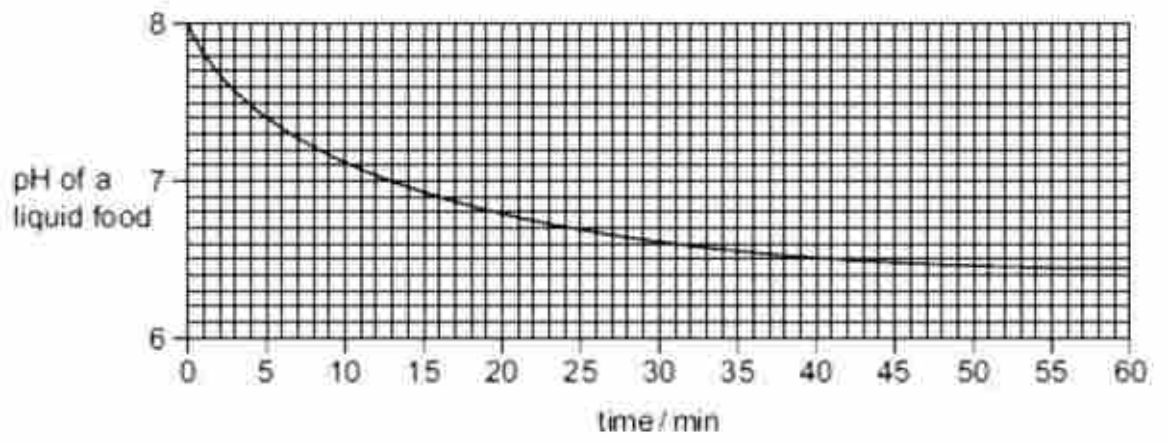
4 The diagram shows the relationship between the levels of protein structure and bonds.



Which row is **correct**?

	1	2	3	4	5
A	primary	peptide	secondary	ionic	tertiary
B	secondary	hydrogen	tertiary	peptide	primary
C	tertiary	ionic	primary	peptide	quaternary
D	quaternary	ionic	tertiary	ionic	secondary

5 Lipase is a digestive enzyme produced by the pancreas that catalyses the hydrolysis of dietary lipids. The table shows how the pH of a liquid food containing a high proportion of lipids decreases over time.



Which of the following statements are possible explanations of the results of the experiment between 50 and 60 minutes?

1 Enzyme concentration becomes the limiting factor.
2 Substrate concentration becomes the limiting factor.
3 All the enzyme active sites are saturated.
4 Denaturation of the enzyme by the products.
5 Products are acting as inhibitors.

A 1, 2 and 3
B 1, 4 and 5
C 2, 3 and 4
D 2, 4 and 5

6 Specific enzyme inhibitors inhibit only one enzyme.

The drug disulfiram, which is used as a treatment for alcoholism, is a specific inhibitor of acetaldehyde dehydrogenase. Acetaldehyde dehydrogenase is involved in the detoxification of ethanol. As a result of inhibition by disulfiram, any ethanol that is present in the system can only be partly broken down, resulting in nausea and vomiting.

Why is it important that the enzyme inhibitor disulfiram is specific?

1 It cannot disrupt other metabolic pathways.
2 It prevents ethanol from binding to the active site.
3 It is unlikely to cause unwanted side effects.
4 It inhibits aldehyde oxidase.

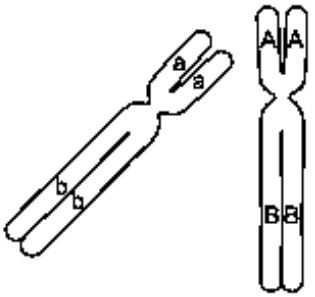
A 1, 2, 3 and 4
B 1, 2 and 3 only
C 1 and 3 only
D 2 and 4 only

7 In a multicellular organism, which of these statements about mitosis can help to explain the control of the mitotic cell cycle?

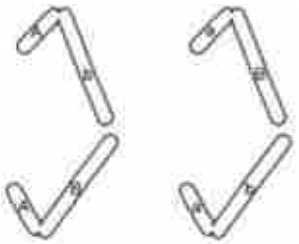
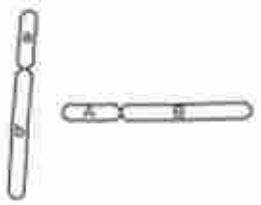
1 In most cells the genes initiating mitosis are not switched on.
2 Mitosis produces cells to replace damaged cells that cannot be repaired.
3 Mitosis transmits a complete copy of all the alleles in a cell to new cells.
4 Daughter cells formed by asexual reproduction develop from unspecialised cells.

A 1 only
B 3 only
C 1 and 4
D 2 and 4

8 The diagram shows two homologous chromosomes in early prophase I of meiosis in an animal cell. Two genes, A/a and B/b, whose loci occur on the homologous chromosomes are also shown.



Which row of diagrams is a possible representation of these chromosomes as they progress from anaphase I to prophase II?

	anaphase I	prophase II
A		
B		
C		
D		

9 The nucleic acids present in a cell of the bacterium *Escherichia coli* were analysed. Some of the results are shown in the table.

type of nucleic acid	number of different variants	number of molecules per cell	percentage of dry mass of cell
1	600	2500	2
2	60	160 000	3
3	2	20 000	21

Which row identifies each type of nucleic acid 1, 2 and 3?

	1	2	3
A	DNA	mRNA	tRNA
B	mRNA	tRNA	rRNA
C	rRNA	DNA	mRNA
D	tRNA	rRNA	DNA

10 How many of these statements about DNA polymerases are **correct**?

1 They transcribe DNA.
2 They synthesise DNA in the 3' to 5' direction.
3 They require a primer to function.
4 They require activated nucleotides.

A 1
B 2
C 3
D 4

11 What is the function of the enzyme RNA polymerase?

A to form a polypeptide using mRNA as a template
B to form a strand of DNA using mRNA as a template
C to form a strand of mRNA using DNA as a template
D to form a strand of mRNA using tRNA as a template

12 The following sequence of bases shows a short section of linear DNA from which mRNA is transcribed.

TACTCACATTAG…

The table shows a number of mRNA codons and their corresponding amino acids.

codon	AGU	AUC	AUG	CAU	GUA	UAC	UAG	UCA
amino acid	serine	iso-leucine	methionine	histidine	valine	tyrosine	'stop'	serine

Which row shows how this short section of linear DNA would be translated into part of a polypeptide chain?

	tRNA anti-codon order	amino acid sequence
A	AUGAGUGUAAUC	methionine, serine, valine, iso-leucine
B	AUGAGUGUAAUC	tyrosine, serine, histidine, stop
C	UACUCACAUUAG	methionine, serine, valine, iso-leucine
D	UACUCACAUUAG	tyrosine, serine, histidine, stop

13 About 20% of all human pregnancies are estimated to be lost by spontaneous abortion (miscarriage). About half of these spontaneous abortions are associated with chromosome aberrations.

The table shows the percentage incidence of each type of chromosome aberration that was detected in spontaneous abortions associated with chromosome aberrations.

chromosome aberration	percentage incidence
trisomy (2n+1)	62
monosomy (2n−1)	18
triploidy (3n)	17
translocations	3

What may be concluded from these data?

1 Numerical aberrations are much more likely to be associated with spontaneous abortions than are structural aberrations.

2 The occurrence of three sets of chromosomes has a similar percentage incidence as monosomy.

3 The presence of an extra chromosome is more likely to be associated with spontaneous abortion than is the lack of one chromosome.

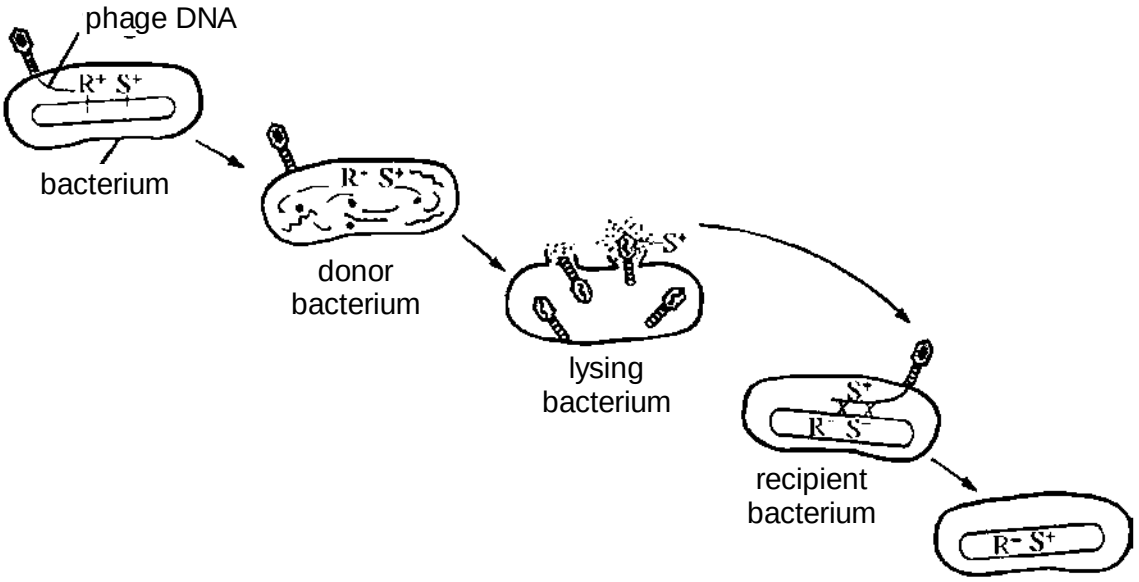
A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

14 The diagram below shows several steps in the gene transfer process between bacteria.



Which of the following statements explain how genetic variation in a population of bacteria may result from this process?

A Bacterial proteins are transferred from the donor bacterium to the recipient bacterium and recombine with the chromosome.

B The recipient bacterium incorporates the transduced genetic material into its own chromosome and synthesizes the corresponding proteins.

C The phage infection of the recipient bacterium and the introduction of the donor's DNA caused random mutations in the recipient's chromosome.

D DNA of the recipient's chromosome undergoes recombination with the donor's DNA, leading to a change in its genotype.

15 The only cells that an enveloped virus can infect are those whose cell surface membranes have specific receptors complementary to proteins in the virus envelope. The virus enters the cell by a type of endocytosis involving the protein clathrin, which is produced in the host cell.

The following are some of the events that follow attachment of an enveloped virus to a cell surface membrane.

1 A vesicle containing a virus fuses with an endosome (cytoplasmic vesicle).

2 The virus is surrounded by its envelope, a membrane and a layer of clathrin.

3 An acid pH causes the viral envelope to fuse with the membrane of an endosome.

4 The protein clathrin produces a depression in a cell surface membrane.

5 Clathrin is removed and recycled.

What is the correct sequence of these events in order to leave the virus free of its envelope in the cytoplasm of an infected cell?

A 2 → 3 → 1 → 4 → 5

B 2 → 4 → 5 → 3 → 1

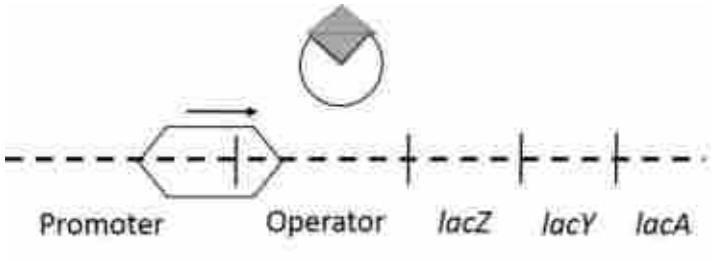
C 4 → 1 → 3 → 2 → 5

D 4 → 2 → 5 → 1 → 3

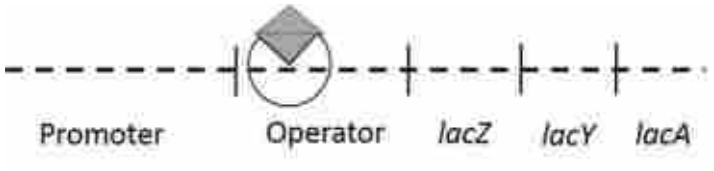
16 Using the legend provided, which of the following correctly depicts the interactions of the components at the *lac* operon when lactose is absent from the medium?

Legend:

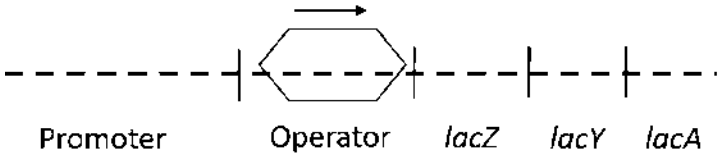
A



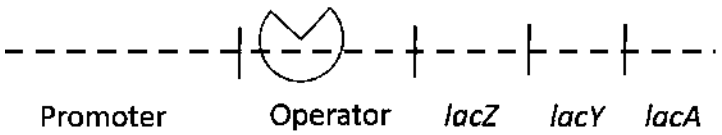
B



C



D



17 A type of bacteria caused fatalities in human. These strains of bacteria possess genes for a toxin not found in the other harmless strains.

In an attempt to find out how these genes can be transferred between bacteria, several experimental set-ups were carried out. The results are shown in the table below.

Conditions	Results
DNA isolated from virulent strain and incubated with harmless strain.	Some virulent strains observed.
Virulent and harmless strains of bacteria incubated in a container with no barrier.	Some virulent strains observed.
Virulent and harmless strains of bacteria incubated in a container but separated by physical membrane barrier.	No virulent strain found in the side with harmless bacteria.

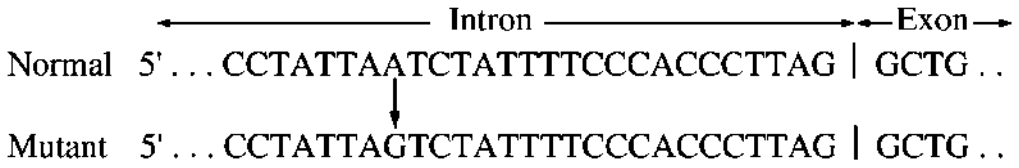
From the information provided only, which of the following gene transfer processes could have taken place?

1 transformation
2 conjugation
3 transduction

A 1 only
B 2 only
C 1 and 2
D 1 and 3

18 Portions of the DNA sequences and mutant *β*-globin genes are shown below.

The arrow (↓) indicates the single base substitution that occurred to result in the disease *β*-thalassemia.



The most plausible explanation for the effects of the mutation is that

A there was a change in the codon that affected the amino acid coded for.
B a recognition site for an restriction enzyme was generated, resulting in a DNA break.
C a nonsense mutation occurred to result in a truncated polypeptide.
D a new splice site was created, such that a portion of the intron was not removed.

19 One form of post-translational modification of a protein is the

A methylation of the CpG islands

B shuffling of exons to produce many types of mRNA from a single gene

C removal of introns from the pre-mRNA

D removal or modification of amino acids in the polypeptide

20 Laboratory mice whose *p53* genes had been switched off developed tumours.

When their *p53* genes were switched on again, the tumour cells stopped dividing and died within a few days. Healthy cells in the mice were unaffected.

What do these observations suggest?

A p53 protein speeds up the mitotic cell cycle

B p53 protein causes all cells to die

C the *p53* gene acts as a tumour suppressor gene

D the *p53* gene encourages the growth of tumours

21 In the breeding season, male Anole lizards court females by bobbing their heads up and down while displaying a colourful throat patch. Both characteristics are controlled by genes found on separate chromosomes. Anoles prefer to mate with lizards, which bob their heads fast and have red throat patches. These two alleles are dominant over their counterparts, slow bobbing and yellow throats.

A male lizard heterozygous for head bobbing and homozygous dominant for the red throat patch mates with a female that is also heterozygous for head bobbing but has yellow throat patch.

What percentage of the offspring has fast bobbing and red throat phenotype?

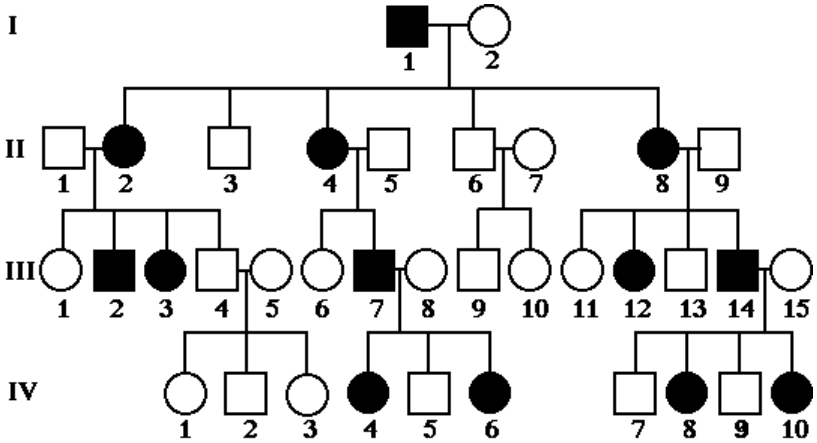
A 25%

B 50%

C 75%

D 100%

22 The inheritance of a genetic disease in a family is presented in a pedigree tree below.



What is the **most likely** type of inheritance shown?

A autosomal dominant

B autosomal recessive

C sex-linked dominant

D sex-linked recessive

23 In a plant, three genes are known to be linked. The table below gives the recombination frequencies obtained from crosses involving pairs of these genes.

pair of linked genes	recombination frequency
colour of flowers (P) x appearance of fruit (Q)	0.43
appearance of fruit (Q) x presence of prickles (R)	0.17
presence of prickles (R) x colour of flowers (P)	0.26

1 The chance of crossing over occurring between genes P and R will be lower than that of Q and R.

2 Genes Q and R are 17 map units apart on the same chromosome.

3 The order of the genes on the chromosome is P – R – Q.

4 The recombination frequencies are obtained based on the proportion of recombinant offspring.

Based on the information, which of the above statement(s) is/are **false**?

A 1 only

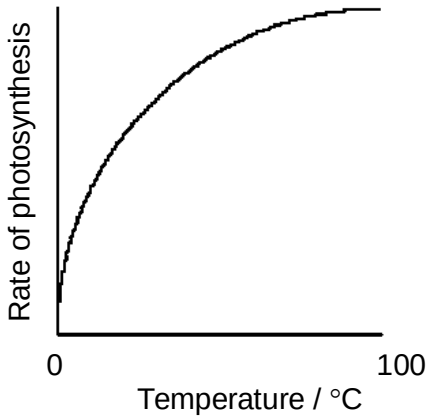
B 1 and 2 only

C 2 and 3 only

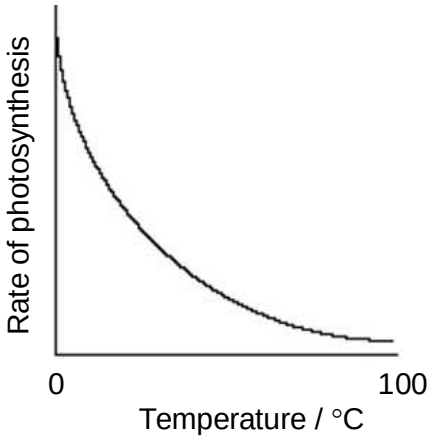
D 2 and 4 only

24 Which graph best represents the effect of temperature on the rate of photosynthesis of a plant?

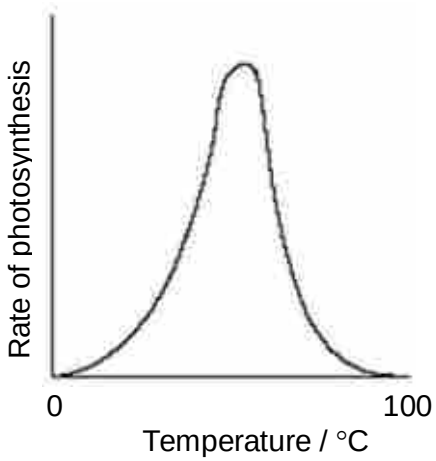
A



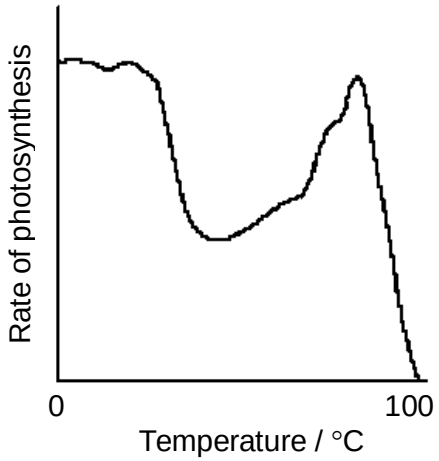
B



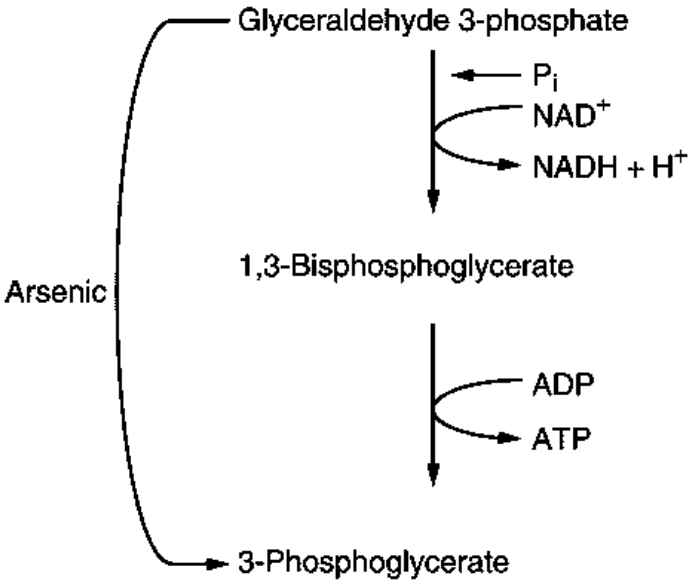
C



D



25 The diagram shows the effect of arsenic on the metabolism of glyceraldehyde-3-phosphate.



What is the net yield of ATP molecules from the glycolysis process involving 2 molecules of glucose in the presence of arsenic?

A 0
B 1
C 2
D 4

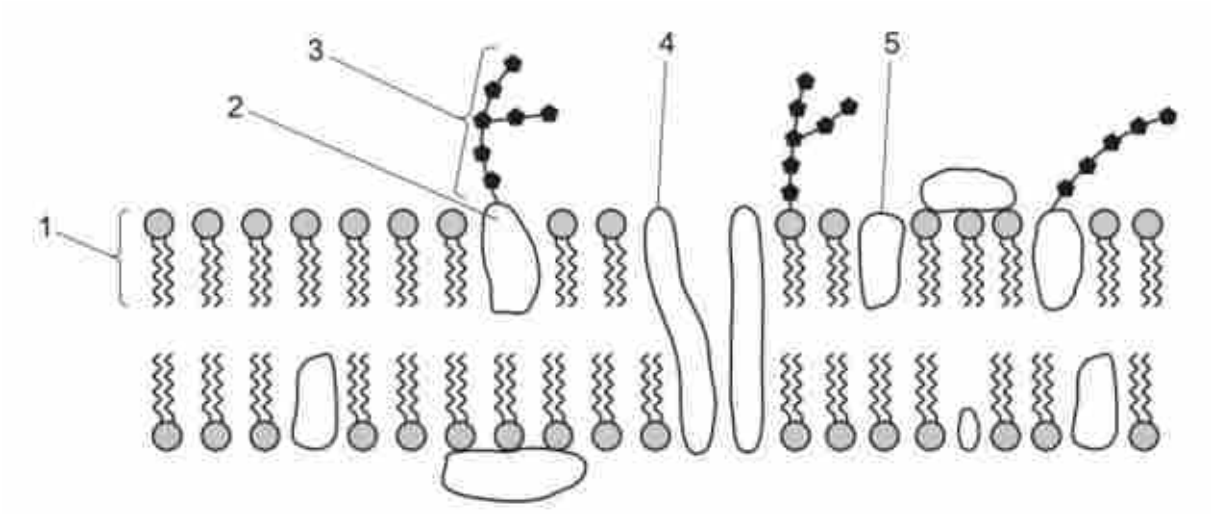
26 For an action potential to occur,

A Na^+ influx must exceed K^+ efflux.
B the membrane must not be in the relative refractory period.
C the stimulus must result in the exocytosis of neurotransmitters.
D voltage-gated potassium channels must be closed.

27 Caffeine is an inhibitor of phosphodiesterase. Therefore, the cells of a person who has recently consumed coffee would have increased levels of

A ATP
B GTP
C AMP
D cAMP

28 The diagram shows part of a cell surface membrane.



Which molecule(s) allow(s) the movement of hydrophilic substances across the membrane?

A 1 only

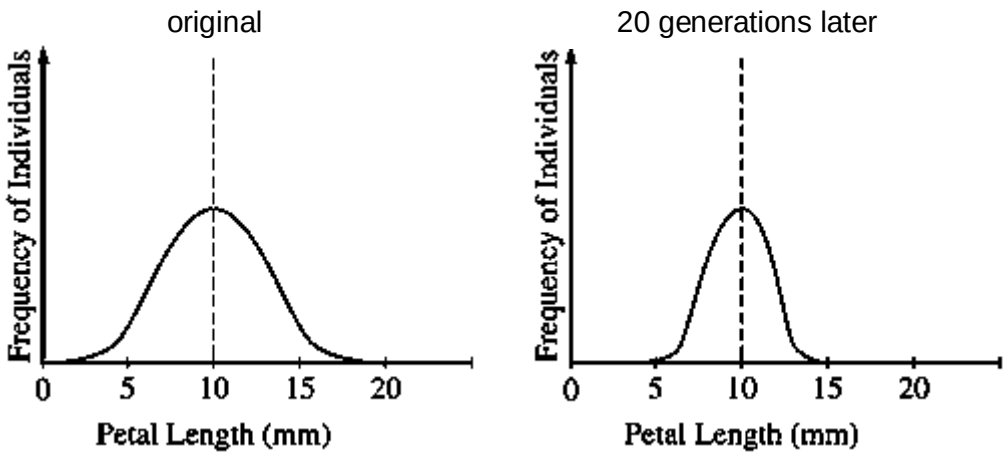
B 4 only

C 2 and 5

D 4 and 5

29 A plant species arrives at a new island and are exposed to a new set of pollinators.

The diagram below shows the frequency distribution of petal length in the original colonising population and 20 generations later.



Which type of selection is shown in this example?

A directional selection

B disruptive selection

C neutral selection

D stabilising selection

30 Q, P, R and S are related species of organisms.

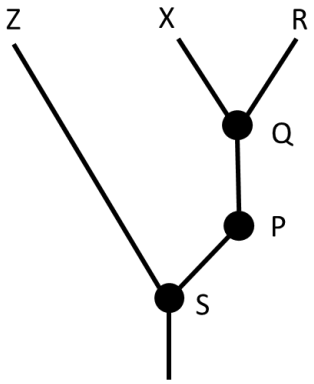
Species X is an extinct recent common ancestor of species Q and R.

X, Q and R all evolved from species P.

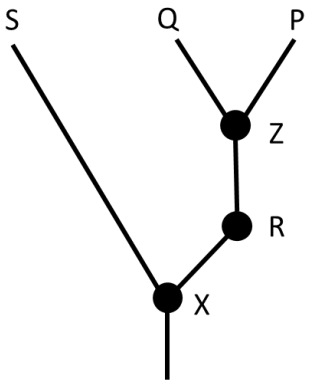
Species S is the least related to the others, with extinct species Z being its most recent phylogenetic link to the other species.

Which of the following phylogenetic trees correctly represents the relationships described above?

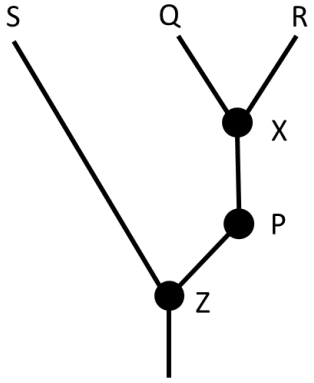
A



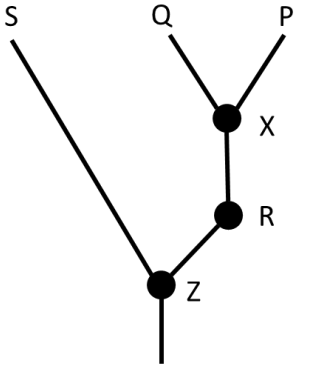
B



C



D



31 When considering the neutral theory of molecular evolution, which of the following is a correct assumption of this model?

A New alleles that confer a higher fitness level tend to increase in frequency over time in the population.

B New alleles that confer a lower fitness level tend to decrease in frequency over time in the population.

C New alleles that confer an advantage to the heterozygotes are maintained in the population.

D New alleles that do not confer any effects on the fitness level tend to fluctuate in the population randomly.

32 The human protein hormone somatotrophin can be produced by genetic engineering using plasmid vectors.

Which statements describe the advantages of using such plasmids?

1 A gene coding for somatotrophin from a cDNA library can be inserted into the plasmid.

2 The plasmid carrying the gene coding for somatotrophin could contain the promoter sequence of DNA that is found in human cells expressing the hormone.

3 A synthetic gene produced from knowledge of the amino acid sequence of somatotrophin can be inserted into the plasmid.

A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 3 only

33 A polymerase chain reaction (PCR) amplification was performed on human genomic DNA.

Multiple products of varying sizes were obtained, including one of the expected size.

Which of the following modifications to the protocol is the most likely to eliminate the extra PCR products?

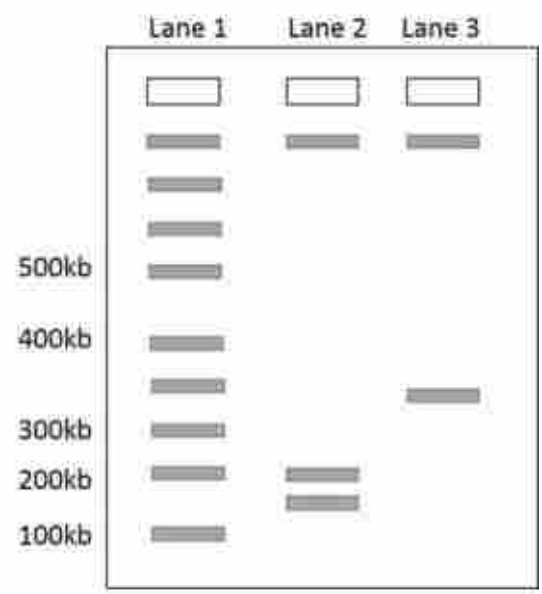
A increasing length of the primer

B increasing the denaturation temperature from 94°C to 96°C

C decreasing the annealing temperature from 56°C to 52°C

D increasing the elongation temperature from 70°C to 74°C

34 The diagram below shows the results from a restriction digestion of a normal CFTR allele (lane 2) and a mutant CFTR allele (lane 3). Lane 1 contains the DNA ladder.



Based on the results shown, which of the following statements best describes the mutation that resulted in the mutant CFTR allele?

A An additional restriction site was generated.

B One restriction site was lost.

C Two restriction sites were lost.

D The number of restriction sites remained unchanged.

35 Within its own environment, a particular cell line cannot be induced to produce a cell from a different cell line.

Which statement explains this?

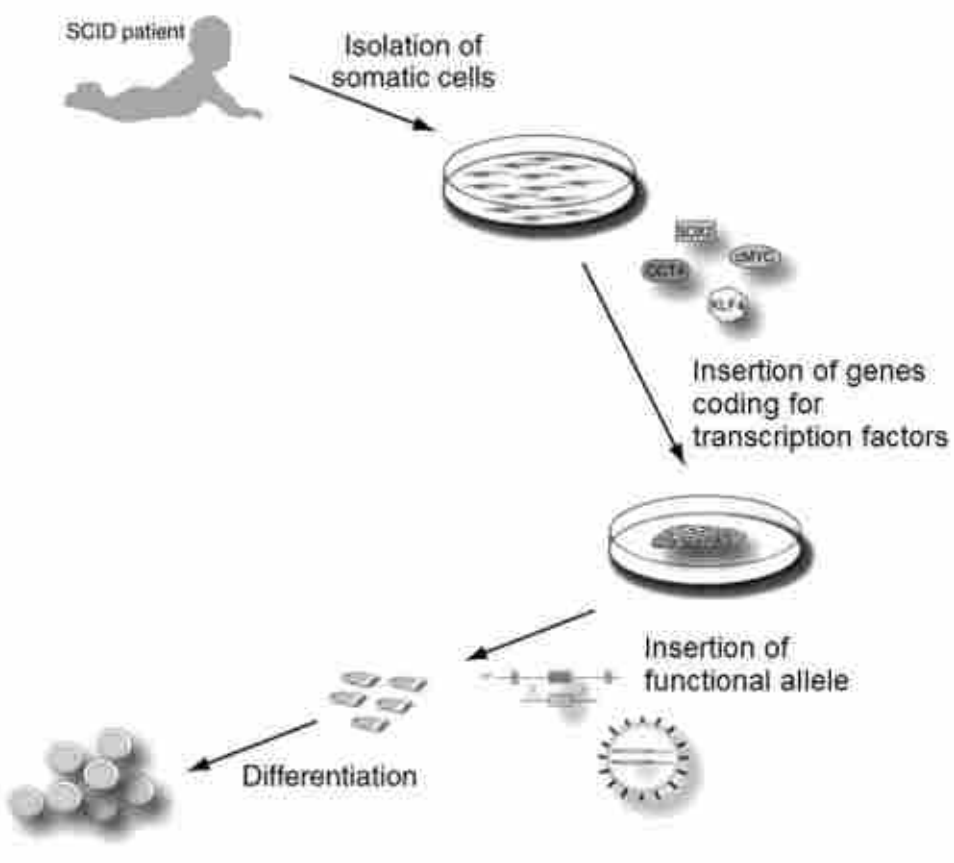
A Genes not required for a particular cell line are methylated.

B Genes not required for a particular cell line are removed by enzymes.

C Only pre-mRNA that is required for a particular cell line is processed.

D Stem cells have only the genes required for their particular cell line.

36 In 2006, scientists have discovered a means to convert somatic cells, such as skin cells, into pluripotent stem cells. By inserting four specific genes which code for transcription factors, somatic cells are able to de-differentiate and achieve pluripotency. Such pluripotent stem cells may one day be used for gene therapy to treat diseases such as severe combined immunodeficiency (SCID), as shown in the following diagram.



Which statement shows one benefit of using these novel pluripotent stem cells over embryonic stem cells?

A A functional copy of the allele could be inserted into these novel stem cells using a retroviral vector during gene therapy.

B These novel stem cells have the potential to differentiate into more types of cells, hence they can be used to treat a greater variety of diseases.

C These novel stem cells will not be rejected by the host after being transplanted back into the body.

D These novel stem cells are able to maintain the undifferentiated state for long periods of time due to the insertion of additional genes.

37 Research into gene therapy that targets germ cells (sperm and ova) has raised some concerns.

1 The inserted gene may interfere with fetal development in unexpected ways.
2 Developing babies cannot choose to have gene therapy.
3 The inserted gene could prevent the inheritance of genetic diseases.

Which concerns are ethical reasons against the use of germ cell gene therapy?

A 1, 2 and 3
B 1 and 2 only
C 1 and 3 only
D 2 and 3 only

38 In a callus culture,

A a high cytokinin to auxin ratio results in root formation.
B a low cytokinin to auxin ratio results in root formation.
C only auxin is required to induce shoot and root formation.
D only cytokinin is required to induce shoot and root formation.

39 Why can improved varieties of plants and animals, used as human food, be developed more quickly by genetic engineering than by traditional selective breeding methods?

A Genetically engineered organisms mature more quickly and breed sooner.
B The existing desirable features of the plants or animals are mostly unchanged.
C The introduced genes can improve the quality of the food produced.
D The organisms used for genetic engineering are already used for food.

40 Which statement supports the view that genetically engineered animals could help to solve the demand for food in the world?

A Transgenic pigs and sheep are produced to express higher levels of growth hormone.

B Biomedical applications of genetically engineered animals have also become routine within the pharmaceutical industry, for drug discovery, drug development and risk assessment.

C Cloning of either extinct or endangered species such as thylacine and woolly mammoth helps to retain genetic diversity in small populations.

D By inserting genes from sea anemone and jellyfish, zebrafish have been genetically engineered to express fluorescent proteins.

2016 JC2 Prelim
9648 H2 Biology
Paper 1
Suggested Answers

Qn	Ans
1	C
2	C
3	C
4	B
5	D
6	C
7	A
8	D
9	B
10	B

Qn	Ans
11	C
12	C
13	A
14	D
15	D
16	D
17	C
18	D
19	D
20	C

Qn	Ans
21	C
22	C
23	A
24	C
25	A
26	A
27	D
28	B
29	D
30	C

Qn	Ans
31	D
32	C
33	A
34	B
35	A
36	C
37	B
38	B
39	A
40	A

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

BIOLOGY

9648/02

Paper 2 Core Paper

19 August 2016

2 hours

Additional Materials: Answer Paper
Cover Page

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question.

At the end of the examination, fasten all your work securely together.

The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/20
2	/11
3	/12
4	/12
5	/13
6	/12
Section B	
7 / 8	/20
Total	/100

This document consists of **18** printed pages.

For Examiner's Use

Section A
Answer **all** questions.

1 A protease is an enzyme that digests protein.

(a) With the aid of a diagram, describe the reaction catalysed by protease.

[3]

Subtilisin is a protease synthesised by bacteria and is made up of 275 amino acids. Chymotrypsin is a protease synthesised by bacteria and is made up of 241 amino acids. Both enzymes have the same arrangement of three amino acids, serine, histidine and aspartic acid in their active sites but they are structurally different with the three amino acids being in different positions in the amino acid sequences shown in Fig. 1.1.

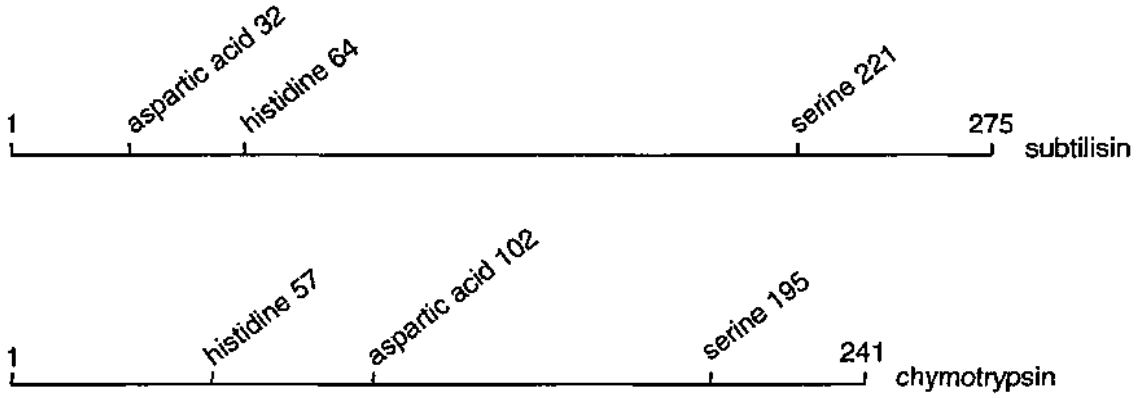


Fig. 1.1

(b) With reference to Fig. 1.1 and your knowledge on levels of protein structure, describe how amino acid residues at different positions in the protein may be brought together in the active site.

[2]

The graph in Fig. 1.2 shows how the activity of a protease varies with temperature.

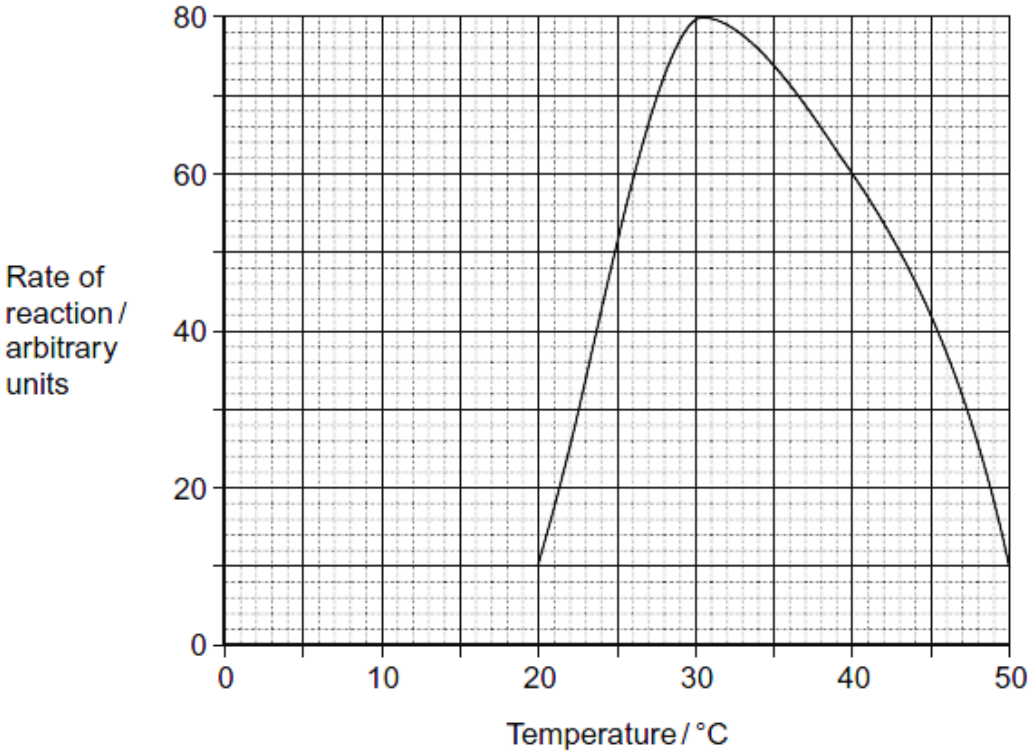


Fig. 1.2

(c) With reference to Fig. 1.2, explain the shape of the graph between 30°C and 50°C.

[3]

Students investigated the effect of pH on the activity of protease.

- The students used agar plates containing protein. The protein made the agar cloudy.
- They made four wells of equal size in the agar of each plate.
- They added a drop of protease solution to each of the wells. The protease solution in each well was at different pH.
- The students incubated the agar plates for 4 hours at constant temperature.

Fig. 1.3 shows the agar plates after they were incubated and the pH of the protease solution in each well.

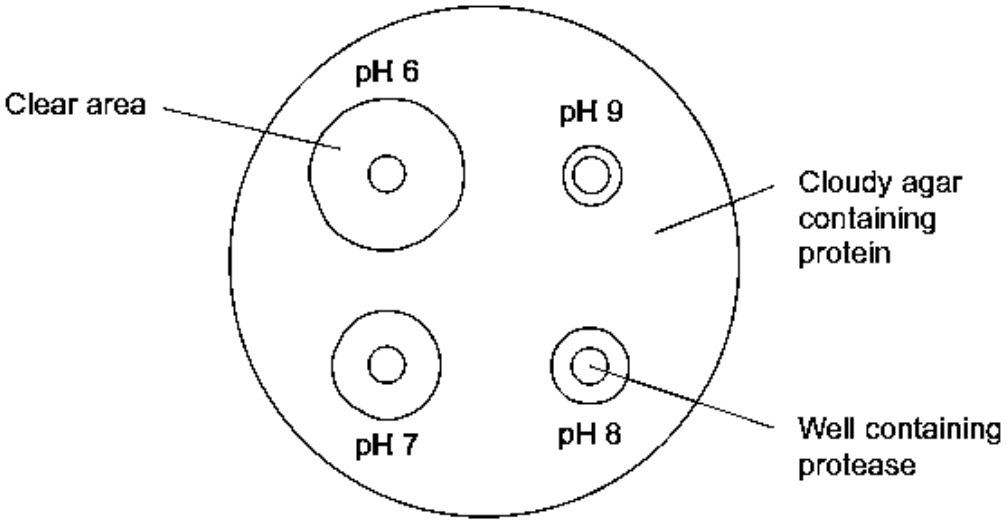


Fig. 1.3

(d) With reference to Fig. 1.3,

(i) suggest a suitable temperature for incubating the agar plates and explain your answer.

.....

.....

..... [2]

(ii) explain the effect of pH on the activity of this protease.

.....

.....

..... [1]

The gene encoding protease is transcribed to give rise to mRNA. The mRNA transcribed leaves the nucleus and is translated by ribosomes in the cytosol. Fig. 1.4 shows the process of translation.

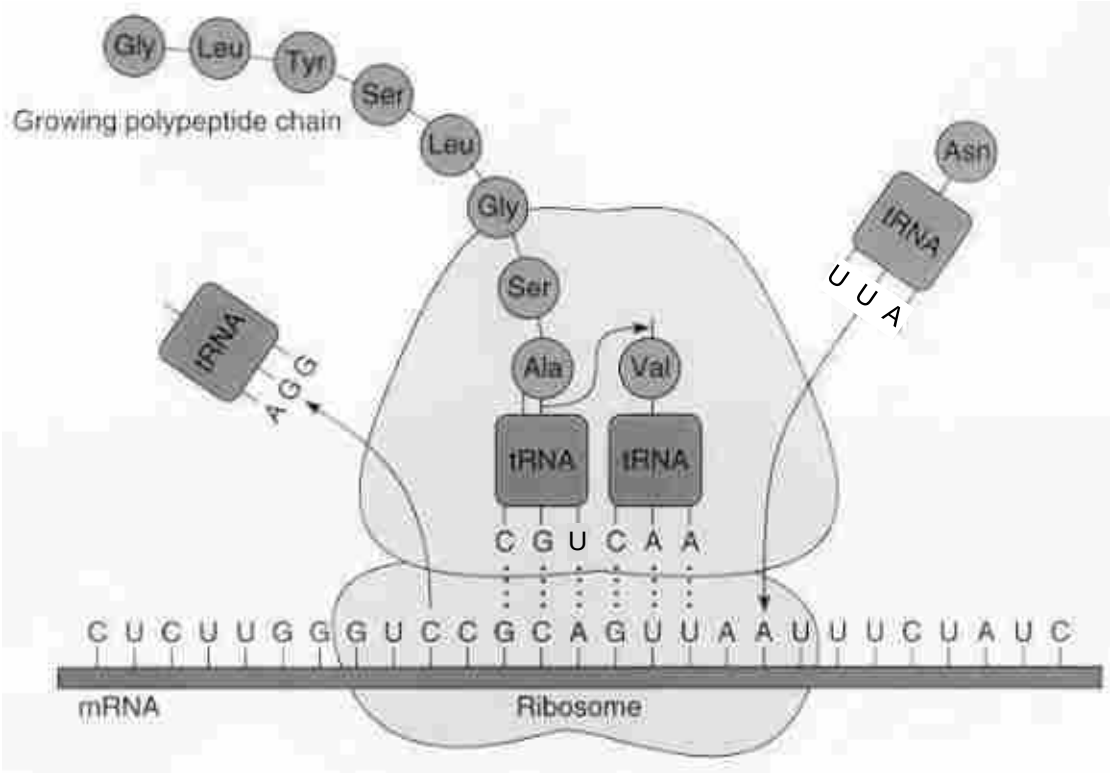


Fig. 1.4

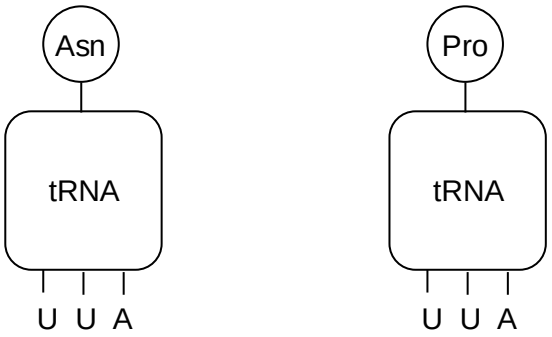
(e) With reference to Fig. 1.4, describe how the amino acid asparagine (asn) is incorporated into the growing polypeptide chain.

[4]

Aminoacyl tRNA synthetase is an enzyme that catalyses the attachment of amino acids to its corresponding tRNA.

A specific aminoacyl tRNA synthetase allows the amino acid asparagine to bind to its active site. A single base substitution occurred in the gene coding for this enzyme, resulting in the enzyme recognising proline instead of asparagine.

Fig. 1.5 shows the effect of this mutation on the resultant aminoacyl tRNA.



in normal cell **in mutated cell**

Fig. 1.5

(f) Explain how the structure of tRNA is adapted to perform its function.

.....

.....

.....

..... [2]

(g) Suggest why a mutation in this gene would have extremely damaging effects on the organism.

.....

.....

.....

.....

.....

..... [3]

[Total: 20]

2 Human Immunodeficiency Virus (HIV) is a retrovirus that causes acquired immune deficiency syndrome (AIDS).

(a) Outline the process by which HIV enters the host cell.

.....

.....

.....

..... [2]

Many integrase inhibitors have been discovered in recent years, and some of them are presently in clinical trials. One such inhibitor is Raltegravir.

In a clinical trial, one group of patients was given Raltegravir while the control group was given a placebo (drug-free pills) over 24 weeks. The number of copies of HIV-1 RNA per ml of blood plasma was measured and the results are given in Fig. 2.1.

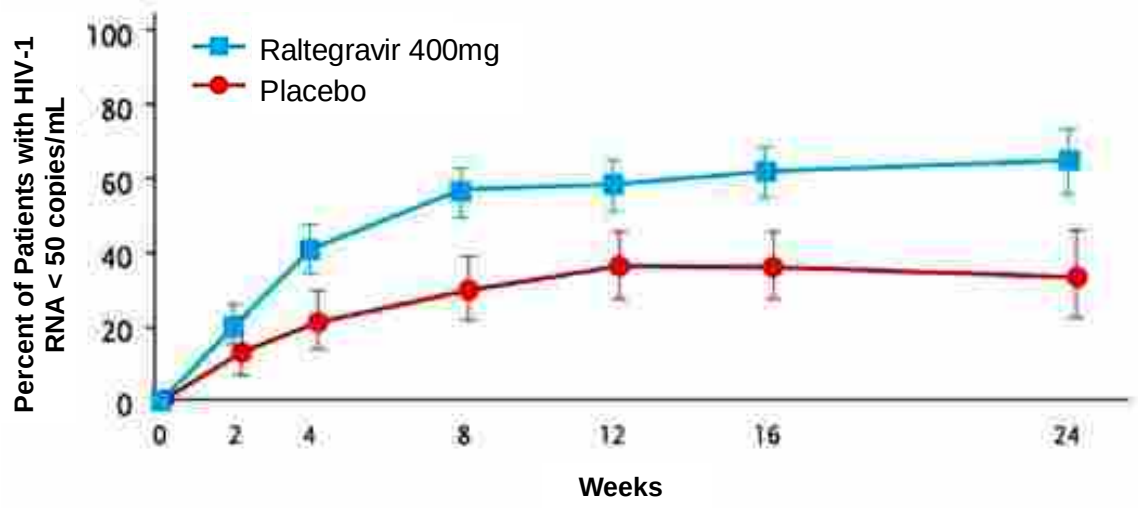


Fig 2.1

(b) With reference to Fig. 2.1, describe the difference in the effect of treating patients with Raltegravir and placebo.

.....

.....

.....

..... [2]

(c) Suggest how Raltegravir works as an antiretroviral drug.

.....

.....

.....

..... [2]

(d) The viral genome undergoes frequent mutation.

Suggest why this means that the action of Raltegravir may no longer be effective in future.

.....

.....

.....

..... [2]

Another important process in the reproductive cycle of HIV is the cleaving of polyproteins into functional proteins using protease. Fig. 2.2 shows such a process.

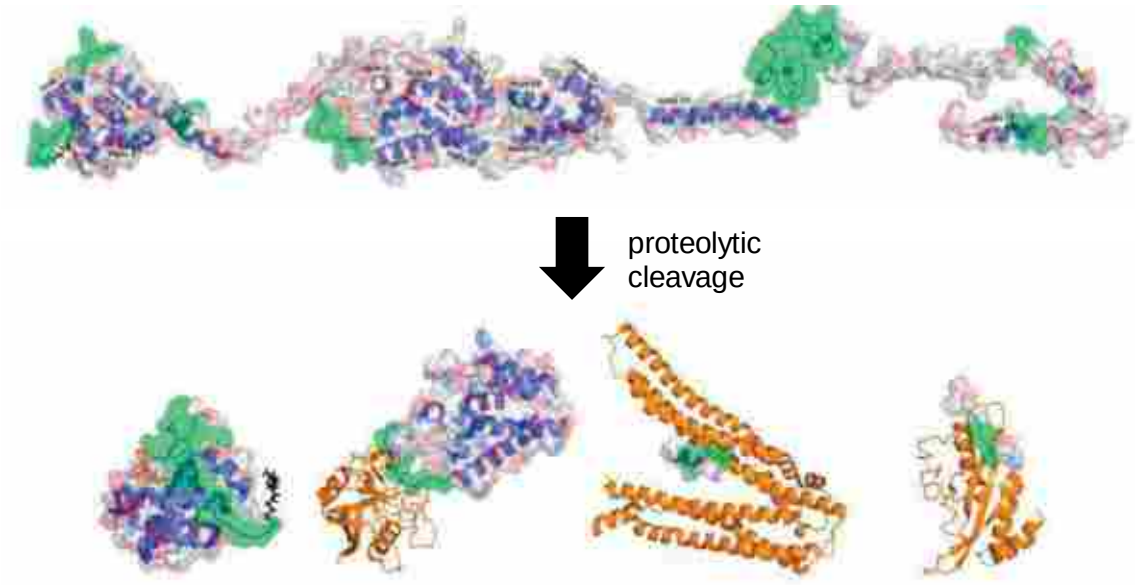


Fig 2.2

(e) Describe the polyproteins and the products formed after proteolytic cleavage.

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.....

.....

..... [3]

[Total: 11]

3 Fig. 3.1 shows the structure of a nucleosome.

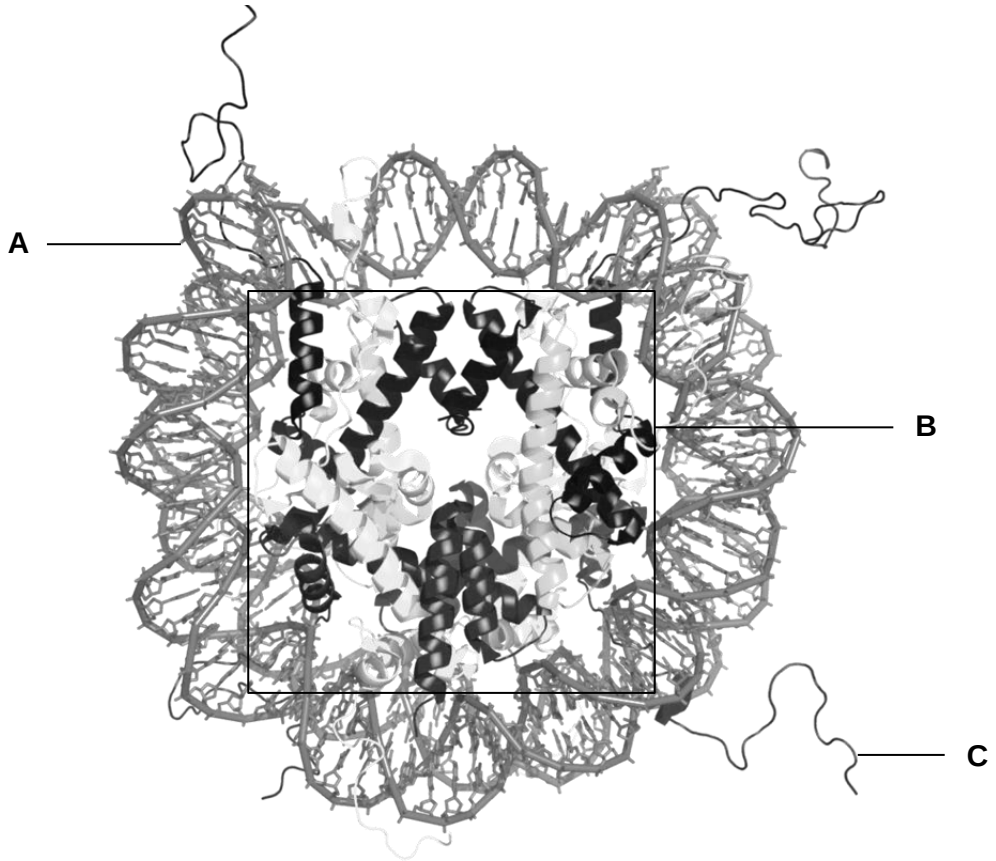

Fig. 3.1

(a) With reference to Fig. 3.1,

(i) label the structures **A** to **C**.

A .....

B .....

C ..... [2]

(ii) describe how structure **A** is stabilised.

[2]

(iii) state the secondary structure observed in structure **B**.

[1]

(iv) describe how structure **C** can be modified to influence gene expression.

[2]

(b) Describe how DNA is packaged in eukaryotes.

[5]

[Total: 12]

For Examiner's Use

4 **(a)** Explain what is meant by *epistasis*.

.....

.....

.....

..... [2]

In some species of plants, malvidin is a primary flower pigment that results in the colour wine red. Gene **A/a** codes for an enzyme that synthesises malvidin while gene **H/h** was discovered to inhibit its synthesis resulting in white flowers.

In one experiment, double heterozygote parents were crossed to produce F1 generation progeny comprising of 452 white flowering plants and 114 red wine flowering plants.

(b) Using the symbols for the alleles stated above, draw a genetic diagram to show the expected phenotypic ratio for the F1 offspring.

[5]

(c) Determine, using an appropriate statistical test, if the observed results are expected. The critical values for the chi-squared test are provided in Table 4.1.

Table 4.1

degree of freedom	Probability, p				
	0.1	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

[5]

[Total: 12]

For Examiner's Use

5 **(a)** A myelinated axon transmits impulses faster than a non-myelinated axon.

Explain this difference.

.....

.....

.....

..... [2]

Doctors investigated the relationship between myelin in the brain tissue and different types of dementia. All types of dementia involve loss of mental ability.

The doctors measured the mean amount of myelin in samples of brain tissue from:

- a control group of 12 people without dementia
- 20 people with vascular dementia (VaD)
- 19 people with Alzhemier's dementia (AD)
- 31 people with Lew body dementia (LD).

The doctors' results are shown in Fig. 5.1. The vertical bars show standard errors.

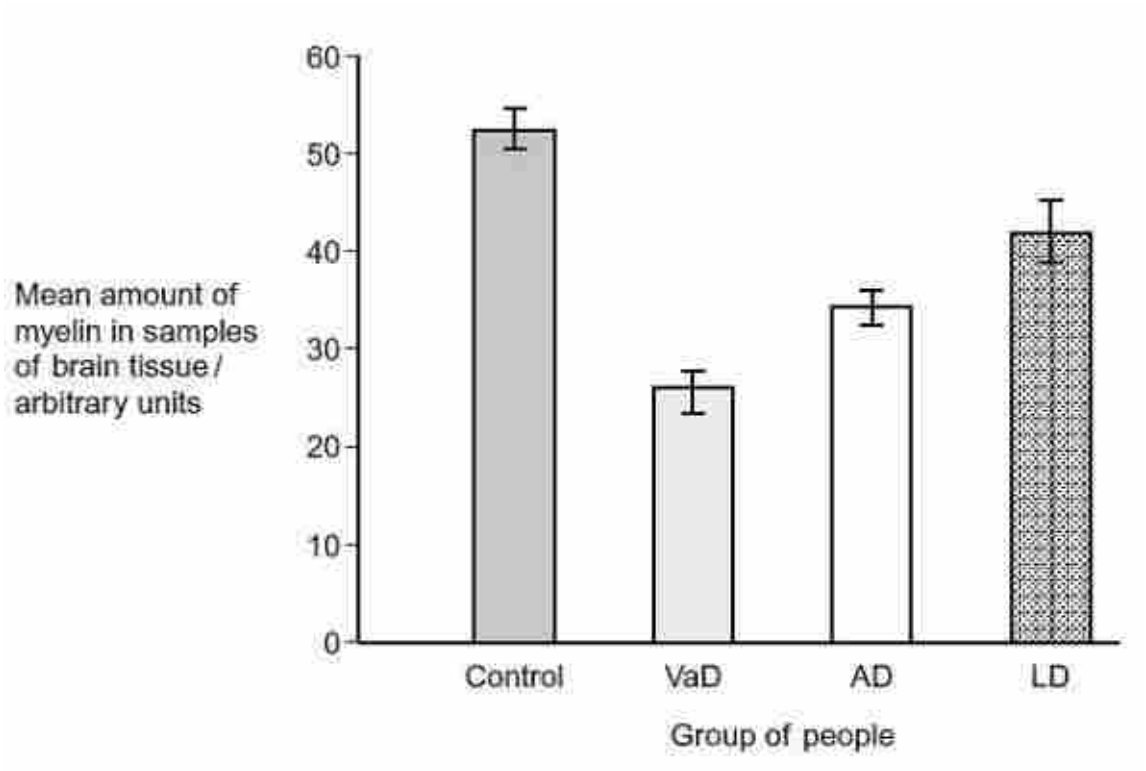

Fig. 5.1

(b) With reference to Fig. 5.1,

(i) explain the significance of the standard error bars.

.....

..... [1]

(ii) discuss whether the data supports the conclusion that there is a relationship between incidence of dementia and the amount of myelin in a person's brain.

.....

.....

.....

.....

.....

..... [3]

Cocaine is a drug that interferes with synaptic transfer. It affects neurones that release dopamine, an excitatory neurotransmitter associated with feelings of pleasure.

Fig. 5.2 shows the mechanism of action of cocaine.

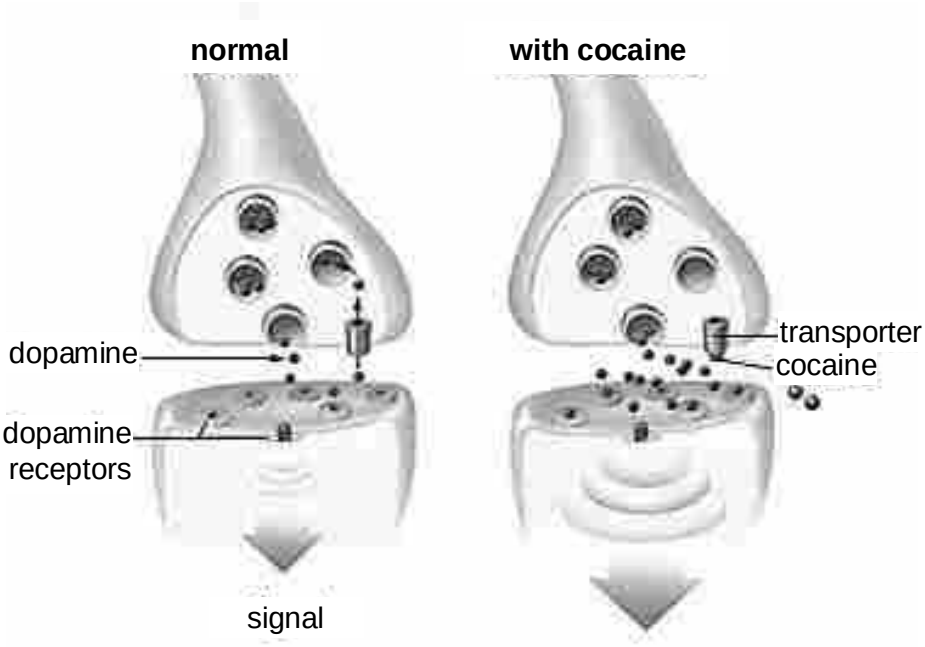

Fig. 5.2

(c) **(i)** Describe the process of synaptic transfer in normal individuals.

[4]

(ii) With reference to Fig. 5.2, explain the effects of cocaine.

[2]

(iii) Long-term cocaine use results in a decrease in the number of dopamine receptors in the post-synaptic membrane.

Suggest why cocaine abusers are no longer able to feel pleasure naturally.

[1]

[Total: 13]

For Examiner's Use

6 A region in Southern Australia used to have a huge lake system. About 500 000 years ago, the lakes started to dry up and they now consists of isolated small pools. Ten different species of a particular fish was found living in these pools. However, fossil evidence indicates that over 500 000 years ago there was only one species of the fish living in the lake.

(a) Explain how the ten species of fish evolved.

[5]

(b) Due to climate change, scientists predict that in 5000 years, water levels will rise and the pools will reform the huge lake system.

Suggest what might happen to the ten species of fish.

[2]

Tree frogs are commonly found in Southern Australia. *Hyla ewingi* and *Hyla verrauxi* are two closely related species of tree frogs. Research from breeding studies and DNA sequence data has shown that they have strong genetic compatibility.

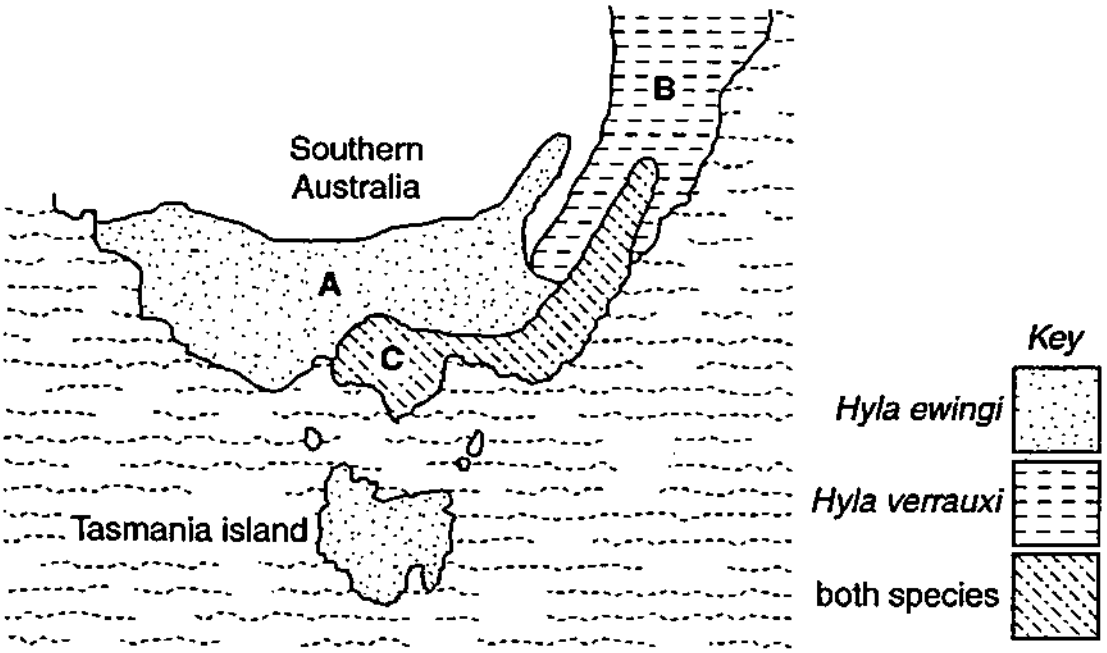

Fig 6.1

(c) **(i)** State the genus of the tree frog.

.....[1]

(ii) With reference to Fig. 6.1 and the research studies, explain how the scientists concluded that the two species of tree frogs are closely related.

.....

.....

.....

.....

.....

.....

.....

.....[4]

[Total: 12]

Section B

Answer **one** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in section **(a)**, **(b)** etc., as indicated in the question.

7 **(a)** Describe the main stages in Calvin cycle. [8]

(b) Describe the roles of membranes in photosynthesis and in respiration. [8]

(c) Explain how membrane fluidity is maintained in a cell when temperature increases. [4]

[Total: 20]

8 **(a)** Describe the structural features of collagen and how they contribute to its function. [8]

(b) Insulin polypeptide synthesised by ribosomes attached to the endoplasmic reticulum will be transported out of the beta cell.

Describe the route taken by insulin out of the beta cell. [8]

(c) Explain the roles of vesicles that emerge from the Golgi body. [4]

[Total: 20]

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	**MARK SCHEME**
CLASS	
INDEX NUMBER	

BIOLOGY

9648/02

Paper 2 Core Paper

19 August 2016

2 hours

Additional Materials: Answer Paper
Cover Page

READ THESE INSTRUCTIONS FIRST

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Section A
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Section A	
1	/20
2	/11
3	/12
4	/12
5	/13
6	/12
Section B	
7 / 8	/20
Total	/100

This document consists of **18** printed pages.

For Examiner's Use

Section A
Answer **all** questions.

1 A protease is an enzyme that digests protein.

(a) With the aid of a diagram, describe the reaction catalysed by protease.

diagram showing substrates – polypeptide / dipeptide and water
breaking of peptide bond
products – amino acids
with appropriate labels;

1. hydrolysis reaction

with the addition of a water molecule;

2. breaking of peptide bond (-CONH)

btwn amino acids; [3]

Subtilisin is a protease synthesised by bacteria and is made up of 275 amino acids. Chymotrypsin is a protease synthesised by bacteria and is made up of 241 amino acids. Both enzymes have the same arrangement of three amino acids, serine, histidine and aspartic acid in their active sites but they are structurally different with the three amino acids being in different positions in the amino acid sequences shown in Fig. 1.1.

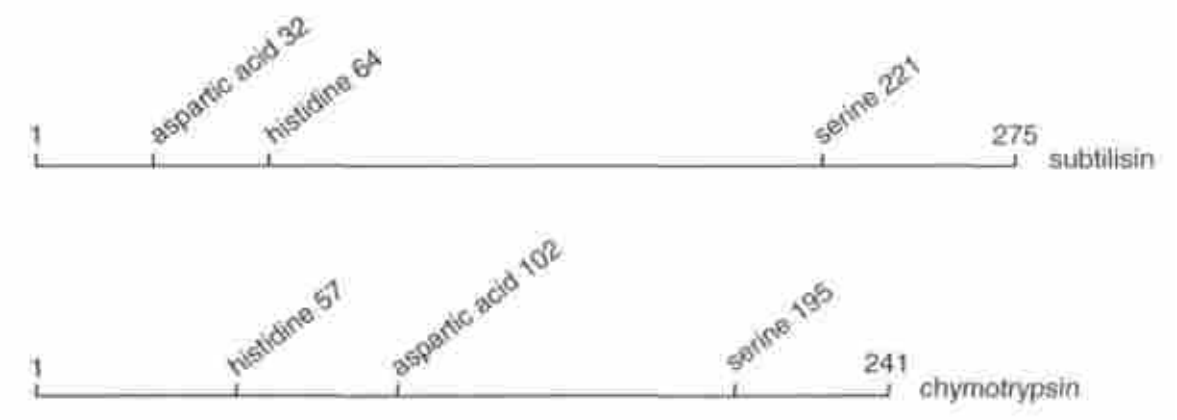


Fig. 1.1

For Examiner's Use

(b) With reference to Fig. 1.1 and your knowledge on levels of protein structure, describe how amino acid residues at different positions in the protein may be brought together in the active site.

1. 1° str is the unique linear seq of aa

e.g. aspartic acid at position 32, histidine at 64 and serine at 221;

2. folding of the polypeptide to form 3° str held by R group interactions (e.g. hydrophobic int, H bond, ionic bond, disulfide bridges)

to bring together catalytic and contact residues in the active site ➡ specific 3D config; [2]

The graph in Fig. 1.2 shows how the activity of a protease varies with temperature.

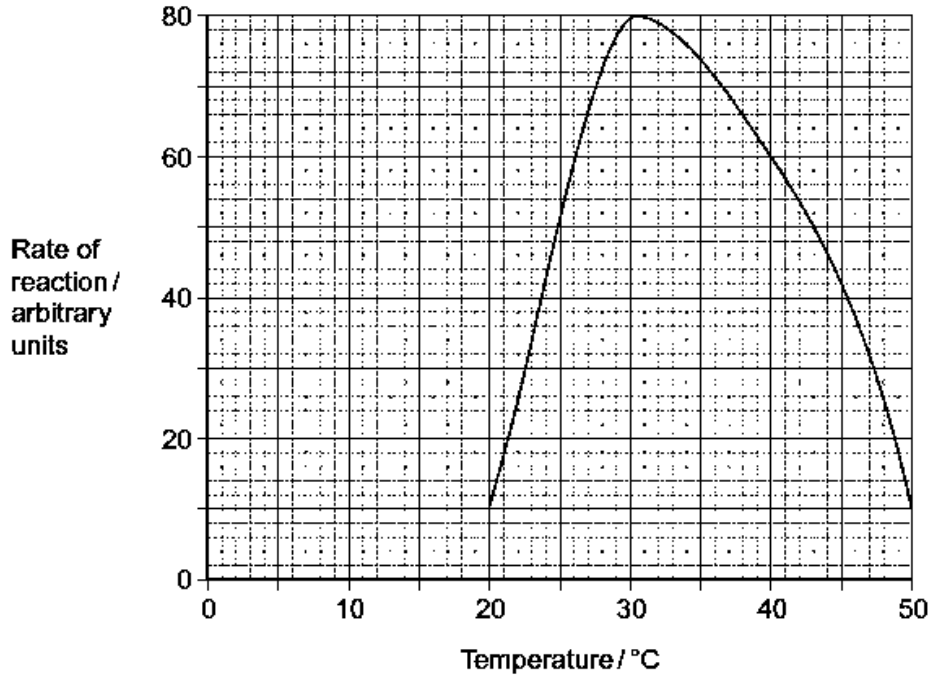


Fig. 1.2

(c) With reference to Fig. 1.2, explain the shape of the graph between 30°C and 50°C.

1. sharp ↓ in rate of reaction from 30 to 50℃

from 80 to 10 au;

2. further ↑ in temp beyond opt temp ➡ ↑ in KE of E

violent molecular vibrations ➡ breaking of intramolecular H bonds and hydrophobic interactions;

3. denaturation of enz due to unfolding of enz / disrupt 3° str

leading loss of specific 3D config of active site ➡ E no longer able to bind to S; [3]

Students investigated the effect of pH on the activity of protease.

- The students used agar plates containing protein. The protein made the agar cloudy.
- They made four wells of equal size in the agar of each plate.
- They added a drop of protease solution to each of the wells. The protease solution in each well was at different pH.
- The students incubated the agar plates for 4 hours at constant temperature.

Fig. 1.3 shows the agar plates after they were incubated and the pH of the protease solution in each well.

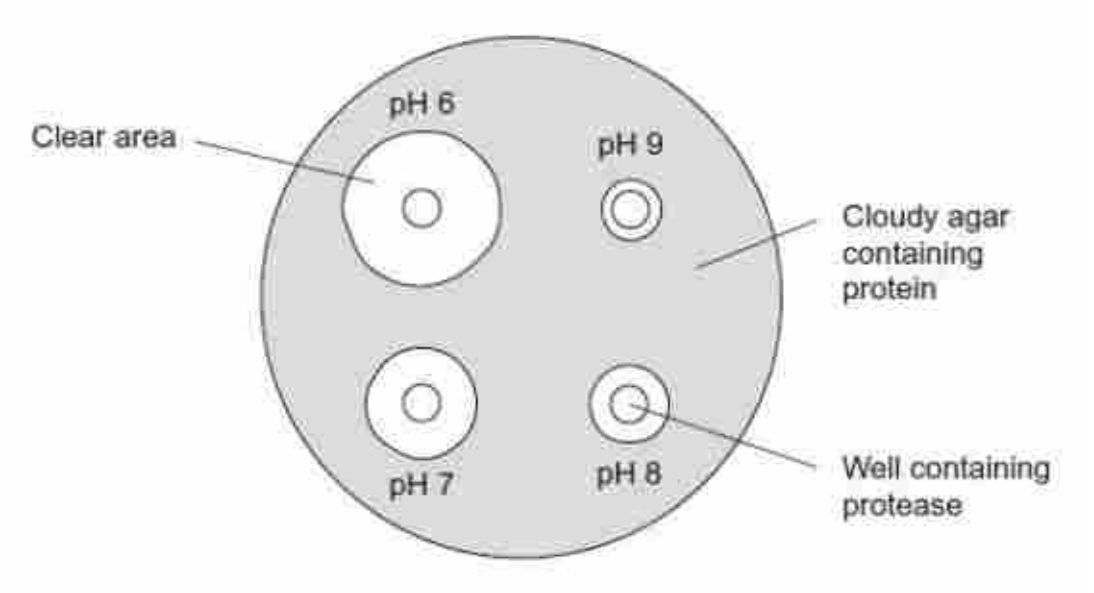


Fig. 1.3

(d) With reference to Fig. 1.3,

(i) suggest a suitable temperature for incubating the agar plates. Explain your answer.

1. 30°C;

2. opt temp of enz

highest rate of rxn / temp is not limiting; [2]

(ii) explain the effect of pH on the activity of this protease.

1. opt pH at pH 6 as seen by the largest clear area ➡ highest rate of digestion of protein in agar plate by protease;

2. ↑ in pH ➡ ↓ in enz activity as seen by ↓ in size of clear area;

[1]

The gene encoding for protease is transcribed to give rise to mRNA. The mRNA transcribed leaves the nucleus and is translated by ribosomes in the cytosol. Fig. 1.4 shows the process of translation.

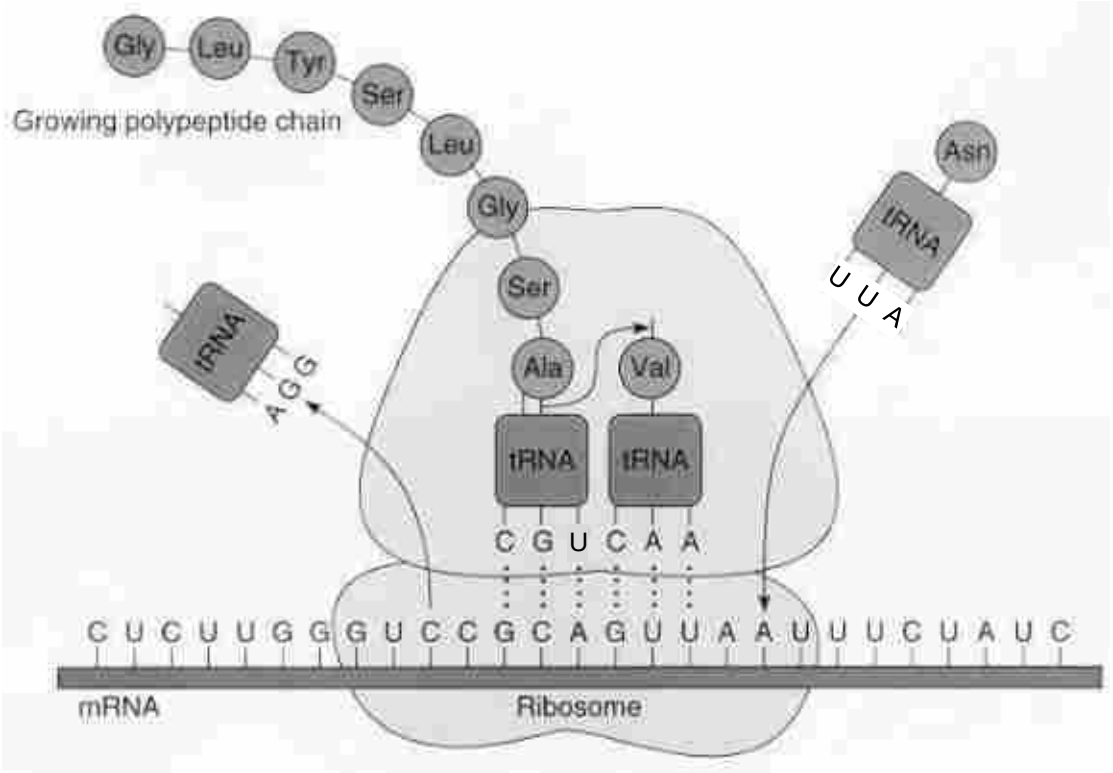


Fig. 1.4

(e) With reference to Fig. 1.4, describe how the amino acid asparagine (Asn) is incorporated into the growing polypeptide chain.

1. tRNA with anticodon UUA carrying the aa asn

binds to mRNA codon AAU via formation of H bonds btwn comp bp at A site of large ribosomal subunit;

2. formation of peptide bond between asn and val

catalysed by peptidyl transferase;

3. ribosome translocates in 5' to 3' direction

tRNA with (asn and) growing polypeptide chain is now at P site;

4. tRNA carrying val / with anticodon CAA is now at the E site

and is released; [4]

Aminoacyl tRNA synthetase is an enzyme that catalyses the attachment of amino acids to its corresponding tRNA.

(f) Explain how the structure of tRNA is adapted to perform its function.

1. contains amino acid attachment arm

for attachment of specific amino acid (via ester bond);

2. contains anticodon

that binds to mRNA codon via H bonds btwn comp bp;

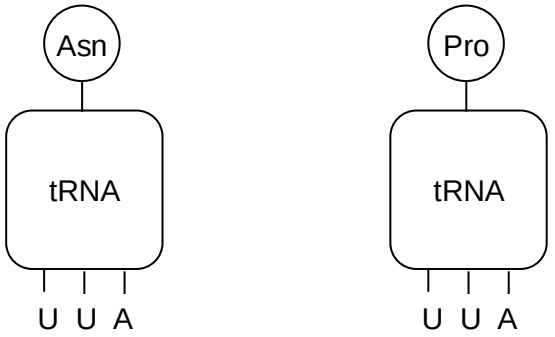
3. clover-leaf shape

contributes to specific 3D config ➡ allows binding to ribosome aminoacyl tRNA synthetase; [2]

(max 2m)

(g) A specific aminoacyl tRNA synthetase allows the amino acid asparagine to bind to its active site. A single base substitution occurred in the gene coding for this enzyme, resulting in the enzyme recognising proline instead of asparagine.

Fig. 1.5 shows the effect of this mutation on the resultant aminoacyl tRNA.



in normal cell **in mutated cell**

Fig. 1.5

Suggest why a mutation in this gene would have extremely damaging effects on the organism.

1. enz would attach pro instead of asn

to the tRNA with anticodon for asn / UUA;

2. during translation, mRNA codon AAU will code for pro instead of asn

all resultant polypeptides will have asn replaced by pro;

3. ⊿ in R group of all resultant polypeptides ➡ ⊿ in R group interactions

⊿ in specific 3D config of all resultant prot ➡ affect cellular f(x); [3]

[Total: 20]

2 HIV is a retrovirus that causes acquired immune deficiency syndrome (AIDS).

(a) Outline the process by which HIV enters the host cell.

1. gp 120 (and gp 41) on HIV envelope

recog and binds to CD4 cell surface receptors on T cells;

2. viral env fuses with CSM of host cell

releases viral nucleocapsid into host cell cytoplasm; [2]

Many integrase inhibitors have been discovered in recent years, and some of them are presently in clinical trials. One such inhibitor is Raltegravir.

In a clinical trial, one group of patients was given Raltegravir while the control group was given a placebo (drug-free pills) over 24 weeks. The number of copies of HIV-1 RNA per ml of blood plasma was measured and the results are given in Fig. 2.1.

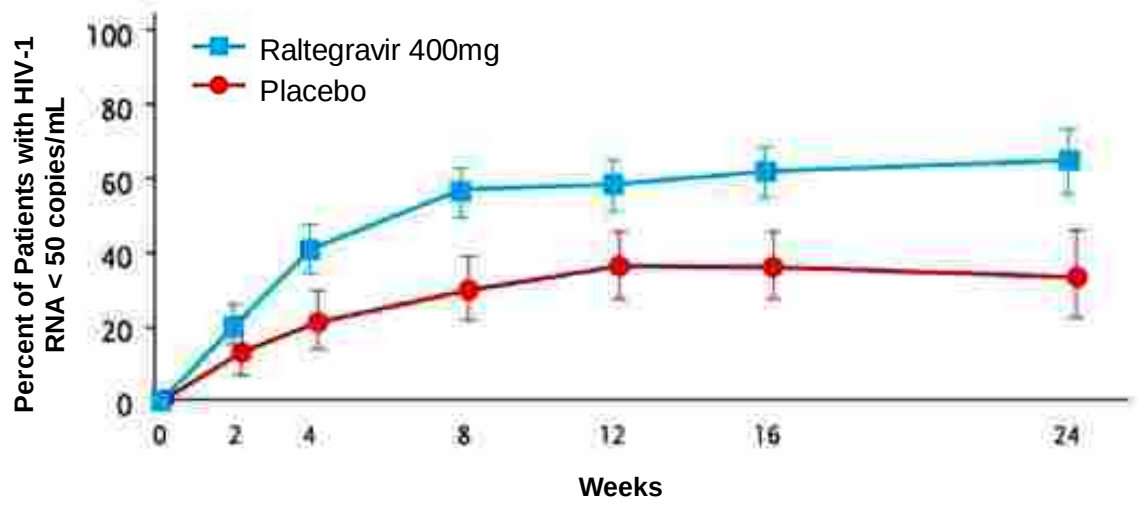


Fig 2.1

(b) With reference to Fig. 2.1, describe the difference in the effect of treating patients with Raltegravir and placebo.

1. higher percentage of patients with HIV-1 RNA<50 copies per ml in grp treated with Raltegravir vs placebo throughout 24 week treatment;

2. [QV] for Raltegravir grp: ↑ to 60% patients with HIV-1 RNA< 50 copies at week 8

for placebo grp: ↑ to 30% patients with HIV-1 RNA< 50 copies at week 8;

[2]

(c) Suggest how Raltegravir works as an antiretroviral drug.

1. (inhibits integrase) ➡ inhibits integration of HIV DNA into human chr

preventing formation of provirus;

2. resulting in HIV unable to undergo replication / viral protein synthesis

preventing formation of new virions; [2]

(d) The viral genome undergoes frequent mutation.

Suggest why this means that the action of Raltegravir may no longer be effective in future.

1. mutations in viral genome alter gene seq coding for integrase

results in change in 3D conformation of enzyme;

2. inability of Raltegravir to bind / inhibit integrase

due to non-complementary to binding site / active site; [2]

Another important process in the reproductive cycle of HIV is the cleaving of polyproteins into functional proteins using protease. Fig. 2.2 shows such a process.

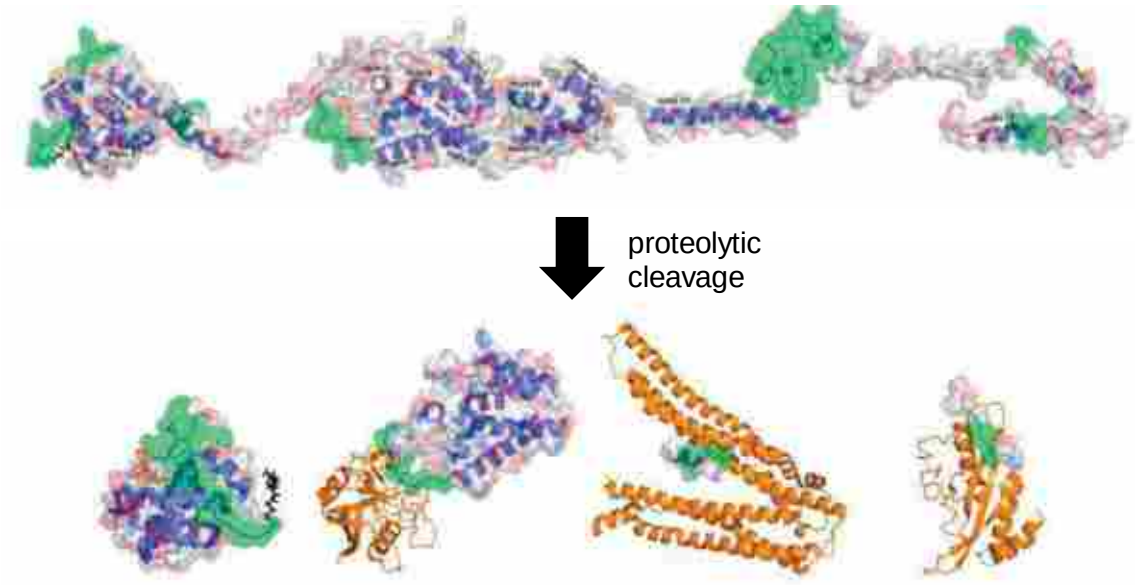


Fig 2.2

(e) Describe the polyproteins and the products formed after proteolytic cleavage.

1. Pol polyprotein cleaved by viral protease

produces enzymes such as RT / IN / HIV protease;

2. Gag polyprotein cleaved by viral protease

produces structural proteins such as capsid proteins;

3. Env polyprotein cleaved by cellular protease

produces glycoproteins gp120 and gp41; [3]

[Total: 11]

3 Fig. 3.1 shows the structure of a nucleosome.

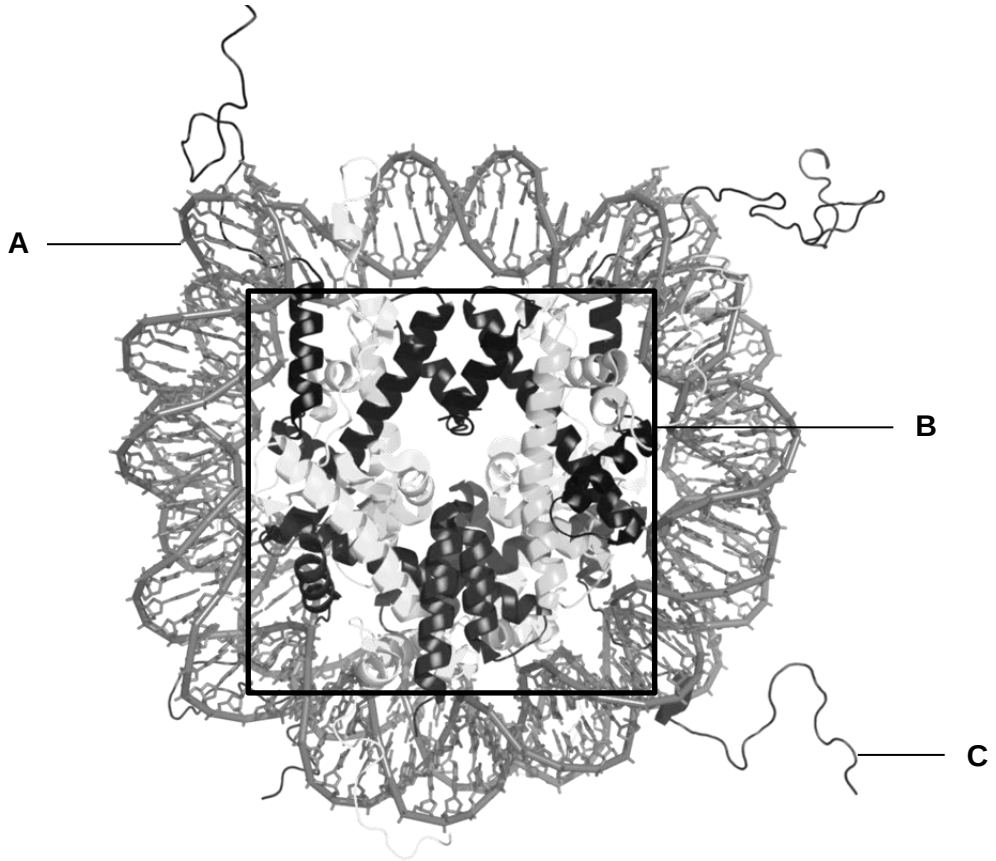


Fig. 3.1

(a) With reference to Fig. 3.1,

(i) label the structures **A** to **C**.

A ***deoxyribonucleic acid***

B ***histone protein / octamer***

C ***histone tail;;*** [2]

(2m for all correct ans, -1m for any wrong ans)

For Examiner's Use

(ii) describe how structure **A** is stabilised.

1. hydrogen bonds btwn comp bp

where A = T, C ≡ G;

2. hydrophobic interactions

btwn stacked bases; [2]

(iii) state the secondary structure observed in structure **B**.

α-helix; [1]

(iv) describe how structure **C** can be modified to influence gene expression.

1. acetylation of (lys residues on) histone tails by histone acetyltransferase

↓ +ve charge of histones ➡ ↓ histone's affinity for -ve charged DNA;

2. chromatin in more relaxed conformation

allow access of TFs and RNA pol to promoter ➡ ↑ transcription; [2]

(accept rev argument, i.e. deacetylation)

(b) Describe how DNA is packaged in eukaryotes.

1. DNA molecule wrapped 1¾ times (146bp) around histone octamer, forming a nucleosome core;

2. nucleosome core assoc with H1 prot forming the complete nucleosome;

3. linked by spacer DNA forming 10nm 'beads on a string' structure;

4. further coiled into solenoid with 6 nucleosomes per turn, forming 30nm fibre;

5. 30 nm fibre assoc with scaffold prot ➡ 300 nm fiber;

6. further coiling to form 700 nm chromatid;

[5]

(max 5m)

[Total: 12]

For Examiner's Use

4 (a) Explain what is meant by *epistasis*.

1. interaction between two genes

coding for gene pdts controlling the same characteristic / in same metabolic pathway;

2. epistatic gene overrides expression of hypostatic gene

to express its own phenotype; [2]

In some species of plants, malvidin is a primary flower pigment that results in the colour wine red. Gene **A/a** codes for an enzyme that synthesises malvidin while gene **H/h** was discovered to inhibit its synthesis resulting in white flowers.

In one experiment, double heterozygote parents were crossed to produce F1 generation progeny comprising of 452 white flowering plants and 114 red wine flowering plants.

(b) Using the symbols for the alleles stated above, draw a genetic diagram to show the expected phenotypic ratio for the F1 offspring.

parental phenotype (1m) ***white flower plant*** ***x*** ***white flower plant***

parental genotype ***AaHh*** ***x*** ***AaHh***

gametes (1m) ***AH Ah aH ah*** ***AH Ah aH ah***

punnett square (1m)

Gametes	***AH***	***Ah***	***aH***	***ah***
AH	***AAHH***	***AAHh***	***AaHH***	***AaHh***
Ah	***AAHh***	***AAhh***	***AaHh***	***Aahh***
aH	***AaHH***	***AaHh***	***aaHH***	***aaHh***
ah	***AaHh***	***Aahh***	***aaHh***	***aahh***

offspring genotype (1m) ***9 A_H_ : 3 aaH_ : 1 aahh : 3 A_hh***

offspring phenotypic ratio (1m) ***13 white : 3 wine red***
(genotype must correlate with phenotype)

[5]

(c) Determine, using an appropriate statistical test, if the observed results are expected. The critical values for the chi-squared test are provided in Table 4.1.

Table 4.1

degree of freedom	Probability, *p*				
	0.1	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

Let H_0 be the inheritance of plant colour that follows the ratio of 13:3

Phenotype	***Expected ratio***	***Observed (O)***	***Expected (E)***	***$\frac{(O-E)^2}{E}$***
white	***13***	***452***	***460***	***0.1349***
red	***3***	***114***	***106***	***0.5844***
df = 2 -1	***Total =***	***566***		

Hence, $\chi^2_{(calculated)}$ = 0.719 (3s.f.)

1. ***correct working;***
2. ***correct answer;***
3. ***at p = 0.05, df = 1, critical χ^2 = 3.84***
   calculated χ^2 < critical χ^2;
4. ***deviation btw observed and expected ratios is not statistically significant and the difference is due to chance alone;***
5. ***hence, H_o is not rejected, inheritance of plant colour follows the expected ratio of 13:3;***

ECF for 12:4 and 9:7 in (b)

For 12:4
(E) 424.5, 142.5
χ^2 = 71.2, reject Ho

For 9:7
(E) 318, 248
χ^2 = 128.9, reject Ho

[5]

[Total: 12]

For Examiner's Use

5 (a) A myelinated axon transmits impulses faster than a non-myelinated axon.

Explain this difference.

1. in myelinated neurone, myelin (is lipid-rich thus) act as electrical insulator

preventing movement of ions across axolemma;

2. cause AP to be generated only at nodes of Ranvier / nerve impulse 'jumps' from node to node

via saltatory conduction;

3. in non-myelinated axon, AP is generated along whole length of axon

via continuous conduction; [2]

Doctors investigated the relationship between myelin in the brain tissue and different types of dementia. All types of dementia involve loss of mental ability.

The doctors measured the mean amount of myelin in samples of brain tissue from:
- a control group of 12 people without dementia
- 20 people with vascular dementia (VaD)
- 19 people with Alzhemier's dementia (AD)
- 31 people with Lew body dementia (LD).

The doctors' results are shown in Fig. 3.1. The vertical bars show standard errors.

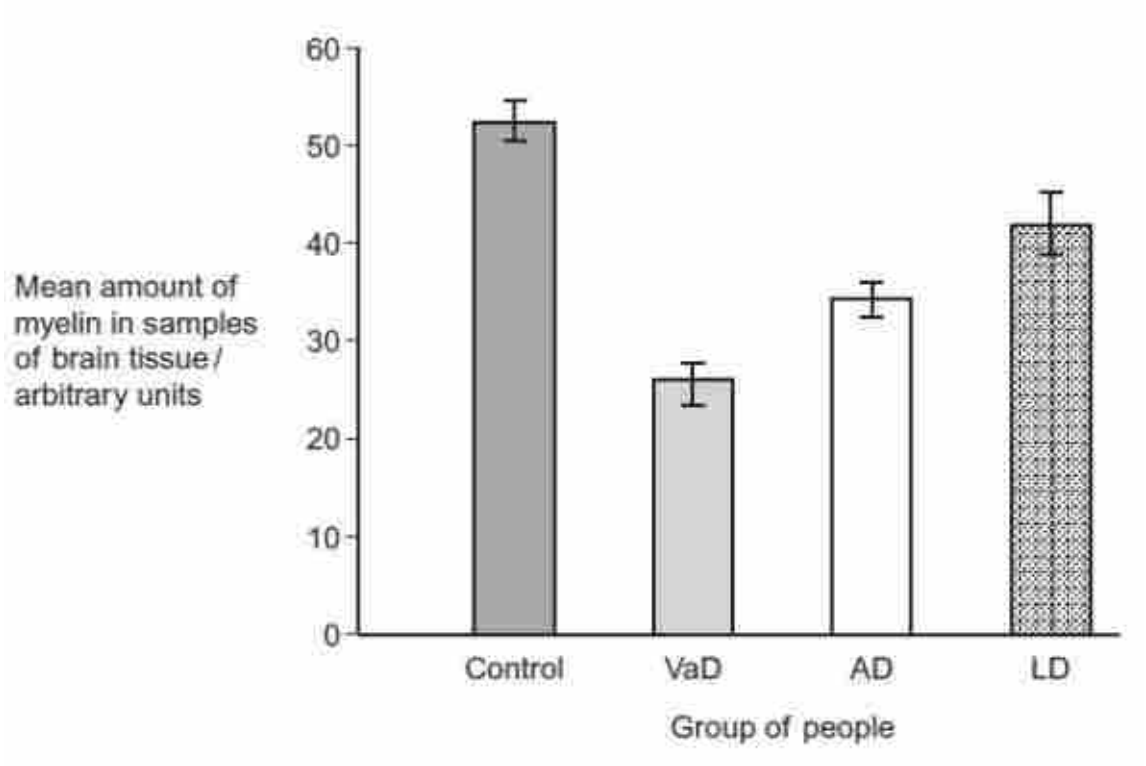


Fig. 5.1

For Examiner's Use

(b) With reference to Fig. 5.1,

(i) explain the significance of the standard error bars.

1. to indicate the range of amount of myelin in samples of brain tissue

to allow for statistical comparison; [1]

(ii) discuss whether the data supports the conclusion that there is a relationship between incidence of dementia and the amount of myelin in a person's brain.

1. mean amt of myelin lower in all dementia groups cf control

[QV] control: 52 au, VaD: 25 au, AD: 33 au, LD: 41 au;

2. [support] error bars do not overlap

diff btw mean amt of myelin are (possibly) significant / statistically significant / not due to chance;

3. [support] diff mean % related to diff types of dementia;

4. [do not support] dementia may be due to other factors / not only due to lack of myelin (e.g. genetic)

as there are significant differences in myelin in different types of dementia;

5. [do not support] small sample sizes

of n < 25 for some grps ➡ large error; [3]

® do not support due to diff sample sizes

Cocaine is a drug that interferes with synaptic transfer. It affects neurones that release dopamine, an excitatory neurotransmitter associated with feelings of pleasure.

Fig. 5.2 shows the mechanism of action of cocaine.

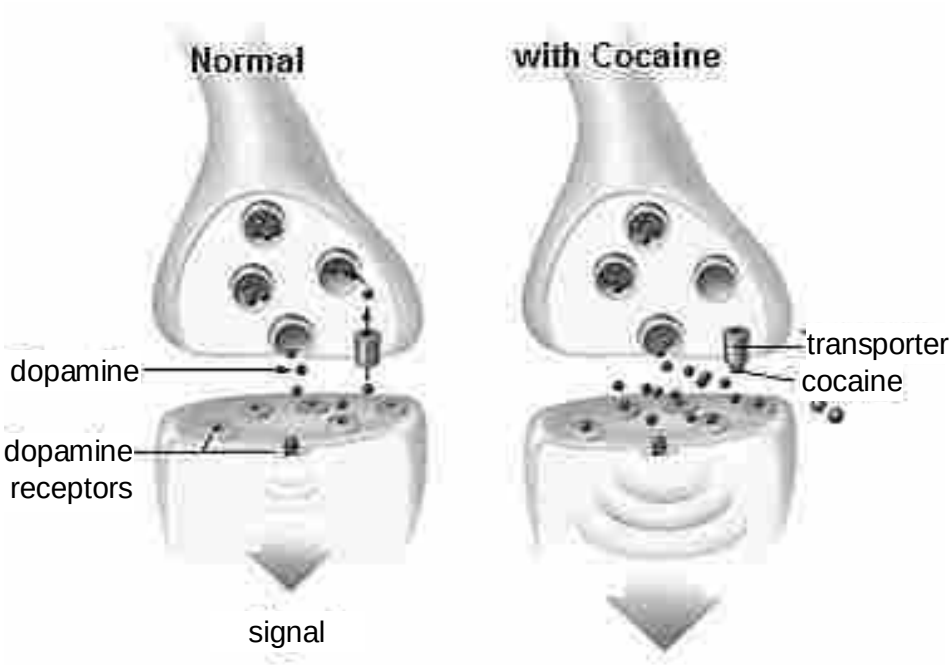


Fig. 5.2

(c) **(i)** Describe the process of synaptic transfer in normal individuals.

1. arrival of stimulus at synaptic knob ➡ opening of voltage-gated Ca^{2+} channel

Ca^{2+} influx;

2. translocation of synaptic vesicles containing dopamine to pre-synaptic mem (with aid of cytosklelton)

fuse pre-synaptic mem to release contents via exocytosis;

3. dopamine diffuses across synaptic cleft

binds to ligand-gated Na^+ channels ➡ opening of ligand-gated Na^+ channel;

4. Na+ influx ➡ depolarisation ≥ threshold pot of -50 mV

generate action potential in post-synaptic neurone; [4]

(ii) With reference to Fig. 5.2, explain the effects of cocaine.

1. cocaine blocks dopamine transporters ➡ ⊗ uptake of dopamine

dopamine accumulates in the synaptic cleft;

2. con't binding of dopamine to dopamine receptor ➡ temporal summation (of graded potential)

resulting in ↑ depol / opening of Na^+ gates thus continued feelings of pleasure; [2]

(iii) Long-term cocaine use results in a decrease in the number of dopamine receptors in the post-synaptic membrane.

Suggest why cocaine abusers are no longer able to feel pleasure naturally.

↓ no. of receptors ➡ < dopamine can bind dopamine receptors

➡ insufficient Na^+ influx to reach threshold pot thus fewer AP generated; [1]

[Total: 13]

6 A region in Southern Australia used to have a huge lake system. About 500 000 years ago, the lakes started to dry up and they now consists of isolated small pools. Ten different species of a particular fish was found living in these pools. However, fossil evidence indicates that over 500 000 years ago there was only one species of the fish living in the lake.

(a) Explain how the ten species of fish evolved.

1. variation present

in ancestral pop of fish (due to spontaneous mutation);

2. drying up of land ➡ diff env condition in each pool ➡ diff selection pressures
indiv with favourable phenotype / adaptations selected for / have selective adv;

3. ↑ survival rate & repro success

advantageous / favourable alleles passed down to offspring ➡ △ in allelic freq in gene pools;

4. geographical isolation / geographical barrier of dry land

fish pop isolated i.e. prevent interbreeding / gene flow btw pops;

5. mutations arise independently in each pop

not shared btw gene pools;

6. ↑ genetic variation between pop ➡ repro isolation / inability to interbreed

resulting in allopatric speciation / adaptive radiation; [5]

(b) Due to climate change, scientists predict that in 5000 years, water levels will rise and the pools will reform the huge lake system.

Suggest what might happen to the ten species of fish.

1. nos of each spp ↑ initially due to ↑ space / food;

2. ↑ competition btw spp ➡ reduction in nos for some / all spp
some spp outcompeted for food / habitat and therefore unable to survive / extinct;

3. spp may be able to interbreed due to lack of repro barriers
as they only diverged fr common ancestor recently (500 000 yrs ago);

4. interbreeding btw spp ➡ hybrids that ⊗ interbreed with parents ➡ new spp;

5. diff spp occupies diff habitats / ecological niches;

6. remain as diff spp / ⊗ interbreed due to presence of repro barriers
e.g. pre/post zygotic as gene pool has become too diversed; [2]

Tree frogs are commonly found in Southern Australia. *Hyla ewingi* and *Hyla verrauxi* are two closely related species of tree frogs. Research from breeding studies and DNA sequence data has shown that they have strong genetic compatibility.

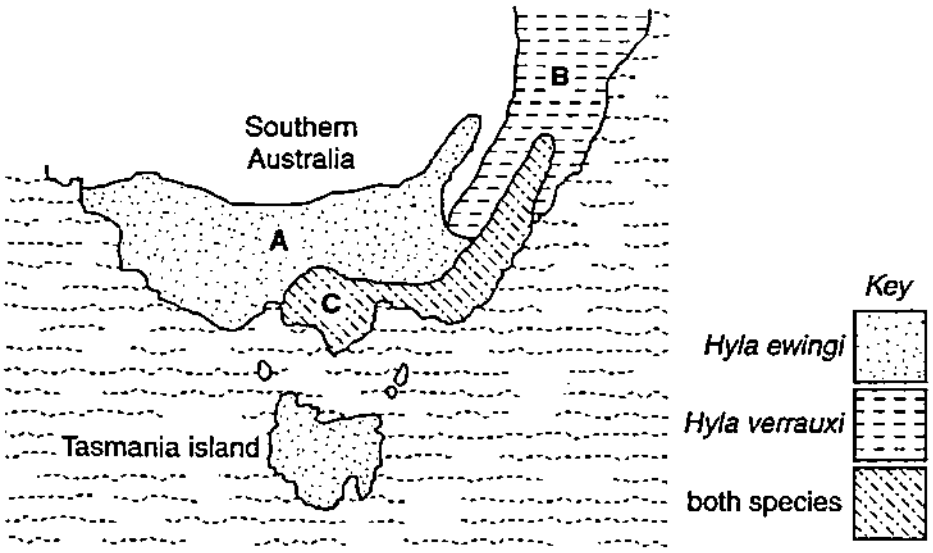


Fig 6.1

(c) **(i)** State the genus of the tree frog.

Hyla; [1]

(ii) With reference to Fig. 6.1 and the research studies, explain how the scientists concluded that the two species of tree frogs are closely related.

1. from breeding studies ➡ both spp able to interbreed

to give viable fertile offspring;

2. absence of genetic isolation / repro barrier

gene flow btw spp still able to occur;

3. strong genetic compatibility ➡ few diff btw DNA seq

short time frame for accumulations of mutations / indicates recent divergence from common ancestor;

4. present in same geographical region (of Southern Australia) overlapping habitat in C

indicates close relatedness according to ESC / biogeographical evidence (as descendants from common ancestor tend to be located in the same region); [4]

[Total: 12]

Section B
Answer **one** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in section **(a)**, **(b)** etc., as indicated in the question.

7 **(a)** Describe the main stages in Calvin cycle. [8]

1. ***occurs in stroma of chloroplast;***
2. ***first stage: carbon fixation, where CO_2 combines with ribulose bisphosphate;***
3. ***catalysed by RuBP carboxylase / Rubisco;***
4. ***forms unstable 6C intermediate, which breaks down to form 2 molecules of 3C glycerate-3-phosphate / PGA;***
5. ***second stage: carbon reduction, where PGA phosphorylated → forms 1,3-bisphosphoglycerate using ATP;***
6. ***then reduced to form 3C glyceraldehyde-3-phosphate / TP using reduced NADP;***
7. ***1 out of 6 G3P exits cycle to be converted to glucose / carbo / lipids;***
8. ***remaining 5 mol of G3P remains in cycle to regenerate (3 mols of) RuBP utilising ATP;***

(b) Describe the roles of membranes in photosynthesis and in respiration. [8]

1. ***contains electron carriers of the ETC;***
2. ***during e^- transfer, energy is released to pump H^+ from mitochondrial matrix and stroma into mitochondrial intermembrane space and thylakoid space;***
3. ***impermeability of membrane to ions;***
4. ***allows formation of proton gradient across inner mito memb and thylakoid memb;***
5. ***contains ATP synthase to harness proton motive force / which allows H^+ to diffuse through;***
6. ***to phosphorylate ADP to form ATP;***
7. ***thylakoid membrane contains photosynthetic pigments that absorb light energy during photosynthesis;***
8. ***membranes of mitochondrion contains transport proteins to allow transport of metabolites e.g. glucose / triose phosphate / pyruvate;***
9. ***the envelopes of mito and chloroplast allows for <u>compartmentalisation</u> of the cell as mito. and chloroplast enz require different / specific conditions from the rest of the cell to function;***

(c) Explain how membrane fluidity is maintained in a cell when temperature increases. [4]

1. ***increase temp ➡ increased KE ➡ phospholipids move further apart ➡ increased fluidity;***
2. ***↑ cholesterol composition ➡ binds to FA tails of phospholipids to restrict movement ➡ ↓ memb fluidity;***
3. ***↑ carbon chain length of FA tails ➡ ↑ SA for hydrophobic int ➡ ↓ memb fluidity;***
4. ***↓ degree of saturation of FA tails ➡ straight chains ➡ more closely packed ➡ more hydrophobic int ➡ ↓ memb fluidity;***

8 (a) Describe the structural features of collagen and how they contribute to its function. [8]

1. ***fibrous protein made up of amino acids linked by peptide bonds;***

[Struct to Fn] allows tight twisting to increase tensile strength

2. ***tropocollagen, 3 polypeptides twisted into triple helix;***
3. ***each polypeptide has gly-X-Y motif where X is usually proline (pro) and Y is usually proline or hydroxyproline (hyp);***
4. ***3.3 a.a. per turn with gly in centre of helix, as it is the smallest amino acid ➡ allow tight twisting to ↑ tensile strength;***

[Struct to Fn] bonds / cross-linkages increase tensile strength

5. ***presence of hydrogen bonds and covalent cross-links (at N-terminals) within the tropocollagen ➡ ↑ tensile strength;***
6. ***covalent cross links form between N terminal and C terminal of tropocollagens involving Lys and Hyl ➡ ↑ tensile strength;***

[Struct to Fn] allows deposition of minerals to increase mechanical strength

7. ***staggered arrangement / array of tropocollagen create hole region / 40nm gaps ➡ allow deposition of minerals ➡ ↑ mechanical strength;***

[Struct to Fn] bundling increases tensile strength

8. ***collagen fibrils are further strengthened and stabilized by the formation of covalent cross-links involving Lys and Hyl between tropocollagen molecules in the fibril ➡ ↑ tensile strength;***
9. ***bundling of collagen fibrils to form collagen fibres ➡ ↑ tensile strength;***
10. ***Insolubility due to position of non-polar amino acids in exterior and interior of tropocollagen/ collagen fibres, do not allow interaction with water ➡ structural support;***

(b) Insulin polypeptide synthesised by ribosomes attached to the endoplasmic reticulum will be transported out of the beta cell.

Describe the route taken by insulin out of the beta cell. [8]

1. ***insulin polypeptide / preproinsulin enters cisternal space of rER;***
2. ***cleaving of signal peptide of preproinsulin ➡ formation of 3 disulfide bridges ➡ folding to form proinsulin;***
3. ***further cleavage of C-peptide to form insulin protein, where chain A and B linked by 2 disulfide bridges;***
4. ***transport vesicle containing insulin protein pinches off from rER and is transported to and fuses with membrane of cis face of GA;***
5. ***protein is packaged, sorted, tagged in cisternae of GA;***
6. ***addition, substitution and deletion of sugar monomers on oligosaccharide chain and phosphorylation to form molecular identification tag;***
7. ***protein moves from cis face to trans face;***
8. ***packaged into secretory vesicle & bud off from trans face of GA ➡ vesicle is transported to CSM via microtubules;***
9. ***membrane of secretory vesicle fuses with CSM ➡ release of insulin out of beta cell via exocytosis;***

(c) Explain the roles of vesicles that emerge from the Golgi body. [4]

1. ***secretory vesicles carrying proteins to be released out of the cell via exocytosis;***
2. ***secretory vesicles containing memb components ➡ insert membrane components such as phospholipids / proteins into CSM;***
3. ***lysosomes containing hydrolytic enz;***
4. ***carry out phagocytosis of pathogens / food particles;***
5. ***digestion of worn-out organelles / autophagy;***
6. ***lysosomal pathway of apoptosis***
7. ***AVP;***

[Total: 20]

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

BIOLOGY

9648/03

Paper 3 Applications Paper

25 August 2016

2 hours

Additional Materials: Answer Paper
Cover Page

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/16
2	/13
3	/11
4	/12
5	/20
Total	/72

This document consists of **16** printed pages.

For Examiner's Use

Section A
Answer **all** questions.

1 Diabetes mellitus is a disease that results in the inability to regulate one's blood glucose levels, either due to lack of insulin or insensitivity to insulin.

Injection of insulin before meals helps patients to keep blood glucose within set point. Insulin used to be purified from animal sources but genetic engineering has now provided an alternative source.

(a) State **two** advantages of genetically engineered insulin compared to those obtained from animal sources.

.....

.....

.....

..... [2]

Human insulin is isolated using *EcoR*I from the cDNA library and ligated into plasmid shown in Fig. 1.1. The number of base pairs between the restriction recognition sites is shown.

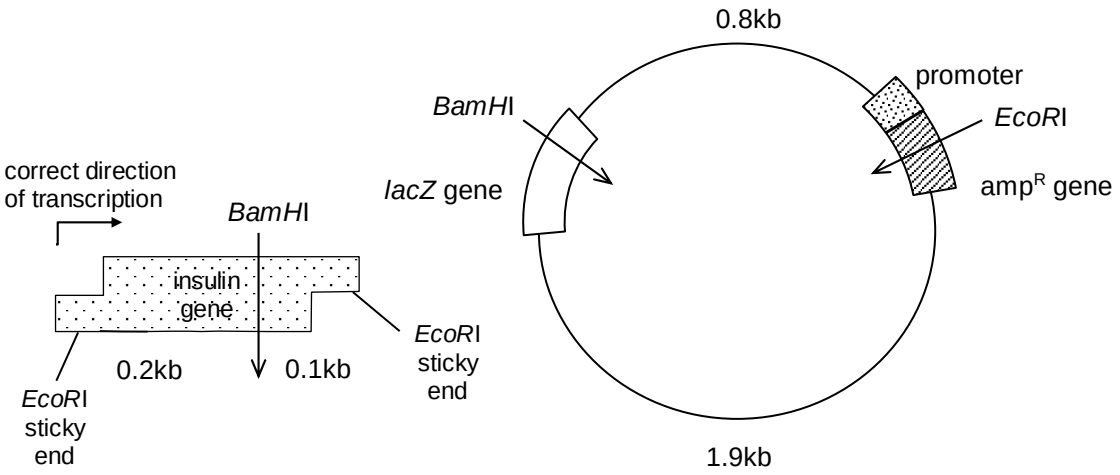


Fig. 1.1

Plasmids were introduced into bacteria host cells and grown on nutrient medium containing X-gal. A replica plate was made by transferring bacteria colonies from the first plate to nutrient medium containing ampicillin. Colonies growing in the two plates are shown in Fig. 1.2.

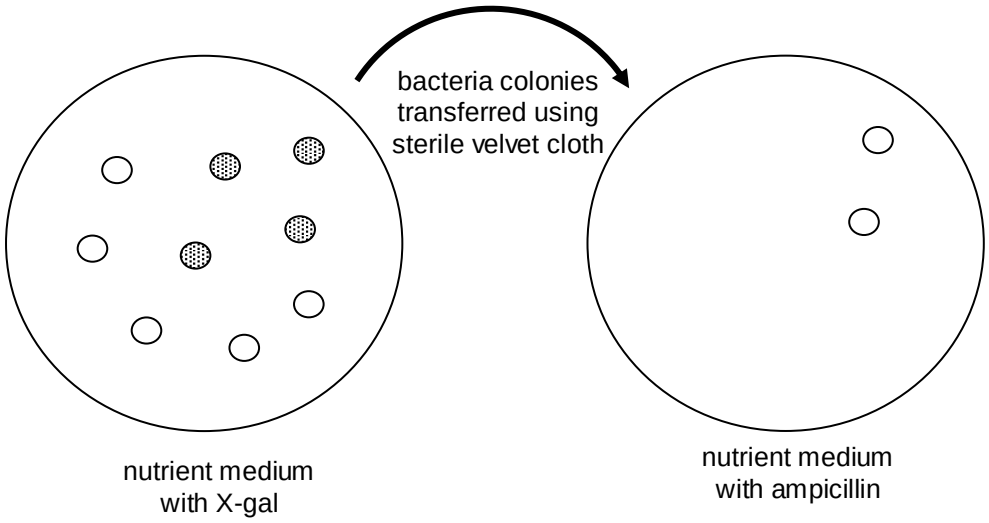


Fig. 1.2

Legend

- blue colony
- white colony

(b) **(i)** State **one** possible bacteria host cell.

.....[1]

(ii) Explain how plasmids were introduced into host cells.

.....

.....

.....

.....

.....

.....

.....

.....[4]

(c) **(i)** On Fig. 1.2, label the recombinant colony/colonies with an '**X**'. [1]

(ii) Explain how you arrive at your answer in **(c)(i).**

.....

.....

.....

..... [2]

The insulin gene was found to be inserted into plasmids in two possible orientations. To determine if the insulin gene was inserted correctly, recombinant plasmids were isolated, digested with *BamH*I and separated by gel electrophoresis.

Fig. 1.3 shows the outline of the electrophoresed gel.

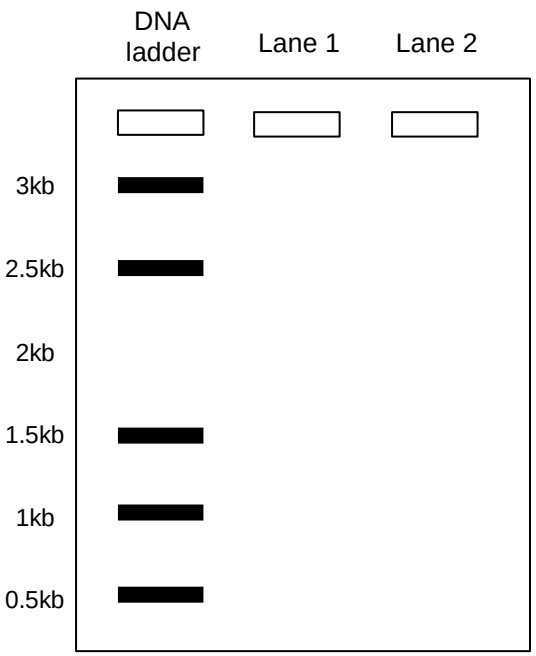


Fig. 1.3

(d) On Fig. 1.3, illustrate the bands found if plasmids with insulin gene inserted

(i) correctly was loaded in lane 1; [1]

(ii) wrongly was loaded in lane 2. [1]

For Examiner's Use

(e) Describe how gel electrophoresis is used to separate the restriction fragments.

[4]

[Total: 16]

2 X-linked Severe Combined Immunodeficiency (X-SCID) is a recessive genetic disorder. Diseased individuals suffer from compromised immune system due to malfunctioning lymphocytes.

(a) **(i)** Describe the cause and explain the symptoms of X-SCID.

[3]

(ii) Explain why males are more likely to suffer from the disease compared to females.

[1]

X-SCID can be treated by *ex vivo* gene therapy shown in Fig. 2.1.

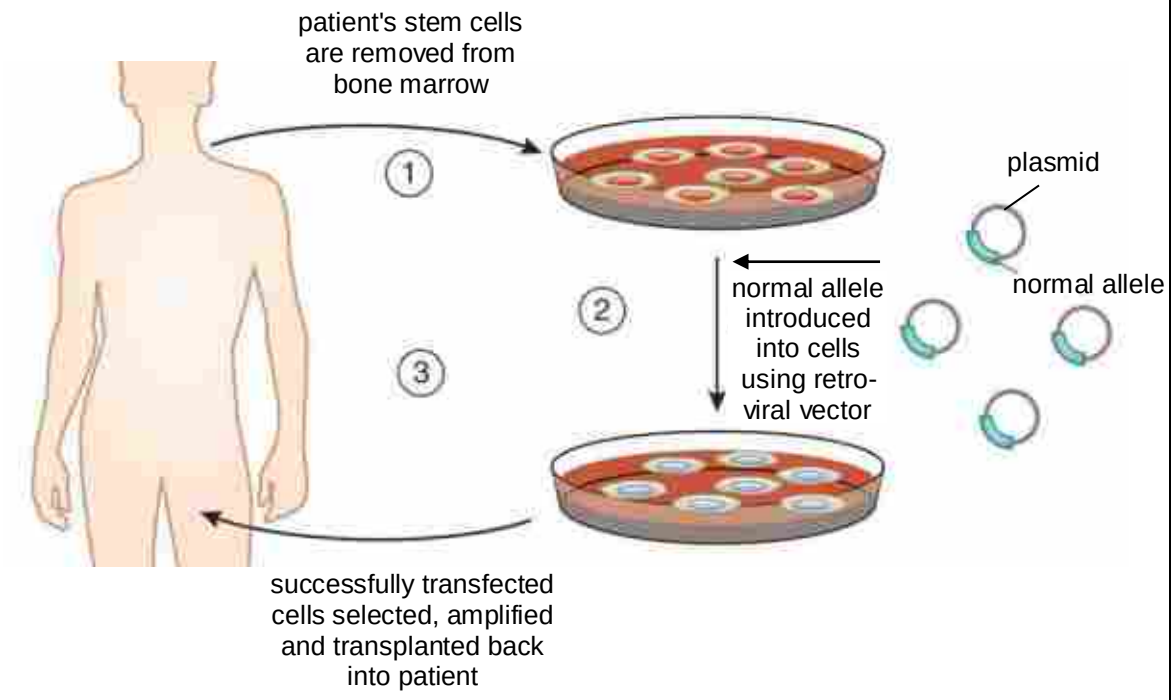


Fig. 2.1

(b) **(i)** State **two** reasons why the *ex vivo* approach was used instead of *in vivo*.

.....

.....

.....

..... [2]

(ii) Suggest why the normal allele was ligated into a plasmid before introduction into cells.

.....

..... [1]

(iii) Suggest how successfully transfected cells were selected.

.....

.....

.....

..... [2]

For Examiner's Use

Normal lymphocytes were detected in some patients' blood for several months following gene therapy. Some of the patients who underwent this treatment were subsequently diagnosed to suffer from leukaemia (cancer of blood cells).

(c) **(i)** Explain why normal lymphocytes were detected in patients' blood for several months following gene therapy.

.....

.....

.....

..... [2]

(ii) Explain how gene therapy could have led to the development of leukaemia in other patients.

.....

.....

.....

..... [2]

[Total: 13]

For Examiner's Use

3 The carp, shown in Fig. 3.1, is a large freshwater fish native to central Asia. It was introduced to Australia by humans in the mid-1800s, where it subsequently became an aquatic pest.

Fig. 3.1

(a) Suggest why the carp became a pest when it was introduced into Australia.

.....

..... [1]

Scientists tried to control the carp by using gene technology. They inserted a gene into carp embryos that prevents the production of an enzyme, aromatase. Aromatase catalyses the conversion of testosterone into oestrogen. The inserted gene causes female embryos to develop as males.

The inserted gene produces mRNA with a base sequence that is complementary to the base sequence of the mRNA produced by the aromatase gene. Table 3 shows part of the base sequence of the aromatase gene. It also shows part of the base sequence of the mRNA produced by the inserted gene.

Table 3

	base sequence					
template strand of aromatase gene	T	G			A	
mRNA transcribed from aromatase gene						
template strand of inserted gene						
mRNA transcribed from inserted gene			G	C		U

(b) Complete Table 3 to show the base sequences in the mRNAs transcribed and the inserted gene. [3]

For Examiner's Use

(c) Describe how the inserted gene was introduced into the carp embryos.

.....

.....

.....

..... [2]

The genetically modified (GM) carp were released into the environment in 2006. Fig. 3.2 shows the effect on wild carp populations for the subsequent years.

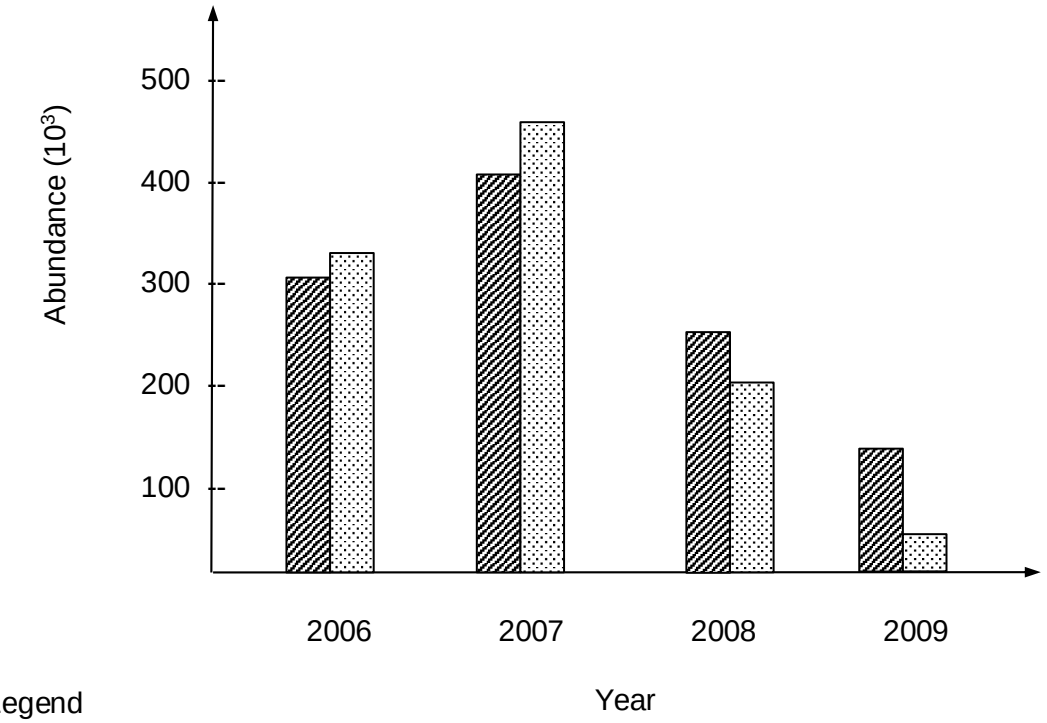


Fig. 3.2

For Examiner's Use

(d) With reference to Fig. 3.2 and information on the inserted gene, explain the effect of releasing GM carp on carp populations.

[5]

[Total: 11]

For Examiner's Use

4 Planning question

Visking tubing is a selectively permeable membrane that allows small molecules like glucose to pass through. Fig. 4.1 shows how a Visking tubing can be set up to investigate diffusion rates.

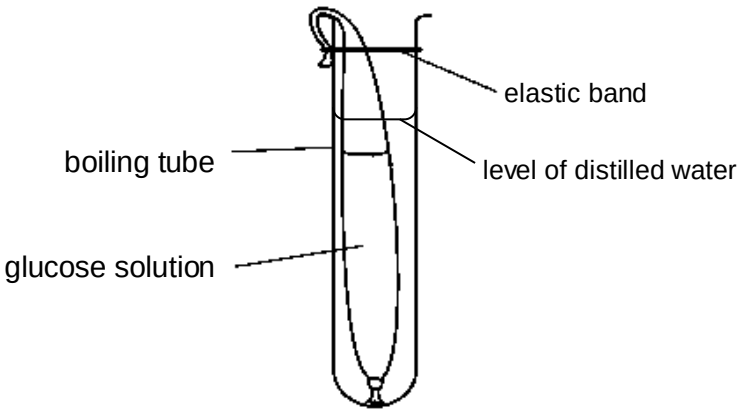


Fig. 4.1

Using this information and your own knowledge, design an experiment to investigate the effect of concentration on rate of glucose diffusion.

You must use:
- 10% glucose solution,
- distilled water,
- Benedict's solution,
- Visking tubing,
- boiling tube,
- elastic band.

You may select from the following apparatus and use appropriate additional apparatus:
- normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods, etc.,
- syringes,
- Bunsen burner, tripod stand.

Your plan should:
- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

For Examiner's Use

For Examiner's Use

For Examiner's Use

For Examiner's Use

5 Free-response question

Write your answers to this question on the separate answer paper provided.

Your answers:
- should be illustrated by large, clearly labelled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a), (b),** etc., as indicated in the question.

(a) The patient's own stem cells are frequently modified for use in treating genetic diseases via gene therapy.

Explain why these stem cells are suited for this purpose. [6]

(b) The therapeutic gene used for gene therapy can be amplified using polymerase chain reaction (PCR). Describe the process of PCR. [8]

(c) The therapeutic gene can be delivered using viral or non-viral vectors. Compare the use of these two modes of gene delivery. [6]

[Total: 20]

INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME **MARK SCHEME**

CLASS _____ INDEX NUMBER _____

BIOLOGY

9648/03

Paper 3 Applications Paper

25 August 2016

2 hours

Additional Materials: Answer Paper
Cover Page

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/16
2	/13
3	/11
4	/12
5	/20
Total	/72

This document consists of **16** printed pages.

For Examiner's Use

Section A
Answer **all** questions.

1 Diabetes mellitus is a disease that results in the inability to regulate one's blood glucose levels, either due to lack of insulin or insensitivity to insulin.

Injection of insulin before meals helps patients to keep blood glucose within set point. Insulin used to be purified from animal sources but genetic engineering has now provided an alternative source.

(a) State **two** advantages of genetically engineered insulin compared to those obtained from animal sources.

1. religious considerations

insulin may be purified from animals that violate religious practices e.g. Muslims cannot use porcine insulin;

2. insulin from animal sources may cause allergy rxn in patients

GE source is identical to human insulin as it is transcribed & translated from human insulin gene;

3. can be produced in larger quantities

to meet high demands; (ANY 2) [2]

Human insulin is isolated using *EcoR*I from the cDNA library and ligated into plasmid shown in Fig. 1.1. The number of base pairs between the restriction recognition sites is shown.

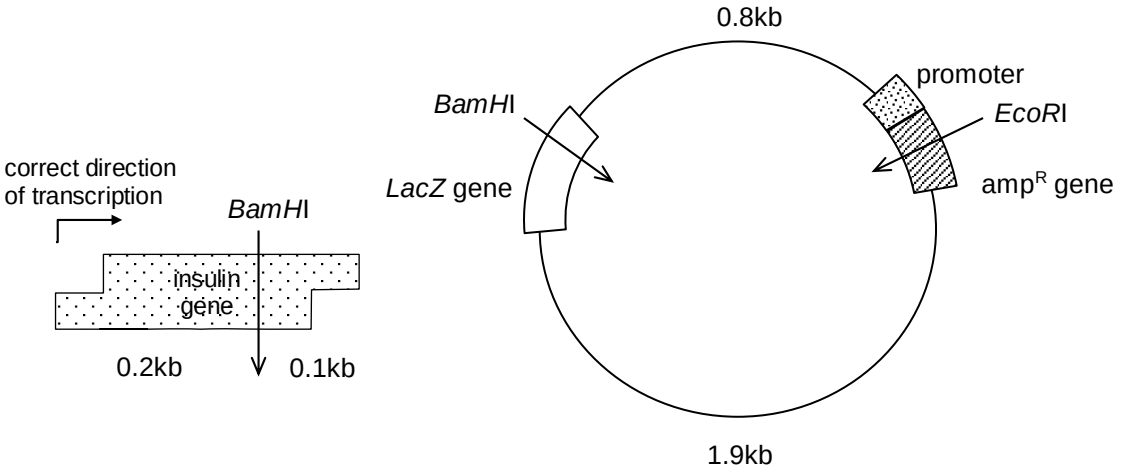


Fig. 1.1

Plasmids were introduced into bacteria host cells and grown on nutrient medium containing X-gal. A replica plate was made by transferring bacteria colonies from the first plate to nutrient medium containing ampicillin. Colonies growing in the two plates are shown in Fig. 1.2.

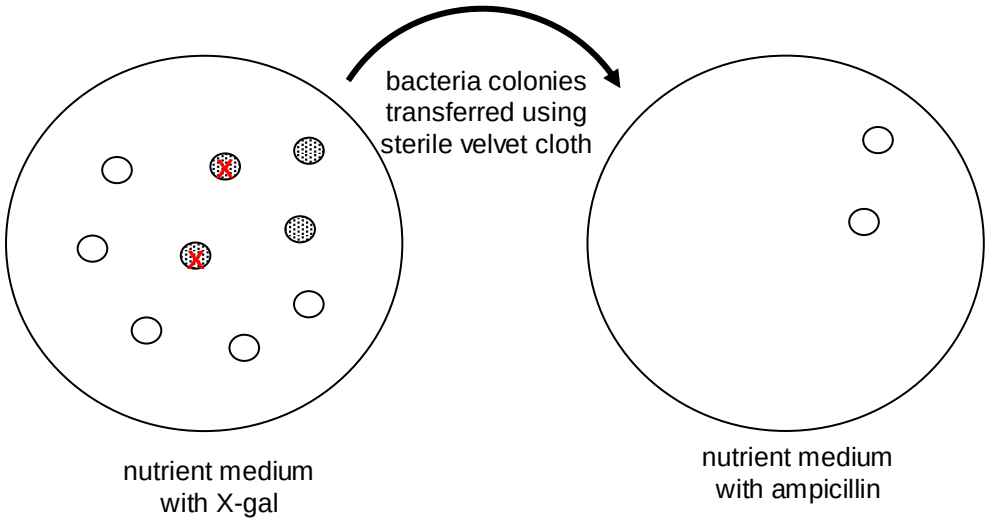


Fig. 1.2

Legend

- blue colony
- white colony

(b) **(i)** State **one** possible bacteria host cell.

Escherichia coli; [1]

(ii) Explain how plasmids were introduced into host cells.

1. (artificial) transformation

via heat shock;

2. in cold $CaCl_2$

to induce competence / reduce repulsion btw mem & DNA;

3. in 42^oC for 1 – 2 min

to cause temporary poration in mem;

4. back into 0^oC

to close pores to prevent plasmid from escaping; [4]

(c) **(i)** On Fig. 1.2, label the recombinant colony/colonies with an '**X**'. [1]

(ii) Explain how you arrive at your answer in **(c)(i).**

1. successfully transformed bact has plasmid intact lacZ gene coding for β-galactosidase which converts X-gal → blue cpd thus are blue;

2. transformed bact with recombinant plasmid will have disrupted amp^R gene / have undergone insertional inactivation thus recombinant bact are blue colonies in the 1st plate that does not grow in replica plate; [2]

The insulin gene was found to be inserted into plasmids in two possible orientations. To determine if the insulin gene was inserted correctly, recombinant plasmids were isolated, digested with *BamH*I and separated by gel electrophoresis.

Fig. 1.3 shows the outline of the electrophoresed gel.

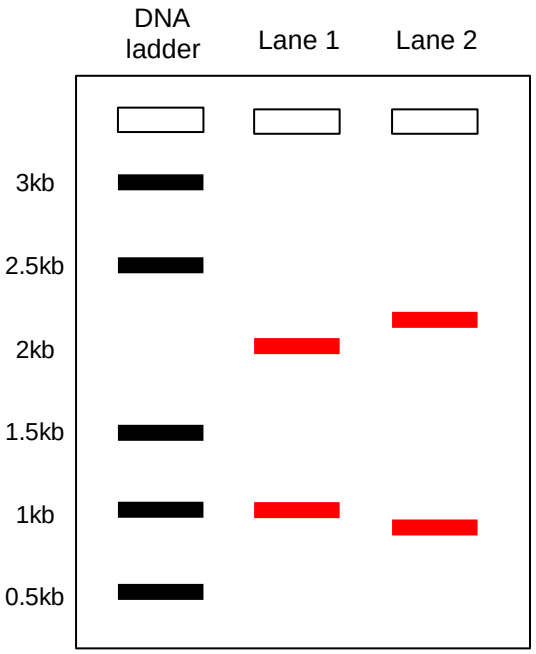


Fig. 1.3

(d) On Fig. 1.3, illustrate the bands found if plasmids with insulin gene inserted

(i) correctly was loaded in lane 1, [1]

(ii) wrongly was loaded in lane 2. [1]

(e) Describe how gel electrophoresis is used to separate the restriction fragments.

1. restriction fragments are loaded in wells of agarose gel near cathode

gel submerged in buffer with ions to maintain pH & conduct electricity;

2. DC / voltage applied aX gel

–vely charged DNA migrates towards anode;

3. with gel acting as molecular sieve that impedes movement of DNA

at speeds inversely proportional to fragment length;

4. fragments of the same length would be found at the same region

forming a band; [4]

[Total: 16]

2 X-linked Severe Combined Immunodeficiency (X-SCID) is a recessive genetic disorder. Diseased individuals suffer from compromised immune system due to malfunctioning lymphocytes.

(a) **(i)** Describe the cause and explain the symptoms of X-SCID.

1. mutation in gene on X chromosome

coding for γ_c chain in IL2;

2. unable to bind cytokines / interleukins

due to $\triangle$ in 3D config;

3. unable to $\oplus$ cell division & proliferation of B & T lymphocytes

lack of / malfunctioning WBC ➡ immune sys is compromised; [3]

(ii) Explain why males are more likely to suffer from the disease compared to females.

males only have 1 copy of X chromosome ➡ inheritance of a single copy of the recessive allele results in the disease;

Accept alternative argument of females having 2 X chromosome [1]

X-SCID can be treated by *ex vivo* gene therapy shown in Fig. 2.1.

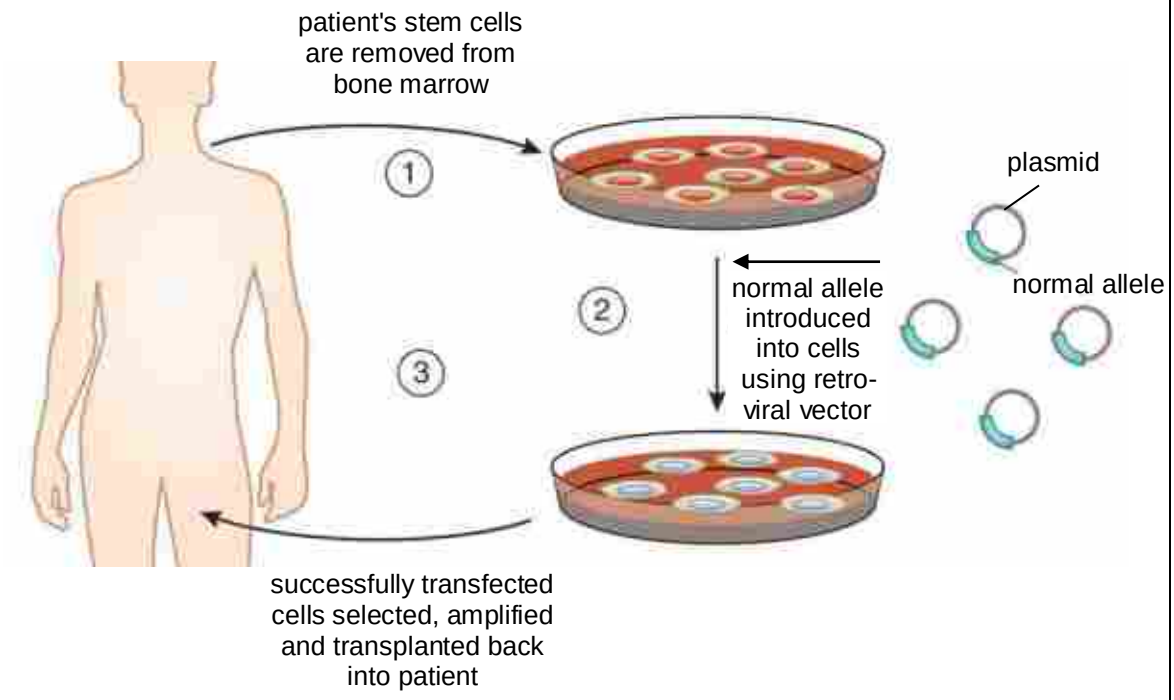


Fig. 2.1

(b) **(i)** State **two** reasons why the *ex vivo* approach was used instead of *in vivo*.

1. allows selection of successfully transfected cells;

2. allows cells to be amplified in culture to ↑ nos. before transplanting

↑ chance of SC successfully residing in bone marrow;

3. allows cells to be screened for insertional mutagenesis; [2]

(ii) Suggest why the normal allele was ligated into a plasmid before introduction into cells.

1. linear fragments of DNA are easily digested by cellular enz

after intro into cells; [1]

(iii) Suggest how successfully transfected cells were selected.

1. DNA from some cells of the colony isolated

subj to restriction digestion;

2. restriction fragments separated by gel electrophoresis

to check for presence of transgene; [2]

Normal lymphocytes were detected in some patients' blood for several months following gene therapy. Some of the patients who underwent this treatment were subsequently diagnosed to suffer from leukaemia (cancer of blood cells).

(c) **(i)** Explain why normal lymphocytes were detected in patients' blood for several months following gene therapy.

1. normal allele is integrated into SC genome

stably propagated to daughter cells when SC divides;

2. transgene is present and expressed in new lymphocytes

allow maturation and proliferation of normal lymphocytes; [2]

(ii) Explain how gene therapy could have led to the development of leukemia in other patients.

1. due to insertional mutagenesis

where transgene is inserted in e.g. TSG;

2. leading to LOF mutation

causing SC to undergo uncontrolled proliferation to give too many WBCs; [2]

[Total: 13]

For Examiner's Use

3 The carp, shown in Fig. 3.1, is a large freshwater fish native to central Asia. It was introduced to Australia by humans in the mid-1800s, where it subsequently became an aquatic pest.

Fig. 3.1

(a) Suggest why the carp became a pest when it was introduced into Australia.

1. no natural predators

thus reproduce at rapid rate; OR

2. is a large fish

able to outcompete local spp for resources / food; [1]

Scientists tried to control the carp by using gene technology. They inserted a gene into carp embryos that prevents the production of an enzyme, aromatase. Aromatase catalyses the conversion of testosterone into oestrogen. The inserted gene causes female embryos to develop as males.

The inserted gene produces mRNA with a base sequence that is complementary to the base sequence of the mRNA produced by the aromatase gene. Table 3 shows part of the base sequence of the aromatase gene. It also shows part of the base sequence of the mRNA produced by the inserted gene.

Table 3

	Base sequence					
Template strand of aromatase gene	T	G	**G**	**C**	A	**T**
mRNA transcribed from aromatase gene	**A**	**C**	**C**	**G**	**U**	**A**
Template strand of inserted gene	**A**	**C**	**C**	**G**	**T**	**A**
mRNA transcribed from inserted gene	**U**	**G**	G	C	**A**	U

(b) Complete Table 3 to show the base sequences in the mRNAs transcribed and the inserted gene. [3]

(c) Describe how the inserted gene was introduced into the carp embryos.

1. by particle bombardment;

2. gene to be inserted is ligated into plasmids & coated on tungsten beads;

and shot at high speed into embryo cells;

[2]

The genetically modified (GM) carp were released into the environment in 2006. Fig. 3.2 shows the effect on wild carp populations for the subsequent years.

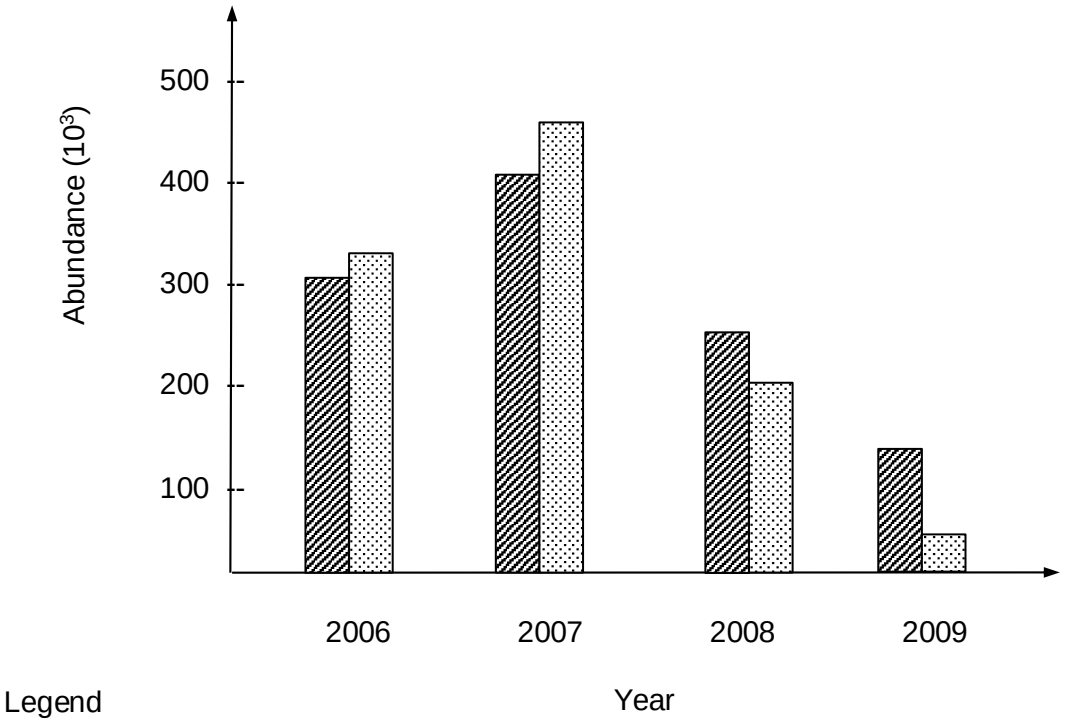


Fig. 3.2

For Examiner's Use

(d) With reference to Fig. 3.2 and information on the inserted gene, explain the effect of releasing GM carp on carp populations.

1. initial ↑ in 2007 due to more carp available for repro

both adult & young carp ↑ from 300,000 to 400,000 & 330,000 to 450,000 respectively;

2. popn of both adult & young carp ↓ from 2008 – 2009

to 150,000 for adult & 50,000 for young carp;

3. as GM carp mating with carp in wild & pass down inserted gene to offspring

inserted gene is transcribed into anti-sense mRNA;

4. that compl bp with aromatase mRNA (forming a duplex)

that ⊗ (ribosome binding thus) translation into aromatase;

5. testosterone is ⊗ converted into oestrogen ➡ all offspring develop into males

➡ ↓ of no. of females in the popn thus ↓ repro rate; [5]

[Total: 11]

For Examiner's Use

4 Planning question

Visking tubing is a selectively permeable membrane that allows small molecules like glucose to pass through. Fig. 4.1 shows how a Visking tubing can be set up to investigate diffusion rates.

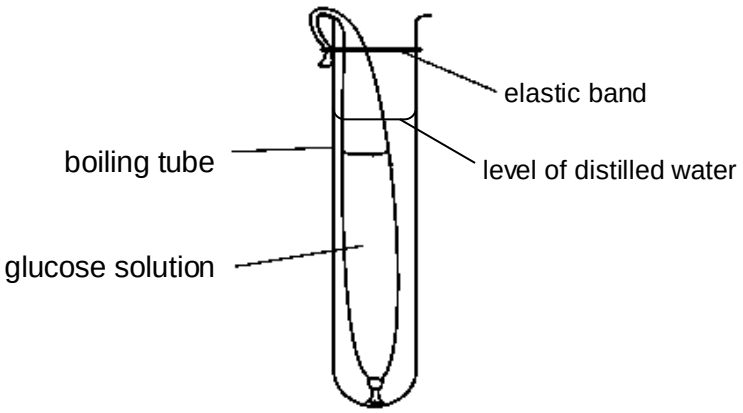


Fig. 4.1

Using this information and your own knowledge, design an experiment to investigate the effect of concentration on rate of glucose diffusion.

You must use:
- 10% glucose solution,
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- boiling tube,
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[Total: 12]

For Examiner's Use

Theoretical background [2m]

1. ***define diffusion ref to movement from region of higher to lower conc., conc. gradient, passive process***
2. ***state hypothesis ref to faster rate when [glc] is higher in Visking tubing, steeper conc. gradient, until equilibrium with no net movement***

ER: Some candidates think glucose diffusion is dependent on water potential rather than solute conc.

Independent variable [1m]

3. ***conc. of glucose, at least 5 conc. of regular interval & wide range, vol of 10% glucose & distilled water used for dilution shown in dilution table (either simple or serial)***

ER: Some attempted to describe vol used in prose resulting in confusing phrasing. Others excluded final glucose conc., an important info, in the table.

Dependent variable [1m]

4. ***amount of glucose diffused into distilled water measured by amount & colour of ppt in Benedict's test / time of 1st ppt appearance***

For Examiner's Use

Benedict's procedure must be feasible to score this mark

ER: Majority of the candidates are not able to describe Benedict's test correctly either adding too little Benedict's soln e.g. 2 – 3 drops or not placing samples in boiling water bath.

Many candidates stated colour of ppt as data to record, failing to understand that amount of ppt also indicates glucose conc.

Candidates also did not think through their answers coherently and examiners wonder how one can calculate an average of colours in the results table.

Controlled variable (any 2) [2m] rationale must be stated

5. ***temperature, use of water bath at specified temp ® direct heating with Bunsen flame***
6. ***time allowed for diffusion***
7. ***vol of glucose in Visking tubing***

Procedure [2m]

8. ***coherent sequence of steps e.g. sequence of adding solns (® set up according to Fig. 1), starting stopwatch***
9. ***rinsing Visking tubing, vol distilled water > glucose, removing sample for Benedict's test, time 1 tube at a time etc.***

ER: Majority of the candidates did not understand the basic principle of conducting expt. Many candidates heated the solutions while diffusion is occurring, being totally oblivious to the obvious fact that diffusion rates would be affected by this setup.

Some candidates listed temperature as a controlled variable and yet still heated the Visking tubing, showing a lack of understanding of what they are writing.

Others decided to record the time taken for brick red ppt to appear even for control setups.

Reliability [1m]

10. ***replicates & repeats (only if procedure is largely feasible)***

Results [1m]

11. ***table of results***

describe means of deciphering conc. of glucose in distilled water

® colour of ppt as results as average of replicates cannot be calculated nor plotted in graph

Graph [1m]

12. ***plots theoretical graph of initial glucose conc. vs conc. of glucose diffused into distilled water / time / amt of ppt***

For Examiner's Use

Safety [1m] (any 1)

13. states hazard, risk, precaution

e.g. hot water from boiling waterbath may cause scalding, handle waterbath with cotton gloves

e.g. Benedict's solution may cause skin & eye irritation, wear gloves & goggles when handling

® Benedict's soln is corrosive

® glucose is skin irritant

® Bunsen flame may cause burns thus handle with gloves. Flames should not be handled.

® hazard not stated in procedure

For Examiner's Use

Free-response question

Write your answers to this question on the separate answer paper provided.

Your answer:
- should be illustrated by large, clearly labelled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a), (b),** etc., as indicated in the question.

5 (a) Patient's own stem cells are frequently modified for use in treating genetic diseases via gene therapy.

Explain why these stem cells are suited for this purpose. [6]

1. ***patient's own cells are used to prevent immune rejection***

   as WBCs would not recognise these cells as foreign due to absence of Ag on cell surface;
2. ***patient will not need to take immunosuppressant & immune sys ⊗ be compromised***

   patient less susceptible to opportunistic infections;
3. ***undifferentiated / unspecialised***

   i.e. they ⊗ possess any specific cellular features;
4. ***and are multipotent***

   able to differentiate to give rise to limited cell types;
5. ***able to undergo asymmetrical division to provide a supply of ASC***

   and progenitor cells to differentiate into a related grp of cells to replace diseased cells;
6. ***unlimited self-renewal capacity***

   due to ✓ active telomerase that prevents telomere shortening with every cell division;
7. ***preventing the cell from undergoing apoptosis due to replicative senescence;***
8. ***provides a supply of normal cells throughout lifetime of patient***

   eliminating the need for repeated treatment;

(b) The therapeutic gene used for gene therapy can be amplified using polymerase chain reaction (PCR). Describe the process of PCR. [8]

1. ***target DNA added to reaction tube with dNTPs, excess fwd & rev primers, Taq DNA pol in buffer***

   in thermal cycler;
2. ***denaturation***

   heated to 95°C;
3. ***↑ KE to break H bonds btw compl bp***

   to separate ds DNA → 2 ssDNA;

4. ***annealing***

   lower temp to 55℃;

5. ***to allow forward & reverse primers to bind***

   to seq flanking the target seq to provide free 3'OH end for Taq pol;

6. ***primers added in excess to ↑ chance of primer binding cf to DNA renaturing;***

7. ***elongation***

   heating to 72℃;

8. ***Taq pol binds to 3' end of primer to add DNA nucleotides w bases compl to target DNA / using target DNA as template;***

9. ***syn new DNA strand in 5' → 3' direction;***

10. ***cycle is repeated 25 – 30 times***

    to produce 2n copies of target DNA where n = no. of cycles;

(c) The therapeutic gene can be delivered using viral or non-viral vectors. Compare the use of these 2 modes of gene delivery. [6]

1. ***cf gene size;***
2. ***cf tissue specificity;***
3. ***cf ability to integrate thus stability of gene propagation;***
4. ***cf possibility of insertional mutagenesis;***
5. ***cf probability of triggering immune response;***
6. ***cf ease of preparation;***

Any elaboration on the answers to this?

[Total: 20]

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Class Adm No

Candidate Name: _____

H

millennia institute

2016 Preliminary Examination II
Pre-university 3

Biology Higher 2 **9648/01**

Paper 1 Multiple Choice **23 September 2016**

1 hour 15 minutes

Additional Materials: Optical answer sheet

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.
Write your name, Adm No. and class on all the papers you hand in.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Paper 1
There are **forty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A, B, C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Multiple Choice Answer Sheet.

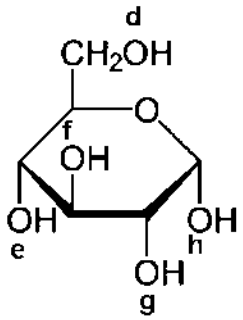
Calculators may be used.

This question paper consists of 30 printed pages

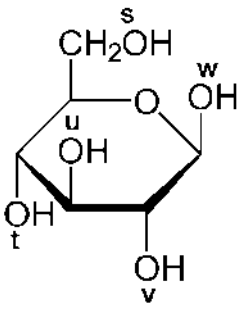
[Turn over

Answer **all** questions

1. The diagram shows two isomers of a hexose labelled **I** and **II.** Four possible bonding positions are labelled **d**, **e**, **f**, **g** and **h** on one isomer, and **s**, **t**, **u**, **v** and **w** on another isomer.



Isomer I

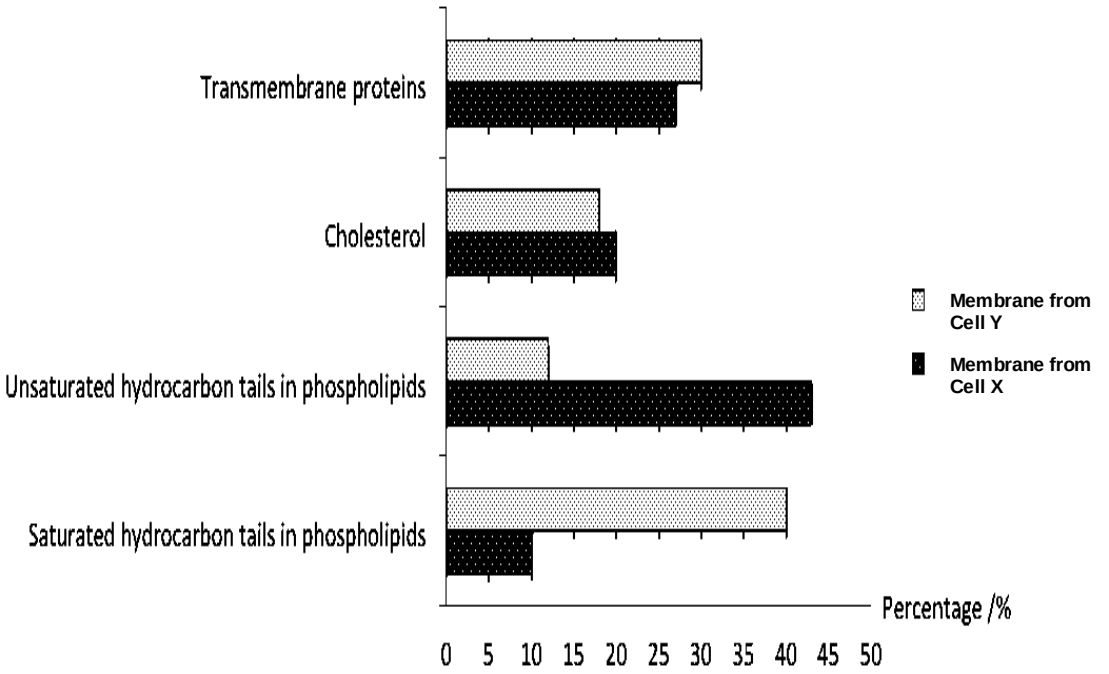


Isomer II

Which isomer and bonding positions are involved in the formation of amylopectin?

	Repeating units	**Bonding position**
A	Isomer **I**	**d**-**g** and **d**-**h**
B	Isomer **I**	**e**-**h** and **d**-**h**
C	Isomer **II**	**s**-**v** and **s**-**w**
D	Isomer **II**	**t**-**w** and **s**-**w**

2. Reindeer are well adapted to survive extreme cold winters. One of these adaptations is the cell membrane composition at different parts of its body. The graph below shows the percentage composition of cell surface membrane components of Cell **X** and Cell **Y** taken from two different parts of the reindeer's body.



Which of the following statement best explains the differences in the membrane composition in Cell **X** and Cell **Y**?

A Cholesterol decreases the membrane fluidity and prevents the membrane from breaking up by restraining the movement of phospholipids.

B Cell **X** is taken from a lower part of the reindeer's leg as the unsaturated hydrocarbon tails in the cell surface membrane will prevent the fatty acids from packing close to each other.

C Cell **Y** is taken from a lower part of the reindeer's leg as the saturated hydrocarbon tails in the cell surface membrane will prevent the fatty acids from packing close to each other.

D Transmembrane proteins maintain the osmotic balance between the interior and exterior of the cell, hence preventing the cell membrane from solidifying at low temperatures.

3. What is the role of a biological catalyst in a metabolic reaction?

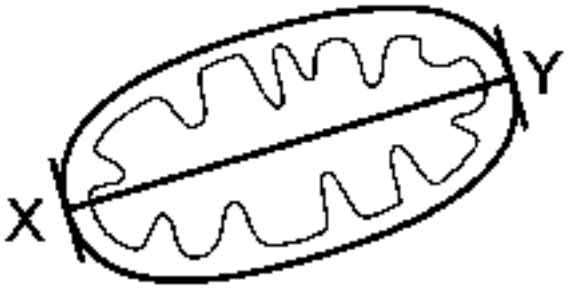
A Increases both the activation energy and the energy yield.

B Decreases the activation energy and increases the energy yield.

C Decreases both the activation energy and the energy yield.

D Decreases the activation energy and has no influence on the energy yield.

4. The diagram shows a mitochondrion drawn from an electron micrograph.



The length of the mitochondrion from X to Y is 3000 nm.

What is the magnification of the drawing of the mitochondrion?

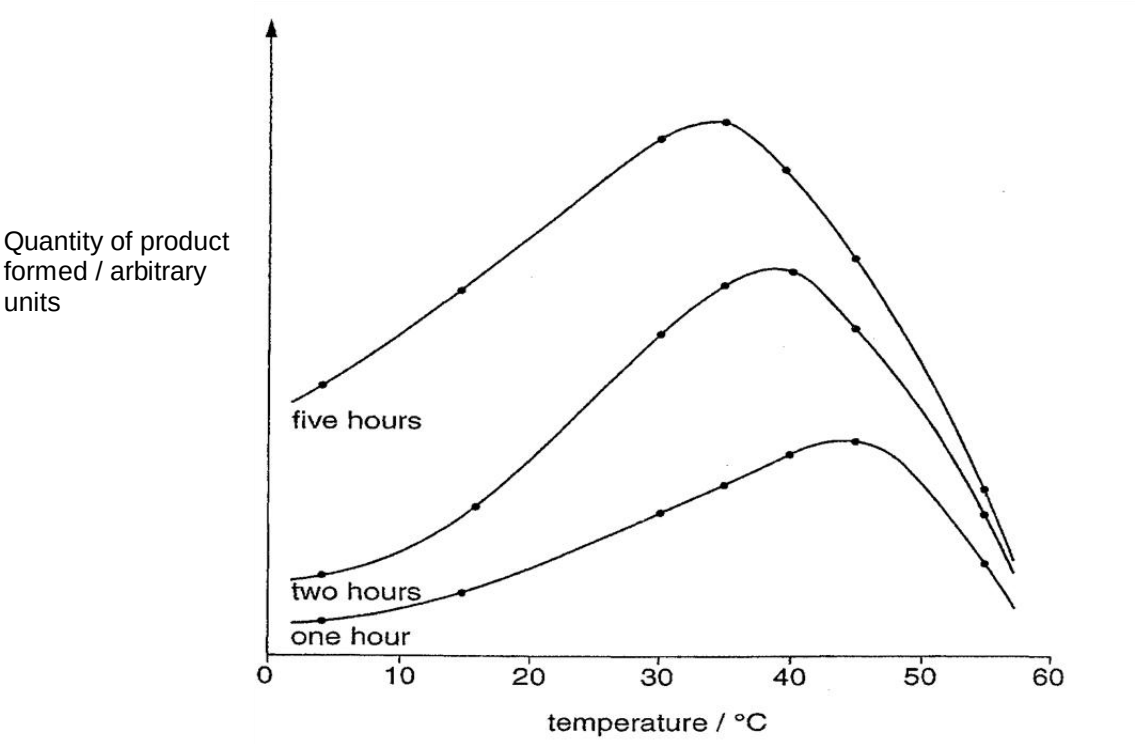
A X 200

B X 2000

C X 20000

D X 200000

5. The following figure shows the results of an experiment, in which, samples containing the same concentration of enzyme and substrate were kept at different temperatures for periods of one, two and five hours. The quantities of product formed were then determined.



Which statement below does not describe the graphs?

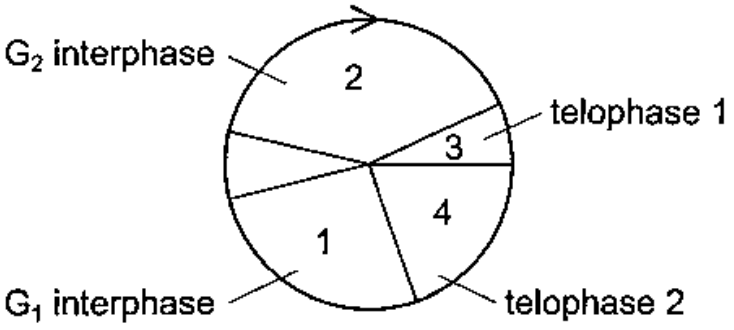
A As temperature increased, the quantity of products formed increased.

B As the duration of the experiment decreased, the quantity of products decreased.

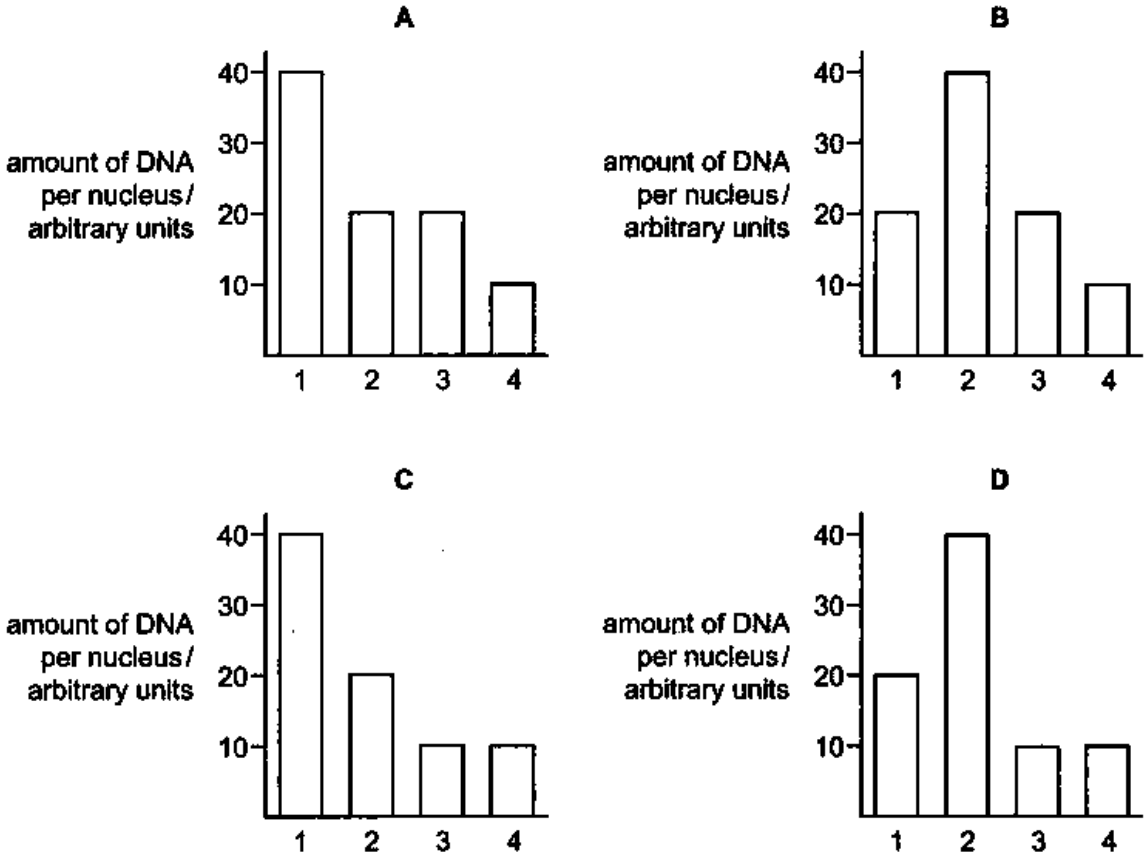
C The enzyme is not active at 50^0C for when the experiment is carried out for five hours.

D Optimum temperature for the experiment held over one hour was highest as the enzyme had more disulfide bonds in stabilizing its structure.

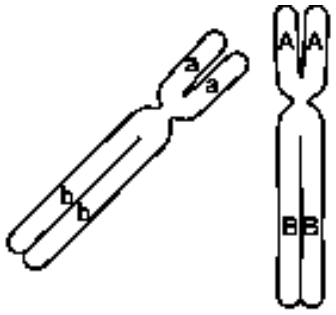
6. The amount of DNA per nucleus in a mouse cell during a meiotic cell cycle, as shown below, was measured.



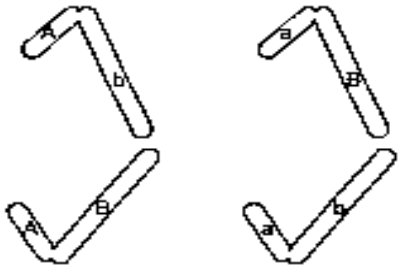
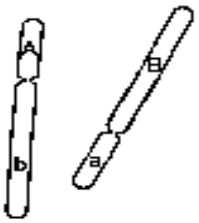
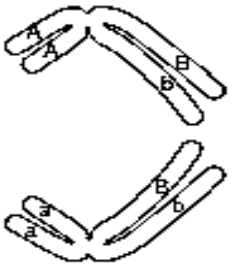
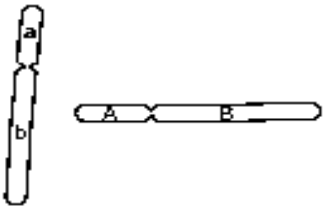
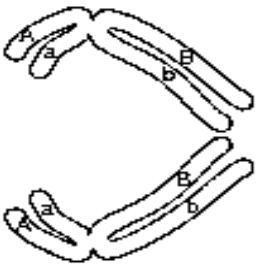
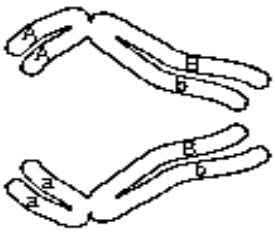
Which bar correctly represents the variation in DNA content?



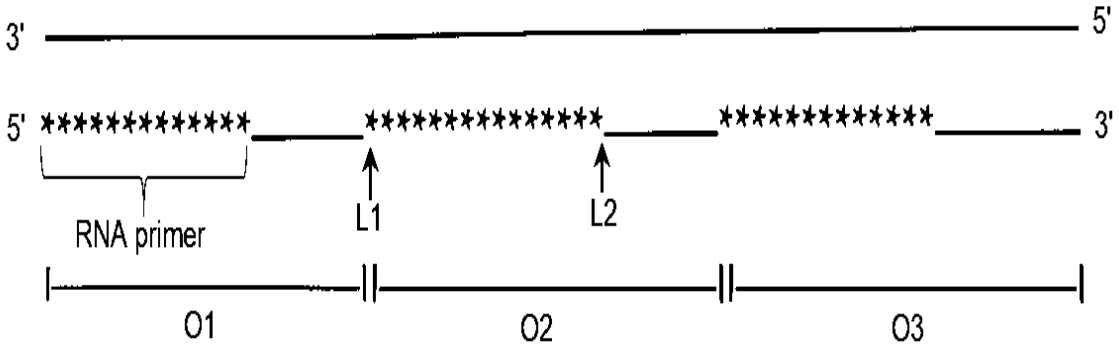
7. The diagram shows two homologous chromosomes in early prophase I of meiosis in a mouse cell. Two genes, A/a and B/b, whose loci occur on the homologous chromosomes are also shown.



Which option is a possible representation of these chromosomes as they progress from anaphase I to prophase II?

	anaphase I	prophase II
A		
B		
C		
D		

8. The diagram shows a DNA template with the lagging strand prior to the removal of the RNA primers.



Which row correctly shows the events taking place during the synthesis of the lagging strand?

	First Okazaki fragment synthesised	Site of phosphodiester bond formation catalysed by DNA ligase
A	O1	L1
B	O1	L2
C	O3	L1
D	O3	L2

9. In a laboratory of Molecular Biology, the amino acids sequence of a cockroach intestine protein has been partially determined. The tRNA molecules used in the synthesis have the following anticodons:

3’ UAC 5’ 3’ CGA 5’ 3’ GGA 5’ 3’ GCU 5’ 3’ UUU 5’ 3’ GGA 5’

What is the DNA nucleotide sequence of the non-template DNA strand?

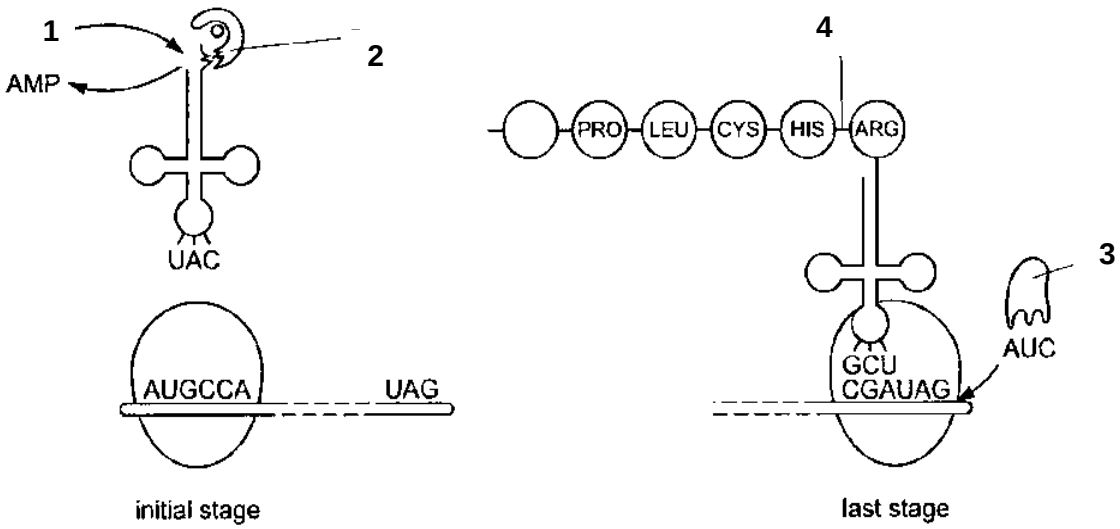
A 5’ ATG-GCT-GGT-CGA-AAA-CCT 3’

B 5’ ATG-GCT-CCT-CGA-AAA-CCT 3’

C 5’ ATG-GCT-GCT-CGA-AAA-GCT 3’

D 5’ ATG-GGT-CCT-CGA-AAA-CGT 3’

10. A number of molecules other than tRNA and mRNA are involved during translation.



Which line in the table is correct for labels **1** – **4**?

	1	2	3	4
A	ADP	Aminoacyl tRNA synthetase	Amino acid	Hydrogen bond
B	ADP	Amino acid	Release factor	Hydrogen bond
C	ATP	Aminoacyl tRNA synthetase	Release factor	Peptide bond
D	ATP	Amino acid	Aminoacyl tRNA	Peptide bond

11. Which of the following statements is true about prokaryotic plasmids?

A Plasmids replicate along with the chromosomal DNA by using chromosomal DNA as a template.

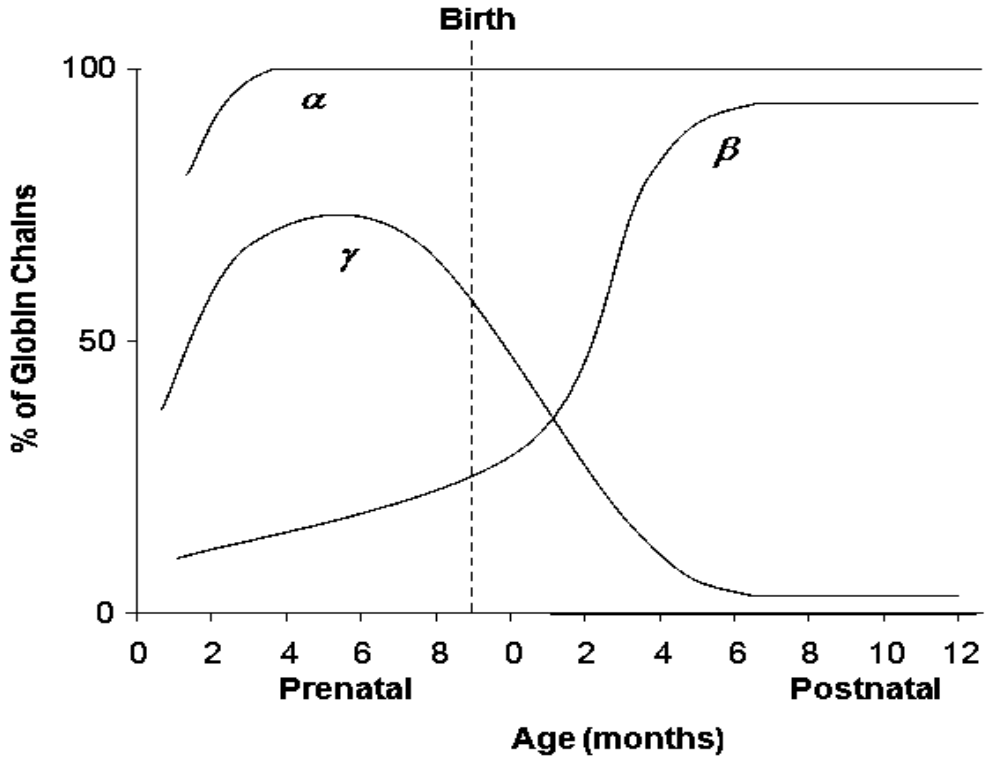
B Antibiotic-resistant genes on plasmids allow them to survive in antibiotic culture medium.

C Plasmid DNA strands run in opposite directions and the copy number varies with the type of plasmid.

D Binary fission ensures that plasmids are equally separated into daughter cells.

12. The globin gene family in humans consists of the ***α*, *β*** and ***γ*** genes. These genes code for the globin chains that make up haemoglobin and are expressed at different levels during different developmental stages.

The graph shows the expression of the various globin chains during the prenatal (fetal) and postnatal (after birth) periods.



Which statement cannot account for the differences in the levels of expression of globin chains?

A Methyl groups are added to regulatory sequences of ***γ-globin*** gene during the postnatal period, allowing for chromatin remodeling complexes to be recruited.

B Alternative splicing occurs in the mature mRNA of the ***α-globin*** and ***β-globin*** genes, resulting in differences in the rate of expression of globin chains during the prenatal period.

C A growth factor triggers the expression of a transcription factor that increases the rate of ***β-globin*** gene expression during the postnatal period.

D The shortening of poly(A) tail in the mRNA of ***γ -globin*** genes reduces its stability, resulting in a decrease in the rate of expression of ***γ-globin*** chains during the postnatal period.

13. An analysis of the cells of a cancer patient revealed the presence of abnormal amounts of Ras proteins.

Which of the following could not explain for this observation?

A Gene amplification of Ras proto-oncogene

B A point mutation in a control element of the Ras proto-oncogene

C Translocation of Ras proto-oncogene to a region under the control of a more active promoter

D A single substitution in the exon of Ras proto-oncogene

14. A point mutation has occurred in *Escherichia coli*. Glucose and lactose are both absent in the culture medium where the mutant *E. coli* is grown in. An analysis of proteins synthesised by mutant *E. coli* found substantial amount of β-galactosidase, transacetylase and permease.

Which of the following mutations could have taken place in the *E. coli* cell?

1 Mutation in the operator of the lac operon
2 Mutation in the *lacI* gene
3 Mutation in the promoter of the lac structural genes

A **1** only

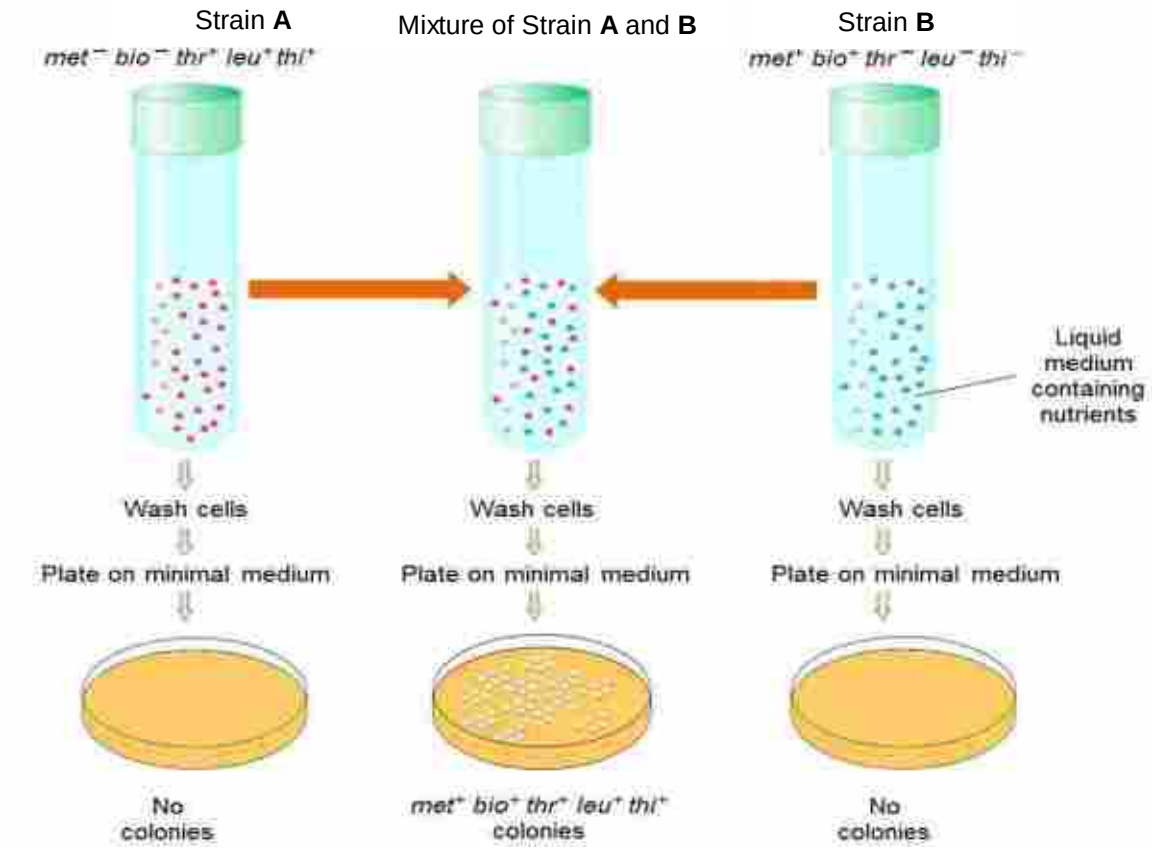
B **2** only

C **1** and **2** only

D **2** and **3** only

15. In an experiment to study genetic recombination, two strains of *Escherichia coli* with different nutritional requirements were used. Strain **A** (met^- bio^- thr^+ leu^+ thi^+) would grow on a minimal medium only if the medium were supplemented with methionine and biotin, while Strain **B** (met^+ bio^+ thr^- leu^- thi^-) would grow on a minimal medium only if it was supplemented with threonine, leucine and thiamine.

Some of the dishes were plated only with Strain **A** bacteria, some only with Strain **B** bacteria, and some with a mixture of Strain **A** and Strain **B** bacteria that had been incubated together for several hours in a liquid medium.



Which conclusion can be best drawn from the experiment?

A The *thr*$^+$, *leu*$^+$ and *thi*$^+$ genes in Strain **A** are located in its F plasmid.

B Cell-to-cell contact is necessary for the exchange of alleles between strain **A** and strain **B**.

C All the five genes are located on the F plasmid.

D Mutations resulted in *thr*$^+$, *leu*$^+$ and *thi*$^+$ genes in Strain **B** to produce colonies on a minimal medium plate.

16. The human immunodeficiency virus (HIV) has a highly specific gp120 glycoprotein that only allows it to infect cells with a CD4 receptor. To increase the host range of HIV in a laboratory setting, scientists often modify these viruses by artificially enclosing the viral nucleocapsid with a viral envelope with VSV-G glycoproteins embedded. VSV-G binds to LDL receptor, found ubiquitously on the cell membranes of many cell types, including kidney and liver cells that HIV do not usually infect.

A scientist has taken the following experimental steps:

1. Extracted an original and unmodified HIV nucleocapsid from wild-type HIV
2. Artificially enclose HIV nucleocapsid in a viral envelope containing VSV-G glycoproteins
3. Infect liver cells
4. Extract only newly synthesized virus particles released and examined them

What can the scientist expect to find in most newly synthesized virus particles extracted?

	Viral envelope	**Viral Genome**
A	VSV-G	VSV-G gene
B	VSV-G	gp120 gene
C	gp120	VSV-G gene
D	gp120	gp120 gene

17. During summer, an isolated population of bighorn ram on a mountain has been captured and the length of their curled horns was measured over 30 years. Horn length of bighorn ram follows a distribution similar to that of its weight.

Which of the following statements describing the features of horn length in bighorn sheep are not correct?

1 Horn length is controlled by multiple alleles with different degrees of dominance.
2 Horn length shows quantitative expression with overlaps between categories.
3 Horn length is polygenic where inherited individual alleles have an additive effect.
4 Horn length is not affected by the environment

A **1** and **2** only

B **1** and **4** only

C **2** and **3** only

D **3** and **4** only

18. Which of the following causes variation in both sexually and asexually reproducing organisms?

A Mutation

B Polygenic inheritance

C Crossing over

D Independent assortment

19. Possession of white or coloured feathers in chickens is controlled by two genes **P**/**p** and **Q**/**q**. The phenotypes of offspring that are expected from mating two chickens, each of which is heterozygous at both loci, are shown in the Punnett square.

Gametes	**PQ**	**Pq**	**pQ**	**pq**
PQ	White feathers	White feathers	White feathers	White feathers
Pq	White feathers	White feathers	White feathers	White feathers
pQ	White feathers	White feathers	Coloured feathers	Coloured feathers
pq	White feathers	White feathers	Coloured feathers	White feathers

What best explains the proportion of white to coloured feathers in the Punnette square?

A Dominant epistasis in which the epistatic allele is **P**
B Dominant epistasis in which the epistatic allele is **Q**
C Recessive epistasis in which the epistatic allele is **p**
D Recessive epistasis in which the epistatic allele is **q**

20. There are two hypotheses to explain the production of white, pale blue or dark blue flowers in a species of plant.

Hypothesis 1: There are two codominant alleles for flower color
Hypothesis 2: There are three alleles, one for each flower colour.

Which procedure is the best way of testing these hypotheses?

A Analysis of the flower pigments in several different flowers by chromatography to find whether some plants contain more than one pigment.
B Controlled cross pollination of all the different colour varieties available, in all possible combinations, and recording the colours shown by the offspring.
C Surveying large wild populations and finding the ratios of the different colours in these.
D Controlled self-pollination of several individuals of each of the colour varieties and recording the colours shown by the offspring of each individual plant sampled.

21. The following claims have been made about respiration.

1 Two turns of the citric acid cycle is required to oxidize 1 molecule of glucose.
2 Four molecules of carbon dioxide are generated for every molecule of acetyl CoA introduced into the Krebs Cycle.
3 During aerobic respiration, glucose produces pyruvate, CO_2 and ATP in the cytoplasm of a muscle cell.
4 Aerobic respiration can produce about 19 times the amount of ATP produced in anaerobic respiration.

Which of the following statements is/are true?

A **1** only
B **1** and **4** only
C **2** and **4** only
D **1, 3** and **4** only

22. *Rafflesia arnoldii* is a parasitic plant that produces the world's largest flower. It survives by invading the underground roots of vines to absorb nutrients essential for polypeptide synthesis. By doing so, it makes use of the nutrients to develop a giant and stinking flower that smells of rotting flesh in order to attract pollinating flies.

Which of the following two factors are most likely to act as limiting factors and inhibit growth of the vines when the Rafflesia parasite is present?

1 Carbon dioxide
2 Light
3 Photosynthetic enzymes
4 Water
5 Temperature

A **1** and **2**
B **2** and **3**
C **3** and **4**
D **4** and **5**

23. Which of the following gives an accurate comparison between intracellular receptors and cell surface receptors?

	Intracellular receptors	**Cell surface receptors**
A	May act as regulatory proteins and bind to DNA	May catalyse the phosphorylation of intracellular proteins
B	Functions as the second messenger to activate other relay proteins	Binding of ligand always trigger the production of second messengers
C	Ligands can be water-soluble or lipid-soluble	Ligands must be lipid-soluble
D	Made up of only hydrophobic amino acids to allow the interaction with lipid-soluble ligands.	Made up of hydrophobic amino acids which interact with the phospholipids of the membrane

24. Which of the following statements about channel proteins is/are correct?

I Channel proteins are either voltage-gated, ligand-gated or mechanically-gated.

II Channel proteins do not undergo conformational changes when transporting molecules.

III Channel proteins contain a hydrophilic pore lined with hydrophilic amino acids.

IV Channel proteins serve to transport hydrophilic molecules of all sizes across the cell membrane.

A **I** and **II** only

B **II** and **III** only

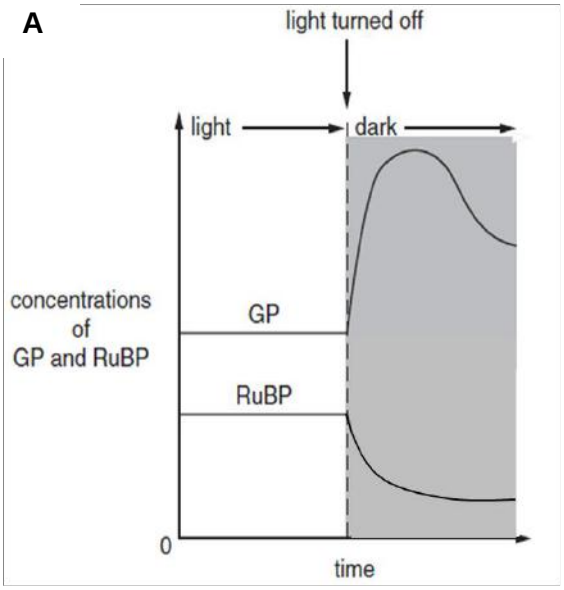
C **I**, **II** and **III** only

D All of the above

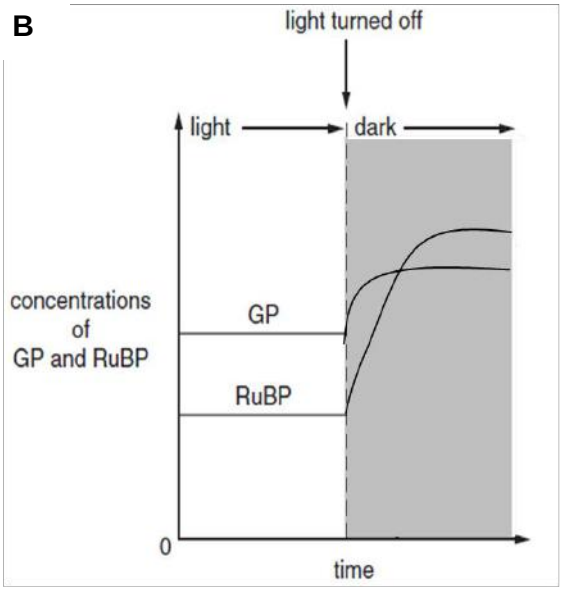
25. Concentrations of glycerate-3-phosphate (GP) and ribulose bisphosphate (RuBP) were measured from samples of actively photosynthesising green algae in an experimental chamber.

Which of the following graphs show how the concentration of these compounds changes when the light source was turned off?

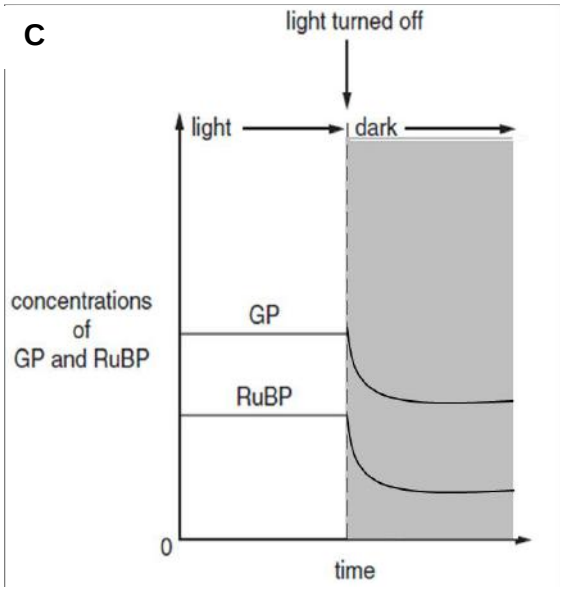
A



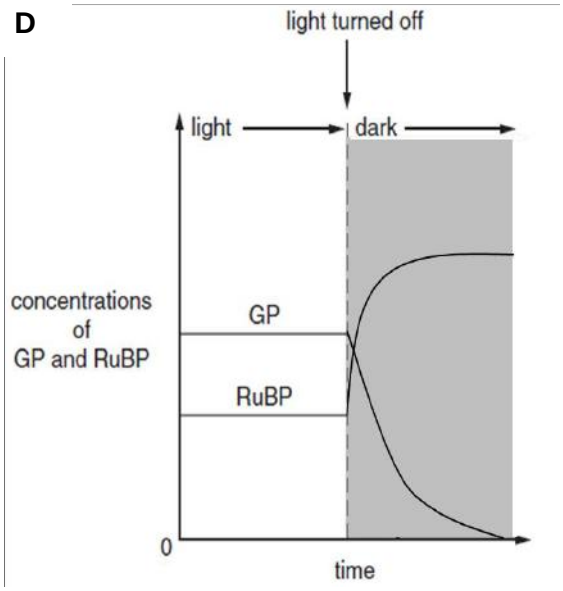
B



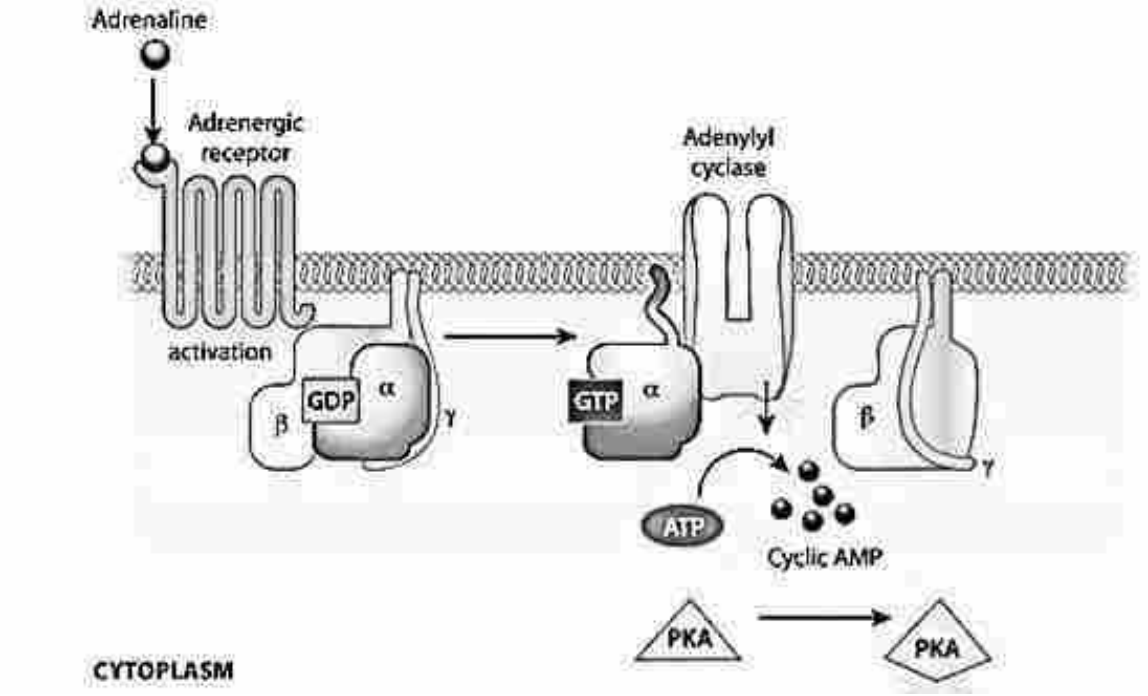
C



D



26. The following diagram shows the activation of the G protein-coupled receptor (GPCR) by the binding of adrenaline to the receptor. A mutation leads to constitutive signal transduction.



Which of the following is a possible result of the mutation?

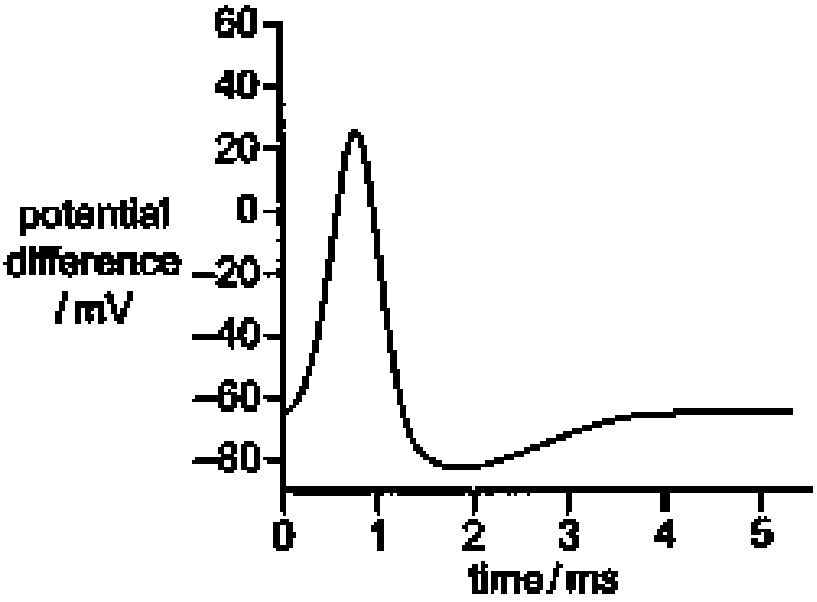
A Conformational change in adenylyl cyclase such that it cannot convert ATP to cyclic AMP.

B Adrenaline not being able to bind to the receptor.

C Cyclic AMP not being able to bind to PKA.

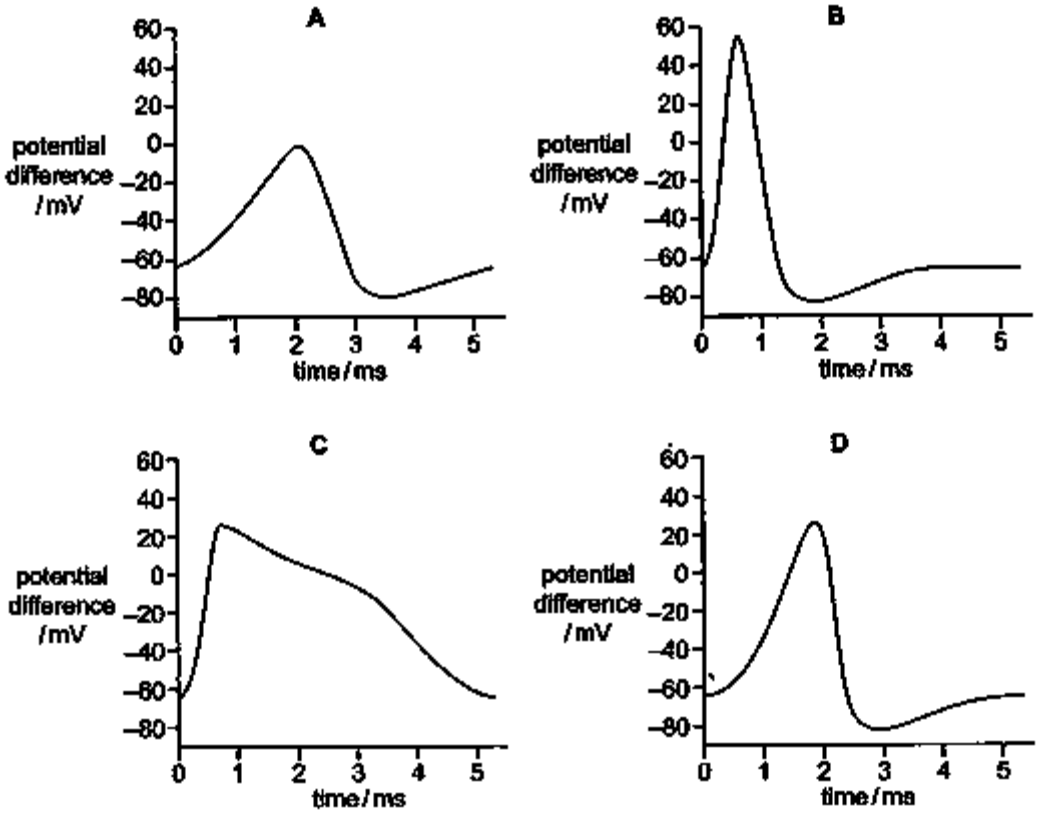
D GTPase in G protein failing to hydrolyse GTP to GDP.

27. The diagram below shows a normal action potential.



Drug **X** can bind and block voltage-gated K^+ channels.

Which of the following diagrams shows an action potential in a neurone affected by such a drug?



28. Which is a correct description of the role of calcium ions in synaptic signalling?

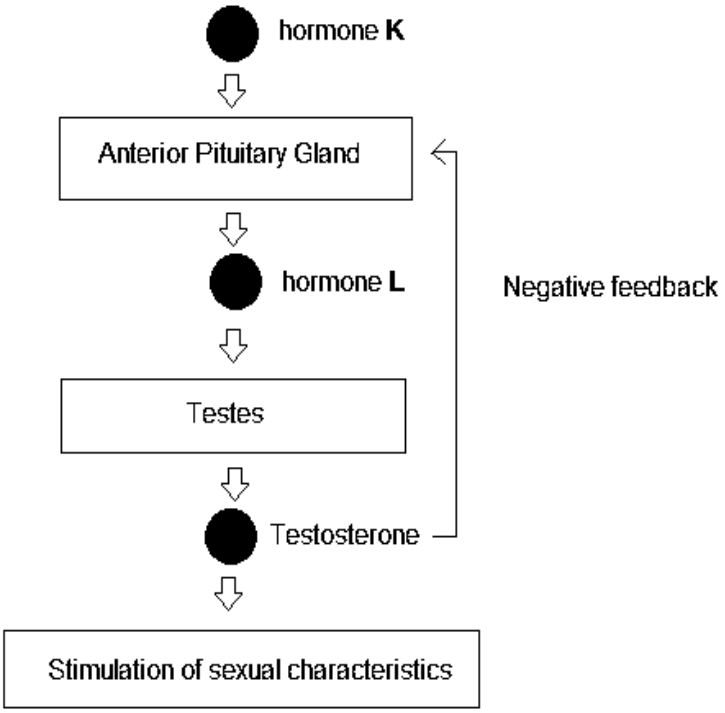
A Calcium ions are moved in by diffusion through ligand gated ion channels in pre-synaptic membranes of excitatory neurons, causing vesicles to move towards the pre-synaptic membrane as an impulse arrives.

B Calcium ions are moved in by diffusion through voltage gated ion channels in pre-synaptic membranes of excitatory neurons, causing vesicles to move towards the pre-synaptic membrane as an impulse arrives.

C Calcium ions are moved in by active transport through calcium pumps in pre-synaptic membranes of excitatory neurons, causing vesicles to move towards the pre-synaptic membrane as an impulse arrives.

D Calcium ions are moved out by active transport through calcium pumps in pre-synaptic membranes of excitatory neurons, causing vesicles to move towards the pre-synaptic membrane as an impulse arrives.

29. The production of testosterone is regulated by the anterior pituitary gland. Upon stimulation by hormone **K**, the gland releases hormone **L** which causes the testes to produce testosterone. The elevated level of testosterone exerts a negative feedback on the anterior pituitary gland.



Which of the following would be observed if a man consumes large amount of steroids containing testosterone?

	Production of hormone K	**Production of hormone L**	**Production of testosterone**	**Stimulation of sexual characteristics**
A	Decrease	Decrease	Decrease	No change
B	Decrease	Decrease	No change	Increase
C	No change	Decrease	Decrease	Increase
D	No change	Decrease	Decrease	No change

30. Which of the following is not a limitation of the use of fossil records as evidence for evolution?

A Fossils are damaged and incomplete.

B Some organisms may not form fossils.

C Fossils are found in different sedimentary rock layers.

D Fossils present in inaccessible areas are not available to us for study.

31. The following statements relate to molecular phylogenetics.

1 Lines of descent from a common ancestor to present-day organisms have undergone similar and fixed rates of DNA mutation.

2 Organisms with similar base sequences in their DNA are closely related to each other.

3 The number of differences in the base sequences of DNA of different organisms can be used to construct evolutionary trees.

4 The proportional rate of fixation of mutations in one gene relative to the rate of fixation of mutations in other genes stays the same in any given line of descent.

Which statements, when taken together, suggest the existence of a 'molecular clock' that enables scientists to estimate the time at which one species might have diverged from another?

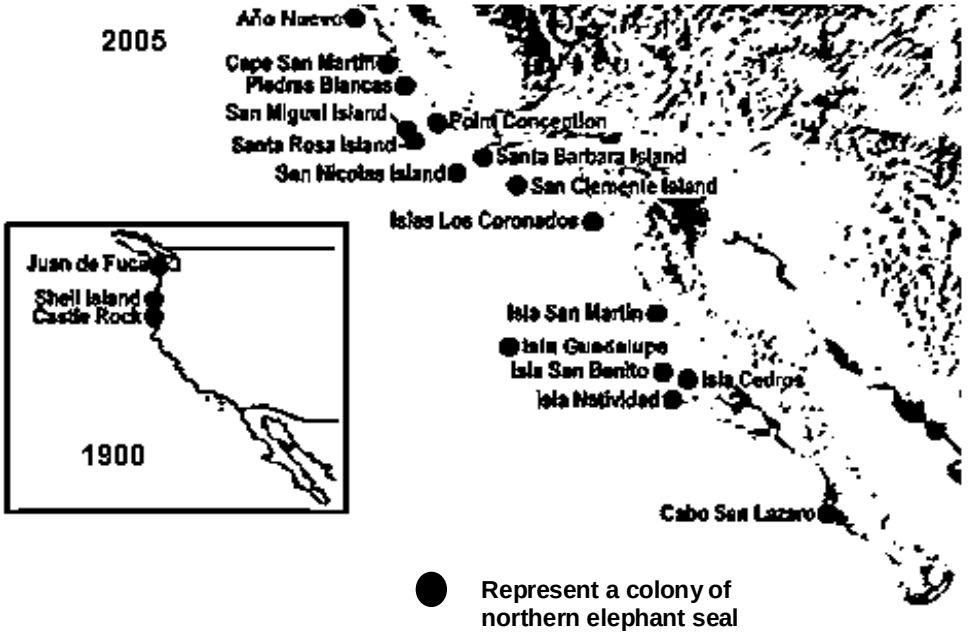
A **1** and **2** only

B **1** and **4** only

C **2** and **3** only

D **3** and **4** only

32. The northern elephant seal almost became extinct in the late 1800's following harvesting by whalers and sealers for their blubber which contains oil. A small colony of between 20 and 100 individuals survived on Guadalupe Island off Baja California. This colony has since given rise to about 160,000 elephant seals on the Pacific coast today. The following figure compares the distribution of elephant seals between 1900 and 2005.

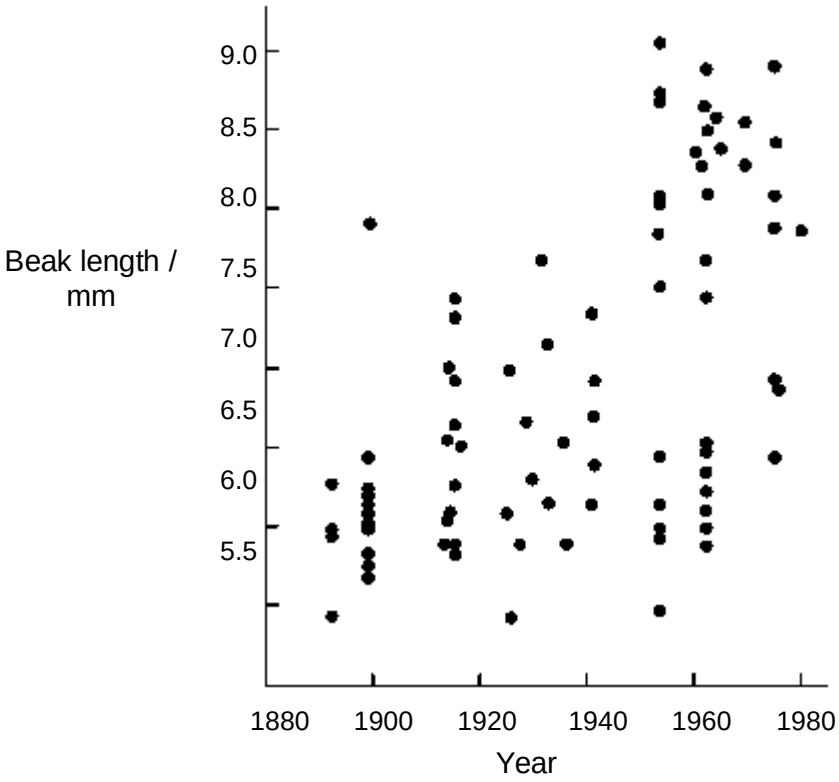


Which evolutionary mechanism could best explain why the degree of homozygosity is higher in the recent population of elephant seals compared to the original population in the 1800s?

A Directional selection
B Bottleneck effect
C Founder effect
D Genetic drift

33. The soapberry bug, *Jadera haematoloma,* uses its long beak to penetrate the fleshy fruit of the native soapberry tree to feed on the seeds at the centre. The bug also feeds on the fruit of the introduced golden rain tree.

Investigators measured the beak length of the soapberry bugs over eighty years. The results are shown in the graph.



Which of the following statements is a reasonable conclusion based on the above information?

A The golden rain tree was introduced around 1970.

B The change in beak length is an example of stabilizing selection.

C The diameter of the golden rain tree fruit acted as a selection pressure on beak length.

D The response of an individual golden rain tree to predation by soapberry bugs would be to grow larger fruit.

34. EcoRI is a restriction enzyme produced by *Escherichia coli*. It recognises the sequence GAATTC and is able to make a staggered cut in the DNA. *E. coli* is susceptible to attack by bacteriophages.

Which of the following correctly describes the natural function of EcoRI?

A It lowers infectivity rate of *E. coli* by bacteriophages that have double-stranded DNA as their genetic material, since EcoRI can recognise and cleave specific viral nucleotide sequences.

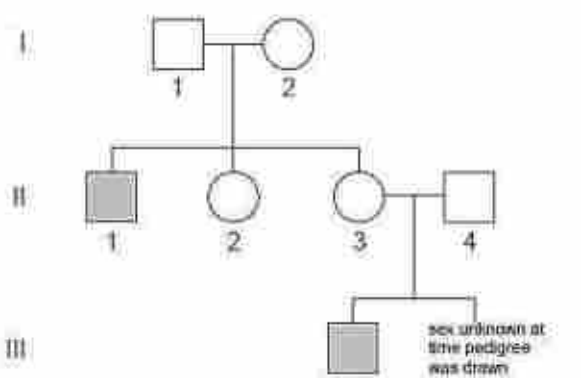
B It cleaves *E. coli* DNA sequences to produce restriction fragments that can be packaged into bacteriophages for infection of new bacterial cells.

C It increases infectivity rate of *E. coli* by bacteriophages because it promotes cleavage of viral DNA at specific nucleotide sequences in order to package more viral DNA into new virus particles.

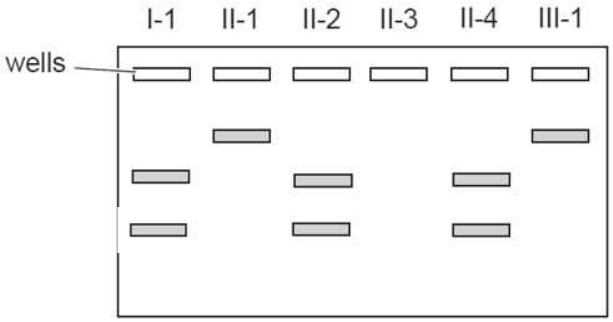
D It cleaves *E. coli* DNA sequences so that the bacterial cell which has been infected will undergo autolysis and self-destruct, preventing further infection of new bacterial cells.

35. Menkes' syndrome in humans is characterised by sparse and wiry hair, growth failure and deterioration of the nervous system. Onset of the Menkes' syndrome usually occurs during infancy.

A family, in which this X-linked disorder was present, underwent Restriction Fragment Length Polymorphism (RFLP) analysis using gel electrophoresis. The family pedigree is shown below.



The RFLP analysis resulted in the following distribution of bands in the gel.



What would be the band pattern of individual II-3?

36. Which of the following options correctly describe the events occurring in each process?

	Action of restriction enzyme	**Ligation**	**Annealing**	**Denaturation**
A	Breaking of hydrogen bonds	Formation of hydrogen bonds	Formation of phosphodiester bonds	Breaking of phosphodiester bonds
B	Breaking of hydrogen bonds	Formation of hydrogen bonds	Formation of phophodiester bonds	Formation of phosphodiester bonds
C	Breaking of phosphodiester bonds	Formation of phosphodiester bonds	Formation of hydrogen bonds	Breaking of hydrogen bonds
D	Breaking of phosphodiester bonds	Formation of phosphodiester bonds	Breaking of hydrogen bonds	Formation of hydrogen bonds

37. Which of the following are ethical concerns arising from the Human Genome Project?

1 Scientists tracing migration of different population groups based on maternal inheritance

2 Genetic counsellors giving advice to people who are genetically pre-disposed to risks

3 Parents choosing to abort foetuses with minor disorders based on genetic testing results

4 Scientists developing tests for only some disease-causing genes

5 Employers refraining from hiring people with greater risk of developing genetic diseases

A **1** and **4**

B **2** and **5**

C **3** and **4**

D **3** and **5**

38. Which of the statements about stem cells are false?

1 Embryonic stem cells are useful as they have the ability to differentiate into any cell type.
2 Embryonic stem cells are less easily isolated compared to neural crest stem cells.
3 Umbilical cord blood stem cells have the same developmental potential as neural crest stem cells.
4 Induced pluripotent stem cells undergo differentiation to give rise to various cell lineages.
5 Stem cells have the ability to self-renew without any stimulus.

A **1**, **2** and **5** only
B **1**, **4** and **5** only
C **2**, **3** and **4** only
D **3**, **4** and **5** only

39. One way to treat β-thalassaemia is to transplant bone marrow cells from a genetically compatible donor into a patient. A potential gene therapy involves adding the normal and dominant allele for β-globin to the patient's cells.

What would ensure that the normal gene is passed on to the next generation?

A Using a retrovirus to introduce the normal β-globin gene into bone marrow cells.
B Using an adenoviral vector to introduce the normal β-globin gene into bone marrow cells.
C Using an adenoviral vector to introduce the normal β-globin gene into an egg cell.
D Using a retrovirus to introduce the normal β-globin gene into an egg cell.

40. Which of the following is an example of genetically modified organisms?

A Cows that grow to adult sizes quickly due to injection of recombinant bovine somatotropin

B Durians that ripen slower due to anti-sense technology

C High yielding rice that are flood resistant, due to intensive self-pollination over generations

D Cows that grow to abnormal size due to inbreeding

End Of Paper

Class Adm No

Candidate Name: _____

H

millennia institute

2016 Preliminary Examination II
Pre-university 3

Biology Higher 2 **9648/01**

Paper 1 Multiple Choice **23 September 2016**

1 hour 15 minutes

Additional Materials: Optical answer sheet

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.
Write your name, Adm No. and class on all the papers you hand in.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Paper 1
There are **forty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A, B, C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Multiple Choice Answer Sheet.

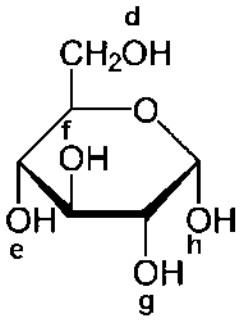
Calculators may be used.

This question paper consists of 30 printed pages

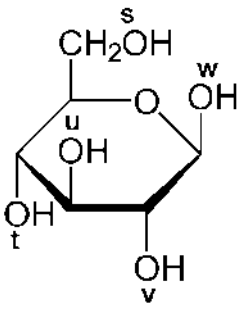
[Turn over

Answer **all** questions

1. The diagram shows two isomers of a hexose labelled **I** and **II.** Four possible bonding positions are labelled **d**, **e**, **f**, **g** and **h** on one isomer, and **s**, **t**, **u**, **v** and **w** on another isomer.



Isomer I

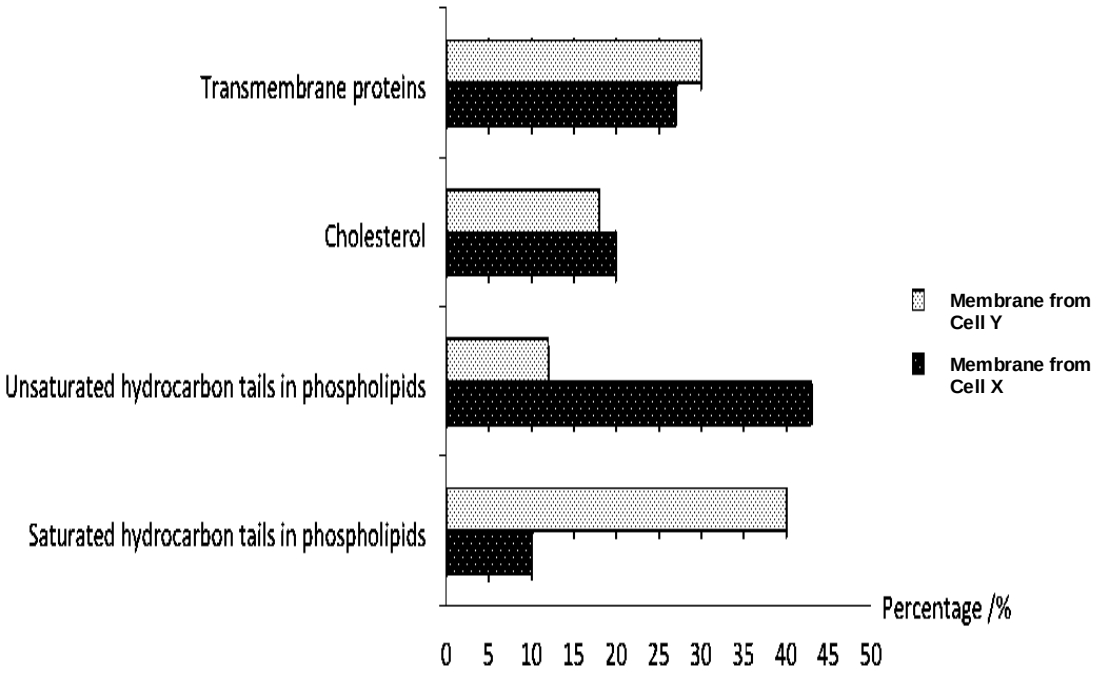


Isomer II

Which isomer and bonding positions are involved in the formation of amylopectin?

	Repeating units	**Bonding position**
A	Isomer **I**	**d**-**g** and **d**-**h**
B	Isomer **I**	**e**-**h** and **d**-**h**
C	Isomer **II**	**s**-**v** and **s**-**w**
D	Isomer **II**	**t**-**w** and **s**-**w**

2. Reindeer are well adapted to survive extreme cold winters. One of these adaptations is the cell membrane composition at different parts of its body. The graph below shows the percentage composition of cell surface membrane components of Cell **X** and Cell **Y** taken from two different parts of the reindeer's body.



Which of the following statement best explains the differences in the membrane composition in Cell **X** and Cell **Y**?

A Cholesterol decreases the membrane fluidity and prevents the membrane from breaking up by restraining the movement of phospholipids.

B Cell **X** is taken from a lower part of the reindeer's leg as the unsaturated hydrocarbon tails in the cell surface membrane will prevent the fatty acids from packing close to each other.

C Cell **Y** is taken from a lower part of the reindeer's leg as the saturated hydrocarbon tails in the cell surface membrane will prevent the fatty acids from packing close to each other.

D Transmembrane proteins maintain the osmotic balance between the interior and exterior of the cell, hence preventing the cell membrane from solidifying at low temperatures.

3. What is the role of a biological catalyst in a metabolic reaction?

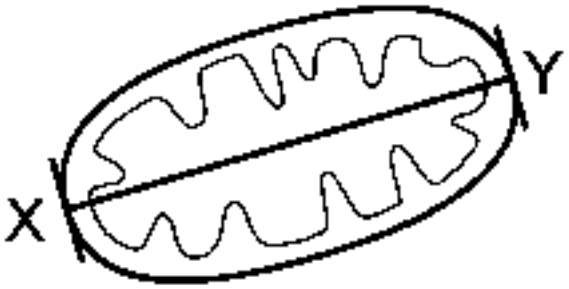
A Increases both the activation energy and the energy yield.

B Decreases the activation energy and increases the energy yield.

C Decreases both the activation energy and the energy yield.

D Decreases the activation energy and has no influence on the energy yield.

4. The diagram shows a mitochondrion drawn from an electron micrograph.



The length of the mitochondrion from X to Y is 3000 nm.

What is the magnification of the drawing of the mitochondrion?

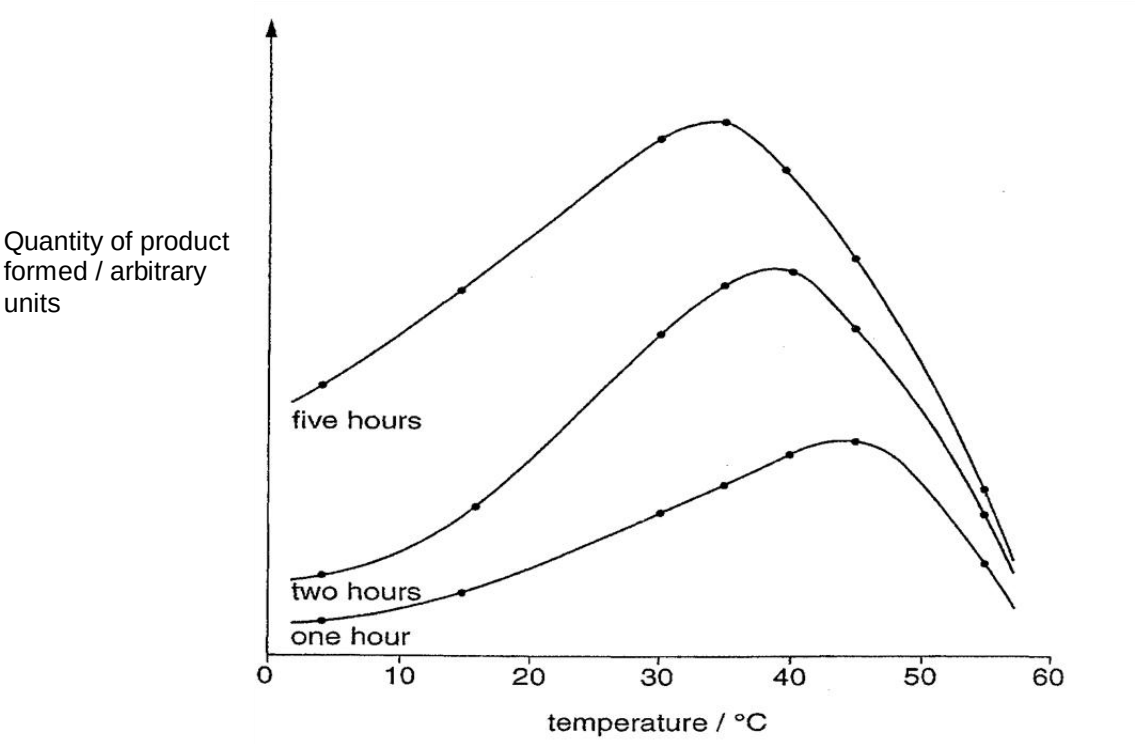
A X 200

B X 2000

C X 20000

D X 200000

5. The following figure shows the results of an experiment, in which, samples containing the same concentration of enzyme and substrate were kept at different temperatures for periods of one, two and five hours. The quantities of product formed were then determined.



Which statement below does not describe the graphs?

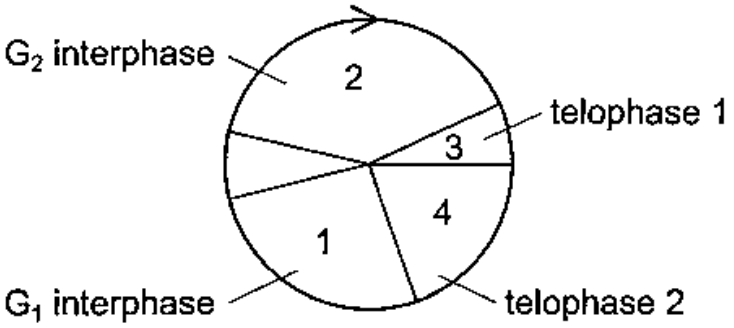
A As temperature increased, the quantity of products formed increased.

B As the duration of the experiment decreased, the quantity of products decreased.

C The enzyme is not active at 50^0C for when the experiment is carried out for five hours.

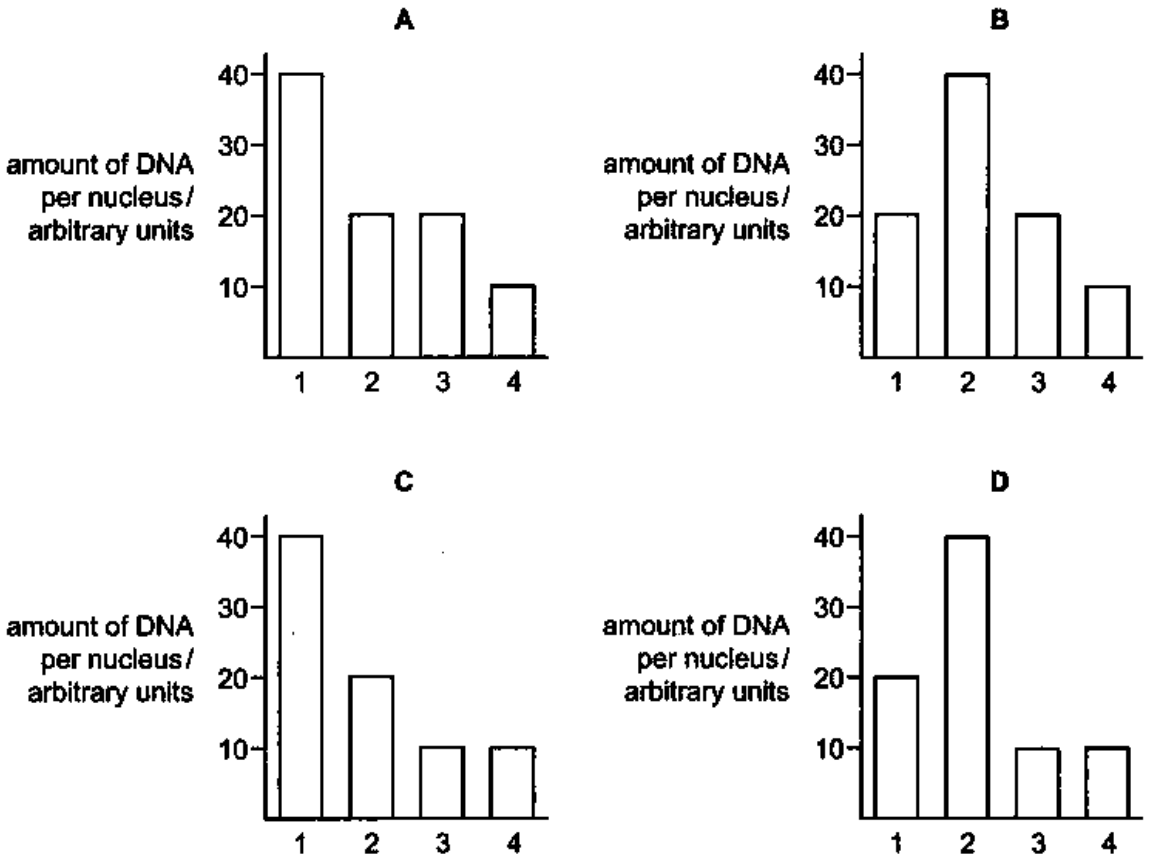
D Optimum temperature for the experiment held over one hour was highest as the enzyme had more disulfide bonds in stabilizing its structure.

6. The amount of DNA per nucleus in a mouse cell during a meiotic cell cycle, as shown below, was measured.

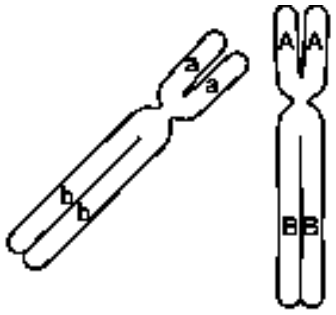


Which bar correctly represents the variation in DNA content?

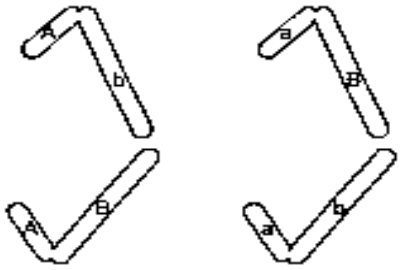
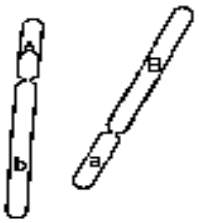
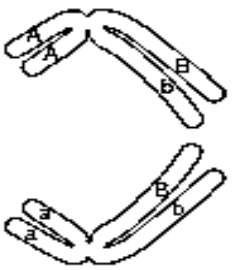
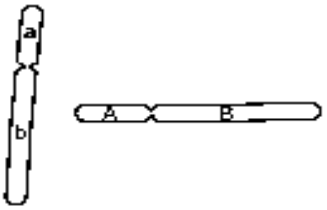
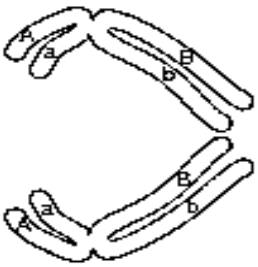
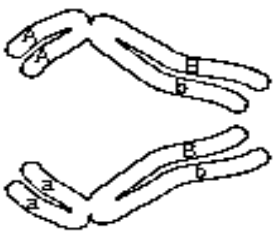
B



7. The diagram shows two homologous chromosomes in early prophase I of meiosis in a mouse cell. Two genes, A/a and B/b, whose loci occur on the homologous chromosomes are also shown.

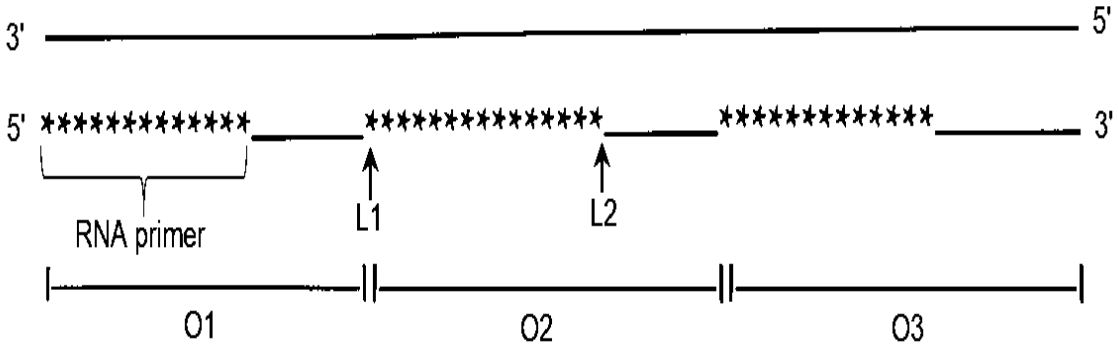


Which option is a possible representation of these chromosomes as they progress from anaphase I to prophase II?

	anaphase I	prophase II
A		
B		
C		
D		

D

8. The diagram shows a DNA template with the lagging strand prior to the removal of the RNA primers.



Which row correctly shows the events taking place during the synthesis of the lagging strand?

	First Okazaki fragment synthesised	Site of phosphodiester bond formation catalysed by DNA ligase
A	O1	L1
B	O1	L2
C	O3	L1
D	O3	L2

9. In a laboratory of Molecular Biology, the amino acids sequence of a cockroach intestine protein has been partially determined. The tRNA molecules used in the synthesis have the following anticodons:

3' UAC 5' 3' CGA 5' 3' GGA 5' 3' GCU 5' 3' UUU 5' 3' GGA 5'

What is the DNA nucleotide sequence of the non-template DNA strand?

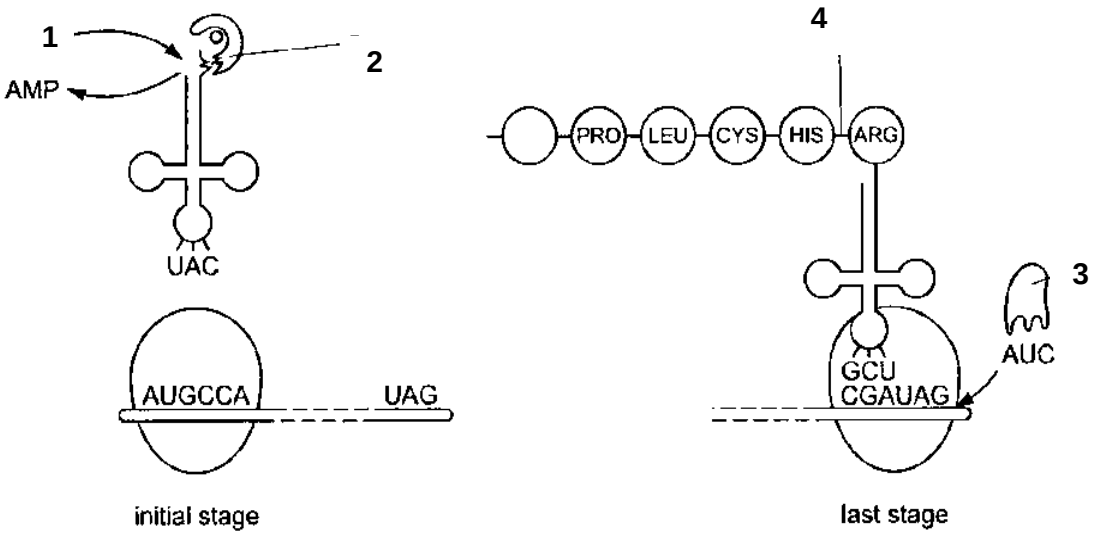
A 5' ATG-GCT-GGT-CGA-AAA-CCT 3'

B 5' ATG-GCT-CCT-CGA-AAA-CCT 3'

C 5' ATG-GCT-GCT-CGA-AAA-GCT 3'

D 5' ATG-GGT-CCT-CGA-AAA-CGT 3'

10. A number of molecules other than tRNA and mRNA are involved during translation.



Which line in the table is correct for labels **1 – 4**?

	1	2	3	4
A	ADP	Aminoacyl tRNA synthetase	Amino acid	Hydrogen bond
B	ADP	Amino acid	Release factor	Hydrogen bond
C	ATP	Aminoacyl tRNA synthetase	Release factor	Peptide bond
D	ATP	Amino acid	Aminoacyl tRNA	Peptide bond

11. Which of the following statements is true about prokaryotic plasmids?

A Plasmids replicate along with the chromosomal DNA by using chromosomal DNA as a template.

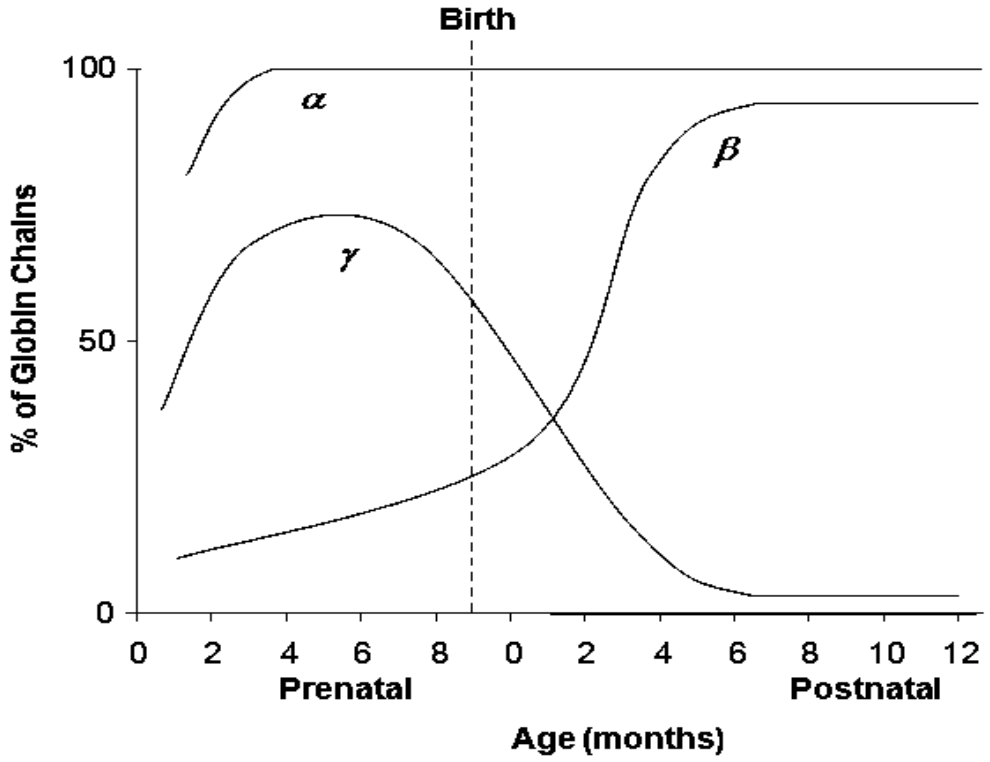
B Antibiotic-resistant genes on plasmids allow them to survive in antibiotic culture medium.

C Plasmid DNA strands run in opposite directions and the copy number varies with the type of plasmid.

D Binary fission ensures that plasmids are equally separated into daughter cells.

12. The globin gene family in humans consists of the ***α*, *β*** and ***γ*** genes. These genes code for the globin chains that make up haemoglobin and are expressed at different levels during different developmental stages.

The graph shows the expression of the various globin chains during the prenatal (fetal) and postnatal (after birth) periods.



Which statement cannot account for the differences in the levels of expression of globin chains?

A Methyl groups are added to regulatory sequences of ***γ**-globin* gene during the postnatal period, allowing for chromatin remodeling complexes to be recruited.

B Alternative splicing occurs in the mature mRNA of the ***α**-globin* and ***β**-globin* genes, resulting in differences in the rate of expression of globin chains during the prenatal period.

C A growth factor triggers the expression of a transcription factor that increases the rate of ***β**-globin* gene expression during the postnatal period.

D The shortening of poly(A) tail in the mRNA of ***γ** -globin* genes reduces its stability, resulting in a decrease in the rate of expression of ***γ**-globin* chains during the postnatal period

13. An analysis of the cells of a cancer patient revealed the presence of abnormal amounts of Ras proteins.

Which of the following could not explain for this observation?

A Gene amplification of Ras proto-oncogene

B A point mutation in a control element of the Ras proto-oncogene

C Translocation of Ras proto-oncogene to a region under the control of a more active promoter

D A single substitution in the exon of Ras proto-oncogene

14. A point mutation has occurred in *Escherichia coli*. Glucose and lactose are both absent in the culture medium where the mutant *E. coli* is grown in. An analysis of proteins synthesised by mutant *E. coli* found substantial amount of β-galactosidase, transacetylase and permease.

Which of the following mutations could have taken place in the *E. coli* cell?

1 Mutation in the operator of the lac operon
2 Mutation in the *lacI* gene
3 Mutation in the promoter of the lac structural genes

A **1** only

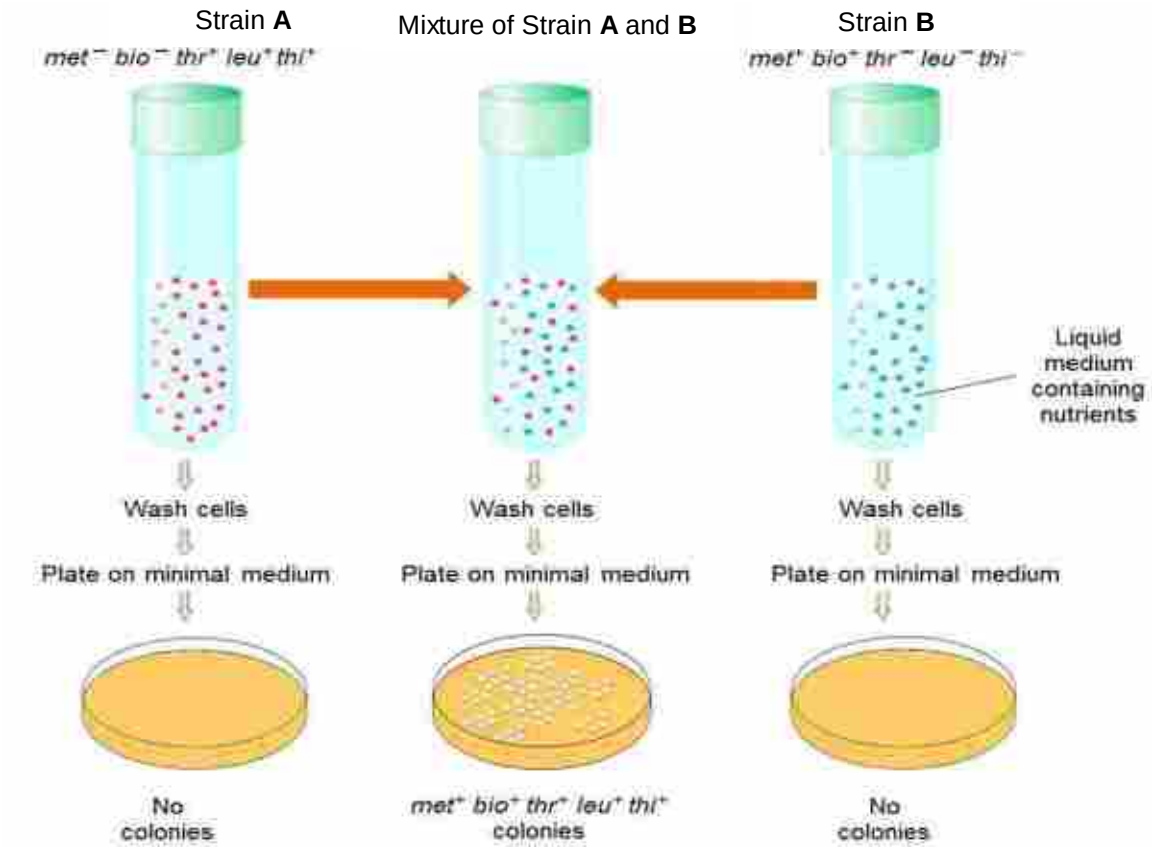
B **2** only

C **1** and **2** only

D **2** and **3** only

15. In an experiment to study genetic recombination, two strains of *Escherichia coli* with different nutritional requirements were used. Strain **A** (met^- bio^- thr^+ leu^+ thi^+) would grow on a minimal medium only if the medium were supplemented with methionine and biotin, while Strain **B** (met^+ bio^+ thr^- leu^- thi^-) would grow on a minimal medium only if it was supplemented with threonine, leucine and thiamine.

Some of the dishes were plated only with Strain **A** bacteria, some only with Strain **B** bacteria, and some with a mixture of Strain **A** and Strain **B** bacteria that had been incubated together for several hours in a liquid medium.



Which conclusion can be best drawn from the experiment?

A The *thr*$^+$, *leu*$^+$ and *thi*$^+$ genes in Strain **A** are located in its F plasmid.

B Cell-to-cell contact is necessary for the exchange of alleles between strain **A** and strain **B**.

C All the five genes are located on the F plasmid.

D Mutations resulted in *thr*$^+$, *leu*$^+$ and *thi*$^+$ genes in Strain **B** to produce colonies on a minimal medium plate.

16. The human immunodeficiency virus (HIV) has a highly specific gp120 glycoprotein that only allows it to infect cells with a CD4 receptor. To increase the host range of HIV in a laboratory setting, scientists often modify these viruses by artificially enclosing the viral nucleocapsid with a viral envelope with VSV-G glycoproteins embedded. VSV-G binds to LDL receptor, found ubiquitously on the cell membranes of many cell types, including kidney and liver cells that HIV do not usually infect.

A scientist has taken the following experimental steps:

1. Extracted an original and unmodified HIV nucleocapsid from wild-type HIV
2. Artificially enclose HIV nucleocapsid in a viral envelope containing VSV-G glycoproteins
3. Infect liver cells
4. Extract only newly synthesized virus particles released and examined them

What can the scientist expect to find in most newly synthesized virus particles extracted?

	Viral envelope	**Viral Genome**
A	VSV-G	VSV-G gene
B	VSV-G	gp120 gene
C	gp120	VSV-G gene
D	gp120	gp120 gene

17. During summer, an isolated population of bighorn ram on a mountain has been captured and the length of their curled horns was measured over 30 years. Horn length of bighorn ram follows a distribution similar to that of its weight.

Which of the following statements describing the features of horn length in bighorn sheep are not correct?

1 Horn length is controlled by multiple alleles with different degrees of dominance.
2 Horn length shows quantitative expression with overlaps between categories.
3 Horn length is polygenic where inherited individual alleles have an additive effect.
4 Horn length is not affected by the environment

A **1** and **2** only

B **1** and **4** only

C **2** and **3** only

D **3** and **4** only

18. Which of the following causes variation in both sexually and asexually reproducing organisms?

A Mutation

B Polygenic inheritance

C Crossing over

D Independent assortment

19. Possession of white or coloured feathers in chickens is controlled by two genes **P**/**p** and **Q**/**q**. The phenotypes of offspring that are expected from mating two chickens, each of which is heterozygous at both loci, are shown in the Punnett square.

Gametes	**PQ**	**Pq**	**pQ**	**pq**
PQ	White feathers	White feathers	White feathers	White feathers
Pq	White feathers	White feathers	White feathers	White feathers
pQ	White feathers	White feathers	Coloured feathers	Coloured feathers
pq	White feathers	White feathers	Coloured feathers	White feathers

What best explains the proportion of white to coloured feathers in the Punnette square?

A Dominant epistasis in which the epistatic allele is **P**
B Dominant epistasis in which the epistatic allele is **Q**
C Recessive epistasis in which the epistatic allele is **p**
D Recessive epistasis in which the epistatic allele is **q**

20. There are two hypotheses to explain the production of white, pale blue or dark blue flowers in a species of plant.

Hypothesis 1: There are two codominant alleles for flower color
Hypothesis 2: There are three alleles, one for each flower colour.

Which procedure is the best way of testing these hypotheses?

A Analysis of the flower pigments in several different flowers by chromatography to find whether some plants contain more than one pigment.
B Controlled cross pollination of all the different colour varieties available, in all possible combinations, and recording the colours shown by the offspring.
C Surveying large wild populations and finding the ratios of the different colours in these.
D Controlled self-pollination of several individuals of each of the colour varieties and recording the colours shown by the offspring of each individual plant sampled.

21. The following claims have been made about respiration.

1 Two turns of the citric acid cycle is required to oxidize 1 molecule of glucose.
2 Four molecules of carbon dioxide are generated for every molecule of acetyl CoA introduced into the Krebs Cycle.
3 During aerobic respiration, glucose produces pyruvate, CO_2 and ATP in the cytoplasm of a muscle cell.
4 Aerobic respiration can produce about 19 times the amount of ATP produced in anaerobic respiration.

Which of the following statements is/are true?

A **1** only
B **1** and **4** only
C **2** and **4** only
D **1, 3** and **4** only

22. *Rafflesia arnoldii* is a parasitic plant that produces the world's largest flower. It survives by invading the underground roots of vines to absorb nutrients essential for polypeptide synthesis. By doing so, it makes use of the nutrients to develop a giant and stinking flower that smells of rotting flesh in order to attract pollinating flies.

Which of the following two factors are most likely to act as limiting factors and inhibit growth of the vines when the Rafflesia parasite is present?

1 Carbon dioxide
2 Light
3 Photosynthetic enzymes
4 Water
5 Temperature

A **1** and **2**
B **2** and **3**
C **3** and **4**
D **4** and **5**

23. Which of the following gives an accurate comparison between intracellular receptors and cell surface receptors?

	Intracellular receptors	**Cell surface receptors**
A	May act as regulatory proteins and bind to DNA	May catalyse the phosphorylation of intracellular proteins
B	Functions as the second messenger to activate other relay proteins	Binding of ligand always trigger the production of second messengers
C	Ligands can be water-soluble or lipid-soluble	Ligands must be lipid-soluble
D	Made up of only hydrophobic amino acids to allow the interaction with lipid-soluble ligands.	Made up of hydrophobic amino acids which interact with the phospholipids of the membrane

24. Which of the following statements about channel proteins is/are correct?

I Channel proteins are either voltage-gated, ligand-gated or mechanically- gated.

II Channel proteins do not undergo conformational changes when transporting molecules.

III Channel proteins contain a hydrophilic pore lined with hydrophilic amino acids.

IV Channel proteins serve to transport hydrophilic molecules of all sizes across the cell membrane.

A **I** and **II** only

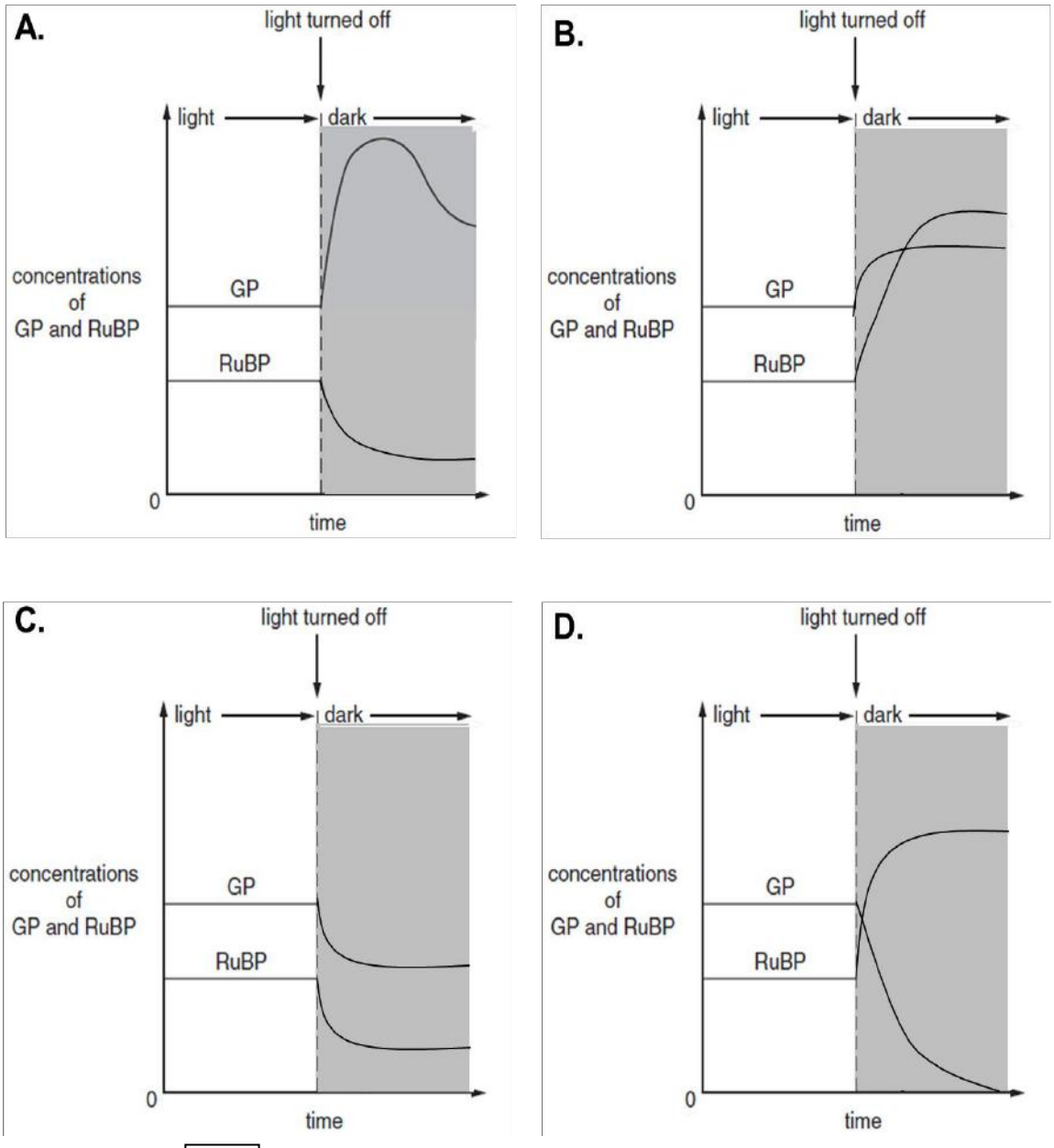
B **II** and **III** only

C **I**, **II** and **III** only

D All of the above

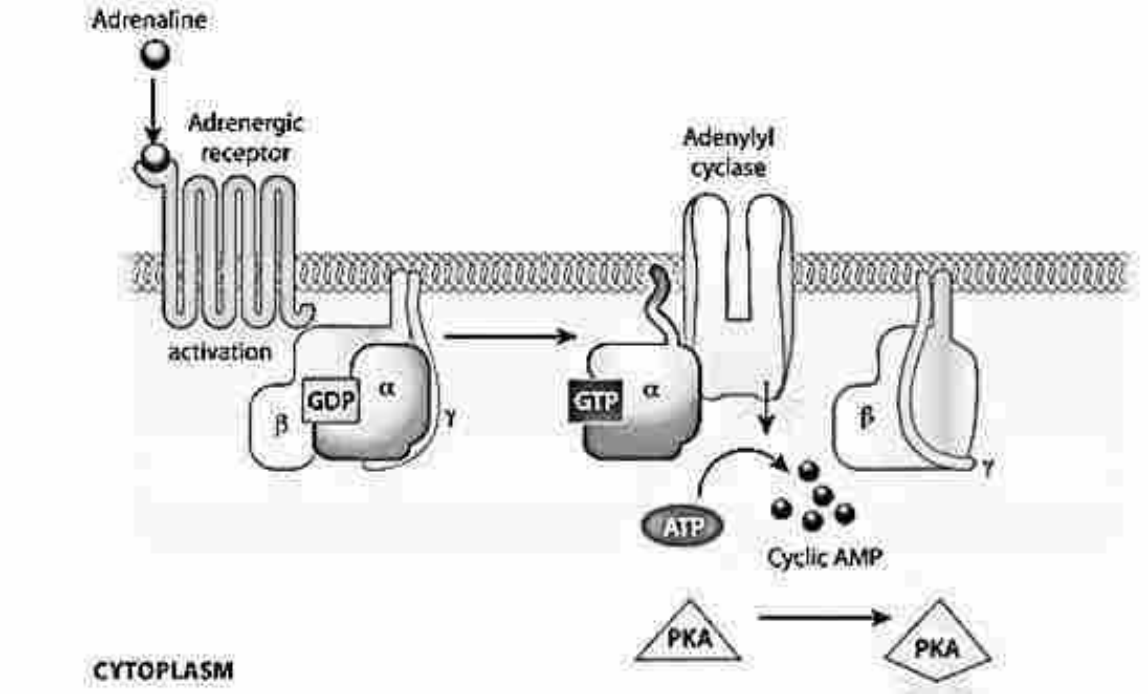
25. Concentrations of glycerate-3-phosphate (GP) and ribulose bisphosphate (RuBP) were measured from samples of actively photosynthesising green algae in an experimental chamber.

Which of the following graphs show how the concentration of these compounds changes when the light source was turned off?



A

26. The following diagram shows the activation of the G protein-coupled receptor (GPCR) by the binding of adrenaline to the receptor. A mutation leads to constitutive signal transduction.



Which of the following is a possible result of the mutation?

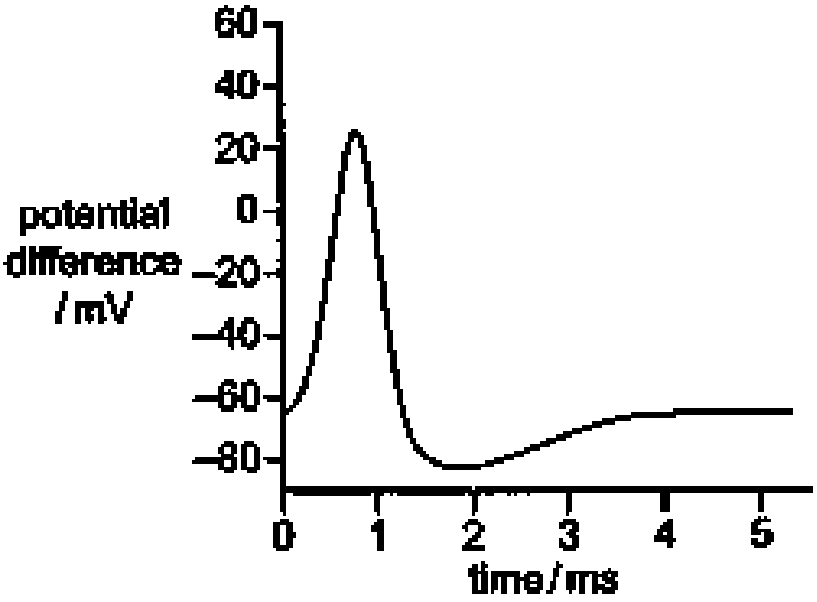
A Conformational change in adenylyl cyclase such that it cannot convert ATP to cyclic AMP.

B Adrenaline not being able to bind to the receptor.

C Cyclic AMP not being able to bind to PKA.

D GTPase in G protein failing to hydrolyse GTP to GDP.

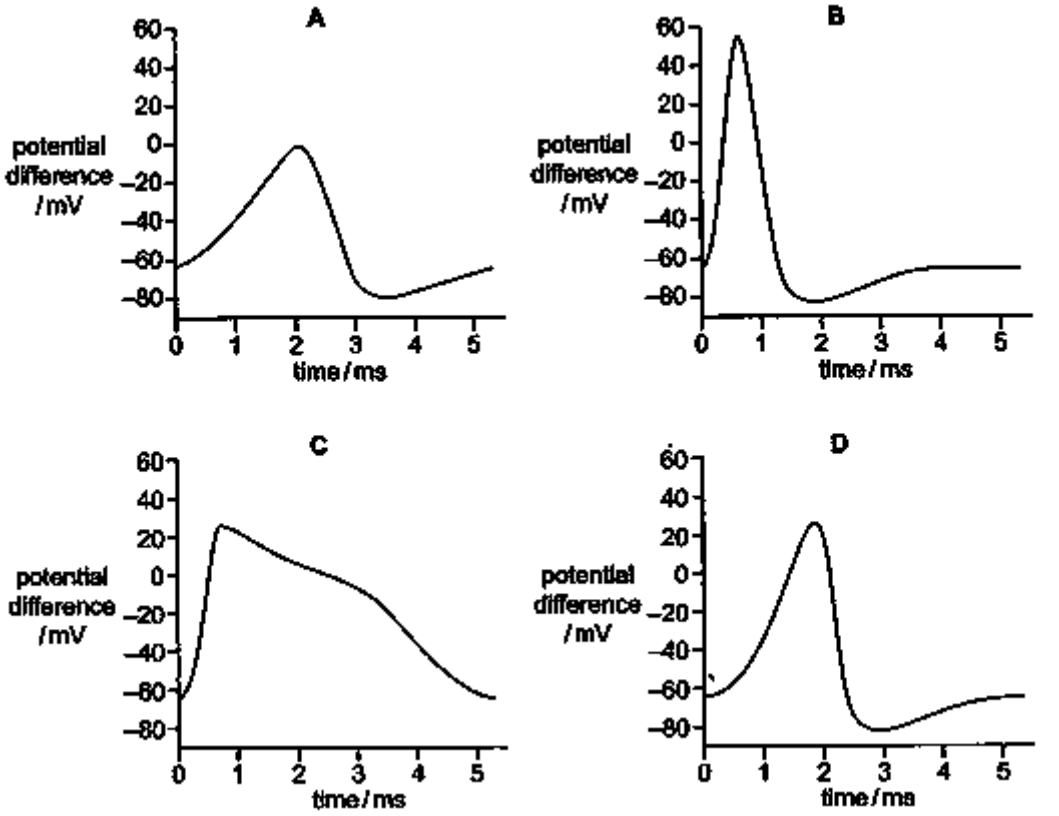
27. The diagram below shows a normal action potential.



Drug **X** can bind and block voltage-gated K^+ channels.

Which of the following diagrams shows an action potential in a neurone affected by such a drug?

C



28. Which is a correct description of the role of calcium ions in synaptic signalling?

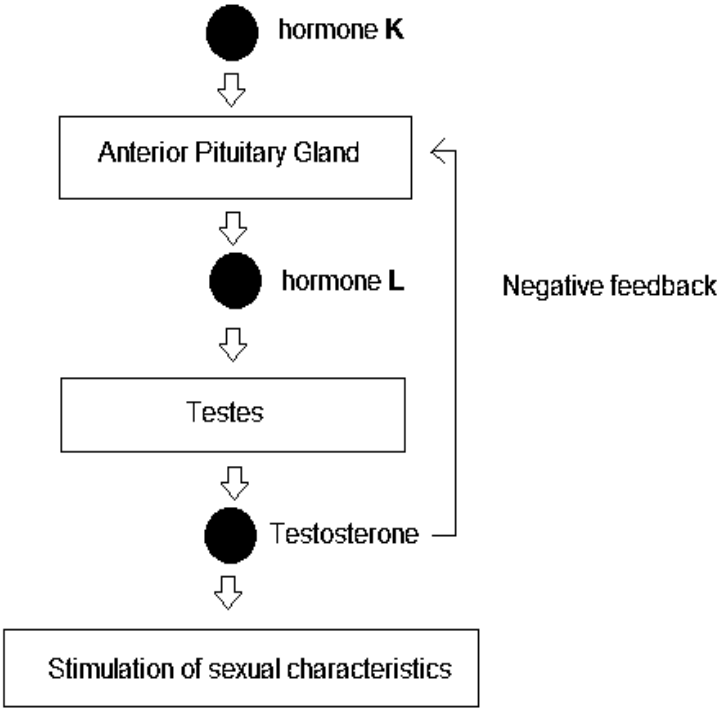
A Calcium ions are moved in by diffusion through ligand gated ion channels in pre-synaptic membranes of excitatory neurons, causing vesicles to move towards the pre-synaptic membrane as an impulse arrives

B Calcium ions are moved in by diffusion through voltage gated ion channels in pre-synaptic membranes of excitatory neurons, causing vesicles to move towards the pre-synaptic membrane as an impulse arrives.

C Calcium ions are moved in by active transport through calcium pumps in pre-synaptic membranes of excitatory neurons, causing vesicles to move towards the pre-synaptic membrane as an impulse arrives.

D Calcium ions are moved out by active transport through calcium pumps in pre-synaptic membranes of excitatory neurons, causing vesicles to move towards the pre-synaptic membrane as an impulse arrives.

29. The production of testosterone is regulated by the anterior pituitary gland. Upon stimulation by hormone **K**, the gland releases hormone **L** which causes the testes to produce testosterone. The elevated level of testosterone exerts a negative feedback on the anterior pituitary gland.



Which of the following would be observed if a man consumes large amount of steroids containing testosterone?

	Production of hormone K	**Production of hormone L**	**Production of testosterone**	**Stimulation of sexual characteristics**
A	Decrease	Decrease	Decrease	No change
B	Decrease	Decrease	No change	Increase
C	No change	Decrease	Decrease	Increase
D	No change	Decrease	Decrease	No change

30. Which of the following is not a limitation of the use of fossil records as evidence for evolution?

A Fossils are damaged and incomplete.

B Some organisms may not form fossils.

C Fossils are found in different sedimentary rock layers.

D Fossils present in inaccessible areas are not available to us for study.

31. The following statements relate to molecular phylogenetics.

1 Lines of descent from a common ancestor to present-day organisms have undergone similar and fixed rates of DNA mutation.

2 Organisms with similar base sequences in their DNA are closely related to each other.

3 The number of differences in the base sequences of DNA of different organisms can be used to construct evolutionary trees.

4 The proportional rate of fixation of mutations in one gene relative to the rate of fixation of mutations in other genes stays the same in any given line of descent.

Which statements, when taken together, suggest the existence of a 'molecular clock' that enables scientists to estimate the time at which one species might have diverged from another?

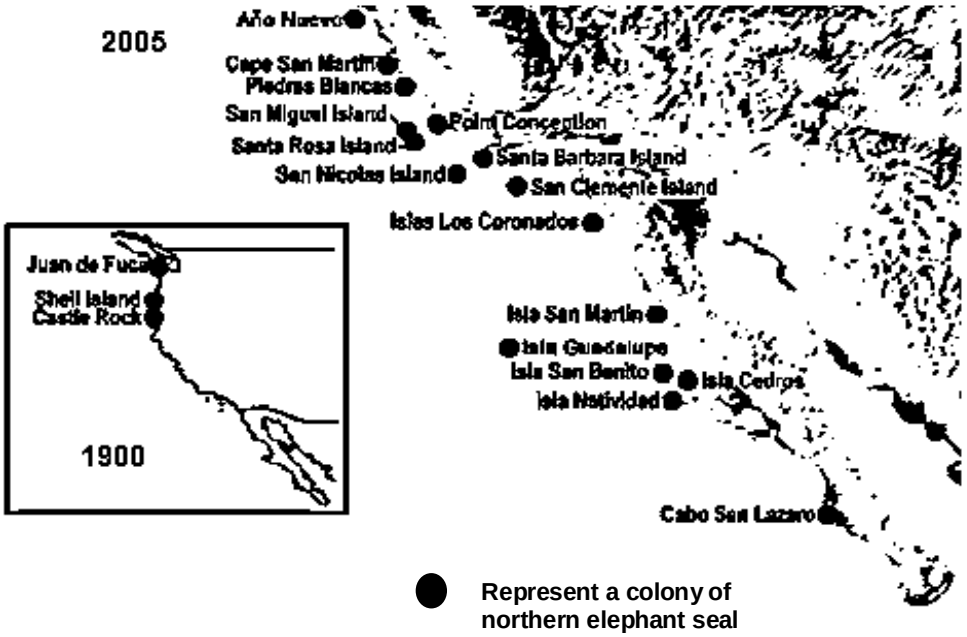
A **1** and **2** only

B **1** and **4** only

C **2** and **3** only

D **3** and **4** only

32. The northern elephant seal almost became extinct in the late 1800's following harvesting by whalers and sealers for their blubber which contains oil. A small colony of between 20 and 100 individuals survived on Guadalupe Island off Baja California. This colony has since given rise to about 160,000 elephant seals on the Pacific coast today. The following figure compares the distribution of elephant seals between 1900 and 2005.



Which evolutionary mechanism could best explain why the degree of homozygosity is higher in the recent population of elephant seals compared to the original population in the 1800s?

A Directional selection

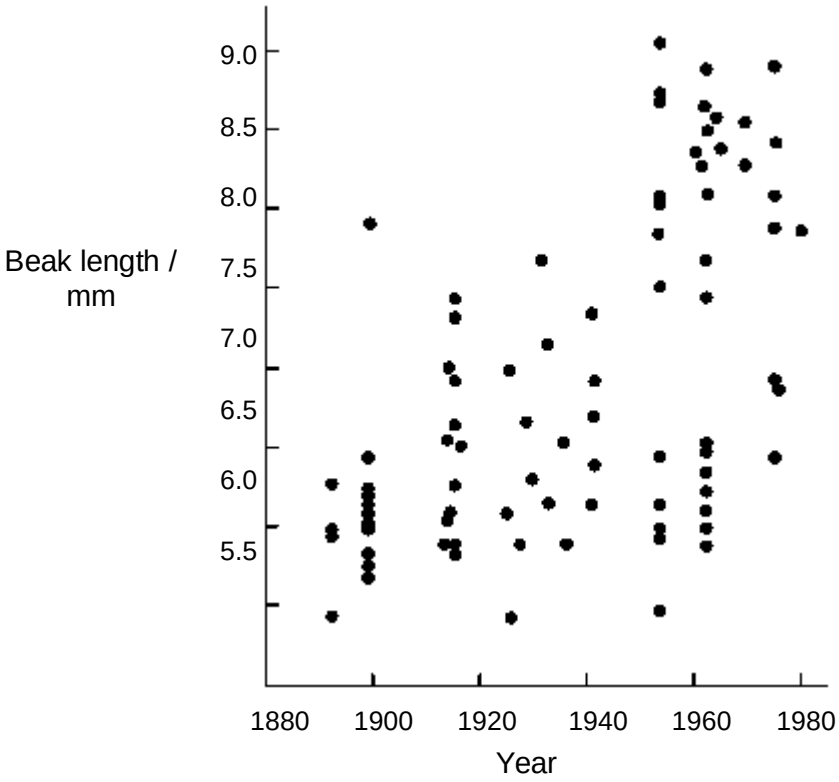
B Bottleneck effect

C Founder effect

D Genetic drift

33. The soapberry bug, *Jadera haematoloma,* uses its long beak to penetrate the fleshy fruit of the native soapberry tree to feed on the seeds at the centre. The bug also feeds on the fruit of the introduced golden rain tree.

Investigators measured the beak length of the soapberry bugs over eighty years. The results are shown in the graph.



Which of the following statements is a reasonable conclusion based on the above information?

A The golden rain tree was introduced around 1970.

B The change in beak length is an example of stabilizing selection.

C The diameter of the golden rain tree fruit acted as a selection pressure on beak length.

D The response of an individual golden rain tree to predation by soapberry bugs would be to grow larger fruit.

34. EcoRI is a restriction enzyme produced by *Escherichia coli*. It recognises the sequence GAATTC and is able to make a staggered cut in the DNA. *E. coli* is susceptible to attack by bacteriophages.

Which of the following correctly describes the natural function of EcoRI?

A It lowers infectivity rate of *E. coli* by bacteriophages that have double-stranded DNA as their genetic material, since EcoRI can recognise and cleave specific viral nucleotide sequences.

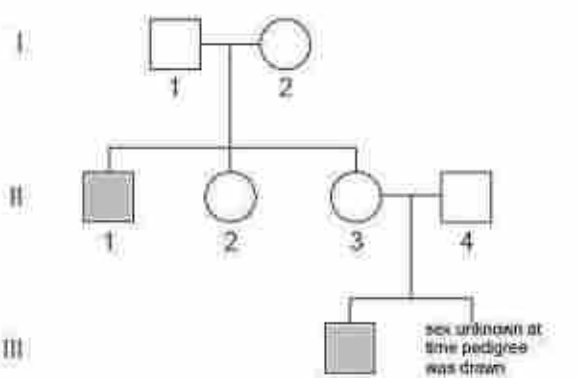
B It cleaves *E. coli* DNA sequences to produce restriction fragments that can be packaged into bacteriophages for infection of new bacterial cells.

C It increases infectivity rate of *E. coli* by bacteriophages because it promotes cleavage of viral DNA at specific nucleotide sequences in order to package more viral DNA into new virus particles.

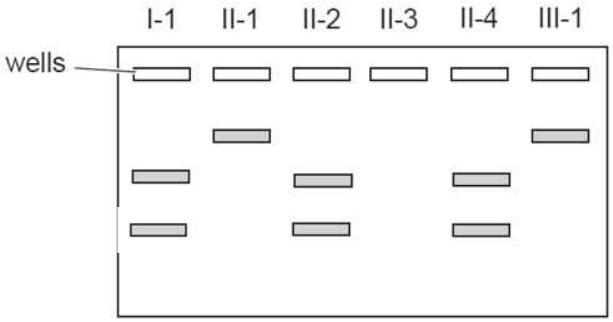
D It cleaves *E. coli* DNA sequences so that the bacterial cell which has been infected will undergo autolysis and self-destruct, preventing further infection of new bacterial cells.

35. Menkes' syndrome in humans is characterised by sparse and wiry hair, growth failure and deterioration of the nervous system. Onset of the Menkes' syndrome usually occurs during infancy.

A family, in which this X-linked disorder was present, underwent Restriction Fragment Length Polymorphism (RFLP) analysis using gel electrophoresis. The family pedigree is shown below.



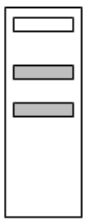
The RFLP analysis resulted in the following distribution of bands in the gel.



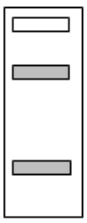
D

What would be the band pattern of individual II-3?

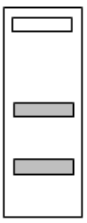
A



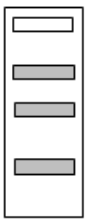
B



C



D



36. Which of the following options correctly describe the events occurring in each process?

	Action of restriction enzyme	Ligation	Annealing	Denaturation
A	Breaking of hydrogen bonds	Formation of hydrogen bonds	Formation of phosphodiester bonds	Breaking of phosphodiester bonds
B	Breaking of hydrogen bonds	Formation of hydrogen bonds	Formation of phophodiester bonds	Formation of phosphodiester bonds
C	Breaking of phosphodiester bonds	Formation of phosphodiester bonds	Formation of hydrogen bonds	Breaking of hydrogen bonds
D	Breaking of phosphodiester bonds	Formation of phosphodiester bonds	Breaking of hydrogen bonds	Formation of hydrogen bonds

37. Which of the following are ethical concerns arising from the Human Genome Project?

1 Scientists tracing migration of different population groups based on maternal inheritance

2 Genetic counsellors giving advice to people who are genetically pre-disposed to risks

3 Parents choosing to abort foetuses with minor disorders based on genetic testing results

4 Scientists developing tests for only some disease-causing genes.

5 Employers refraining from hiring people with greater risk of developing genetic diseases

A **1** and **4**

B **2** and **5**

C **3** and **4**

D **3** and **5**

38. Which of the statements about stem cells are false?

1 Embryonic stem cells are useful as they have the ability to differentiate into any cell type.
2 Embryonic stem cells are less easily isolated compared to neural crest stem cells.
3 Umbilical cord blood stem cells have the same developmental potential as neural crest stem cells.
4 Induced pluripotent stem cells undergo differentiation to give rise to various cell lineages.
5 Stem cells have the ability to self-renew without any stimulus.

A **1**, **2** and **5** only
B **1**, **4** and **5** only
C **2**, **3** and **4** only
D **3**, **4** and **5** only

39. One way to treat β-thalassaemia is to transplant bone marrow cells from a genetically compatible donor into a patient. A potential gene therapy involves adding the normal and dominant allele for β-globin to the patient's cells.

What would ensure that the normal gene is passed on to the next generation?

A Using a retrovirus to introduce the normal β-globin gene into bone marrow cells.
B Using an adenoviral vector to introduce the normal β-globin gene into bone marrow cells.
C Using an adenoviral vector to introduce the normal β-globin gene into an egg cell.
D Using a retrovirus to introduce the normal β-globin gene into an egg cell.

40. Which of the following is an example of genetically modified organisms?

A Cows that grow to adult sizes quickly due to injection of recombinant bovine somatotropin

B Durians that ripen slower due to anti-sense technology

C High yielding rice that are flood resistant, due to intensive self-pollination over generations

D Cows that grow to abnormal size due to inbreeding

End Of Paper

Class Adm No

Candidate Name: _____

H

millennia institute

2016 Preliminary Examination II
Pre-University 3

H2 Biology **9648/02**

Paper 2 Core Paper **16 September 2016**

2 hours

Additional Materials: Writing paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your Admission number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question. At the end of the examination, fasten all your work securely together.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
Total	

This question paper consists of 28 printed pages.

[Turn over

For Examiner's Use

Section A

Answer **all** questions in this section.

1. Figure 1.1 shows a mid-section of a mammalian DNA molecule, comprising Strand **A** and Strand **B**, during the S phase of interphase.

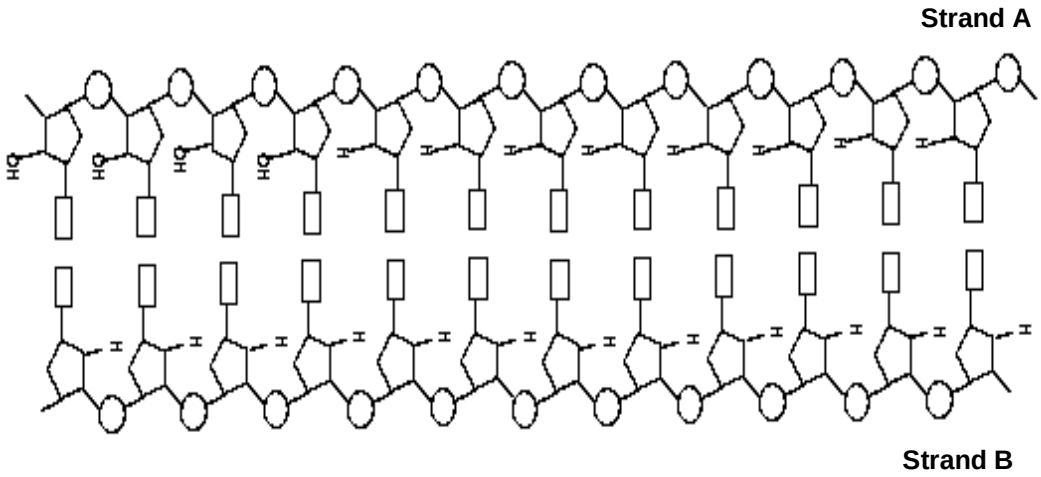


Figure 1.1

(a) With reference to Figure 1.1,

(i) account for the difference in the nucleotides in Strand **A** compared to Strand **B.**

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…… [3]

(ii) Outline the next immediate step in the further processing of Strand **A.**

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…… [1]

Figure 1.2 depicts a telomere complex at the end of a chromosome in a human zygote. Telomeres are lengthened during embryonic development to compensate for shortening due to the end-replication problem.

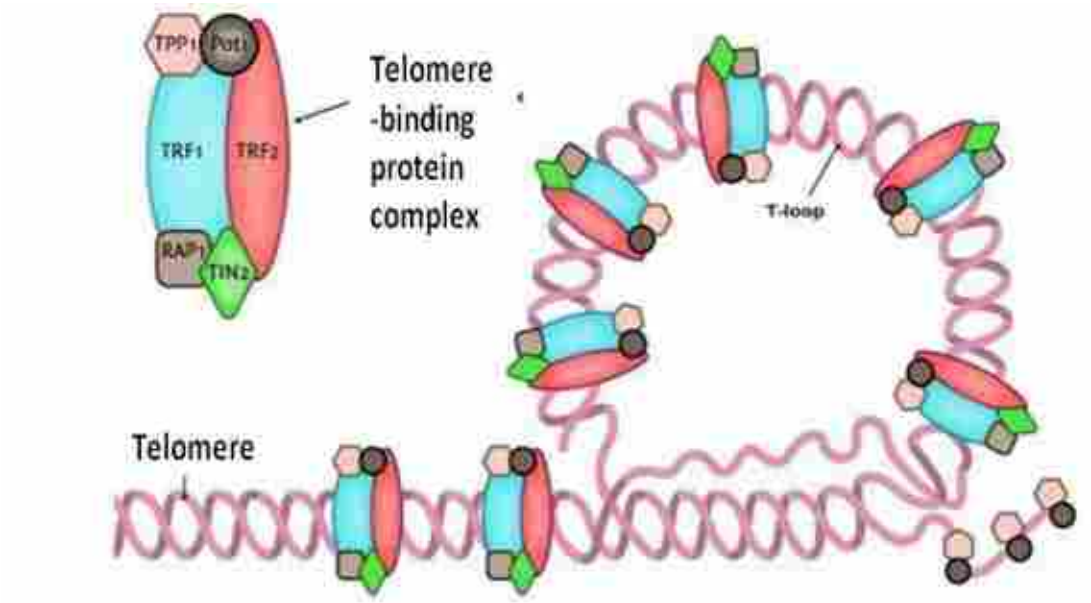

Figure 1.2

(b) Describe two differences between transcription and the process of telomere lengthening.

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[Turn over

A study was conducted to investigate gene expression in yeast. Yeast strain **X** and strain **Y** were used in this study. These strains differed in the location of the *ADE2* gene. In strain **X**, *ADE*2 gene is at its normal locus on chromosome 5. An engineered inversion event is responsible for creating strain **Y** where *ADE2* gene locus is near the telomere. Figure 1.3 depicts the loci of the *ADE2* gene in both strain **X** and strain **Y**.

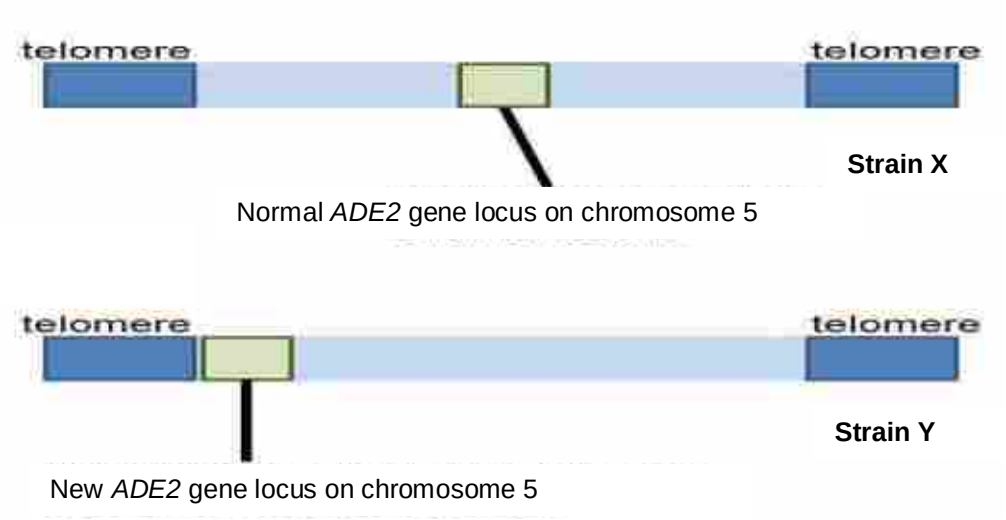

Figure 1.3

The above yeast strains were cultured on specially supplemented agar plates and incubated for one week to produce yeast colonies. Based on the constituents of the agar, expression of *ADE2* gene prevents accumulation of red pigments and results in cells being white in colour. The colonies produced from this period of incubation are represented in Figure 1.4.

White Colonies from Strain **X**

Red Colonies from Strain **Y**

Figure 1.4

Previous studies have shown that some proteins bind to yeast telomeres to recruit histone deacetylase enzymes. These enzymes then act on the chromatin regions around the telomeres.

(c) Using the above information, explain the difference in colony colour between strain **X** and strain **Y** after one week of incubation.

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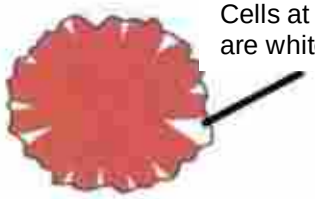
The colonies from both strains were allowed incubate for an additional week. Following this, it is then observed that some cells at the edges of the Strain **Y** colonies appeared white in colour, as depicted in Figure 1.5.



Appearance of colonies from Strain **Y** after two weeks of incubation

Figure 1.5

(d) Explain why the cells at the edges of Strain **Y** colonies appear white in colour after two weeks of incubation.

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[Total: 13]

[Turn over

2. In the cytosol, chaperone proteins can bind reversibly to newly synthesized polypeptides and shield them from other molecules. This prevents the R groups of amino acids from forming bonds with the wrong molecular partners, hence allowing the polypeptides to fold correctly.

Figure 2.1 below shows how chaperone proteins work.

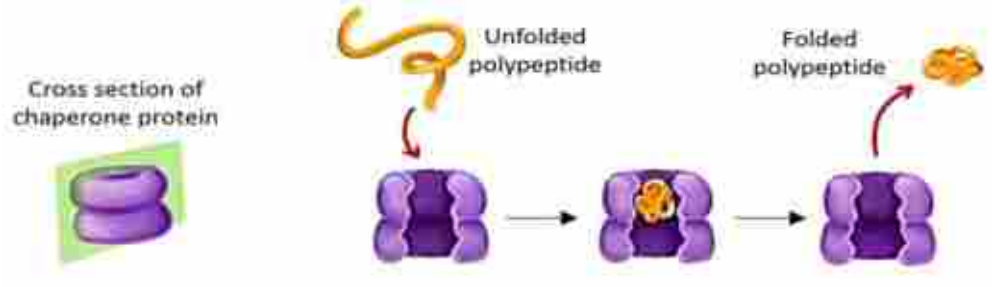

Figure 2.1

(a) With reference to Figure 2.1, explain how chaperone proteins regulate gene expression.

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.... [2]

(b) Describe how cytosolic proteins are degraded in cells.

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.... [2]

When a protein fails to fold correctly upon synthesis or misfolds at a later stage in its cellular life time, it can no longer fulfil its biological function. Protein misfolding may occur due to mutations in genes or interference with expression of chaperone proteins. Figure 2.2 shows how misfolded proteins may aggregate in a cell.

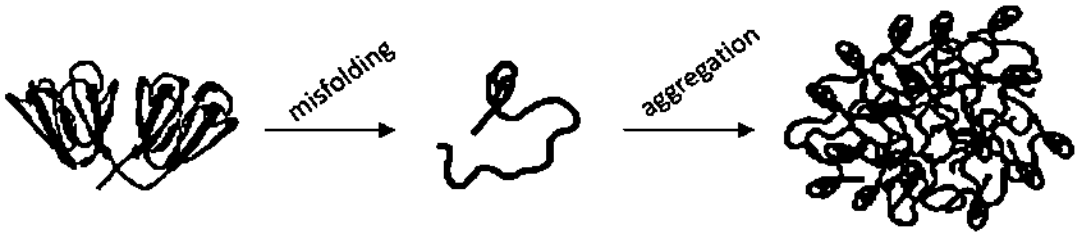

Figure 2.2

(c) With reference to Fig. 2.2, suggest why misfolded proteins tend to aggregate in the cell.

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[Turn over

An example of a misfolding disease is Bovine spongiform encephalopathy (BSE), a neurodegenerative disease in cattle and commonly referred to as mad cow disease. In BSE, there is an aggregation of misfolded prion proteins in the neurons of cattle, which results in degeneration of the brain and spinal cord.

Hereditary forms of BSE have been associated with a mutation in the brain prion protein (PrP) gene, which encodes the PrP protein. The PrP protein is a transmembrane glycoprotein found on the surface of neurons. Figure 2.3 shows the ribbon model of a normal PrP protein.

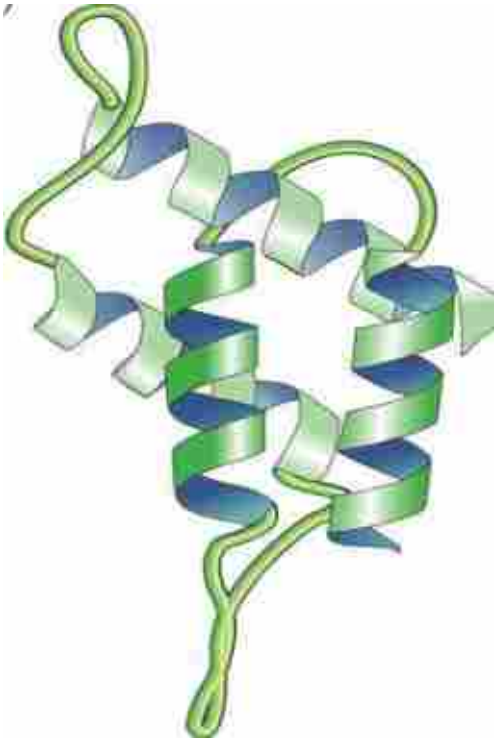

Figure 2.3

(d) Explain how the the PrP protein would maintain its position within the cell membrane.

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(e) Describe how the PrP protein on the cell surface membrane is formed after its polypeptide chain has been synthesized.

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A human version of BSE called variant Creutzfeldt-Jakob disease (vCJD) is believed to be caused by eating beef products contaminated with central nervous system tissue from infected cattle. Studies have shown that the introduction of misfolded cattle PrP by consuming contaminated meat can cause normal human prion protein to misfold and form aggregated plagues in the brain.

Health advisories have cautioned that cooking contaminated meat will not provide protection from infection that would lead to vCJD.

(f) Suggest why cooking contaminated meat products will not provide protection from contracting vCJD.

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.... [1]

[Total: 13]

[Turn over

3. Burmese cats, *Felis catus*, show discontinuous variation in the colour of their eyes and hearing ability. A large scale investigation was conducted to study the inheritance pattern of eye colour and deafness in such cats.

Pure-breeding blue eyed cats which were deaf were crossed with pure-breeding yellow eyed cats with normal hearing.

The F_1 all had yellow eyes and normal hearing.

Female cats from the F_1 were crossed with male cats with blue eyes and were deaf. 668 offspring were produced.

The observed numbers of F_2 cats with each phenotype were as follows:

Blue eyes, deaf	259
Blue eyes, normal hearing	72
Yellow eyes, deaf	53
Yellow eyes, normal hearing	284

(a) State what is meant by pure-bred cats for eye colour and hearing ability.

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…. …… [1]

A chi-squared test, with the guide of Table 3.1, was planned to evaluate the difference between observed and expected results.

Table 3.1

Degree of Freedom	Probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(b) Based on this study, state the expected results for F_2 cats produced from crossing F_1 female cats with male cats with blue eyes and were deaf.

…. …… [1]

(c) With reference to Table 3.1, outline how the significance of the difference between observed and expected results can be evaluated with 98% confidence (Formulae not required).

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The difference between observed and expected results was eventually concluded to be significant.

(d) Using the symbols Y/y for eye colour and H/h for hearing ability, draw a genetic diagram to explain the observed results of the cross between F_1 female cats and male cats with blue eyes and were deaf.

[4]

[Turn over

The coordinated activity of higher order organisms like cats relies upon a continuous input of information from the internal and external environments. Information is in the form of stimuli, which are detected by receptors. One such receptor is called a Pacinian corpuscle, which is found in the skin.

Fig. 3.1 shows the electrical activity recorded by two microelectrodes inserted into:

- the axon within the Pacinian corpuscle at site **P**, and
- the axon of the sensory neurone leaving the corpuscle at site **Q**

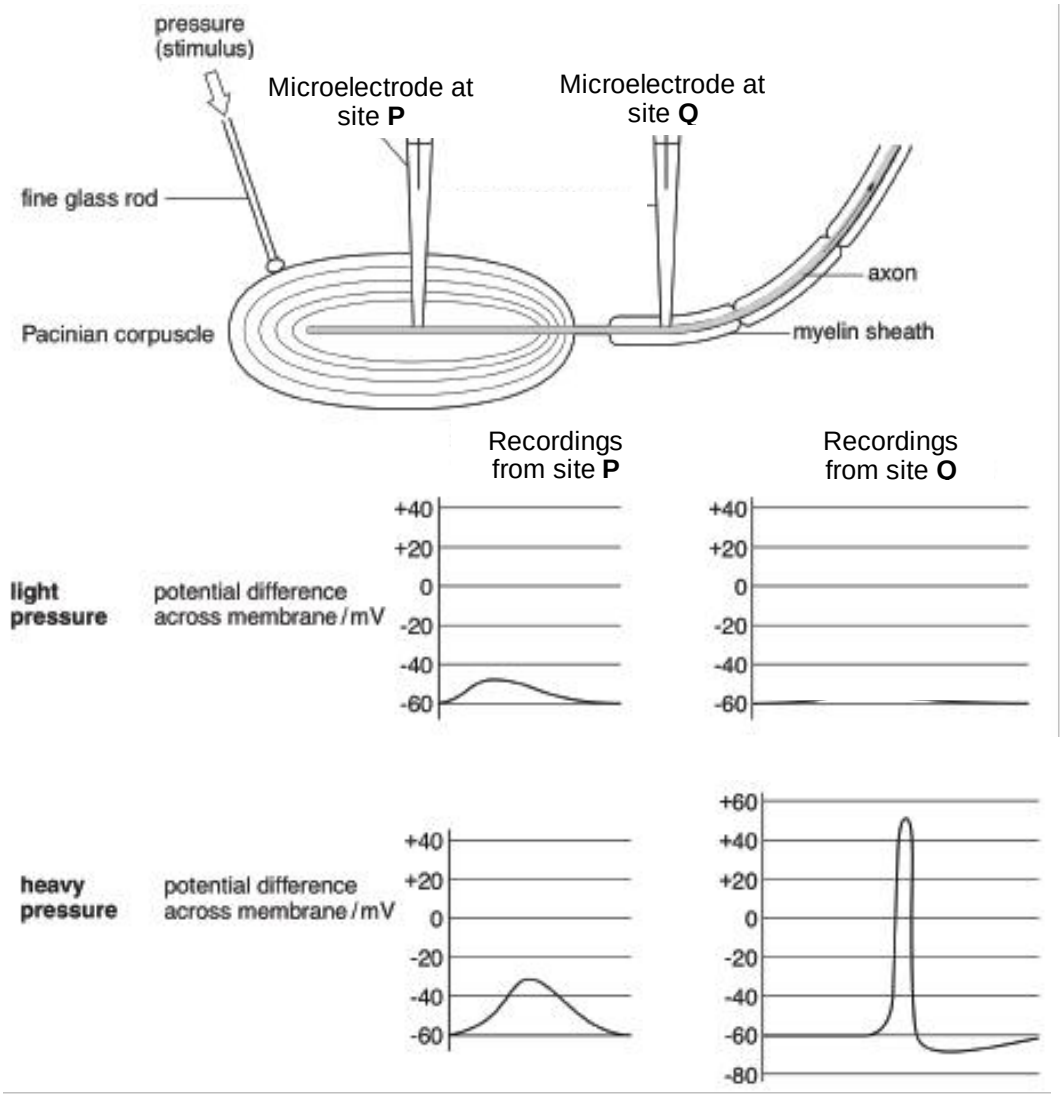

Figure 3.1

(e) With reference to Figure 3.1, account for the changes in electrical activity in site **P** and **Q** as increasing pressure is applied to the Pacinian corpuscle.

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[Total: 12]

[Turn over

4. Rhinoviruses are the most common viral infectious agents in humans and are the predominant cause of the common cold. Symptoms include sore throat, runny nasal congestion, sneezing and cough which may be accompanied by muscle aches and loss of appetite.

The structure of the human rhinovirus is depicted in Figure 4.1. Human rhinoviruses are composed of a capsid that contains four viral proteins **VP1**, **VP2**, **VP3** and **VP4**. Each viron has one copy of single-stranded positive sense RNA genome of between 7200 and 8500 nucleotides in length.

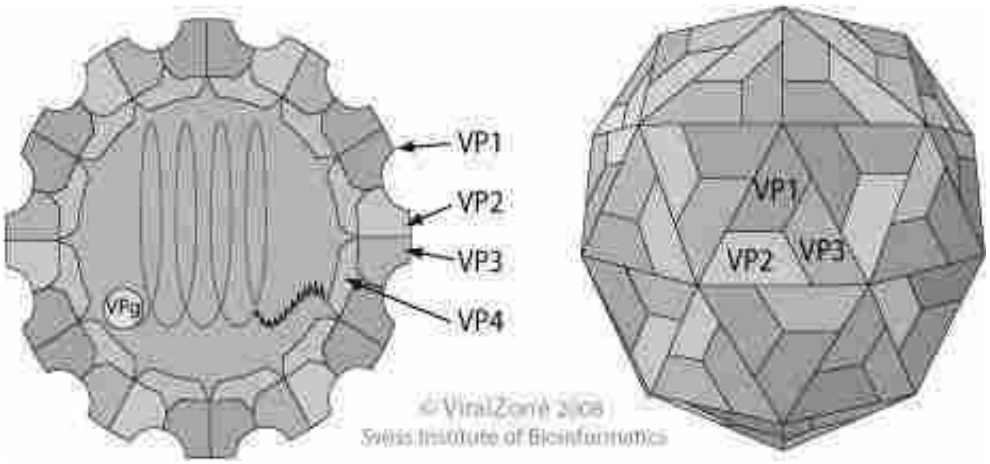


Figure 4.1

Despite structural differences, both human rhinovirus and influenza virus are able to penetrate respiratory epithelial cells for infection.

(a) Explain how it is possible for both human rhinovirus and influenza virus to be able to penetrate human respiratory epithelial cells.

....

....

.... [1]

The enzyme neuraminidase plays an important role after new influenza virions exit their host cells from each round of infection.

(b) Describe the role of neuraminidase in the reproductive cycle of the influenza virus.

....

....

.... [2]

(c) With reference to Figure 4.1, explain why it is unlikely that the newly assembled human rhinovirus exit their host cells in the same way as influenza virions.

…. ……

…. ……

…. …… [2]

[Turn over

H7N9 is a subtype of Avian Influenza virus, which normally circulates amongst the avian populations with some variants known to occasionally infect humans. An H7N9 virus was first reported to have infected humans in 2013 in China and now this virus has spread among humans. Figure 4.2 shows the proposed evolution of H7N9 virus.

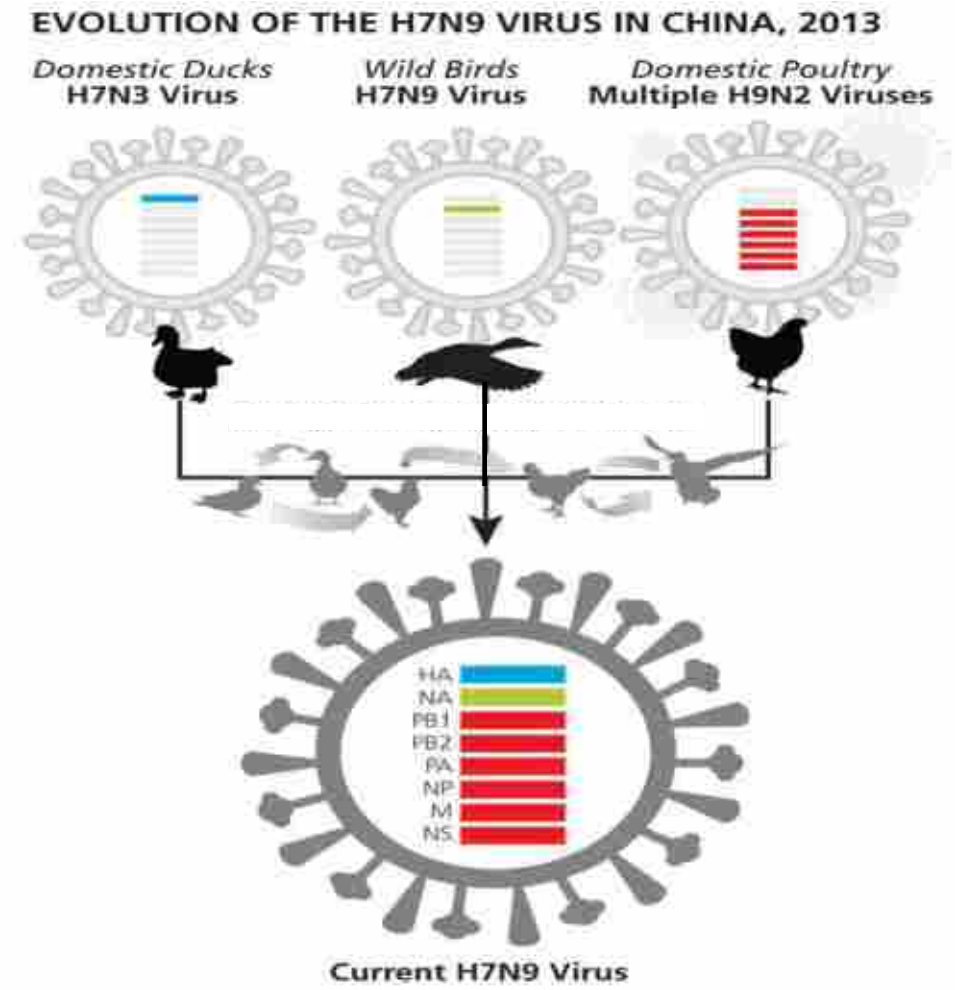


Figure 4.2

(d) With reference to Figure 4.2, explain how the new combination of RNA segments in H7N9 was proposed to have arisen.

…. ……

…. ……

…. ……

…. ……

…. …… [3]

Today viruses are considered an exception to the cell theory which states that the basic units of life are cells. Viruses have been referred to as "organisms at the edge of life".

(e) State one characteristic of viruses that may classify them as being

(i) living

……

……. [1]

(ii) non-living

……

……. [1]

[Total: 10]

[Turn over

5. A study was carried out to measure the concentrations of glucose and insulin in the blood of students. The results are summarised in Fig. 5.1.

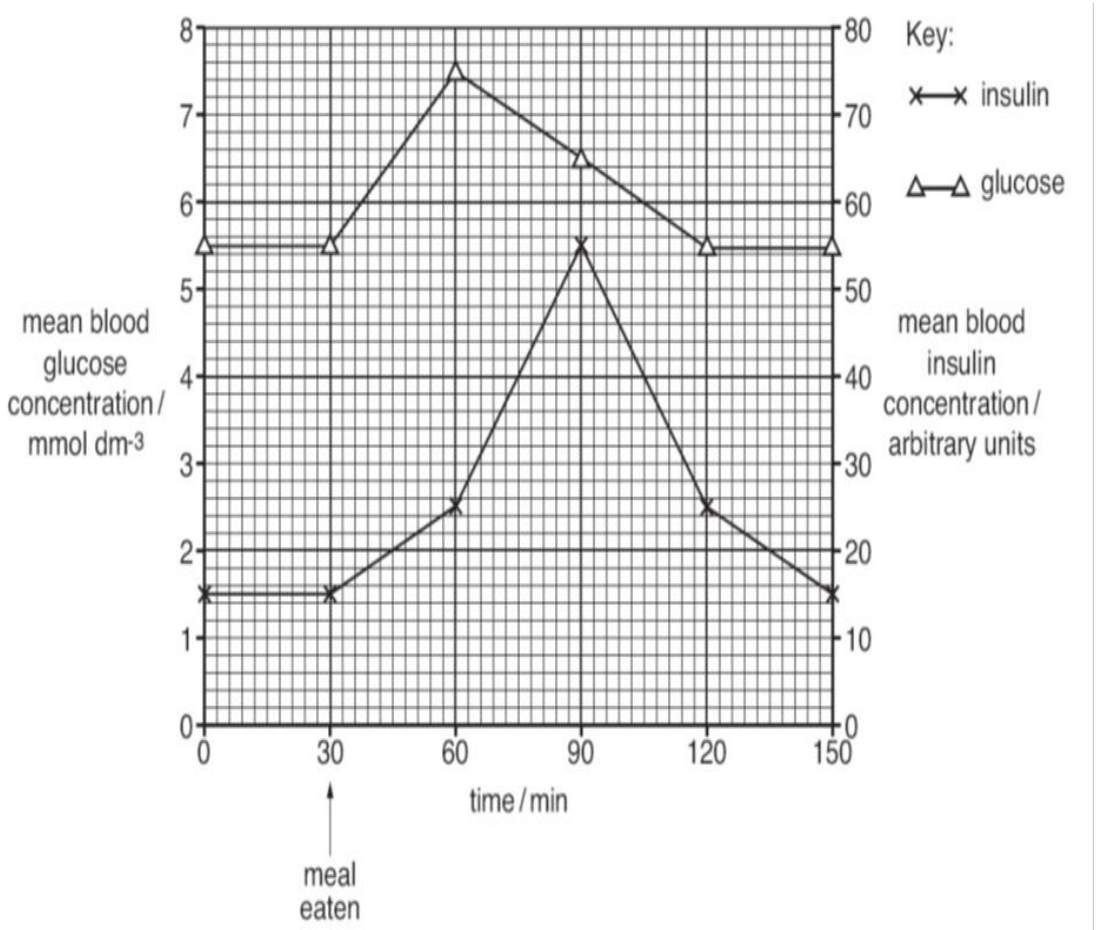


Figure 5.1

(a) With reference to Figure 5.1, account for the relationship between the concentration of glucose and the concentration of insulin in the blood after a meal.

…… [5]

Figure 5.2 outlines some steps in glucose metabolism in human muscle cells.

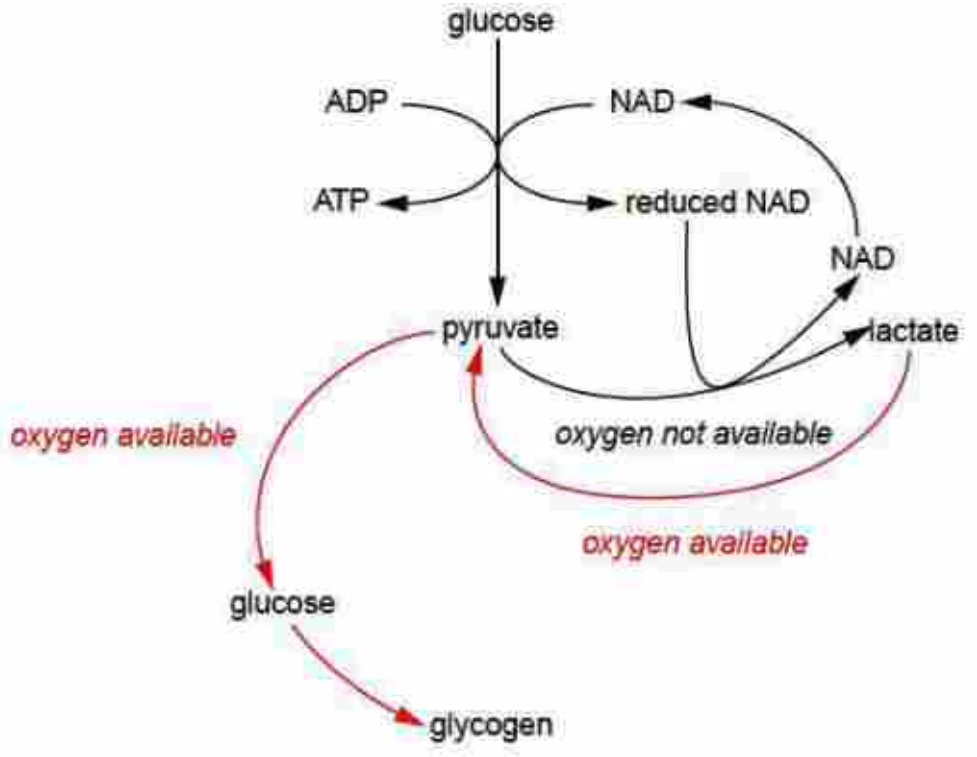


Figure 5.2

(b) Explain why pyruvate needs to be converted to lactate in the absence of oxygen.

…. ……

…. ……

…. ……

…. …… [2]

[Turn over

Hexokinase is an enzyme that plays a critical role in glucose metabolism. This enzyme converts glucose into glucose-6-phosphate. This step is important as it energises glucose for further metabolic reactions. Fig. 5.3 is a computer-generated image of the enzyme hexokinase binding with its substrate, glucose.

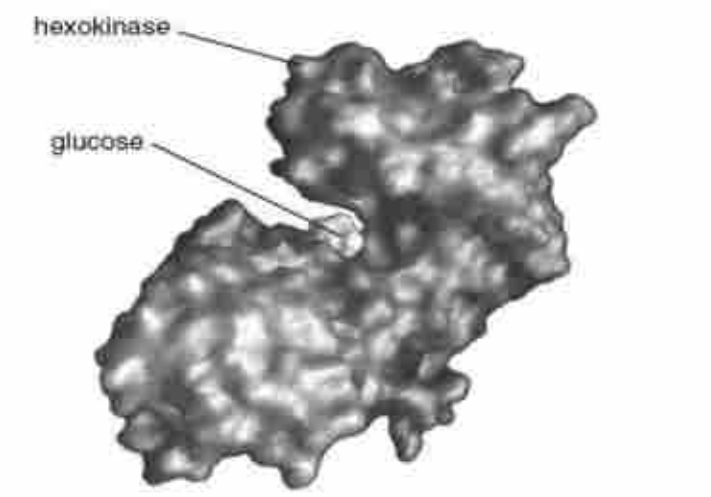


Figure 5.3

Crystallization studies have shown that the shape of hexokinase's active site is not complementary to the shape of glucose.

(c) Describe the mechanism by which hexokinase binds to glucose.

....

....

....

.... [2]

The phosphorylation of glucose by hexokinase also prevents it from leaving the liver cells.

(d) Suggest why glucose-6-phosphate cannot move out of liver cells.

....

....

.... [2]

[Total: 11]

6. Most ATP is made in cells by membrane systems that create proton gradients by pumping protons from one compartment to another. Figure 6.1 show two such organelles.

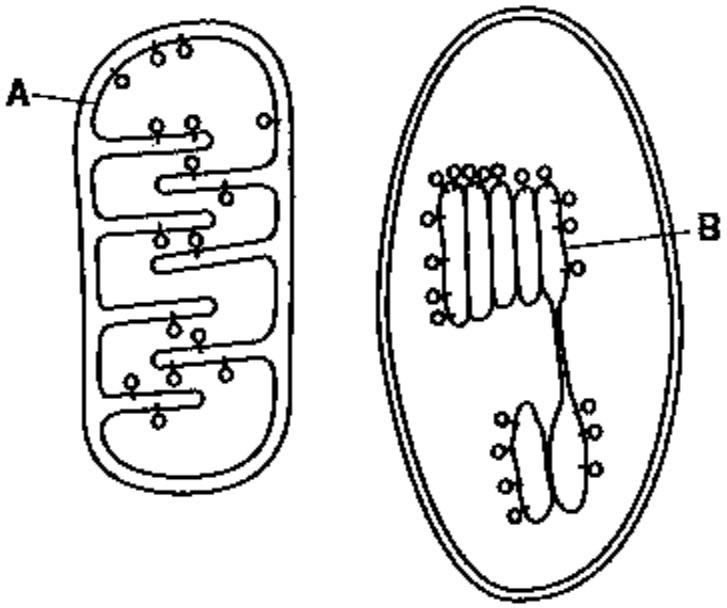


Figure 6.1

(a) Draw arrows onto each organelle in Figure 6.1 to show the direction in which protons are pumped.

[2]

(b) In addition to facilitating the formation of proton gradients, state one other importance of compartmentalisation within organelles **A** or **B** for ATP
synthesis.

…. .....

[Turn over

In 1882, the German botanist T.W. Engelmann performed an experiment to investigate the effects of different wavelengths of light on the rate of photosynthesis using *Spirogyra*. *Spirogyra* is a type of green alga that contains photosynthetic organelles. Other studies have shown that there are pigments that absorb blue, green, yellow and red light in these organelles.

A strand of *Spirogyra* was placed into water containing aerobic bacteria. Different parts of the strand were exposed to different colours of light. After a period of time, the bacteria had moved into the positions shown in Figure 6.2.

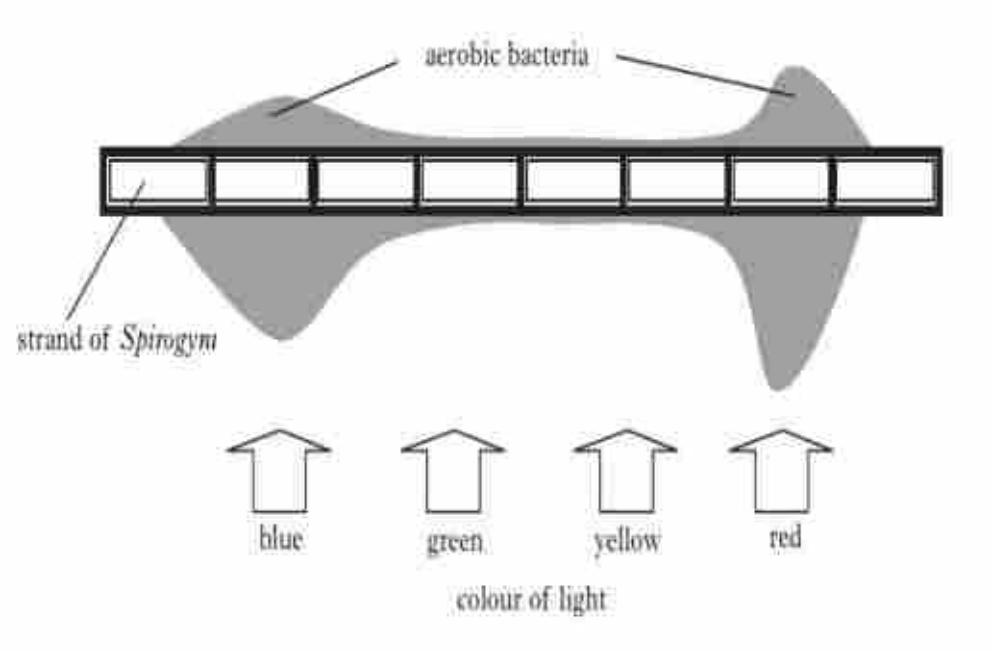


Figure 6.2

It was concluded that wavelengths corresponding to red and blue light caused a higher rate of photosynthesis compared to wavelengths corresponding to green and yellow light.

(c) With reference to Figure 6.2,

(i) explain why the abovementioned conclusion was drawn.

.....

.....

.....

.....

..... [3]

(ii) suggest a role for the pigments absorbing green and yellow light in Spirogyra's photosynthetic organelles.

.....

.....

..... [2]

[Total: 8]

[Turn over

7. Wolf, *Canis lupus,* is one of the world's best known and well researched species, with arguably more books written about it than any other wildlife species. It is the largest extant member of its family, *Canidae,* with males averaging 45kg and females 37kg.

Wolves are further classified into a number of sub-species based on marked phenotypic differences, such as body size and colour. Figure 7.1 shows the several sub-species of wolves in existence today.

Figure 7.1

(a) Suggest one reason why the existing populations of wolves are classified as different sub-species rather than different species.

…. ……

…. …… [1]

Timber wolves are native to the wilderness of Eurasia and North America. Studies have suggested that the timber wolves once co-existed with the extinct dire wolf, *Canis dirus,* on the North American continent.

Figure 7.2 depicts skeletal models of a timber and dire wolf. Dire wolves were larger and had more powerful jaws compared to timber wolves. However, they had proportionally much shorter legs than timber wolves, and were as such slower runners. They are known to feed on different prey, with the large dire wolves favouring larger prey and the timber wolves favouring smaller prey. It is known that the dire wolves went extinct approximately 8000 years ago, which coincides the time period when its large prey declined in numbers.

Figure 7.2

(b) Using Darwin's theory of evolution, explain why the dire wolves went extinct.

....

....

....

....

.... [3]

(c) Explain why a population is the smallest unit that can evolve.

....

....

....

.... [2]

[Turn over

Scientists used DNA hybridisation to determine the evolutionary relationships between five members of the *Canidae* family. The temperature at which a molecule of double-stranded DNA separates into two single strands is the separation temperature. A region of non-coding DNA was analysed for the study. The scientists recorded the mean separation temperature of this region of DNA in which both strands were from the same species. The scientists then recorded the mean decrease in separation temperature of DNA in which one of the strands was from another species. Their results are shown in Table 7.1

Table 7.1

	Mean decrease in separation temperature/ ºC				
	Timber wolf	Dog	Coyote	Ethiopian wolf	Dhole
Timber wolf					
Dog	1.7				
Coyote	2.3	2.3			
Ethiopian wolf	3.6	3.6	3.5		
Dhole	4.8	4.8	4.7	4.9	

(d) With reference to Table 7.1, explain why Dholes are most distantly related to the timber wolf based on the *Canidae* members studied.

…. ……

…. ……

…. ……

…. ……

…. …… [3]

The scientists assume that the decreases in separation temperatures are directly proportional to the time since the evolutionary lines of Canidae members separated. Dogs are thought to have separated from timber wolves 40000 years ago.

(e) Using this information, calculate how long ago, to the nearest year, Ethiopian wolves and timber wolves separated. Show your working.

[2]

(f) Distinguish classification from phylogeny.

....

....

....

.... [2]

[Total: 13]

[Turn over

Section B

Answer **one** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a), (b)** etc., as indicated in the question.

8.

(a) Compare and contrast the reproductive cycles of lambda phage and HIV. [8]

(b) Describe the structural features and regulation of the tryptophan operon. [7]

(c) Explain the role of geographical and behavioural isolating mechanisms in the evolution of new species [5]

[Total: 20]

9.

(a) Compare and contrast triglyceride and starch as a storage molecule. [6]

(b) Explain why cancer is a multi-step disease. [8]

(c) Describe the role of receptor tyrosine kinases in insulin signalling. [6]

[Total: 20]

End Of Paper

Class Adm No

Candidate Name: _____

H

millennia institute

2016 Preliminary Examination II
Pre-University 3

H2 Biology **9648/02**

Paper 2 Core Paper **16 September 2016**

2 hours

Additional Materials: Writing paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your Admission number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question. At the end of the examination, fasten all your work securely together.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
Total	

This question paper consists of 28 printed pages.

[Turn over

For Examiner's Use

Section A

Answer **all** questions in this section.

1. Figure 1.1 shows a mid-section of a mammalian DNA molecule, comprising Strand **A** and Strand **B**, during the S phase of interphase.

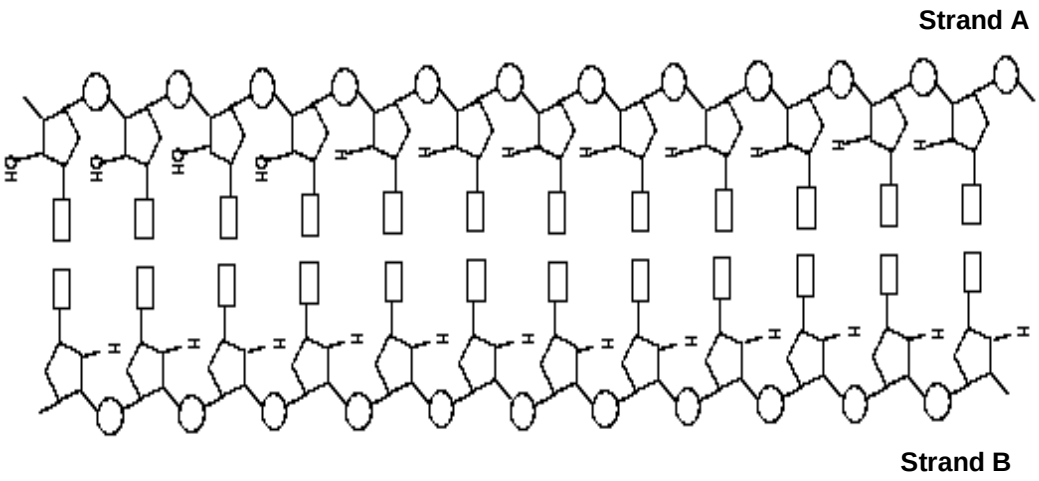


Figure 1.1

(a) With reference to Figure 1.1,

(i) account for the difference in the nucleotides in Strand **A** compared to Strand **B.**

Strand A has ribonucleotides and deoxyribonucleotides while Strand B has only deoxyribonucleotides;

AND

Strand B is used as the template to guide the synthesis of strand A by semi-conservative replication;
The synthesis of a complementary RNA primer by RNA primase explains the ribonucleotides;
RNA primer is needed as DNA polymerase III can only add deoxyribonucleotides to the free 3' OH end of an already existing polynucleotide;
Max 2

(ii) Outline the next immediate step in the further processing of Strand **A**.

……

DNA polymerase I removes the RNA primer;
DNA polymerase I replaces RNA primer with complementary deoxyribonucleotides based on the DNA sequence of the intact template strand/Strand **B**;
Max 1

Figure 1.2 depicts a telomere complex at the end of a chromosome in a human zygote. Telomeres are lengthened during embryonic development to compensate for shortening due to the end-replication problem.

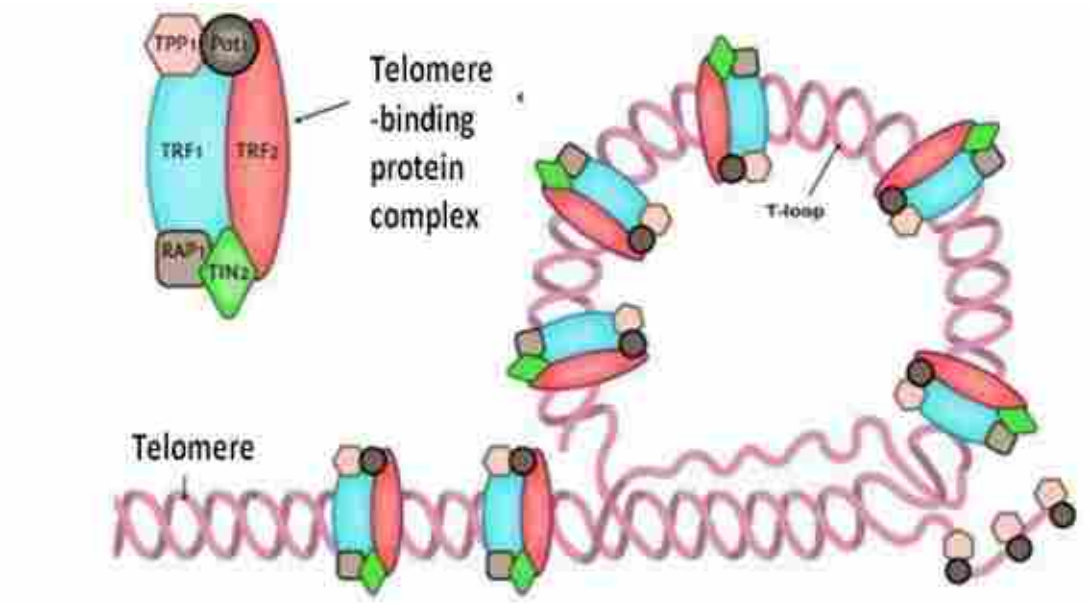


Figure 1.2

(b) Describe two differences between transcription and the process of telomere lengthening.

..
..
..
..

RNA is used as a template to lengthen the telomere while DNA is used as a template strand in transcription;
The product synthesised is DNA in the lengthening of the telomere while the product synthesised is RNA in transcription;
Enzyme involved is telomerase in lengthening of telomere while enzyme involved in transcription is RNA polymerase
Monomers used in lengthening of the telomere are DNA nucleotides while monomers used in transcription are RNA nucleotides;
Max 2

A study was conducted to investigate gene expression in yeast. Yeast strain **X** and strain **Y** were used in this study. These strains differed in the location of the *ADE2* gene. In strain **X**, *ADE*2 gene is at its normal locus on chromosome 5. An engineered inversion event is responsible for creating strain **Y** where *ADE2* gene locus is near the telomere. Figure 1.3 depicts the loci of the *ADE2* gene in both strain **X** and strain **Y**.

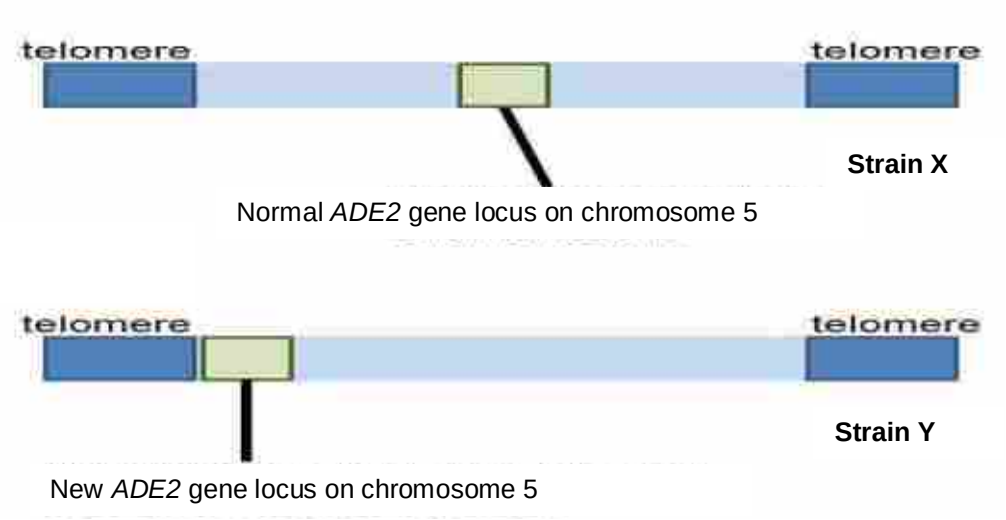


Figure 1.3

The above yeast strains were cultured on specially supplemented agar plates and incubated for one week to produce yeast colonies. Based on the constituents of the Agar, expression of *ADE2* gene prevents accumulation of red pigments and results in cells being white in colour. The colonies produced from this period of incubation are represented in Figure 1.4.

White Colonies from Strain **X**

Red Colonies from Strain **Y**

Figure 1.4

Previous studies have shown that some proteins bind to yeast telomeres to recruit histone deacetylase enzymes. These enzymes then act on the chromatin regions around the telomeres.

(c) Using the above information, explain the difference in colony colour between strain **X** and strain **Y** after one week of incubation.

....

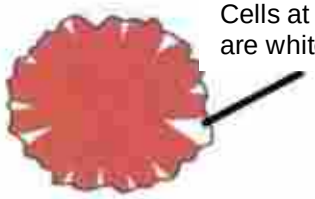
ADE2 gene expression is affected by histone deacetylase recruited by telomere bound proteins in Strain Y while the gene is not affected in strain X due to different positions in the genome;

AND

Histone deacetylase remove acetyl group from the lysine tails of the histone proteins;
The histone proteins regain positive charges;
This increases ionic interactions between histone proteins and DNA;
Result in closer packing of DNA around histone proteins;
Prevents transcription factors/RNA polymerase from accessing promoter of ADE2 gene;
Max 3

4]

The colonies from both strains were allowed incubate for an additional week. Following this, it is then observed that some cells at the edges of the Strain **Y** colonies appeared white in colour, as depicted in Figure 1.5.



Appearance of colonies from Strain **Y** after two weeks of incubation

Figure 1.5

(d) Explain why the cells at the edges of Strain **Y** colonies appear white in colour after two weeks of incubation.

....

Telomere length shortens as cells undergo repeated rounds of DNA replication;
Short telomeres in cells at the edge of colony unable to bind to proteins which recruit histone deacetylase;
RNA polymerase and transcription factors are able to bind to *ADE2* promoter sequence to form transcription initiation complex;
ADE2 gene is expressed;

[Total: 13]

2. In the cytosol, chaperone proteins can bind reversibly to newly synthesized polypeptides and shield them from other molecules. This prevents the R groups of amino acids from forming bonds with the wrong molecular partners, hence allowing the polypeptides to fold correctly.

Figure 2.1 below shows how chaperone proteins work.

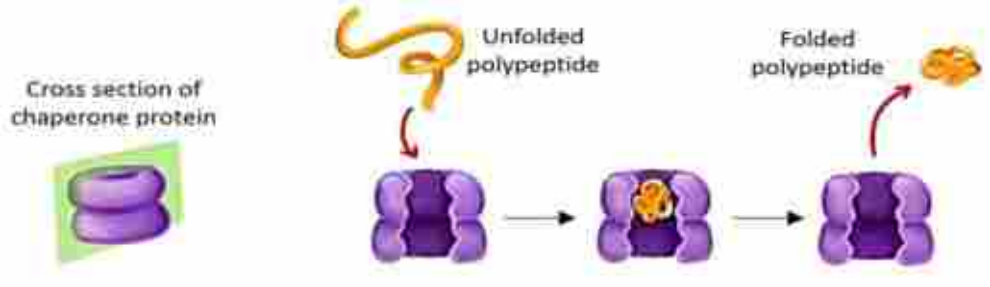


Figure 2.1

(a) With reference to Figure 2.1, explain how chaperone proteins regulate gene expression.

Chaperone proteins regulate gene expression at the post-translational level;
Chaperone proteins support production of functional proteins;
Chaperone proteins provide them with an isolated environment to fold properly;
Max 2

[2]

(b) Describe how cytosolic proteins are degraded in cells.

Proteins to be degraded are tagged with ubiquitin molecules;
Large protein complexes called proteasomes recognise the ubiquitin and degrade the tagged cytosolic proteins;
Proteases and peptidases may also degraded cytosolic proteins;
Proteins are degraded into smaller peptides or amino acids by hydrolysis of peptide bonds;
Max 2

[2]

When a protein fails to fold correctly upon synthesis or misfolds at a later stage in its cellular life time, it can no longer fulfil its biological function. Protein misfolding may occur due to mutations in genes or interference with expression of chaperone proteins. Figure 2.2 shows how misfolded proteins may aggregate in a cell.

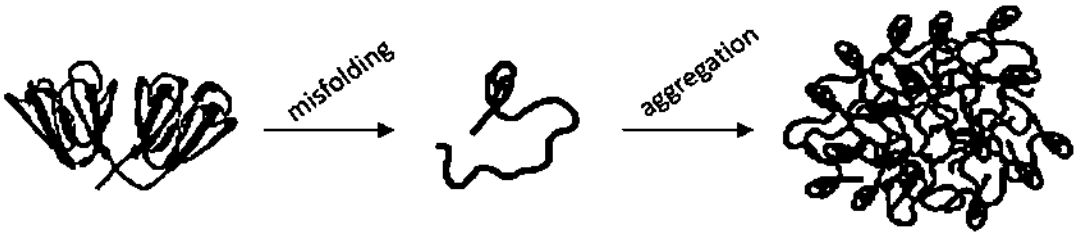


Figure 2.2

(c) With reference to Fig. 2.2, suggest why misfolded proteins tend to aggregate in the cell.

Hydrophobic amino acids are exposed in misfolded protein;
Hydrophobic interactions between these amino acids of multiple misfolded proteins cause aggregation;
Misfolded proteins may not have a shape that is complementary to the active site of proteases for degradation;
Protein aggregates are too large to enter proteasome to be degraded;
Max 2;

... [2]

An example of a misfolding disease is Bovine spongiform encephalopathy (BSE), a neurodegenerative disease in cattle and commonly referred to mad cow disease. In BSE, there is an aggregation of misfolded prion protein in the neurons of cattle, which results in degeneration of the brain and spinal cord.

Hereditary forms of BSE have been associated with a mutation in the brain prion protein (PrP) gene, which encodes the PrP protein. The PrP protein is a transmembrane glycoprotein found on the surface of neurons. Figure 2.3 shows the ribbon model of a normal PrP protein.

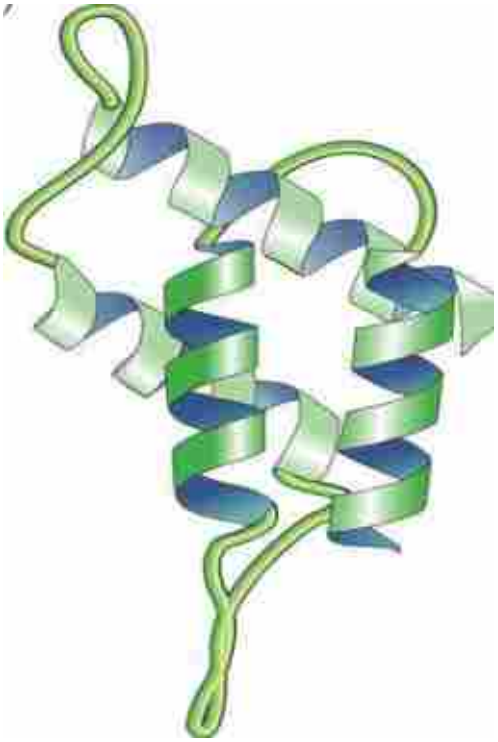


Figure 2.3

(d) Explain how the PrP protein would maintain its position within the cell membrane.

… Polar and charged amino acids of the PrP will interact with the phosphate heads of neighbouring phospholipids by hydrophilic interactions;
… Non-polar amino acids of the PrP will interact with the fatty acid tails of neighbouring phospholipids by hydrophobic interactions;
… Positon of PrP is also stabilized by cytoskeletal filaments within the cytoplasm;
Max 2

(e) Describe how the PrP protein on the cell surface membrane is formed after its polypeptide chain has been synthesized.

Following synthesis, the PrP polypeptide is inserted into the lumen of the RER;
The PrP polypeptide chain folds into its 3D conformation in the lumen and undergoes post-translational modification;
Transport vesicles containing PRP buds off from the RER and travel towards and fuses with the cis face of the Golgi apparatus;
The PrP protein is further modified to become a functional glycoprotein;
The protein gets embedded in the GA membrane and is packaged into a Golgi vesicle which buds off from the trans face of the Golgi apparatus;

Max 3

AND

The Golgi vesicle with the embedded PrP moves towards and fuses with the cell surface membrane to insert protein into cell membrane;

4]

A human version of BSE called variant Creutzfeldt-Jakob disease (vCJD) is believed to be caused by eating beef products contaminated with central nervous system tissue from infected cattle. Studies have shown that the introduction of misfolded cattle PrP by consuming contaminated meat can cause normal human prion protein to misfold and form aggregated plagues in the brain.

Health advisories have cautioned that cooking contaminated meat will not provide protection from infection that would lead to vCJD.

(f) Suggest why cooking contaminated meat products will not provide protection from contracting vCJD.

Heat from cooking is unable to denature misfolded PrP;
PrP is able to refold into infectious form after heating/cooking;
Max 1

[1]

3]

For Examiner's Use

3. Burmese cats, *Felis catus*, show discontinuous variation in the colour of their eyes and hearing ability. A large scale investigation was conducted to study the inheritance pattern of eye colour and deafness in such cats.

Pure-breeding blue eyed cats which were deaf were crossed with pure-breeding yellow eyed cats with normal hearing.

The F_1 all had yellow eyes and normal hearing.

Female cats from the F_1 were crossed with male cats with blue eyes and were deaf. 668 offspring were produced.

The observed numbers of F_2 cats with each phenotype were as follows:

Blue eyes, deaf	259
Blue eyes, normal hearing	72
Yellow eyes, deaf	53
Yellow eyes, normal hearing	284

(a) State what is meant by pure-bred cats for eye colour and hearing ability.

Cats are homozygous for eye colour and hearing ability;
Cats have identical alleles at the loci for eye colour and hearing ability;
Max 1

..... [1]

A chi-squared test, with the guide of Table 3.1, was planned to evaluate the difference between observed and expected results.

Table 3.1

Degree of Freedom	Probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

167 Blue eyes, deafness, 167 Blue eyes, normal hearing, 167 Yellow eyes, deadness, 167 Yellow eyes, and normal hearing;
1 Blue eyes, deafness: 1 Blue eyes, normal hearing: 1Yellow eyes, deadness: 1 Yellow eyes, normal hearing;
Equal ratio for all 3 phenotypes;
Max 1m

sing F_1

..... [1]

For Examiner's Use

(c) With reference to Table 3.1, outline how the significance of the difference between observed and expected results can be evaluated with 98% confidence (Formulae not required).

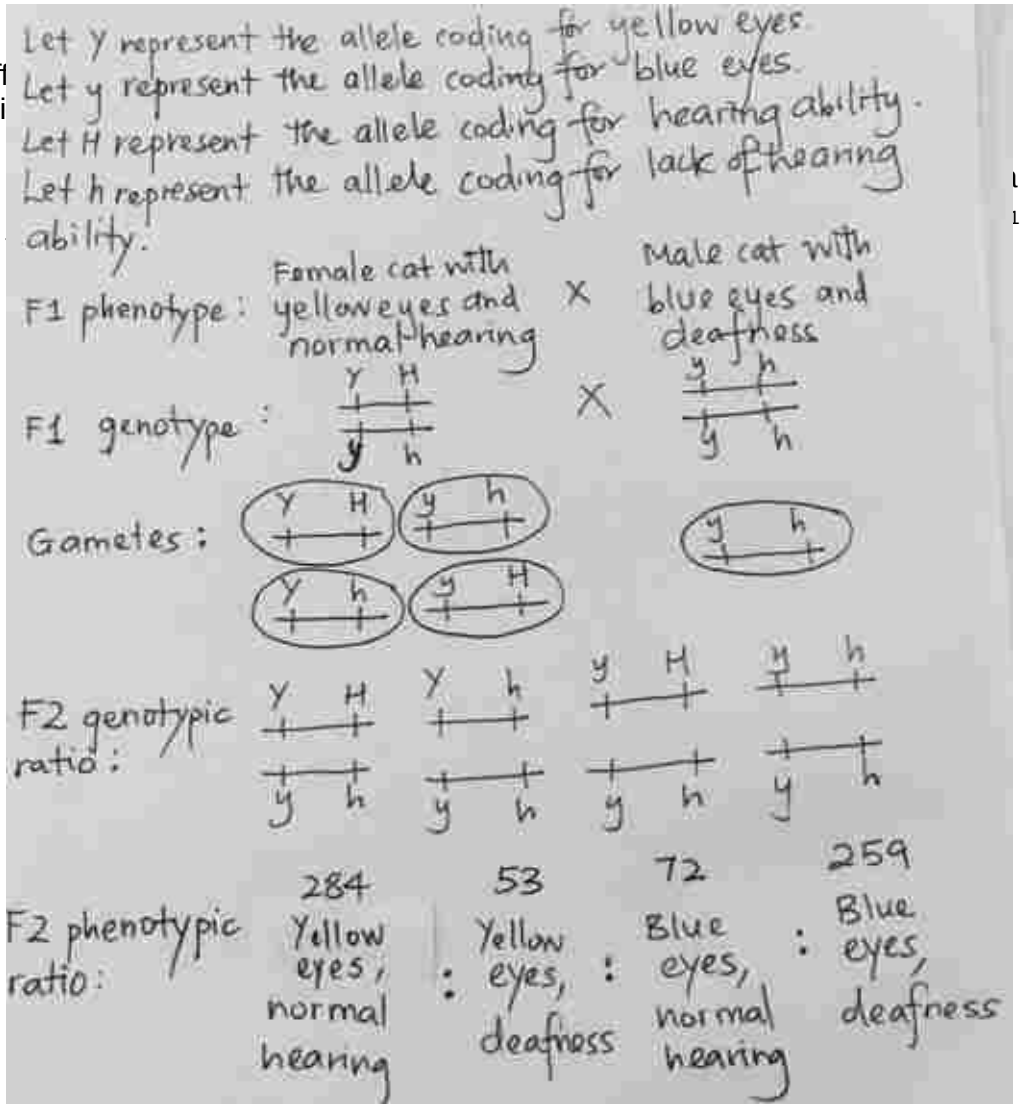
....

... Carry out chi-squared test with degree of freedom =3 and p=0.02;
If calculated $\chi 2$ is >9.84 difference is significant;
If calculated $\chi 2$ is <9.84 difference is not significant;
... If calculated $\chi 2$ is <9.84 difference is due to chance deviation;
Max 2
...

.... [2]

The diff
to be si

(d)



Definition of alleles;
Correct matching of F1 phenotypes and genotypes;
Correct gametes (must be circled) + distinguishing parental and recombinant gametes;
Correct linking of F2 genotype to phenotype;

[4]

The coordinated activity of higher order organisms like cats relies upon a continuous input of information from the internal and external environments. Information is in the form of stimuli, which are detected by receptors. One such receptor is called a Pacinian corpuscle, which is found in the skin.

Fig. 3.1 shows the electrical activity recorded by two microelectrodes inserted into:

- the axon within the Pacinian corpuscle at site **P**, and
- the axon of the sensory neurone leaving the corpuscle at site **Q**

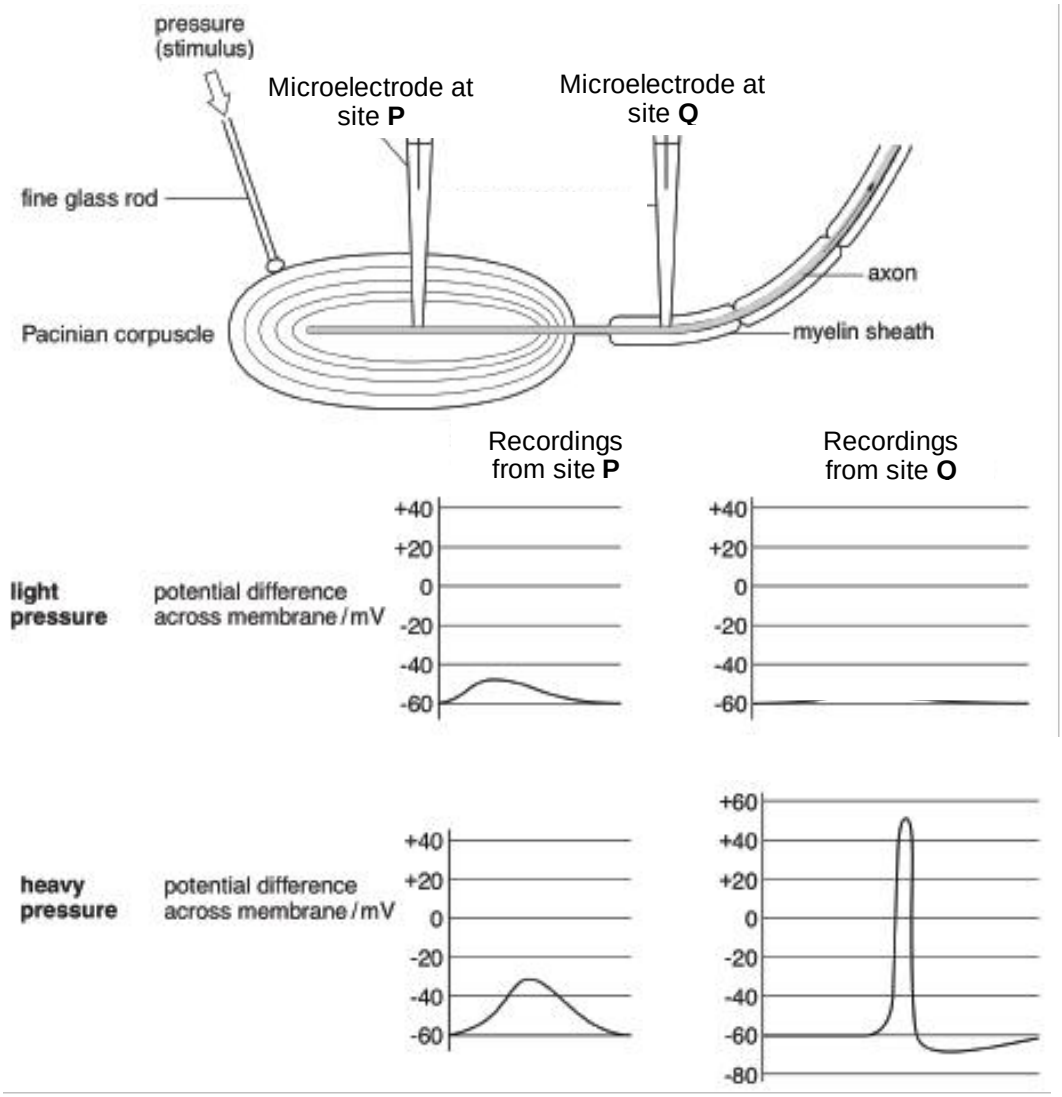


Figure 3.1

(e) With reference to Figure 3.1, account for the changes in electrical activity in site **P** and **Q** as increasing pressure is applied to the Pacinian corpuscle.

When light pressure is applied, potential difference at **P** increases from -60 to -55mV and there is no change in potential difference at **Q;**

Depolarization at **P** produces a graded potential that is below threshold potential and therefore no Action potential is generated and transmitted to **Q**;

When heavy pressure is applied, potential difference at **P** increases from -60 to -30mV and potential difference at **Q** increases from -60 to +40mV;

Depolarization at **P** produces a potential that is above threshold due to the opening of more voltage-gated sodium channels;
This generates an action potential in line with all or none principle;
Depolarisation of adjacent region of axon from influx of sodium ions at **P** during action potential generates action potential at **Q** results in propagation of impulse from **P** to **Q**;
Max 2m

.... [4]

[Total: 12]

[Turn over

4. Rhinoviruses are the most common viral infectious agents in humans and are the predominant cause of the common cold. Symptoms include sore throat, runny nasal congestion, sneezing and cough which may be accompanied by muscle aches and loss of appetite.

The structure of the human rhinovirus is depicted in Figure 4.1. Human rhinoviruses are composed of a capsid that contains four viral proteins **VP1**, **VP2**, **VP3** and **VP4**. Each viron has one copy of single-stranded positive sense RNA genome of between 7200 and 8500 nucleotides in length.

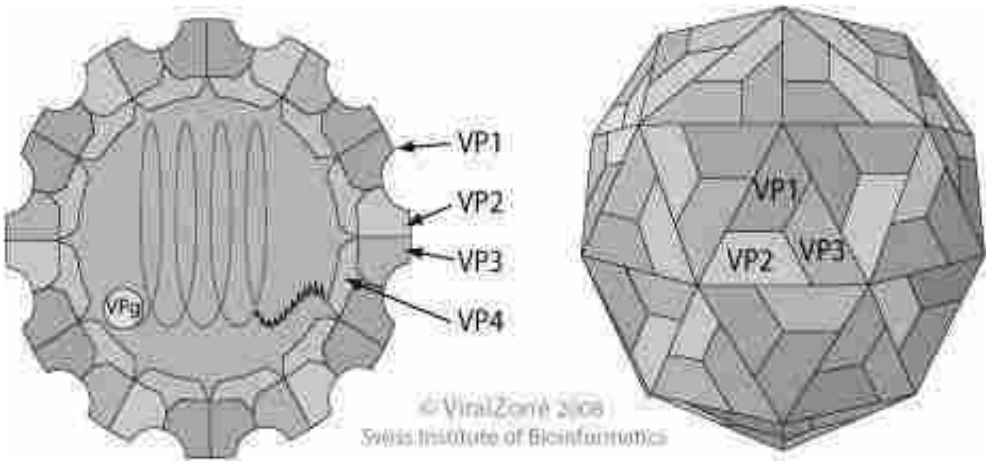


Figure 4.1

Despite structural differences, both human rhinovirus and the influenza virus are able to penetrate respiratory epithelial cells for infection.

(a) Explain how it is possible for both human rhinovirus and the influenza virus to be able to penetrate human respiratory epithelial cells.

Surface proteins on human rhinovirus and the Influenza virus can bind to different receptors on human respiratory epithelial cells;
Max 1

.... [1]

The enzyme neuraminidase plays an important role after new influenza virions exit their host cells from each round of infection.

(b) Describe the role of neuraminidase in the reproductive cycle of the influenza

Neuraminidase prevents the clumping of influenza virions to host cell/among themselves after they have budded from cell membrane;
It cleaves the attachment/bond between the HA on influenza and sialic acid residues on the host cell membrane;
Neuraminidase therefore promotes the spread of progeny influenza virions from the host cell surface to infect other host cells;
Max2

(c) With reference to Figure 4.1, explain why it is unlikely that the newly assembled human rhinovirus exit their host cells in the same way as influenza virions.

Human rhinovirus is a non-enveloped virus;
When influenza viruses bud from host cell, they acquire part of the host cell surface membrane as their viral envelop;
Human rhinovirus is likely to lyse host cell for release;
Max2

..

[Turn over

H7N9 is a subtype of Avian Influenza virus, which normally circulates amongst the avian populations with some variants known to occasionally infect humans. An H7N9 virus was first reported to have infected humans in 2013 in China and now this virus has spread among humans. Figure 4.2 shows the proposed evolution of H7N9 virus.

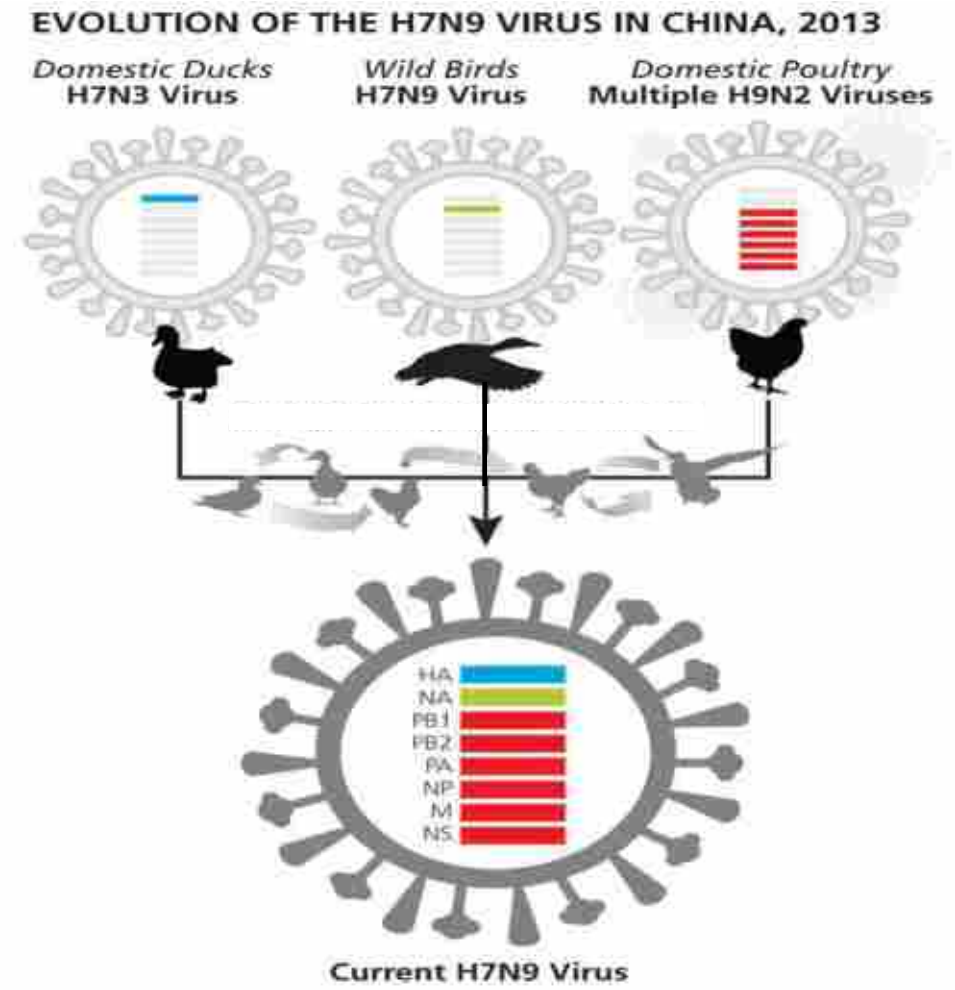


Figure 4.2

(d) [illegible] A

Antigenic shift;
Where H7N3, H7N9 and H9N2 strains infect a series of intermediate host cells at the same time;
The cell is replicating the viral genomes of multiple strains at the same time;
RNA segments are randomly assembled from multiple strains during replication of viral genomes;
Reassortment of genes from these strains occurs resulting in the new combination of RNA segments for H7N9;
Max 3

.... [3]

Today viruses are considered an exception to the cell theory which states that the basic units of life are cells. Viruses have been referred to as "organisms at the edge of life".

(e) State one characteristic of viruses that may classify them as being

Adapt to unfavourable environments by exhibiting high mutation rates which increase genetic variation;
Able to reproduce by taking over the genetic machinery of its host cells;
Certain viruses are able to respond to external stimuli by switching reproductive cycle;
Contains nucleic acid (DNA or RNA) as its genome to pass on genetic characteristics from one viral generation to the next;
Max 1

.....

They are acellular and contain no cytoplasm or cellular organelles;
Viruses do not grow, divide or increase in size;
Viruses do not move on its own and can only be carried by host cells or extracellular medium;
Viruses have no ability of regulating internal environment;
Viruses carry out no metabolism on their own;
Viruses lack enzymes to carry out nucleic acid, protein or ATP synthesis.
Max 1

... [1]

al: 10]

5. A study was carried out to measure the concentrations of glucose and insulin in the blood of students. The results are summarised in Fig. 5.1.

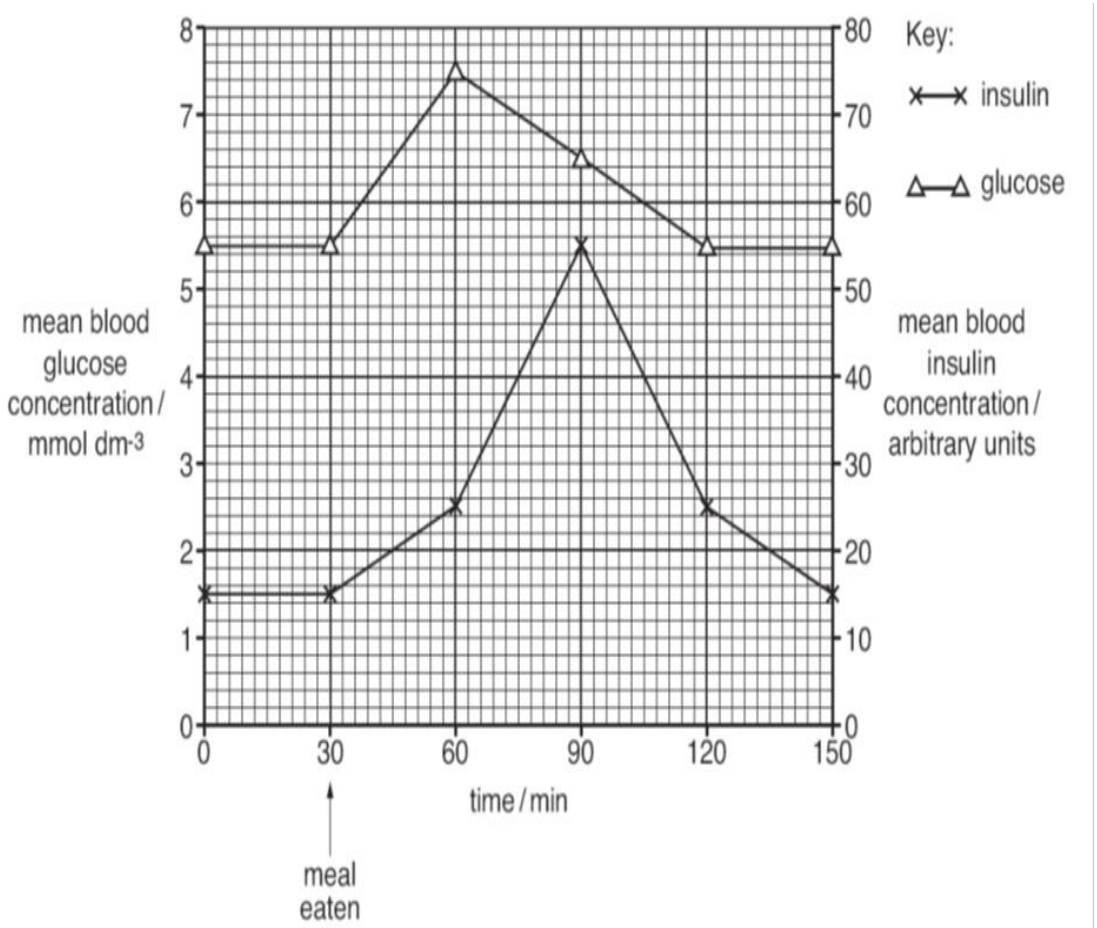


Figure 5.1

(a) With reference to Figure 5.1, account for the relationship between the concentration of glucose and the concentration of insulin after a meal

Rise in glucose concentration from 5.5 to 7.4 mmol/dm3 between 30 to 60min is detected by β cells islets;
This results in the increase in insulin secretion into the blood from 15 to 55 arbitrary units between 30 to 90min;

AND

Insulin binding to receptors on the liver / muscle/ adipose cells;
Insulin signalling results in
- Increased glucose uptake; and utilization in target cells;
- Increased glycogenesis in liver cells;
- Increased protein synthesis;
- Inhibition of glycogenolysis and gluconeogenesis;

Max 2

This results in glucose concentration being lowered from 7.4 to 5.5mmol/dm3 between 60 to 120min;
Decreased blood glucose levels serves as negative feedback to the β-cells which decreased the secretion of insulin, lowering insulin levels from 55 to 15 arbitrary units from 60 to 150mins;

[5]

Figure 5.2 outlines some steps in glucose metabolism in human muscle cells.

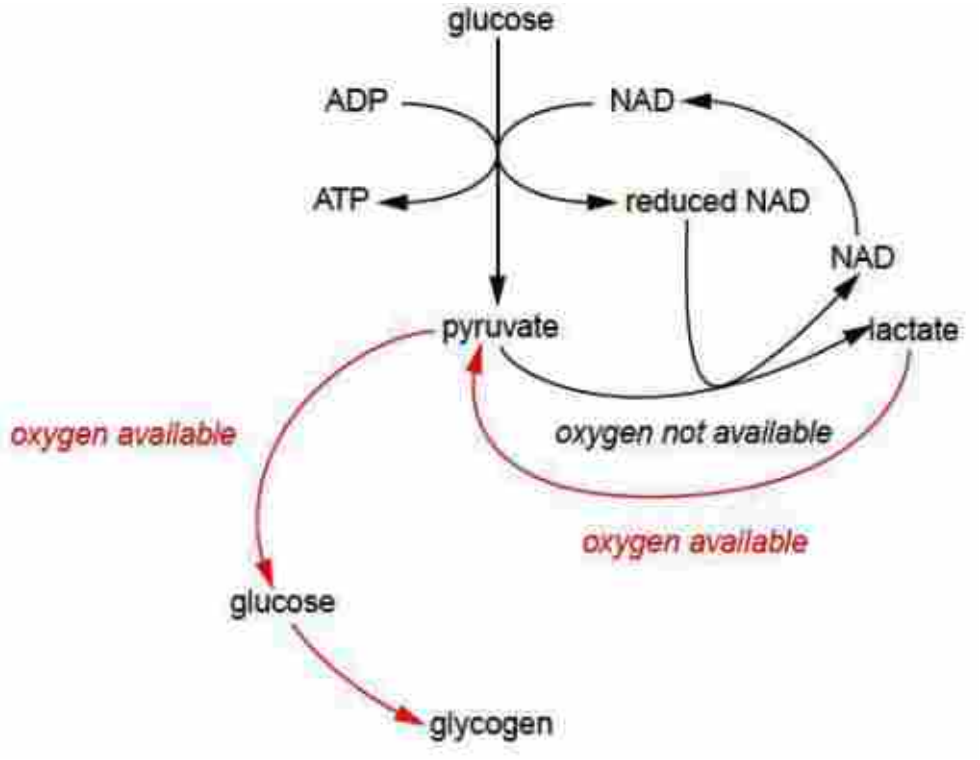


Figure 5.2

(b) Explain why pyruvate needs to be converted to lactate in the absence of oxygen.

When oxygen is absent, cells will not be able to produce ATP by oxidative phosphorylation;
Conversion of pyruvate to lactate is needed to regenerate NAD so that glycolysis can continue;
NAD is needed during glycolysis to produce 2 net ATP via substrate level phosphorylation during glycolysis;
Max2

]

[Turn over

Hexokinase is an enzyme that plays a critical role in glucose metabolism. This enzyme converts glucose into glucose-6-phosphate. This step is important as it energises glucose for further metabolic reactions. Fig. 5.3 is a computer-generated image of the enzyme hexokinase binding with its substrate, glucose.

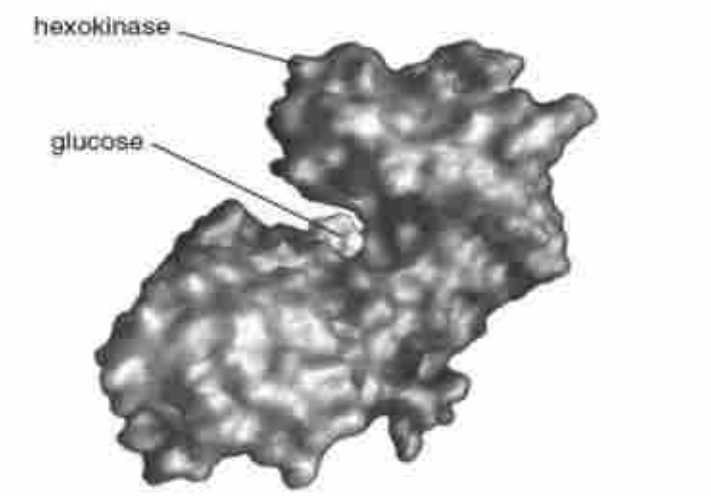


Figure 5.3

Crystallization studies have shown that the shape of hexokinase's active site is not complementary to the shape of glucose.

(c) Describe the mechanism by which hexokinase binds to glucose.

Induced fit mechanism;
Loose association with substrate causes conformation change in enzyme's active site;
Conformational change causes enzyme active site to be complementary to the shape of glucose;
Allows active site to fit to substrate more precisely /allows stronger binding of substrate with enzyme's active site;
Max 2

.....
.....
.....
..... [2]

The phosphorylation of glucose by hexokinase also prevents it from leaving the liver cells.

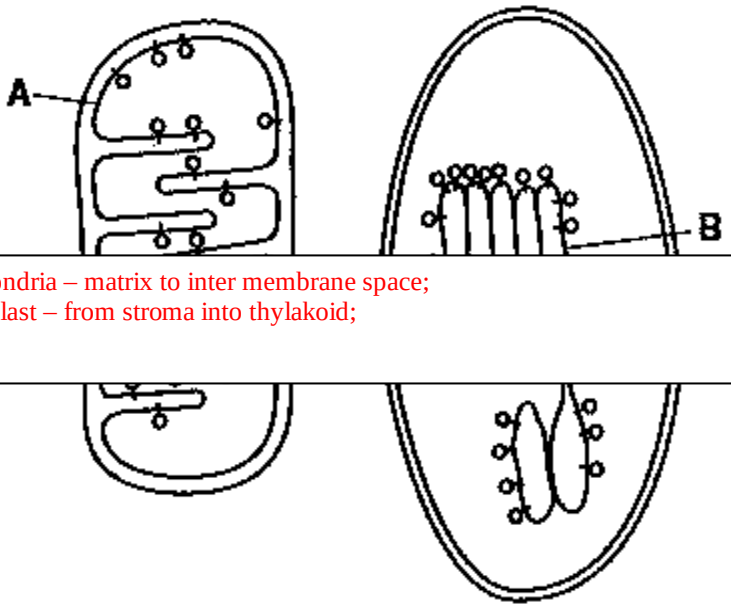
(d) Suggest why glucose-6-phosphate cannot move out of liver cells.

Glucose-6-phosphate is polar;
Hydration shell of Glucose-6-phosphate prevents it from passing through hydrophobic core of membrane;
There are no specific transport protein for Glucose-6-phosphate to facilitate transport out of cells;
Max 2

.....
.....
..... 2]

[Total: 11]

6. Most ATP is made in cells by membrane systems that create proton gradients by pumping protons from one compartment to another. Figure 6.1 show two such organelles.



Mitochondria – matrix to inter membrane space;
Chloroplast – from stroma into thylakoid;

Figure 6.1

(a) Draw arrows onto each organelle in Figure 6.1 to show the direction in which protons are pumped.

[2]

(b) In addition to facilitating the formation of proton gradients, state one other importance of compartmentalisation within organelles **A** or **B** for ATP

Enzymes and substrates of Krebs cycle are kept in close proximity/ confined within the matrix optimising rate of reactions
OR
Enzymes and substrates of Calvin cycle are kept in close proximity/ confined within the stroma optimising rate of reactions;

Optimal conditions e.g. pH for enzymes of Krebs cycle can be maintained within matrix for higher rate of reaction;
OR
Optimal conditions e.g. pH for enzymes of Calvin cycle can be maintained within stroma for higher rate of reaction;

Prevent intermediates from different metabolic pathways from interfering from each other;

AVP

[Turn over

In 1882, the German botanist T.W. Engelmann performed an experiment to investigate the effects of different wavelengths of light on the rate of photosynthesis using *Spirogyra*. *Spirogyra* is a type of green alga that contains photosynthetic organelles. Other studies have shown that there are pigments that absorb blue, green, yellow and red light in these organelles.

A strand of *Spirogyra* was placed into water containing aerobic bacteria. Different parts of the strand were exposed to different colours of light. After a period of time, the bacteria had moved into the positions shown in Figure 6.2.

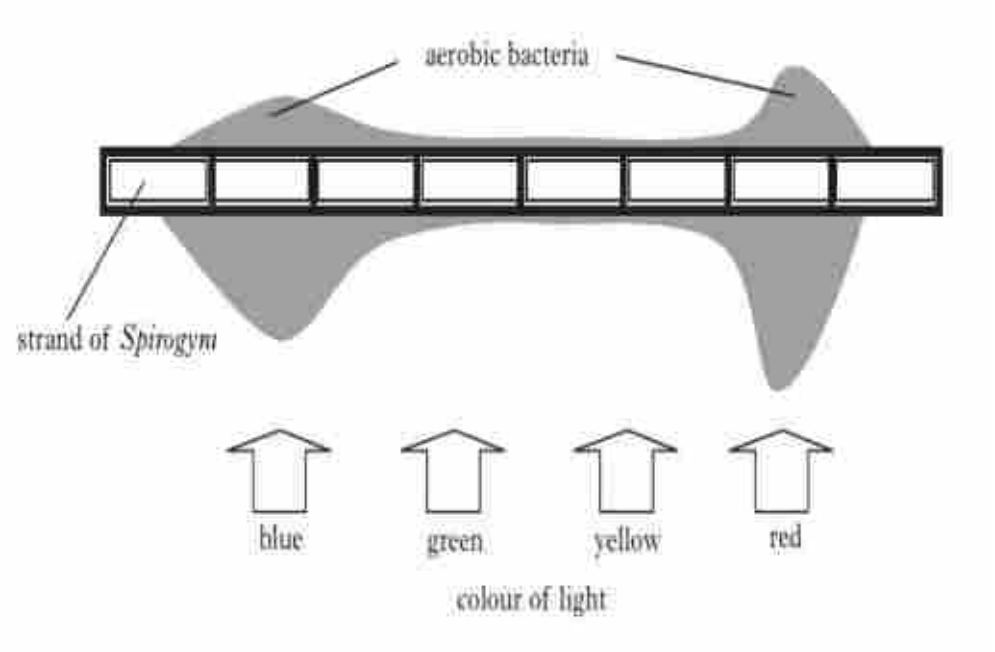


Figure 6.2

It was concluded that wavelengths corresponding to red and blue light caused a higher rate of photosynthesis compared to wavelengths corresponding to green and yellow light.

(c) With reference to Figure 6.2,

(i) explain why the abovementioned conclusion was drawn.

.....

.....

There is a more/greater distribution of aerobic bacteria in the regions with red and blue light compared to regions with yellow and green light;

AND

Aerobic bacteria is attracted towards oxygen produced by the algae;
Oxygen is produced by photolysis of water during non-cyclic photophosphorylation within the light dependent reactions;
A greater amount of oxygen produced with red and blue light attracts more aerobic bacteria;
Max2

(ii) suggest a role for the pigments absorbing green and yellow light in Spirogyra's photosynthetic organelles.

Broadened/widen the absorption spectrum / widen action spectrum;
They channel light energy of different wavelengths to chlorophyll a/main photosynthetic pigment/reaction centre;
Increase the efficiency of photosynthesis;
Max 2

[Total: 8]

[Turn over

7. Wolf, *Canis lupus,* is one of the world's best known and well researched species, with arguably more books written about it than any other wildlife species. It is the largest extant member of its family, *Canidae,* with males averaging 45kg and females 37kg.

Wolves are further classified into a number of sub-species based on marked phenotypic differences, such as body size and colour. Figure 7.1 shows the several sub-species of wolves in existence today.

Figure 7.1

(a) Suggest one reason why the existing populations of wolves are classified

Can interbreed to produce fertile and viable offspring (although geographically isolated);
DNA sequence of many genes very similar;
Morphological/physiological/behavioural/biochemical features (name 2 out of the 4) are very similar but not different enough to be classified as distinct species;
Occupy same ecological niche;
Max 1

Timber wolves are native to the wilderness of Eurasia and North America. Studies have suggested that the timber wolves once co-existed with the extinct dire wolf, *Canis dirus,* on the North American continent.

Figure 7.2 depicts skeletal models of a timber and dire wolf. Dire wolves were larger and had more powerful jaws compared to timber wolves. However, they had proportionally much shorter legs than timber wolves, and were as such slower runners. They are known to feed on different prey, with the large dire wolves favouring larger prey and the timber wolves favouring smaller prey. It is known that the dire wolves went extinct approximately 8000 years ago, which coincides the time period when its large prey declined in numbers.

(b) Usin

Dire wolves faced a lack of large prey / competition from timber wolves as selection pressure;

Dire wolves had a selective disadvantage as:
Larger prey declined in numbers compared to small prey;
Timber wolves are more agile and can outcompete dire wolves for small prey;
Dire wolves were larger and slower in catching small prey;
(Max 2 marks for selective disadvantage)
AVP

Dire wolves had lower fitness compared to timber wolves and reproduced in smaller numbers eventually leading to their extinction;

Max 3

[3]

(c) Explain why a population is the smallest unit that can evolve

Although natural selection acts on individuals, individuals do not change or evolve over their lifespan;
Variation (within the gene pool) only occurs at the population level;
Evolution is determined by change in allele frequency in a population over several generations of individuals/time.
Individuals must be able to interbreed with other members within the population to pass on alleles for any possible change in allele frequency;
Max 2

[2]

[Turn over

Scientists used DNA hybridisation to determine the evolutionary relationships between five members of the *Canidae* family. The temperature at which a molecule of double-stranded DNA separates into two single strands is the separation temperature. A region of non-coding DNA was analysed for the study. The scientists recorded the mean separation temperature of this region of DNA in which both strands were from the same species. The scientists then recorded the mean decrease in separation temperature of DNA in which one of the strands was from another species. Their results are shown in Table 7.1

Table 7.1

	Mean decrease in separation temperature/ ºC				
	Timber wolf	Dog	Coyote	Ethiopian wolf	Dhole
Timber wolf					
Dog	1.7				
Coyote	2.3	2.3			
Ethiopian wolf	3.6	3.6	3.5		
Dhole	4.8	4.8	4.7	4.9	

(d) With reference to Table 7.1, explain why Dholes are most distantly related to the timber wolf based on the *Canidae* members studied.

The mean decrease in separation temperature is greatest for between dhole and timber wolf at 4.8 ºC as compared to other animals with respect to timber wolf;
This implies that there are fewer hydrogen bonds/ complementary base pairs in tested DNA sequence between timber wold and dhole;
Fewer complementary base pairs in DNA sequences between different organisms reflect a greater number of nucleotide differences in the DNA sequence;
Relatedness decreases with increasing number of nucleotide difference in DNA sequence (OWTTE);

The scientists assume that the decreases in separation temperatures are directly proportional to the time since the evolutionary lines of *Canidae* members separated. Dogs are thought to have separated from timber wolves 40000 years ago.

(e) Using this information, calculate how long ago, to the nearest year, Ethiopian wolves and timber wolves separated. Show your working.

3.6/1.7 X 40,000;
84706 years;

Feature	Classification	Phylogeny
Basis of grouping	Organisms are grouped based on similarities in characteristics; and does not consider evolutionary relationships;	Organisms are grouped into taxons; that is based on evolutionary relationships;
Format of organisation	Organisation is in the form of a hierarchy of increasingly specific/exclusive categories;	Organisation is in the form of phylogenetic tree;
Natural / man-made organisation	Classification is human effort to give order to data via binomial nomenclature and hierarchy to ensure that organisms can be universally identified by their scientific name;	Phylogeny reflects natural relationship among organisms;

Identification vs studying relationships

;; for 1m
Marks awarded for point to point comparison
Max 2

[Turn over

For Examiner's Use

Section B

Answer **one** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a), (b)** etc., as indicated in the question.

8.

(a) Compare and contrast the reproductive cycles of lambda phage and HIV. [8]

(b) Describe the structural features and regulation of the tryptophan operon. [7]

(c) Explain the role of geographical and behavioural isolating mechanisms in the evolution of new species [5]

[Total: 20]

9.

(a) Compare and contrast triglyceride and starch as a storage molecule. [6]

(b) Explain why cancer is a multi-step disease. [8]

(c) Describe the role of receptor tyrosine kinases in insulin signalling. [6]

[Total: 20]

End of Paper

(a) Compare and contrast the reproductive cycles of lambda phage and HIV. [8]

	Lambda Phage	Human immunodeficiency virus (HIV)
Host	*E. coli;*	$CD4^+$ T cells;
Attachment	Tail fibres bind to the surface receptor of cell	HIV GP120 on viral envelope binds to CD4 receptors on T4-lymphocytes
Penetration	Viral tail sheath contracts to injects viral DNA into the host cell.	HIV envelope fuses with host cell surface membrane to enter viral nucleocapsid containing viral genome into host cell.
Synthesis	Does not need reverse transcriptase to produce viral DNA	Uses reverse transcriptase to produce viral DNA
	When viral DNA incorporated into host chromosome, it can also leave to enter lytic cycle	Integrated viral DNA remains a permanent resident of the host cell's genome.
Release	Released by cell lysis of host cell during lytic cycle	Released by budding off from host cell
	Host cells are killed after release of virions.	Host cell still intact after reproduction. Will not die immediately.

Max 4

Both involve binding to specific receptor sites on host cell for attachment.
Both viral genomes are capable of integration into host cell's genome.
Both viruses are able to propagate without killing the host cells which they are dependent on.
Both viruses require host cell machinery for replication and synthesis of new viral particles;
Max 3

[Turn over

(b) Describe the structural features and regulation of the tryptophan operon. [7]

The tryptophan operon has a promoter which is the RNA polymerase binding site;
Operator which is the binding site for repressor protein;
5 structural genes which are clustered together and controlled by one promoter;
The structural genes are trpE, trpD, trpC, trpB, trpA;
These genes code for enzymes that catalyse the metabolic pathway for tryptophan synthesis;
The operator is sandwiched between the promoter and the structural genes;
Max 4

Trp operon is controlled by negative regulation
Negative regulation of lac operon involves the use of the trp repressor coded by regulatory gene trpR;
In absence of tryptophan the trp repressor is inactive and unable to bind to the operator resulting in transcription of the structural genes for tryptophan synthesis;
When tryptophan is present in high amounts, it acts as a co-repressor and binds to the trp repressor to activate it;
Activated trp repressor binds to the operator and blocks access of RNA polymerase to promoter to inhibit transcription of the trp operon;
Max 4

(c) Explain the role of geographical and behavioural isolating mechanisms in the evolution of new species [5]

Speciation occurs when there is disruption to gene flow in a population of a particular species;
Disruption of gene flow can occur by behavioural isolation;
Geographical isolation occurs when there is a physical barrier separates members of a population into 2 sub populations, preventing interbreeding;
Behavioural isolation, occurs when there is variation in behaviour in a population and members tend to mate preferentially with members with similar behaviour;
Changes in allele frequency occur independently in isolated subpopulation resulting in genetic divergence;

Genetic divergence between isolated sub-populations results in genetically distinct species which are unable to interbreed and produce fertile viable offspring;
Geographical isolation results in allopatric speciation;
Behavioural isolation results in sympatric speciation;

[Total: 20]

(a) Compare and contrast triglyceride and starch as a storage molecule. [6]

Feature	Triglyceride	Starch
Basic units	Triglyceride is made up of 1 glycerol and 3 fatty acid chains;	Starch is made up of repeating units of α glucose;
Type of Bonds	bonds linking up the monomers are ester linkages;	bonds linking up the monomers are glycosidic linkages;
Type of biomolecule	Triglyceride is not a polymer;	Starch is a polymer of glucose;
As energy store	Higher/ twice amount of energy stored/ superior long term energy store per unit mass Due to greater number of carbon atoms/ more C-H bonds for the same mass; lesser amount of fats needs to be stored for the same amount of energy;	Lower/ 2X less energy stored per unit mass; Due to more –OH groups and so less carbon atoms/ less C-H bonds for the same mass; More starch molecules need to be stored for the same amount of energy;

Max 3

Both have high percentage of hydrocarbons and hence stores energy;
Both are macromolecules formed through condensation reactions;
Both are compact;
Both are insoluble and therefore do not affect water potential of cells;
Max 3

[Turn over

(b) Explain why cancer is a multi-step disease. [8]

The development of cancer requires the accumulation of mutations;
Mutations occur in multiple genes which control regulatory checkpoints of the cell cycle;
Such mutations disrupt the normal cell cycle, thus causing the cell to undergo excessive cell growth and proliferation/division;
A gain-in-function mutation must occur in at least one proto-oncogene;
A gain-of function is a dominant mutation where mutation in just one allele of a proto-oncogene will result in oncogenic conversion;
Oncogenes promote uncontrolled cell growth and proliferation/division;
A loss-of-function must occur in at least one tumour suppressor gene;
As loss-of- function mutations is a recessive mutation, such changes must occur in both copies of the tumour suppressor gene /alleles to disrupt the function of tumour suppressor gene;
Disruption of tumour suppressor genes results in loss of ability to inhibit cell cycle progression/activate DNA repair/ activate apoptosis;
Activation/up-regulation of telomerase gene should also occur for cancer cells to divide indefinitely;
Loss of contact inhibition will enable the cells to grow into a tumour/mass of cells;
Angiogenesis must occur within the tumour so that the blood vessels formed can transport oxygen and nutrients for its growth;
Finally the cells must be able to undergo metastasis/ leave the primary site and spread to other tissues in different parts of the body via the blood stream and form multiple tumours;

(c) Describe the role of receptor tyrosine kinases in insulin signalling. [6]

Insulin as a polar peptide hormone that cannot diffuse/pass through the phospholipid bilayer of the cell membrane;

RTK spans the cell membrane/ is a transmembrane protein;

Each RTK has an extracellular insulin binding domain that is specific / has a complementary shape to that of insulin;

Upon binding of insulin to the extracellular domain, receptor polypeptides dimerise;

Each RTK contains an intracellular /cytoplasmic tyrosine kinase domain;

The tyrosine kinase domain of each polypeptide is activated upon dimerization;

Tyrosine kinase domain transfers / adds a phosphate from an ATP molecule to a tyrosine residue on the intracellular domain of the other polypeptide;

Addition of phosphate groups enables relay proteins binding to specific tyrosine residues on RTKs;

Upon binding, relay proteins undergo conformational changes that results in activation and subsequent signal transduction;

[Total: 20]

[Turn over

Class Adm No

Candidate Name: _____

H

millennia institute

2016 Preliminary Examination II
Pre-University 3

H2 Biology **9648/03**

Applications Paper and Planning Question **22 September 2016**

2 hours

Additional Materials: Writing paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your Admission number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

The use of an approved scientific calculator is expected, where appropriate.
You will lose marks if you do not show your working or if you do not use appropriate units.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This question paper consists of 21 printed pages including 1 blank page

[Turn over

Answer **all** questions.

1. Before the emergence of more advanced technologies, cDNA libraries have been used to study the genetic changes involved in cancer development.

Normal and tumour cells are obtained from the same patient. Reverse transcription is carried out on mRNA isolated from the tumour cells. Primers consisting of thymine repeats were used during reverse transcription to form single-stranded cDNA as depicted in Figure 1.1. These cDNA are then labelled with fluorescent dyes.

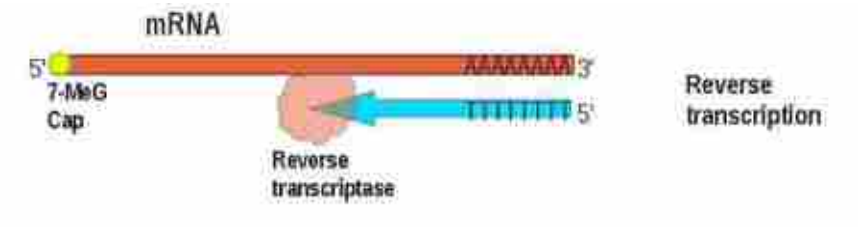


Figure 1.1

Normal cell mRNA and tumour cell cDNA are allowed to hybridise; the resulting double-stranded hybrid molecules and remaining single-stranded mRNA are discarded. Subtracted cDNA (also known as non-hybridized cDNA) are used to form a subtracted cDNA library. The process is summarized by Figure 1.2.

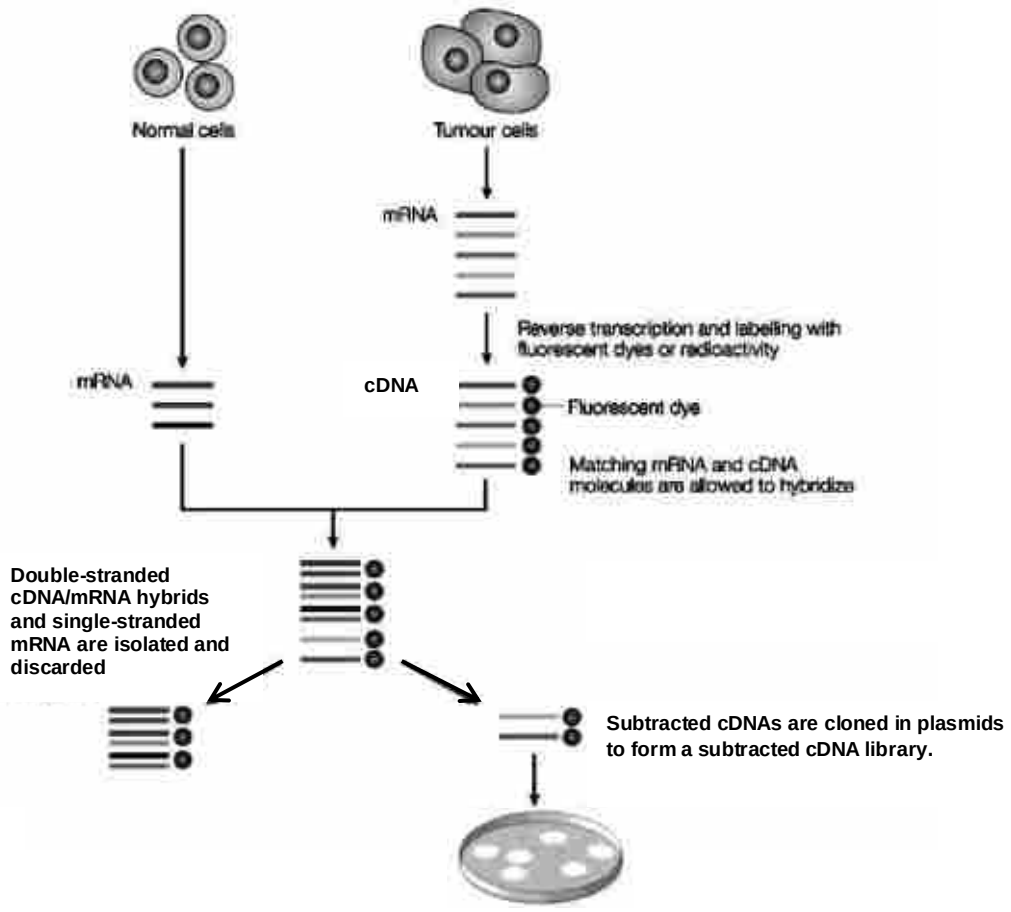


Figure 1.2

A young scientist conducting this procedure was concerned that possible presence of bacteria within cell samples might result in production of bacteria cDNA. This would contaminate downstream processes. However, her concerns were dismissed by her partners who assured her that reverse transcription of bacterial mRNA is unlikely to occur.

(a) Using the information given, explain why reverse transcription of bacterial mRNA is unlikely to occur.

....

....

.... [2]

(b) Describe the steps needed to create recombinant DNA molecules that are used to assemble a plasmid library of subtracted cDNA.

....

....

....

....

....

.... [4]

(c) Explain why the DNA sequences in the subtracted cDNA library are considered mutant alleles implicated in cancer.

....

....

....

.... [2]

(d) Suggest why the subtracted cDNA library may not fully capture all possible DNA sequences implicated in cancer.

....

....

.... [1]

[Turn over

Screening of the subtracted cDNA library of a cancer patient revealed a mutated protein kinase gene. A research team decided to clone this gene to isolate the mutant protein and study it to better understand its role in cancer development.

The protein kinase gene was first isolated. The artificial plasmid, pKY350, was constructed to act as an expression vector.

The plasmid was constructed to include two genes, each giving resistance to a different antibiotic: an ampicillin resistance gene and a tetracycline resistance gene. The plasmid also has a target site for the restriction enzyme, *BamHI*, in the middle of the tetracycline resistance gene.

A pKY350 plasmid was cut using *BamHI* and the cDNA sequence for the mutant protein kinase was inserted into it. Figure 1.3 shows pKY350 and the recombinant plasmid.

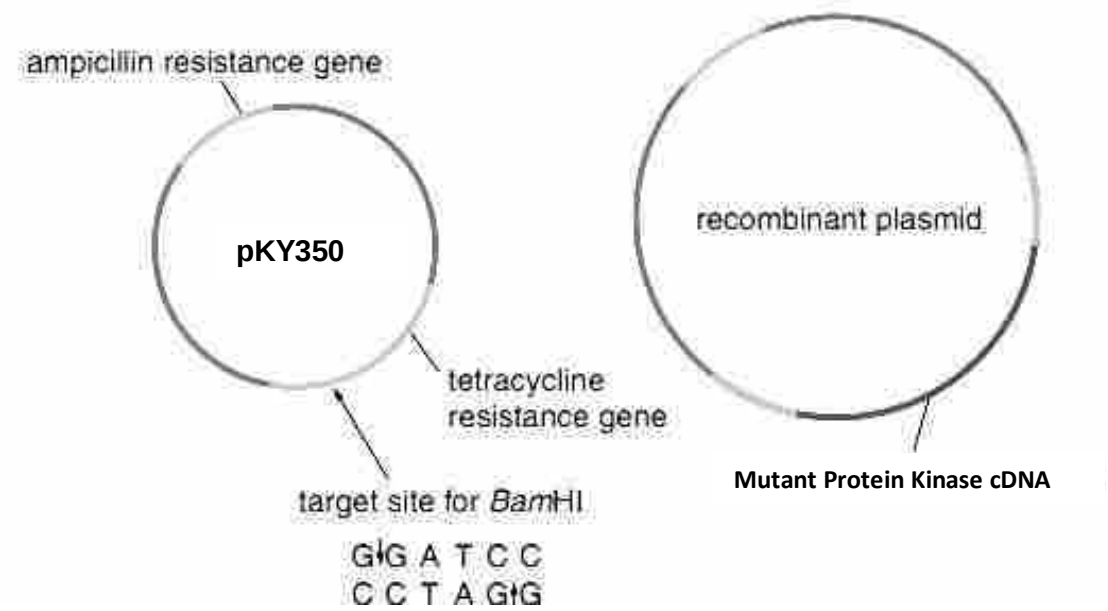


Figure 1.3

The mixture containing recombinant DNA was used to transform *E.coli* bacteria. Replica plating was used to identify recombinant bacteria with the mutant protein kinase gene. Figure 1.4 shows the bacterial colonies that grew on different nutrient agar plates.

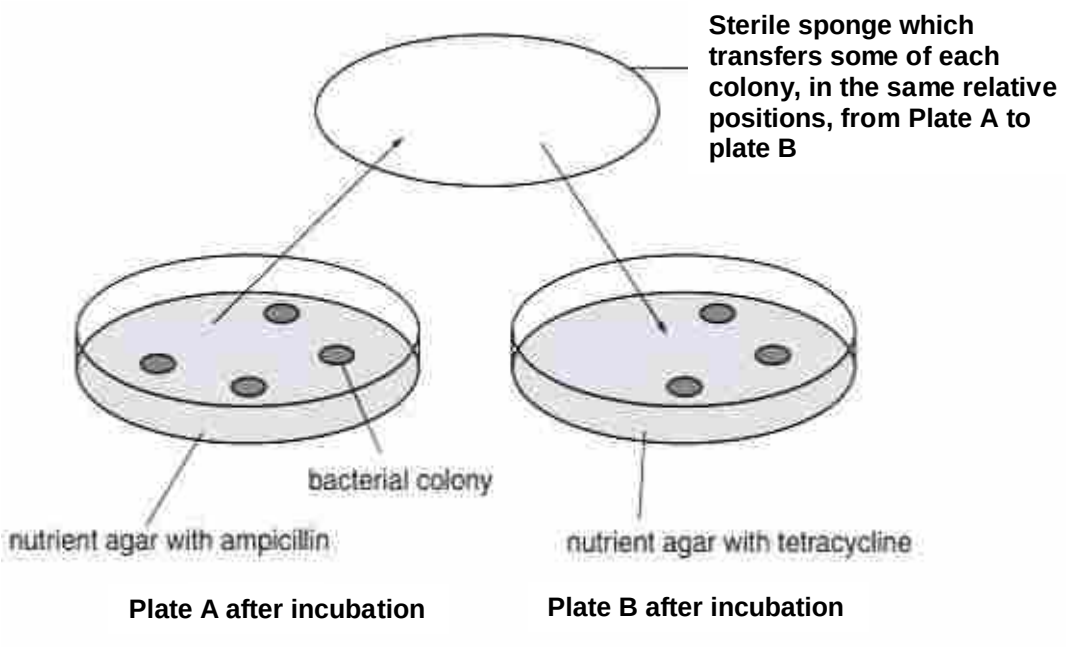


Figure 1.4

(e) Use a label line and the letter C to identify, on Figure 1.4, a colony of bacteria that contain the recombinant plasmid.

[1]

A senior scientist declared that it would be a challenge to develop a good understanding of the role of the mutant protein kinase in cancer development from studying the recombinant protein produced by a bacterial cloning system.

(f) Explain why recombinant mutant protein kinase produced by a bacterial cloning system may not be a good model of study for understanding cancer development.

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…. ..... [2]

[Turn over

Today, due to the findings of the human genome project, polymerase chain reaction (PCR) has largely replaced cDNA libraries to directly isolate genes in the study of diseases. PCR is normally carried out using the enzyme Taq DNA polymerase. This enzyme was originally extracted from the bacterium *Thermus aquaticus*. This bacterium was found in Mushroom Spring, one of the hot springs in Yellowstone National Park in the USA.

Taq DNA polymerase is now obtained from genetically modified *Escherichia coli* that carry the Taq DNA polymerase gene. The optimum temperature of this enzyme is 75-80°C.

After 40 minutes at 95°C, the activity of the enzyme is reduced by half. This means that the half-life of this enzyme at 95°C is 40 minutes.

(g) Using your knowledge of PCR, explain why a half-life of 40 minutes at 95°C allows many cycles of PCR before the enzyme needs to be replaced.

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.... [3]

(h) Suggest why Taq DNA polymerase is now obtained from genetically modified *E.coli.*

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.... [2]

Work on the human genome project was able to provide many benefits to the field of molecular medicine.

(i) State 2 other areas that have benefited from work on the human genome project.

....

.... [2]

[Total: 19]

2. Pluripotent stem cells are one type of stem cells and there is widespread interest in their study today. One key reason is because pluripotent stem cells can be induced to differentiate into the specific cell type required to repair damaged or destroyed cells or tissues. Addtionally pluripotent stem cells can be used to study early events in human development and find out more about how cells differentiate and function. This may help researchers find out why some cells become cancerous and how some genetic diseases develop.

In 2006, a Japanese Scientist, Shinya Yamanaka, made a ground-breaking finding that would win him the Nobel Prize in Physiology or Medicine just six years later. He discovered that specialized cells can be stimulated to dedifferentiate and change back into pluripotent stem cells in tissue culture. Such cells are called induced pluripotent stem cells (iPS cells).

In experiments with mice, Yamanaka showed that the introduction of four genes caused specialized cells to change to iPS cells. Further studies have shown that these four genes indirectly result in the reprogramming of specialized cells by influencing the activity of many other genes.

(a) Outline how the addition of the four genes may influence the activity of many other genes to result in the reprogramming of specialized cells into iPS cells.

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[Turn over

Pluripotent stem cells can also be derived from cytoplasmic hybrid (cybrid) cells through the method of somatic cell nuclear transfer (SCNT). A procedure for producing pluripotent stem cells by SCNT is outlined in Figure 2.1.

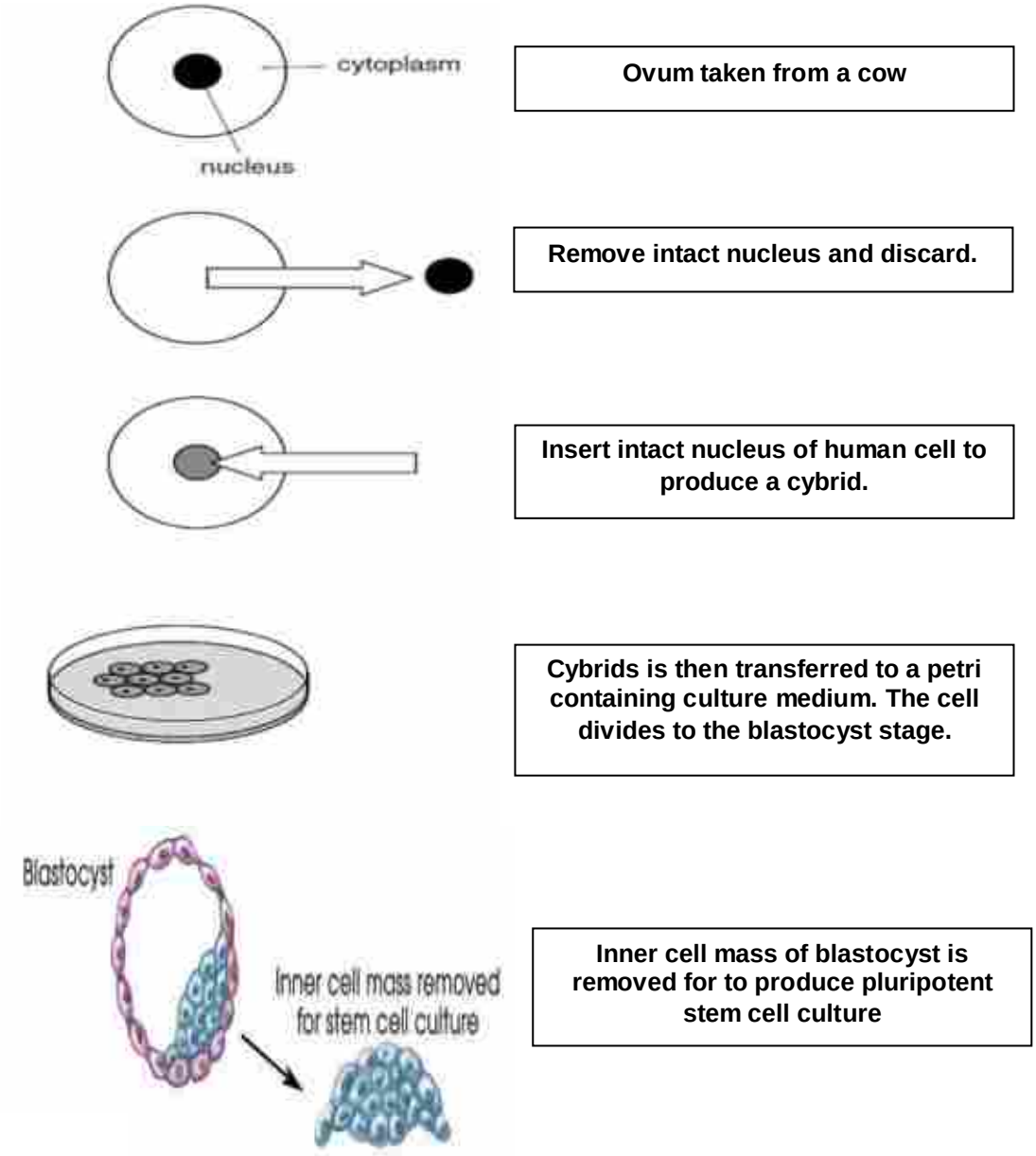

Figure 2.1

The DNA from the pluripotent stem cells generated by the above method is found to be 99.6% human.

(b) Explain the origins of the 0.04% cow DNA that is found in these cells.

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…. ……

…. …… [2]

Some people have argued that it is unethical to allow the production of cybrids.

(c) Suggest why the production of hybrids may be considered unethical.

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…. …… [1]

In 2008, a woman had her damaged left bronchus replaced by one constructed using her own stem cells. Adult stem cells derived from the woman's own bone marrow were used. Samples of these stem cells, together with cells derived from the lining of her trachea, were placed in a bioreactor for four days during which time they multiplied to coat a collagen framework. This cell coated framework was then used to replace the damaged section of her bronchus. A month later the transplanted tissue had developed its own blood supply. This was claimed to be the first successful transplant using tissues derived from the patient's own stem cells.

(d) State two reasons why using the patient's own stem cells to treat a damaged bronchus is preferred to a transplant involving another donor.

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(e) Describe the unique features of the adult stem cells derived from the bone marrow.

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[Total: 10]

[Turn over

3. Iron-deficient anaemia is one of the most serious problems worldwide. Some scientists decided to explore the use of transgenic rice with increased copies of the Nicotianamine Synthase (NAS) gene to address the problem of iron deficiency. NAS is an enzyme in the metabolic pathway involved with iron acquisition in the rice plant. In these regards, the use of transgenic rice to address human iron deficiency is based on developing rice with increased iron content as transgenic rice would contain more copies of the NAS gene and produce more NAS enzymes compared to wild type rice.

To produce transgenic rice, a recombinant Ti plasmid containing NAS gene is engineered and reintroduced back into the bacteria *Agrobacterium tumeficiens*. The recombinant bacteria is then allowed to infect the plant. The process showing how transgenic rice plant is produced is illustrated in Figure 3.1.

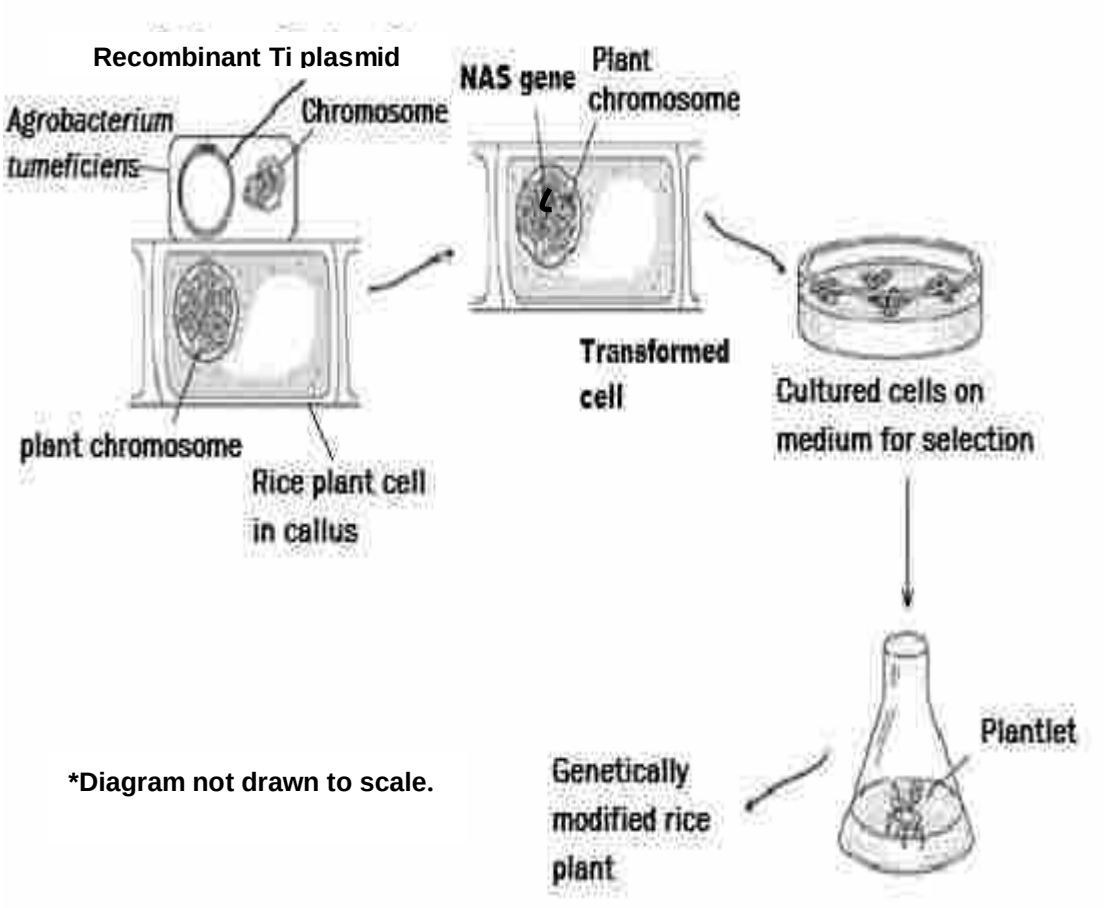

Figure 3.1

The naturally occurring Ti plasmid derived from *Agrobacterium tumefaciens*, is commonly used as a vector for introducing new foreign genes into plant cells. This plasmid integrates a segment of its DNA known as T-DNA, into the chromosomal DNA of host plant cells after infection. Figure 3.2 shows the structure of a natural Ti plasmid.

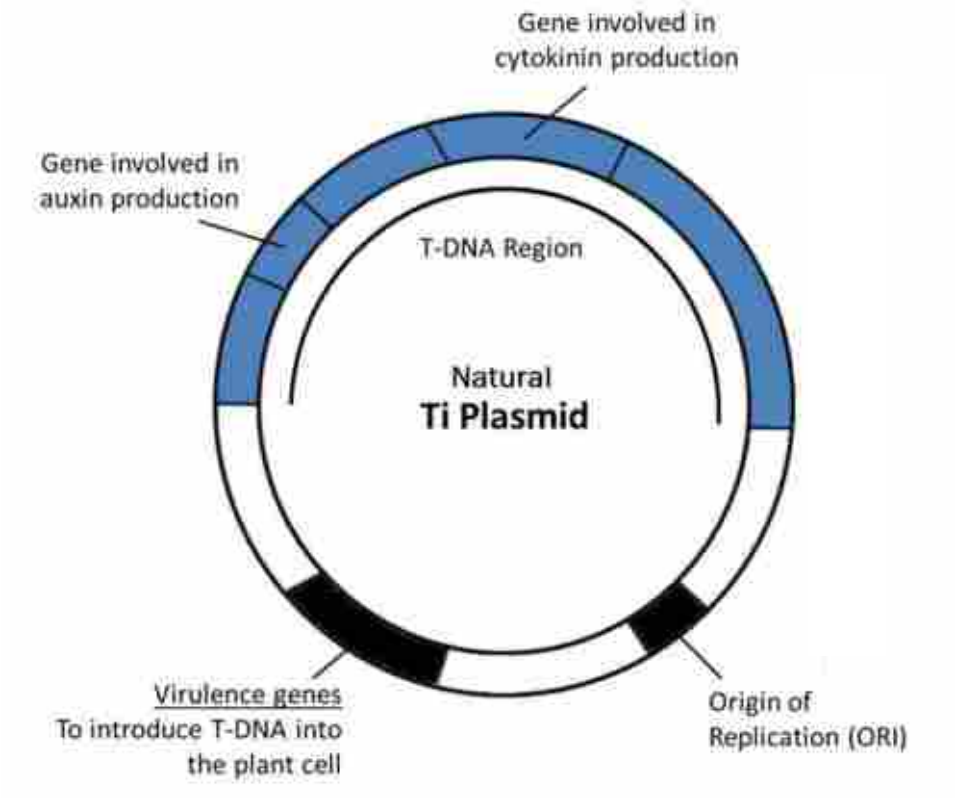

Figure 3.2

The genes for auxin and cytokinin are removed from the T-DNA region from the Ti plasmid before it can be used in the production of transgenic rice.

(a) Explain why the genes for auxin and cytokinin are removed from the T-DNA region of the Ti Plasmid.

…. ……

…. ……

…. ……

…. …… [2]

[Turn over

Transgenic rice plants have to undergo a process of acclimatization before they can be transferred to a natural environment for growth.

(b)

(i) Explain the importance of acclimatization.

.....

..... [1]

(ii) Describe a key step in this process.

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..... [1]

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A study was carried out to evaluate the efficacy of such transgenic rice with increased iron content. Twenty iron-deficient 12-year old girls were selected for the study. The haemoglobin count for each girl chosen was similarly below 12.8gdl^{-3}. The normal haemoglobin count for girls at the age of 12 is 12.8 to 16.0gdl^{-3}.

The girls selected for the study were randomly and equally sorted into a treatment group and a control group. The girls in the treatment group were requested to adhere to a diet of transgenic rice with increased iron content, three times a day, for 5 months. The girls in the control group were requested to adhere to a diet of normal rice grown in the same rice field, three times a day, for 5 months. The mean haemoglobin count for each group was tracked over this period.

The results of the analysis are shown in Figure 3.3.

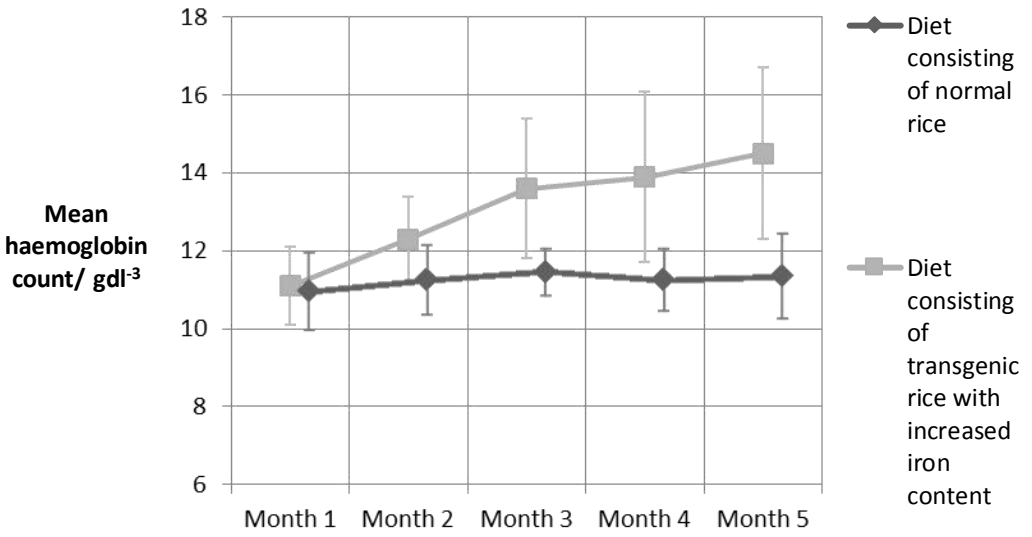

Figure 3.3

At the end of the study, the scientists involved concluded that the transgenic rice was more effective than normal rice in helping iron-deficient children.

(c) With reference to Figure 3.3, discuss the validity of this conclusion.

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In addition to producing more nutritious food, genetically engineered crops like Bt corn can also be used in solving the world demand for food.

(d) Explain how Bt corn helps solve the global food challenge.

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…. …… [4]

[Total: 11]

[Turn over

4. Beetroot is a starchy edible root from the *Beta vulgaris* plant whose cells contain a water-soluble red pigment, betacyanin, in their vacuoles. Beet root pigment is used commercially as a food dye and different methods have been used to extract the pigment from intact beetroot cells. This pigment cannot pass through membranes unless the membranes are damaged.

A colorimeter can be used to measure the absorbance of light at 550 nm by betacyanin solution. The concentration of betacyanin is proportional to its absorbance. The use of a colorimeter to measure absorbance by betacyanin is depicted in Figure 4.1.

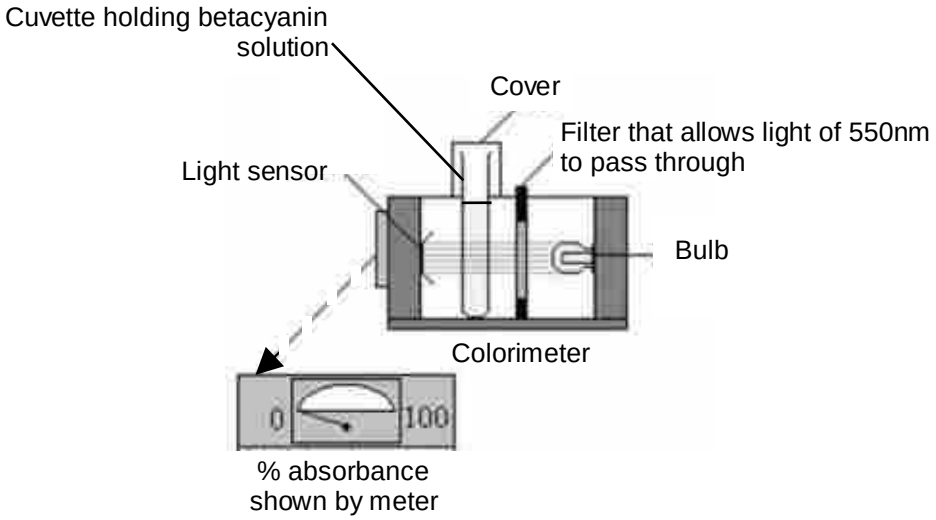

Fig. 4.1

Using the above information and your own knowledge, you are required to plan, but not carry out, an investigation into the effect of alcohol concentration on the permeability of the cell membrane of beetroot tissue.

Your planning must be based on the assumption that you have been provided with the following equipment and material which you must use.

- A large piece of beetroot tissue with the skin removed
- Sharp knife
- 10.0% Alcohol
- White tile
- Ruler
- Stopwatch
- Distilled water
- Colorimeter set at 550nm
- Cuvettes
- Normal laboratory glassware

Your plan should:

- have a clear and helpful structure such that the method you use can be repeated by anyone reading it,
- be illustrated by labelled diagrams, if necessary,
- identify independent and dependent variables,
- describe the method with scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- include layout of results table(s) and graph(s) with clear headings and labels,
- use the correct technical and scientific terms,
- include reference to safety measures to minimize any risks associated with the proposed experiment.

[Total: 12]

[Turn over

For Examiner's Use

[Turn over

Free-response question

Write your answers to this question on the separate answer paper provided.

Your answer:

- should be illustrated by large, clearly labelled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5.

(a) Describe cystic fibrosis and explain how it can be treated using a non-viral gene delivery system. [8]

(b) Discuss the advantages and limitations of plant tissue culture. [6]

(c) Discuss the ethical concerns pertaining to the use of genetically modified animals. [6]

[Total: 20]

End Of Paper

Class Adm No

Candidate Name: _____

H

millennia institute

2016 Preliminary Examination II
Pre-University 3

H2 Biology **9648/03**

Applications Paper and Planning Question **22 September 2016**

2 hours

Additional Materials: Writing paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your Admission number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

The use of an approved scientific calculator is expected, where appropriate.
You will lose marks if you do not show your working or if you do not use appropriate units.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This question paper consists of 21 printed pages including 1 blank page

[Turn over

Answer **all** questions.

1. Before the emergence of more advanced technologies, cDNA libraries have been used to study the genetic changes involved in cancer development.

Normal and tumour cells are obtained from the same patient. Reverse transcription is carried out on mRNA isolated from the tumour cells. Primers consisting of thymine repeats were used during reverse transcription to form single-stranded cDNA as depicted in Figure 1.1. These cDNA are then labelled with fluorescent dyes.

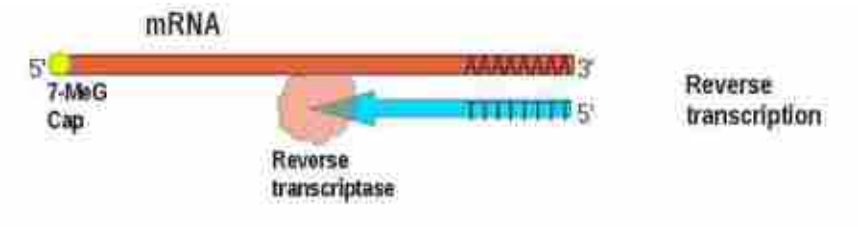

Figure 1.1

Normal cell mRNA and tumour cell cDNA are allowed to hybridise; the resulting double-stranded hybrid molecules and remaining single-stranded mRNA are discarded. Subtracted cDNA (also known as non-hybridized cDNA) are used to form a subtracted cDNA library. The process is summarized by Figure 1.2.

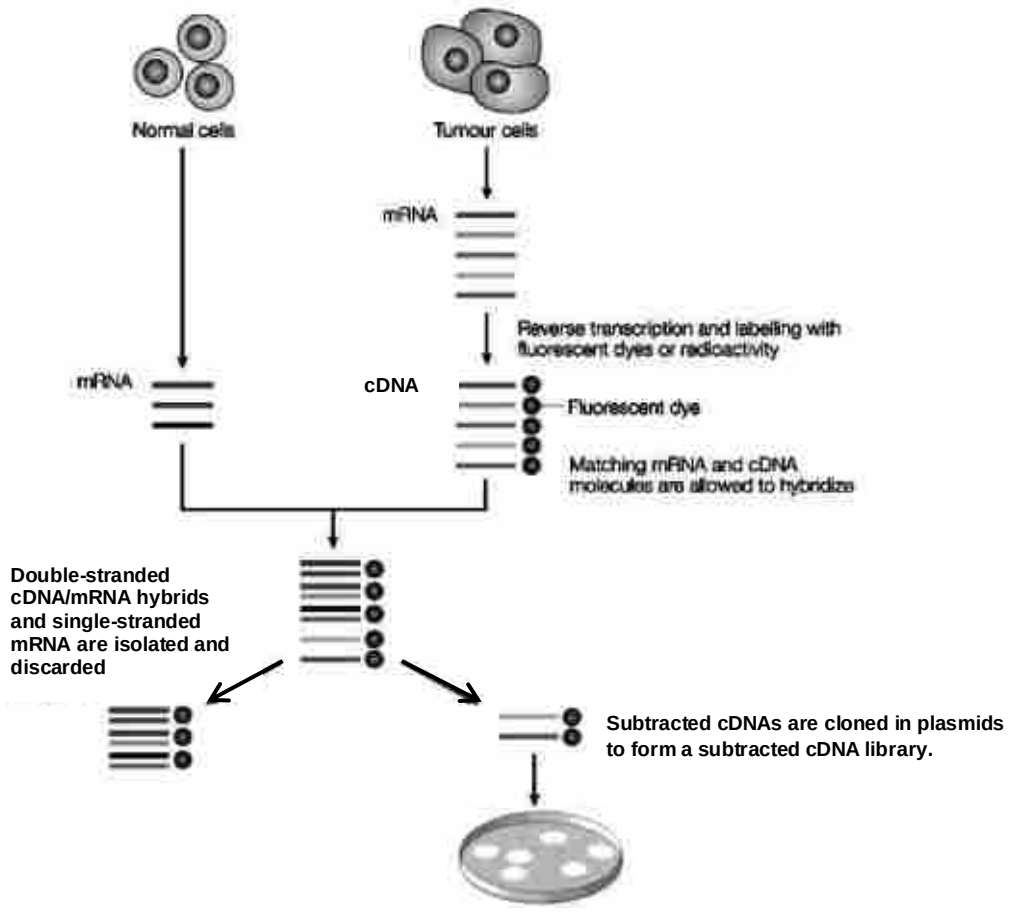

Figure 1.2

A young scientist conducting this procedure was concerned that possible presence of bacteria within cell samples might result in production of bacteria cDNA. This would contaminate downstream processes. However, her concerns were dismissed by her partners who assured her that reverse transcription of bacterial mRNA is unlikely to occur.

(a) Using the information given, explain why reverse transcription of bacterial mRNA is unlikely to occur.

Bacterial mRNA do not possess a 3' poly(A) tail ;
This because bacteria does not carry out post-transcriptional modification to its mRNA.
Hence oligonucleotide primer is unlikely to anneal to bacterial mRNA for reverse transcription;
Max 2

[2]

(b) Describe the steps needed to create recombinant DNA molecules that are used to assemble a plasmid library of subtracted cDNA.

Complementary strand of cDNA with respect to subtracted cDNA sequences are synthesized using DNA polymerase;
Linkers containing appropriate restriction sites are ligated to the double stranded cDNA;
cDNA and plasmids are cut/digest using the same restriction enzyme to produce complementary sticky ends;
Digested cDNA are ligated with digested plasmids;
During ligation digested cDNA and plasmids anneal with each other by complementary base pairing / Hydrogen bonding and are joined using DNA ligase which catalyses the formation of phosphodiester bonds;
Max 4

[4]

(c) Explain why the DNA sequences in the subtracted cDNA library are considered mutant alleles implicated in cancer.

cDNA from tumour cells that hybridizes with mRNA from normal cells represent alleles that are expressed in both tumour and normal cells;
Alleles that are expressed in both tumour and normal cells may not be implicated in cancer;
Alleles that are expressed in both tumour and normal cells are removed by discarding double stranded cDNA/mRNA hybrids;
Subtracted cDNA derived from tumour cells represents the alleles that are expressed in tumour cells but not in normal cells;
Max 2

[2]

(d) Suggest why the subtracted cDNA library may not fully capture all possible DNA sequences implicated in cancer.

Loss- of-function mutations in promotor sequence of tumour suppressor genes would not be captured by subtracted cDNA library;
Loss- of-function mutations in promotor sequence would inhibit gene expression;
AVP
Max 1;

[1]

[Turn over

Screening of the subtracted cDNA library of a cancer patient revealed a mutated protein kinase gene. A research team decided to clone this gene to isolate the mutant protein and study it to better understand its role in cancer development.

The protein kinase gene was first isolated. The artificial plasmid, pKY350, was constructed to act as an expression vector.

The plasmid was constructed to include two genes, each giving resistance to a different antibiotic: an ampicillin resistance gene and a tetracycline resistance gene. The plasmid also has a target site for the restriction enzyme, *BamHI*, in the middle of the tetracycline resistance gene.

A pKY350 plasmid was cut using *BamHI* and the cDNA sequence for the mutant protein kinase was inserted into it. Figure 1.3 shows pKY350 and the recombinant plasmid.

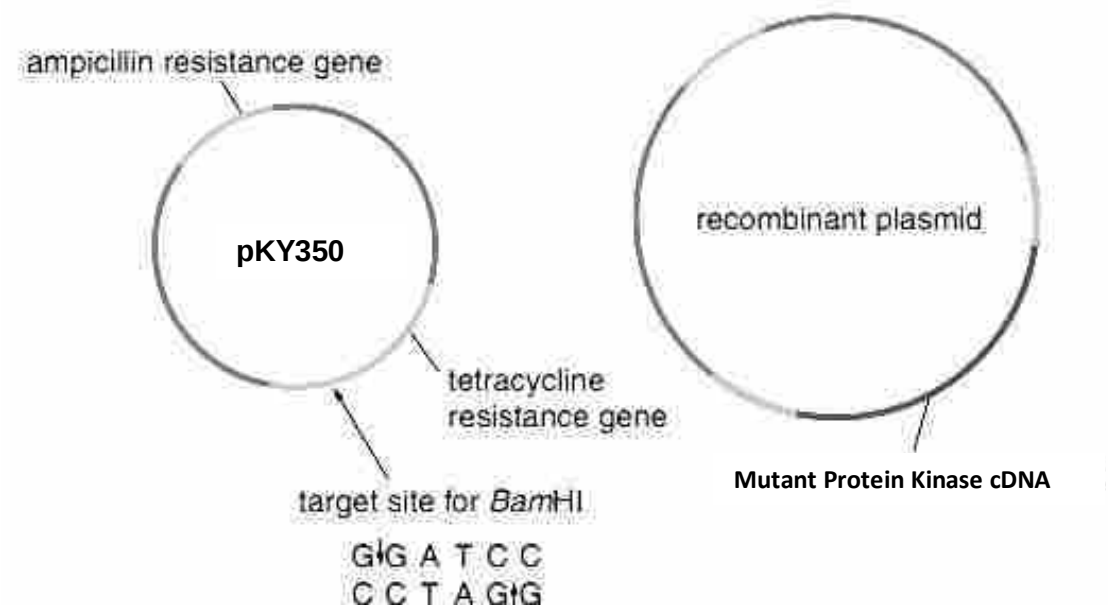

Figure 1.3

The mixture containing recombinant DNA was used to transform *E.coli* bacteria. Replica plating was used to identify recombinant bacteria with the mutant protein kinase gene. Figure 1.4 shows the bacterial colonies that grew on different nutrient agar plates.

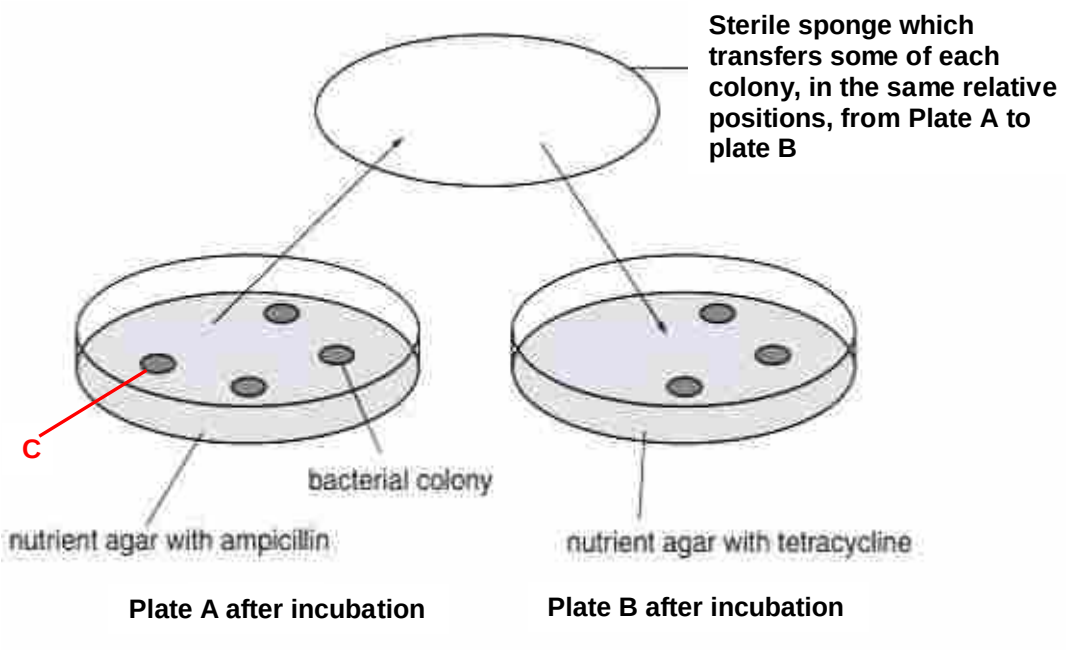

Figure 1.4

(e) Use a label line and the letter C to identify, on Figure 1.4, a colony of bacteria that contain the recombinant plasmid.

[1]

A senior scientist declared that it would be a challenge to develop a good understanding of the role of the mutant protein kinase in cancer development from studying the recombinant protein produced by a bacterial cloning system.

(f) Explain why recombinant mutant protein kinase produced by a bacterial cloning system may not be a good model of study for understanding cancer deve

Mutant tyrosine kinase synthesized in bacteria cells will not undergo post-translational modifications;
Therefore the mutant protein may not have the same structure as it would adopt in normal cancer cells;
Mutant protein kinase may function differently with a different structure which would undermine inferences about its role in cancer cells;
Max 2m

…… [2]

[Turn over

Today, due to the findings of the human genome project, polymerase chain reaction (PCR) has largely replaced cDNA libraries to directly isolate genes in the study of diseases. PCR is normally carried out using the enzyme Taq DNA polymerase. This enzyme was originally extracted from the bacterium *Thermus aquaticus*. This bacterium was found in Mushroom Spring, one of the hot springs in Yellowstone National Park in the USA.

Taq DNA polymerase is now obtained from genetically modified *Escherichia coli* that carry the Taq DNA polymerase gene. The optimum temperature of this enzyme is 75-80°C.

After 40 minutes at 95°C, the activity of the enzyme is reduced by half. This means that the half-life of this enzyme at 95°C is 40 minutes.

(g) Using your knowledge of PCR, explain why a half-life of 40 minutes at 95°C allows many cycles of PCR before the enzyme needs to be replaced.

Each cycle of PCR consists of the 3 stages of denaturation, annealing and extension;
Only the denaturation stage occurs at 95^0C and annealing and extension occur at lower temperatures of 54^0C and 72^0C respectively;
Each cycle is completed within a short period of time which allows for many cycles of PCR to occur in 40min.
Taq DNA polymerase has a high optimum temperature which results in a long half-life of 40 minutes;

Max 3

[3]

(h) Suggest why Taq DNA polymerase is now obtained from genetically modified *E.coli.*

Cloning with E.coli allows for large scale production of Taq DNA polymerases;
It is inconvenient to recover *Thermus aquaticus* to maintain constant supply of natural Taq DNA polymerases;
Thermus aquaticus is not easily cultured under laboratory conditions;
AVP
Max 1

[2]

Work on the human genome project was able to provide many benefits to the field of molecular medicine.

(i) State 2 other areas that have benefited from work on the human genome pr

Study of Microbial Genomics;
Risk Assessment;
Study of Bioarcheology, Anthropology, Evolution, and Human Migration;
Genomic Mapping;
Max 2

[2]

[Total: 19]

2. Pluripotent stem cells are one type of stem cells and there is widespread interest in their study today. One key reason is because pluripotent stem cells can be induced to differentiate into the specific cell type required to repair damaged or destroyed cells or tissues. Additionally pluripotent stem cells can be used to study early events in human development and find out more about how cells differentiate and function. This may help researchers find out why some cells become cancerous and how some genetic diseases develop.

In 2006, a Japanese Scientist, Shinya Yamanaka, made a ground-breaking finding that would win him the Nobel Prize in Physiology or Medicine just six years later. He discovered that specialized cells can be stimulated to dedifferentiate and change back into pluripotent stem cells in tissue culture. Such cells are called induced pluripotent stem cells (iPS cells).

In experiments with mice, Yamanaka showed that the introduction of four genes caused specialized cells to change to iPS cells. Further studies have shown that these four genes indirectly result in the reprogramming of specialized cells by influencing the activity of many other genes.

(a) Outline how the addition of the four genes may influence the activity of many other genes to result in the reprogramming of specialized cells into iPS cells.

.....

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.....

..... [2]

The genes code for transcription factors / activators and repressors respectively/chromatin remodelling enzymes;
These proteins mediate changes in gene expression to result in dedifferentiation into pluripotent stem cells;
These proteins act to increases the expression of genes that control pluripotency of cells;
These proteins act to decreases the expression of genes that resulted in differentiation of cells;
Max 2

[Turn over

Pluripotent stem cells can also be derived from cytoplasmic hybrid (cybrid) cells through the method of somatic cell nuclear transfer (SCNT). A procedure for producing pluripotent stem cells by SCNT is outlined in Figure 2.1.

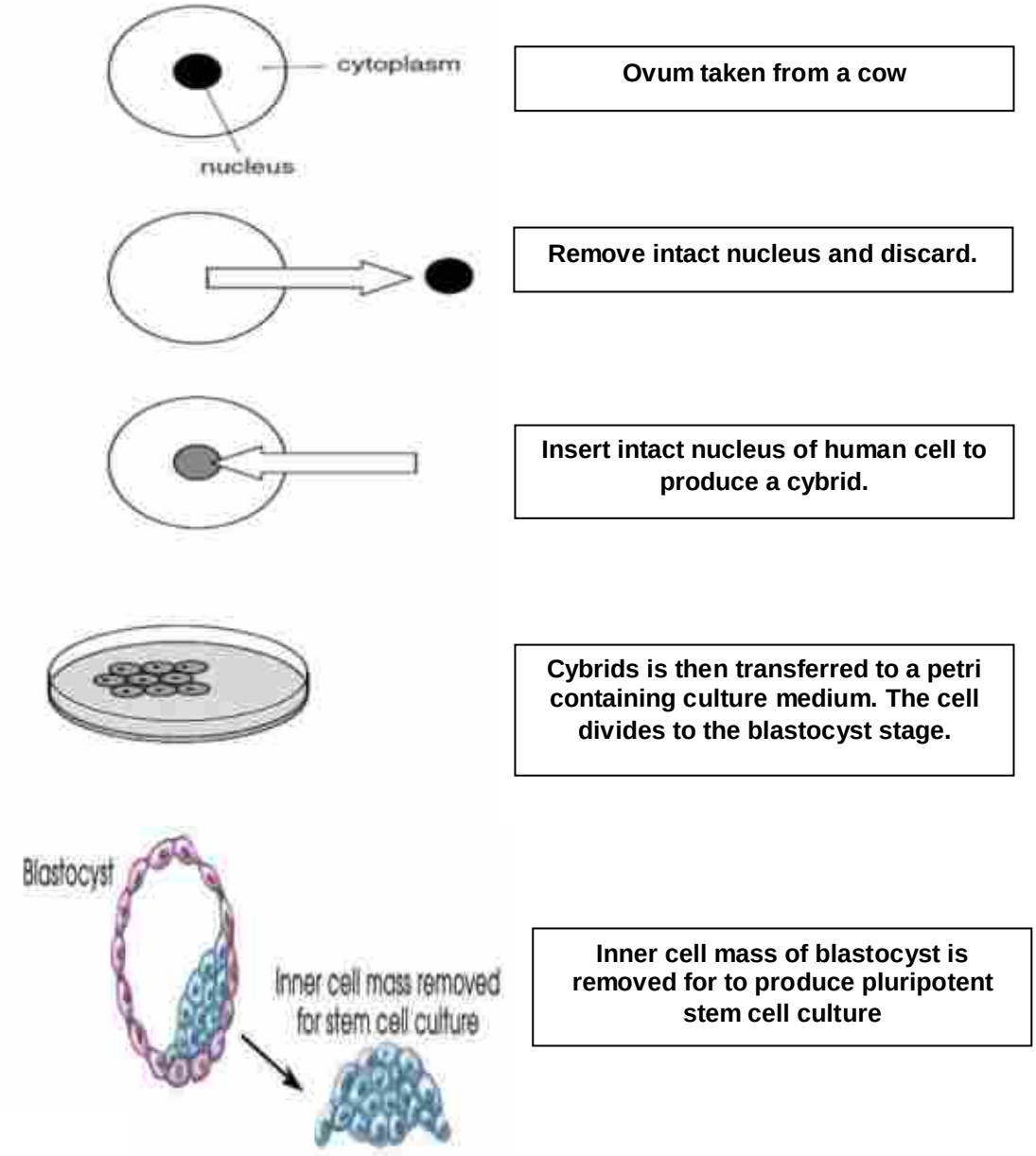

Figure 2.1

The DNA from the pluripotent stem cells generated by the above method is found to be 99.6% human.

(b) Explain the origins of the 0.04% cow DNA that is found in these cells.

....

.... Mitochondria from cow's ovum; Binary division of mitochondria as cells divides account for presence in descendent pluripotent cells; .....

..... [2]

Some people have argued that it is unethical to allow the production of cybrids.

(c) Suggest why the production of hybrids may be considered unethical.

Presence of human and animal DNA means it is partly human and partly cow/ a human-animal hybrid which would not happen in nature;
Claims of the benefits of embryonic stem cell research are overrated/ few examples of success of using embryonic stem cells in medical field;
May lead to abuse of technology in future;
Unnecessary because, there already are alternative techniques to generate pluripotent stem cells such as by iPS technology;
Adult stem cells can be used to treat diseases;
AVP

Reject idea that human embryos will be destroyed
Max 2

In 2008 ... her ow... were u... her tra... multipli... replace the damaged section of her bronchus. A month later the transplanted tissue had developed its own blood supply. This was claimed to be the first successful transplant using tissues derived from the patient's own stem cells.

(d) State two reasons why using the patient's own stem cells to treat a damaged bronchus is preferred to a transplant involving another donor.

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.... [2]

(e)

There will not be any immune response / tissue rejection since no foreign antigens, foreign tissue from the donated bronchus;
Overcomes the problem of finding and locating suitable donors;
No risk of infection arising from donor tissue / no need to decide who is eligible;
No need for immunosuppressant drugs to avoid rejection of transplanted organ;
Bronchus cells can be obtained / cultured in large quantities from the patient's stem cells;
Healthy culture of patient's stem cells can be stored for future needs;
AVP
Max 2

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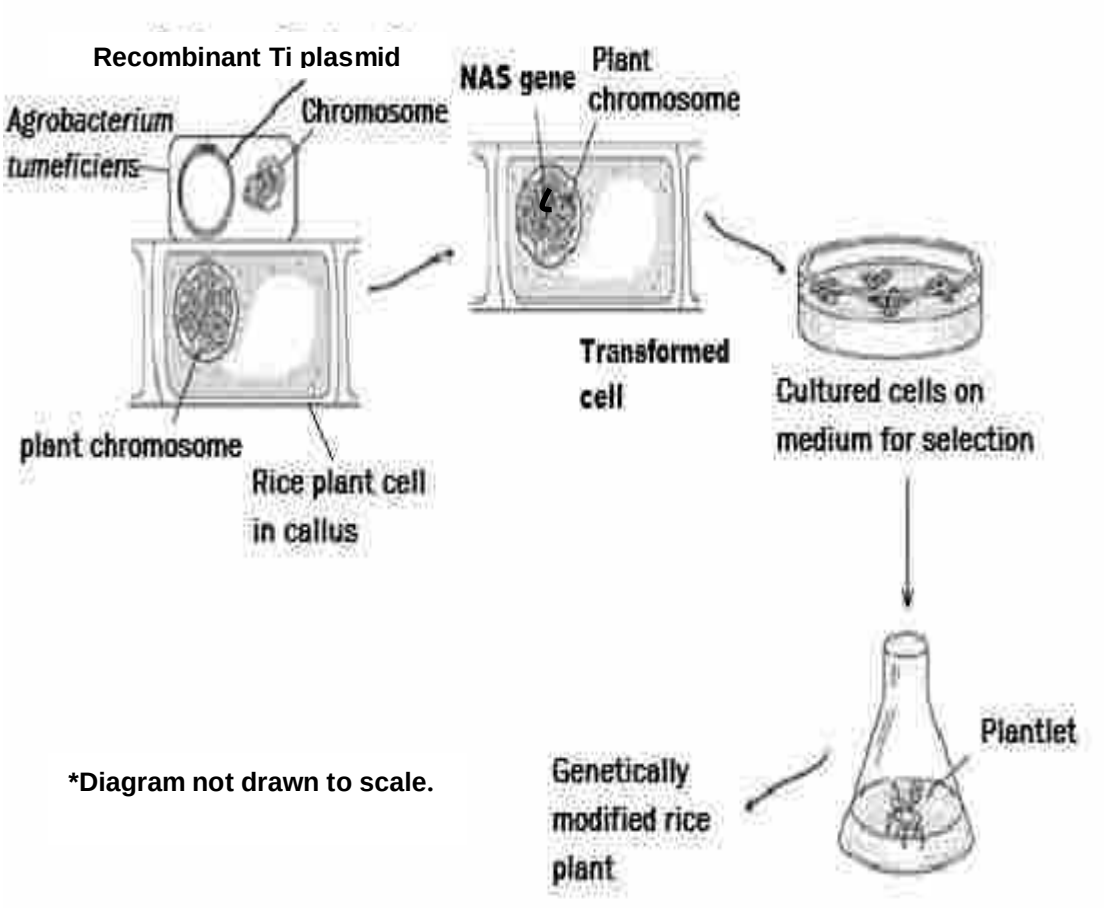
.... [3]

Multipotent stems;
Partially differentiated;
Can differentiate further to produce cells within the same family;
Adult stem cells are self-renewing and can go through many rounds of cell division without differentiating;
AVP
Max 3

[Turn over

3. Iron-deficient anaemia is one of the most serious problems worldwide. Some scientists decided to explore the use of transgenic rice with increased copies of the Nicotianamine Synthase (NAS) gene to address the problem of iron deficiency. NAS is an enzyme in the metabolic pathway involved with iron acquisition in the rice plant. In these regards, the use of transgenic rice to address human iron deficiency is based on developing rice with increased iron content as transgenic rice would contain more copies of the NAS gene and produce more NAS enzymes compared to wild type rice.

To produce transgenic rice, a recombinant Ti plasmid containing NAS gene is engineered and reintroduced back into the bacteria *Agrobacterium tumeficiens*. The recombinant bacteria is then allowed to infect the plant. The process showing how transgenic rice plant is produced is illustrated in Figure 3.1.



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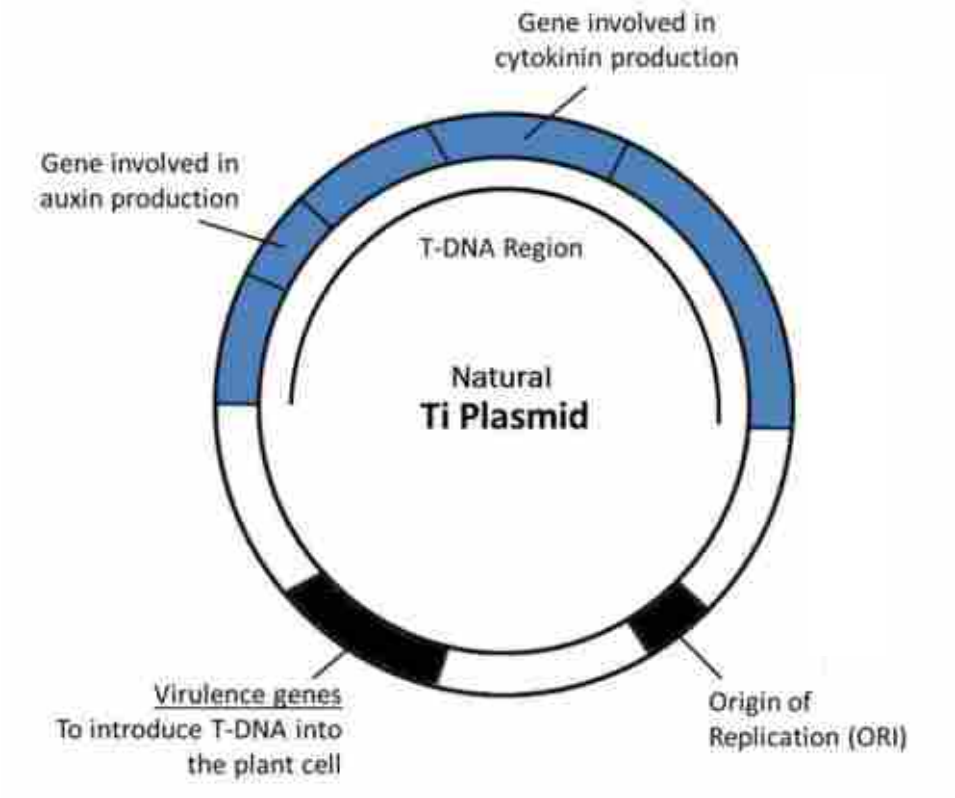

Figure 3.2

The genes for auxin and cytokinin are removed from the T-DNA region from the Ti plasmid before it can be used in the production of transgenic rice.

(a) Explain why the genes for auxin and cytokinin are removed from the T-DNA region of the Ti Plasmid.

Auxins and cytokinins are plant growth hormones;
These genes are expressed at high levels within the T-DNA region to promote tumour formation;
Tumours will depress the yield of transgenic rice that can be harvested;
Max 2

[2]

[Turn over

Transgenic rice plants have to undergo a process of acclimatization before they can be transferred to a natural environment for growth.

(b)

(i) Explain the importance of acclimatization.

Process of acclimatization allows plantlets to gradually get used to external uncontrolled conditions compared in vitro environment where they were previously grown in;
Plantlets are chemoheterotrophs and require time to become photosynthetically competent;
Max 1

(ii) Describe a key step in this process.

Plantlets are first transplanted to sterile soil for further growth in a sheltered environment before they are replanted in an open uncontrolled environment.
Max 1

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A study was carried out to evaluate the efficacy of such transgenic rice with increased iron content. Twenty iron-deficient 12-year old girls were selected for the study. The haemoglobin count for each girl chosen was similarly below 12.8gdl^{-3}. The normal haemoglobin count for girls at the age of 12 is 12.8 to 16.0gdl^{-3}.

The girls selected for the study were randomly and equally sorted into a treatment group and control group. The girls in the treatment group were requested to adhere to a diet of transgenic rice with increased iron content, three times a day, for 5 months. The girls in the control group were requested to adhere to a diet of normal rice grown in the same rice field, three times a day, for 5 months. The mean haemoglobin count for each group was tracked over this period.

The results of the analysis are shown in Figure 3.3.

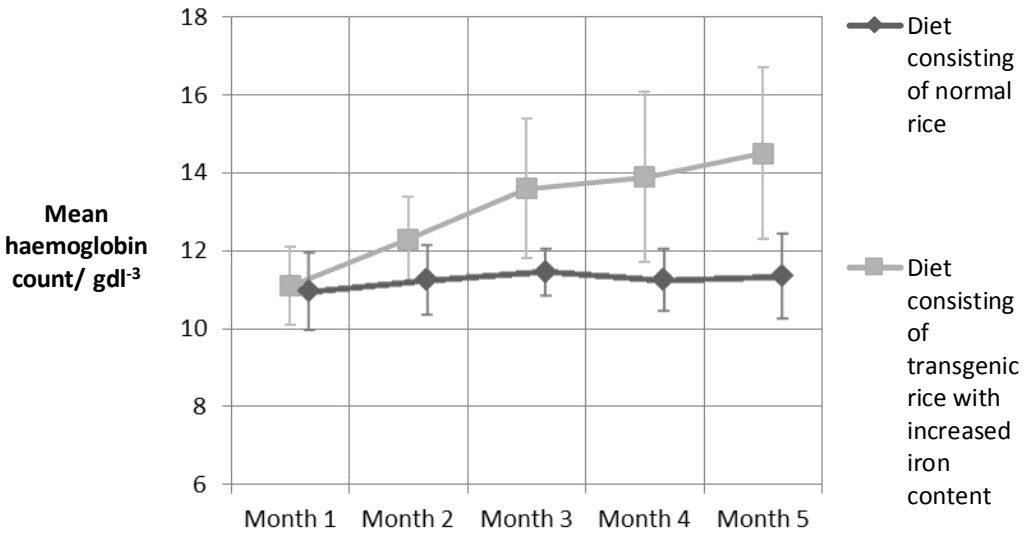


Figure 3.3

At the end of the study, the scientists involved concluded that the transgenic rice was more effective than normal rice in helping iron-deficient children.

(c) With reference to Figure 3.3, discuss the validity of this conclusion.

The conclusion is not valid;
The error bars for the mean haemoglobin count from transgenic rice diet indicate there is large/wide variation among the subjects studied;
This is exemplified by 11.5 to 16 gdl^{-3} for 4th month and 12.5 to 17 gdl^{-3} for 5th month
Therefore even through there seems a rise in mean haemoglobin count from transgenic diet compared to normal rice diet the difference in mean haemoglobin count between both diets is not considered significant;
The sample size/ the number of people studied is also too small to justify this conclusion;
Max 3m

In addition to producing more nutritious food, genetically engineered crops like Bt corn can also be used in solving the world demand for food.

(d) Explain how Bt corn helps solve the global food challenge.

....

Bt gene codes for a large crystal-like protein known as the Bt toxin;
The toxin is ingested by target insect pests when they feed on transgenic corn;
The toxin binds to the specific receptors on the cell membranes of insect gut epithelial cells and causes them to be permeable;
The toxin therefore causes gut cells of insect to lyse, eventually leading to the death of the insects;
Bt toxin is not known to have any harmful effects on humans as the acid in our stomach will denature the protein;
Bt crop therefore increases yield of crops by reducing damage caused by insect pests;
Max4

.... [4]

[Total: 11]

[Turn over

4. Beetroot is a starchy edible root from the *Beta vulgaris* plant whose cells contain a water-soluble red pigment, betacyanin, in their vacuoles. Beet root pigment is used commercially as a food dye and different methods have been used to extract the pigment from intact beetroot cells. This pigment cannot pass through membranes unless the membranes are damaged.

A colorimeter can be used to measure the absorbance of light at 550 nm by betacyanin solution. The concentration of betacyanin is proportional to its absorbance. The use of a colorimeter to measure absorbance by betacyanin is depicted in Figure 4.1.

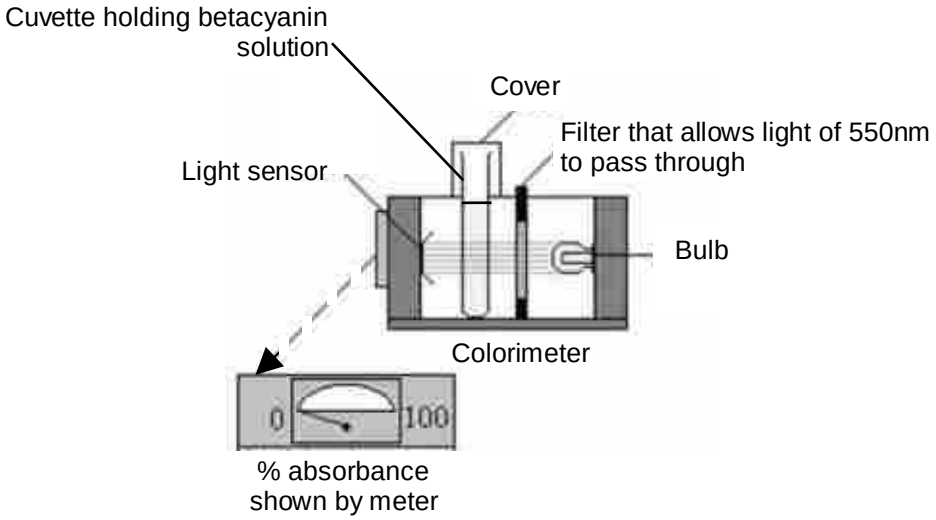


Fig. 4.1

Using the above information and your own knowledge, you are required to plan, but not carry out, an investigation into the effect of alcohol concentration on the permeability of the cell membrane of beetroot tissue.

Your planning must be based on the assumption that you have been provided with the following equipment and material which you must use.

- A large piece of beetroot tissue with the skin removed
- Sharp knife
- 10.0% Alcohol
- White tile
- Ruler
- Stopwatch
- Distilled water
- Colorimeter set at 550nm
- Cuvettes
- Normal laboratory glassware

Your plan should:

- have a clear and helpful structure such that the method you use can be repeated by anyone reading it,
- be illustrated by labelled diagrams, if necessary,
- identify independent and dependent variables,
- describe the method with scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- include layout of results table(s) and graph(s) with clear headings and labels,
- use the correct technical and scientific terms,
- include reference to safety measures to minimize any risks associated with the proposed experiment.

[Total: 12]

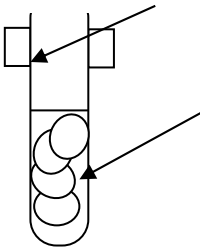
<table>
<tr><th>Section</th><th>Mark Scheme</th><th>Max marks</th></tr>
<tr><td>T</td><td>T1.Betacyanin pigment is large/ hydrophilic and cannot pass through hydrophobic core of phospholipid bilayer;
T2.Increasing alcohol concentration increases damage/disruption to the integrity of cell membrane/regular arrangement of the membrane;
T3.This is due to solubilisation of phospholipids/alcohol dissolving phospholipids;
T4.Vacuole membrane/tonoplast AND cell surface membrane lose selective permeability/become more permeable, allowing pigment to diffuse out of the cell;
T5.As concentration of alcohol increases, membrane permeability of beetroot tissue increases, leading to an increase in absorbance value;

T6.The independent variable in this experiment is alcohol concentration while the dependent variable is absorbance at 550nm;
T7.Other variables to be kept constant (any 2);
-washing and rinsing cut beetroot cylinders before start of experiment.
-calibration of colorimeter using alcohol solution;
- Dimensions of beetroot tissue used (if using scalpel).
-Time the beetroot cubes were immersed in the alcohol solution.
-Same volume of alcohol used (e.g. 10-15cm^3)
-Same cuvette used
-Same beetroot used
-Constant temperature (e.g. 28°C -30°C)</td><td>Max 2 marks

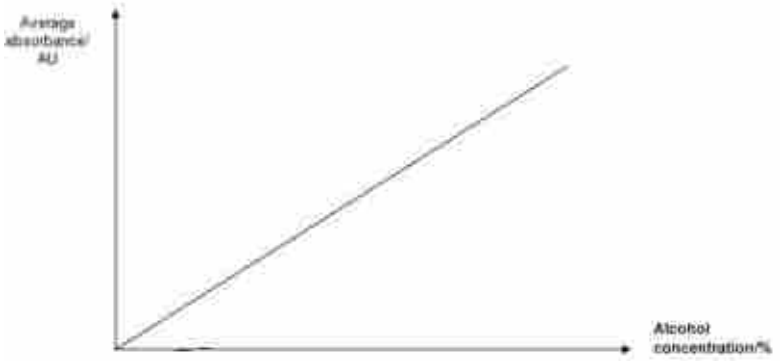
Max 1 mark</td></tr>
<tr><td>M</td><td>1. Prepare 10 c^{m3} each of 2.0%, 4.0%, 6.0%, 8.0% and 10.0% alcohol solution and control by diluting the 10.0% stock alcohol solution and place them in labelled test tubes;

<table><tr><th>Test tubes</th><th>Concentration of alcohol solution/%</th><th>Volume of 10% alcohol/cm^3</th><th>Volume of distilled water/cm^3</th></tr><tr><td>A</td><td>2.0</td><td>2.0</td><td>8.0</td></tr><tr><td>B</td><td>4.0</td><td>4.0</td><td>6.0</td></tr><tr><td>C</td><td>6.0</td><td>6.0</td><td>4.0</td></tr><tr><td>D</td><td>8.0</td><td>8.0</td><td>2.0</td></tr><tr><td>E</td><td>10.0</td><td>10.0</td><td>0.0</td></tr><tr><td>Control</td><td>0.0</td><td>0.0</td><td>10.0</td></tr></table>1m for completed dilution table;</td><td>6 marks max</td></tr>
</table>

[Turn over

	2. Cut the beetroot tissue into cubes of 1cm^3 (Or identical dimensions) on a white tile using a ruler and scalpel; 3. Wash and rinse beetroot cubes in distilled water to remove any pigments which may leak out during cutting. There should be no further leakage of colour from the beetroot tissue; 4. Place 5 beetroot cubes into a test tube A; 5. Immediately start timing for 5 minutes using a stopwatch; 6. After 5 minutes, remove 1 cm^3 of extract from test tube A and transfer to a cuvette; 7. Measure absorbance value at 550nm using colorimeter; 8. Repeat steps 4-7 for 4%, 6%, 8%, 10% alcohol solutions and control; 9. Before measuring absorbance, colorimeter should be calibrated with matching concentration of alcohol solution with respect to each sample; 10. Perform 2 more replicates for each concentration of alcohol solution to obtain average absorbance + repeat entire experiment twice with fresh batch of reagents to ensure reproducibility; Test tube containing 5 1cm^3 beet root cubes in alcohol solution  Extract is removed after 5 minutes of incubation and transferred to cuvette to measure absorbance at 550nm by colorimeter 1m for labelled diagram;	
R	R1. Table with correct headings with appropriate units + Replicate and average included; R2. Graph showing x-axis: Alcohol concentration A, y-axis: average absorbance / A.U;	2 marks max

Concentration of alcohol solution/%	Absorbance / A.U			
	Replicate 1	Replicate 2	Replicate 3	Average
2.0				
4.0				
6.0				
8.0				
10.0				
0.0				

		
S	S1.Handle scalpel carefully or place them away from main work area after use to avoid injuring/cutting oneself; S2.Handle liquid chemicals such as the 10% alcohol with care or wear protective goggles to prevent eyes from being in contact with alcohol; S3.Handle fragile objects like test tubes with care. Arrange test tubes neatly in the test tube rack, ensuring that they are placed where they cannot be knocked over or roll off the bench to prevent breakage;	1 mark max

Free-response question

Write your answers to this question on the separate answer paper provided.

Your answer:

- should be illustrated by large, clearly labelled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5.

(a) Describe cystic fibrosis and explain how it can be treated using a non-viral gene delivery system. [8]

(b) Discuss the advantages and limitations of plant tissue culture. [6]

(c) Discuss the ethical concerns pertaining to the use of genetically modified animals. [6]

[Total: 20]

End of Paper

1.

(a) Describe cystic fibrosis and how it can be treated using a non-viral gene delivery system [8]

Description of cystic fibrosis:

Cystic fibrosis (CF) is an autosomal recessive disease;
Caused by mutation of cystic fibrosis transmembrane conductance regulator gene;
The CFTR protein is a chloride channel which regulates the transport of chloride ions across epithelial cells;
Mutations in the CFTR gene disrupt the function of the chloride channels, preventing them from regulating the flow of chloride ions and water across cell membranes;
The most common mutation is a deletion of three nucleotides on chromosome 7 that results in a loss of the amino acid phenylalanine (F) at the 508th (508) position on the protein;
As a result, cells that line the passageways of the lungs, pancreas, and other organs produce mucus that is unusually thick and sticky;
This abnormal mucus can clog the airways, leading to severe problems with breathing and bacterial infections in the lungs;
Over time, mucus build-up and infections result in permanent lung damage, including the formation of scar tissue (fibrosis) and cysts in the lungs;
A build-up of thick, sticky mucus in the pancreas can block the pancreatic duct from secreting digestive enzymes and importance hormones (e.g. insulin);
Problems with digestion can lead to diarrhoea, malnutrition, poor growth, and weight loss;
AVP
Max 4

Treatment of cystic fibrosis:

A normal functioning CFTR gene is isolated;
The allele is cloned many times by PCR;
The allele is then encapsulated into liposomes;
Liposomes are then delivered to epithelial cell in the lung by aerosol spray (nasal spray);
The gene particles are inhaled, so that they can pass into the epithelial cells of the lung to be incorporated into the DNA of the cells;
The liposome fuses with the plasma membrane of the epithelial cell lining the lung and releases the DNA into the cell;
The normal CFTR enters nucleus and is transcribed and translated to produce normal CFTR protein which can be incorporated into plasma membrane to facilitate the transport of chloride;
AVP
Max 4

[Turn over

(b) Discuss the advantages and limitations of plant tissue culture. [6]

Advantages

Rate of growth by micro-propagation is also greater than conventional propagation;

The genetic makeup of all plants possessing desirable phenotypes can be preserved generation after generation;

Possible to produce clones of some plants species that are otherwise difficult or slow to propagate by conventional means (e.g. orchid);

Able to multiply plants which produce little or no seeds (e.g. bananas);

Production of disease free plants when explants are taken from meristematic regions (shoot tips, root tips), which are free from viruses;

Production of new plants can be continued all year round and is independent of seasonal/climate changes;

Relatively low space requirement, as compared to growing plants in greenhouses or farms;

Max 3

Disadvantages

The limited gene pool and genetic uniformity of plants cultured make them vulnerable to new diseases or drastic changes in the environment;

Very expensive due to several factors due to high overhead (specialized equipment, facilities, supplies) and labour costs;

It is also labour intensive as labour is required to transfer plantlets from laboratory to soil. Therefore this may not be economical for crops with low financial returns like carrots;

Plants produced from calli may undergo genetic changes to produce genetic variations, which usually result in undesirable phenotypes;

Max 3

(c) Discuss the ethical concerns pertaining to the use of genetically modified animals. [6]

Genetically modifying organisms will mean tampering with nature and hence going against the natural way of life;

There is concern about whether the animals are biologically capable of withstanding the additional stress of increased production of milk, meat and other products;

Increased use of growth hormone has harmful effects on the health of animals;

The use of bovine somatotropin in dairy cattle increases the risk of mastitis, which is a disease of the udder;

Medical experiments may cause suffering in animals;

For example, oncogenes are cloned into mice to study cancer. These transgenic mice develop tumours more frequently than normal ones and suffer the symptoms of cancer development;

In US, there is no mandatory labelling of GM food or GM processed food;

This may pose health risks as the consumer may have an unwanted reaction towards these products;

Some religions and ethnic groups avoid eating certain foods, but the food they eat might contain genes from other sources which they must not eat;

The concern rises from the belief that consumers should have right to know and choose what they are purchasing and consuming;

There is fear that cloning techniques (e.g. those used in the cloning of Dolly the sheep in 1997) may be used on humans, to create beings with desirable qualities race/ used to eventually practice eugenics;

[Total: 20]

[Turn over

Civics Group | Reg Number

Candidate Name: _____

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations 2016
Higher 2

H2 BIOLOGY 9648/01

Paper 1 Multiple Choice Questions

22 September 2016
1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write in soft pencils.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.
Write your name, civics group and index number on the Multiple Choice Answer Sheet provided.

There are **forty** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

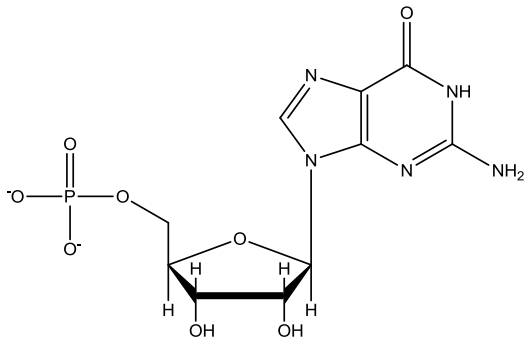
You may keep this booklet after the examination.

This paper consists of **22** printed pages.

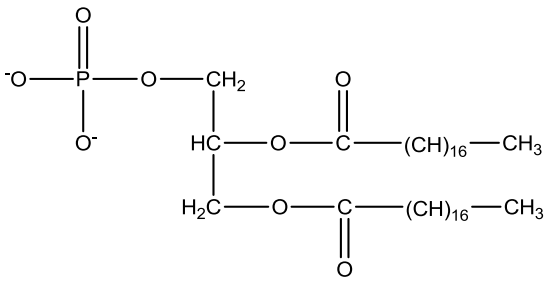
[Turn over]

QUESTION 1

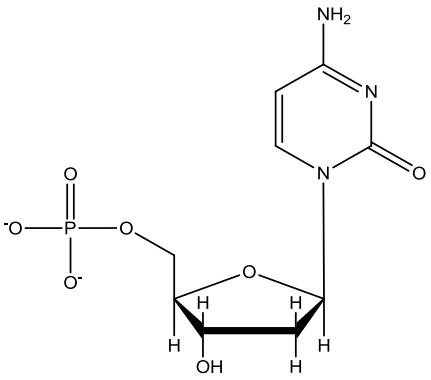
A student used centrifugation to separate the various intracellular structures of human liver cells by size and density. Which of the following molecule(s) would you expect to find in the fraction containing the mitochondria?



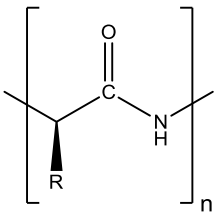
I



II



III



IV

A. II only

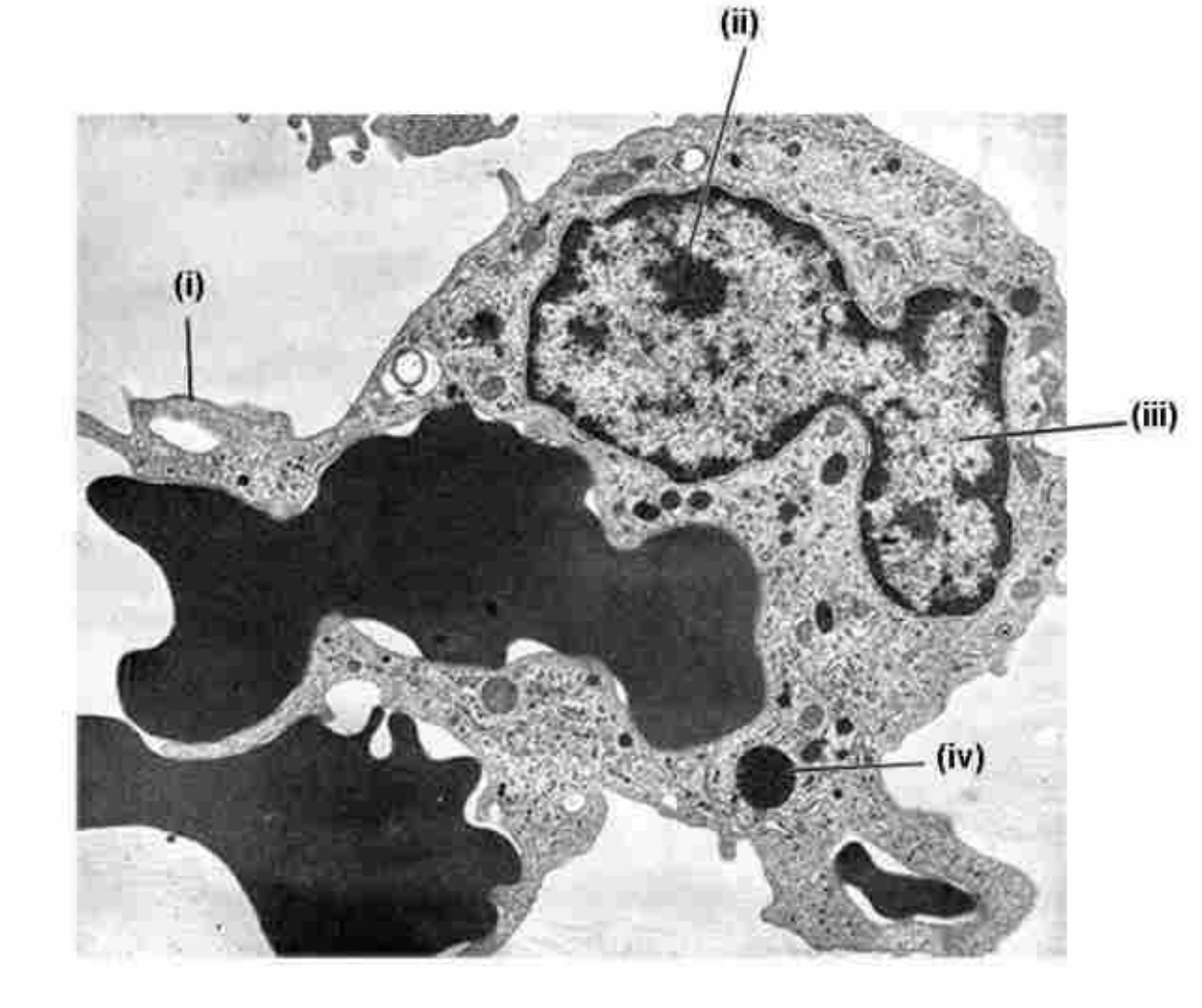
B. II and **IV** only

C. I, **II** and **IV** only

D. I, **II** , **III** and **IV**

QUESTION 2

The figure below is an electron micrograph of a human macrophage, a type of white blood cell.



Which of the options correctly matches structure with function?

	Structure (i)	Structure (ii)	Structure (iii)	Structure (iv)
A.	Engulfs foreign bacteria	Contains genes that code for hydrolytic enzymes	Transcription of ribosomal RNA	Contains enzymes for secretion
B.	Engulfs worn out red blood cells	Partial assembly of ribosomes	Contains genes that code for specific receptor proteins	Contains hydrolytic enzymes
C.	Engulfs foreign bacteria	Transcription of ribosomal RNA	Contains genes that code for specific receptor proteins	Contains enzymes for secretion
D.	Engulfs worn out red blood cells	Contains genes that code for hydrolytic enzymes	Transcription of ribosomal RNA	Contains hydrolytic enzymes

QUESTION 3

The phospholipid bilayer of a certain type of cell was analysed by separating the two layers and analysing the components of each layer.

Which option shows the composition of each layer?

A.	Glycolipids	Phospholipids	Glycoproteins	Cholesterol
Inner layer	0%	80%	0%	20%
Outer layer	15%	50%	15%	20%

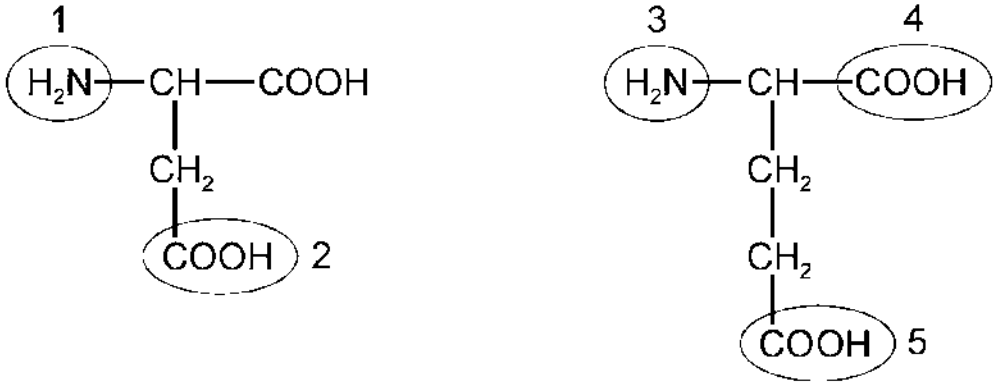
B.	Glycolipids	Phospholipids	Glycoproteins	Cholesterol
Inner layer	15%	50%	15%	20%
Outer layer	0%	80%	0%	20%

C.	Glycolipids	Phospholipids	Glycoproteins	Cholesterol
Inner layer	10%	60%	20%	10%
Outer layer	30%	50%	0%	20%

D.	Glycolipids	Phospholipids	Glycoproteins	Cholesterol
Inner layer	30%	50%	0%	20%
Outer layer	15%	50%	15%	20%

QUESTION 4

The diagrams show the structures of two amino acids, each of which has two carboxylic acid groups (–COOH).



Which groups form the bonds that maintain the configuration of α-helices?

A. 1 and 4 **B.** 1 and 5 **C.** 2 and 3 **D.** 2 and 5

QUESTION 5

Which features adapt a cellulose molecule for its function?

1. Long chains of β-glucose molecules have multiple branches.
2. Many hydrogen bonds are formed between adjacent chains.
3. Cellulose is insoluble in water.

A. 1, 2 and 3 **B.** 1 and 3 only **C.** 2 and 3 only **D.** 2 only

QUESTION 6

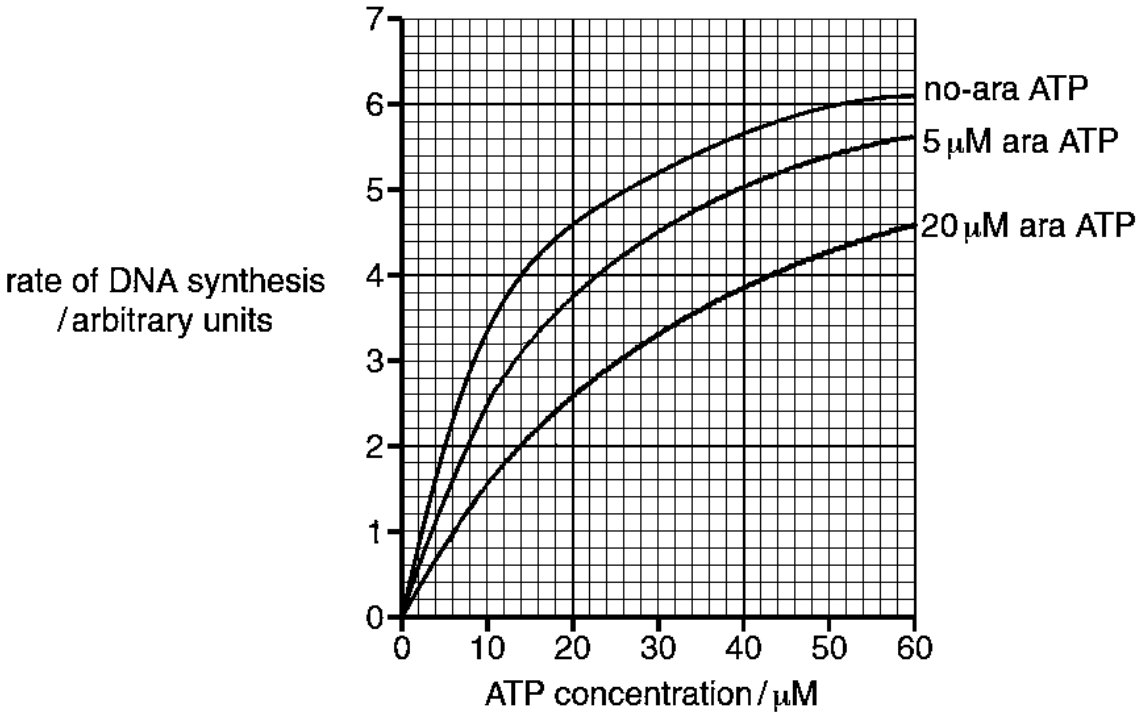
DNA polymerase is an enzyme involved in the replication of DNA. One of the substrates required by DNA polymerase is ATP.

ara-ATP is a chemical that affects DNA polymerase activity.

In an investigation, the effect of different concentrations of ATP on the rate of DNA synthesis was determined:

- with no ara-ATP
- with a low concentration of ara-ATP
- with a high concentration of ara-ATP

The results of the investigation are shown in the graph below:



Which of the following statements about the effects of ara-ATP are **false**?

1. ara-ATP binds to an allosteric site on DNA polymerase.
2. ara-ATP binds to the active site on DNA polymerase.
3. ara-ATP is similar in structure to ATP.
4. When ara-ATP binds to DNA polymerase, the shape of its active site changes.
5. When ara-ATP binds to DNA polymerase, the rate of DNA synthesis can be increased by increasing the concentration of ATP.

A. 1 and 4 **B.** 1 and 5 **C.** 2 and 3 **D.** 2 and 5

QUESTION 7

Which is the correct statement concerning cell and nuclear division?

A. At prophase, the mass of DNA is doubled. Following anaphase, this mass is reduced by half and following cytokinesis this mass halves again.

B. Mutagens can cause mutations whereas carcinogens can cause cancer. This means that all mutagens are carcinogenic.

C. Some of the roles of mitosis are growth, asexual reproduction, cell repair following tissue damage and cell replacement.

D. Haploid eukaryotes can reproduce by mitosis whereas diploid eukaryotes can reproduce by mitosis or meiosis.

QUESTION 8

Some plants, such as wheat or banana plants, can produce diploid or haploid gametes. These gametes can fertilise other diploid or haploid gametes.

Which statements are correct for plants like these?

1. Diploid gametes may be produced by non-disjunction during meiosis.

2. The offspring will always show an increased chromosome number.

3. The offspring could be 2n, 3n or 4n.

4. The chromosome number could increase with each generation.

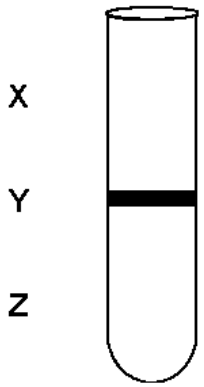
A. 1, 2 and 3 **B.** 1, 2 and 4 **C.** 1, 3 and 4 **D.** 2, 3 and 4

QUESTION 9

A culture of bacteria was allowed to reproduce using nucleotides containing ^{14}N for many generations. The culture was then allowed to reproduce using nucleotides with the heavy isotope of nitrogen, ^{15}N, for one generation. The DNA of the bacterial cells was then examined using a centrifuge before it was returned to a culture medium with nucleotides containing ^{14}N.

The DNA of the bacterial cells was then examined again after two subsequent generations in the culture medium with nucleotides containing ^{14}N.

The diagram below shows the position of the DNA band at **Y** in the centrifuge tube when the DNA was first labelled.

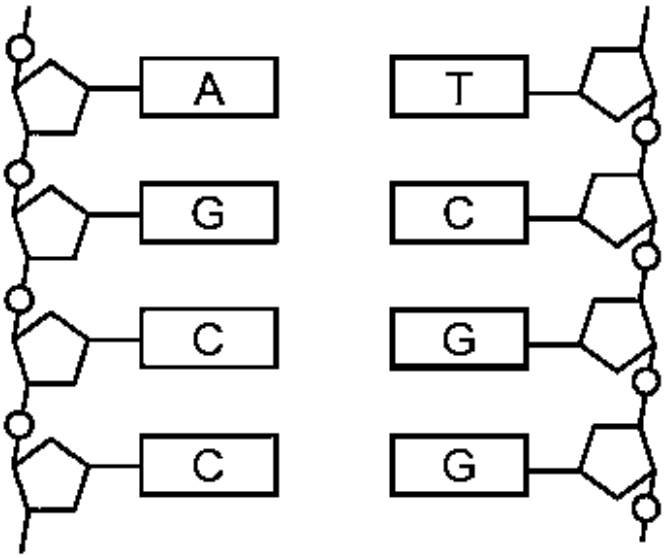


Which option shows the number of bands and their respective band positions for the two subsequent generations in the culture medium with nucleotides containing ^{14}N.

	After one generation in ^{14}N medium	**After another generation in ^{14}N medium**
A.	Two bands, 50% at **Y** and 50% at **Z**	Two bands, 75% at **Y** and 25% at **Z**
B.	Two bands, 50% at **Y** and 50% at **Z**	Two bands, 25% at **Y** and 75% at **Z**
C.	Two bands, 50% at **X** and 50% at **Y**	Two bands, 75% at **X** and 25% at **Y**
D.	Two bands, 50% at **X** and 50% at **Y**	Two bands, 25% at **X** and 75% at **Y**

QUESTION 10

The diagram shows part of a DNA molecule.



How many hydrogen bonds are involved in holding these strands of DNA together?

A. 12 **B.** 11 **C.** 9 **D.** 8

QUESTION 11

In 1985, it was discovered that a bacterium, *Mycoplasma capricolum*, used a deviant genetic code. The codon UGA resulted in the addition of tryptophan to the growing polypeptide chain.

A short sequence of nucleotides was synthesised with the following base sequence:

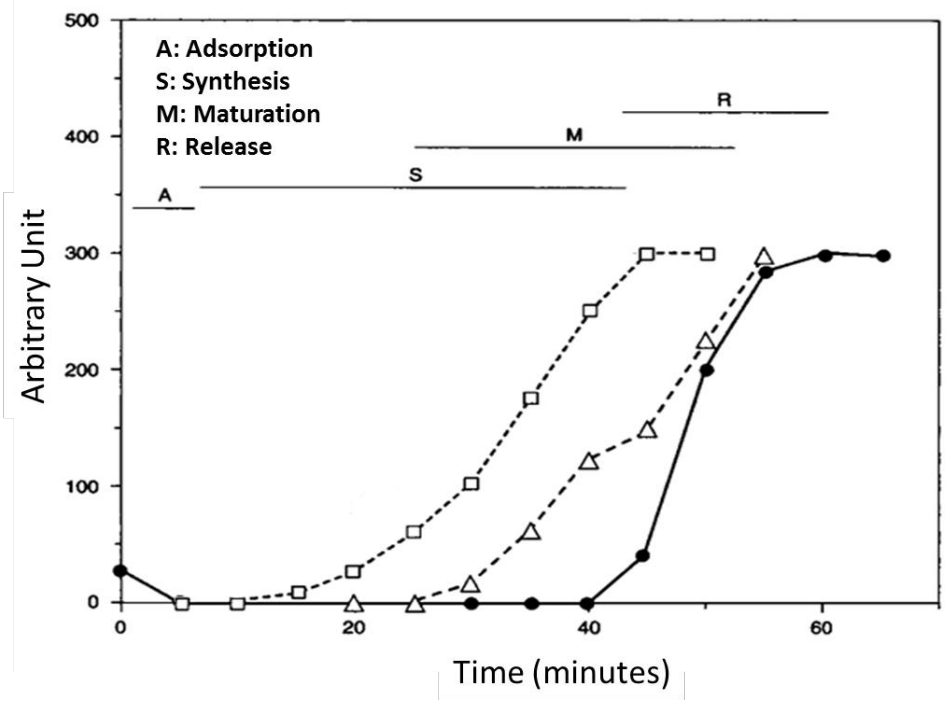
3' CTGGCAACTATTTCAACTCATATC 5'

How many peptide bonds would be formed by ribosomes when this sequence under goes transcription and translation in *Mycoplasma capricolum* and a human liver cell?

	Mycoplasma capricolum	Human liver cell
A.	1	0
B.	2	1
C.	3	2
D.	4	3

QUESTION 12

The graph represents the process of viral replication.



Which of the following option is correct?

	●	□	△
A.	extracellular virions	nucleic acids and proteins	intracellular viral particles
B.	extracellular virions	nucleic acids	intracellular viral particles
C.	intracellular viral particles	nucleic acids and proteins	extracellular virions
D.	intracellular viral particles	nucleic acids	extracellular virions

QUESTION 13

Which of the following correctly describe drugs that are effective in treating viral infection?

1. Antibiotics that induce the body to produce antibodies
2. Drugs that interfere with the synthesis of viral nucleic acid
3. Drugs that prevent viral protein synthesis by interfering with viral ribosomes
4. Drugs that change the cell surface receptor on the host cell
5. Drugs that prevent uncoating of the nucleocapsids

A. 2 and 5 **B.** 4 and 5 **C.** 2 and 3 **D.** 1 and 3

QUESTION 14
Which of the following statements is true for generalized and specialized transduction?

	Generalized	Specialized
A.	Transfers any bacterial DNA	Transfers one specific bacterial gene
B.	Contains a hybrid DNA in its capsid	Contains only bacterial DNA in its capsid
C.	The host cell will die	The host cell will not die
D.	Viral DNA is replicated by host cell machinery	Viral DNA is replicated by binary fission

QUESTION 15
Which statements about bacterial genetic transfer are **not** correct?

1. In transformation, bacterial cells which possess competence factors can only take up the plasmids from the surroundings.

2. Homologous recombination is always involved in bacterial genetic transfer.

3. After conjugation, the donor and recipient cells contain the same genetic information.

4. Binary fission will not contribute to genetic variation in bacterial cells without plasmids.

A. 1 and 3 **B.** 1, 2 and 3 **C.** 2 and 3 **D.** 1, 2, and 4

QUESTION 16
Which statement describes the difference between an inducible and repressible operon?

	Inducible operon	Repressible operon
A.	Functions in catabolic pathways	Functions in anabolic pathways
B.	Repressor genes are usually not expressed	Repressor genes are usually expressed
C.	Synthesizes inactive repressor	Synthesizes active repressor
D.	Repressor protein activated by substrate	Repressor protein repressed by substrate

QUESTION 17

In 1979, six groups of investigators independently reported the discovery of a p53 protein (encoded by *TP53* gene) that was present in human and mouse cells. One of the groups discovered that the p53 protein level was highly expressed in several types of mouse tumour cells. In 1980s, another research group discovered the association of high p53 protein level with human intestinal tumour cells but not normal cells.

What conclusion did the scientists arrive at based on the information above?

A. *TP53* is a tumour suppressor gene

B. *TP53* is a proto-oncogene

C. p53 is a transcription factor

D. *TP53* is not expressed in normal cells

QUESTION 18

Which statement concerning polypeptide synthesis is correct?

A. A particular cell type will transcribe all the genes present in one set of chromosomes but will only process particular pre-mRNA transcripts to enable polypeptide synthesis.

B. Different cell types contain different sets of genes to produce different pre-mRNA transcripts and synthesise different polypeptides.

C. The same pre-mRNA transcripts are synthesised by all cell types but different introns are removed from the transcripts before translation to synthesise polypeptides.

D. Different polypeptides can be synthesized from the same pre-mRNA in different cell types.

QUESTION 19

Gene expression in eukaryotes can be regulated at the translational level.

Which combination of statements correctly describes eukaryotic translational control?

	Condition	**Effect**
A.	Lack of translation initiation factor proteins	Inhibition of translation of selected mRNA
B.	Presence of repressor proteins binding to 5'-UTR of selected mRNA	Prevents small ribosomal subunit from binding
C.	Presence of repressor proteins to distal control elements	mRNA is translationally-repressed
D.	mRNA with a long poly-A tail	mRNA is degraded slowly by restriction endonuclease

QUESTION 20

In fruit flies, one gene controls wing form (normal or vestigial) and one gene controls eye colour (red or normal brown).

A fly with normal wings and normal brown eyes is crossed with a fly with vestigial wings and red eyes. All the F_1 are normal for both characteristics.

However, when F_1 are crossed with each other, the resulting F_2 is:

45 normal wing, normal brown eye
17 normal wing, red eye
16 vestigial wing, normal brown eye
5 vestigial wing, red eye
1 normal wing, orange eye

What is the best explanation for the results of this dihybrid cross?

A. Codominance

B. Gene mutation

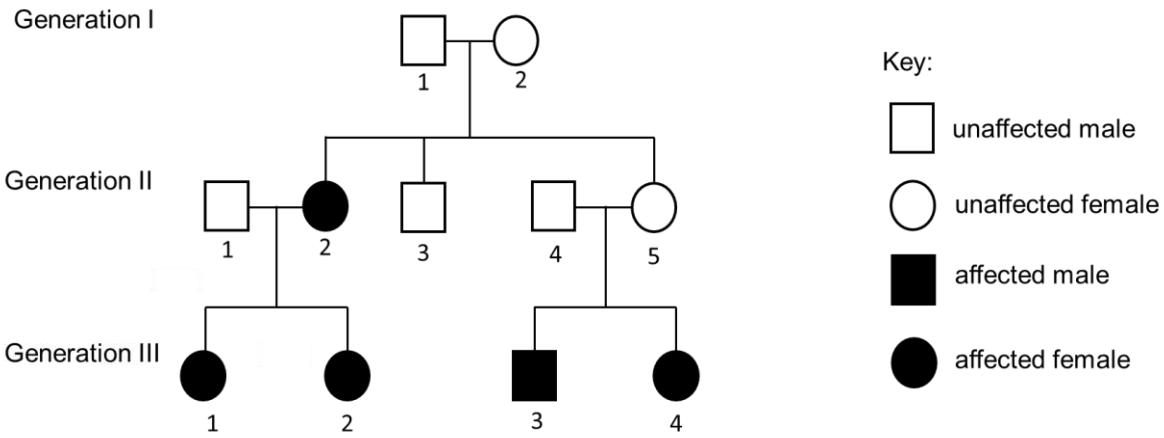
C. Multiple alleles

D. Sex linkage

QUESTION 21

Multiple Sclerosis (MS) is a neurodegenerative disease in which the immune system attacks the myelin that protects nerve fiber, upsetting the flow of information between the brain and the body.

The pedigree chart below shows the pattern of MS inheritance in a family.



Which of the following states the inheritance pattern of MS?

A. Sex-linked dominant

B. Sex-linked recessive

C. Autosomal dominant

D. Autosomal recessive

QUESTION 22

Two parents have a son who has blood group **O** and haemophilia. One parent has blood group **O** and the other has blood group **B**. Neither parent has haemophilia.

What is the probability that the second child of these parents is a son with blood group **B** who does not have haemophilia?

A. 1 in 4 **B.** 1 in 8 **C.** 2 in 4 **D.** 3 in 8

QUESTION 23

Feathers in poultry can be white or coloured and this is controlled by two genes, **P/p** and **Q/q**. The phenotypes of offspring that are expected from mating two birds, each of which is heterozygous at both loci, are shown in the Punnett square.

gametes	**PQ**	**Pq**	**pQ**	**pq**
PQ	white feathers	white feathers	white feathers	white feathers
Pq	white feathers	white feathers	white feathers	white feathers
pQ	white feathers	white feathers	coloured feathers	coloured feathers
pq	white feathers	white feathers	coloured feathers	white feathers

Which of the following best explains the proportion of white to coloured feathers in the Punnett square?

A. Dominant epistasis in which a suppressor prevents the expression of epistatic gene.

B. Dominant epistasis in which the epistatic allele is **P**.

C. Recessive epistasis in which colour is recessive to no colour at one allelic pair.

D. Recessive epistasis in which the epistatic allele is **p**.

QUESTION 24

Coat colour in rabbits is controlled by a gene with four alleles. The order of dominance for these alleles is as follows:

agouti (**C**) > chinchilla ($\mathbf{C^c}$) > himalayan ($\mathbf{C^h}$) > albino (**c**)

What is the maximum number of different coat colours obtained from a cross between an agouti rabbit and a Himalayan rabbit?

A. 1 **B.** 2 **C.** 3 **D.** 4

QUESTION 25

Which of the following statements is true?

A. Continuous variation shows a normal distribution and is only influenced by genetic factors.

B. Continuous variation is controlled by many genes and the traits are usually well defined with no gradation.

C. Discontinuous variation shows traits that follow discrete distribution and is mostly influenced by environmental factors.

D. Discontinuous variation shows traits that are controlled by one or two genes and is relatively unaffected by environmental factors.

QUESTION 26

Scorpions have a pair of grasping claws at the front of their bodies and a tail with a stinger. The stinger is used to inject venom into their prey to cause paralysis and convulsion.

Scorpion venom contains two active components:

- a toxin that affects ion channels at synapse of the nervous system of their prey
- an inhibitor of an enzyme found at these synapses

Which of the following statements **incorrectly** explain how the scorpion venom may stop the functioning of the synapse?

1. The toxin prevents the opening of the voltage-gated Na^+ channel at the presynaptic membrane while the inhibitor will cause the opening of the ligand-gated Na^+ channel.

2. Toxin will stop the release of the neurotransmitter into synaptic cleft and inhibitor will stop the recycling of neurotransmitter.

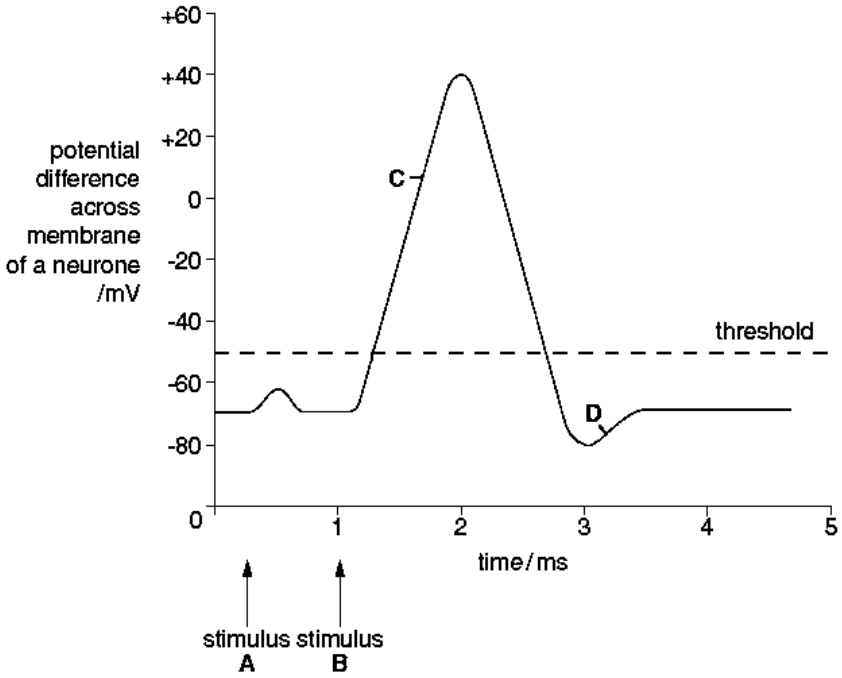
3. Toxin will prevent the entry of Na^+ ions into the postsynaptic knob and inhibitor will allow continuous depolarisation of postsynaptic membrane.

4. Both the toxin and inhibitor do not result in depolarisation of postsynaptic membrane.

A. 1 and 2 **B.** 2 and 3 **C.** 1 and 4 **D.** 3 and 4

QUESTION 27

The diagram shows an action potential.



1. Stimulus **B** is a stronger stimulus than stimulus **A** and will open more voltage-gated Na^+ channels to overcome the threshold potential.
2. At point **C**, the axon membrane is most permeable to sodium ions.
3. At point **D**, sodium conductance changes more slowly than potassium conductance.
4. A strong intensity stimulus can initiate a second action potential at point **D**.

How many of the above statement(s) is/are correct?

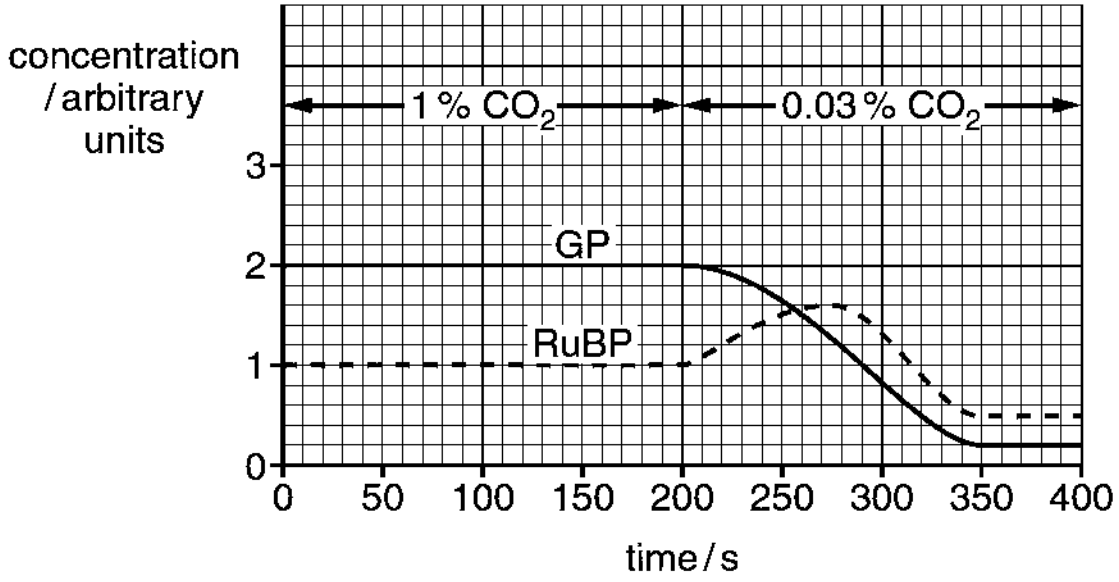
A. 1 **B.** 2 **C.** 3 **D.** 4

QUESTION 28

In an experiment, carbon dioxide concentration was altered to investigate its effects on the light-independent stage of photosynthesis.

- A cell suspension of *Chlorella* was illuminated using a bench lamp.
- The suspension was supplied with carbon dioxide at a concentration at 1% for 200 seconds.
- The concentration of carbon dioxide was then reduced to 0.03% for a further 200 seconds.
- The concentrations of RuBP (ribulose bisphosphate) and GP (glycerate-3-phosphate) were measured at regular intervals.
- Throughout the investigation the temperature of the suspension was maintained at 25°C.

The results are shown below.



Which of the following statements is/are correct?

1. At 0.03% of CO_2, concentration of GP decreases due to the decrease in the rate of carbon fixation.

2. The concentration of RuBP increases between 210s and 250s due to more CO_2 fixation and more RuBP regenerated from triose phosphate.

3. There is an accumulation of triose phosphate between 250s to 290s.

4. There is an accumulation of RuBP in the chloroplast between 210s and 250s.

A. 1 and 4 **B.** 1 only **C.** 2 only **D.** 3 and 4

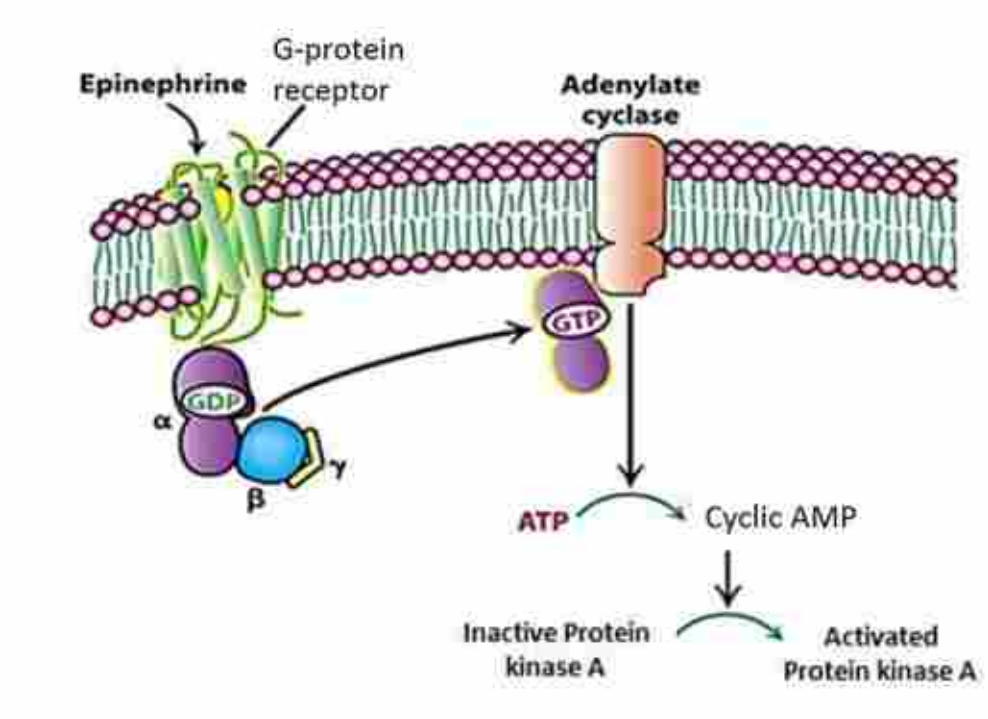
QUESTION 29
Both glucose and appropriate enzymes are necessary for the process of glycolysis to begin.

Which additional compound must also be present?

A. acetyl coenzyme A
B. ATP
C. pyruvate
D. reduced NAD

QUESTION 30
The G protein-coupled receptor is activated by the binding of epinephrine to the receptor.

A mutation leads to constitutive signal transduction.



Which of the following explanations of the mutation are **incorrect**?

1. adenylate cyclase cannot bind to activated GTP
2. conformation change in G-protein receptor causes epinephrine to bind tightly
3. GTPase in G protein cannot hydrolyse GTP to GDP
4. conformation change in adenylate cyclase prevents the conversion of ATP to cyclic AMP

A. 1 and 3 **B.** 3 and 4 **C.** 1 and 4 **D.** 2 and 3

Question 31

Lucilia cuprina, the sheep blowfly, lays its eggs in wounds and the wet fleece of sheep. The larvae hatch and burrow into the sheep's skin, reduced wool production and sometimes cause death. Particular chemicals were used in the past to control the *L. cuprina* but these became less effective as sheep blowfly developed a resistance to the chemicals.

The cause of the increased resistance to the chemicals was most likely due to

A. farmers successively reducing the levels of insecticide applied to sheep.

B. the insecticide producing a change in a gene which enhanced the survival of the blowfly.

C. a chance mutation in a blowfly gene conferring a survival advantage in the chemical environment.

D. the insecticide producing a change in phenotype which enhanced reproduction of the blowfly.

Question 32

Which of the following options is correct?

	Factors that are important for a species to evolve by natural selection	**Evidence for evolution**
A.	Environmental change and inbreeding	Homologous structures and selective breeding of domesticated animals
B.	Environmental change and variation	Homologous structures and overproduction of offspring
C.	Variation and inbreeding	Homologous structures and overproduction of offspring
D.	Environmental change and variation	Homologous structures and selective breeding of domesticated animals

QUESTION 33

The following statements relate to molecular phylogenetics.

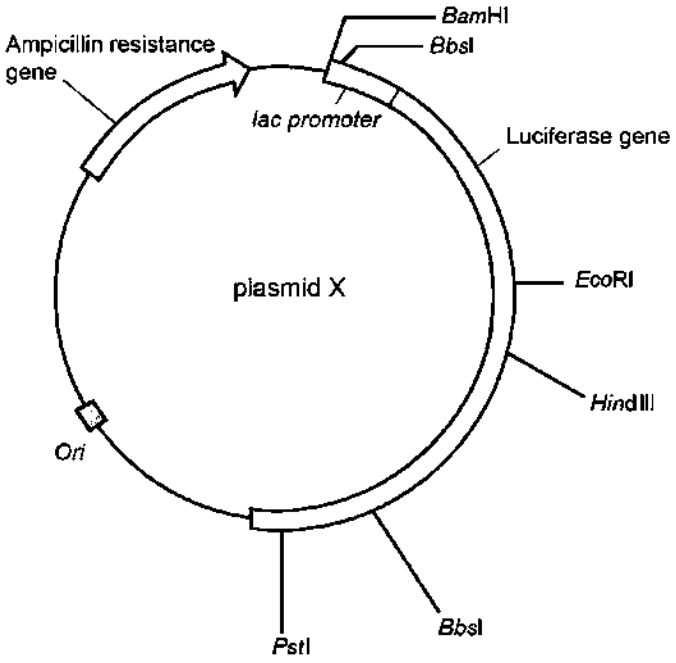
1. Lines of descent from a common ancestor to present-day organisms have undergone fixed rates of accumulation of DNA mutation in any given gene.
2. Organisms with similar base sequences in their DNA are closely related to each other.
3. The number of differences in the base sequences of DNA of different organisms can be used to construct evolutionary trees.
4. Fossil records provide evidence for established periods of evolutionary divergence.

Which statements, when taken together, suggest the existence of a 'molecular clock' that enables scientists to estimate the time at which one species might have diverged from another?

A. 1 and 2 only **B.** 1 and 4 only **C.** 2 and 3 only **D.** 3 and 4 only

QUESTION 34

Plasmid **X** can serve as a vector for the insertion of genes to be cloned. Luciferase will allow the bacteria to emit light in presence of luciferin as a substrate.



How many possible restriction sites can be used for the expression of human growth hormone gene?

A. 1 **B.** 2 **C.** 3 **D.** 5

QUESTION 35

Synthesis of human insulin by genetically-modified bacteria involves the use of the enzyme reverse transcriptase.

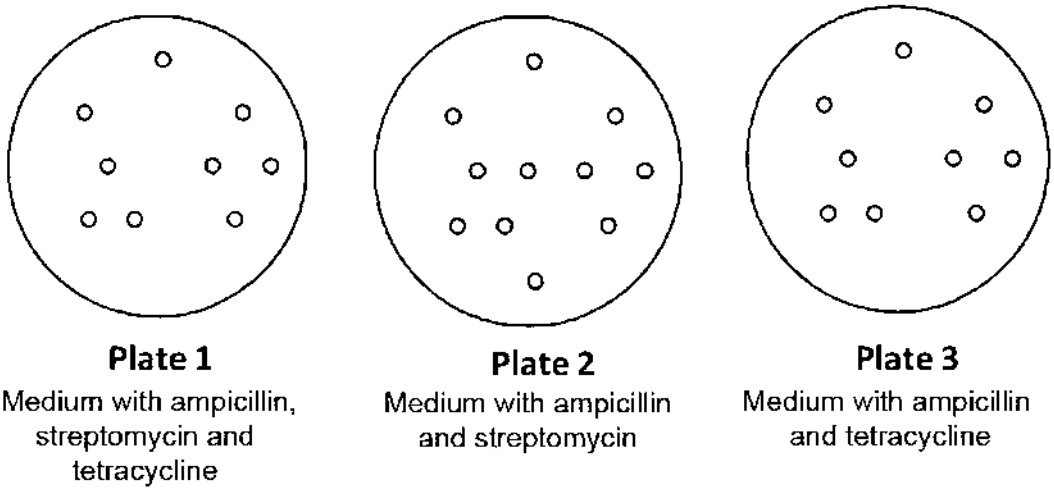
Which of the following statement(s) correctly describe(s) reverse transcriptase used in the above process?

1. It causes complementary DNA to be formed from mRNA
2. It causes single-stranded DNA to be converted to double-stranded DNA
3. It is found in prokaryotic cells
4. It is found in eukaryotic cells

A. 1 only **B.** 1 and 3 **C.** 2 and 4 **D.** 1 and 4

QUESTION 36

A gene coding for the production of a human gene product was inserted into a plasmid with genes coding for resistance to antibiotics ampicillin, streptomycin and tetracycline. The plasmids were used to transform *E. coli* and the bacteria were grown on a nutrient medium with various antibiotics using replica plating. The resulting plates are shown in the diagram.



Which antibiotic gene(s) contain(s) the restriction site that was used for the insertion of the human gene?

A. Ampicillin

B. Streptomycin

C. Tetracycline

D. Ampicillin and tetracycline

QUESTION 37
Which of the following statements about PCR are **false**?

1. The PCR cycle involves denaturation of the template, annealing of the RNA primers and polymerization of nucleotides.
2. PCR uses thermostable DNA-dependent DNA polymerases.
3. Magnesium ion ensures the stability of the thermostable DNA polymerases in PCR as it functions as a cofactor for the thermostable DNA polymerases in PCR.
4. Shorter duration of denaturation temperature at 95^{o}C is required if the DNA template has high guanine and cytosine content.

A. 1 and 3 **B.** 1 and 4 **C.** 2 and 3 **D.** 3 and 4

QUESTION 38
Which of the following is true of a genomic library?

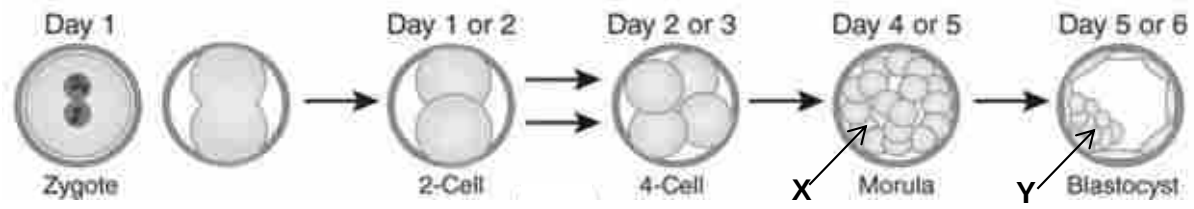
A. It is a collection of the different RFLPs of organisms within a population.

B. It is a collection of DNA fragments that make up the entire genome of a particular organism.

C. It is a collection of DNA fragments created by reverse transcriptase which are then inserted into vectors.

D. It is a collection of all genes of an organism's genome which have been sequenced.

QUESTION 39
The figure below shows several stages in the development of an embryo.



Which of the following statements is true about the cells labelled **X** and **Y**?

A. **X** is a pluripotent cell while **Y** is a multipotent cell.
B. **X** is a pluripotent cell while **Y** can give rise to multipotent cells.
C. **Y** will develop into the entire foetus including its placenta.
D. **X** can only give rise to totipotent cells but **Y** will give rise to pluripotent cells.

QUESTION 40

What are the possible arguments against the use of genetically modified organisms (GMOs)?

1. Insufficient testing of genetically modified crop for their side effects
2. Unforeseen long-term effects of genetic manipulation
3. Accidental genetic recombination in bacteria present in the lower intestines of humans as a result of consuming food derived from GMOs
4. Control of food supply by a small number of companies that have access to genetic engineering technology

A. 1 and 2 **B.** 2 and 3 **C.** 1, 2 and 3 **D.** 1, 2, 3 and 4

END OF PAPER 1

MERIDIAN JUNIOR COLLEGE
Preliminary Exam 2016
JC2 H2 (9648) BIOLOGY

ANSWERS

Multiple-Choice Question (40 marks)

Question	Answer	Question	Answer
1	**D**	21	**D**
2	**B**	22	**B**
3	**A**	23	**B**
4	**A**	24	**C**
5	**C**	25	**D**
6	**A**	26	**C**
7	**D**	27	**C**
8	**C**	28	**A**
9	**C**	29	**B**
10	**B**	30	**C**
11	**B**	31	**C**
12	**A**	32	**D**
13	**A**	33	**B**
14	**D**	34	**C**
15	**B**	35	**A**
16	**A**	36	**C**
17	**B**	37	**B**
18	**D**	38	**B**
19	**B**	39	**B**
20	**B**	40	**D**

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations 2016
Higher 2

CANDIDATE NAME

CIVICS GROUP

INDEX NUMBER

H2 BIOLOGY

9648/02

Paper 2 Core Paper

16 September 2016
2 hours

Additional Materials: Answer papers

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.
Write your name, civics group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

Section A
Answer **all** questions in the spaces provided on the question paper.

Section B
Answer **one** question on the answer paper provided.

At the end of the examination,
1. Fasten your answer papers to section B securely together.
2. Hand in the following separately:
   - Section A (Part I)
   - Section A (Part II)
   - Section B

The number of marks is given in brackets [ ] at the end of each question or part question.

For examiner's Use	
Section A	
1	/ 10
2	/ 9
3	/ 10
4	/11
5	/ 11
6	/ 9
7	/ 11
8	/ 9
Section B	
9 / 10	/ 20

This paper consists of **20** printed pages.

[Turn over]

Section A (Part I)

Answer **all** the questions in this section.

For Examiner's Use

QUESTION 1

The structure of the tubulin dimer, the protein that forms microtubules by polymerisation, is shown in **Fig. 1.1**.

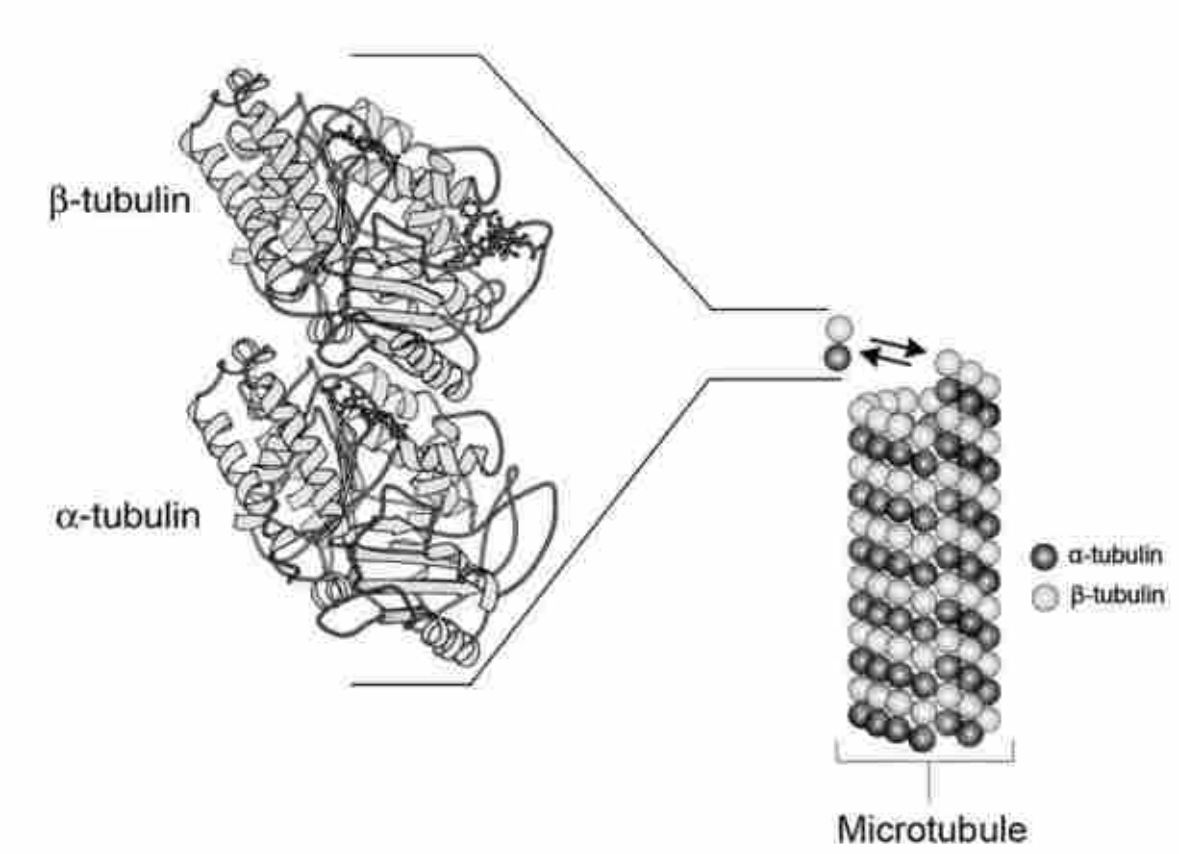


Fig. 1.1

(a) With reference to **Fig. 1.1**, name the secondary structures present in tubulin. [1]

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Tubulin inhibitors like paclitaxel and vinblastine have been utilised in chemotherapy drug trials to treat cancers. All tubulin inhibitors are known to bind to the β-tubulin subunit.

(b) Explain how tubulin inhibitors reduce tumour formation. [3]

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A trial was conducted to compare the effects of vinblastine and paclitaxel on the SKOV3 ovarian cancer cell line and the PC3 prostate cancer cell line.

For Examiner's Use

Table 1.1 below shows the results of the trial. The researcher measured the number of months in which the mass of tumours increased to critical mass after treatment with vinblastine and paclitaxel.

	No. of months in which the mass of tumours increased to critical mass	
	SKOV3	PC3
Untreated	0.5	1.0
Vinblastine	5.7	10.0
Paclitaxel	10.1	9.1

Table 1.1

(c) With reference to **Table 1.1**, compare the effects of vinblastine and paclitaxel on tumour growth in the two cancer cell lines. [4]

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(d) Suggest and explain why different tumour cells may exhibit different levels of resistance to the same drug. [2]

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[Total: 10]

QUESTION 2

Fig. 2.1 shows the process of translation.

For Examiner's Use

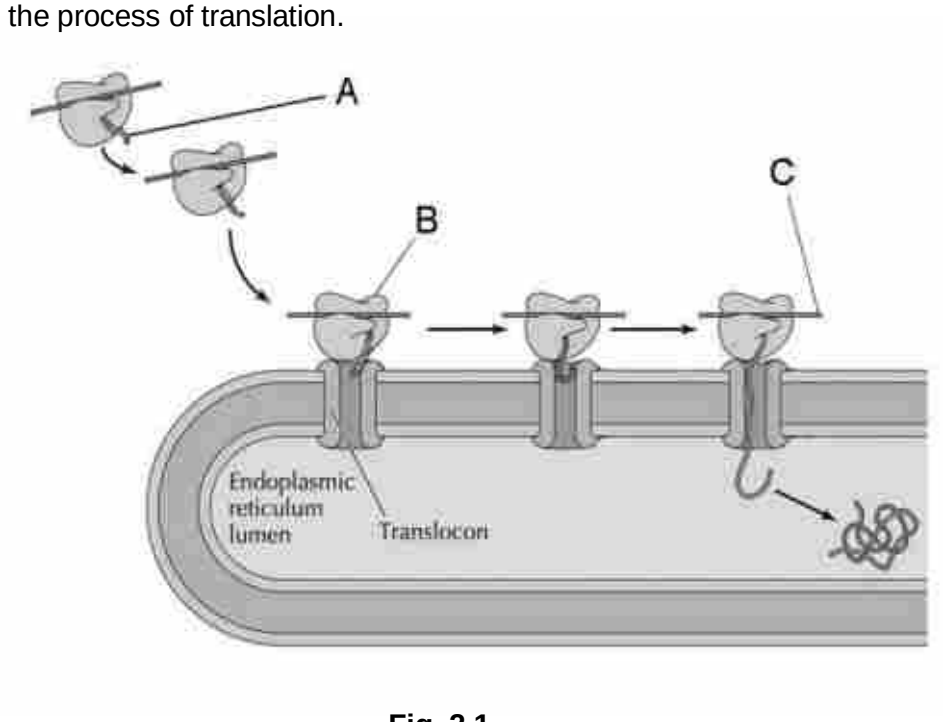

Fig. 2.1

(a) (i) Label structures **A**, **B** and **C**. [3]

A ……..

B……..

C ……..

(ii) Suggest the role of the translocon in protein synthesis. [1]

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(b) List two ways in which transcription differs from DNA replication. [2]

1. ……..

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2. ……..

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(c) Explain how complementary base pairing facilitates the storage and transmission of genetic information. [3]

For Examiner's Use

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[Total: 9]

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QUESTION 3

For Examiner's Use

The measles virus (MV) is a spherical, non-segmented, single-stranded negative sense RNA virus. The structure of MV is shown in **Fig. 3.1.**

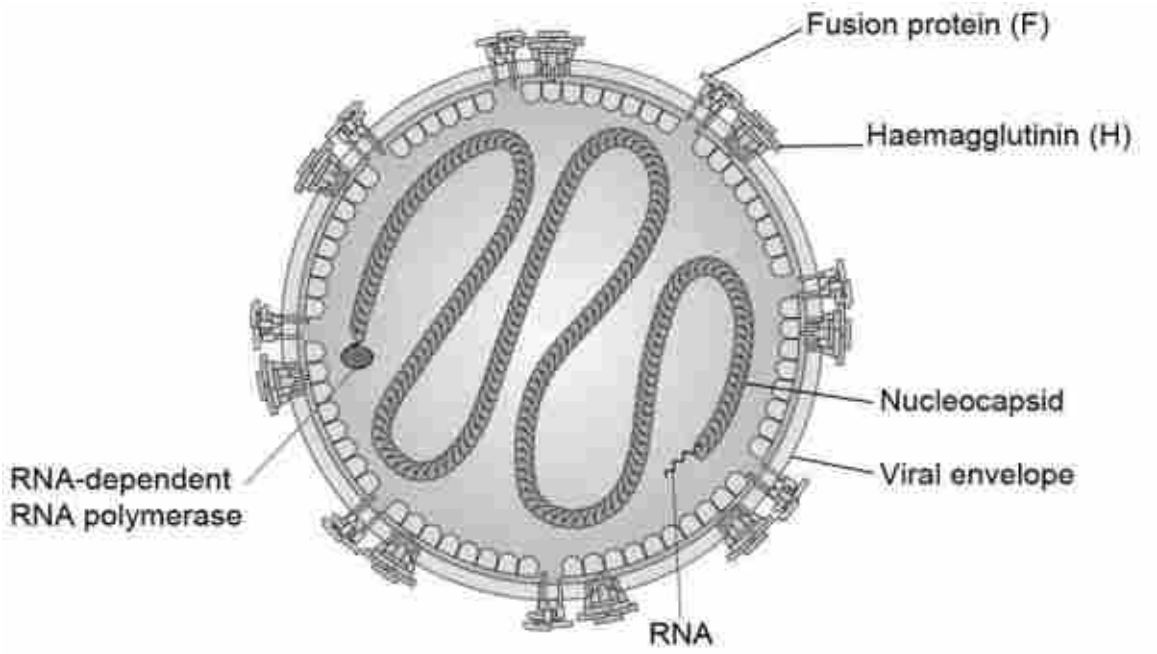

Fig. 3.1

(a) With reference to **Fig. 3.1**, describe two structural differences between MV and HIV. [2]

1. ……..

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2. ……..

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MV only infects cells that have a membrane glycoprotein known as signaling lymphocyte activation molecule (SLAM). When MV infects a cell, **H** acts before **F**. After the virus binds to the host cell, only the nucleoprotein with the viral polymerase enters the host cell and the virus is replicated.

(b) With reference to **Fig. 3.1** and the information provided, suggest how MV infects a cell with SLAM glycoproteins. [3]

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Both MV and HIV infect cells of the immune system. Upon infection, MV causes highly contagious measles which is an airborne disease spreads through the coughs and sneezes of those infected.

For Examiner's Use

(c) (i) Explain how HIV infection causes diseases. [4]

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(ii) Suggest why MV is transmitted at a faster rate as compared to HIV. [1]

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[Total: 10]

QUESTION 4

For Examiner's Use

(a) Telomerase is a ribonucleoprotein which comprises telomerase reverse transcriptase (TERT) protein and telomerase RNA.

Outline how telomerase is formed. [4]

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During human embryonic development, telomerase activity is activated in embryonic stem cells to enable high proliferation rate of the cell. However, the telomerase activity is usually diminished after birth and the level of telomerase activity is absent in most of the somatic cells.

Fig. 4.1 shows the *TERT* promoter in the two types of cells.

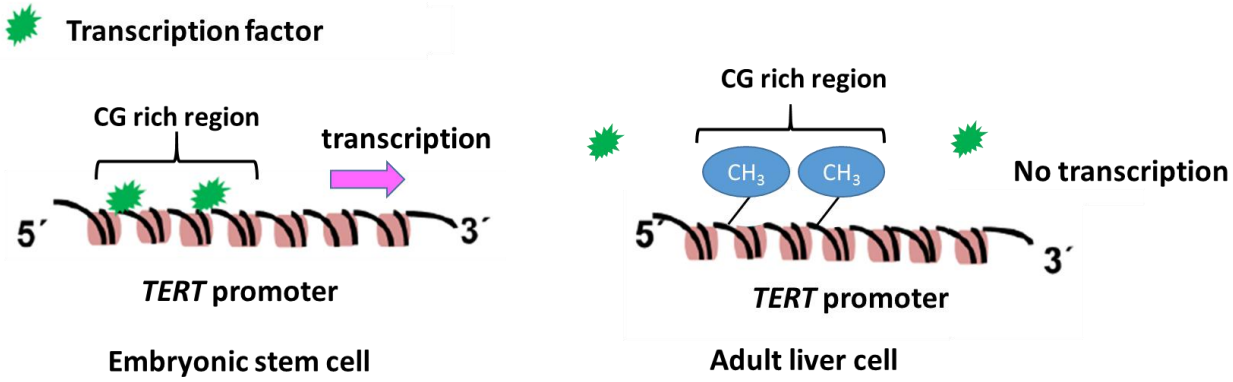

Fig. 4.1

(b) With reference to **Fig. 4.1** and your knowledge, explain why telomerase activity is absent in adult liver cells. [3]

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(c) The process occurring in adult liver cells shown in **Fig. 4.1** also occurs in prokaryotic cells.

State how the outcome of the process in prokaryotes differs from that in adult liver cells. [1]

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For Examiner's Use

(d) Outline the roles of telomeres in eukaryotic cells. [3]

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[Total: 11]

QUESTION 5

For Examiner's Use

To study the inheritance of coat colour and eye colour in deer-mice, scientists performed two crosses and the table below shows the phenotypes of the F_1 generations from these two crosses.

Cross	Parents (pure bred)	F_1 phenotype	Number of F_1 progeny
1	Black eye, coloured female X Pink eye, albino male	All black eye, coloured mice	77
2	Black eye, coloured male X Pink eye, albino female	All black eye, coloured mice	68

The F_1 generation were then interbred and the following F_2 offspring were produced:

Black eye, coloured	295
Black eye, albino	42
Pink eye, coloured	46
Pink eye, albino	33

(a) Explain the purpose of carrying out crosses 1 and 2. [2]

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(b) Using suitable symbols, draw a genetic diagram to explain the results of F_1 cross. [5]

For Examiner's Use

(c) State the expected ratio of the F_2 phenotypes if Mendelian law applies to the two gene loci. [1]

For Examiner's Use

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The chi-squared (χ^2) test was performed on these results, giving a calculated value for χ^2 of 47.527.

The χ^2 distribution table and equation to calculate χ^2 is shown below.

number of degrees of freedom (v)	probability
	0.05
1	3.84
2	5.99
3	7.82
4	9.49

(d) Using the calculated value of χ^2 and the table of probabilities provided in the table above, explain the conclusions drawn from the (χ^2) test. [3]

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[Total: 11]

Candidate Name	Civics Group	Index No.

For Examiner's Use

Meridian Junior College
JC2 Preliminary Examinations 2016
H2 Biology (9648/02)

Question 6	Question 7	Question 8
/ 9	/ 11	/ 9

Section A (Part II)
Answer **all** the questions in this section.

QUESTION 6
Two groups of white mustard plants, *Sinapis alba*, were grown, one group under high illumination, the other under low illumination. When fully grown, the effect of increasing light intensity on the rate of photosynthesis in the two groups of plants was measured.

Fig. 6.1 shows the results.

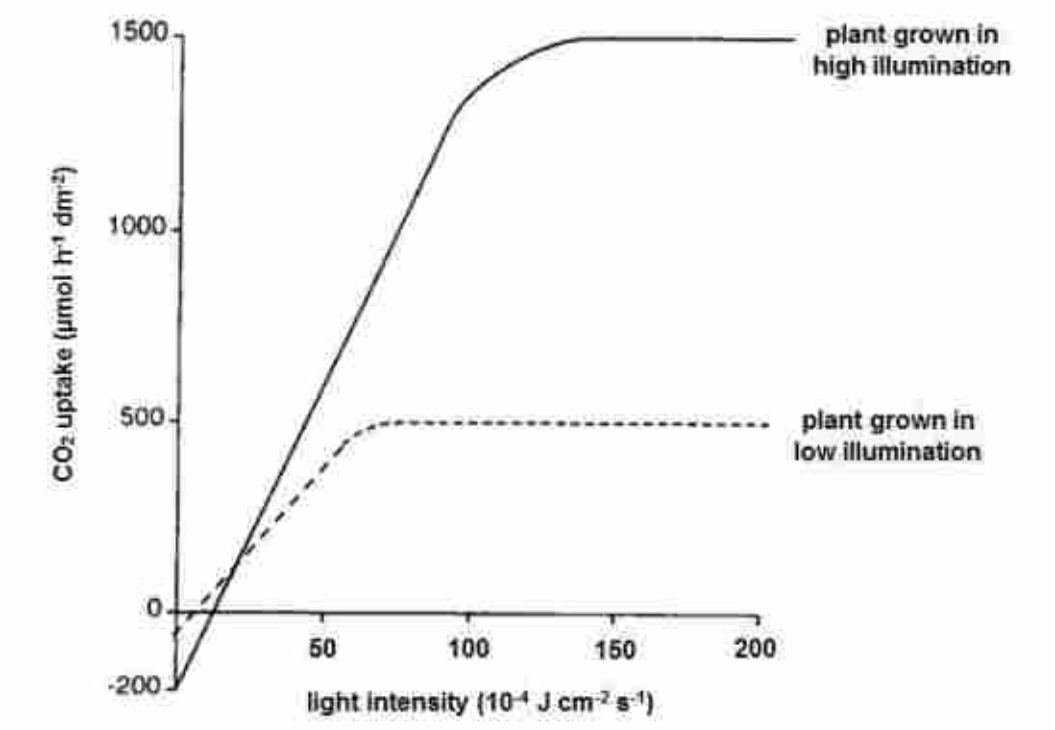

Fig. 6.1

(a) With reference to **Fig. 6.1**,

(i) state and explain the effect of light intensities above 150 x 10^{-4} $Jcm^{-2}s^{-1}$ on the rate of photosynthesis in plants grown in high illumination. [2]

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(ii) state with evidence, **two** ways in which the carbon dioxide uptake of both plants differ at light intensities below 50 x 10^{-4} $Jcm^{-2}s^{-1}$. [4]

For Examiner's Use

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(b) Outline the fate of each product of photolysis in the light dependent reaction. [3]

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[Total: 9]

QUESTION 7

For Examiner's Use

Fig. 7.1 is an electron micrograph of a section through a myelinated neurone showing the Schwann cell and axon membrane.

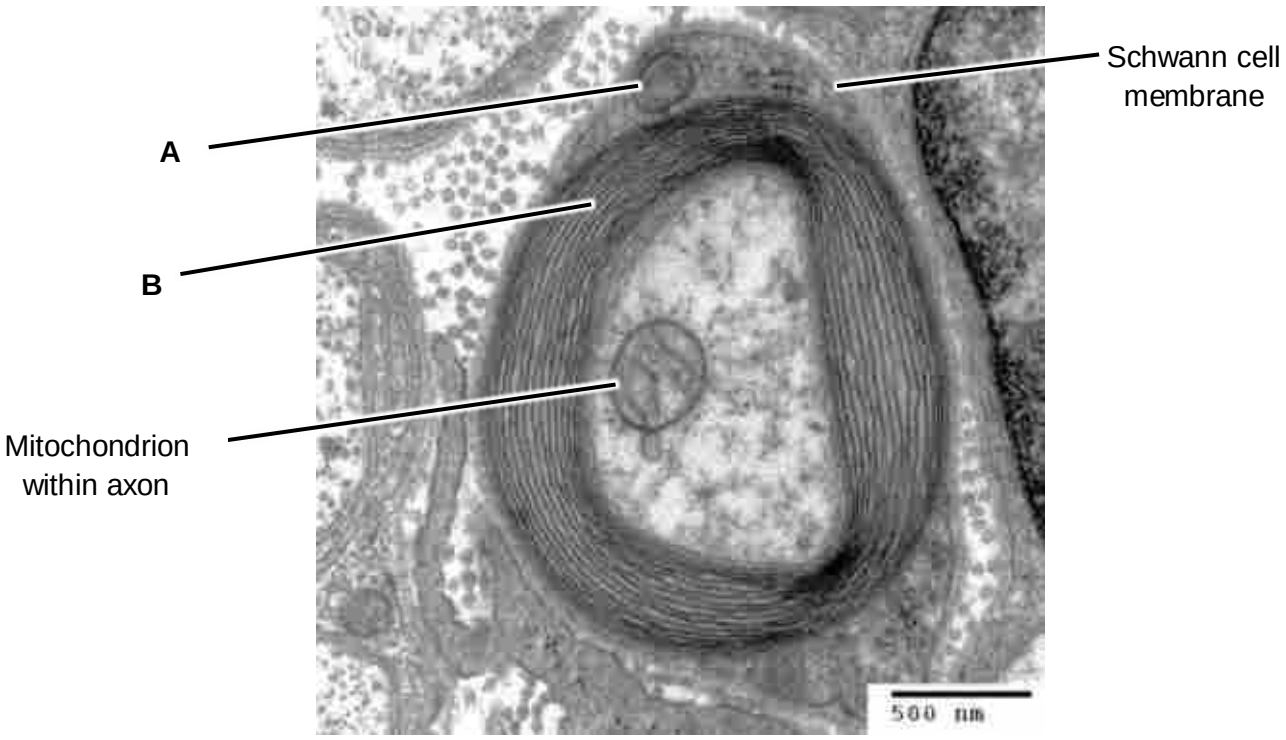

Fig. 7.1

(a) Identify the structures labelled **A** and **B**. [2]

A ……

B ……

(b) **Fig. 7.2** shows the percentage of energy used for various processes involved in the maintenance of resting potentials and in the reception and transmission of action potentials by a neuron.

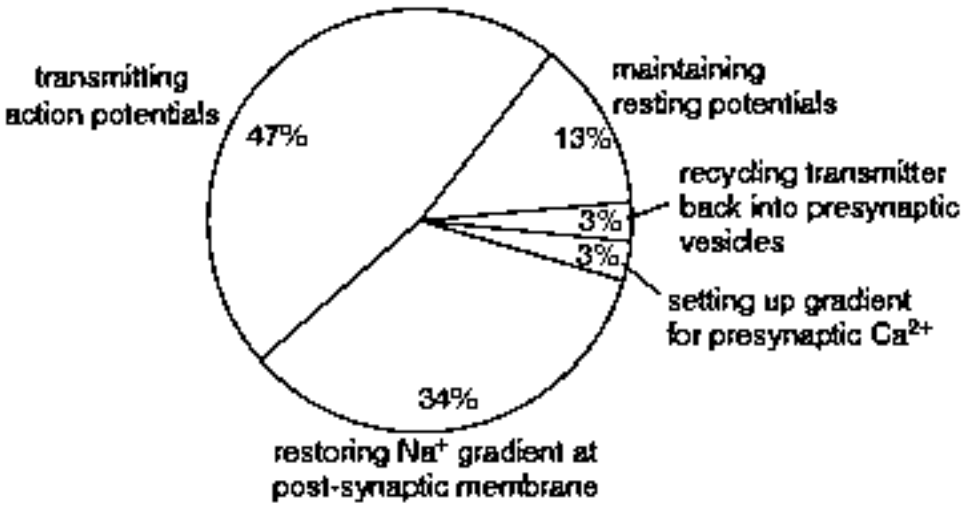

Fig. 7.2

(i) Explain why maintaining a resting potential requires energy. [2]

For Examiner's Use

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(ii) Neurons contain large numbers of mitochondria. There are more mitochondria in each dendrite than in the axon.

With reference to **Fig. 7.2**, suggest reasons for the distribution of mitochondria. [3]

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(c) Describe the role of Ca^{2+} in the passage of impulses across a synapse. [2]

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(d) Synapses slow down the rate of transmission of nerve impulses but serve other important roles in the nervous system.

Outline two roles of synapses in the nervous system. [2]

1. ……

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2. ……

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[Total: 11]

QUESTION 8

For Examiner's Use

Mole rats, *Spalax ehrenbergi,* are mammals that live in groups in underground burrows. They are blind, and communicate with each other through sound and scent. Males make a purring call when they attempt to persuade females to mate with them.

In Israel, the mole rats found in different parts of the country all look identical. However, there are actually four different populations with different chromosome numbers, which live in different climatic regions.

Table 8.1 shows the four populations of mole rats and information about the purring calls used by the males in each population. The call of the males were analysed by measuring the number of sound pulses per second, and also the frequencies of the sounds that they made.

Chromosome number of population		52	54	58	60
Climatic region in which population lives		Cool and humid	Cool and dry	Warm and humid	Warm and dry
Purring call made by males	Mean number of pulses per second	21.0	25.3	23.9	23.2
	Mean major frequency/ kHz	595	555	583	562

Table 8.1

Researchers investigated how female mole rats from each of the four populations responded to purring calls made by males from the same population, and by males from different populations.

A female was placed midway between two loudspeakers, and recorded calls from two males were played to her simultaneously. The researchers noted which loudspeaker the female moved towards. This was repeated with many different females from each population.

The results are shown in **Table 8.2.**

Population chromosome number	Percentage of females preferring the purring call of males from their own population
52	79
54	77
58	78
60	44

Table 8.2

(a) With reference to **Table 8.2**, describe the extent to which female mole rats show a preference for the purring calls of males from their own population. [2]

For Examiner's Use

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(b) With reference to the data in both **Table 8.1** and **Table 8.2**, discuss whether these four populations of mole rats should be classified as different species. [4]

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The phylogenetic relationship of seven genera of mole rats was investigated using nucleotide sequences of the *12S rRNA* gene obtained from mitochondrial DNA.

Fig. 8.1 shows a phylogenetic tree of the mole rats based on this *rRNA* gene nucleotide sequence data.

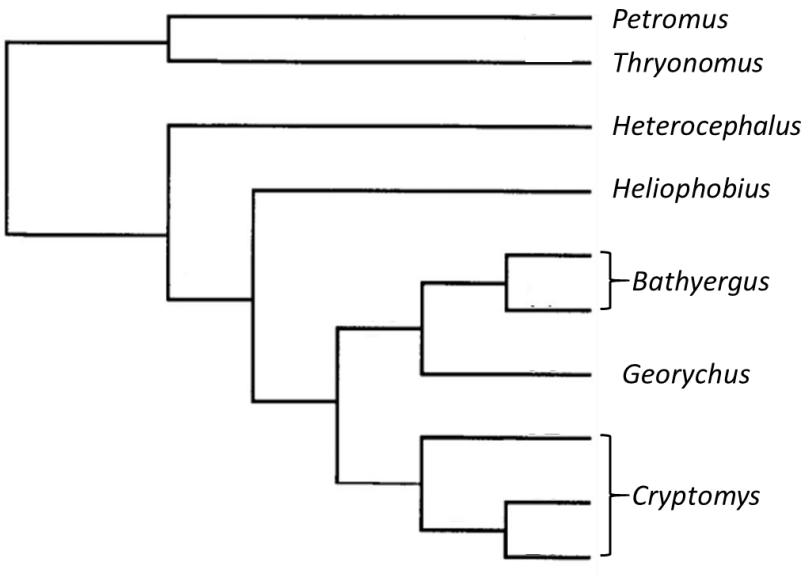

Fig. 8.1

(c) Describe the advantages of using nucleotide data such as the *12S rRNA* gene in classifying the mole rats. [3]

For Examiner's Use

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[Total: 9]

For Examiner's Use

Section B

Answer **one** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labeled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be in set out in questions **(a)**, **(b)**, etc., as indicated in the question.

QUESTION 9

(a) Describe the role of vesicles in a cell. [6]

(b) Describe one causative factor of cancer and explain how this factor increases the chances of cancerous growth. [6]

(c) Describe the differences between the control of gene expression in prokaryotic and eukaryotic cells. [8]

[Total: 20]

QUESTION 10

(a) Describe the structure of collagen and how it is related to its function. [8]

(b) Explain why antibiotic resistance spreads so rapidly among bacteria. [6]

(c) Describe the main differences between glucagon and insulin signalling in liver cells. [6]

[Total: 20]

• END OF PAPER 2 •

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations 2016
Higher 2

CANDIDATE NAME

CIVICS GROUP

INDEX NUMBER

H2 BIOLOGY

9648/02

Paper 2 Core Paper

16 September 2016
2 hours

Additional Materials: Answer papers

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.
Write your name, civics group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

Section A
Answer **all** questions in the spaces provided on the question paper.

Section B
Answer **one** question on the answer paper provided.

At the end of the examination,
1. Fasten your answer papers to section B securely together.
2. Hand in the following separately:
   - Section A (Part I)
   - Section A (Part II)
   - Section B

The number of marks is given in brackets [ ] at the end of each question or part question.

For examiner's Use	
Section A	
1	/ 10
2	/ 9
3	/ 10
4	/11
5	/ 11
6	/ 9
7	/ 11
8	/ 9
Section B	
9 / 10	/ 20

ANSWER SCHEME

This paper consists of __ printed pages.

[Turn over]

Section A (Part I)
Answer **all** the questions in this section.

QUESTION 1
The structure of the tubulin dimer, the protein that forms microtubules by polymerisation, is shown in **Fig. 1.1**.

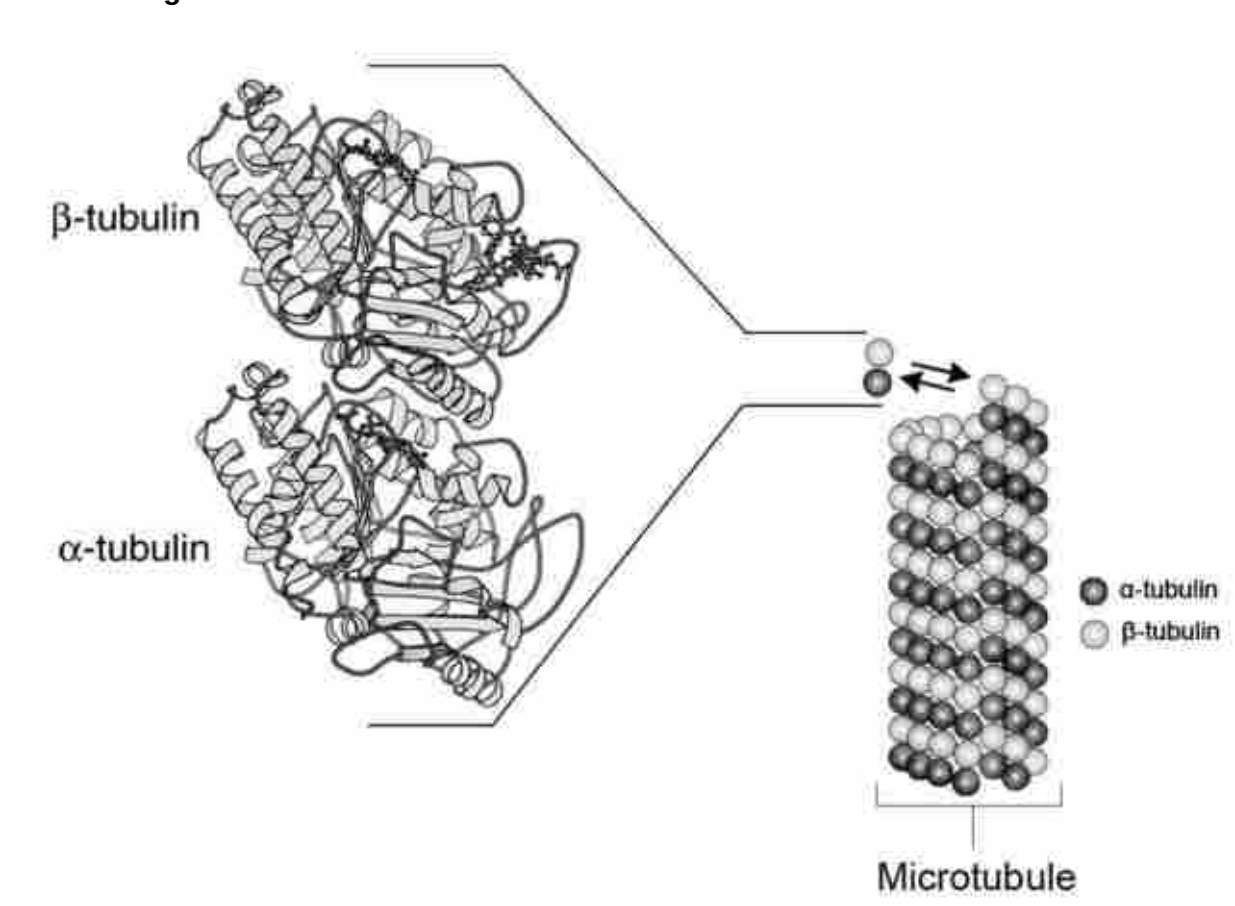


Fig. 1.1

(a) With reference to **Fig. 1.1**, name the secondary structures present in tubulin. [1]

- **α-helices and β-pleated sheets.**

Tubulin inhibitors like paclitaxel and vinblastine have been utilised in chemotherapy drug trials to treat cancers. All tubulin inhibitors are known to bind to the β-tubulin subunit.

(b) Explain how tubulin inhibitors reduce tumour formation. [3]

- Tubulin inhibitors **interfere / prevent polymerisation** of tubulin dimers to form microtubules / **spindle fibres** that make up the **mitotic spindle**.
- Without spindle fibres, **chromosomes cannot divide** / mitosis **stops at prophase** / mitosis **cannot take place**.
- Hence affected cells **exit the cell cycle / go into G_0** and **uncontrolled cell division is prevented**.

A trial was conducted to compare the effects of vinblastine and paclitaxel on the SKOV3 ovarian cancer cell line and the PC3 prostate cancer cell line.

Table 1.1 below shows the results of the trial. The researcher measured the number of months in which the mass of tumours increased to critical mass after treatment with vinblastine and paclitaxel.

	No. of months in which the mass of tumours increased to critical mass	
	SKOV3	PC3
Untreated	0.5	1.0
Vinblastine	5.7	10.0
Paclitaxel	10.1	9.1

Table 1.1

(c) With reference to **Table 1.1**, compare the effects of vinblastine and paclitaxel on tumour growth in the two cancer cell lines. [4]

Similarities (max 2):

- **Both** vinblastine and paclitaxel **reduces** / **slowed down tumour growth** in **both** the SKOV3 and PC3 cells lines. [Coupled with data citation]

- Vinblastine and paclitaxel were **equally effective** in slowing down tumour growth in **PC3** tumours.

    - Data citation: **Untreated SKOV3 tumours** grew critical mass in **0.5 months** as compared to tumour cells treated with **vinblastine** which only grew to critical mass after **5.7 months** and tumour cells treated with **paclitaxel** which only grew to critical mass after **10.1 months**.

    - Data citation: **Untreated PC3 tumours** grew to critical mass in **1.0 months** as compared to tumour cells treated with **vinblastine** which only grew to critical mass after **10.0 months** and tumour cells **treated** with **paclitaxel** which only grew to critical mass after **9.0 months**.

Differences (max 2):

- Vinblastine **slowed down tumour growth to a lesser extent / was less effective in treating the SKOV3 cell lines** as compared to paclitaxel. [Coupled with data citation]

    - SKOV3 tumour cells **treated** with **vinblastine** grew to critical mass in **5.7 months** as compared to SKOV3 cells treated with **paclitaxel** which only grew to critical mass after **10.1 months**.

(d) Suggest and explain why different tumour cells may exhibit different levels of resistance to the same drug. [2]

- Different tumour cells exhibit **variation due to random mutation** to certain genes / **differential gene expression** / **gene amplification**.
- Leading to formation of new alleles coding for / more functional proteins that serve as

    - **transporter proteins** that **pump out** drugs.
    - **Tubulin** with a non-complementary **binding site** where the drug usually binds to.
    - **enzymes** that **hydrolyses** the drug.
    - **inhibitors** that bind to the drugs and render them ineffective.
    - AVP, e.g. cell surface receptors, proteins that regulate the cell cycle, etc

[Total: 10]

QUESTION 2

Fig. 2.1 shows the process of translation.

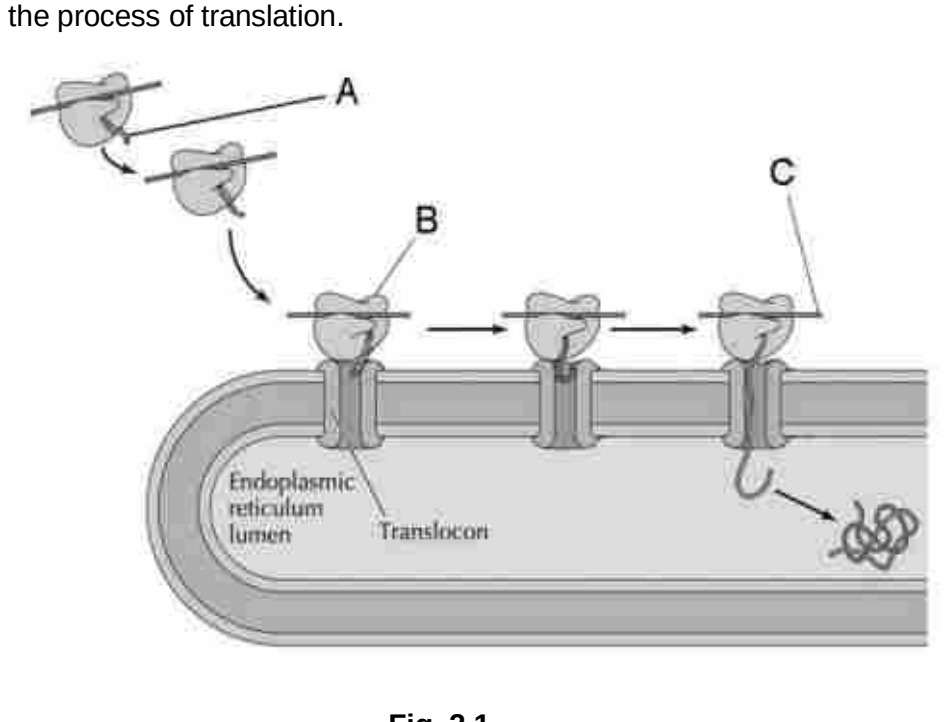


Fig. 2.1

(a) (i) Label structures **A**, **B** and **C**. [3]

- A – polypeptide chain
- B – small ribosomal subunit (accept ribosome)
- C – mRNA

(ii) Suggest the role of the translocon in protein synthesis. [1]

- The translocon serves as a **hydrophilic channel** to allow the passage of the polypeptide chain into the **lumen** of the endoplasmic reticulum.

(b) List two ways in which transcription differs from DNA replication. [2]

	DNA Replication	**Transcription**
Template	Both strands of DNA	Template strand / one of two DNA strands
Raw materials	Deoxyribonucleotides	riboxynucleotides
Final product	DNA	mRNA, rRNA, tRNA
Enzymes that catalyse the formation of the bonds between monomers	DNA Polymerase catalyses the formation of phosphodiester bonds between deoxyribonucleotides	RNA Polymerase catalyses the formation of phosphodiester bonds between ribonucleotides

(c) Explain how complementary base pairing facilitates the storage and transmission of genetic information. [3]

- [Compulsory for Storage] Complementary base pairing between bases of the two template strands / parental strands is important as it **stabilises** the **double-stranded helix structure** of DNA for storage of genetic information.

- [Transmission] Complementary base pairing enables . . .

- [Replication] the **formation of daughter strands during DNA replication** before mitosis in order to transmit genetic information to daughter cells.
- [Replication] the **proofreading function of DNA polymerase to find and repair mutations** to maintain genetic fidelity.

- [Transcription] the **formation of mRNA during transcription** in order to **transmit information** for the synthesis of **the primary sequence of polypeptides** in protein synthesis. [Mention of the type of genetic information – mark **once** in either this point or the next]

- [Translation] Complementary base pairing **between mRNA codons and tRNA anticodons during translation** transmits information for the primary sequence of polypeptides in protein synthesis.

[Total: 9]

QUESTION 3

The measles virus (MV) is a spherical, non-segmented, single-stranded negative sense RNA virus. The structure of MV is shown in **Fig. 3.1.**

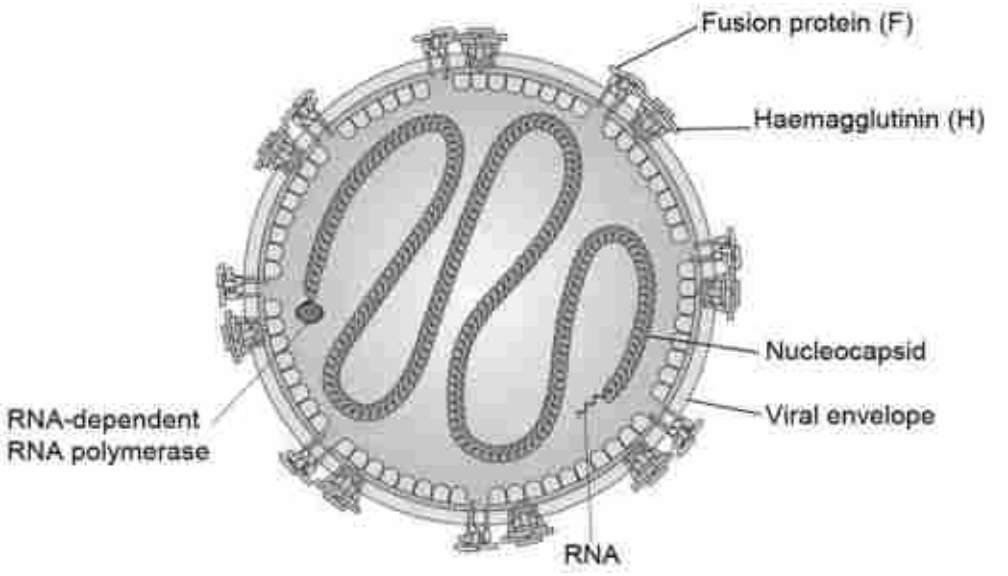


Fig. 3.1

(a) With reference to **Fig. 3.1**, describe two structural differences between MV and HIV. [2]

- **The glycoproteins** embedded in the envelope of MV consist of **Haemagglutinin/H and fusion protein/F** whereas in HIV they are **gp120 and gp41**.
- HIV contains a **capsid surrounding the nucleocapsid** whereas **MV does not.**
- HIV carries **two copies** of linear **(+) single-stranded RNA** for its genome whereas MV carries one copy of **(-) single-stranded RNA**
- HIV contains **reverse transcriptase** whereas MV contains **RNA-dependent RNA polymerase**.

MV only infects cells that have a membrane glycoprotein known as signaling lymphocyte activation molecule (SLAM). When MV infects a cell, **H** acts before **F**. After the virus binds to the host cell, only the nucleoprotein with the viral polymerase enters the host cell and the virus is replicated.

(b) With reference to **Fig. 3.1** and the information provided, suggest how MV infects a cell with SLAM glycoproteins. [3]

- **Haemagglutinin/H** is **complementary in shape to** the **binding site of SLAM receptor**
- **Fusion protein /F** causes **fusion of the viral envelope** to the **cell surface membrane**
- which **releases nucleoprotein and viral polymerase** for viral replication

Both MV and HIV infect cells of the immune system. Upon infection, MV causes highly contagious measles which is an airborne disease spreads through the coughs and sneezes of those infected.

(c) (i) Explain how HIV infection causes diseases. [4]

- *Idea that* HIV infects and kills T helper cells [all descriptions about the death of T-cells fall under this point].
- *Idea that* **B lymphocytes cannot produce antibodies** without the help of T lymphocytes.
- This **compromise the immune system**. Leading to **opportunistic infections**
- **Integration of viral DNA** into **proto-oncogene** of the host genome, which may also cause **cancer.**

(ii) Suggest why MV is transmitted at a faster rate as compared to HIV. [1]

- The mode of transmission of MV is **through aerosol/droplet** (OWTTE) hence spread more easily whereas HIV is transmitted through **transfer of body fluids (**OWTTE**).**

[Total: 10]

QUESTION 4

(a) Telomerase is a ribonucleoprotein which comprises telomerase reverse transcriptase (TERT) protein and telomerase RNA.

Outline how telomerase is formed. [4]

- **Telomerase RNA** is produced through **transcription** of the **telomerase RNA genes** in the nucleus (must differentiate between Telomerase RNA gene and TERT gene!)
- Idea that the telomerase RNA folds into a 3D structure and remain in the nucleus
- **Genes of TERT** are transcribed in nucleus to form **TERT mRNA…**
- …which is **translated** by free **ribosomes** in cytosol to form **TERT proteins**
- **TERT protein** is **transported from the cytoplasm into nucleus** via nuclear pore
- **Assembly of telomerase RNA and TERT proteins** into telomerase in the **nucleus**.

During human embryonic development, telomerase activity is activated in embryonic stem cells to enable high proliferation rate of the cell. However, the telomerase activity is usually diminished after birth and the level of telomerase activity is absent in most of the somatic cells.

Fig. 4.1 shows the *TERT* promoter in the two types of cells.

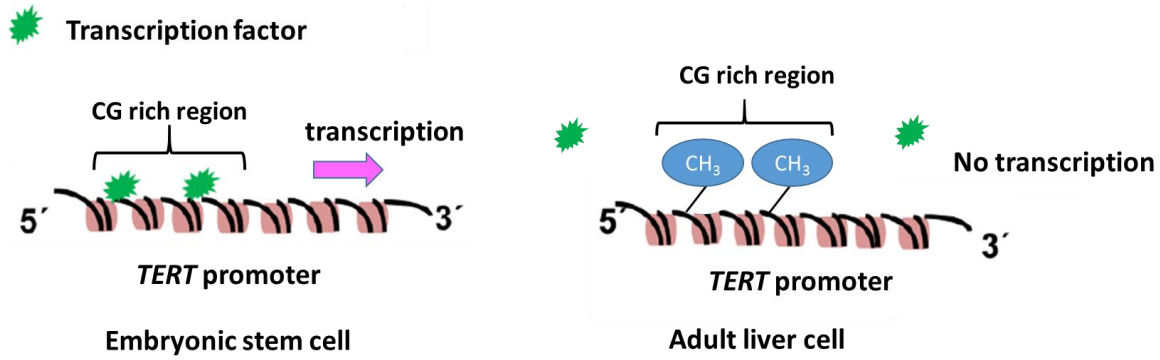


Fig. 4.1

(b) With reference to **Fig. 4.1** and your knowledge, explain why telomerase activity is absent in adult liver cells. [3]

- **DNA methylation** occur at the **CG rich region** of the TERT promoter
- which **recruits histone deacetylase** to **promote chromatin compaction**
- **Transcription factors** and **RNA polymerase** cannot access the **promoter** of *TERT,* hence prevent gene expression

(c) The process occurring in adult liver cells shown in **Fig. 4.1** also occurs in prokaryotic cells.

State how the outcome of the process in prokaryotes differs from that in adult liver cells. [1]

- DNA methylation in adult liver cell leads to **long-term inactivation of genes/turning genes** off whereas it **protects the bacteria DNA from being degraded by restriction enzymes.**

(d) Outline the roles of telomeres in eukaryotic cells. [3]

- **Protect the organism's genes from being lost with each round of DNA replication.**
- **Protect the chromosome by binding proteins that prevents the ends from joining to other chromosomes.**
- Telomeres and associated proteins **prevent the exposed staggered ends of DNA from activating the cell's monitoring system to cause apoptosis** of cell.
- Allow the **completion of DNA synthesis at the ends of eukaryotic chromosomes.**

[Total: 11]

QUESTION 5

To study the inheritance of coat colour and eye colour in deer-mice, scientists performed two crosses and the table below shows the phenotypes of the F_1 generations from these two crosses.

Cross	Parents (pure bred)	F_1 phenotype	Number of F_1 progeny
1	Black eye, coloured female X Pink eye, albino male	All black eye, coloured mice	77
2	Black eye, coloured male X Pink eye, albino female	All black eye, coloured mice	68

The F_1 generation were then interbred and the following F_2 offspring were produced:

Black eye, coloured	295
Black eye, albino	42
Pink eye, coloured	46
Pink eye, albino	33

(a) Explain the purpose of carrying out crosses 1 and 2. [2]

- A **reciprocal cross** **to determine whether** **the two gene loci** for coat colour and eye colour **are sex-linked.**
- **[Context required]** The **same F1 results** (all black eye, coloured mice) are observed suggesting that the two genes are **autosomal /not sex-linked.**

(b) Using suitable symbols, draw a genetic diagram to explain the results of F_1 cross. [5]

B represents the dominant allele for black eye
b represents the recessive allele for pink eye
A represents the dominant allele for coloured coat
a represents the recessive allele for albino

[1]

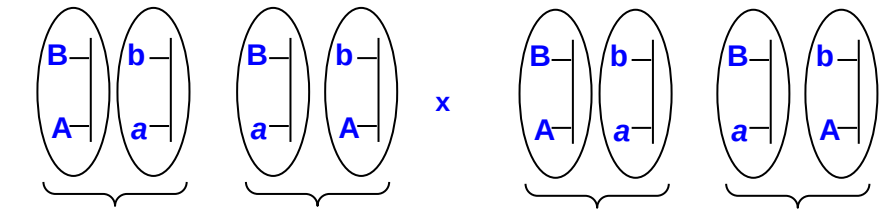
F_1 genotype (2n): $\frac{B\ \ A}{b\ \ a}$ **[1]**

F_1 phenotype: Black eye, coloured

Selfing F_1: Black eye, coloured x Black eye, coloured

F_1 genotype: B–b / A–a x B–b / A–a

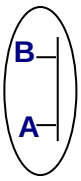
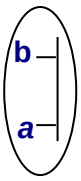
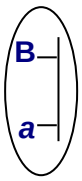
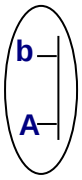
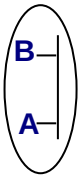
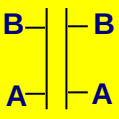
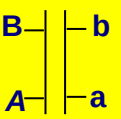
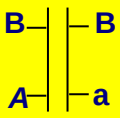
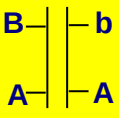
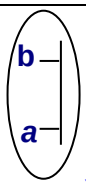
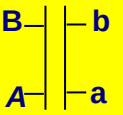
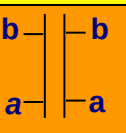
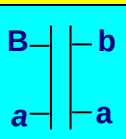
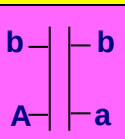
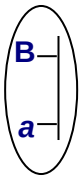
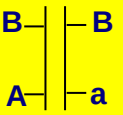
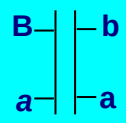
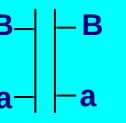
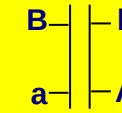
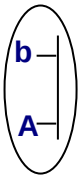
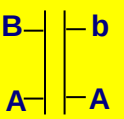
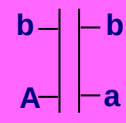
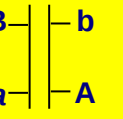
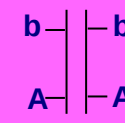
Gametes:



Non-recombinant gametes (large no.) | Recombinant gametes (small no.) x Non-recombinant gametes (large no.) | Recombinant gametes (small no.)

[1]

genotypes and phenotypes:

	 (Large no.)	 (Large no.)	 (small no.)	 (small no.)
 (Large no.)	 Black eye, coloured	 Black eye, coloured	 Black eye, coloured	 Black eye, coloured
 (Large no.)	 Black eye, coloured	 Pink eye, albino	 Black eye, albino	 pink eye, coloured
 (small no.)	 Black eye, coloured	 Black eye, albino	 Black eye, albino	 Black eye, coloured
 (small no.)	 Black eye, coloured	 pink eye, coloured	 Wide paws, hair	 pink eye, coloured

[1]

Match phenotype with genotype

F_2 phenotypes:	Black eye, coloured	pink eye, albino	Black eye, albino	pink eye, coloured
	Non-recombinant phenotypes (large numbers)		**Recombinant phenotypes (small numbers)**	

[1]

Observed no.	295	:	33	42	:	46

(c) State the expected ratio of the F_2 phenotypes if Mendelian law applies to the two gene loci. [1]

9:3:3:1

The chi-squared (χ^2) test was performed on these results, giving a calculated value for $\chi^2$of 47.527.

The χ^2 distribution table and equation to calculate χ^2 is shown below.

number of degrees of freedom (v)	probability
	0.05
1	3.84
2	5.99
3	7.82
4	9.49

(d) Use the calculated value of χ^2 and the table of probabilities provided in the table above, explain the conclusions drawn from the (χ^2) test. [3]

- The calculated χ^2 value of 47.527 is **greater than** the **critical value of 7.82 at 5% significance** level
- The **probability** that the **difference between expected and observed number is due to chance** is **less than 0.05**.
- Difference is **significant / not due to chance**, the observed number of 295:42:46:33 does not **conform to the expected ratio 9:3:3:1**, hence the two gene loci are **linked.**

[Total: 11]

QUESTION 6

Two groups of white mustard plants, *Sinapis alba*, were grown, one group under high illumination, the other under low illumination. When fully grown, the effect of increasing light intensity on the rate of photosynthesis in the two groups of plants was measured.

Fig. 6.1 shows the results.

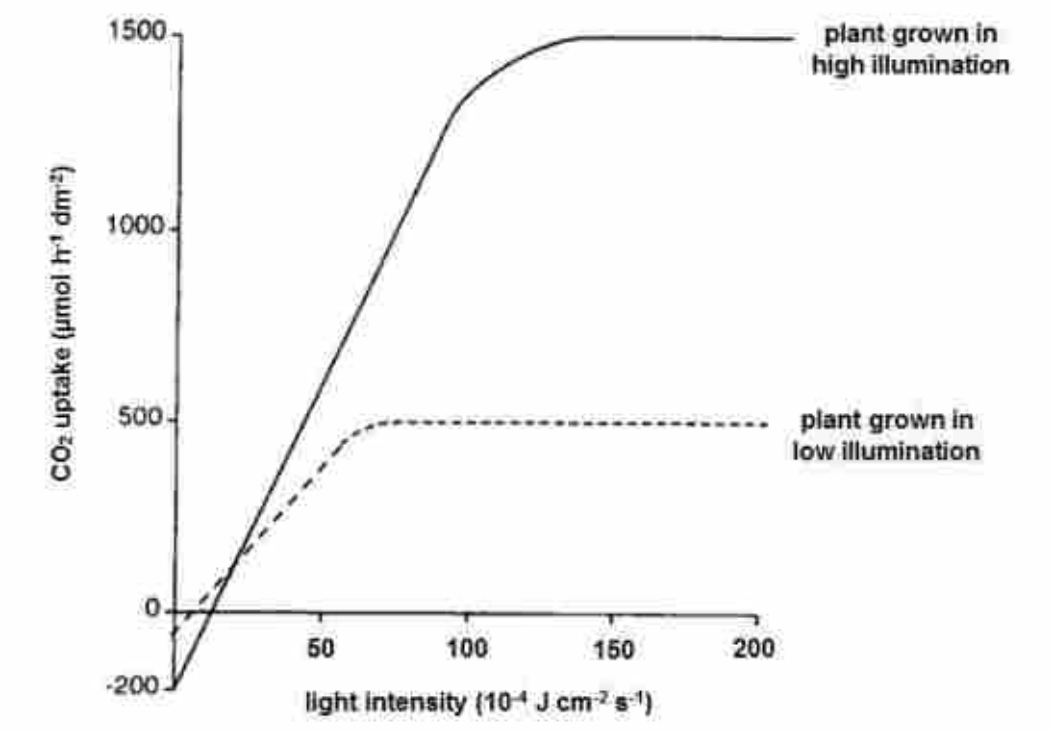


Fig. 6.1

(a) With reference to **Fig. 6.1**,

(i) state and explain the effect of light intensities above 150 x 10^{-4} $Jcm^{-2}s^{-1}$ on the rate of photosynthesis in plants grown in high illumination. [2]

- **For light intensity above 150x10^{-4} Jcm^{-2} s^{-1}, CO_2 uptake remains constant at 1500 µmol$h^{-1}dm^{-2}$.**
- **Light saturation is reached /light intensity is no longer the limiting factor.**

(ii) state with evidence, **two** ways in which the carbon dioxide uptake of both plants differ at light intensities below 50 x 10^{-4} $Jcm^{-2}s^{-1}$. [4]

Any two:

- **For light intensity between 20-50 x10^{-4} Jcm^{-2} s^{-1}, (rate of) CO_2 uptake for the plants grown in high illumination is higher than that grown in low illumination. [1]**
  - **Figures – [1]**
- **The compensation point for plants grown in high illumination occurs at a higher light intensity than those grown in low illumination or vice versa [1]**
  - **High illumination:15 x 10^{-4} Jcm^{-2} s^{-1} and Low illumination: 7x 10^{-4} Jcm^{-2} s^{-1}– [1]**

- **Below the compensation point, plants grown at high illumination give out more carbon dioxide than plants grown in low illumination. [1]**
  - **High illumination: -200 µmol $h^{-1}dm^{-2}$ and Low illumination: -50µmol$h^{-1}dm^{-2}$– [1]**

- **Below the compensation point, plants grown at high illumination give out more carbon dioxide than plants grown in low illumination. [1]**
  - **High illumination: -200 µmol $h^{-1}dm^{-2}$ and Low illumination: -50µmol$h^{-1}dm^{-2}$– [1]**

- ***(not a good answer)*** **rate of CO_2 uptake increases at a faster rate for plant grown in high illumination than plants grown in low illumination. [1]**
  - **High illumination: -200 µmol $h^{-1}dm^{-2}$ to 650 µmol $h^{-1}dm^{-2}$ and Low illumination: -50µmol$h^{-1}dm^{-2}$ to 400 µmol $h^{-1}dm^{-}$– [1]**

(b) Outline the fate of each product of photolysis in the light dependent reaction. [3]

1. Oxygen used by cells for aerobic respiration
2. Excess oxygen is released out of plant through stomata

3. Protons diffuse through ATP synthase **from thylakoid space to stroma** to generate ATP
4. protons combine with electrons from PS-I and **NADP to form NADPH**

5. Electrons are used to **replace electrons loss from PS-II**
6. Electrons are transported along **electron transport chain** by **electron carrie**rs of progressively lower energy levels
7. In cyclic photophosphorylation, **electron from PS-I goes back to PS-I**
8. In non-cyclic photophosphorylation, electrons from PS-I **combine with protons and NADP to form NADPH**

[Total: 9]

QUESTION 7

Fig. 7.1 is an electron micrograph of a section through a myelinated neurone showing the Schwann cell and axon membrane.

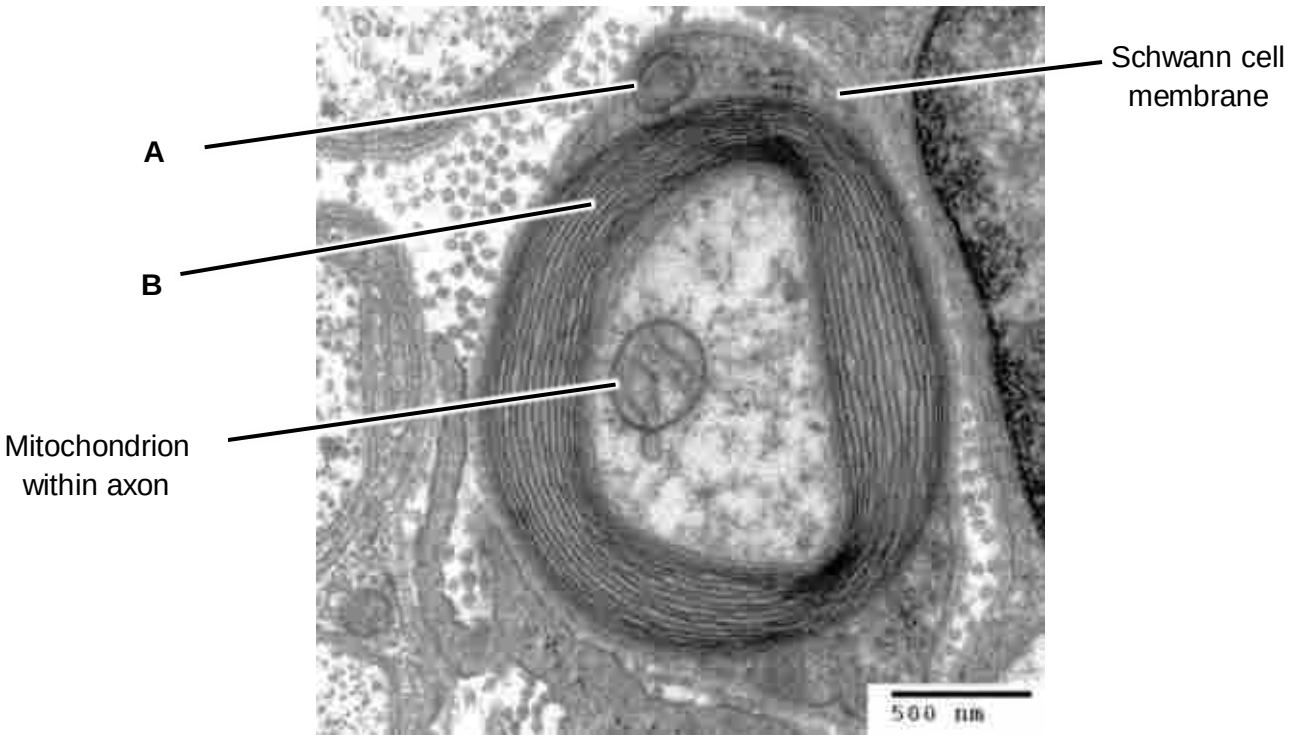


Fig. 7.1

(a) Identify the structures labelled **A** and **B**. [2]

A **Nucleus** of the Schwann cell

B **Myelin sheath**

(b) **Fig. 7.2** shows the percentage of energy used for various processes involved in the maintenance of resting potentials and in the reception and transmission of action potentials by a neuron.

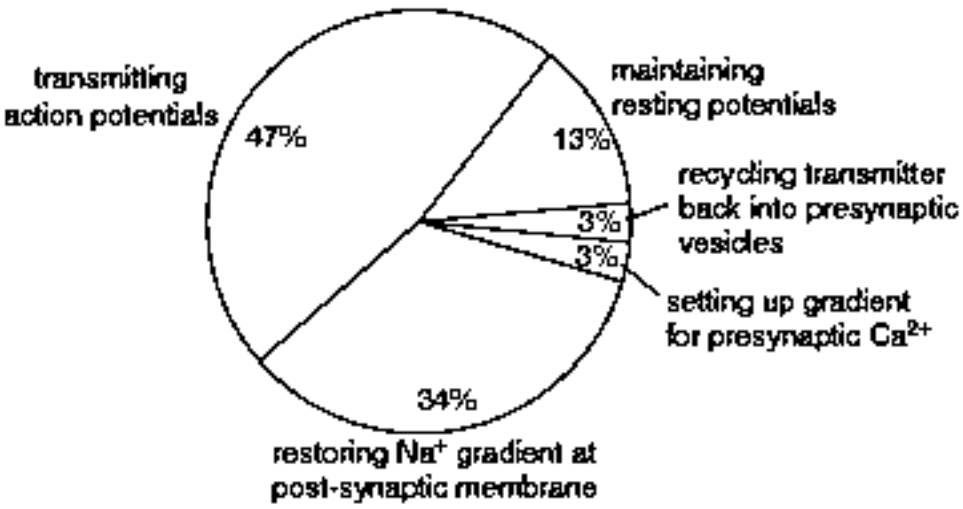


Fig. 7.2

(i) Explain why maintaining a resting potential requires energy. [2]

- Active transport of **3 sodium ions out and 2 potassium ions in** via the **sodium potassium pump**
- ..**against concentration gradient** which requires hydrolysis of **ATP**

(ii) Neurons contain large numbers of mitochondria. There are more mitochondria in each dendrite than in the axon.

With reference to **Fig. 7.2**, suggest reasons for the distribution of mitochondria. [3]

- Mitochondria is the site for **ATP synthesis**
  Restoring Na+ gradient at post-synaptic membrane uses **34% energy** which occurs in **dendrites**
- Recycling neurotransmitter **and** setting up Ca2+ gradient requires only **6% energy in terminal end of axons**

(c) Describe the role of Ca^{2+} in the passage of impulses across a synapse. [2]

- **Ca^{2+} influx into presynaptic neuron** via facilitated diffusion through voltage-gated Ca^{2+} channels
- The increase in Ca^{2+} causes **vesicles that contain neurotransmitters** move to and **fuse** with **presynaptic membrane**
- causes the **neurotransmitter to be released into the synaptic cleft** by **exocytosis**

(d) Synapses slow down the rate of transmission of nerve impulses but serve other important roles in the nervous system.

Outline two roles of synapses in the nervous system. [2]

Ensure **one-way transmission**

- **Filter out infrequent impulses**/ temporal summation
- Allow spatial summation/ convergence of impulse/ interconnection of many nerve cells
- Allow transmission of information between neuron
- Prevent overstimulation **[Total: 11]**

QUESTION 8

Mole rats, *Spalax ehrenbergi,* are mammals that live in groups in underground burrows. They are blind, and communicate with each other through sound and scent. Males make a purring call when they attempt to persuade females to mate with them.

In Israel, the mole rats found in different parts of the country all look identical. However, there are actually four different populations with different chromosome numbers, which live in different climatic regions.

Table 8.1 shows the four populations of mole rats and information about the purring calls used by the males in each population. The call of the males were analysed by measuring the number of sound pulses per second, and also the frequencies of the sounds that they made.

Chromosome number of population		52	54	58	60
Climatic region in which population lives		Cool and humid	Cool and dry	Warm and humid	Warm and dry
Purring call made by males	Mean number of pulses per second	21.0	25.3	23.9	23.2
	Mean major frequency/ kHz	595	555	583	562

Table 8.1

Researchers investigated how female mole rats from each of the four populations responded to purring calls made by males from the same population, and by males from different populations.

A female was placed midway between two loudspeakers, and recorded calls from two males were played to her simultaneously. The researchers noted which loudspeaker the female moved towards. This was repeated with many different females from each population.

The results are shown in **Table 8.2.**

Population chromosome number	Percentage of females preferring the purring call of males from their own population
52	79
54	77
58	78
60	44

Table 8.2

(a) With reference to **Table 8.2**, describe the extent to which female mole rats show a preference for the purring calls of males from their own population. [2]

- **High percentage of 79%, 77% and 78%** females from populations with **52, 54 and 58 chromosome number respectively** prefer calls from their own population
- **Low percentage of 44% of females from population with 60 chromosome number** prefer calls from their own population

(b) With reference to the data in both **Table 8.1** and **Table 8.2**, discuss whether these four populations of mole rats should be classified as different species. [4]

- **Yes**
- mole rats with different chromosome numbers
- **cannot interbreed to form fertile and viable offspring**
- as not all chromosomes will be able to pair up in meiosis/prophase 1/ idea of producing offspring with odd no. of chromosome (OWTTE)
- Geographically isolated/ live in different habitats so unlikely to interbreed
- Most females prefer males from their own population due to differences in mating call

The phylogenetic relationship of seven genera of mole rats was investigated using nucleotide sequences of the *12S rRNA* gene obtained from mitochondrial DNA.

Fig. 8.1 shows a phylogenetic tree of the mole rats based on this *rRNA* gene nucleotide sequence data.

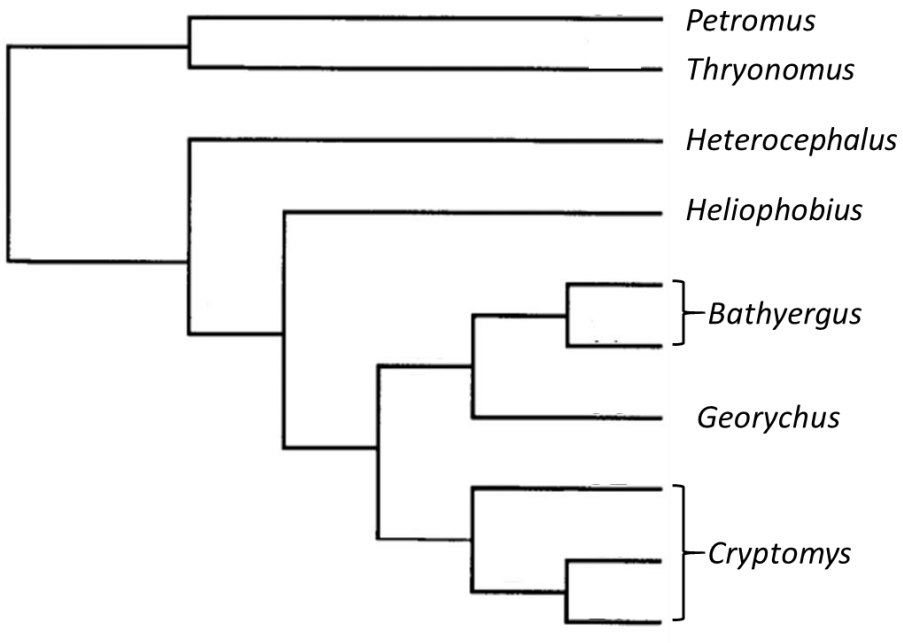


Fig. 8.1

(c) Describe the advantages of using nucleotide data such as the *12S rRNA* gene in classifying the mole rats. [3]

- The mole rats share the **same kind of genetic material** — **DNA**. Hence it is a good basis of comparison.
- It is **objective** as **homologous nucleotide sequence** can be **compared**. It is also **quantitative** as the **differences** can be **counted** and subjected to **statistical analysis.**
- Nucleotide sequence comparison is more complete as it takes into consideration of **silent mutations and changes in non-coding sequences** (not expressed in phenotype)…
- The **rate of accumulation of mutation** in the gene coding for 12s RNA occurred at a **constant rate** through time
- The number of nucleotide differences can be used as a gauge to estimate when **two species diverged from a common ancestor**
- *12S rRNA* gene is found on mtDNA which **lacks germline recombination** (crossing over, independent assortment). Thus, variation in the cytochrome b gene sequence is largely by mutation.
- The probability of recovery of mtDNA from very small or degraded biological samples is higher than the one of nuclear DNA, because the mitochondrial DNA molecules exist in **thousands of copies per cell**, while nuclear DNA has only two copies per cell.
- mtDNA has a **high level of variability** (due to high rate of mutation) in the **non-coding sequence** (control region) which can be used to elucidate phylogenetic relationships among **recently diverged species**. This high rate of mutation of mtDNA is due to the absence of DNA repair mechanism in mitochondria.

[Total: 9]

QUESTION 9

(a) Describe the role of vesicles in a cell. [6]

1. For transport of proteins from **Endoplasmic Reticulum** to **Golgi Apparatus**
2. For transport of proteins from **Golgi Apparatus** to **Cell Surface Membrane**
3. For transport of proteins from **Golgi Apparatus** to other cellular organelles or destinations
4. For **fusion** of vesicle with **cell surface membrane** which results in **replenishment of** cell **surface membrane**
5. For **fusion** of transport vesicle with GA which results in **replenishment of Golgi Apparatus membrane**
6. For **enclosing** foreign particles by the process of **endocytosis**
7. Functions as **lysosomes that store hydrolytic enzymes [at least 1 function** of lysosome]
8. **Cellulose**-containing vesicles fuse to form the **cell plate** during cytokinesis in plant cells
9. Named examples, e.g. insulin (secreted), G-protein coupled receptor (embedded in CSM), proton pumps (embedded in lysosomal membrane), neurotransmitters (exocytosis).

(b) Describe one causative factor of cancer and explain how this factor increases the chances of cancerous growth. [6]

1. **ONE Causative Factor:** Excessive **UV radiation / chemical carcinogens / viruses / inherited genetic factors**

2. Describe: viruses may **insert** their **genetic material** / DNA into the **host cell genome** may disrupt proto-oncogenes or tumour-suppressor genes.

   Describe: Excessive UV radiation / ionising radiation may cause **mutations** to proto-oncogenes or tumour-suppressor genes.

   Describe: **Exposure** to **carcinogens** (chemicals that cause cancer) e.g. ethidium bromide, benzo(a)pyrene in cigarette smoke, sodium nitrite in preserved foods may cause mutations

   Describe: An individual inheriting an **oncogene** (a mutated proto-oncogene) or a **mutant** allele of a **tumor-suppressor gene** will be one step closer to accumulating the necessary mutations for cancer development.

3. **Mutated proto-oncogenes** code for **hyperactive proteins** that cause uncontrolled cell division.
4. **Mutated tumour suppressor** genes code for **non-functional proteins** that cause uncontrolled cell division.
5. Cancer is a **multi-step process**, which requires **accumulation of mutations in multiple genes**.
6. Mutations in proto-oncogenes and tumour-suppressor genes can cause cell to **bypass cell cycle checkpoints/ dysregulation** of checkpoints.
7. **Damaged DNA / mutations are not repaired /** arrested at the cell cycle checkpoints**.**

8. leading to the **accumulation of mutations in a <u>SINGLE</u> cell,** resulting in formation of a cancerous cell that undergoes **uncontrolled cell division**.

(c) Describe the differences between the control of gene expression in prokaryotic and eukaryotic cells. [8]

	Eukaryotic genome	Prokaryotic genome
At chromosomal level		
	1. **Histone modifications** to regulate how compact the DNA region is	**No histone modification** as DNA not associated with histones
At transcriptional level		
Control at Promoter	2. **One promoter** for **each gene**	**One promoter** occurs for **each operon** which **consist of several functionally related structural genes**
Induction/ repression in response to external stimuli	3. In response to external stimuli, **transcription factors** may bind to regulatory sequences and activate or silence transcription	In response to external stimuli, **regulatory proteins** bind to control regions for each operon, inducing or repressing transcription
At post-transcriptional level		
	4. **Transcription and translation processes are separated** due to presence of nuclear membrane 5. **post transcriptional modifications** (addition of 5'cap, 3' poly-A tail, splicing) occur	• **Transcription and translation occur simultaneously** due to the **absence of a nuclear membrane** • **No controls at post-transcriptional level**
At translational level		
	6. **repressor proteins** bind to 5' UTR and blocks translation	**No repressor proteins** bind to the 5' region of mRNA, translation not blocked
At post-translational level		
	7. **degradation of proteins** by ubiquitin 8. **cleavage may occur for some proteins**	**Ubiquitin is not involved in degradation of proteins** **No cleavage of proteins**

[Total: 20]

QUESTION 10

(a) Describe the structure of collagen and how it is related to its function. [8]

1. **Tropocollagen** is formed when **three** collagen **polypeptide chains** wound around each other to give a **triple helix**.
2. Each collagen polypeptide chain is in the shape of a **loosely wound left-handed helix** that wind around the other two.
3. The three strands are linked together by **hydrogen bonds** formed between peptide N-H group of glycine and peptide C=O group of other amino acids on the other strands.
4. The sequence of amino acids of each strand is usually a repeat of
   Glycine – Proline – X, or
   Glycine – X – Hydroxyproline where X is any other amino acids except glycine
5. The presence of **glycine** at every third amino acid within each polypeptide chain allows **close packing** of the triple helix to form a **tight coil**.
6. Each complete triple helix of tropocollagen interacts with other tropocollagen molecules running parallel to each other by forming **covalent bonds** between the **lysines** in chains lying next to each other.
7. These cross-links hold many tropocollagen molecules side by side, forming **fibrils**, giving rise to **high tensile strength** (mark once for high tensile strength).
8. In collagen **fibrils**, tropocollagens lie **parallel** with **staggered ends,** which would permit them to **overlap** with the tropocollagens in adjacent fibrils.
9. Aggregation of overlapping collagen **fibrils** form strong collagen **fibers.**
10. **[Function]** Hence collagen is able to **provide structural support** for skin, tendons, cartilage, bones, teeth and connective tissue of blood vessels.

(b) Explain why antibiotic resistance spreads so rapidly among bacteria. [6]

High rate of DNA replication

- Idea that bacteria reproduces rapidly/ frequent DNA replication
- Higher chances for mutation

Mutation transferred to another bacteria by genetic recombination

- Mutation may be on plasmid which can be transferred to the recipient bacterial cell via conjugation ; brief description of **conjugation** [max 2]
- Describe process of **transformation** [max 2]
- Describe process of **transduction** [max 2]

Natural selection

- Those bacteria with antibiotic resistance gene are at **selective advantage** when subjected to antibiotic (selection pressure)
- ..able to survive to reproduce and passed on the mutation/ antibiotic resistance gene to large no. of offspring

(c) Describe the main differences between glucagon and insulin signalling in liver cells. [6]

Stages	Insulin	Glucagon
Reception	1. Tyrosine kinase receptor;	1. G-protein coupled receptor
Transduction	2. Dimerization 3. Phosphorylation of tyrosine residues 4. Activation of relay proteins	2. Receptor activated and changes shape 3. Activates G protein 4. Activation of adenyl cyclase to form cAMP/activates kinases
Response	5. Facilitates transport of glucose into cells 6. Increasing number of glucose carriers 7. Synthesis of glycogen from glucose	5. Facilitates release of glucose out of cells 6. No Increase in number of glucose carriers 7. Breakdown of glycogen by glycogen phosphorylase

[Total: 20]

• END OF PAPER 2 •

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations 2016
Higher 2

CANDIDATE NAME

CIVICS GROUP | | | | | | |

INDEX NUMBER | | |

H2 BIOLOGY

9648/03

Applications Paper and Planning Question
Paper 3
Additional Materials: Answer papers

20 September 2016
2 hours

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.
Write your name, civics group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough workings.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

At the end of the examination,
1. Fasten all your work securely together.
2. Hand in the following separately:
   - Structured questions 1 – 3
   - Planning question
   - Essay question

The number of marks is given in brackets [ ] at the end of each question or part question.

For examiner's Use	
1	/ 13
2	/ 13
3	/ 14
4 Planning	/ 12
5 Essay	/ 20

This paper consists of **12** printed pages.

[Turn over]

Answer **all** questions.

For Examiner's Use

QUESTION 1

ABL1 is a proto-oncogene that encodes a protein tyrosine kinase involved in a variety of cellular processes, including cell division. A researcher intended to mass produce ABL1 protein tyrosine kinase using bacterial cells. He obtained *ABL1* cDNA from the cDNA library and the complete sequence of *ABL1* cDNA non-template strand is shown in **Fig. 1.1**. The start and stop triplets are bolded.

```
5' 1   CCTATTATTACTTTATGGGGCAGCAGCCTGGATCCGT----------
  61   ----------
 121   ----------GCATCTGACTTTG
 181   AGCCTCAGGG TCTGAGTGAAGCTTCT 3'
```

Fig. 1.1

(a) Explain why the gene of interest is obtained from cDNA library instead of genomic DNA library. [2]

……

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……

……

The plasmid pUC18, was first chosen for the cloning of *ABL1* cDNA. **Fig. 1.2a** shows a diagram of the plasmid pUC18 and the position of the restriction sites found in the plasmid.

Fig. 1.2b shows two restriction sites commonly used in genetic engineering.

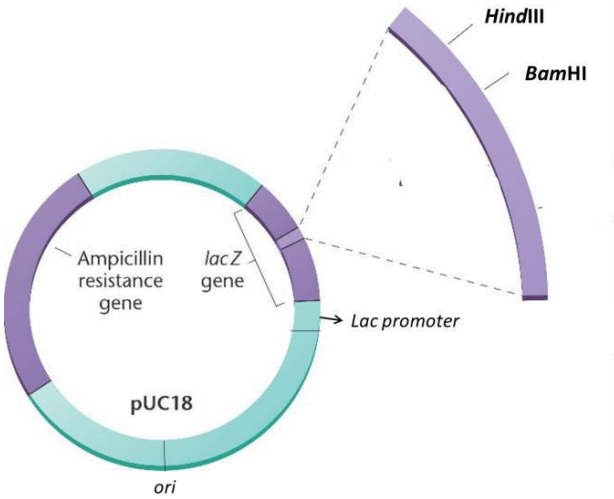

Fig. 1.2a

Fig. 1.2b

(b) With reference to **Fig. 1.1 and Fig. 1.2**, comment on the effectiveness of using pUC18 for ABL1 protein production. [3]

For Examiner's Use

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The researcher found that the *ABL*1 cDNA is present in low copy number in the cDNA library. Hence, he carried out PCR to amplify the *ABL1* cDNA.

(c) Suggest two reasons why the total amount of amplified *ABL1* cDNA did not increase between the 30th cycle and the 40th cycle. [2]

1. ……

……

2. ……

……

An alternative cloning technique called **TA** cloning shown in **Fig. 1.3** can also be used to clone the *ABL1* cDNA. The *Taq* DNA polymerase used in PCR has a non-template dependent activity which preferentially adds a single adenine nucleotide to the 3'-ends of a double stranded DNA molecule. This results in PCR product with 3'-A overhangs. This enables the *ABL1* cDNA to be inserted into a plasmid designed to have 3'-T overhangs.

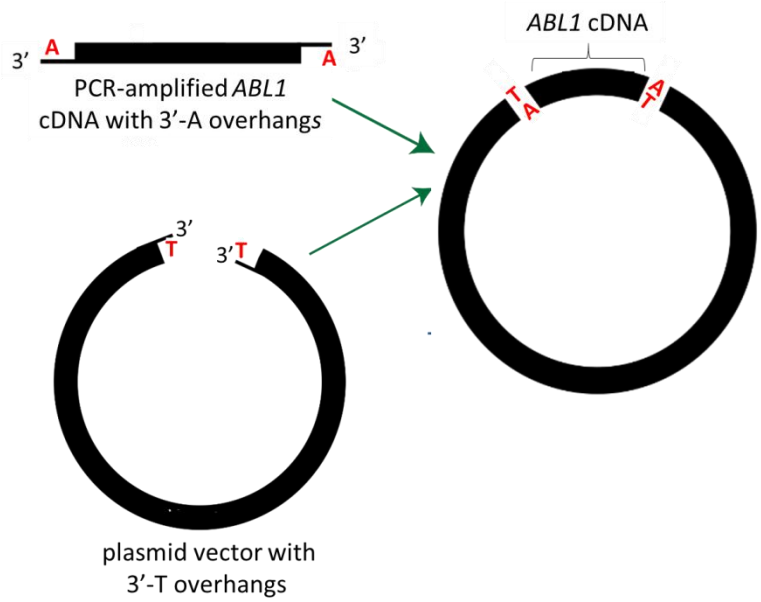

Fig. 1.3

(d) (i) With reference to **Fig. 1.3**, describe how the PCR-amplified *ABL1* cDNA can be inserted into the plasmid using **TA** cloning technique. [4]

For Examiner's Use

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(ii) Suggest one advantage and one disadvantage of using **TA** cloning. [2]

Advantage:

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Disadvantage:

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[Total: 13]

QUESTION 2

For Examiner's Use

Plants have developed defence mechanisms against pathogens such as bacteria, fungi and viruses. Chemicals released by these pathogens can trigger a defence response in infected plant cells. For example, the production of hydrogen peroxide (H_2O_2) which reacts with pathogen membranes and cellular chemicals eventually kills both the cell and pathogen.

The *OSRac1* gene from another plant species was isolated and introduced into a number of rice plant (*Oryza spp.*) lines to study its role in disease resistance of plants to blast fungus. Experiments were carried out to see if the *OSRac1* gene was part of the signalling pathway for hydrogen peroxide production. A control (**C**) and four other genetically modified rice plant lines (**A1**, **A2**, **D1** and **D2**) grown *in vitro* from calluses were exposed to chemicals known to initiate a defence response by producing hydrogen peroxide. **A1** and **A2** are rice plants with the *OSRac1* gene always turned on. **D1** and **D2** are rice plants with the *OSRac1* gene suppressed. The results are shown in the **Fig. 2.1**.

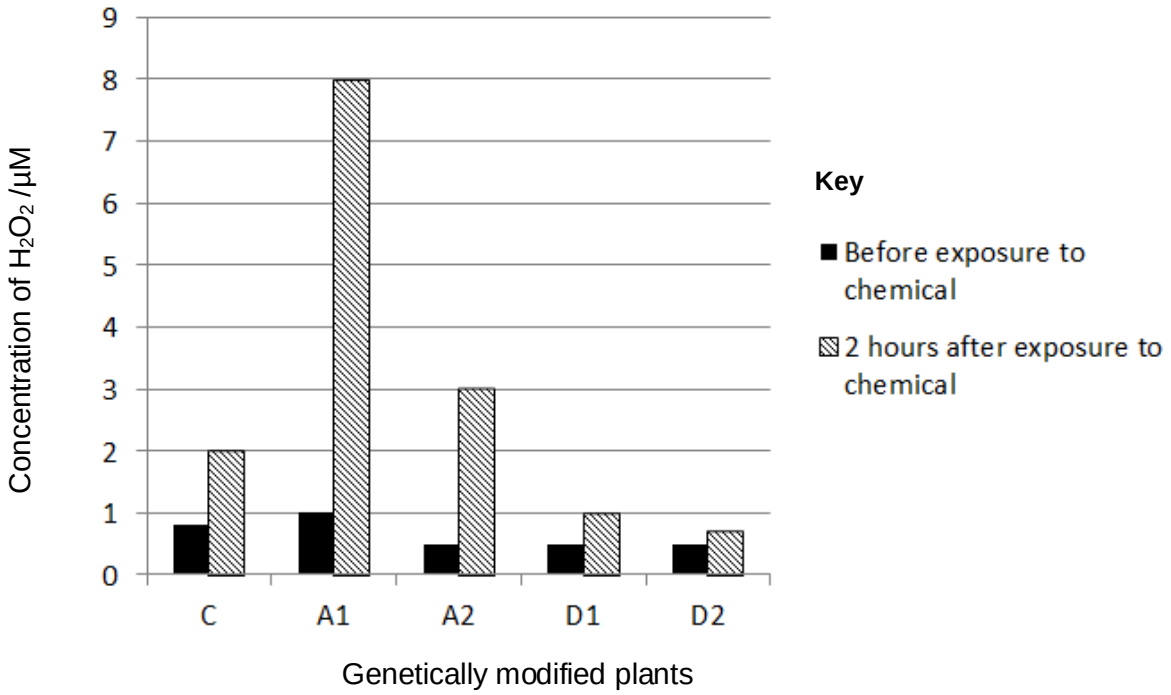

Fig. 2.1

(a) Describe how calluses are obtained from rice plants. [3]

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(b) With reference to **Fig. 2.1**, compare the **change in H_2O_2 production** between the control and genetically modified plants two hours after the chemical was applied. [2]

For Examiner's Use

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(c) Evaluate whether the data supports the hypothesis that *OSRac1* gene is involved in disease resistance. [2]

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Rice blast caused by the fungal pathogen is a destructive disease of rice. The use of blast resistance genes is an effective way to control the fungal disease in rice and to reduce losses in crop yield.

For Examiner's Use

Recently, researchers identified a known genetic marker that is tightly linked to the blast resistance genes in some fungal resistant crops. This allows the identification of crops with blast resistance and subsequent cloning of transgenic rice with the blast resistance gene.

In a rice breeding programme, researchers wanted to identify the blast resistant crops from those that are susceptible to blast.

(d) Using the information provided, describe how RFLP analysis can help to distinguish between blast resistant crops and those that are susceptible to blast. [6]

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[Total: 13]

QUESTION 3

For Examiner's Use

(a) Describe how the normal copy of a gene can be introduced to a patient's cells via non-viral method. [3]

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Type 1 diabetes is a condition where an individual's Islet cells cannot produce insulin in response to high blood glucose levels. Patients usually are dependent on insulin injections.

Transplanting Islets from donors has been studied as a form of treatment for Type I diabetes for over three decades.

Islet cells are usually encapsulated in alginate microspheres before transplanting them into patients. The alginate microsphere creates a barrier between the donor cells and the recipient's cells.

Fig. 3.1 shows some Islet cells encapsulated in an alginate microsphere.

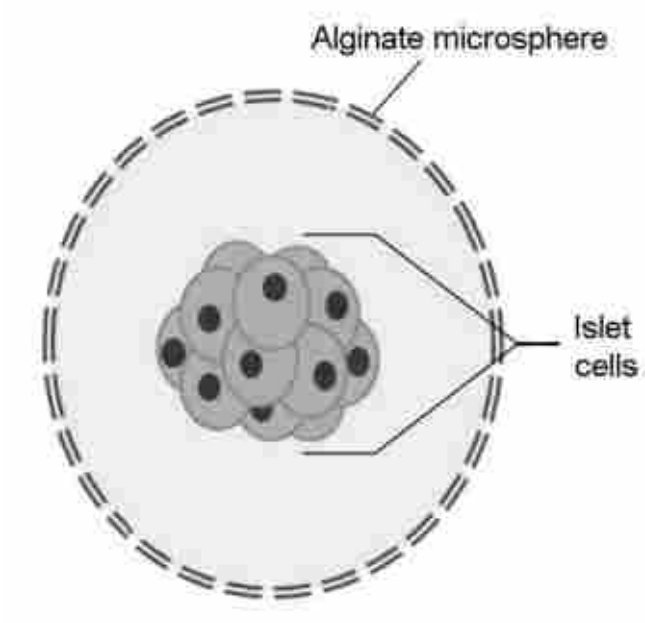

Fig. 3.1

(b) Suggest why Islet cells were encapsulated before they were transplanted into a patient. [1]

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Patients transplanted with human Islet cells obtained from deceased individuals can be made insulin independent for around 5 years using the Islet encapsulation treatment. However, this approach is limited because of the scarcity and quality of donor Islet cells.

For Examiner's Use

(c) Suggest why Islet encapsulation treatment lasts only approximately 5 years. [2]

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(d) Researchers have also looked into producing human insulin-producing beta cells from stem cells.

A recent study in 2014 used a human embryonic stem cell line (HUES8) and a human induced pluripotent stem cell (hiPSC) line to develop two types of human insulin-producing beta cells called HUES8 SC-β and hiPSC SC-β respectively to overcome the problem of scarcity.

The human induced pluripotent stem cells were derived from fully differentiated adult somatic cells as shown in **Fig. 3.2.**

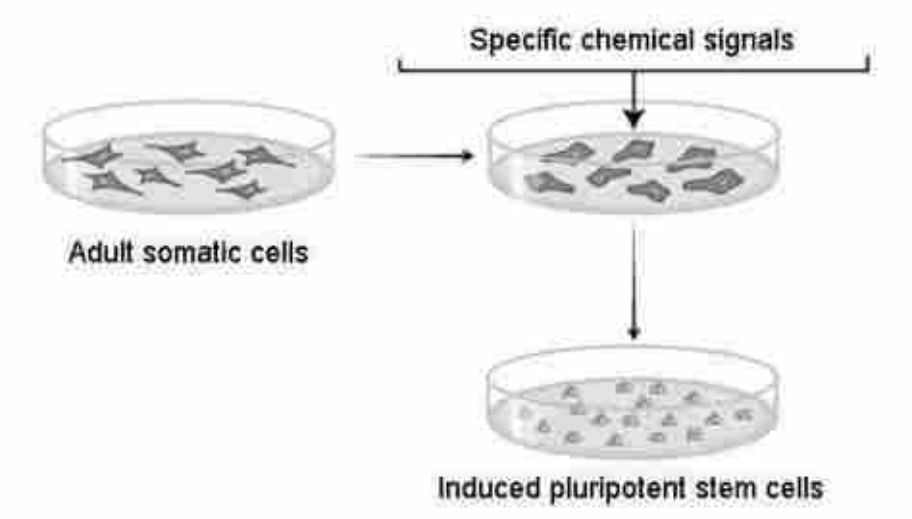

Fig. 3.2

(i) Explain why fully differentiated somatic cells can be induced to become pluripotent. [2]

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(ii) State one ethical issue related to stem cell research and explain how using induced pluripotent stem cells would address this issue. [2]

For Examiner's Use

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(e) Trials have been done by transplanting HUES8 SC-β cells and hiPSC SC-β cells into diabetic mice using alginate microsphere encapsulation. Human insulin produced by the mice was measured following a high carbohydrate meal.

The results of this study were recorded in **Table 3.1**.

Type of beta cell transplanted into diabetic mice	Mean concentration of human insulin secreted ± standard deviation / μg per ml of blood
HUES8 SC-β cells	2.3 ± 0.2
hiPSC SC-β cells	2.2 ± 0.3
Normal human beta cells	2.1 ± 0.9

Table 3.1

(i) Compare the secretion of insulin by these three types of transplanted cells. [3]

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(ii) Explain the purpose of the normal human beta cells. [1]

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[Total: 14]

QUESTION 4 – Planning question

For Examiner's Use

You are required to plan, but not carry out, an experiment to investigate the effect of temperature on the rate of respiration in mung beans.

Germination of mung beans can be initiated by soaking the seeds overnight. The mung beans can then be placed into a simple respirometer (**Fig. 4.1**) to measure the rate of respiration by measuring oxygen uptake of the seeds. Soda lime pellets absorb any carbon dioxide produced by the germinating seeds. As oxygen is taken up during respiration, the drop of coloured liquid introduced in the capillary tube by capillary action is displaced.

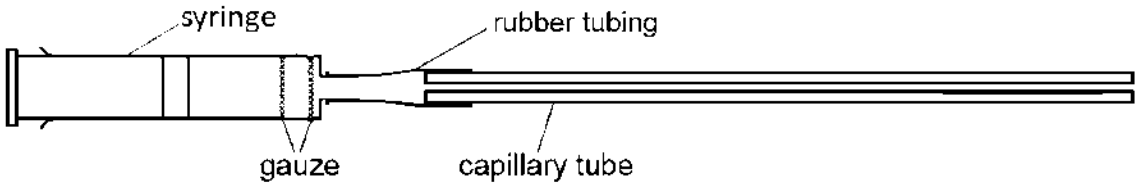

Fig. 4.1: A respirometer

You must use the items from this list:

- 200 mung beans of equal size that have been soaked for 24 hours
- Soda lime pellets 

- Syringes
- Rubber tubing connected to glass capillary tube with 1mm bore diameter
- Beaker of coloured liquid
- Ruler marked in mm
- Paper towels
- Stop watch
- Thermostatically controlled incubator
- Other available laboratory apparatus and equipment

Your plan should have a clear and helpful structure to include:

- a description of the method used including the scientific reasoning behind the method,
- an explanation of the dependent and independent variables involved,
- relevant, clearly labelled diagrams,
- how you will record your results and ensure that they are as accurate and as reliable as possible,
- proposed layout of results tables and graphs with clear headings and labels,
- the correct use of technical and scientific terms,
- relevant risks and precautions taken

[Total: 12]

Free-response question

For Examiner's Use

Write your answer to this question on the separate answer paper provided.

Your answer:

- should be illustrated by large, clearly labeled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a), (b)** etc., as indicated in the question

QUESTION 5

(a) Discuss the detrimental environmental and economic effects of growing genetically-modified herbicide resistant crops. [6]

(b) Discuss the ethical and social issues of the Human Genome Project. [6]

(c) Describe how a genetic condition like SCID may be treated with viral gene therapy and discuss the potential limitations of this kind of treatment. [8]

[Total: 20]

• END OF PAPER 3 •

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations 2016
Higher 2

CANDIDATE NAME

CIVICS GROUP

INDEX NUMBER

H2 BIOLOGY

9648/03

Applications Paper and Planning Question

20 September 2016

Paper 3

2 hours

Additional Materials: Answer papers

READ THESE INSTRUCTIONS FIRST

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   - Essay question

The number of marks is given in brackets [ ] at the end of each question or part question.

ANSWER SCHEME

For examiner's Use	
1	/ 13
2	/ 13
3	/ 14
4 Planning	/ 12
5 Essay	/ 20

This paper consists of __ printed pages.

[Turn over]

Answer **all** questions.

QUESTION 1

ABL1 is a proto-oncogene that encodes a protein tyrosine kinase involved in a variety of cellular processes, including cell division. A researcher intended to mass produce ABL1 protein tyrosine kinase using bacterial cells. He obtained *ABL1* cDNA from the cDNA library and the complete sequence of *ABL1* cDNA non-template strand is shown in **Fig. 1.1**. The start and stop triplets are bolded.

```
5' 1   CCTATTATTACTTT ATG GGGCAGCAGCCTGGATCCGT----------------------------------------
  61   ----------------------------------------------------------------------------------------
 121   ----------------------------------------------------------------------GCATC TGA CTTTG
 181   AGCCTCAGGG TCTGAGTGAAGCTTCT 3'
```

Fig. 1.1

(a) Explain why the gene of interest is obtained from cDNA library instead of genomic DNA library. [2]

- cDNA library contains the *ABL1* gene **without introns** while genomic DNA library contains *ABL1* gene **with introns**
- Thus *ABL1* can be successfully **expressed/ used to synthesise functional protein** by bacteria.

The plasmid pUC18, was first chosen for the cloning of *ABL1* cDNA. **Fig. 1.2a** shows a diagram of the plasmid pUC18 and the position of the restriction sites found in the plasmid.

Fig. 1.2b shows two restriction sites commonly used in genetic engineering.

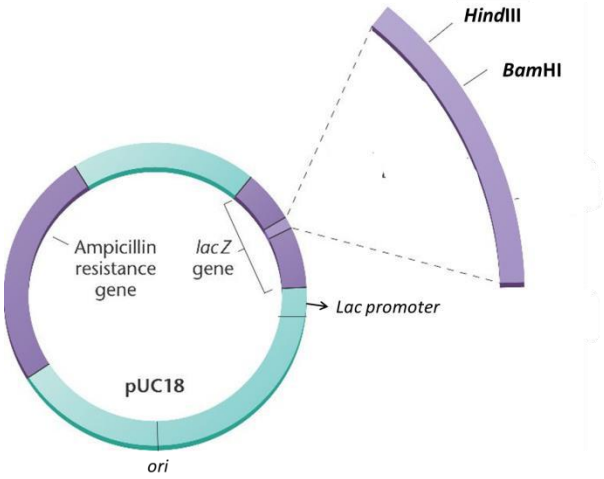


Fig. 1.2a

Fig. 1.2b

(b) With reference to **Fig. 1.1 and Fig. 1.2**, comment on the effectiveness of using pUC18 for ABL1 protein production. [3]

- **Ineffective**
- The ***BamH1* restriction site** is **downstream of the start codon** in *ABL1* cDNA (OWTTE) and ***HindIII*** restriction site is **downstream of stop codon**
- Hence the **cDNA cloned** into the plasmid will be **incomplete (OWTTE)** and **non-functional proteins** will be produced.

The researcher found that the *ABL*1 cDNA is present in low copy number in the cDNA library. Hence, he carried out PCR to amplify the *ABL1* cDNA.

(c) Suggest two reasons why the total amount of amplified *ABL1* cDNA did not increase between the 30th cycle and the 40th cycle. [2]

- Nucleotides are used up
- Primers are used up
- *Taq* DNA polymerase gradually becomes denatured

An alternative cloning technique called **TA** cloning shown in **Fig. 1.3** can also be used to clone the *ABL1* cDNA. The *Taq* DNA polymerase used in PCR has a non-template dependent activity which preferentially adds a single adenine nucleotide to the 3'-ends of a double stranded DNA molecule. This results in PCR product with 3'-A overhangs. This enables the *ABL1* cDNA to be inserted into a plasmid designed to have 3'-T overhangs.

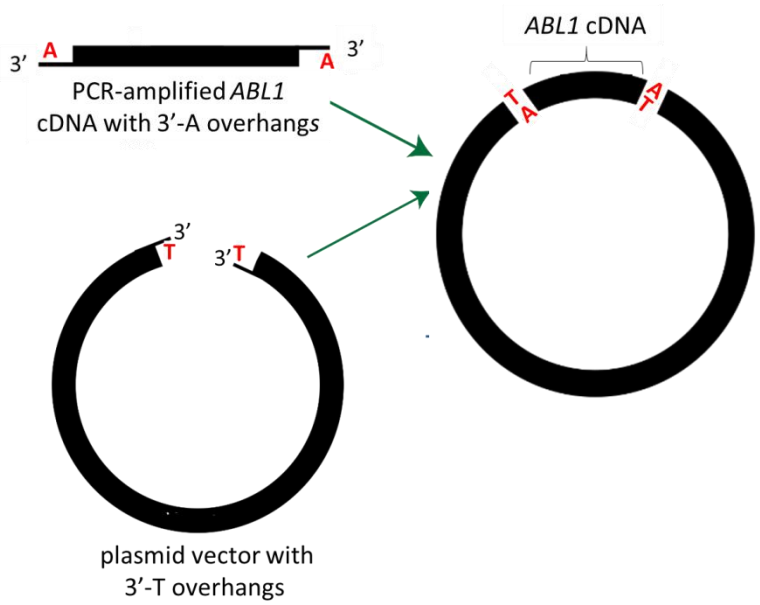


Fig. 1.3

(d) (i) With reference to **Fig. 1.3**, describe how the PCR-amplified *ABL1* cDNA can be inserted into the plasmid using **TA** cloning technique. [4]

- PCR products of *ABL1* cDNA contain 3'-A overhangs and the plasmid have **3'-T overhang**
- **Mix** the PCR products with the plasmid
- Anneal by **complementary base pairing between A and T** through formation of hydrogen bonds
- **DNA ligase** seals the sugar-phosphate backbone by forming **phosphodiester bonds**

(ii) Suggest one advantage and one disadvantage of using **TA** cloning. [2]

Advantage:

- Allows cloning of GOI that does not have restriction sites / do not require the use of restriction enzymes
- Prevents reannealing of plasmid via complementary base pairing

Disadvantage:

- **Does not allow directional insertion** of GOI (OWTTE), hence bacteria transformed with recombinant plasmid may produce wrong/non-functional proteins.

[Total: 13]

QUESTION 2

Plants have developed defence mechanisms against pathogens such as bacteria, fungi and viruses. Chemicals released by these pathogens can trigger a defence response in infected plant cells. For example, the production of hydrogen peroxide (H_2O_2) which reacts with pathogen membranes and cellular chemicals eventually kills both the cell and pathogen.

The *OSRac1* gene from another plant species was isolated and introduced into a number of rice plant (*Oryza spp.*) lines to study its role in disease resistance of plants to blast fungus. Experiments were carried out to see if the *OSRac1* gene was part of the signalling pathway for hydrogen peroxide production. A control (**C**) and four other genetically modified rice plant lines (**A1**, **A2**, **D1** and **D2**) grown *in vitro* from calluses were exposed to chemicals known to initiate a defence response by producing hydrogen peroxide. **A1** and **A2** are rice plants with the *OSRac1* gene always turned on. **D1** and **D2** are rice plants with the *OSRac1* gene suppressed. The results are shown in the **Fig. 2.1**.

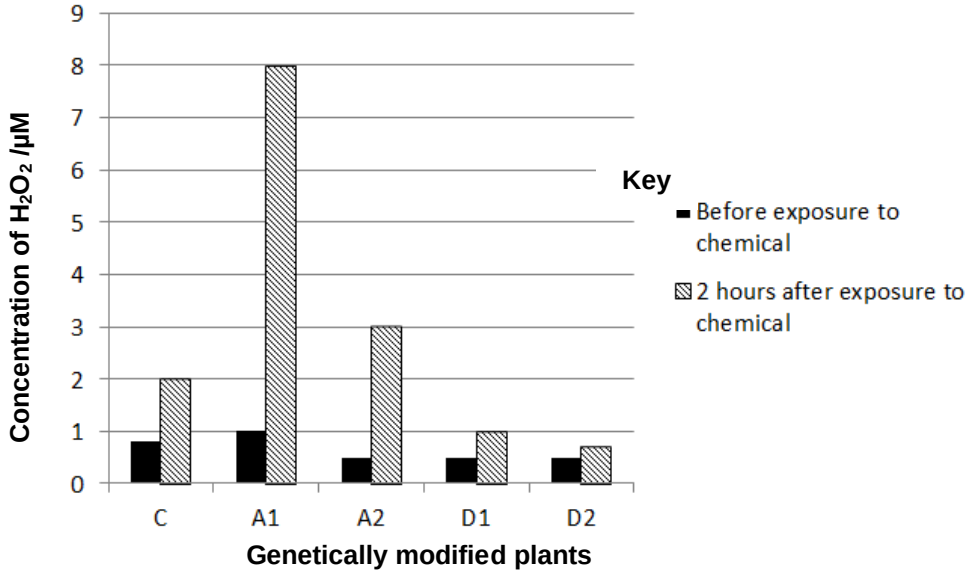


Fig. 2.1

(a) Describe how calluses are obtained from rice plants. [3]

- Surface of **explants** from rice is **sterilized** using dilute **sodium hypochlorite**.
- Rice explants are **aseptically** transferred to **sterile** culture vessels **containing nutrients** and **intermediate auxin:cytokinin ratio**
- …to **induce callus formation** by **mitosis**.

(b) With reference to **Fig. 2.1**, compare the **change in H_2O_2 production** between the control and genetically modified plants two hours after the chemical was applied. [2]

- **A1 and A2** showed a **higher increase** in H_2O_2 production of **8 times and 6 times respectively** as compared to **control** which showed an increase in H_2O_2 production of **2.5 times**
  OR
  A1 and A2 showed a **higher increase** in H_2O_2 production **by 700% and 500% respectively** as compared to **control** which showed an increase in H_2O_2 production of **150%**
- **D1 and D2** which showed a **lower increase in H_2O_2 production of 2.0 and 1.4 times** as compared to **control** which showed an increase in H_2O_2 production of **2.5 times**

OR

- **D1 and D2** which showed a **lower increase in H_2O_2 production by 100% and 40%** as compared to **control** which showed an increase in H_2O_2 production of **150%**

(c) Evaluate whether the data supports the hypothesis that *OSRac1* gene is involved in disease resistance. [2]

- **Supported** [1] ***[mark awarded only if full explanation is given]***

- **Both A1 and A2 genetically modified plants** with *OSRac1* gene always turned on showed **greater change in the number of times** of **H_2O_2 production** so hypothesis is supported.
  OR
- **Both D1 and D2 genetically modified plants** with *OSRac1* gene suppressed showed **smaller change in the number of times** of **H_2O_2 production** so hypothesis is supported.

Rice blast caused by the fungal pathogen is a destructive disease of rice. The use of blast resistance genes is an effective way to control the fungal disease in rice and to reduce losses in crop yield.

Recently, researchers identified a known genetic marker that is tightly linked to the blast resistance genes in some fungal resistant crops. This allows the identification of crops with blast resistance and subsequent cloning of transgenic rice with the blast resistance gene.

In a rice breeding programme, researchers wanted to identify the blast resistant crops from those that are susceptible to blast.

(d) Using the information provided, describe how RFLP analysis can help to distinguish between blast resistant crops and those that are susceptible to blast. [6]

1. DNA samples of blast resistant and susceptible crops are cut with the **same specific restriction enzyme** to generate **DNA fragments of different lengths**

2. **Restriction fragments** are subjected to **gel electrophoresis** where the fragments are separated according to **molecular weight/size**

10. **larger DNA fragments travel slower and smaller fragments travel faster.**

3. DNA being **negatively charged** due to the presence of phosphate group, moves towards the **anode** / positive end of the electric field.

4. A **DNA ladder** is loaded in another well to calibrate the **size of DNA fragments**.

5. **Add bromophenol blue and glycerol with purpose given**

6. (a) Southern blot and Nucleic acid hybridization are carried out .. **sodium hydroxide** denature double-stranded DNA to **single-stranded DNA**…

   (b) …using a **radioactively-labelled DNA/RNA probe complementary to the tightly linked RFLP marker**

7. DNA bands of interest are detected using **autoradiography**

8. **Analyze and compare** the **unique band patterns of DNA** of the blast resistant and susceptible crops.

9. **[idea of ..]** The RFLP variant that is linked to the resistant allele will give a different band pattern to the RFLP variant that is linked to the susceptible allele.

[Total: 13]

QUESTION 3

(a) Describe how the normal copy of a gene can be introduced to a patient's cells via non-viral method. [3]

Mention any **one** of the methods:

Liposome method

- **Cationic liposomes** made of **positively charged** lipids are created.
- Positively charged liposomes are attracted to **negatively charged** recombinant plasmid DNA, forming **liposome-DNA complexes**.
- The liposome-DNA complexes are then **introduced directly into the target cells via endocytosis.**

Cationic polymer

- **Cationic polymers** designed to be able to **bind to the receptors** on the **target cells** are used.
- **Positively-charged** cationic polymer is attracted to **negatively-charged** recombinant DNA plasmid, forming a **polymer-DNA complex/ polyplexes**.
- The polyplexes bind to receptors on the target cells in culture, hence allowing the **uptake** of the complex by **receptor mediated endocytosis** forming endosomes.

Direct Injection and Electroporation

- The **normal allele** is inserted into a **DNA plasmid** to form a **recombinant plasmid DNA**.
- The recombinant plasmid DNA is **injected directly** into the tissue /**in vivo** technique
- The target cells are subjected to **electrical current** which **increases** the **permeability** of the membrane for the cells to take up DNA plasmids.

Gene gun

- The **normal allele** is inserted into a **DNA plasmid** to form a **recombinant plasmid DNA**.
- The recombinant plasmid DNA is coated onto **microscopic gold / tungsten particles**
- A **gene gun** is used to accelerate these particles towards the target cells in culture/ ex vivo
- These particles **penetrate** the **plasma membrane** of the target cells and deliver the DNA into the **nucleus**

Type 1 diabetes is a condition where an individual's Islet cells cannot produce insulin in response to high blood glucose levels. Patients usually are dependent on insulin injections.
Transplanting Islet cells from donors has been studied as a form of treatment for Type I diabetes for over three decades.
Islet cells are usually encapsulated in alginate microspheres before transplanting them into patients. The alginate microsphere creates a barrier between the donor cells and the recipient's cells.

Fig. 3.1 shows some Islet cells encapsulated in an alginate microsphere.

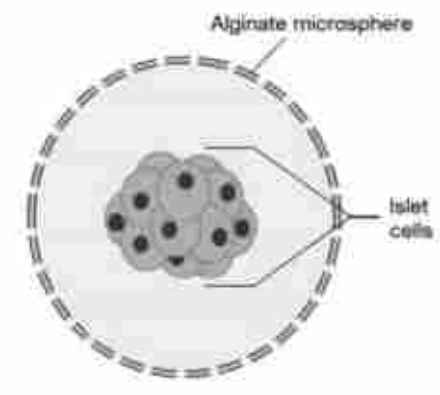


Fig. 3.1

(b) Suggest why Islet cells were encapsulated before they were transplanted into a patient. [1]

- Idea of immune system rejection.

Patients transplanted with human Islet cells obtained from deceased individuals can be made insulin independent for around 5 years using the Islet encapsulation treatment. However, this approach is limited because of the scarcity and quality of donor Islet cells.

(c) Suggest why Islet encapsulation treatment lasts only approximately 5 years. [2]

- The donated islet cells are **specialised** cells that **cannot divide / renew themselves**.
- Hence the islets cells would **die** and **stop producing insulin** after 5 years, hence the treatment would stop being effective.

OR

- The alginate microsphere **degrades** after 5 years,
- …the patient's immune system destroys the islet cells, hence no more insulin is produced.

(d) Researchers have also looked into producing human insulin-producing beta cells from stem cells.

A recent study in 2014 used a human embryonic stem cell line (HUES8) and a human induced pluripotent stem cell (hiPSC) line to develop two types of human insulin-producing beta cells called HUES8 SC-β and hiPSC SC-β respectively to overcome the problem of scarcity.

The human induced pluripotent stem cells were derived from fully differentiated adult somatic cells as shown in **Fig. 3.2.**

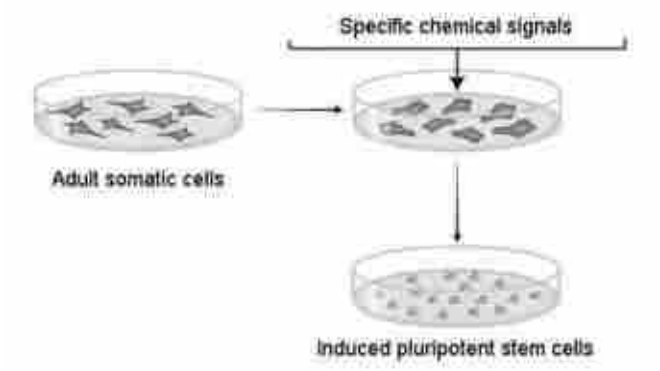


Fig. 3.2

(i) Explain why fully differentiated somatic cells can be induced to become pluripotent. [2]

- Fully differentiated somatic cells contain the **entire genome**
- **Chemical signals** enable the cells to **express genes** important for maintaining **pluripotency /** idea that **genes for pluripotency are turned on**.

(ii) State one ethical issue related to stem cell research and explain how using induced pluripotent stem cells would address this issue. [2]

- Pluripotent cells are usually obtained by **removing the inner cell mass of a blastocyst** and this is problematic as some believe that **life begins at conception** and this is **equivalent to destroying a human life**.
- Using iPSCs does not have as many ethical issues as **no embryos were destroyed in the process**.

(e) Trials have been done by transplanting HUES8 SC-β cells and hiPSC SC-β cells into diabetic mice using alginate microsphere encapsulation. Human insulin produced by the mice was measured following a high carbohydrate meal.

The results of this study were recorded in **Table 3.1**.

Type of beta cell transplanted into diabetic mice	Mean concentration of human insulin secreted ± standard deviation / µg per ml of blood
HUES8 SC-β cells	2.3 ± 0.2
hiPSC SC-β cells	2.2 ± 0.3
Normal human beta cells	2.1 ± 0.9

Table 3.1

(i) Compare the secretion of insulin by these three types of transplanted cells. [3]

Similarity:

- High glucose concentrations resulted in **all three types of cells secreting approximately the same amount of insulin / relatively similar mean amount of insulin**.
- Normal human beta cells, HUES8 SC-β cells and hiPSC SC-β cells secreted 2.1 2.3, 2.2 µg of insulin per ml of blood respectively.

Difference:

- HUES8 SC-β cells and hiPSC SC-β cells showed smaller variation in insulin secretion (with standard deviation of 0.2 µg of insulin per ml of blood and 0.3 µg of insulin per ml of blood respectively) than normal human beta cells (0.9 µg of insulin per ml of blood).

(ii) Explain the purpose of the normal human beta cells. [1]

- As a control / reference to ascertain if HUES8 SC-β cells and hiPSC SC-β cells could produce comparable levels **[key idea]** of insulin in response to high glucose concentrations.

[Total: 14]

QUESTION 4 – Planning question

You are required to plan, but not carry out, an experiment to investigate the effect of temperature on the rate of respiration in mung beans.

Germination of mung beans can be initiated by soaking the seeds overnight. The mung beans can then be placed into a simple respirometer (**Fig. 4.1**) to measure the rate of respiration by measuring oxygen uptake of the seeds. Soda lime pellets absorb any carbon dioxide produced by the germinating seeds. As oxygen is taken up during respiration, the drop of coloured liquid introduced in the capillary tube by capillary action is displaced.

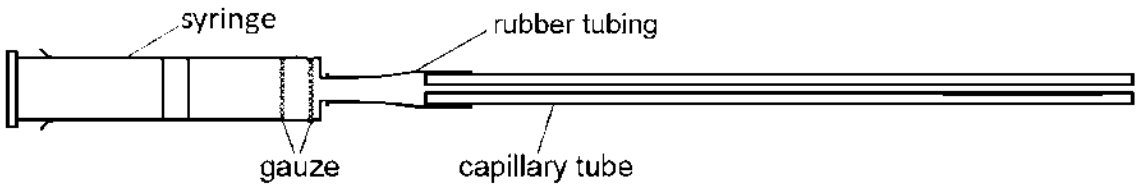


Fig. 4.1: A respirometer

You must use the items from this list:

- 200 mung beans of equal size that have been soaked for 24 hours
- Soda lime pellets 

- Syringes
- Rubber tubing connected to glass capillary tube with 1mm bore diameter
- Beaker of coloured liquid
- Ruler marked in mm
- Paper towels
- Stop watch
- Thermostatically controlled incubator
- Other available laboratory apparatus and equipment

Your plan should have a clear and helpful structure to include:

- a description of the method used including the scientific reasoning behind the method,
- an explanation of the dependent and independent variables involved,
- relevant, clearly labelled diagrams,
- how you will record your results and ensure that they are as accurate and as reliable as possible,
- proposed layout of results tables and graphs with clear headings and labels,
- the correct use of technical and scientific terms,
- relevant risks and precautions taken

[Total: 12]

Suggested answer scheme:

Linking theory to investigation: [1]

- O_2 acts as the **final electron acceptor** in the **electron transport chain** during **oxidative phosphorylation**. The protons and electrons combine with oxygen to form water. The higher the rate of respiration, the higher the rate of O_2 uptake, and the further the displacement of the coloured drop

- As temperature increases, kinetic energy increases, more enzyme-substrate complexes are formed, hence the rate of respiration increases. At optimum temperature, rate of respiration is highest. When temperatures goes beyond the optimum temperature, 3D structure of enzymes involved in respiration disrupted, enzymes are denatured, rate of respiration decreases.

Stating the hypothesis [1]

- As temperature **increases towards the optimum**, rate of **oxygen consumption will increase**, reflecting an **increase in the rate of respiration**.

Independent and dependent variables [1, both variables]

Independent variable: Temperature / °C, with 5 values within a reasonable range (e.g. 15°C, 25°C °C, 35°C, 45°C, 55°C) maintained using an incubator.

Dependent variable: Distance moved by the drop of coloured liquid in 5 min / mm

Variables to be kept constant and scientific reasoning [1, min 1 variable and rationale]

- **Duration** of each experiment should be kept constant to ensure a fair comparison.

- **Number** of **germinating mung beans** used - determines the concentration of enzymes present, and hence affects the rate of respiration. Hence, use the same number of beans (less than or equal to 10 per experiment) for each temperature.

- **Mass of soda lime pellets** (in excess) used should be kept constant as carbon dioxide production will affect the reading of the volume of oxygen absorbed / used up / distance moved by drop of liquid.

- **Volume of air in syringe** used should be kept constant as the volume will affect the amount of oxygen available for respiration.

Methods [2]

- Setting up the respirometer – putting in mung beans, soda lime pellets, coloured liquid
- Describing method to measure dependent variable
- How other variables are kept constant – number of seeds, duration in incubator
- Equilibration of set-up to each temperature / **acclimatisation**

1. Remove the plunger from the syringe and place 2g of soda lime inside the syringe.

2. Weigh 5 g of the germinating mung beans (*Accept 10 or less mung beans*) using a weighing balance and place them in the syringe barrel and replace the plunger by pushing it in until it is about 0.5 cm from the germinating seeds. Connect the glass capillary tube securely to the syringe via the rubber connecting tubing.

3. Dip the end of the glass capillary tube into the coloured liquid so that a drop enters the capillary tube. Remove any excess liquid with paper towels.

4. Set the incubator to 15˚C and place the respirometer horizontally on the incubator shelf.

5. Place a ruler beside the capillary tube and mark the position of the coloured drop.

6. Wait for 3 minutes to ensure equilibration/acclimatization of temperature between the respirometer and the incubator. Also ensure that the drop of coloured liquid is moving smoothly towards the syringe.

7. After 5 minutes, record the distance travelled by the drop of coloured liquid.

Replicates and repeats [1 for 8-9]

8. Repeat steps 1 to 7 to obtain another two readings for this temperature to ensure **accuracy by taking the average reading.**

9. Repeat steps 1 to 8 for the other four temperatures, using fresh germinating seeds.

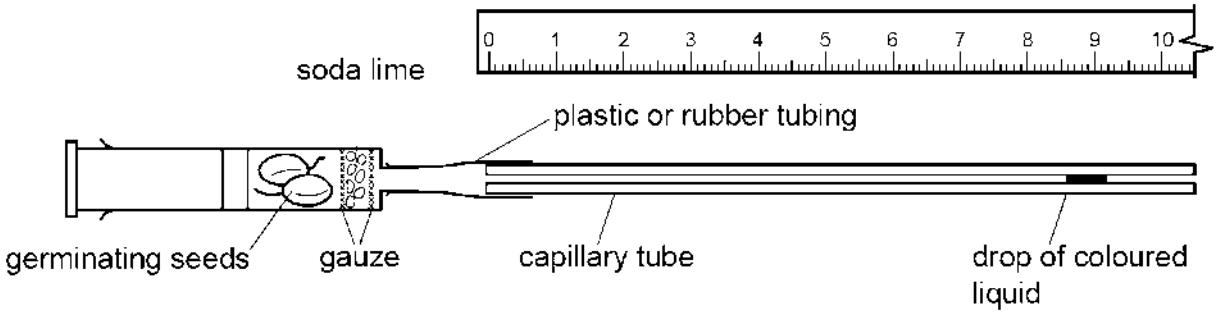
10. Repeat the experiment at **least two more times to ensure reproducibility / reliability** of experimental results.

Controls and justification [1]

- Replace germinating beans with equal mass of **boiled beans** at the optimum temperature.

- Rationale: To show that oxygen uptake is due to the germinating beans undergoing respiration and no other factors

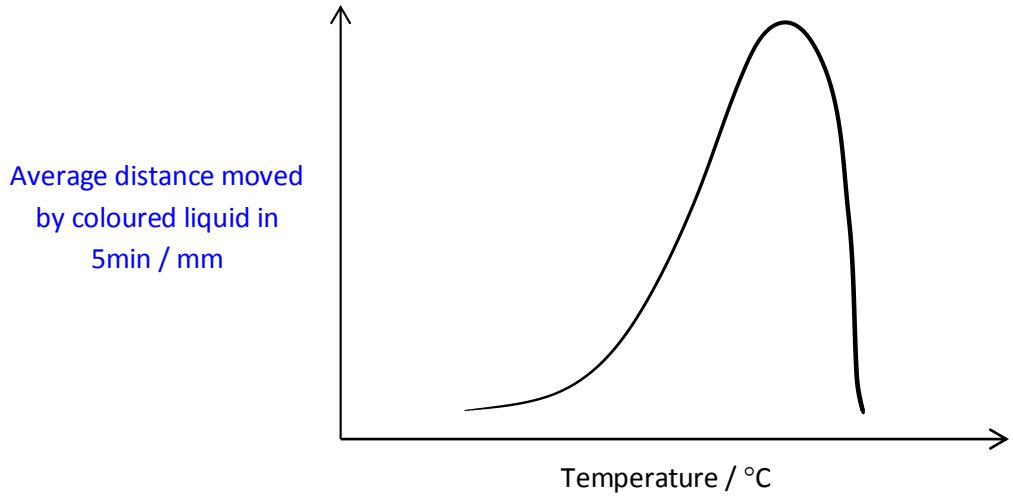
Labelled diagram [1]



Proposed layout of table with appropriate headings (independent & dependent variables consistent with axes of graph) [1]

Temperature / °C	Distance travelled by coloured liquid in 5 minutes / mm			
	Reading 1	Reading 2	Reading 3	Average
15				
25				
35				
45				
55				

Theoretical graph with correct axes and units (optimum temperature included) [1]



Risk assessment and precautions taken [1]

- Soda lime is an irritant/corrosive; handle with gloves and wash affected area immediately if it comes into contact with skin.

QUESTION 5

(a) Discuss the detrimental environmental and economic effects of growing genetically-modified herbicide resistant crops. [6]

Environmental effects:

(1) **Genetically-modified crop plants** may be hardier and become **agricultural weeds** that invade natural habitats
(2) The **introduced transgene(s) to wild species** may result in **more invasive hybrid offspring** when pollen transfer to wild relatives.
(3) **Intensive** use of herbicide selects for **herbicide-resistant weeds**
(4) Intensive use of herbicide **reduces biodiversity**, **upsetting the natural balance of the ecological system**.

Economic effects (4 max):
(5) High cost of GM seeds/plants, farmers cannot afford/ erode farmers' income
(6) Heavy use of herbicide, thus, cost more
(7) contamination of organic farming due to accidental mixing of GM crops with non-GM crops
(8) cleaning pollution associated with heavy use of herbicide
(9) human health problems associated with the use of herbicide

(b) Discuss the ethical and social issues of the Human Genome Project. [6]

Ethical issues arise…

(1) on the **fairness** in the use of genetic information by insurers or other organisations, etc which may create a situation in which less healthy individuals / those with genetic predisposition are marginalised or discriminated.

(2) on the **confidentiality and privacy** of genetic information - the right of ownership of the genetic information has yet to be determined.

(3) on the use of genetic information in controversial decisions in reproduction, such as **modifying genotypes** through gene therapy. Hence resulting in the ethical issue of

a) one generation determining the next generation's genotype before birth without their **consent**.
OR
b) going **against nature** by tampering with the next generation's genetic make-up.

(4) on the use of genetic information in controversial decisions in reproduction, such as **termination of pregnancies**. Issue – selective breeding / abortion based on genetic tests that may not be fully reliable/understood. → increased abortion rate / decline in appreciation of the dignity of life

(5) from clinical issues that the doctors, other health service providers, patients and the public must be educated to make **informed choices**, and be aware of scientific capabilities and limitations.

OR

Unethical for doctors or health care providers to carry out genetic tests
a) and draw conclusions on data that may not be fully reliable, **or**
b) without informing the patient of the limitations and capabilities of genetic technology, **or**
c) leaving patient to interpret complex results without sufficient explanation.

(6) from **commercialization/patenting** of genetic information and their product by companies which may limit their accessibility and development of useful medicinal products.

(7) from the conceptual and philosophical understanding of human responsibility, **free will versus genetic determinism**, and concepts of health and disease. E.g. difficult to determine if a person's behaviour is genetically determined or can be controlled by the individual.

(8) when an individual identified to have life-threatening genetic condition experience **immense psychological ramification**.

Social issue arises

(9) Due to possibility of social and **economic stigmatization/discrimination** as well as **genetic discrimination** that arises due to the knowledge of individual's genetic difference.

(c) Describe how a genetic condition like SCID may be treated with viral gene therapy and discuss the potential limitations of this kind of treatment. [8]

SCID gene therapy: Outline **[Max 6]**

(1) SCID (both types accepted) is a **recessive** condition that may be treated by the introduction of the **dominant normal allele**.

(2) A **retrovirus vector is modified** such that it **does not cause disease.**

(3) **Hematopoietic stem cells or T cells** are harvested from the **SCID patient** and are cultured *ex vivo.*

(4) **RNA** copies of **normal** human **ADA gene** or **ILRG-2 gene** are obtained from **bone marrow** of a donor.

(5) This **ADA RNA** is then used to make a **recombinant RNA** molecule, which is **packaged into the modified retrovirus vector.**

(6) The retrovirus is allowed to **infect** the harvested hematopoietic stem cells / T cells. The recombinant RNA molecules are **injected** into the cells.

(7) **Reverse transcription** catalysed by viral reverse transcriptase occurs and **double-stranded complementary copies of ADA DNA** are produced.

(8) The normal ADA allele **integrates randomly** into the host **genome**. Expression of the ADA allele produces functional ADA enzymes.

(9) The **hematopoietic stem cells / T cells** are **transplanted back** into the body of the patient.

(10) t
These cells **divide** and proliferate to produce **normal** T cells and/or B cells.

Limitations of gene therapy:

(11) If the normal allele is **not** successfully **integrated** into the stem cell **genome**, the treatment is **short term** as the **episomal DNA** may be **hydrolysed** and **gene expression will be lost**. Thus the therapy has to be **repeated**.

(12) If the normal allele is integrated into the host genome at random, **insertional mutagenesis** may occur.

(13) If **viruses** are used to introduce the normal allele, viral **proteins** may trigger an **immune response** in body due to expression of viral genes, and the capsid itself may also trigger immune response.

(14) Virus may regain virulence which cause disease in the patients

[Total: 20]

• END OF PAPER 3 •

H

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME

BIOLOGY CLASS 2bi2 __ / 2IPbi2 __

REGISTRATION NUMBER

BIOLOGY

9648/01

Paper 1 Multiple Choice

15 September 2016

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your Biology class, registration number and name above and on the Answer Sheet provided.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

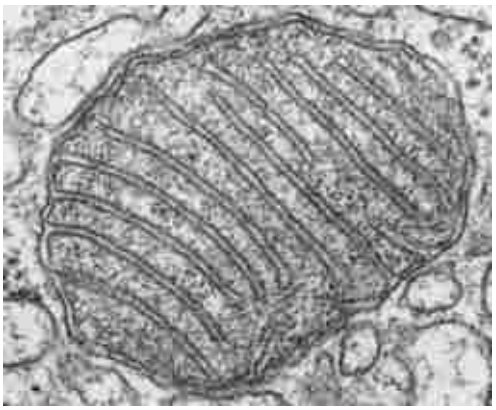
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **23** printed pages.

[Turn over

1 The electron micrographs, which are taken at different magnifications, show four different organelles that can be found in different eukaryotic cells.

1



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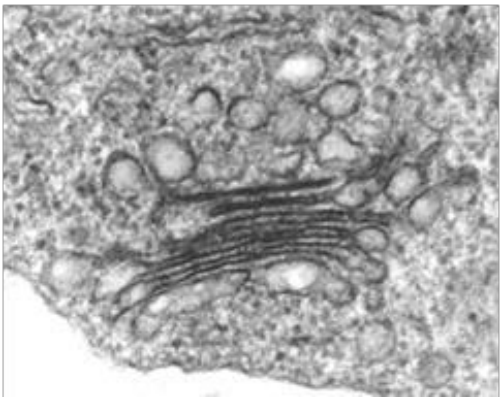

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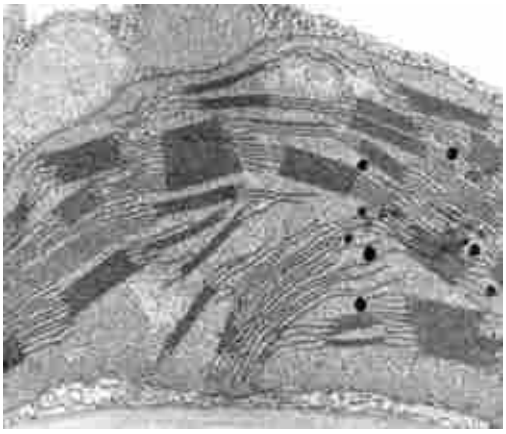


Which organelle(s) contain(s) nucleic acids?

A 4 only

B 1 and 4 only

C 1, 3 and 4 only

D 1, 2, 3 and 4

2 Which statements about membrane fluidity are correct?

1 The less unsaturated the fatty acid chains of the phospholipids, the more fluid the membrane is.

2 The greater the amount of cholesterol in the membrane, the less fluid the membrane is at high temperatures.

3 The longer the hydrocarbon tails of the phospholipids, the more fluid the membrane is.

4 The lower the temperature, the less fluid the membrane is.

A 1 and 3

B 2 and 4

C 1, 2 and 3

D 2, 3 and 4

3 The following statements describe three orders of structure of the insulin molecule.

1 The molecule consists of two polypeptide chains joined and folded around one another.

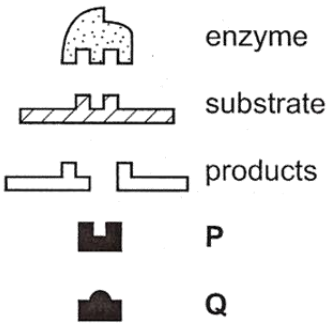
2 The sequence and number of amino acids in each polypeptide chain are known.

3 The amino acids in each chain are coiled into a helix and held in position by hydrogen bonds.

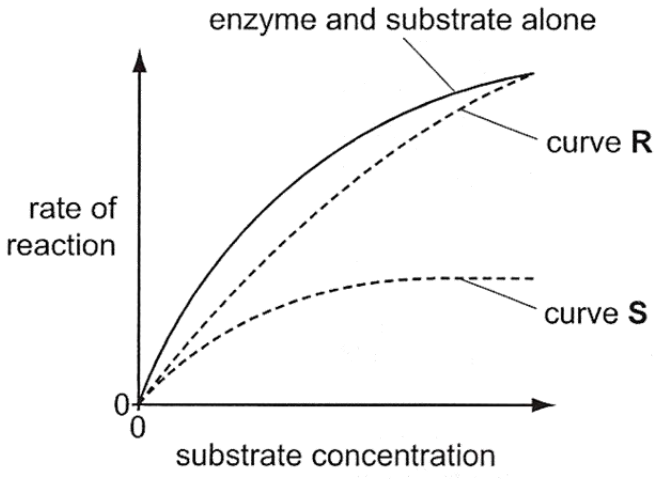
Which order is described by each statement?

	1	2	3
A	primary	secondary	tertiary
B	quaternary	primary	secondary
C	quaternary	primary	tertiary
D	secondary	tertiary	primary

4 The diagram shows an enzyme molecule with its normal substrate and products. P and Q are other molecules that can bind to the enzyme.



The graph shows the effect of P and Q on the rate of reaction of the enzyme at different substrate concentrations.



Which statement correctly describes the activity of the enzyme?

A P is a competitive inhibitor that binds to the active site, resulting in curve R.

B P is a non-competitive inhibitor that distorts the shape of the enzyme, resulting in curve S.

C Q is a competitive inhibitor that distorts the shape of the enzyme, resulting in curve R.

D Q is a non-competitive inhibitor that binds to the active site, resulting in curve S.

5 How does the second meiotic division differ from mitosis?

A Chiasmata form between the chromatids of a bivalent in the second meiotic division but not in mitosis.

B Each chromosome replicates to form two chromatids during metaphase in the second meiotic division but not in mitosis.

C Exchange of genetic material occurs between chromatids in the second meiotic division but not in mitosis.

D The separating chromatids of a pair differ genetically in the second meiotic division but not in mitosis.

6 Suppose a cell with 14 chromosomes divides mitotically and one of the two new cells has 13 chromosomes and the other has 15 chromosomes.

At which phase of the cell cycle could an error have occurred and resulted in the unequal number of chromosomes in the two new cells?

A anaphase

B interphase

C prophase

D telophase

7 The following DNA sequence of the coding strand, which is complementary to the mRNA, is taken randomly from a bacterial genome.

3' TTACGCTTCGAAATAGGAATATCATAGGCT 5'

This DNA sequence is cloned into a plasmid, which is introduced into a suitable host.

The table shows the mRNA codons for some amino acids.

arg	CGA, CGG, AGA, AGG	leu	CUU, CUC, CUA, CUG
asp	GAU, GAC	lys	AAA, AAG
ile	AUU, AUC, AUA	phe	UUU, UUC
met	AUG	ser	UCA, UCG, AGU, AGC
stop	UAG, UGA, UAA	tyr	UAU, UAC

What are the first four amino acids of the polypeptide generated from this DNA sequence?

A met-arg-ser-lys

B met-arg-ser-phe

C met-ile-phe-leu

D met-tyr-lys-asp

8 What is true about the regulation of gene expression in both prokaryotes and eukaryotes?

1 involves histone modifications

2 involves helicase to separate the DNA so that transcription can take place

3 involves binding of specific transcription factors to enhancers or silencers that are some distance from the gene(s) to be transcribed

4 involves binding of a protein that can regulate transcription of several genes at the same time

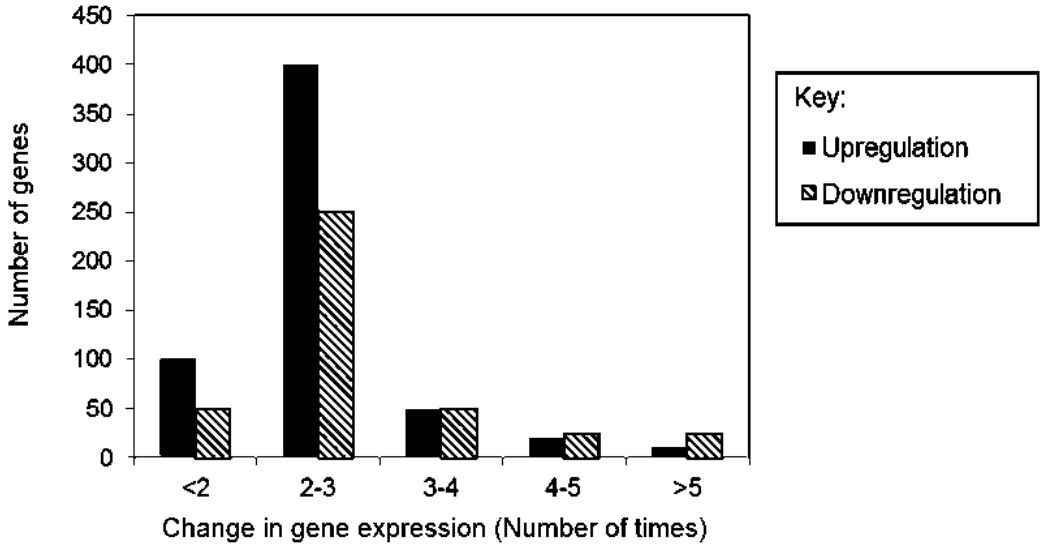
A 4 only

B 2 and 3 only

C 3 and 4 only

D 1, 2 and 4 only

9 The graph shows the changes in gene expression in the liver cells of a group of mice after oxygen deprivation for four minutes.



What can result in all the observed changes?

A activation of specific transcription factors

B alternative splicing of mRNA

C increase in activity of histone acetyltransferase

D methylation of cytosine at the promoters of the genes

10 Which statement best defines an oncogene?

A An oncogene codes for a cell cycle control protein.

B An oncogene codes for a mutated form of a protein that forms part of a signal transduction pathway.

C An oncogene codes for a protein that prevents the cell from undergoing apoptosis.

D An oncogene is a dominantly expressed mutated gene that gives a cell a growth advantage.

11 A scientist is studying a strain of bacteria whose genes are commonly transferred to other bacteria.

What could serve as evidence that the genes are transferred through specialized transduction?

A Cells that are treated with calcium ions show a higher rate of gene transfer.

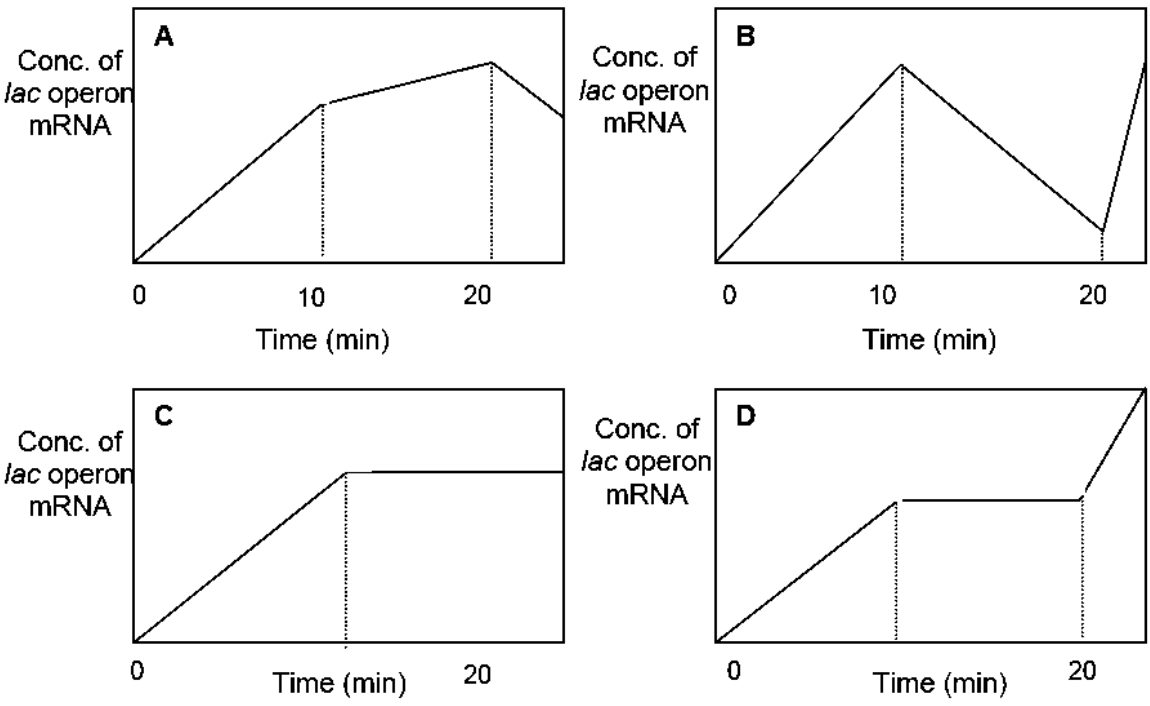
B F plasmid is always transferred from donor cell to recipient cell.

C Only certain genes are transferred in the process.

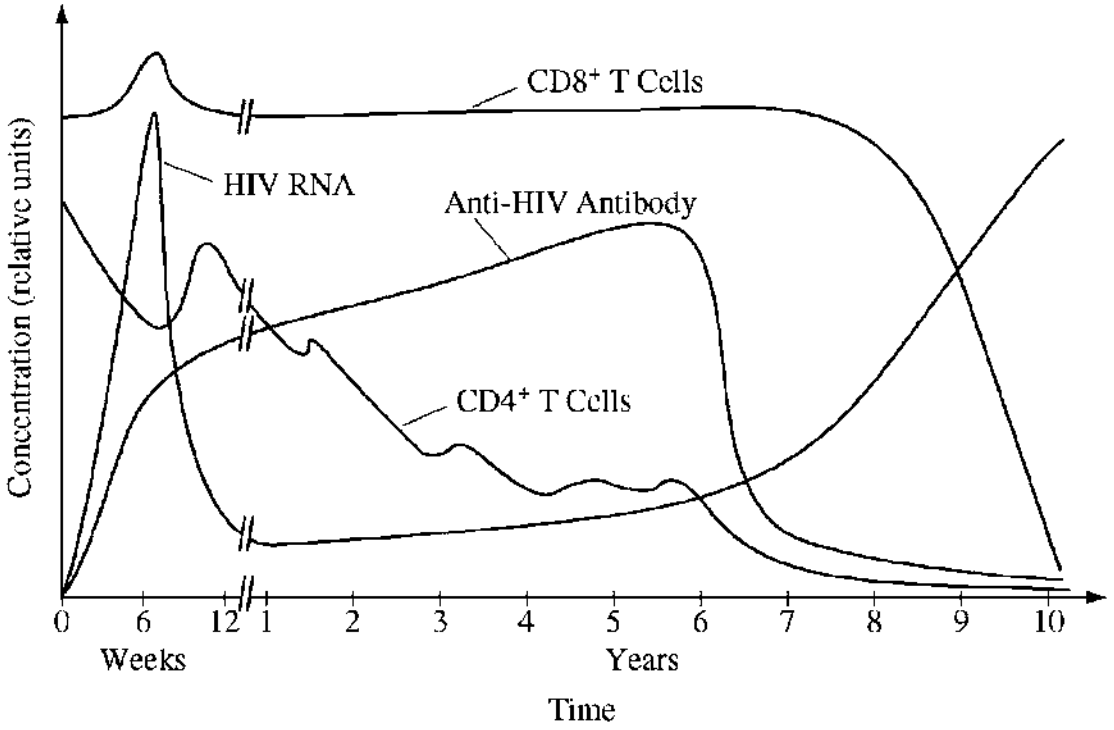
D The strain of bacteria is often infected by a virulent phage.

12 IPTG is an analogue of lactose that binds to the *lac* repressor in the same fashion as allolactose. However, it cannot be metabolized by β-galactosidase. *E. coli* cells, which were grown in the absence of lactose and glucose, were initially supplemented with IPTG. After 10 minutes, glucose was added to the cells. 10 minutes later, cAMP was added to the cells.

Which graph best represents the amount of *lac* operon mRNA during the time course of the experiment?



13 The graph shows the relationship among serum concentrations of human immunodeficiency virus (HIV) RNA, anti-HIV antibody, $CD4^+$ and $CD8^+$ T-cells over a ten-year period following infection of an individual by the virus.



What is the primary explanation for the drop in serum concentration of HIV-RNA during 6- to 12- week period following infection?

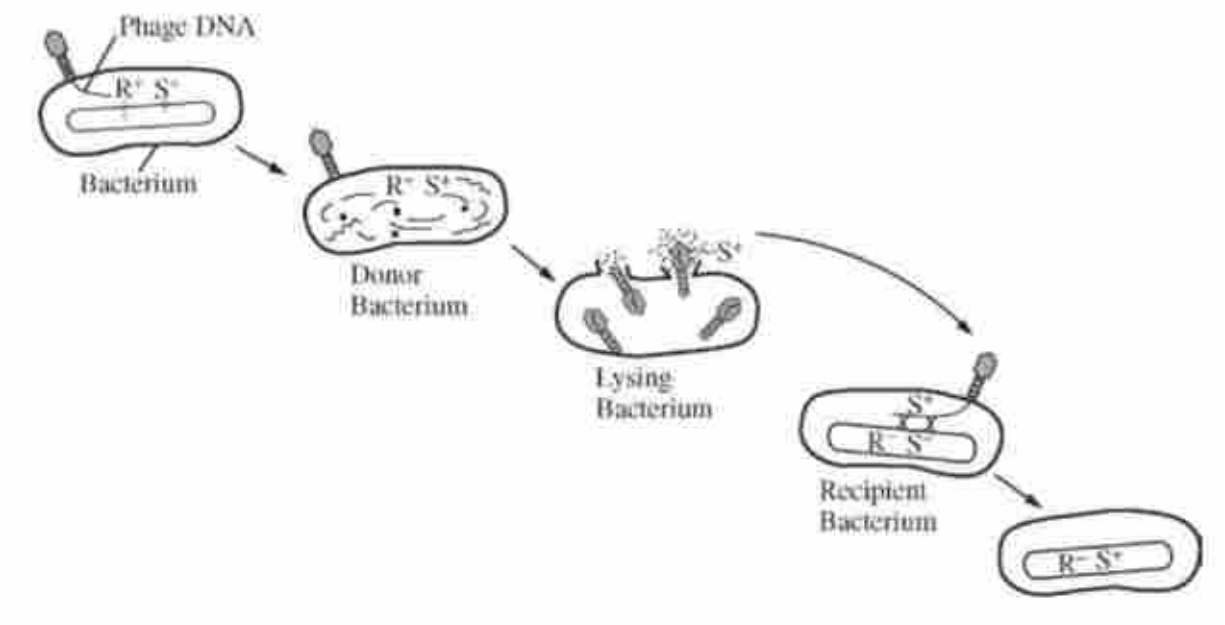
A The viruses enter host cells via endocytosis to evade the immune system.

B The viruses have a protein that accelerates viral replication.

C The viruses that are actively replicating are eliminated by the immune system.

D The viruses undergo rapid mutation.

14 The diagram shows several steps in the process of bacteriophage transduction in bacteria.



Which statement explains how genetic variation in a population of bacteria results from this process?

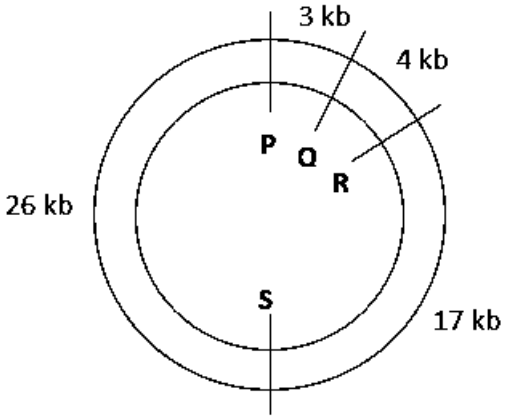
A Bacterial proteins transferred from the donor bacterium by the phage to the recipient bacterium recombine with genes on the recipient's chromosome.

B DNA of the recipient bacterial chromosome undergoes recombination with DNA introduced by the phage from the donor bacterium, leading to a change in the recipient's genotype.

C The phage infection of the recipient bacterium and the introduction of DNA carried by the phage cause increased random point mutations of the bacterial chromosome.

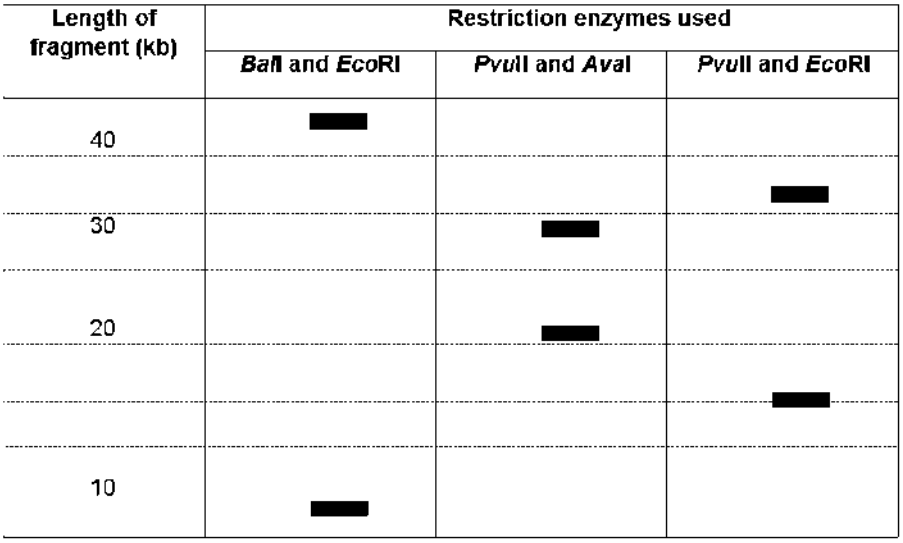
D The recipient bacterium incorporates the transduced genetic material coding for phage proteins into its chromosome and synthesizes the corresponding proteins.

15 The diagram shows a plasmid with the positions of four restriction sites P to S indicated.



Copies of the plasmid were cut using two different restriction enzymes at a time, and the resulting fragments were separated by gel electrophoresis.

The diagram shows the results following gel electrophoresis of three samples.



Which row correctly matches the four restriction enzymes to their respective restriction sites on the plasmid?

	P	Q	R	S
A	*Ava*I	*Eco*RI	*Pvu*II	*Bam*I
B	*Bam*I	*Ava*I	*Eco*RI	*Pvu*II
C	*Eco*RI	*Pvu*II	*Bam*I	*Ava*I
D	*Pvu*II	*Bam*I	*Ava*I	*Eco*RI

16 The statements are about the preparation and application of DNA libraries.

1 A cDNA library allows the study of the functions of introns of specific genes.

2 A genomic library enables detection of genes that, in the host, have no detectable level of expression.

3 Alternative splicing can be studied using a cDNA library.

4 The preparation of a genomic DNA library requires restriction enzyme, reverse transcriptase and DNA ligase.

Which statements are correct?

A 1 and 4 only

B 2 and 3 only

C 1, 2 and 4 only

D 2, 3 and 4 only

17 A sample of DNA was treated separately with two different restriction enzymes. The products of digestion were then run on a gel and stained with ethidium bromide.

Which of the following statements cannot account for the difference in the number of bands seen on the gel?

1 The two enzymes have active sites that are of different shapes.

2 One of the enzymes produces blunt ends while the other produces sticky ends.

3 Ethidium bromide binds with greater affinity to double stranded DNA than single stranded DNA.

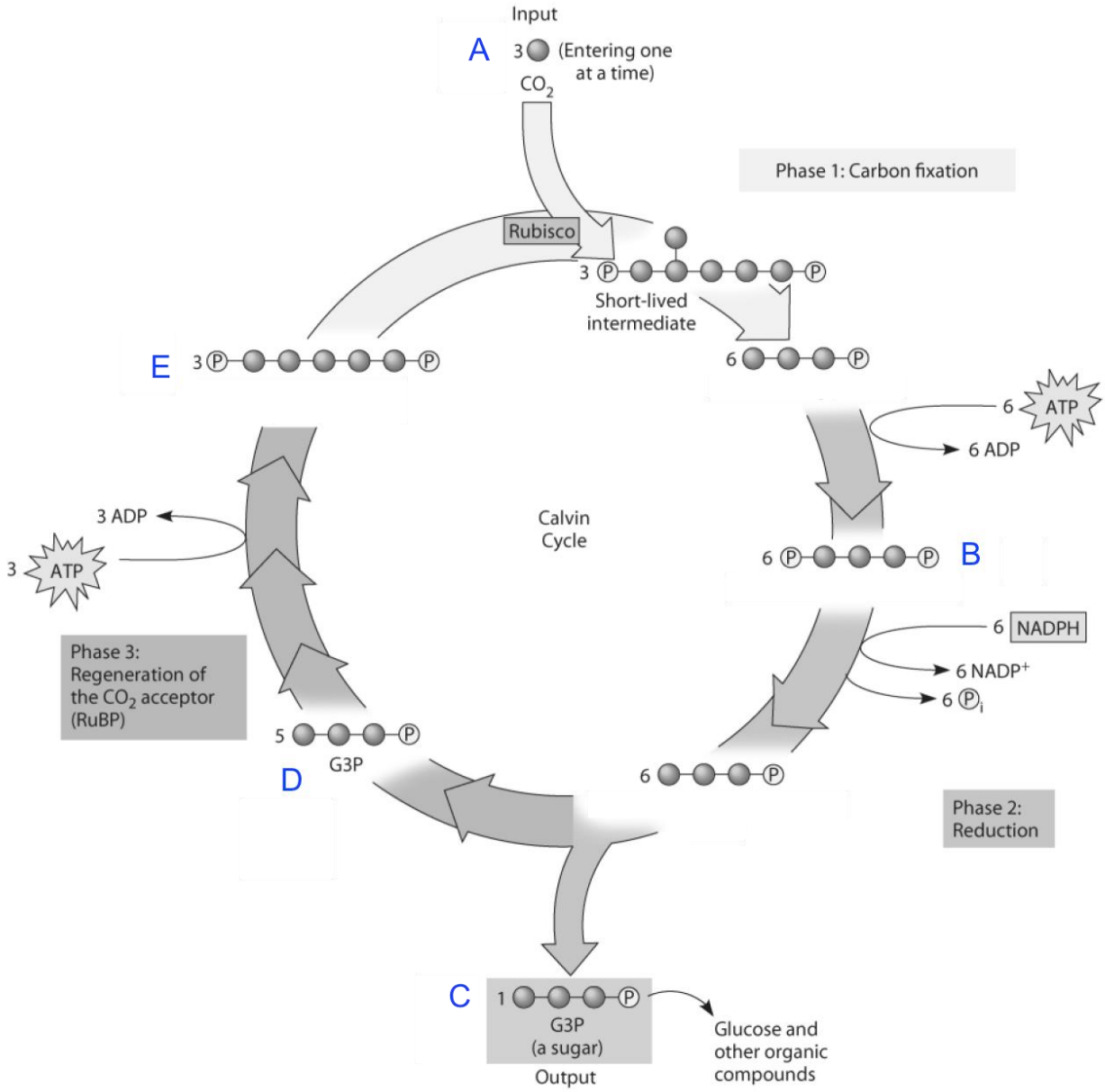
A 1 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

18 The diagram shows some molecules that are involved in the Calvin cycle.



If ATP used by a plant is labelled with radioactive phosphorus, in which molecules would the radioactivity be measurable after one "turn" of the Calvin cycle?

A A and B only

B A, C and D only

C B, D and E only

D B, C, D and E only

19 Which statement about the Krebs cycle is correct?

A Oxygen is used to oxidise the acetyl group carbons of acetyl-CoA in the Krebs cycle.

B Oxygen is not used in the Krebs cycle, so the cycle can occur in anaerobic conditions.

C The Krebs cycle produces the water that is formed during the complete oxidation of glucose.

D Three molecules of NADH and one molecule of $FADH_2$ are produced in one turn of the Krebs cycle.

20 Which statement correctly describes the role of lactate dehydrogenase?

A Lactate dehydrogenase catalyses the oxidation of pyruvate to lactate to regenerate NAD+.

B Lactate dehydrogenase catalyses the reduction of pyruvate to lactate to regenerate NAD+.

C Lactate dehydrogenase catalyses the oxidation of pyruvate to lactate to regenerate NADH.

D Lactate dehydrogenase catalyses the reduction of pyruvate to lactate to regenerate NADH.

21 In humans, hair colour is determined by the pigment produced by hair follicle cells. The genes determining pigment colour are found on chromosome 15.

Which statement is true?

A Chromosome 15 in liver cells also contains genes determining pigment colour.

B Chromosome 15 in liver cells contains genes that are different from that of chromosome 15 in hair follicle cells as liver cells do not produce hair.

C Hair follicle cells do not contain homologous chromosomes of chromosome 15 as the cells only undergo mitosis.

D Homologous chromosomes of chromosome 15 in hair follicle cells contain the same genes but at different loci.

22 A strain of toad has only one nucleolus in the nucleus of each cell instead of the usual two. When such toads are mated, approximately one quarter of the offspring have two nucleoli per nucleus, one half have one nucleolus per nucleus, and one quarter have no nucleoli at all.

What is the most likely explanation of these results?

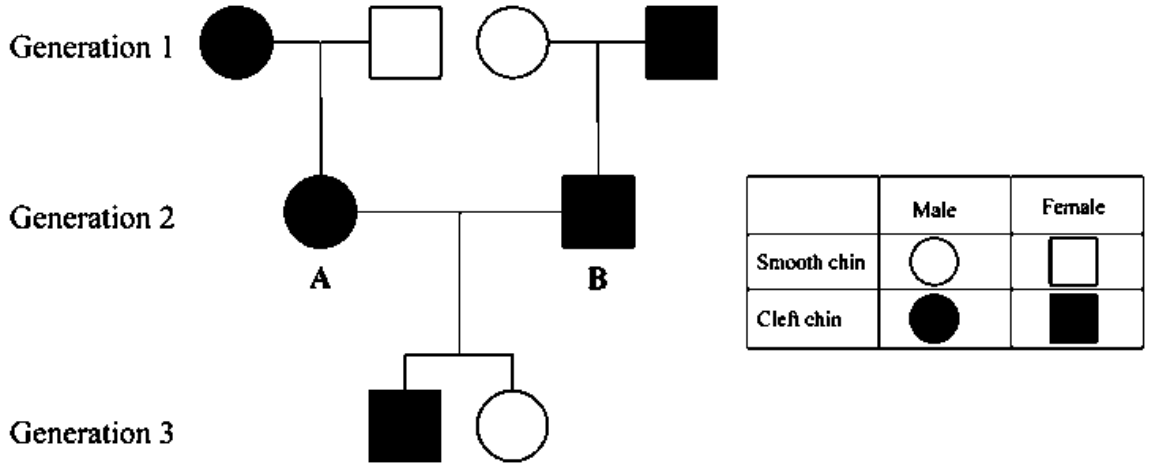
A The allele for the inheritance of two nucleoli per nucleus is dominant.

B The allele for the inheritance of two nucleoli per nucleus is recessive.

C The possession of one nucleolus per nucleus is due to the effect of crossing over.

D The possession of one nucleolus per nucleus is due to the heterozygous condition.

23 The pedigree diagram shows the chin types in a family.



Which statement correctly describes the cleft chin allele and the smooth chin allele?

A Both alleles are codominant.

B Both alleles are linked on the X chromosome.

C The cleft chin allele is dominant over the smooth chin allele.

D The smooth chin allele is epistatic to the cleft chin allele.

24 The rate of divergence of different proteins is shown in the table below.

Protein	Amino acid substitutions per site per billion years
fibrinopeptide	8.3
lysozyme	2.0
α-globin	1.2
insulin	0.44
cytochrome *c*	0.3
histone H4	0.01

What may be concluded from the data about the neutral theory of molecular evolution?

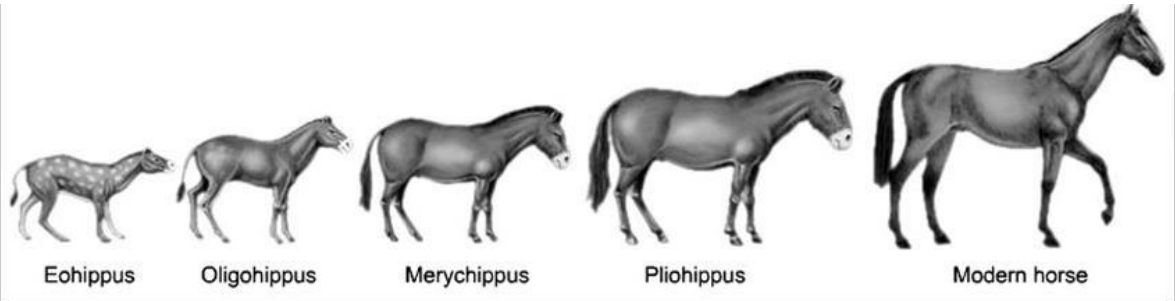
A All of these proteins are found in a common ancestor of all Earth's known living organisms before they started evolving at the molecular level.

B Genetic drift could play a greater role in the evolution of the gene for fibrinopeptide resulting in greater number of amino acid substitutions per site per billion years.

C Some essential proteins allow for fewer amino acid substitutions per site than others in order to maintain the same function.

D The rate of neutral mutations that result in the amino acid substitutions for all proteins is the same.

25 The diagram suggests the evolution of horses beginning from the Eophippus 58 million years ago.



Fossil records show that the ancestor of the modern horse is believed to have had relatively short legs. According to Darwinian views, what best explains the evolution of horses?

A acquired characteristics

B directional selection

C disruptive selection

D stabilising selection

26 When organochlorine insecticides such as DDT were in widespread use, mosquitoes in malarial regions developed resistance more rapidly than houseflies in Britain.

What could account for the difference in the rate of development of resistance against organochlorine insecticides?

A More insecticides were used in Britain.

B More insecticides were used in malarial regions.

C Mosquitoes have fewer random mutations when exposed to insecticides.

D Mosquitoes have more random mutations when exposed to insecticides.

27 Which process involves one stem cell giving rise to two distinct daughter cells: one copy of the original stem cell as well as a second daughter cell programmed to differentiate into a non-stem cell?

A asymmetric replication

B differentiation

C potency

D self renewal

28 Which is not a source for stem cells?

A bone marrow

B early embryos

C egg cells

D umbilical cord blood

29 Which is a reason why gene therapy involving the delivery of a normal allele of a proto-oncogene is not likely to be successful in the treatment of cancer?

A The proto-oncogene has many alleles controlling the production of the normal protein.

B The delivery of the normal allele of the proto-oncogene is likely to cause the cell cycle to stop.

C The normal allele for the proto-oncogene is not expressed in the presence of the dominant mutated allele.

D The normal allele of the proto-oncogene codes for a protein that will allow the formation of a tumour.

30 The adenoviral vector is used to introduce the normal CFTR allele into patients with cystic fibrosis (CF). The main procedures involved in the treatment are listed below.

- Genes for replication are removed from the vector to prevent respiratory infections caused by adenoviruses.
- Genes that causes the vector to elicit immune response are removed from the vector.
- After treatment, patients are screened to ensure that replication of adenoviral vectors is not occurring in their system.
- Patients are screened to ensure that shedding airway cells contain the normal CFTR allele

What limits the effectiveness of this type of gene therapy for CF?

A The adenoviral vector always causes infections in young and old patients.

B The adenoviral vector delivers the normal CFTR allele to the airway cells that are gradually shed.

C The adenoviral vector multiplies and make more copies of the normal CFTR allele.

D The adenoviral vector will cause immune response in patients undergoing this treatment.

31 Which of the following is/are reason(s) for scientists to employ the method of plant cloning?

1 introduction of animal genes into plants
2 create large changes at a rapid pace
3 large scale production of pharmaceutical drugs
4 selective breeding is too slow

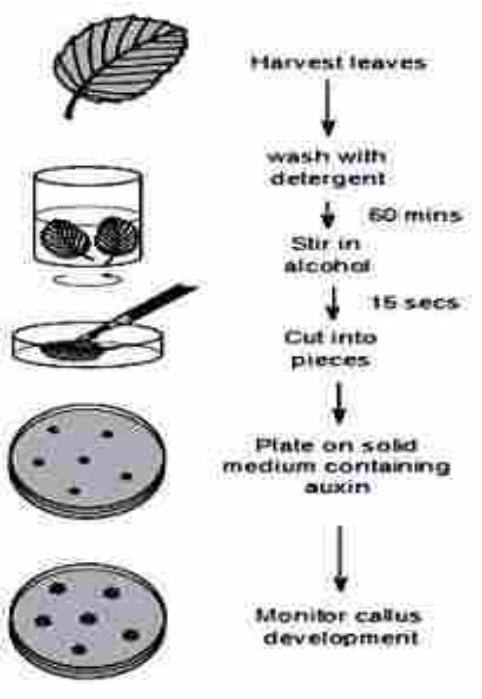
A 3 only

B 1, 3 and 4 only

C 2, 3 and 4 only

D 1, 2, 3 and 4

32 Callus tissue is produced using leaves by the technique shown in the diagram below. Using this, a student investigated the effect of two different concentrations of auxin on the volume of callus material produced. The table shows the results obtained over five days.



time (day)	volume of callus tissue (cm^3)	
	low concentration of auxin added	high concentration of auxin added
0	1.0	1.0
1	1.3	1.7
2	1.9	4.1
3	3.0	8.3
4	3.9	10.6
5	5.4	12.9

Which of the following statements about the experiment is / are true?

1 The leaves are disinfected and sterilised by washing with detergent and stirring in alcohol.

2 The leaves are wounded in order for callus tissue to form.

3 The concentration of auxin affects the volume of callus tissue formed.

4 Continued subculturing at three- to four-week intervals of small cell clusters taken from callus tissue can maintain the callus cultures for long periods of time.

A 3 only

B 1 and 3 only

C 1, 2 and 3 only

D 1, 2, 3 and 4

33 Which statements are possible issues of concern over the creation of genetically modified farmed animals?

1 Genetic engineering may result in the creation of new proteins that are harmful to the organisms that produce or consume them.

2 Cross species gene transfer may compromise the genome integrity of the species involved.

3 Over production of certain gene products may cause undue stress to the genetically modified farmed animals.

4 Some genetically modified food products may not be acceptable to certain groups of people.

A 1 and 4 only

B 2 and 3 only

C 1, 3 and 4 only

D 1, 2, 3 and 4

34 Scientists are concerned about the escape of genetically modified mosquitoes into the wild.

What is the most likely reason for this concern?

A The genetically modified mosquitoes may not survive in the wild.

B The mutation rate of the genetically modified mosquitoes will increase.

C The genetically modified mosquitoes may replace the wild mosquitoes population.

D The growth rate of the genetically modified mosquitoes will be affected.

35 Which statement best describes homeostasis?

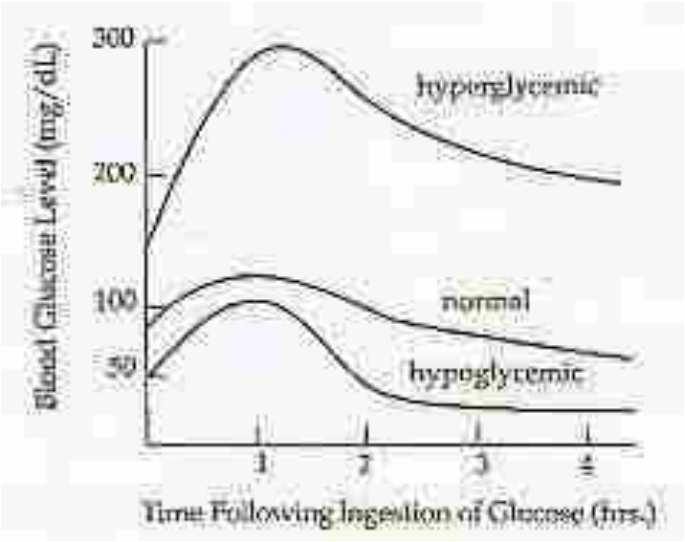
A achieving independence from fluctuating internal conditions

B altering the external environment to accommodate the body's needs

C keeping the body in a fixed and unaltered state

D maintaining a near-constant internal environment

36 The graph shows the blood glucose levels for normal, hyperglycaemic and hypoglycaemic individuals. The values in the graph represent averaged data from 10 subjects for each condition.



A glucose tolerance test was administered to evaluate the glucose levels in the blood of experimental subjects. Subjects were asked to fast for 12 hours before they were administered glucose at time 0 and then had blood samples drawn to assess the blood glucose levels. Glucose concentration was monitored every 30 minutes for a total of five hours. If the blood concentration exceeded 130 mg / dl, the subject was considered hyperglycaemic. Typically, hyperglycaemic patients exhibit symptoms such as thirst, increased appetite, and weight loss.

Why would a physician prescribe a diet consisting of several small meals to hypoglycaemic individuals?

A to cause the liver to convert more glucose to glycogen

B to cause the pancreas to release more glucagon

C to maintain a steady blood glucose concentration

D to rapidly decrease the blood glucose concentration

37 What is the first event that happens to insulin receptor after binding to insulin?

A Binding of insulin activates the receptor's cytosolic tyrosine kinase domain.

B Binding of insulin causes the receptors to dimerise.

C Binding of insulin causes the receptor to recruit a tyrosine kinase from the cytosol.

D Binding of insulin causes tyrosines in the receptor's C-terminal tail to become phosphorylated.

38 Which enzyme is activated by cyclic AMP in the signal transduction pathway after glucagon binds to its receptor?

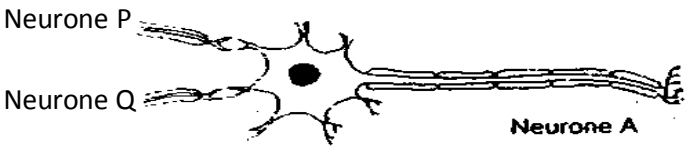
A adenylyl cyclase

B phosphorylase kinase

C protein kinase A

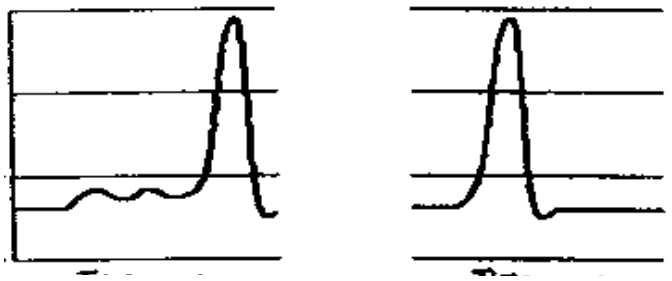
D protein kinase B

39 The diagram shows the effect of impulses from neurones P and Q on the production of an action potential in neurone A.



Action potentials in neurones P and Q

Membrane potential in neurone A / mV



Which of the following best describes X and Y?

	X	Y
A	EPSP	IPSP
B	IPSP	EPSP
C	spatial summation	temporal summation
D	temporal summation	spatial summation

40 Certain drugs act at the synapses and affect the action of neurotransmitters.

The table shows the effects of four different drugs.

drug	effect
1	competes with acetylcholine at the receptor sites
2	inhibits the enzyme acetylcholinesterase
3	inhibits the opening of voltage-gated sodium ion channels
4	uncontrolled release of acetylcholine

Which combination of drugs will reduce the possibility of the formation of an excitatory postsynaptic potential?

A 1 and 3

B 2 and 4

C 1, 3 and 4

D 2, 3 and 4

- **End of paper -**

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

BIOLOGY

Paper 1 Multiple Choice

9648/01

15 September 2016

1 hour 15 minutes

ANSWERS

1	C	11	C	21	A	31	D
2	B	12	B	22	D	32	D
3	B	13	C	23	C	33	D
4	A	14	B	24	B	34	C
5	D	15	B	25	B	35	D
6	A	16	B	26	B	36	C
7	B	17	C	27	A	37	B
8	A	18	D	28	C	38	C
9	A	19	D	29	C	39	D
10	D	20	B	30	B	40	A

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME

BIOLOGY CLASS 2bi2____ / 2IPbi2__

REGISTRATION NUMBER

BIOLOGY

9648/02

Paper 2

26 August 2016

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and Biology class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Sections A - D
Answer **all** questions in the spaces provided on the question paper.

Section E
Answer any **one** question on the answer paper provided.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	(Total: 23)
1	/ 12
2	/ 11
Section B	(Total: 19)
3	/ 7
4	/ 12
Section C	(Total: 19)
5	/ 12
6	/ 7
Section D	(Total: 19)
7	/ 7
8	/ 12
Section E	(Total: 20)
9 or 10	/ 20
Total	**/ 100**

This document consists of **24** printed pages.

Section A

Answer **all** the questions in this section.

1 Many bacteria can digest cellulose using a group of enzymes called cellulases. Cellulases **A** and **T** were extracted from two different bacteria, *Agrobacterium tumefaciens* and *Thermotoga maritima*, respectively.

Fig. 1.1 shows the results of an investigation into the effect of temperature on the activity of each enzyme.

L represents the lowest temperature at which activity of each enzyme was detected.
H represents the highest temperature at which activity of each enzyme was detected.

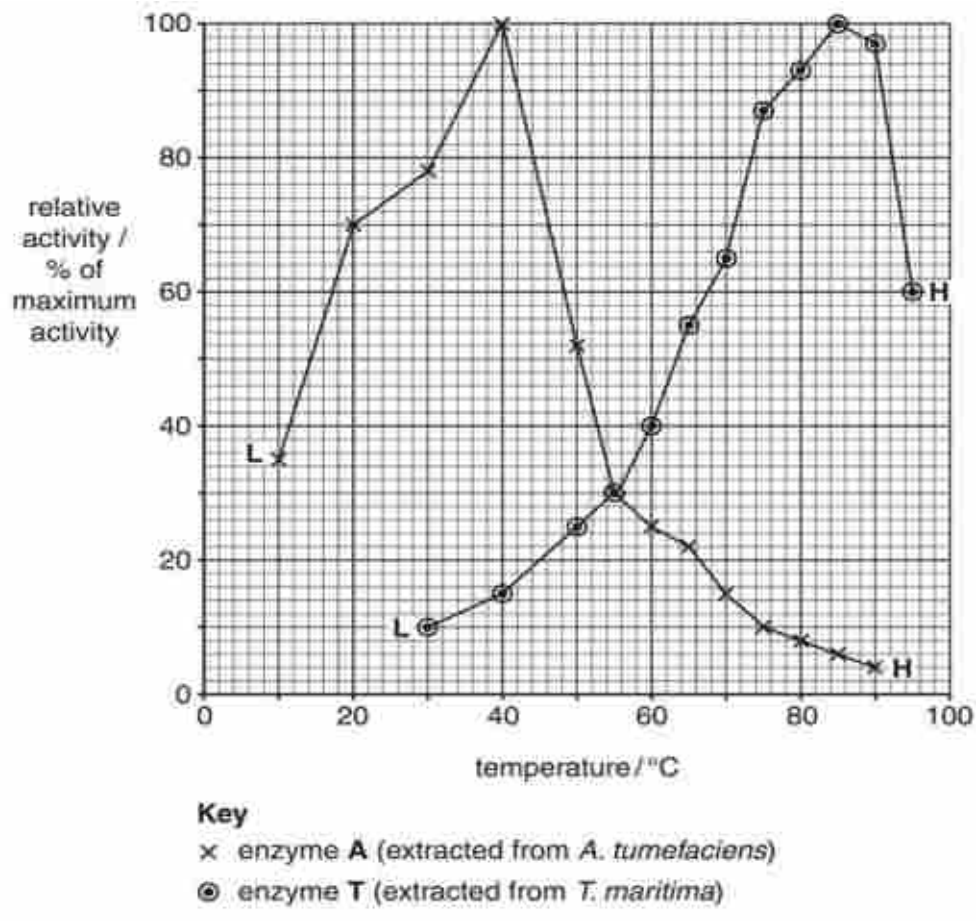


Fig.1.1

(a) With reference to Fig. 1.1, describe two differences in the results for the two enzymes, **A** and **T**. [2]

.....

.....

.....

[2]

(b) With reference to Fig. 1.1, explain the effect of increasing temperature on the relative activity of enzyme **T**.

[3]

(c) Suggest a structural feature of enzyme **T**, which helps to explain the results obtained in the investigation.

[2]

Fig. 1.2 shows the structure of small sections of DNA and messenger RNA (mRNA) in the nucleus of *Agrobacterium tumefaciens* during transcription of the gene coding for cellulase.

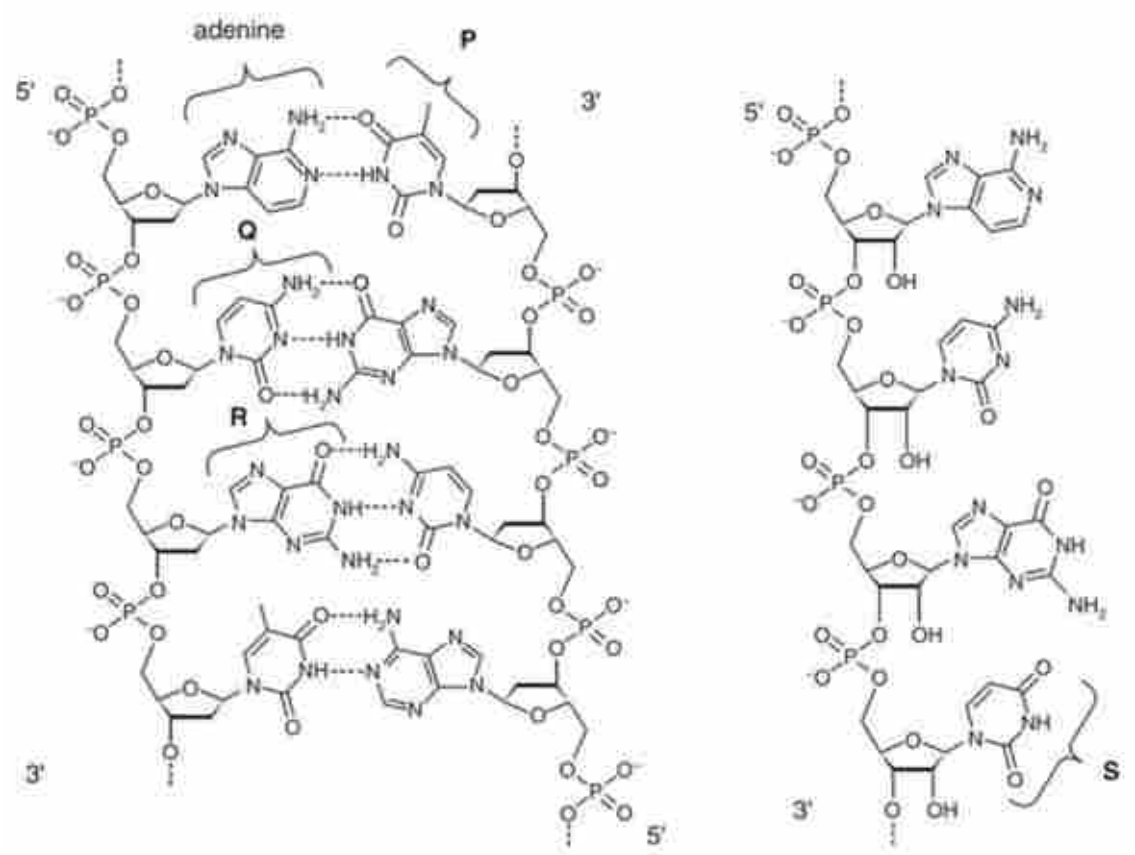


Fig. 1.2

(d) Name the bases **P** to **S**.

P: .....

Q: .....

R: .....

S: ..... [2]

(e) Describe how messenger RNA coding for cellulase is synthesised in *Agrobacterium tumefaciens*.

[3]

[Total: 12]

2 Fig. 2.1 shows the main steps involved in the synthesis of preproinsulin to insulin in the pancreatic β-cell. The preproinsulin is synthesised into the lumen of organelle **A** as proinsulin.

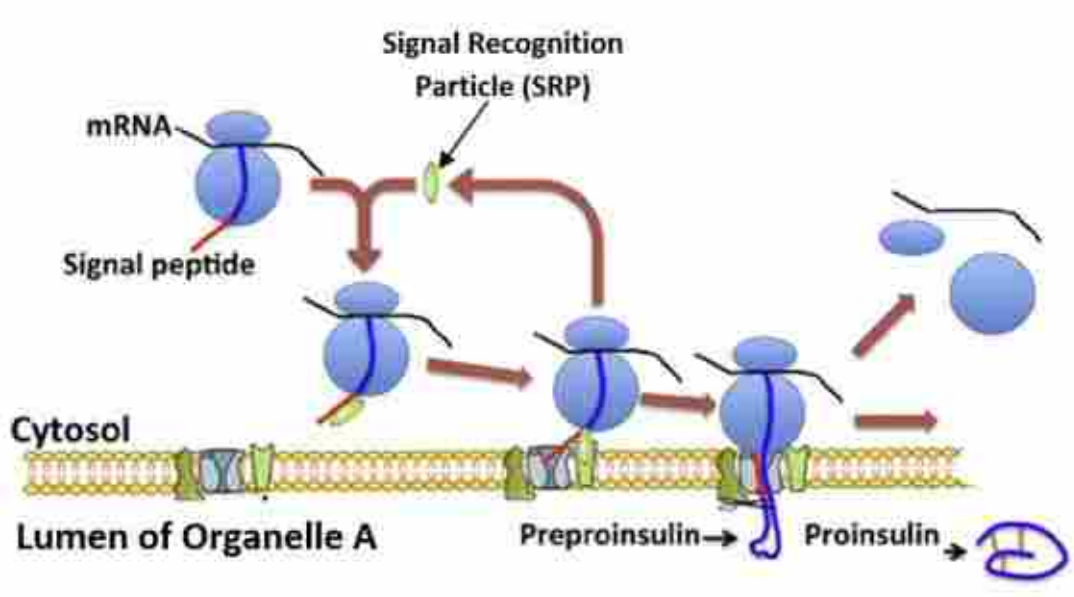


Fig. 2.1

The proinsulin is then be transported to organelle **B** where it is further processed to form insulin.

Fig. 2.2 shows the conversion of proinsulin to insulin in organelle **B**.

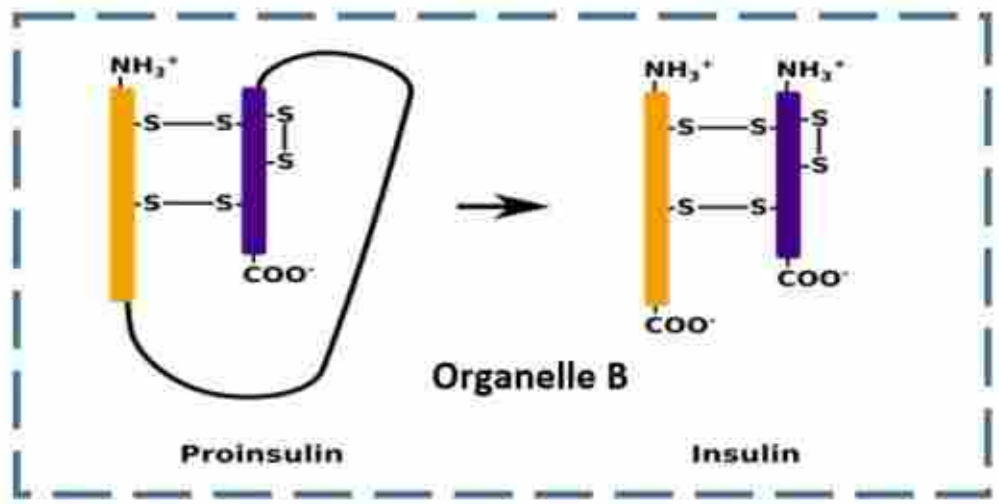


Fig. 2.2

(a) Name the organelles labelled **A** and **B**.

organelle **A:** .....

organelle **B:** ..... [1]

(b) State the role of rRNA in insulin synthesis.

.....

.....

.....

.....

..... [2]

(c) Insulin is released by pancreatic β-cell. Outline the route taken by proinsulin.

.....

.....

.....

.....

..... [2]

The synthesis of insulin is regulated at the transcriptional levels in β-cell.

Fig. 2.3 shows the binding of three β-cell-specific transcriptional factors, Pdx-1, MafA and NeuroD1 E47 in response to high glucose levels in β-cell.

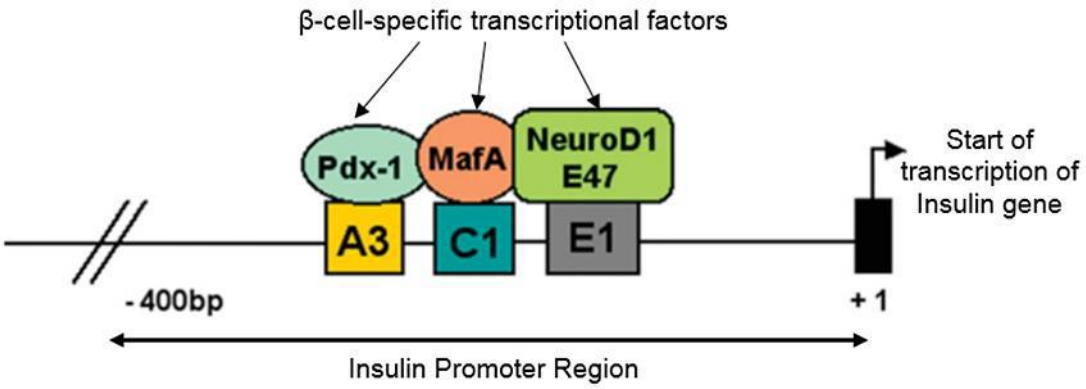


Fig. 2.3

(d) Explain how β-cell-specific transcriptional factors will lead to high level of insulin gene expression.

[2]

(e) It has been found that insulin promoters differ widely in efficiency among individuals. Strong promoters cause frequent initiations of transcription while weak promoters have low frequency of initiations of transcription. Explain what may have caused the difference in efficiency of the insulin promoters.

[2]

(f) Explain why gene mutations do not always produce mutated insulin protein whereas mutations of the splicing sites involved in RNA splicing will produce mutated insulin.

[2]

[Total: 11]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section B
Answer **all** the questions in this section.

3 Fig. 3.1 shows the life cycle of a water flea.

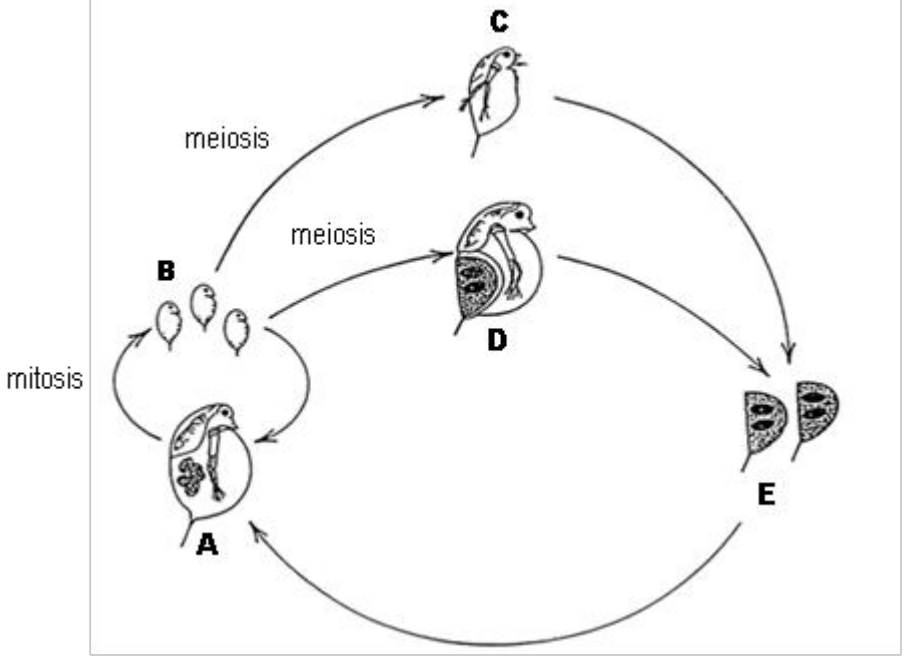


Fig. 3.1

In favourable conditions, all the animals in a population are females (**A**). These females produce eggs by mitosis, which develop into young females (**B**) without being fertilized. In unfavourable conditions, eggs produced by meiosis develop directly without fertilization into either males (**C**) or females (**D**). The eggs produced by the females (**D**) are fertilized by the sperms from the males (**C**), then released in protective egg cases (**E**) which enable them to survive unfavourable conditions. When favourable conditions return, these eggs develop back into females (**A**).

(a) The females at stage **A** of the life cycle have 18 chromosomes.

Complete the table to show the number of chromosomes at the other stages of the life cycle.

stage of life cycle	chromosome number
A	18
B	
C	
D	
E	

[1]

(b) Explain why the eggs from **D** and the sperms from **C** must be produced by mitosis.

[2]

(c) Explain why females **A**, developed from fertilized eggs **E**, are genetically different from each other.

[3]

(d) Give an example of a favourable condition in which females will develop from eggs formed via mitosis.

[1]

[Total: 7]

4 Cattle were found to have three different coat colours: brown, white and roan. Roan cattle have both brown and white patches. When two roan cattle were crossed, a ratio of 1:2:1 was obtained for brown, roan and white coat colour respectively. A separate gene on X chromosome in cattle code for a disease called Agnathia. The absence of a normal allele causes a deformity in the lower jaw.

(a) Construct a genetic diagram to show the expected ratio when brown carrier cows are crossed with normal jawed white bulls.

[5]

(b) State the mode of inheritance of the two traits. Explain how you arrive at your answer.

.....

.....

.....

..... [2]

(c) When a geneticist carried out a cross between brown carrier cows and normal jawed white bulls, he obtained the following phenotypes.

normal jawed, roan cows	55
normal jawed, roan bulls	37
deformed jawed, roan bulls	28

Fig. 4.1 shows the table of probabilities.

df	probability				
	0.10	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.69	13.28	18.47
5	9.24	11.07	13.39	15.09	20.52

Fig. 4.1

The formula for the chi-square statistic used in the chi square test is as follows:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

where O = observed value;
E = expected value.

With reference to Fig. 4.1, carry out a chi-square test to support your explanation in (b). Show your workings clearly in the space below.

[3]

(d) In some cases, the environment may affect the phenotype.

Give one named example to illustrate such an environmental effect.

.....

.....

.....

..... [2]

[Total: 12]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section C
Answer **all** the questions in this section.

5 Hepatitis C virus (HCV) is an enveloped, positive-strand RNA virus within the family Flaviviridae. HCV undergoes reproductive cycles similar to other enveloped viruses, such as influenza virus and dengue virus.

Fig. 5.1 shows a model of a HCV particle.

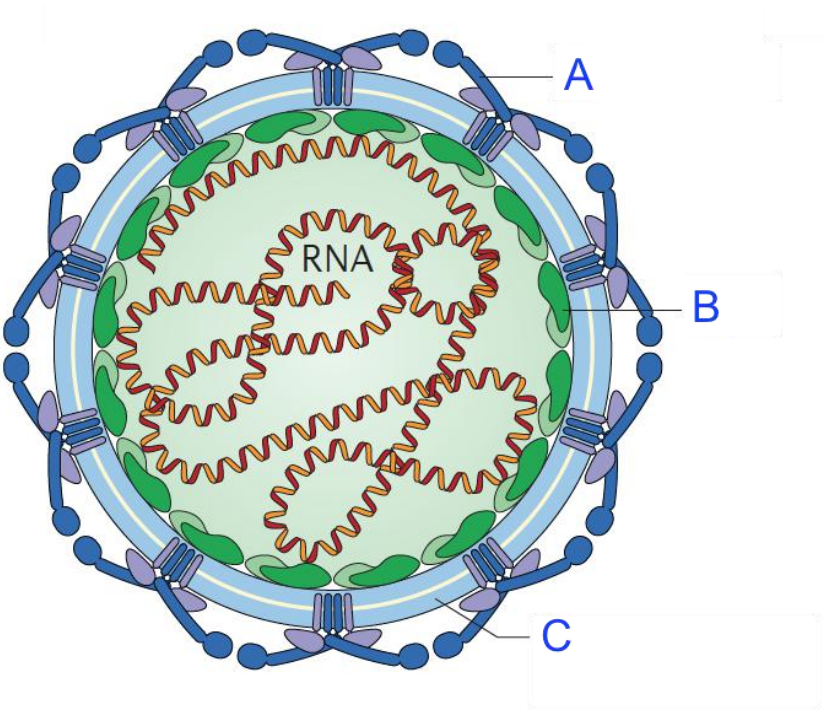


Fig. 5.1

(a) Identify the labelled structures **A**, **B** and **C**.

A: .....

B: .....

C: ..... [2]

(b) Explain why HCV is considered an obligate parasite.

.....

.....

..... [2]

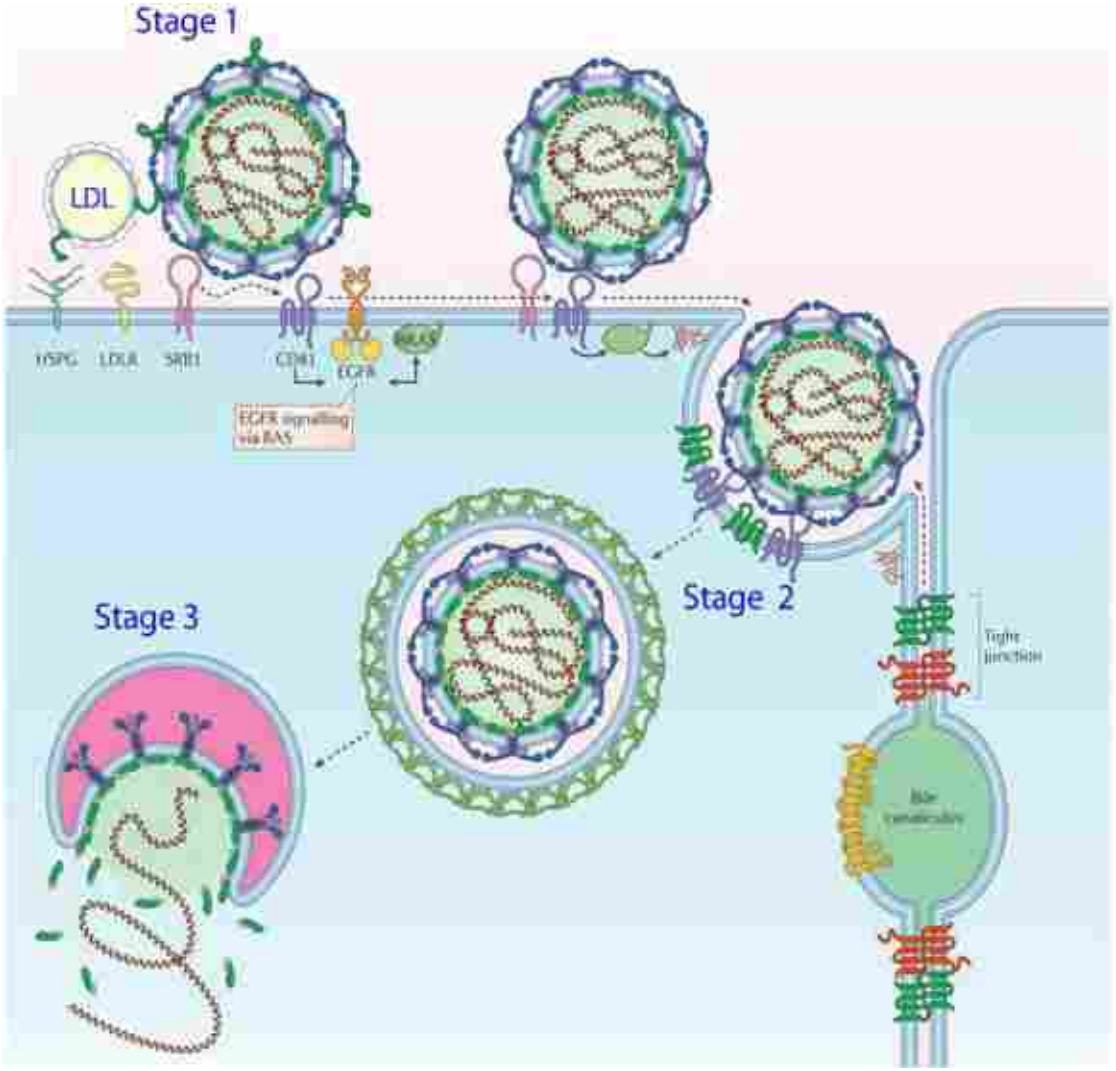


Fig. 5.2

(c) With reference to all labelled stages in Fig. 5.2, describe how HCV gains entry into its host cell.

.....

.....

.....

.....

.....

..... [3]

Fig. 5.3 shows the positive-strand RNA genome of HCV genome.

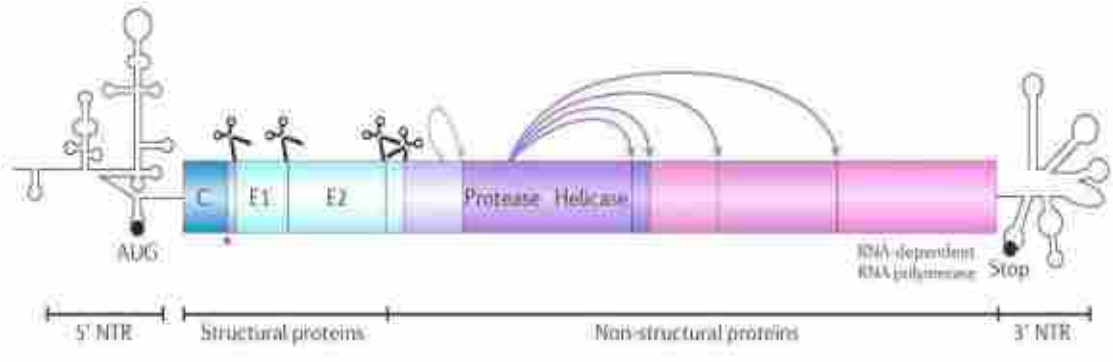


Fig. 5.3

(d) With reference to Fig. 5.3, describe the role of HCV genome in the infection process.

[2]

Hepatitis B virus (HBV) and HCV are known to be two major causative agents of hepatocellular carcinoma. Studies have shown that HBV DNA can be integrated during the early stages of infection. The integration of viral DNA is associated with deletions in portions of the host chromosomes. Many of these chromosomal segments contain known genes such as p53.

(e) Explain how HBV infection may lead to cancer.

[3]

[Total: 12]

6 **(a)** Human newborns and hibernating mammals contain large amounts of brown adipose tissue ('body fat').

Fig 6.1 shows the electron micrograph of a brown adipocyte. Brown adipocytes are characterised by the presence of numerous vacuoles and organelle **X** throughout the cell.

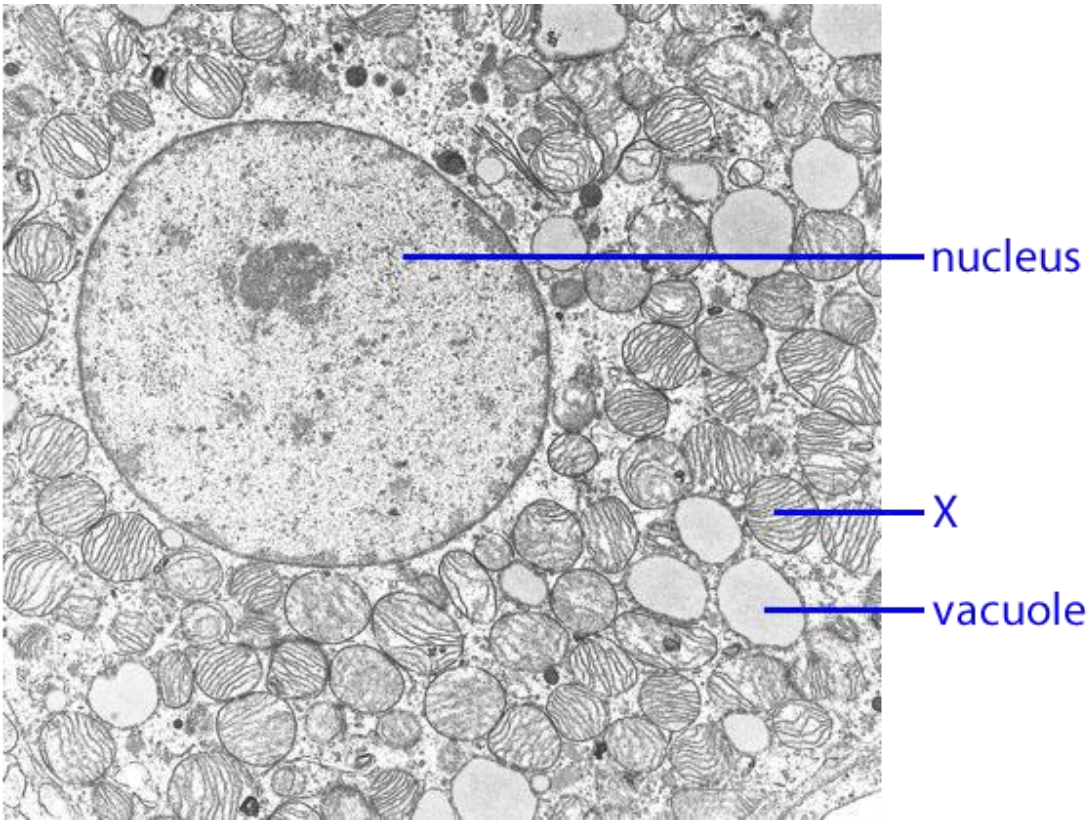


Fig. 6.1

(i) Identify organelle **X**.

.....[1]

(ii) Suggest the role of the numerous vacuoles found in brown adipocytes.

.....[1]

(b) Fig. 6.2 shows the schematic representation of a series of protein complexes found on the inner membrane of organelle **X**.

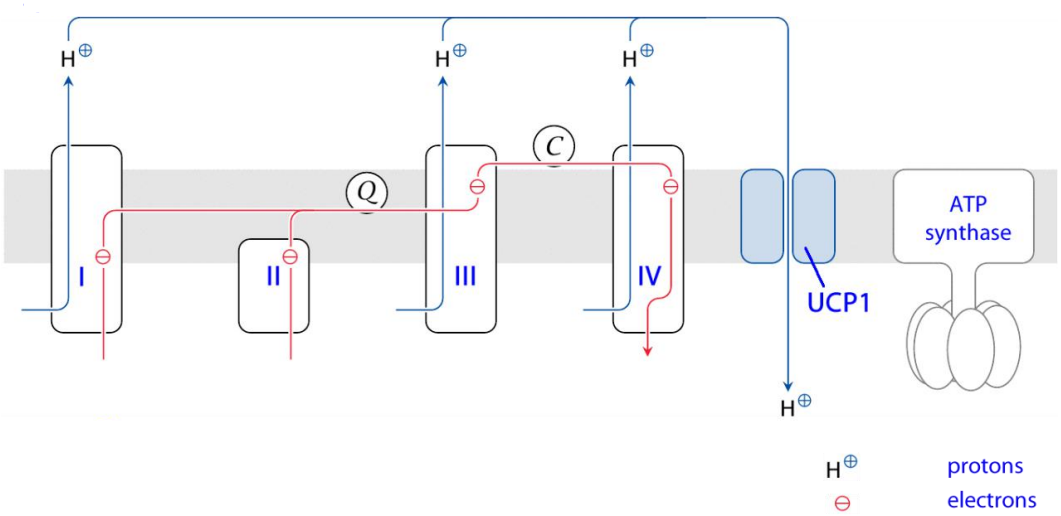


Fig. 6.2

(i) Oxygen is required to sustain the process illustrated in Fig. 6.2.
With reference to Fig. 6.2, describe the role played by oxygen.

.....

..... [1]

(ii) Brown adipocytes contain a unique protein, UCP1, which is not found in organelle **X** in any other cell type.

Evaluate the impact of UCP1 on the normal functioning of the process illustrated in Fig. 6.2 and suggest the physiological significance of brown adipose tissue.

.....

.....

.....

..... [2]

(c) In other cell types, NADH and $FADH_2$ are used to drive ATP synthesis by ATP synthase. Using relevant information from Fig. 6.2, suggest and explain why more ATP is produced from NADH.

.....

.....

.....

..... [2]

[Total: 7]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section D

Answer **all** the questions in this section.

7 The cardiac action potential is a specialised action potential with unique properties necessary for the electrical conduction system of the heart. The cardiac muscle cells share many things in common with nerve cells.

Fig. 7.1 shows the five phases of a cardiac action potential. Each of which is characterised with their respective changes in membrane potential.

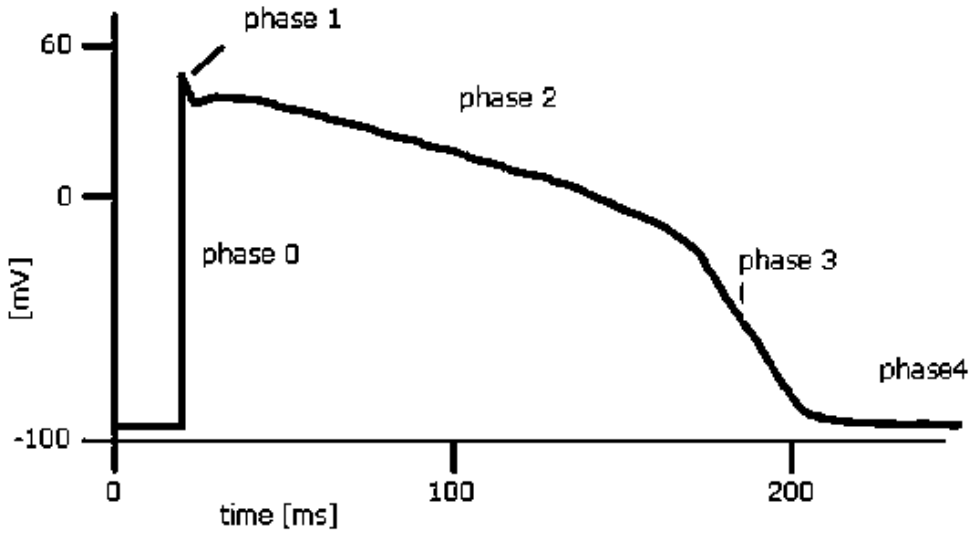


Fig. 7.1

The table shows the relative concentrations of ions inside and outside of the cardiac muscle cells.

element	ion	extracellular	intracellular
sodium	Na^+	135 – 145	10
potassium	K^+	3.5 – 5.0	155
chloride	Cl^-	95 – 110	20 – 30
calcium	Ca^{2+}	2	10^{-4}

(a) Estimate the resting potential for the cardiac action potential shown in Fig. 7.1.

.....

[1]

(b) Using the information from the table, explain how the resting potential can be produced in the heart muscles using sodium and potassium ions.

[3]

(c) Compare phase 2 of the action potential of a cardiac muscle cell with that of a nerve cell.

[1]

(d) Cardiac arrhythmia refers to any abnormal electrical activity in the heart. As a result, the heart may beat too fast. Calcium channel blockers such as Verapamil are often used to treat this condition.

Suggest and explain the action of Verapamil in controlling this symptom of arrhythmia.

[2]

[Total: 7]

8 The table shows the amino acid differences in the cytochrome b protein between various vertebrates.

	Human	Elephant	Platypus	Ostrich	Starling	Crocodile	Lungfish	Coelacanth	Goldfish	Shark
Human		26	40	43	41	47	83	70	68	71
Elephant			45	45	48	50	84	72	63	74
Platypus				54	52	51	89	74	70	76
Ostrich					26	36	91	75	68	73
Starling						47	91	77	67	70
Crocodile							85	78	70	77
Lungfish								90	94	86
Coelacanth									83	78
Goldfish										88
Shark										

Fig. 8.1 shows the phylogenetic tree based on differences between the cytochrome b proteins.

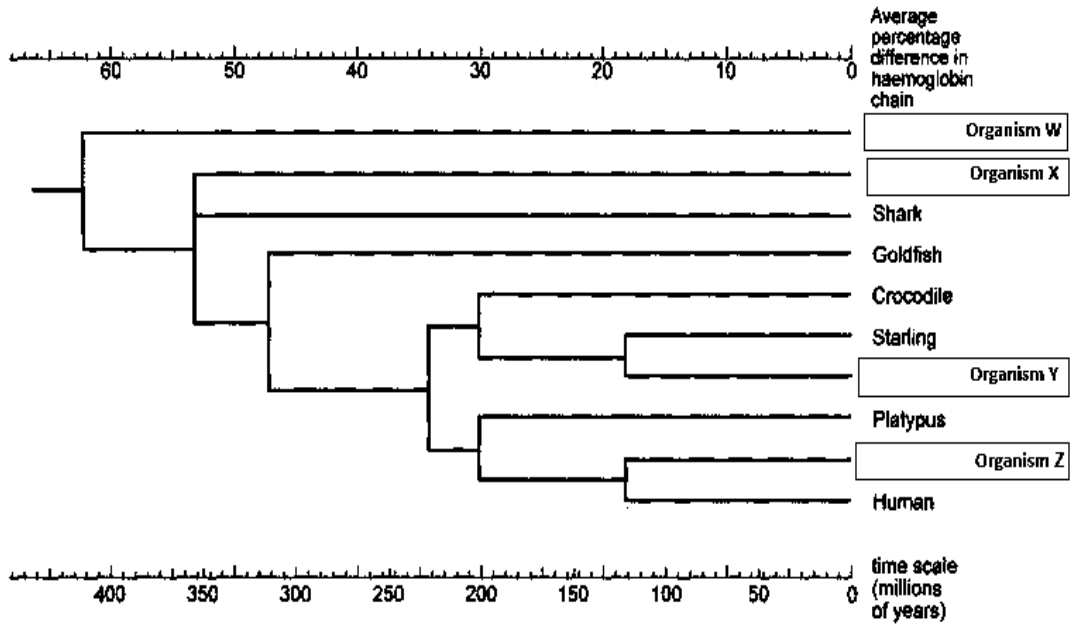


Fig. 8.1

(a) Using information from the table and Fig. 8.1, identify organisms **W** to **Z**.

W: .....

X: .....

Y: .....

Z: ..... [2]

(b) Explain how differences in amino acid sequences in the cytochrome b chain allow the establishment of the phylogenetic tree.

[3]

(c) Explain the difference between classification and phylogeny.

[2]

(d) Suggest why homology still features prominently in evolutionary studies despite the advantages that molecular evidence can confer.

[2]

(e) Explain the role of neutral mutations in evolutionary studies.

[3]

[Total: 12]

Section E

Answer **one** question.

Write your answers on the separate answer paper provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

9 **(a)** Compare the role of nervous system and endocrine system as communication systems within organisms. [6]

(b) Explain the meaning of the term homeostasis with specific reference to the control of raised blood glucose concentration in humans. [8]

(c) Describe the cell signalling pathway that glucagon initiates in order to regulate blood glucose concentration. [6]

[Total: 20]

10 **(a)** Compare the structural and regulatory genes in prokaryotes. [6]

(b) Explain the roles of the operator and activator binding site in the *lac* operon. [8]

(c) Describe how the molecular structure of phospholipids is related to their function in the plasma membrane. [6]

[Total: 20]

- End of paper -

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME **ANSWERS**

BIOLOGY CLASS 2bi2____ / 2IPbi2__ REGISTRATION NUMBER

BIOLOGY 9648/02

Paper 2 **26 August 2016**

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and Biology class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Sections A - D
Answer **all** questions in the spaces provided on the question paper.

Section E
Answer any **one** question on the answer paper provided.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	(Total: 23)
1	/ 12
2	/ 11
Section B	(Total: 19)
3	/ 7
4	/ 12
Section C	(Total: 19)
5	/ 12
6	/ 7
Section D	(Total: 19)
7	/ 7
8	/ 12
Section E	(Total: 20)
9 or 10	/ 20
Total	**/ 100**

This document consists of **28** printed pages.

Section A

Answer **all** the questions in this section.

1 Many bacteria can digest cellulose using a group of enzymes called cellulases. Cellulases **A** and **T** were extracted from two different bacteria, *Agrobacterium tumefaciens* and *Thermotoga maritima*, respectively.

Fig. 1.1 shows the results of an investigation into the effect of temperature on the activity of each enzyme.

L represents the lowest temperature at which activity of each enzyme was detected.
H represents the highest temperature at which activity of each enzyme was detected.

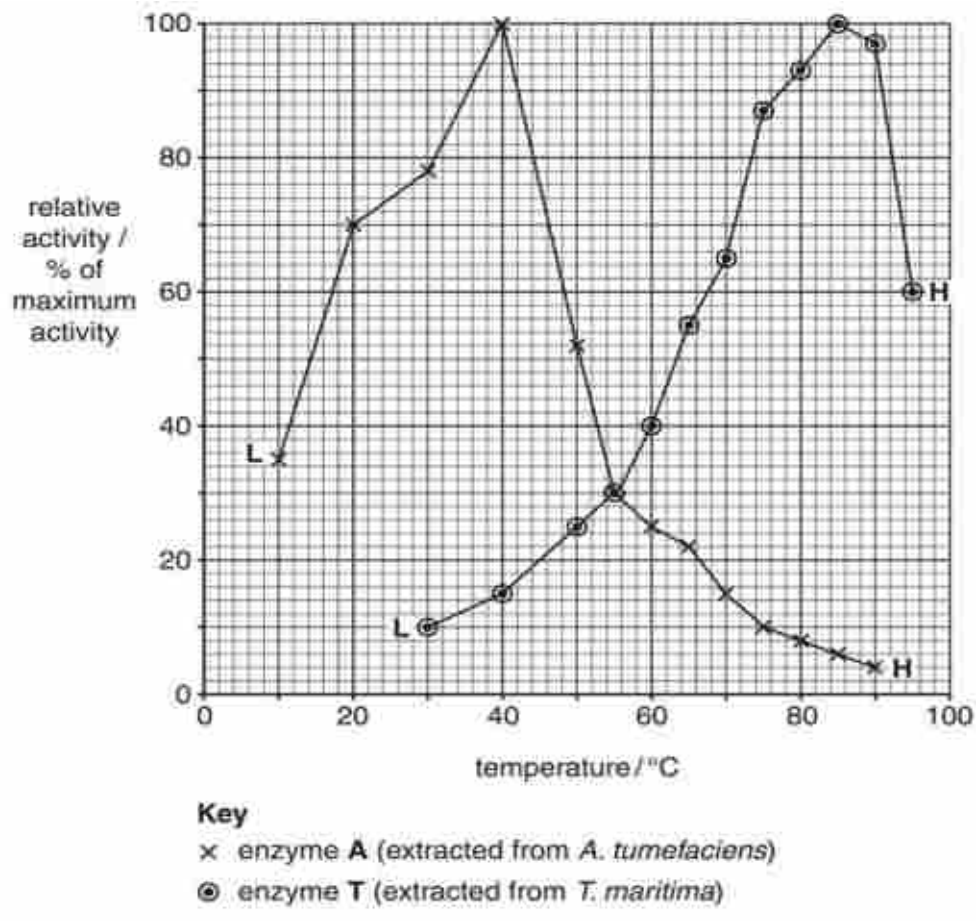


Fig.1.1

(a) With reference to Fig. 1.1, describe two differences in the results for the two enzymes, **A** and **T**. [2]

1. **Optimum temperature for enzyme A (40°C) is lower than that for enzyme T (85°C).**
   (Accept: "enzyme A optimum temperature is lower than enzyme T by 45 °C")
   (Accept: "maximum activity of enzyme A is at a lower temperature than T)

2. **Temperature range for enzyme A (10–90°C / spans 80°C range) is greater than that for enzyme T (30-95°C / spans 65°C range).** [2]

3. **Difference in shape of curve before or after optimum**
   E.g. before optimum, enzyme A has a steep increase, whereas enzyme T has a more gradual increase.
   E.g. after optimum, enzyme T has a steep decrease, whereas enzyme A has an initial steep decrease followed by a subsequent less steep gradient (Accept: enzyme A has a gradual decrease).

4. **Lowest temperature for enzyme A (at 10°C) as compared to lowest temperature for enzyme T (at 30°C)**

5. **Highest temperature for enzyme A (at 90°C) as compared to highest temperature for enzyme T (at 95°C)**

6. **Enzyme A works better at lower temperatures (10-55°C) as compared to enzyme T, which works better at higher temperatures (55-95°C).**

@ 1mark each, max 2

(b) With reference to Fig. 1.1, explain the effect of increasing temperature on the relative activity of enzyme **T**.

To *explain* the effect,

1. **As temperature increases from 30°C to 95°C, increase in <u>kinetic energy of enzyme and substrate molecules</u>, hence increasing the <u>rate of effective collisions</u> between them.**

2. **This facilitates the formation of <u>more enzyme-substrate (ES) complexes</u> resulting in an increase in relative activity.**

3. **However, as the temperature <u>increases beyond the optimum temperature of 85°C</u>, the enzyme molecules start to vibrate violently with the excess kinetic energy. As a result, the <u>weak (non-covalent) intramolecular bonds break.</u> These bonds maintain the secondary and tertiary structures/ specific 3D conformation of the enzyme. Enzyme becomes <u>denatured</u>.**

[3]

(c) Suggest a structural feature of enzyme **T**, which helps to explain the results obtained in the investigation.

1. **Enzyme T contains many <u>cysteine</u> amino acid residues (that maintain the tertiary structure by forming disulphide bonds).**

2. **<u>Higher temperature required</u> to break the <u>many/multiple disulphide bonds</u> within enzyme T (cysteine R-groups form covalent disulphide bonds)** [2]

Fig. 1.2 shows the structure of small sections of DNA and messenger RNA (mRNA) in the nucleus of *Agrobacterium tumefaciens* during transcription of the gene coding for cellulase.

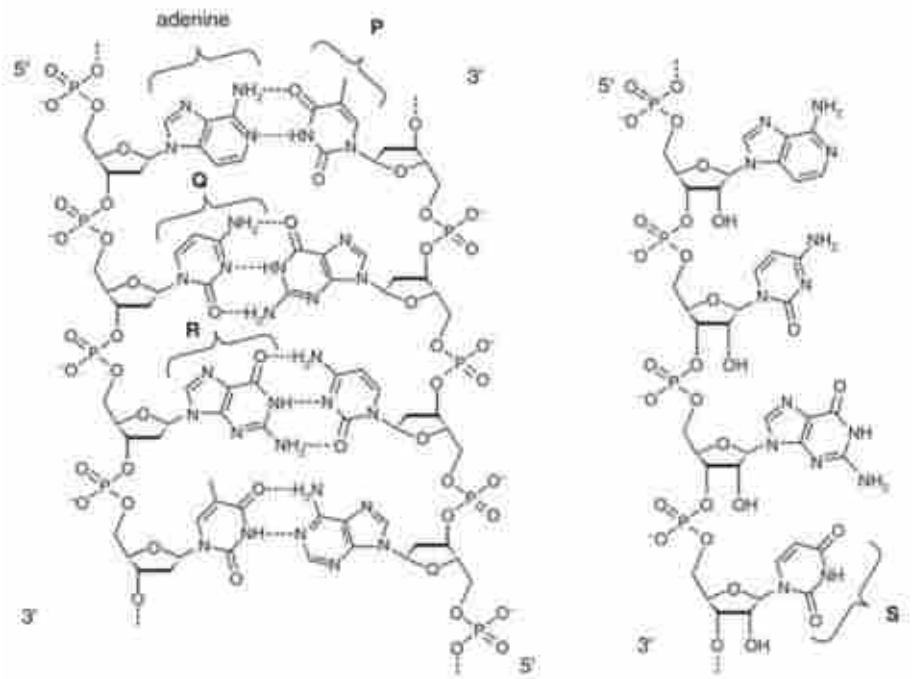


Fig. 1.2

(d) Name the bases **P** to **S**.

P: Thymine , Q: Cytosine , R: Guanine , S: Uracil

(all 4 correct – 2 mark, 2-3 correct – 1 mark) [2]

(e) Describe how messenger RNA coding for cellulase is synthesised in *Agrobacterium tumefaciens*.

1. **<u>RNA polymerase</u> (with the aid of Sigma factor) binds to cellulose gene <u>promoter</u> (Pribnow box), causing the DNA double helix to <u>unzip (separate)</u>** [3]
2. **<u>One</u> of the two DNA strands serves as <u>template strand</u>**
3. **<u>Free ribonucleotides / free ribonucleoside triphosphates / rNTPs</u> form <u>complementary base pairing</u> with bases/deoxyribonucleotides on the template DNA strand**
4. **RNA polymerase catalyses <u>formation of phosphodiester bonds</u> (between ribonucleotides via condensation reactions)**
5. **Template DNA strand is read from 3' to 5' direction, and mRNA is synthesized from 5' to 3' direction**
6. **Transcription ends when RNA polymerase transcribes a <u>terminator</u> sequence**

@1 mark each, max 3

[Total: 12]

2 Fig. 2.1 shows the main steps involved in the synthesis of preproinsulin to insulin in the pancreatic β-cell. The preproinsulin is synthesised into the lumen of organelle **A** as proinsulin.

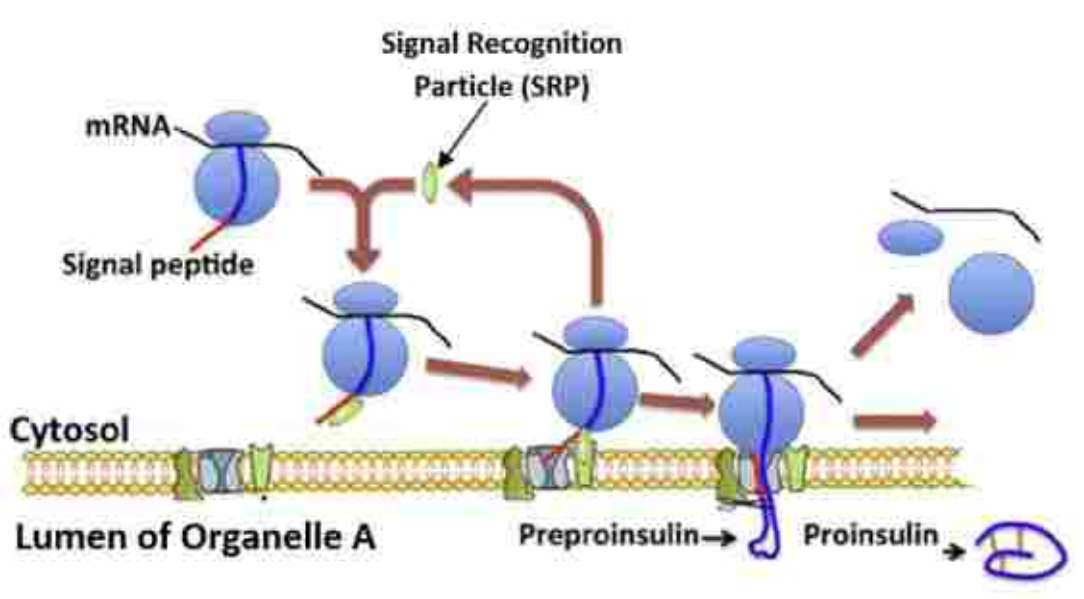


Fig. 2.1

The proinsulin is then be transported to organelle **B** where it is further processed to form insulin.

Fig. 2.2 shows the conversion of proinsulin to insulin in organelle **B**.

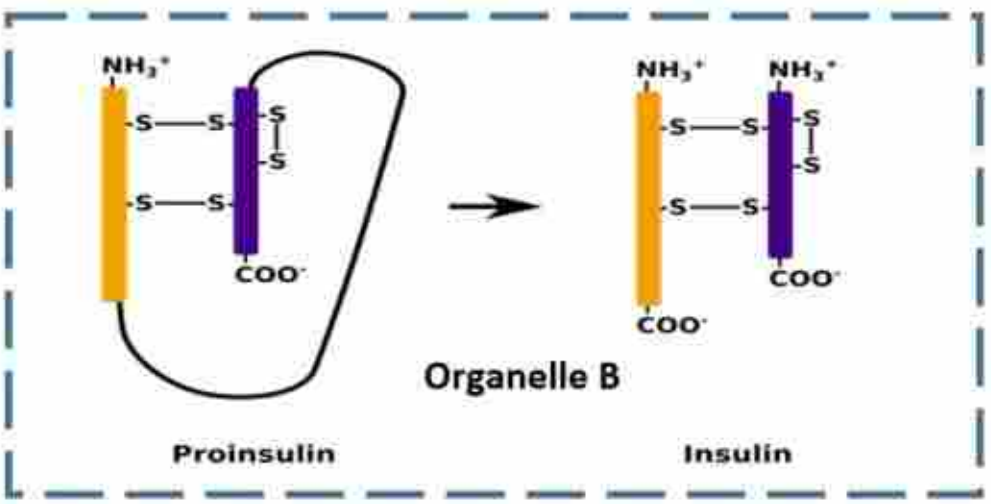


Fig. 2.2

(a) Name the organelles labelled **A** and **B**.

Organelle A: Rough Endoplasmic reticulum (Must spell in FULL)

Organelle B: Golgi apparatus / Golgi body [1]

(b) State the role of rRNA in insulin synthesis.

1. **rRNA along with ribosomal proteins forms the <u>structural component of ribosome (large and small sub-unit)</u>.**
2. **rRNA is responsible for <u>catalytic function</u> of ribosome in the formation of <u>peptide bond</u> between amino acids (found at the large sub-unit).**
3. **rRNA in the <u>small ribosomal subunit</u> binds to <u>5' end of mRNA sequence during protein translation</u>.**
4. **rRNA at the <u>A site</u> binds to the <u>amino-acyl tRNA</u> while the rRNA at the <u>P site</u> binds to the <u>peptidyl-tRNA</u>.**

OWTTE

*** Any 2 of the above**

[2]

(c) Insulin is released by pancreatic β-cell. Outline the route taken by proinsulin.

1. **From Rough ER, a <u>transport vesicle</u> takes the proinsulin to the <u>Golgi apparatus</u> (GA).**
2. **After chemical <u>modification and packaging</u>, a secretory vesicle pinched/buds off from GA.**
3. **The <u>transport of secretory vesicles</u> (aided by microtubules-the cytoskeletal elements) in the cytoplasm, until they fuse to the plasma membrane.**
4. **<u>Secretory vesicle</u> <u>fuses</u> with the cell surface membrane before releasing insulin by <u>exocytosis</u>.**

[2]

* 3 points to get 2 marks. Pt 4 is crucial to talk about.

The synthesis of insulin is regulated at the transcriptional levels in β-cell.

Fig. 2.3 shows the binding of three β-cell-specific transcriptional factors, Pdx-1, MafA and NeuroD1 E47 in response to high glucose levels in β-cell.

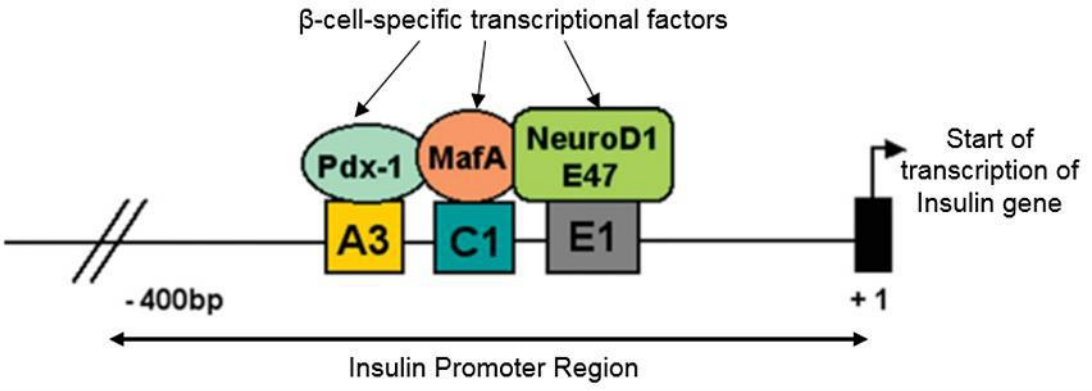


Fig. 2.3

(d) Explain how β-cell-specific transcriptional factors will lead to high level of insulin gene expression.

[2]

1. **β-cell-specific transcriptional factors are activators that bind to the enhancer region found in the insulin promoter region.**

2. **Binding of β-cell-specific transcription factors will lead to <u>increase in the formation of transcription initiation complex</u> / <u>helps RNA polymerase, transcription initiation factors to bind to promoter region with greater affinity</u>.**

3. **β-cell-specific transcriptional factors act as activators and <u>lead to chromatin remodelling / changes in chromatin structure</u> to increase rate of transcription. E.g. via histone acetylation *to allow greater accessibility to RNA polymerases for transcription to occur.***

   E.g of changes:
   - ***a. <u>Aacetylation of histone tails / addition of acetyl groups</u> catalyzed by histone acetyltransferase***
   - ***b. Cause, the chromatin structure becomes <u>less compact and</u> <u>allow access to RNA polymerase</u> to insulin gene promoter sequence. Transcription can take place.***

Any 2 of the above point

(e) It has been found that insulin promoters differ widely in efficiency among individuals. Strong promoters cause frequent initiations of transcription while weak promoters have low frequency of initiations of transcription. Explain what may have caused the difference in efficiency of the insulin promoters.

1. **Gene mutation / base substitutions in the insulin promoter sequence result in changes in the base sequence of the promoter**

2. **This change will cause the structure of the promoter to be of less complementary to the DNA binding site of the RNA polymerase and affects the binding of the RNA polymerase to the promoter sequence / Resulting in a promoter which initiates transcription less strongly;**

Other accepted answers:

- **Promoter region found in tightly coiled region of DNA molecule, affects accessibility by RNA polymerases- Level of supercoiling of the DNA affects accessibility to RNA polymerase.**
- **Methylation of the promoter regions, which affects the binding by RNA polymerases.**

[2]

(f) Explain why gene mutations do not always produce mutated insulin protein whereas mutations of the splicing sites involved in RNA splicing will produce mutated insulin.

[2]

Why gene mutations do not always produce mutated insulin:

1. **Gene mutations that involve substitution may result in the same amino acid being coded for and due to the degenerate code/ same amino acid can be coded for by different codons.**
2. **Gene mutation could occur at the intro region instead of exons.**

Why mutations at RNA splicing sites will produce mutated insulin:

Mutation at the splice site will affect the binding of spliceosome, and will affect the removal of introns & exons, hence giving rise to a mutated protein with loss of function.

Example of the kind of mutations at RNA splicing sites and the outcome:

An example of mutation at RNA splicing sites *(any one)*	Effect of such mutation (i.e. production of mutated collagen) *(any one)*
Different combinations of exons being produced	**Different primary sequences of amino acids resulting in different protein (mutated protein)**
An exon is lost/ wrong excision of exons	**Large number of bases and hence amino acids is lost/ as above**
Introns not removed by spliceosome	**Introns translated and became additional amino acids, this will lead to change the protein structure**

[Total: 11]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section B

Answer **all** the questions in this section.

3 Fig. 3.1 shows the life cycle of a water flea.

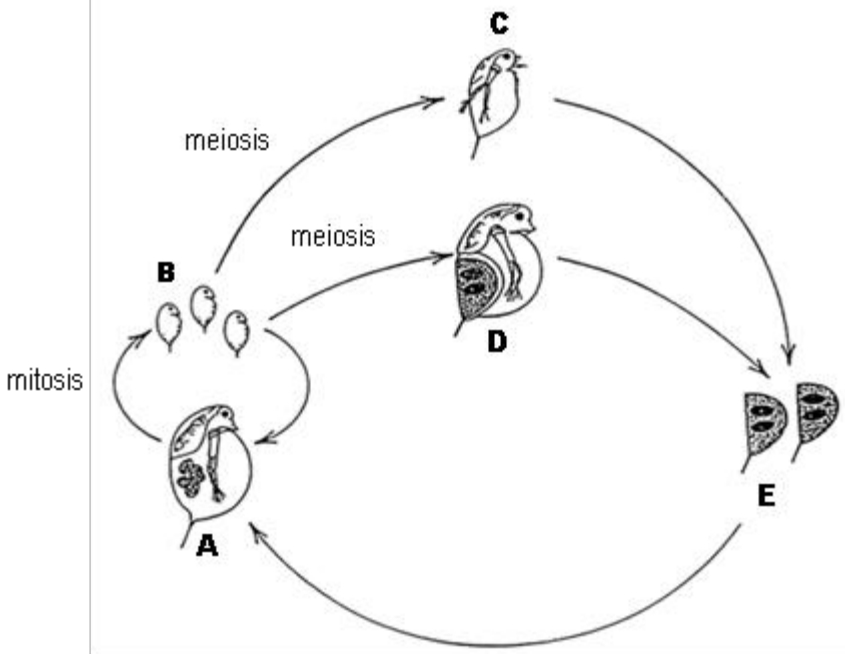


Fig. 3.1

In favourable conditions, all the animals in a population are females (**A**). These females produce eggs by mitosis, which develop into young females (**B**) without being fertilized. In unfavourable conditions, eggs produced by meiosis develop directly without fertilization into either males (**C**) or females (**D**). The eggs produced by the females (**D**) are fertilized by the sperms from the males (**C**), then released in protective egg cases (**E**) which enable them to survive unfavourable conditions. When favourable conditions return, these eggs develop back into females (**A**).

(a) The females at stage **A** of the life cycle have 18 chromosomes.

Complete the table to show the number of chromosomes at the other stages of the life cycle.

stage of life cycle	chromosome number
A	18
B	**18**
C	**9**
D	**9**
E	**18**

[1]

(b) Explain why the eggs from **D** and the sperms from **C** must be produced by mitosis.

1. **Since C and D (developed from unfertilised eggs from B) are haploid, mitosis ensures that the haploid chromosome number is preserved / the eggs and sperms are haploid.**

2. **Thus, when the haploid sperm and haploid egg fuse, the original diploid chromosome number is restored.** [2]

(c) Explain why females **A**, developed from fertilized eggs **E**, are genetically different from each other.

(Any 3)

1. **C and D developed from eggs that are produced by meiosis in B.**

2. **Crossing over between non-sister chromatids of homologous chromosomes at prophase 1 of meiosis**

3. **Independent assortment of homologous chromosomes at metaphase 1 of meiosis**

4. **Independent assortment of non-identical chromatids at metaphase 2 of meiosis**

5. **Random mating between C and D**

6. **Mutations can occur at any time.** [3]

(d) Give an example of a favourable condition in which females will develop from eggs formed via mitosis.

(Any 1)

- **Presence of water in a previously dry pond**
- **Reasonably high temperature (~20°C)**
- **Abundant food source**
- **Lack of competition**
- **Stable environment**
- **Few or no predators**
- **Appropriate photoperiod**
- **Water of optimal pH**
- **Suitable salinity**
- **(any other valid point)** [1]

[Total: 7]

4 Cattle were found to have three different coat colours: brown, white and roan. Roan cows have both brown and white patches. When two roan cattle were crossed, a ratio of 1:2:1 was obtained for brown, roan and white coat colour respectively. A separate gene on X chromosome in cattle code for a disease called Agnathia. The absence of a normal allele causes a deformity in the lower jaw.

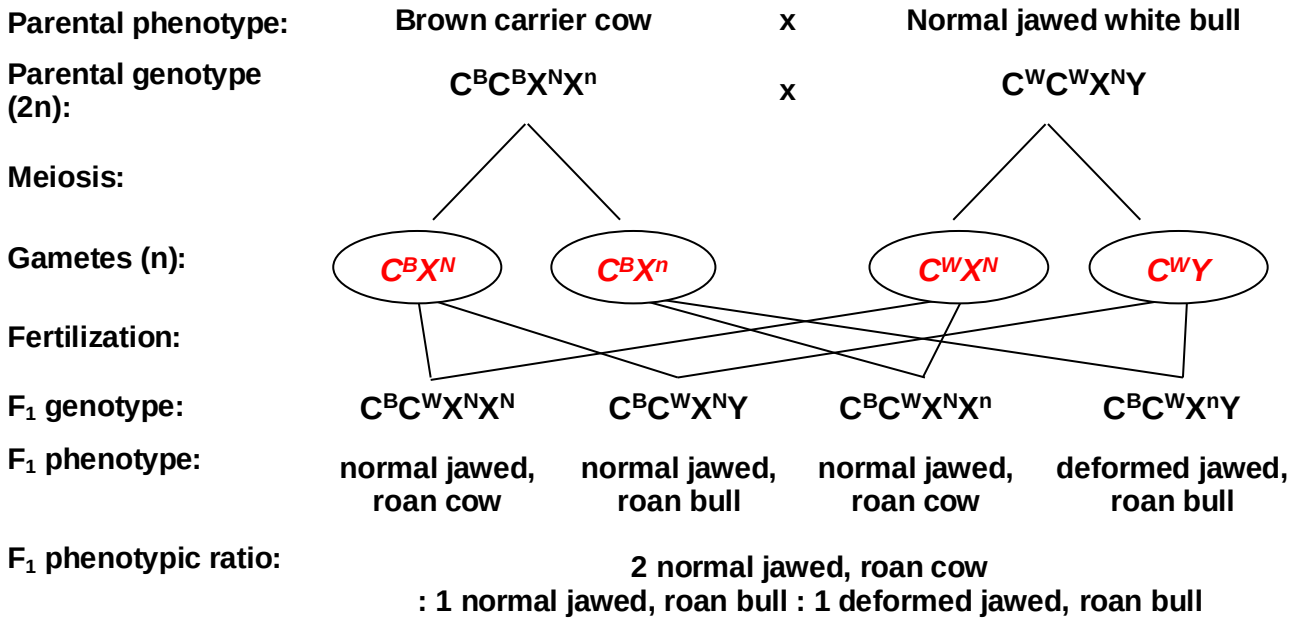
(a) Construct a genetic diagram to show the expected ratio when brown carrier cows are crossed with normal jawed white bulls.

Let C^B represent the codominant allele for brown coat.

Let C^W represent the codominant allele for white coat.

Let X^N represent the X-linked dominant allele for normal jaw.

Let X^n represent the X-linked recessive allele for deformed jaw.



Both parental phenotypes and genotypes are correct (with appropriate use of symbols). [1]

All possible gametes from each parent are correct. [1]

Genetic diagram correctly shows 4 possible combinations of gametes. [1]

The phenotypes of all F_1 genotypes are correct. [1]

Expected F_1 phenotypic ratio is correct. [1]

[5]

(b) State the mode of inheritance of the two traits. Explain how you arrive at your answer.

- **agnathia: X-linked / sex-linked recessive**
- **gene is on X chromosome AND absence of normal allele causes it**
- **coat colour: codominance**
- **roan cattle have both brown and white patches (intermediate phenotype)**

Award 1 m if mention any 2 of the above
Award 2 m if mention all of the above [2]

(c) When a geneticist carried out a cross between brown carrier cows and normal jawed white bulls, he obtained the following phenotypes.

normal jawed, roan cows	55
normal jawed, roan bulls	37
deformed jawed, roan bulls	28

Fig. 4.1 shows the table of probabilities.

df	probability				
	0.10	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.69	13.28	18.47
5	9.24	11.07	13.39	15.09	20.52

Fig. 4.1

The formula for the chi-square statistic used in the chi square test is as follows:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$ where O = observed value; E = expected value.

[3]

With reference to Fig. 4.1, carry out a chi-square test to support your explanation in (b). Show your workings clearly in the space below.

Null Hypothesis: H_0: There is no significant difference between observed and expected data. i.e. the observed data follows a 2:1:1 distribution. Any difference is due to chance.

Phenotype	Ratio	(O)	(E)	$(O-E)^2/E$
Normal jawed, roan cows	2	55	60	0.42
Normal jawed, roan bulls	1	37	30	1.63
Deformed jawed, roan bulls	1	28	30;	0.13;
		$\Sigma_{(O)} = 120$	$\Sigma_{(E)} = 120$	$X^2_{cal} = 2.18$;

Correct working for calculation of chi-square statistic (i.e. 2.18) [1]

Use correct df (i.e. 2) and probability (i.e. 0.05) in Fig. 4.1 to determine critical chi-square value (i.e. 5.99) [1]

State / Accept the null hypothesis [1]

(d) In some cases, the environment may affect the phenotype.

Give one named example to illustrate such an environmental effect. [2]

- **(valid character) e.g. fur colour / synthesis pf black pigment**
- **(type of organism) e.g. Himalayan rabbit**
- **(change in environment) e.g. exposure to heat**
- **(corresponding change in phenotype) e.g. white fur formed instead of black fur / no synthesis of black pigment**

[Total: 12]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section C

Answer **all** the questions in this section.

5 Hepatitis C virus (HCV) is an enveloped, positive-strand RNA virus within the family Flaviviridae. HCV undergoes reproductive cycles similar to other enveloped viruses, such as influenza virus and dengue virus.

Fig. 5.1 shows a model of a HCV particle.

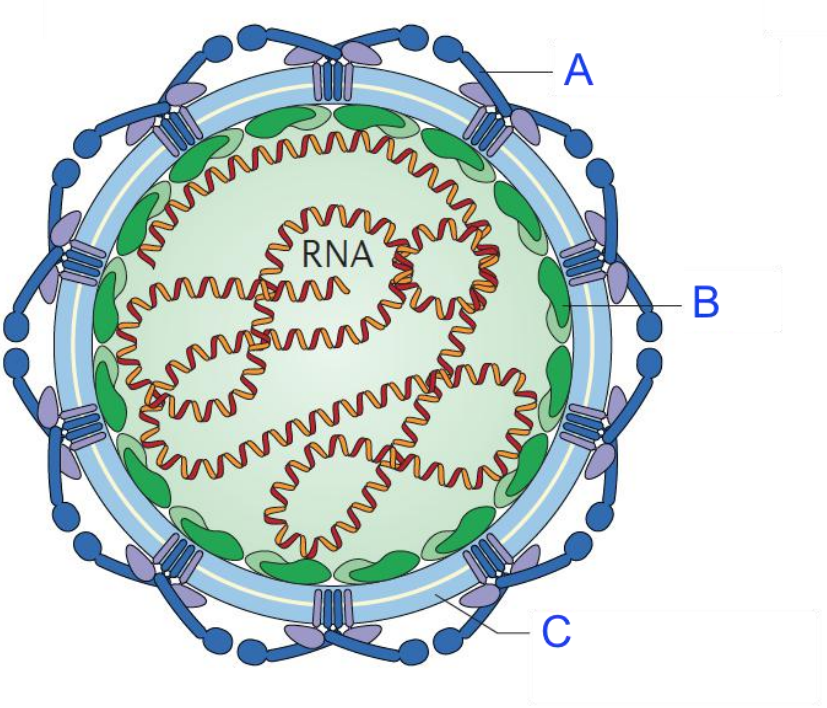


Fig. 5.1

(a) Identify the labelled structures **A**, **B** and **C**.

A: glycoprotein/ envelope glycoprotein

B: capsid/ capsomere

C: envelope [2]

(b) Explain why HCV is considered an obligate parasite.

1. **HCV can only survive and reproduce in living host cells.**
2. **HCV uses host cell's machinery and resources to replicate and assemble new viral particles.** [2]

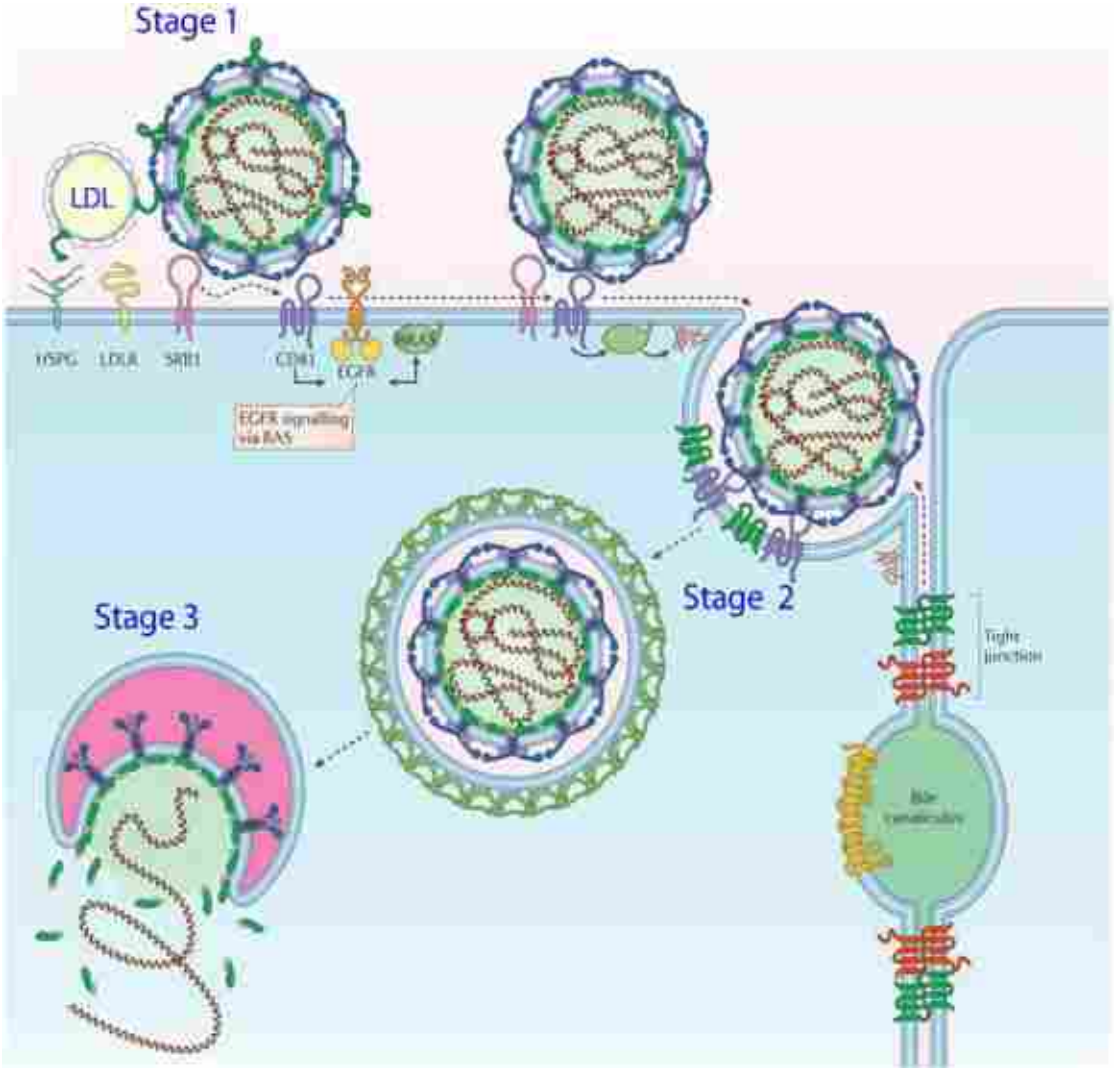


Fig. 5.2

(c) With reference to all labelled stages in Fig. 5.2, describe how HCV gains entry into its host cell.

1. **HCV binds to SRB1/ CD81 in stage 1.**

2. **Host cell membrane invaginates and HCV enters host cell through receptor-mediated endocytosis in stage 2.**

3. **Low pH within endosome stimulates fusion of viral envelope with endosome membrane, exposing capsid to digestion by cellular enzymes, releasing viral RNA into the cytoplasm in stage 3.** [3]

Fig. 5.3 shows the positive-strand RNA genome of HCV genome.

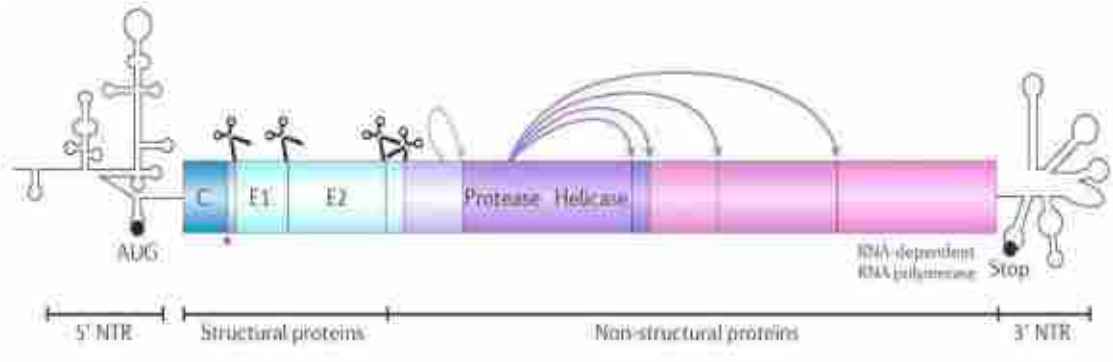


Fig. 5.3

(d) With reference to Fig. 5.3, describe the role of HCV genome in the infection process.

1. **Positive-stranded RNA is translated into a polyprotein by host ribosomes and cleaved into individual proteins.**

2. **RNA-dependent RNA polymerase coded by viral genome synthesizes a negative-sense RNA intermediate which is used as a template for synthesizing**

[2]

Hepatitis B virus (HBV) and HCV are known to be two major causative agents of hepatocellular carcinoma. Studies have shown that HBV DNA can be integrated during the early stages of infection. The integration of viral DNA is associated with deletions in portions of the host chromosomes. Many of these chromosomal segments contain known genes such as p53.

(e) Explain how HBV infection may lead to cancer.

1. **p53 is a tumour suppressor gene, which bring about inhibition of cell cycle and activation of DNA repair genes when DNA damage is detected.**

2. **Deletion of p53 results in loss of function mutation of p53, allowing DNA damage to accumulate in cells.**

3. **As cells accumulate 4-6/ more mutations in key regulatory genes, including appearance of <u>at least 1 active oncogene</u>, they become cancerous.**

[3]

[Total: 12]

6 **(a)** Human newborns and hibernating mammals contain large amounts of brown adipose tissue ('body fat').

Fig 6.1 shows the electron micrograph of a brown adipocyte. Brown adipocytes are characterised by the presence of numerous vacuoles and organelle **X** throughout the cell.

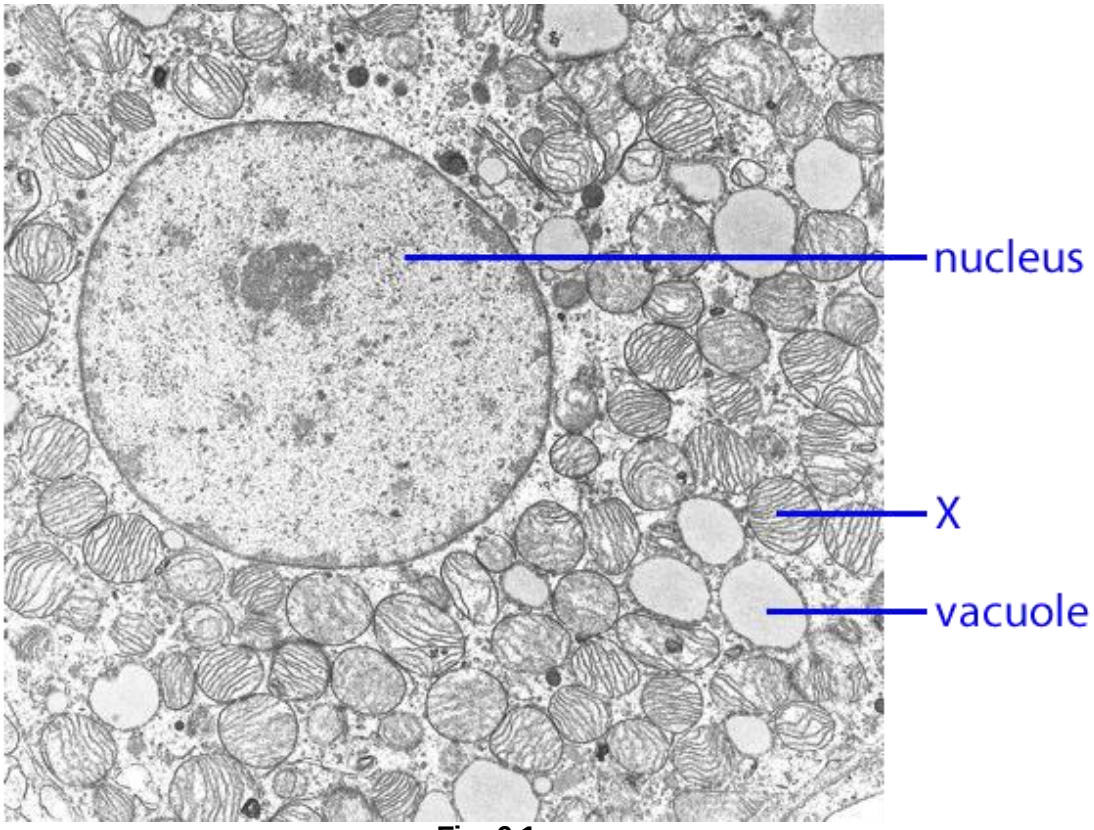


Fig. 6.1

(i) Identify organelle **X**.

mitochondrion [1]

(ii) Suggest the role of the numerous vacuoles found in brown adipocytes.

They store lipids / triglycerides / fats. [1]

(b) Fig. 6.2 shows the schematic representation of a series of protein complexes found on the inner membrane of organelle **X**.

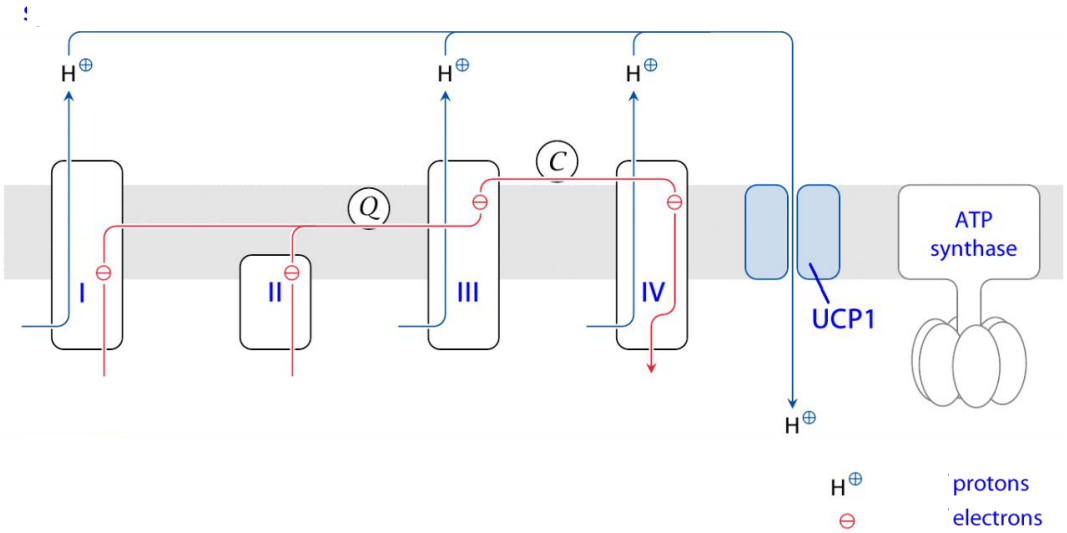


Fig. 6.2

(i) Oxygen is required to sustain the process illustrated in Fig. 6.2.
With reference to Fig. 6.2, describe the role played by oxygen.

Oxygen serves as the final electron acceptor, receiving electrons from complex IV to form water. [1]

(ii) Brown adipocytes contain a unique protein, UCP1, which is not found in organelle **X** in any other cell type.

Evaluate the impact of UCP1 on the normal functioning of the process illustrated in Fig. 6.2 and suggest the physiological significance of brown adipose tissue.

1. **As UCP1 allows protons to leak back into the matrix without passing through the ATP synthase, no ATP will be synthesized from the NADH and $FADH_2$.**

2. **The energy released from the spontaneous flow of protons through UCP1 is lost as heat, which helps to keep the organisms warm.** [2]

(c) In other cell types, NADH and $FADH_2$ are used to drive ATP synthesis by ATP synthase. Using relevant information from Fig. 6.2, suggest and explain why more ATP is produced from NADH.

1. **NADH and $FADH_2$ donates electrons to complex I and II respectively, the energy released from transfer of electrons through the complexes is used to pump protons across the inner membrane.**

2. **Because NADH started with Complex I, it had more chances to pumps more protons across the gradient, which powers the ATP synthase and gives us 3 ATP per molecule of NADH, while $FADH_2$ produces 2 ATP during the ETC because it gives up its electron to complex II, bypassing complex I.** [2]

[Total: 7]

Name: _____ Class: 2bi2___ / 2IPbi2___	19

Section D

Answer **all** the questions in this section.

7 The cardiac action potential is a specialised action potential with unique properties necessary for the electrical conduction system of the heart. The cardiac muscle cells share many things in common with nerve cells.

Fig. 7.1 shows the five phases of a cardiac action potential. Each of which is characterised with their respective changes in membrane potential.

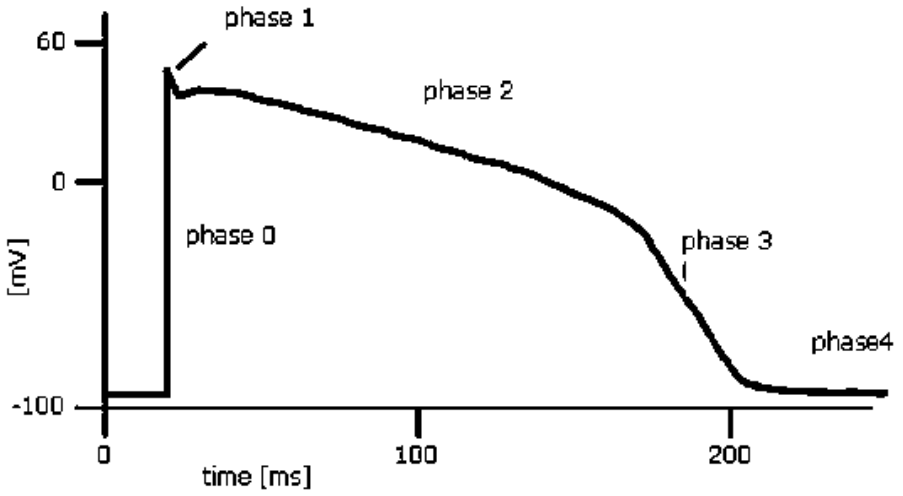


Fig. 7.1

The table shows the relative concentrations of ions inside and outside of the cardiac muscle cells.

element	ion	extracellular	intracellular
sodium	Na^+	135 – 145	10
potassium	K^+	3.5 – 5.0	155
chloride	Cl^-	95 – 110	20 – 30
calcium	Ca^{2+}	2	10^{-4}

(a) Estimate the resting potential for the cardiac action potential shown in Fig. 7.1.

Between (-90 mV to -95 mV) [1]

(b) Using the information from the table, explain how the resting potential can be produced in the heart muscles using sodium and potassium ions.

- **[Na+] outside the cell > [Na+] inside the cell while [K+] outside the cell < [K+] inside the cell**
- **Possible involvement of a protein pump: Requires energy in the form of ATP for movement of ions against concentration gradient**
- **More Na+ pumped out than K+ pumped in → Nett loss of +ve ions from inside the cell thus inside –ve 90mv**

[3]

(c) Compare phase 2 of the action potential of a cardiac muscle cell with that of a nerve cell.

- **The fall in membrane potential in a nerve cell is more drastic/ shows a steeper gradient/ faster rate/ longer time in** **OR**
- **Nerve cell only shows Phase 3/ Phase 2 is absent in nerve cells.**

[1]

(d) Cardiac arrhythmia refers to any abnormal electrical activity in the heart. As a result, the heart may beat too fast. Calcium channel blockers such as Verapamil are often used to treat this condition.

Suggest and explain the action of Verapamil in controlling this symptom of arrhythmia. [2]

- **Interrupts inflow of Ca2+ during plateau phase to prolong the refractory period/ depresses Phase 2 and 3**
- **Reduces the rate of heart contraction → heart rate declines**

[Total: 7]

8 The table shows the amino acid differences in the cytochrome b protein between various vertebrates.

	Human	Elephant	Platypus	Ostrich	Starling	Crocodile	Lungfish	Coelacanth	Goldfish	Shark
Human		26	40	43	41	47	83	70	68	71
Elephant			45	45	48	50	84	72	63	74
Platypus				54	52	51	89	74	70	76
Ostrich					26	36	91	75	68	73
Starling						47	91	77	67	70
Crocodile							85	78	70	77
Lungfish								90	94	86
Coelacanth									83	78
Goldfish										88
Shark										

Fig. 8.1 shows the phylogenetic tree based on differences between the cytochrome b proteins.

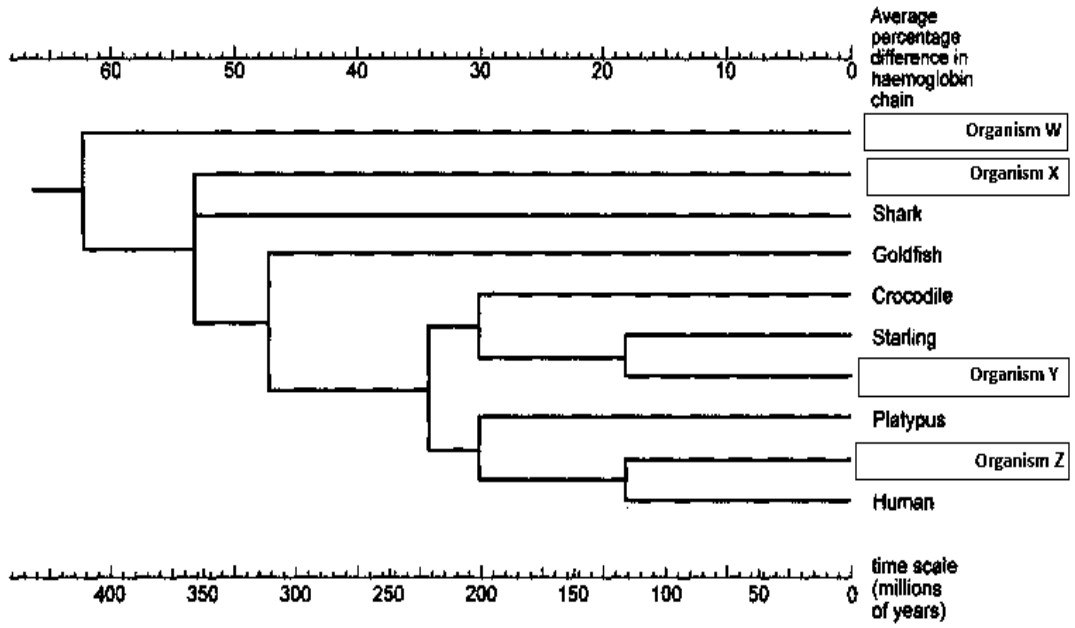


Fig. 8.1

(a) Using information from the table and Fig. 8.1, identify organisms **W** to **Z**.

W: lungfish

X: coelacanth

Y: ostrich

Z: elephant [2]

(b) Explain how differences in amino acid sequences in the cytochrome b chain allow the establishment of the phylogenetic tree.

- **% of aa difference in Hb chain indicates relatedness;;**
- **few difference indicates recent common ancestor / large difference indicates early divergence** OWTTE
- **provides quantitative data to construct phylogenetic tree**

[3]

(c) Explain the difference between classification and phylogeny.

- **classification refers to grouping organisms based on similar characteristics**
- **characteristics may be analogous and not homologous**
- **phylogeny involves grouping organisms based on evolutionary relationship**
- **similarity is due to inheritance from common ancestry**

[2]

(d) Suggest why homology still features prominently in evolutionary studies despite the advantages that molecular evidence can confer.

- **easier to use / often requires observation rather than machines**
- **DNA / protein not always available e.g. in fossils**

[2]

(e) Explain the role of neutral mutations in evolutionary studies.

- **constant rate of mutation**
- **act as molecular clock**
- **genetic differences act as an indicator of time / period of divergence**
- **genetic differences act as an indicator of speciation event** OWTTE

[3]

[Total: 12]

9 (a) Compare the role of nervous system and endocrine system as communication systems within organisms. [6]

Similarities

S1. Both systems communicate through use of signalling molecules that bind to specific receptors on effector cells.

S2. They function in response to stimuli

Differences

D1. Nervous system transmit information in the form of electrical impulses along an axon and in the form of chemical signals known as neurotransmitters across a synapse. Endocrine system transmit information in the form of chemical signals known as hormones only.

D2. Signals are transmitted via specific neural pathways consisting of communicating neurons in the nervous system. In contrast, signals are transported by the circulatory system via bloodstream.

D3. Transmission of signals via nervous system is rapid, where transmission of nerve impulses to effector cells bringing about response is completed in milliseconds. Transmission of signals via endocrine system is slow, which may take minutes to days for hormones to be produced and carried by blood to target organs for response to occur.

D4. Communication through nervous system results in localized responses from the target cell(s) that are post-synaptic to the motor neurons. In contrast, endocrine system results in responses that may be widespread as various tissues/ organs can respond to a single hormone.

D5. The response brought about by nervous system is immediate and short-lived, while the response brought about by endocrine system is slow and long-lasting.

D6. Communication via nervous system results in "all or none" response, where the magnitude of action potential is the same regardless of the strength of the stimuli. Whereas communication through endocrine system can bring about graded response.

D7. The control of response in nervous system may be voluntary or involuntary, while the control of response in endocrine system is always involuntary.

(b) Explain the meaning of the term homeostasis with specific reference to the control of raised blood glucose concentration in humans. [8]

1. **Homeostasis is the maintenance of a constant internal environment.**
2. **One of the principles underpinning homeostasis is self-regulation, in that the control mechanism is triggered by the parameter that is being regulated.**
3. **Another principle of homeostasis is negative feedback, whereby deviation from set/reference point triggers response which counteracts/ reverses the deviation, restoring the parameter to set/reference point.**
4. **The set/reference point for blood glucose level is 90mg glucose/100cm^3.**
5. **The rise in blood glucose level from set point is the stimulus that triggers the control mechanism to reduce blood glucose level back to set point.**
6. **The rise in blood glucose level is detected by the alpha and beta cells of the Islets of Langerhans in the pancreas (detector).**
7. **Beta cells are triggered to secrete insulin into bloodstream,**
8. **Alpha cells are signalled to stop glucagon secretion.**
9. **Insulin is transported via bloodstream to target cells, such as liver cells (effector). Insulin binds to receptors and acts to bring about responses that restore the set point.**
10. **One response is increased fusion of vesicles containing glucose-carrier/glucose-transporter proteins with the plasma membrane so as to increase rate of uptake of glucose in the effector cells.**
11. **These cellular responses result in a decrease in blood glucose level back to the set point of 90mg glucose/100cm^3 of blood. This is negative feedback regulation of blood glucose level.**
12. **As blood glucose level return to the set point, beta cells will no longer be triggered to secrete insulin, hence insulin level in the blood decreases.**

(c) Describe the cell signalling pathway that glucagon initiates in order to regulate blood glucose concentration. [6]

1. **Glucagon binds to extracellular binding site of G protein-coupled receptor (GPCR) on the plasma membrane of liver cells.**

2. **Binding of glucagon triggers a change in 3D conformation in the GPCR, resulting in the release of GDP followed by binding of GTP, thus activating G protein.**

3. **(a) Activated G protein dissociates from receptor and diffuses along the plasma membrane to bind to and activate adenylyl cyclase.; (b) Adenylyl catalyses the conversion of many cyclic AMP (cAMP) from ATP.;**

4. **cAMP acts as second messenger to activate enzymes such as protein kinase A.**

5. **Protein kinase A activate other enzymes by phosphorylating them, triggering a phosphorylation cascade that help to amplify the initial signal and bring about the necessary cellular responses.**

6. **For example, glycogen phosphorylase brings about increased glycogenolysis by catalysing the breakdown of glycogen to glucose-1-phosphate which is then converted to glucose and transported out of the liver cell into the bloodstream to increase blood glucose level back to the set point.**

7. **Another cellular response is increased activity of enzymes involved in gluconeogenesis (synthesis of glucose from non-carbohydrate sources) forming more glucose to increase availability of glucose for cellular respiration**

[Total: 20]

10 (a) Compare the structural and regulatory genes in prokaryotes. [6]

(Maximum 2 marks for similarities)

- **Both do not contain introns.**
- **Both are transcribed by RNA polymerase.**
- **Both are on the same chromosome.**
- **(any other valid point)**

(Maximum 5 marks for differences)

	Point of comparison	Structural gene	Regulatory gene
1	Codes for?	Codes for a protein or RNA molecule that forms part of a structure or has an enzymatic function	Codes for a specific protein product that regulates the expression of the structural genes
2	Gene product interacts with DNA?	May not interact with DNA	Yes, e.g. the operator of the operon
3	Example?	*lacZ* = β-galactosidase gene *lacY* = permease gene *lacA*= transacetylase gene	*lacI* = *lac* repressor gene *trpR* = *trp* repressor gene gene for Catabolite Activator Protein (CAP)
4	Expression?	Regulated as in *lac* operon	Constitutive
5	Location?	Related structural genes found within operon	Regulatory genes exist singly outside operon (*lacI* is near *lac* operon) (gene for CAP is not anywhere near *lac* operon)
6	Presence of promoter/operator?	Both promoter and operator upstream of structural genes	Only promoter precedes it
7	Type of mRNA formed?	Polycistronic	Monocistronic

(b) Explain the roles of the operator and activator binding site in the *lac* operon.

[8]

(Any 8)

1. **An operon is a unit of genetic function consisting of a promoter, an operator, and a coordinately regulated cluster of related (structural) genes whose products function in a common pathway.**
2. **Regulated / Controlled / Switched off and on / Transcribed together as a unit to produce a single messenger RNA (mRNA)**
3. **The operator can lie within the promoter or between the promoter and the structural genes. / The activator binding site can lie within or upstream of the promoter.**
4. **The operator is a binding site for the *lac* repressor.**
5. **Binding of *lac* repressor to the operator will deny the RNA polymerase access to the promoter and hence inhibit transcription.**
6. **Presence of the inducer allolactose / lactose inactivates the *lac* repressor by changing its conformation such that it can no longer bind to the operator, and transcription can be carried out / RNA polymerase can bind to the promoter.**
7. **The activator binding site is the binding site for Catabolite Activator Protein (CAP) / cAMP-CAP complex.**
8. **Low level of glucose leads to high level of cAMP in the cell, which results in high level of cAMP-CAP complex / activated CAP.**
9. **Binding of cAMP-CAP complex / activated CAP to the activator binding site will stimulate transcription / switch the *lac* operon on by increasing the affinity of RNA polymerase for the promoter.**
10. **Both the operator and activator binding site allow the expression of the lactose metabolizing enzymes to be responsive to changes in the environment (e.g. glucose and lactose concentrations) / prevent the waste of energy and resources.**

(c) Describe how the molecular structure of phospholipids is related to their function in the plasma membrane. [6]

(Any 6)

- **Each phospholipid consists of a phosphate group, a glycerol backbone and two fatty acid chains.**
- **Each phospholipid is amphipathic / contains both a hydrophilic region and a hydrophobic region within the same molecule.**
- **Hydrophilic phosphate heads are on the outside of the bilayer, in contact with the surrounding aqueous medium.**
- **Hydrophobic fatty acid chains point towards the interior of the bilayer, away from the surrounding aqueous medium.**
- **Major component of the plasma membrane / Form a bilayer**
- **Selectively permeable to solutes due to presence of hydrophobic core in the bilayer**
- **Determine the fluidity of membrane**
- **The more unsaturated fatty acid chains are, the more fluid the membrane is.**
- **Kinks in unsaturated fatty acid chains prevent close packing of the phospholipids and decrease the interaction between adjacent fatty acid chains.**
- **Phospholipids with shorter fatty acid chains are more fluid.**
- **Shorter chain length reduces the tendency of the hydrocarbon tails to interact with one another.**
- **Some types of phospholipid can be split to produce products that function as second messengers in signal transduction.**

[Total: 20]

- End of paper -

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME

BIOLOGY CLASS 2bi2____ / 2IPbi2__

REGISTRATION NUMBER

BIOLOGY 9648/03

Paper 3 **31 August 2016**

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your Biology class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Sections A - C
Answer **all** questions in the spaces provided on the question paper.

Sections D - E
Answer **all** questions on the answer paper provided.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or id you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 14
2	/ 14
3	/ 12
4	/ 12
5	/ 20
TOTAL	**/ 72**

This document consists of **11** printed pages.

[Turn over

Section A

Answer the question in this section.

1 In a maternity ward at a local hospital, a mix-up involving three couples and three babies caused a lot of confusion. Based on phenotypic characteristics, the nurses were unable to correctly identify the parents of the babies. In order to solve the case, a scientist was called in to carry out a DNA test to identify the parents of the babies. The test was based on the principle that different individuals have a different number of repeating units at a particular locus in a chromosome.

Chromosome 13 was isolated from the DNA samples that were obtained from the three couples and three babies and used for further analysis. The sequence below shows a segment of chromosome 13, which was used in the analysis where (TTAGGAT) is the repeating unit and n is the number of repeats.

5' …GCTAAGTATTGCTCAAGA… (TTAGGAT)n…GATAAATAACTGGCTAGTA…-3'
3' …CGATTCATAACGAGTTCT… (AATCCTA)n… CTATTTATTGACCGATCAT…-5'

Fig. 1.1 shows the results of the DNA test obtained from each individual.

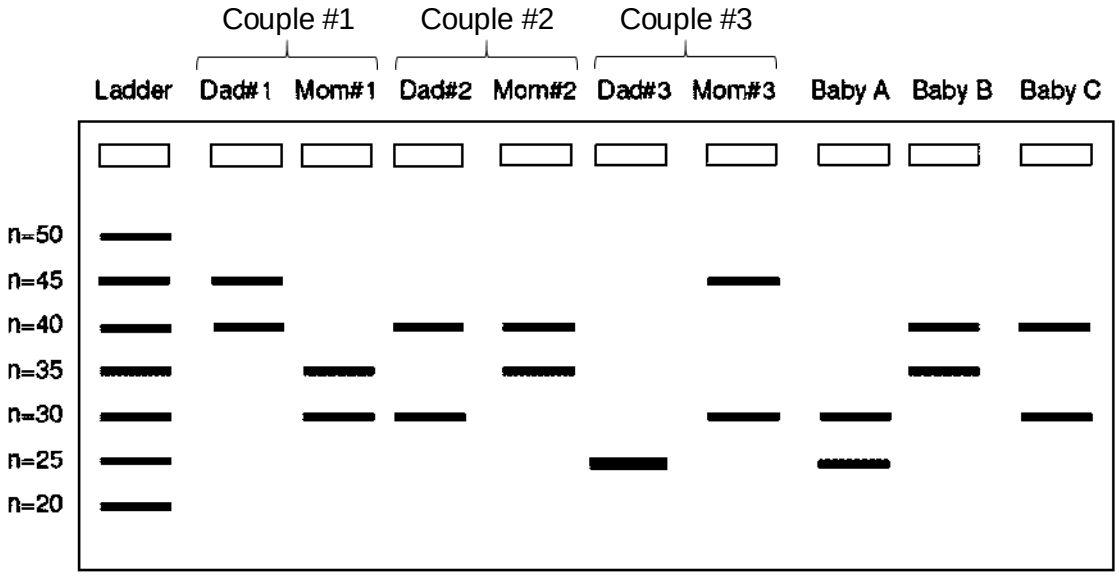


Fig.1.1

(a) Describe how the DNA bands in the gel could be made visible.

.....[1]

(b) State the purpose of the DNA ladder.

.....

.....[1]

(c) Explain how gel electrophoresis is used to separate fragments of DNA.

[5]

(d) Explain the banding pattern of Dad #3.

[3]

(e) Identify the couple that Baby A belongs to.

[1]

(f) Explain why the results shown in Fig. 1.1 could not confirm which couple that Baby B belongs to.

[2]

(g) Suggest an alternative DNA test to identify the couple that each of the three mixed up babies belongs to.

.....[1]

[Total: 14]

Name: _____ Class: 2bi2___ / 2IPbi2___

14

Section B

Answer the question in this section

2 Haemophilia is an X-linked recessive disorder that impairs the body's ability to form blood clots. There are two main types, haemophilia A and haemophilia B, resulting from deficiencies in clotting factors VIII and IX respectively.

Both *ex vivo* and *in vivo* gene therapy approaches are undergoing clinical trials.

(a) (i) Explain why gene therapy approach for treatment of haemophilia is possible.

.....

..... [1]

(ii) Distinguish between *ex vivo* and *in vivo* gene therapy approaches.

.....

.....

.....

..... [2]

Haematopoietic stem cells (HSC) are ideal vehicles for *ex vivo* gene therapy application.

(b) (i) Describe the normal function of HSC.

.....

..... [1]

(ii) Explain why HSC are ideal vehicles for *ex vivo* gene therapy application.

.....

.....

.....

.....

..... [3]

The liver is an ideal target for *in vivo* gene therapy application. As a major organ and central metabolic hub, it receives an abundant blood supply through sinusoids with highly permeable walls, which facilitates easy access of blood-borne particles to the hepatocytes. Hepatocytes are long-lived and robust protein factories that can efficiently release their products into the blood circulation. Both viral and non-viral vectors have been and continued to be investigated.

(c) Use of non-viral vectors for gene therapy has met with low success rate.

Describe one method of non-viral vector delivery and explain why the method has achieved low success.

[3]

(d) Many ongoing clinical trials are focused on the application of adeno-associated viral (AAV) vectors, which are found to remain as episomes within the nucleus.

Explain an advantage and a disadvantage of the use of such adeno-associated viral vectors compared to retroviral vectors.

[2]

(e) Somatic cell nuclear transfer (SCNT), also known as therapeutic cloning, involves the replacement of an egg nucleus with a somatic cell nucleus. As the oocyte develops into a blastocyst, cells from the inner cell mass can be isolated and purified to serve as a source of pluripotent stem cells.

Explain why such an approach cannot be used to treat patients with haemophilia.

.....

.....

.....

..... [2]

[Total: 14]

Name: _____ Class: 2bi2___ / 2IPbi2___	12

Section C

Answer the question in this section.

3 The success of culturing callus is low due to the difficult task of removing contaminants. It has proven more challenging for plants taken from the wild in tropical countries. In Sumbawa, Indonesia, plant tissue samples were sampled at three different times of the year. They were grown in medium containing no fungicide or antibiotic.

Table 3.1 shows the results.

Table 3.1

explant	time of year	number of explants	number of cultured explants with no fungal or bacterial contamination	percentage of cultured explants with no fungal or bacterial contamination
leaf disc	April	153	12	8
	August	322	16	5
	January	332	30	9
shoot tip	April	194	116	60
	August	191	122	64
	January	211	156	74

(a) Describe and explain the results of using the two types of explant.

[3]

(b) Besides using the appropriate explant, suggest how the number of contaminated samples could be reduced when using wild plant samples.

[1]

(c) Explain, with relevant examples, how genetic engineering has helped to increase the quantity of crops for farmers.

[3]

(d) Describe two disadvantages of plant tissue culture.

[2]

(e) In several countries including China, Korea and the United States, human DNA has already been put into eggs from both rabbits and cows.

Discuss the ethical concerns of conducting such experiments.

[3]

[Total: 12]

Section D

Answer the question in this section on the answer paper provided.

4 Planning Question

You are required to plan, but not carry out, an investigation into the effect of increasing concentration of glucose on rate of respiration of yeast.

Yeast synthesizes ATP through two major biochemical pathways: aerobic respiration and fermentation. During both aerobic respiration and fermentation, yeast cells break down glucose molecules within the cell to release energy, and some of this energy is captured and stored in the ATP's high-energy phosphate bonds. The breakdown of glucose also releases carbon atoms, which become available for biosynthetic reactions, enabling the yeast to grow and reproduce by budding. The rest of the carbon ends up in the by-products of these reactions.

You are to use methylene blue in your investigation. Methylene blue acts as an artificial electron acceptor during respiration, which changes from blue to colourless as a result of its reduction in the enzymatic reaction.

Your plan should have a clear and helpful structure to include:

- a description of the method used including the scientific reasoning behind the method,
- an explanation of the dependent and independent variables involved,
- relevant, clearly labelled diagrams,
- how you will record your results and ensure that they are as accurate and reliable as possible,
- proposed layout of results tables and graphs with clear headings and labels,
- the correct use of technical and scientific terms,
- relevant risks and precautions taken.

Your planning must be based on the assumption that you have been provided with the following equipment and materials, which you must use:

- yeast suspension,
- 10% glucose solution,
- distilled water,
- access to tap water,
- thermostatically controlled water bath,
- methylene blue,
- stopwatch,
- a variety of different sized beakers, test-tubes, boiling tubes, measuring cylinders or syringes for measuring volumes.

[Total: 12]

Section E

Answer the question in this section on the answer paper provided.
Begin each part of the question on a new piece of answer paper.

5 Free-response question

Your answers:

- should be illustrated by large, clearly labelled diagrams, where appropriate,
- must be in continuous prose, where appropriate,
- must be set out in sections **(a)**, **(b)**, etc., as indicated in the question.

(a) Describe the goals, benefits and ethical concerns of human genome project. [8]

(b) Explain the significance of genetic engineering in improving food quality. [6]

(c) Discuss the social and ethical implications of genetically modified crop plants. [6]

[Total: 20]

--- End of Paper ---

NATIONAL JUNIOR COLLEGE, SINGAPORE
Senior High 2
Preliminary Examination
Higher 2

CANDIDATE NAME

BIOLOGY CLASS 2bi2____ / 2IPbi2__

REGISTRATION NUMBER

BIOLOGY 9648/03

Paper 3 **31 August 2016**

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your Biology class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Sections A - C
Answer **all** questions in the spaces provided on the question paper.

Sections D - E
Answer **all** questions on the answer paper provided.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or id you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 14
2	/ 14
3	/ 12
4	/ 12
5	/ 20
TOTAL	**/ 72**

This document consists of **11** printed pages.

[Turn over

Section A

Answer the question in this section.

1 In a maternity ward at a local hospital, a mix-up involving three couples and three babies caused a lot of confusion. Based on phenotypic characteristics, the nurses were unable to correctly identify the parents of the babies. In order to solve the case, a scientist was called in to carry out a DNA test to identify the parents of the babies. The test was based on the principle that different individuals have a different number of repeating units at a particular locus in a chromosome.

Chromosome 13 was isolated from the DNA samples that were obtained from the three couples and three babies and used for further analysis. The sequence below shows a segment of chromosome 13, which was used in the analysis where (TTAGGAT) is the repeating unit and n is the number of repeats.

5' …GCTAAGTATTGCTCAAGA… (TTAGGAT)n…GATAAATAACTGGCTAGTA…-3'
3' …CGATTCATAACGAGTTCT… (AATCCTA)n… CTATTTATTGACCGATCAT…-5'

Fig. 1.1 shows the results of the DNA test obtained from each individual.

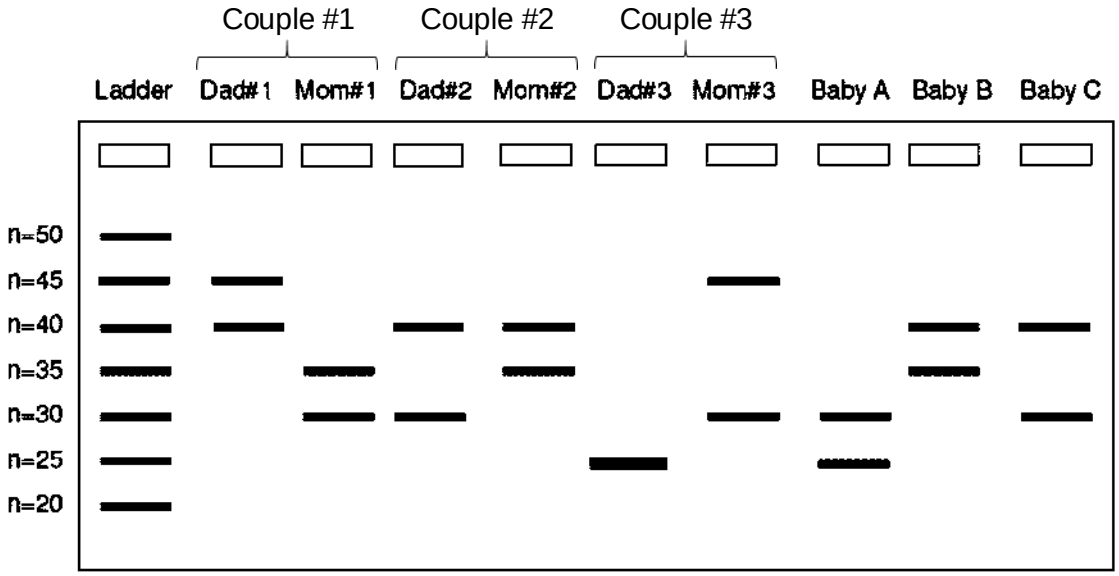


Fig.1.1

(a) Describe how the DNA bands in the gel could be made visible.

Staining with ethidium bromide and viewing under UV light
OR
Staining with methylene blue [1]

(b) State the purpose of the DNA ladder.

Each band serves as a comparison / reference for the size / number of repeats present in the individuals tested. [1]

(c) Explain how gel electrophoresis is used to separate fragments of DNA.

1. **Because all DNA molecules are negatively charged, regardless of the length or source, the rate of DNA migration and separation through an agarose gel depends on the size / molecular length of the DNA molecule.**

2. **An agarose gel is submerged in a buffer solution containing ions that will conduct electricity.**

3. **DNA samples are loaded into small depressions in the gel called wells, which are close to the negative electrode / cathode.**

4. **A direct current is applied through electrodes at opposite ends of the gel.**

5. **The negatively charged DNA molecules move toward the positive electrode / anode, with shorter DNA molecules moving faster and further than the longer ones.** [5]

(d) Explain the banding pattern of Dad #3.

(Any 3)

1. **Only one band corresponding to n=25**

2. **Band is twice as thick as the other bands**

3. **Homozygous for the locus being examined**

4. **25 repeats on both copies of chromosome 13** [3]

(e) Identify the couple that Baby A belongs to.

Couple #3 [1]

(f) Explain why the results shown in Fig. 1.1 could not confirm which couple that Baby B belongs to.

(Any 2)

1. **Each band in Baby B's DNA fingerprint would match the band in either the mum's or dad's DNA fingerprint.**

2. **The band corresponding to n=40 in Baby B's DNA fingerprint can be found in Dad#1, Dad#2 and Mom#2, whereas the band corresponding to n=35 in Baby B's DNA fingerprint can be found in Mom#1 and Mom#2.**

3. **Hence, Baby B could belong to either Couple #1 or Couple #2.** [2]

(g) Suggest an alternative DNA test to identify the couple that each of the three mixed up babies belongs to.

Analysis of Restriction Fragment Length Polymorphism (RFLP) or other Short Tandem Repeats (STR) [1]

[Total: 14]

Name: _____ Class: 2bi2___ / 2IPbi2___	14

Section B

Answer the question in this section

2 Haemophilia is an X-linked recessive disorder that impairs the body's ability to form blood clots. There are two main types, haemophilia A and haemophilia B, resulting from deficiencies in clotting factors VIII and IX respectively.

Both *ex vivo* and *in vivo* gene therapy approaches are undergoing clinical trials.

(a) (i) Explain why gene therapy approach for treatment of haemophilia is possible.

.....

..... [1]

(ii) Distinguish between *ex vivo* and *in vivo* gene therapy approaches.

.....

.....

.....

..... [2]

Haematopoietic stem cells (HSC) are ideal vehicles for *ex vivo* gene therapy application.

(b) (i) Describe the normal function of HSC.

.....

..... [1]

(ii) Explain why HSC are ideal vehicles for *ex vivo* gene therapy application.

.....

.....

.....

.....

..... [3]

The liver is an ideal target for *in vivo* gene therapy application. As a major organ and central metabolic hub, it receives an abundant blood supply through sinusoids with highly permeable walls, which facilitates easy access of blood-borne particles to the hepatocytes. Hepatocytes are long-lived and robust protein factories that can efficiently release their products into the blood circulation. Both viral and non-viral vectors have been and continued to be investigated.

(c) Use of non-viral vectors for gene therapy has met with low success rate.

Describe one method of non-viral vector delivery and explain why the method has achieved low success.

[3]

(d) Many ongoing clinical trials are focused on the application of adeno-associated viral (AAV) vectors, which are found to remain as episomes within the nucleus.

Explain an advantage and a disadvantage of the use of such adeno-associated viral vectors compared to retroviral vectors.

[2]

(e) Somatic cell nuclear transfer (SCNT), also known as therapeutic cloning, involves the replacement of an egg nucleus with a somatic cell nucleus. As the oocyte develops into a blastocyst, cells from the inner cell mass can be isolated and purified to serve as a source of pluripotent stem cells.

Explain why such an approach cannot be used to treat patients with haemophilia.

[2]

[Total: 14]

2 Haemophilia is X-linked recessive disorder that impairs the body's ability to form blood clots. There are two main types, haemophilia A and haemophilia B, resulting from deficiencies in clotting factor VIII and IX respectively.

Both *ex vivo* and *in vivo* gene therapy approaches are undergoing clinical trials.

(a) **(i)** Explain why gene therapy approach for treatment of haemophilia is possible. [1]

1. Haemophilia is caused by single defective gene.

(ii) Distinguish between *ex vivo* and *in vivo* gene therapy approaches. [2]

1. In *ex vivo* gene therapy, the therapeutic gene is introduced into target cells extracted from patient, and the altered cells are injected back into the patient.
2. In *in vivo* gene therapy, the therapeutic gene is introduced directly into target cells/tissues in the patient's body.

Haematopoietic stem cells (HSC) are ideal vehicles for *ex vivo* gene therapy application.

(b) **(i)** Describe the normal function of HSC. [1]

1. HSC normally differentiates to give rise to many types of blood cells, such as red blood cells, white blood cells and platelets.

(ii) Explain why HSC are ideal vehicles for *ex vivo* gene therapy application. [3]

1. HSC can undergo indefinite self-renewal, hence they can multiply indefinitely, thus sustaining the gene therapy treatment.
2. HSC are unspecialised

3. HSC have potential to differentiate, they can be stimulated to differentiate to produce the therapeutic gene product
4. HSCs multiply themselves >106 fold during haematopoietic reconstitution
5. HSCs can be manipulated to secrete biotherapeutic molecules such as FVIII directly into the bloodstream
6. HSCs can induce a state of immune tolerance or nonresponsiveness to the therapeutic transgene product

Accept:
A1. Given that HSCs are derived from patient, there is lower risk of immune rejection.

Reference: Spencer et.al. (2016). State of the art; gene therapy of haemophilia
HSCs are ideal cellular vehicles for gene therapy applications since they can (i) self-renew, (ii) multiply themselves >106 fold during haematopoietic reconstitution, and (iii) secrete biotherapeutic molecules such as FVIII directly into the bloodstream. Another critical property of HSC-directed gene therapy is the ability to induce a state of immune tolerance or nonresponsiveness to the therapeutic transgene product, which in the case of haemophilia A is a single protein, FVIII, that is known to possess a higher degree of immunogenic potential.

Reject:
(R!) HSCs can be isolated/ culture easily
(R!) lower risk of tumor formation compared to using pluripotent cells

The liver is an ideal target for *in vivo* gene therapy application. As a major organ and central metabolic hub, it receives an abundant blood supply through sinusoids with highly permeable walls, which facilitates easy access of blood-borne particles to the hepatocytes. Hepatocytes are long-lived and robust protein factories that can efficiently release their products into the blood circulation. Both viral and non-viral vectors have been and continue to be investigated.

(c) Use of non-viral vectors for gene therapy has met with low success rate.

Describe one method of non-viral vector delivery and explain why the method has achieved low success. [3]

Naked DNA method
L1. Therapeutic DNA is injected directly into target tissues.
L2. Target cells take up DNA randomly
L3. Poor transfection efficiency
L4. Not integrated into genome, hence transient expression

Liposomes
N1. Therapeutic DNA is encapsulated in anionic liposome.
N2. Mixing of liposomes and target cells result in fusion, thus introducing gene into target cell
N3. Poor transfection efficiency
N4. Not integrated into genome, hence transient expression

Molecular conjugates
M1. Therapeutic DNA is coupled to a targeting molecule.

M2. Targeting molecule binds to specific cell surface receptor and induces endocytosis and transfer of DNA into cells.
M3. Molecular conjugate often remain trapped in endosome resulting in poor gene transfer
M4. Not integrated into genome, hence transient expression.

(d) Many ongoing clinical trials are focused on the application of adeno-associated viral (AAV) vectors, which are found to remain as episomes within the nucleus.

Explain an advantage and a disadvantages of use of such adeno-associated viral vectors compared to retroviral vectors. [2]

Advantages:
A1. AAV vectors does not result in integration of therapeutic DNA into host genome unlike retroviral vectors hence less likely to cause insertional mutagenesis.
A2. AAV vectors readily infects both dividing and non-dividing cells, unlike retroviral vectors which can only infect dividing cells

Disadvantages
D1. AAV vectors does not result in integration of therapeutic DNA into host genome unlike retroviral vectors hence expression may be transient.
D2. AAV vectors can only accept smaller insert size, up to 4.5kb, compared to retroviral vectors which can accepts to larger insert size of up to 8 kb.
D3. AAV vectors require helper virus to infect target cells, while retroviral vectors do not.

Reject:
Advantage:
1. AAV vectors have higher transfection efficiency. (A!)
2. AAV vectors can target specific tissues and organs, which is not the case for retroviral vectors. (A!)
3. AAV vectors elicits lesser immune response (A!)
4. AAV vectors less likely to regain viral properties than retroviral vectors (A!)

Disadvantage
5. AAV vectors have lower transfection efficiency. (A!)
6. Less familiarity with AAV vectors, thus potential danger of AAV vectors is unknown. (R!)
7. DNA insert in AAV vectors is not inserted into cell genome, hence level of DNA expression is significantly lower. (A!)
8. Repeated therapy cycles may be needed hence more costly.

(e) Somatic cell nuclear transfer (SCNT), also known as therapeutic cloning, involves the replacement of an egg nucleus with a somatic cell nucleus. As the oocyte develops into a blastocyst, cells from the inner cell mass can be isolated and purified to serve as a source of pluripotent stem cells.

Explain why such as approach cannot be used to treat patients with haemophilia. [2]
1. All somatic cells from the patient will contain the defective gene.
2. The resulting pluripotent cells isolated from inner cell mass from such a procedure will contain the same genetic defect, hence remain unable to produce the necessary clotting factors.
3. If a donor cell nucleus containing a functional gene is used for SCNT, the stem

cells may contain antigens that cause them to be rejected by the immune system.

[Total: 14]

Name: _____ Class: 2bi2___ / 2IPbi2___

12

Section C

Answer the question in this section.

3 The success of culturing callus is low due to the difficult task of removing contaminants. It has proven more challenging for plants taken from the wild in tropical countries. In Sumbawa, Indonesia, plant tissue samples were sampled at three different times of the year. They were grown in medium containing no fungicide or antibiotic.

Table 3.1 shows the results.

Table 3.1

explant	time of year	number of explants	number of cultured explants with no fungal or bacterial contamination	percentage of cultured explants with no fungal or bacterial contamination
leaf disc	April	153	12	8
	August	322	16	5
	January	332	30	9
shoot tip	April	194	116	60
	August	191	122	64
	January	211	156	74

(a) Describe and explain the results of using the two types of explant.

Using shoot tip had higher rate of success;

Where for example in April, using shoot tip explant produced 60% cultured

explants with no contamination compared to the 8% of uncontaminated explants that

were produced when leaf discs were used; (A! any appropriate comparison of values

in the months of august or January) OR

Explant taken during January had a higher success rate with 8% for leaf disc

and 74% for shoot tip;

Shoot tip contains meristematic cells which are actively dividing; [3]

> making infection difficult.

Use antibiotics/fungicide;

Use of dilute sodium hypochlorite/ bleach to sterilise wild plant samples; [1]

(b) Besides using the appropriate explant, suggest how the number of contaminated samples could be reduced when using wild plant samples.

(c) Explain, with relevant examples, how genetic engineering has helped to increase the quantity of crops for farmers.

Any relevant technology;

Change;

Benefit to farmers;

E.g. Super Salmon àpromotor for AFP plus beside the gene coding for growth; > hormone
Gene will be activated all year round due to cold environment and growth hormone produced all
year round;

Salmon can grow twice as fast with same amount of feed; [3]

(d) Describe two disadvantages of plant tissue culture.

Contamination of cultures poses the greatest problem to commercial tissue culture as

it can cause very high losses in a short time;

Micropropagation is tedious and costly as it requires much labour (e.g transfer of

plantlets from the laboratory to the soil), trained personnel with specialized skills,

sophisticated facilities and organization, sterile laboratory conditions and special

nutrient media. This may not be economical for crops with low financial returns like

carrots;

Plants produced from calli may undergo genetic changes to produce genetic off-types. > hormone
For example, bananas can produce a lot of genetic off-types in culture. Most of these produced all
changes are undesirable;

The limited genetic pool and genetic uniformity of plants cultured make them

vulnerable to new diseases or drastic changes in the environment;

[Any two points] [2]

(e) In several countries including China, Korea and the United States, human DNA has already been put into eggs from both rabbits and cows.

Discuss the ethical concerns of conducting such experiments.

Humans should not be tampering with nature by creating living organisms which may

be objectionable by certain religious groups;

Crossing the species barrier and violating the genetic integrity of the organism;

The research may not be justified if it is not to address the urgent needs of mankind but
only the desires of mankind;

Exploitation of animals in the process/ Lack of concern for their welfare;

Slippery slope that may lead to human cloning; AVP [3]

Section D

Answer the question in this section on the answer paper provided.

4 Planning Question

You are required to plan, but not carry out, an investigation into the effect of increasing concentration of glucose on rate of respiration of yeast.

Yeast synthesizes ATP through two major biochemical pathways: aerobic respiration and fermentation. During both aerobic respiration and fermentation, yeast cells break down glucose molecules within the cell to release energy, and some of this energy is captured and stored in the ATP's high-energy phosphate bonds. The breakdown of glucose also releases carbon atoms, which become available for biosynthetic reactions, enabling the yeast to grow and reproduce by budding. The rest of the carbon ends up in the by-products of these reactions.

You are to use methylene blue in your investigation. Methylene blue acts as an artificial electron acceptor during respiration, which changes from blue to colourless as a result of its reduction in the enzymatic reaction.

Your plan should have a clear and helpful structure to include:

- a description of the method used including the scientific reasoning behind the method,
- an explanation of the dependent and independent variables involved,
- relevant, clearly labelled diagrams,
- how you will record your results and ensure that they are as accurate and reliable as possible,
- proposed layout of results tables and graphs with clear headings and labels,
- the correct use of technical and scientific terms,
- relevant risks and precautions taken.

Your planning must be based on the assumption that you have been provided with the following equipment and materials, which you must use:

- yeast suspension,
- 10% glucose solution,
- distilled water,
- access to tap water,
- thermostatically controlled water bath,
- methylene blue,
- stopwatch,
- a variety of different sized beakers, test-tubes, boiling tubes, measuring cylinders or syringes for measuring volumes.

[Total: 12]

Mark Scheme (details)

ariables

The independent variable in this experiment is the glucose concentration while the dependent variable is average time taken for methylene blue to decolourise.

rediction of the likely outcome of the experiment/Trend

As glucose concentration increases, the average time taken for blue colour of methylene blue to disappear decreases. [1]

xplain the likely outcome of the experiment

- When glucose concentration increases, more hydrogen atoms are removed from glucose molecules by enzymes called dehydrogenases and passed to hydrogen acceptor NAD+ and FAD (co-enzyme) [1]

Method of measuring rate of respiration/rational of experiment

- Methylene blue mimic the action of NAD+ and FAD
  Methylene blue turns from blue to colourless when it is reduced by hydrogen. [1]
- Respiration rate is measured by average time taken for methylene blue to turn from blue to colourless **[1]**

1. **Procedure** Set up a thermostatically controlled water bath at 37 ˚C.

2. Using **dilution** to obtain at least five known glucose solution concentrations; and placed them in separate labelled test-tubes.

   Concentration stated 0.1% - 10% (any reasonable range). Final volume stated. **[1]**

Tubes	Volume of **10%** glucose / cm^3	Volume of distilled water / cm^3	Concentration of glucose solution / %
A			
B			
C			
D			
E			

3. Label 6 boiling tubes A – E and F (control). Using a 5 cm^3 syringe, add 5 cm^3 of each glucose solution concentration to A – E and 5 cm^3 of distilled water to F.

4. Label another 6 boiling tubes A1 – F1. Using a 5 cm^3 syringe, add 5 cm^3 of yeast suspension to A1 – F1.
   Use the same concentration of yeast suspension from the same stock for each reading and repeat as it affects the rate of respiration. This ensures initial concentration of the respiratory enzymes is kept constant. **(Controlled variable)**

5. Using another 5 cm^3 syringe, add 3cm^3 of pH buffer to A1 – F1. Changes in pH may affect the active site configuration and therefore enzyme activity. Addition of pH buffer will keep pH constant. **(Controlled variable)**

6. Leave boiling tubes A – F and A1 – F1 in the thermostatically controlled water bath for 5 min **(equilibration/acclimatization time)** using stopwatch to time. **[1]**

   Temperature must be kept constant as it affects enzyme activity, hence the rate of respiration. **(Controlled variable)**

7. Pour contents from A into A1, B into B1, C into C1, D into D1, E into E1 and F into F1.

8. **Add 3 drops of methylene blue into each tube and shake/stir each tube to mix the contents and place them back into the water bath. [1] (key step)**
   The same amount and concentration of methylene blue used ensures consistency in the time taken for complete decolourisation. (**Controlled variable)**

   Any 2 controlled variables – [1]

9. **Start the stopwatch and note the time taken for the blue colour to disappear from each tube. [1] (Method to measure)**

10. Repeat steps 1 to 9 to obtain a total of three readings, using freshly prepared yeast suspension, glucose solution and methylene blue each time. **(Reliability of results)**

11. Repeat the entire experiment (steps 1 to 10) twice using fresh yeast suspension, glucose solution and methylene blue of a different batch, to ensure reproducibiltity of results.
    Replicate + Repeat [1]

12. Plot a graph of rate of respiration / s^{-1} against glucose concentration / %. **[1] (with correctly plotted graph)**

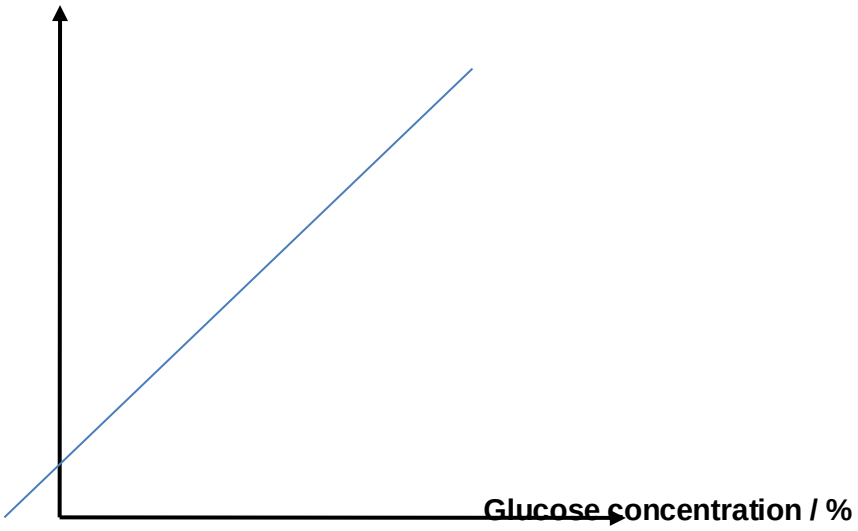
Control

A control (test tube F) is set up which has 5 cm^3 of distilled water instead of glucose added to it and subjected to the same conditions as the rest of the tubes. To show that the colour change of methylene blue is due to the oxidation of glucose by yeast enzymes**. [1]**

Table showing rate of respiration with varying glucose concentration [1]

Glucose concentration / %	Time taken for blue colour to disappear / s				Rate of respiration/ s^{-1}
	Reading 1	Reading 2	Reading 3	Average	

Graph of AVG rate of respiration/s^{-1} against glucose concentration / %.



Safety Precaution

- Methylene blue can be a skin irritant – Wash under running water when in contact with skin.
- Water bath may be hot and may scald. Wear gloves when handling beaker of hot water. [1] for 2 precautions

Fully Labelled Diagram [1]

Section E

Answer the question in this section on the answer paper provided.
Begin each part of the question on a new piece of answer paper.

5 Free-response question

Your answers:

- should be illustrated by large, clearly labelled diagrams, where appropriate,
- must be in continuous prose, where appropriate,
- must be set out in sections **(a)**, **(b)**, etc., as indicated in the question.

(a) Describe the goals, benefits and ethical concerns of human genome project. [8]

(b) Explain the significance of genetic engineering in improving food quality. [6]

(c) Discuss the social and ethical implications of genetically modified crop plants. [6]

[8]

[6]

[6]

9 (a) Describe the goals, benefits and ethical concerns of Human Genome Project. [Total: 20] [8]

Goals of Human Genome Project: [Any 2 of the]

1. To determine the sequences of all the 3 billion DNA base pairs in the human genome and to store them in databases accessible to the public.
2. To identify and sequence all the 20,000 to 25,000 genes in the human DNA.
3. Using the gene sequences obtained, to construct a detailed genetic linkage map and physical map of the human genome to understand genetic basis of diseases.
4. The Project also aimed to sequence the genomes of several other organisms that are important to medical research, such as the mouse and the fruit fly.
5. Develop new tools to obtain and analyse the data and to make this information widely available. Computer programs or software would be developed and improved to analyze the data because the data are difficult to interpret without such programs. (OWTTE)
6. Develop genetic tests/screening for diseases and develop more efficient methods for DNA sequencing and sequence analysis and the transfer of these technologies to industry. (OWTTE)
7. Address the ethical, legal and social issues (ELSI) that may arise from the project.

[Max 3 of the above with elaboration]

Benefits of Human Genome Project (HGP) – Max 3 Marks

State + describe one example within category (include explanation to get full mark)

1. **Advancement in Genetic testing / Molecular Medicine** [8]

a) The HGP has allowed for discovery of genes/alleles/ associated with human diseases/ understanding genetics basis of disease; this allows for improved diagnosis of disease / genetic testing.
b) Earlier detection of genetic predispositions to disease (eg. breast cancer, cystic fibrosis, Alzheimer's disease).
c) It also allows scientists to design drugs to target a specific gene/protein.

2. Personalised Medicine / Pharmacogenomics

a) The HGP allows scientists/doctors to know which genes/alleles affect a person's response to a drug since genetic differences affect the way we react to the same drug.
b) It is now possible to tailor drugs/treatments to fit patient's genome for greater efficacy / avoiding dangerous side effects;

3. Improvement in Gene therapy

a) Since we are able to have a understanding which genes/alleles are associated with which diseases, It is possible to use gene therapy to treat certain diseases since gene sequences are now readily available via databases,

4. Risk assessment of individuals upon exposure to toxic agents

a) The HGP has allowed for **discovery of genes/alleles associated** with resistance/susceptibility to radiation/carcinogens. Individuals' genome can be used as a means of risk assessment to evaluate health risks of individuals who may be exposed to radiation or carcinogens. This will help to reduce the likelihood of heritable mutations.

5. Anthropology, Evolution, and Human Migration
a) study **evolution through germline** mutations in lineages
b) study population migration through matrilineal line based on female genetic inheritance or patrilineal line through Y chromosome mutations

6. Energy and Environmental Applications
a) Use microbial genomics research to create new energy sources (biofuels)
b) Use microbial genomics research to develop environmental monitoring techniques to detect pollutants
c) Use microbial genomics research for safe, efficient environmental remediation

7. Advancement in Agriculture, Livestock Breeding (GMO)
a) Creation of Disease-, insect-, and drought-resistant crops. E.g. BT corn,
b) Creation of healthier, more productive, disease-resistant farm animals.

Ethical Concerns – 3 Marks

1. Privacy and confidentiality of genetic information. [Elaboration with one point from below]

a) The issue of who owns genetic information – whether the individual has

complete control over who has access to his genetic information, or is access controlled by the company/researcher who carries out the genome sequencing, or even controlled the government.

b) Fairness in the use of genetic information by insurers, employers, courts, schools, adoption agencies, and the military, among others.

c) The issue of whether insurers / employers / courts / schools / adoption agencies / military may request for and have access to personal genetic information to discriminate people based on their genomes.

2. Psychological impact and stigmatization due to an individual's genetic differences.

a) It is unclear how personal genetic information affects an individual and society's perceptions of that individual

b) Will the genomic information lead to discrimination and affect members of minority communities

3. Reproductive issues including adequate informed consent for complex and potentially controversial procedures, use of genetic information in reproductive decision making, and reproductive rights.

a) There is an issue of whether healthcare personnel are properly counseling parents about the risks and limitations of genetic technology (eg. with regards to the reliability of the genetic test, or whether the detected condition can be treated, and to help patients anticipate and deal with options to deal with the disease, if present, and whether relatives should be informed of the condition so that they can decide whether to test for the condition as well).

b) To-be parents may have to make difficult decisions of whether to terminate pregnancy due to presence of genetic disorder (especially one for which there is currently no cure or treatment for).

4. Uncertainties associated with gene tests for susceptibilities and complex conditions (e.g., heart disease) linked to multiple genes and gene-environment interactions.

a) The issue of whether testing should be performed when no treatment is available/treatment is extremely expensive and the patient cannot afford it, as diagnosing such a condition could lead to more anxiety and frustration.

b) The issue of whether parents have the right to have their children tested for adult-onset diseases, as there is potential for conflict between a parent's choice and a child's welfare (eg. a parent refuses to consent to a test that is clearly in their child's best interest, or a parent who decides to pursue a genetic "enhancement" that involves significant risks for a child, or that may limit a child's life prospects)

c) There is also the related issue of who has the right to determine whether newborns or others who are incapable of valid consent (eg. mentally incapacitated) should undergo genetic screening.

d) The genetic tests may only indicate a probability and not a certainty of a particular polymorphism/allele being associated with a disease or condition. (There is difficulty in interpreting a positive result because some people who carry a disease-associated mutation never develop the disease.) Hence the genetic tests may not be reliable.

(b) Explain the significance of Genetic Engineering in improving food quality.

Define Genetic Engineering [1]
Define genetic engineering:
the application of recombinant DNA technology to introduce genetic material/ foreign genes in order to alter the hereditary traits/ genetic makeup of a cell, organism, or population;

Genetically Modified Organism: Refers to an organism that has acquired one or more genes by artificial means. The genes may or may not be from the same species. OR
Transgenic organism: to describe organisms that had been genetically engineered to express a foreign gene from another species.

Improving Food Quality + Explain briefly [max 2 Marks each]

1. Improved Quality and Yield in Plants e.g. **Bt corn [2]**

- Development of plants resistant to insects / pests. E.g. BT corn express Bt toxins from the Bt toxin gene (Bt toxin gene is isolated from Bacillus thuringiensis and genetically engineered into corn crops).
- Growers use Bt corn as an alternative to spraying insecticides for control of corn borer. Consequently, farmers use less pesticides because BT corn express their own insecticidal proteins.
- This gene crystal proteins (Cry proteins) which acts as insect stomach poisons that must be eaten to kill the insect. Once eaten, the insect's own digestive enzymes activate the toxic form of the protein.
- The Cry proteins bind to specific receptors on the intestinal lining and rupture the cells causing death of the organism within 2 or 3 days.
- Bt maize has revolutionized pest control and many farmers have benefited financially.
- As this toxin is lethal to the pest but harmless to other animals, this Bt corn allows farmers to control pest infestations in order to reduce crop losses.

Others:
Development of Frost Resistance Plants. E.g. Frost-resistant Strawberries, edible vaccines
- *Development of crops with frost resistance. E.g. frost-resistant strawberries can be made by inserting the gene for antifreeze proteins from winter fishes into strawberry crops using recombinant DNA Technology.*
- *Development of bananas that contains human vaccines against infectious diseases such as hepatitis B*

2. Improved quality e.g. golden rice [2]

- Modification of crops by allowing them to produce additional vitamins / minerals. E.g. Golden rice has been genetically engineered to produce beta-carotene a pre-cursor of vitamin A. Production of golden rice will help to provide nutritionally enriched foods particularly to those in developing countries.
- Vitamin A deficiency is the leading cause of preventable blindness in children and increases the risk of disease and death from severe infections.
- Rice grain, which serves as a food staple for much of the world do not contain vitamin A naturally.

- It was discovered that **geranyl geranyl diphosphate (GGPP)** found in rice seed can be a precursor to carotenoid production. **Beta-carotene** and other carotenes are natural **precursors** (inactive form) **of vitamin A.**
- Thus it is possible to genetically engineer a new breed of rice variety, **golden rice** which can **express the enzymes** necessary for the **conversion of GGPP to beta-carotene**.
- To engineer **golden rice**, genes coding for **phytoene synthase** (obtained from plant) and **phytoene desaturase** (obtained from bacteria) must be introduced into the rice plant cells. These enzyme-coding genes catalyze the biosynthesis of beta-carotene from precursor GGPP in the endosperm (edible part of the grain)
- A bacterium, ***Agrobacterium tumefaciens***, containing a **Ti plasmid**, was used to introduce all the **enzyme-coding genes**. OR another way of introducing DNA into plant cells is through DNA coated particles that are literally shot through the cell wall using a modified gun. This is commonly referred to as the use of a 'gene gun'.

3. Improved yield e.g. GM salmon [2]

- Production of GM salmon that grow and reach market size twice as fast as non-transgenic salmon for greater production of fish meat.
- Recombinant DNA composed of an **antifreeze promoter** from an ocean pout and a **growth hormone gene** from a Pacific Chinook salmon is synthesized. Fusing of a strong gene promoter such as the ocean pout antifreeze promoter leads to enhancement in the expression of the gene construct.
- The recombinant DNA is then introduced into fertilized eggs of Atlantic salmon. Subsequent selection and breeding led to development of the genetically modified salmon.
- Due to the year-round production of growth hormone (due to the antifreeze promoter), this allows for continuous feeding and growth of the GM salmon.
- The GM salmon is able to grow quicker in size while feeding more efficiently (less feed is consumed to reach a larger size).

Others:

Improving the nutrient and quality of food. E.g.

- *Pharming of animals to produce vaccines or drugs for therapy / medicine. E.g. genetically engineering goats to produce anti-thrombin in their milk.*
- *For increase quality of meat, pigs have been genetically engineered to produce higher content of omega-3 fatty acid.*

(c) Discuss the social and ethical implications of GM crop plants.

[6]

Social Implications [Max 3 Marks]

1. Cost Savings for famers and cheaper foods for consumers {social}

a) Growth of pest-resistant plants means that lesser crops are lost due to insect damage / diseases spread by insect vectors, therefore resulting in higher yield.
b) Lesser insecticide / pesticide is used, therefore the farmers can save more money.
c) Growth of herbicide-resistant plants means that farmers can spray herbicides to kill weeds without harming the crops. This results in reduction in competition from weeds, resulting in higher crop yield.
d) Savings for famers translate into cheaper foods for consumers.

2. Malnutrition and reduce mortality rate {social}

a) Enhanced quality of crop (e.g. Golden rice, expression of beta-carotene in endosperm in rice, which is converted into Vitamin A in the body when eaten) which helps to keep people healthy and to prevent malnutrition.
b) Doing so will have a positive impact on public health, improving economic productivity, and individual well-being.

3. Rise of super-weeds lead to increase in expenses for Farmers {social}

a) There is a risk of transgene transfer to closely-related non-crop species. For e.g. for herbicide-resistant GM crops, the use of herbicides can lead to the rise of super-weeds that are resistant to herbicides as weeds are grown alongside herbicide-resistant GM crops, due to crossing with the closely related GM plant;
b) Herbicide acts as a selection pressure when a grower continues to use only one particular herbicide without any other herbicide modes of action, or doesn't use any other cultural practices. The resistant weed type continues to survive, mature and produce seed. Subsequent populations of the resistant biotype will continue to increase, reducing crop yields.
c) Farmers would then have to resort to heavy / excessive usage of herbicide, which persist in the environment (i.e. runoff of chemicals into waterways), affecting the ecosystem.

4. Big biotechnology companies will monopolise the seed market, poor farmers not able to afford such seeds (Widening the gap between the rich and poor)

a) GM suppliers could make farmers buy new seed every year. E.g., when farmers purchase a patented seed variety from Monsanto, they sign an agreement that they will not save and replant seeds produced from the seed they buy from Monsanto.
b) Concerns that a few big biotechnology companies will dominate the world seed market.
c) There are also concerns that GM crops might prove too expensive for poor farmers in developing countries to cultivate, thus widening the gap between the rich and poor.

d) Using gene from animals in plant food foods may pose ethical or religious problems.
e) Increasing dependence of developing nations on industrialized nations as the GM crops / seeds may be too expensive for the poor famers in developing countries;

5. Increase in antibiotic-resistance genes found in crops and gut bacteria

Concerns over effects in agriculture of crops interbreeding with closely related species making them resistant. E.g., there is a possibility that bacteria in our guts could pick up antibiotic-resistance genes found in any GM food. If this transfer occurs, it might exacerbate the already worrisome spread of disease-causing bacteria that are resistant to antibiotics.

Ethical Issues: Max 3 Marks

1. GM crops may have long-term effects on humans which are yet unknown. The FDA currently does not require safety assessments of GM foods to be done, in part due to the difficulty of conducting long term feeding trials.
2. There are concerns whether genetically modified foods would be acceptable to various religions or vegetarians. E.g. a vegetarian might not feel comfortable eating strawberries bearing antifreeze proteins from a winter fish / a person observing kosher dietary laws might be offended to know that a tomato he / she has eaten carried a gene isolated from pigs.
3. There are calls for GM food products to be labelled so that consumers can make informed choices. Currently, in the United States, food labeling of GM food is optional / voluntary, so consumers do not know they are consuming GM foods.
4. Critics argue that raising GM crops is an uncontrolled experiment with unknown consequences to the surrounding ecosystems, such as causing “genetic pollution” from the out-crossing of transgenic / GM organisms with wild populations. This mixing of genes and the formation of hybrids result in changes in the gene pools, causing a loss in biodiversity. This might lead to reduction in biodiversity and changes. Cite study showing reduced survival of Monarch caterpillars fed on milkweed dusted with Bt maize pollen.
5. Some critics oppose to GMOs on religious grounds, arguing that the act of altering genetic material goes against Nature and raises the idea of “playing of” god.

--- End of Paper ---

H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME

CLASS

BIOLOGY **9648/01**

Paper 1 Multiple Choice **28 September 2016**

1 hour 15 min

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name and CT on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
Calculators may be used.

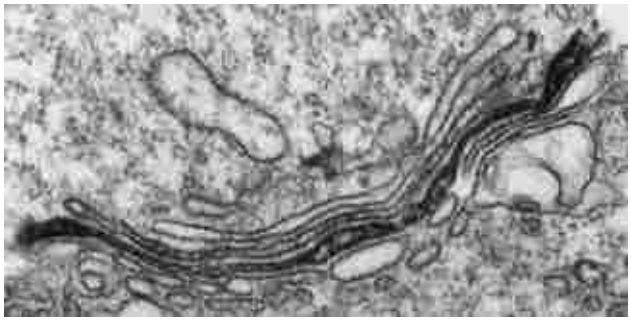
This document consists of **27** printed pages and **1** blank page.

[Turn over

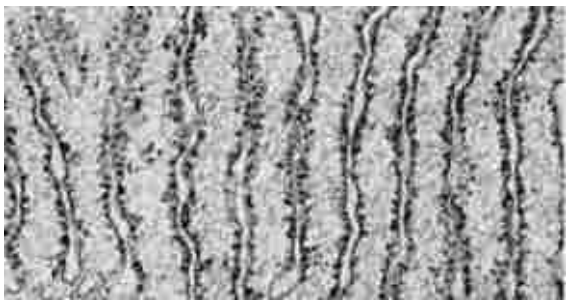
1 In an active cell, the pathway of a protein synthesis to maturation involves the endomembrane system.

(I)

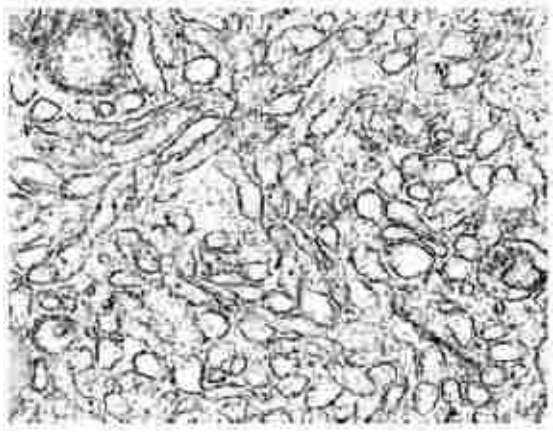
(II)



(III)



(IV)



The following are several processes that occur in an active cell.

w. modification of carbohydrates on protein

x. folding of protein into its 3 dimensional conformation

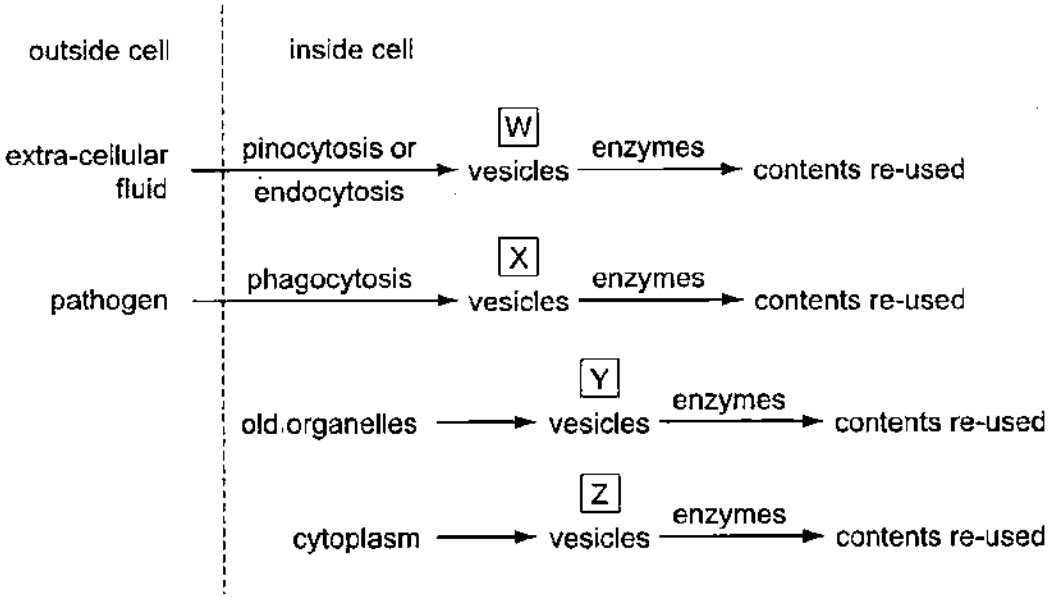
y. synthesis of steroids

z. storage of synthesized proteins

Where in the above diagrams do these processes take place?

	(I)	(II)	(III)	(IV)
A	z	w	y	x
B	z	w	x	y
C	y	w	x	z
D	z	y	x	w

2 The flow chart shows processes which takes place inside animal cells.



Which processes require the activity of lysosomes?

A **W, X, Y** and **Z**
B **W** and **X** only
C **X** and **Y** only
D **Y** and **Z** only

3 Which of the following lists of processes matches the type of movement across membrane correctly?

	Passive diffusion	Facilitated diffusion	Active transport	Endocytosis	Exocytosis
A	Exit of CO_2 from mitochondria	Chemiosmosis of H^+ through ATP synthase	Exit of Ca^{2+} from synaptic knob	Entry of HIV	Budding of influenza virus
B	Exit of CO_2 from mitochondria	Exit of K^+ from neuron	Entry of Na^+ into neuron	Entry of HIV	Budding of influenza virus
C	Entry of O_2 into mitochondria	Exit of K^+ from neuron	Exit of Ca^{2+} from synaptic knob	Entry of influenza virus	Release of insulin from β cells
D	Entry of O_2 into mitochondria	Chemiosmosis of H^+ through ATP synthase	Entry of Na^+ into neuron	Entry of influenza virus	Release of insulin from β cells

4 Raffinose is a trisaccharide which can be degraded by enzymes. The results of two different enzymatic incubations are shown in the table below:

Enzyme used	Products
Sucrase	Melibiose and fructose
Galactosidase	Galactose and sucrose

Which of following statements are consistent with the results shown above?

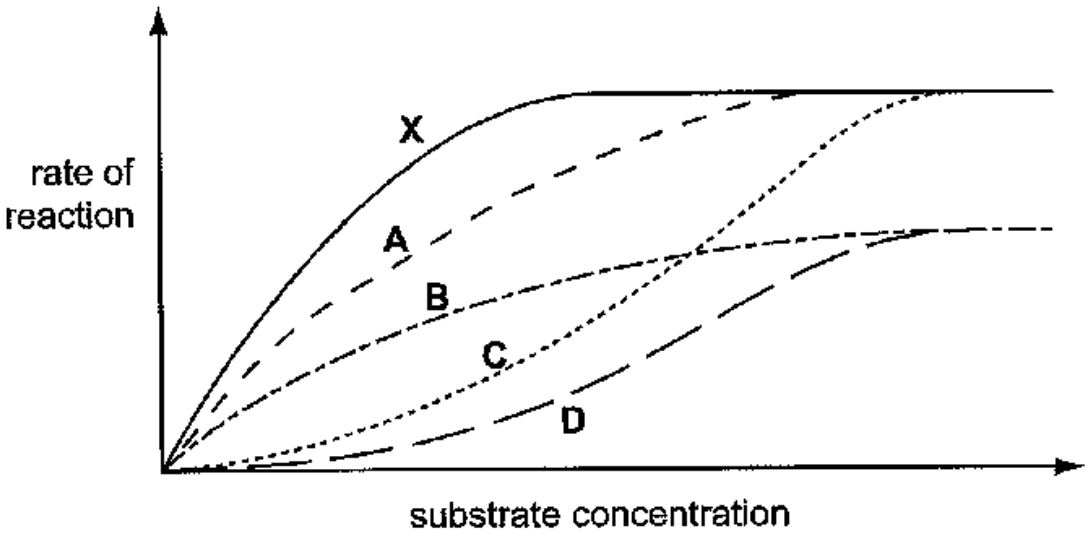
I Raffinose is composed of three different monosacchardies.
II Melibiose is a dissacharide.
III One of the products of acid hydrolysis of raffinose is glucose.
IV The products of raffinose digestion by sucrase and galactosidase respectively will yield a brick-red precipitate when heated with Benedict's reagent.

A I and III only
B II and IV only
C I, II and III only
D All of the above

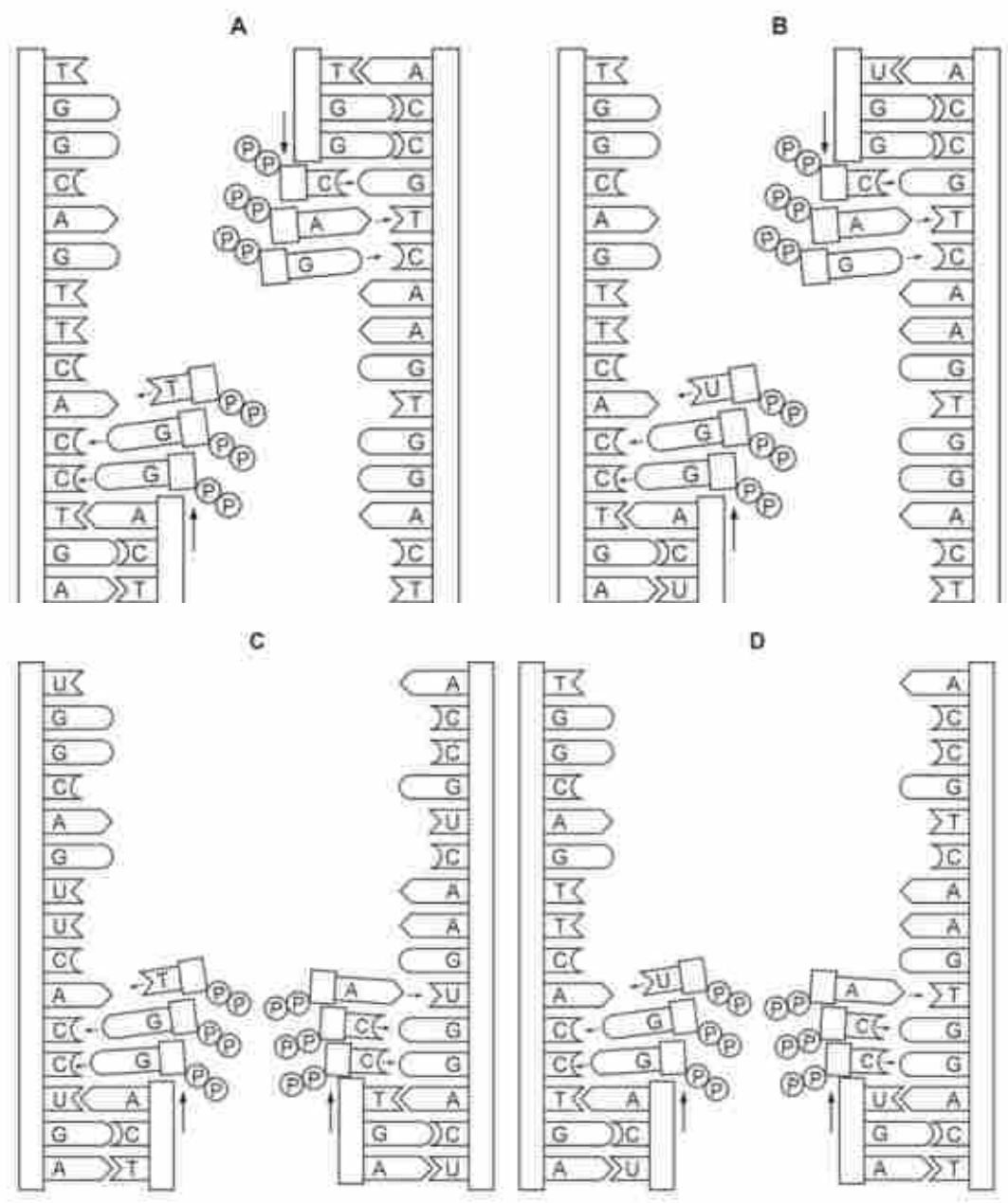
5 The reaction rate of salivary amylase on starch decreases as the concentration of chloride ions is reduced. Which of the following describes the role of the chloride ions?

A Allosteric inhibitors
B Co-enzymes
C Co-factors
D Competitive inhibitors

6 In the graph, X represents the initial rate of reaction of an enzyme in increasing substrate concentrations under optimum temperature and pH, in the absence of an inhibitor. Which curve represents the result when the same experiment is carried out under a lower temperature?



7 Which diagram shows the semi-conservative replication of a section of a molecule of DNA?



8 The diagram represents part of a DNA molecule.

G A T A C C A
C T A T G G T

Mutation	Name
from purine to other purine	transition
from pyrimidine to other pyrimidine	transition
from purine to pyrimidine	transversion
from pyrimidine to purine	transversion

Which diagram shows the DNA molecule with only transversion(s)?

A

G T T A T C A
C A A T A G T

B

G A A A C A A
C T T T G T T

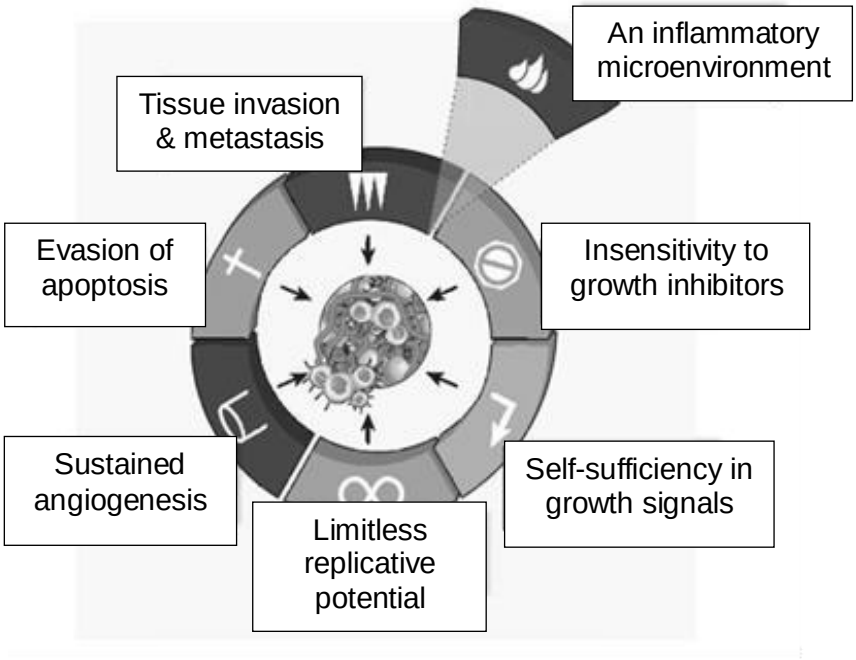
C

A A T A C C A
T T A T G G T

D

G A T A T C A
C T A T A G T

9 The diagram illustrates the hallmarks of cancer.



Which of the following statements correctly describe the changes in cancer cells?

I	Limitless replicative potential often results in the accumulation of chromosomal mutations in many cancer cells.
II	Cancer cells could overproduce signal molecules so that they become self-sufficient in growth signals.
III	Angiogenesis is the result of expression of oncogenes in a cell line that produces blood vessels.
IV	Loss-of-function mutations in tumour suppressor genes contribute to tissue invasion and metastasis.

A **I** and **IV** only

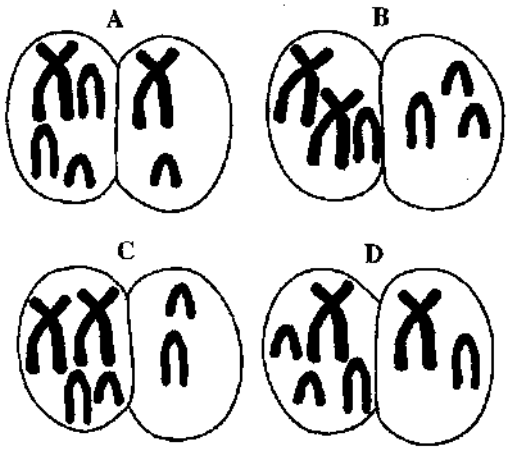
B **II** and **III** only

C **I, II** and **IV** only

D **II, III** and **IV** only

10 The diagram shows three of the 23 pairs of chromosomes found in a human cell.

Which diagram shows an example of non-disjunction in the formation of an egg, that could lead to the formation of a Down's syndrome zygote?



11 A toxic chemical causes malfunction of the centrioles in animal cells.

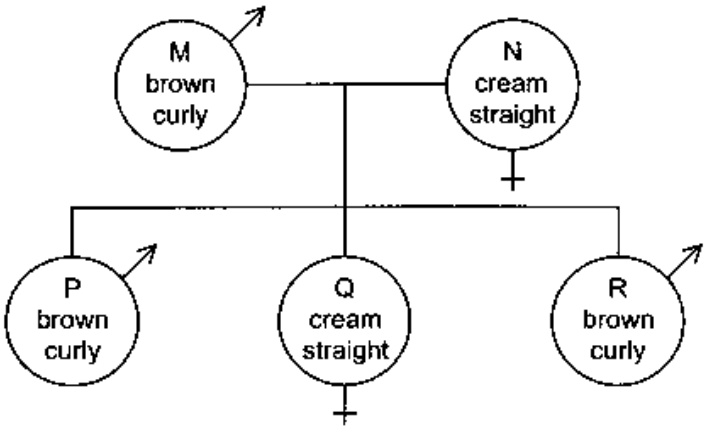
Which process in mitosis is likely to be directly affected by the chemical?

1 migration of the chromosomes
2 replication of centromeres
3 chromosome shortening
4 alignment of chromosomes

A 1 and 4 only
B 2 and 4 only
C 1, 3 and 4
D 2, 3 and 4

12 Assume that in goats a pair of alleles is responsible for the inheritance of hair colour and that another pair controls hair texture. These pairs are located on different autosomes. The allele for brown hair (B) is dominant to the allele for cream hair (b), and the allele for curly hair (C) is dominant to the allele for straight hair (c).

The diagram shows a cross between two goats.



If R is mated with a female goat of the same genotype as M, what are the chances of the first offspring being a male with cream coloured, straight hair?

A 0
B 1 in 32
C 1 in 16
D 1 in 4

13 A cross between a round-leafed, tall plant and round-leafed, dwarf plant produced the following offspring:

121 round-leafed, tall plants	R – round leaf
121 round-leafed, dwarf plants	r – oval leaf
42 oval-leafed, tall plants	T – tall
37 oval-leafed, dwarf plants	t – dwarf

What were the genotypes of the parents?

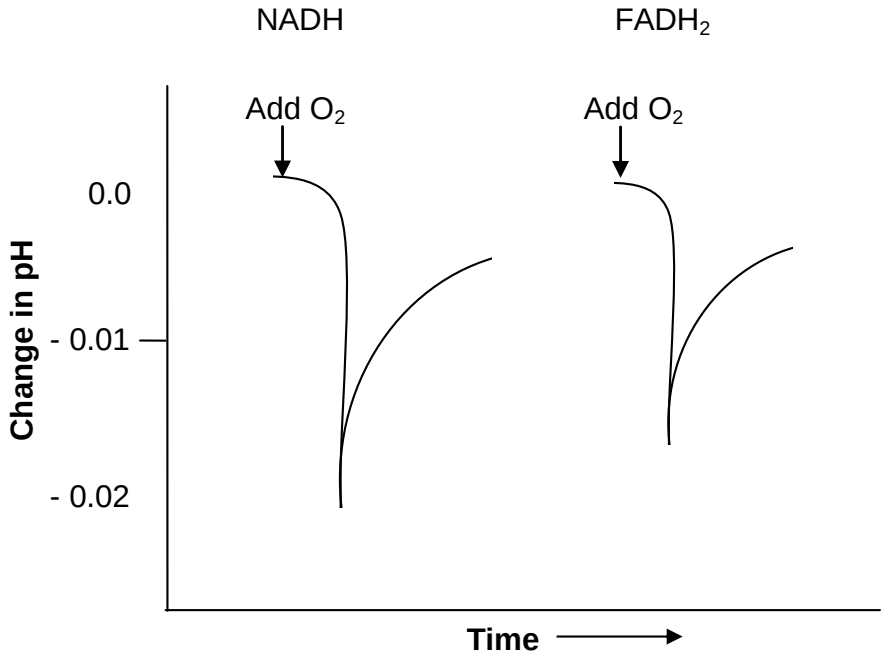
A RrTt x Rrtt
B RrTt x RRtt
C RrTT x Rrtt
D RrTT x RRtt

14 Black, chestnut and bay (reddish brown with black mane, tail, eartips and lower legs) coat colour in horses is determined by two genes. The dominant E allele codes for black and red pigment, while the recessive e allele codes only for red pigment. At a separate gene, the dominant A allele restricts any black pigment produced to the horse's mane, tail, eartips and lower legs, while the recessive allele allows any black pigment produced to show up throughout.

Two black horses were mated. Which of the following coat colours will definitely **not** show up in their offspring?

A Bay
B Black
C Chestnut
D All three colours are possible

15 Isolated mitochondria were incubated with NADH in one experiment and an equal amount of $FADH_2$ in another experiment. The mitochondria were initially deprived of oxygen. The pH of the intermembrane space was then monitored as a known quantity of oxygen was added. The results are shown in the graph.

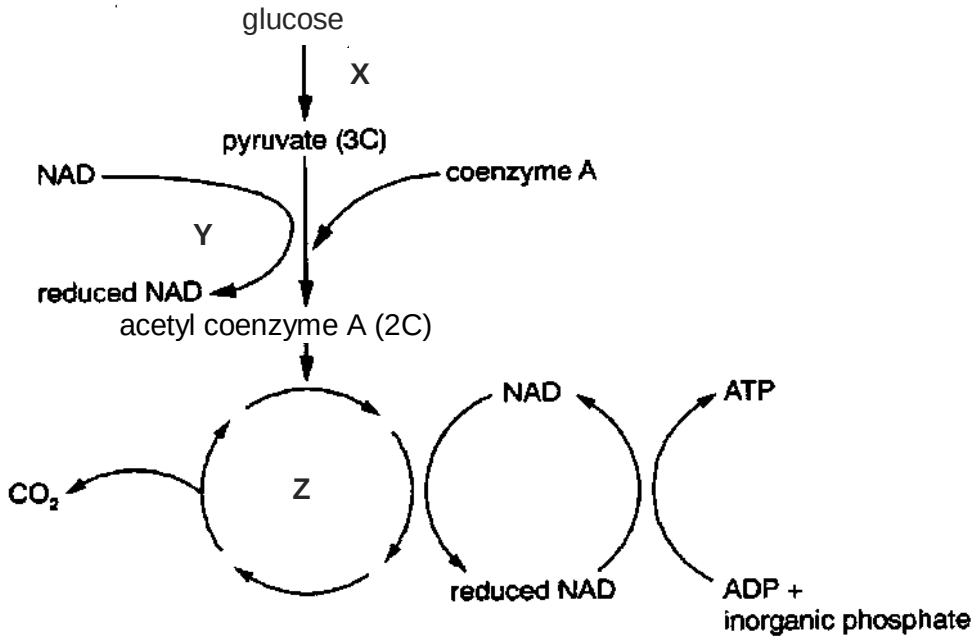


Which of the following can be concluded based on the results?

I	Upon the addition of oxygen, glycolysis and subsequently, link reaction, Krebs cycle and oxidative phosphorylation occurred.
II	Electron transfer was initiated by the addition of oxygen.
III	The pH drop was greater with NADH than with $FADH_2$, which is consistent with the greater ATP yield that accompanies the oxidation of NADH.
IV	The rapid decline in pH indicates that protons were pumped into the intermembrane space when oxygen was available.

A **I** only
B **II** and **IV** only
C **II, III** and **IV** only
D All of the above

16 The flow chart shows a series of reactions occurring in an animal cell.



Which of the following statements correctly describes the flow chart?

A Reaction **X**, which occurs in the cytosol, is an anabolic reaction.
B Reaction **Y** involves the process of substrate-level phosphorylation, whereby pyruvate is first converted to a compound called acetyl coenzyme A.
C Reaction **Y** occurs in the cytoplasm whereas reaction **Z** occurs in the mitochondria.
D Reaction **Z** is a catabolic pathway which occurs twice for every glucose molecule to be completely oxidised.

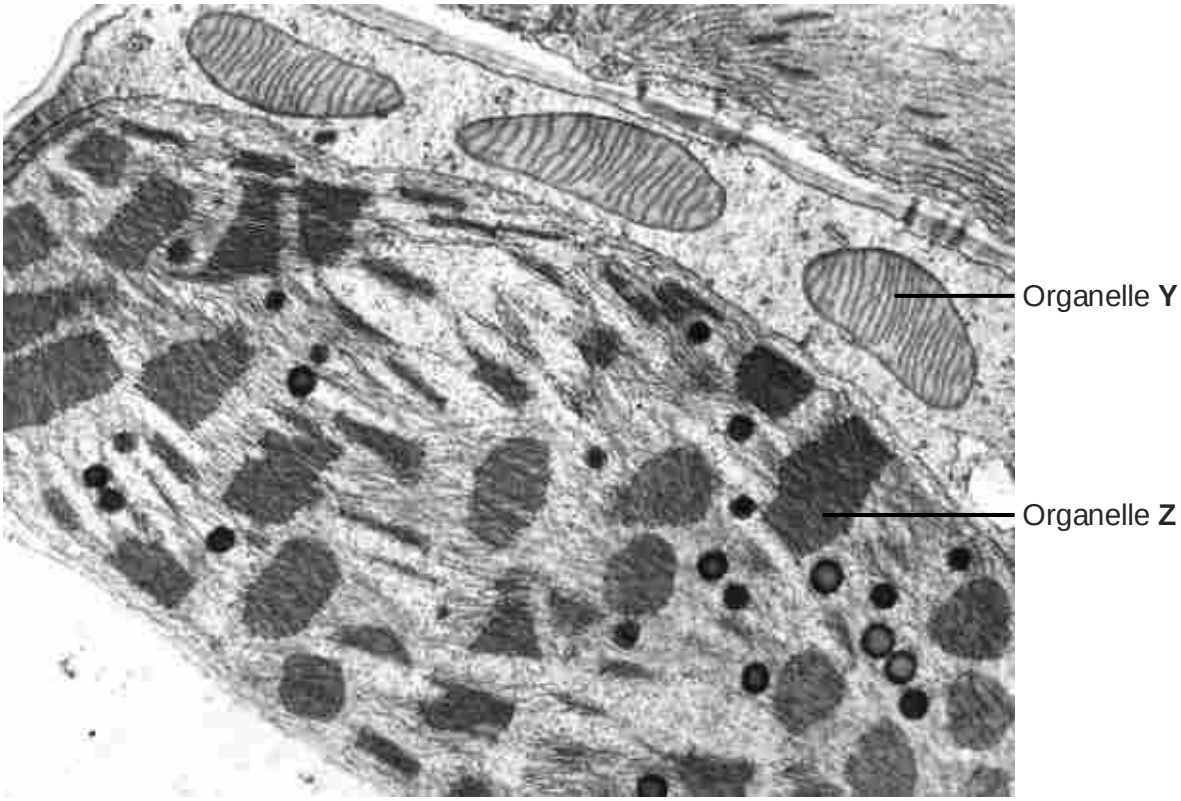
17 In a laboratory, a plant with variegated leaves (containing orange and green pigments) was supplied with radioactive carbon dioxide, $^{14}CO_2$. The plant was kept in the dark for 12 hours and then illuminated for the next 12 hours. A leaf from the plant was obtained and its level of radioactivity was measured both in the absence and presence of light. The results are shown in the table.

	Level of radioactivity in leaf (Arbitrary units)	
	Orange region of leaf	**Green region of leaf**
Absence of light	225	225
Presence of light	410	9271

Which of the following could be the most likely explanation for the level of radioactivity found in the orange region of the leaf in the presence of light?

A Some photosynthesis occurs in the orange region but due to the absence of chlorophyll in that region, the rate of photosynthesis is low.
B Photosynthesis occurs in the orange region but no storage of starch occurs.
C Photosynthetic products diffuse into the orange region.
D Radioactive $^{14}CO_2$ diffuses into the orange region and accumulates in that region.

18 A new species of plant was recently discovered in the Amazon forest. The electron micrograph shows two organelles **Y** and **Z** in a leaf mesophyll cell of the plant.

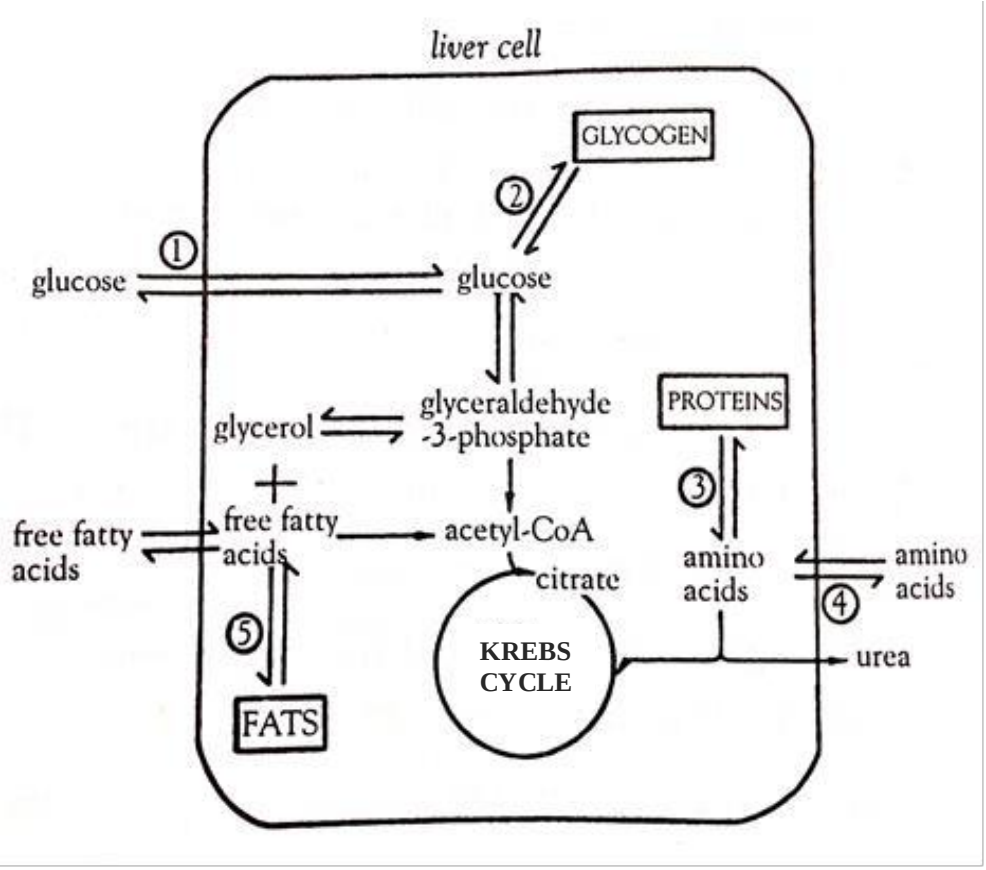


Which of the following statements are **not** true about organelles **Y** and **Z**?

I	Organelle **Z** utilises transporters to export ATP to organelle **Y** to drive cellular activities.
II	Oxygen released by organelle **Z** is used in organelle **Y** during Krebs cycle.
III	Phosphate ions in organelle **Y** is used for the production of ATP during Calvin cycle.
IV	NADPH molecules produced in organelle **Z** are used in organelle **Y** for the production of triose phosphate.

A **I** and **IV** only
B **II** and **III** only
C **II** and **IV** only
D All of the above

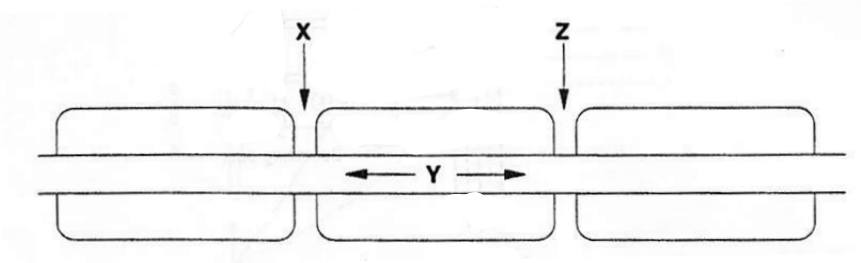
19 The diagram shows some biochemical pathways in a liver cell. Some of the points where hormones affect the pathways are labelled 1 to 5.



At which numbered points would the hormone insulin accelerate the pathway in the directions indicated?

A 1, 2 and 3
B 1, 2 and 5
C 1, 3 and 4
D 3, 4 and 5

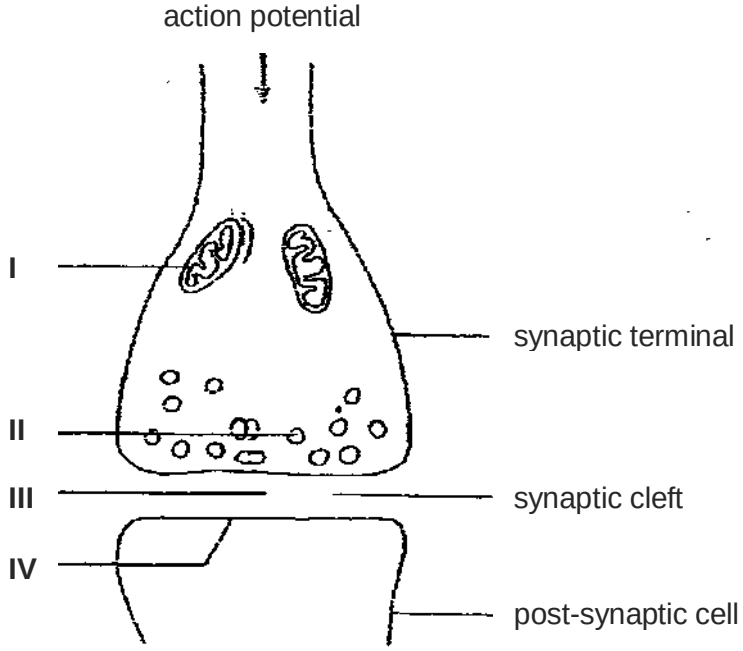
20 The diagram below shows a myelinated axon



How does the myelin sheath increase the speed of impulse transmission along the axon?

A It ensures that the ions are kept close to the axon membrane in region Y.
B It insulates the axon, so increasing the potential at regions X and Z.
C It restricts the change in potential difference to regions X and Z.
D It promotes a change in potential difference in region Y.

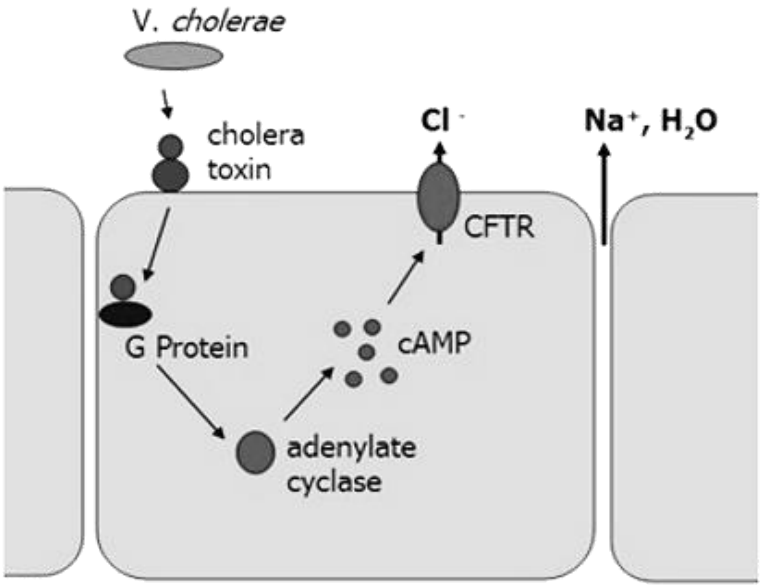
21 Snake venom contains a neurotoxin that affects synaptic transmission. The toxin can cause paralysis and death.



Which of the following is **NOT** a possible way for the toxin to act?

A The toxin reduces enzyme activity in structure **I**.
B The toxin diffuses into structure **II** and binds to its contents.
C The toxin binds with the contents of structure **II** after they are released into site **III**.
D The toxin lodges itself in between the phospholipids found on site **IV**.

22 Cholera is a disease caused by infection of the intestine with the bacterium *Vibrio cholera*. This disease is characterised by profuse diarrhoea, leading to excessive loss of fluids and dehydration. Cholera toxin binds to receptor, resulting in the activation of G protein involved in regulating salt and water secretion.



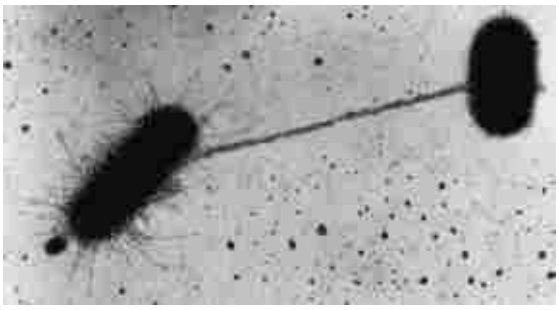
The toxin of *Vibrio cholera* causes profuse diarrhoea because

A cytosolic concentration of ions is decreased, making the cells hypotonic to the lumen of intestine
B phosphodiesterase is permanently activated
C G protein is modified such that it is unable to hydrolyse GTP to GDP
D cystic fibrosis transmembrane conductance regulator (CFTR) Cl^- channel is permanently activated due to binding of cAMP

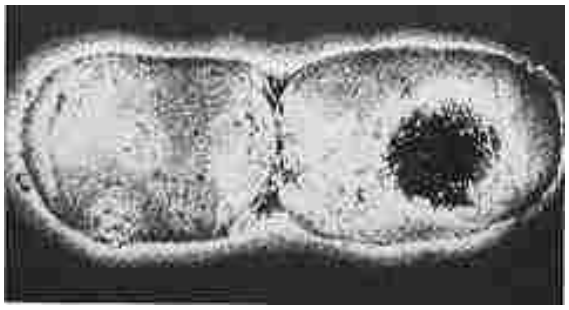
23 What is an example of a step that amplifies the signal during its transduction in a cell?

A the action of adenylyl cyclase in converting ATP to ADP
B the activation of protein kinase A by cAMP
C the binding of a steroid hormone to its intracellular receptor
D the phosphorylation of many mitogen-activated protein (MAP) kinase by an activated MAP kinase kinase

24 The photomicrographs below show two different processes occurring in two different species of bacteria.



Process 1



Process 2

Which of the following statements is/are true of both processes?

(i) For both processes, only bacteria with genes that code for cytoplasmic bridge are involved.

(ii) Process 1 requires direct contact between 2 different bacteria whereas process 2 can occur with 1 bacterium.

(iii) Process 1 will result in an increase in the number of identical bacteria whereas process 2 will result in an increase in the number of different bacteria.

(iv) Both processes involve DNA replication.

A (i) and (iii) only
B (ii) and (iv) only
C (i), (ii) and (iv) only
D (i), (ii), (iii) and (iv)

25 Which of the following statements could explain why a combination of different drugs rather than a single drug is being used to treat HIV patients?

(i) HIV has a short generation span (eg. 2 days).

(ii) In an AIDS patient, the HIV infection produces many new viruses per day (eg. 10^{10} new viruses per day or more).

(iii) HIV has an RNA genome which has a higher mutation rate than DNA as it is single stranded.

(iv) The RNA genome allows the HIV to mutate rapidly to acquire the resistance to the drug being used.

(v) Insertion of the HIV genome into the host cells will result in the host cells mutations that will confer resistance to the drug.

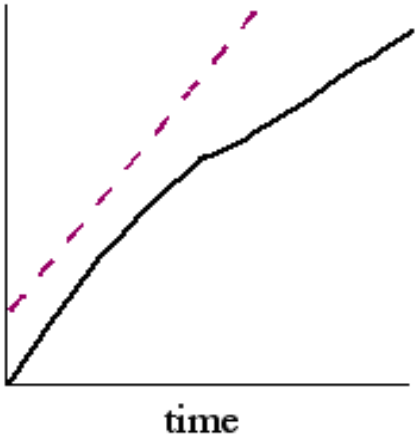
A (i) and (ii) only
B (iii) and (v) only
C (i), (ii) and (iii) only
D (iii), (iv) and (v) only

26 Which combination is true about bacteria?

	presence of methylated DNA	interaction of DNA with histone proteins	transcription initiation at promoter site
A	√	√	√
B	√	x	√
C	x	√	√
D	x	x	x

27 The graph shows the bacterial growth and β-galactosidase production of mutant *Escherichia coli* cells (unable to produce *lacI* protein) with time.

- *Bacterial growth is represented by solid line (——).*
- *β-galactosidase production is represented by dashed line (- - -).*



Which of the following best explains the graph?

A high level of cAMP due to high concentration of glucose
B high level of cAMP due to low concentration of glucose
C low level of cAMP due to high concentration of glucose
D low level of cAMP due to low concentration of glucose

28 Four different genes are regulated in different ways.

Gene C: regulatory gene whose product binds to an operator site

Gene D: product undergoes tissue-specific patterns of alternative splicing

Gene E: acetylation and deacetylation occurs to histones binding to the gene

Gene F: part of a group of structural gene controlled by the same regulatory sequence

Which combination correctly identifies which genes are prokaryotic and which are eukaryotic?

	Prokaryotic	**Eukaryotic**
A	C and F	D and E
B	C and D	E and F
C	D and E	C and F
D	D and F	C and E

29 Which of the following is a feature of eukaryotic gene expression?

A Genes are organized in operons.
B Polycistronic mRNA is common.
C Transcription and translation are spatially separated.
D Translation initiation occurs with a molecule of formyl-methionine.

30 How is translation controlled in eukaryotes?

A By differential removal of introns enabling a gene to code for more than one protein.
B By activation of the protein by folding or cleavage after it is formed.
C By the production of RNA from the non-coding strand of the DNA.
D By protein factors that bind to specific sequences in the mRNA.

31 DNA methylation is known to silence genes because it prevents transcription factors from binding. Which of the following best explains this phenomenon?

A DNA methylation modifies the shape of the transcription factor.
B DNA methylation prevents dimerization of DNA binding proteins.
C DNA methylation modifies the shape of the DNA element where the transcription factor binds.
D DNA methylation causes acetylation of histone proteins which causes heterochromatin to be formed.

32 Some statements concerning evolution are listed:

1 Offspring tend to resemble their parents.

2 Individuals in a sexually reproducing population are different.

3 The fossil record shows that many species have become extinct.

4 More offspring are produced than can possibly survive to sexual maturity.

5 Characteristics acquired during an organism's lifetime are passed to its offspring.

Which of these statements form the basis of Darwin's theory of evolution by natural selection?

A 1, 2 and 3
B 1, 2 and 4
C 1, 3 and 5
D 1, 4 and 5

33 Which of the following pairs is *least* likely to represent homology?

A the haemoglobin of a baboon and that of a gorilla
B the mitochondria of a plant and those of an animal
C the wings of a bird and those of an insect
D the wings of a bat and the arms of a human

34 Which of the following statements does not correctly compare the neutral theory of molecular evolution and natural selection?

A Neutral theory of molecular evolution accounts for most of the differences that we observe at the phenotypic level as compared to natural selection.

B Neutral theory of molecular evolution accounts for most of the differences that we observe at the genotypic level as compared to natural selection.

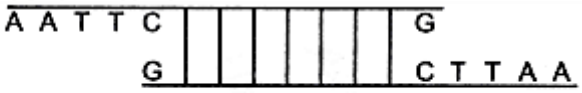
C The rate of change in the nucleotide sequence brought about by neutral theory of molecular evolution occurs at a constant rate due to random chance events while the rate of change brought about by natural selection can be fast or slow depending on the strength of the selection pressure.

D Neutral theory of molecular evolution is largely responsible for the RFLP that we observe between species as compared to natural selection.

35 In genetic engineering, a restriction enzyme is used to cut plasmid DNA at a specific target site. The enzyme recognises a sequence of six bases and forms sticky ends.

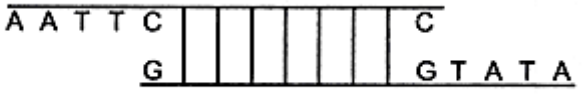
Which diagram of such a cut section of DNA is correct?

A

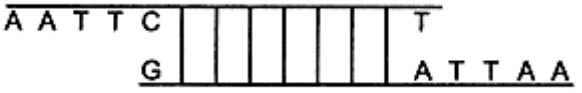


B

C



D



36 The human genome project has identified and mapped the genes on human chromosomes. This is allowing scientists to identify specific, faulty genes which contribute to inherited conditions.

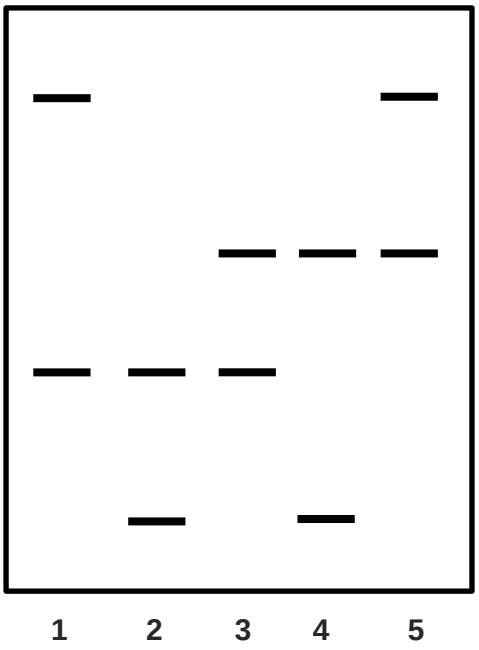
This is useful in many ways, for example

1 carriers of faulty genes can be advised about changes in lifestyle to minimise risks.
2 carriers of faulty genes can be identified and informed of their risk status.
3 diagnostic tests can be developed to identify carriers of faulty genes.
4 drugs can be developed to block the action of problem genes.
5 embryos can be screened to avoid the birth of affected children.
6 employers can take account of the genetic predisposition of employees.

Which two uses arise **directly** from the information provided by the project?

A 1 and 2
B 2 and 5
C 3 and 4
D 5 and 6

37 Results from the DNA fingerprint analysis of a single VNTR locus for a man and his 4 different children are shown in the autoradiograph.



Which lane contains the DNA of the father?

A Lane **1**
B Lane 2
C Lane **3**
D Lane **4**

38 The common gene delivery system for in vivo gene therapy is

I microinjection

II liposome mediated gene transfer (lipofection)

III electroporation

IV adenoviruses

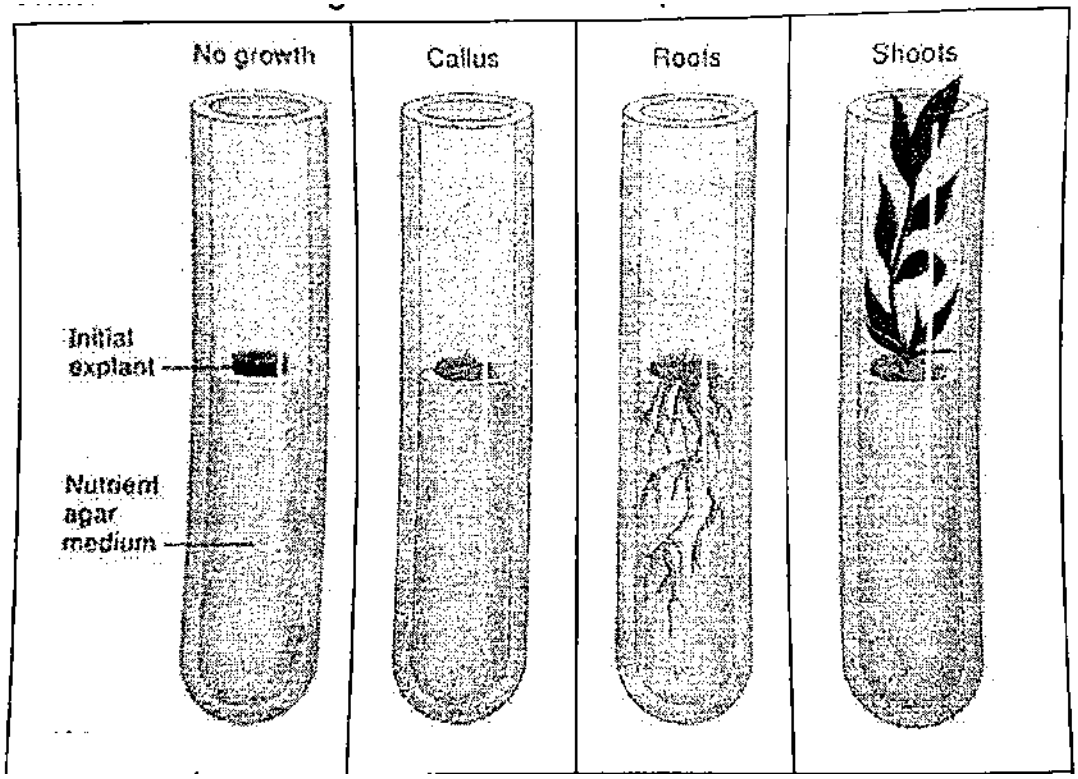
A **I** only
B **I, II** and **III** only
C **II** and **IV** only
D All of the above

39 A student wanted to investigate the response of an explant to various concentrations of IAA (auxin) and kinetin (cytokinin). He labelled and prepared the test tubes as follows:

Test tubes	**1**	**2**	**3**	**4**
IAA (mg/L)	0.02	0.00	1.00	2.00
Kinetin (mg/L)	1.00	0.20	0.20	0.02

After preparation, he handled the test tubes while his gloves were still wet with ethanol. Hence all labels were wiped off. After 2 weeks, his results were shown below.

Which of the following observations correspond to the correct test tube?



A	Tube 3	Tube 2	Tube 1	Tube 4
B	Tube 2	Tube 3	Tube 4	Tube 1
C	Tube 1	Tube 4	Tube 3	Tube 2
D	Tube 4	Tube 1	Tube 2	Tube 3

40 Which of the following statements best support the view that genetically modified crops could help resolve world food shortages?

I Genetic engineering enables production of drought resistant crops more quickly than selective breeding.

II Genetically modified crops are produced by adding single genes.

III Genetically modified crops can cross-fertilise with non-modified related plants.

IV Genetically modified crops can be adapted to their environment when crossed with local varieties of the crop.

A **I** only
B **II** and **III** only
C **II** and **IV** only
D **I** and **IV** only

H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME

MARK SCHEME

CLASS

BIOLOGY **9648/01**

Paper 1 Multiple Choice **28 September 2016**

1 hour 15 min

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name and CT on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
Calculators may be used.

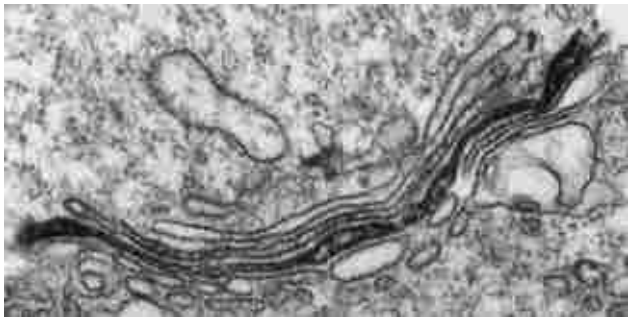
This document consists of **27** printed pages and **1** blank page.

[Turn over

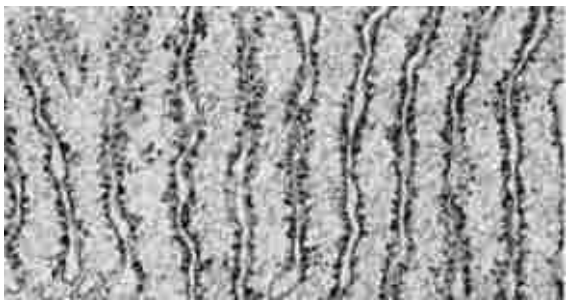
1 In an active cell, the pathway of a protein synthesis to maturation involves the endomembrane system.

(I)

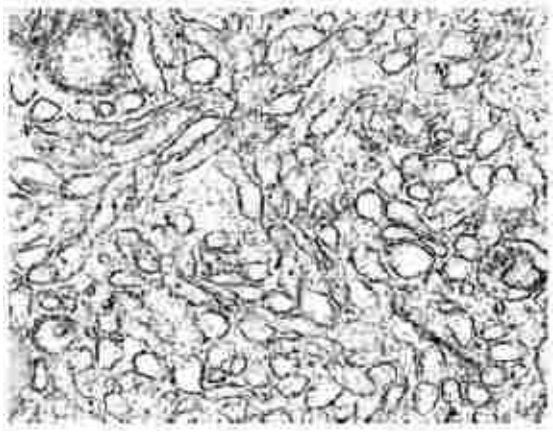
(II)



(III)



(IV)



The following are several processes that occur in an active cell.

w. modification of carbohydrates on protein

x. folding of protein into its 3 dimensional conformation

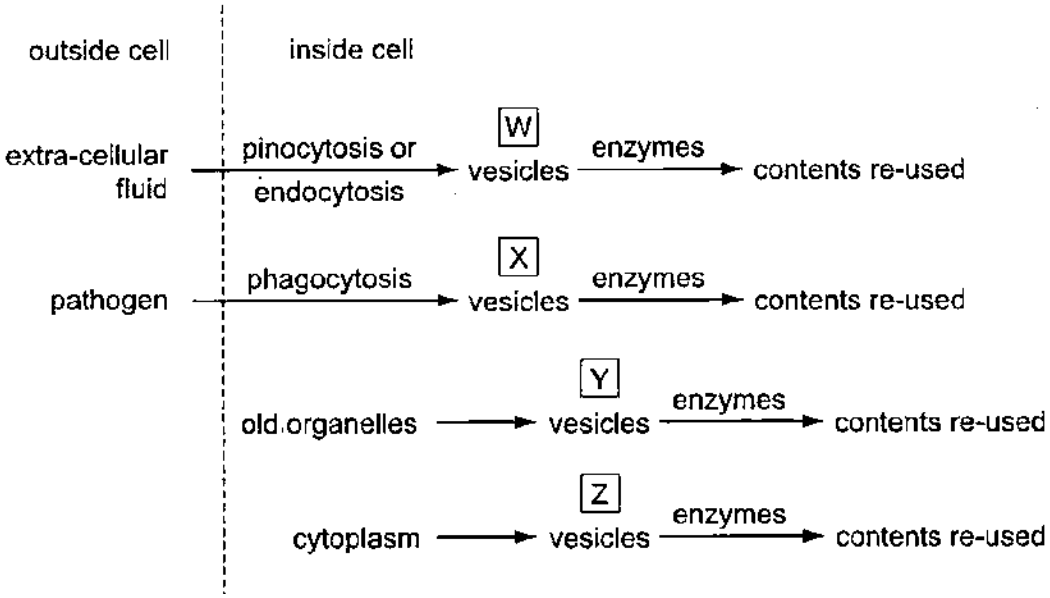
y. synthesis of steroids

z. storage of synthesized proteins

Where in the above diagrams do these processes take place?

	(I)	(II)	(III)	(IV)
A	z	w	y	x
B	z	w	x	y
C	y	w	x	z
D	z	y	x	w

2 The flow chart shows processes which takes place inside animal cells.



Which processes require the activity of lysosomes?

A **W, X, Y** and **Z**
B **W** and **X** only
C **X** and **Y** only
D **Y** and **Z** only

3 Which of the following lists of processes matches the type of movement across membrane correctly?

	Passive diffusion	Facilitated diffusion	Active transport	Endocytosis	Exocytosis
A	Exit of CO_2 from mitochondria	Chemiosmosis of H^+ through ATP synthase	Exit of Ca^{2+} from synaptic knob	Entry of HIV	Budding of influenza virus
B	Exit of CO_2 from mitochondria	Exit of K^+ from neuron	Entry of Na^+ into neuron	Entry of HIV	Budding of influenza virus
C	Entry of O_2 into mitochondria	Exit of K^+ from neuron	Exit of Ca^{2+} from synaptic knob	Entry of influenza virus	Release of insulin from β cells
D	Entry of O_2 into mitochondria	Chemiosmosis of H^+ through ATP synthase	Entry of Na^+ into neuron	Entry of influenza virus	Release of insulin from β cells

4 Raffinose is a trisaccharide which can be degraded by enzymes. The results of two different enzymatic incubations are shown in the table below:

Enzyme used	Products
Sucrase	Melibiose and fructose
Galactosidase	Galactose and sucrose

Which of following statements are consistent with the results shown above?

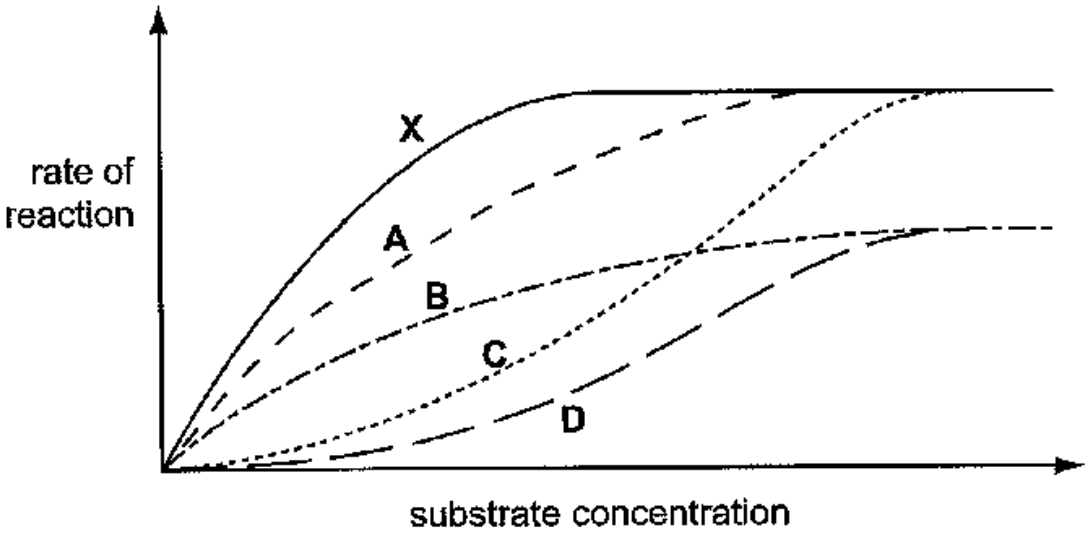
I Raffinose is composed of three different monosacchardies.
II Melibiose is a dissacharide.
III One of the products of acid hydrolysis of raffinose is glucose.
IV The products of raffinose digestion by sucrase and galactosidase respectively will yield a brick-red precipitate when heated with Benedict's reagent.

A I and III only
B II and IV only
C I, II and III only
D All of the above

5 The reaction rate of salivary amylase on starch decreases as the concentration of chloride ions is reduced. Which of the following describes the role of the chloride ions?

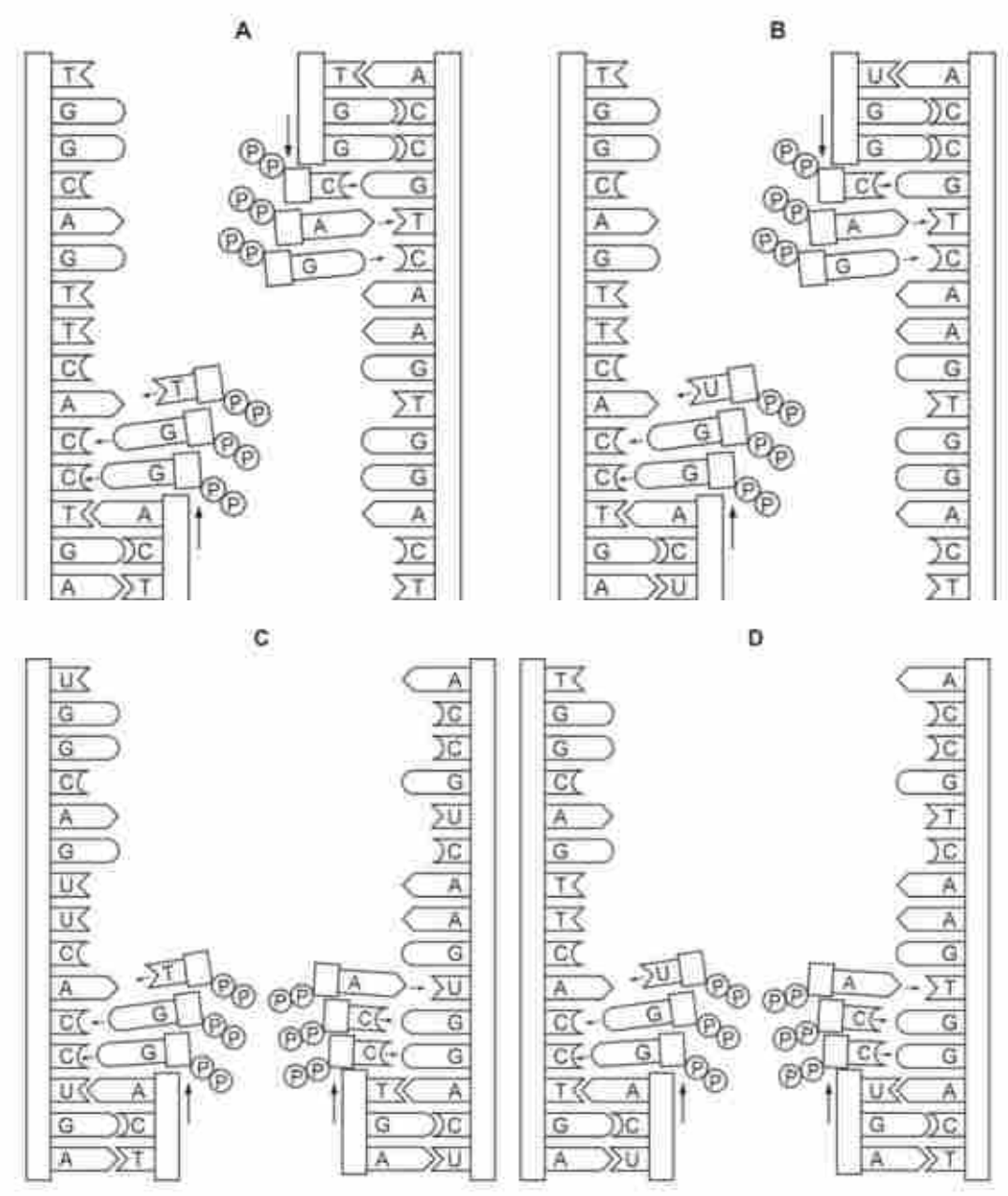
A Allosteric inhibitors
B Co-enzymes
C Co-factors
D Competitive inhibitors

6 In the graph, X represents the initial rate of reaction of an enzyme in increasing substrate concentrations under optimum temperature and pH, in the absence of an inhibitor. Which curve represents the result when the same experiment is carried out under a lower temperature? BBBBBBBBBBB



7 Which diagram shows the semi-conservative replication of a section of a molecule of DNA?

AAAAAAAAAAAAAAAAA



8 The diagram represents part of a DNA molecule.

G A T A C C A
C T A T G G T

Mutation	Name
from purine to other purine	transition
from pyrimidine to other pyrimidine	transition
from purine to pyrimidine	transversion
from pyrimidine to purine	transversion

Which diagram shows the DNA molecule with only transversion(s)?

A

G T T A T C A
C A A T A G T

B

G A A A C A A
C T T T G T T

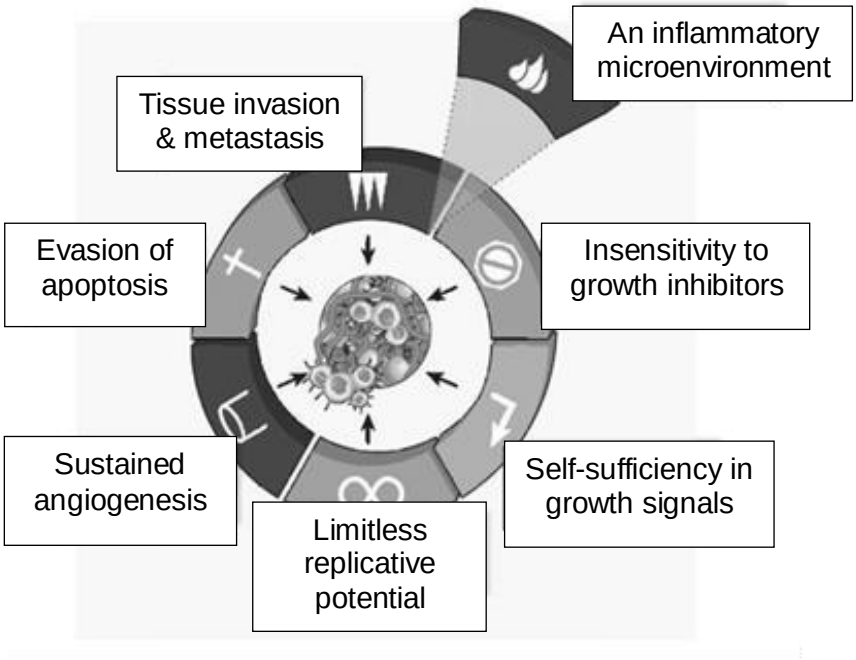
C

A A T A C C A
T T A T G G T

D

G A T A T C A
C T A T A G T

9 The diagram illustrates the hallmarks of cancer.



Which of the following statements correctly describe the changes in cancer cells?

I	Limitless replicative potential often results in the accumulation of chromosomal mutations in many cancer cells.
II	Cancer cells could overproduce signal molecules so that they become self-sufficient in growth signals.
III	Angiogenesis is the result of expression of oncogenes in a cell line that produces blood vessels.
IV	Loss-of-function mutations in tumour suppressor genes contribute to tissue invasion and metastasis.

A **I** and **IV** only

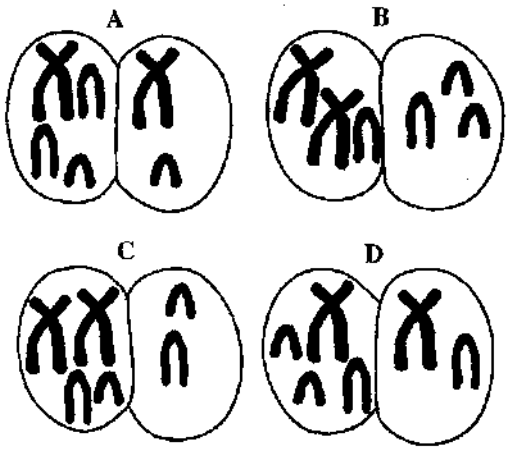
B **II** and **III** only

C **I, II** and **IV** only

D **II, III** and **IV** only

10 The diagram shows three of the 23 pairs of chromosomes found in a human cell.

Which diagram shows an example of non-disjunction in the formation of an egg, that could lead to the formation of a Down's syndrome zygote? DDDDDDDD



11 A toxic chemical causes malfunction of the centrioles in animal cells.

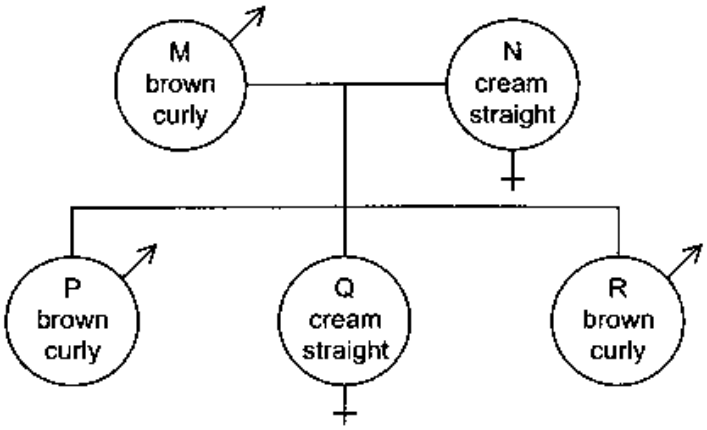
Which process in mitosis is likely to be directly affected by the chemical?

1 migration of the chromosomes
2 replication of centromeres
3 chromosome shortening
4 alignment of chromosomes

A 1 and 4 only
B 2 and 4 only
C 1, 3 and 4
D 2, 3 and 4

12 Assume that in goats a pair of alleles is responsible for the inheritance of hair colour and that another pair controls hair texture. These pairs are located on different autosomes. The allele for brown hair (B) is dominant to the allele for cream hair (b), and the allele for curly hair (C) is dominant to the allele for straight hair (c).

The diagram shows a cross between two goats.



If R is mated with a female goat of the same genotype as M, what are the chances of the first offspring being a male with cream coloured, straight hair?

A 0
B 1 in 32
C 1 in 16
D 1 in 4

13 A cross between a round-leafed, tall plant and round-leafed, dwarf plant produced the following offspring:

121 round-leafed, tall plants	R – round leaf
121 round-leafed, dwarf plants	r – oval leaf
42 oval-leafed, tall plants	T – tall
37 oval-leafed, dwarf plants	t – dwarf

What were the genotypes of the parents?

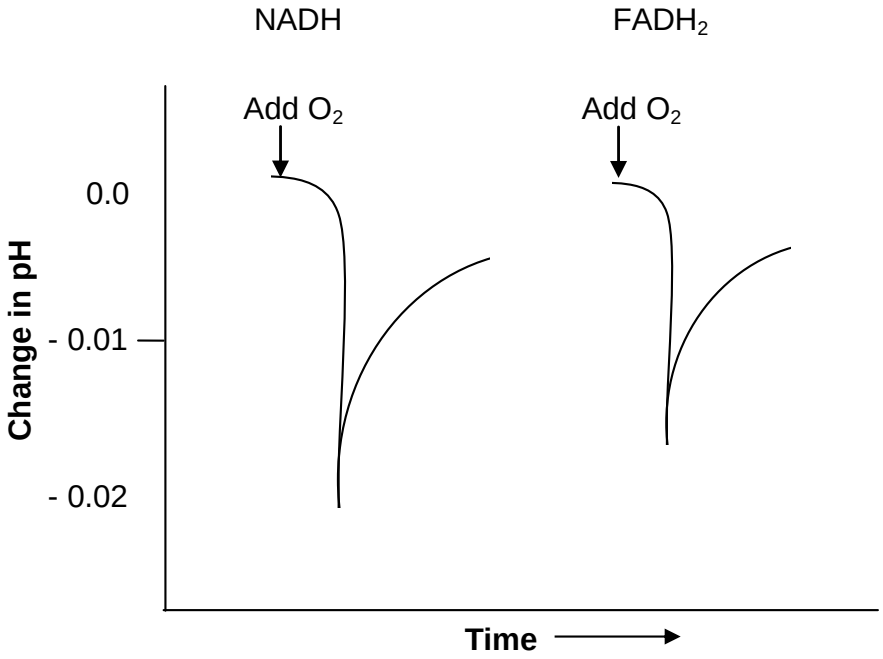
A RrTt x Rrtt
B RrTt x RRtt
C RrTT x Rrtt
D RrTT x RRtt

14 Black, chestnut and bay (reddish brown with black mane, tail, eartips and lower legs) coat colour in horses is determined by two genes. The dominant E allele codes for black and red pigment, while the recessive e allele codes only for red pigment. At a separate gene, the dominant A allele restricts any black pigment produced to the horse's mane, tail, eartips and lower legs, while the recessive allele allows any black pigment produced to show up throughout.

Two black horses were mated. Which of the following coat colours will definitely **not** show up in their offspring?

A Bay
B Black
C Chestnut
D All three colours are possible

15 Isolated mitochondria were incubated with NADH in one experiment and an equal amount of $FADH_2$ in another experiment. The mitochondria were initially deprived of oxygen. The pH of the intermembrane space was then monitored as a known quantity of oxygen was added. The results are shown in the graph.

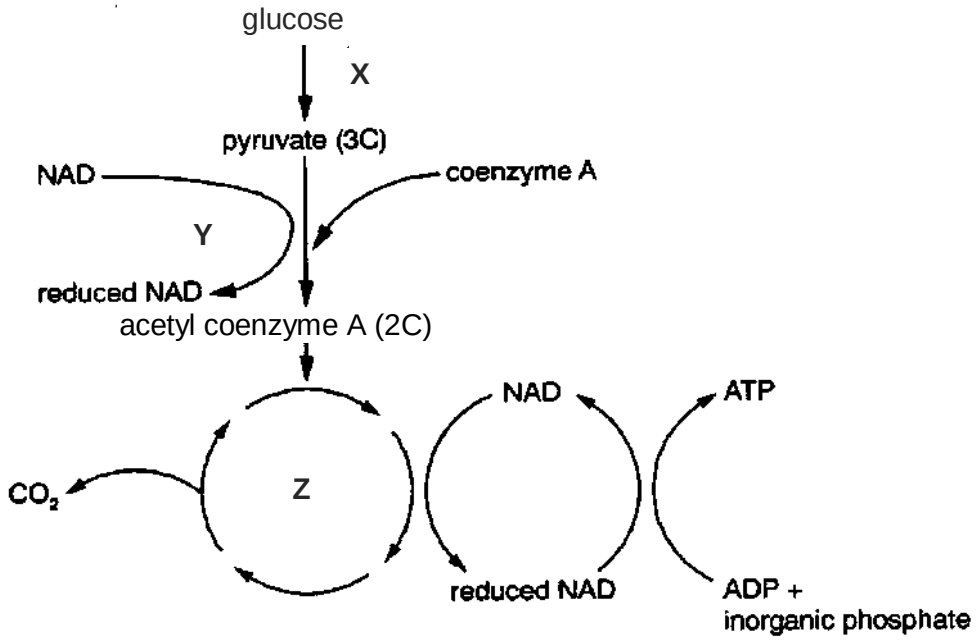


Which of the following can be concluded based on the results?

I	Upon the addition of oxygen, glycolysis and subsequently, link reaction, Krebs cycle and oxidative phosphorylation occurred.
II	Electron transfer was initiated by the addition of oxygen.
III	The pH drop was greater with NADH than with $FADH_2$, which is consistent with the greater ATP yield that accompanies the oxidation of NADH.
IV	The rapid decline in pH indicates that protons were pumped into the intermembrane space when oxygen was available.

A **I** only
B **II** and **IV** only
C **II, III** and **IV** only
D All of the above

16 The flow chart shows a series of reactions occurring in an animal cell.



Which of the following statements correctly describes the flow chart?

A Reaction **X**, which occurs in the cytosol, is an anabolic reaction.
B Reaction **Y** involves the process of substrate-level phosphorylation, whereby pyruvate is first converted to a compound called acetyl coenzyme A.
C Reaction **Y** occurs in the cytoplasm whereas reaction **Z** occurs in the mitochondria.
D Reaction **Z** is a catabolic pathway which occurs twice for every glucose molecule to be completely oxidised.

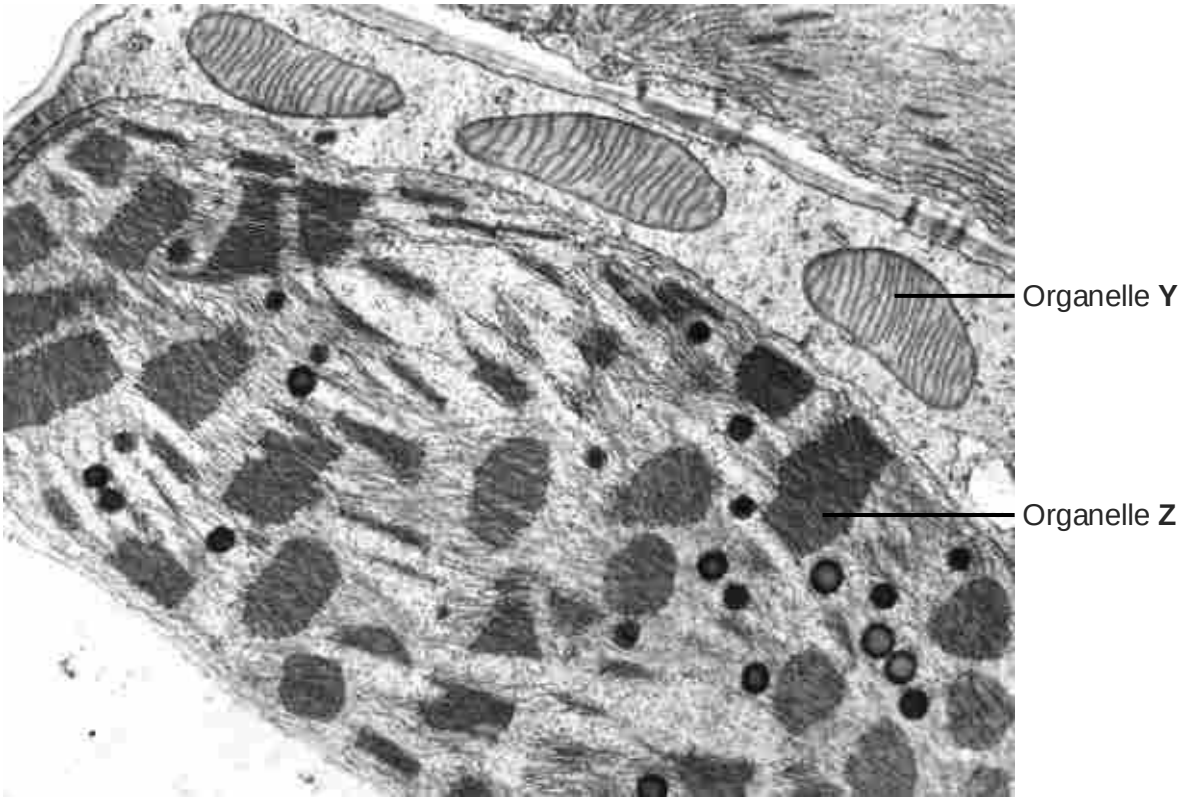
17 In a laboratory, a plant with variegated leaves (containing orange and green pigments) was supplied with radioactive carbon dioxide, $^{14}CO_2$. The plant was kept in the dark for 12 hours and then illuminated for the next 12 hours. A leaf from the plant was obtained and its level of radioactivity was measured both in the absence and presence of light. The results are shown in the table.

	Level of radioactivity in leaf (Arbitrary units)	
	Orange region of leaf	**Green region of leaf**
Absence of light	225	225
Presence of light	410	9271

Which of the following could be the most likely explanation for the level of radioactivity found in the orange region of the leaf in the presence of light?

A Some photosynthesis occurs in the orange region but due to the absence of chlorophyll in that region, the rate of photosynthesis is low.
B Photosynthesis occurs in the orange region but no storage of starch occurs.
C Photosynthetic products diffuse into the orange region.
D Radioactive $^{14}CO_2$ diffuses into the orange region and accumulates in that region.

18 A new species of plant was recently discovered in the Amazon forest. The electron micrograph shows two organelles **Y** and **Z** in a leaf mesophyll cell of the plant.

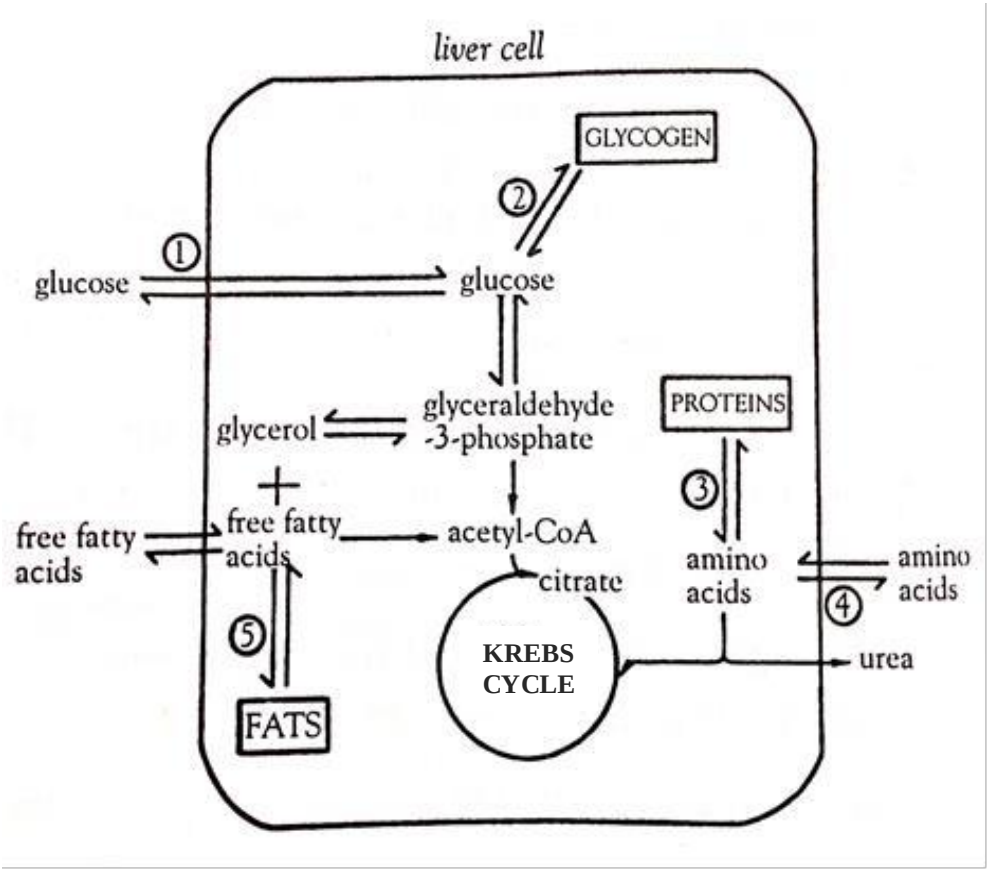


Which of the following statements are **not** true about organelles **Y** and **Z**?

I	Organelle **Z** utilises transporters to export ATP to organelle **Y** to drive cellular activities.
II	Oxygen released by organelle **Z** is used in organelle **Y** during Krebs cycle.
III	Phosphate ions in organelle **Y** is used for the production of ATP during Calvin cycle.
IV	NADPH molecules produced in organelle **Z** are used in organelle **Y** for the production of triose phosphate.

A **I** and **IV** only
B **II** and **III** only
C **II** and **IV** only
D All of the above

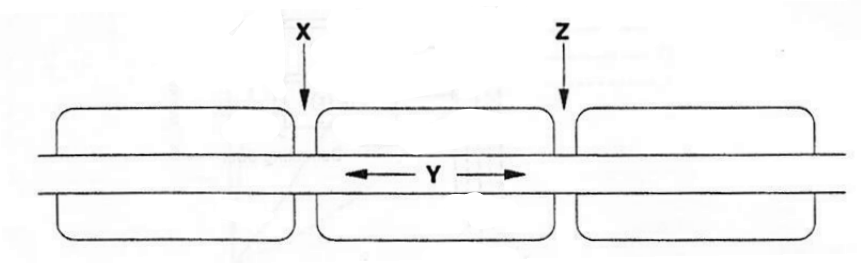
19 The diagram shows some biochemical pathways in a liver cell. Some of the points where hormones affect the pathways are labelled 1 to 5.



At which numbered points would the hormone insulin accelerate the pathway in the directions indicated?

A 1, 2 and 3
B 1, 2 and 5
C 1, 3 and 4
D 3, 4 and 5

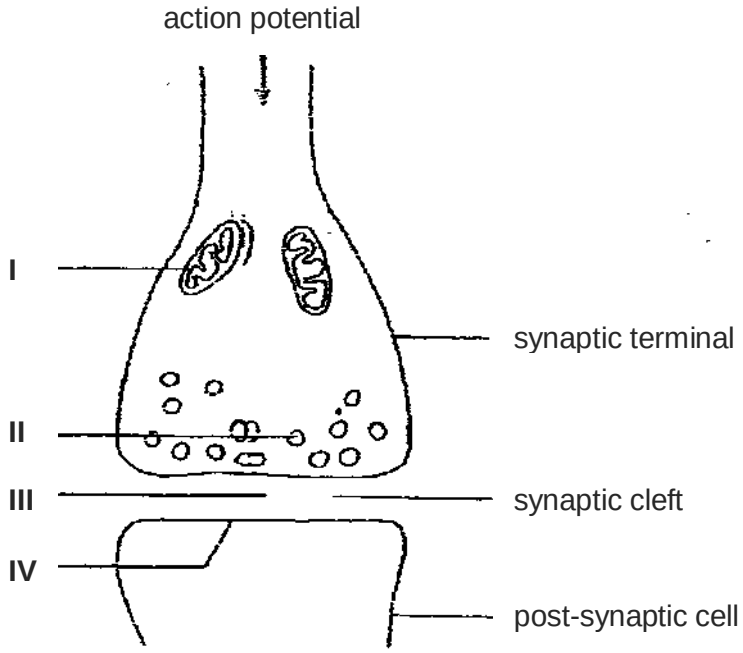
20 The diagram below shows a myelinated axon



How does the myelin sheath increase the speed of impulse transmission along the axon?

A It ensures that the ions are kept close to the axon membrane in region Y.
B It insulates the axon, so increasing the potential at regions X and Z.
C It restricts the change in potential difference to regions X and Z.
D It promotes a change in potential difference in region Y.

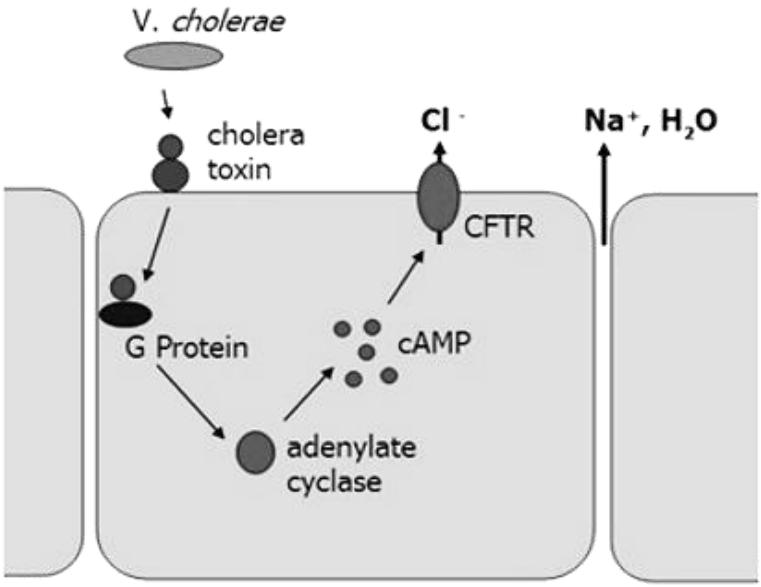
21 Snake venom contains a neurotoxin that affects synaptic transmission. The toxin can cause paralysis and death.



Which of the following is **NOT** a possible way for the toxin to act?

A The toxin reduces enzyme activity in structure **I**.
B The toxin diffuses into structure **II** and binds to its contents.
C The toxin binds with the contents of structure **II** after they are released into site **III**.
D The toxin lodges itself in between the phospholipids found on site **IV**.

22 Cholera is a disease caused by infection of the intestine with the bacterium *Vibrio cholera*. This disease is characterised by profuse diarrhoea, leading to excessive loss of fluids and dehydration. Cholera toxin binds to receptor, resulting in the activation of G protein involved in regulating salt and water secretion.



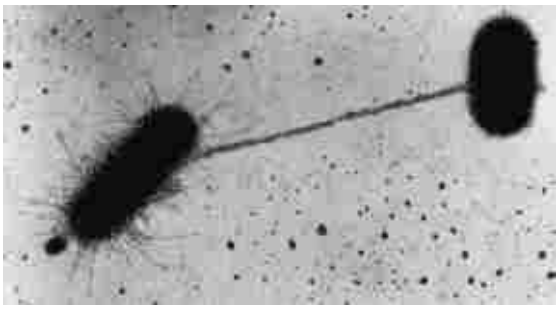
The toxin of *Vibrio cholera* causes profuse diarrhoea because

A cytosolic concentration of ions is decreased, making the cells hypotonic to the lumen of intestine
B phosphodiesterase is permanently activated
C G protein is modified such that it is unable to hydrolyse GTP to GDP
D cystic fibrosis transmembrane conductance regulator (CFTR) Cl^- channel is permanently activated due to binding of cAMP

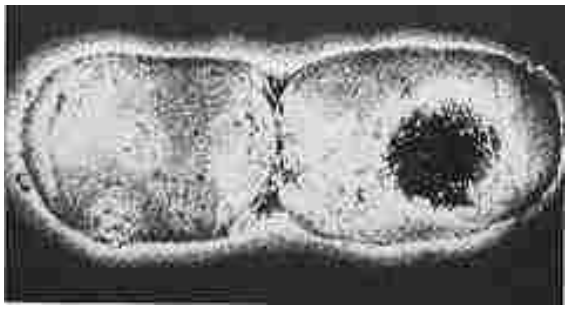
23 What is an example of a step that amplifies the signal during its transduction in a cell?

A the action of adenylyl cyclase in converting ATP to ADP
B the activation of protein kinase A by cAMP
C the binding of a steroid hormone to its intracellular receptor
D the phosphorylation of many mitogen-activated protein (MAP) kinase by an activated MAP kinase kinase

24 The photomicrographs below show two different processes occurring in two different species of bacteria.



Process 1



Process 2

Which of the following statements is/are true of both processes?

(i) For both processes, only bacteria with genes that code for cytoplasmic bridge are involved.

(ii) Process 1 requires direct contact between 2 different bacteria whereas process 2 can occur with 1 bacterium.

(iii) Process 1 will result in an increase in the number of identical bacteria whereas process 2 will result in an increase in the number of different bacteria.

(iv) Both processes involve DNA replication.

A (i) and (iii) only
B (ii) and (iv) only
C (i), (ii) and (iv) only
D (i), (ii), (iii) and (iv)

25 Which of the following statements could explain why a combination of different drugs rather than a single drug is being used to treat HIV patients?

(i) HIV has a short generation span (eg. 2 days).

(ii) In an AIDS patient, the HIV infection produces many new viruses per day (eg. 10^{10} new viruses per day or more).

(iii) HIV has an RNA genome which has a higher mutation rate than DNA as it is single stranded.

(iv) The RNA genome allows the HIV to mutate rapidly to acquire the resistance to the drug being used.

(v) Insertion of the HIV genome into the host cells will result in the host cells mutations that will confer resistance to the drug.

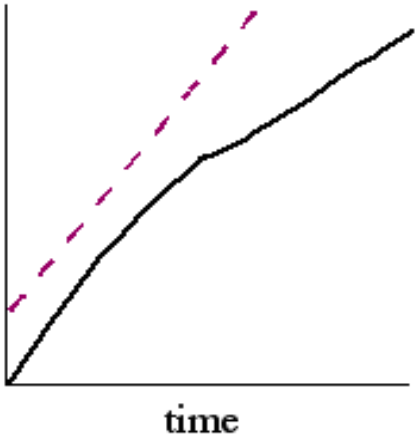
A (i) and (ii) only
B (iii) and (v) only
C (i), (ii) and (iii) only
D (iii), (iv) and (v) only

26 Which combination is true about bacteria?

	presence of methylated DNA	interaction of DNA with histone proteins	transcription initiation at promoter site
A	√	√	√
B	√	x	√
C	x	√	√
D	x	x	x

27 The graph shows the bacterial growth and β-galactosidase production of mutant *Escherichia coli* cells (unable to produce *lacI* protein) with time.

- *Bacterial growth is represented by solid line (——).*
- *β-galactosidase production is represented by dashed line (- - -).*



Which of the following best explains the graph?

A high level of cAMP due to high concentration of glucose
B high level of cAMP due to low concentration of glucose
C low level of cAMP due to high concentration of glucose
D low level of cAMP due to low concentration of glucose

28 Four different genes are regulated in different ways.

Gene C: regulatory gene whose product binds to an operator site

Gene D: product undergoes tissue-specific patterns of alternative splicing

Gene E: acetylation and deacetylation occurs to histones binding to the gene

Gene F: part of a group of structural gene controlled by the same regulatory sequence

Which combination correctly identifies which genes are prokaryotic and which are eukaryotic?

	Prokaryotic	**Eukaryotic**
A	C and F	D and E
B	C and D	E and F
C	D and E	C and F
D	D and F	C and E

29 Which of the following is a feature of eukaryotic gene expression?

A Genes are organized in operons.
B Polycistronic mRNA is common.
C Transcription and translation are spatially separated.
D Translation initiation occurs with a molecule of formyl-methionine.

30 How is translation controlled in eukaryotes?

A By differential removal of introns enabling a gene to code for more than one protein.
B By activation of the protein by folding or cleavage after it is formed.
C By the production of RNA from the non-coding strand of the DNA.
D By protein factors that bind to specific sequences in the mRNA.

31 DNA methylation is known to silence genes because it prevents transcription factors from binding. Which of the following best explains this phenomenon?

A DNA methylation modifies the shape of the transcription factor.
B DNA methylation prevents dimerization of DNA binding proteins.
C DNA methylation modifies the shape of the DNA element where the transcription factor binds.
D DNA methylation causes acetylation of histone proteins which causes heterochromatin to be formed.

32 Some statements concerning evolution are listed:

1 Offspring tend to resemble their parents.

2 Individuals in a sexually reproducing population are different.

3 The fossil record shows that many species have become extinct.

4 More offspring are produced than can possibly survive to sexual maturity.

5 Characteristics acquired during an organism's lifetime are passed to its offspring.

Which of these statements form the basis of Darwin's theory of evolution by natural selection?

A 1, 2 and 3
B 1, 2 and 4
C 1, 3 and 5
D 1, 4 and 5

33 Which of the following pairs is *least* likely to represent homology?

A the haemoglobin of a baboon and that of a gorilla
B the mitochondria of a plant and those of an animal
C the wings of a bird and those of an insect
D the wings of a bat and the arms of a human

34 Which of the following statements does not correctly compare the neutral theory of molecular evolution and natural selection?

A Neutral theory of molecular evolution accounts for most of the differences that we observe at the phenotypic level as compared to natural selection.

B Neutral theory of molecular evolution accounts for most of the differences that we observe at the genotypic level as compared to natural selection.

C The rate of change in the nucleotide sequence brought about by neutral theory of molecular evolution occurs at a constant rate due to random chance events while the rate of change brought about by natural selection can be fast or slow depending on the strength of the selection pressure.

D Neutral theory of molecular evolution is largely responsible for the RFLP that we observe between species as compared to natural selection.

35 In genetic engineering, a restriction enzyme is used to cut plasmid DNA at a specific target site. The enzyme recognises a sequence of six bases and forms sticky ends.

Which diagram of such a cut section of DNA is correct?
AAAAAAAAAAAAAAAAAAAAAA

36 The human genome project has identified and mapped the genes on human chromosomes. This is allowing scientists to identify specific, faulty genes which contribute to inherited conditions.

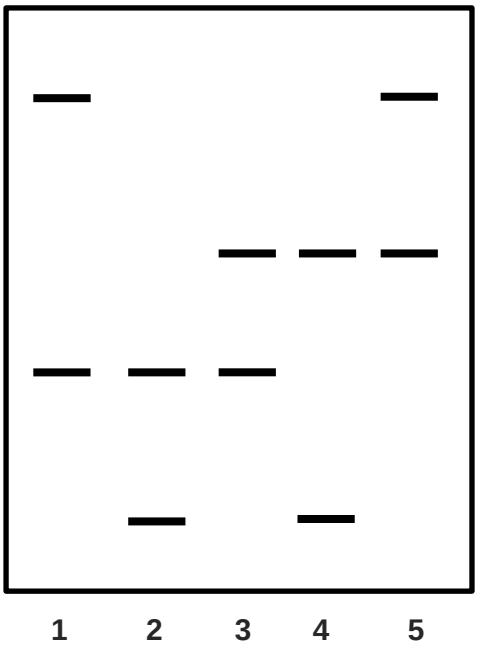
This is useful in many ways, for example

1 carriers of faulty genes can be advised about changes in lifestyle to minimise risks.
2 carriers of faulty genes can be identified and informed of their risk status.
3 diagnostic tests can be developed to identify carriers of faulty genes.
4 drugs can be developed to block the action of problem genes.
5 embryos can be screened to avoid the birth of affected children.
6 employers can take account of the genetic predisposition of employees.

Which two uses arise **directly** from the information provided by the project?

A 1 and 2
B 2 and 5
C 3 and 4
D 5 and 6

37 Results from the DNA fingerprint analysis of a single VNTR locus for a man and his 4 different children are shown in the autoradiograph.



Which lane contains the DNA of the father?

A Lane **1**
B Lane **2**
C Lane **3**
D Lane **4**

38 The common gene delivery system for in vivo gene therapy is

I microinjection

II liposome mediated gene transfer (lipofection)

III electroporation

IV adenoviruses

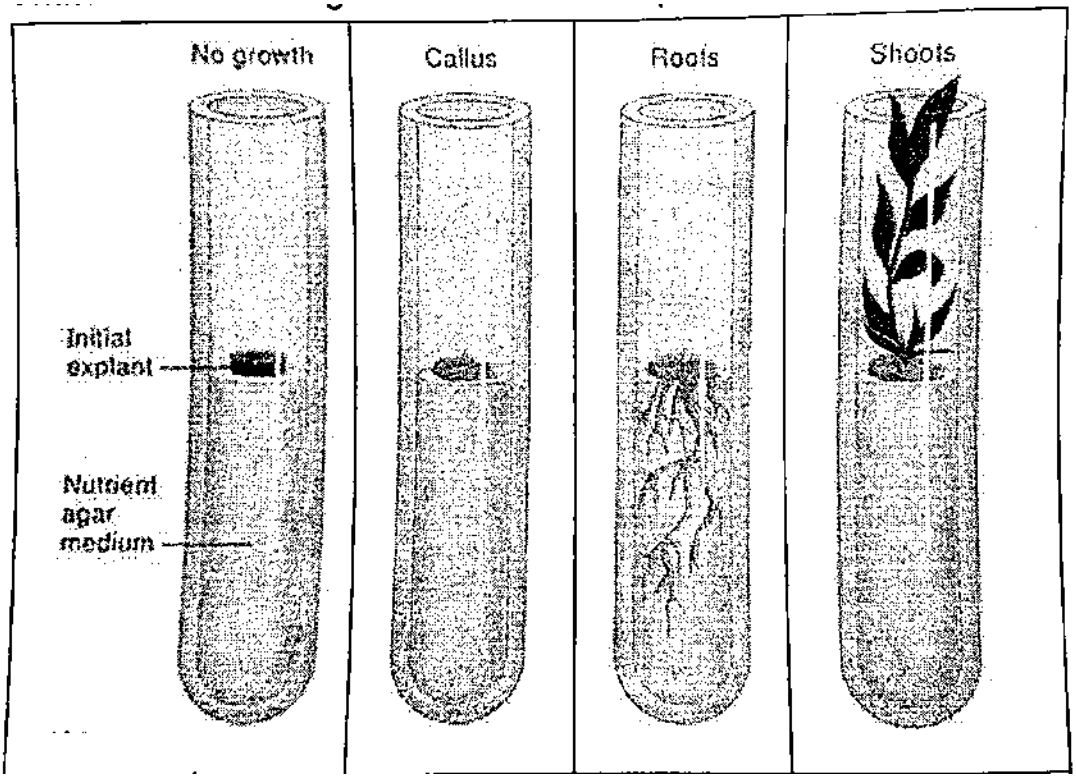
A **I** only
B **I, II** and **III** only
C **II** and **IV** only
D All of the above

39 A student wanted to investigate the response of an explant to various concentrations of IAA (auxin) and kinetin (cytokinin). He labelled and prepared the test tubes as follows:

Test tubes	**1**	**2**	**3**	**4**
IAA (mg/L)	0.02	0.00	1.00	2.00
Kinetin (mg/L)	1.00	0.20	0.20	0.02

After preparation, he handled the test tubes while his gloves were still wet with ethanol. Hence all labels were wiped off. After 2 weeks, his results were shown below.

Which of the following observations correspond to the correct test tube?



A	Tube 3	Tube 2	Tube 1	Tube 4
B	Tube 2	Tube 3	Tube 4	Tube 1
C	Tube 1	Tube 4	Tube 3	Tube 2
D	Tube 4	Tube 1	Tube 2	Tube 3

40 Which of the following statements best support the view that genetically modified crops could help resolve world food shortages?

I Genetic engineering enables production of drought resistant crops more quickly than selective breeding.

II Genetically modified crops are produced by adding single genes.

III Genetically modified crops can cross-fertilise with non-modified related plants.

IV Genetically modified crops can be adapted to their environment when crossed with local varieties of the crop.

A **I** only
B **II** and **III** only
C **II** and **IV** only
D **I** and **IV** only

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME

CLASS

BIOLOGY

9648/02

Paper 2 Core Paper

19 September 2016

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and CT on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use soft pencil for any diagrams, graphs or rough working.
Do no use staples, paper clips, highlighters, glue or correction fluid.

Section A

Answer **all** questions.

Section B

Answer any **one** question.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
Total	

This document consists of **22** printed pages and **0** blank page.

[Turn over

Section A

Answer **all** the questions in this section.

1 Fig 1.1 shows a molecule of tRNA and the enzyme that attaches the correct amino acid to it

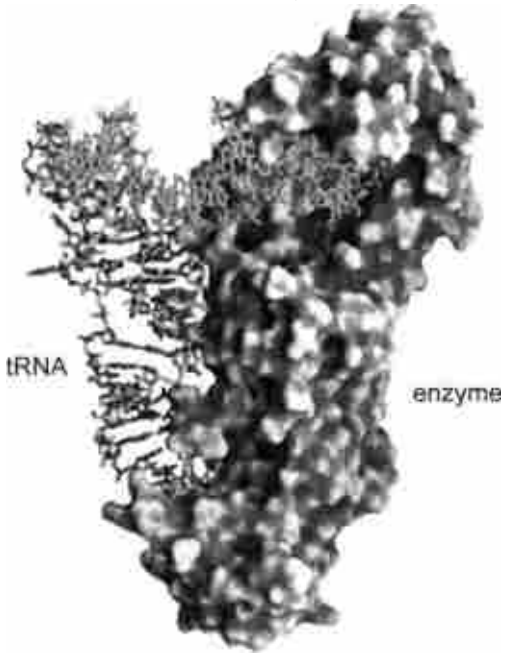


Fig. 1.1

(a) With reference to **Fig. 1.1**, explain how the enzyme is suited to its function.

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[3]

(b) The average molecular weight of proteins encoded in the human genome is about 50,000 daltons. Given the average molecular mass of an amino acid is about 110 daltons and 5% of the initial transcript is converted to mature mRNA, estimate how long it will take a muscle cell to transcribe a gene for an average protein. Assume that the transcription rate is 20 nucleotides per second.

Show your working and express your answer to the nearest whole number (in minutes).

Answer: …… minutes [2]

(c) Edeine is an antibiotic that inhibits protein synthesis but has no effect on either DNA synthesis or RNA synthesis. When added to the cell extract of an immature red blood cell, edeine stops protein synthesis after a short lag, as shown in **Fig. 1.2.** By contrast, cycloheximide, which is also an inhibitor, stops protein synthesis immediately. Protein synthesis is measured via radioactivity in haemoglobin.

Analysis of the edeine-inhibited cell extract showed that no polyribosomes remained at the time protein synthesis had stopped. Instead, all the globin mRNA were found associated with small ribosomal subunit and initiator tRNA.

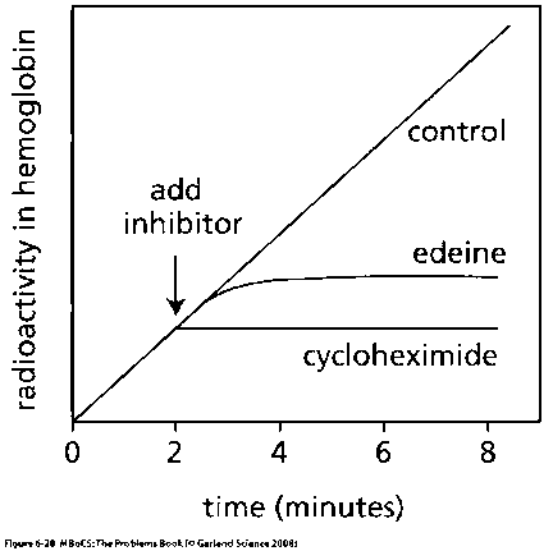

Fig. 1.2

(i) Explain how protein synthesis is measured via radioactivity in haemoglobin.

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[1]

(ii) Describe how edeine inhibits protein synthesis.

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[2]

(iii) Explain why there is a lag between the addition of edeine and cessation of protein synthesis.

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[2]

Protein synthesis in an organism is illustrated in **Fig 1.3.**

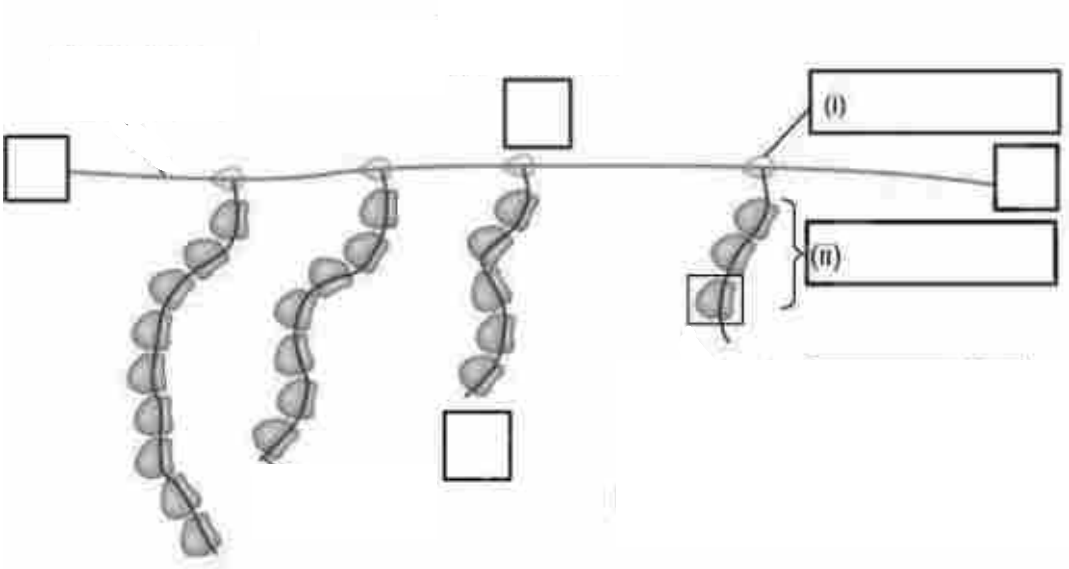

Fig. 1.3

(d) Label the 5' and 3' ends of the mRNA and DNA template strand in the boxes provided and structures (i) and (ii) on **Figure 1.3.** [2]

[Total: 12]

2 A gene for feather colour in chickens is carried on an autosome. This gene has two alleles, black (C^B) and splashed-white (C^W). When a male chicken with black feathers is mated with a female chicken with splashed-white feathers, all the offspring have blue feathers. This also occurs when a male chicken with splashed-white feathers is crossed with a female with black feathers.

Black feathers

Splashed-white feathers

Barred feathers

Another gene may cause stripes on feathers (barred feathers). The gene is carried on the X chromosome. The allele for barred feathers (X^A) is dominant to the allele for non-barred feathers (X^a). In chickens the male is homogametic, while the female is heterogametic.

(a) A male chicken with black, non-barred feathers was crossed with a female chicken with splashed-white, barred feathers. All the offspring had blue feathers, but the males were barred and the females were non-barred.

(i) Using the symbols given, draw a genetic diagram to show this cross.

Parental phenotype	Male, black, non-barred feathers	Female, splashed-white, barred feathers
Genotype		
Gametes		
Offspring genotypes		
Phenotypes		

[2]

(ii) Explain how a farmer could use a breeding programme to find out the genotype of a male chicken with blue, barred feathers.

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[3]

(b) The table below shows the genotypes and wool length in two breeds of sheep, **X** and **Y,** and their F1 hybrids.

	Genotype	***Mean wool length/cm***
Breed **X**	**DDEEff**	**18**
Breed **Y**	**ddeeFF**	**14**
F1 (breed **X** x Breed **Y**)	**DdEeFf**	**16**

When the F1 were crossed among themselves, the F2 offspring had a mean wool length ranging from 10cm to 22cm.

Assume that the inheritance of wool length in sheep depends upon alleles at three loci acting additively and that all variation in wool length in the F2 population is due to the segregation of alleles at these three loci.

(i) How many different types of gametes would be produced by an organism of genotype DdEeFF, if all of the genes assort independently?

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[1]

(ii) What proportion of the F2 offspring are expected to have a mean wool length of 22 cm? Explain your reasoning.

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[4]

[Total: 10]

3 Phosphofructokinase (PFK) is a tetrameric enzyme that plays a central role in controlling the rate of glycolysis. In many organisms, the activity of PFK is enhanced allosterically by several substances, including ADP, and is inhibited allosterically by several other substances, including ATP and citrate. **Fig. 3.1** shows part of the glycolysis reactions.

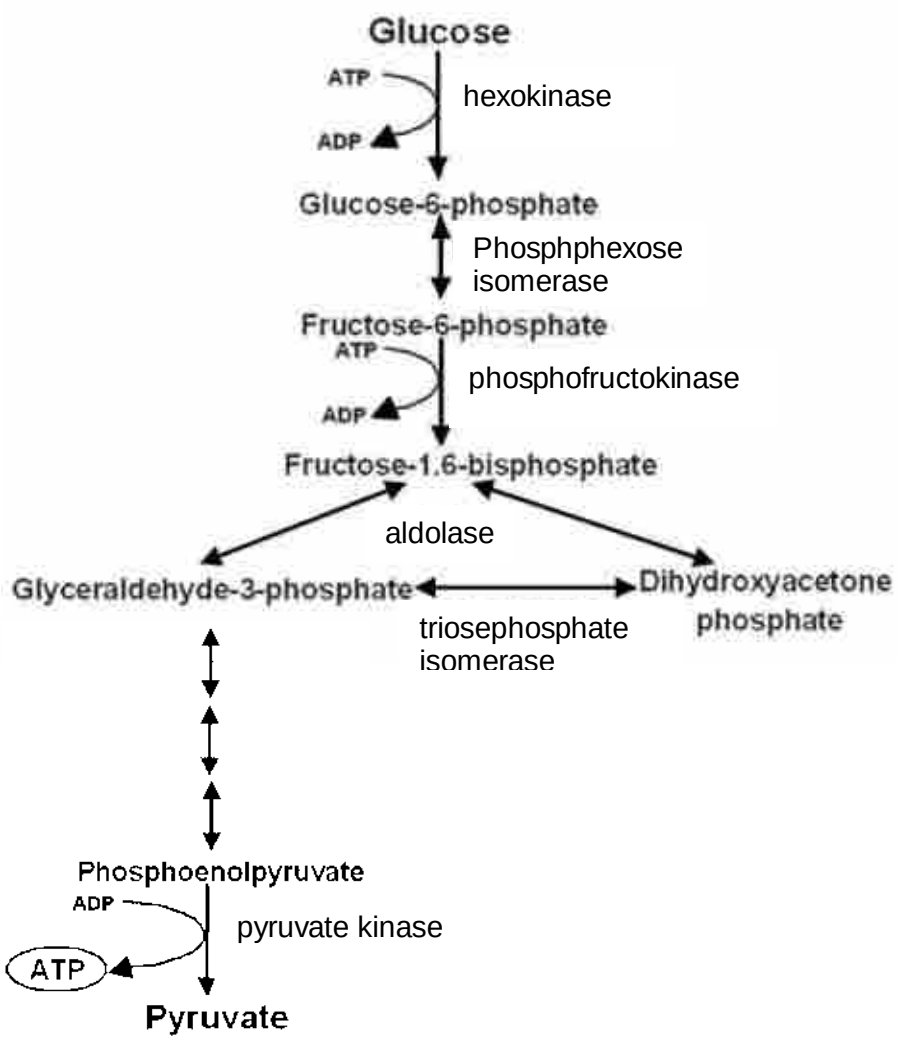

Fig. 3.1

(a) Explain why phosphofructokinase is a quaternary protein.

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[1]

(b) Besides PFK, hexokinase and pyruvate kinase also play a role in determining the overall rate of glycolysis.

With reference to **Fig. 3.1**, suggest why reactions catalyzed by these three enzymes determine the rate of glycolysis.

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[2]

(c) Explain the importance of inhibition of PFK by citrate when citrate concentration in the cell is high.

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[2]

(d) Describe how citrate inhibits PFK.

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[3]

(e) In mammals, under anaerobic condition, both Krebs cycle and oxidative phosphorylation do not occur. Instead, lactate fermentation occurs.

Explain the significance of lactate fermentation.

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[2]

(f) Hexokinase, the enzyme involved in the first step of glycolysis, is able to utilize various hexoses such as glucose, fructose and mannose.

Suggest how hexokinase is able to utilize different substrates.

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[2]

[Total: 12]

4 Norepinephrine is a stress hormone secreted during fight-or-flight response. **Fig. 4.1** shows an example of a G-protein signalling pathway.

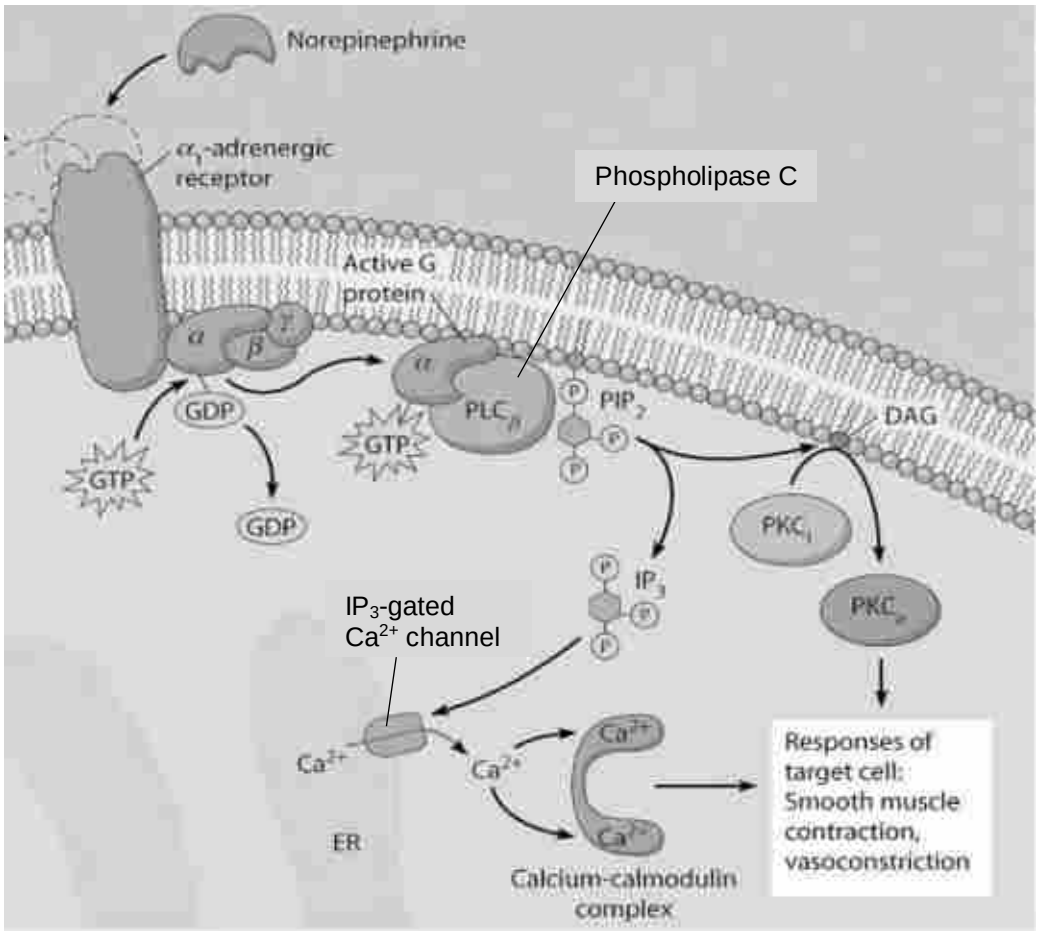

Fig. 4.1

(a) With reference to **Fig. 4.1**, describe explain how the presence of norepinephrine leads to the opening of IP_3-gated Ca^{2+} channels.

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[4]

(b) With reference to **Fig. 4.1**, explain the significance of IP_3 and Ca^{2+} in the cell signalling pathway.

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[2]

(c) The same signalling molecule norepinephrine usually targets more than one cell type. For e.g. muscle, heart and liver cells.

Explain how the same norepinephrine molecule can have different effects on different cells.

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[2]

(d) Suggest how signal termination can occur.

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[1]

Most people with type I diabetes inject insulin. A recent product contains insulin that can be administered using a nasal spray. The spray is inhaled and the insulin is taken up through the lungs.

Fig. 4.2 shows the concentration of insulin in the blood plasma in the 480 minutes after injecting or inhaling insulin. In both cases, the insulin was of the same type, obtained from genetically engineered *Escherichia coli*.

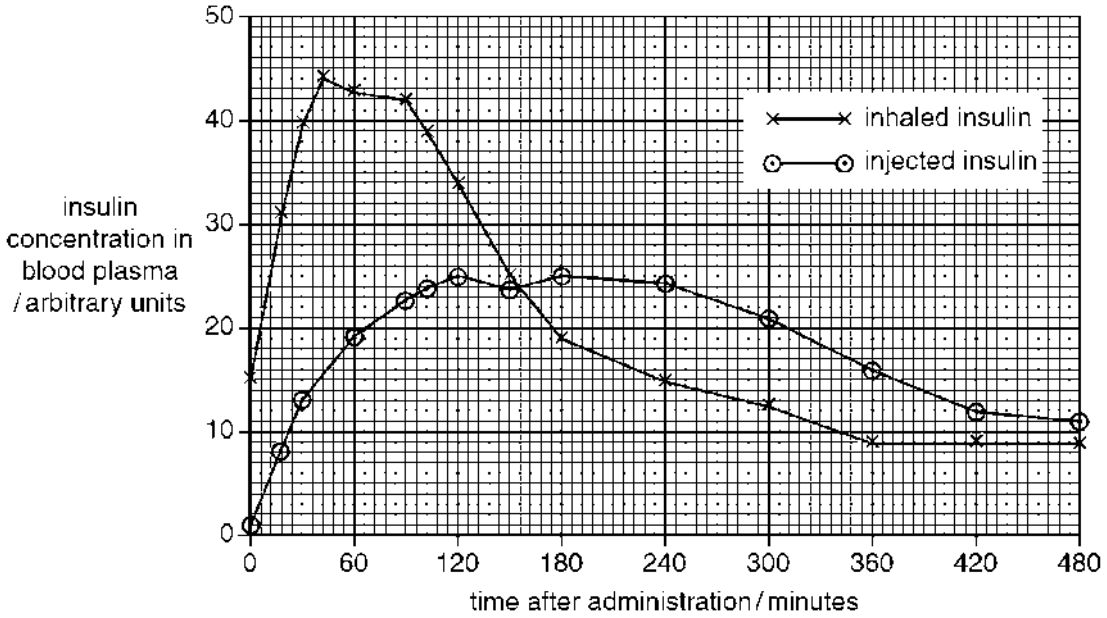

Fig 4.2

Fig. 4.3 shows the concentration of glucose in the blood plasma in the 480 minutes after injecting or inhaling insulin.

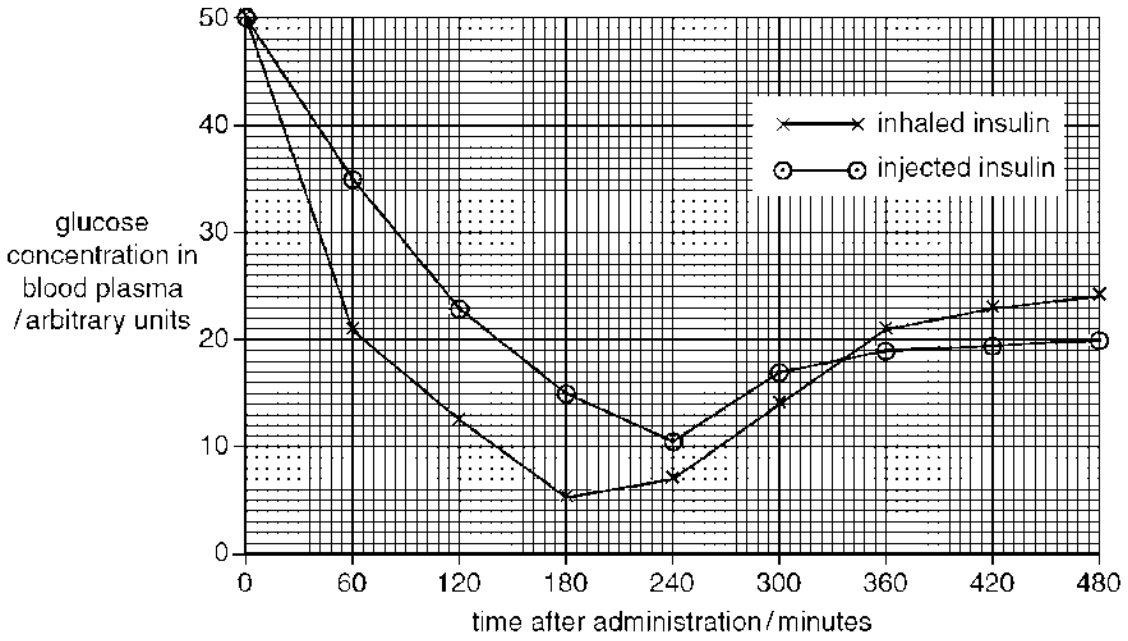

Fig 4.3

(e) Compare the results for injected insulin and inhaled insulin shown in **Fig. 4.2**.

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[2]

(f) With reference to **Fig. 4.2**, explain the differences in the blood glucose levels after injecting or inhaling insulin shown in **Fig. 4.3**.

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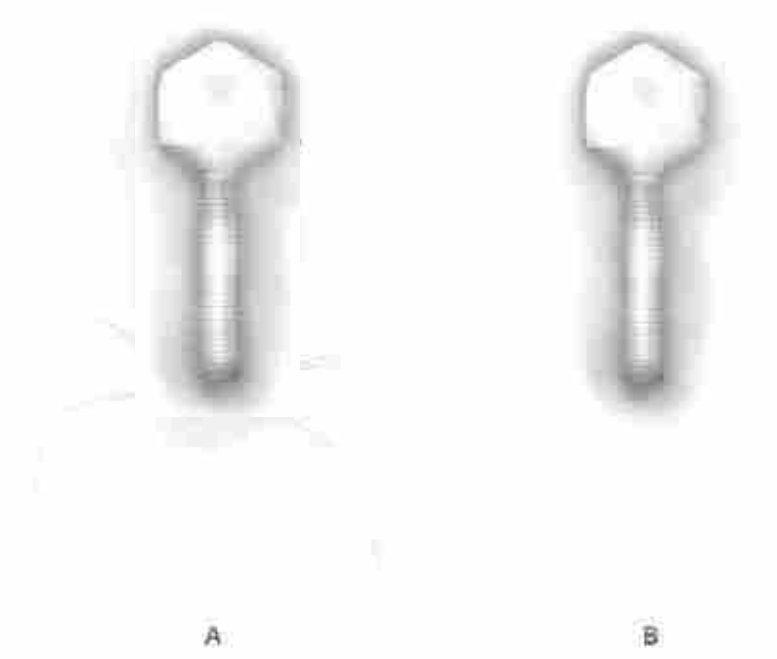
[3]

[Total: 14]

5 Lambda is a bacteriophage that uses *Escherichia coli* as its host cell. **Fig. 5.1 A** is an electron micrograph (EM) of a wild-type bacteriophage lambda while **Fig. 5.1 B** is an EM of a laboratory-cultured lambda.



(a) State one main difference between the two bacteriophages.

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[1]

(b) Suggest how the laboratory-cultured bacteriophage binds to the host cell, *Escherichia coli*.

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[1]

(c) Explain how lambda phage enters the host cell.

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[2]

(d) Suggest why it is sometimes difficult to distinguish between a plasmid and the DNA of the bacteriophage lambda inside an *Escherichia coli*, when viewed under the electron microscope.

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[1]

Some of the *Escherichia coli* are infected with the laboratory-cultured lambda phage. It is observed that no new phages are produced. The bacteria are initially cultured in a nutrient medium without X-gal. The bacteria colonies produced are replica plated onto two agar plates, one containing X-gal and lactose and the other containing X-gal without lactose.

There is no glucose in either plates. **Fig. 5.2.** shows the results of this experiment.

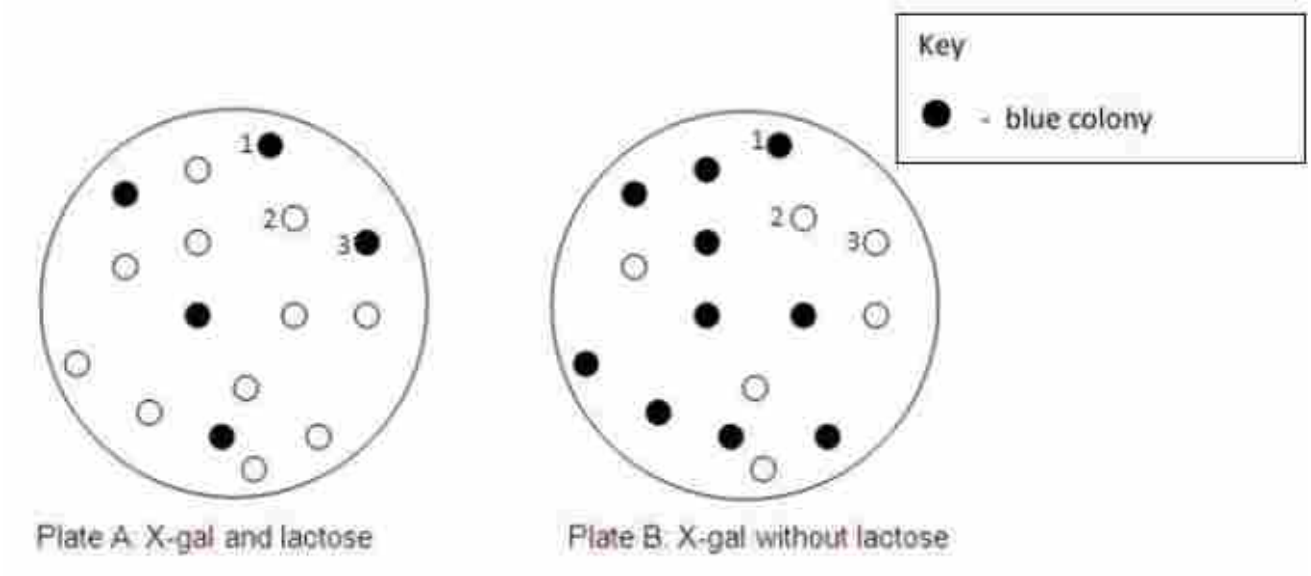

Fig. 5.2

(e) Suggest why no new phages were formed.

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[1]

(f) Account for the observations seen in:

(i) Colony 1

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[2]

(ii) Colony 2

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[2]

(iii) Colony 3

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[2]

[Total: 12]

6 **Fig. 6.1** below is an electron micrograph of a microorganism that is isolated from the stools of cholera patients.

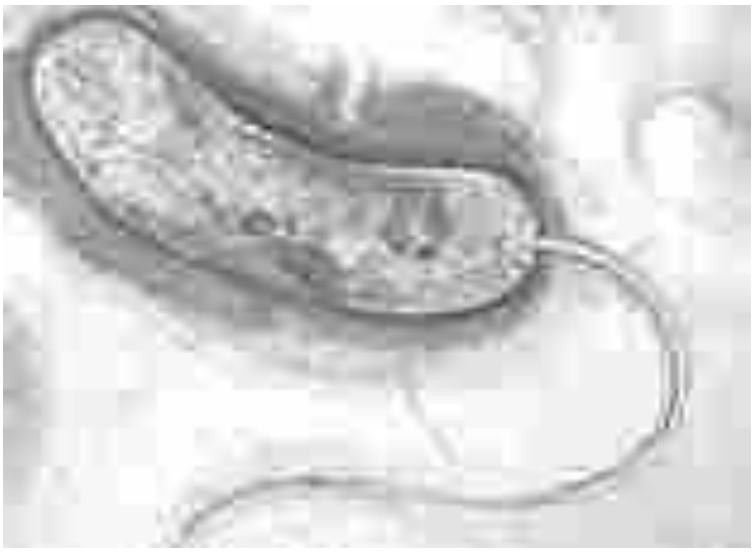

Fig. 6.1

(a) With reference to Fig. 6.1, state **two** structural differences between the chromosome of this type of microorganism and a human cell.

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[2]

(b) The enzyme lactase is responsible for lactose metabolism in humans and is encoded by a gene on chromosome 2.

Based on your understanding of eukaryotic and prokaryotic genomes, describe how the genes in humans and *Escherichia coli* that are responsible for lactose metabolism differ in terms of:

(i) their organisation;

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[1]

(ii) the control of gene expression.

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[2]

(c) Streptomycin is an antibiotic that binds to bacterial ribosomes.

(i) Explain how this effect of streptomycin prevents the growth of bacteria.

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(ii) Suggest why streptomycin does not affect the growth of human cells.

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[1]

[Total: 8]

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The giant tortoises had been previously classified based on morphological differences, primarily using carapace (shell) shape, which varies from domed to saddleback with intermediate forms also occurring.

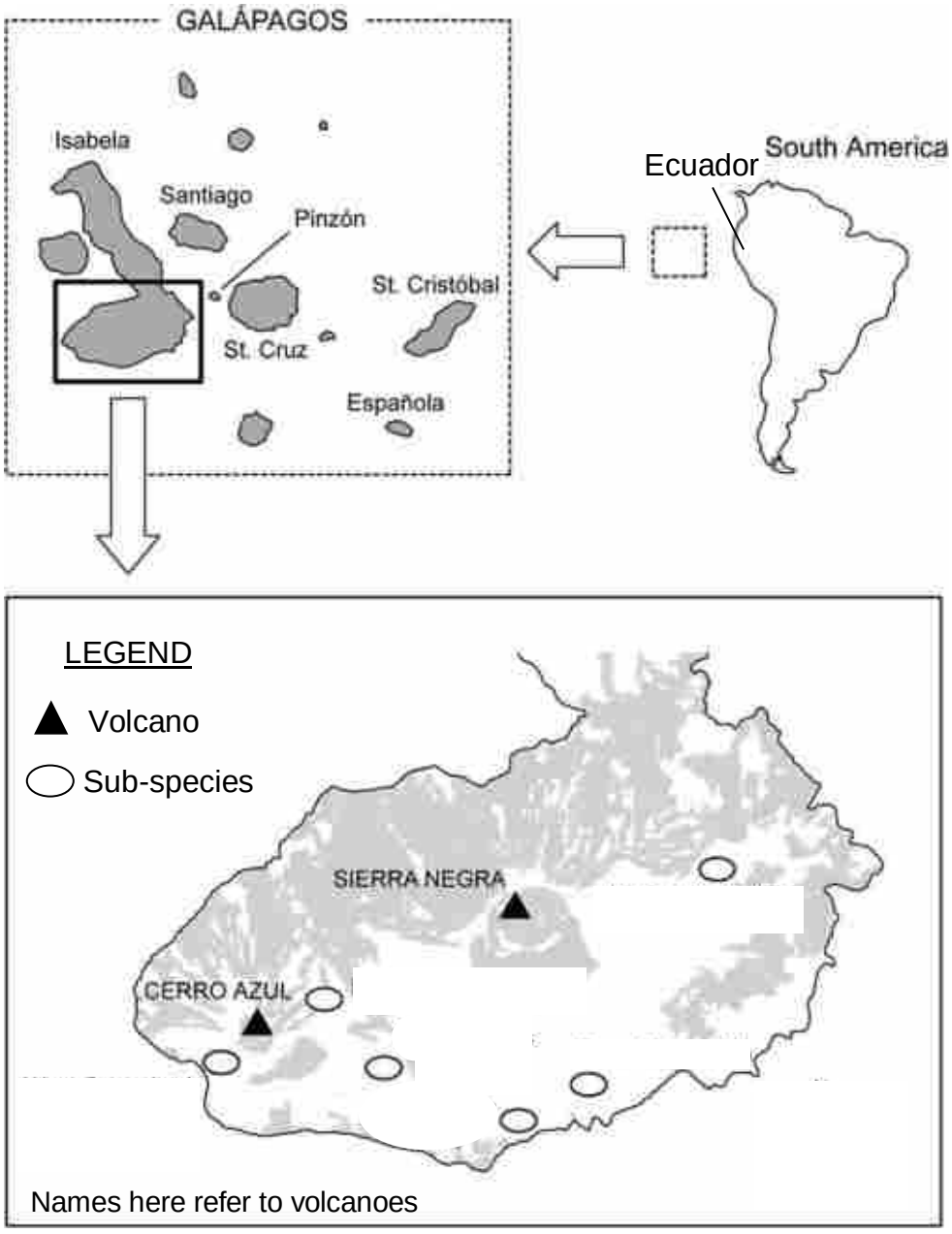

Fig. 7.1

(a) With reference to **Fig. 7.1**, explain how biogeography supports the evolutionary deductions that the tortoises are all evolutionally related.

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[2]

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Scientists have tested this idea by observing different groups of small fish *Poecilopsis* species (Gila topminnow) in Mexico. Some populations of the topminnow reproduce sexually, while others practice parthenogenesis. Parthenogenesis occurs when females produce offspring without any male contribution and the female's gametes develop directly into female offspring.

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However, it was observed that after a drought, the sexually reproducing topminnows were more heavily parasitized than the cloned topminnows. This process of whereby chance events cause the allele frequency to change unpredictably is known as genetic drift.

(d) Name the evolutionary event that resulted in this genetic drift.

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(e) Explain why there was an increase in the number of parasitized sexually reproducing topminnows after the drought.

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[2]

The Neutral Theory of Molecular Evolution proposed that frequencies of alleles are not affected by natural selection but may increase or decrease as a result of genetic drift.

(f) Briefly describe the Neutral Theory of Molecular Evolution.

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[3]

[Total: 12]

Section B

Answer **one** question.

Write your answers on the separate answer paper provided.
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H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME

CLASS

BIOLOGY

9648/02

Paper 2 Core Paper

September 2016

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and CT on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use soft pencil for any diagrams, graphs or rough working.
Do no use staples, paper clips, highlighters, glue or correction fluid.

Section A

Answer **all** questions.

Section B

Answer any **one** question.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
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3	
4	
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7	
Section B	
Total	

This document consists of **20** printed pages and **no** blank page.

[Turn over

Section A

Answer **all** the questions in this section.

1 Fig 1.1 shows a molecule of tRNA and the enzyme that attaches the correct amino acid to it

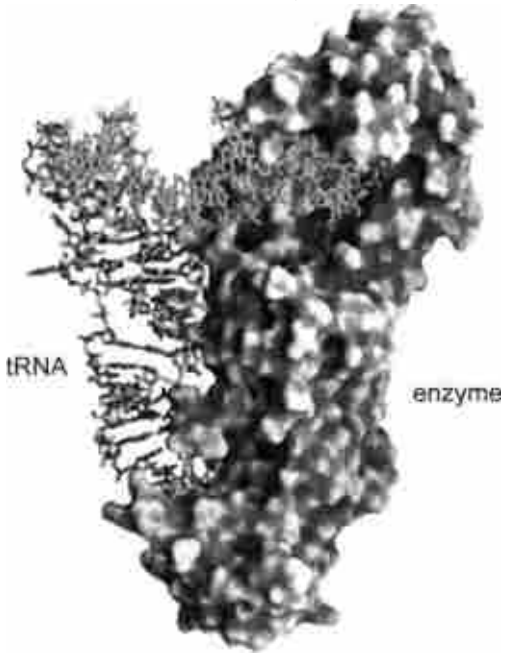

Fig. 1.1

(a) With reference to **Fig. 1.1**, explain how the enzyme is suited to its function **[AJC 2011]**

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[3]

(b) The average molecular weight of proteins encoded in the human genome is about 50,000 daltons. Given the average molecular mass of an amino acid is about 110 daltons and 5% of the initial transcript is converted to mature mRNA, estimate how long it will take a muscle cell to transcribe a gene for an average protein. Assume that the transcription rate is 20 nucleotides per second.

Show your working and express your answer to the nearest whole number (in minutes).

Answer: …… minutes [2]

(c) Edeine is an antibiotic that inhibits protein synthesis but has no effect on either DNA synthesis or RNA synthesis. When added to the cell extract of an immature red blood cell, edeine stops protein synthesis after a short lag, as shown in Fig. 1.2. By contrast, cycloheximide, which is also an inhibitor, stops protein synthesis immediately. Protein synthesis is measured via radioactivity in haemoglobin.

Analysis of the edeine-inhibited cell extract showed that no polyribosomes remained at the time protein synthesis had stopped. Instead, all the globin mRNA were found associated with small ribosomal subunit and initiator tRNA.

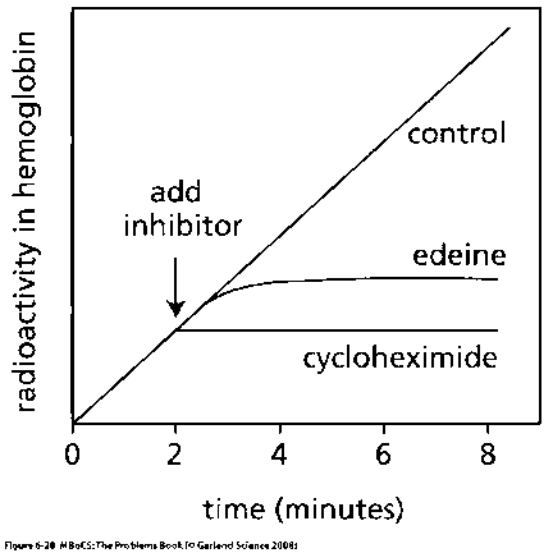

Fig. 1.2

(i) Explain how protein synthesis is measured via radioactivity in haemoglobin.

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[1]

(ii) Describe how edeine inhibits protein synthesis.

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[2]

(iii) Explain why there is a lag between the addition of edeine and cessation of protein synthesis.

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[2]

Protein synthesis in an organism is illustrated in Fig 1.3. (MJC 2011)

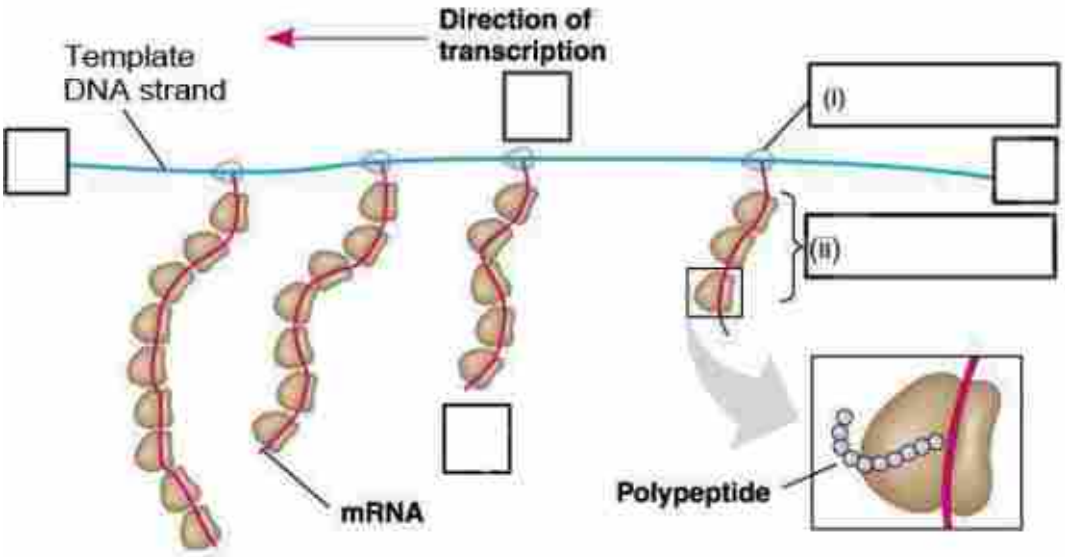

Fig. 1.3

(a) Label the 5' and 3' ends of the mRNA and DNA template strand and structures (i) and (ii) on Figure 1.2. [2]

[Total: 12]

2 A gene for feather colour in chickens is carried on an autosome. This gene has two alleles, black (C^B) and splashed-white (C^W). When a male chicken with black feathers is mated with a female chicken with splashed-white feathers, all the offspring have blue feathers. This also occurs when a male chicken with splashed-white feathers is crossed with a female with black feathers.

Black feathers

Splashed-white feathers

Barred feathers

Another gene may cause stripes on feathers (barred feathers). The gene is carried on the X chromosome. The allele for barred feathers (X^A) is dominant to the allele for non-barred feathers (X^a). In chickens the male is homogametic, while the female is heterogametic.

(a) A male chicken with black, non-barred feathers was crossed with a female chicken with splashed-white, barred feathers. All the offspring had blue feathers, but the males were barred and the females were non-barred.

(i) Using the symbols given on the previous page draw a genetic diagram to show this cross.

Parental phenotype	Male, black, non-barred feathers	Female, splashed-white, barred feathers
Genotype		
Gametes		
Offspring genotypes		
Phenotypes		

[4]

(ii) Explain how a farmer could use a breeding programme to find out the genotype of a male chicken with blue, barred feathers.

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[3]

(b) The table below shows the genotypes and wool length in two breeds of sheep, **X** and **Y,** and their F1 hybrids.

	Genotype	***Mean wool length/cm***
Breed **X**	**DDEEff**	**18**
Breed **Y**	**ddeeFF**	**14**
F1 (breed **X** x Breed **Y**)	**DdEeFf**	**16**

When the F1 were crossed among themselves, the F2 offspring had a mean wool length ranging from 10cm to 22cm.

Assume that the inheritance of wool length in sheep depends upon alleles at three loci acting additively and that all variation in wool length in the F2 population is due to the segregation of alleles at these three loci.

How many different types of gametes would be produced by an organism of genotype DdEeFF, if all of the genes assort independently?

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[1]

What proportion of the F2 offspring are expected to have a mean wool length of 2 cm? Explain your reasoning.

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[4]

[Total: 12]

3 Phosphofructokinase (PFK) is a tetrameric enzyme that plays a central role in controlling the rate of glycolysis. In many organisms, the activity of PFK is enhanced allosterically by several substances, including ADP, and is inhibited allosterically by several other substances, including ATP and citrate. Fig. 3.1 shows part of the glycolysis reactions.

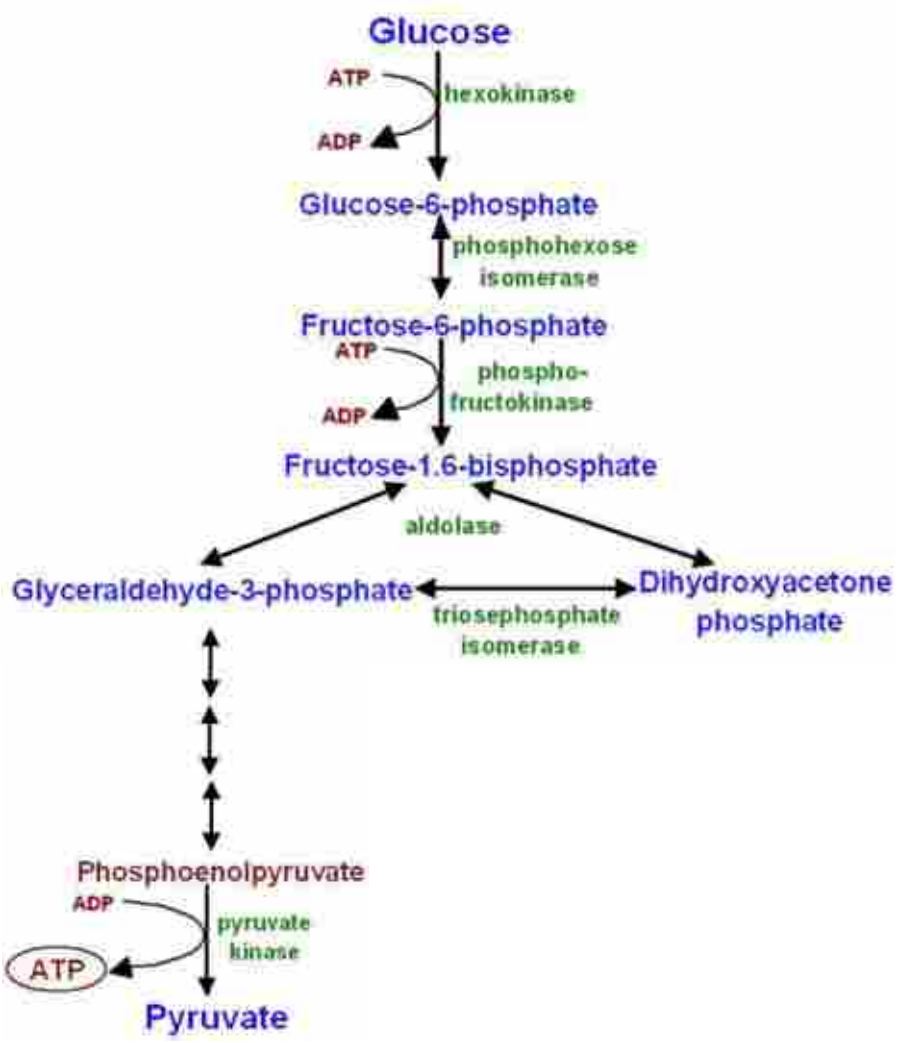

Fig. 3.1

(a) Explain why phosphofructokinase is a quaternary protein. MJC 2011

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[1]

(b) Besides PFK, hexokinase and pyruvate kinase also play a role in determining the overall rate of glycolysis.

With reference to Fig. 3.1, suggest why reactions catalyzed by these three enzymes determine the rate of glycolysis.

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[1]

(c) Explain the importance of inhibition of PFK by citrate when citrate concentration in the cell is high.

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[2]

(d) Describe how citrate inhibits PFK.

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[3]

(e) In mammals, under anaerobic condition, both Krebs cycle and oxidative phosphorylation do not occur. Instead, lactate fermentation occurs.

Explain the significance of lactate fermentation.

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[2]

(f) Hexokinase, the enzyme involved in the first step of glycolysis, is able to utilize various hexoses such as glucose, fructose and mannose.

Suggest how hexokinase is able to utilize different substrates.

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[2]

[Total: 12]

4 Norepinephrine is a stress hormone secreted during fight-or-flight response. Fig. 6.1 shows an example of a G-protein signalling pathway.

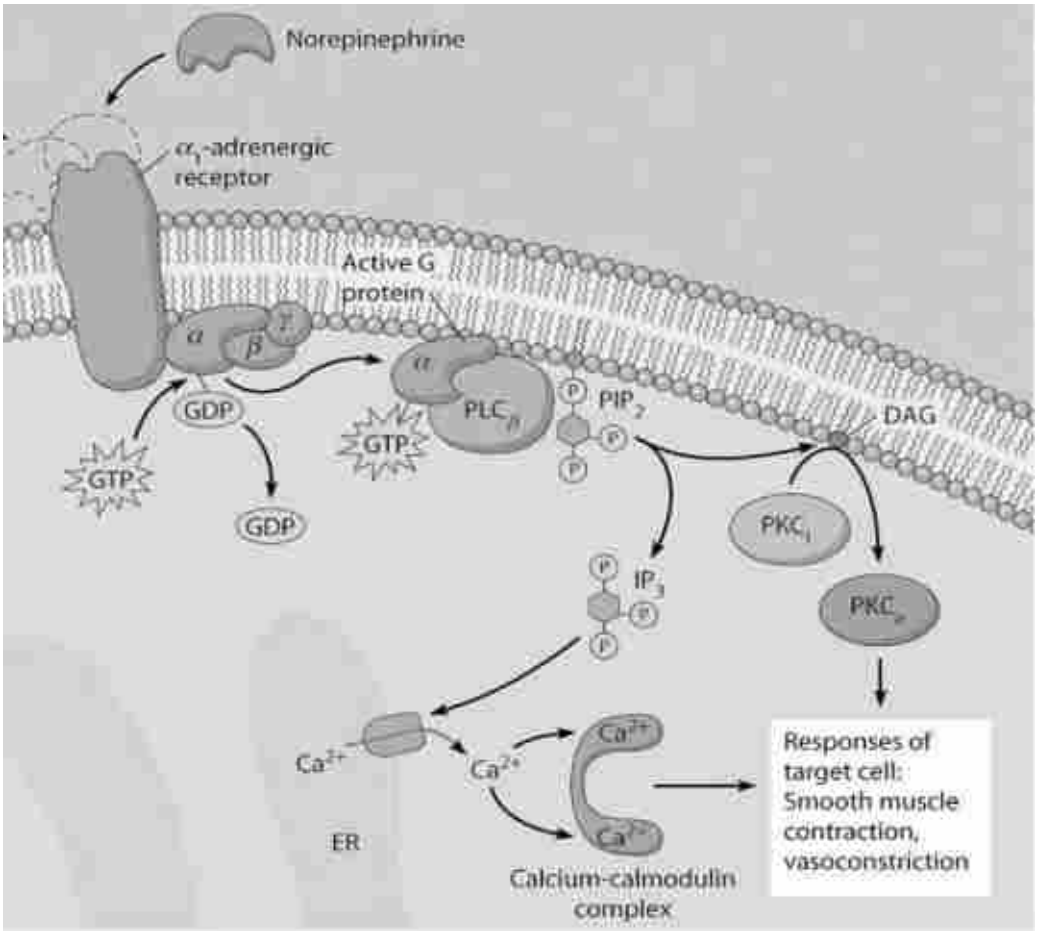

Fig. 4.1

(a) With reference to Fig. 6.1, describe explain how the presence of norepinephrine leads to the opening of IP_3-gated Ca^{2+} channels.

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[4]

(b) With reference to Fig. 6.1, explain the significance of IP_3 and Ca^{2+} in the cell signalling pathway.

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[2]

(c) The same signalling molecule norepinephrine usually targets more than one cell type. For e.g. muscle, heart and liver cells.

Explain how the same norepinephrine molecule can have different effects on different cells.

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[2]

(d) Suggest how signal termination can occur.

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[1]

Most people with type I diabetes inject insulin. A recent product contains insulin that can be administered using a nasal spray. The spray is inhaled and the insulin is taken up through the lungs.

Fig. 6.2 shows the concentration of insulin in the blood plasma in the 480 minutes after injecting or inhaling insulin. In both cases, the insulin was of the same type, obtained from genetically engineered *Escherichia coli*.

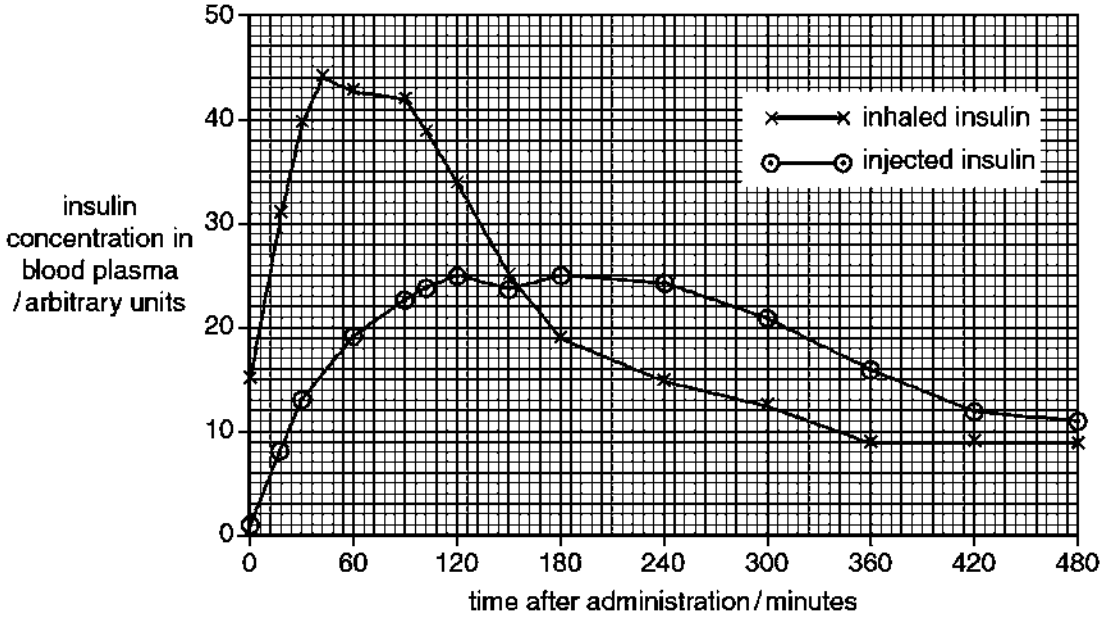

Fig 6.2

Fig. 6.3 shows the concentration of glucose in the blood plasma in the 480 minutes after injecting or inhaling insulin.

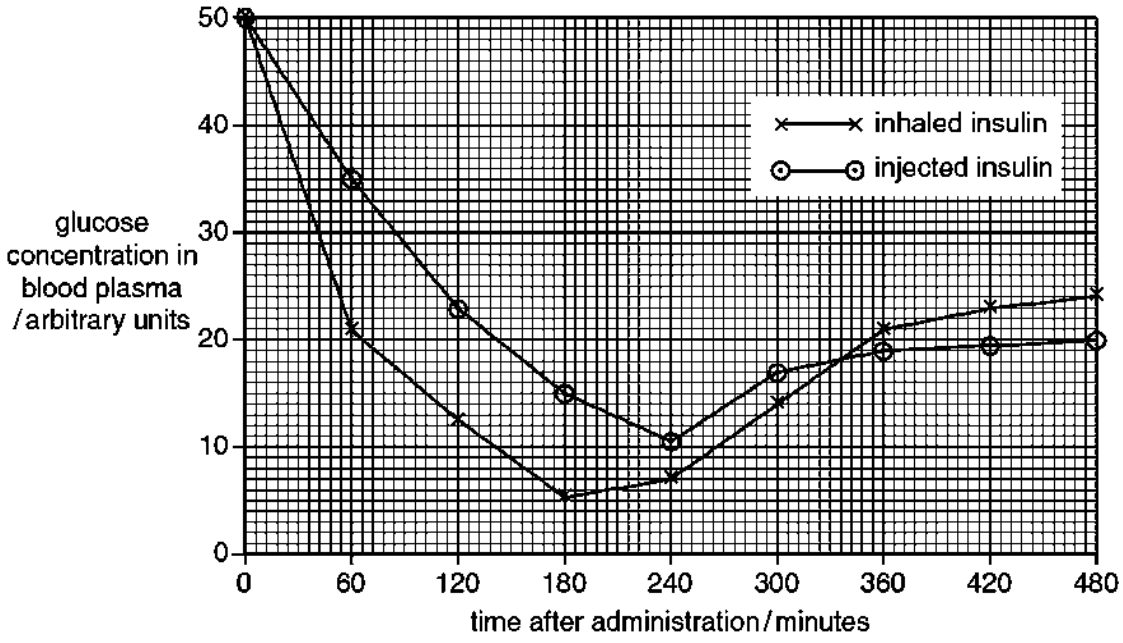

Fig 6.3

(e) Compare the results for injected insulin and inhaled insulin shown in Fig. 6.2.

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[2]

(f) With reference to Fig. 6.2, explain the differences in the blood glucose levels after injecting or inhaling insulin shown in Fig. 6.3.

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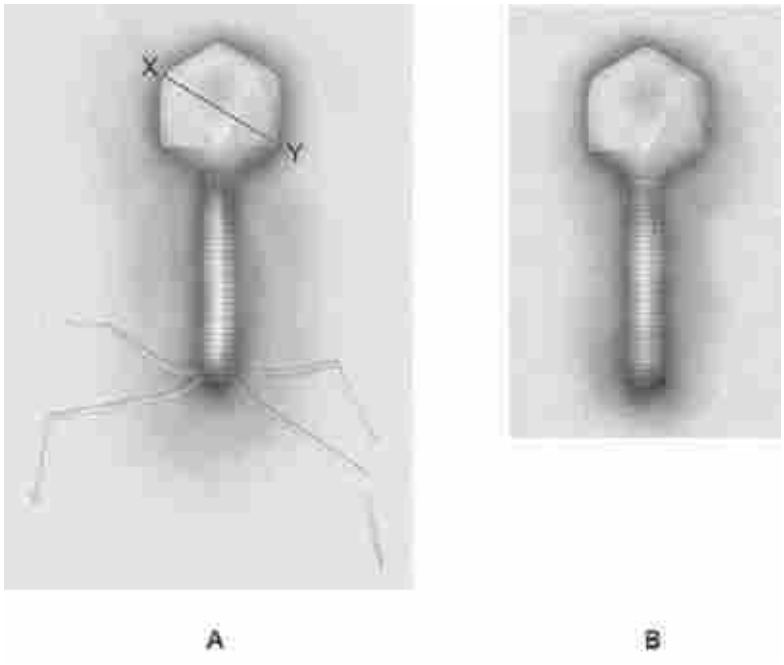
[3]

[Total: 14]

5 Lambda is a bacteriophage that uses *Escherichia coli* as its host cell. Fig. 5.1 A is an electron micrograph (EM) of a wild-type bacteriophage lambda while Fig. 5.1 B is an EM of a laboratory-cultured lambda. MJC 2010



(a) State one main difference between the two bacteriophages.

Presence or tail fibres in phage A

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[1]

(b) Studies have shown that laboratory-cultured bacteriophage can bind to the host cell, *Escherichia coli*. But no new phages are formed.

Suggest how the laboratory-cultured bacteriophage binds to the host cell, *Escherichia coli*.

Binding to host cell via base plate

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[1]

(c) Suggest why no new phages were formed.

Phage DNA integrates into bacterial genome as prophage ; undergoing lysogenic cycle

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[1]

(d) Explain how lambda phage enters the host cell.

Lambda phage recognises and binds / attaches to specific receptor sites on host cells' surface (attachment phase)

Penetrates into host by injecting its DNA into the cytosol of the host bacteria

[2]

(e) Suggest why it is sometimes difficult to distinguish between a plasmid and the DNA of the bacteriophage lambda inside an *Escherichia coli*, when viewed under the electron microscope.

Both may be similar in size / circular in shape

[1]

Some of the *Escherichia coli.* are infected with the laboratory-cultured lambda phage. The bacteria are initially cultured in a nutrient medium without X-gal. The bacteria colonies produced are replica plated onto two agar plates, one containing X-gal and lactose and the other containing X-gal without lactose.

There is no glucose in either plates. Fig. 5.2. shows the results of this experiment.

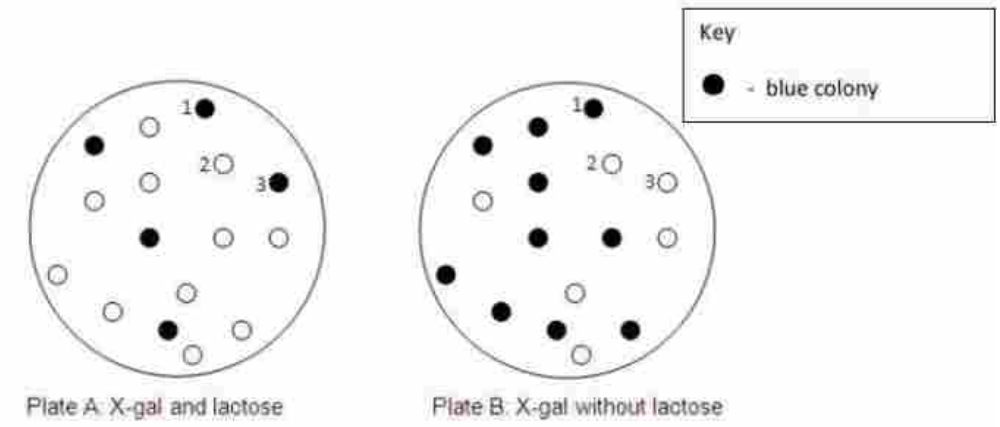

Fig. 5.2

(f) Account for the observations seen in:

(i) Colony 1

Colony 1 is blue in both plates because transcription of Lac Z gene is turned on all the time so β galactosidase is continuously translated to break dwon X-gal into a blue compound

Phage DNA is integrated into the operator by transduction and repressor cannot find to operator OR phage DNA is integrated inot lacI gene and no repressor is produced;

[2]

(ii) Colony 2

Colony 2 is white in both plates because transcription of lac Z gene cannot take place and β galactosidase is not translated ;

Viral DNA is integrated into the promoter and RNA polymerase cannot bind to promoter OR viral DNA is integrated into lac Z gene and lac Z gene is disrupted leading to insertional inactivation ;

[2]

(iii) Colony 3

Observation for colony 3 is as expected. Blue when lactose is present and white when lactose is absent / regulation of lac operon is normal ;

Viral genome is not integrated into the lac operon / no transduction occurs ;

[1]

[Total: 11]

6 **(a)** With reference to the *lac* operon, explain what is meant by : CJC 2011 Q3

(i) regulatory genes;

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[2]

(ii) structural genes

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[2]

(b) Fig. 6.1 below is an electron micrograph of a microorganism that is isolated from the stools of cholera patients.

Fig. 6.1

With reference to Fig. 6.1, state **two** structural differences between the chromosome of this type of microorganism and a human cell.

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(c) The enzyme lactase is responsible for lactose metabolism in humans and is encoded by a gene on chromosome 2.

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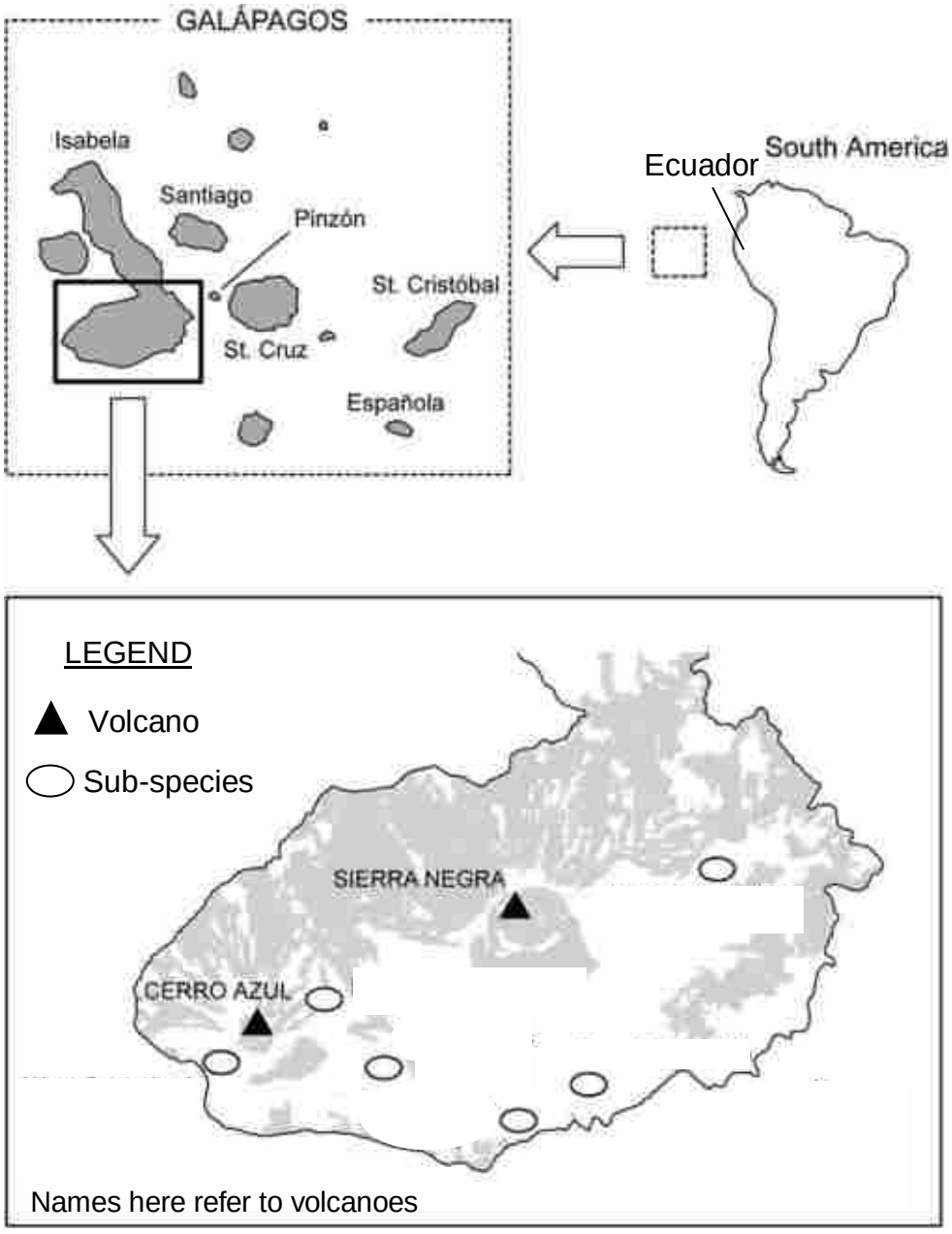

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However, it was observed that after a drought, the sexually reproducing topminnows were more heavily parasitized than the cloned topminnows. This process of whereby chance events cause the allele frequency to change unpredictably is known as genetic drift.

(i) Name the evolutionary event that resulted in this genetic drift.

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[1]

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[2]

The Neutral Theory of Molecular Evolution proposed that frequencies of alleles are not affected by natural selection but may increase or decrease as a result of genetic drift.

(iii) Briefly describe the Neutral Theory of Molecular Evolution.

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[3]

[Total: 12]

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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME

CLASS

BIOLOGY

9648/03

Paper 3 Applications and Planning

26 September 2016

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and CT on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use soft pencil for any diagrams, graphs or rough working.
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The number of marks is given in brackets [ ] at the end of each question or part question.

Answer questions **1** to **4** in the spaces provided on the question paper.

Answer question **5** on the separate answer paper provided.

For Examiner's Use	
1	
2	
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Total	60
For Examiner's Use	
4	12

This document consists of **12** printed pages and **0** blank page.

[Turn over

Section A

Answer **all** the questions in this section.

1 Insulin deficiency is one of the causes of diabetes. There are a few methods to synthesize recombinant insulin using genetic engineering, one of the methods involve cloning the human insulin cDNA.

(a) Compare the differences on how a genomic library and a cDNA library are produced.

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[2]

(b) Explain the advantages of obtaining human insulin gene from a cDNA library instead of a genomic DNA library.

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[3]

Fig. 1.1 shows the bacteria plasmid containing the positions of the restriction sites of the restriction enzymes available at its multiple cloning site. These restriction sites do not occur elsewhere within the plasmid.

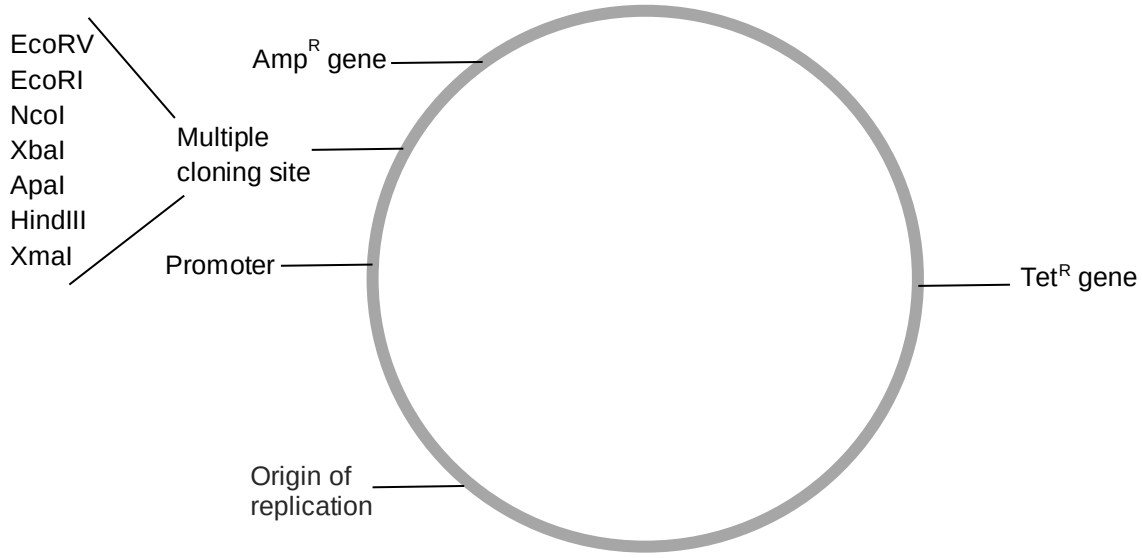

Fig. 1.1

Fig. 1.2 shows the restriction enzymes and their corresponding specific recognition sequences with respect to human insulin cDNA sequence. With the exception of *EcoRV*, all the restriction sites (*Apa I*, *Nco I*) generate sticky ends when cut.

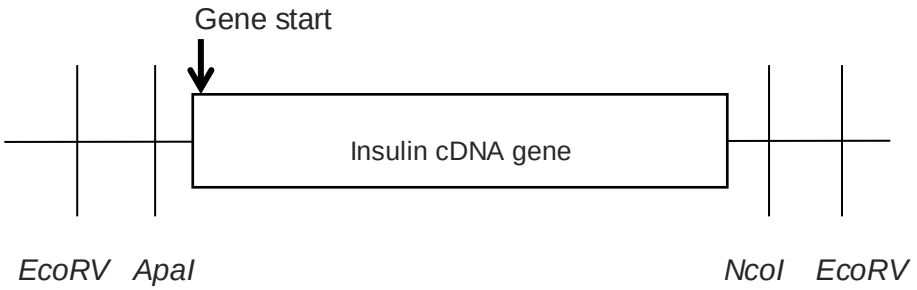

Fig. 1.2

(c) In order to obtain a recombinant plasmid containing the human insulin gene, the human insulin cDNA and vector needs to be digested with restriction enzymes prior to annealing them together.

(i) State the restriction enzymes used in order to obtain **efficient** gene expression.

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[1]

(ii) Explain your choice of restriction enzymes.

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[2]

(iii) With reference to **Fig. 1.1** and **1.2**, explain how recombinant bacteria (formed using the recombinant plasmids) can be selected using antibiotics.

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[4]

(d) Suggest a reason why functional insulin was not expressed in the recombinant E.coli cells.

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[2]

(e) Bacteriophages can be used to transfer foreign DNA into bacteria cells. Suggest **one** advantage of the use of phage vectors over plasmid vectors in transferring DNA into bacteria.

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[1]

[Total: 15]

2 A violent air crash resulted in the death of 150 passengers. The poor condition of the crash victims made physical identification impossible. Forensic scientists were tasked to confirm the identities of victims by using molecular techniques for families who have come forward to claim the correct remains of their relatives.

DNA samples of human remains and surviving relatives were subjected to restriction enzyme digest and Southern blot analysis to analyse VNTR band patterns. Single locus VNTR probes will yield DNA patterns of seven individuals at a single locus, as shown in **Fig. 2.1**. On the other hand, multi-locus VNTR probes can yield more information about each individual since 10 to 30 loci can be simultaneously analysed. This is illustrated in five different individuals in **Fig. 2.2**.

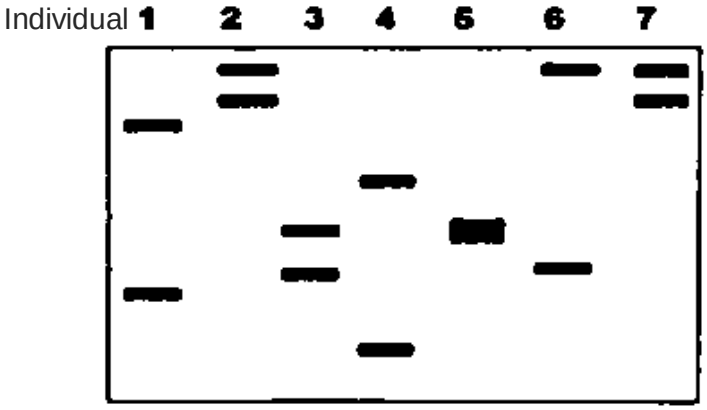

Fig. 2.1

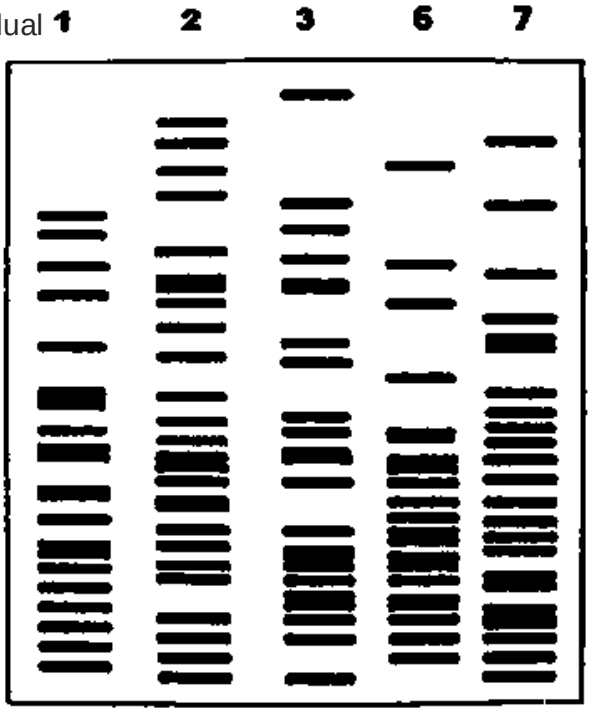

Fig. 2.2

(a) (i) Explain the basis of application of VNTR in DNA profiling.

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[3]

(ii) With reference to **Fig. 2.1**, explain the different numbers of fragments seen in different individuals.

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[2]

(iii) With reference to **Fig. 2.1** and **Fig. 2.2**, suggest why using multi-locus probes is preferred.

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[2]

(b) VNTRs can be analysed by Southern blotting or by PCR analysis.

Describe **two** differences between Southern blotting and PCR analysis in the analysis of the single locus VNTR shown in **Fig. 2.1.**

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[2]

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(c) The fully sequenced human genome contains many unknown genes. Suggest how RFLP analysis can help to identify **unknown** genes that are responsible for heritable diseases.

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[2]

[Total: 12]

3 Plant tissue culture is a method used to propagate plants. **Fig. 3.1** shows one method of plant tissue culture.

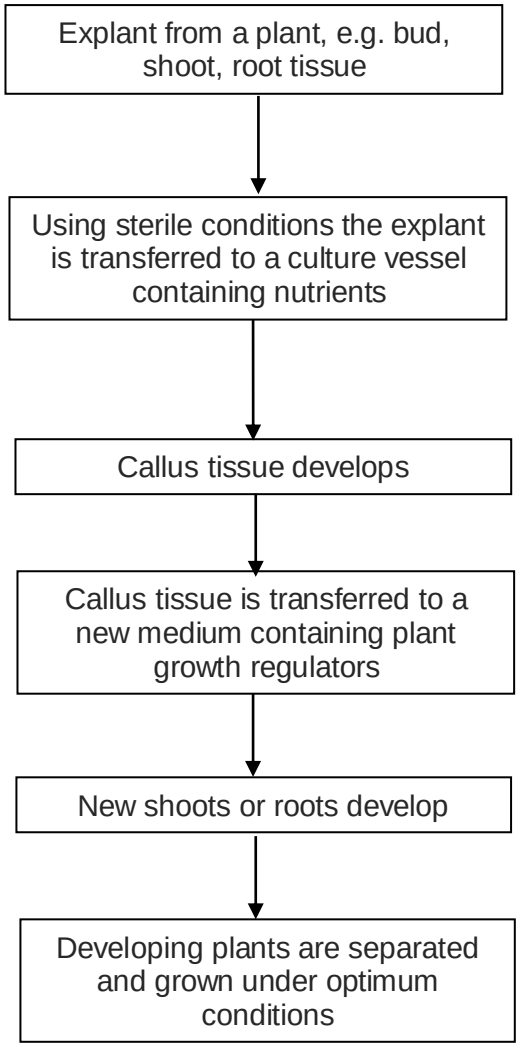

Fig. 3.1

(a) Suggest why explants are used in tissue culture.

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[1]

(b) Suggest why the explant is initially grown in sterile conditions.

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[2]

After the callus tissue develops, equal masses of the plant callus were cultured for four weeks on media containing different concentrations of two plant growth regulators: auxin and cytokinin. The results are shown in **Fig. 3.2.**

Treatment	Concentration of plant growth regulators/ mg dm^{-3}		Effect of plant growth regulators on callus growth
	auxin	cytokinin	
A	2.00	0.00	little or no growth
B	2.00	0.02	growth of roots
C	2.00	0.20	increased growth of callus with no differentiation
D	2.00	0.50	growth of shoots
E	0.00	0.20	little or no growth

Fig. 3.2

(c) Explain why growing plantlets from a callus in tissue culture results in a clone.

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[3]

(d) With reference to **Fig. 3.2**, describe the effects of auxin and cytokinin on callus growth.

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[3]

(e) Outline using **one** named example, the process of genetic engineering that could increase crop yield.

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[4]

(f) Suggest one possible risks to the environment of growing genetically engineered crops.

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[1]

[Total: 14]

Planning Question

4 Amylases are naturally found in wheat flour. During bread-making when water is added to flour, amylases are activated and break down starch in flour into maltose. Maltose is a reducing sugar and its presence can be tested with Benedict's solution.

Amylase activity can be inhibited by heavy metals ions such as iron (Fe^{2+}). Using this information and your knowledge, design an experiment to determine if Fe^{2+} functions as a competitive inhibitor or a non-competitive inhibitor and its effect on the rate of amylase activity.

You must use:

- 1.0% stock α-amylase solution
- 0.3% iron sulfate solution
- 5.0% starch solution
- distilled water
- Benedict's solution
- 10.0% maltose solution

You may select from the following apparatus and use appropriate additional apparatus:

- normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods etc. ,
- syringes,
- white card,
- white tile,
- blunt forceps,
- Bunsen burner with tripod, gauze and bench mat,
- thermometer.
- water bath
- timer e.g. stopwatch or stop clock

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

Write your answers on the separate answer paper provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5 **(a)** Explain how a disease such as cystic fibrosis can be treated by gene therapy, using **non-viral** delivery systems. [6]

(b) Explain, with specific examples, how genetic engineering can improve the quality and yield of crop plants and animals in solving the demand for food in the world. [7]

(c) Discuss the ethical and social implications of genetically modified organisms. [7]

[Total: 20]

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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME **Mark Scheme**

CLASS

BIOLOGY

9648/03

Paper 3 Applications and Planning

September 2016

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and CT on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use soft pencil for any diagrams, graphs or rough working.
Do no use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Answer questions **1** to **4** in the spaces provided on the question paper.

Answer question **5** on the separate answer paper provided.

For Examiner's Use	
1	
2	
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Total	60
For Examiner's Use	
4	12

This document consists of **15** printed pages and **1** blank page.

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Section A

Answer **all** the questions in this section.

1 Insulin deficiency is one of the causes of diabetes. There are a few methods to synthesize recombinant insulin using genetic engineering, one of the methods involve cloning the human insulin cDNA.

(a) Compare the differences on how a genomic library and a cDNA library are produced.

Source: Genomic DNA, which is the complete set of genetic material of an organism VS mature messenger RNA, which is present in a specific cell type at a specific stage;

Obtaining the DNA/ mRNA to be inserted: Digestion by restriction enzymes VS no need, use reverse transcriptase and DNA polymerase instead

Vectors used: Plasmids, BAC, YAC VS Plasmids, phage.

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[2]

(b) Explain the advantages of obtaining human insulin gene from a cDNA library instead of a genomic DNA library.

Insulin gene isolated from cDNA library contains only coding regions/ does not contain introns but gene isolated from genomic DNA library contains both coding and non-coding sequence;

Bacterial cells used for cloning cannot undergo RNA processing/remove introns/RNA splicing;

Insulin gene isolated from cDNA library is intact but gene isolated from genomic DNA library may be fragmented;

Easier to find the Insulin gene from cDNA library since it smaller;

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[3]

Fig. 1.1 shows the bacteria plasmid containing the positions of the restriction sites of the restriction enzymes available at its multiple cloning site. These restriction sites do not occur elsewhere within the plasmid.

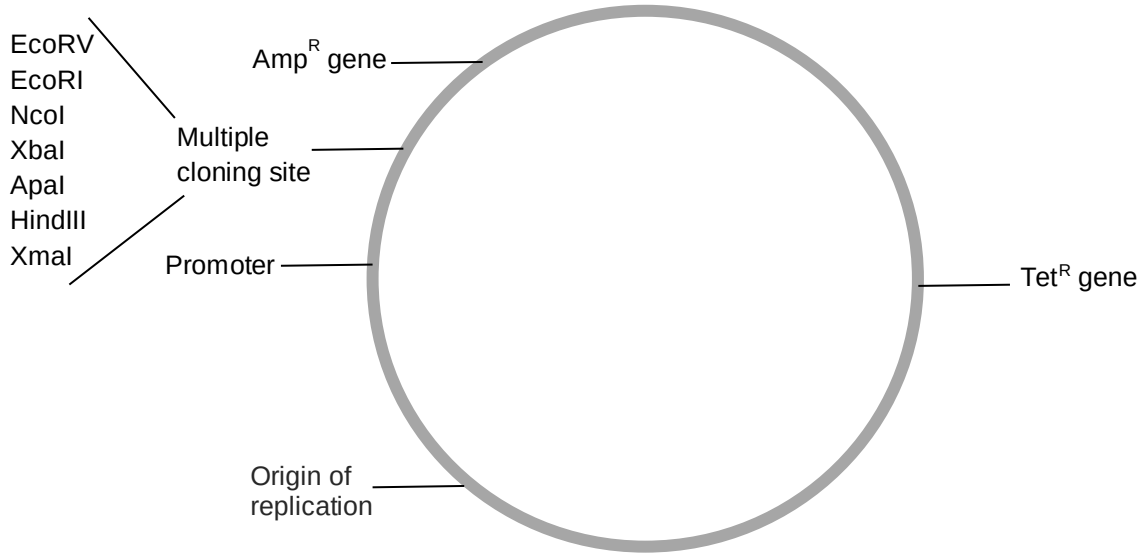

Fig. 1.1

Fig. 1.2 shows the restriction enzymes and their corresponding specific recognition sequences with respect to human insulin cDNA sequence. With the exception of *EcoRV*, all the restriction sites (*Apa I*, *Nco I*) generate sticky ends when cut.

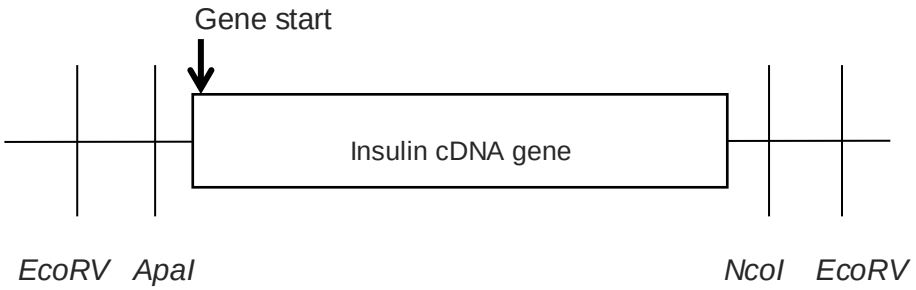

Fig. 1.2

(c) In order to obtain a recombinant plasmid containing the human insulin gene, the human insulin cDNA and vector needs to be digested with restriction enzymes prior to annealing them together.

(i) State the restriction enzymes used in order to obtain **efficient** gene expression.

ApaI and NcoI ;

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[1]

(ii) Explain your choice of restriction enzymes.

Create two different **sticky ends**, ***Apa*I** near to the gene start site and **NcoI** at the gene end;
Ensure only **1 correct orientation** of inserting the gene (Transcription can occur in the correct direction);
Prevent self-annealing of gene/plasmid;

[2]

(iii) With reference to **Fig. 1.1** and **1.2**, explain how recombinant bacteria (formed using the recombinant plasmids) can be selected using antibiotics.

Two antibiotic resistance genes (Ampicillin and tetracycline resistance genes) on the plasmid are used as selection markers;

Transformed cells are grown on tetracycline plate and tetracycline selects for bacterial cells that are successfully transformed and contains the plasmid as untransformed bacterial cells without tetracycline gene dies;

Replica plating is carried out with transfer of bacterial colonies onto ampicillin plate. Transformed bacterial cells with recombinant plasmid has inserted gene of interest and thus disrupting ampicillin resistance gene, resulting in insertional inactivation thus these cells are susceptible to ampicillin and dies;

Comparison between the plates allows identification of bacterial colonies with recombinant plasmid. Those bacteria colonies that survive on Tet plate and died on Amp plate contain recombinant plasmids and the corresponding bacteria colonies are isolated from the Tet plate;

[4]

(d) Suggest a reason why functional insulin was not expressed in the recombinant E.coli cells.

Euk post-translational modifications not present in prok cells;

Signal peptide cannot be removed from preproinsulin to form proinsulin, which usually happens in rER in euk cells;

Proinsulin cannot undergo modification whereby A chain and B chain are joined via disulfide bonds and the C chain removed, so as to form functional insulin.

® no post transcriptional modification

[2]

(e) Bacteriophages can be used to transfer foreign DNA into bacteria cells. Suggest **one** advantage of the use of phage vectors over plasmid vectors in transferring DNA into bacteria.

Higher transformation efficiency as bacteriophages specifically target bacteria cells (must have reference to specificity);

(Temperate) phages can integrate their genomes together with the gene of interest into the bacterial chromosome, hence the gene of interest is replicated together with the bacterial chromosome during DNA replication;

Phage vectors can accommodate large DNA inserts/ longer DNA fragments;

[1]

[Total: 15]

2 A violent air crash resulted in the death of 150 passengers. The poor condition of the crash victims made physical identification impossible. Forensic scientists were tasked to confirm the identities of victims by using molecular techniques for families who have come forward to claim the correct remains of their relatives.

DNA samples of human remains and surviving relatives were subjected to restriction enzyme digest and Southern blot analysis to analyse VNTR band patterns. Single locus VNTR probes will yield DNA patterns of seven individuals at a single locus, as shown in **Fig. 2.1**. On the other hand, multi-locus VNTR probes can yield more information about each individual since 10 to 30 loci can be simultaneously analysed. This is illustrated in five different individuals in **Fig. 2.2**.

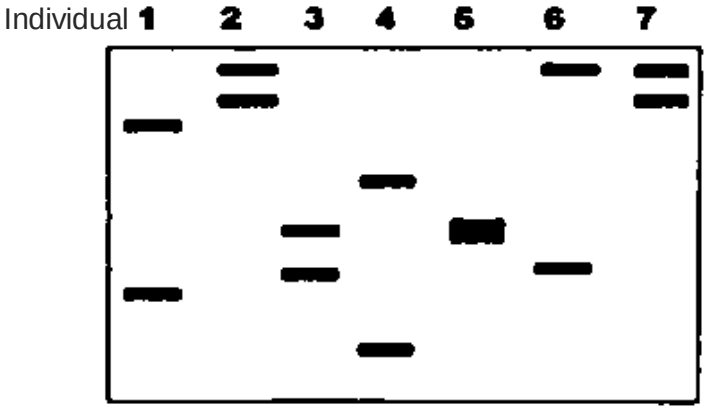

Fig. 2.1

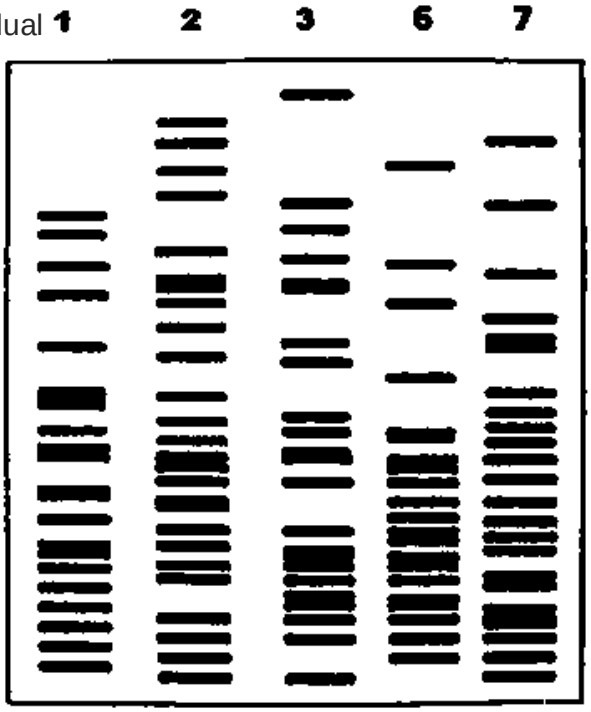

Fig. 2.2

(a) (i) Explain the basis of application of VNTR in DNA profiling.

Each individual has a different number of tandem repeats;

As such, their DNA fragments which are cut from the genome will be of different sizes;

Which will affect their position on the agarose gel during gel electrophoresis, and subsequently nitrocellulose membrane during Southern Blotting;

[3]

(ii) With reference to **Fig. 2.1**, explain the different numbers of fragments seen in different individuals.

For individuals with 2 fragments, they are heterozygous for that gene and each allele will be a different VNTR. Therefore, different sized fragments are produced, resulting in 2 bands;

Individuals who have singe band are homozygous for that gene. Therefore, both alleles have the same VNTR, and only 1 sized DNA fragment is produced;

[2]

(iii) With reference to **Fig. 2.1** and **Fig. 2.2**, suggest why using multi-locus probes is preferred.

They provide more points of comparison as when using a single locus, the victim would have a different VNTR for that locus from his relative.

However, it is more likely to identify the correct human remains with multi-locus as there are higher chances of finding similarities in DNA banding patterns of multiple locus.

[2]

(b) VNTRs can be analysed by Southern blotting or by PCR analysis.

Describe **two** differences between Southern blotting and PCR analysis in the analysis of the single locus VNTR shown in **Fig. 2.1.**

DNA probes are used in Southern blotting, whereas DNA primers are used in PCR.

Autoradiography is used in Southern blotting but not in PCR analysis.

[2]

(c) The fully sequenced human genome contains many unknown genes. Suggest how RFLP analysis can help to identify **unknown** genes that are responsible for heritable diseases.

RFLP markers are linked to the genes and so, even if the genes are unknown;

probing for the presence of the specific RFLP restriction site would indicate a high probability of the presence of the disease allele;

[2]

[Total: 12]

3 Plant tissue culture is a method used to propagate plants. **Fig. 3.1** shows one method of plant tissue culture.

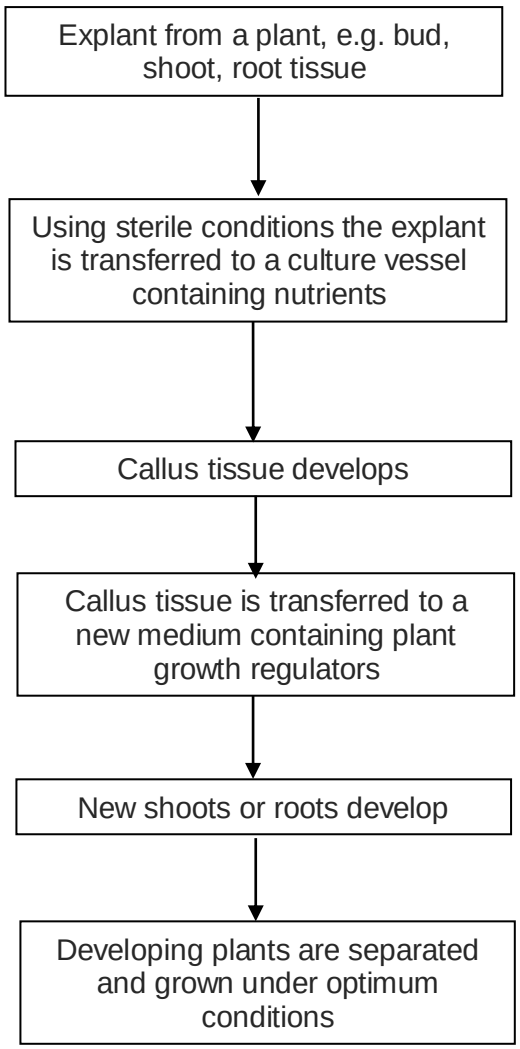

Fig. 3.1

(a) Suggest why explants are used in tissue culture.

Contain meristematic cells which are able to **divide** and **differentiate** into any cell type / **regenerate** the whole plant / are **totipotent;**

[1]

(b) Suggest why the explant is initially grown in sterile conditions.

To prevent **contamination** by bacteria / fungi / micro-organisms (® pathogens);
which can (grow very rapidly on the media and) compete with explant for nutrients;

OR

To prevent infection by bacteria / fungi / micro-organisms / pathogens;

Which can spread very rapidly to other cells as they are genetically identical; (®

because they do not have any defense mechanism)

[2]

After the callus tissue develops, equal masses of the plant callus were cultured for four weeks on media containing different concentrations of two plant growth regulators: auxin and cytokinin. The results are shown in **Fig. 3.2.**

Treatment	Concentration of plant growth regulators/ mg dm^{-3}		Effect of plant growth regulators on callus growth
	auxin	cytokinin	
A	2.00	0.00	little or no growth
B	2.00	0.02	growth of roots
C	2.00	0.20	increased growth of callus with no differentiation
D	2.00	0.50	growth of shoots
E	0.00	0.20	little or no growth

Fig. 3.2

(c) Explain why growing plantlets from a callus in tissue culture results in a clone.

This is a type of **asexual** reproduction / derived from a single parent;

All the plantlets are **genetically identical** (® genetically similar) / have the same genotype; (® same genome)

Due to **semi-conservative replication** of the parental DNA;

Examiner's Comments

Students might fail to identify the last point.

[3]

(d) With reference to **Fig. 3.2**, describe the effects of auxin and cytokinin on callus growth.

Both hormones need to be present for any growth to occur / The type of growth depends on the relative concentrations of the auxin and cytokinin;

A low level of cytokinin, i.e. 0.02 mg dm to auxin, triggers root growth

Increasing the relative level of cytokinin, i.e. 0.50 mg dm to auxin, i.e. 2.00 mg dm triggers shoot growth;

[3]

(e) Outline using **one** named example, the process of genetic engineering that could increase crop yield.

Example: Pest-resistant (NOT pesticide-resistant / insect-resistant);

The gene of interest is inserted into a tumour-inducing / Ti plasmid, using same restriction enzyme;

Selection for *Agrobacterium* cells that have successfully taken up recombinant plasmid, which are then cultured with leaf discs / callus tissue;

Transgenic plants containing the Bt gene are protected against damage by insect pests;

[4]

(f) Suggest one possible risks to the environment of growing genetically engineered crops.

Gene transfer to other plants/crops due to cross pollination;
Contamination of other crop (e.g. ref to organic crop);
Gene transfer to wild relative;
Gene transfer from crop to crop via bacteria or viruses with unknown effect;;
Recipient plant (plant that receives the gene) outcompetes others / ref to 'superweed';
Toxic to non pests;

[1]

[Total: 14]

Planning Question

4 Amylases are naturally found in wheat flour. During bread-making when water is added to flour, amylases are activated and break down starch in flour into maltose, which is a reducing sugar. Maltose is a reducing sugar therefore its presence can be tested with Benedict's solution.

Amylase activity can be inhibited by heavy metals ions such as iron (Fe^{2+}). Plan an investigation to determine if Fe^{2+} functions as a competitive inhibitor or a non-competitive inhibitor of amylase.

You must use:

- 1.0% stock α-amylase solution
- 0.3% iron sulfate solution
- 5.0% starch solution
- distilled water
- Benedict's solution
- 10.0% maltose solution

You may select from the following apparatus and use appropriate additional apparatus:

- normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods etc. ,
- syringes,
- white card,
- white tile,
- blunt forceps,
- Bunsen burner with tripod, gauze and bench mat,
- thermometer.
- water bath
- timer e.g. stopwatch or stop clock

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
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- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

Theoretical Background (2M max)

- Heavy metals are positively charged and form strong bonds with negatively-charged carboxyl R-groups of proteins, disrupting ionic bonds.
- With less negative charges on the protein, the solubility of protein is reduced, as there is less interaction with polar water molecules.
- Protein denaturation
    - loss of specific 3D conformation → loss of enzymatic function, amylase unable to catalyse the breakdown of starch to form maltose
    - enzyme inhibitors affect enzyme activity resulting in a decrease in the rate of enzyme catalyzed reactions
    - **Competitive inhibitor** is structurally similar to the substrate
    - Binds reversibly to the active site of the enzyme and competes for the substrate for active site
    - Effect of inhibition overcome by increasing substrate concentration
    - **Non-competitive inhibitor** does not bind to active site of the enzyme
    - Binds to site away from the active site
    - Inhibition cannot be overcome by increasing substrate concentration
    - active site distorted, fewer E-S complex formed per unit time
- Maltose is produced when amylase digests starch, which can be detected using the reducing sugar test.
- Maltose reacts with Benedict's solution to give precipitate. The colour and the cloudiness of the mixture reflect the amount of maltose present.
- As the amount of maltose increases, the colour of the mixture changes from green to yellow to orange-red and the degree of cloudiness increases.
- The concentration of the maltose can thus be estimated by comparing the colour and the degree of cloudiness against the mixture obtained from Benedict's test conducted on maltose solutions of known concentration.

Hypothesis (1M)

- If Iron ion functions as a non-competitive inhibitor, it prevents the rate of reaction from reaching Vmax.
- When concentration of starch solution increases, the rate of amylase activity does not reach the maximum rate.
- The lesser the number of functional amylases, the lesser the number of E-S complexes formed per unit time, amount of reducing sugar produced decreases.
- The colour of the precipitate will be less orange-red when inhibitor is used, as compared to the absence of inhibitor.

Variables (2M)

Dependent

- Rate of enzyme amylase activity
- Measure by concentration of reducing sugars produced per unit time (% min^{-1})

Independent

- Concentration of starch solution (at least 5, with regular spacing between intervals)

Constant

- Time taken for reaction, temperature, pH, vol of inhibitor solution, vol of starch solution, vol of amylase, volume of Benedict's solution, vol of sample of Benedict's solution + *Explain how to keep them constant*

Procedure (*Apparatus and Quantity) (4M)

Preparation of maltose standards

1. Prepare 20 cm3 of various concentrations of maltose solutions as shown in the table below. Perform dilutions of 10.0% reducing sugar solution to produce 5.0%, 4.5%, 4.0%, 3.5%, 3.0%, 2.5%, 2.0%, 1.5%, 1.0%, 0.5%, using 10cm3-syringes and place the solution into 10 separate boiling tubes.

Concentration of maltose solution to be prepared /%	Volume of 10% maltose solution /cm3	Volume of distilled water / cm3
0.5	1	19
1.0	2	18
1.5	3	17
2.0	4	16
2.5	5	15
3.0	6	14
3.5	7	13
4.0	8	12
4.5	9	11

3. Label 10 test-tubes 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0%, 3.5%, 4.0%, 4.5% and 5.0%.
4. Using a 5-cm3 syringe, add 2 cm^3 of each concentration of maltose solution into their respective test-tubes.
5. Using a 5-cm3 syringe, add 2 cm^3 of Benedict's solution. Shake gently to mix the contents of the tube
6. Place all the test tubes in the boiling / (between 80-100°C) water bath for two minutes. Start the stopwatch.
7. After two minutes, stop the stopwatch. Remove the tubes from the boiling water and place them on the rack.
8. Shake gently to mix the contents of the tube and observe the contents of the test-tubes immediately after mixing. Record the observations in a table, noting any differences in terms of colour and cloudiness.

Preparation for different concentrations of starch

Concentration of starch solution to be prepared /%	Volume of 5% starch solution /cm3	Volume of distilled water / cm3
1.0	10	10
2.0	12	8

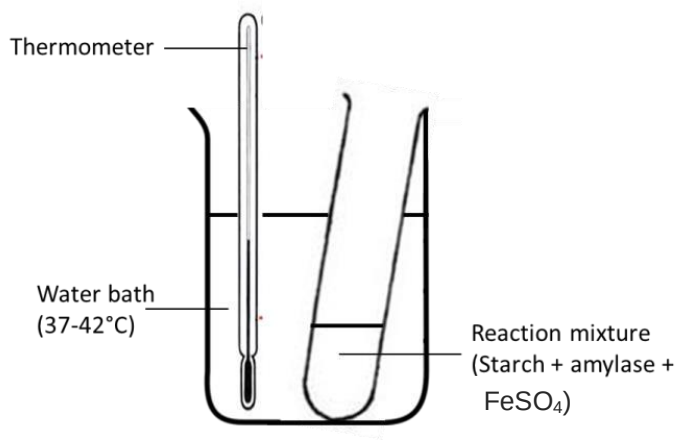
3.0	14	6
4.0	16	4
5.0	18	2

3. Prepare 20cm^3 of 5 different concentrations of starch according to the dilution table. Perform dilutions of 5.0% starch solution to produce 1.0%, 2.0% 3.0%, 4.0%, 5.0% using 10cm^3-syringes and place the solution into 5 separate boiling tubes.
4. Using a 10-cm^3 syringe, add 5 cm^3 of each concentration of starch solution into their respective test-tubes.
5. Label 5 test tubes separately and add 1cm^3 of the amylase solutions into each test tube.
6. Equilibrate the amylase solutions and starch suspension in the constant 38-42°C water bath for 2 min.
7. After 2 min, add 1cm^3 of the 0.3% $FeSO_4$ solution and 1cm^3 amylase solution to 5cm^3 starch solution.
8. Mix well by stirring with a glass rod and start time. Allow the reaction to take place for 2 minute.
9. Immediately after 2 minutes, remove the reaction mixture.
10. To 2cm^3 of the reaction mixture, add equal volume of Benedict's solution. Shake gently to mix the contents of the tube
11. Place the test tube in the boiling / (between 80-100°C) water bath for two minutes. Start the stopwatch.
12. After two minutes, stop the stopwatch. Remove the tube from the boiling water and place them on the rack.
13. Shake gently to mix the contents of the tube and observe the contents of the test-tubes immediately after mixing. Record the observations in a table, noting any differences in terms of colour and cloudiness.
14. Place the tubes containing the reaction mixture after Benedict's test and the glucose standards against a white card. Compare with the glucose standards (from Part I, Step 8) to determine the amount of maltose present. Shake the tube gently to mix the contents before comparison.
15. Record the amount of maltose present (%) in a table.
16. To ensure reliability of results, **repeat steps 4 to 14** to obtain a total of three readings (triplicates**)** at this starch concentration using fresh samples
17. Repeat steps 4 to 15 using the other starch concentrations as prepared.
18. To show that the inhibitor affects the function of amylase, a control is set up with 0% $FeSO_4$ solution. Steps 4 to 14 are performed with equivalent volume of distilled water in place of $FeSO_4$ solution. This is to obtain results of the effect of starch concentration on the rate of starch hydrolysis / enzyme activity on starch hydrolysis in the absence of inhibitor.
19. To ensure reproducibility of data, **repeat the entire experiment** twice using freshly prepared reagents and solutions and maltose standards.

Standards – known concentrations of maltose solution

Controls – absence of iron sulfate (0%)

Annotated diagram

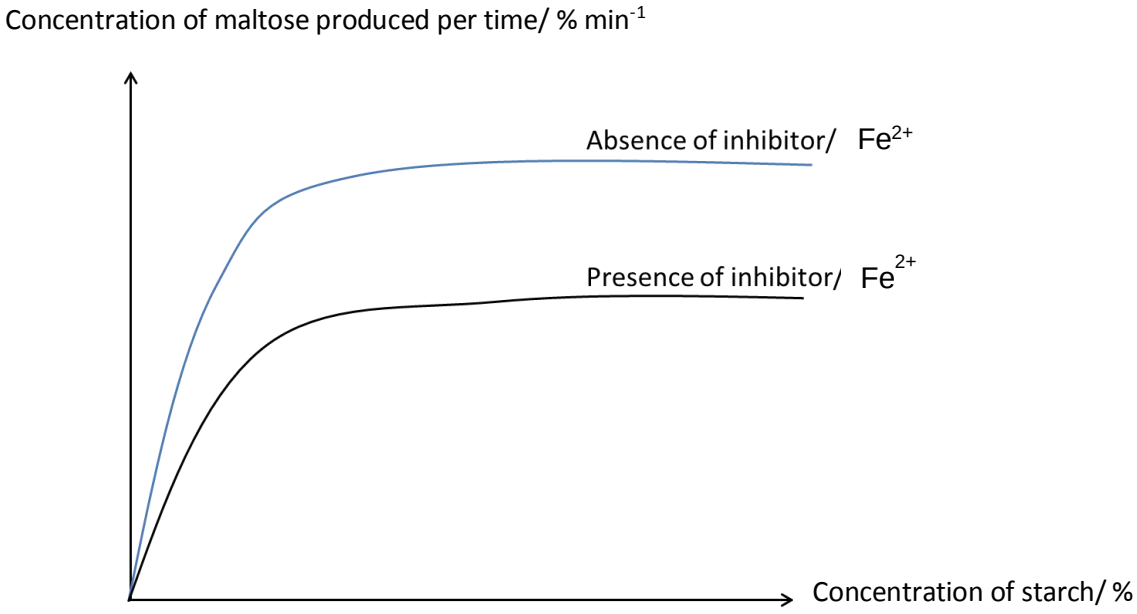


Data recording & processing (2M max)

Table

Concentration of starch / gdm^{-3}	• Concentration of maltose produced in the **presence** of Cu^{2+} / %				• Rate of production of maltose in the **presence** of Cu^{2+} / % min^{-1}	• Concentration of maltose produced in the **absence** of Cu^{2+} / %				• Rate of production of maltose in the **absence** of Cu^{2+} / % min^{-1}
	R1	R2	R3	Average		R1	R2	R3	Average	
5.0										
4.0										
3.0										
2.0										
1.0										
0.0										

Graph



Risks and precautions (1M)

- Iron sulfate / amylase /starch/ Benedict's solution is an irritant to the skin → Wear gloves and safety goggles when handling / Wash hands thoroughly if hands come into contact with solution.
- Boiling water may scald/burn skin → Use a test-tube holder to hold test-tube. Care must be taken when handling the boiling water.

Write your answers on the separate answer paper provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5 **(a)** Explain how a disease such as cystic fibrosis can be treated by gene therapy, using **non-viral** delivery systems. [6]

(b) Explain, with specific examples, how genetic engineering can improve the quality and yield of crop plants and animals in solving the demand for food in the world. [7]

(c) Discuss the ethical and social implications of genetically modified organisms. [7]

[Total: 20]

5 **(a)** Explain how a disease such as cystic fibrosis can be treated by gene therapy, using **non-viral** delivery systems. [6]

1. Preparing sterile media containing nutrients and hormones needed for plant growth / antibiotics / herbicides for selection of successfully transformed cells;
2. Insertion of transgene via microprojectile bombardment / electroporation / *Agrobacterium tumefaciens*-mediated transformation;
3. Explant containing meristematic cells is selected and surface sterilized before growing on medium;
4. As callus increases in size, pieces of callus is sliced off and grown on new medium composition;
5. By adjusting concentration of plant hormones in growth medium, cells in callus can be induced to differentiate into roots and shoots;
6. Plantlets are removed from agar medium and transplanted to sterile soil for further growth;

(b) Explain, with specific examples, how genetic engineering can improve the quality and yield of crop plants in solving the demand for food in the world. [7]

Candidate must elaborate on at least 3 specific e.g. which must cover both improvements in 'quality' and 'yield'. If candidate only elaborated in one aspect, maximum of 6 marks will be awarded.

Examples for improvement in yield of crop plants (any 2 e.g.)

Pest-resistant transgenic plants

1. Trangenic plants containing the Bt gene will produce the protoxin which is ingested by the insect; Protoxin is cleaved in the insect gut and the active Bt toxin is released;
2. Protein binds to cell membranes and causes them to be permeable causing gut cells of insect to lyse, eventually killing insects;

Herbicide-resistant transgenic plants

3. Glyphosate is a herbicide used to get rid of weeds which compete with crops for soil nutrients;
4. Inhibits 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase needed for biosynthesis of essential amino acids;
5. Transgenic plants contain mutated gene which codes for mutant EPSP synthase that is not inhibited by glyphosate;

Extension of shelf life of produce

6. Transgenic plants contain antisense polygalacturonase mRNA;
7. Results in the formation of mRNA-antisense RNA hybrid, which prevents the polygalacturonase mRNA from being translated;
8. Enzyme will not be synthesized, thus ensures fruits are not damaged / too ripe / soft when it reaches consumer in market place;

Examples for improvement in quality of crop plants (must have this e.g.)

Improving nutritional value of crops

9. Golden rice is a transgenic plant that three beta-carotene biosynthesis genes;
10. Produces yellow rice grains containing beta-carotene, which is a precursor to vitamin A;
11. Prevent vitamin A deficiency in world's population that depends on rice as a staple food;

(c) Discuss the ethical and social implications of genetically modified organisms. [7]

Social implications (maximum 4 marks)

1. Transfer of antibiotic resistance markers to pathogenic microorganisms which may result in increase in resistance to clinically important antibiotics;
2. Probability of introducing novel allergens as GM foods may contain proteins introduced from sources people are allergic to;
3. Possibility of GM food being toxic or carcinogenic as they may cause over-expression of other proteins;
4. Monopolistic behaviour of biotechnology companies as terminator gene is likely to be inserted into many GMO seeds, causing second generation seeds to be sterile;
5. Scientists have raised concerns about innovations in research that are not shared, raising fears that world food production may be dominated by a few large biotechnology companies;
6. Increasing dependence of developing nations on industrialized nations;
7. Impact on international trade as Europe has been much more hesitant than the United States in accepting GM products in processed food;

Ethical issues (maximum 3 marks)

8. Tampering with nature as it is going against the natural way of life;
9. Lack of mandatory food labelling in some countries;
10. Religious groups are concerned that GM foods might contain genes from animals prohibited by their religion;

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examinations
In preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME									
CT GROUP	1	5	S			INDEX NUMBER			

BIOLOGY

9648/01
22 September 2016

Paper 1 Multiple Choice

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, CT class and index number on the Answer Sheet.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

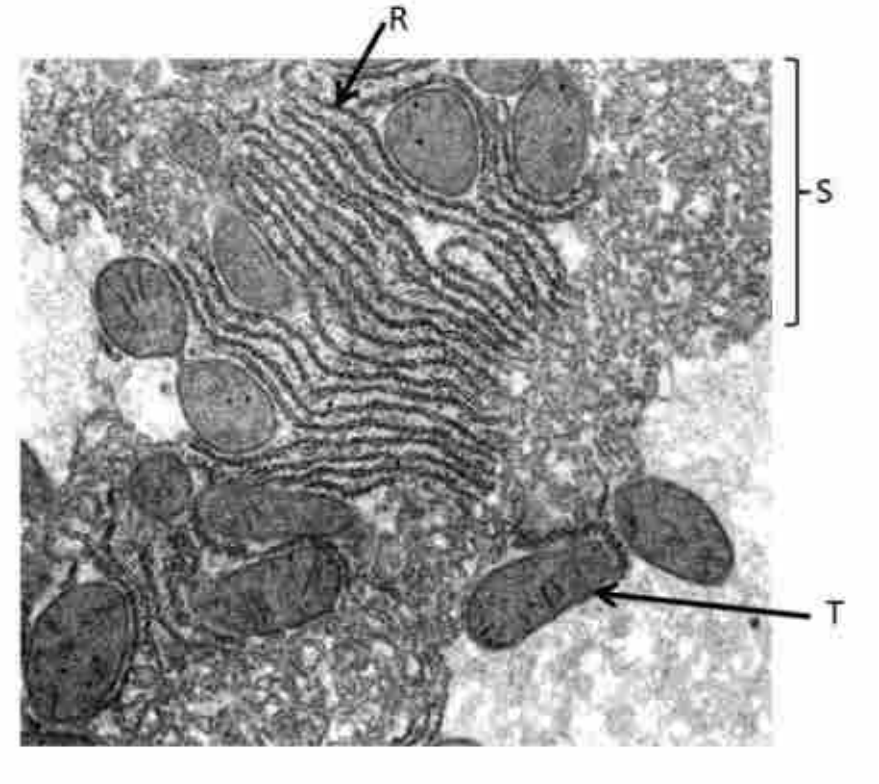
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **27** printed pages and **1** blank page.

[Turn Over

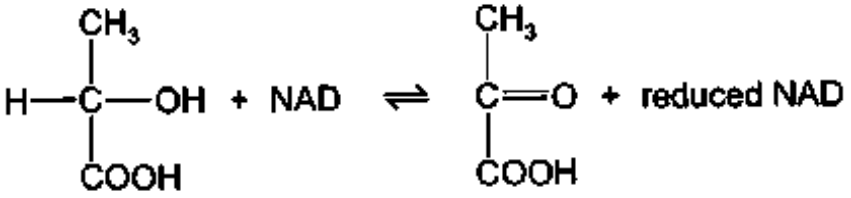
1 The figure below shows an electron micrograph of an eukaryotic cell.



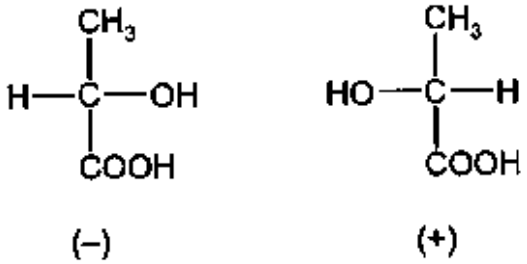
Which of the following option correctly matches the structures **R**, **S** and **T** to their respective functions?

	R	**S**	**T**
A	Involved in proteins glycosylation	Site of lipid synthesis	To convert light energy to chemical energy
B	Site of protein synthesis	Site of detoxification reaction	Supplying cellular energy
C	Site of detoxification reaction	Involved in protein glycosylation	Remove worn out organelles
D	Site of protein synthesis	Contains proteins to be secreted	Supplying cellular energy

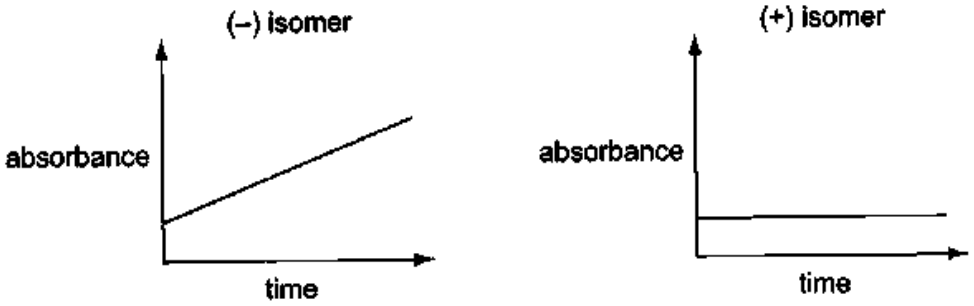
2 Lactic dehydrogenase catalyses the conversion of lactic acid as shown in the following equation.



Two forms (isomers) of lactic acid exist, (-) and (+), as shown below.



Reduced NAD absorbs ultraviolet light. NAD does not. The activity of bacterial lactic dehydrogenase on two different isomers of lactic acid was compared. The absorbance of ultraviolet light was measured using an ultraviolet spectrophotometer. The graphs show the results.



What can be concluded about bacterial lactic dehydrogenase?

A Molecules of both isomers fit the active site.

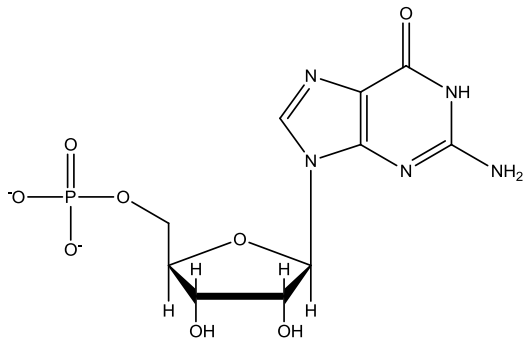
B Molecules of neither isomer fit the active site.

C The enzyme is specific to the (-) isomer.

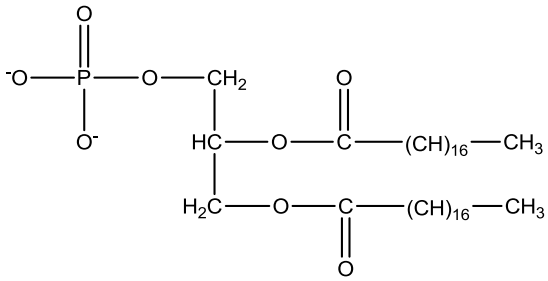
D The enzyme is specific to the (+) isomer.

[Turn Over

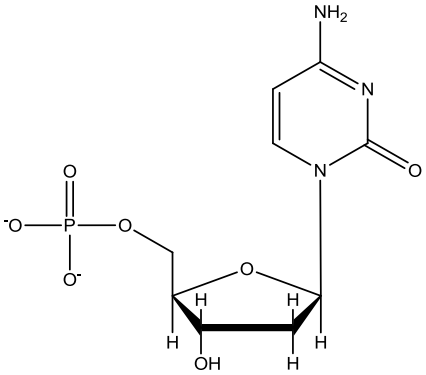
3 A student uses centrifugation to separate the various subcellular structures of human epithelial cells by size and density.



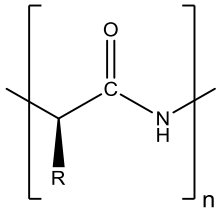
I



II



III



IV

Which of the following molecule(s) would you expect to find in the pellet containing the cell membrane?

A **II** only

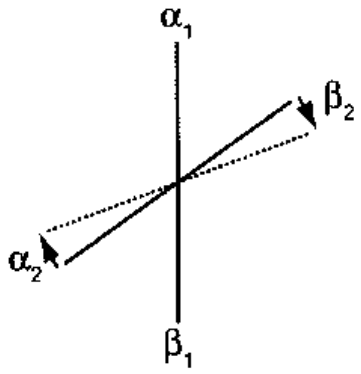
B **III** only

C **II** and **IV** only

D **I**, **III** and **IV** only

4 A molecule of haemoglobin is made up of two α polypeptide subunits (α_1 and α_2) and two β polypeptide subunits (β_1 and β_2).

The relative positions of these subunits change when a deoxygenated haemoglobin molecule takes up oxygen. The axis joining the α_2 and β_2 subunits rotates by about 15° in relation to the axis joining the α_1 and β_1 subunits, as shown in the diagram.



Which statements about this rotation are correct?

1 The points of contact between the four subunits are altered.
2 The rotation resulting from adding one oxygen molecule to one of the subunits makes it easier to add oxygen to the other subunits.
3 The rotation makes different amino acids available for binding oxygen.
4 The rotation alters the quaternary structure of the molecule.

A 1, 2 and 3 only

B 1, 2 and 4 only

C 1, 3 and 4 only

D 2, 3 and 4 only

5 A group of diploid cells with x amount of DNA and 36 chromosomes each is capable of undergoing mitosis and meiosis.

During which stage(s) could a cell with 2x amount of DNA and 72 chromosomes be found?

A anaphase of mitosis only

B anaphase of meiosis I only

C anaphase of mitosis and anaphase of meiosis I

D anaphase of mitosis and anaphase of meiosis II

[Turn Over

6 Below are statements that describe the control of transcription for genes encoding for enzymes in a metabolic pathway.

1 The genes are transcribed as a single transcription unit, with each gene having its own promoter.
2 The genes respond similarly to the same set of general transcription factors but respond differently to a certain set of specific transcription factors.
3 The genes have various combinations of control elements that enable different activators and repressors to bind and affect the rate of transcription.
4 The genes are found close to each other on the chromosome with chromatin remodelling as a form of transcriptional control.

Which combination of statements is true?

A 1 only

B 2 only

C 2 and 3

D 3 and 4

7 The active messenger RNAs (active mRNAs) in tissue cells can be isolated by passing the homogenized cell contents through a fractionating column. The column has short length of uracil nucleotides attached to a solid supporting material. Most molecules of mRNA that pass through the column quickly break up into small pieces and cannot be translated.

The active mRNAs that attached to the column can be separated again by appropriate treatment.

Which statements correctly describe active mRNA?

1 Active mRNAs are held to the fractionating column by bonds between adenine and uracil bases.
2 Active mRNAs can be released from the fractionating column by breaking hydrogen bonds.
3 Only mRNAs with polyadenine tailing can be translated.
4 Polyadenine tailing destabilizes mRNA and prevents it from being broken up.

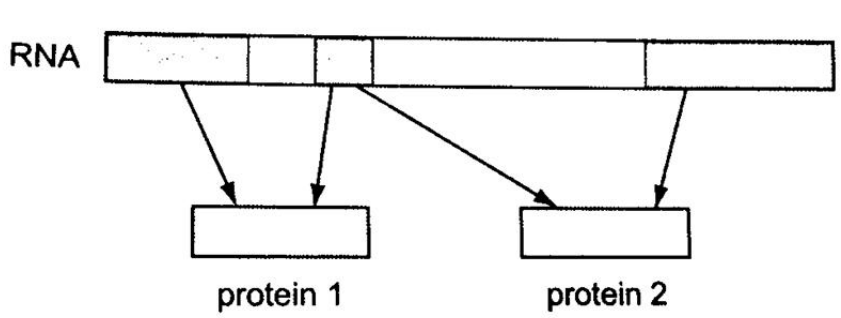
A 1 and 2 only

B 1, 2 and 3 only

C 3 and 4 only

D 1, 2, 3 and 4

8 RNA transcribed from a length of DNA of a chromosome was found to code for two different protein, as shown in the diagram.



Which is correct?

A The DNA from which this RNA was transcribed was part of a eukaryotic chromosome because this is a way of saving space in a small genome.

B The DNA from which this RNA was transcribed was part of a eukaryotic chromosome because introns have been edited out of the RNA.

C The DNA from which this RNA was transcribed was part of a prokaryotic chromosome because introns have been edited out of the RNA.

D The DNA from which this RNA was transcribed was part of a prokaryotic chromosome because this a way of saving space in a small chromosome.

9 Below are the descriptions of different gene mutations.

1 deletion toward the end of the code sequence
2 insertion in the middle of the code sequence
3 substitution close to the beginning of code sequence

Which row correctly identifies the possible effects of these mutations on the synthesis of polypeptides?

	Premature ending of a polypeptide	A non-functional polypeptide	A polypeptide with unchanged function	A polypeptide with a different function
A	1,2,3	1,2,3	1,2,3	1,2,3
B	1,2,3	2 only	1,3 only	1,2 only
C	1,3 only	1,2,3	3 only	1,2,3
D	2,3 only	2,3 only	1,2,3	2,3 only

[Turn Over

10 The coding region of a gene is 135 nucleotides long, including both the start and stop codons. Which of the following would be the most likely effect of a single nucleotide deletion at position 102 in the coding region?

A Only the active site would be affected.

B The entire amino acid sequence of the polypeptide would change.

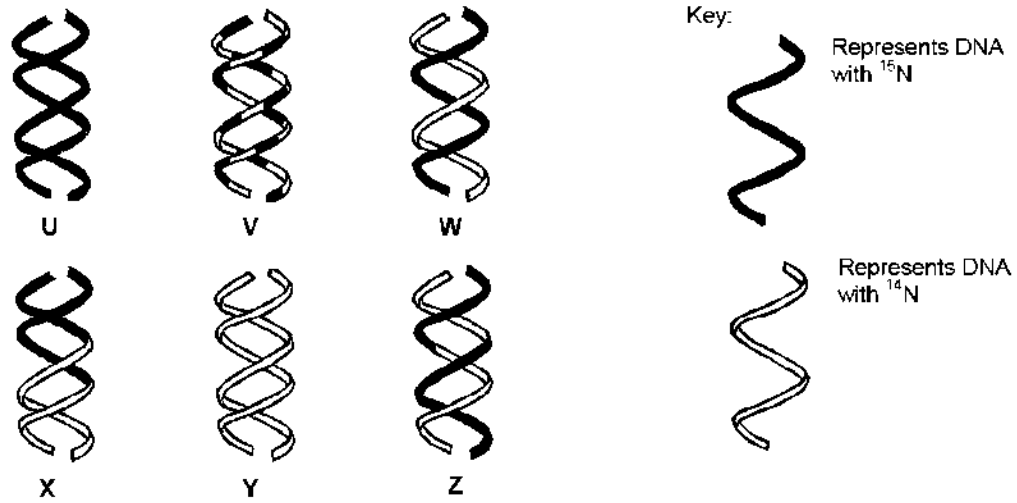
C There would be changes in only the first 34 amino acids.

D There would be changes in only the last 10 amino acids.

11 Three experiments were carried out to investigate the mode of DNA replication in bacteria.

- Experiment 1: Bacteria were grown for many generations with only the light isotope of nitrogen, ^{14}N, and then allowed to replicate once with the heavy isotope, ^{15}N.
- Experiment 2: Bacteria were grown for many generations with only the heavy isotope of nitrogen, ^{15}N, and then allowed to replicate once with the light isotope, ^{14}N.
- Experiment 3: Bacteria were grown for many generations with only the heavy isotope of nitrogen, ^{15}N, and then allowed to replicate twice with the light isotope, ^{14}N.

The figure shows possible DNA molecules U to Z and indicates the varying proportion of nitrogen isotopes present in each DNA molecule.

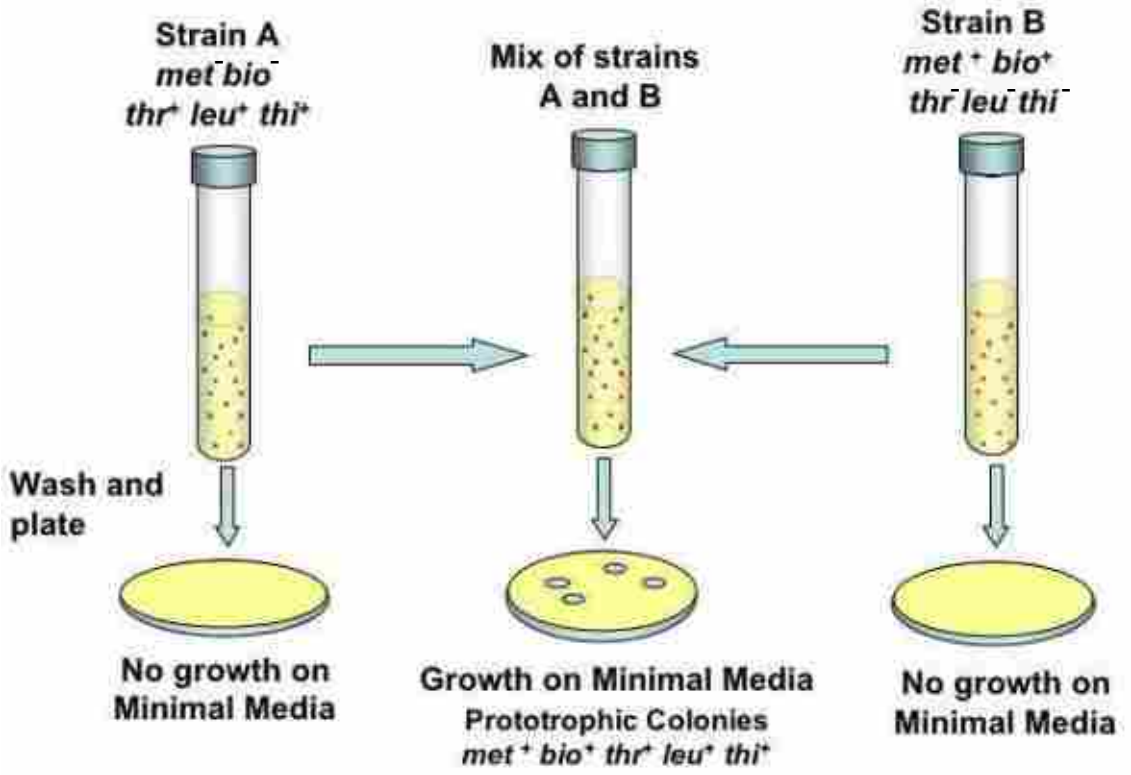


Which of the following products shows the semi-conservative mode of DNA replication?

	Experiment 1	Experiment 2	Experiment 3
A	W	W	W and Y
B	U	W	W and Y
C	W	W	X and Z
D	U	W	V and Z

12 The diagram shows an investigation into bacterial genetics.

The researchers used 2 strains of bacteria. Strain A coded for 3 essential amino acids (thr^+ leu^+ thi^+) while Strain B coded for 2 essential amino acids (met^+ bio^+). For the 2 strains of bacteria to grow on minimal medium, the bacteria need to encode for all 5 essential amino acids.



Which process or processes could explain these results?

1 Conjugation
2 Transduction
3 Transformation

A 1 only

B 3 only

C 1 and 2

D 1 and 3

[Turn Over

13 A single mutation has occurred in an *E. coli* cell. If the structural genes in a *trp* operon were not expressed regardless of the presence or absence of the amino acid tryptophan, which of the following mutations could have taken place?

1 The cell had a mutation at the operator of the *trp* operon.
2 The cell had a mutation at the *trpR* gene.
3 The cell had a mutation at the promoter of the *trp* structural genes.

A 3 only

B 1 and 2

C 2 and 3

D 1, 2 and 3

14 When the *lac* operon for lactose metabolism is switched off, which of the following genes would still be expressed?

I β-galactosidase gene
II RNA polymerase gene
III CAP gene
IV Repressor gene

A I and II

B I and III

C II, III and IV

D All of the above

15 Which features of viruses account for them being obligate parasites?

1 All viruses are very small, ranging in size from 20 – 300nm.
2 Each virus contains only one type of nucleic acid.
3 Viruses can be crystallised.
4 Viruses cannot synthesis ATP.
5 Viruses have no cellular structure.
6 Viruses have no enzymes involved in metabolism outside a host cell.

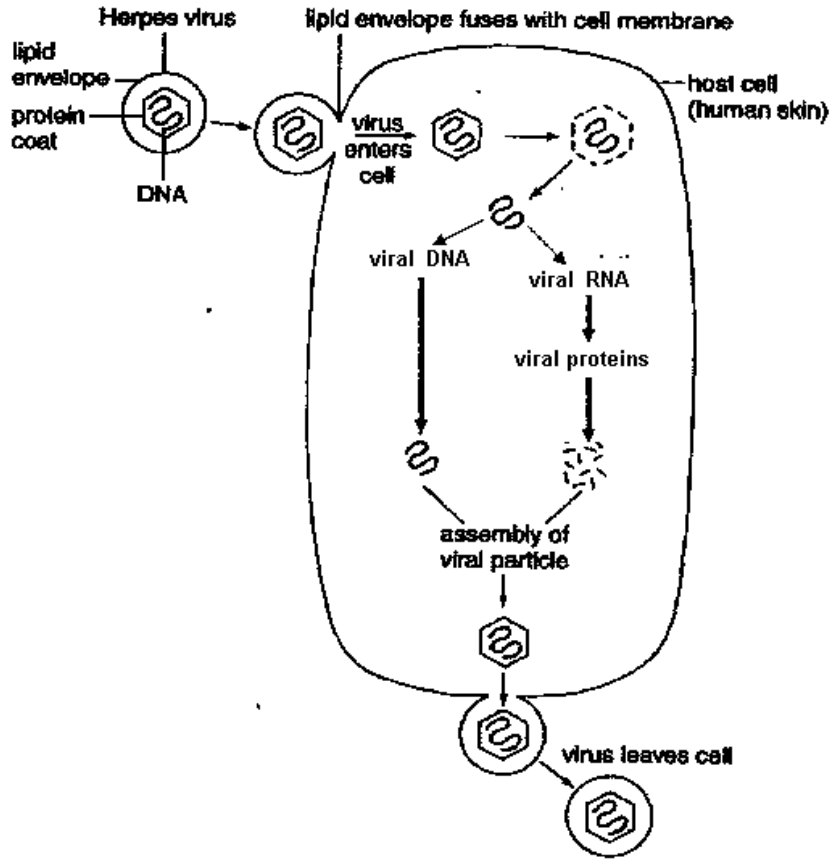
A 1, 3 and 5

B 1, 4 and 6

C 2, 3 and 5

D 2, 4 and 6

16 The diagram below shows the reproductive cycle of the herpes virus which causes cold sores on the mouth. With reference to the diagram below, which of the following statements best describes the herpes virus?



A It is not a retrovirus as it does not contain RNA as its genetic material.

B Its mode of replication is similar to that of HIV.

C Its replication cycle includes a lysogenic phase.

D Death of the host cell is necessary for the release of the viral progeny.

[Turn Over

17 The MDR1 gene codes for a membrane transport protein in mammalian cells. The protein has the ability to prevent the entry of, or remove, molecules such as chemotherapeutic drugs, from cells. Gene amplification of the MDR1 gene can arise from environmental signals.

Which statement is not consistent with the information above?

A Amplification of the MDR1 gene in mammalian cancer cells could lead to the cells becoming resistant to chemotherapeutic drugs.

B Cancer cells, with initially the same level of MDR1 gene expression as healthy cells, may respond to chemotherapy by increasing the number of MDR1 genes, which increases expression.

C Development of chemotherapeutic drug resistance can be progressive, rather than spontaneous, and can hinder chemotherapy in patients with cancer.

D Since gene amplification has not arisen by genetic causes, descendant cells from a cancer cell with MDR1 gene amplification will be normal for MDR1 gene expression.

18 Cells taken from a human bone cancer multiplied readily in culture. Analysis showed that the cells were unable to produce the protein, RB.

Addition of RB to these cells reduced their rate of division.

Which of the following statement accounts for the observation?

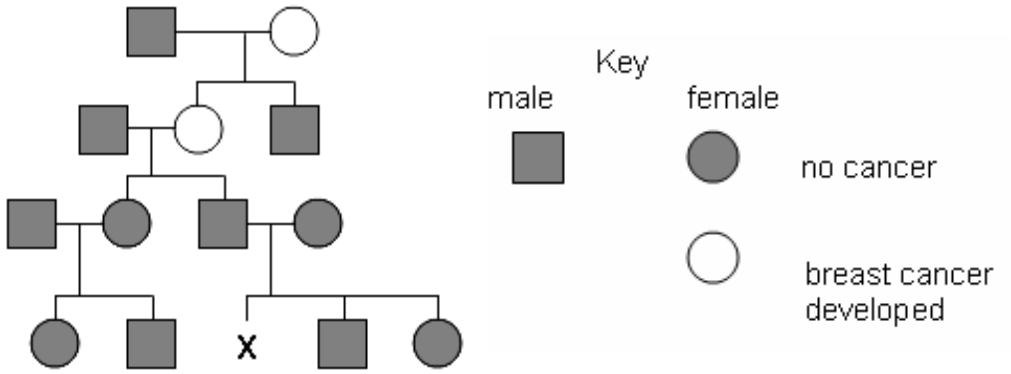
A Both chromosomes in the cancer cell carry alleles for tumour suppressor gene.

B Both chromosomes in the cancer cell have the allele for tumour suppressor gene deleted.

C Both chromosomes in the cancer cell carry alleles for proto-oncogene.

D Both chromosomes in the cancer cell have the allele for proto-oncogene deleted.

19 The diagram shows the inheritance of a form of breast cancer associated with the presence of just one allele of the autosomal gene BRCA 1.



What is the probability that woman **X** inherits the BRCA 1 allele associated with breast cancer?

A 0.00
B 0.25
C 0.50
D 1.00

20 The table summarises a breeding experiment with *Drosophila melanogaster*.

parents	**BBNN x bbnn**			
F1	**BbNn**			
test cross	**BbNn x bbnn**			
test cross offspring	**BbNn**	**bbNn**	**Bbnn**	**bbnn**
number of test cross offspring	493	125	101	585

key

B	wild type body colour	**N**	normal wings
b	black body colour	**n**	vestigial wings

What do these results suggest?

A The alleles N and n are linked.
B Independent assortment has not occurred.
C The alleles for normal and vestigial wings are codominant.
D The gene loci for body colour and wing shape are not linked.

[Turn Over

21 The length of the petiole (leaf stalk) in a type of flowering plant is controlled by two genes, P1 and P2. These genes are at different loci on non-homologous chromosomes.
Plants with long petioles (30 cm) are homozygous dominant.
Plants with short petioles (10 cm) are homozygous recessive.
Each dominant allele contributes an equal length to the petiole.

To obtain plants which have medium length petioles (20 cm), a plant breeder carries out the cross below.

Parents plant with short petioles (10 cm) x plant with long petioles (30 cm)

p1p1p2p2 P1P1P2P2

↓

F1 all plants with medium length petioles (20 cm)
P1p1P2p2

If the F1 generation plants with medium length petioles were allowed to cross, what proportion of their offspring would be expected to have medium length (20 cm) petioles?

A 0.0625

B 0.250

C 0.375

D 0.5

22 The diagram shows the phenotypes of the different shape combs that some breeds of chicken have on their heads.

A cross between pure-breeding chickens with rose combs and pure-breeding chickens with pea combs, gave F1 generation offspring with walnut combs.

Interbreeding these F1 generation chickens with walnut combs produced offspring which showed all four of the possible comb phenotypes.

What is the expected phenotypic ratio of the offspring of a cross between a chicken with a single comb and one of the F1 generation chickens with a walnut comb?

A 1 rose : 1 pea : 1 walnut : 1 single

B 1 rose : 2 walnut : 1 pea

C 1 walnut : 1 single

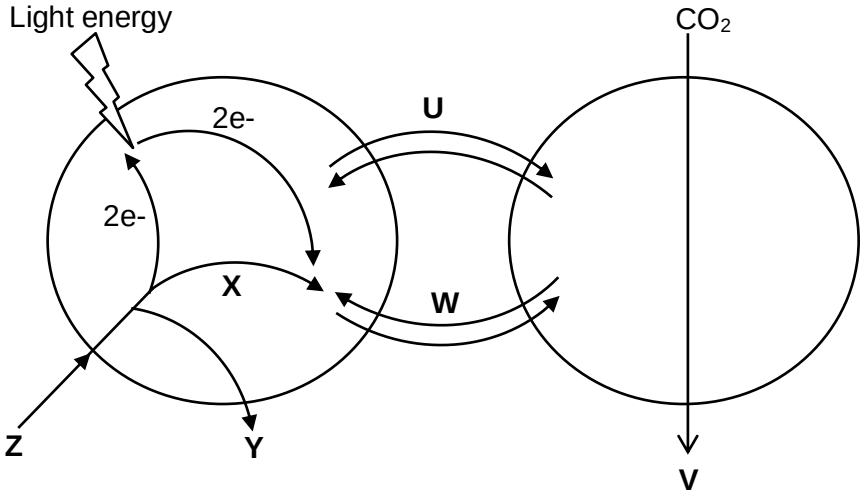
D 9 walnut : 7 single

23 The enzyme phosphofructokinase is involved in the phosphorylation of hexose phosphate sugars during glycolysis. It is involved in the control of the rate of glycolysis, and thus respiration, by end-product inhibition.

Which of the following is a description of this enzyme?

	shape of binding site(s)	substrate	products
A	no allosteric site, active site complementary to ATP and hexose	hexose	hexose phosphate
B	allosteric site complementary to glucose active site complementary to hexose phosphate	hexose phosphate	hexose
C	allosteric site complementary to ATP, active site complementary to ATP and hexose phosphate	hexose phosphate	hexose bisphosphate
D	no allosteric site, active site complementary to hexose bisphosphate	hexose bisphosphate	fructose bisphosphate

24 The diagram summarises the reactions of photosynthesis in a plant.

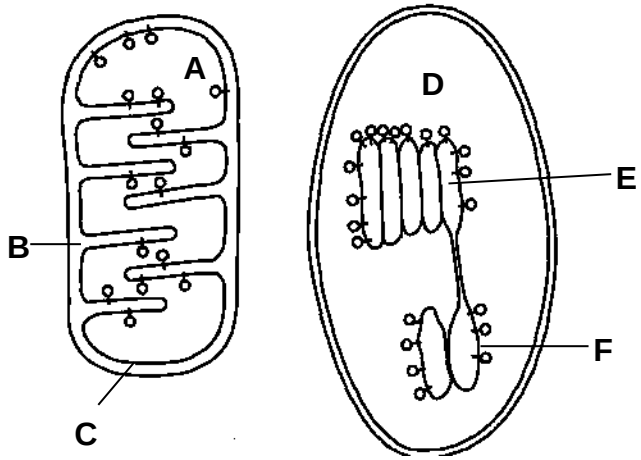


Which of the following correctly identifies the substances involved?

	U	**V**	**W**	**X**	**Y**	**Z**
A	triose phosphate	cellulose	ATP	H+	O_2	H_2O
B	NADP+	triose phosphate	ATP	H+	H_20	O_2
C	NADPH	triose phosphate	ADP	H+	O_2	H_2O
D	NADPH	cellulose	ADP	H+	H_20	O_2

[Turn Over

25 Most ATP is made in cells by membrane systems that create proton gradients by pumping protons from one compartment to another. Figure below shows two such membrane systems.



Which statements about the two membrane systems are correct?

1 There is production of NADH and ATP within structure **F**.

2 Structure **D** is the location in which glyceraldehyde-3-phosphate is produced.

3 Protons are pumped from structure **D** to structure **E** against its electrochemical gradient via ATP synthase on structure **F**.

4 Electrons flow from structure **B** to structure **A** down its electrochemical gradient via cytochromes.

5 Protons diffuse down its proton gradient via ATP synthase on structure **C** and ATP are produced in structure **A**.

A 1 and 4

B 2 and 5

C 1, 2 and 5

D 2, 3 and 5

26 The table below shows a description of the activity of 4 drugs.

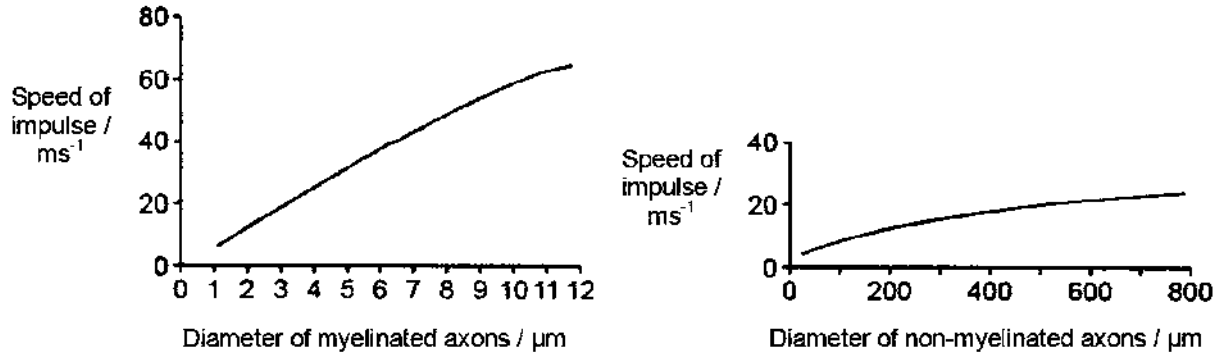
Drug	Description
1	Inhibit cAMP synthesis
2	Inhibit acetylcholinesterase
3	Block ligand gated Ca^{2+} channels
4	Block K^+ channels

Which of the following combination shows the consequence for each of the four drugs?

	Drug 1	Drug 2	Drug 3	Drug 4
A	Decreased action potential initiation	Decreased signal transduction efficiency	Decreased action potential initiation	Increased action potential initiation
B	Decreased activation of signalling pathways	Increased action potential initiation	Decreased action potential initiation	Delayed response to stimulus
C	Decreased activation of signalling pathways	Decreased action potential initiation	Increased action potential initiation	Increased action potential initiation
D	Decreased signal transduction efficiency	Increased action potential initiation	Increased action potential initiation	Delayed response to stimulus

[Turn Over

27 The ability of organisms to respond rapidly to stimuli is limited by the speed of the impulses in their neurons. The axons of invertebrate neurones lack a myelin sheath. The axons of most vertebrate neurons are myelinated. The graphs show the speed of impulses in these two types of axon.



Which of the following statements are correct?

1 The action potential in myelinated axons is greater than the action potential in non-myelinated axons.

2 The speed of impulses is changed by the diameter of the axon.

3 Increasing the diameter of a myelinated axon causes a greater change in the speed of conduction than increasing the diameter of a non-myelinated axon.

4 The presence of myelin increases the speed at which impulses are conducted.

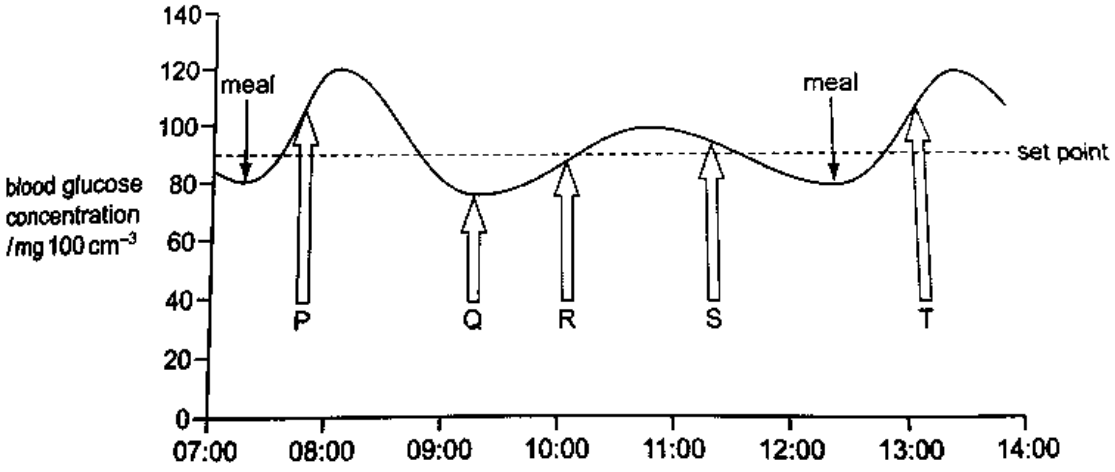
A 1, 2 and 3 only

B 1, 2 and 4 only

C 2, 3 and 4 only

D 3 and 4 only

28 The graph shows the way in which blood glucose concentrations vary over part of a day for a person who does not have diabetes. The set point, indicated by a dotted line, is the blood glucose concentration that is maintained by homeostasis. During this time the person has two meals.



Which row correctly identifies times at which insulin secretion, glucose absorption from the small intestine and conversion of glucose to glycogen occur?

	Insulin secretion	Glucose absorption	Glucose converted to glycogen
A	P, S and T	P and T	P, S and T
B	P, R and T	P and T	S
C	P, S and T	P, R and T	Q and S
D	R and S	P, Q, R and T	P, Q, S and T

29 Which statements are acceptable parts of Darwinian evolutionary theory?

1 Advantageous behaviour acquired during the lifetime of an individual is likely to be inherited.
2 In competition for suvival, the more aggressive animals are more likely to survive.
3 Species perfectly adapted to a stable environment will continue to evolve.
4 Variation between individuals of a species is essential for evolutionary change.

A 1, 2 and 4 only
B 2 and 3 only
C 3 and 4 only
D 4 only

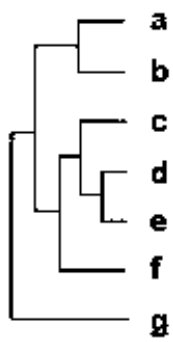
[Turn Over

30 The table shows the number of estimated nucleotide substitutions that have occurred since the divergence of seven species **a** to **g**.

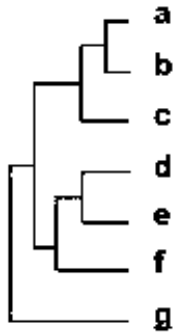
	b	**c**	**d**	**e**	**f**	**g**
a	39	72	128	126	127	269
b		81	130	128	129	268
c			129	127	128	267
d				56	154	271
e					151	268
f						273

Which of the following phylogenetic trees best shows the relationship among these seven species?

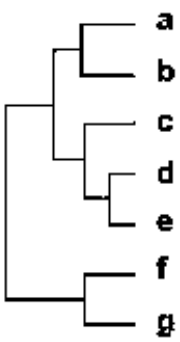
A



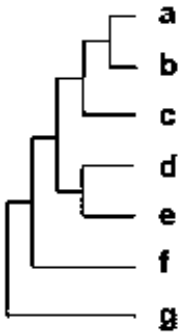
B



C



D

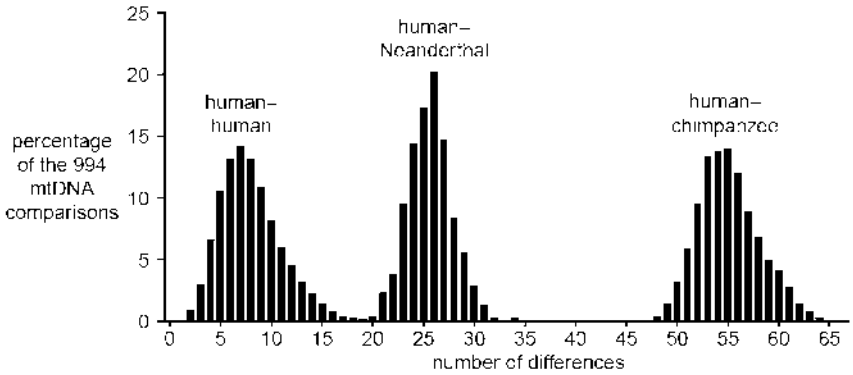


31 A scientist isolated and analysed the nucleotide sequence of the mtDNA of

- 994 modern humans
- One Neanderthal fossil
- Nine chimpanzees.

They compared these sequences. They were able to make human to human, Neanderthal to human and chimpanzee to human comparisons. The number of differences in the nucleotide sequence for each comparison was then recorded. The differences in mtDNA were quite small – no more than a few nucleotide bases – and relatively neutral in terms of evolution.

The results of these comparisons are shown in the graph below.



Which of the following statements is **not** true?

A This is an example of continuous variation.

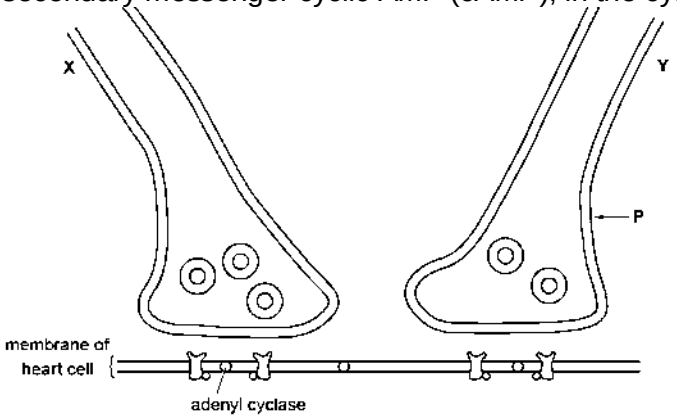
B The difference between human mtDNA and that of the chimpanzees was greater than between Neanderthals and humans.

C Neanderthals are evolutionarily closer to humans than to chimpanzees.

D The differences between the DNA of modern humans are much less than the differences between modern humans and Neanderthals.

[Turn Over

32 Figure below shows ending of neurone Y in the heart. Stimulation of Y leads to an increase in the concentration of the secondary messenger cyclic AMP (cAMP), in the cytoplasm of the heart cell.



The stages involved in this cell signaling process include:

1 Vesicles fuse with post-synaptic membrane and exit via exocytosis and diffuse across the synaptic cleft.

2 Voltage-gated calcium channel opens leading to an influx of calcium ions into the neurone.

3 Adenyl cyclase becomes activated and converts ATP to cAMP.

4 Calcium ions cause movement of neurotransmitter vesicles towards post-synaptic membrane (along microtubules).

5 Neurotransmitter binds to G protein coupled receptor on the membrane of heart cell and activates G protein.

What is the sequence of these stages?

A 5 → 2 → 4 → 1 → 3

B 5 → 2 → 4 → 3 → 1

C 2 → 4 → 1 → 5 → 3

D 2 → 1 → 4 → 5 → 3

33 Chemical T is known to act on the cell signaling pathway of glucagon. It is found to diminish the effect of glucagon.

Which of the following is **not** a possible effect of Chemical T?

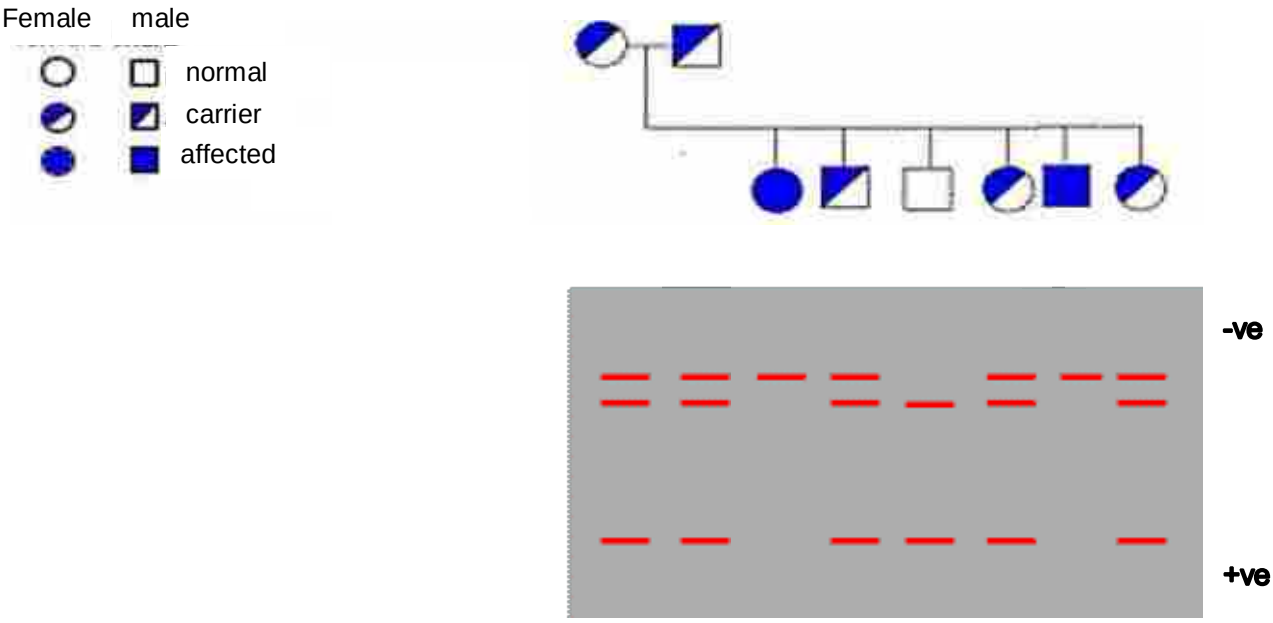
A Chemical T interferes with release of glucagon from the pancreas.

B Chemical T activates the hydrolysis of GTP on the G protein.

C Chemical T inactivates the enzyme adenylyl cyclase.

D Chemical T act as a competitive inhibitor of the protein kinase.

34 The diagram below shows an autoradiograph, post-gel electrophoresis, showing the restriction fragments obtained from various members of a family with respect to a disease.



Which of the following statements can be concluded from this autoradiograph?

1 The recessive allele is missing a restriction site.

2 The disease is autosomal recessive.

3 The radioactive probe is able to bind to a specific sequence on the recessive allele only.

A 1 and 2

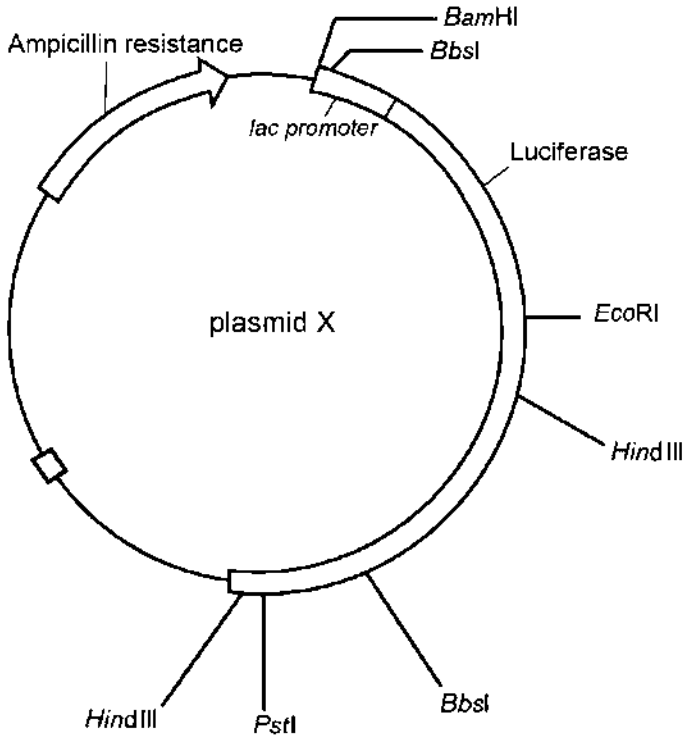
B 2 and 3

C 1 and 3

D All of the above

[Turn Over

35 Plasmid **X** can serve as a vector for the insertion of genes to be cloned.



Which of the following options will allow the selection of the colonies containing the recombinant form of plasmid **X**?

	Selection medium	Phenotype of colonies that contain the inserted gene
A	Containing ampicillin and lactose	White colonies
B	Containing ampicillin and luciferase	Colonies that emit light
C	Containing ampicillin, lactose and luciferin	White colonies
D	Containing ampicillin, lactose and luciferin	Colonies that emit light

36 The dashed lines in the template sequence represent a long sequence of bases to be amplified.

Template
5' ATTCGGACTTG - GTCCAGCTAGAGG 3'

3' TAAGCCTGAAC - CAGGTCGATCTCC 5'

Which of the following sets of primers can be used in the PCR for the amplification of the following DNA sequence?

A **3'** TAAGCCT **5'** & **5'** CTAGAGG **3'**

B **5'** ATTCGGA **3'** & **3'** GATCTCC **5'**

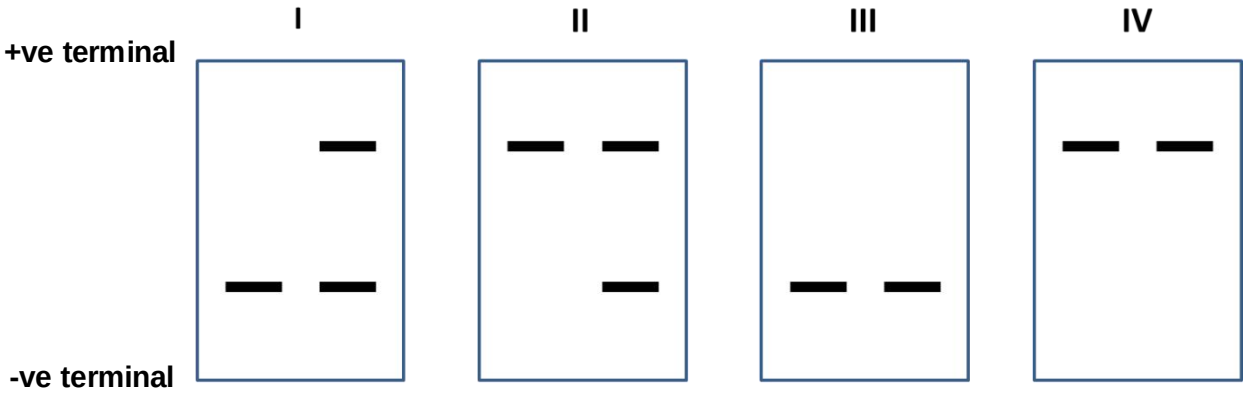
C **3'** UAAGCCU **5'** & **5'** CUAGAGG **3'**

D **5'** AUUCGGA **3'** & **3'** GAUCUCC **5'**

37 Cystic fibrosis (CF) is an autosomal recessive genetic disorder. An individual must have two copies of the mutated CFTR gene to express the disease phenotype. One of the most common CF-causing mutation resulted in a loss of phenylalanine located at position 508 of the protein.

The DNA sequence of the CF locus from the offspring of 2 carriers are removed and separated by gel electrophoresis.

Which pattern of bands corresponds to two of the offspring that are phenotypically normal?



A I only

B II only

C I and III

D II and IV

[Turn Over

38 The statements are about the preparation and application of DNA libraries.

1 A cDNA library allows the study of the functions of introns of specific genes
2 A genomic library enables detection of genes that, in the host, have no detectable level of expression.
3 Alternative splicing can be studied using a cDNA library
4 The preparation of a genomic DNA library requires restriction enzyme, reverse transcriptase and DNA ligase

Which statements are correct?

A 1, 2 and 4

B 1 and 4 only

C 2, 3 and 4

D 2 and 3 only

39 Stem cells are found in many tissues that require frequent cell replacement such as the skin, the intestine or the blood.

However, within their own environments, a bone marrow cell cannot be induced to produce a skin cell and a skin cell cannot be induced to produce a bone marrow cell.

Which statement explains this?

A Different stem cells have only the genes required for their particular cell line.

B Genes not required for a particular cell line are methylated.

C Genes not required for a particular cell line are removed using restriction enzymes.

D mRNA that is not required for a particular cell line is destroyed.

40 Gene therapy is used to treat inherited diseases such as cystic fibrosis. Some of the scientific and ethical concerns about gene therapy are listed below.

1 Most gene therapy must be repeated in succeeding generations since germ cells are not involved.

2 Genetically modified organisms used in producing the gene therapy may escape into the environment with unforeseen consequences.

3 Putting genes into the germ line affects subsequence generations and is banned in many countries.

4 The same techniques for treating serious, life-threatening conditions may be used to try to change other things such as intelligence and skin colour.

5 Viral vectors, such as those used in the treatment of cystic fibrosis, have been known to produce harmful side-effects.

Which row identifies the types of concern?

	Scientific concerns	ethical concerns
A	1 and 2	3, 4 and 5
B	2 and 4	1, 3 and 5
C	1 and 5	2, 3 and 4
D	3, 4 and 5	1 and 2

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PIONEER JUNIOR COLLEGE
JC2 Preliminary Examinations
In preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME									
CT GROUP	1	5	S			INDEX NUMBER			

BIOLOGY

9648/01
22 September 2016

Paper 1 Multiple Choice **1 hour 15 minutes**

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, CT class and index number on the Answer Sheet.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

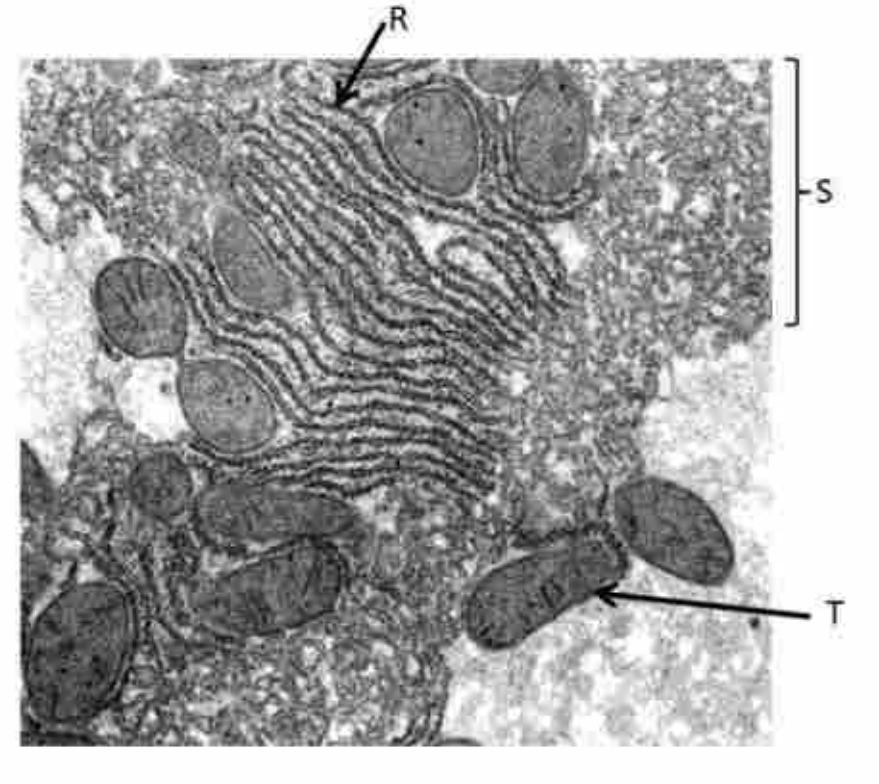
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **27** printed pages and **1** blank page.

[Turn Over

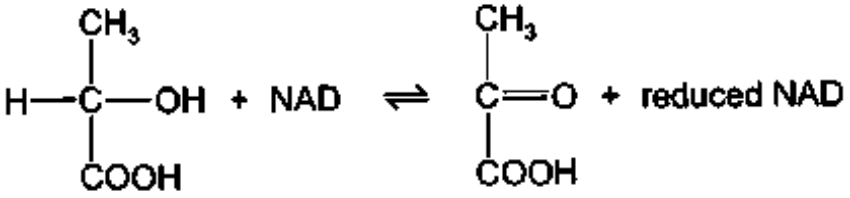
1 The figure below shows an electron micrograph of an eukaryotic cell.



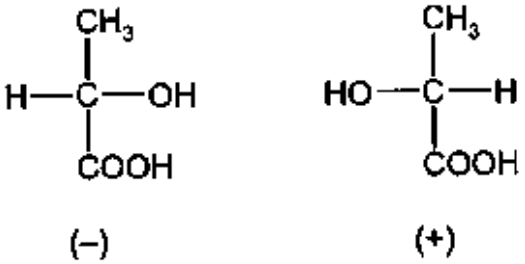
Which of the following option correctly matches the structures **R**, **S** and **T** to their respective functions?

	R	**S**	**T**
A	Involved in proteins glycosylation	Site of lipid synthesis	To convert light energy to chemical energy
B	Site of protein synthesis	Site of detoxification reaction	Supplying cellular energy
C	Site of detoxification reaction	Involved in protein glycosylation	Remove worn out organelles
D	Site of protein synthesis	Contains proteins to be secreted	Supplying cellular energy

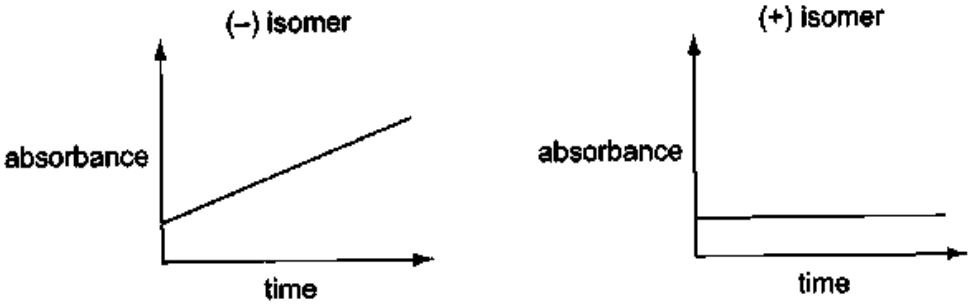
2 Lactic dehydrogenase catalyses the conversion of lactic acid as shown in the following equation.



Two forms (isomers) of lactic acid exist, (-) and (+), as shown below.



Reduced NAD absorbs ultraviolet light. NAD does not. The activity of bacterial lactic dehydrogenase on two different isomers of lactic acid was compared. The absorbance of ultraviolet light was measured using an ultraviolet spectrophotometer. The graphs show the results.



What can be concluded about bacterial lactic dehydrogenase?

A Molecules of both isomers fit the active site.

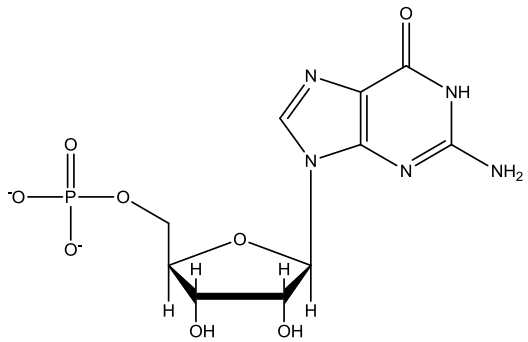
B Molecules of neither isomer fit the active site.

C The enzyme is specific to the (-) isomer.

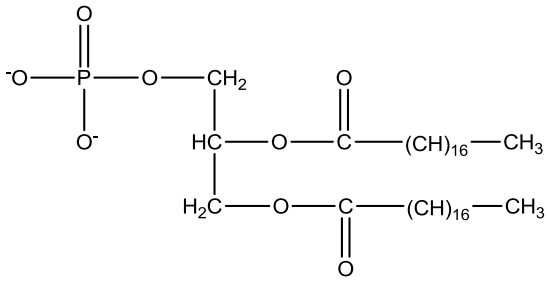
D The enzyme is specific to the (+) isomer.

[Turn Over

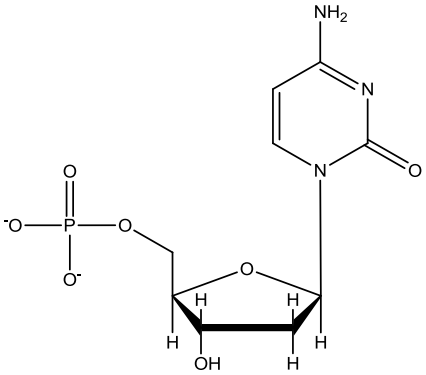
3 A student uses centrifugation to separate the various subcellular structures of human epithelial cells by size and density.



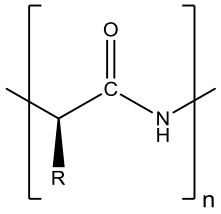
I



II



III



IV

Which of the following molecule(s) would you expect to find in the pellet containing the cell membrane?

A **II** only

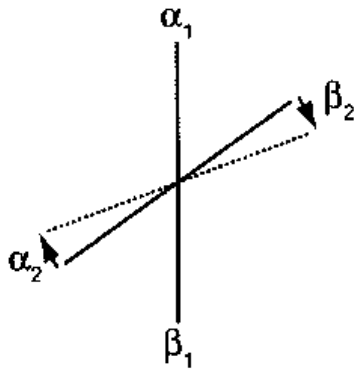
B **III** only

C **II** and **IV** only

D **I**, **III** and **IV** only

4 A molecule of haemoglobin is made up of two α polypeptide subunits (α_1 and α_2) and two β polypeptide subunits (β_1 and β_2).

The relative positions of these subunits change when a deoxygenated haemoglobin molecule takes up oxygen. The axis joining the α_2 and β_2 subunits rotates by about 15° in relation to the axis joining the α_1 and β_1 subunits, as shown in the diagram.



Which statements about this rotation are correct?

1 The points of contact between the four subunits are altered.
2 The rotation resulting from adding one oxygen molecule to one of the subunits makes it easier to add oxygen to the other subunits.
3 The rotation makes different amino acids available for binding oxygen.
4 The rotation alters the quaternary structure of the molecule.

A 1, 2 and 3 only
B 1, 2 and 4 only
C 1, 3 and 4 only
D 2, 3 and 4 only

5 A group of diploid cells with x amount of DNA and 36 chromosomes each is capable of undergoing mitosis and meiosis.

During which stage(s) could a cell with 2x amount of DNA and 72 chromosomes be found?

A anaphase of mitosis only
B anaphase of meiosis I only
C anaphase of mitosis and anaphase of meiosis I
D anaphase of mitosis and anaphase of meiosis II

[Turn Over

6 Below are statements that describe the control of transcription for genes encoding for enzymes in a metabolic pathway.

1 The genes are transcribed as a single transcription unit, with each gene having its own promoter.
2 The genes respond similarly to the same set of general transcription factors but respond differently to a certain set of specific transcription factors.
3 The genes have various combinations of control elements that enable different activators and repressors to bind and affect the rate of transcription.
4 The genes are found close to each other on the chromosome with chromatin remodelling as a form of transcriptional control.

Which combination of statements is true?

A 1 only
B 2 only
C 2 and 3
D 3 and 4

7 The active messenger RNAs (active mRNAs) in tissue cells can be isolated by passing the homogenized cell contents through a fractionating column. The column has short length of uracil nucleotides attached to a solid supporting material. Most molecules of mRNA that pass through the column quickly break up into small pieces and cannot be translated.

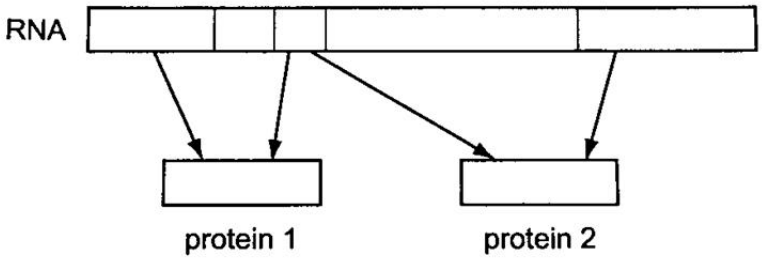
The active mRNAs that attached to the column can be separated again by appropriate treatment.

Which statements correctly describe active mRNA?

1 Active mRNAs are held to the fractionating column by bonds between adenine and uracil bases.
2 Active mRNAs can be released from the fractionating column by breaking hydrogen bonds.
3 Only mRNAs with polyadenine tailing can be translated.
4 Polyadenine tailing destabilizes mRNA and prevents it from being broken up.

A 1 and 2 only
B 1, 2 and 3 only
C 3 and 4 only
D 1, 2, 3 and 4

8 RNA transcribed from a length of DNA of a chromosome was found to code for two different protein, as shown in the diagram.



Which is correct?

A The DNA from which this RNA was transcribed was part of a eukaryotic chromosome because this is a way of saving space in a small genome.

B The DNA from which this RNA was transcribed was part of a eukaryotic chromosome because introns have been edited out of the RNA.

C The DNA from which this RNA was transcribed was part of a prokaryotic chromosome because introns have been edited out of the RNA.

D The DNA from which this RNA was transcribed was part of a prokaryotic chromosome because this a way of saving space in a small chromosome.

9 Below are the descriptions of different gene mutations.

1 deletion toward the end of the code sequence
2 insertion in the middle of the code sequence
3 substitution close to the beginning of code sequence

Which row correctly identifies the possible effects of these mutations on the synthesis of polypeptides?

	Premature ending of a polypeptide	A non-functional polypeptide	A polypeptide with unchanged function	A polypeptide with a different function
A	1,2,3	1,2,3	1,2,3	1,2,3
B	1,2,3	2 only	1,3 only	1,2 only
C	1,3 only	1,2,3	3 only	1,2,3
D	2,3 only	2,3 only	1,2,3	2,3 only

[Turn Over

10 The coding region of a gene is 135 nucleotides long, including both the start and stop codons. Which of the following would be the most likely effect of a single nucleotide deletion at position 102 in the coding region?

A Only the active site would be affected.

B The entire amino acid sequence of the polypeptide would change.

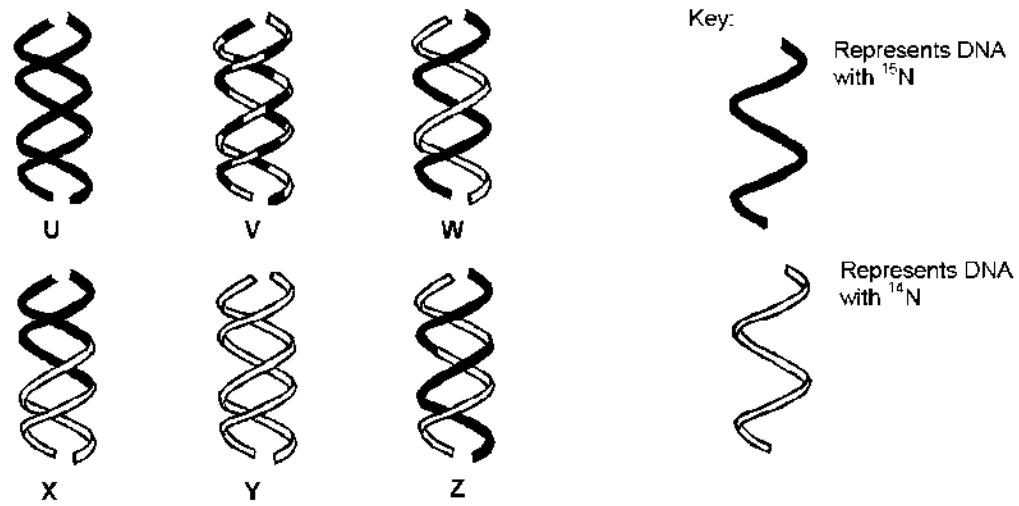
C There would be changes in only the first 34 amino acids.

D There would be changes in only the last 10 amino acids.

11 Three experiments were carried out to investigate the mode of DNA replication in bacteria.

- Experiment 1: Bacteria were grown for many generations with only the light isotope of nitrogen, ^{14}N, and then allowed to replicate once with the heavy isotope, ^{15}N.
- Experiment 2: Bacteria were grown for many generations with only the heavy isotope of nitrogen, ^{15}N, and then allowed to replicate once with the light isotope, ^{14}N.
- Experiment 3: Bacteria were grown for many generations with only the heavy isotope of nitrogen, ^{15}N, and then allowed to replicate twice with the light isotope, ^{14}N.

The figure shows possible DNA molecules U to Z and indicates the varying proportion of nitrogen isotopes present in each DNA molecule.

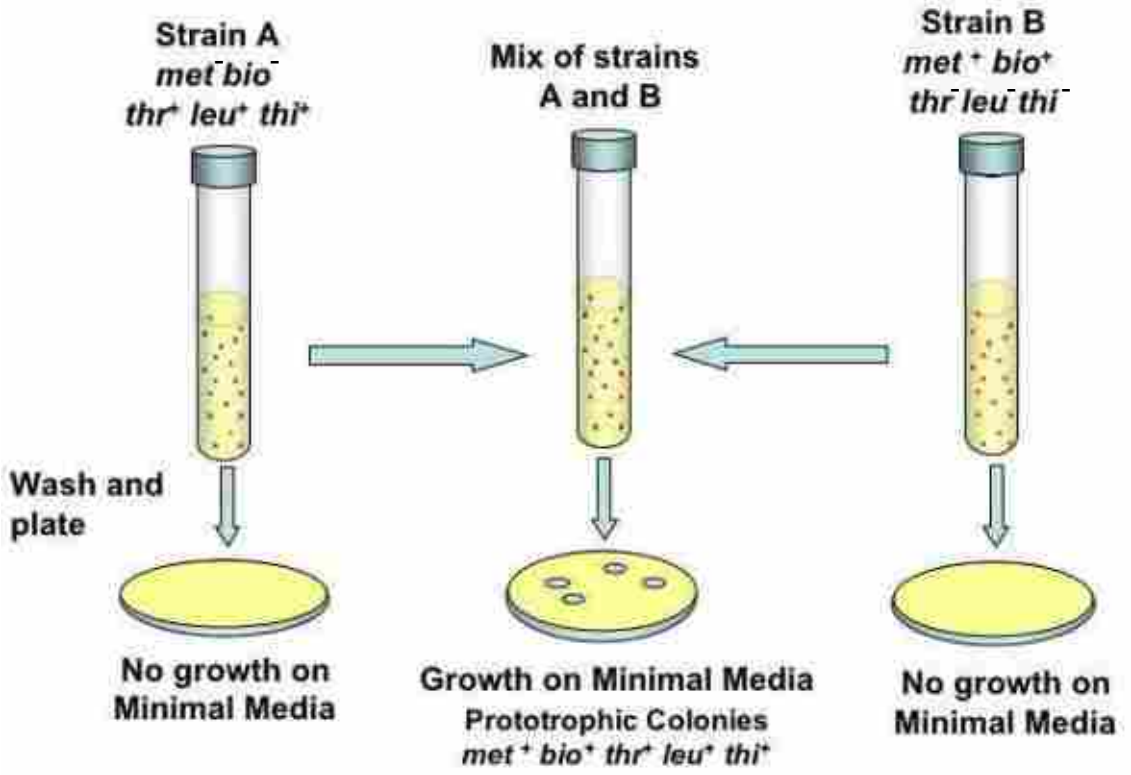


Which of the following products shows the semi-conservative mode of DNA replication?

	Experiment 1	Experiment 2	Experiment 3
A	W	W	W and Y
B	U	W	W and Y
C	W	W	X and Z
D	U	W	V and Z

12 The diagram shows an investigation into bacterial genetics.

The researchers used 2 strains of bacteria. Strain A coded for 3 essential amino acids (thr^+ leu^+ thi^+) while Strain B coded for 2 essential amino acids (met^+ bio^+). For the 2 strains of bacteria to grow on minimal medium, the bacteria need to encode for all 5 essential amino acids.



Which process or processes could explain these results?

1 Conjugation
2 Transduction
3 Transformation

A 1 only

B 3 only

C 1 and 2

D 1 and 3

[Turn Over

13 A single mutation has occurred in an *E. coli* cell. If the structural genes in a *trp* operon were not expressed regardless of the presence or absence of the amino acid tryptophan, which of the following mutations could have taken place?

1 The cell had a mutation at the operator of the trp operon.
2 The cell had a mutation at the trpR gene.
3 The cell had a mutation at the promoter of the trp structural genes.

A 3 only

B 1 and 2

C 2 and 3

D 1, 2 and 3

14 When the *lac* operon for lactose metabolism is switched off, which of the following genes would still be expressed?

I β-galactosidase gene
II RNA polymerase gene
III CAP gene
IV Repressor gene

A I and II

B I and III

C II, III and IV

D All of the above

15 Which features of viruses account for them being obligate parasites?

1 All viruses are very small, ranging in size from 20 – 300nm.
2 Each virus contains only one type of nucleic acid.
3 Viruses can be crystallised.
4 Viruses cannot synthesis ATP.
5 Viruses have no cellular structure.
6 Viruses have no enzymes involved in metabolism outside a host cell.

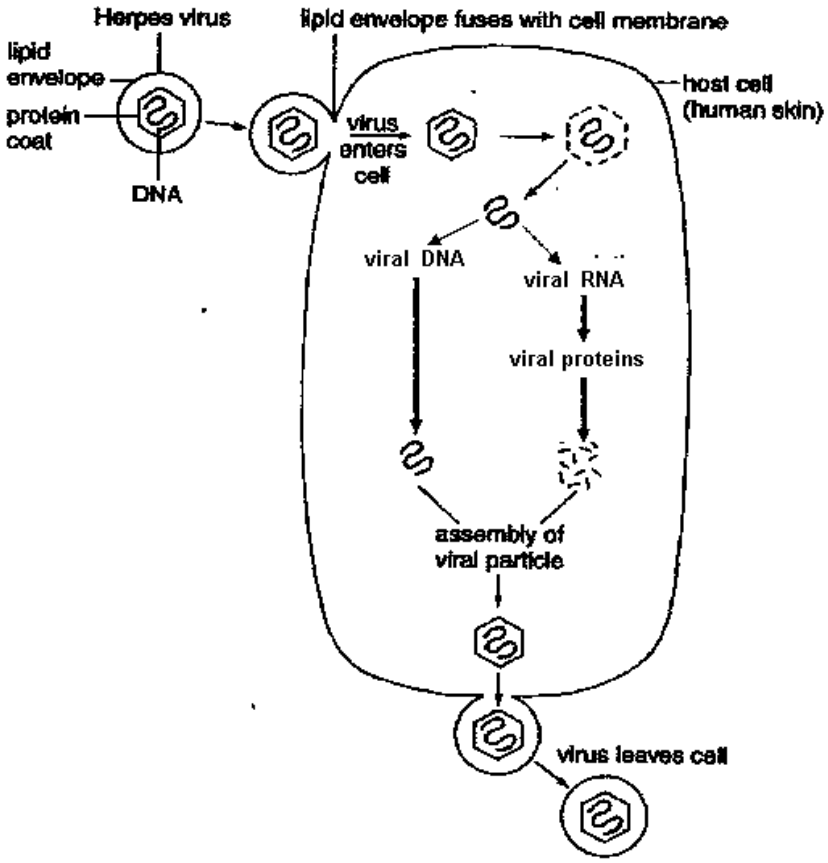
A 1, 3 and 5

B 1, 4 and 6

C 2, 3 and 5

D 2, 4 and 6

16 The diagram below shows the reproductive cycle of the herpes virus which causes cold sores on the mouth. With reference to the diagram below, which of the following statements best describes the herpes virus?



A It is not a retrovirus as it does not contain RNA as its genetic material.

B Its mode of replication is similar to that of HIV.

C Its replication cycle includes a lysogenic phase.

D Death of the host cell is necessary for the release of the viral progeny.

[Turn Over

17 The MDR1 gene codes for a membrane transport protein in mammalian cells. The protein has the ability to prevent the entry of, or remove, molecules such as chemotherapeutic drugs, from cells. Gene amplification of the MDR1 gene can arise from environmental signals.

Which statement is not consistent with the information above?

A Amplification of the MDR1 gene in mammalian cancer cells could lead to the cells becoming resistant to chemotherapeutic drugs.

B Cancer cells, with initially the same level of MDR1 gene expression as healthy cells, may respond to chemotherapy by increasing the number of MDR1 genes, which increases expression.

C Development of chemotherapeutic drug resistance can be progressive, rather than spontaneous, and can hinder chemotherapy in patients with cancer.

D Since gene amplification has not arisen by genetic causes, descendant cells from a cancer cell with MDR1 gene amplification will be normal for MDR1 gene expression.

18 Cells taken from a human bone cancer multiplied readily in culture. Analysis showed that the cells were unable to produce the protein, RB.

Addition of RB to these cells reduced their rate of division.

Which of the following statement accounts for the observation?

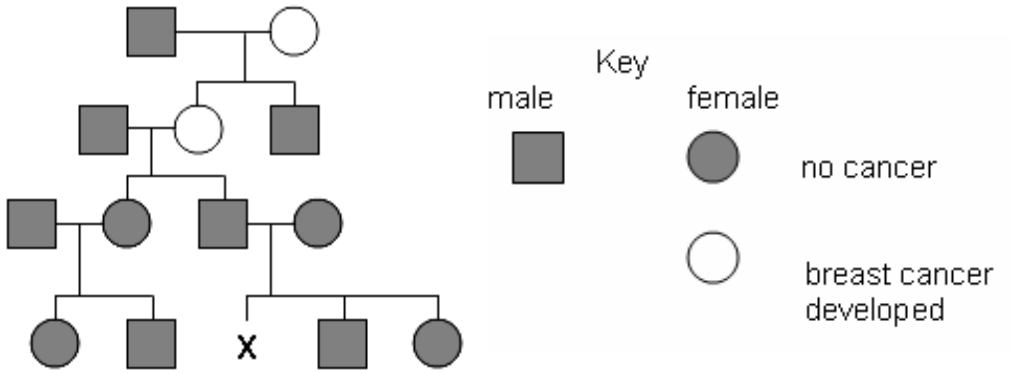
A Both chromosomes in the cancer cell carry alleles for tumour suppressor gene.

B Both chromosomes in the cancer cell have the allele for tumour suppressor gene deleted.

C Both chromosomes in the cancer cell carry alleles for proto-oncogene.

D Both chromosomes in the cancer cell have the allele for proto-oncogene deleted.

19 The diagram shows the inheritance of a form of breast cancer associated with the presence of just one allele of the autosomal gene BRCA 1.



What is the probability that woman **X** inherits the BRCA 1 allele associated with breast cancer?

A 0.00
B 0.25
C 0.50
D 1.00

20 The table summarises a breeding experiment with *Drosophila melanogaster*.

parents	**BBNN x bbnn**			
F1	**BbNn**			
test cross	**BbNn x bbnn**			
test cross offspring	**BbNn**	**bbNn**	**Bbnn**	**bbnn**
number of test cross offspring	493	125	101	585

key

B	wild type body colour	**N**	normal wings
b	black body colour	**n**	vestigial wings

What do these results suggest?

A The alleles N and n are linked.
B Independent assortment has not occurred.
C The alleles for normal and vestigial wings are codominant.
D The gene loci for body colour and wing shape are not linked.

[Turn Over

21 The length of the petiole (leaf stalk) in a type of flowering plant is controlled by two genes, P1 and P2. These genes are at different loci on non-homologous chromosomes.
Plants with long petioles (30 cm) are homozygous dominant.
Plants with short petioles (10 cm) are homozygous recessive.
Each dominant allele contributes an equal length to the petiole.

To obtain plants which have medium length petioles (20 cm), a plant breeder carries out the cross below.

Parents plant with short petioles (10 cm) x plant with long petioles (30 cm)

p1p1p2p2 P1P1P2P2

↓

F1 all plants with medium length petioles (20 cm)
P1p1P2p2

If the F1 generation plants with medium length petioles were allowed to cross, what proportion of their offspring would be expected to have medium length (20 cm) petioles?

A 0.0625

B 0.250

C 0.375

D 0.5

22 The diagram shows the phenotypes of the different shape combs that some breeds of chicken have on their heads.

A cross between pure-breeding chickens with rose combs and pure-breeding chickens with pea combs, gave F1 generation offspring with walnut combs.

Interbreeding these F1 generation chickens with walnut combs produced offspring which showed all four of the possible comb phenotypes.

What is the expected phenotypic ratio of the offspring of a cross between a chicken with a single comb and one of the F1 generation chickens with a walnut comb?

A 1 rose : 1 pea : 1 walnut : 1 single

B 1 rose : 2 walnut : 1 pea

C 1 walnut : 1 single

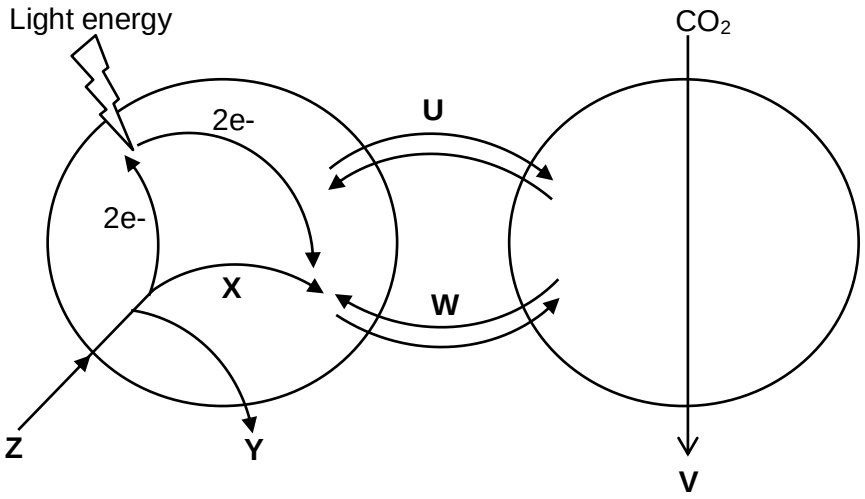
D 9 walnut : 7 single

23 The enzyme phosphofructokinase is involved in the phosphorylation of hexose phosphate sugars during glycolysis. It is involved in the control of the rate of glycolysis, and thus respiration, by end-product inhibition.

Which of the following is a description of this enzyme?

	shape of binding site(s)	substrate	products
A	no allosteric site, active site complementary to ATP and hexose	hexose	hexose phosphate
B	allosteric site complementary to glucose active site complementary to hexose phosphate	hexose phosphate	hexose
C	allosteric site complementary to ATP, active site complementary to ATP and hexose phosphate	hexose phosphate	hexose bisphosphate
D	no allosteric site, active site complementary to hexose bisphosphate	hexose bisphosphate	fructose bisphosphate

24 The diagram summarises the reactions of photosynthesis in a plant.

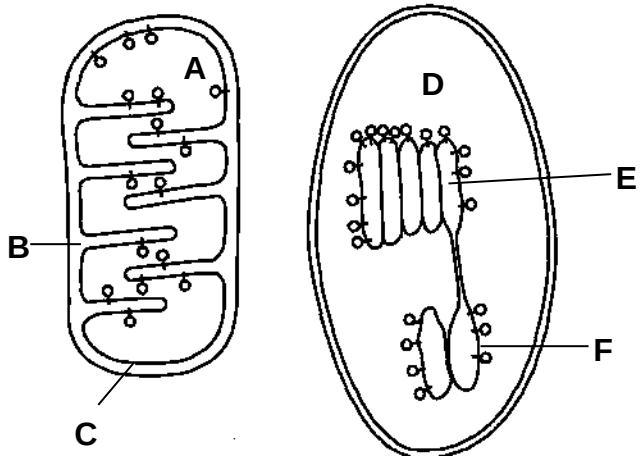


Which of the following correctly identifies the substances involved?

	U	V	W	X	Y	Z
A	triose phosphate	cellulose	ATP	H+	O_2	H_2O
B	NADP+	triose phosphate	ATP	H+	H_20	O_2
C	NADPH	triose phosphate	ADP	H+	O_2	H_2O
D	NADPH	cellulose	ADP	H+	H_20	O_2

[Turn Over

25 Most ATP is made in cells by membrane systems that create proton gradients by pumping protons from one compartment to another. Figure below shows two such membrane systems.



Which statements about the two membrane systems are correct?

1 There is production of NADH and ATP within structure **F**.

2 Structure **D** is the location in which glyceraldehye-3-phosphate is produced.

3 Protons are pumped from structure **D** to structure **E** against its electrochemical gradient via ATP synthase on structure **F**.

4 Electrons flow from structure **B** to structure **A** down its electrochemical gradient via cytochromes.

5 Protons diffuse down its proton gradient via ATP synthase on structure **C** and ATP are produced in structure **A**.

A 1 and 4

B 2 and 5

C 1, 2 and 5

D 2, 3 and 5

26 The table below shows a description of the activity of 4 drugs.

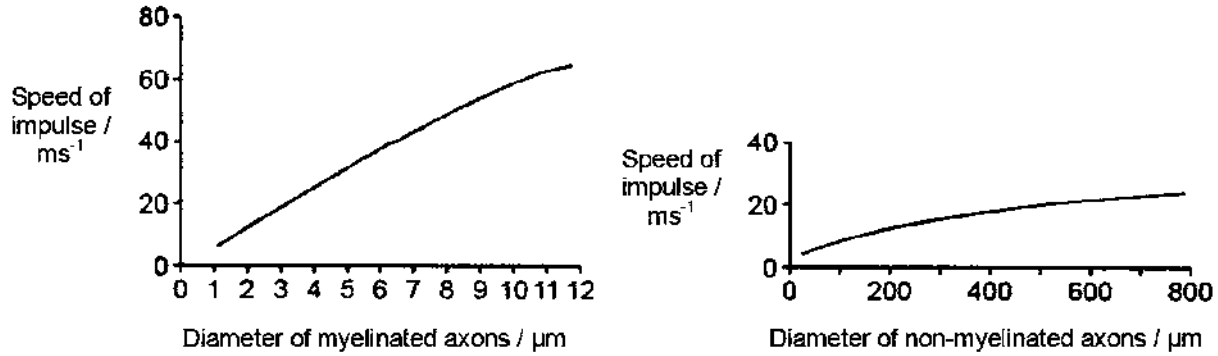
Drug	Description
1	Inhibit cAMP synthesis
2	Inhibit acetylcholinesterase
3	Block ligand gated Ca^{2+} channels
4	Block K^+ channels

Which of the following combination shows the consequence for each of the four drugs?

	Drug 1	Drug 2	Drug 3	Drug 4
A	Decreased action potential initiation	Decreased signal transduction efficiency	Decreased action potential initiation	Increased action potential initiation
B	Decreased activation of signalling pathways	Increased action potential initiation	Decreased action potential initiation	Delayed response to stimulus
C	Decreased activation of signalling pathways	Decreased action potential initiation	Increased action potential initiation	Increased action potential initiation
D	Decreased signal transduction efficiency	Increased action potential initiation	Increased action potential initiation	Delayed response to stimulus

[Turn Over

27 The ability of organisms to respond rapidly to stimuli is limited by the speed of the impulses in their neurons. The axons of invertebrate neurones lack a myelin sheath. The axons of most vertebrate neurons are myelinated. The graphs show the speed of impulses in these two types of axon.



Which of the following statements are correct?

1 The action potential in myelinated axons is greater than the action potential in non-myelinated axons.

2 The speed of impulses is changed by the diameter of the axon.

3 Increasing the diameter of a myelinated axon causes a greater change in the speed of conduction than increasing the diameter of a non-myelinated axon.

4 The presence of myelin increases the speed at which impulses are conducted.

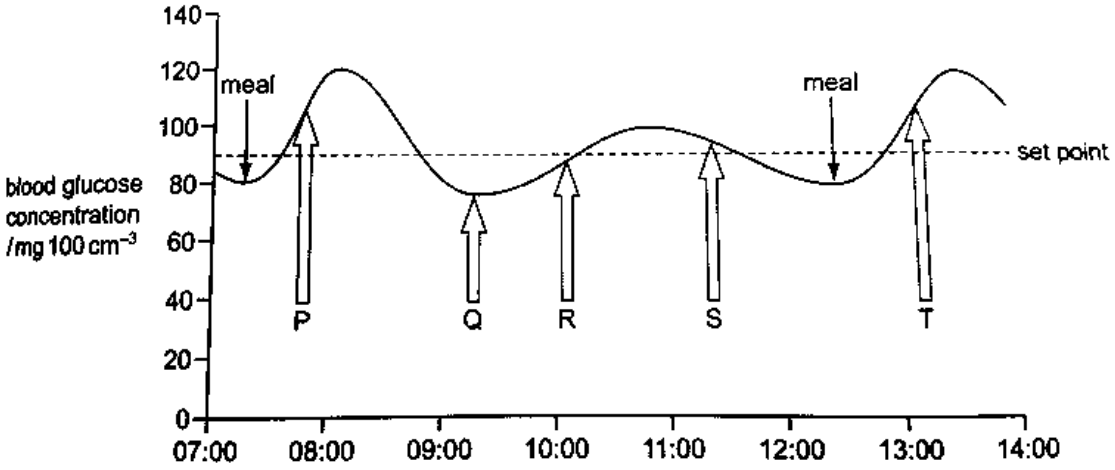
A 1, 2 and 3 only

B 1, 2 and 4 only

C 2, 3 and 4 only

D 3 and 4 only

28 The graph shows the way in which blood glucose concentrations vary over part of a day for a person who does not have diabetes. The set point, indicated by a dotted line, is the blood glucose concentration that is maintained by homeostasis. During this time the person has two meals.



Which row correctly identifies times at which insulin secretion, glucose absorption from the small intestine and conversion of glucose to glycogen occur?

	Insulin secretion	Glucose absorption	Glucose converted to glycogen
A	P, S and T	P and T	P, S and T
B	P, R and T	P and T	S
C	P, S and T	P, R and T	Q and S
D	R and S	P, Q, R and T	P, Q, S and T

29 Which statements are acceptable parts of Darwinian evolutionary theory?

1 Advantageous behaviour acquired during the lifetime of an individual is likely to be inherited.
2 In competition for suvival, the more aggressive animals are more likely to survive.
3 Species perfectly adapted to a stable environment will continue to evolve.
4 Variation between individuals of a species is essential for evolutionary change.

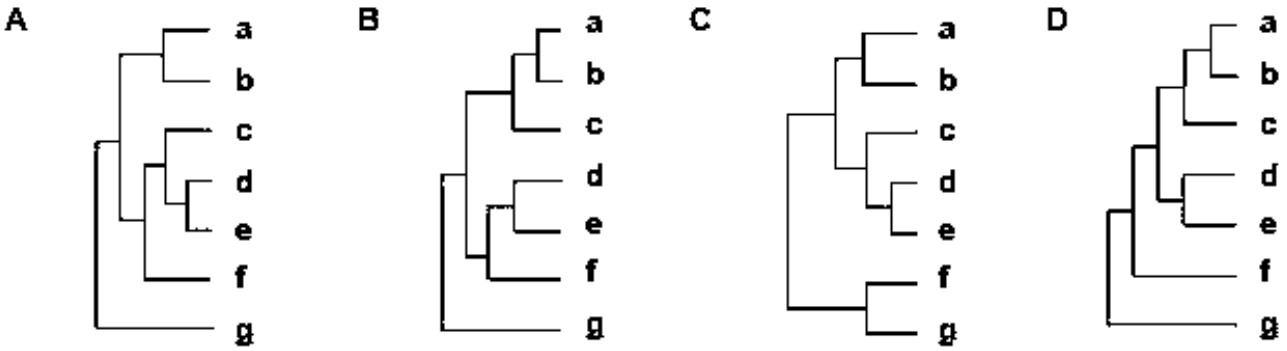
A 1, 2 and 4 only
B 2 and 3 only
C 3 and 4 only
D 4 only

[Turn Over

30 The table shows the number of estimated nucleotide substitutions that have occurred since the divergence of seven species **a** to **g**.

	b	**c**	**d**	**e**	**f**	**g**
a	39	72	128	126	127	269
b		81	130	128	129	268
c			129	127	128	267
d				56	154	271
e					151	268
f						273

Which of the following phylogenetic trees best shows the relationship among these seven species?
B

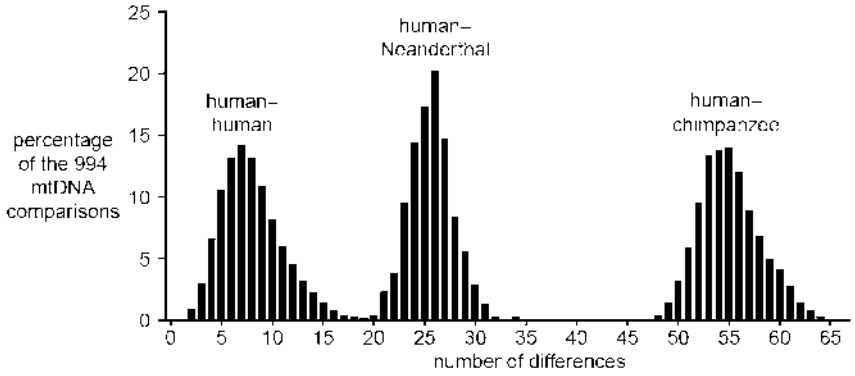


31 A scientist isolated and analysed the nucleotide sequence of the mtDNA of

- 994 modern humans
- One Neanderthal fossil
- Nine chimpanzees.

They compared these sequences. They were able to make human to human, Neanderthal to human and chimpanzee to human comparisons. The number of differences in the nucleotide sequence for each comparison was then recorded. The differences in mtDNA were quite small – no more than a few nucleotide bases – and relatively neutral in terms of evolution.

The results of these comparisons are shown in the graph below.



Which of the following statements is **not** true?

A This is an example of continuous variation.

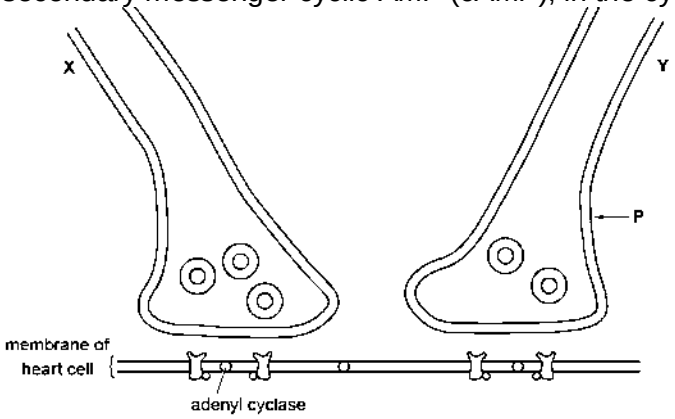
B The difference between human mtDNA and that of the chimpanzees was greater than between Neanderthals and humans.

C Neanderthals are evolutionary closer to humans than to chimpanzees.

D The differences between the DNA of modern humans are much less than the differences between modern humans and Neanderthals.

[Turn Over

32 Figure below shows ending of neurone Y in the heart. Stimulation of Y leads to an increase in the concentration of the secondary messenger cyclic AMP (cAMP), in the cytoplasm of the heart cell.



The stages involved in this cell signaling process include:

1 Vesicles fuse with post-synaptic membrane and exit via exocytosis and diffuse across the synaptic cleft.

2 Voltage-gated calcium channel opens leading to an influx of calcium ions into the neurone.

3 Adenyl cyclase becomes activated and converts ATP to cAMP.

4 Calcium ions cause movement of neurotransmitter vesicles towards post-synaptic membrane (along microtubules).

5 Neurotransmitter binds to G protein coupled receptor on the membrane of heart cell and activates G protein.

What is the sequence of these stages?

A 5 → 2 → 4 → 1 → 3

B 5 → 2 → 4 → 3 → 1

C 2 → 4 → 1 → 5 → 3

D 2 → 1 → 4 → 5 → 3

33 Chemical T is known to act on the cell signaling pathway of glucagon. It is found to diminish the effect of glucagon.

Which of the following is **not** a possible effect of Chemical T?

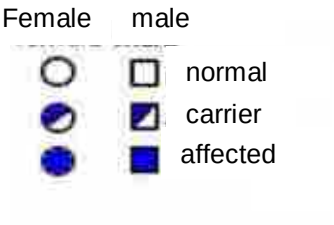
A Chemical T interferes with release of glucagon from the pancreas.

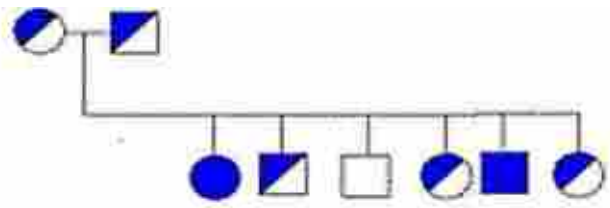
B Chemical T activates the hydrolysis of GTP on the G protein.

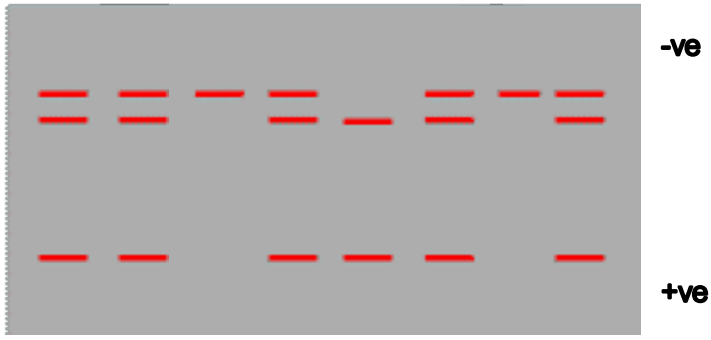
C Chemical T inactivates the enzyme adenylyl cyclase.

D Chemical T act as a competitive inhibitor of the protein kinase.

34 The diagram below shows an autoradiograph, post-gel electrophoresis, showing the restriction fragments obtained from various members of a family with respect to a disease.







Which of the following statements can be concluded from this autoradiograph?

1 The recessive allele is missing a restriction site.

2 The disease is autosomal recessive.

3 The radioactive probe is able to bind to a specific sequence on the recessive allele only.

A 1 and 2

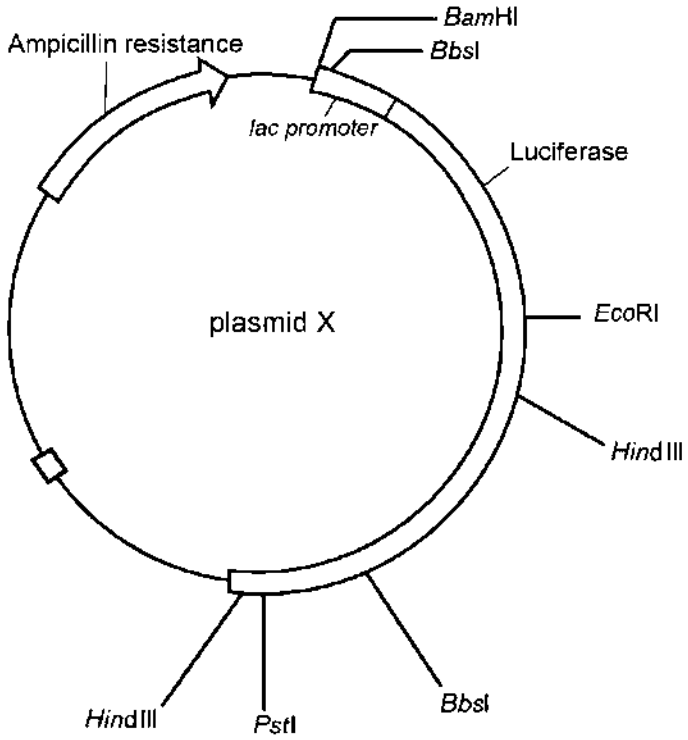
B 2 and 3

C 1 and 3

D All of the above

[Turn Over

35 Plasmid **X** can serve as a vector for the insertion of genes to be cloned.



Which of the following options will allow the selection of the colonies containing the recombinant form of plasmid **X**?

	Selection medium	Phenotype of colonies that contain the inserted gene
A	Containing ampicillin and lactose	White colonies
B	Containing ampicillin and luciferase	Colonies that emit light
C	Containing ampicillin, lactose and luciferin	White colonies
D	Containing ampicillin, lactose and luciferin	Colonies that emit light

36 The dashed lines in the template sequence represent a long sequence of bases to be amplified.

Template
5' ATTCGGACTTG - GTCCAGCTAGAGG 3'

3' TAAGCCTGAAC - CAGGTCGATCTCC 5'

Which of the following sets of primers can be used in the PCR for the amplification of the following DNA sequence?

A **3'** TAAGCCT **5'** & **5'** CTAGAGG **3'**

B **5'** ATTCGGA **3'** & **3'** GATCTCC **5'**

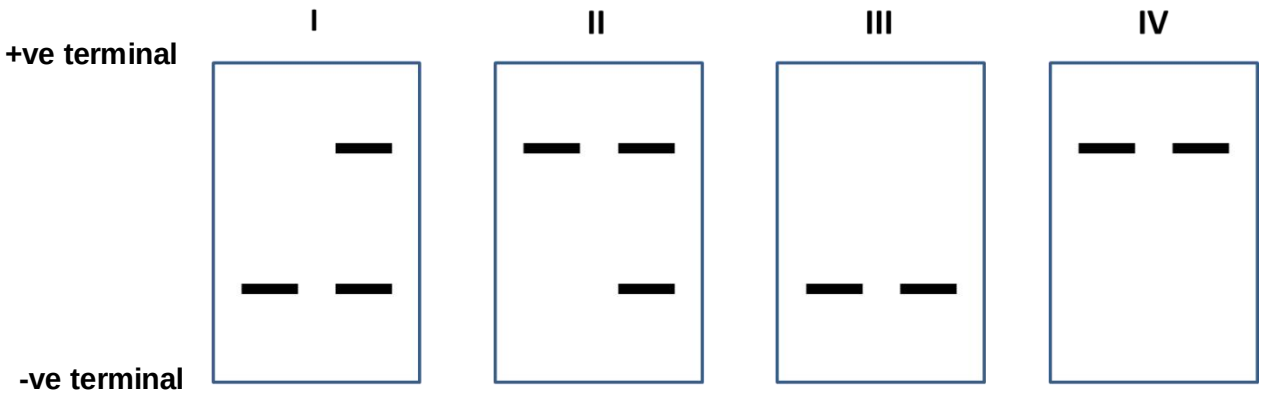
C **3'** UAAGCCU **5'** & **5'** CUAGAGG **3'**

D **5'** AUUCGGA **3'** & **3'** GAUCUCC **5'**

37 Cystic fibrosis (CF) is an autosomal recessive genetic disorder. An individual must have two copies of the mutated CFTR gene to express the disease phenotype. One of the most common CF-causing mutation resulted in a loss of phenylalanine located at position 508 of the protein.

The DNA sequence of the CF locus from the offspring of 2 carriers are removed and separated by gel electrophoresis.

Which pattern of bands corresponds to two of the offspring that are phenotypically normal?



A I only

B II only

C I and III

D II and IV

[Turn Over

38 The statements are about the preparation and application of DNA libraries.

1 A cDNA library allows the study of the functions of introns of specific genes
2 A genomic library enables detection of genes that, in the host, have no detectable level of expression.
3 Alternative splicing can be studied using a cDNA library
4 The preparation of a genomic DNA library requires restriction enzyme, reverse transcriptase and DNA ligase

Which statements are correct?

A 1, 2 and 4

B 1 and 4 only

C 2, 3 and 4

D 2 and 3 only

39 Stem cells are found in many tissues that require frequent cell replacement such as the skin, the intestine or the blood.

However, within their own environments, a bone marrow cell cannot be induced to produce a skin cell and a skin cell cannot be induced to produce a bone marrow cell.

Which statement explains this?

A Different stem cells have only the genes required for their particular cell line.

B Genes not required for a particular cell line are methylated.

C Genes not required for a particular cell line are removed using restriction enzymes.

D mRNA that is not required for a particular cell line is destroyed.

40 Gene therapy is used to treat inherited diseases such as cystic fibrosis. Some of the scientific and ethical concerns about gene therapy are listed below.

1 Most gene therapy must be repeated in succeeding generations since germ cells are not involved.

2 Genetically modified organisms used in producing the gene therapy may escape into the environment with unforeseen consequences.

3 Putting genes into the germ line affects subsequence generations and is banned in many countries.

4 The same techniques for treating serious, life-threatening conditions may be used to try to change other things such as intelligence and skin colour.

5 Viral vectors, such as those used in the treatment of cystic fibrosis, have been known to produce harmful side-effects.

Which row identifies the types of concern?

	Scientific concerns	ethical concerns
A	1 and 2	3, 4 and 5
B	2 and 4	1, 3 and 5
C	1 and 5	2, 3 and 4
D	3, 4 and 5	1 and 2

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PIONEER JUNIOR COLLEGE
JC2 Preliminary Examinations
In preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME									
CT GROUP	1	5	S			INDEX NUMBER			

BIOLOGY 9648/02

Paper 2 Core Paper **16 September 2016**

2 hours

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your name, CT class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

All working for numerical answers must be shown.
The use of an approved scientific calculator is expected, where appropriate.

At the end of the examination, fasten all your work securely together in 2 separate section A and B.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	**80**
1	
2	
3	
4	
5	
6	
7	
8	
Section B	**20**
9 / 10	
Total	

This document consists of **25** printed pages including the cover page and **1** blank page.

[Turn Over

Section A

Answer **all** questions in this section.

1 Fig 1.1 shows some plant cells undergoing mitosis.

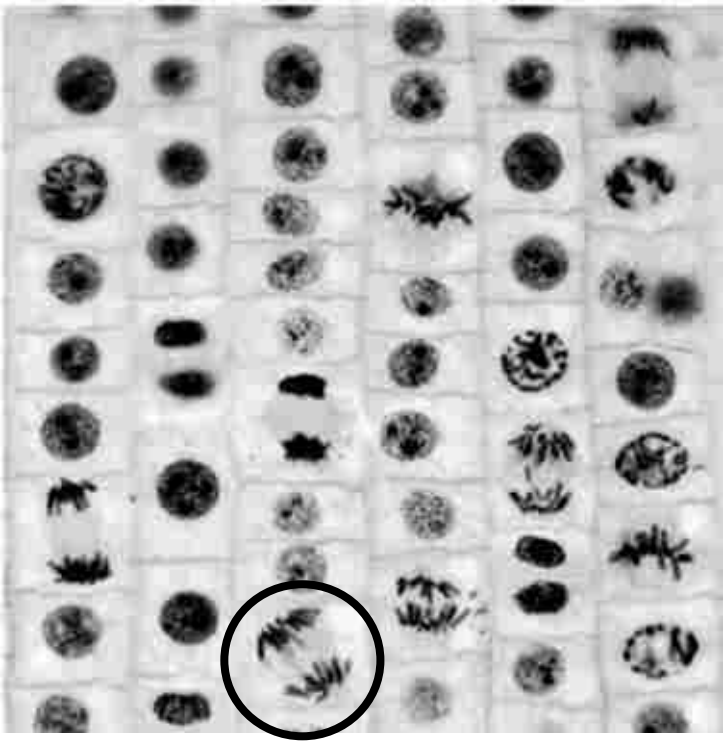

Fig. 1.1

Fig. 1.2 shows the changes in amount of DNA at different stages of the plant life cycle.

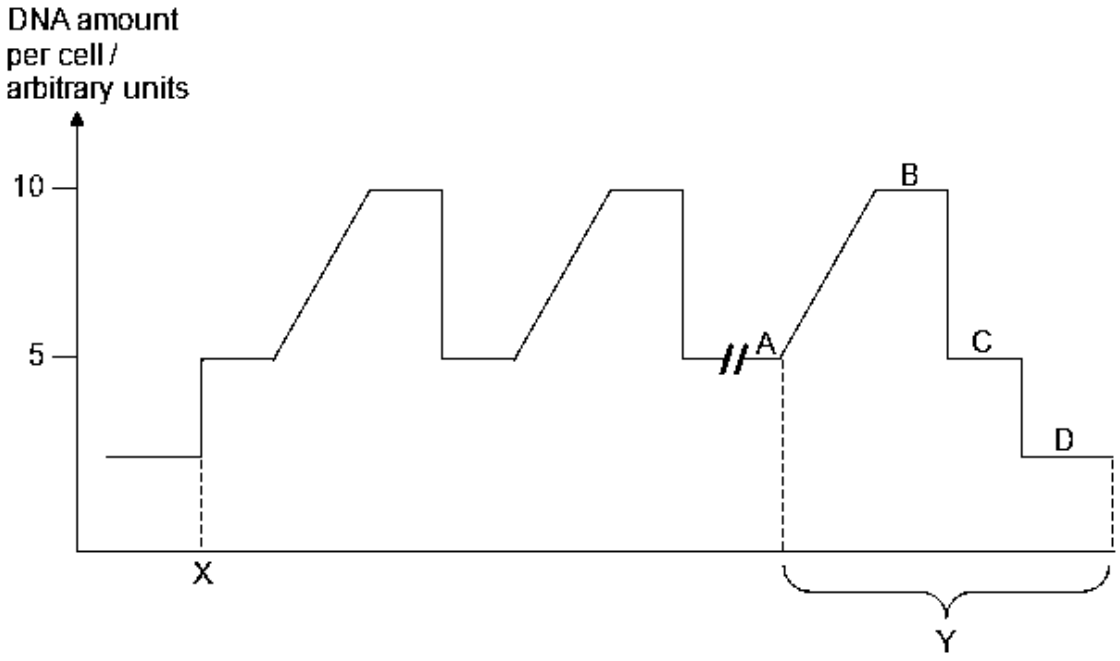

Fig. 1.2

(a) Mark out with an arrow ↓ clearly on Fig. 1.2 which part of the graph corresponds to the stage circled in Fig. 1.1. [1]

(b) From stages **A** to **D** in Fig. 1.2, state all stages

(i) that has/have the same number of chromosomes as shown in Fig. 1.1;

…… [1]

(ii) that has/have the **different** number of chromosomes as shown in Fig. 1.1;

…… [1]

(c) Explain the significance of the stages in **Y** in genetic variation.

……

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…… [4]

(d) Explain the significance of the event occurring at **X**.

……

……

…… [1]

[Total: 8]

[Turn Over

2 Fig. 2.1 shows a bacterial cell during protein synthesis.

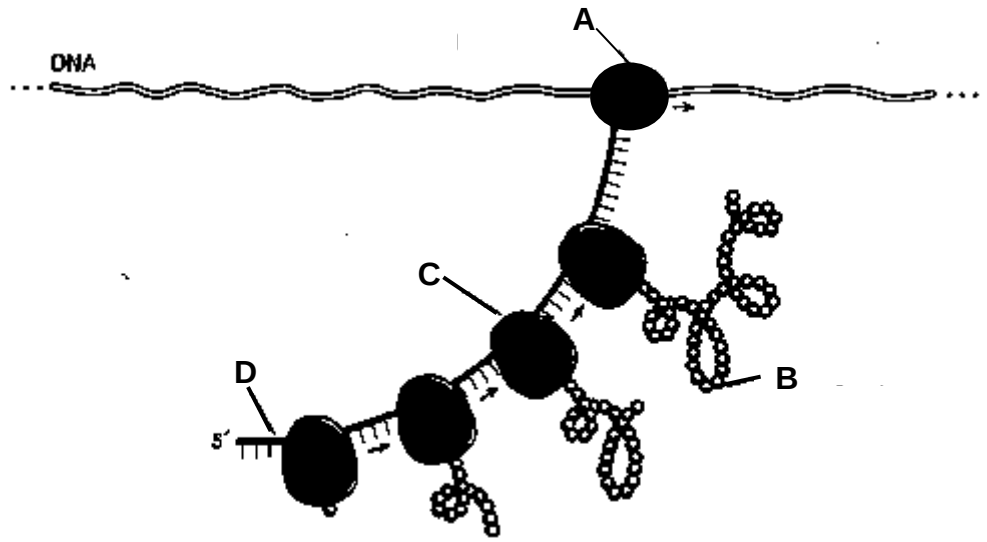

Fig. 2.1

(a) Identify **A** – **D**.

A ……

B ……

C ……

D …….. [2]

(b) With reference to Fig. 2.1, suggest evidences that indicate that these processes occurred in a prokaryotic cell.

……

……

…….. [1]

(c) Briefly describe how structure **A** differs from structure **C**.

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…….. [2]

(d) Activated tRNA can be seen entering structure **C**. Explain how the correct amino acid is joined to a tRNA.

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…….. [4]

[Total: 9]

[Turn Over

3 **(a)** Fig. 3.1 shows the viral load in the blood and CD4+ T cell counts over the course of a typical HIV infection.

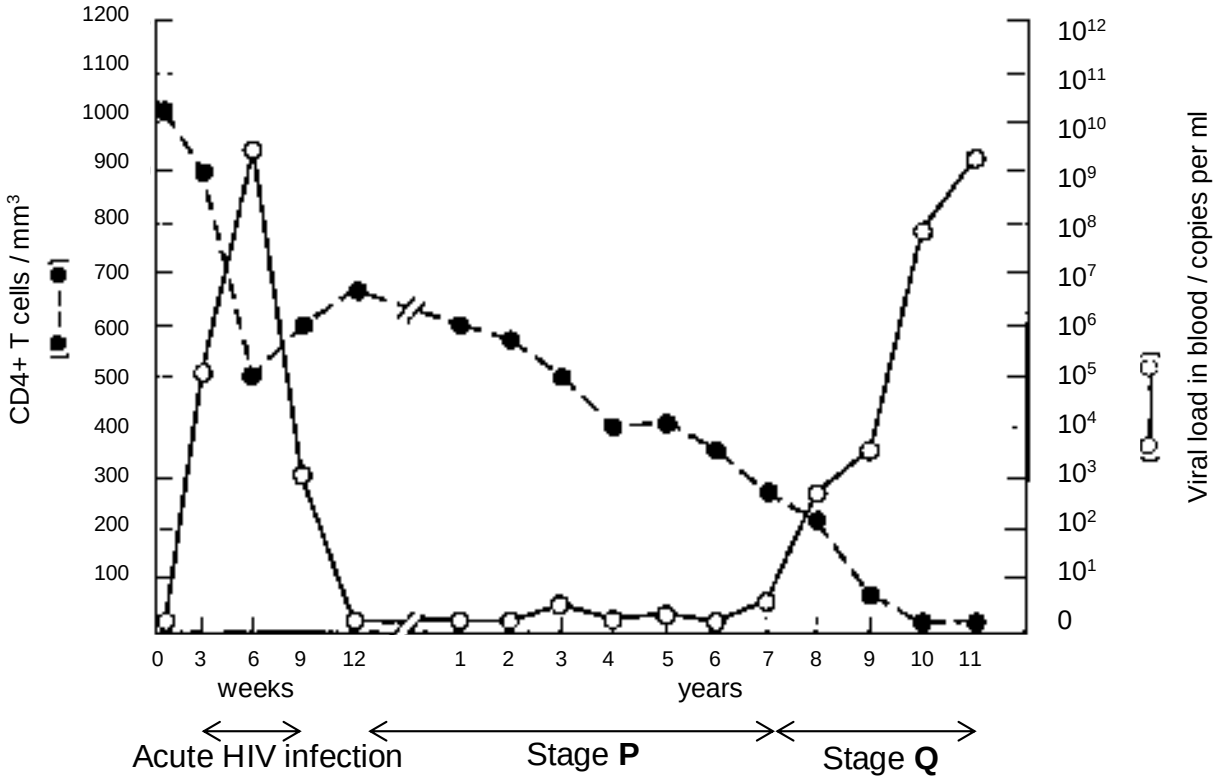

Fig. 3.1

(i) Many cells in Stage **P** were found to contain viral DNA. Explain the significance of Stage **P**.

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…… [2]

(ii) In an experiment, it was found that the concentration of the enzyme, histone deacetylase (HDAC) in infected cells at Stage **P** was higher than in infected cells not at Stage **P**.

Suggest an explanation for the presence of abnormally high levels of HDAC in infected cells at Stage **P**.

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…….. [2]

(iii) With reference to Fig. 3.1, describe and explain the changes in the amount of HIV proteins and CD4+ T cells count during Stage **Q**.

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…….. [2]

(iv) Suggest how viral load may be measured in the blood.

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…….. [1]

[Turn Over

(b) HIV enters a CD4+ T cell. Gp120 binds to CD4 receptor on host cell surface membrane. Gp120 undergoes conformational change enabling gp120 to bind to co-receptors CCR5 on host cell membrane. Interaction between gp120 and co-receptor brings about conformational change to gp41 on viral envelop leads to fusion of HIV envelope to the host cell surface membrane, gaining entry.

Fig. 3.2 shows a CCR5 co-receptor, which is a protein.

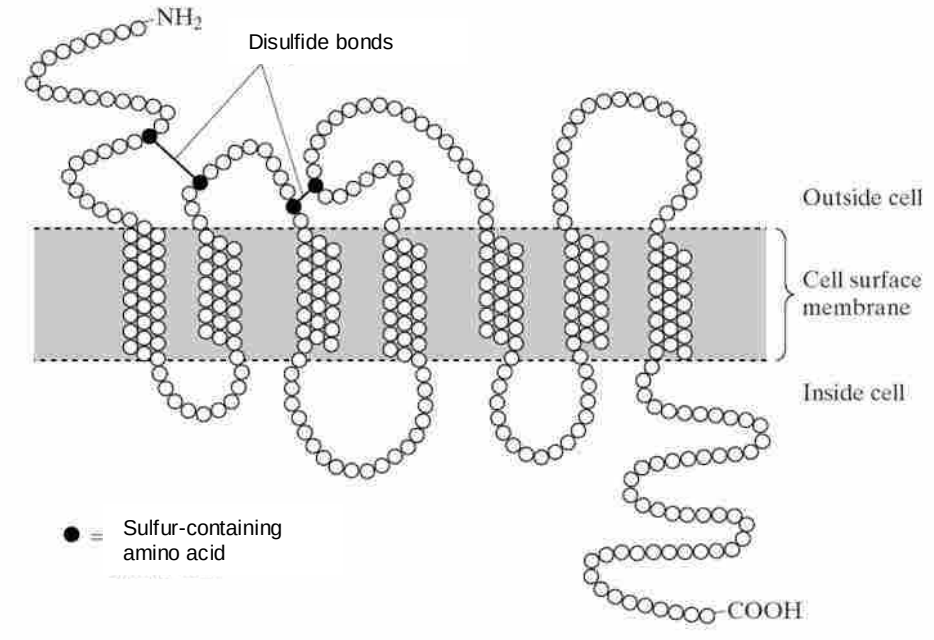

Fig. 3.2

Using information from Fig. 3.2, describe the protein structure of the CCR5 co-receptor.

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…….. [2]

(c) Integrase is one of the key targets for anti-retroviral therapy. An example of an anti-retroviral drug that acts on integrase is raltegravir. Fig. 3.3 shows the normal reaction catalysed by integrase, and Fig. 3.4 shows the effect of raltegravir on integrase.

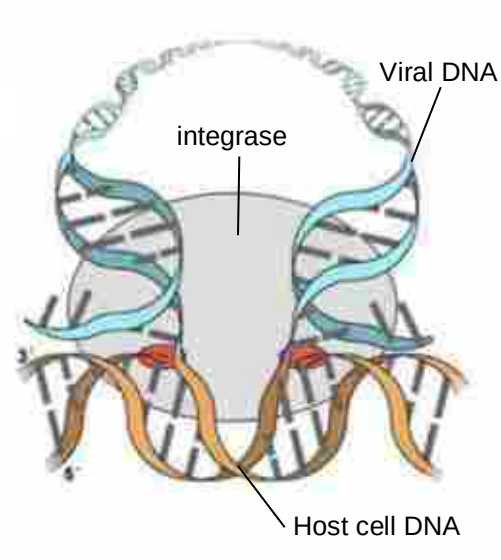

Fig. 3.3

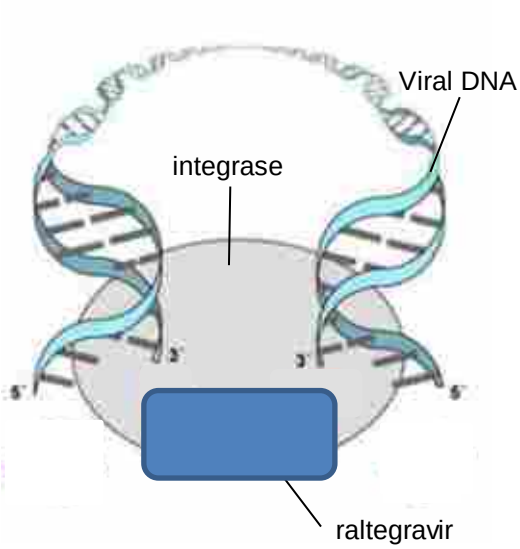

Fig. 3.4

Based on Fig. 3.3 and Fig. 3.4, describe the mode of action of raltegravir on integrase.

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…….. [2]

[Total: 11]

[Turn Over

4 "Cancer is a disease of the genome, triggered by the accumulation of genetic errors that eventually transform a normal cell into a tumour cell. Such mutations might inactivate genes that normally oppose tumour development, or activate genes that drive cell growth or interfere with cell differentiation or death.

This leads to the 2 classes of genes which are responsible for cancer formation."

Nature **417**, 906-907 (June 2002)

"Cancer is largely a disease of older people."

Nature Reviews Cancer **5**, 655-662 (August 2005)

(a) Using the above information, explain why cancer usually occurs in older individuals.

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…….. [2]

(b) With specific named examples, distinguish between the 2 classes of genes stated in **line 5**.

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…….. [3]

Fig. 4.1 illustrates the Ras–Braf–MAPK (mitogen-activated protein kinase) signalling pathway, to control cell proliferation or differentiation by changes in gene expression. Signal-transduction genes such as Braf and those of the Ras family, which encode components of the MAPK pathway, are frequently mutated in cancers.

Extracellular signals (growth factors) that activate one of two types of receptor — receptor tyrosine kinases and G-protein-coupled receptors — can result in the activation of Ras, leading to activation of Braf and the downstream cascade

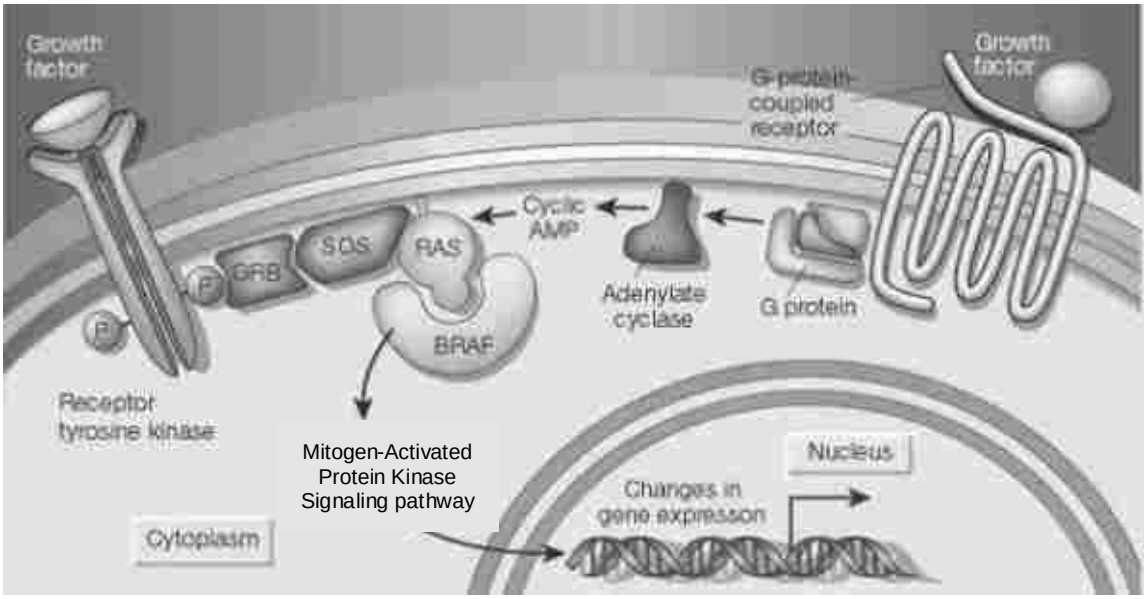

Fig. 4.1

(c) With reference to Fig. 4.1,

(i) describe how Ras protein can be activated by **one** of the growth factors.

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…….. [4]

[Turn Over

(ii) describe how Ras may contribute towards the development of cancer.

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…… [3]

[Total: 12]

5 Fig. 5.1 shows the electron micrograph of a chloroplast with structures **X**, **Y** and **Z** labelled.

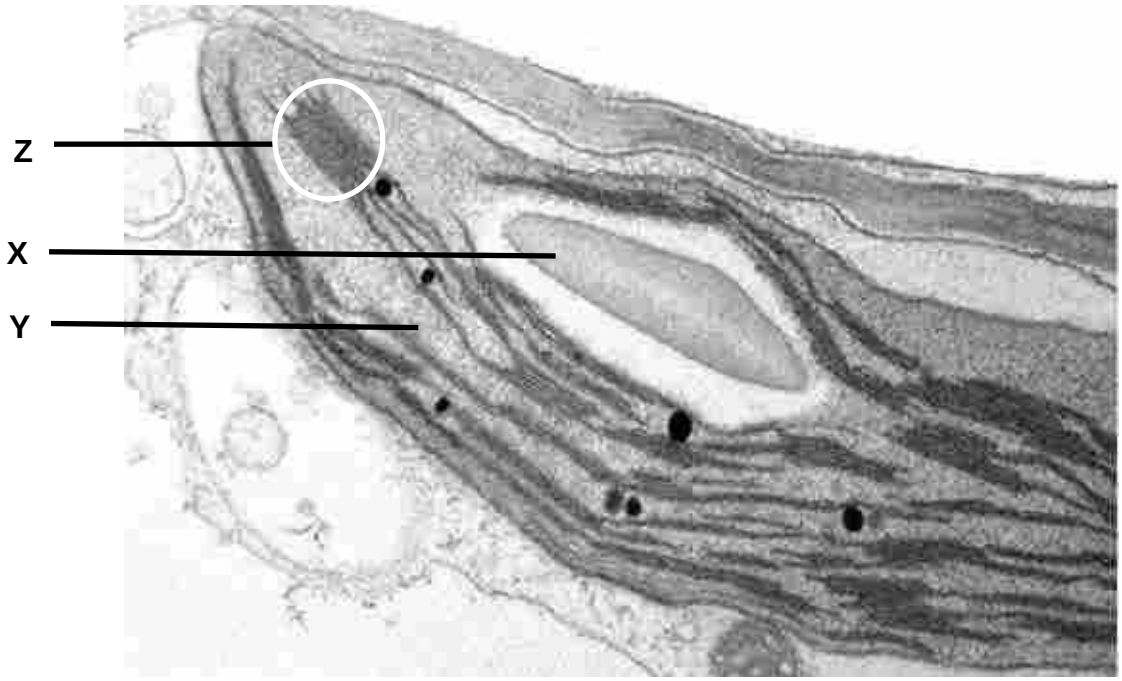

Fig. 5.1

(a) (i) Identify structures **X** and **Y.**

X ……

Y …….. [2]

(ii) Explain how **Z** is adapted to carry out photophosphorylation.

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…….. [2]

[Turn Over

(b) Rubsico is an important enzyme responsible for carbon fixation in the Calvin cycle. As Rubisco has an optimum pH of 9, it is most active during the daytime when the pH in the stroma is high.

Explain why Rubisco is most active during the daytime.

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…….... [2]

A process known as photorespiration also takes place in photosynthetic cells. In this process, oxygen competes with carbon dioxide for the active site of the enzyme Rubisco.

Fig. 5.2 outlines the process of photorespiration.

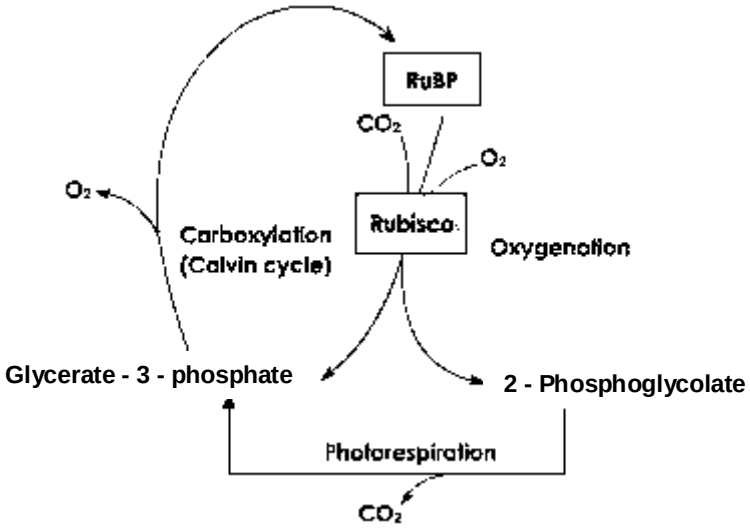

Fig. 5.2

(c) (i) Describe and explain the effects of an increase in oxygen concentration on photosynthesis.

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…… [3]

(ii) Suggest why the process outlined in Fig. 5.2 is known as photorespiration.

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…… [1]

[Total: 10]

[Turn Over

6 An inbred variety of maize, **A**, with finely striped leaves was found to have high resistance to the fungus that causes the disease, corn leaf blight.

Plants of variety **A** were crossed with another inbred variety of maize, **B**, which had entirely green leaves and low resistance to the fungus. All the F_1 generation had entirely green leaves and low resistance.

The above F_1 generation was test crossed with variety **A** and yielded the following results:

finely striped leaves and high resistance	80
finely striped leaves and low resistance	20
entirely green leaves and high resistance	22
entirely green leaves and low resistance	78

(a) A chi-squared test was performed on the results of the cross to determine if the results of the test cross depart significantly from the expected ratio. Calculate the χ^2 value using the formula provided below.

Formula for χ^2 calculation

$$\chi^2 = \Sigma \frac{(O-E)^2}{E} \qquad v = c - 1$$

where Σ = 'sum of…'

v = degrees of freedom
c = number of classes
O = observed 'value'
E = expected 'value'

χ^2 value: …… [1]

Table 6.1

	probability, p				
degree of freedom	0.10	0.05	0.02	0.01	0.001
1	2.31	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(b) Using Table 6.1, explain the conclusion drawn from the χ^2 test to determine if the observed numbers conformed to the expected.

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…….. [3]

[Turn Over

(c) Using the following symbols:

G	entirely green leaf	**g**	finely striped leaf
R	low resistance	**r**	high resistance;

Draw a genetic diagram to show the actual results of the test cross.

[4]

[Total: 8]

7 **(a)** Fig. 7.1 is an electron micrograph of a mitochondrion in a neurone.

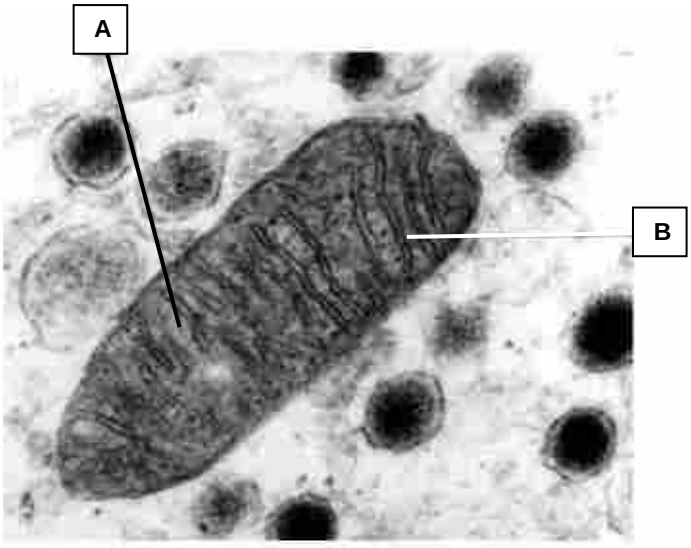

Fig. 7.1

Two stages of respiration occur in mitochondria. These are the Krebs cycle and oxidative phosphorylation.

(i) Complete the table below by naming the structures labelled **A** and **B** and stating which of the stages of respiration occur in each.

	Name of structure	Stage of respiration
A	…… ..... ……	…… ..... ……
B	…… ..... ……	…… ..... ……

[2]

[Turn Over

(ii) Explain the need for mitochondria along the axon in terms of nerve impulse conduction.

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…… [3]

(b) Serotonin is a neurotransmitter which is produced by certain neurones in the brain. One of its effects is to increase the activity of sensory neurones in the brain. It also usually improves a person's mood and keeps the person awake. Fig. 7.2 shows a synapse at which serotonin is the neurotransmitter.

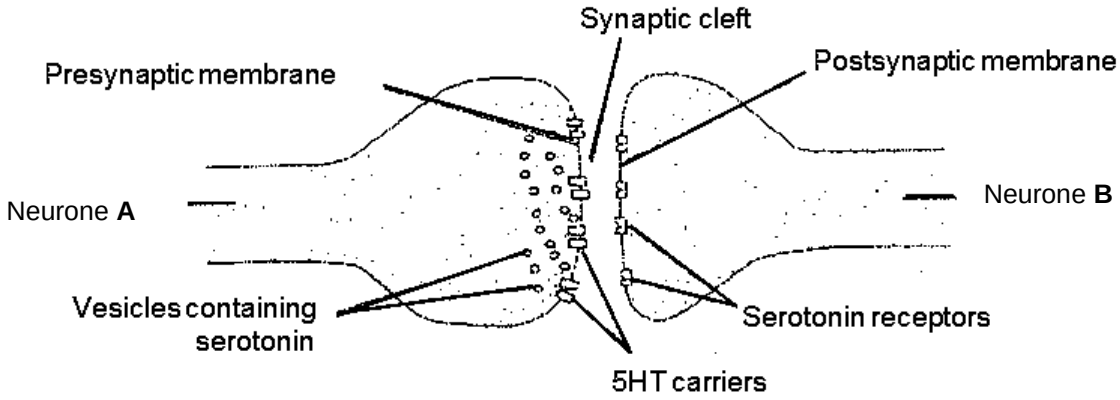

Fig. 7.2

(i) Describe how the neurotransmitter is released into the synaptic cleft.

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…… [2]

(ii) Explain how the release of the neurotransmitter, serotonin, results in the transmission of an impulse from neurone **A** to neurone **B**.

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…….. [2]

(iii) Suggest why nerve impulse can only travel in one direction across a synapse.

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…….. [1]

[Total: 10]

[Turn Over

8 There are over 40 Galapagos Islands including the small and isolated island named Daphne Major.

Studies were made every year from 1970 to 1989 on the beak size of the island's population of ground finch, *Geospiza fortis*, by measuring the beak length of every bird (Fig. 8.1). Larger finches with larger beaks are better at opening large seeds.

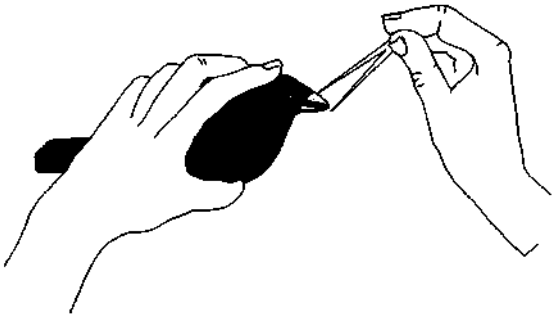

Fig. 8.1

From 1976 to 1978 there was a drought and only 15% of the ground finches survived and these did not breed during drought years. The most conspicuous feature of the survivors of the drought years was their large beak size.

During normal years, many drought-intolerant grasses and herbs produce an abundance of small seeds. A few other drought-tolerant plants produce a much smaller number of large seeds which are not normally eaten.

(a) Describe how environmental factors act as forces of natural selection, during drought years, on the beak size of finches.

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……... [4]

(b) Suggest the role of the islands in the evolution of thirteen species of Darwin finches now found on the Galapagos Islands.

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…….... [2]

Molecular analysis was carried out on the mitochondrial DNA (mtDNA) sequences of the Galapagos Islands finches and the Cocos finch found on the island of Cocos, 830 km to north-east of the Galapagos Islands. Using mtDNA analysis data, a map showing the phylogeny of these finches was constructed as shown below in Fig. 8.2.

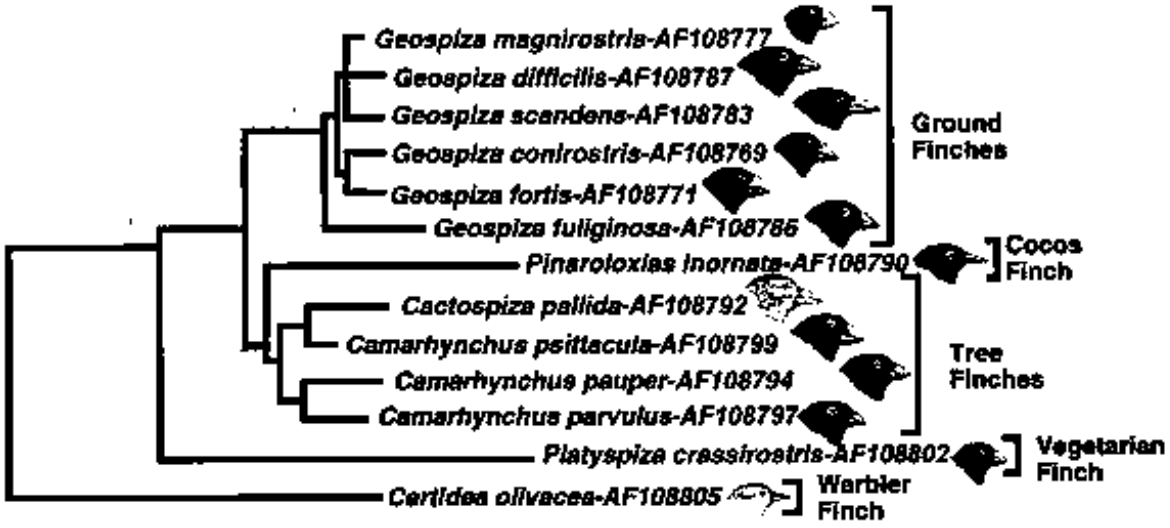

Fig. 8.2

(c) Explain how DNA sequences can be used to determine evolutionary relatedness between species.

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…….. [2]

[Turn Over

(d) Describe the advantages of using nucleotide data such as mtDNA in classifying organisms.

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…….. [2]

Differences in the *cytochrome b* DNA sequence of several finches' species from Galapagos Islands and island of Cocos were measured and plotted against time since divergence from the primitive ancestor (MYA) as seen in Fig. 8.3.

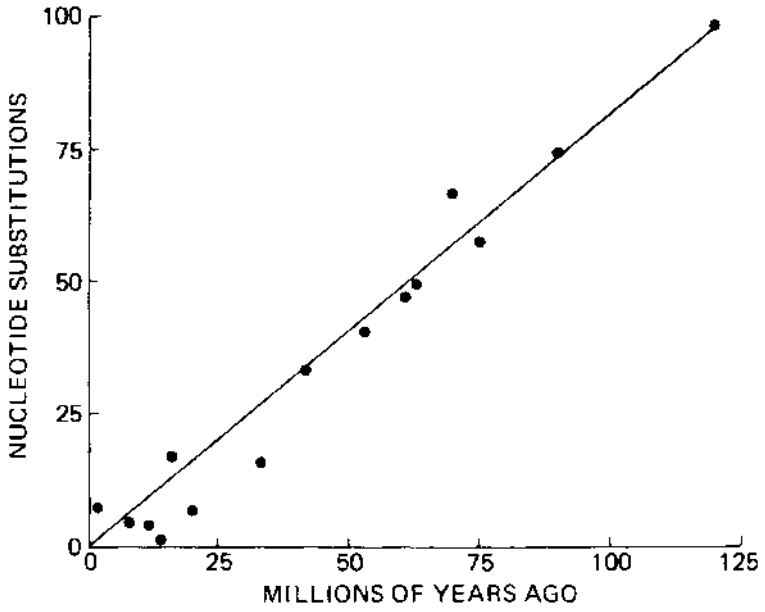

Fig 8.3

(e) Describe how these differences support the neutral theory of molecular evolution.

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……

…….. [2]

[Total: 12]

Section B

Answer **one** question.

Write your answers to this question on the separate answer paper provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

9 **(a)** Compare and contrast between glucagon and glycogen. [4]

(b) Explain what is meant by primary, secondary, tertiary, and quaternary structure of a named protein. [8]

(c) Describe the main properties of an enzyme and discuss their mode of action. [8]

[Total: 20]

10 **(a)** With reference to the islets of Langerhans, describe what is meant by an endocrine gland. [7]

(b) Explain how the blood glucose concentration is regulated by insulin and glucagon. [8]

(c) Describe how the endocrine system differs from the nervous system. [5]

[Total: 20]

[Turn Over

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PIONEER JUNIOR COLLEGE
JC2 Preliminary Examinations
In preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME									
CT GROUP	1	5	S			INDEX NUMBER				

BIOLOGY 9648/02

16 September 2016

Paper 2 Core Paper **2 hours**

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your name, CT class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

All working for numerical answers must be shown.
The use of an approved scientific calculator is expected, where appropriate.

At the end of the examination, fasten all your work securely together in 2 separate section A and B.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	**80**
1	
2	
3	
4	
5	
6	
7	
8	
Section B	**20**
9 / 10	
Total	

This document consists of **26** printed pages including the cover page.

[Turn Over

Section A

Answer **all** questions in this section.

1 Fig 1.1 shows some plant cells undergoing mitosis.

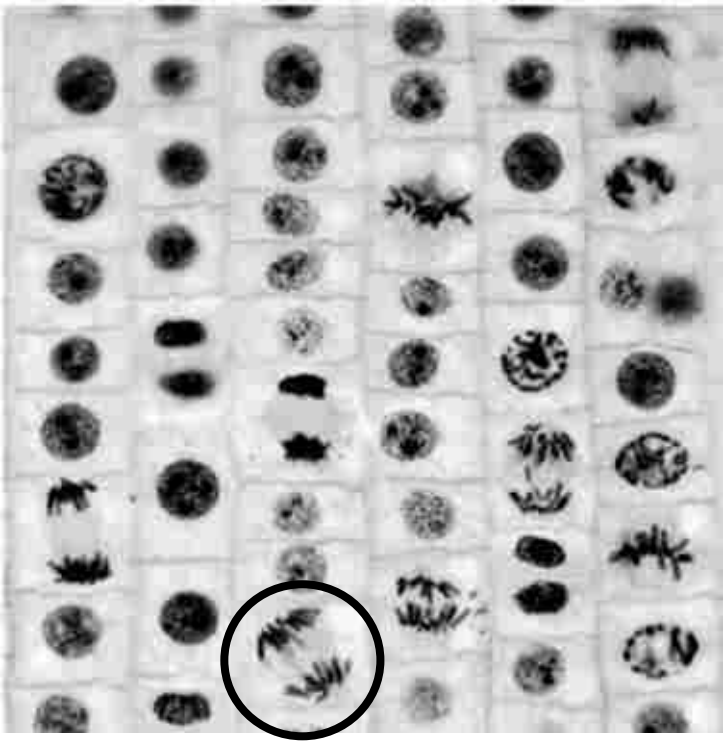


Fig. 1.1

Fig. 1.2 shows the changes in amount of DNA at different stages of the plant life cycle.

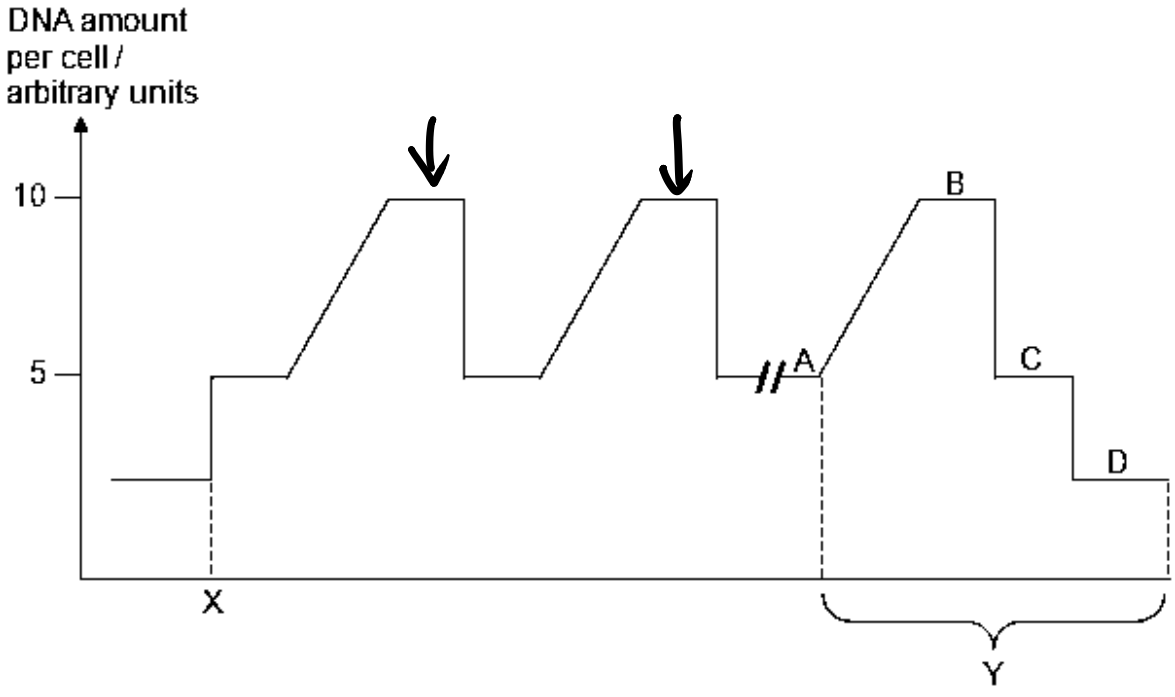


Fig. 1.2

(a) Mark out with an arrow ↓ clearly on Fig 1.2 which part of the graph corresponds to the stage circled in Fig. 1.1. [1]

Accept all part of line except the corners (accept one arrow on either plateau, but not on the Meiosis plateau)

(b) From stages **A** to **D** in Fig. 1.2, state all stages

(i) that has/have the same number of chromosomes as shown in Fig. 1.1; [1]

A and B;;

(ii) that has/have the **different** number of chromosomes as shown in Fig. 1.1; [1]

C and D;;

(c) Explain the significance of the stages in **Y** in genetic variation. [4]

a) Crossing over between non-sister chromatids of homologous chromosomes/bivalents/homologous pair takes place during prophase I*;;
OR
where equivalent portions of non-sister chromatids of homologous chromosomes break and rejoin during prophase I;;

b) gives rise to new combination of alleles / mixing of alleles from both parental chromosomes which creates genetic variation in gametes;;
A: new linkage groups in place of new combination of alleles

c) Independent assortment of homologous chromosomes/bivalents/homologous pair at metaphase plate during metaphase I and their subsequent separation during anaphase I;;
OR
Homologous chromosomes are arranged independently of other homologous pairs at metaphase plate during metaphase I and their subsequent separation during anaphase I;;

d) results in 2^n possible (types of) gametes where n is the number of homologous pairs;;
OR
Gametes with different combinations of parental (maternal and paternal) chromosomes;;

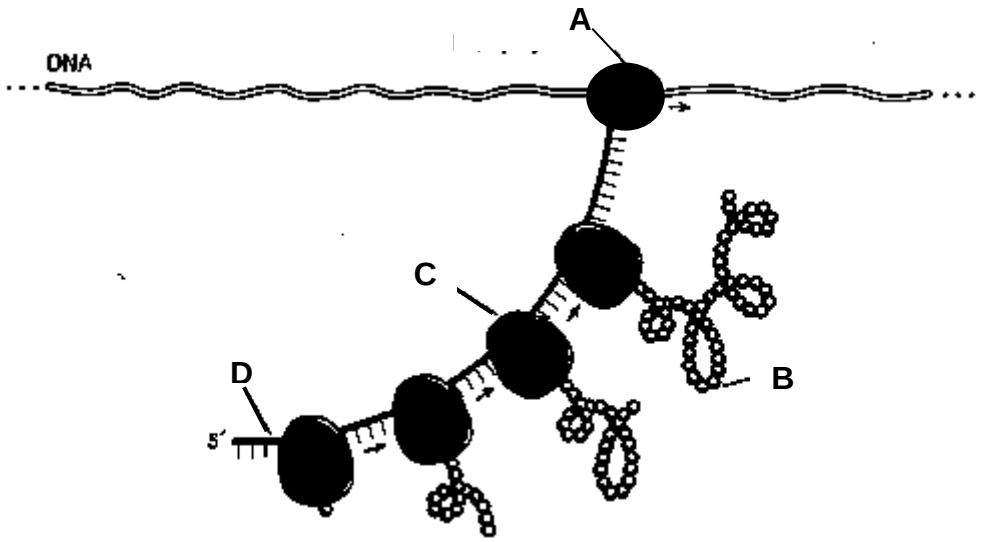
(d) Explain the significance of the event occurring at **X**. [1]

a) X refers to fertilisation*; Or random fusion of gametes* results in
b) greater variation/varied offspring with different genotypes and phenotypes;
OR
Restoration of the diploid number of chromosomes;

[Total: 8]

[Turn Over

2 Fig. 2.1 shows a bacterial cell during protein synthesis.



(a) Identify **A** – **D**. [2]

A - RNA polymerase
B- growing polypeptide chain
C - ribosome
D - mRNA

(b) With reference to Fig. 2.1, suggest evidences that indicate that these processes occurred in a prokaryotic cell. [1]

a) Presence of polyribosomes/ polysomes;
b) Transcription and translation occur simultaneously;
c) No membrane separates transcription and translation; (OWTTE).
Any 2

(c) Briefly describe how structure **A** differs from structure **C**.[2]

Structure C is ribosome, Structure A is RNA polymerase
a) Ribosome composed of ribosomal RNA and proteins while RNA polymerase is a protein made up of amino acids;;
b) RNA polymerase is single unit while ribosome consists of 2 subunits (1 large and 1 small ribosomal subunit);;
c) Ribosomes have 3 binding sites (APE) while RNA polymerase has 1 active site present;;

(d) Activated tRNA can be seen entering structure **C**. Explain how the correct amino acid is joined to a tRNA. [4]

a) The process that joins the correct amino acid to the tRNA is known as amino acid activation.
b) Attachment of amino acid to a specific tRNA is catalysed by an enzyme called aminoacyl tRNA synthetase
c) These enzymes have active sites which will recognize and fit only a specific combination of amino acid and anticodon of a tRNA that are complementary to the active sites
d) As there are 20 commonly found amino acids, there will be at least 20 different aminoacyl tRNA synthetases.
e) The synthetase enzyme catalyses the covalent attachment of the amino acid to its tRNA
f) In a energy releasing process driven by hydrolysis of ATP.
g) The resulting aminoacyl tRNA complex is released from the enzyme and will deliver its amino acid to the growing polypeptide chain on a ribosome.
h) ensures that correct amino acid as specified by the genetic code is matched to the correct tRNAs

[Total: 9]

3 **(a)** Fig. 3.1 shows the viral load in the blood and CD4 T cell counts over the course of a typical HIV infection.

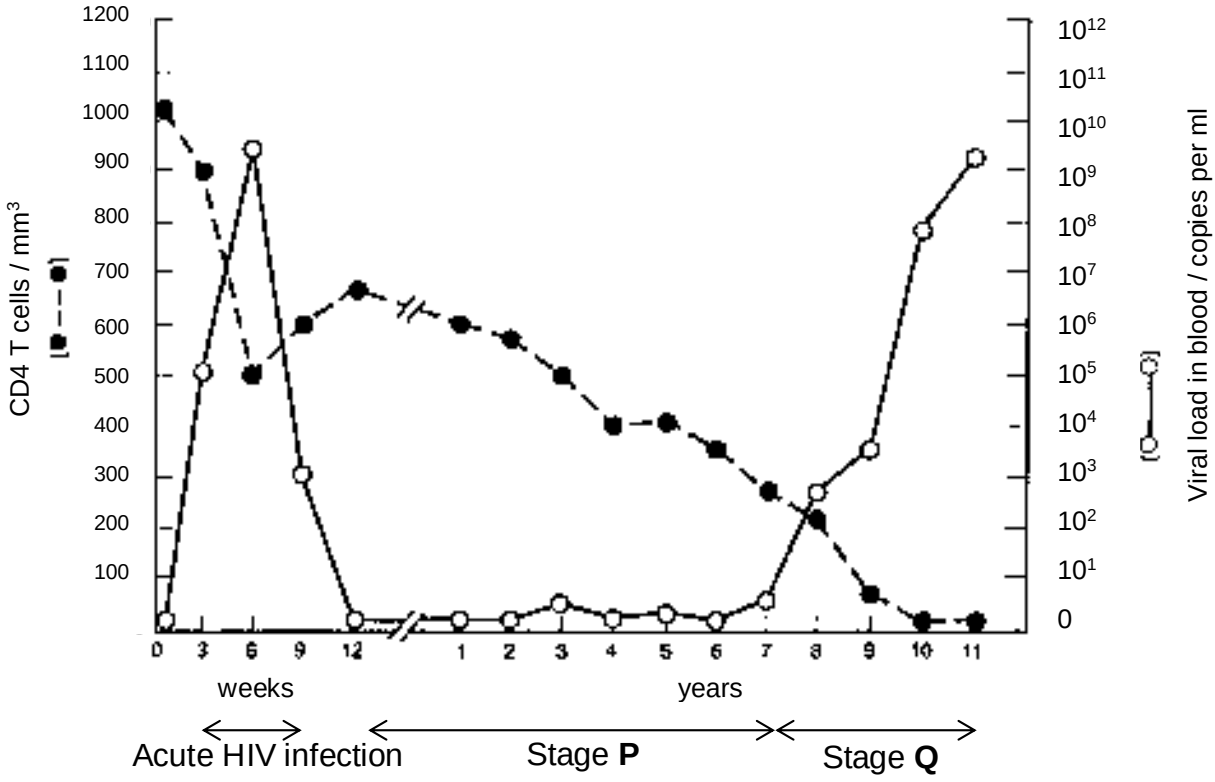


Fig. 3.1

(i) Many cells in Stage **P** were found to contain viral DNA. Explain the significance of Stage **P**. [2]

a) Double stranded DNA reverse transcribed from the viral RNA ;
b) integrates into the host cell DNA via integrase ;
c) So that the viral DNA (encoding viral proteins) can replicate along together with the host cell DNA;
d) Idea of results in production of more virions that carries the viral DNA (hence more viral progeny can be produced upon activation of the host cells) ;

(ii) In an experiment, it was found that the concentration of the enzyme, histone deacetylase (HDAC) in infected cells at Stage P was higher than in infected cells not at Stage **P**.

Suggest an explanation for the presence of abnormally high levels of HDAC in infected cells at Stage **P**. [2]

a) Deacetylation of lysine residues in histone tails become positively charged
b) results in increased affinity of the histone complex for the DNA molecule. Histone deacetylase cause chromatin to be more condensed / compacted/ packed more tighter
c) Prevents transcription and translation of viral proteins during stage P
d) Viral proteins not present on infected cells → not detected and destroyed by immune system;

(iii) With reference to Fig. 3.1, describe and explain the changes in the amount of HIV proteins and CD4+ T-cells count during Stage **Q**. [2]

a) From 7 to 11 years after infection, viral proteins increases from 5 copies per ml to $10^9/10^{10}$ copies per ml because viral proteins are actively transcribed from integrated HIV DNA/provirus to form new viruses;;
b) CD4 T cells decrease from 300 cells per mm^3 to 10 cells per mm^3 as budding of large amount of virions from the cell surface of CD4 T cells may disrupt the cell membrane sufficiently for cell to die / Hijacking of cellular machinery and resources towards producing new virions disrupts normal activities needed for cell survival, eventually causing cell death.;;

(iv) Suggest how viral load may be measured in the blood. [1]

a) Via detection of HIV RNA in blood sample;; OR
b) Via detection of viral proteins ;;

(b) HIV enters a CD4 cell. Gp120 binds to CD4 receptor on host cell surface membrane. Gp120 undergoes conformational change enabling gp120 to bind to co-receptors CCR5 on host cell membrane. Interaction between gp120 and co-receptor brings about conformational change to gp41 on viral envelop leads to fusion of HIV envelope to the host cell surface membrane, gaining entry.

Fig. 3.2 shows a CCR5 co-receptor, which is a protein.

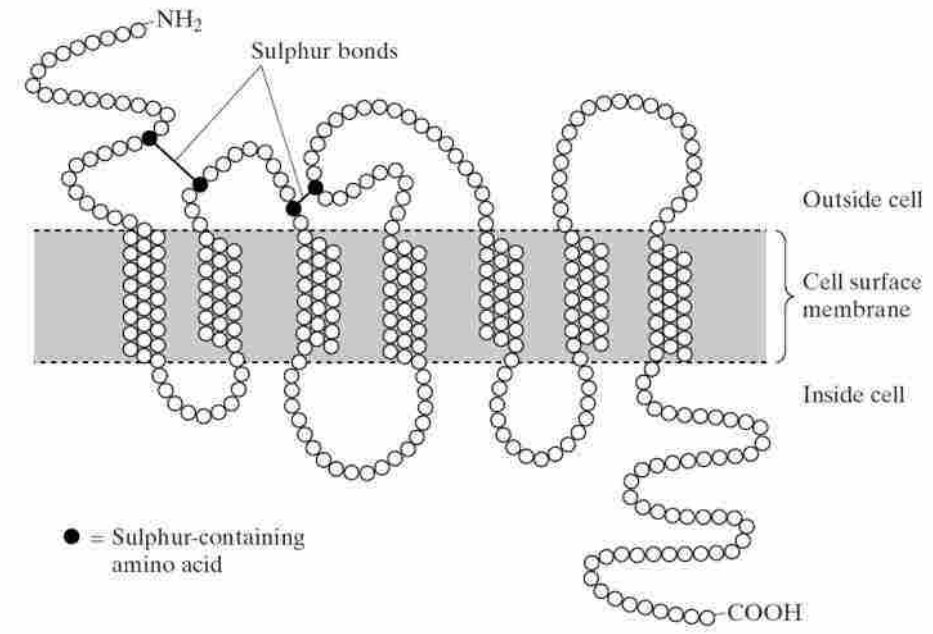


Fig. 3.2

Using information from Fig. 3.2, describe the protein structure of the CCR5 co-receptor. [2]

a) Primary Structure – sequence of amino acid in polypeptide chain;
b) Secondary structure consist of folding/helix in membrane involving mainly H-bonds between carbonyl and amino group;
c) Tertiary structure – Loops outside membrane and involves R group interactions;
d) Role of disulphide bonds present to maintain the tertiary structure of the protein;

(c) Integrase is one of the key targets for anti-retroviral therapy. An example of an anti-retroviral drug that acts on integrase is raltegravir. Fig. 3.3 shows the normal reaction catalysed by integrase, and Fig. 3.4 shows the effect of raltegra vir on integrase.

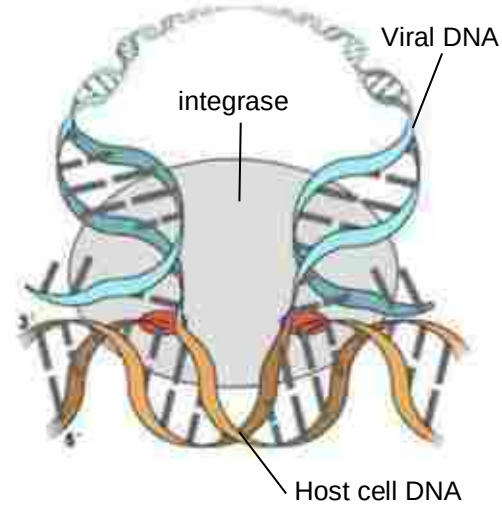


Fig. 3.3

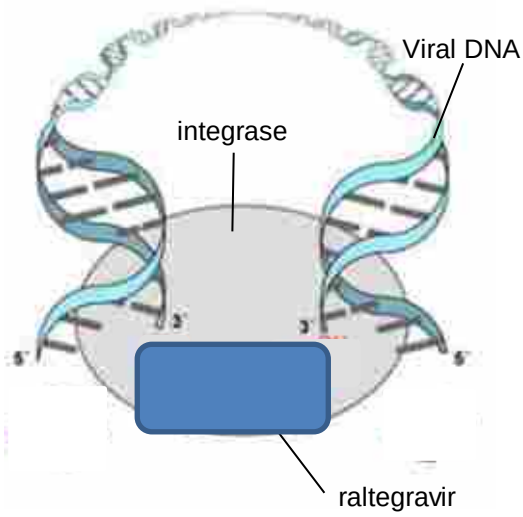


Fig. 3.4

Based on Fig. 3.3 and Fig. 3.4, describe the mode of action of raltegravir on integrase. [2]

a) **Raltegravir is a competitive inhibitor;**
b) **It binds to the active site of integrase;**
c) **Prevents integrase from binding to dsDNA;**
d) **double stranded DNA will not be incorporated into the host cell's DNA as a provirus (by integrase);**

[Total: 11]

4 "Cancer is a disease of the genome, triggered by the accumulation of genetic errors that eventually transform a normal cell into a tumour cell. Such mutations might inactivate genes that normally oppose tumour development, or activate genes that drive cell growth or interfere with cell differentiation or death.

This leads to the 2 classes of genes which are responsible for cancer formation."

Nature **417**, 906-907 (June 2002)

"Cancer is largely a disease of older people."

Nature Reviews Cancer **5**, 655-662 (August 2005)

(a) Using the above information, explain why cancer usually occurs in older individuals [2]

a) **a single mutation in the cell is not enough to cause the cell to be cancerous as cancer development is a multi-step process;**
b) **Time is required to accumulate mutations in many genes in the same cell for it to become fully cancerous;**
c) **Older individuals are exposed longer to mutagens over their lifetime;**
d) **Increasing the chance/probability of mutations occurring;**

(b) With specific named examples, distinguish between the 2 classes of genes stated in **line 5**. [3]

1 mark for both correct named examples
Any 2 differences

	Proto-oncogene (e.g. Ras gene)	Tumor Suppressor Gene (e.g. p53)
a) Primary function of gene product	stimulate normal cell division	prevent uncontrolled cell division
b) How does it attribute to the occurrence of cancer?	Over-activation (turn on) of proto-oncogenes→ oncogene →occurrence of cancer	Inactivation (turn off) of TSG →occurrence of cancer
c) Type of mutation and its consequence	Gain of function mutation → increase in the amount of gene product/ increase in the intrinsic activity of the gene product A mutation in only one allele of	Loss of function mutation →decrease in the amount/elimination of gene product, decrease in the activity of the gene products Mutations in both alleles of a

	a proto-oncogene, converting to an oncogene, is needed for the cell to lose growth control	**TSG are needed for the cell to lose growth control.**
d) Is inheritance involved?	**Majority of oncogenes develop from mutations in normal genes (proto-oncogenes) during the life of the individual** **→somatic mutations**	**Abnormalities of tumor suppressor genes can be inherited as well as acquired during the life of the individual.** **→Germline and somatic mutation.**

Fig. 4.1 illustrates the RAS–BRAF–MAPK (mitogen-activated protein kinase) signalling pathway, to control cell proliferation or differentiation by changes in gene expression. Signal-transduction genes such as Braf and those of the Ras family, which encode components of the MAPK pathway, are frequently mutated in cancers.

Extracellular signals (growth factors) that activate one of two types of receptor — receptor tyrosine kinases and G-protein-coupled receptors — can result in the activation of Ras, leading to activation of Braf and the downstream cascade

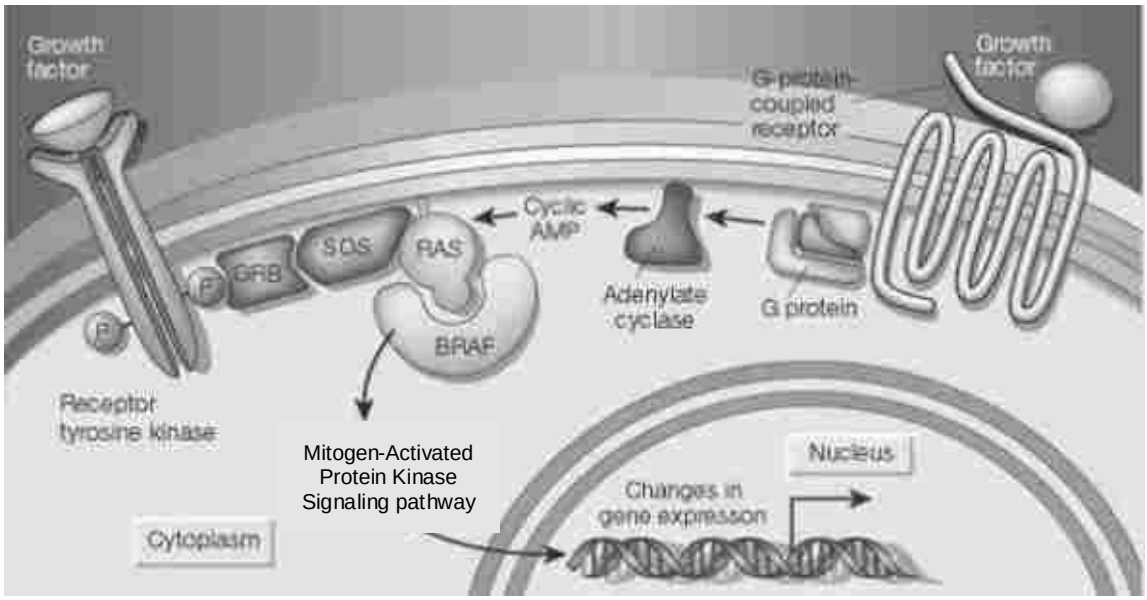


Fig. 4.1

(c) With reference to Fig. 4.1,

(i) Describe how Ras protein can be activated by **one** of the growth factors. [4]

a) Growth factor (ligand) binds to G-protein-coupled receptors, receptor undergoes change in conformation which binds to inactive G-protein;;
b) Causes a GTP to displace GDP on the G protein, activating it;;
c) Activated G protein binds to adenylate cyclase, activating it;;
d) Activated adenylate cyclase will catalyse the formation of cAMP from ATP, cAMP will trigger activation of Ras protein;;

OR

e) **Binding of growth factor causes two receptor polypeptides to associate, forming a dimer;;**
f) **Dimerisation activates the tyrosine kinase parts of both polypeptides → each add phosphates to tyrosines on the tail of the other polypeptide/resulting in autophosphorylation of the tyrosines on the tail of the other polypeptide;;**
g) **Activated tyrosine kinase is recognised by relay protein GRB which binds to phosphorylated tyrosine and undergoes structural change that activates it;;**
h) **Activated GRB will in turn allow SOS to bind and be activated, which will in turn bind to Ras protein and activate it;;**

(ii) Describe how Ras may contribute towards the development of cancer. [3]

a) **Single point-mutation of the *Ras* proto-oncogene could potentially lead to the production of a hyperactive Ras protein which is active even when growth factors are absent;;**
b) **Leading to an overactivation of Braf protein which could then overstimulate the mitogen-activated protein kinase signalling pathway;;**
c) **This may then lead to an increase in gene expression of growth factors/proteins which stimulate cell proliferation;;**

[Total: 12]

5 Fig. 5.1 shows the electron micrograph of a chloroplast with structures **X**, **Y** and **Z** labelled.

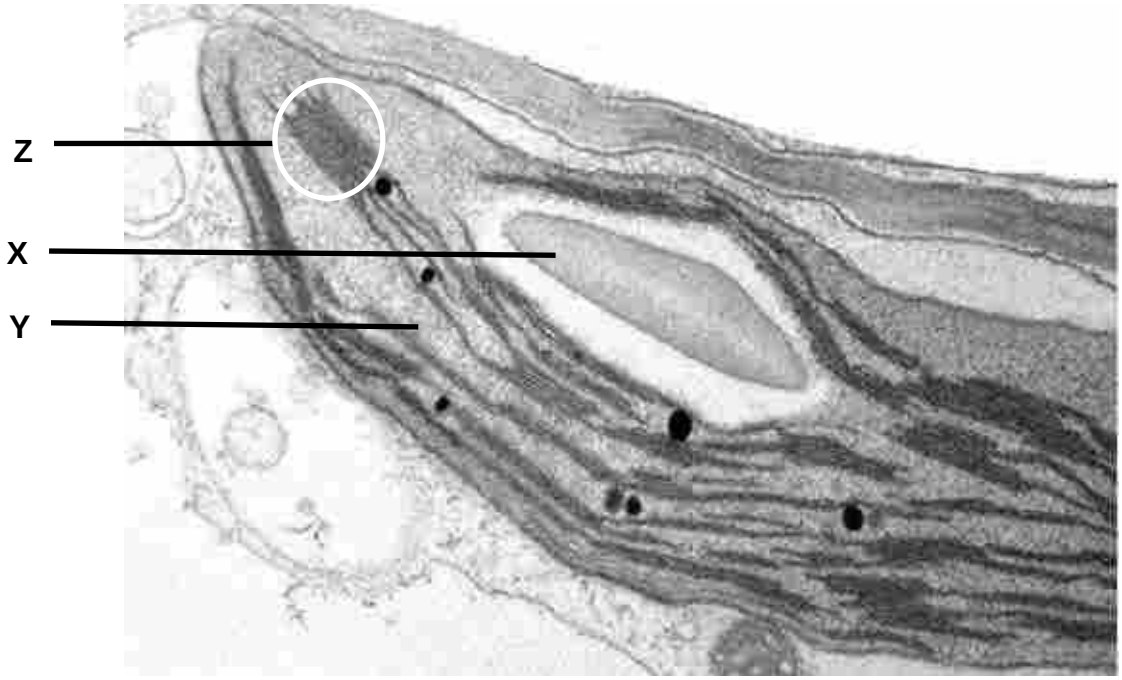


Fig. 5.1

(a) (i) Identify structures **X** and **Y.** [2]

X : Starch grain/granule **Y : stroma**

(ii) Explain how the **Z** is adapted to carry out photophosphorylation. [2]

a. Z, is made from a stack of thylakoid membranes, / provides a large surface area;;

b. **Allows for embedding of many photosynthetic pigments / photosystems / light harvesting complexes, for light, harvesting / absorption;;**
c. **The thylakoid membrane is impermeable to H^+ thus protons can only diffuse through stalked particles embedded in the membrane down its concentration gradient;;**

(b) Rubsico is an important enzyme responsible for carbon fixation in the Calvin cycle. As Rubisco has an optimum pH of 9, it is most active during the daytime when the pH in the stroma is high.

Explain why Rubisco is most active during the daytime. [2]

a. **In the daytime, presence of light cause photophosphorylation to occur;;**
b. **energy released from ETC is used to pump H+ / actively transport H+ from stroma into thylakoid space;;**
c. **(low H+ concentration in the stroma)→ reference to active site: the contact residues and/or catalytic residues in the active site are of the correct charge to bind the substrate molecules and catalyse the reaction respectively;;**
d. **OR Ionic bonds between R-groups are stabilized confirmation of active site (most) complementary to substrate**
e.

A process known as photorespiration also takes place in photosynthetic cells. In this process, oxygen competes with carbon dioxide for the active site of the enzyme Rubisco.

Fig. 5.2 outlines the process of photorespiration.

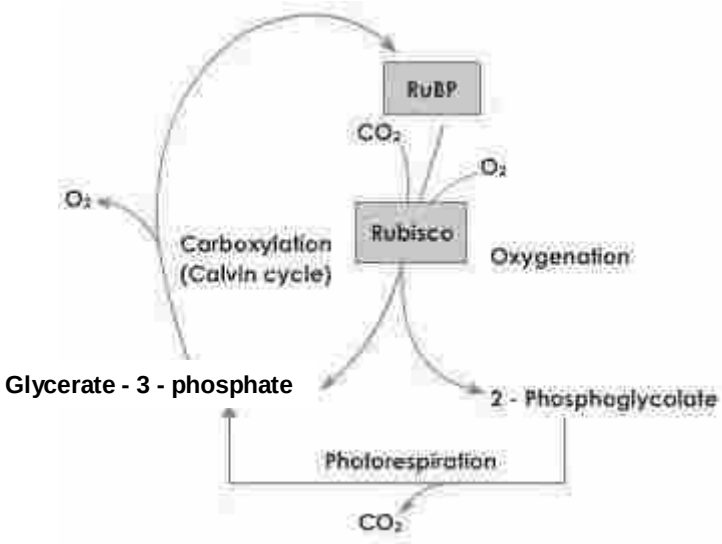


Fig. 5.2

(c) (i) Describe and explain the effects of an increase in oxygen concentration on photosynthesis. [3]

a. **An increase in oxygen concentration reduces the rate of photosynthesis / increases the rate of photorespiration;;**
b. **This is less Rubisco is available for CO_2 / more oxygen competing with CO_2 for Rubisco;;**
c. **This results in less CO_2 , fixation for Calvin cycle;;**
d. **There is less, glycerate-3-phosphate, produced and less RuBP being, regenerated ;;**

(iii) Suggest why the process outlined in Fig. 5.2 is known as photorespiration. [1]

a. The process uses oxygen and, excretes / produces , carbon dioxide;
b. Light energy / non-cyclic photophosphorylation / light dependent reaction / products of the light dependent reaction / ATP and NADPH, is required for this process to occur;
c. The same photosynthetic enzyme / Rubisco is used and allows the Calvin cycle to continue;;

[Total: 10]

6 An inbred variety of maize, **A**, with finely striped leaves was found to have high resistance to the fungus that causes the disease, corn leaf blight.

Plants of variety **A** were crossed with another inbred variety of maize, **B**, which had entirely green leaves and low resistance to the fungus. All the F_1 generation had entirely green leaves and low resistance.

The above F_1 generation was test cross with variety **A** and yielded the following results:

finely striped leaves and high resistance	80
finely striped leaves and low resistance	20
entirely green leaves and high resistance	22
entirely green leaves and low resistance	78

(a) A chi-squared test was performed on the results of the cross to determine if the results of the test cross depart significantly from the expected ratio. Calculate the χ^2 value using the formula provided below. [1]

Formula for χ^2 calculation

$$\chi^2 = \Sigma \frac{(O-E)^2}{E} \qquad v = c - 1$$

where Σ = 'sum of…'

v = degrees of freedom
c = number of classes
O = observed 'value'
E = expected 'value'

.

Category	Observed number (O)	Expected ratio	Expected number (E)	$(O-E)^2$	$\frac{(O-E)^2}{E}$
finely striped leaves and high resistance	80	1	50	900	18
finely striped leaves and low resistance	20	1	50	900	18
entirely green leaves and high resistance	22	1	50	784	15.68

entirely green leaves and low resistance	**78**	**1**	**50**	**784**	**15.68;**
TOTAL	***200***				**67.36 (2 d.p.);**

Table 6 .1

	probability, p				
degree of freedom	0.10	0.05	0.02	0.01	0.001
1	2.31	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(b) Using Table 6.1, explain the conclusion drawn from the χ^2 test to determine if the observed numbers conformed to the expected. [3]

a) Since the calculated χ^2 value 67.36more than critical value 7.82 at p = 0.05 at d.f.= 3, null hypothesis is rejected.
b) At 3 degree of freedom
c) Value of p is less than 0.001.;
d) The results of the χ^2 test suggest that there is a significant difference between the observed and the expected values(1:1:1:1).
e) Any difference is not due to chance alone but other factors e.g linked genes are at work.
f) Reject null hypothesis;

(c) Using the following symbols:

G entirely green leaf **g** finely striped leaf
R low resistance **r** high resistance;

Draw a genetic diagram to explain the difference between expected and actual results of the cross.

F_1 phenotype : **entirely green leaves and low resistance** x **finely striped leaves and high resistance**

F_1 genotype (test cross) : $\frac{G\ R}{g\ r}$ x $\frac{g\ r}{g\ r}$;

Gametes formed : (GR) (gr) (Gr) (gR) x (gr)

Parental type **recombinant type**

Punnett square

	(GR)	(gR)	(Gr)	(gr)
(gr)	$\frac{G\ R}{g\ r}$ entirely green, low resistance (Parental typed offspring)	$\frac{g\ R}{g\ r}$ striped leaves, low resistance (recombinant typed offspring)	$\frac{G\ r}{g\ r}$ entirely green, high resistance (recombinant typed offspring)	$\frac{g\ r}{g\ r}$ striped leaves, high resistance (parental typed offspring)

offspring Genotype : $\frac{G\ R}{g\ r}$ $\frac{g\ R}{g\ r}$ $\frac{G\ r}{g\ r}$ $\frac{g\ r}{g\ r}$

offspring Phenotype : **entirely green, low resistance** | **striped leaves, low resistance** | **entirely green, high resistance** | **striped leaves, high resistance** ;

[4]
[Total:8]

7(a) Fig. 7.1 is an electron micrograph of a mitochondrion in a neurone.

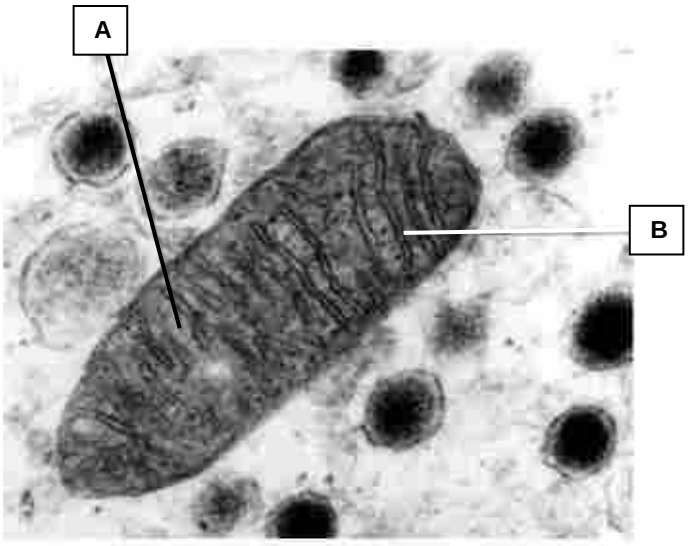


Fig. 7.1

Two stages of respiration occur in mitochondria. These are the Krebs cycle and oxidative phosphorylation.

(i) Complete the table below by naming the structures labelled **A** and **B** and stating which of the stages of respiration occur in each.

	name of structure	stage of respiration
A	**matrix**	**Kreb cycle**
B	**cristae / inner membrane**	**oxidative phosphorylation**

[2]

(ii) Explain the need for mitochondria along the axon in terms of nerve impulse conduction. [3]

Along the neurone:
- **a) For production of ATP to release energy**
- **b) required to drive sodium potassium pumps**
- **c) Where 3 Na+ are pumped out of cells and 2 K+ are pumped into nerve cell; → impt for RP**

At end of axon where synapse is found:
- **a) For the active pumping of Ca2+ out of the synapses after nerve impulses have been conducted across synapses.**
- **b) To release energy for the transport of synaptic vesicles which carry materials for the synthesis of membrane & neurotransmitter substances;**
- **c) For vesicles containing neurotransmitters to release their contents via exocytosis into the synaptic cleft when impulses arrive at the synapses;**

(b) Serotonin is a neurotransmitter which is produced by certain neurons in the brain. One of its effects is to increase the activity of sensory neurones in the brain. It also usually improves a person's mood and keeps the person awake. Fig. 7.2 shows a synapse at which serotonin is the neurotransmitter.

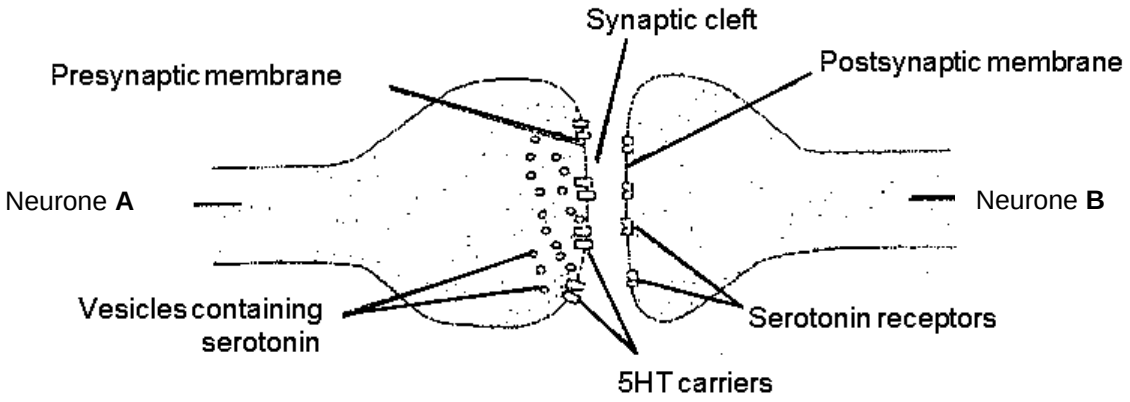


Fig. 7.2

(i) Describe how the neurotransmitter is released into the synaptic cleft. [2]

a) Arrival of nerve impulse/action potential
b) causes Ca^{2+} to enter/ influx of Ca^{2+} to cause
c) synaptic vesicles carrying the neurotransmitter, serotonin, move towards and fuse with the presynaptic membrane and
d) releases serotonin into synaptic cleft via exocytosis .

(ii) Explain how the release of the neurotransmitter, serotonin, results in the transmission of an impulse from neuron **A** to neuron **B**. [2]

a) Serotonin diffuses across the 20nm synaptic cleft post synaptic membrane
b) binding of serotonin to the receptors of ligand-gated Na+ channel on postsynaptic membrane;
c) As a result, ligand gated sodium ion gates on membrane open. Sodium ions rush/influx of sodium into membrane down its electrochemical gradient
d) to depolarize the post-synaptic membrane to generate an EPSP.

(iii) Suggest why nerve impulse can only travel in one direction across a synapse. [1]

a) Voltage-gated Ca channels are found only on the pre-synaptic membrane, allowing translocation of neurotransmitter vesicles;
b) Neurotransmitter vesicles are only found in the pre-synaptic neuron;
c) Receptors for neurotransmitter are only found on the post-synaptic membrane;

[Total: 10]

8 There are over 40 Galapagos Islands including the small and isolated island named Daphne Major.

Studies were made every year from 1970 to 1989 on the beak size of the island's population of ground finch, *Geospiza fortis*, by measuring the beak length of every bird (Fig. 8.1). Larger finches with larger beaks are better at opening large seeds.

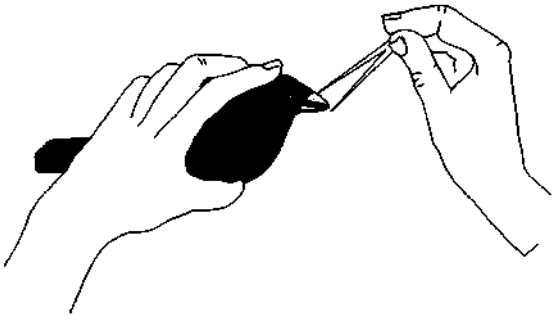


Fig. 8.1

From 1976 to 1978 there was a drought and only 15% of the ground finches survived and these did not breed during drought years. The most conspicuous feature of the survivors of the drought years was their large beak size.

During normal years, many drought intolerant grasses and herbs produce an abundance of small seeds. A few other drought-tolerant plants produce a much smaller number of large seeds which are not normally eaten.

(a) Describe how environmental factors act as forces of natural selection, during drought years, on the beak size of finches. [4]

a. Drought-tolerant plants which produced large seeds survived the drought better;;
b. The selection pressure being the type / availability of food source e.g. large seeds;;
c. Birds with larger beaks that can feed on large seeds are at selective advantage;;
d. can survive to maturity, mate, reproduce and pass on their favourable <u>alleles</u> (for larger beaks) to their offsprings;;

(b) Suggest the role of the islands in the evolution of thirteen species of Darwin finches now found on the Galapagos Islands. [2]

a. Geographical barrier / isolation between islands leads to reproductive isolation;;
b. Results in a lack of gene flow between population of finches;;
c. Different selection pressures on the different islands;;

Molecular analysis was carried out on the mitochondrial DNA (mtDNA) sequences of the Galapagos Islands finches and the Cocos finch found on the island of Cocos, 830 km to north-east of the Galapagos islands. Using mtDNA analysis data, a map showing the phylogeny of these finches was constructed as shown below in Fig. 8.2

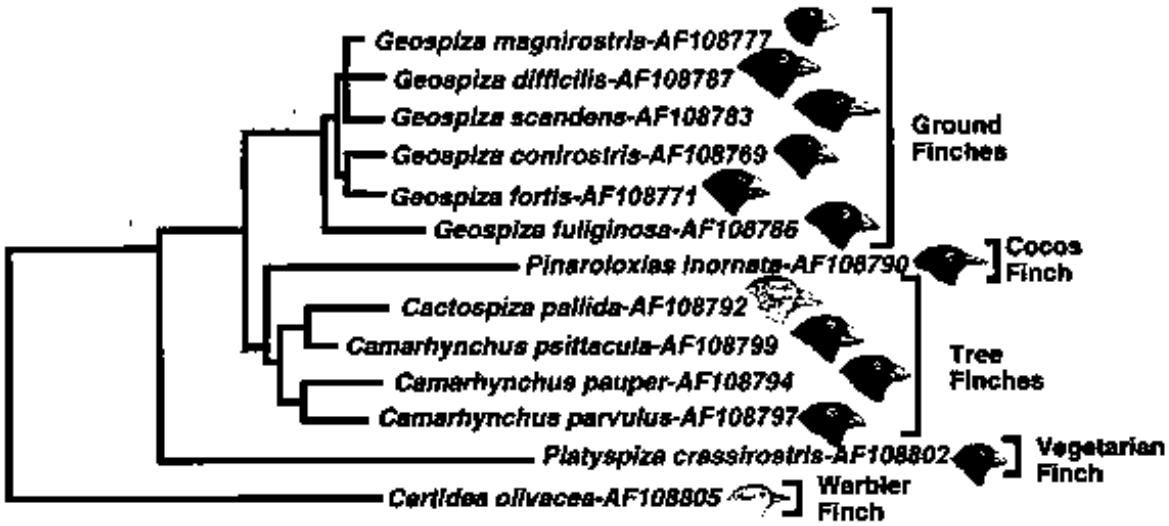


Fig. 8.2

(c) Explain how DNA sequences can be used to determine evolutionary relatedness between species. [2]

a. Compare regions of homology in the same gene e.g. cytochrome c gene / β-chain haemoglobin gene found in different species / compare homologous genes between species;;
b. The fewer the differences in DNA sequences of homologous genes between species, the more closely related the species are (vice-versa);;

(d) Describe the advantages of using nucleotide data such as mtDNA in classifying organisms.[2]

OWTTE

a. Using nucleotide data is unambiguous and objective. A, T, G, C are easily recognized and not confused with one another. They are not dependent on subjective judgements or observations involving quantitative differences;;
b. Nucleotide data are quantifiable and can be converted to numerical form and open to statistical and mathematical analysis. This provides a quantitative tool for constructing phylogenetic trees with branch points defined by mutations in DNA sequence;;

Differences in the *cytochrome b* DNA sequence of several finches' species from Galapagos Islands and Island of Cocos were measured and plotted against time since divergence from the primitive ancestor (MYA) as seen in Fig. 8.3.

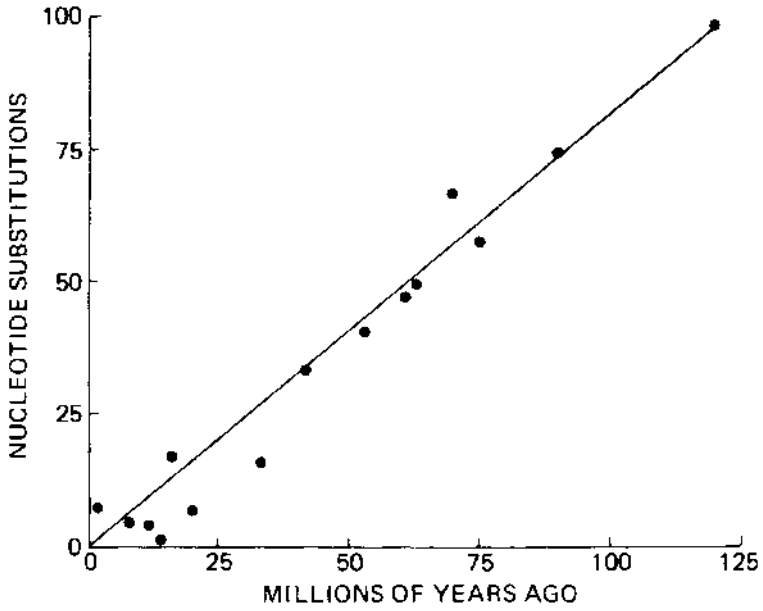


Fig 8.3

(e) Describe how these differences support the neutral theory of molecular evolution. [2]

a. **Changes in the nucleotide sequence arise through neutral mutation;**
b. **for e.g. silent mutation or missense mutation where the change in amino acid does not occur in a critical region of the enzyme;**
c. **There is no effect on the phenotype and fitness of organism/no selective advantage and thus allowed to accumulate;**
d. **Small number of changes over millions of years indicating that rate of mutation is slow as cytochrome b gene is a crucial gene in living organisms;**
e. **The plot of the line is straight, indicating that the rate of mutation is constant;**

[Total: 12]

Section B

Answer **one** question.

Write your answers to this question on the separate answer paper provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

9 **(a)** Compare and contrast between glucagon and glycogen. [4]

Compare (At least 1m)

a) **Both are macromolecules.**
b) **Both are involved in maintaining blood glucose concentration.**

Contrast

Points of comparison	Glucagon	Glycogen
c) Type of biomolecule	Protein	Carbohydrate / Polysaccharide
d) Site of production	Alpha cells of islets of Langerhans in pancreas	Liver cells, Muscle cells
e) Monomer	Amino acids	Alpha glucose molecules
f) Bonds between monomers	Peptide bonds	Alpha 1,4 glycosidic bonds, alpha 1,6 glycosidic bonds for branching
g) Structure adopted by each biomolecule	Tertiary structure – precise globular conformation	Helical structures with regular branching
h) Bonds stabilizing structure	Ionic bonds between charged R-groups, hydrogen bonds between polar R groups, disulfide bridges, and hydrophobic interactions	Hydrogen bonds between –OH groups projecting into the helix
i) Solubility in water	Soluble	Insoluble
j) Function	A hormone that raises blood glucose level	Energy storage molecules in animals

(b) Explain what is meant by primary secondary, tertiary and quaternary structure of a named protein. [8]

R: collagen

a) A protein with all 4 levels of structure is that of a globular protein, haemoglobin;
b) Primary structure refers to the number, type and unique sequence of amino acids found;
c) in each of the 4 polypeptide chains (2 alpha and 2 beta globin chains) linked by peptide bonds in a polypeptide chain;
d) Secondary structure: segments of their polypeptide chain repeatedly coiled or folded;
e) into some kind of geometrically regular secondary structure;
f) The 2 main kinds are the α-helix and the β-pleated sheet;
g) Both structures are stabilized by intrachain hydrogen bonds between the amino and carboxyl groups of the polypeptide backbone;
h) The secondary structures then fold back on themselves to form a precise globular structure;
i) Tertiary structure refers to the overall compact, globular, 3-D structure of each haemoglobin polypeptide chain;
j) conformation of a polypeptide resulting from interactions between side-chains of the various amino acids in a polypeptide chain;
k) The compact structure is maintained by four types of bonds, namely hydrogen bonds, ionic bonds, hydrophobic interactions as well as the stronger disulfide bonds;
l) As the polypeptide folds into its functional conformation, amino acids with hydrophobic (non-polar) side chains congregate in clusters via hydrophobic interactions at the core of the protein, out of contact with water;
m) Meanwhile, hydrogen bonds between polar side-chains and ionic bonds between positively and negatively charged side-chains also help stabilize tertiary structure;
n) These are all weak interactions but their cumulative effect help to stabilize and give the protein a unique shape;
o) Quaternary structure refers to the specific orientation of 2 or more polypeptide chains with respect to one another and the nature of interactions that stabilize this orientation;
p) Each polypeptide chain in such a protein is called a subunit;
q) There are 4 subunits for haemoglobin, namely 2 alpha and 2 beta polypeptide chains;
r) The subunits are held together by hydrogen bonds, ionic bonds and hydrophobic interactions to form a multimeric functional protein;

(c) Describe the main properties of an enzyme and discuss their mode of action. [8]

a) Enzyme acts as a biological catalyst which speeds up the rate of chemical reaction by lowering activation energy;
b) It remains unchanged at the end of reaction and it can be reused;
c) They are globular proteins with the specific 3D conformation;
d) and specific distribution of electrical charges at its active site;
e) They highly specific for the substrates they recognise and the reactions they catalyse;
f) Some enzymes recognises also one type of substrate (eg: catalase) or a specific functional group (eg: phosphate group) or type of chemical bond (eg: peptide bonds).
g) Enzyme activity is affected by changes in pH, temperature, substrate and enzyme concentration and in the presence of cofactors and inhibitors;
h) Enzymes are extremely efficient. Catalysed reactions are 10^3 to 10^8 times faster than uncatalysed reactions;
i) Enzymes have high turnover number. The turnover number refers to the number of substrate molecules converted into products by one molecule of enzyme in one second;
j) They are required only in small amounts;

k) Precise active site to which the substrate molecules with complementary conformation and compatible chemical groups become attached;
l) Collision between substrate and enzyme at the correct orientation causes the substrate molecules to bind to the enzyme molecule at its active site to form an enzyme-substrate (E-S) complex;
m) Enzyme and substrate are held together by weak bonds, such as ionic, hydrogen and hydrophobic bonds, which can be made and broken rapidly;

Lock and Key hypothesis

n) The conformation and chemical groups of the substrate is exactly complementary to the enzyme active site;
o) Substrate binds to the active site by weak bonds such as hydrogen and ionic bonds to form an enzyme-substrate complex;
p) It is then activated to form the products of the reaction, which no longer fit into the active site of the enzyme;
q) Products are released into the surrounding medium;
r) leaving the active site unchanged and free to receive other substrate molecules;

Induced-fit hypothesis

s) Initially, the active site does not exist in a conformation that is exactly complementary to the substrate;
t) As the substrate enters the active site, the amino acids which make up the active site are moulded or 'induced' into a precise shape complementary to the substrate;
u) This brings a greater interaction between the chemical groups of the substrate and active site. (greater chemical and spatial compatibility);
v) Enables the enzyme to perform its catalytic function more efficiently;
w) For example, in reactions involving 2 or more reactants, the active site brings the substrates together in the proper orientation for the reaction to occur;
x) As the active site clutches the substrates, the enzyme may stress the substrate molecules, stretching and bending critical chemical bonds within the molecule that must be broken during the reaction;
y) The active site may also provide a microenvironment that is conducive to a particular type of reaction;

[Total: 20]

10 (a) With reference to the islets of Langerhans, describe what is meant by an endocrine gland. [7]

a) Islets of Langerhans are clusters of cells in pancreas;
b) A gland is a structure which secretes specific chemical substances called hormones;
c) Each islet has a population of alpha cells which secrete glucagon and;
d) a population of beta cells which secrete insulin;
e) Endocrine gland is ductless instead;
f) hormones are secreted into blood to be distributed throughout the body;
g) transported to target cells/tissue;
h) Thus, islets of Langerhans have a rich supply of blood vessels;
i) Endocrine glands secrete hormones in small quantities;
j) Endocrine glands are involved in homeostatic control/homeostasis that operates by negative feedback;
k) E.g. islets of Langerhans control the secretion of hormones/ adjust hormonal output by monitoring/detecting blood glucose concentration;

@ 1m each

(b) Explain how the blood glucose concentration is regulated by insulin and glucagon. [8]

Regulation by insulin:

a) **Blood glucose level is normally maintained at ~90 mg/100 ml blood;**
b) **High blood glucose (>90 mg/100 ml blood) is detected by beta cells of islets of Langerhans;**
c) **Beta cells are stimulated to secrete insulin directly into the bloodstream;**
d) **Insulin binds to the (insulin) receptors on target cells e.g. liver and muscle cells;**
e) **After insulin-binding process induces dimerisation & autophosphorylation of tyrosine amino acids on the RTK,**
f) **the activated receptor tyrosine kinase then activates a number of bound intracellular relay proteins.**
g) **As insulin level rises,**
   i. **increases rate of glycogenesis (= conversion of glucose to glycogen) in liver and muscle cells;**
   ii. **increases rate of glucose uptake/permeability esp. by muscle cells;**
   iii. **increases conversion of glucose into fats in liver cells i.e. fat deposition;**
   iv. **Increase in the rate of amino acid absorption and protein synthesis;**
   v. **increases rate of respiration of glucose instead of other energy source(glycolysis);**
   vi. **inhibits/decreases gluconeogenesis (= conversion of proteins and fats into glucose)**
   vii. **Decrease in glycogenolysis, ie. breakdown of glycogen to glucose in skeletal muscle and liver cells.**
   (max 1m - any 2 pt)
h) **These mechanisms by insulin will lower blood glucose levels;**
i) **When blood glucose level is restored to the normal set point/normal blood glucose concentration, beta cells detect and reduce insulin secretion.**

Regulation by glucagon:

j) **Low blood glucose (< 90 mg/100 ml blood) is detected by alpha cells of islets of Langerhans;**
k) **Alpha cells are stimulated to secrete glucagon directly into the bloodstream;**
l) **Glucagon binds to the (glucagon) receptors on liver cells** (only liver cells are glucagon's target i.e. only liver cells are sensitive to glucagon)**;**
m) **to activate adenyl cyclase (enzyme) to form cAMP i.e. increases cAMP level**
n) **which activates phosphorylase enzymes that catalyse glycogenolysis (= conversion of glycogen to glucose);**
o) **As glucagon level rises,**
   i. **Increase in glycogenolysis = stimulate breakdown of glycogen to glucose;**
   ii. **Stimulates triglyceride breakdown in adipocytes.**
   iii. **Inhibits glycogenesis in liver and skeletal muscle cells**
   iv. **Increase in gluconeogenesis**
   (max 1m - any 2 pt)
p) **Newly synthesized glucose leaves target cells into the bloodstream;**
q) **These mechanisms by glucagon will increase blood glucose levels;**
r) **Secretions of insulin and glucagon are regulated by negative feedback mechanism.**

(c) Describe how the endocrine system differs from the nervous system. [5]

	Endocrine / hormonal system	Nervous system
a) Anatomical arrangement	Endocrine glands widely dispersed in your body and not structurally related to one another or to their target cells.	Specific structural arrangement betwn neurons and their target cells; interlinked → structural continuity in the system.

b) Type of information being transmitted and the messenger (s) involved	Relies on chemical transmission through the circulatory system; Information passes as a chemical messenger (hormone) thru blood stream. Hormones released into blood.	Involves both electrical & chemical transmissions along nerve fibres and between nerve fibres; information passes as electrical impulses along axons of neurons and as chemical messenger (neurotransmitters) across synapses. Neurotransmitters released into synaptic cleft, never into blood. Electrical signal via nerve fibres.
c) Distance of action of chemical messenger	Long distance (carried by bloodstream – always exert its effect on target organs away from the site of synthesis)	Very short distance (diffuses across synaptic cleft) - neurotransmitter
d) Speed of transmission	Slow rate (relies on diffusion through the bloodstream)	Rapid rate (due to saltatory conduction of nerve impulses at the nodes of Ranvier)
e) Speed of response	Slow acting (from minutes to hours)	Rapid / immediate (in milliseconds)
f) Duration of action	Long lasting (from minutes to days or longer)	Brief / short-lived (in milliseconds)
g) Effects	Diffused; usu. Widespread	Localized; very precise & exact
h) Major functions	Controls activities that require long duration rather than speed.	Coordinates rapid, precise reponses; esp important in mediating interactions with the external environment.

[Total: 20]

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examinations
In preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME								
CT GROUP	1	5	S			INDEX NUMBER		

BIOLOGY 9648/03

Application Paper and Planning Question **19 September 2016**

Paper 3 **2 hours**

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your name, CT class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions.
The use of an approved scientific calculator is expected, where appropriate.
All working for numerical answers must be shown.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question

For Examiner's Use	
1	
2	
3	
4 Planning	
5	
Total	

This document consists of **17** printed pages including the cover page and **1** blank page.

[Turn Over

Answer **all** questions.

1 Bloom's syndrome is a rare autosomal recessive disorder. It is characterized by short stature, predisposition to the development of cancer and genomic instability. Bloom's syndrome is caused by mutations in the BLM gene leading to mutated DNA helicase protein formation.

In the early 1980s, attempts were made to map the BLM gene on chromosome 15 using DNA markers. The relationship between the BLM gene and two DNA markers DM1 and DM2 were studied in a family with many affected children. DNA were extracted from these individuals and cut with two different restriction enzymes separately. The products of digestion were separated using gel electrophoresis and the RFLP banding patterns is shown in Fig. 1.1 below.

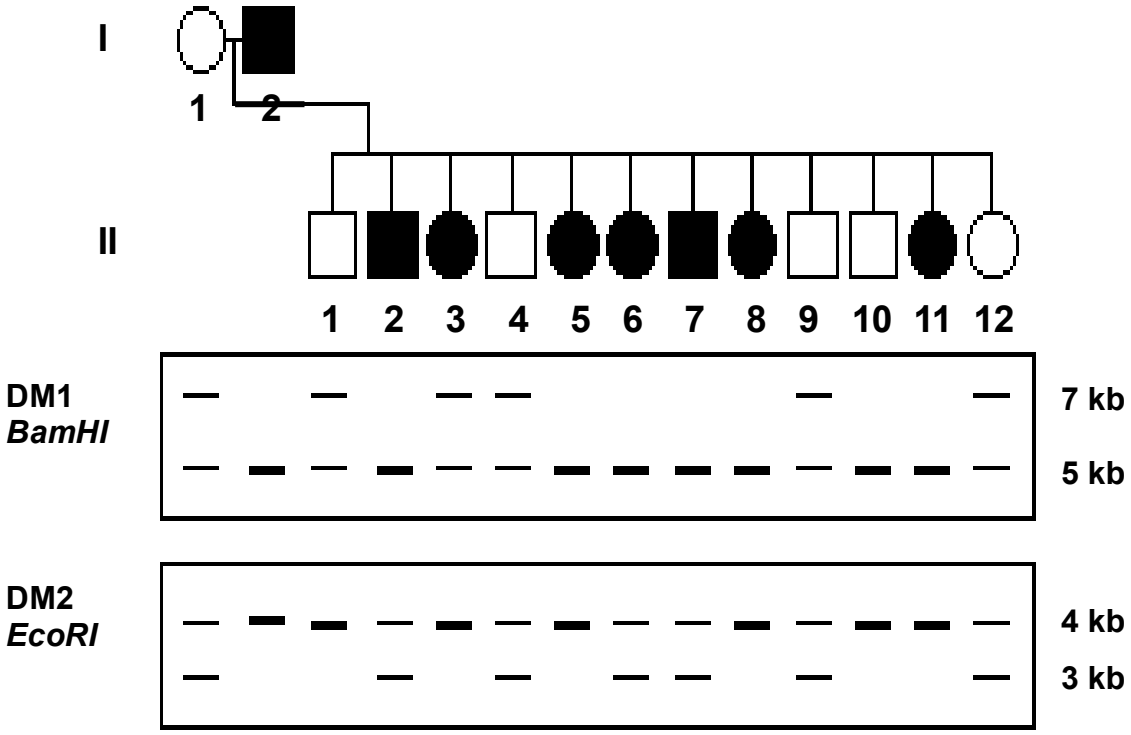


Fig. 1.1
(Note: *BamHI* was used on DM1 and *EcoRI* on DM2)

Key

Male with Bloom's syndrome	Female with Bloom's syndrome
Normal male	Normal Female

(a) Explain why genes are seldom used as markers for genetic testing.

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(b) What is meant by a restriction enzyme?

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(c) Explain the principles behind Restriction Fragment Length Polymorphism (RFLP) analysis.

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(d) Explain how gel electrophoresis can be used to distinguish between the different band patterns as observed in Fig. 1.1 using *BamHI*.

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[Turn Over

(e) Using the information provided in Fig. 1.1, deduce and explain which marker is more suitable in detecting the presence of Bloom's syndrome.

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(f) Using your understanding of linked genes, provide a possible explanation for your answer in **(e)**.

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…… [2]

[Total: 14]

2 Severe Combined Immunodeficiency Disease (SCID) is the most severe of the immune deficiency diseases. SCID is a group of very rare, life-threatening diseases that are present at birth. Fig. 2.1 shows the pattern of inheritance of X-linked SCID in a family.

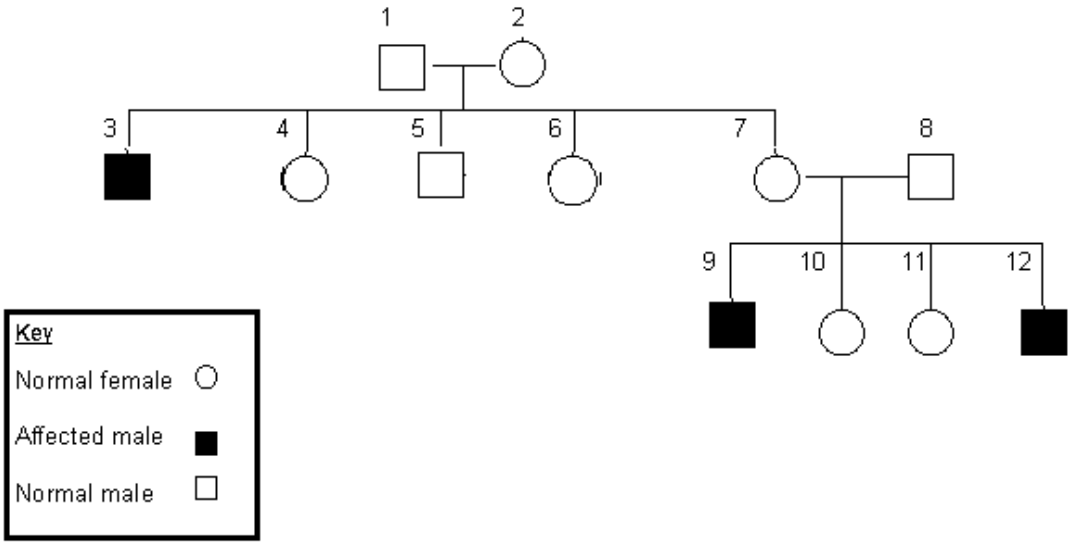

Fig. 2.1

(a) State and explain the nature of alleles that gives rise to SCID illustrated in Fig. 2.1.

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(b) Describe the genetic basis of X-linked SCID.

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[Turn Over

(c) Give one reason why SCID is a suitable choice for gene therapy.

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…….. [1]

Babies born with SCID have no defence against common infections and quickly become ill when the protection from maternal antibodies is lost. Gene therapy for SCID has been carried out using the general procedure shown in Fig. 2.2.

Step 1: Hematopoietic stem cells retrieved from baby's umbilical cord blood.

↓

Step 2: Stem cells infected with harmless genetically engineered virus containing the normal, dominant allele.

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Step 3: Stem cells take up normal allele.

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Step 4: Stem cells transfused back into baby.

↓

Step 5: Immune system develops T and B lymphocytes.

Fig. 2.2

(d) Using the information given, state **two** reasons why stem cells were used in this treatment.

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In 2002, two young patients with X-linked SCID were treated with their own blood stem cells that had been subjected to the same treatment as the earlier attempts at gene therapy.

The two different forms of SCID require different cells to be targeted for gene therapy. For X-linked SCID, only stem cells can be used while in autosomal recessive form of SCID (ADA), both T cells and stem cells could be used. If T cells are used, they will be induced to proliferate *in vitro* by treatment with relevant signalling molecules before infection with viral vectors.

(e) From the information given and your knowledge of SCID, explain why different cells are used for different treatments.

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…… [2]

Fig. 2.3 shows the lymphocyte counts (both T & B) of two infant patients that underwent two separate types of gene therapy treatments for SCID. Patient A was treated with a retrovirus while Patient B was treated with an adenovirus. The lymphocyte count of the patients was monitored by a doctor at the end of every month for a period of 12 months. (The acceptable range of lymphocyte count for non-SCID patients is 5 to 10 x 10^3/mm^3).

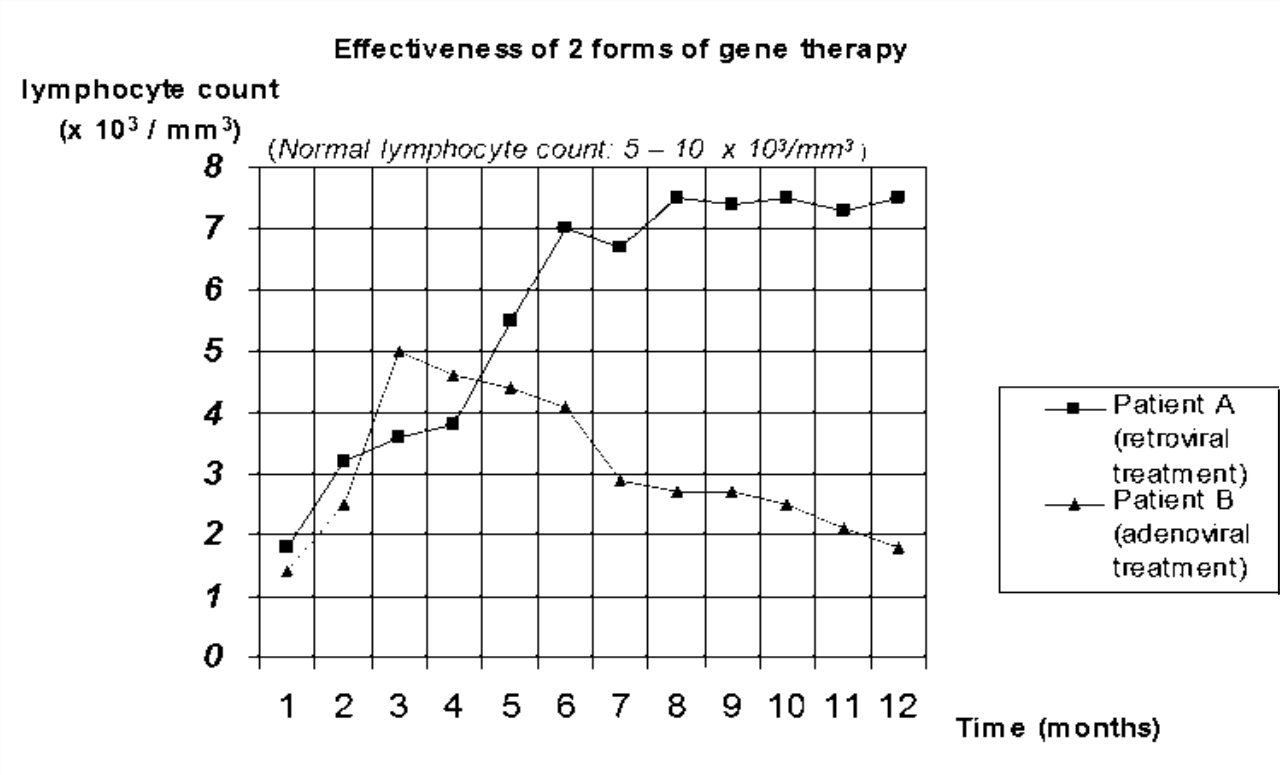

Fig. 2.3

[Turn Over

(f) With reference to Fig. 2.3,

(i) describe the trends observed in both patients' lymphocyte count.

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(ii) account for the difference in lymphocyte count at the end of 12 months.

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[Total: 14]

3 In 2012, permission was granted for a field trial in the UK of genetically modified wheat, *Triticum aestivum*. The wheat carries a gene, taken from peppermint plants, which results in the wheat leaves releasing a volatile, non-toxic chemical, (E)-β-farnesene (Eβf), into the atmosphere.

Eβf is not only produced by various species of plants. It is also secreted by aphids when they are disturbed by a predator.

Two experiments have been performed into the effect of Eβf on the behaviour of aphids feeding on leaves in closed containers.

Experiment 1
Either 10 cm^3 of air from a syringe that contained plant leaves that secrete Eβf
or 10 cm^3 of air from a syringe with normal leaves
was added to the containers of feeding aphids.

Experiment 2
Either 10 cm^3 of air containing 50 ng of Eβf
or 10 cm^3 of air containing no Eβf
was added to the containers of feeding aphids.

In both experiments, the number of aphids that stopped feeding and moved away from the food leaves was counted. The results are shown in Table 3.1.

Table 3.1

	Experiment 1		**Experiment 2**	
Air added to containers of feeding aphids	10 cm^3 air that had been in contact with leaves secreting Eβf	10 cm^3 air that had not been in contact with leaves secreting Eβf	10 cm^3 air containing 50 ng Eβf	10 cm^3 air containing no Eβf
Number of aphids in container	99	113	132	106
Number of aphids that stopped feeding and moved away from the food leaves	54	1	111	0

(a) With reference to Table 3.1, describe the evidences which support the idea that Eβf is an alarm signal for aphids.

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[Turn Over

(b) Other experiments show that Eβf attracts predators of aphids, such as ladybirds. Suggest how growing genetically modified wheat secreting Eβf could increase the yield of wheat.

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(c) Suggest why growing this genetically modified wheat might be acceptable to people who object to the growth of genetically modified insect-resistant maize or cotton.

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In a separate experiment, Ti (Tumour-inducing) plasmid found in *Agrobacterium tumefaciens* was used to transfer DNA of interest into *T. triticum.* The transformed wheat protoplasts are stimulated to divide by mitosis to form calli and regenerated into whole plants by tissue culture techniques.

(d) With reference to tissue culture techniques, describe how plant growth regulators can result in plantlet formation from calli.

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Plasmids are small circles of DNA that can be found in many bacteria which can be used for cloning foreign genes in suitable bacteria.

The plasmid, pUC19, shown in Fig. 3.2 has been developed for specific purposes by genetic engineers.

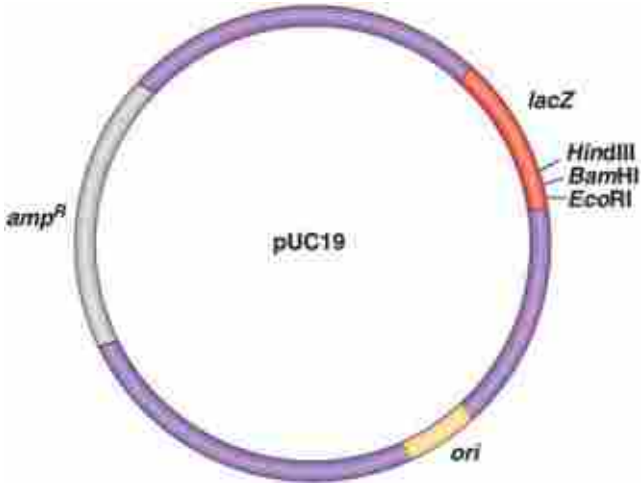

Fig. 3.2

pUC19 can be cleaved using restriction enzymes such as HindIII. HindIII can be found naturally in *Haemophilus influenzae*.

(e) What is the natural role of restriction enzymes in *H. influenzae*?

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(f) With reference to Fig. 3.2, explain how the cells which contain the recombinant plasmids are identified.

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[Total: 12]

[Turn Over

4 Planning question

Dormant seeds have a very low rate of respiration. When water is absorbed by dormant seeds, growth hormones are activated. These hormones activate genes that code for enzymes that hydrolyse stored food reserves used in respiration allowing the seed to grow and germinate. The respiration rate can be measured by oxygen usage per unit mass using a respirometer.

You are required to investigate the respiration rate of germinating seeds of different mass.

You are provided with the following materials and apparatus which you must use:

- Mung bean seeds of different mass that have been soaked in water for 24 hours
- Blue dye
- Soda lime pellets 
- Glass beads
- Rubber tubing connected to capillary tube of 4mm diameter
- Syringes
- Electronic weighing balance
- Scale paper

You may select from the following apparatus and use appropriate additional apparatus:

- Normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods etc
- Forceps
- Ruler
- Stopwatch
- Thermometer

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagram(s), if necessary,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

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5 Free-response question

Write your answers to this question on the separate answer paper provided.

Your answers:
- should be illustrated by large, clearly labelled diagrams, where appropriate,
- must be in continuous prose, where appropriate,
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

(a) Describe PCR and explain the advantages and limitations of this technique. [8]

(b) Describe how plant tissue culture is used to clone plant cells. Explain the scientific reasons for each step in the process. [8]

(c) Distinguish between a genomic DNA library and a cDNA library. [4]

[Total: 20]

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In preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME									
CT GROUP	1	5	S			INDEX NUMBER				

BIOLOGY 9648/03

Application Paper and Planning Question **19 September 2016**

Paper 3 **2 hours**

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your name, CT class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions.
The use of an approved scientific calculator is expected, where appropriate.
All working for numerical answers must be shown.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question

For Examiner's Use	
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This document consists of **17** printed pages including the cover page and **1** blank page.

[Turn Over

Answer **all** questions.

1 Bloom's syndrome is a rare autosomal recessive disorder. It is characterized by short stature, predisposition to the development of cancer and genomic instability. Bloom's syndrome is caused by mutations in the BLM gene leading to mutated DNA helicase protein formation.

In the early 1980s, attempts were made to map the BLM gene on chromosome 15 using DNA markers. The relationship between the BLM gene and two DNA markers DM1 and DM2 were studied in a family with many affected children. DNA were extracted from these individuals and cut with two different restriction enzymes separately. The products of digestion were separated using gel electrophoresis and the RFLP banding patterns is shown in Fig. 1.1 below.

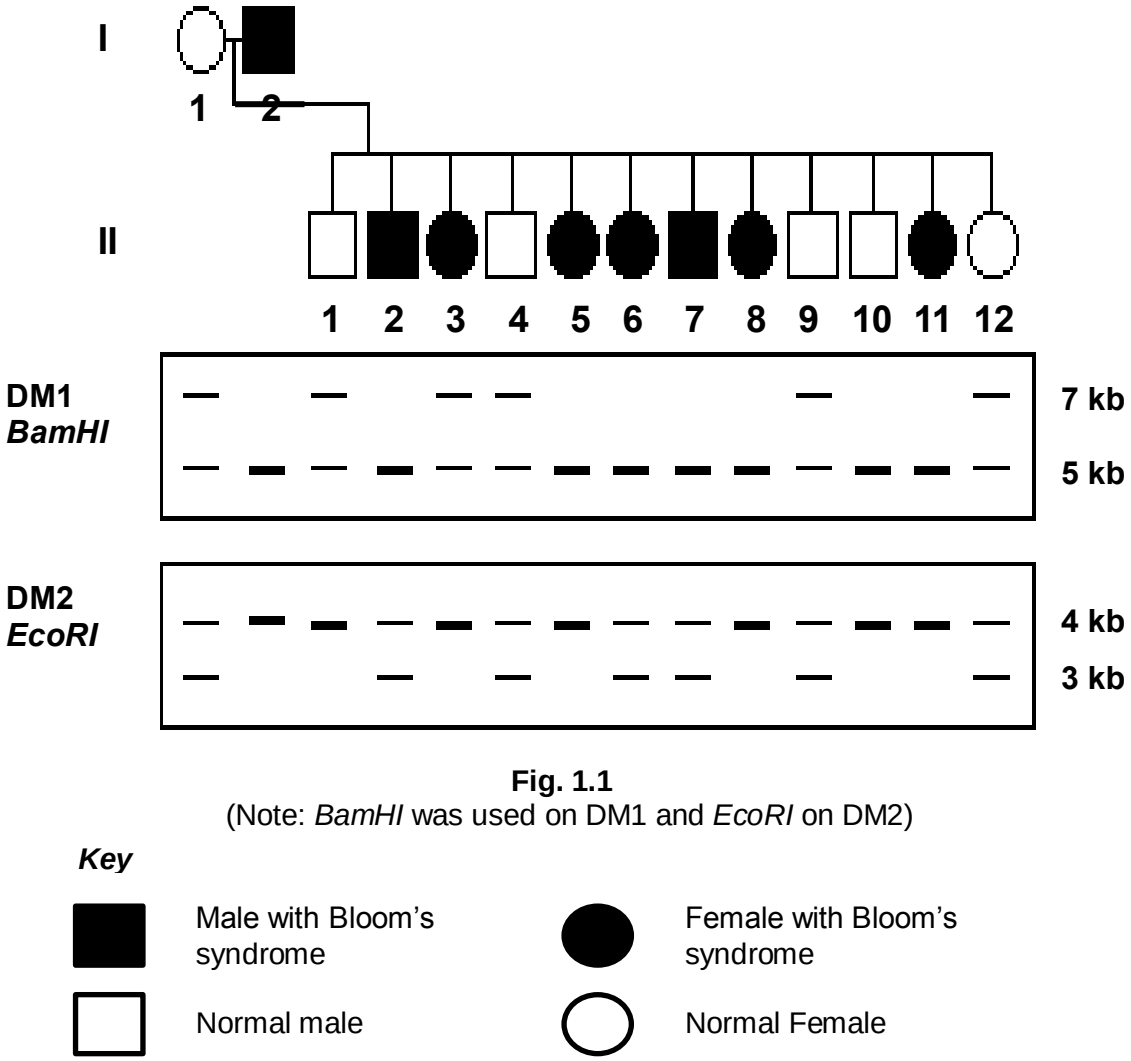

Fig. 1.1
(Note: *BamHI* was used on DM1 and *EcoRI* on DM2)

(a) Explain why genes are seldom used as markers for genetic testing. [2]

a) genes encodes a functional polypeptide;
b) sequence of DNA is normally conserved due to its important biological function;
c) mutation rate in genes is lower than in non-coding regions;
d) not able to differentiate between individuals;

(b) What is meant by a restriction enzyme? [2]

a) recognise a specific sequence at the RE site;
b) ref. RE site being 4-6 bases long;

c) and binds to the specific sequence of bases;
d) cuts/cleaves DNA;
e) through hydrolysis of phosphodiester bonds between nucleotides;
Max 2

(c) Explain the principles behind Restriction Fragment Length Polymorphism (RFLP) analysis. [3]

a) different individuals have genetic variations / different nucleotide sequences at same locus;
b) among individuals of a species;
c) caused by mutations;
d) found within coding or non-coding region;
e) giving rise to Gain or loss restriction sites;
f) cut with same RE;
g) result in different length of DNA fragments;
Max 3m

(d) Explain how gel electrophoresis can be used to distinguish between the different band patterns as observed in Fig. 1.1 using *BamHI*. [3]

a) DNA fragments can be separated based on molecular size using gel electrophoresis;
b) The gel provides a matrix, in which the DNA fragments have to maneuver through the pores of the gel;
c) Thus, in a fixed amount of time;
d) the larger DNA (7kb) will move a shorter distance, compared to a small fragment(5kb), which will move a longer distance thus nearer to the well;
e) DNA is negatively charged at neutral pH due to the phosphate group;
f) The wells in the gel are located near the cathode;
g) therefore DNA sample will migrate from negative (cathode) to positive (anode) poles when subjected to an electric field;
Max 3m

(e) Using the information provided in Fig. 1.1, deduce and explain which marker is more suitable in detecting the presence of Bloom's syndrome. [2]

a) DM1 – more suitable OR DM2 – less suitable;;

Either
b) For DM1, 7 out of 8 (88%) of the individuals with BS have the only one 5kb band/ homozygous for the 5 kb fragments;
c) 5 out of 8 (62.5%) of the BS individuals have only one 4kb band/ homozygous for the 4 kb fragments for DM2;

Or
d) For DM1 - All individuals with Bloom's syndrome have only one 5kb band/ homozygous for the 5 kb fragments except II-3 who has 2 bands 5kb and 7 kb;
e) For DM2 - 5 BS individuals have only one 4kb band/ homozygous for the 4 kb fragments and 4 BS individuals have 2 bands 3kb and 4kb / about equal number of BS individuals and normal individuals have a single 4kb band as well as 2 bands 3kb and 4kb;

f) (So the inheritance of the DM1/5kb fragment is more consistent compared to DM2)

(f) Using your understanding of linked genes, provide a possible explanation for your answer in **(e)**. [2]

a) DM1 closer to BLM gene compared to DM2;;
(note: some form of comparison required between DM1 and DM2 before a full mark is given)
b) Higher tendency for the 5kb fragment to be inherited together with the BLM gene;
c) Hence lower number of recombinants for DM1 (individuals II-3 and II-10) compared to DM2 (II-1,2,6,7 and 10);

[Total: 14]

2 Severe Combined Immunodeficiency Disease (SCID) is the most severe of the immune deficiency diseases. SCID is a group of very rare, life-threatening diseases that are present at birth. Fig. 2.1 shows the pattern of inheritance of X-linked SCID in a family.

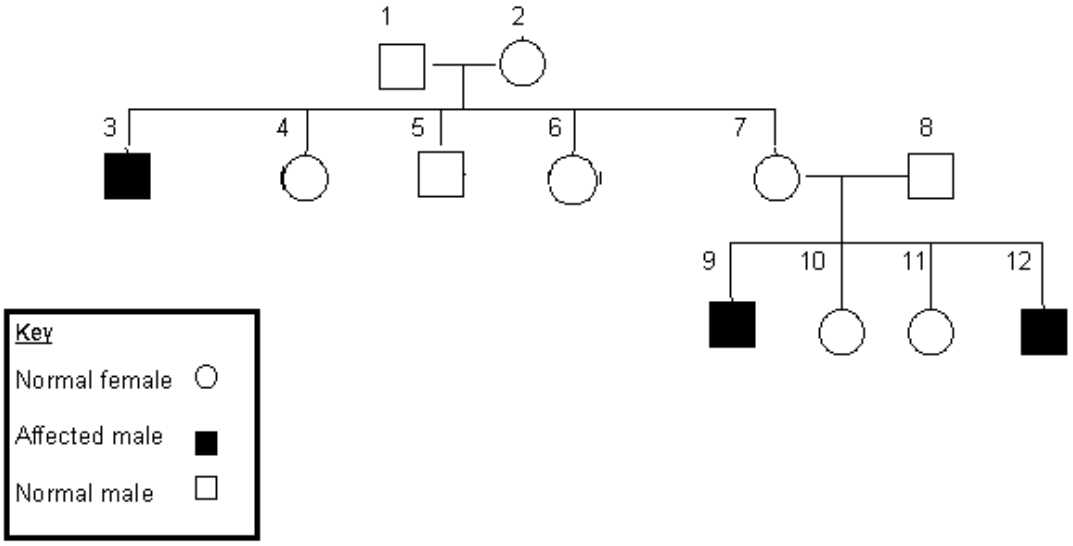

Fig. 2.1

(a) State and explain the nature of alleles that gives rise to SCID illustrated in Fig. 2.1. [2]

a) Recessive alleles;;
b) Unaffected parents 1 & 2 have affected son 3/ Unaffected parents 7 & 8 with affected sons 9 & 12;;

(b) Describe the genetic basis of X-linked SCID. [3]

a) Interleukin-2-Receptor Gamma (IL2RG) gene found on the X chromosome;
b) encodes common gamma chain subunit of the interleukin receptor;
c) These receptors reside in the plasma membrane of immune cells;
d) and allow communications between T and B cells/ immune cells;
e) Mutations of IL2RG gene results in a non-functional version of the common gamma chain, or no protein formation;
f) Without the common gamma chain, these interleukin-2-receptors cannot form /are absent from immune cells;
g) hence preventing communication between T and B lymphocytes;
h) These interleukins and their receptors are also involved in the development and differentiation of T and B cells;

i) **The result is a near complete failure of the immune system to develop and function / low number or absence of T cells and non-functional B cells (B cells need T-helper cells to function);**

Max 3m

(c) Give one reason why SCID is a suitable choice for gene therapy. [1]

a) **A mutation in 2 copies of IL2RG gene/ADA gene gives rise to SCID;**
b) **Only require one copy of normal/functional allele to be delivered to target cell for restoring the normal phenotype;**

Babies born with SCID have no defence against common infections and quickly become ill when the protection from maternal antibodies is lost. Gene therapy for SCID has been carried out using the general procedure shown in Fig. 2.2.

Step 1: Hematopoietic stem cells retrieved from baby's umbilical cord blood.

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Step 2: Stem cells infected with harmless genetically engineered virus containing the normal, dominant allele.

↓

Step 3: Stem cells take up normal allele.

↓

Step 4: Stem cells transfused back into baby.

↓

Step 5: Immune system develops T and B lymphocytes.

Fig. 2.2

(d) Using the information given, state **two** reasons why stem cells were used in this treatment. [2]

a) **multipotent + differentiate into limited range of cell type;;**
b) **Unspecialised, no tissue-specific structures that allow specialized functions;;**
Reject: undifferentiated only
c) **capable of dividing by mitosis and renew for long period of time/long term proliferation;;**
d) **stem cells used belong to the patient's hence there is low/no risk of immune rejection;;**

In 2002, two young patients with X-linked SCID were treated with their own blood stem cells that had been subjected to the same treatment as the earlier attempts at gene therapy.

The two different forms of SCID require different cells to be targeted for gene therapy. For X-linked SCID, only stem cells can be used while in autosomal recessive form of SCID (ADA), both T cells and stem cells could be used. If T cells are used, they will be induced to proliferate *in vitro* by treatment with relevant signalling molecules before infection with viral vectors.

(e) From the information given and your knowledge of SCID, explain why different cells are used for different treatments. [2]

a) In X-linked SCID, IL2RG gene is mutated which results in the absence of functioning interleukin receptors;
b) The patient's T cells cannot be stimulated to proliferate by treating them with Interleukin 2 (IL-2) before the infection with viral vector; therefore, T cells are not used for gene therapy for X-linked SCID and stem cells are used instead
c) In autosomal recessive form of SCID, normal IL2RG gene is present;
d) interleukin 2 receptors are functional in immune cells and can bind to IL2 therefore, both T cells and stem cells can be targeted;

Fig. 2.3 shows the lymphocyte counts (both T & B) of two infant patients that underwent two separate types of gene therapy treatments for SCID. Patient A was treated with a retrovirus while Patient B was treated with an adenovirus. The lymphocyte count of the patients was monitored by a doctor at the end of every month for a period of 12 months. (The acceptable range of lymphocyte count for non-SCID patients is 5 to 10 x 10^3/mm^3).

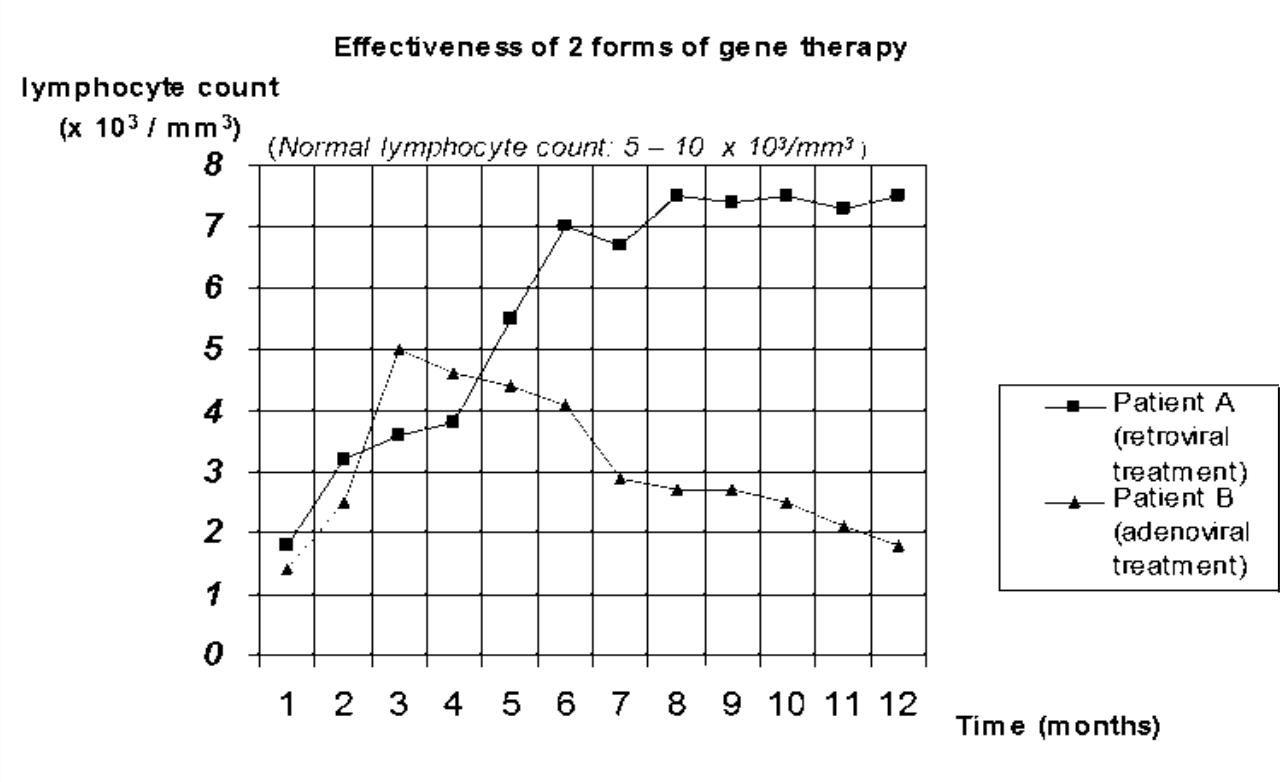


Fig. 2.3

(f) With reference to Fig. 2.3,

(i) describe the trends observed in both patients' lymphocyte count. [2]

a) Patient A lymphocyte count increase from 1.8 to 7.5 x 10^3 / mm^3 from 1 to 12 months / entered normal range by 5th month;;
b) Patient B lymphocyte count increase to 5 x 10^3 / mm^3, from 1 to 3 months but decreased thereafter to 1.8 x10^3 / mm^3 from 3 to 12 months / entered into normal range by 3rd month;;

(ii) account for the difference in lymphocyte count at the end of 12 months. [2]

a) retroviral vector allowed for integration of recombinant DNA that could be stably propagated hence resulting in long term stable expression / pass from parent to daughter cells;;
b) adenovirus however could not integrate / exists extrachromosomally, into chromosomal DNA hence transferred gene does not segregate equally into daughter cells;;
Reject: DNA gets degraded

[Total: 14]

3 In 2012, permission was granted for a field trial in the UK of genetically modified wheat, *Triticum aestivum*. The wheat carries a gene, taken from peppermint plants, which results in the wheat leaves releasing a volatile, non-toxic chemical, (E)-β-farnesene (Eβf), into the atmosphere.

Eβf is not only produced by various species of plants. It is also secreted by aphids when they are disturbed by a predator.

Two experiments have been performed into the effect of Eβf on the behaviour of aphids feeding on leaves in closed containers.

Experiment 1
Either 10 cm^3 of air from a syringe that contained plant leaves that secrete Eβf
or 10 cm^3 of air from a syringe with normal leaves
was added to the containers of feeding aphids.

Experiment 2
Either 10 cm^3 of air containing 50 ng of Eβf
or 10 cm^3 of air containing no Eβf
was added to the containers of feeding aphids.

In both experiments, the number of aphids that stopped feeding and moved away from the food leaves was counted. The results are shown in Table 3.1.

Table 3.1

	Experiment 1		**Experiment 2**	
Air added to containers of feeding aphids	10 cm^3 air that had been in contact with leaves secreting Eβf	10 cm^3 air that had not been in contact with leaves secreting Eβf	10 cm^3 air containing 50 ng Eβf	10 cm^3 air containing no Eβf
Number of aphids in container	99	113	132	106
Number of aphids that stopped feeding and moved away from the food leaves	54	1	111	0

(a) With reference to Table 3.1, describe the evidences which support the idea that Eβf is an alarm signal for aphids. [2]

Either

a) In the presence of Eβf, large number of aphids stopped feeding and moved away from food source (leaves), with 55% / 54 out of 99 aphids in experiment 1 compared to 84% / 111 out of 132 aphids in experiment 2 respectively;;

b) In the absence of Eβf, few / no aphids stopped feeding and moved away from food source with 1 aphid and none, in experiment 1 and 2 respectively;;

Or

c) In experiment 1, 55% / 54 out of 99 aphids that were exposed to air that had been in contact with leaves secreting Eβf, stopped feeding and moved away from food source, compared to 0.9% / 1 out of 113 aphids that were exposed to air that had not been in contact with leaves secreting Eβf, stopped feeding and moved away from food source;;

d) In experiment 2, 84% / 111 out of 132 aphids that were exposed to air containing 50ng Eβf, stopped feeding and moved away from food source, compared to 0% / none of the 106 aphids that were exposed to 20 cm^3 air containing no Eβf, stopped feeding and moved away from food source;;

(b) Other experiments show that Eβf attracts predators of aphids, such as ladybirds. Suggest how growing genetically modified wheat secreting Eβf could increase the yield of wheat. [1]

Either

a) Eβf attracts predators of aphids / ladybirds which will prey on aphids;

Or

b) attacked aphids / aphids disturbed by predators / ladybirds will secrete even more Eβf, which attracts more predators / ladybirds;

c) Aphids are not able to feed on wheat / obtain nutrients from GM wheat;

(c) Suggest why growing this genetically modified wheat might be acceptable to people who object to the growth of genetically modified insect-resistant maize or cotton. [2]

a) gene encoding for Eβf is already found in peppermint / various plant species' genomes;;

b) Eβf is not toxic / harmful to human health / no new chemical is added to human diet;;

c) Unlike Bt maize or Bt cotton, Eβf does not kill insects (since it is naturally secreted from aphids);;

d) Aphids are thus still available for their predators / minimal impact on the food chain;;

In a separate experiment, Ti (Tumour-inducing) plasmid found in *Agrobacterium tumefaciens* was used to transfer DNA of interest into *T. triticum.* The transformed wheat protoplasts are stimulated to divide by mitosis to form calli and regenerated into whole plants by tissue culture techniques.

(d) With reference to tissue culture techniques, describe how plant growth regulators can result in plantlet formation from calli. [2]

(Achieved by varying the ratio of plant growth regulators)

a) Higher proportion of auxin to cytokinin stimulates root growth and cell elongation;;

b) Higher proportion of cytokinin to auxin stimulates shoot growth and cell division;;

Plasmids are small circles of DNA that can be found in many bacteria which can be used for cloning foreign genes in suitable bacteria.

The plasmid, pUC19, shown in Fig. 3.2 has been developed for specific purposes by genetic engineers.

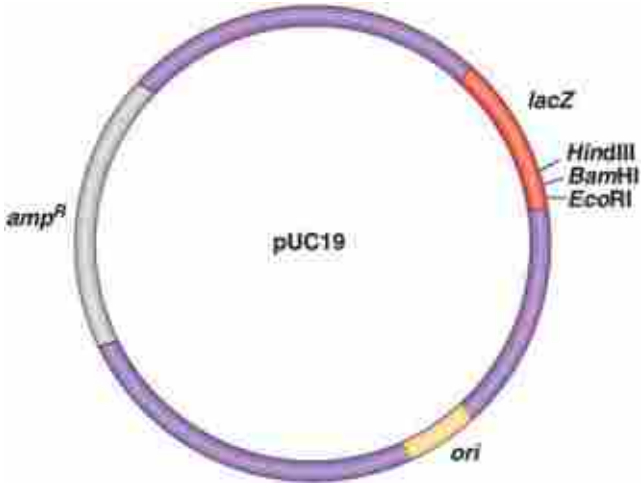


Fig. 3.2

pUC19 can be cleaved using restriction enzymes such as HindIII. HindIII can be found naturally in *Haemophilus influenzae*.

(e) What is the natural role of restriction enzymes in *H. influenzae*? [2]

a) Protect bacterium against invading virus DNA/ foreign DNA;
b) by cutting it up at specific sites (via breaking of phosphodiester bonds);
c) Thus the enzyme helps to restrict foreign DNA from surviving/replicating in bacterium;
d) Bacterium's own DNA is protected from digestion by methylation to the restriction sites;
R: any usefulness to humans in genetic engineering

(f) With reference to Fig. 3.2, explain how the cells which contain the recombinant plasmids are identified. [3]

a) The bacteria are plated on an agar plate containing ampicillin to eliminate those with no uptake of the cloning vectors/untransformed cells (OWTTE);
b) As those cells that are not transformed do not have the ampicillin resistant gene are not able to produce the enzyme that breaks down ampicillin;
c) The same agar plate also contains X-Gal to select for cells with recombinant plasmids;
d) Clones of bacteria that contain the gene of interest will appear white while those that do not contain the gene of interest will appear blue;
e) As the gene of interest caused the insertional inactivation of the lac Z gene;
f) β-galactosidase is not produced to break down X-gal, hence the colony remains white;
g) Cells with normal plasmids will have an intact lac Z gene;
h) which can be transcribed to produce β-galactosidase to break down X-gal to a blue product, causing the colony to appear blue;
Max 3m

[Total: 12]

4 Planning question

Dormant seeds have a very low rate of respiration. When water is absorbed by dormant seeds, growth hormones are activated. These hormones activate genes that code for enzymes that hydrolyse stored food reserves used in respiration allowing the seed to grow and germinate. The respiration rate can be measured by oxygen usage per unit mass using a respirometer.

You are required to investigate the respiration rate of germinating seeds of different mass.

You are provided with the following materials and apparatus which you must use:

- Mung bean seeds of different mass that have been soaked in water for 24 hours
- Blue dye
- Soda lime pellets 
- Glass beads
- Rubber tubing connected to capillary tube of 4mm diameter
- Syringes
- Electronic weighing balance
- Scale paper

You may select from the following apparatus and use appropriate additional apparatus:

- Normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods etc
- Forceps
- Ruler
- Stopwatch
- Thermometer

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagram(s), if necessary,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

Suggested answer

Aim:
To investigate the respiration rate of germinating seeds of different mass.

Background:
a. Ref to intake of H_2O, activation of growth hormone & enzyme that hydrolyse food reserves for respiration
b. ref to aerobic respiration for production of ATP for cell division / growth
c. need for O_2 in respiration as final electron acceptor;;
d. relate measurement of O_2 uptake as indication of respiration rate

Null Hypothesis: Mung beans of different mass may have same / different respiration rate with logical suggestion e.g. same spp thus likely to be the same rate;;

Experimental Procedure:
Labelled diagram

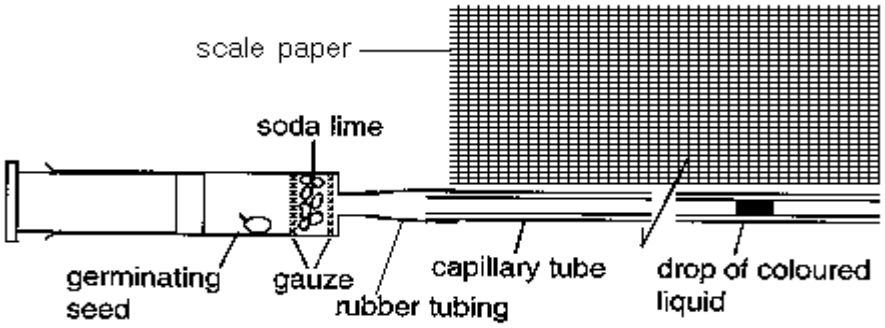


Fig. 1.0

1. Set up the experiment in sets of 3.
2. Remove the plunger from the syringe and place soda lime granules inside the syringe as shown in the set up above.
3. Using a forceps, take 1 mung bean seedling and carefully remove and discard its testa (seed coat).
4. Weigh it on the electronic weighing balance. Record your results.
5. Place the mung bean in the syringe barrel and replace the plunger by pushing it in until it is about 0.5 cm from the seedling.
6. Connect the glass capillary tube securely to the syringe using a rubber connecting tubing.
7. Dip the end of the glass capillary tube into the blue dye so that a drop enters the capillary tube. (see the set up above)
8. Remove any excess liquid with paper toweling.
9. Place the respirometer horizontally on a piece of graph paper. Start the stopwatch and wait for 3 minutes to ensure that the manometer fluid is moving smoothly towards the syringe. Stop the stopwatch.
10. Without handling the apparatus, measure the distance travelled by the manometer fluid in 3 consecutive time intervals of 1 min.

11. Do this by marking the position of the fluid on the graph paper and reading off the distances. (Alternatively, a piece of white paper can be used, and the markings measured using a ruler).

12. Record these results in the following table.

Table of results recording the distance travelled by 5 different mung beans in each minute/mm

Mung Bean	Weight of Mung Bean/g	Minute	Distance travelled in each minute/mm	Average distance travelled in each minute/mm	Rate of Respiration /min^{-1} g^{-1}
1		1			
		2			
		3			
2		1			
		2			
		3			
3		1			
		2			
		3			
4		1			
		2			
		3			
5		1			
		2			
		3			

13. Detach the syringe from the capillary tube by pulling it gently from the rubber connecting tube.

14. Fit another empty syringe to the capillary tube and flush out the manometer fluid onto a piece of filter paper so that the bore of the capillary tube is empty.

15. Carry out the same procedure for the rest of the 4 mung beans.

16. Repeat the entire experiment from step 1 to 15 twice more to ensure reproducibility of the experiment with fresh materials.

17. Calculate the rate of respiration in mm^3 of O_2 taken in min^{-1} g^{-1}

Variables

Independent variable: 5 different masses of mung beans of reasonable range & regular intervals/g, weigh using electronic balance;;

Dependent variable: respiration rate measured by vol of O_2 uptake, inclusion of soda lime to absorb CO_2 , calculated from distance moved by dye droplet;;

Control: description of an appropriate setup using glass beads that occupies similar vol as mung beans to ensure that the mung beans are directly involved in the reaction.

Safety Precautions:

1. Soda lime is corrosive and a skin irritant. Be careful when handling this chemical and to be sure googles and gloves are worn at all times.
2. Handle glass wear with caution to prevent breaking of any fragile items.

5 Free-response question

Write your answers to this question on the separate answer paper provided.

Your answers:
- should be illustrated by large, clearly labelled diagrams, where appropriate,
- must be in continuous prose, where appropriate,
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

(a) Describe PCR and explain the advantages and limitations of this technique. [8]

Stage 1: Denaturation
a) by heating to 90^0C; [accept 90 – 100^0C]
b) DNA is separated into single strands by; R: unwind
c) breaking of hydrogen bonds;

Stage 2: Annealing of primers
d) by cooling to 54^0C; [accept 30 – 65^0C]
e) single-stranded;
f) primers/ oligonucleotides bind to single (DNA) strands / 3' ends;
g) by annealing/hybridise;
h) to their complementary sequences on either side of the target sequence;

Stage 3: Extension
i) by heating to 72^0C; [accept 60 – 75^0C]
j) optimum temperature (for Taq polymerase);
k) new strands (of DNA) are synthesised by Taq/ DNA polymerase;
l) starts at position of primers;
m) addition of free deoxyribonucleotide to the free 3'OH end;
n) through the formation of phosphodiester bond between the nucleotides;
o) using the single strand DNA (target sequence) as a template;

Points a) to o): ½ m each (max 5 m)

Advantages of PCR:

p) Fast and efficient way to amplify DNA with the exponential increase of the amount of DNA because the process of PCR can be automated;;

q) PCR is highly sensitive. A target sequence can be amplified even when there is only a very small amount of the DNA available;;

r) Give one useful example;;

- **Many copies of a gene of interest can be amplified for cloning purposes, as long as the primer sequences are known.**
- **Clinical diagnosis e.g. in prenatal diagnosis of human genetic disorders. DNA from single embryonic cells is amplified using PCR. Screening for certain genetic diseases e.g. cystic fibrosis even before the phenotype is expressed provides assurance to the couple. If child is diagnosed with certain diseases, couple can then be prepared and make informed choices.**
- **Early detection of infection with HIV: PCR can detect the presence of the HIV genome at very early stages of the diseases before symptoms appear.**

- **Forensic science: minute amount of DNA found e.g. at crime scene can be amplified to sufficiently large amounts to be analysed.**
- **Study of fossil: PCR is used to amplify fragments of ancient DNA from a 40,000 year old frozen woolly mammoth.**

Limitations of PCR:

s) Taq polymerase lacks the 3' to 5' proofreading mechanism. This makes it impossible for the enzyme to check the base it has just inserted and remove it if it is incorrect. Polymerase induced errors may accumulate during PCR;;

t) PCR requires at least the knowledge of the sequences that flank the target DNA to synthesis the primers. Without proper primers, then PCR cannot take place;;

u) DNA fragments are limited to 3 kb. Further increase in length will decrease the efficiency of amplification;;

Points p) to u): 1 m each
Max 2m each for advantages/limitations

(b) Describe how plant tissue culture is used to clone plant cells. Explain the scientific reasons for each step in the process. [8]

a) In micropropagation, plant tissues or explants e.g. meristematic cells are removed from plants or explants only;
b) Reason: Meristematic regions are preferred as they are undifferentiated and virus-free;
c) Surface of explants sterilised with dilute sodium hypochlorite (Clorox);
d) Reason: To kill bacterial and fungal pathogens or organisms;
e) And grown in a containing sterile media containing nutrients and plant growth regulators needed for plant growth;
f) Containers holding the explants are then sealed and incubated for 1-9 weeks;
g) Reason: All procedures must be sterile to ensure that microorganisms do not grow in the cultures as they would grow faster and out-compete the plants in these conditions;
h) During this period, the cultured cells divide by mitosis;
i) to form a mass of undifferentiated tissue called a callus;
j) As callus increases in size, pieces of callus is sliced off and grown on new medium composition (subculturing);
k) Reason: This creates many genetically identical clones of the original plant;
l) By adjusting concentration of auxin to cytokinin ratio in growth medium;
m) cells in callus can be induced to differentiate into roots and shoots;
n) Reason: To enable plantlet formation;
o) Further growth being encouraged by the use of plant growth substances until plantlets are large enough;
p) Plantlets are taken out from culture vessels, washed to remove the agar, soaked in fungicide and antibiotics and then planted in sterile soil in green house for 4-8 weeks;
q) Reason: This is to allow the plants to acclimatise from a heterotrophic to an autotrophic existence and the acclimatization of the plant to the outdoor environment;
r) After acclimatization in green house, the plant are transferred to soil for field planting;

Points a) to r): ½ m each (max 8 m)

(c) Distinguish between a genomic DNA library and a cDNA library. [4]

Genomic DNA library	cDNA library
a) Contains all coding and non-coding sequences;	Expressed genes in the tissue – lack non-coding regions;
b) Cell's DNA cut using RE and inserted into vectors;	mRNA → cDNA using reverse transcriptase which is then inserted into vectors;
c) Need vectors ranging from plasmids to BAC to accommodate larger DNA sequences;	cDNA is relatively short, plasmids and λ phage often used as vectors;
d) A single gene can be spread out over different clones - A lot of DNA to isolate and analyse;	only contain coding sequences for that gene, which reduces the amount of DNA one has to isolate and analyse;
e) To study control of gene expression;	Isolate a particular gene that is active in a specialized cell and analyse its properties;

Any 4 differences, must be point to point comparisons (max 4 m)

[Total: 20]

H

Year 6 Preliminary Examination
Higher 2

BIOLOGY 9648/01

Paper 1 Multiple Choice **27th September 2016**

1 hour 15 min

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name and shade your Index Number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** questions in this paper. Answer all questions. For each question there are four possible answers **A, B, C**, and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

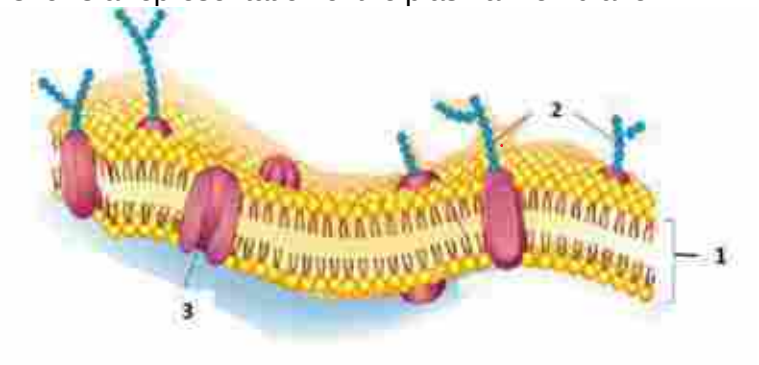
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

(Erase all mistakes completely. Do not bend or fold the OMR Answer Sheet).

This document consists of **29** printed pages.

Raffles Institution
Internal Examination

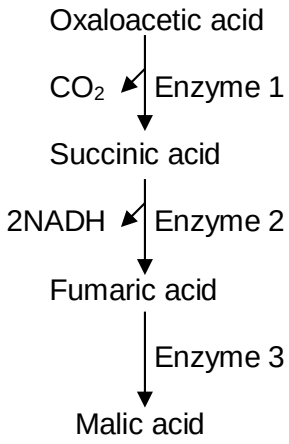
1. The diagram below shows a representation of the plasma membrane.



Which of the following structures are correctly matched with their role(s)?

	cell-cell recognition	**maintenance of resting membrane potential**	**uptake of steroid hormones**
A	**2** only	**1** and **3** only	**1** only
B	**2** only	**1** only	**1** and **3** only
C	**2** and **3** only	**1** only	**3** only
D	**3** only	**1** and **3** only	**1** only

2. The figure below shows an enzyme-catalysed pathway.



The addition of malonic acid results in no change in the concentration of oxaloacetic acid, an accumulation of succinic acid, and a very low concentration of both fumaric acid and malic acid.

What does this information indicate about malonic acid?

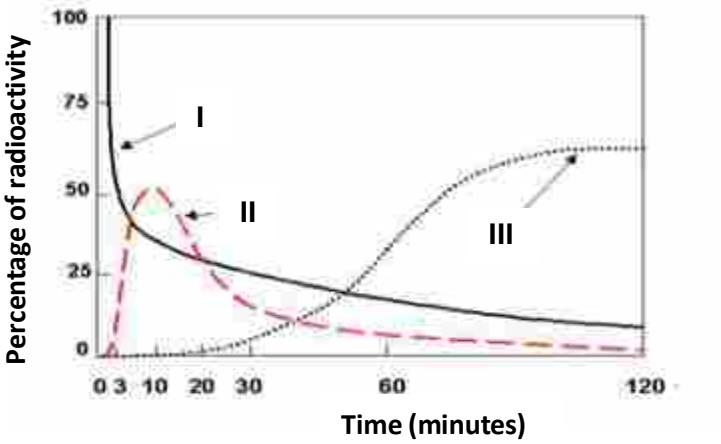
A It is an inhibitor of enzyme 1.

B It catalyses the formation of succinic acid.

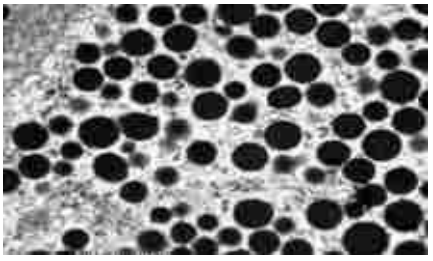
C It is an inhibitor to enzyme 2.

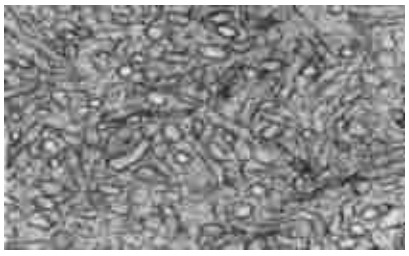
D Malonic acid is reduced in the process.

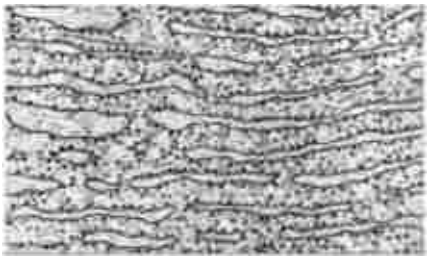
3. A pulse-chase experiment was used to trace the path taken by amino acids in a cell over a period of time. During the experiment, a cell producing salivary amylase was grown in a culture containing radioactive amino acids for a few minutes. The percentage of radioactivity at the various organelles was then measured and the results of the experiment are shown in the graph below.

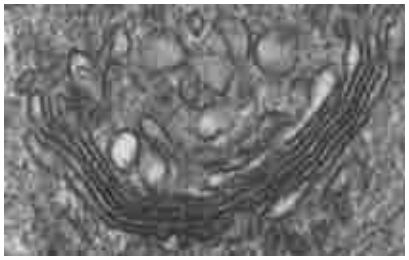


The micrographs of four different organelles from the cell producing salivary amylase are shown below.


P


Q


R

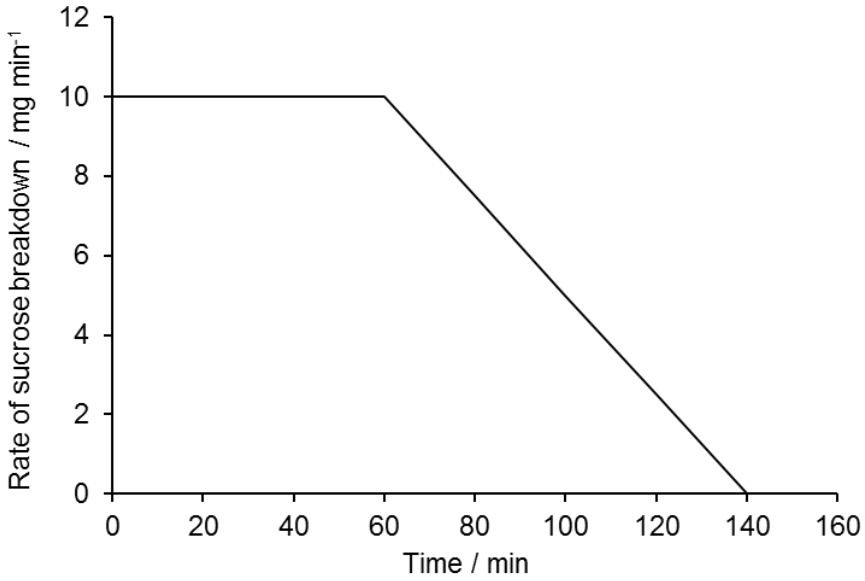

S

Each graph corresponds to an organelle in the cell where the radioactivity was measured.

Which of the organelles shown above are correctly matched with the graphs?

	graph I	graph II	graph III
A	**R**	**S**	**P**
B	**P**	**R**	**S**
C	**Q**	**R**	**S**
D	**R**	**S**	**Q**

4. The graph shows the results of an investigation using invertase, an enzyme that breaks down sucrose into glucose and fructose. 1 g of sucrose was dissolved in 100 cm^3 of water and 2 cm^3 of a 1% invertase solution was added.



Which conclusion can be drawn from this information?

A Between 0 and 60 min, the concentration of the substrate remains constant.

B After 60 min, the concentration of enzymes becomes the limiting factor.

C At 140 min, some of the enzyme molecules are denatured.

D Between 60 and 140 min, the concentration of the substrate is the limiting factor.

5. Vitamin C adds hydroxyl groups to two amino acids, proline and lysine. Without the presence of Vitamin C, the production of collagen is disrupted.

This is due to the inability to form

A the tertiary structure of tropocollagen.

B collagen fibrils.

C the secondary structure of collagen.

D disulfide bonds.

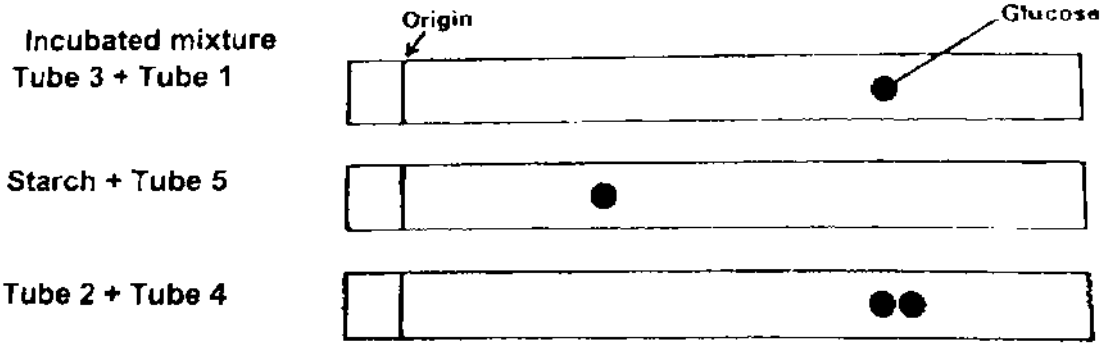
6. 3 samples of common carbohydrates and 3 samples of enzymes were randomly mixed in different combinations in 5 different tubes. The following statements are some observations of various tests that were conducted on the contents of the 5 tubes.

I Sample in tube 2 is soluble in water. Sample in tube 3 was insoluble in water.

II Tube 5 tested positive with Biuret's test.

III All 6 individual samples tested negative with Benedict's test. However, certain mixtures showed positive test after incubation with other tubes.

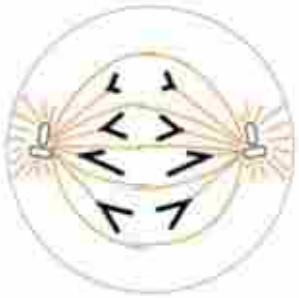
IV The mixtures were subjected to paper chromatography, and the results were shown below.



Which of the following correctly shows the contents of each tube?

	tube 1	tube 2	tube 3	tube 4	tube 5
A	amylase	cellulose	sucrose	cellulase	sucrose
B	cellulase	sucrose	cellulose	sucrase	amylase
C	cellulose	sucrose	cellulose	sucrase	amylase
D	sucrose	cellulose	sucrase	amylase	cellulase

7. The following diagram shows a stage during cell division in a eukaryotic diploid cell.



Which of the following statement(s) is/are false?

I The diagram represents a stage in mitosis.

II The diagram represents a stage in meiosis **II**.

III The chromosome number of the cell at interphase is 2n = 4.

IV This process occurs in the root tips of plants.

A **II** and **III** only

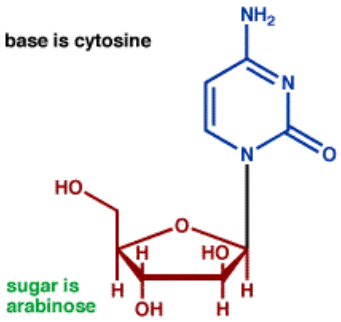
B **I**, **III** and **IV** only

C **I** and **IV** only

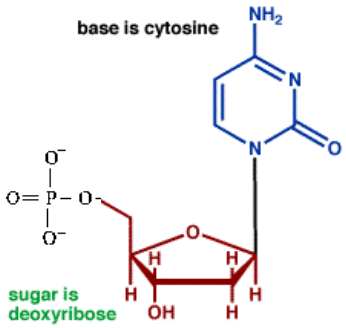
D **III** only

8. Cytarabine is a drug used to treat certain cancers. It consists of a cytosine base and an arabinose sugar.

The diagram below shows the structures of cytarabine and the deoxyribonucleotide, deoxycytidine triphosphate (dCTP).



Cytarabine



Deoxycytidine triphosphate

Which of the following statements are true?

I Cytabarine has a hydroxyl group attached to carbon number 4 of its sugar while deoxycytidine triphosphate has a phosphate group attached to carbon number 4 of its sugar.

II Cytarabine prevents DNA replication.

III Deoxycytidine triphosphate molecule has a free 3' hydroxyl group that can form a phosphodiester bond with another ribonucleotide during DNA replication.

IV Cytarabine has a greater effect on cancer cells than healthy cells as cancer cells divide faster than healthy cells.

A **I** and **II** only

B **II** and **IV** only

C **I** and **III** only

D **II, III** and **IV** only

9. Fig. 9.1 and Fig. 9.2 are electron micrographs that show ribosomes (dark circular structures) involved in protein synthesis. One figure illustrates protein synthesis in a eukaryotic cell while the other illustrates protein synthesis in a prokaryotic cell.

Fig. 9.1

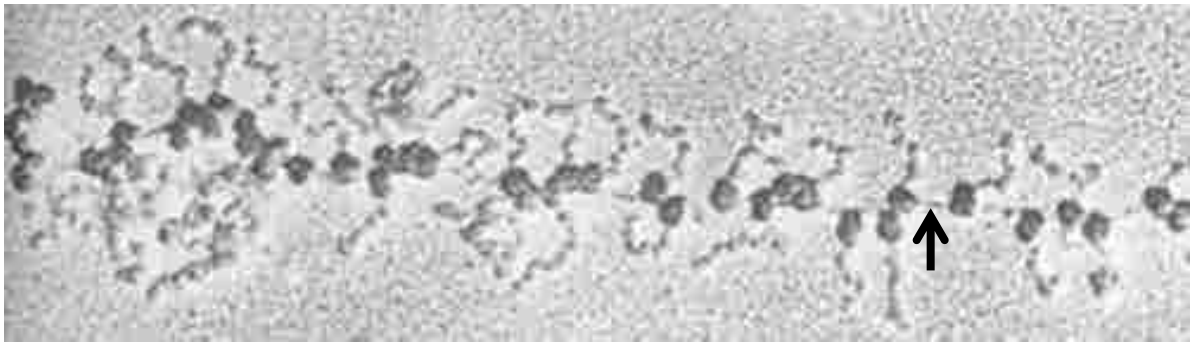


Fig. 9.2

Which of the following statement(s) is/are false?

I Fig. 9.1 illustrates a process that occurs in prokaryotic cells while fig. 9.2 illustrates a process that occurs in eukaryotic cells.

II The arrows in both fig. 9.1 and fig. 9.2 are pointing to the chromosomal DNA.

III Complementary base pairing occurs between the rRNA in the mRNA binding site of the small ribosomal subunit and the mRNA.

IV The rRNA molecule in the ribosomal subunit catalyses the formation of a peptide bond between the amino group of the incoming amino acid at the P site and the carboxyl end of the growing polypeptide chain at the A site.

A **II** only

B **II** and **IV** only

C **I** and **III** only

D All of the above

10. Sickle cell anaemia is caused by a mutation in the gene that codes for the β-globin polypeptide of haemoglobin.

The sequence of bases below is a small section of the template strand of DNA for both the normal allele (HbA) and the sickle cell allele (HbS).

HbA allele CTGACTCCTGAGGAGAAGTCT

HbS allele CTGACTCCTGTGGAGAAGTCT

How will the mutation in the HbS allele result in the production of a non-functional β-globin polypeptide?

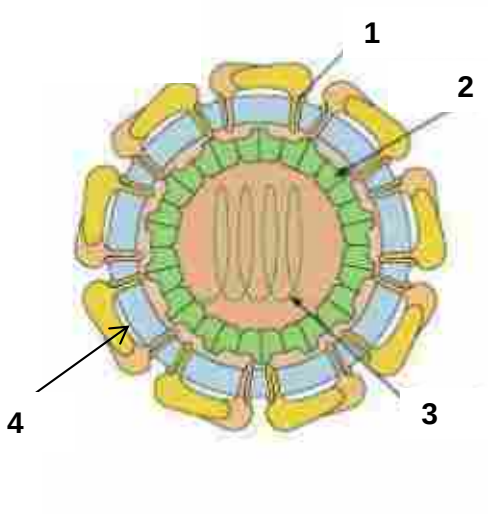
A The mRNA transcribed from the HbS allele will contain the codon CAC instead of the codon CTC.

B All the amino acids coded for after the mutation will differ from those in the HbA protein.

C A tRNA molecule with the anticodon GUG will hydrogen bond to the altered codon on mRNA.

D The ribosome will be unable to continue translation of the HbS mRNA after the altered codon.

11. The Zika virus is a type of flavivirus. Its replication cycle is similar to that of the influenza virus. The diagram below shows the structure of the Zika virus.



Which of the following correctly matches the numbered structures?

	1	2	3	4
A	transmembrane protein	capsid	DNA genome	lipid bilayer
B	viral glycoprotein	capsomere	RNA genome	viral envelope
C	receptor	matrix protein	viral genome	capsid
D	viral glycoprotein	capsomere	nucleoprotein	matrix protein

12. During the replication cycle of the human immunodeficiency virus (HIV), the polyprotein that is produced is cleaved by a viral protease enzyme, producing several smaller peptides. This viral enzyme is the target of anti-HIV drugs.

Which feature is essential for the success of these drugs?

A A complex structure that inhibits many types of enzymes.

B A molecule containing a heavy metal atom that is non-competitive inhibitor of enzymes.

C A protein that can act as a competitive inhibitor of protease enzymes.

D A specific structure that inhibits only viral protease.

13. Which of the following statement(s) concerning *trp* operon is/are true?

I A deletion mutation of the operator will lead to the constitutive production of tryptophan.

II There is one start and one stop codon in the mRNA of *trp* operon.

III The repressor is inactive in the presence of excess tryptophan.

IV The mRNA codes for 3 polypeptides involved in the synthesis of tryptophan.

A **I** only

B **I, II** and **III** only

C **II** and **III** only

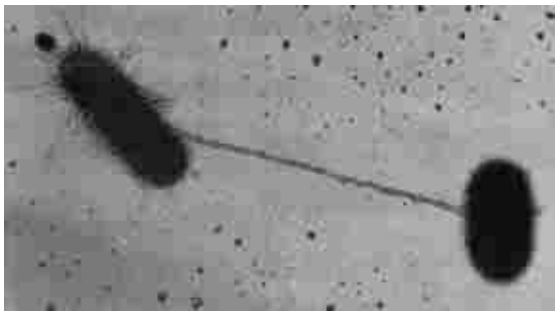
D **I** and **IV** only

14. The following electron micrographs show processes involving bacteria.

X

Y

Z



Which of the following statement(s) is/are true?

I All the processes, **X, Y** and **Z** increase the genetic diversity in bacteria.

II The rolling circle mechanism of DNA replication occurs in processes **Y** and **Z**.

III Process **X** may lead to the introduction of new bacterial DNA into the bacteria.

IV DNA replication occurs in processes **Y** and **Z**.

A **I**, **II** and **III** only

B **II** and **III** only

C **I** and **IV** only

D **III** and **IV** only

15. The following processes are different means by which gene expression can be regulated.

I amplification of a specific gene by rolling circle replication

II small effector molecules bound to activator protein controlling an inducible operon

III regulatory protein bound to control element causing spacer DNA to bend such that this regulatory protein interacts with TATA box directly

IV removal of acetyl groups from lysine residue of histones

Which of the above processes would result in the upregulation of gene expression?

A **I** and **II** only

B **II** and **IV** only

C **I**, **II** and **III** only

D All of the above

16. *BRCA1* and *BRCA2* genes codes for gene products with DNA repair functions. Mutations in these two genes increase the risk of female breast cancer or ovarian cancer. It is observed that individuals who inherit mutations in *BRCA1* and *BRCA2* genes tend to develop breast or ovarian cancer at a younger age.

Which of the following statements provides the best explanation for such observation?

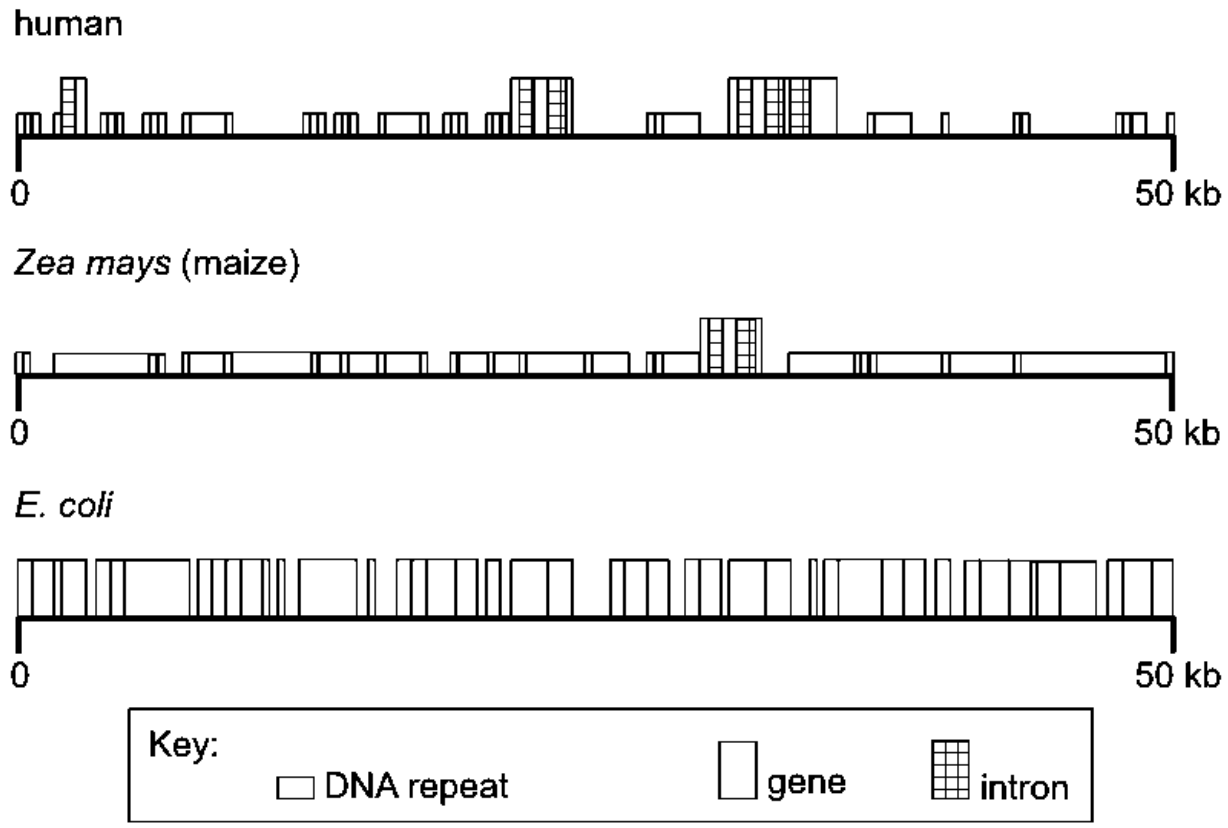
A Both *BRCA1* and *BRCA2* genes are proto-oncogenes. When mutated, their non-functional protein products cannot repair damaged DNA.

B Other oncogenes may accumulate mutations quickly to form proto-oncogenes as there are no protein products to carry out DNA repair.

C Development of cancer is a multistep process that requires accumulation of mutations in more than 1 gene.

D Individuals have mutations in a copy of each tumour suppressor gene, *BRCA1* and *BRCA2*. Thus less time is required for a single cell to acquire another loss-of-function mutation in the other copy of the tumour suppressor gene and a gain-in-function mutation in a proto-oncogene to become cancerous.

17. The diagram shows 50 kb segments of the human, *E.coli* and *Zea mays* genomes.



Which one of the following statements can be concluded from the above results showing the genetic organisation of a 50 kb portion of the human, *E.coli* and *Zea mays* genomes?

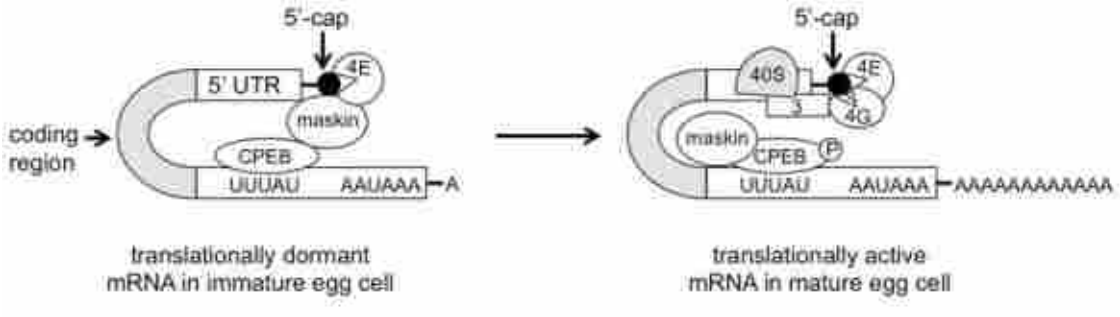
A More complex organisms have lower gene density.

B Organisms with smaller chromosome number have higher gene density.

C *Zea mays* has a higher density of DNA repeats as compared to humans and *E. coli*.

D The presence of introns in DNA of eukaryotes allows alternative splicing to occur to synthesise as many proteins as prokaryotes.

18. During development, an immature egg cell of *Xenopus* has many translationally dormant mRNAs in its cytoplasm. The figure below shows how one of these mRNAs becomes active upon maturation of the egg cell. In the figure, 4E, 4G and 3 are eukaryotic translation initiation factors.



Which one of the statements describes how translation is repressed in the immature egg cell?

A Mutation in the 5' UTR of mRNA in immature egg cell causes maskin protein to temporary interact with the 5' cap until its original mRNA sequence is restored in mature egg cell.

B CPEB needs to be phosphorylated in order for maskin protein to detach from it and enable large ribosomal subunits and eukaryotic translation initiation factors to bind to 5' of mRNA.

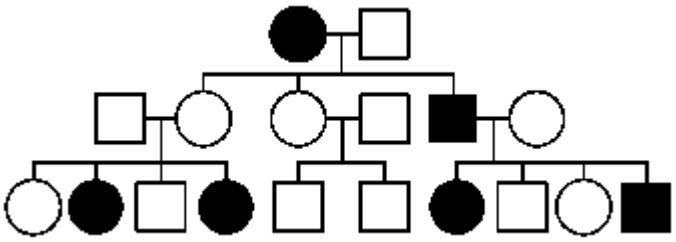
C Maskin protein interacts with the 5' cap of mRNA in immature egg cell to prevent formation of translation initiation complex that is made up of small ribosomal subunit and a set of eukaryotic translation initiation factors.

D Absence of poly(A) tail of mRNA in immature egg cell prevents assembly of translation initiation complex.

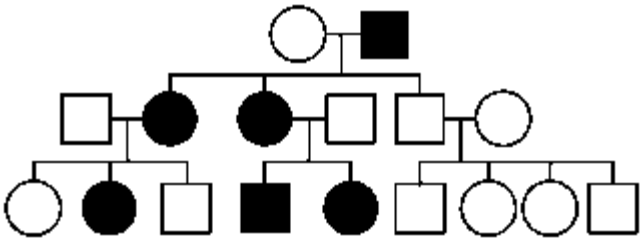
19. Kearns-Sayre syndrome is a rare genetic trait caused by a deletion of up to 10 000 nucleotides from the mitochondrial DNA (mtDNA). Most individuals with this syndrome have weak eye muscles, drooping eyelids, vision loss and, often, short stature.

Which pedigree shows a family affected by Kearns-Sayre syndrome?

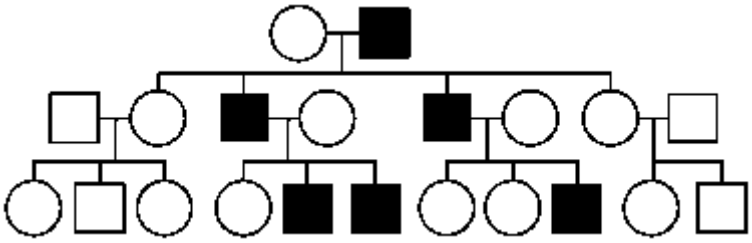
A



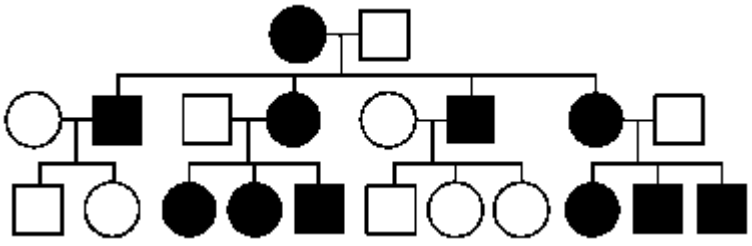
B



C



D



20. Flamingos are birds that live by lakes. The feather colour of flamingos may vary from white to pink to red. To investigate the inheritance of feather colour, a scientist performed the following crosses and recorded the feather colour of all the offspring when they were one year old. The diet of the offspring was also recorded.

cross	feather colour of parents	feather colour of all one-year old offspring	diet of offspring
1	white x white	white	aquatic plants
2	red x white	white	aquatic plants
3	white x white	pink	algae and crustaceans
4	red x white	pink	algae and crustaceans

Based on the above information, which of the following is a correct conclusion?

A Both the parents in cross 1 must be homozygous for white feather colour.

B White feather colour is recessive to red feather colour.

C The feather colour of flamingos is influenced by their environment.

D Two pink-feathered parents would only produce one year old offspring with pink feathers.

21. In guinea pigs, the genes for hair length and hair type have the following alleles:

allele S : long hair
allele s : short hair
allele W : straight hair
allele w : wavy hair

A breeder first carried out a cross between pure-breeding long, straight hair guinea pigs and short, wavy hair guinea pigs. The offspring of this cross were then subjected to many test crosses to determine if the two genes were linked.

If the two genes were closely linked, which of the following is a likely result of the test crosses?

A There will be more guinea pigs with long, wavy hair than short, wavy hair.

B There will be more guinea pigs with short, straight hair than short, wavy hair.

C There will be approximately equal numbers of long, straight hair and long, wavy hair guinea pigs.

D There will be approximately equal numbers of long, straight hair and short, wavy hair guinea pigs.

22. In an experiment, chloroplast extracts were first treated with a chemical that 'snatches' away the electron that was accepted by the electron acceptor in photosystem I. The extracts were then treated with 2 hours of light and were provided with ample carbon dioxide and water.

Which of the following correctly shows the products that were formed after the experiment?

	O_2	ATP	reduced NADP	glucose
A	+	+	–	–
B	–	+	+	+
C	+	–	–	–
D	–	–	+	–

Key: (+) = present, (–) = absent

23. The blue dye DCPIP can be converted to colourless DCPIP as shown below:

DCPIP (blue) → reduced DCPIP (colourless)

A suspension of chloroplasts was made by grinding fresh leaves in buffer solution and centrifuging the mixture. Tubes were then prepared and treated in the following ways.

tube	contents	treatment	colour	
			at start	after 20 minutes
1	1 cm^3 chloroplast suspension + 5 cm^3 DCPIP	illuminated strongly	blue green	green
2	1 cm^3 buffer solution + 5 cm^3 DCPIP	illuminated strongly	blue	blue
3	1 cm^3 chloroplast suspension + 5 cm^3 DCPIP	left in the dark	blue green	blue green

Which one of the following statements is a possible conclusion for the observation above?

A Electron transfer from reduced NAD to DCPIP causes the decolourisation of DCPIP.

B NADP was oxidised and the electron was used to decolourise DCPIP.

C Light dependent reaction which occurs in the chloroplasts yield free electrons which reduced DCPIP.

D Either strong illumination or the buffer solution used in the extraction of chloroplasts could oxidise DCPIP.

24. Six tubes were set up as shown in the table and incubated.

tube	contents
1	glucose + homogenized plant cells
2	glucose + mitochondria
3	glucose + cytoplasm from liver cells lacking organelles
4	pyruvate + homogenized liver cells
5	pyruvate + mitochondria
6	pyruvate + cytoplasm from liver cells lacking organelles

Which of the following tubes will contain lactate?

A **1** and **3** only

B **2, 3, 5** and **6** only

C **4, 5,** and **6** only

D **3** and **6** only

25. One form of fur color in mice is controlled by the interaction of two gene resulting in three phenotypes: agouti (alternating dark and light bands), black, and albino. Both genes affect the same trait (fur color). One gene controls the formation of pigment (A) and the other controls the distribution of the pigment (B) when it is produced.

Two agouti mice which bred repeatedly produced the following offspring: 46 agouti, 16 black, and 23 albino.

Which of the following statements are true?

I The gene interaction pattern is indicative of recessive epistasis.

II The gene interaction pattern is indicative of dominant epistasis.

III The genotype of both the agouti parents is AaBb.

IV The offspring genotypic ratio is: 9A_B_: 3A_bb: 3aaB_: 1aabb
The offspring phenotypic ratio is: 9 agouti: 3 black: 4 albino

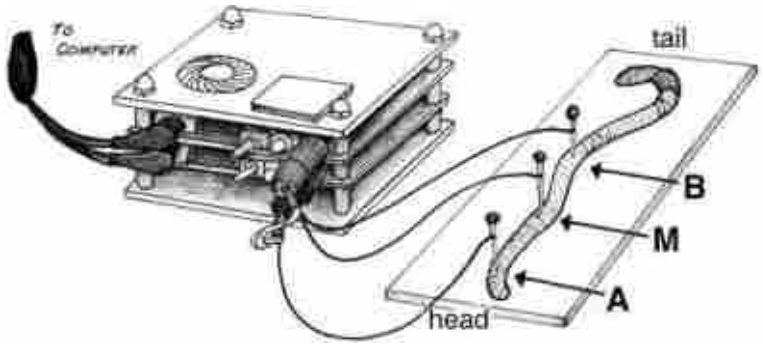
A **I** and **III** only

B **II** and **III** only

C **II** and **IV** only

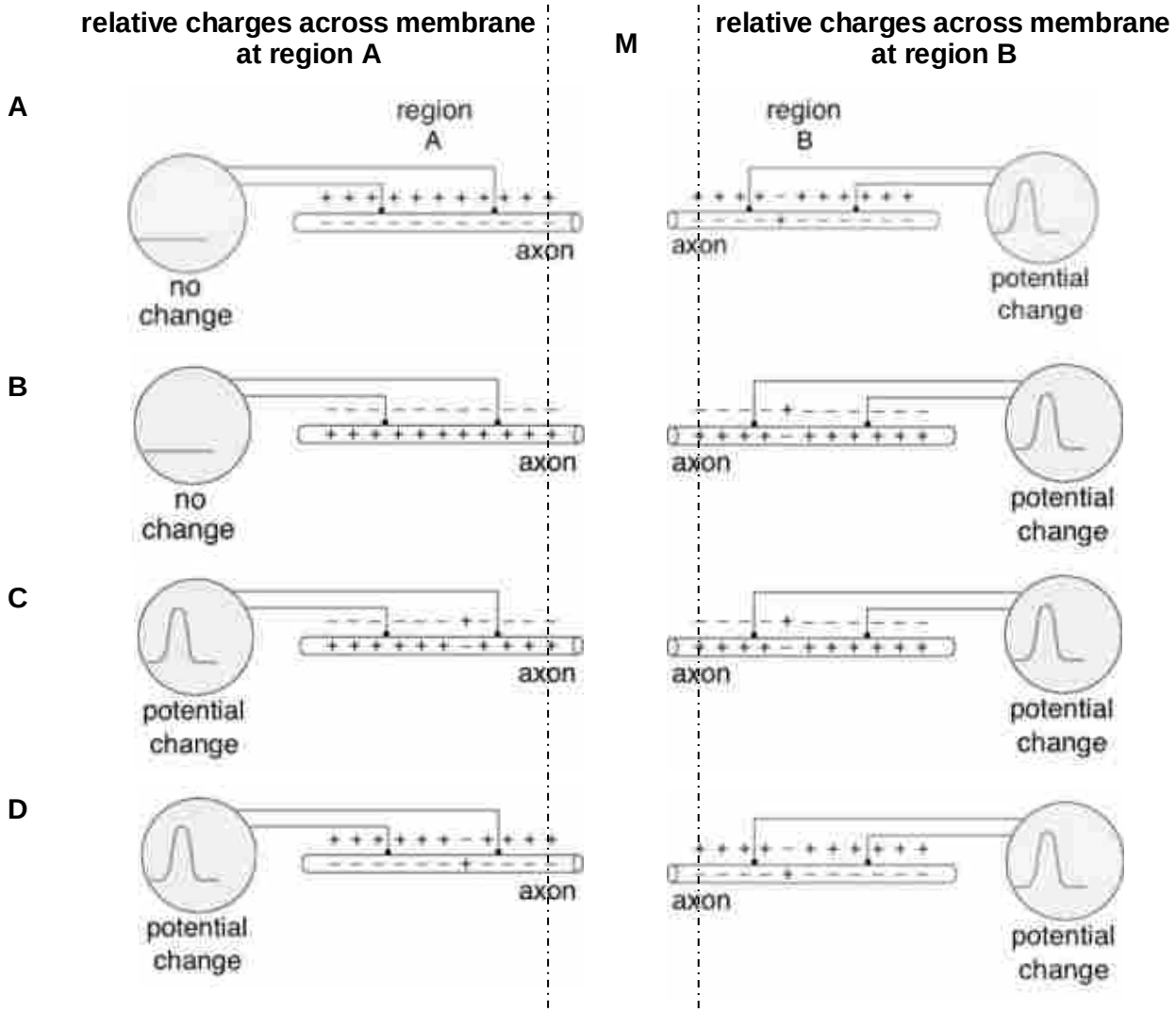
D **I**, **III** and **IV** only

26. An experiment that records the change in the membrane potential from the giant fibre of an anesthetised earthworm was performed. As shown in the simplified diagram below, an electrical stimulus was applied to point M (middle of the axon) while recording electrodes were present at regions A and B.

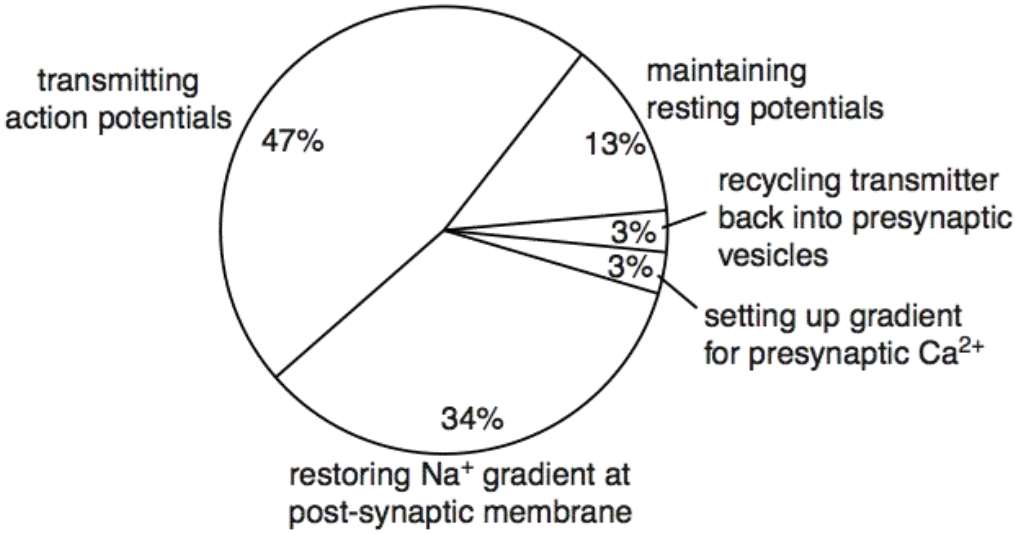


The following shows the possible results at the recording electrodes at regions A and B after a stimulus was applied to point M.

Which of the following is correct?



27. The pie chart shows the percentage of energy used by a myelinated motor neurone for various processes related to impulse transmission.



Which of the following statements about the neurone can be inferred from the results shown in the pie chart?

A The percentage of energy required at the nodes of Ranvier is 60%.

B 3 sodium ions move out to extracellular and 2 potassium ions move in to cytosol of axon to maintain resting potentials.

C 34% of energy is used to transport Na^+ into the post-synaptic neurone to restore the Na^+ gradient.

D 3% energy is required to open the voltage-gated calcium ion channel to enable influx of calcium ions into the presynaptic knob.

28. All of the following statements about events involved in glycogen metabolism are true except

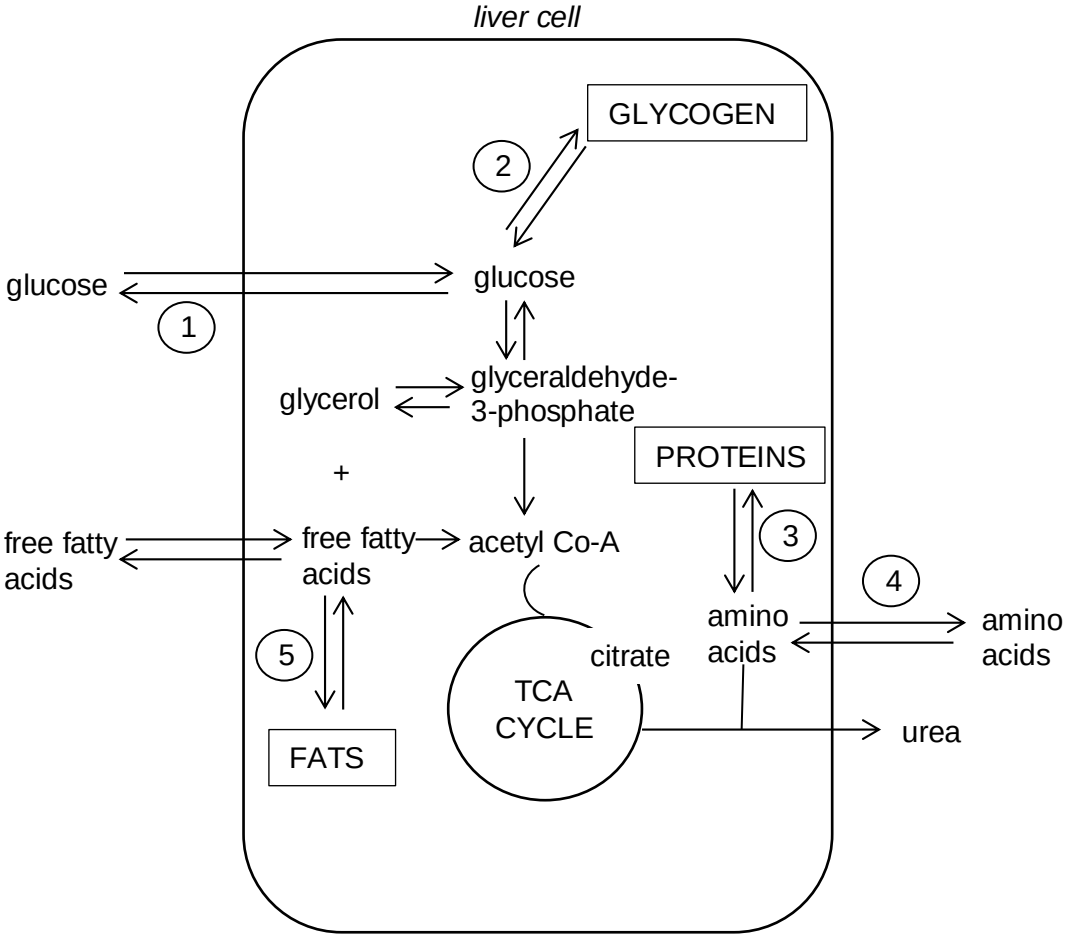
A cAMP-activated protein kinase stimulates glycogen synthesis.

B Kinases are activated by phosphorylation.

C cAMP levels are raised during glycogen hydrolysis.

D Cross-phosphorylation of receptor subunits leads to glycogenesis.

29. The diagram below shows the biochemical pathways in a liver cell. Some of the points where hormones affect the pathways are labelled 1 to 5.



At which numbered points would the hormone insulin accelerate the pathways in the directions indicated?

A 1, 2 and 3 only

B 1, 2 and 5 only

C 2, 3 and 4 only

D 2, 3 and 5 only

30. Which of the following statement(s) about receptor tyrosine kinases (RTKs) is/are true?

I The insulin receptors has a 7-pass transmembrane domain.

II RTKs can auto-phosphorylate tyrosine residues on other proteins.

III RTKs have transmembrane domains.

IV RTKs are subunits that can dimerise.

A **III** and **IV** only

B **II** and **IV** only

C **I, III** and **IV** only

D All of the above

31. Two areas of molecular biology that have received considerable attention in evolutionary studies are the genetic code and cytochrome C. Cytochrome C is an essential component of all respiratory electron transport chains.

Which statements lend evidence to the following 2 ideas?
Idea 1: All living organisms are related, and
Idea 2: There is a single, rather than a multiple, origin of life?

1	The almost universal nature of the genetic code is a result of evolutionary convergence from multiple lineages.
2	The sequence of amino acids in cytochrome C is similar in organisms that are from similar environments or with similar metabolic demands.
3	The majority of organisms have the same, or similar, amino acid sequences for cytochrome C.
4	When transferred into a very dissimilar organism, a gene coding for cytochrome C will lead to the expression of a protein that will function in the other organism.

A **1** and **2** only

B **2** and **3** only

C **3** and **4** only

D **1**, **3** and **4** only

32. Which of the following shows the correct sequence of events?

I	adaptation of a population	competition and predation leading to natural selection	behavioural isolation	allopatric speciation
II	adaptation of a population	competition and predation leading to natural selection	physiological isolation	allopatric speciation
III	competition and predation leading to natural selection	physiological isolation	adaptation of isolated populations	sympatric speciation
IV	competition and predation leading to natural selection	geographical isolation	adaptation of isolated populations	allopatric speciation

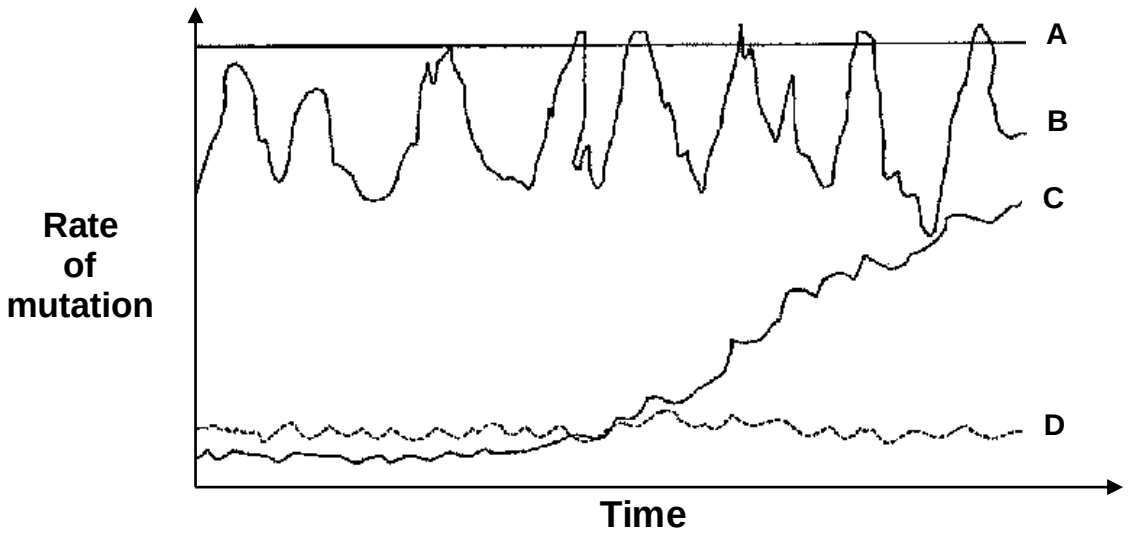
A **III** only

B **I** and **II** only

C **III** and **IV** only

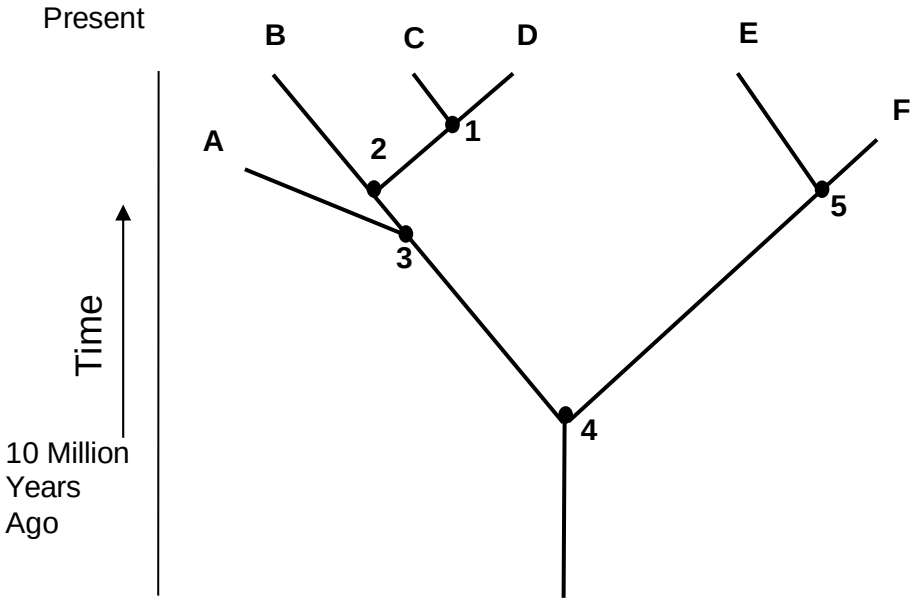
D **I**, **III** and **IV** only

33. The rate of mutation of 4 different genes were investigated and the results shown below.



Which pattern of mutation is most suitable if one desires to use a gene as a molecular clock to determine evolutionary relatedness of different species?

34. The diagram below shows a phylogenetic tree.



Which of the following statements are true?

I Organisms A, B, C, D, E and F are of different species, derived from a common ancestor.

II Organisms A and B are more closely related than organisms E and F.

III Organisms A and F are extinct.

IV Organisms C share more homologous structures with B than with D.

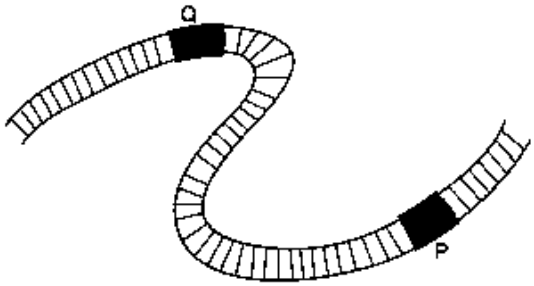
A **I**, **II** and **III** only

B **I** and **III** only

C **II** and **IV** only

D **III** and **IV** only

35. The genome of a small virus is depicted below, showing the positions of restriction sites P and Q for two different restriction enzymes.



The length of DNA fragments obtained when using these restriction enzymes is shown in the table alone.

restriction site	restriction enzyme	length of DNA fragments obtained (kb)
Q	*Eco*RI	3, 7
P	*Bam*HI	8, 2

If both *Eco*RI and *Bam*HI are used to cut this viral DNA, what will the length (in kb) of the DNA fragments obtained be?

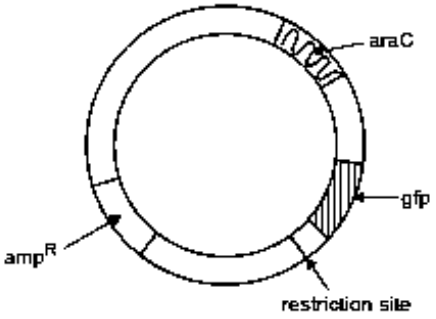
A 1, 2, 7

B 1, 3, 6

C 2, 3, 5

D 2, 3, 7

36. A diagram of a plasmid used in cloning is shown below.

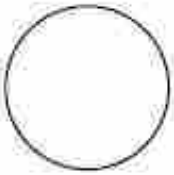
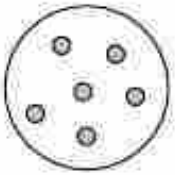
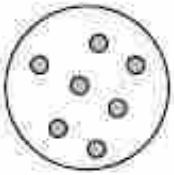


This plasmid contains a restriction site and three genes:
• *amp*^{R} – confers resistance to the ampicillin antibiotic
• *gfp* – encodes the green fluorescent protein (GFP), which fluoresces under UV light
• *araC* – encodes a protein that enables the expression of gfp when arabinose is present

E.coli were transformed with the above plasmids.

Untransformed bacteria were grown on nutrient agar plates W and X, while transformed bacteria were grown on nutrient agar plates Y and Z.

The results of the experiment are shown in the table below.

Plate	W untransformed bacteria only	X untransformed bacteria only	Y transformed bacteria	Z transformed bacteria
Diagram of plate				
Added to plate	nutrient agar only	nutrient agar and ampicillin	nutrient agar, ampicillin and arabinose	nutrient agar and ampicillin
Description of result	lawn of bacteria	no growth	bacterial colonies present	bacterial colonies present

Which one of the following statement(s) is/are true?

I Plate W shows that the nutrient agar promoted the growth of viable bacteria.

II Plate Y and Z contained bacteria that are ampicillin resistant and are able to produce arabinose.

III Plate Y contains bacteria that fluoresce under UV light.

IV Plate X is the negative control.

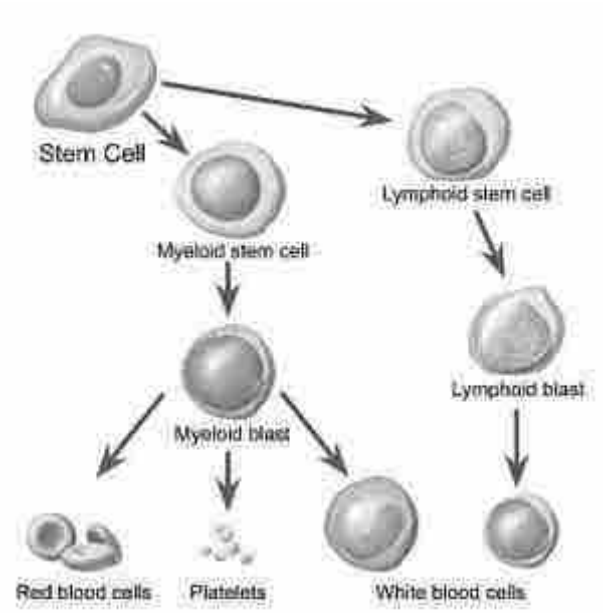
A **III** and **IV** only

B **III** only

C **I**, **III** and **IV** only

D **I** and **III** only

37. The following diagram shows how a stem cell can differentiate into different specialized cell types.



Which of these statements is false with regards to the stem cells shown?

A The stem cells are multipotent.

B The stem cells can be found in both a developing fetus and adult.

C The stem cells can differentiate into the endothelial layers in the blood vessels in the adult body.

D The stem cells may be used in to treat a patient suffering from SCID.

38. Which statement(s) explain(s) the limited success of somatic gene therapy as a permanent cure for genetic disorders in human populations?

I Somatic cells cannot pass the modified gene on to any offspring.

II The treatment does not last long as the treated somatic cells die and are replaced.

III Post-translational modification may be missing in the treated cells.

A **I** only

B **I** and **II** only

C **II** and **III** only

D All of the above

39. Corn is a major crop grown in Europe. In the past, it was either ruined by attack from the corn borer larvae or intensively sprayed with pesticides each year. The biotech company Novartis gained approval to insert a *Bt* gene into corn. This gene codes for a protein that kills the larvae feeding on the corn. The genetically engineered *Bt* corn initially thrived without the addition of any pesticides, but later suffered damage from pests again.

Which of the following are possible reasons why the yield of *Bt* corn decreased again over a few generations?

I A strain of resistant larvae has emerged due to a chance mutation. The frequency of the gene conferring resistance as well as the number of larvae with resistance has increased. The *Bt* gene is now ineffective.

II Corn is being attacked by other pests which are not killed by the *Bt* gene protein.

III Mutations in corn may have led to the loss of the *Bt* allele.

A **I** and **II** only

B **I** and **III** only

C **II** and **III** only

D All of the above

40. Which of the following matches between the process and its outcome is incorrect?

	process	outcome
A	anther culture	production of homozygous plants
B	embryo culture	production of distantly related plants
C	protoplast culture	formation of hybrid plants from parent plants of different species
D	callus culture	generation of differentiated tissues

End of Paper

H

RAFFLES INSTITUTION

2016 Year 6 Preliminary Examination
Higher 2

CANDIDATE NAME												
CIVICS GROUP	1	6	S	0	3		INDEX NUMBER						

BIOLOGY 9648/02

Paper 2 Core Paper

15th September 2016

2 hours

Additional materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your index number, CT group & name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A

Answer **all** questions.

Section B

Answer **one** question.

At the end of the examination, **hand in your essay SEPARATELY.**
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
8 or 9	
Total	

This document consists of **20** printed pages.

Section A

Answer **all** the questions in this section.

1 *Sordaria fimicola* is a fungus that produces long and narrow spore-bearing sacs. The fungus has a unique spore forming process. After fertilisation each zygote undergoes a single meiotic division followed by a single mitotic division to yield 8 spores (haploid cells) in a sac. Fig. 1.1 shows these sacs, each containing 8 haploid spores.

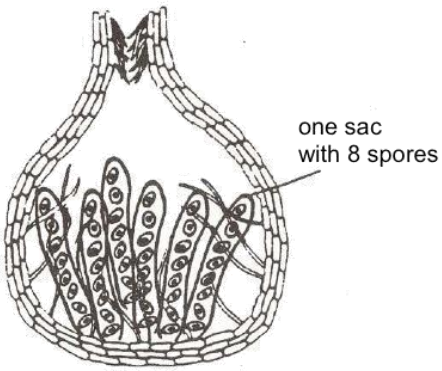


Fig. 1.1

(a) Black spores in the fungus inherit the wildtype allele B that codes for black pigment while white spores inherit the mutant allele b. When a strain of *Sordaria fimicola* that produced only black spores were crossed with another strain that produced only white spores, their hybrid zygote produced both black and white spores in each sac. Fig. 1.2 shows 3 out of the 6 possible arrangements of the black and white spores.

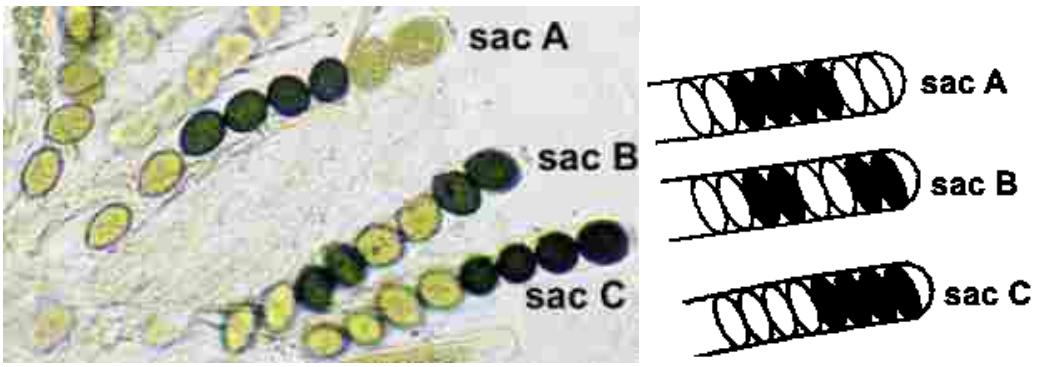


Fig. 1.2

(i) In Fig. 1.3, fill in the boxes with the genotype of the hybrid zygote and the genotypes of each spore in sac C. [2]

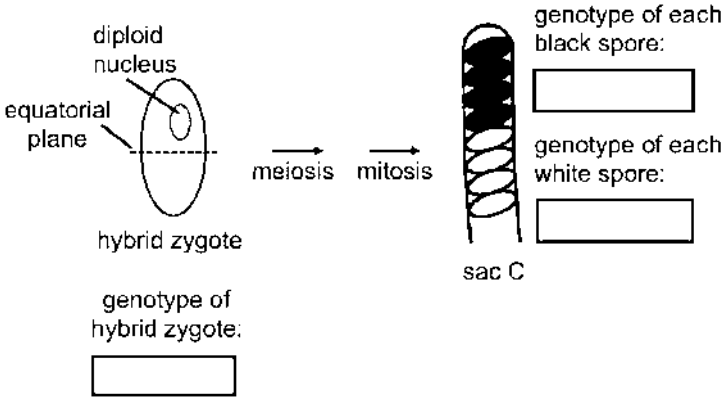


Fig. 1.3

(ii) The arrangement of the black and white spores in a sac depends on whether crossing over occurred in the hybrid zygote. For instance, the arrangement of spores in sac C was the result of a hybrid zygote that did not undergo crossing over but the arrangement of spores in sac B was the result of a hybrid zygote that underwent crossing over.

Fig. 1.4 shows a hybrid zygote that is undergoing meiosis to form sac B. In Fig. 1.4, draw the arrangement of chromosomes that contain alleles B/b at the end of prophase I of meiosis. Label your drawings clearly. [2]

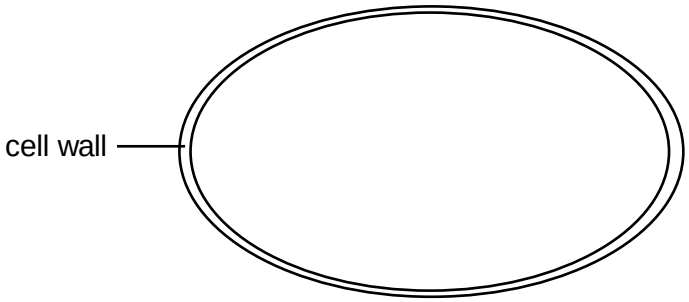


Fig. 1.4

(iii) Explain how 4 haploid spores of alternating black and white spore arrangement were formed due to meiosis.

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……

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…… [3]

(b) Further studies of the spindle fibers in the spore-forming fungus were carried out during its mitotic division. Fig. 1.5 is a graph showing the distance between poles of the spindle during mitosis.

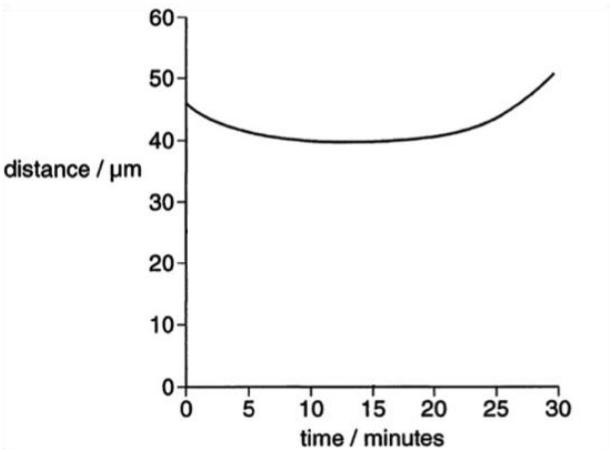

Fig. 1.5

It was observed that anaphase started at minute 15. On Fig. 1.5, sketch and label

(i) graph Y, that shows the distance between centromere and poles of the spindle, and

(ii) graph Z, that shows the distance between centromeres of sister chromatids. [2]

(iii) Outline the role of centromeres.

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…… [3]

[Total : 12]

2 The structure of a lytic bacteriophage is shown in Fig. 2.1.

(a) Identify components **A** to **D** in Fig. 2.1. [2]

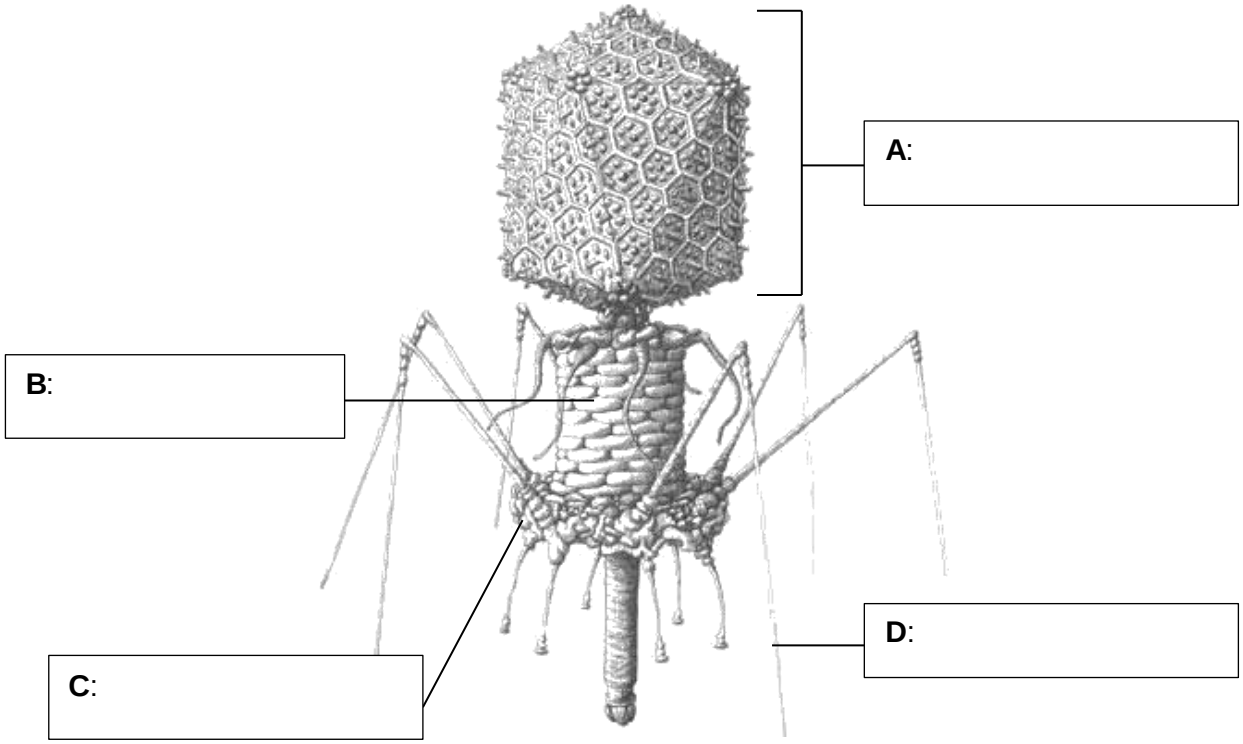

Fig. 2.1

(b) A strain of bacteria was spread throughout growth media on a petri dish. Different types of lytic bacteriophages were then introduced as shown in Fig. 2.2. Areas where infected bacterial cells are lysed show up as zones of clearings.

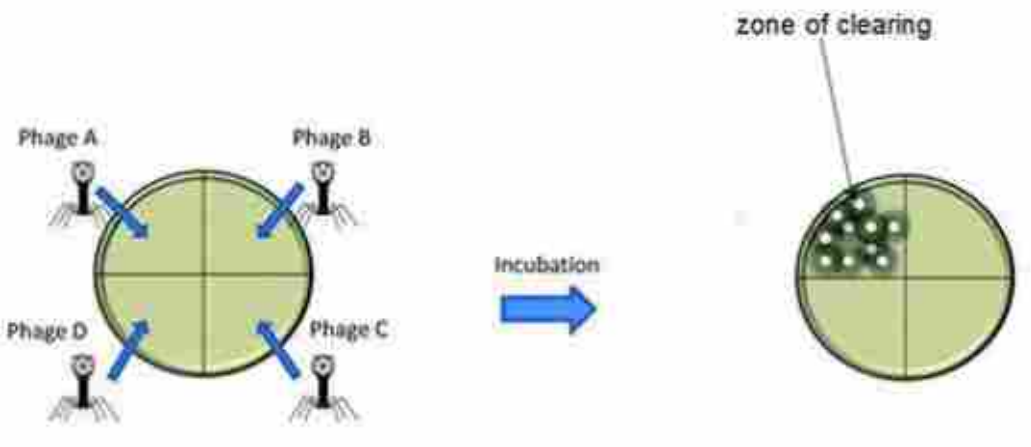

Fig. 2.2

With reference to Fig. 2.2,

(i) identify the bacteriophage(s) that did not undergo replication.

…….. [1]

(ii) suggest why the identified bacteriophage(s) in (b)(i) could not undergo replication.

……

……

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…….. [2]

(c) The life cycle of a lytic bacteriophage is shown in Fig. 2.3.

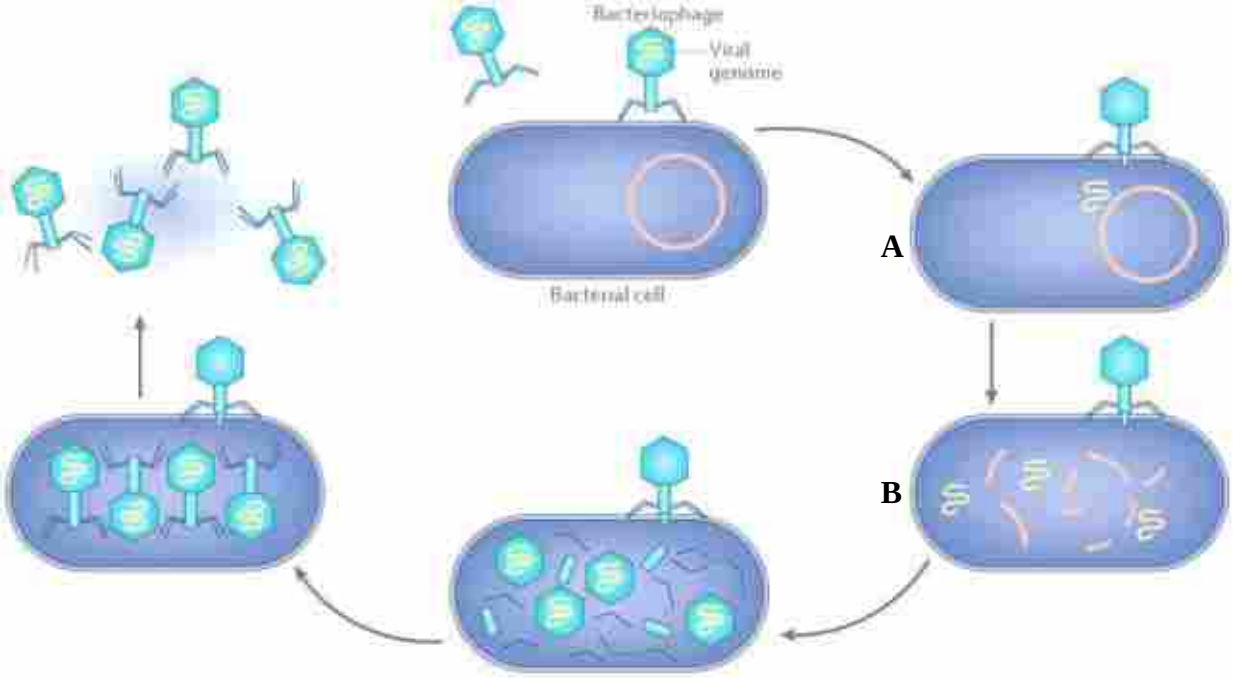

Fig. 2.3

With reference to Fig. 2.3,

(i) describe stage A.

……

……

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……

……

…… [3]

(ii) suggest why there is a need for the bacterial chromosome to be cleaved at stage B.

……

…… [1]

(iii) State a difference between the life cycles of a lytic and temperate bacteriophage.

……

…… [1]

[Total : 10]

3 Telomere length has been associated with cell division and cell cycle arrest. Fig 3.1 shows the telomere length over time in various cell types. If telomeres are shortened to a 'critical length', the cell will undergo permanent growth arrest or apoptosis.

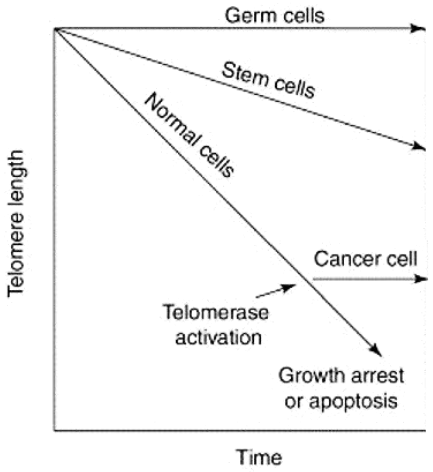

Fig. 3.1

(a) (i) With reference to Fig. 3.1, describe the difference in telomere length between normal cells and germ cells (cells that give rise to gametes) over time.

……

…….. [1]

(ii) Telomerase results in the extension of the telomere length. Explain the significance of telomerase in germ cells.

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…….. [2]

(iii) Describe how telomerase extends telomere length.

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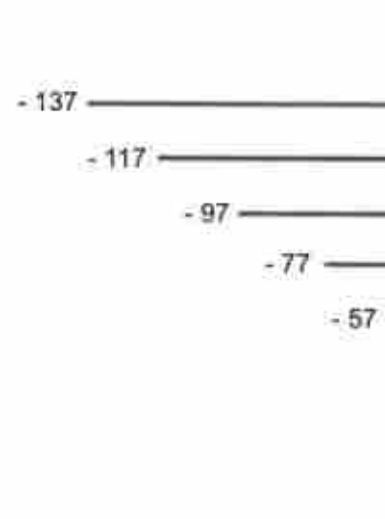
…….. [4]

(b) Transcriptional regulation of human telomerase (hTERT) gene is the major mechanism in regulating telomerase amount in human cells. The hTERT gene promoter is found to be inactive in normal cells but is activated in germline cells and stem cells.

The luciferase gene (*LUC*) is placed under the control of hTERT gene promoter of varying lengths as shown in Fig. 3.2. Luciferase produces a fluorescent green protein when luciferin is added. The intensity of the florescence was quantified and the results are shown below.



Intensity of florescence (A.U.)
100
100
100
89
69
0
0
0

Fig. 3.2

With reference to Fig. 3.2, explain the decrease in intensity of fluorescence when the region between -97 to -37 in the promoter is deleted.

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……

……

…… [2]

(c) Methylation of histones results in the recruitment of chromatin remodeling complexes that cause formation of heterochromatin.

Suggest why histone methylation occurs over large areas of chromatin in a differentiated cell.

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…… [3]

[Total : 12]

4 Fig. 4.1 shows an electron micrograph of normal liver tissues of mice.

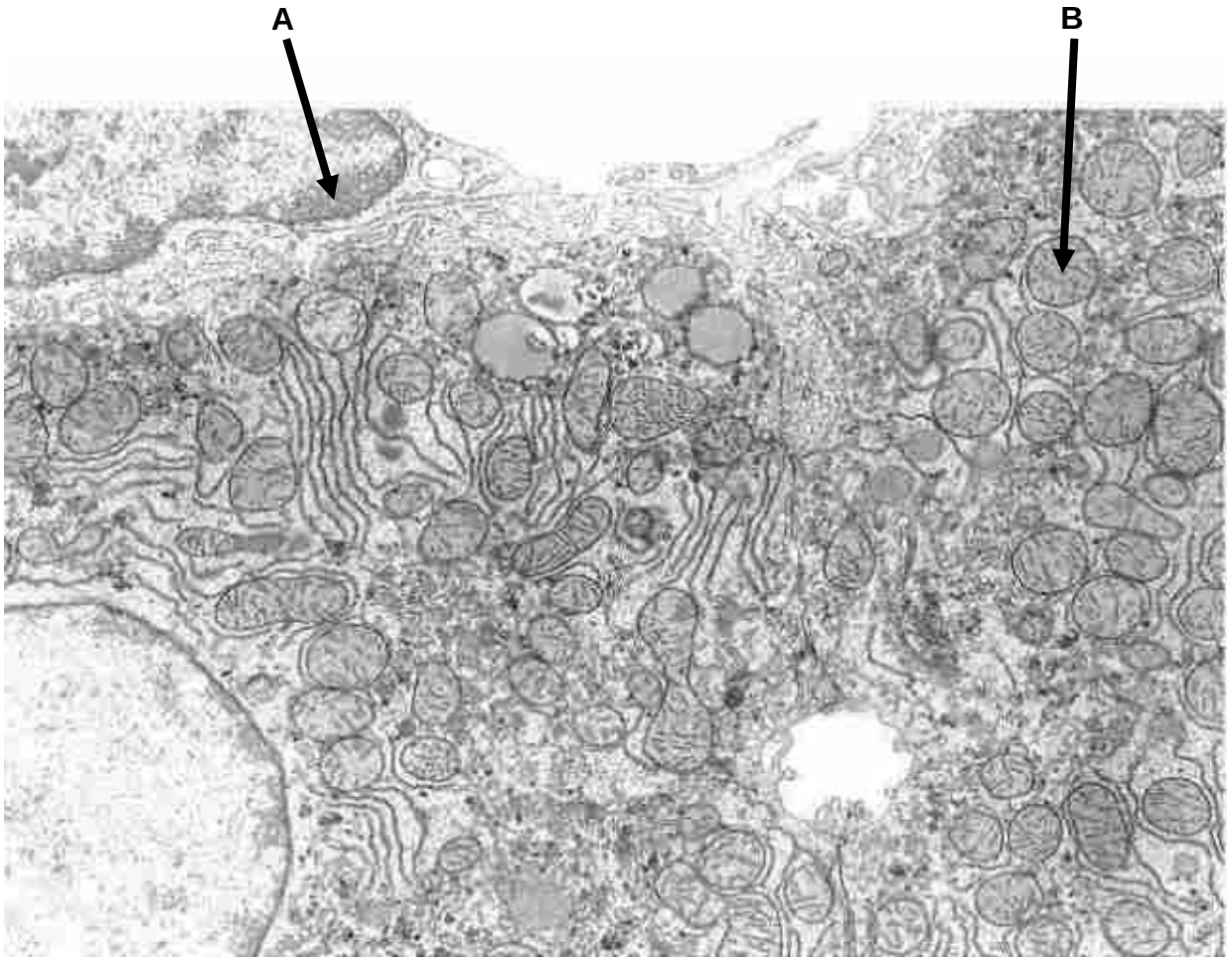

Fig. 4.1

(a) Identify organelles **A** and **B**. [1]

organelle **A**	

organelle **B**	

The liver tissue was homogenized and cell fractionation was performed. A sample of organelle B was obtained by differential centrifugation resuspended in a buffer. The concentration of H^+ in the various compartments within organelle B was measured at regular intervals. 10 minutes after the start of the experiment, a 10nM pyruvate solution was added to the buffer containing organelle B.

The results of the experiment are shown in Fig 4.2.

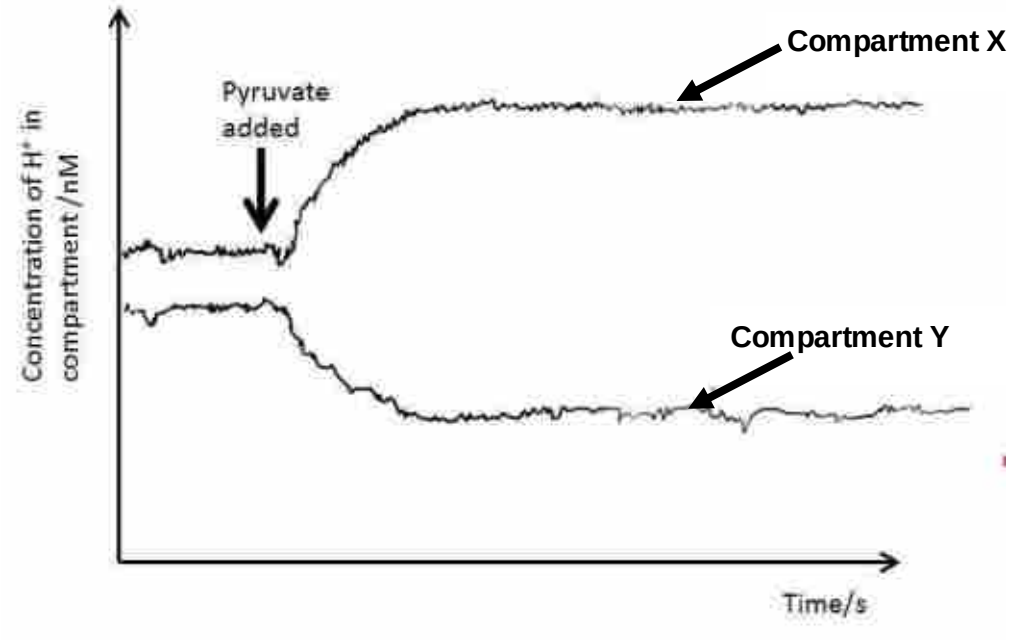

Fig. 4.2

(b) **(i)** Identify compartments **X** and **Y**. [1]

compartment **X**		compartment **Y**	

(ii) Explain the changes in the concentration of H^+ in compartment X following the addition of pyruvate into the buffer.

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…… [4]

(c) A metabolic poison, 2,4-dinitrochlorobenzene (2DNP), acts as a proton ionophore, an agent that can transport protons across biological membranes down a concentration gradient.

(i) The experiment was repeated in the presence of high concentration of 2DNP. Sketch on Fig 4.2, a graph that shows the concentration of H^+ in compartment Y in the presence of 2DNP. [1]

(ii) Explain the effect of 2DNP on ATP synthesis.

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……

…… [3]

(d) Compare the production of ATP in photophosphorylation and oxidative phosphorylation.

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……

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…… [3]

[Total : 13]

5 To study the inheritance of the cob length of maize, scientists crossed a variety of maize with long cobs with another variety of maize with short cobs. Cob length of the two varieties, Tom Thumb and Black Mexican and their hybrids are shown in Fig. 5.1.

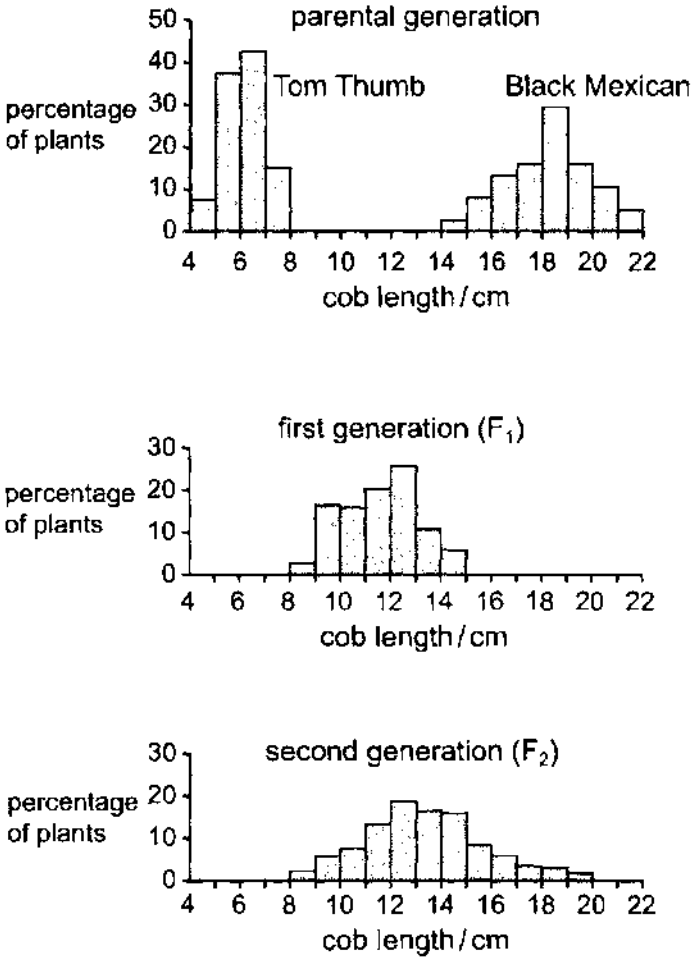

Fig. 5.1

(a) **(i)** State the term used to describe the range of phenotypes in the first generation (F_1) of offspring.

…… [1]

(ii) Explain why there is a range of phenotypes for cob length in the F_1 generation.

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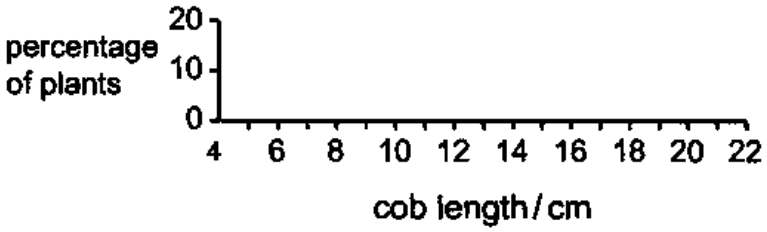
…… [3]

(b) Sketch in the space below, the graph showing the expected cross between F_1 and the parental variety Tom Thumb. [2]



(c) Two gene loci, A/a and B/b, control the kernel colour of maize plants. Two homozygous varieties with white kernels were crossed to produce F_1 plants with purple kernels. When F_1 plants were selfed, 477 purple kernels and 371 white kernels were produced in the F_2 generation.

(i) State the genotypes of the parental generation.

…… [1]

(ii) Draw a genetic diagram to show the selfing of the F_1 generation.

[3]

[Total : 10]

6 An experiment was conducted on an animal axon to measure how the intensity of stimulus affects nerve impulse transmission along the axon. Fig. 6.1 shows how a stimulating electrode was used to change the potential difference across an axon membrane. Two other electrodes, P and Q, were used to record any potential difference produced after stimulation.

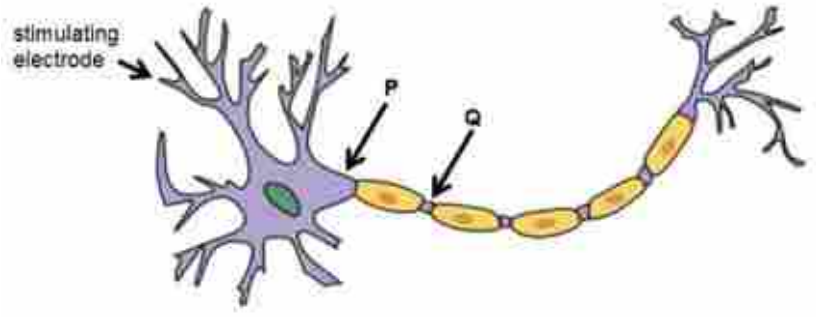


Fig. 6.1

The experiment was repeated six times, using a stimulus of different intensity each time.
Fig. 6.2 shows the stimulus potential and the membrane potential at P and Q. In experiments 1 to 4, the stimulating voltage made the inside of the axon less negative. In experiments 5 and 6, it made the inside of the axon more negative.

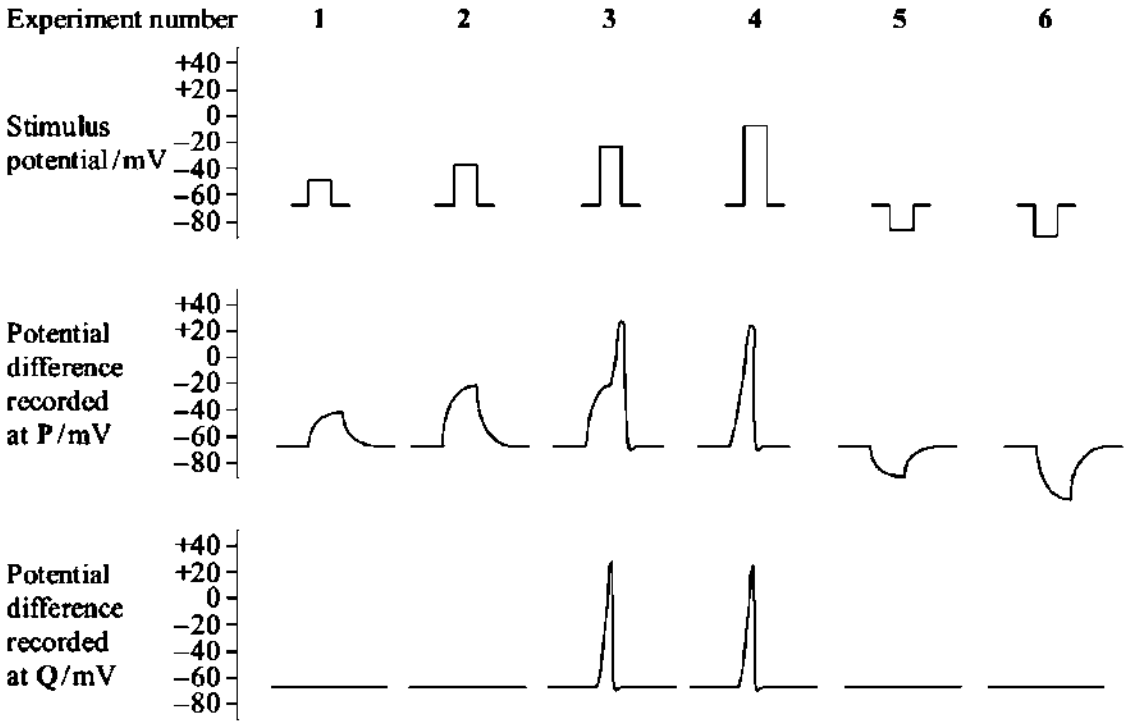


Fig. 6.2

(a) Explain the results of experiments 2 and 3.

(i) Experiment 2

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…… [2]

(ii) Experiment 3

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…….. [3]

(b) Suggest one significance of the refractory period.

……

…….. [1]

When a part of the body is damaged or injured, action potentials are sent to the areas of the brain responsible for the perception of pain.

The pain associated with osteoarthritis is often treated with morphine, a painkiller. Morphine is able to block the transmission of action potentials to the brain at the synaptic junction.

The pain from osteoarthritis can also be relieved using transcutaneous electrical nerve stimulation (TENS). It uses electrical impulses to stimulate the nerve endings at, or near, the site of the pain.

Self-adhesive electrodes are stuck on the skin and attached to a small, portable power unit. Fig. 6.3 shows a TENS machine in use.

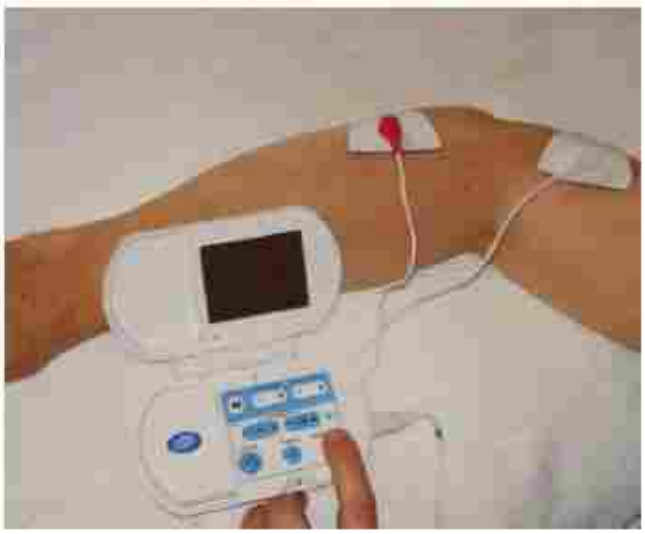

Fig. 6.3

It is thought that TENS triggers the release of natural painkillers called endorphins, which are similar in shape to painkilling drugs such as morphine.

Fig. 6.4 shows synapses in a pain pathway from a damaged joint to the brain.

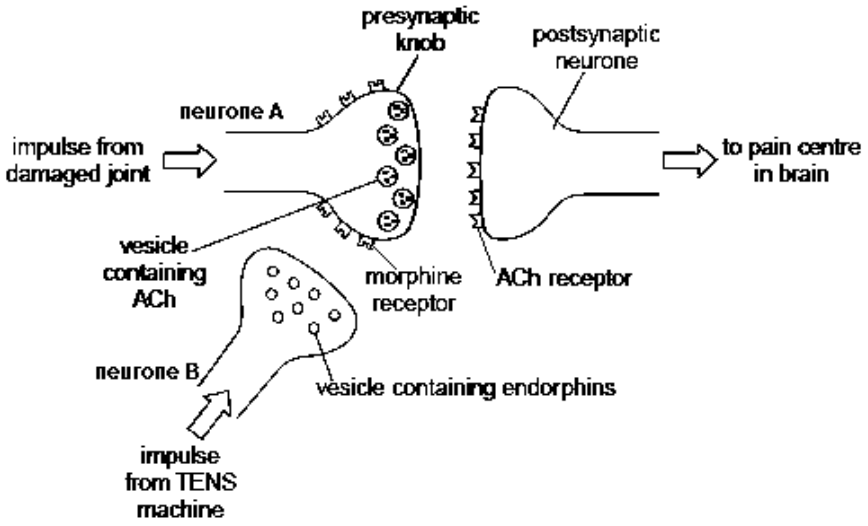

Fig. 6.4

(c) Using your knowledge of synaptic transmission and with reference to Fig. 6.4, describe how impulse from the TENS machine can help to reduce pain.

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…… [4]

(d) The acetylcholine (ACh) receptor is a type of G-protein-linked receptor. When acetylcholine binds to it, the receptor will activate an attached G protein. The activated G protein translocates along the cytoplasmic side of the membrane and activates a membrane-bound adenylyl cyclase.

Explain the role of adenylyl cyclase in signal transduction that leads to a response in the postsynaptic neurone.

……

……

……

…… [2]

[Total : 12]

7 The rock wallabies, *Petrogale lateralis pearsonii*, (Fig. 7.1) on Pearson Island off the coast of South Australia have had no genetic contact with rock wallabies in the Australian mainland since they were isolated by rising sea levels at the end of the last glacial period, around 10 000 years ago.

Fig. 7.1

Scientists have taken blood samples from the wallabies and compared the distribution of unique DNA sequences called microsatellites, which are scattered across the wallabies' chromosomes. These microsatellites give a measure of the population's genetic diversity, or lack of it. In this case, the microsatellite data showed that the Pearson Island population has low genetic diversity. The scientists concluded that the Pearson Island population of rock wallabies has been through a genetic bottleneck event.

(a) **(i)** Explain how a genetic bottleneck event may lead to a decrease in genetic diversity.

……

……

……

…… [2]

(ii) The population of rock wallabies on Pearson Island is most closely related to small populations of rock wallabies in southern Western Australia. Some scientists argue that some individuals from the southern Western Australian populations should be released onto Pearson Island.

Explain the rationale for such a suggestion.

……

……

……

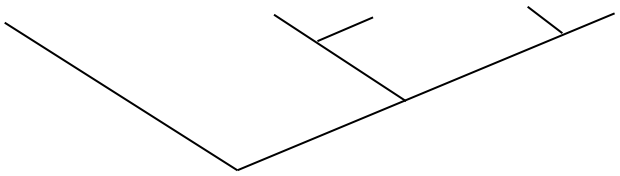
…… [2]

(b) The amino acid sequences of cytochrome c from 5 different species of wallabies, A, B, C, D and E were compared. Table 7.1 below shows the number of differences in the sequences between each pair of species.

species	A	B	C	D	E
A	0	21	11	13	1
B	-	0	18	17	20
C	-	-	0	3	10
D	-	-	-	0	12
E	-	-	-	-	0

Table 7.1

(i) Using the data in Table 7.1, create a phylogenetic tree on the template provided to reflect the evolutionary relationships of the organisms. [3]



(ii) Provide a reason for the placement on the tree of the species that is least related to the others.

……

……[1]

(c) The *Dolichotis patagonum* shown in Fig. 7.2, which is also known as a dillaby, is a mammal that looks similar to the marsupial rock wallaby (Fig. 7.1).

Fig. 7.2

The marsupial wallaby and placental dillaby are morphologically similar. Explain why morphological data alone, may not accurately represent the degree of relatedness of 2 different species.

……

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……

……

…… [3]

[Total : 11]

Section B
Answer EITHER 8 OR 9.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labeled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

8 **(a)** Compare the structure of cellulose with that of collagen. [6]

(b) Explain how enzymes speed up reactions. [6]

(c) Discuss the role of proteins in insulin signalling. [8]

[Total: 20]

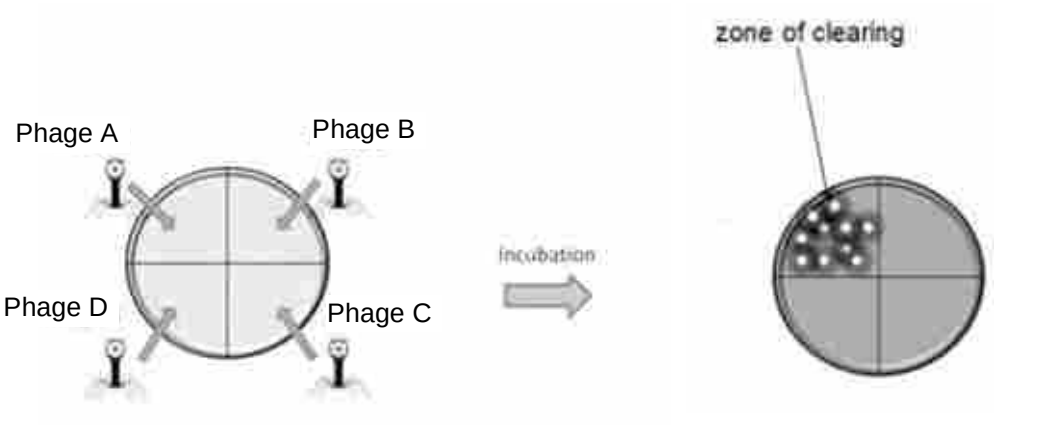
9 **(a)** Describe how genetic variation can arise in a population of bacteria. [6]

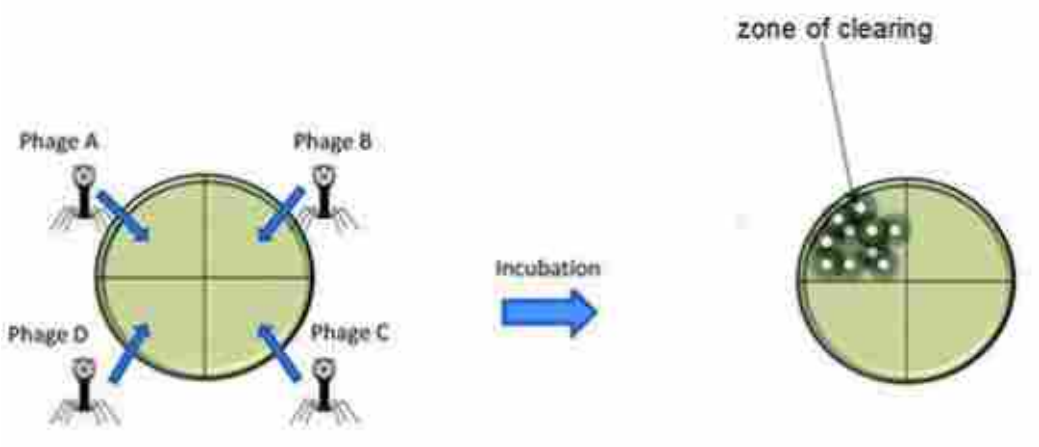
(b) Outline the advantages of using mitochondrial DNA in creating phylogenetic trees. [6]

(c) With reference to the structure of ribosome, describe the role of the ribosome in translation. [8]

[Total: 20]

End of Paper





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RAFFLES INSTITUTION

2016 Year 6 Preliminary Examination
Higher 2

CANDIDATE NAME												
CIVICS GROUP	1	6	S	0	3		INDEX NUMBER					

BIOLOGY 9648/03

Paper 3 **20th September 2016**

2 hours

Additional materials: Answer paper

READ THESE INSTRUCTIONS FIRST

Write your index number, CT group & name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, **hand in your planning question (question 4) and essay question (question 5) SEPARATELY.**
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
Total	

This document consists of **12** printed pages.

Raffles Institution
Internal Examination

For Examiner's Use

Section A

Answer **all** the questions in this section.

1 In 2015, total DNA was isolated from the tissues of 9 sea turtles. PCR amplification of a region in the cytochrome b gene was performed. The PCR products were digested either with restriction enzymes, *Alu* I or *Msp* I. Fig. 1.1A and Fig. 1.1B show photographs of gels for all the samples digested with *Alu* I and with *Msp* I respectively.

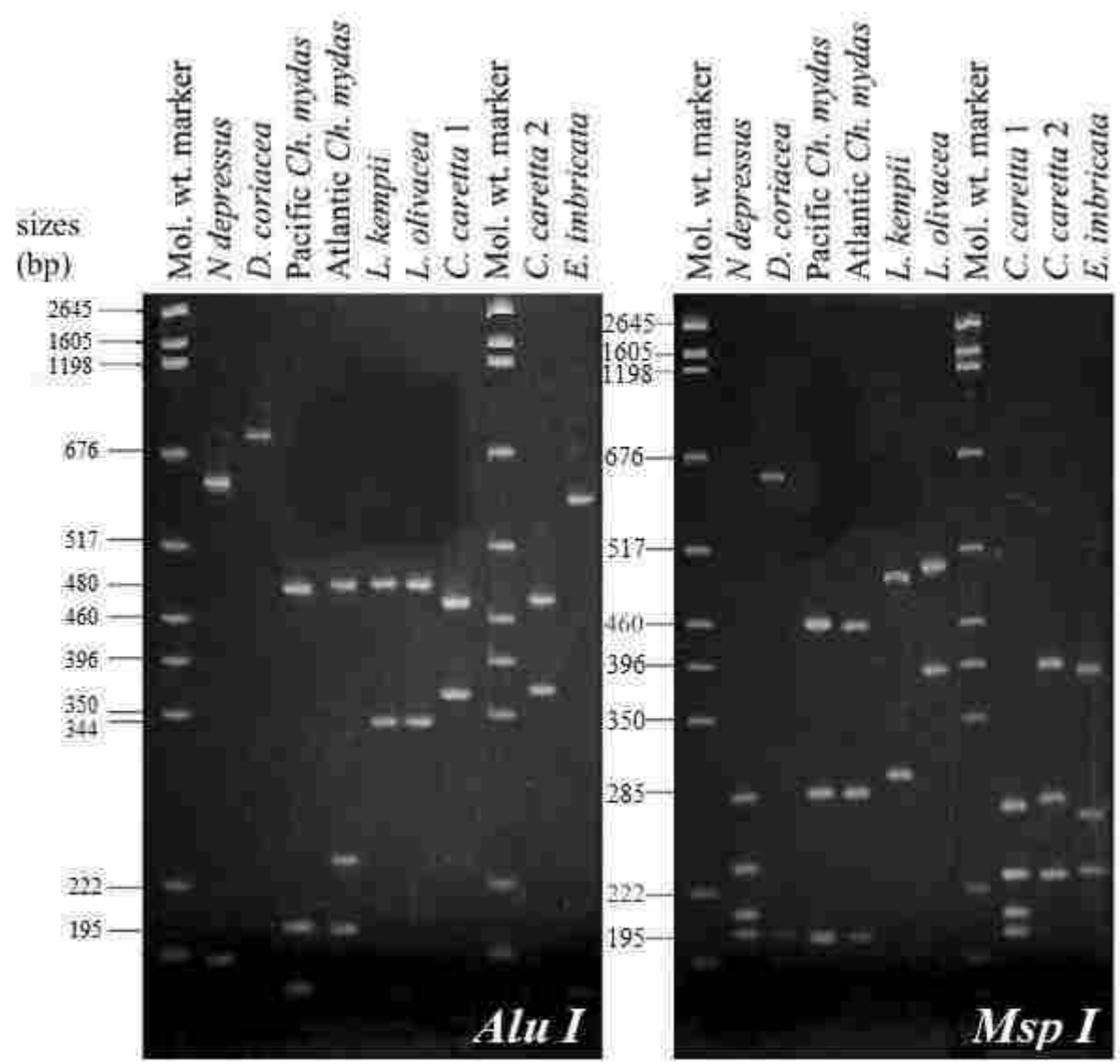

Fig. 1.1A **Fig. 1.1B**

(a) **(i)** With reference to Fig. 1.1A, explain how gel electrophoresis is used to separate the RFLP fragments of the sample from *L. kempii*.

……

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……[4]

(ii) With reference to Fig. 1.1A and Fig 1.1B, explain why two restriction enzymes, *Alu* I and *Msp* I, were used in this analysis.

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……[3]

(b) Explain why Southern blotting was not required to visualize the results shown in Fig. 1.1A and Fig. 1.1B.

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……[2]

For Examiner's Use

(c) Natal homing is a pattern of behaviour in which certain types of animals migrate away from the geographic area where they were born and then return to that same geographic area to reproduce.

Fig. 1.2 shows 2 different sea turtle nesting sites in Western Australia where tissue samples had been taken in 2015 and 20 years ago, in 1995.

DNA samples were taken from 2 different *C. caretta* turtles, A and B, 20 years ago from nesting sites in Western Australia as shown in Fig. 1.2. PCR amplification of the same region in cytochrome b gene was performed and the PCR products were digested with *Msp* I. In addition to gel electrophoresis, Southern blotting was carried out as a means to further confirm the identity of the PCR products. Probes were added and the resulting southern blot is shown in Fig. 1.3.

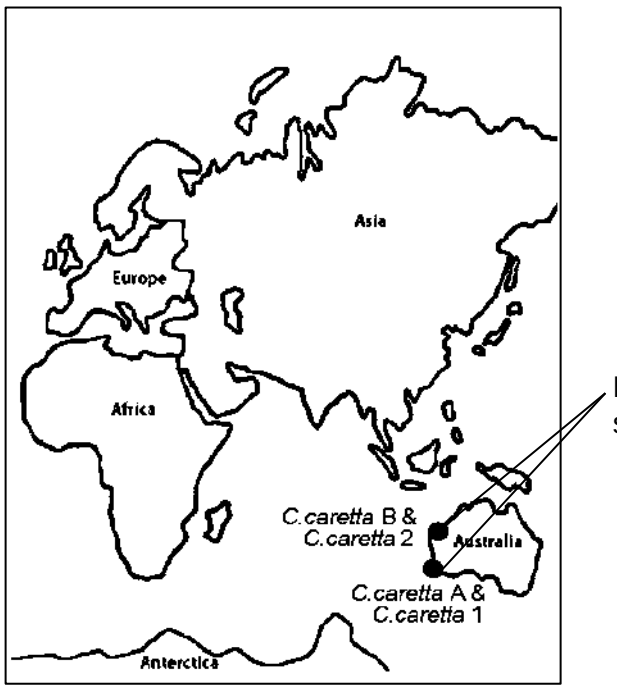

Fig. 1.2

Fig. 1.3

(i) Outline the process of obtaining a southern blot after gel electrophoresis.

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……[3]

(ii) DNA samples of *C. caretta* A and *C. caretta* B were extracted 20 years ago in 1995, while DNA samples of *C. caretta* 1 and *C. caretta* 2 were extracted in 2015. These DNA samples were digested with *Msp* I (as shown in Fig. 1.3).

Suggest how the information provided in Fig. 1.1B, 1.2 and 1.3 could prove the hypothesis of natal homing in sea turtles.

……

……

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……[2]

[Total: 14]

2 **(a)** In a person with cystic fibrosis (CF), the decline in lung function and the likelihood of chronic infections are a result of thickened mucus.

Explain why the lungs of a person with CF can become choked with thick mucus.

……

……

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……[3]

(b) The use of a viral-mediated gene delivery system to treat CF showed an increase in chloride ion (Cl^-) transport across the membrane. However, the transport of Cl^- across the membrane in the treated cells was significantly lower than that observed in the normal cells.

Suggest three reasons for the significantly lower transport of Cl^- across the membrane in the treated cells.

……

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……[3]

For Examiner's Use

(c) In another attempt at gene therapy, the CFTR mRNA was found to be translated only by free ribosomes. In these cells, there was no increase in the transport of Cl^- across the membrane.

Suggest an explanation for the failure of this attempt at gene therapy.

……..

……..[1]

(d) Discuss the limitations of the use of liposomes as vectors for gene therapy for CF.

……..……

……..

……..

……..[2]

High percentage of patients who suffer from cystic fibrosis (CF) develop a form of diabetes known as cystic fibrosis-related diabetes (CFRD).

Research was carried out to investigate whether the lung function of patients with CFRD is affected by their gender and bacteria *Pseudomonas aeruginosa* infection.

The extent of the lung function was measured by the FEV_1, the volume of air that has been exhaled by forced expiration at the end of the first second. A larger FEV_1 volume indicates better lung function.

Table 2.1 shows the results of this investigation involving cystic fibrosis patients.

	Patients without *P. aeruginosa* infection				Patients with *P. aeruginosa* infection			
	Male		Female		Male		Female	
	Non-CFRD	CFRD	Non-CFRD	CFRD	Non-CFRD	CFRD	Non-CFRD	CFRD
Average FEV_1 / A.U.	71.4	71.1	73.6	53.6	59.0	57.0	61.0	42.0

Table 2.1

(e) Calculate the percentage difference between expiration volume, FEV_1 of :

(i) the non-infected females with and without CFRD

Show working

Ans ……..[1]

(ii) in non-CFRD males who are infected and who are not infected with *P. aeruginosa*.

Show working

Ans ……[1]

(f) Based on the results, what can be concluded about the relationship between gender and severity of lung damage in CFRD patients without *P. aeruginosa* infection?

……

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……

……..[2]

[Total:13 marks]

For Examiner's Use

3 The lack of vitamin A in the diet is a major problem in the rice-based societies of South-East Asia. Rice seeds lack the enzymes involved in two steps of the pathway for β-carotene production.

The genes coding for these two enzymes were inserted into rice embryos by genetic engineering, giving rise to the Golden Rice prototype. This rice produces seeds containing β - carotene.

The inserted genes were:
• the *psy* gene from daffodil plants,
• the *crt 1* gene from the bacterium *Erwinia uredovora*.

(a) The following steps were carried out to produce Golden Rice:

step 1: A DNA construct consisting of a rice endosperm-specific promoter and the coding regions of the *psy* gene and the *crt* 1 gene was made.
step 2: Copies of this DNA construct were inserted into plasmids isolated from the bacterium, *Agrobacterium tumefaciens*.
step 3: *Agrobacterium tumefaciens* transformed with the recombinant plasmids were mixed with rice embryos in tissue culture.
step 4: The embryos were induced to form callus which were grown into plantlets and then plants.

(i) Explain why the endosperm-specific promoter was added to *psy* and *crt* 1 in step 1.

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……[2]

(ii) Besides using *Agrobacterium*-mediated transfer, state one other way that is commonly used to insert DNA into plant cells.

……[1]

(b) Two rice crop farmers have farms adjacent to each other in which they grow rice crop.

• Farmer X wishes to grow GM rice crops that are resistant to a herbicide.
• Farmer Y wishes to continue to grow non-GM rice.

Farmer Y was concerned, and suggested to farmer X that pollen from the GM rice crop could fertilise the non-GM rice crop.

(i) Suggest why farmer Y might be concerned about the possibility of his crop being fertilised by pollen from farmer X's crop.

……

……[1]

The farmers agreed to carry out field trials to establish whether leaving a gap between the rice crops reduced the likelihood of cross-pollination. A number of trials were carried out. The percentage of seeds that contain the transgene was measured in the non-GM field for each trial. The outline of these trials and the results gathered are shown in Table. 3.2.

	Percentage of seeds that contain transgene in non-GM field due to cross-pollination / %
Trial 1 GM non-GM no gap between plots	10
Trial 2 GM non-GM 5 metres between plots	1
Trial 3 GM non-GM 7 metres between plots	1

Table 3.2

(ii) With reference to Table 3.2, explain how the distance between rice plots affects cross-pollination.

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……[3]

(iii) Apart from physical separation, suggest what can be done to prevent the spread of the transgene to non-GM rice plants.

……

……[1]

For Examiner's Use

(c) A group of transmembrane channel proteins which transport sugars out of cells through their pores have been identified and called SWEETs. They are found in the cell surface membranes of rice mesophyll cells. The bacterium, *Xanthomonas oryzae* (Xoo), causes the disease known as bacterial leaf blight in rice plants. It infects the intercellular spaces of the leaves of the host plant. Then, by switching on *SWEET* genes in the mesophyll cells, it stimulates the secretion of glucose into the intercellular spaces.

Several different recessive alleles of *SWEET* have been found in rice plants from different countries. All these alleles have a mutation in the promoter of the *SWEET* gene. These recessive alleles give resistance to bacterial leaf blight.

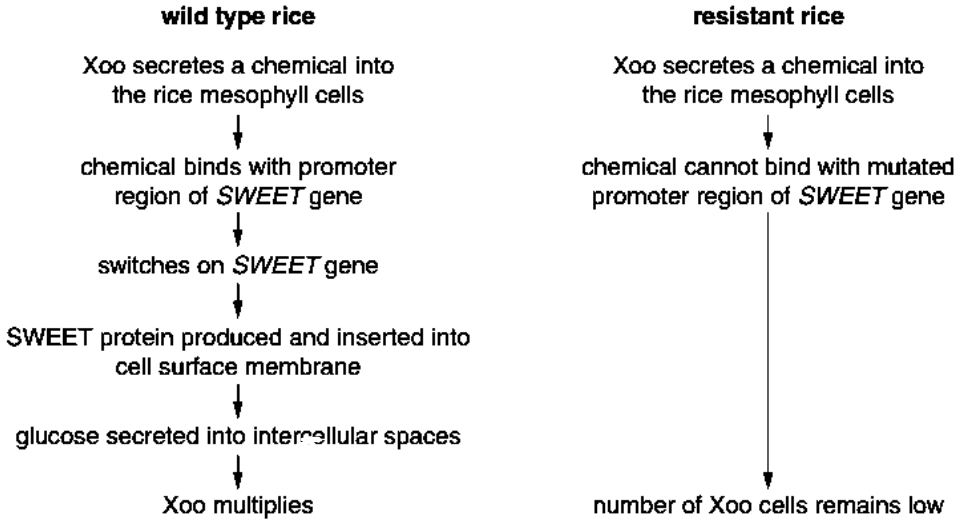

Fig. 3.2

(i) Using the information in Fig. 3.2, explain this resistance of rice plants to Xoo.

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……[3]

(ii) Explain why transfer of the allele for resistance into susceptible rice plants by genetic engineering does not result in resistant plants.

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……[2]

[Total: 13]

4 Planning question

Murashige and Skoog (MS) medium is a plant growth medium used in laboratories for plant tissue culture. MS medium is frequently used in combination with different plant growth regulator to stimulate callus, root and shoot formation. This involves adding 1 cm^3 of each plant growth regulators, auxin and cytokinin to 10cm^3 of molten MS agar medium and poured into petri dishes.

You have been given a supply of *Ananas comosus* callus and molten MS agar medium containing 0.2 $mgdm^{-3}$ auxin. Using your own knowledge and the given information, design an experiment to investigate the optimum concentration of cytokinin in MS agar medium that can be used to induce shoot formation from *Ananas comosus* callus.

You may select from the following apparatus and chemicals:

- callus from *Ananas comosus*
- 10 $mgdm^{-3}$ cytokinin solution
- distilled water,
- molten MS agar medium containing 0.2 $mgdm^{-3}$ auxin
- 80% ethanol
- hypochlorite/bleach solution
- sterile petri dishes
- sterile forceps
- sterile scapel
- sterile weighing boat
- weighing balance
- laminar flow cabinet
- sterile syringe (1cm^3)
- sterile syringe (10cm^3)
- sterile measuring cylinder (10cm^3)
- ruler
- bunsen burner
- incubator
- normal laboratory glassware (e.g. beakers, measuring cylinders)

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

For Examiner's Use

5 Free-response question

Write your answers to this question on the separate answer paper provided.

Your answers:
- should be illustrated by large, clearly labelled diagrams, where appropriate,
- must be in continuous prose, where appropriate,
- must be set out in sections (a), (b) etc. as indicated in the question.

(a) Discuss the goals of the human genome project. [5]

(b) Explain the limitations of the polymerase chain reaction (PCR). [6]

(c) Describe how stem cells and gene therapy can be used to treat Severe Combined Immunodeficiency (SCID) due to an autosomal mutation. Include in your answer the significance of using stem cells for the treatment. [9]

[Total: 20]

End of Paper

RIVER VALLEY HIGH SCHOOL
YEAR 6
PRELIMINARY EXAMINATION II

H2 BIOLOGY 9648

PAPER 1
26 SEP 2016
1 HOUR 15 MIN

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER				

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, centre and index number on the Answer Sheet in the spaces provided.
DO **NOT** WRITE IN ANY BARCODES.

There are **forty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This Question Paper consists of **25** printed pages.

For each question, there are four possible answers, **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

1 A sample of yeast cells were grown in a culture with radioactive amino acids. At various times, samples of the cells were taken and the amount of radioactivity in different organelles was measured. The results are shown in the table below.

Time after radioactive amino acids were added to the solution/ minute	Amount of radioactivity present/arbitrary units		
	P	**Q**	**R**
10	21	120	6
20	42	68	6
40	86	39	8
60	76	28	15
90	50	27	28
120	38	26	56

Which of the following best describes the identities of organelles **P**, **Q** and **R**?

	P	**Q**	**R**
A	Golgi apparatus	Rough endoplasmic reticulum	Secretory vesicles
B	Rough endoplasmic reticulum	Smooth endoplasmic reticulum	Golgi apparatus
C	Rough endoplasmic reticulum	Secretory vesicles	Golgi apparatus
D	Smooth endoplasmic reticulum	Golgi apparatus	Secretory vesicles

2 Three unknown specimens were tested to determine the identity of biomolecule(s) present. The results are shown in the table below.

	biuret solution	benedict's solution and heated	dilute hydrochloric acid, benedict's solution and heated	iodine in potassium iodide solution
Specimen 1	purple	blue	brick-red	brown
Specimen 2	purple	blue	blue	blue-black
Specimen 3	blue	brick-red	brick-red	brown

Using the results shown, which of the following can be concluded?

1 When treated with amylase, Specimen 2 will yield the same result as Specimen 1.
2 No lipids are present in Specimens 1, 2 and 3.
3 Sucrose is present in Specimen 3.

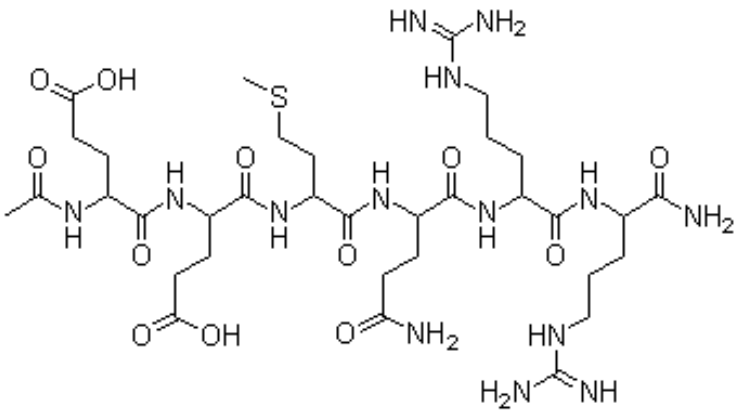
A 2 only

B 1 and 2

C All of the above

D None of the above

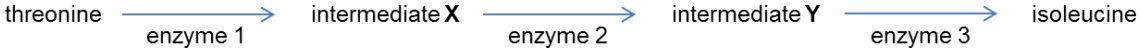
3 The diagram shows the chemical structure of a polypeptide chain. The polypeptide chain can be broken down by proteases to yield amino acids.



Which of the following combination is correct?

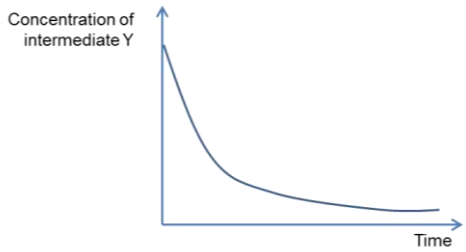
	type of reaction	number of bonds broken	number of amino acids
A	hydrolysis	5	6
B	hydrolysis	4	5
C	condensation	6	7
D	condensation	7	6

4 In the production of isoleucine from threonine, the end product acts as an inhibitor of the first enzyme of the pathway. The pathway is shown below.

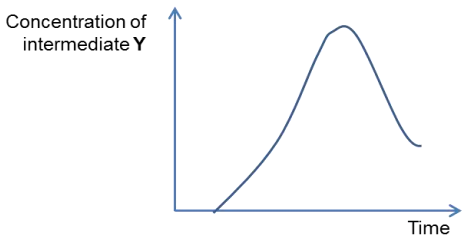


Which of the following graphs shows the concentration of intermediate **Y** when threonine is supplied in excess?

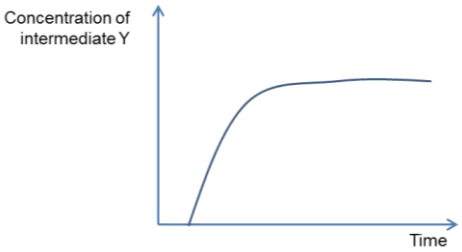
A



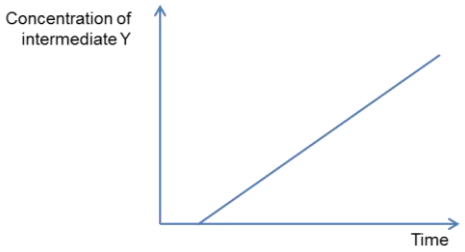
B



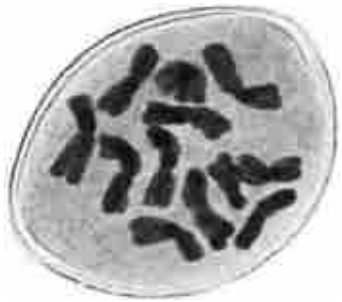
C



D



5 The diagram below shows a stage of mitosis in a cell. The amount of DNA present is 12 picograms (pg).



Which row correctly identifies the number of DNA molecules and amount of DNA in each nucleus at different stages of nuclear division?

	telophase of mitosis		telophase II of meiosis	
	number of DNA molecules	amount of DNA / pg	number of DNA molecules	amount of DNA / pg
A	12	6	6	3
B	24	12	12	6
C	12	12	6	3
D	24	6	12	6

6 The table below shows the events that occur at different stages of meiosis.

Which row correctly shows the correct events for the respective stage?

	Interphase II	Prophase I	Metaphase I	Anaphase II
A	replication of DNA	condensation of chromosomes	alignment of chromosomes at the equator	separation of homologous chromosomes
B	replication of DNA	pairing of bivalents	alignment of bivalents at the equator	separation of sister chromatids
C	intense protein synthesis	crossing over	alignment of bivalents at the equator	separation of sister chromatids
D	replication of organelles	pairing of bivalents	alignment of chromosomes at the equator	separation of homologous chromosomes

7 An unknown organism has a linear double-stranded DNA genome like that in a eukaryote. When its DNA replication was examined, it was revealed that although the process is semi-conservative, no Okazaki fragments were observed in the multiple replication forks. In addition, the end-replication problem of shortened daughter strands was not observed.

Which statement correctly explains this phenomenon?

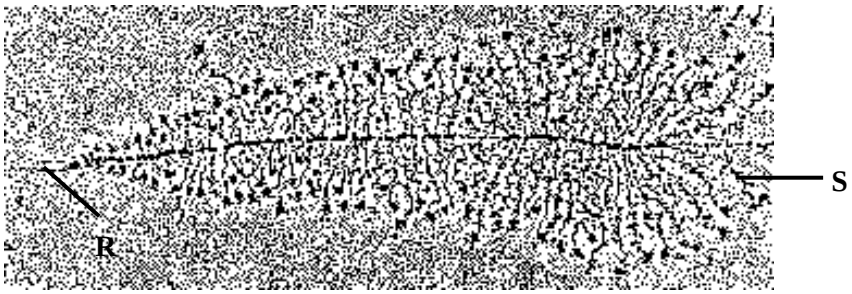
A The organism's DNA is antiparallel.

B DNA replication only starts at the 3' end of each template strand.

C DNA polymerases synthesise DNA in both 5' to 3' and 3' to 5' direction.

D DNA ligases are not involved in the DNA replication process.

8 The electron micrograph shows protein synthesis in a yeast cell.



Which statements about processes occurring in this cell are correct?

1 Transcription occurs from left to right along template DNA.
2 **S** is used as template during translation.
3 Transcription and translation occur simultaneously in the cell.
4 Many RNA polymerases are transcribing **R**.

A 1 and 3 only

B 2 and 4 only

C 1, 2 and 4

D All of the above

9 Which statements about tRNA are correct?

1 There is a binding site for the attachment of a specific amino acid, as well as a different binding site for the attachment to the ribosome, in order to allow translation to occur.
2 There is a ribose-phosphate backbone with strong covalent phosphoester bonds and areas within the polynucleotide chain where base-pairing by hydrogen bonding occurs.
3 There is a section known as an anticodon that contains the same triplet of bases as the triplet of DNA bases that has been transcribed to produce the mRNA codon.
4 There is a specific enzyme to load each tRNA with its respective amino acid.

A 1 and 2 only

B 2 and 3 only

C 1, 2 and 3

D 1, 2 and 4

10 A segment of an mRNA sequence bearing a point mutation is shown. What is the sequence of the corresponding DNA coding strand prior to the mutation?

5’-ACCGUAGCAGCU-3’

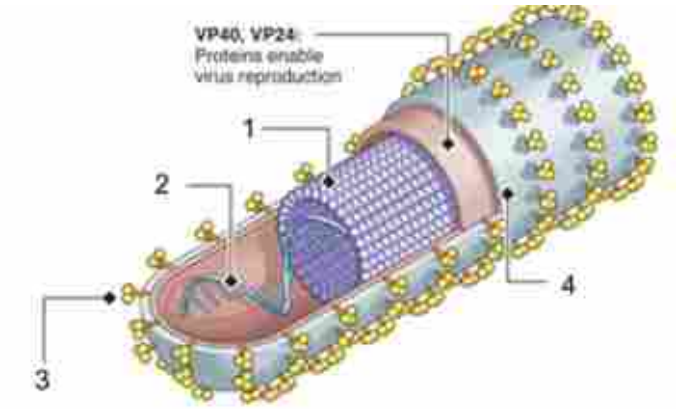
A 5’-AGCTGCTACGGT-3’

B 5’-ACCGTAGCAGCT-3’

C 5’-ACCGGAGCAGCT-3’

D 5’-AGCTGCTCCGGT-3’

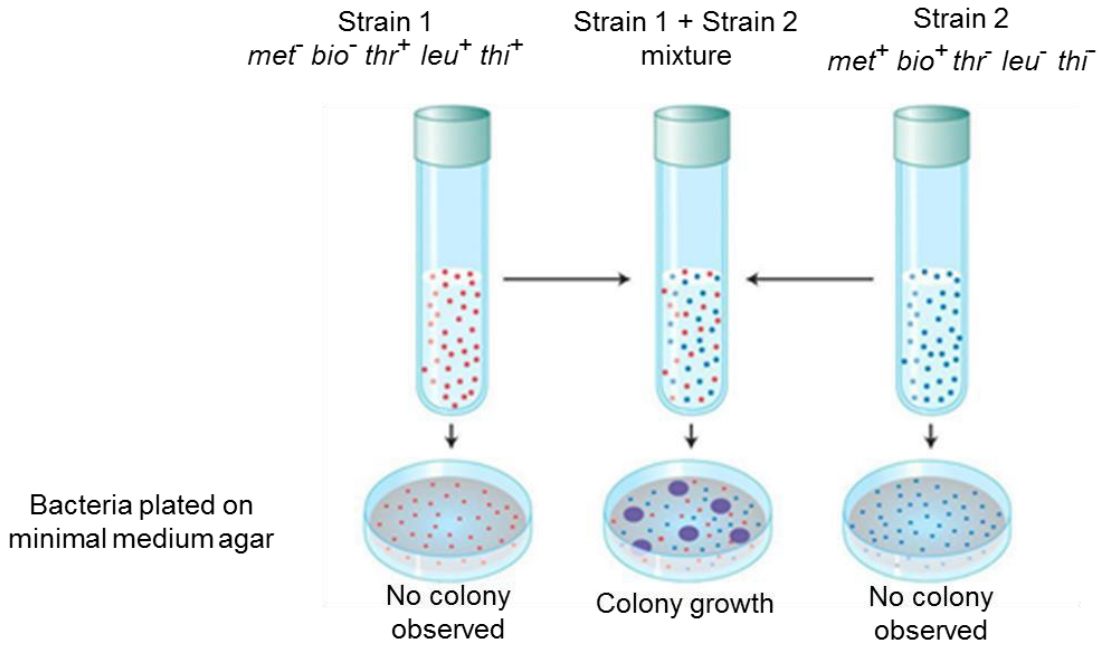
11 In 2015, Ebola Virus Disease outbreak in West Africa is the largest outbreak of the disease since the Ebola virus was first identified. Ebola virus is an animal virus and has structural components similar to that of influenza virus and human immunodeficiency virus. The structure of the Ebola virus is shown below.



Which of the following correctly identifies the function of the labelled structures?

	bind to specific receptor on human cell surface membrane	contain viral genes	fuse with host cell membrane	enclose viral genome
A	3	2	1	4
B	3	2	4	1
C	1	4	3	2
D	1	2	3	4

12 In 1947, Lederberg and Tatum conducted an experiment to study gene transfer between bacteria. Methionine, biotin, threonine, leucine and thienylalanine are essential for bacteria growth. Strain 1 has genes *thr*, *leu* and *thi* which can be used to synthesise threonine, leucine and thienylalanine. Strain 2 has genes *met* and *bio* which can be used to synthesise methionine and biotin. In the experiment, Strain 1 and Strain 2 are mixed and cultured on a minimal agar plate which does not contain any amino acids and biotin. The result of the experiment is shown below.



What conclusion can be made from the results shown?

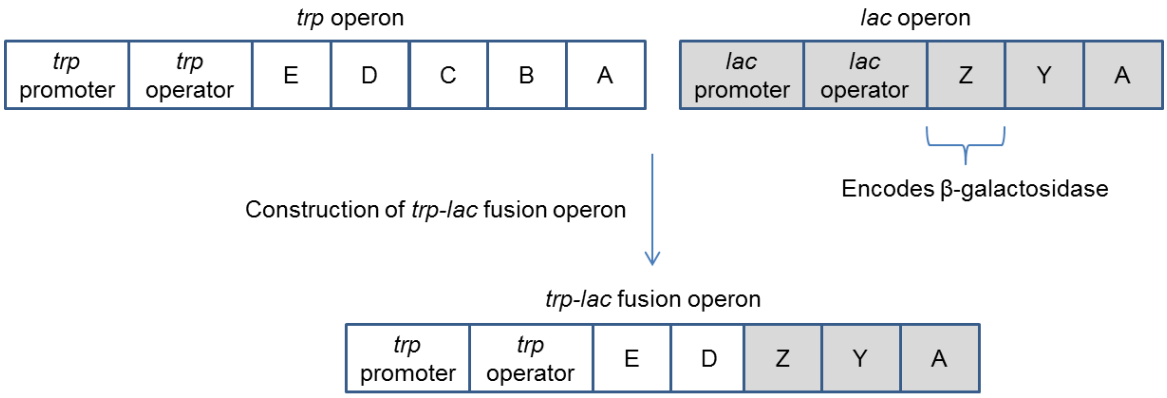
A Direct cell-cell contact is required for conjugation to take place.

B The resulting bacteria from the colony grown from the Strain 1 and Strain 2 mixture has has genes *met*, *bio*, *thr*, *leu* and *thi.*

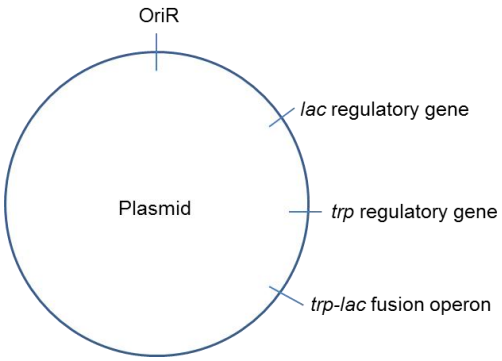
C Mutation has occurred in the genes of Strain 1 and Strain 2, hence no colony growth is observed.

D The resulting bacteria from the colony grown from the Strain 1 and Strain 2 mixture has taken up DNA through transformation.

13 A *trp-lac* fusion operon is constructed as shown in the figure below.



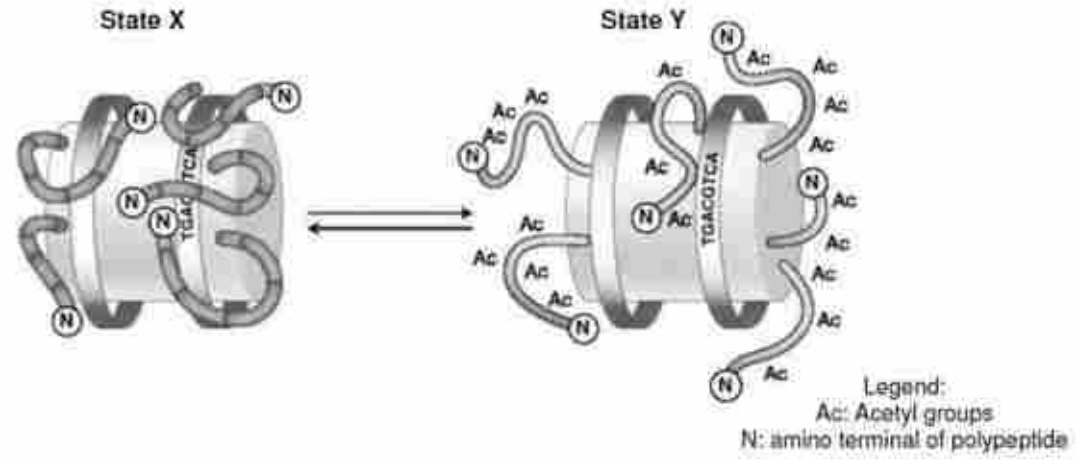
A plasmid containing the *trp-lac* fusion operon is introduced into bacterial cells by heat shock procedures.



β-galactosidase is encoded by *lac Z* gene. Which of the following combinations best shows the conditions required for the synthesis of β-galactosidase?

	tryptophan	lactose	glucose	amino acids	deoxyribonucleoside triphosphate
A	√	√	√	x	√
B	x	√	x	√	x
C	x	x	x	√	√
D	x	x	x	√	x

14 The diagram below shows two possible states of chromatin.



Which of the following statements are true?

1 State **X** may be a result of DNA methylation.
2 State **X** is only present during the beginning of mitosis or meiosis.
3 State **Y** is the result of acetylation which decreases the positive charges on the polypeptides.
4 Transition between State **X** and **Y** are carried out by DNA acetylases and deacetylases in all cells.

A 1 and 3

B 2 and 4

C 1, 2 and 3

D 1, 3 and 4

15 Which of the following statement(s) about eukaryotic gene expression is true?

1 By binding to the 5' UTR of an mRNA, a translational regulatory protein blocks the initiation of translation.
2 Having a relatively shorter mRNA half-life allows more rapid control of gene expression at the translational level.
3 Different transcription factors help the same RNA polymerase recognise different promoters.
4 By binding to the 3' UTR of the mRNA, a translational regulatory protein increases the stability of an mRNA.

A 1 only

B 1 and 3

C 2 and 4

D 1, 3 and 4

16 Which of the following statements about transcription in eukaryotes are **incorrect**.

1 Specific sequences found near the promoter may increase the affinity of RNA polymerase binding, thus increases the probability of forming transcription initiation complex.
2 RNA polymerase, general transcription factors and specific transcription factors make up the transcription initiation complex.
3 Specific transcription factors such as repressors bind to silencers to prevent assembly of the transcription initiation complex.
4 The binding of enhancer proteins to activators results in enhanced rate of transcription.

A 1 and 2 only

B 1 and 3 only

C 2 and 4 only

D None of the above

17 Which of the following shows the types of genetic changes **least** likely to be found in an proto-oncogene and a tumour suppressor gene of tumour cells?

	proto-oncogene	tumour suppressor gene
A	gene amplification	chromosomal deletion
B	chromosomal deletion	substitution mutation
C	substitution mutation	chromosomal translocation
D	nonsense mutation	gene amplification

18 The table shows the loci of certain genes in *Drosophila melanogaster.* These genes are found either on chromosome 1 or 3.

Character controlled by gene	Chromosome	Position on chromosome
cut wings	1	20
body stripe	3	62
vermillion eye	1	33
rough eye	3	91
pink eyes	3	48
forked bristles	1	57

Which pair of characteristics will produce the highest crossing over value when the F_1 generation is test-crossed?

A body stripe and rough eye

B cut wing and vermillion eye

C rough eye and cut wing

D rough eye and pink eye

19 Pure breeding plants of contrasting traits were cross fertilised and the seeds were planted in pots of soil containing equal proportion of fertiliser. The pots were then exposed to different light conditions for 60 days. Throughout the investigation, the plants were watered with equal amount of water twice daily.

At the end of the investigation, the plants' height, number of leaves, length of leaves and colour of leaves were measured and summarised in the table below.

	No light	Dim Light	Bright light
Height/cm	10.3 ± 0.3	8.1 ± 0.5	6.6 ± 0.4
Length of leaves/cm	1.7 ± 0.3	1.7 ± 0.2	1.6 ± 0.1
Colour of leaves	Yellow	Pale green	Dark green

Which of the following statement(s) cannot be explained by the data?

1 The height and length of leaves exhibit continuous variation as different plants have different genotypes.
2 The additive effect of genes is responsible for the continuous variation observed in the height and length of leaves.
3 The genes involved in chlorophyll pigment synthesis are activated by light.
4 The colour of leaves is due to a single gene whereby heterozygotes have pale green leaves.

A 3 only

B 1 and 4

C 1, 2 and 4

D All of the above

20 In a mammalian species, the inheritance of skin colour is controlled by three pairs of genes, **A**/**a**, **B**/**b** and **C**/**c**, which are inherited independently.

The genes for dark pigmentation **A**, **B** and **C** code for the production of about the same degree of pigmentation. If skin colour is proportional to the sum of the dominant alleles present, how many classes of skin colour would be expected from a mating between two individuals that are heterozygous at all three loci?

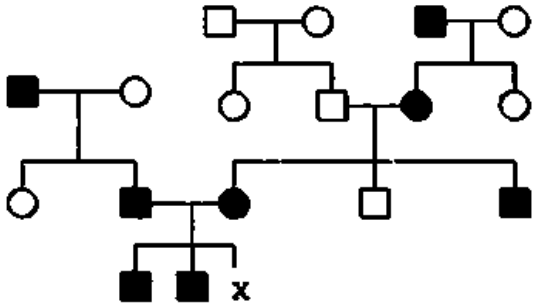
A 3

B 5

C 7

D 9

21 The family tree below was constructed by a genetic counsellor of a family with history of heart disease due to hypercholesterolaemia. Children who inherit the dominant mutant allele from both parents rarely survive beyond puberty.



What is the probability that X will be unaffected?

A 0.75

B 0.50

C 0.25

D 0.00

22 Colour of flower petals of a plant species is controlled by two independently assorting genes. Plants with genotypes **AABB** and **aabb** have flowers with white petals.

Pure breeding plants with genotypes **AABB** and **aabb** were crossed. The resulting F_1 plants had flowers with white petals. F_2 progenies from the self-fertilisation of F_1 generation is summarised in the table below.

Colour of petals	Number of plants
White	406
Blue	94

Which of the following statement(s) is true?

1 The two genes controlling colour of petals are found on the same chromosome.
2 The phenotypes observed in the F_2 generation are due to interaction with the environment.
3 The gene products of gene **A** and gene **B** are involved in the same metabolic pathway.
4 Gene **A** is an epistatic gene whereby the presence of two copies of recessive alleles at the epistatic gene locus masks the expression of Gene **B**.
5 Gene **A** encodes for an inhibitor that prevents the production of a white intermediate.

A 2 and 3 only

B 3 and 5 only

C 1, 3 and 5 only

D 2, 3 and 4 only

23 In a buffered suspension of freshly isolated thylakoids incubated in light, the rate of photolysis can be measured using DCPIP. DCPIP is reduced at Photosystem I and changes its colour from blue to colourless.

Which of the following modification(s) of the experiment will significantly reduce the rate of this reaction?

1 Raising the temperature of the solution from 15ºC to 30ºC.
2 Removing soluble gases from the buffer solution before adding the thylakoids.
3 Adding DCMU, a herbicide that binds to Photosystem II.
4 Adding 2,4-D, a herbicide that acts as a synthetic auxin.

A 3 only

B 1 and 3 only

C 2 and 3 only

D All of the above

24 Six tubes containing preparations from animal tissue were set up as shown below.

Tube	Contents
1	Glucose + homogenised cells
2	Glucose + mitochondria
3	Glucose + cytoplasm lacking organelles
4	Pyruvate + homogenised cells
5	Pyruvate + mitochondria
6	Pyruvate + cytoplasm lacking organelles

After incubation, in which three tubes would carbon dioxide be produced?

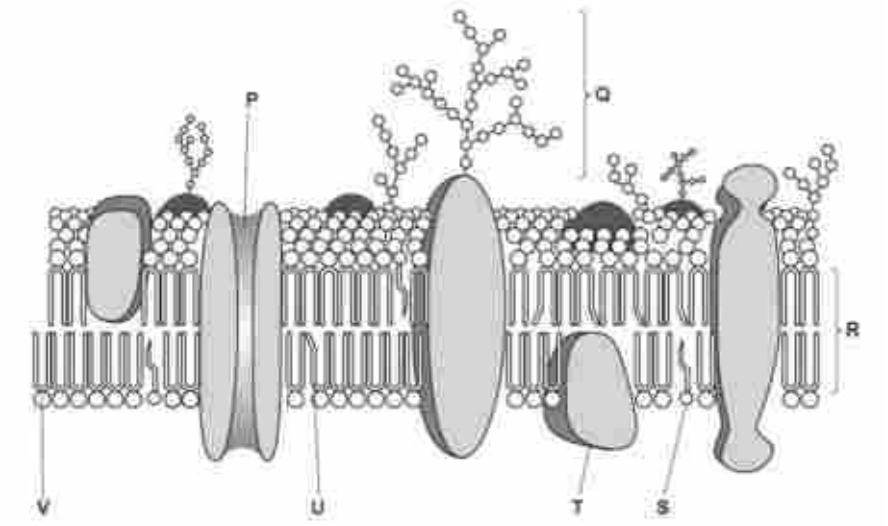
A 1, 2 and 3

B 1, 4 and 5

C 2, 4 and 6

D 4, 5 and 6

25 The diagram shows a section through a cell surface membrane from a typical animal cell.



When compared to the cell surface membrane of a phagocytic cell, a number of differences in the membrane components can be observed.

Which is the most likely set of differences that will be observed in the phagocytic cell?

A a complete absence of component **Q** and a higher proportion of component **P**

B a higher proportion of component **S** and a higher proportion of component **T**

C a lower proportion of component **V** and a higher proportion of component **U**

D an increased distance across **R** and a higher proportion of component **U**

26 Diagrams **1** and **2** show how the longitudinal section of a stem changes when moved from solution **W** to a different solution, **Y**.

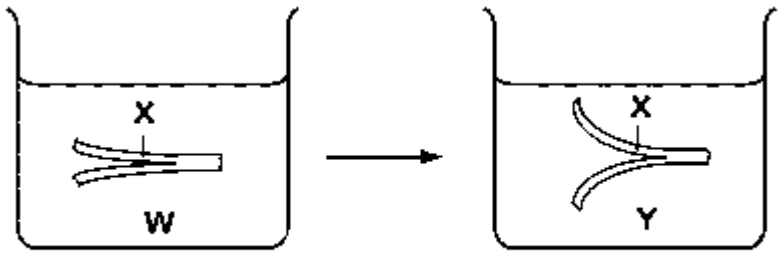


Diagram 1 Diagram 2

How has the respective water potential changed in diagram 2?

	water potential of cells at **X** in solution **Y** compared to the same cells in solution **W**	water potential of solution **Y** compared to solution **W**
A	less negative	less negative
B	less negative	more negative
C	more negative	less negative
D	more negative	more negative

27 The Ca^{2+} in blood is maintained at the normal level of 10mg/100ml. When blood Ca^{2+} levels rise above the normal level, the thyroid gland releases calcitonin, which stimulates Ca^{2+} deposition in bones and reduces the uptake of Ca^{2+} by the kidneys.

When blood Ca^{2+} levels fall below the normal level, the parathyroid glands release the parathyroid hormone, which stimulates the release of Ca^{2+} from bones and increases Ca^{2+} uptake by the kidneys.

Which of the following shows the correct receptor, control centre, and effector in the regulation of blood Ca^{2+} levels?

	Receptor	Control centre	Effector
A	Bones	Parathyroid glands	Bones
B	Parathyroid glands	Parathyroid glands	Parathyroid hormone
C	Calcitonin	Thyroid gland	Bones
D	Thyroid gland	Thyroid gland	Kidneys

28 Which of the following process(es) leads to signal amplification in the cell?

1 Binding of multiple signal molecules to the membrane bound receptor.
2 Phosphorylation of the first kinase of a cascade.
3 Branching of different signalling pathways that produces multiple cellular responses.
4 Activation of numerous intracellular receptors that acts as transcription factors in gene expression.

A 3 only

B 2 and 3 only

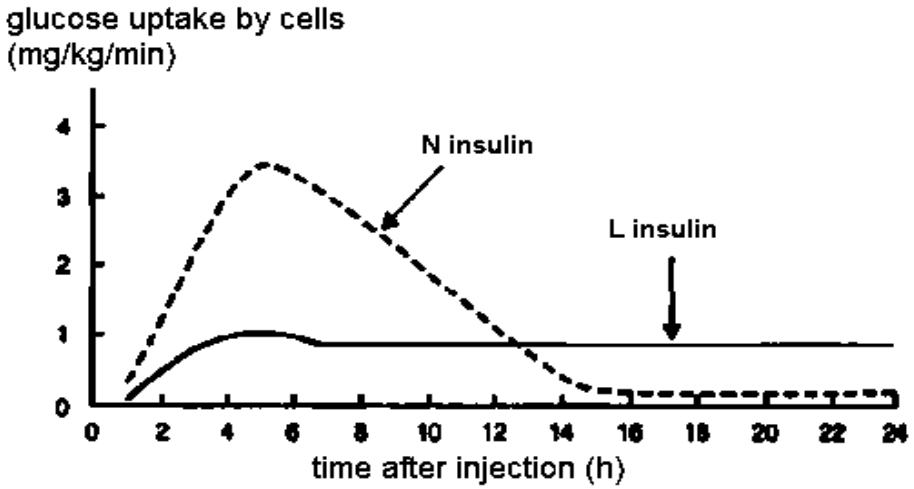
C 1 and 4 only

D All of the above

29 Insulin is a hormone involved in the regulation of blood glucose levels. Failure to produce insulin results in insulin-dependence (type I diabetes), and people with this condition must have regular injections of insulin.

The effectiveness of two types of insulin was tested. Participants in this test were divided into two groups. One group received **N** insulin. The second group received **L** insulin. All participants received the same amount and concentration of the respective insulin.

The following graph shows the average results for participants in each of the two groups.



Which of the following statement(s) is true about the effectiveness of the two types of insulin?

1 **N** insulin needs to be given more frequently than **L** insulin in a day.

2 A dose of **N** insulin is more effective than **L** insulin in reducing blood glucose level in one day.

3 Using **L** insulin may be more advantageous for a person with type I diabetes.

A 2 only

B 1 and 2

C 1 and 3

D 1, 2 and 3

30 Certain drugs act at synapses and affect ATP production.

Which of the following correctly matches the protein affected to its effect on synaptic transmission, when ATP production is inhibited?

	protein affected	effect
A	Na^+ / K^+ ATPase	no restoration of Na^+ and K^+ gradient across membrane
B	acetylcholinesterase	acetylcholine cannot be broken down and hence remains in synaptic cleft
C	Ca^{2+} pump	no restoration of Ca^{2+} gradient across membrane
D	voltage-gated Ca^{2+} channel	no influx of Ca^{2+} and fusion of synaptic vesicles with membrane

31 *Staphylococcus aureus* is a common bacteria found on human skin. There are many strains of *S. aureus*. The antibiotic methicillin was used to treat infection by *S. aureus*. Now, there are at least 15 different strains of methicillin resistant *S. aureus* (MRSA).

Which of the following are valid reasons for the emergence of 15 different strains of MRSA?

A Different mutations occur to the bacteria's DNA when the bacteria are exposed to methicillin, thus becoming resistant.

B Some bacteria in the population of *S. aureus* had genes for enzymes which break down methicillin, before exposure to methicillin.

C Different strains of MRSA emerged as a result of neutral selection.

D Bacteria cells undergo asexual reproduction, giving rise to a population of genetically identical cells.

32 The classification of the domestic horse, *Equus ferus caballus* and the Przewalski horse, *Equus ferus przewalskii*, is not fully established.

They were considered to be members of the same species, but some evidence suggests that they should be classified as separate species.

Extinct in the wild, Przewalski's horse survived in zoos and has now been successfully reintroduced into the steppe area of Mongolia.

Which statements would suggest that these two types of horse are members of the same species?

1 Domestic horses in the Mongolian steppe area are capable of interbreeding with the re-introduced Przewalski horse to produce fertile offspring.
2 DNA testing suggests that the two types of horse diverge from wild horse ancestor at similar time.
3 The diploid number of domestic horse is 64 and that of the Przewalski's horse is 66.
4 DNA testing has found few differences between the two types of horse.

A 1 and 2

B 1 and 4

C 2 and 4

D 3 and 4

33 The DNA for β-globin subunit of haemoglobin in organism **X** was compared with that in five other organisms of different species.

A segment of DNA bases of the β-globin gene in organism **X** and the 5 organisms are shown below.

organism	DNA bases
X	TTACCACGCCACTTT
1	TAACCACCCCACTAT
2	TTACCACCCTACATT
3	TTTCCACCCCACTTT
4	TTACCACGCCACATT
5	TTTCAACGCCACCTT

Which organisms are most closely related to organism **X**?

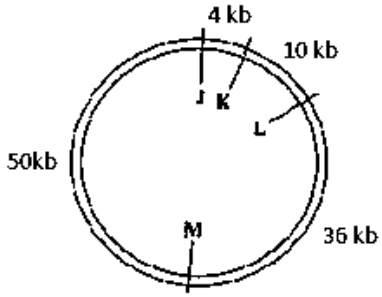
A 1 and 2

B 2 and 3

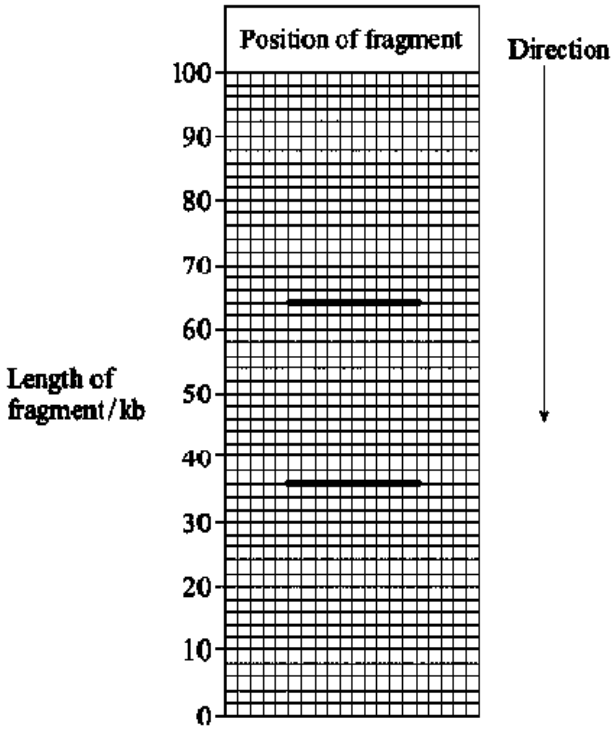
C 3 and 4

D 4 and 5

34 The diagram below shows the positions of four restriction sites **J**, **K**, **L** and **M** for four different restriction enzymes in a plasmid. The distances between these sites are measured in kilobases of DNA.



The plasmid was cut using only two restriction enzymes. The resulting fragments were separated by gel electrophoresis. The positions of the fragments are shown in the chart below.



Which restriction sites were cut?

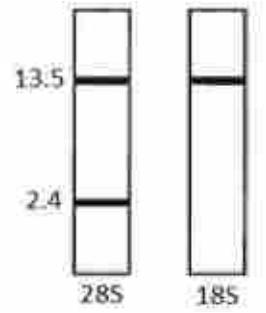
A **J** and **K**

B **L** and **M**

C **J** and **M**

D **L** and **K**

35 Human DNA is digested with a specific restriction enzyme and subjected to gel electrophoresis. Following which, Southern blotting is carried out using a nitrocellulose membrane. Probes complementary to 28S region and 18S region respectively are then added to the nitrocellulose membrane. Lastly, autoradiography is carried out to give the autoradiogram shown below.



With arrows indicating the restriction sites, which of the following restriction maps best explains the results shown?

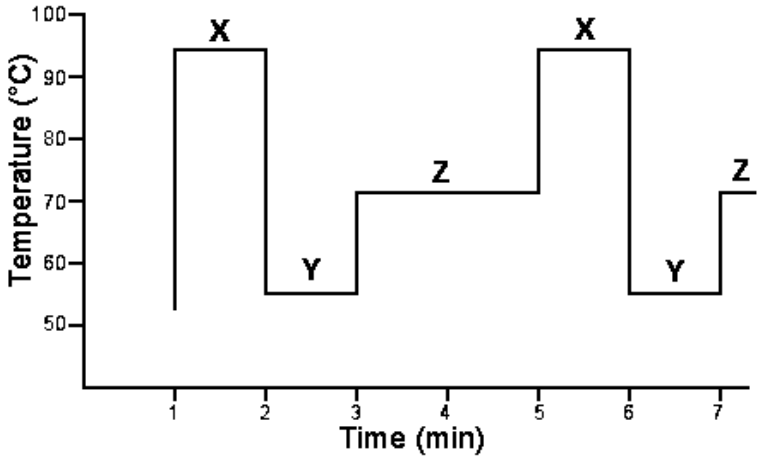
A

B

C

D

36 The diagram below shows the changes in temperature in a thermal cycler over time during polymerase chain reaction.



How many of the following statements are true?

1 Elongation of new strands occurs during **Y**.
2 Taq polymerase functions optimally at **Z**.
3 DNA primers are annealed to the DNA template during **X**.
4 Double stranded DNA template denatures into single strands during **X**.

A One

B Two

C Three

D Four

37 The human genome project (HGP) was successfully completed on 14 April 2003. Several ethical concerns were raised during the HGP. Which of the following is **not** an ethical concern of the HGP?

A Anxiety and frustration may arise in patients when genetic testing is conducted for diseases with no medical treatment currently available.

B If genetic sequences are patented, it will increase the cost of genetic research and treatment.

C Mankind is tampering with nature when the human genome is modified.

D The use of genetic test results may lead to discrimination of individuals by insurance companies and employers.

38 What is the role of stem cells with regard to the function of adult tissues and organs?

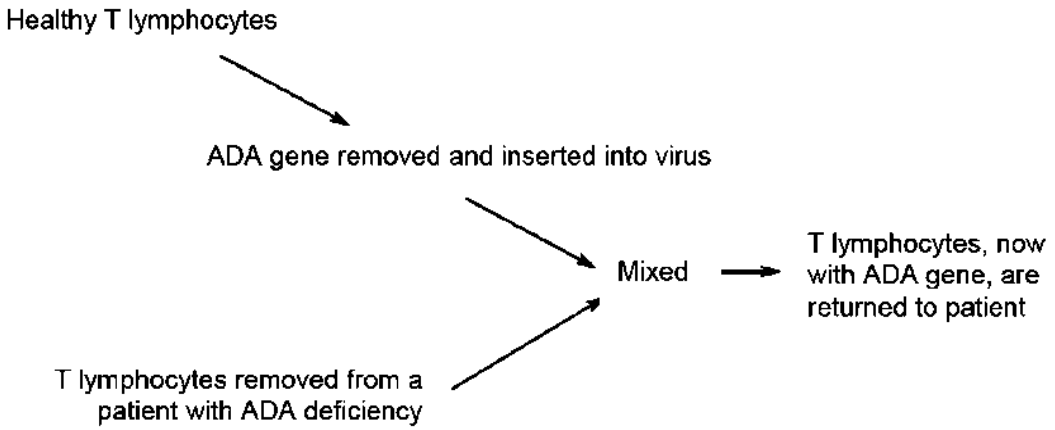
A Stem cells are undifferentiated cells that divide asymmetrically, giving rise to one daughter cell that remains a stem cell and one daughter that will differentiate to replace damaged and worn out cells in the adult tissue or organ.

B Stem cells are embryonic cells that persist in the adult, and can give rise to all of the cell types in the body.

C Stem cells are undifferentiated cells that have expressed the genes and produced proteins characteristic of their differentiated state for repair of tissues and organs.

D Stem cells are fully differentiated cells that reside under the surface of epithelial tissue, in position to take over the function of the tissue when the overlying cells become damaged or worn out.

39 Gene therapy is used to treat a genetic disorder which results from a deficiency of the enzyme, adenosine deaminase (ADA). Without this enzyme, T lymphocytes have impaired function and the immune system of the affected individual is compromised.



If the therapy failed in the first round, which of the following is **not** a possible explanation for the failure?

A Insertion of the ADA gene into the enhancer region of the viral genome.

B ADA was expressed in very low amounts.

C Expressed ADA failed to fold in the correct conformation.

D The viral vector in the modified T lymphocytes stimulated the patient's immune system to mount an attack on the T lymphocyte.

40 The development of genetically modified organisms (GMO) has conferred many benefits and advantages to mankind. However, there are many who are still sceptical of GMOs.

Which of the following is **not** a reason for opposing the use of GMOs?

A Genetically modified herbicide-resistant crops may result in the excessive use of herbicides by farmers, hence polluting the agricultural land and surrounding waterways.

B Genetically modified Bt corn will only kill the European corn borers that feed on them.

C Genetically modified salmon, if accidentally released into the wild, may outcompete local resident salmon fish populations, and lead to decreased biodiversity.

D The antibiotic-resistant marker gene used in genetically modified tomatoes Flavr Savr may be taken up by bacteria through transformation process, hence leading to an increase in antibiotic-resistant bacteria harmful to mankind.

- End of Paper 1 -

RV H2 Bio P1 Solution

1	A	**11**	B	**21**	C	**31**	B
2	D	**12**	B	**22**	B	**32**	B
3	A	**13**	D	**23**	A	**33**	C
4	B	**14**	A	**24**	B	**34**	B
5	A	**15**	D	**25**	C	**35**	B
6	C	**16**	C	**26**	A	**36**	B
7	C	**17**	D	**27**	D	**37**	C
8	C	**18**	D	**28**	A	**38**	A
9	D	**19**	C	**29**	C	**39**	A
10	D	**20**	C	**30**	C	**40**	B

RIVER VALLEY HIGH SCHOOL
YEAR 6
PRELIMINARY EXAMINATION II

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER				

H2 BIOLOGY **9648/02**

Paper 2 Core Paper **15 Sep 2016**

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section A
Answer **all** questions in the spaces provided on the question paper.

Section B
Answer any **one** question on the answer paper provided.
Circle the question attempted on the cover page.

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/ 10**
2	**/ 10**
3	**/ 9**
4	**/ 10**
5	**/ 10**
6	**/ 11**
7	**/ 10**
8	**/ 10**
Section B	
9 or 10*	**/ 20**
Total	**/ 100**

This Question Paper consists of **23** printed pages.

Section A (80 marks)

Answer **all** the questions in this section.

1 **Fig. 1.1** shows electronmicrographs of a zebrafish cell undergoing mitotic cell division.

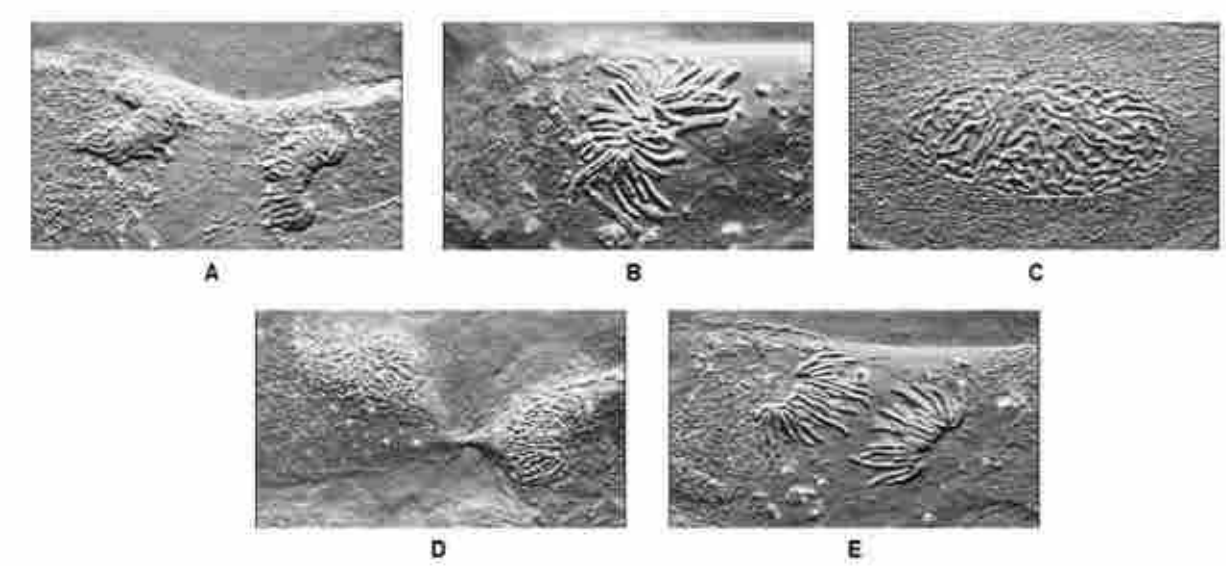


Fig. 1.1

(a) Explain the significance of mitosis to the development of zebrafish. [2]

(b) **(i)** Identify stage **A**. [1]

(ii) With reference to **Fig. 1.1**, describe two visible features that support the identification in **1(b)(i)**. [2]

(iii) Explain the significance of stage **D** to cell division. [2]

(c) Explain why sister chromatids are genetically identical. [3]

[Total: 10]

2 Human Immunodeficiency Virus (HIV) is a retrovirus which infects immune cells expressing CD4 receptor on its cell surface membrane.

(a) Explain the term *retrovirus*. [2]

In 2012, the United States Food and Drug Administration (FDA) approved the OraQuick In-Home HIV Test, which is the first test kit which can be bought at pharmacies.

The test kit relies on the presence of antibodies against gp120 in blood. Antibodies are produced by immune cells in response to exposure to foreign particles. If an individual had been infected by HIV for at least a month, there is a low probability of a false-negative result, whereby the kit incorrectly reports a negative result.

Fig 2.1 shows the changes in concentration of HIV RNA and antibodies against gp120 in the blood stream after HIV infection.

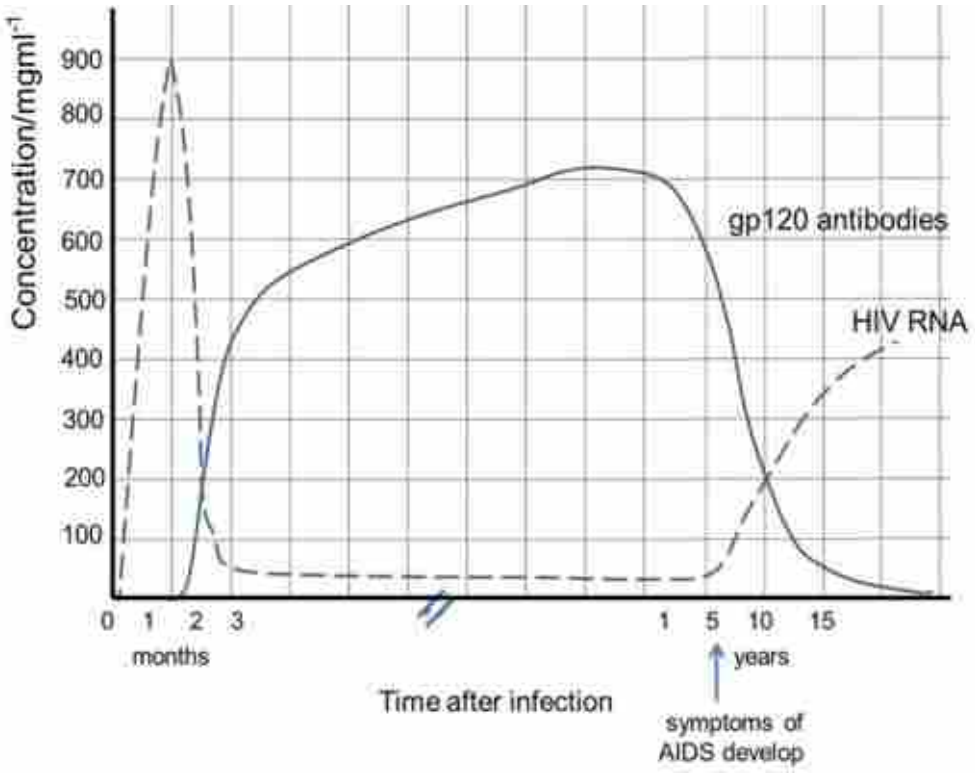


Fig 2.1

Adapted from Hunt, 2016, Virology, Microbiology and Immunology On-line.

http://www.microbiologybook.org/lecture/hiv3.htm

(b) With reference to **Fig 2.1**,

(i) describe how the concentration of gp120 antibodies in blood changes in relation to the concentration of HIV RNA in the first 3 months after infection; [2]

(ii) explain how HIV RNA concentration increases in the first month after infection; [1]

(iii) explain why presence of gp120 antibodies is used as a basis for the detection of HIV infection. [2]

Enveloped viruses like HIV leave the host cell via budding, but T4 bacteriophages use a different mechanism for release.

(c) Explain why release of HIV differs from the release of bacteriophages. [3]

[Total: 10]

Part I

3 An *in-vitro* transcription system allows a DNA segment from yeast to be successfully transcribed under the control of a eukaryotic promoter. Transcription of this DNA segment occurs when purified components (RNA polymerase II and general transcription factors) are added.

However, this *in-vitro* transcription system using purified components occurs at low efficiency, as compared to that using nuclear extract. This suggests that an important gene regulatory protein present in the nuclear extract is missing from the purified components.

(a) (i) State a possible identity of the missing gene regulatory protein. [1]

(ii) Describe how the gene regulatory protein identified in **3(a)(i)** could result in higher efficiency of transcription. [1]

To search for the DNA sequence to which this gene regulatory protein binds, five segments located upstream of the transcription start site (+1) is each deleted in various experimental set-ups. The TATA box is located 15 base-pairs upstream of the transcription start site. Each deleted template is incubated with a non-deleted template, which serves as a control. The four deletion sites are shown in **Fig. 3.1**.

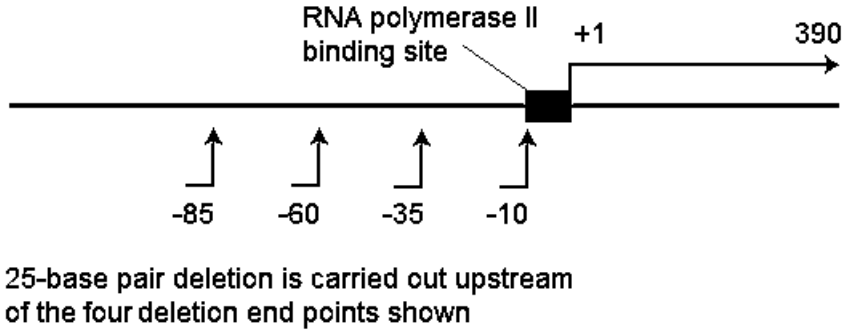


Fig. 3.1

The transcription activity of these deletions in the transcription system using nuclear extract is shown in **Table 3.1**.

Table 3.1

Deletion end point	-10	-35	-60	-85
Activity in deleted template / a.u.	0	10	24	23
Activity in non-deleted template / a.u.	23	24	24	23

(b) With reference to **Fig. 3.1** and **Table 3.1**,

(i) describe the extent of change in transcription activity caused by different deletions. [2]

(ii) Suggest a reason for the transcription activity at -10 deletion end point. [2]

(iii) Deduce the binding site of the gene regulatory protein. [1]

Part II

In a separate experiment that studies the effect of starvation on yeast cells, it was observed that the cells upregulate the synthesis of GCN4 protein when deprived of purine. The α subunit of eukaryotic initiation factor 2 (eIF2) was found to be phosphorylated, and this leads to increased translation of mRNA encoding GCN4.

(c) **(i)** State the level of gene regulation employed for GCN4. [1]

(ii) Explain why this level of gene regulation may be advantageous to the survival of yeast cells. [1]

[Total: 9]

4 In pigeon, pigment distribution is controlled by two genes. In the presence of the dominant allele for spread pigmentation, no pattern is observed. **Fig 4.1** shows the appearance of pigeon with spread and patterned pigmentation. In a farm, pure-breeding pigeon with spread pigmentation and pure-breeding pigeon with barless pattern pigmentation were bred, all the pigeons in the F_1 generation have spread pigmentation.

Patterned pigmentation

Spread pigmentation

Fig. 4.1

When the F_1 pigeons were allowed to interbreed, the phenotype and number of offspring were recorded.

Pigeon with spread pigmentation	86
Pigeon with barless pattern pigmentation	8
Pigeon with bar pattern pigmentation	23

Use the following symbols to represent the alleles:

S – Spread **s** – no spread **B** – Bar pattern **b** – barless

(a) Draw a genetic diagram in the space below to explain the F_1 cross. [4]

(b) State the name for this type of interaction between gene loci. [1]

(c) Explain how different genotypes give rise to spread pigmentation in pigeons. [2]

The χ^2 equation and distribution table are shown below. The calculated χ^2 value for the cross is 4.3.

$$\chi^2 = \Sigma \frac{(O-E)^2}{E}$$

Table 4.1

Degree of freedom	Probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(d) Using the calculated χ^2 value and **Table 4.1,** explain what conclusion can be drawn from the recorded data. [2]

(e) Suggest one reason why the conclusion in **4(d)** may not be valid. [1]

[Total: 10]

5 **Fig 5.1A** and **Fig 5.1B** are electron micrographs of the same plant cell.

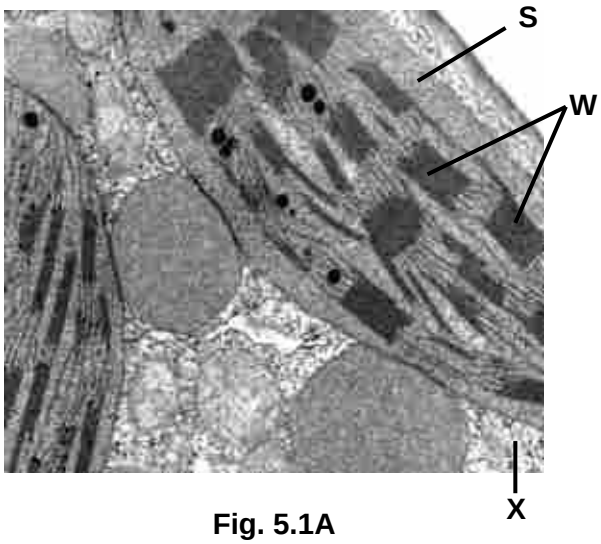


Fig. 5.1A

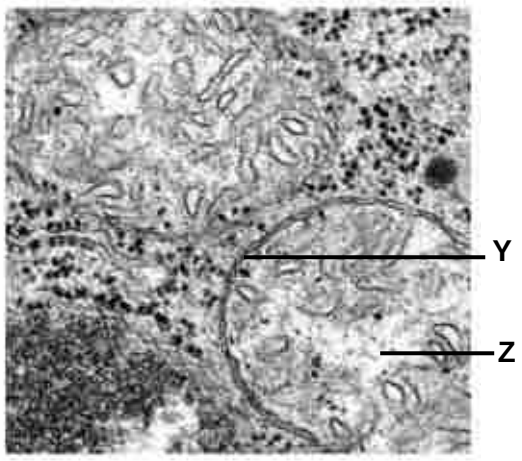


Fig. 5.1B

Source: http://botit.botany.wisc.edu/Resources/Botany/

(a) State in which labelled component(s) will there be the highest concentration of [2]

RuBP carboxylase _____

ATP synthase _____

pyruvate decarboxylase _____

acetyl-coA _____

The optimum pH for the activity of RuBP carboxylase is pH8.

(b) Explain why the illumination of chloroplasts leads to optimum pH condition for RuBP carboxylase. [3]

_____

_____

_____

_____

_____

_____

(c) A herbicide binds irreversibly to RuBP carboxylase. Explain how this herbicide kills weeds. [3]

(d) Describe two ways in which the reactions of the Calvin cycle differs from Krebs cycle. [2]

[Total: 10]

6 ATP-binding cassette (ABC) transporters are transmembrane proteins that utilises the energy from ATP binding and hydrolysis to transport various substances across cellular membranes. They exhibit the ability to switch between two states upon hydrolysis of ATP. Most eukaryotic ABC transporters function as part of the efflux system, removing substances out of cells.

The human ABC-B1 transporter is responsible for multiple drug resistance observed in patients, rendering a variety of structurally unrelated drugs ineffective in treatment of diseases. **Fig. 6.1** shows the structure of a ABC-B1 transporter.

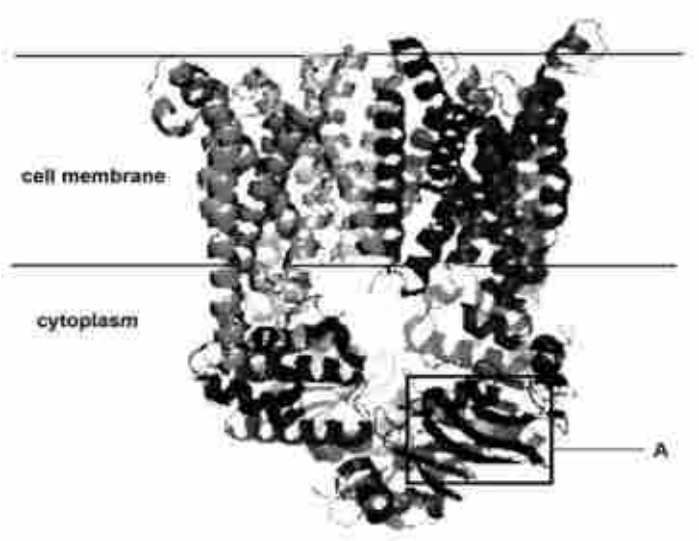


Fig. 6.1

(a) **(i)** Describe how structure **A** is folded. [2]

(ii) Explain how ABC-B1 transporter is held in the cell membrane. [3]

Digoxin is drug derived from the leaves of a plant, and is used in treatment of congestive heart failure. Digoxin is polar in nature, thus is retained in cells by the cell membrane to exert its effect. However, patients are observed to develop resistance to digoxin due to the increased number of ABC-B1 transporters removing digoxin out of cells.

(b) Explain how ABC-B1 transporter removes digoxin out of cells. [3]

To overcome the drug-resistance, patients may be prescribed with verapamil, an inhibitor of ABC-B1 transporter.

In a clinical trial to determine the effectiveness of verapamil, fluorescent-tagged verapamil was administered to a patient with overexpression of ABC-B1 transporter proteins.

At various time intervals, the relative fluorescence of the target cells was measured and the results are recorded in **Table 6.1**.

Table 6.1

Time after administration of verapamil / h	Relative fluorescence / rfu
20	15.7
40	9.8
60	5.4
80	2.3

(c) **(i)** State a feature of verapamil that allows for it to carry out its function. [1]

(ii) Describe the results shown in **Table 6.1**. Suggest a reason for the observation. [2]

[Total: 11]

7 **(a)** Explain the role of calcium ions in synaptic transmission. [3]

GABA is a neurotransmitter which inhibits the production of action potential. **Fig. 7.1** and **Fig. 7.2** shows how the release of GABA from a pre-synaptic neurone affects the membrane potential of a post-synaptic membrane.

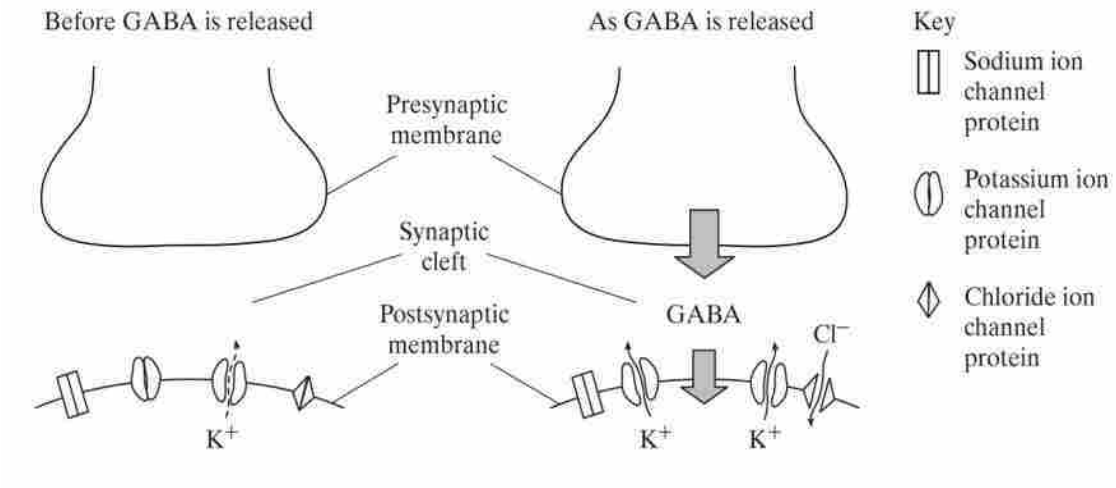


Fig. 7.1

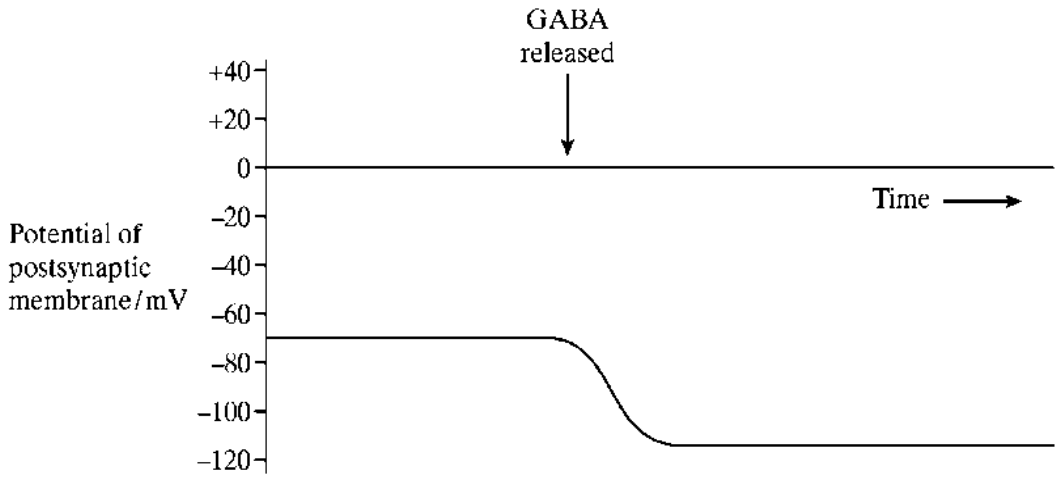


Fig. 7.2

(b) When the post-synaptic membrane is stimulated by acetylcholine, an action potential is less likely to occur if GABA is released. Explain why. [3]

Epilepsy is a neuronal disorder which causes recurrent, unprovoked seizures. This may result when there is increased neuronal activity in the brain.

One form of epilepsy is due to insufficient GABA. GABA is broken down on the post-synaptic membrane by the enzyme transaminase. Vigabatrin is a new drug used to treat this form of epilepsy. The drug has a similar molecular structure to GABA.

(c) Suggest how Vigabatrin may be effective in treating this form of epilepsy. [2]

Fig. 7.3 shows the relationship between diameter of the axon and the speed of conduction of nerve impulses in the myelinated axons of a cat.

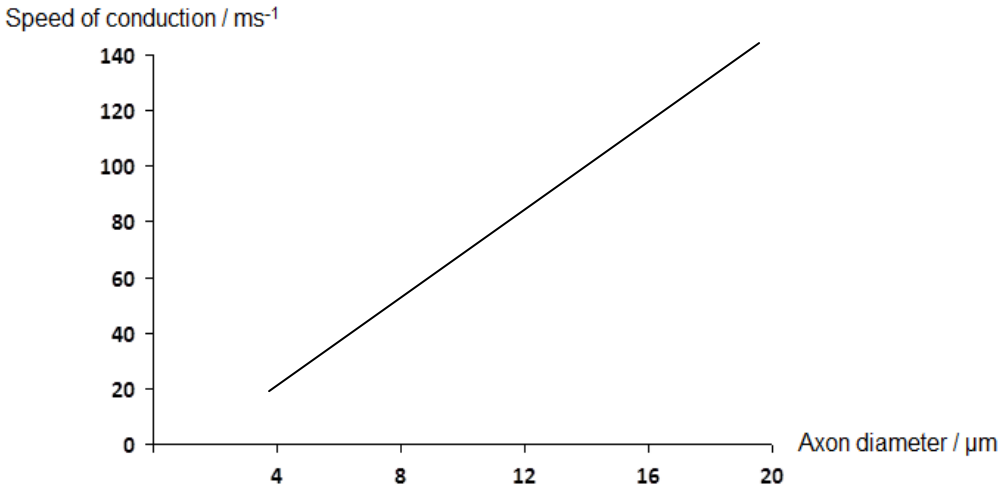


Fig. 7.3

(d) As the diameter of the axon increases, the length of myelination between the nodes increases.

Explain how this resulted in the speed of conduction shown in **Fig 7.3**. [2]

[Total: 10]

8 The Canary Islands form an archipelago of seven volcanic islands just west of the African continent. Lanzarote is the oldest island of about 24.0 million years old in the island chain while Hierro is the youngest island of about 0.8 million years old. The distribution of three species of lizards of the genus *Gallotia* in the Canary Islands is investigated.

Fig 8.1 shows the distribution of the lizard species in these islands and the maximum age of the island. **Fig 8.2** shows the relative body size of the lizards found in these islands.

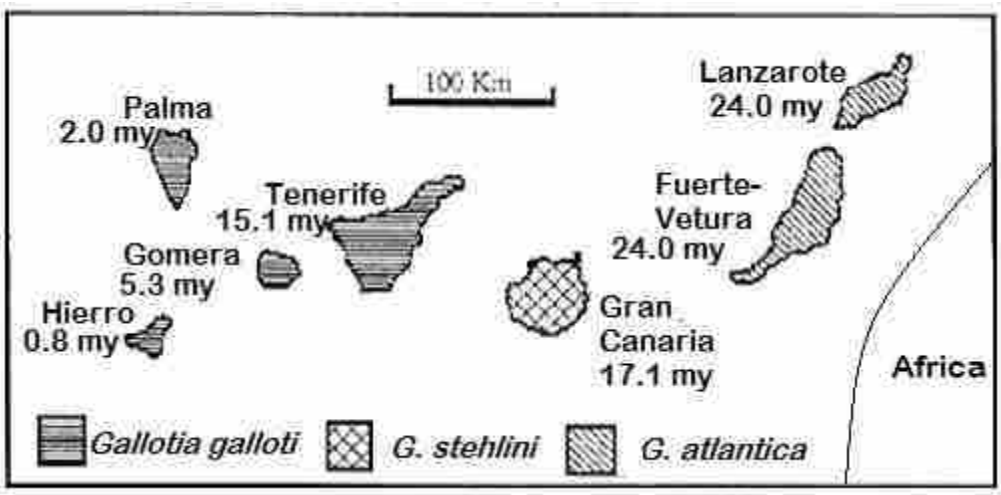


Fig. 8.1

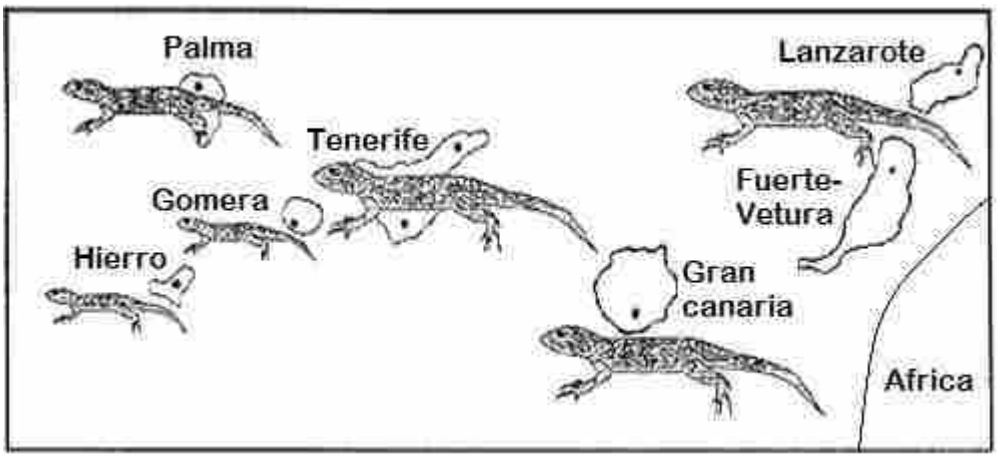


Fig. 8.2

(a) **(i)** Explain how the distinct phenotypic differences between the lizard populations may have arisen. [5]

(ii) Suggest why the lizard populations on Tenerife, Palma, Gomera and Hierro are classified as a single species. [1]

The cytochrome b genes from the different populations of lizards are sequenced. The cytochrome b gene sequences were then compared and the difference in number of base pairs is summarised in **Table 8.1**.

Table 8.1

G. stehlini	*G. stehlini*					
G. atlantica	36	*G. atlantica*				
G. galloti Palma	41	25	*G. galloti* Palma			
G. galloti N. Tenerife	40	23	8	*G. galloti* N. Tenerife		
G. galloti S. Tenerife	40	19	10	6	*G. galloti* S. Tenerife	
G. galloti Gomera	45	24	19	19	15	*G. galloti* Gomera
G. galloti Hierro	49	28	19	21	17	4

N. Tenerife - North of Tenerife island
S. Tenerife - South of Tenerife island

G. galloti Palma — species name / location

(b) Describe how these changes in DNA sequences and dates of island formation can help taxonomist to classify the lizards on the Canary Islands accurately. [4]

[Total: 10]

Section B (20 marks)

Answer **one** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

A **NIL** return is necessary if you have not attempted this section.

9. **(a)** Outline how the structure of membranes in the endomembrane system facilitates their function. [10]

(b) Distinguish between tropocollagen and amylose. [10]

[Total: 20]

10. **(a)** Using a named example, describe how mutation may result in a disease and its associated symptoms. [11]

(b) Explain the role of nuclear membrane in regulating eukaryotic gene expression. [9]

[Total: 20]

RIVER VALLEY HIGH SCHOOL
YEAR 6
PRELIMINARY EXAMINATION II

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER				

H2 BIOLOGY **9648/02**

Paper 2 Core Paper **15 Sep 2016**

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section A
Answer **all** questions in the spaces provided on the question paper.

Section B
Answer any **one** question on the answer paper provided.
Circle the question attempted on the cover page.

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/ 10**
2	**/ 10**
3	**/ 9**
4	**/ 10**
5	**/ 10**
6	**/ 11**
7	**/ 10**
8	**/ 10**
Section B	
9 or 10*	**/ 20**
Total	**/ 100**

This Question Paper consists of **23** printed pages.

Section A (80 marks)

Answer **all** the questions in this section.

1 **Fig. 1.1** shows photomicrographs of a zebrafish cell undergoing mitotic cell division.

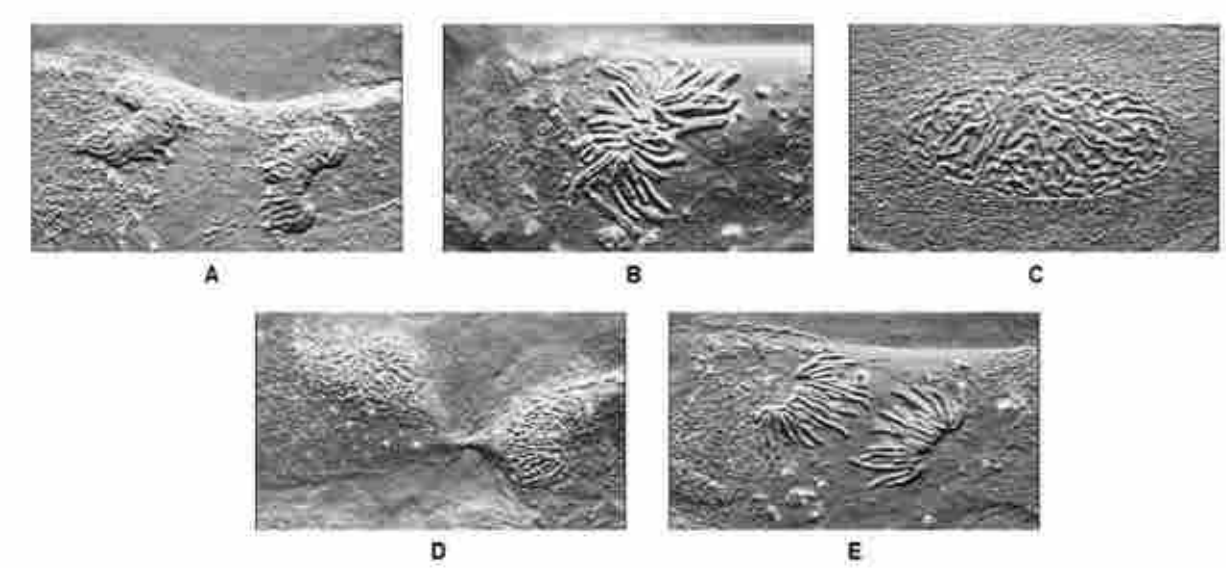


Fig. 1.1

(a) Explain the significance of mitosis in the development of zebrafish. [2]

1. **Produces genetically identical cells;**
2. **resulting in genetic stability in a zebrafish;**
3. **Allows growth;**
4. **into a multicellular zebrafish;**
5. **Allows replacement of worn-out / damaged tissues;**

Reject: asexual reproduction as context given is zebrafish

(b) **(i)** Identify stage **A**. [1]

Telophase;;

(ii) With reference to **Fig. 1.1**, describe two visible features that support the identification in **1(b)(i)**. [2]

1. **Chromosomes de-condense into chromatins;;**
2. **Chromatin are gathered at opposite poles of the cell;;**

(iii) Explain the significance of stage **D** in cell division. [2]

1. **Cytokinesis;**
2. **Separation of cytoplasmic materials;**
3. **and chromosomes;**
4. **into <u>two</u> daughter cells;**

(c) Explain why sister chromatids are genetically identical. [3]

1. **Sister chromatids are formed by DNA replication (in S phase);**
2. **which is semi conservative;**
3. **The two parental strands separate;**
4. **Each parental strand act as a template;**
5. **for the synthesis of a daughter strand;**
6. **via complementary base pairing;**

[Total: 10]

2 Human Immunodeficiency Virus (HIV) is a retrovirus which infects immune cells expressing CD4 receptor on its cell surface membrane.

(a) **(i)** Explain the term retrovirus. [2]

1. **Obligate parasite;**
2. **with single stranded RNA/RNA genome (positive sense);**
3. **Contains enzyme <u>reverse transcriptase</u>;**
4. **which can reverse transcribe <u>RNA to cDNA</u>;**
5. **which can be <u>integrated</u> into host chromosome;**

In 2012, the United States Food and Drug Administration (FDA) approved the OraQuick In-Home HIV Test, which is the first test kit which can be bought at pharmacies. If an individual had been infected by HIV for at least a month, there is a low probability of a false-negative result, whereby the kit incorrectly reports a negative result.

The test kit relies on the presence of antibodies against gp120 in blood. Antibodies are produced by immune cells in response to exposure to foreign particles.

Fig 2.1 shows the changes in concentration of HIV RNA and antibodies against gp120 in the blood stream after HIV infection.

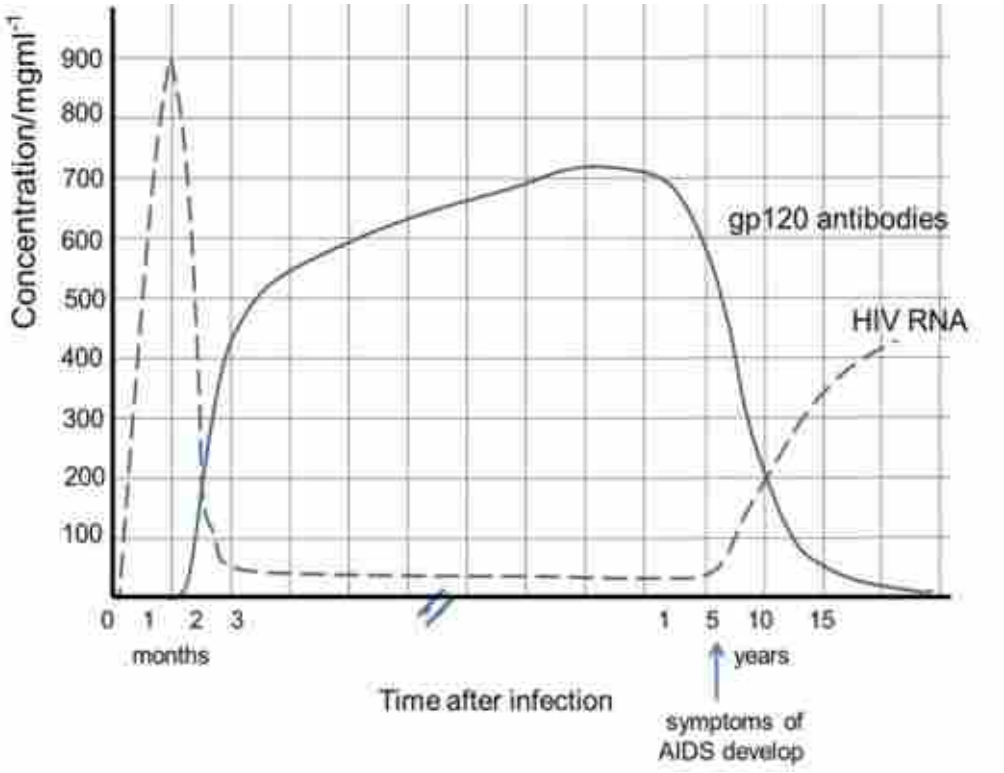


Fig 2.1

Adapted from Hunt, 2016, Virology, Microbiology and Immunology On-line.

http://www.microbiologybook.org/lecture/hiv3.htm

(b) With reference to **Fig 2.1**,

(i) describe how the concentration of gp120 antibodies in blood changes in relation to the concentration of HIV RNA in the first 3 months after infection; [2]

1. **From 0 to 1.5 month after infection, concentration of HIV RNA increases from 0 to 900 mgml^{-1} while concentration of gp120 antibodies remains at 0 mgml^{-1};;**
2. **From 1 to 3 months after infection, concentration of HIV RNA decreases from 900 mgml^{-1} to 50 mgml^{-1}while concentration of gp120 antibodies increases from 0 mgml^{-1} to 410 mgml^{-1};;**

(ii) explain how HIV RNA concentration increases in the first month after infection; [1]

1. **HIV RNA synthesised using HIV cDNA;**
2. **as a template;**
3. **using host cell machinery;**

(iii) explain why presence of gp120 antibodies is used as a basis for the detection of HIV infection. [2]

1. **A month after infection, gp120 antibodies concentration in blood increases;**
2. **and remains high throughout dormant period;**

or

1. **HIV RNA concentration is low after 3 months/during dormancy;**
2. **May not be accurately detected by kit (leading to false negative test results)**

Enveloped viruses like HIV leave the host cell via budding, but T4 bacteriophages use a different mechanism for release.

(c) Explain why release of HIV differs from the release of bacteriophages. [3]

1. **Budding from host cell allows HIV to acquire glycoproteins gp120 and gp41;;**
2. **which are embedded on host cell surface membrane;**
3. **While T4 bacteriophages exit the host cell via lysis of host cell;**
4. **If HIV is released via lysis of host cell, it will not be enclosed by viral envelope/lysis does not allow for virus to acquire viral envelope;;**

[Total: 10]

3 **Part I**

An *in-vitro* transcription system allows a DNA segment from yeast to be successfully transcribed under the control of a eukaryotic promoter. Transcription of this DNA segment occurs when purified components (RNA polymerase II and general transcription factors) are added.

However, this *in-vitro* transcription system using purified components occurs at low efficiency, as compared to that using nuclear extract. This suggests that an important gene regulatory protein present in the nuclear extract is missing from the purified components.

(a) **(i)** State a possible identity of the missing gene regulatory protein. [1]

Activator protein;;

(ii) Describe how the gene regulatory protein identified in **3(a)(i)** could result in higher efficiency of transcription. [1]

1. **Binds to enhancer;**
2. **Increases the probability of (general) transcription factors binding / RNA polymerase (II) binding / forming transcription initiation complex;**

To search for the DNA sequence to which this gene regulatory protein binds, five segments located upstream of the transcription start site (+1) is each deleted in various experimental set-ups. The TATA box is located 15 base-pairs upstream of the transcription start site. Each deleted template is incubated with a non-deleted template, which serves as a control. The four deletion sites are shown in **Fig. 3.1**.

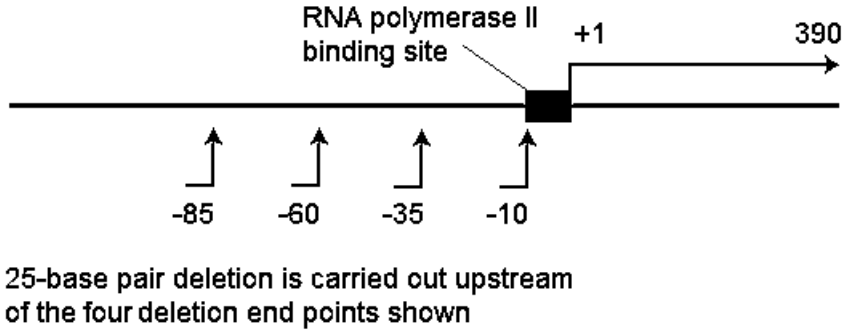


Fig. 3.1

The transcription activity of these deletions in the transcription system using nuclear extract is shown in **Table 3.1**.

Table 3.1

Deletion end point	-10	-35	-60	-85
Activity in deleted template / a.u.	0	10	24	23
Activity in non-deleted template / a.u.	23	24	24	23

(b) **(i)** With reference to **Fig. 3.1** and **Table 3.1**, describe the extent of change in transcription activity caused by different deletions. [2]

1. **Deletion end point of -10 resulted in no transcription;**

Accept: quoting of drop from 23 a.u to 0 a.u.

2. **Deletion end point of -35 reduces transcription activity by 14 a.u.;**

Accept: quoting of drop from 24 a.u to 10 a.u.

3. **Deletion end points of -60 has no impact on transcription activity;**
4. **Deletion end points of -85 has no impact on transcription activity;**

(ii) Suggest a reason for the transcription activity at -10 deletion end point. [2]

1. **Deletion of the TATA box;**
2. **results in (general) transcription factors unable to bind;**
3. **RNA polymerase (II) could not bind / transcription initiation complex could not form;**
4. **Transcription not initiated;**

(ii) Deduce the binding site of the gene regulatory protein. [1]

35 to 59 base pairs upstream of start site;;

Accept: 35 to 60 base pairs

Part II

In a separate experiment that studies the effect of starvation on yeast cells, it was observed that the cells upregulate the synthesis of GCN4 protein when deprived of purine. The α subunit of eukaryotic initiation factor 2 (eIF2) was found to be phosphorylated, and this leads to increased translation of mRNA encoding GCN4.

(c) **(i)** State the level of gene regulation employed for GCN4. [1]

Translation control;;

(ii) Explain why this level of gene regulation may be advantageous to the survival of yeast cells. [1]

1. **Allows for yeast cells to respond quickly to environment changes;**
2. **gaining selective advantage;**

[Total: 9]

4 In pigeon, pigment distribution is controlled by two genes. In the presence of the dominant allele for spread pigmentation, no pattern is observed. **Fig 4.1** shows the appearance of pigeon with spread and patterned pigmentation. In a farm, pure-breeding pigeon with spread pigmentation and pure-breeding pigeon with barless pattern pigmentation were bred, all the pigeons in the F1 generation have spread pigmentation.

Patterned pigmentation

Spread pigmentation

Fig. 4.1

When the F_1 pigeons were allowed to interbreed, the phenotype and number of offspring were recorded.

Pigeon with spread pigmentation	86
Pigeon with barless pattern pigmentation	8
Pigeon with bar pattern pigmentation	23

Use the following symbols to represent the alleles:

S – Spread **s** – no spread

B – Bar pattern **b** – barless

(a) Draw a genetic diagram in the space below to explain the cross described. [4]

F1 phenotype: Spread pigment x Spread pigment

Interbreeding between F_1: **SsBb;** x **SsBb;**

F1 gametes;; **SB** **Sb** **sB** **sb** x **SB** **Sb** **sB** **sb**

Random fertilization of F1 gametes:

Genotype;;

Phenotype;;

	SB	**Sb**	**sB**	**sb**
SB	SSBB Spread	SsBb Spread	SsBB Spread	SsBb Spread
Sb	SsBb Spread	SSbb Spread	SsBb Spread	Ssbb Spread
sB	SsBB Spread	SsBb Spread	ssBB bar	ssBb bar
sb	SsBb Spread	Ssbb Spread	ssBb bar	ssbb barless

F2 phenotypic ratio 12 spread: 3 bar : 1 barless

(b) State the name for this type of interaction between gene loci. [1]

Dominant epistasis;;

(c) Explain how different genotypes give rise to spread pigmentation in pigeons [2]

1. **Genotypes S_ _ _, result in spread pigmentation;**
2. **Dominant allele S is epistatic over gene locus B/b;**
3. **Encodes for sufficient amount of inhibitor;**
4. **To prevent formation of patterned pigmentation;**

The χ^2 distribution table and equation to calculate χ^2 is shown below. Using the formula shown below, the calculated χ^2 value for the cross is 4.3.

$$\chi^2 = \Sigma \frac{(O-E)^2}{E}$$

Table 4.1

Degree of freedom	Probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(d) Using the calculated χ^2 value and **Table 4.1,** explain what conclusion can be drawn from the recorded data. [2]

1. **At v=2, calculated χ^2 value corresponds to p-value more than 0.10;**
2. **Which is more than 0.05;**
3. **Do not reject H_0 in favour of H_1;**
4. **There is no significant difference between the observed and expected values;**

(e) Suggest one reason why the conclusion in **(d)** may not be valid. [1]

Small sample size;;

[Total: 10]

5 **Fig 5.1A** and **Fig 5.1B** are electron micrographs of the same plant cell.

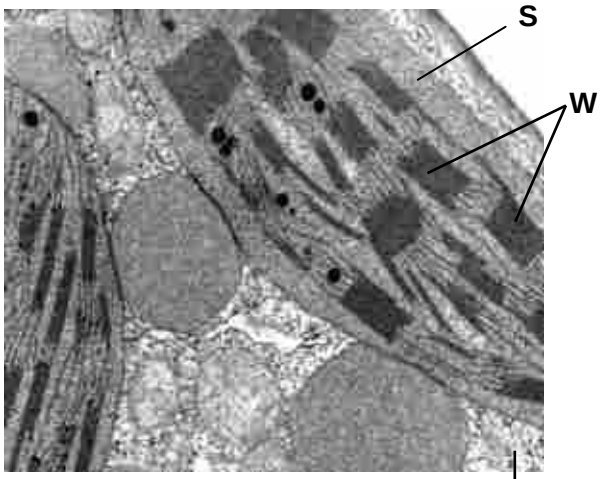


Fig. 5.1A

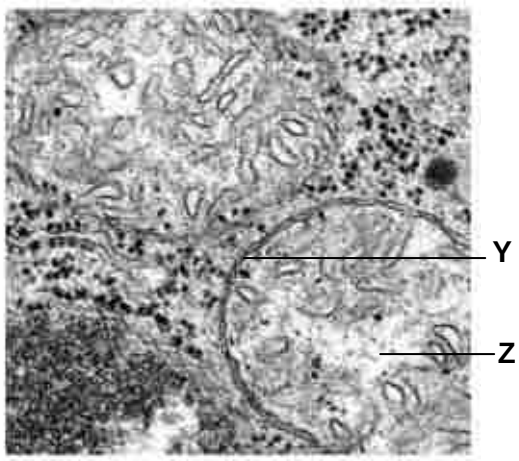


Fig. 5.1B

Source: http://botit.botany.wisc.edu/Resources/Botany/

(a) State in which labelled component(s) will there be the highest concentration of [2]

RuBP carboxylase	**S;**
ATP synthase	**W, Y;**
pyruvate decarboxylase	**X;**
acetyl-coA	**Z;**

The optimum pH for the activity of RuBP carboxylase is pH8.

(b) Explain why the illumination of chloroplasts leads to optimum pH condition for RuBP carboxylase. [3]

1. **RuBP carboxylase function in the stroma;**
2. **Where protons are present from photolysis of water;**
3. **Light results in high energy electrons displaced from special chlorophyll a/photosystem;**
4. **Pass along the electron transport chain;**
5. **Protons pumped from stroma to thylakoid lumen;**
6. **Protons leaving the stroma increases the pH;**

(c) Herbicide **X** binds irreversibly to RuBP carboxylase. Explain how herbicide **X** kills weeds. [3]

1. **RuBP and CO_2;**
2. **cannot bind to active site of RuBP carboxylase;**
3. **Carbon fixation cannot take place;;**
4. **Triose phosphate not produced;**
5. **Weeds die because cells cannot synthesis glucose for aerobic respiration/cannot synthesised amino acids for translation;**

(d) Describe two ways in which the reactions of the Calvin cycle differs from Kreb's cycle. [2]

Factor	Calvin cycle	Kreb's cycle
Type of reactions;;	Reduction reactions	Oxidation reactions
Coenzyme;;	NADPH/H+	NAD+
Role of ATP;;	ATP hydrolysed to provide energy for phosphorylation of GP / regeneration of RuBP	ATP produced from substrate level phosphorylation
Role of CO_2;;	Reduced to form triose phosphate	Released as by-product during oxidative decarboxylation

1 mark per comparison;;

Reject comparison relating to location

[Total: 10]

6 ATP-binding cassette (ABC) transporters are transmembrane proteins that utilises the energy from ATP binding and hydrolysis to transport various substances across cellular membranes. They exhibit the ability to switch between two states upon hydrolysis of ATP. Most eukaryotic ABC transporters function as part of the efflux system, removing substances out of cells.

The human ABC-B1 transporter is responsible for multiple drug resistance observed in patients, rendering a variety of structurally unrelated drugs ineffective in treatment of diseases. **Fig. 6.1** shows the structure of a ABC-B1 transporter.

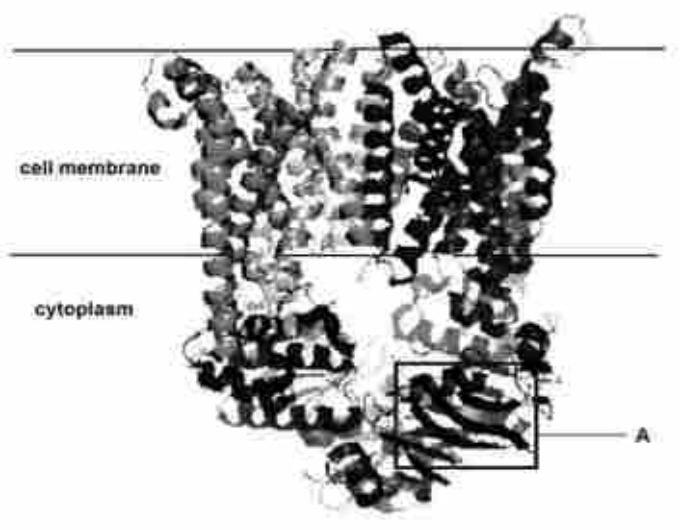


Fig. 6.1

(a) **(i)** Describe how structure **A** is folded. [2]

1. **Hydrogen bonds;**
2. **form between CO and NH groups;**
3. **of adjacent regions of a polypeptide chain;**
4. **that lie parallel to each other;**

(ii) Explain how ABC-B1 transporter is held in the cell membrane. [3]

1. **Hydrophobic interaction;**
2. **between non-polar R groups of ABC-B1 transporter;**
3. **and non-polar hydrocarbon tails of phospholipid molecules;**
4. **H bonds;**
5. **between polar R groups of ABC-B1 transporter;**
6. **and polar phosphate head of phospholipid molecules;**

Accept: ionic bonds between oppositely charged R groups and phosphate heads

Digoxin is drug derived from the leaves of a plant, and is used in treatment of congestive heart failure. Digoxin is polar in nature, thus is retained in cells by the cell membrane to exert its effect. However, patients are observed to develop resistance to digoxin due to the increased number of ABC-B1 transporters removing digoxin out of cells.

(b) Explain how ABC-B1 transporter removes digoxin out of cells. [3]

1. **Via active transport;**
2. **Digoxin binds to (cytoplasmic) binding site of ABC-B1 transporter;**
3. **triggering change in three dimensional conformation of ABC-B1 transporter;**
4. **with the binding / hydrolysis / investment of ATP;**
5. **This allows digoxin to move through its hydrophilic channel;**
6. **against its concentration gradient;**
7. **shielded from hydrophobic core of membrane;**

To overcome the drug-resistance, patients may be prescribed with verapamil, an inhibitor of ABC-B1 transporter.

In a clinical trial to determine the effectiveness of verapamil, fluorescent-tagged verapamil was administered to a patient with overexpression of ABC-B1 transporter proteins.

At various time intervals, the relative fluorescence of the target cells was measured and the results are recorded in **Table 6.1**.

Table 6.1

Time after administration of verapamil / h	Relative fluorescence / rfu
20	15.7
40	9.8
60	5.4
80	2.3

(c) **(i)** State a feature of verapamil that allows for it to carry out its function. [1]

Complementary shape to binding site on ABC-B1 transporter protein;;

Permanent / stable / irreversible binding to ABC-B1 transporter protein;;

Reject: structurally different from digoxin, as this does not help in its function.

(ii) Describe the results shown in **Table 6.1**. Suggest a reason for the observation. [2]

Describe

The relative fluorescence of the target cells decreases from 15.7 rfu 20h after administration of verapamil to 2.3 rfu 80h after administration of verapamil;;

Reason

Verapamil is broken down / transported out of the cell;;

Binding of verapamil is not stable / permanent;;

Reject: metabolised with no reference to anabolised / catabolised.

[Total: 11]

7 **(a)** Explain the role of calcium ions in synaptic transmission. [3]

1. **Influx of Ca^{2+};**
2. **into synaptic knob / pre-synaptic membrane;**
3. **causing membrane of vesicles to fuse with pre-synaptic membrane;**
4. **releasing acetylcholine;**
5. **into synaptic cleft;**
6. **via exocytosis;**

GABA is a neurotransmitter which inhibits the production of action potential. **Fig. 7.1** and **Fig. 7.2** shows how the release of GABA from a pre-synaptic neurone affects the membrane potential of a post-synaptic membrane.

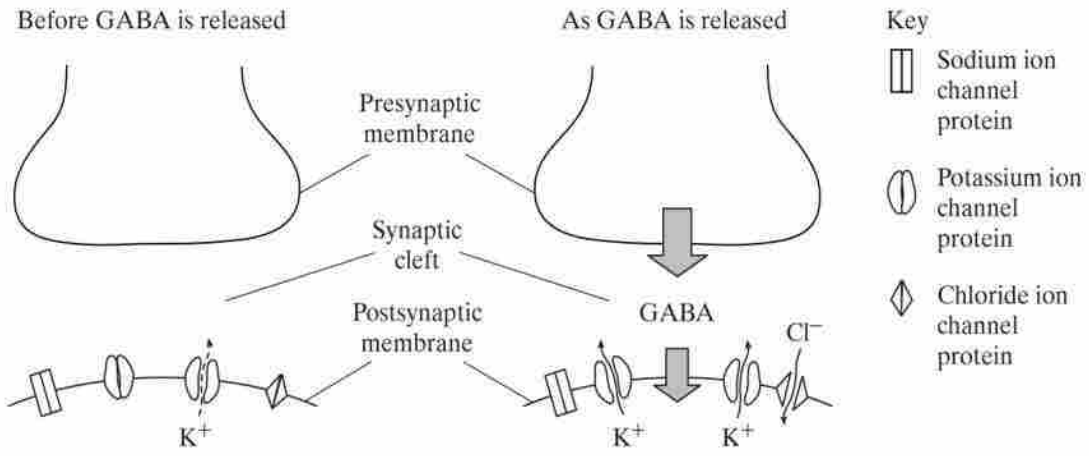


Fig. 7.1

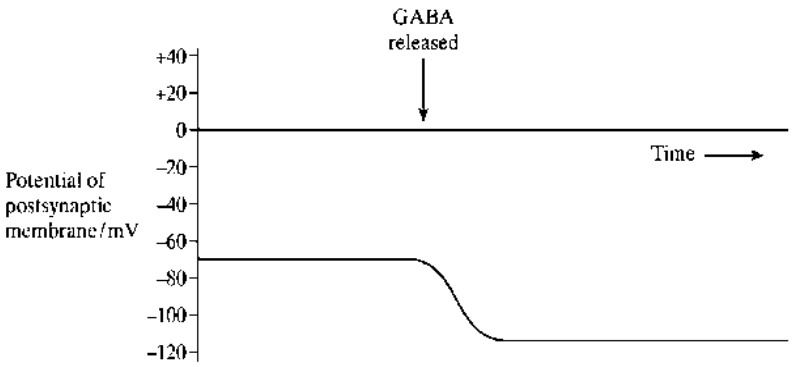


Fig. 7.2

(b) When the post-synaptic membrane is stimulated by acetylcholine, an action potential is less likely to occur if GABA is released. Explain why. [3]

1. **GABA opens ligand-gated K^+ and Cl^- channels (in post-synaptic membrane);**
2. **Allowing K^+ to diffuse out of post-synaptic neurone;**
3. **and Cl^- to diffuse into post-synaptic neurone;**
4. **Causing hyperpolarisation;**

Accept: membrane potential below resting potential

5. **Stimulation greater than normal / more Na+ influx is required;**
6. **to reach threshold potential (to trigger action potential);**

Epilepsy is a neuronal disorder which causes recurrent, unprovoked seizures. This may result when there is increased neuronal activity in the brain.

One form of epilepsy is due to insufficient GABA. GABA is broken down on the post-synaptic membrane by the enzyme transaminase. Vigabatrin is a new drug used to treat this form of epilepsy. The drug has a similar molecular structure to GABA.

(c) Suggest how Vigabatrin may be effective in treating this form of epilepsy. [2]

1. **Vigabatrin binds to GABA transaminase;**
2. **via complementary shape;**
3. **Prevents breakdown of GABA / more GABA available;**
4. **Reduces neuronal activity / frequency of action potential;**

Fig. 7.3 shows the relationship between diameter of the axon and the speed of conduction of nerve impulses in the myelinated axons of a cat.

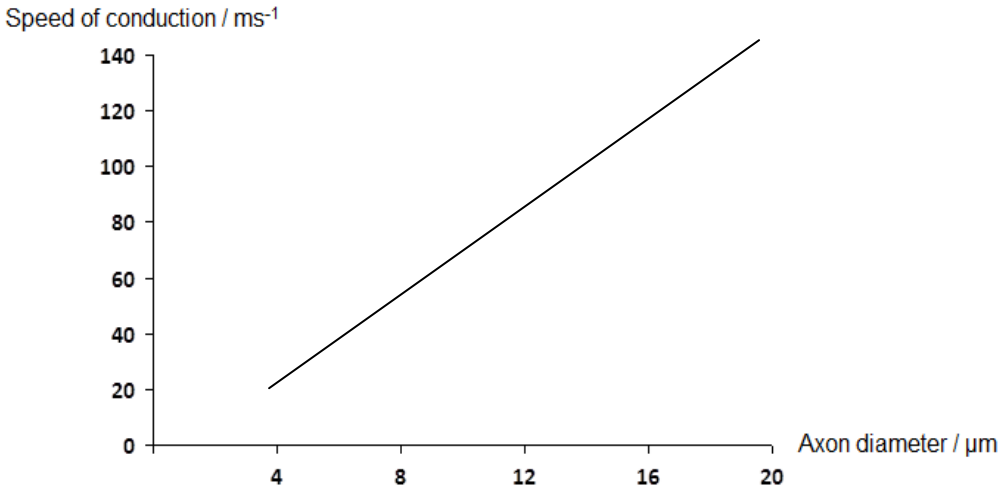


Fig. 7.3

(d) As the diameter of the axon increases, the length of myelination between the nodes increases.

Explain how this resulted in the speed of conduction shown in **Fig 7.3**. [2]

1. **As diameter of axon increases from 4µm to 20µm, length of myelination between nodes increases, thus speed of conduction increases from 20ms^{-1} to 140ms^{-1};;**
2. **Fewer depolarisations/action potentials to travel the length of the axon;**
3. **when impulse transmits from node to node / travel by saltatory conduction;**

[Total: 10]

8 The Canary Islands form an archipelago of seven volcanic islands just west of the African continent. Lanzarote is the oldest island of about 24.0 million years old in the island chain while Hierro is the youngest island of about 0.8 million years old. The distribution of three species of lizards of the genus Gallotia in the Canary Islands is investigated.

Fig 8.1 shows the distribution of the lizard species in these islands and the maximum age of the island. **Fig 8.2** shows the relative body size of the lizards found in these islands.

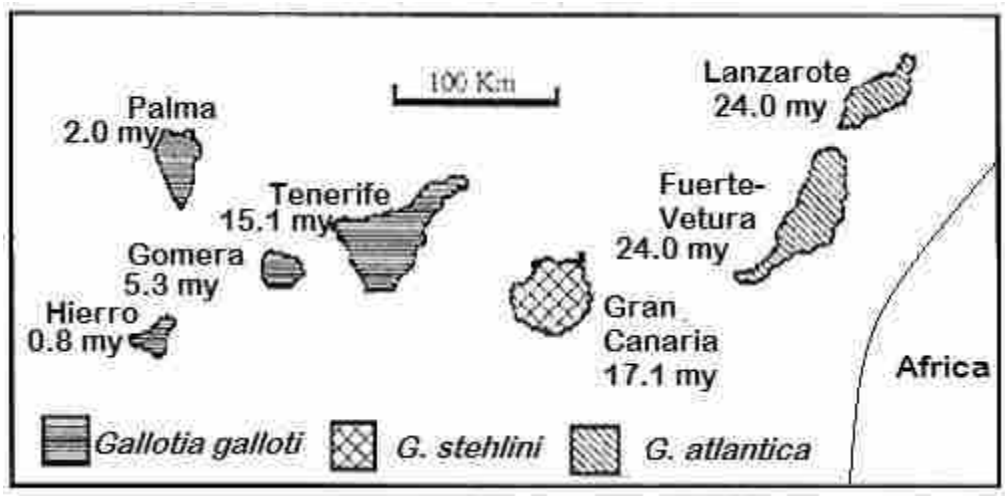


Fig. 8.1

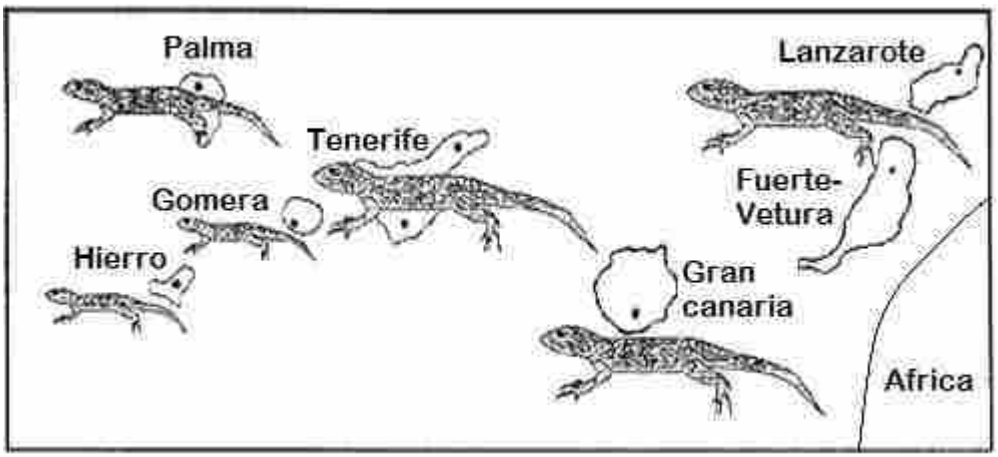


Fig. 8.2

(a) **(i)** Explain how the distinct phenotypic differences between the lizard populations may have arisen. [5]

1. **Geographical isolation as a result of separated islands;**
2. **No gene flow between populations on different islands;**
3. **Mutation;**
4. **Leads to variation in body size in a population;**
5. **Different environment on different islands acts as selection pressure;**
6. **Natural Selection occurs;**

7. **Lizards with body size <u>best suited</u> for the environment are selected for;**
8. **Survive and <u>reproduce</u>**
9. **Pass on favourable alleles to offspring;**
10. **Change in <u>allelic frequency</u> over time;**
11. **Genetic drift (such as founder's effect);**

(a) (ii) Suggest why the lizard populations on Tenerife, Palma, Gomera and Hierro are classified as a single species. [1]

1. **Individuals from different population able to interbreed;**
2. **To produce fertile offspring;**

The cytochrome b gene from the different populations of lizard is sequenced. The cytochrome b gene sequences were then compared and the difference in number of base pairs is summarised in the table below.

Table 8.1

G. stehlini	*G. stehlini*					
G. atlantica	36	*G. atlantica*				
G. galloti Palma	41	25	*G. galloti* Palma			
G. galloti N. Tenerife	40	23	8	*G. galloti* N. Tenerife		
G. galloti S. Tenerife	40	19	10	6	*G. galloti* S. Tenerife	
G. galloti Gomera	45	24	19	19	15	*G. galloti* Gomera
G. galloti Hierro	49	28	19	21	17	4

N. Tenerife - North of Tenerife island
S. Tenerife - South of Tenerife island

G. galloti Palma — species name / location

(b) Describe how these changes in DNA sequences and dates of island formation can help taxonomist to classify the lizards on the Canary Islands accurately. [4]

1. **Neutral mutations are accumulated at a relatively constant rate;;**
2. **By determining the number of mutations/differences in DNA bases between lizards of different populations;**
3. **And by using the age of the island for calibration;**
4. **Can be used to track mutations accumulated over a period of time / calculate rate of mutation;**
5. **via a molecular clock;;**
6. **Can calculate time since divergence;**

[Total: 10]

Section B (20 marks)

Answer **one** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

A **NIL** return is necessary if you have not attempted this section.

9. **(a)** Outline how the structure of membranes in the endomembrane system facilitates their function. [10]

1. **The endomembrane system comprises the (outer nuclear membrane), rough endoplasmic reticulum, Golgi apparatus, (associated vesicles) and cell surface membrane;;**
2. **Membranes in the endomembrane system forms a continuous network for protein synthesis;;**
3. **Membranes of endomembrane system have similar composition allowing transfer of membrane (as vesicles) from one organelle to the next organelle;;**
4. **Fluid nature of phospholipid bilayer allows for fusion and budding of vesicles with membrane;;**
5. **Nuclear pores of nuclear membrane allows export of mRNA for protein synthesis at RER;;**
6. **Endoplasmic reticulum membrane allows for ribosomes to be embedded for protein synthesis;;**
7. **Endoplasmic reticulum membrane enclose lumen for folding of protein;;**
8. **RER membrane forms transport vesicle through budding for**

(intracellular) transport;;

9. **Membrane on the cis face of Golgi apparatus allows for fusion with transport vesicle membrane/for proteins can enter;;**
10. **Golgi apparatus membrane enclose lumen for modification/sorting;;**
11. **Membrane on the trans face of Golgi Apparatus allows for Golgi vesicle to bud off;**
12. **Membrane of secretory vesicle fuse with cell surface membrane, leading to exocytosis;;**
13. **AVP;;**

(b) Distinguish between tropocollagen and amylose. [10]

Differences

Factor	Tropocollagen	Amylose
1. Element present;;	C, H, O, N, S	C, H, O
2. Monomer;;	Amino acids	α-glucose
3. Types of monomers;;	20	1
4. Bonds between monomers;;	Peptide bond	α(1-4) glycosidic bonds
5. Inter-chain association;;	Yes (hydrogen bonds)	No
6. Number of chains;;	3 polypeptide chains	1 polysaccharide chain
7. Shape;;	Linear	Helical
8. Function;;	Structural role	Energy store
9. Further assembly;;	Can further assemble to form collagen fibres	Do not further assemble
10. Tensile strength;;	High tensile strength	Low tensile strength
11. Site of synthesis;;	Ribosomes/RER	Golgi apapatus;;
12. Occurrence;;	Animal cells	Plant cells

[Total: 20]

10. (a) Using a named example, describe how mutation may result in a disease and its associated symptoms. [11]

1. **Sickle cell anemia;;**

2. **Base pair substitution;**
3. **thymine replaced by adenine;**
4. **changes nucleotide sequence;**
5. **of β globin gene;**

6. **This changes codon 6 on mRNA;**
7. **to GUA;**
8. **resulting in missense mutation;**
9. **that changes glutamic acid;**
10. **to valine;**
11. **resulting in a neutral amino acid;**

Accept: hydrophobic amino acid

12. **This changes the folding / three dimensional conformation of haemoglobin / β globin;**
13. **generating a sticky patch;**
14. **on the surface of haemoglobin;**

15. **The deoxygenated form of mutant haemoglobin;**
16. **is insoluble in red blood cells;**
17. **forming crystalline arrays;**
18. **This causes red blood cells to form a sickle shape;**

19. **Sickle-shaped red blood cells are rigid;**
20. **and are often trapped in blood capillaries;**
21. **causing pain;**

22. **reduced oxygen supply to tissues;**
23. **causes cell death / tissue damage / organ failure;**
24. **haemolyse readily**
25. **accumulate in spleen / abnormal enlargement of spleen**

(b) Explain the role of nuclear membrane in regulating eukaryotic gene expression. [9]

1. **Nuclear membrane forms a barrier;**
2. **between nucleus and cytoplasm;**

3. **protect DNA / mRNA from degradation;**
4. **by cytoplasmic enzymes;**
5. **maintaining integrity of <u>template</u> for transcription / translation;**

6. **prevents mixing of intermediates;**
7. **of transcription and translation;**

8. **allows for post-transcriptional modification;**
9. **such as 5' capping / 3' polyadenylation / mRNA splicing;**

10. **Nuclear membrane is made up of phospholipid bilayer;**
11. **comprising a hydrophobic core;**
12. **rendering it selectively permeable;**
13. **Nuclear pores;**

14. **regulate the movement of mRNA out of the nucleus;**
15. **control availability of <u>template</u> for translation;**

16. **regulates the movement of ribosomal proteins into the nucleus;**
17. **and ribosomal subunits out of nucleus;**
18. **controlling synthesis of ribosomes;**
19. **for initiation of translation;**

20. **concentrates the enzymes / proteins;**
21. **such as RNA polymerase / transcription factors;**
22. **to increase frequency of transcription;**

[Total: 20]

RIVER VALLEY HIGH SCHOOL
YEAR 6
PRELIMINARY EXAMINATION II

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER				

H2 BIOLOGY **9648/03**

Paper 3 Application Paper **20 Sep 2016**

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section A
Answer **all** questions in the spaces provided on the question paper.

Section B
Answer **all** question on the answer paper provided.

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/ 13**
2	**/ 13**
3	**/ 14**
4	**/ 12**
Section B	
5	**/ 20**
Total	**/ 72**

This Question Paper consists of **16** printed pages.

Section A (80 marks)

Answer **all** the questions in this section.

1 The coat colour of Norwegian cattle is mainly determined by the distribution of two pigments: red and black. Both pigments are produced by the action of the enzyme tyrosinase, in cells called melanocytes. A low level of activity of the enzyme leads to the production of red pigment, while a high activity of the enzyme produces black pigment.

The activity of the enzyme is increased by the melanocyte stimulating hormone (MSH), which binds to the MSH receptor. The receptor is encoded by gene **E**, which has three alleles, $\mathbf{E^D}$, $\mathbf{E^A}$ and **e**. $\mathbf{E^D}$ and $\mathbf{E^A}$ each encodes a receptor with different activity. No receptor is produced by the recessive allele, **e**.

Alleles $\mathbf{E^D}$ and $\mathbf{E^A}$ differs by a single base substitution; while alleles **e** and $\mathbf{E^A}$ differs by a single base deletion.

(a) Explain how a mutation at $\mathbf{E^A}$ allele may result in the protein encorded by **e** allele. [3]

DNA was extracted from the frozen semen of six bulls with different genotypes at the E locus. The DNA from each animal was separately digested with two different restriction enzymes, **P** and **Q**.

The products of each digestion were separated on a gel and the banding pattern shown in **Fig. 1.1**.

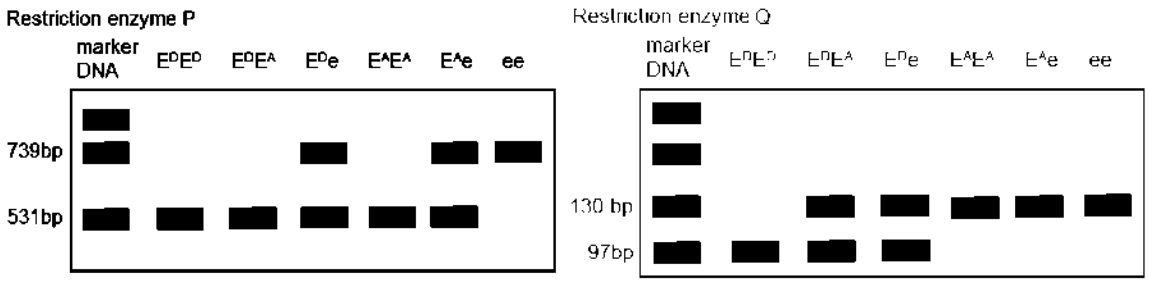


Fig. 1.1

(b) **(i)** Explain why the banding patterns from the same genotype are different when a different restriction enzyme is used. [2]

(ii) Explain the role of marker DNA. [2]

(iii) State which genotype(s) can be identified by using each of the two restriction enzymes. [2]

P:

Q:

Bovine somatotropin (BST) is an animal hormone used to increase milk production in dairy cows. BST is naturally produced in the cow pituitary gland in small quantity and is used to regulate metabolic processes. With the advent of biotechnology, *BST* gene can be cloned in *Escherichia coli*. The bacteria are grown in bioreactors to produce BST, which is purified to produce hormone for injection.

Fig. 1.2 shows the plasmid map of the BGH1 plasmid, used for transformation of *BST* gene into *E.coli*. Sal 1 restriction enzyme was used to cut the BGH1 plasmid for insertion of *BST* gene.

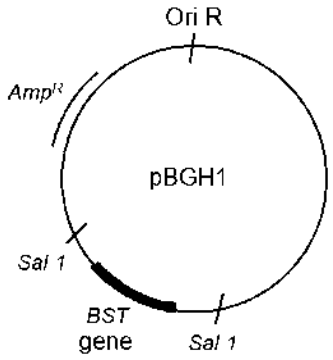


Fig. 1.2

(c) **(i)** Describe the natural role of Sal 1 restriction enzyme. [2]

(ii) Explain how Amp^R gene facilitates *BST* gene cloning. [2]

[Total: 13]

2 Omega-3 fatty acids are polyunsaturated fats that are often marketed as health supplements to prevent cholesterol deposits in arterial walls.

In the wild, omega-3 fatty acids are produced by marine algae and accumulate in small fishes that feed on them. These small fishes are then fed to farmed fishes to increase their omega-3 fatty acid content. Farmed fishes high in omega-3 fatty acids serve as a good source for omega-3 fatty acid extraction for the health supplement industry.

A new method to produce omega-3 fatty acids involves insertion of seven genes of the marine algae into oilseed plant, *Camelina sativa.* The resulting seed pods contain as much as 200 milligrams of omega-3 fatty acids in a single tablespoon of 'fish oil' extracted. Currently, this 'fish oil' is fed to farmed fishes, in replacement of small fishes.

The effect of human consumption of 'fish oil' from genetically modified *C. sativa* seed pods is still under investigation.

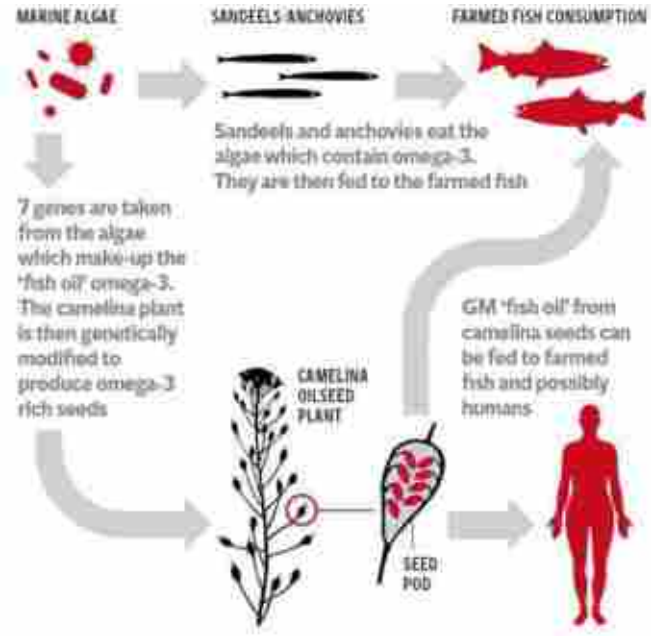


Fig. 2.1

Source: http://www.independent.co.uk/news/science/new-gm-cereal-crop-produces-fish-oil-in-its-seeds-10372772.html

(a) A Ti plasmid containing the seven genes from marine algae is constructed and introduced into *A. tumefaciens* before infecting *C. sativa* plant cells. Describe the properties of Ti plasmids that make them suitable as vectors in this process. [2]

(b) Suggest why crop plants like *C. sativa* are better candidates for genetic modification than fishes. [2]

(c) **(i)** With reference to **Fig 2.1**, suggest two benefits of using genetically modified *C. sativa* as an omega-3 fatty acid source for farmed fishes. [2]

(ii) Describe an ethical and a social implication associated with genetically modified *C. sativa* 'fish oil'. [2]

The effectiveness of genetically modified *C. sativa* seed pods in preventing cholesterol deposition in arteries was investigated using rodents, to evaluate if they can be used to substitute fish oil from farmed fishes. Effectiveness is evaluated by analysing the levels of total omega-3 fatty acids available in blood and the diameter of rodents' arteries.

Rodents were divided into three groups of 10 and were subjected to respective treatment for a period of six months as shown below.

Group A: High fat diet enriched with 'fish oil' from genetically modified *C. sativa* seed pods

Group B: High fat diet enriched with fish oil from farmed fishes fed with small fishes

Control: High fat diet without fish oil

The results are summarised in the **Table 2.1**.

Table 2.1

	Group A	**Group B**	**Control**
Total omega-3 fatty acids level/ mmolL^{-1}	33.7 ± 0.3	27.1 ± 0.1	20.0 ± 0.3
Cross section of artery after 6 months			

(d) With reference to **Table 2.1**, comment on whether genetically modified *C. sativa* is a more effective substitute. [3]

(e) Describe how genetic engineering is used to increase quality of another named crop plant. [2]

[Total: 13]

3 Severe combined immunodeficiency disease (SCID) is caused by a severe genetic defect often found in newborns. The condition must be diagnosed and treated quickly to prevent serious complications. However, doctors continue to struggle with often ineffective treatment options.

In recent studies, researchers found that blood stem cells may effectively treat SCID caused by a deficiency in the adenosine deaminase (ADA) gene. The ADA gene is critical for the proper functioning of the immune system.

(a) Explain how an individual with SCID caused by ADA deficiency inherited this condition. [2]

(b) **(i)** Describe the normal functions of adult stem cells obtained from the bone marrow and stem cells obtained from the zygote. [2]

(ii) Explain how the properties of blood stem cells allow for them to effectively treat SCID. [3]

A trial was carried out on an ADA-SCID patient of age 7 months. Blood stem cells were collected from the patient's bone marrow, transduced with a retroviral vector containing the therapeutic ADA allele, and injected back to the patient. The patient received 8.8 x 10^6 blood stem cells per kg body weight, containing 25% successfully transduced cells in culture.

Fig. 3.1 shows the total T cell count in the blood sample of this patient.

These cells were then isolated and analysed for presence of ADA mRNA in the cytoplasm. **Fig. 3.2** shows the percentage of cells carrying ADA mRNA.

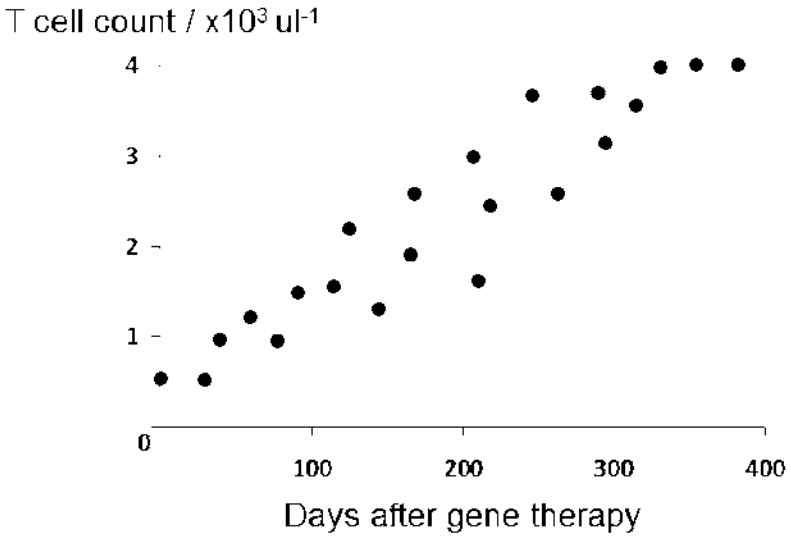


Fig. 3.1

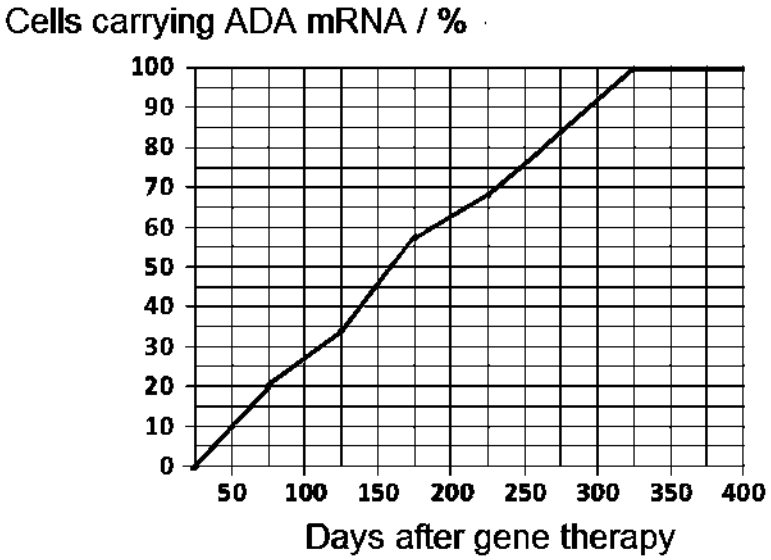


Fig. 3.2

(c) **(i)** Suggest a medical advantage of using patient's own blood stem cells rather than stem cells from a healthy donor. [1]

(ii) Explain why a retroviral vector was chosen for this trial. [2]

(d) With reference to **Fig. 3.1** and **3.2**, account for the success of this gene therapy in treatment of SCID, 350 days after the therapy. [4]

[Total: 14]

4 Planning question

The use of β-galactosidase for the hydrolysis of lactose in milk is a promising enzyme application in the food processing industry. A large fraction of the human population is lactose intolerant, due to the low levels of β-galactosidase present in the intestine. This causes difficulty in digesting milk products. Therefore lactose hydrolysis, which lowers lactose concentration in milk, allows the lactose intolerant population to consume milk.

Milk products containing lactose may have different pH. In order for β-galactosidase to work, its optimal pH for catalytic activity must coincide with the pH of the milk product. Hence, β-galactosidase is extracted from different sources due to their difference in optimal pH. Sources of β-galactosidase include mould species such as *Aspergillus niger*, and yeast species such as *Saccharomyces cerevisiae*.

ONPG, can be used to study the catalytic function of β-galactosidase as shown in the following reaction:

$$\text{ONPG} \xrightarrow{\beta\text{-galactosidase}} \text{ONP} + \text{Galactose}$$

ONPG is a colourless solution while ONP produced from the reaction is a yellow solution. The reaction can be stopped by adding sodium carbonate solution in 1:1 ratio. By comparing the colour intensity of the resulting product to a colour standard, the concentration of ONP at the end of the reaction can be determined.

Using this information and your own knowledge, design an experiment to determine the respective optimal pH at which β-galactosidase of *Aspergillus niger* and *Saccharomyces cerevisiae* work.

You must use:

- 10% ONPG solution
- *A. niger* β-galactosidase
- *S. cerevisiae* β-galactosidase
- pH buffers for different pH
- 10% ONP solution
- 10% sodium carbonate solution
- Distilled water
- Stopwatch

You may select from the following apparatus:

- Normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipette, glass rods, etc.
- Droppers
- Eye protection
- Gloves

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variables,
- describe the method with scientific reasoning used to decide the method so that the results are as accurate and reliable as possible
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimize any risks associated with the proposed experiment.

[Total: 12]

Section B (20 marks)

Answer **all** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

A **NIL** return is necessary if you have not attempted this section.

5. **(a)** Explain how restriction fragment length polymorphism (RFLP) analysis facilitates the construction of a genomic linkage map. [6]

(b) Plant tissue culture techniques allows for aseptic growth of excised plant parts *in-vitro*. Describe how this is carried out. [9]

(c) *"The Human Genome Project was one of the great feats of exploration in history… (giving) us the ability, for the first time, to read nature's genomic blueprint for building a human being." – National Human Genome Research Institute.* [5]

Discuss the main objectives of this project.

[Total: 20]

RIVER VALLEY HIGH SCHOOL
YEAR 6
PRELIMINARY EXAMINATION II

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER				

H2 BIOLOGY **9648/03**

Paper 3 Application Paper **20 Sep 2016**

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section A
Answer **all** questions in the spaces provided on the question paper.

Section B
Answer **all** question on the answer paper provided.

The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/ 13**
2	**/ 13**
3	**/ 14**
4	**/ 12**
Section B	
5	**/ 20**
Total	**/ 72**

This Question Paper consists of **16** printed pages.

Section A (80 marks)

Answer **all** the questions in this section.

1 The coat colour of Norwegian cattle is mainly determined by the distribution of two pigments: red and black. Both pigments are produced by the action of the enzyme tyrosinase, in cells called melanocytes. A low level of activity of the enzyme leads to the production of red pigment, while a high activity of the enzyme produces black pigment.

The activity of the enzyme is increased by the melanocyte stimulating hormone (MSH), which binds to the MSH receptor. The receptor is encoded by the gene at **E** locus, which has three alleles, $\mathbf{E^D}$, $\mathbf{E^A}$ and **e**. $\mathbf{E^D}$ and $\mathbf{E^A}$ each encodes a receptor with different activity. No receptor is produced by the recessive allele, **e**.

Alleles $\mathbf{E^D}$ and $\mathbf{E^A}$ differs by a single base substitution; while alleles **e** and $\mathbf{E^A}$ differs by a single base deletion.

(a) Explain how a mutation at $\mathbf{E^A}$ allele may result in **e** allele. [3]

1. **This results in a nonsense mutation;**
2. **by changing reading frame of codons on mRNA;**

Accept: frameshift mutation

3. **This give rise to a stop codon;**
4. **thus premature termination of translation;**
5. **Resulting in a truncated polypeptide;**
6. **thus no protein produced;**

DNA was extracted from the frozen semen of six bulls with different genotypes at the E locus. The DNA from each animal was separately digested with two different restriction enzymes, **P** and **Q**.

The products of each digestion were separated on a gel and the banding pattern shown in **Fig. 1.1**.

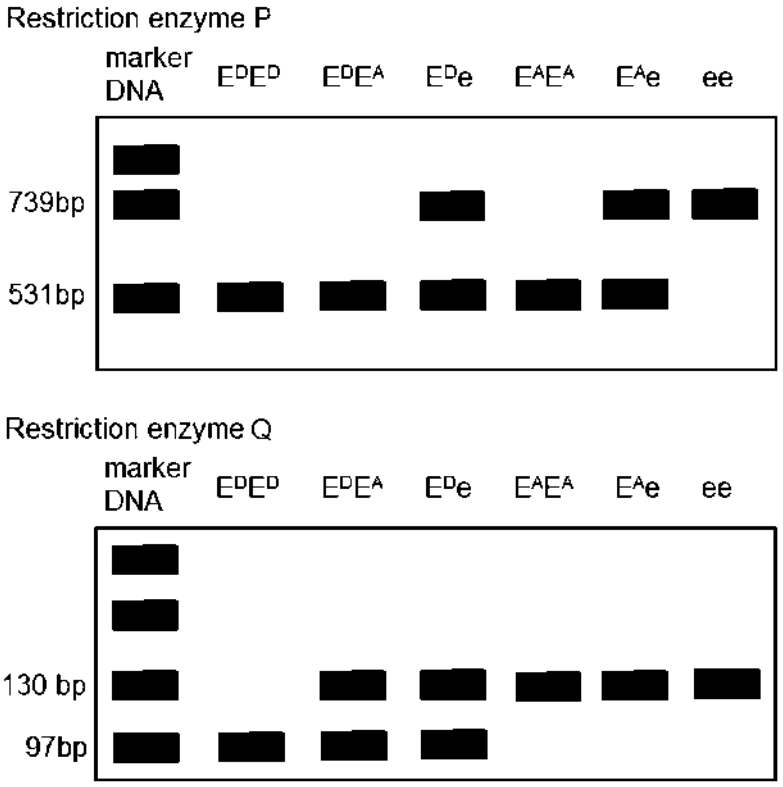


Fig. 1.1

(b) **(i)** Explain why the banding pattern from the same genotype are different when a different restriction enzyme is used. [2]

1. **Different restriction enzymes recognizes different <u>restriction sites</u>;**
2. **thus cuts the DNA at different positions;**
3. **resulting in different number;**
4. **and length of restriction fragments;**

(ii) Explain the role of marker DNA. [2]

1. **Comprises a collection of DNA fragments;**
2. **<u>Compare</u> marker DNA with DNA fragements;;**
3. **to measure length / size / base pair of DNA fragment;**

(iii) State which genotype(s) can be identified by using each of the two restriction enzymes. [2]

P: **ee**;;

Reject: multiple listing

Q: **E^DE^D**;;

Reject: multiple listing

Bovine somatotropin (BST) is an animal hormone used to increase milk production in dairy cows. BST is naturally produced in the cow pituitary gland in small quantity and is used to regulate metabolic processes. With the advent of biotechnology, *BST* gene can be cloned in *Escherichia coli*. The bacteria are grown in bioreactors to produce BST, which is purified to produce hormone for injection.

Fig. 1.2 shows the plasmid map of the plasmid BGH1, used for transformation of *BST* gene into *E.coli*. Sal 1 restriction enzyme was used to cut the pBGH1 plasmid for insertion of *BST* gene.

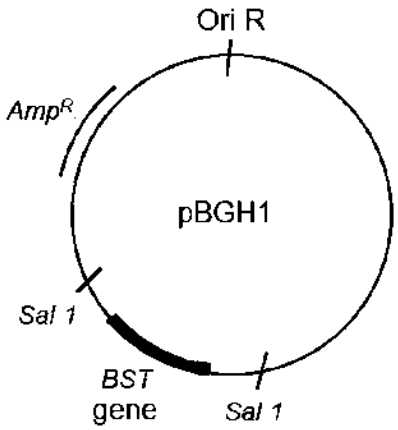


Fig. 1.2

(c) **(i)** Describe the natural role of Sal 1 restriction enzyme. [2]

1. **To protect <u>bacteria</u>;**
2. **by cutting <u>foreign</u> <u>DNA</u>;;**
3. **Such as that of invading viruses;**

(ii) Explain how *Amp^R* gene facilitates *BST* gene cloning. [2]

1. **Functions as a selectable marker;**
2. **to identify <u>transformed</u> bacteria / bacteria that took up <u>pBGH1 plasmid</u>;**
3. **Amp^R gene codes for (β-lactamase) <u>enzyme</u>;**
4. **that inactivate / breakdown ampicillin / allow bacteria to survive (in ampicillin);**

[Total: 13]

2 Omega-3 fatty acids are polyunsaturated fats that are often marketed as health supplements to prevent cholesterol deposits in arterial walls.

In the wild, omega-3 fatty acids are produced by marine algae and accumulate in small fishes that feed on them. These small fishes are then fed to farmed fishes to increase their omega-3 fatty acid content. Farmed fishes high in omega-3 fatty acids serve as a good source for omega-3 fatty acid extraction for the health supplement industry.

A new method to produce omega-3 fatty acids involves insertion of seven genes of the marine algae into oilseed plant, *Camelina sativa.* The resulting seeds contain as much as 200 milligrams of omega-3 fatty acids in a single tablespoon of 'fish oil' extracted. Currently, this 'fish oil' is fed to farmed fishes, in replacement of small fishes.

The effect of human consumption of 'fish oil' from genetically modified *C. sativa* seed pods is still under investigation.

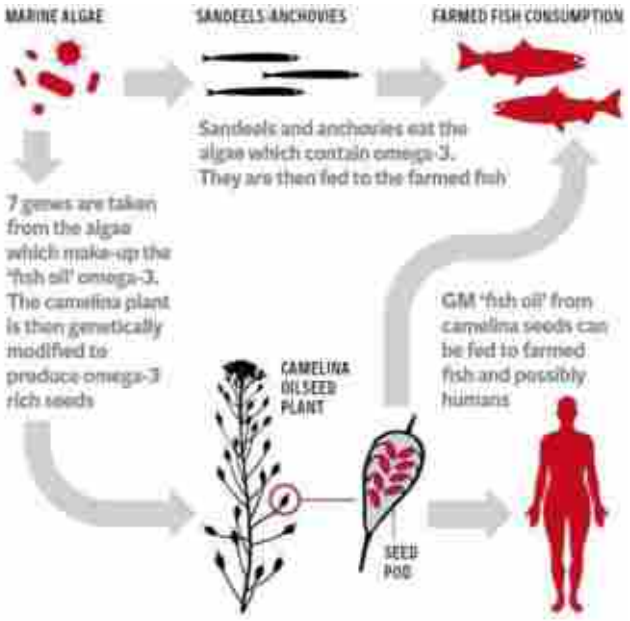


Fig. 2.1

Source: http://www.independent.co.uk/news/science/new-gm-cereal-crop-produces-fish-oil-in-its-seeds-10372772.html

(a) A Ti plasmid containing the seven genes from marine algae is constructed and reintroduced into *A. tumefaciens* before infecting *C. sativa* plant cells. Describe the properties of Ti plasmids that make them suitable as vectors in this process. [2]

1. **Ti plasmids contain T-DNA region which can be integrated into plant chromosome;;**
2. **Ti plasmids are small allowing it to be taken up by *C. sativa* cell;;**
3. **Ti plasmids contain origin of replication, allows independent replication of plasmid and the inserted genes;;**
4. **Ti plasmids contain selectable marker allows for identification of transformed *C. sativa* cells;;**
5. **Ti plasmids have multiple restriction sites, to allow introduction of genes;;**

Any 2

(b) Suggest why crop plants like *C. sativa* are better candidates for genetic modification than fishes. [2]

1. ***C. sativa* cells are totipotent / can give rise to a whole plant;;**
2. **Genetic manipulation can be performed on any somatic/plant cell (to generate crop plants with new traits);;**
3. **To create GM fishes, genes need to be injected into nucleus of fertilised egg;;**

(c) **(i)** With reference to **Fig 2.1**, suggest two benefits of using genetically modified *C. sativa* as an omega-3 fatty acid source for farmed fishes. [2]

1. **Increase the <u>quality</u> of farmed fishes as fishes will be rich in omega-3 oil;;**
2. **Possibility of mass production of genetically modified *C. sativa*, reduces need for fishing, less disturbance to marine food chain;;**
3. **More sustainable source of omega-3 fatty acids, seeds produced can be used to plant new genetically modified *C. sativa*;;**
4. **Easy storage of seed pods as compared to live feed;;**
5. **Reduces possibility of farmed fish contracting disease from the wild fishes;;**

(c) **(ii)** Describe an ethical and a social implication associated with genetically modified *C. sativa* 'fish oil'. [2]

Social:

1. **Healthcare threat due to possible transfer of antibiotic resistance gene to *E. coli* found in the gut;;**
2. **Possible transfer of allergens to human when consuming genetically modified *C. sativa* fish oil;;**

[Max 1 mark]

Ethical:

3. **Violation of organisms intrinsic values through mixing of genes from different species;;**
4. **Lack of consumer awareness due to lack of labelling laws;;**

[Max 1 mark]

The effectiveness of genetically modified *C. sativa* seed pods in preventing cholesterol deposition in arteries was investigated using rodents, to evaluate if they can be used to substitute fish oil from farmed fishes. Effectiveness is evaluated by analysing the levels of total omega-3 fatty acids available in blood and analysis of diameter of rodents' arteries.

Rodents were divided into three groups of 10 and were subjected to treatment for a period of six months as shown below.

Group A: High fat diet enriched with 'fish oil' from genetically modified *C. sativa* seed pods

Group B: High fat diet enriched with fish oil from farmed fishes fed with small fishes

Control: High fat diet without fish oil

The results are summarised in the **Table 2.1**.

Table 2.1

	Group A	Group B	Control
Total omega-3 fatty acids level/ $mmolL^{-1}$	33.7 ± 0.3	27.1 ± 0.1	20.0 ± 0.3
Cross section of artery after 6 months			

(d) **(i)** With reference to **Table 2.1**, comment on whether genetically modified *C. sativa* is a more effective substitute. [3]

1. **Genetically modified *C. sativa* is a more effective substitute;;**
2. **Total omega-3 fatty acid levels in group A is 33.7 $mmolL^{-1}$ while in group B is 27.1 ± 0.1 $mmolL^{-1}$;**
3. **indicating that higher availability/absorption of omega 3- fatty acid from *C. sativa* fish oil compared to natural fish oil;**

4. **Genetically modified *C. sativa* is not a more effective substitute;;**
5. **There is no obstruction/buildup of cholesterol in both group A and B as compared to control group where cholesterol is deposited on arterial walls/ similar diameter of arterial lumen in group A and control group;**

(e) Describe how genetic engineering is used to increase quality of another named crop plant. [2]

1. **Golden rice;**
2. **Introduced genes encoding <u>enzymes</u>;**
3. **which convert a natural compound in rice to beta-carotene;**
4. **a precursor of vitamin A;**

[Total: 13]

3 Severe combined immunodeficiency disease (SCID) is caused by a severe genetic defect often found in newborns. The condition must be diagnosed and treated quickly to prevent serious complications. However, doctors continue to struggle with often ineffective treatment options.

In recent studies, researchers found that blood stem cells may effectively treat SCID caused by a deficiency in the adenosine deaminase (ADA) gene. The ADA gene is critical for the proper functioning of the immune system.

(a) Explain how an individual with SCID caused by ADA deficiency inherited this condition. [2]

1. Inherited a recessive (ADA) allele from father;

2. and a recessive (ADA) allele from mother;

3. Thus has a homozygous recessive genotype for ADA gene;;

Accept: 2 copies of recessive alleles for ADA gene

(b) **(i)** Describe the normal functions of adult stem cells obtained from the bone marrow and stem cells obtained from the zygote. [2]

Adult stem cells from bone marrow serves to

1. Maintain / replenish population;

2. of blood cells in the organism;

Stem cells from zygote responsible for

3. growth / development;

4. of embryo;

(ii) Explain how the properties of blood stem cells allow for them to effectively fight SCID. [3]

1. Blood stem cells are relatively unspecialised cells;

2. thus can differentiate into T cells;

3. under appropriate conditions;

4. through selective changes in genetic activity;

Accept: some genes turned on and some genes turned off

5. Blood stem cells can grow and divide indefinitely;

6. thus replenish (T) cells population indefinitely (via mitosis);

Accept: grow more (T) cells

A trial was carried out on an ADA-SCID patient of age 7 months. Blood stem cells were collected from the patient's bone marrow, transduced with a retroviral vector containing the therapeutic ADA allele, and injected back to the patient. The patient received 8.8 x 10^6 blood stem cells per kg body weight, containing 25% successfully transduced cells in culture.

Fig. 3.1 shows the total T cell count in the blood sample of this patient.

These cells were then isolated and analysed for presence of ADA mRNA in the cytoplasm. **Fig. 3.2** shows the percentage of cells carrying ADA mRNA.

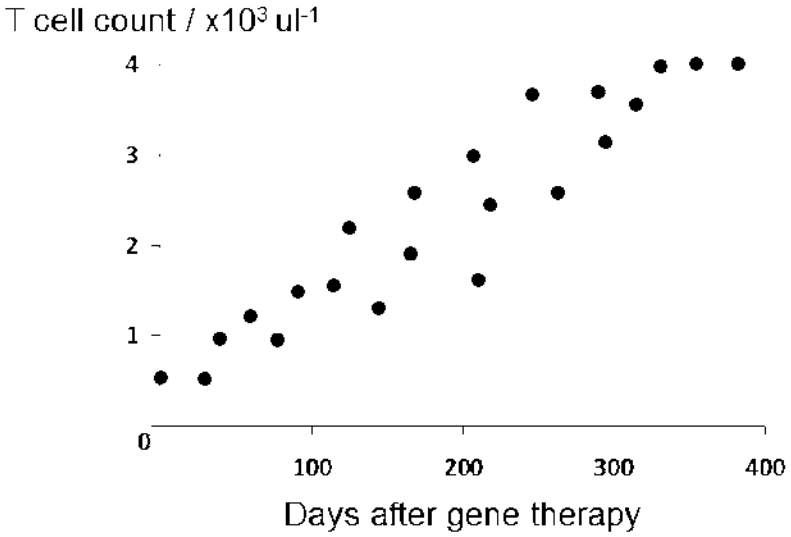


Fig. 3.1

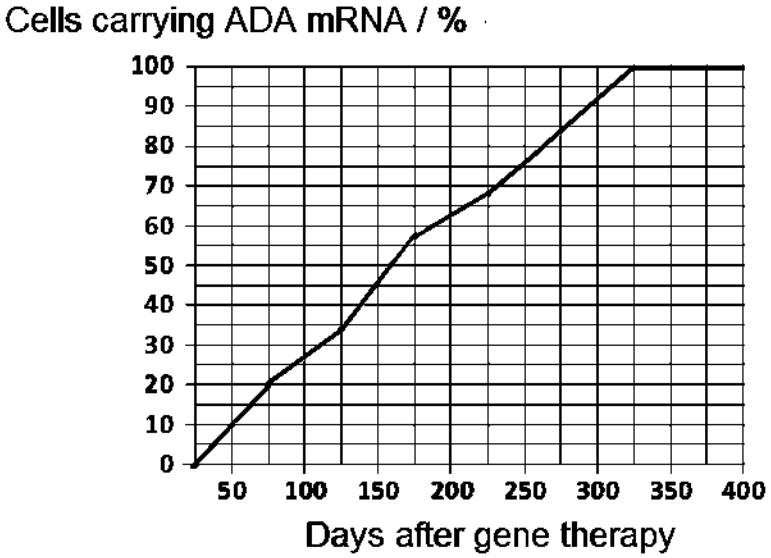


Fig. 3.2

(c) **(i)** Suggest a medical advantage of using patient's own blood stem cells rather than stem cells from a healthy donor. [1]

No cell rejection;

Reject: tissue rejection as blood cells do not form tissues

(ii) Explain why a retroviral vector was chosen for this trial. [2]

1. **Able to insert the therapeutic allele into the host <u>chromosome</u>;**
2. **offering opportunity for long-term stability;**
3. **Able to introduce therapeutic allele into the nucleus;**
4. **protecting it from degradation by (cytoplasmic) enzymes;**

Reject: targeted gene delivery as this is ex-vivo gene therapy / large capacity to carry foreign genes as this is not unique to retroviral vector

(d) With reference to **Fig. 3.1** and **3.2**, account for the success of this gene therapy in treatment of SCID, 350 days after the therapy. [4]

1. **T cell count increases from 500μl^{-1} on day of treatment to 4000μl^{-1} at 350 days after treatment;;**
2. **for immune response;**
3. **Percentage of cells carrying ADA mRNA increases from 0% on day of treatment to 100% at 350 days after treatment;;**
4. **All cells are actively <u>transcribing</u> the ADA gene;**
5. **to produce ADA enzyme;**
6. **thus reduces dATP buildup;**

[Total: 14]

4 Planning question

The use of β-galactosidase for the hydrolysis of lactose in milk is a promising enzyme application in the food processing industry. A large fraction of the human population is lactose intolerant, due to the low levels of β-galactosidase present in the intestine. This causes difficulty in digesting milk products. Therefore lactose hydrolysis, which lowers lactose concentration in milk, allows the lactose intolerant population to consume milk.

Milk products containing lactose may have different pH. In order for β-galactosidase to work, its optimal pH for catalytic activity must coincide with the pH of the milk product. Hence, β-galactosidase is extracted from different sources due to their difference in optimal pH. Sources of β-galactosidase include mould species such as *Aspergillus niger*, and yeast species such as *Saccharomyces cerevisiae*.

ONPG, can be used to study the catalytic function of β-galactosidase as shown in the following reaction:

$$\text{ONPG} \xrightarrow{\beta\text{-galactosidase}} \text{ONP} + \text{Galactose}$$

ONPG is a colourless solution while ONP produced from the reaction is a yellow solution. The reaction can be stopped by adding sodium carbonate solution in 1:1 ratio. By comparing the colour intensity of the resulting product to a colour standard, the concentration of ONP at the end of the reaction can be determined.

Using this information and your own knowledge, design an experiment to determine the respective optimal pH at which β-galactosidase of *Aspergillus niger* and *Saccharomyces cerevisiae* work.

You must use:

- 10% ONPG solution
- *A. niger* β-galactosidase
- *S. cerevisiae* β-galactosidase
- pH buffers for different pH
- 10% ONP solution
- 10% sodium carbonate solution
- Distilled water
- Stopwatch

You may select from the following apparatus:

- Normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, graduated pipette, glass rods, etc.
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repeated by anyone reading it,

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- Show how you will record your results and the proposed layout of results tables and graphs,
- Use the correct technical and scientific terms,
- Include reference to safety measures to minimize any risks associated with the proposed experiment.

Mark scheme

Theoretical consideration or rationale of the plan to justify the practical procedure, including the effect of pH on rate of enzyme-catalysed reaction. [1]

1. **β-galactosidase speeds up rate of reaction/lower activation energy;**
2. **β-galactosidase has specific active site;**
3. **ONPG fits into active site to form an E-S complex;**

Describe expected results [1]

4. **At optimum pH, rate of reaction/concentration of ONP produced in a fixed time is the highest;**
5. **Beyond optimal pH/ above or below optimum pH, rate of reaction decreases/concentration of ONP produced in a fixed time decreases.;**

Explanation of results [2]

6. **At optimum pH, shape of β-galactosidase active site intact;**
7. **Highest number of enzyme-substrate complex form per unit time;**
8. **Above and below optimal pH, ionic and hydrogen bonds between R group of amino acid residues at active site disrupted;**
9. **Number of enzyme-substrate complex formed per unit time decreases;**

Variables [2]

10. **IV – 5 pH of equal intervals e.g. pH4, pH6, pH8, pH10, pH12);**
11. **DV – concentration of ONP produced;**
12. **Controlled variable – CV w quantity; CV w quantity;**

Procedure [4.5]

13. **Correct dilution of ONP;**
14. **Use diluted ONP to construct colour standards;**
15. **Investigation carried out using 5 different pH buffers;**
16. **Description of correct sequence of adding reagents to test tube (i.e. enzyme/substrate added just before start time;**
17. **Description of quenching reaction using equivolume of sodium carbonate;**
18. **Description of concentration determination using colour standard;;**

19. **Reaction using *A. niger* β-galactosidase;**
20. **Reaction using *S. cerevisiae* β-galactosidase;**

Reliability of results [0.5]

21. **Three replicates/repeat experiment two more times/statistical test;**

Data recording and manipulation [2]

22. **Data recording for *A. niger* β-galactosidase and *S. cerevisiae* β-galactosidase;**
23. **Correct headings and units for Table showing effect of pH on concentration of ONP produced/rate of reaction;**
24. **Replicates and average;**
25. **Correct labelling of axis (x-axis - pH, y-axis - concentration of ONP/rate of reaction);**
26. **Correct shape of graph;**

Risk assessment [1]

27. **Description of 2 risk and precaution;;**

[Total: 12]

Section B (20 marks)

Answer **all** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

A **NIL** return is necessary if you have not attempted this section.

5. (a) Explain how restriction fragment length polymorphism (RFLP) analysis facilitates the construction of a genomic linkage map. [6]

1. **A linkage map portrays the order of genes along a chromosomes;**
2. **and their relative distance;**
3. **RFLPs serves as a genetic marker for a locus in the genome;**
4. **Linkage map can be constructed based on recombination frequencies;**
5. **between two RFLPs;**
6. **and the map units calculated;**
7. **using the formula;**

$$\text{Recombinant frequency} = \frac{\text{number of recombinant offspring}}{\text{total number of offspring}} \times 100\%$$

8. **Two homozygous individuals with different RFLPs at both loci are crossed;**
9. **to produce a heterozygote;**
10. **The heterozygote is then crossed with a homozygous individual;**
11. **The resulting offspring will have more parental RFLP combinations than recombinant RFLP combinations;;**

Reject: offspring phenotypic ratio is not 1:1:1:1 ratio, without reference to expected phenotypic outcome

12. **The genotype is detected using two probes;**

Accept: nucleic acid hybridisation

13. **One for each RFLP;**
14. **and analysed using Southern Blot;**

Accept: gel electrophoresis followed by autoradiography

(b) Plant tissue culture techniques allows for aseptic growth of excised plant parts *in-vitro*. Describe how this is carried out. [9]

1. **Cells from meristematic regions of a plant are excised;;**
2. **and sterilized;;**
3. **before transferring to culture vessels containing essential minerals / vitamins / amino acids / fixed carbon (any 2);;**
4. **Cells grown in culture to form callus tissue;;**
5. **Number of calli is increased via subculturing;;**
6. **Callus can be induced to differentiate by varying the ratio of plant growth regulators;;**
7. **Low level of cytokinin and high level of auxin triggers root growth;;**
8. **High level of cytokinin and low level of auxin triggers shoot growth;;**
9. **Organised callus tissues form a plantlet;;**
10. **which is acclimatised in enriched soil;;**
11. **before transferring to a greenhouse to grow into a whole plant;;**

(b) *"The Human Genome Project was one of the great feats of exploration in history… (giving) us the ability, for the first time, to read nature's genomic blueprint for building a human being." – National Human Genome Research Institute.* [5]

Discuss the main objectives of this project.

1. **To map all human genetic markers by identification of their chromosomal location;;**
2. **To construct a detailed physical map of the entire human genome;;**
3. **To determine the base sequence of all 24 human chromosomes;;**
4. **To develop a technology for the management of human genomic information;;**
5. **To serve as an umbrella for similar mapping / sequencing of the genomes of other organisms;;**

[Total: 20]

Civics Group	Index Number	Name (use BLOCK LETTERS)	H2

ST. ANDREW'S JUNIOR COLLEGE
2016 JC2 Preliminary Examinations

H2 BIOLOGY **9648/1**

Paper 1: Multiple Choice

Tuesday 20th September 2016 1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet
Soft clean eraser (not supplied)
Soft pencil (type B or HB is recommended)

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your name, civics group and index number on the multiple choice answer sheet in the spaces provided.

There are **40** questions in this paper. Answer all questions. For each question, there are four possible answers, A, B, C and D.

Choose the one you consider correct and record your choice in soft pencil on the separate multiple choice answer sheet.

INFORMATION TO CANDIDATES

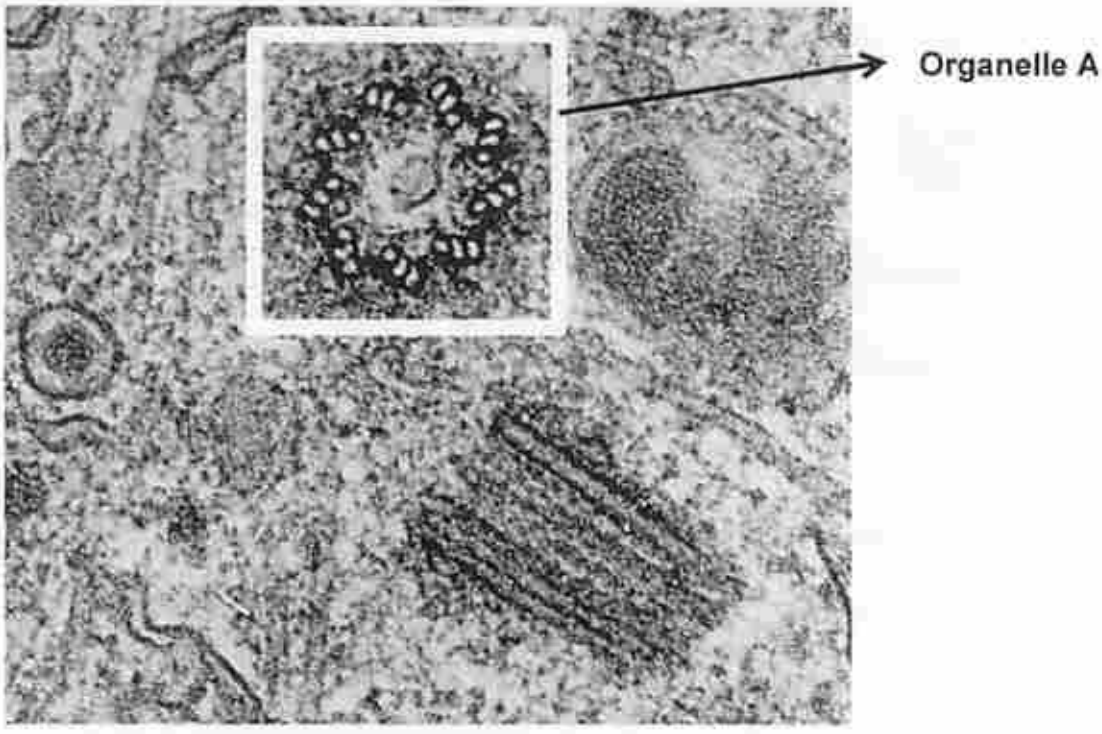
Each correct answer will score one mark. A mark will not be deducted for wrong answer. Any rough working should be done in this booklet.

At the end of the examination, submit the multiple choice answer sheet only.

This document consists of **27** printed pages.

[Turn over

1 The figure below shows an electron micrograph of a cross-section of an animal (rat) cell.

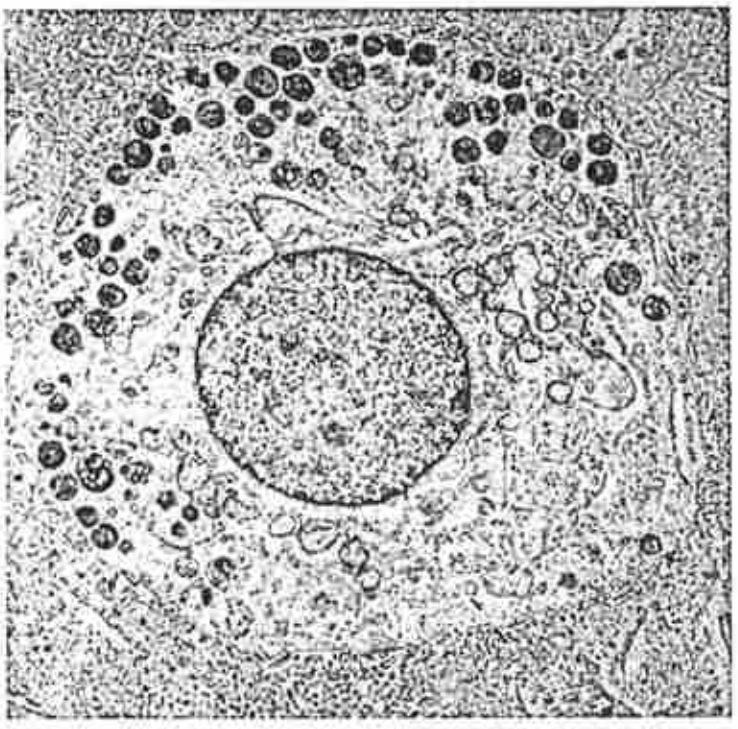


Which of the following describes organelle A?

1 9 triplets of microtubules arranged in a ring
2 Inner membrane folded into cristae
3 Synthesises spindle fibres during nuclear division
4 Involved in aerobic respiration

A 1 only
B 1 and 3 only
C 2 and 3 only
D 2 and 4 only

2 The electronmicrograph shows a cell magnified 5700 times.

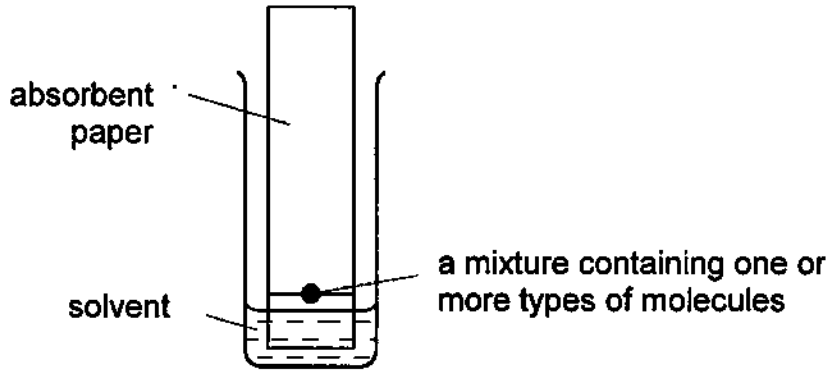


×5700

What is the actual diameter of the nucleus?

A 0.6 µm
B 6 µm
C 35 µm
D 350 µm

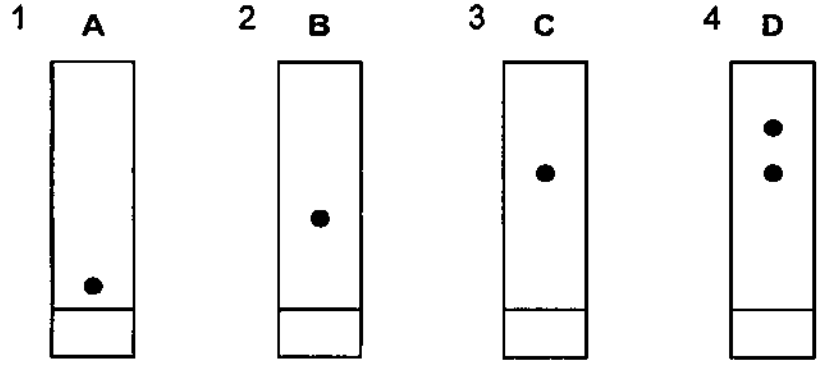
3 Chromatography is a technique used to separate molecules by their solubility. The diagram shows an apparatus used for this technique.



As the solvent rises up the paper, the molecules with the greatest solubility in the solvent travel the greatest distances up the paper. When the solvent reaches the top of the paper, the paper is removed, dried and sprayed with a dye. The different molecules appear as coloured spots.

Chromatography was carried out on four different samples – sucrose, cellulose as well as the products of complete hydrolysis of sucrose and cellulose.

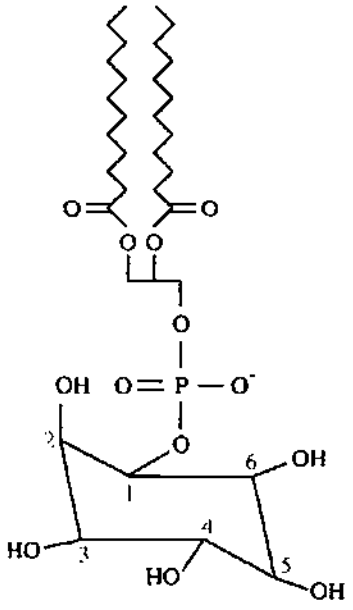
The diagram shows the chromatography results:



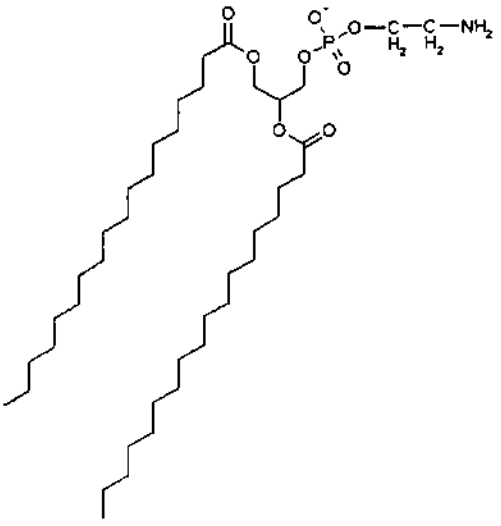
Which row shows the correct results?

	sucrose	cellulose	products of complete hydrolysis of sucrose	products of complete hydrolysis of cellulose
A	4	3	1	2
B	3	4	2	1
C	1	2	3	4
D	2	1	4	3

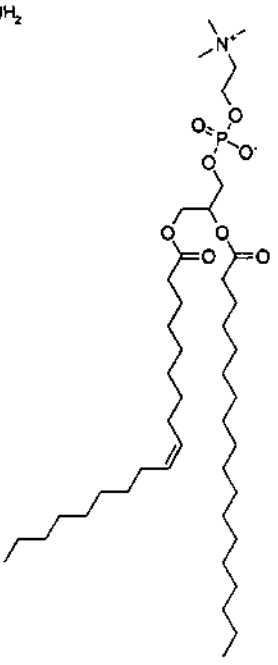
4 The diagram below shows three different phospholipids: phosphatidylcholine, phosphatidylethanolamine and phosphatidylinositol.



phosphatidylinositol



phosphatidylethanolamine



phosphatidylcholine

Which of the following statements is correct?

A Membranes with a higher phosphatidylcholine content are more fluid.
B Phosphatyidylinositol is unable to form a bilayer in an aqueous environment.
C Only phosphatyidylethanolamine is amphipathic.
D Only phosphatidylinositol has two fatty acid side chains.

5 How many different types of oligopeptides, each composed of 6 amino acids, may be synthesized using the 20 common amino acids?

A 6^4
B 20^6
C 6^{20}
D 20^4

6 During the oxidative phosphorylation process in respiration, energy released from the transport of electrons along the electron transport chain, is used to transport H^+ ions from the mitochondrial matrix to the intermembrane space through membrane proteins.

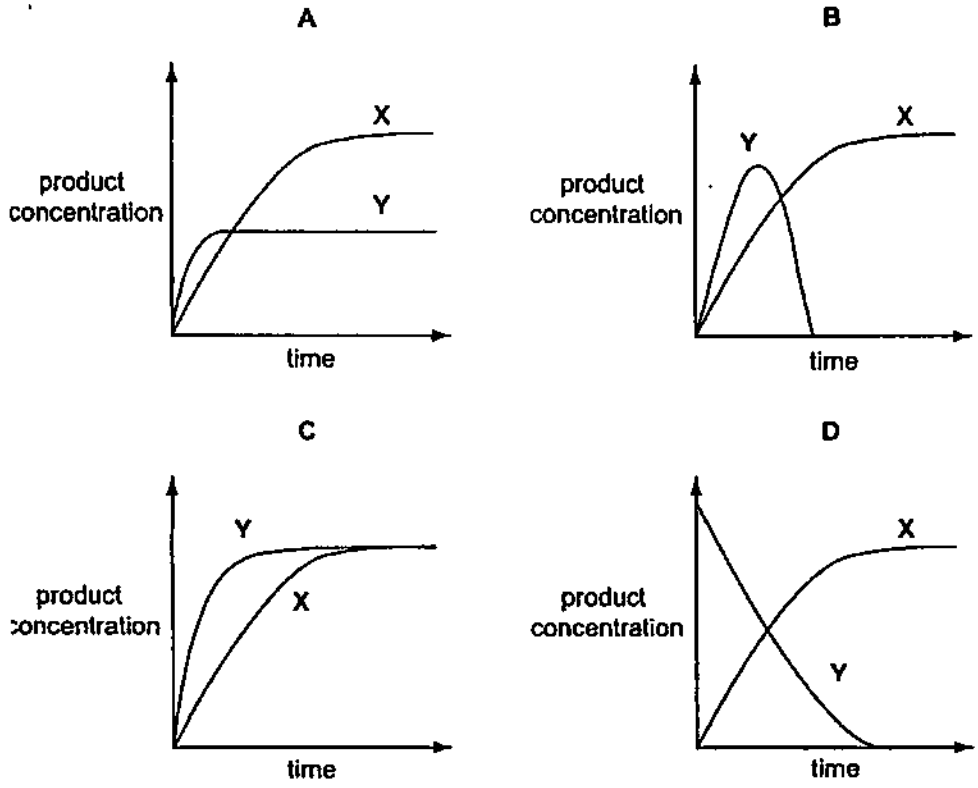
H^+ ions are also transported through ATP synthase from the intermembrane space back into the mitochondrial matrix.

Which of the following shows the correct membrane transport process involved?

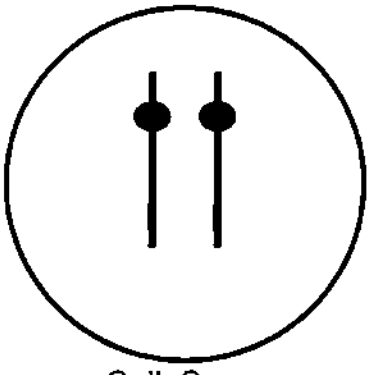
	Transport H^+ ions from the mitochondrial matrix to the intermembrane space.	Transport of H^+ ions from intermembrane space back into the mitochondrial matrix through the ATP synthase
A	Facilitated diffusion	Facilitated diffusion
B	Facilitated diffusion	Active transport
C	Active transport	Facilitated diffusion
D	Active transport	Active transport

7 Two enzyme experiments were carried out. The first, experiment **X**, was carried out at a constant temperature of 37°C. During the second experiment, **Y**, the temperature was increased from 37°C to 80°C.

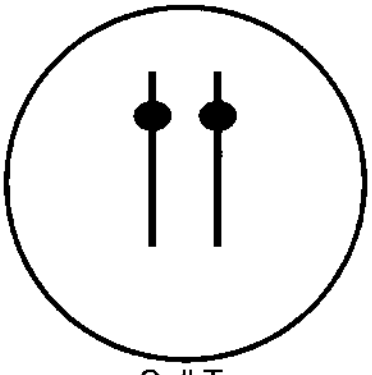
Which graph shows the results?



8 S and T are two identical cells. Only the X chromosomes are shown in these cells. When these cells undergo meiosis to form gametes, non-disjunction of the chromosomes occurred. In cell S, it occurred during meiosis I whereas in cell T, it occurred during meiosis II.



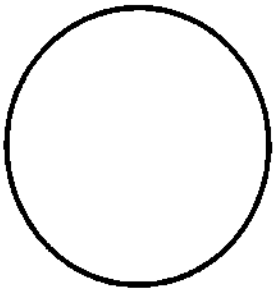
Cell S
(nondisjunction at meisois I)



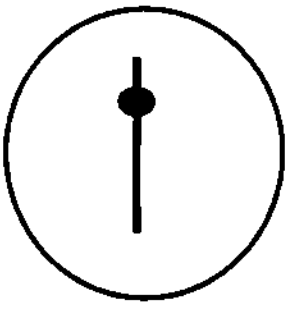
Cell T
(nondisjunction at meisois II)

The diagrams below show some combination of X chromosome(s) in gametes.

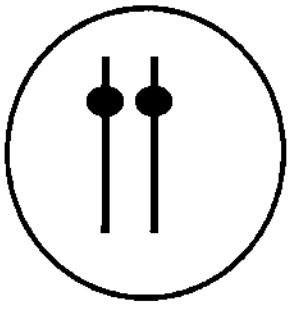
(1)



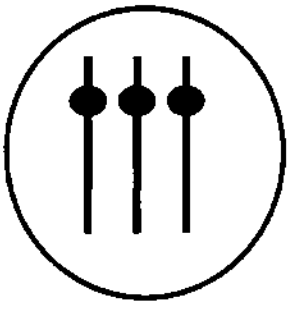
(2)



(3)



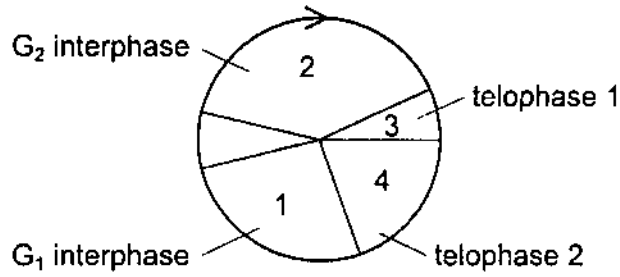
(4)



Which of the following options shows correctly the type of gametes that is/are **common** to **both** forms of non-disjunction?

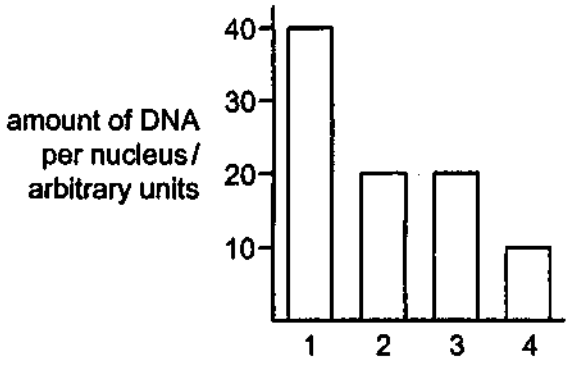
A 1 only
B 2 only
C 1 and 3 only
D 2 and 4 only

9 The figure below shows the different stages (1 to 4) of a meiotic cell cycle.

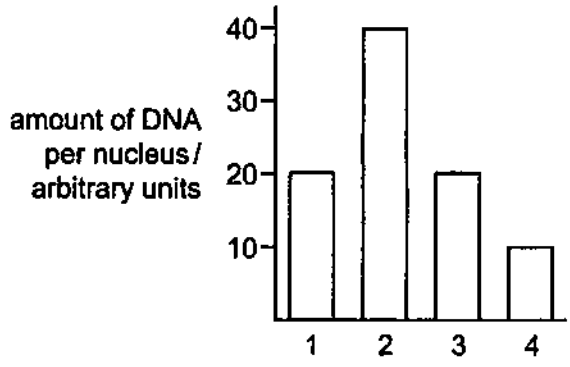


Which bar graph correctly represents the variation in the amount of DNA content per nucleus?

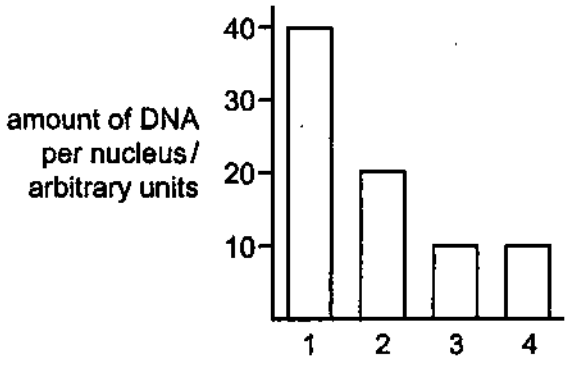
A



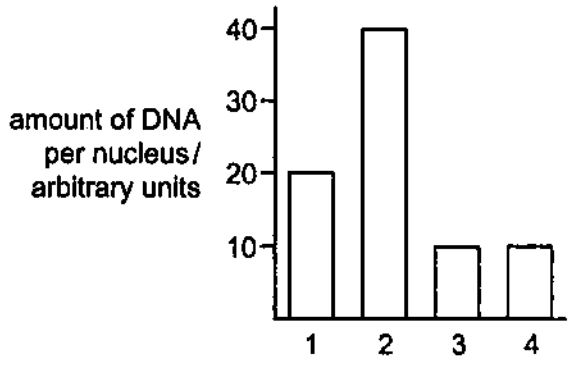
B



C

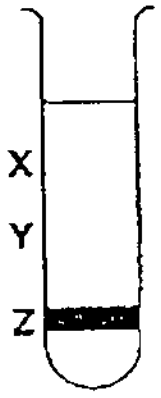


D



10 A culture of bacteria had all its DNA labelled with the heavy isotope of nitrogen, ^{15}N. The culture was then allowed to reproduce using nucleotides containing normal ^{14}N. The DNA was examined using a centrifuge after one generation and again after two generations.

The diagram shows the position of the DNA band at **Z** in the centrifuge tube when the DNA was first labelled.



In which pattern would the DNA be found after the first and after the second cell generations?

	After first generation	After second generation
A	Half at **X** and half at **Y**	Quarter at **X** and at **Z** and half at **Y**
B	Half at **X** and half at **Z**	Quarter at **X** and at **Z** and half at **Y**
C	All at **X**	Half at **X** and half at **Y**
D	All at **Y**	Half at **X** and half at **Y**

11 The sequence of DNA bases

GGCAATTGGAAACGAATACCCAGT

codes for the following sequence of amino acids.

glycine-asparagine-tryptophan-lysine-arginine-isoleucine-proline-serine

A mutant organism, in which one of the bases was deleted and then inserted at a different point in the DNA molecule, produced a peptide with the following sequence:

glycine-asparagine-tryptophan-asparagine-glutamine-isoleucine-proline-serine

Which base was removed by this mutation?

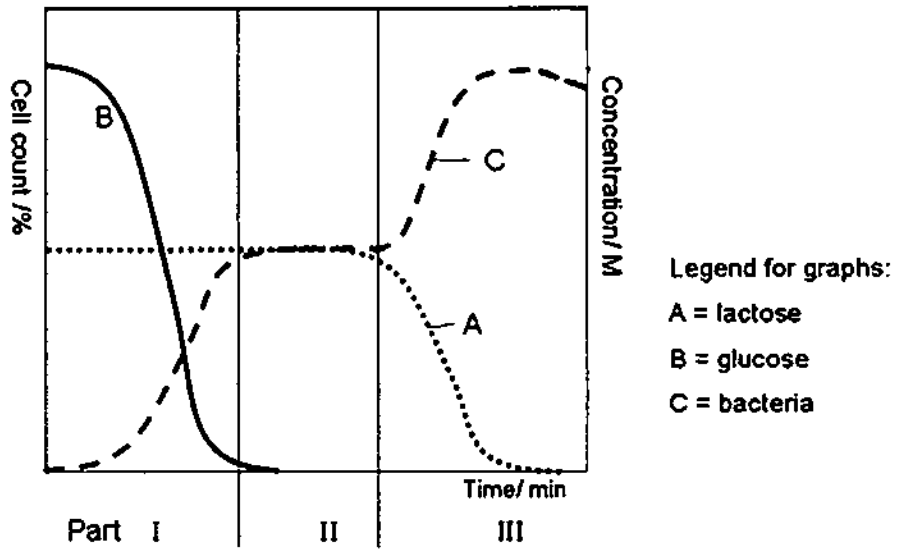
A adenine
B guanine
C cytosine
D thymine

12 Which of the following statements about bacterial chromosome structure is/are true?

1 Not associated with histone proteins
2 Single-stranded chromosome
3 Located in the nucleoid region of a nucleus
4 Most genes are separated by intergenic DNA sequences

A 1 only
B 1 and 2 only
C 2 and 3 only
D 2 and 4 only

13 The graph below shows the number of bacteria growing in the presence of varying concentrations of glucose and lactose.



Which of the following statements correctly accounts for the bacteria growth at different parts of the graph?

1 In Part I, the *lac* repressor is not bound to the operator and the catabolite activator protein (CAP) is not bound to the CAP-binding site, hence expression of structural genes is low.

2 In Part II, cAMP levels are high and binding of cAMP to the CAP binding site, hence expression of structural genes is high.

3 In Part III, as allolactose levels are depleted, *lac* repressor is active, bacteria growth plateaus.

A 1 only
B 1 and 3 only
C 2 and 3 only
D 1, 2 and 3

14 There are three different types of influenza viruses, types A, B and C. A common vaccine for influenza targets all three of these viral strains, containing inactivated forms of all three viral strains.

However, the vaccine is usually effective only for one year, after which it loses its effectiveness and has to be reformulated. As a result, a new vaccine needs to be administered to an individual every year.

Why do influenza vaccines need to be reformulated every year?

A Neuraminidase on the viral envelope may undergo mutation due to lack of proofreading by DNA polymerase.
B Antigenic drift may occur where different influenza strains infect the same host cell and exchange genetic material.
C Antigenic shift may occur where random mutations result in change in structure of glycoproteins on the viral envelope.
D The influenza genome consists of separate RNA segments which allow recombination between different haemagglutinin and neuraminidase genes.

15 Influenza virus and Human Immunodeficiency Virus (HIV) differ in their reproductive life cycles.

Which of the following correctly describes the differences in their life cycles?

1 Influenza virus enters the host cell via receptor-mediated endocytosis while HIV enters via fusion of HIV envelope with host cell membrane.
2 The RNA-dependent RNA polymerase of the influenza virus uses a positive sense RNA strand as the template while the reverse transcriptase of the HIV uses negative sense RNA strand as the template.
3 The influenza virus uses the host cell's ribosomes for synthesis of viral proteins while HIV does not.

A 1 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

16 The table shows the differences in the average length in kilobases (kb) of a gene and of messenger RNA (mRNA) in a bacterium and a mammal.

organism	average length of gene/kb	average length of mRNA / kb
bacterium	2.0	2.0
mammal	16.6	2.2

Which feature of the mammalian genome does **not** account for these differences?

A 94% of mammalian genes are interrupted by introns.
B Mammalian genes have an average of seven introns.
C Initial transcripts of pre-mRNA are shortened by splicing in a mammal.
D The mammalian genome is 1000 times longer than the bacterial genome.

17 About 12,000 genes are expressed in both chick liver and oviduct. However an estimated additional 5,000 genes are expressed only in liver, while an additional 3,000 genes are expressed only in oviduct.

Which of the following could explain these observations?

1	The additional genes may have different methylation patterns in different tissues.
2	The concentrations of transcriptional enhancer elements for the additional genes vary in different tissues.
3	The number of genome copies is different in different somatic cells.
4	A common set of genes are expressed for normal functions in liver and oviduct.

A 1 only
B 2 and 3 only
C 1 and 4 only
D 2 and 4 only

18 A eukaryotic gene of 255 base-pairs codes for 3 different polypeptides of 84 amino acids, 49 amino acids and 35 amino acids.

Which of the following would be possible explanation(s) for the above?

1	Proteolytic cleavage has occurred.
2	Exon skipping has occurred.
3	Polycistronic mRNA contains multiple start and stop codons.
4	Use of alternative polyadenylation signals.

A 1 and 2
B 1, 2 and 4
C 1, 3 and 4
D 2, 3 and 4

19 Within a cell, the amount of polypeptide made using a given mRNA molecule depends partly on:

A the degree of DNA methylation
B the rate at which the mRNA is degraded
C the presence of transcription factors
D the types of ribosomes present in the cytoplasm

20 Ras protein is a G-protein involved in a cell-signalling pathway. This protein is coded for by a proto-oncogene. Which of the following would lead to the cell undergoing uncontrolled cell division?

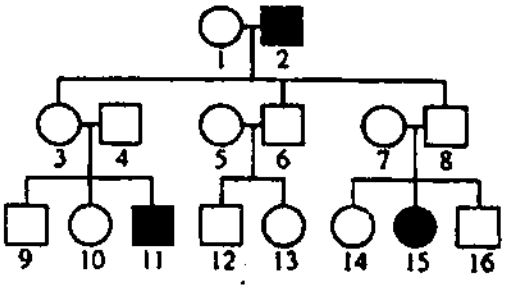
A Deletion of the Ras proto-oncogene.
B Duplication of the Ras promoter that controls the proto-oncogene.
C Translocation of the proto-oncogene upstream of a hyperactive promoter.
D Point mutation within the proto-oncogene, forming mutant Ras which is constitutively active.

21 The pedigrees show the inheritance of two genetically transmitted diseases.

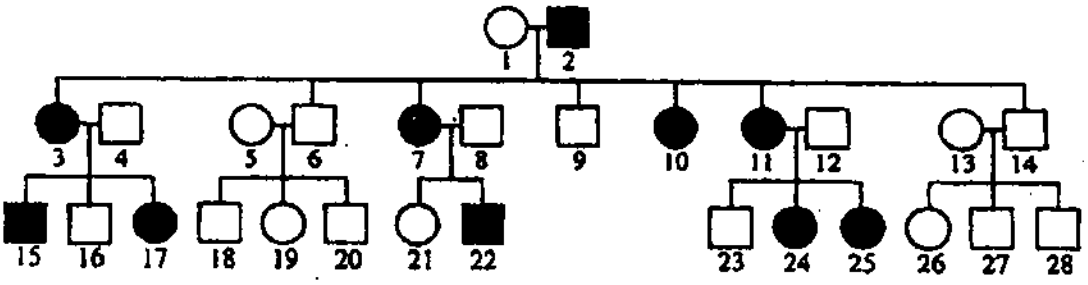
Key:

female male affected individuals

Galactosaemia



Hypophosphataemic rickets



Which row correctly describes the mode of inheritance of galactosaemia and hypophosphataemic rickets?

	Galactosaemia	Hypophosphataemic rickets
A	Autosomal dominant	Sex-linked recessive
B	Autosomal recessive	Sex-linked dominant
C	Sex-linked recessive	Autosomal recessive
D	Sex-linked dominant	Autosomal dominant

22 Some beetles have spines on their legs to help them capture prey. Three alleles determine the presence and type of spines a beetle will produce. The inheritance of a single L^C allele produces curved spines on the legs. The L^s allele is recessive to L^C allele, and produces straight spines. Beetles that are homozygous recessive for the L^n allele produces no spines on its legs.

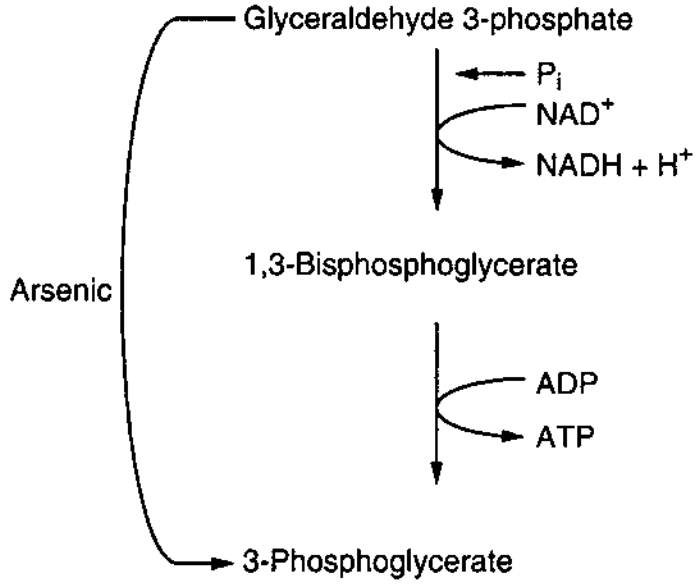
When a beetle with curved spines was crossed with a beetle with straight spines, they produced the following F_1 generation:

62 curved spines
28 straight spines
30 no spines

If an F_1 offspring with curved spines was picked at random and test crossed with a beetle with no spines, what is the probability of producing beetles with no spines?

A ¼
B ½
C ¾
D 1

23 The diagram shows the effect of arsenic on the metabolism of glyceraldehyde-3-phosphate. What is the net yield of ATP molecules from the conversion of one glucose molecule to two pyruvate molecules in the presence of arsenic?



A 0
B 1
C 2
D 3

24 Which of the following is true about both cyclic and non-cyclic photophosphorylation?

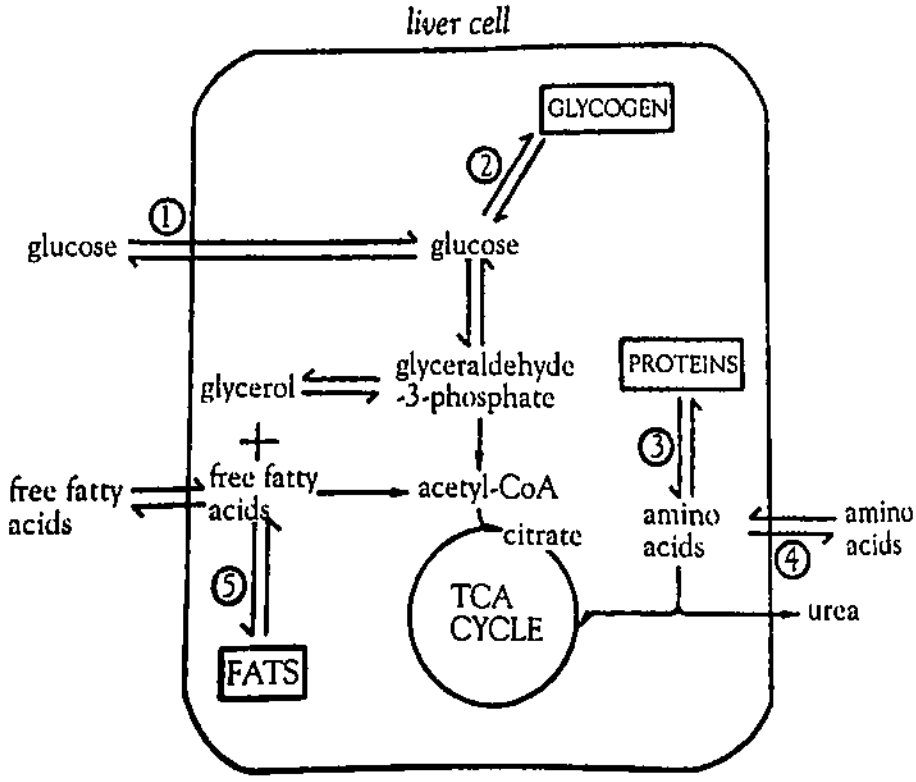
1 Establishes an electrochemical gradient across the thylakoid membrane
2 Involve photosystem II
3 Require oxygen as the final electron acceptor
4 Photolysis of water occurs

A 1 only
B 1 and 2 only
C 2 and 4 only
D 1, 3 and 4 only

25 Which of the following describes the state of a non-propagating (resting) mammalian axon?

	Concentration in axoplasm		Condition of Na^+/K^+ pumps in axon membrane
	Na+	K+	
A	High	Low	Active
B	High	Low	Inactive
C	Low	High	Inactive
D	Low	High	Active

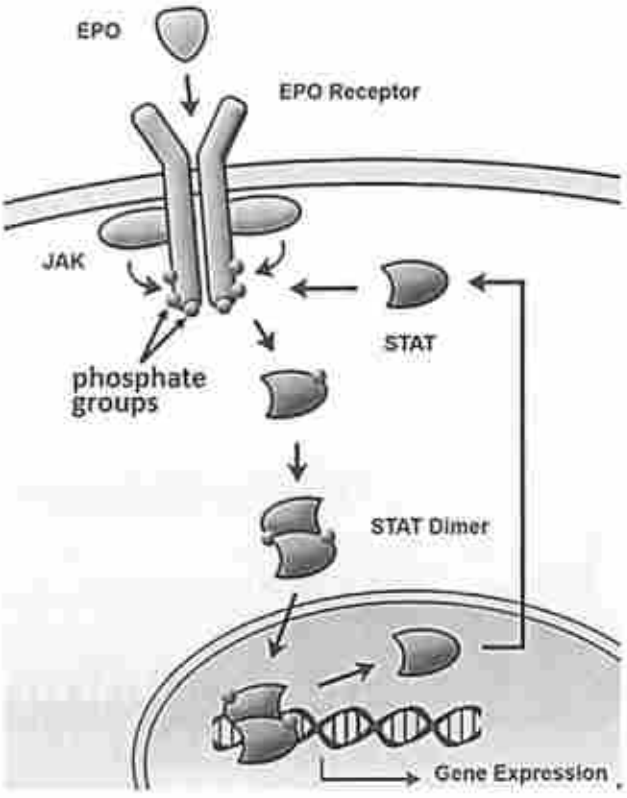
26 The diagram shows some biochemical pathways in a liver cell.



At which numbered points would the hormone insulin accelerate the pathway in the directions indicated?

A 1, 2 and 3
B 1, 2 and 5
C 1, 3 and 4
D 3, 4 and 5

27 The diagram shows the Jak-STAT cell signalling pathway.

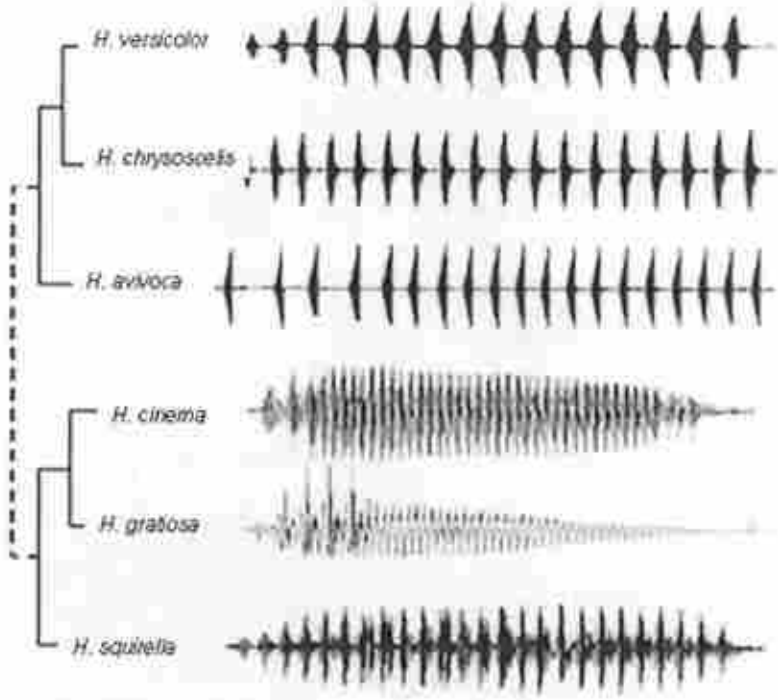


Which of the following statements is/are correct?

1 EPO can be a type of steroid hormone.
2 Phosphorylation of STAT changes its 3D conformation.
3 Gene expression is terminated when phosphatases remove phosphate groups from STAT dimers.
4 Signal amplification occurs as JAK phosphorylates multiple tyrosine residues on the EPO receptor.

A 1 and 3 only
B 2 and 3 only
C 2 and 4 only
D 2, 3 and 4 only

28 The figure below show the phylogenetic tree of six different species of frogs belonging to the Hyla genus and their mating calls.



Which of the following can be inferred from the chart?

1 Frogs with more similar call patterns are more closely related.
2 The frogs are classified based on the duration, intensity, and frequency of their calls.
3 The calls act as a form of isolation mechanism which disrupts gene flow between different species of frogs.
4 Genetic variations exist in the calls among frog populations of each species due to mutations.

A 1 and 3 only
B 2 and 3 only
C 1, 3 and 4 only
D All of the above

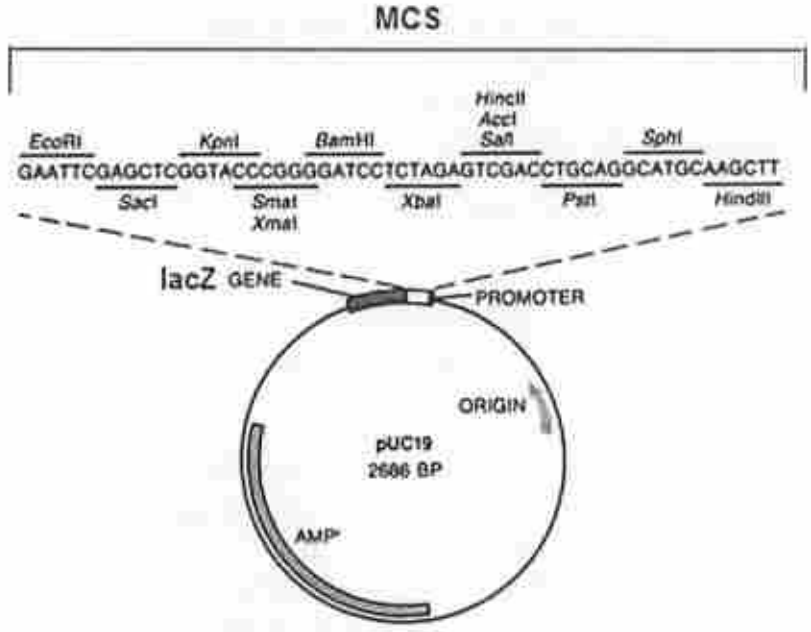
29 Which one of the following statements is related to the principle of adaptive radiation in evolution?

A Unrelated organisms living in similar environments may tend to resemble each other.
B Species evolve by natural selection, which alters the allele frequencies in interbreeding populations.
C Related organisms living in different environments show modifications of an underlying unity of pattern.
D Selection in a constant environment tends to maintain the most frequently occurring variety of a species.

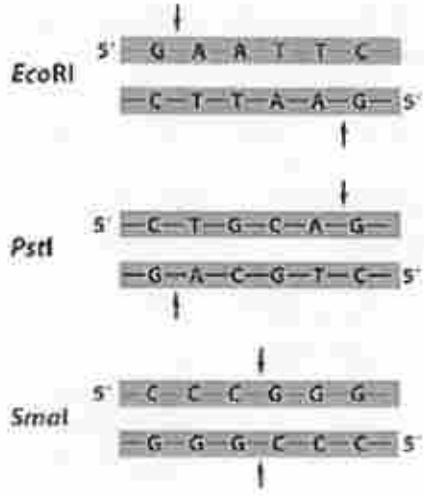
30 Which of the following correctly describes the type of sequences used when investigating closely related and distantly related species?

	Closely related species	Distantly related species
A	DNA sequences which more conserved, such as those found within non-coding sequences	DNA sequences which evolve more quickly, such as those found within coding sequences that codes for proteins that are biologically important for survival.
B	DNA sequences which more conserved, such as those found within coding sequences that codes for proteins that are biologically important for survival	DNA sequences which evolve more quickly, such as those found within non-coding sequences
C	DNA sequences which evolve more quickly, such as those found within coding sequences that codes for proteins that are biologically important for survival.	DNA sequences which are more conserved, such as those found within non-coding sequences
D	DNA sequences which evolve more quickly, such as those found within non-coding sequences	DNA sequences which are more conserved, such as those found within coding sequences that codes for proteins that are biologically important for survival

31 The figure shows the plasmid map of pUC19, which includes the positions of the origin of replication (ORI), multiple cloning site (MCS) and two genes – AMP^r and lacZ. pUC19 is used for the production of human anti-thrombin III (hATIII) in the bacterium *E. coli*.



The restriction sites of three particular restriction enzymes, *Eco*RI, *Pst*I and *Sma*I are shown below.



Which of the following can be concluded from the figures?

1	It is possible to ensure that the gene is inserted into pUC19 in the correct orientation by using both EcoRI and PstI to cleave pUC19 and the hATIII cDNA.
2	pUC19 cleaved with *Eco*RI can anneal to hATIII cDNA cleaved with *Pst*I as both restriction enzymes generate single-stranded overhangs of the same length.
3	The use of *Sma*I will require an additional step of ligating linkers to the ends of pUC19 and hATIII cDNA.
4	Colonies of *E. coli* transformed with recombinant pUC19 will survive on agar plates containing ampicillin and X-gal, giving a blue appearance.

A 1 and 3
B 1 and 4
C 2 and 3
D All of the above

32 Human insulin can now be obtained using genetic engineering.

Which of the following are possible explanations to why functional insulin cannot be produced simply by inserting a recombinant plasmid with an insulin cDNA into a bacteria host?

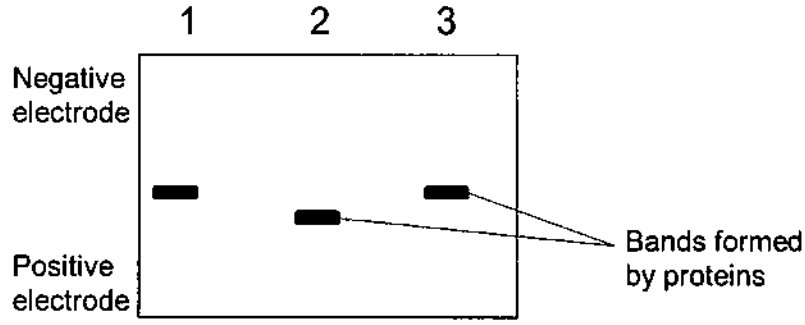
1	The bacteria have no spliceosome.
2	The bacteria will not be able to perform cleavage of polypeptide.
3	The bacteria will not be able to add disulfide bonds to the polypeptide chain.
4	The recombinant plasmid does not contain prokaryotic promoter.

A 4 only
B 1 and 2 only
C 2, 3 and 4 only
D All of the above

33 Which of the following primers would allow copying of the single stranded DNA sequence 5' ATGGTACCCTAAGTC 3'?

A 5' ATGGT 3'
B 5' TACCA 3'
C 5' CTGAA 3'
D 5' GACTT 3'

34 The diagram shows the results of electrophoresis of the human growth hormone protein extracted from three different individuals.



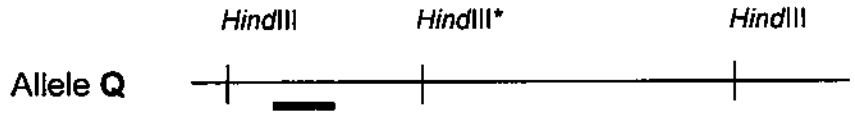
A mutation occurred in individual 2. Which one of the following can best account for the different banding pattern?

A A polar amino acid has been replaced by a non-polar amino acid.
B A polar amino acid has been replaced by a positively-charged amino acid.
C A negatively charged amino acid has been replaced by a non-polar amino acid.
D A non-polar amino acid has been replaced by a negatively-charged amino acid.

35 Which of the following poses the greatest limitation of the Human Genome Project in disease analysis?

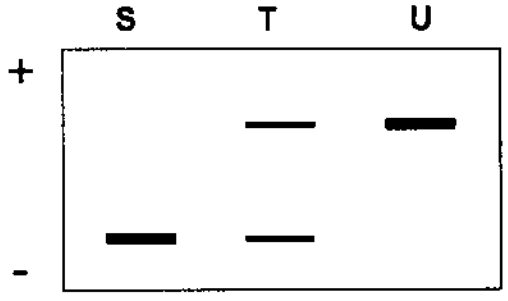
A It is not possible to store the genomic information of all individuals.
B There is too large a genetic difference between individuals to determine the loci of genes of interest.
C Too few model organisms exist for comparative genomic studies to take place.
D Environmental factors and gene interactions in disease are not taken into account.

36 The region of the genome containing the RFLP used in this analysis is shown below.



*Hind*III indicates the restriction sites for this enzyme and * indicates the polymorphic site which is missing in the recessive allele **q**. The black bar indicates the position of the probe used to detect the RFLP.

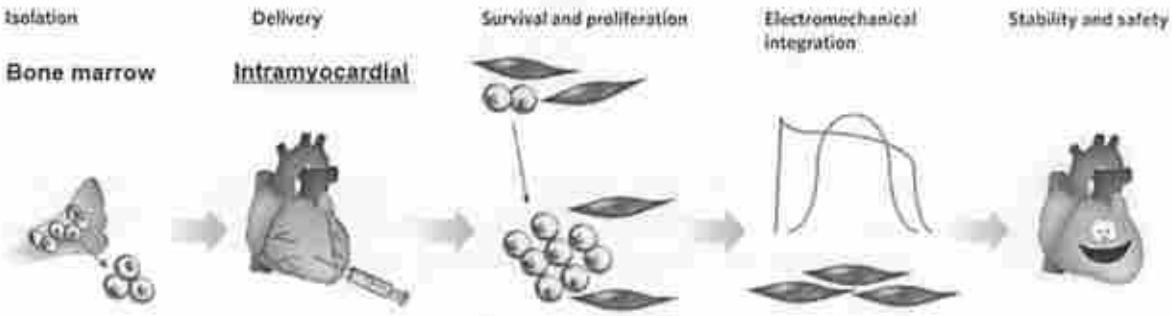
DNA fragments from three different individuals, **S**, **T** and **U**, were subjected to restriction digestion by *Hind*III and separated by gel electrophoresis. The following results were obtained.



Deduce the genotype of individual **S**.

A QQ
B X^qY
C qq
D X^QY

37 Stem cells hold promises for repairing damaged tissues. Recently the use of bone marrow blood stem cells has helped in cardiac repair as shown in the diagram below.



Which of the following conventional notion of stem cells is/are challenged as a result of this experiment?

1 The ability of stem cells to self-renew by mitosis.
2 The role of the local tissue environment in stem cell differentiation.
3 The adult stem cells are undifferentiated.
4 The multi-potency of bone marrow blood stem cells.

A 3 only.
B 4 only.
C 3 and 4
D All of the above

38 One therapy to treat β-thalassaemia is to transplant bone marrow cells from a genetically compatible donor into a patient. A potential gene therapy involves adding the normal, dominant allele for β-globin to the patient's cells.

Which of the following would ensure that the normal gene is passed on to the next generation?

A Using a retrovirus to introduce the mRNA of normal β-globin gene into bone marrow cells.
B Using a retrovirus to introduce the mRNA of normal β-globin gene into an egg cell.
C Using an adenoviral vector to introduce the normal β-globin gene into bone marrow cells.
D Using an adenoviral vector to introduce the normal β-globin gene into an egg cell.

39 Which parts of the plant can be used as a choice for an explant in micro-propagation?

1 Pollen
2 Root hair
3 Apical bud
4 Flower Petals

A 1 only
B 2 and 3 only
C 2, 3 and 4
D All of the above

40 In terms of containment (prevention of genetic pollution of wild plant or non-GM crop populations), which of the following is an advantage of chloroplast transformation (introducing foreign genes into chloroplasts of host plants) over nuclear transformation?

A Chloroplasts are surrounded by a double membrane.
B There are no chloroplasts in pollen of most plant species.
C Chloroplasts are smaller than the nucleus.
D There is no DNA in chloroplasts.

END OF PAPER

Civics Group	Index Number	Name (use BLOCK LETTERS)

H2

ST. ANDREW'S JUNIOR COLLEGE
2016 JC2 Preliminary Examinations

H2 BIOLOGY 9648/2

Paper 2: Core

Monday 29th August 2016 2 hours

Additional Materials: Answer Paper
Cover Sheet for Section B

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagram, graph or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A (Structured Questions)
Answer **all seven** questions.
Write your answers in the spaces provided on the question paper.

Section B (Essay Question)
Answer **one** essay question only.
Write your answers on the separate answer paper provided.
All working for numerical answers must be shown.

INFORMATION TO CANDIDATES

At the end of the examination,
1. Attach Section B answers to the **cover sheet** provided.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/12
2	/9
3	/13
4	/7
5	/11
6	/17
7	/11
Total	/80

This document consists of **19** printed pages.

[Turn over

Section A

Answer **all** *questions.*

1. Lysosomes play an important role in autophagy as they contain enzyme complexes that can break down worn out organelles. A section of the lysosomal membrane is magnified and shown in Fig. 1.1.

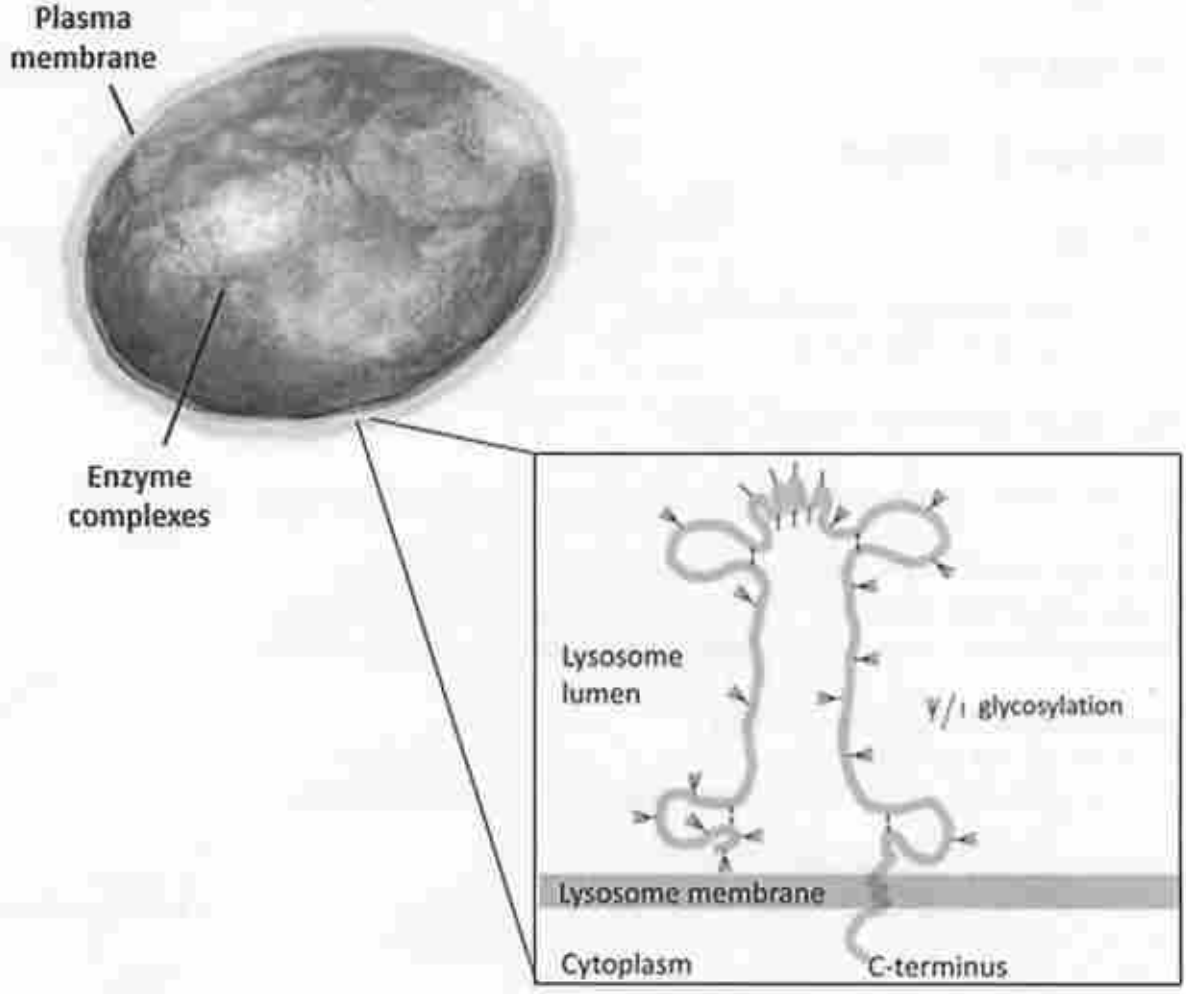


Fig. 1.1

(a) Describe and explain how the structure of the lysosomal membrane protects it from being degraded by the hydrolytic enzyme complexes it contains.

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.....[2]

(b) Collagen is an important structural component of skin, ligament and tendons. Describe the various levels of protein folding that gives it its fibrous structure.

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.....[4]

(c) Fig. 1.2 and 1.3 show the structures of lysine and glycine respectively. In the space provided, draw a lys-gly dipeptide and label the peptide bond.

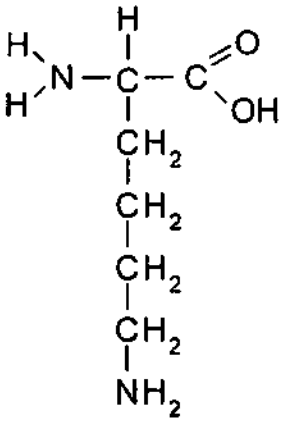

Fig. 1.2

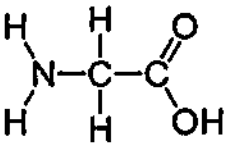

Fig. 1.3

.....[1]

(d) Fig. 1.4 shows some onion cells undergoing mitosis.

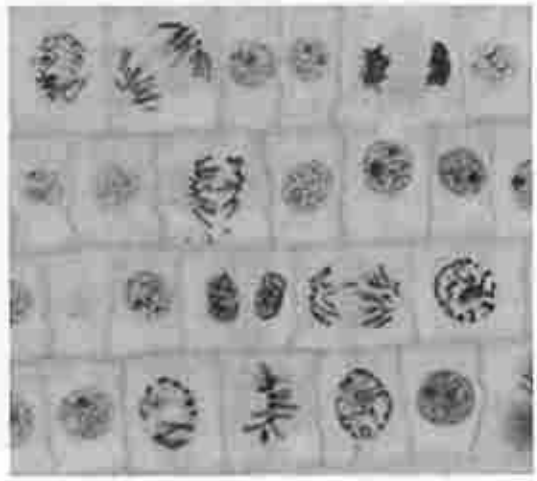

Fig. 1.4

(i) Identify (with arrows and labels) one cell each that is undergoing prophase, metaphase, anaphase and telophase.

.....[1]

(ii) Describe the events of anaphase.

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.....[2]

(iii) Describe the process of cytokinesis in the onion cells.

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.....[2]

[Q1 Total: 12]

2. Fig. 2.1 shows a process happening in a eukaryotic cell.

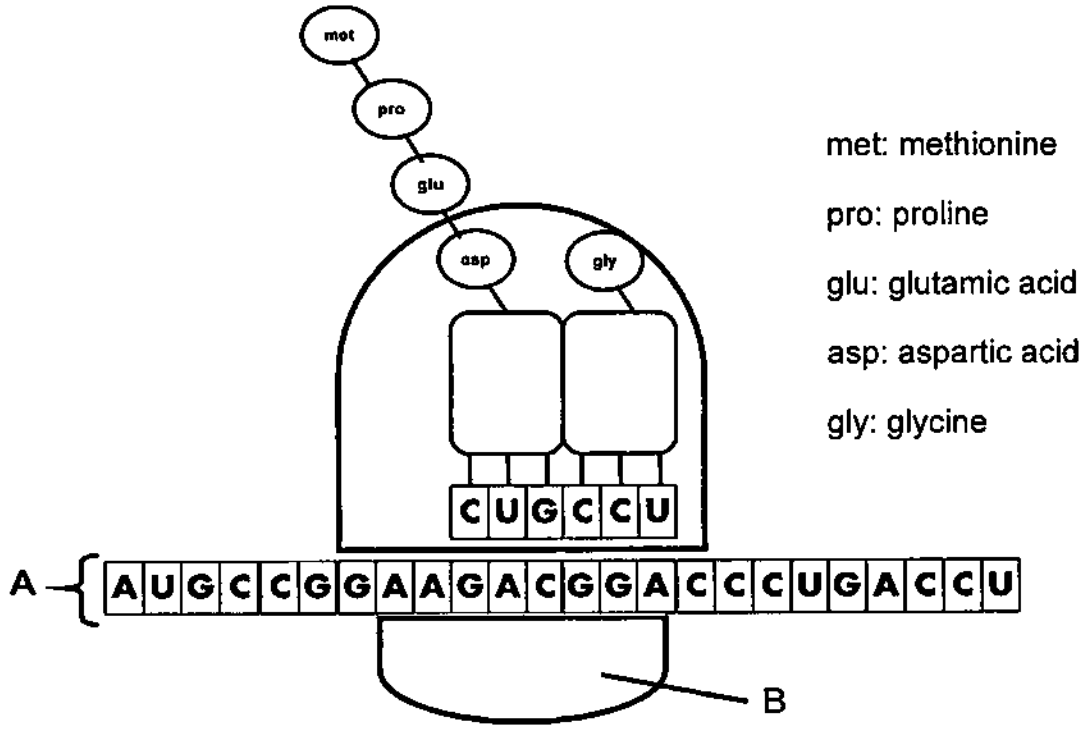

Fig. 2.1

(a) Name the structures labelled **A** and **B**. [1]

A: .....

B: .....

(b) Relate the structure of **A** to its role in protein synthesis.

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.....[1]

(c) Outline one change to **A**, following completion of transcription in the nucleus before it can used for the process in Fig. 2.1.

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.....[1]

(d) How many amino acids does the protein, encoded by the section of **A** shown in Fig. 2.1, have?

.....[1]

(e) An antibiotic which affects the elongation stage of the process in Fig. 2.1, is added shortly after initiation, such that truncated polypeptides are formed instead.

With reference to Fig. 2.1, suggest and explain how the antibiotic works to give rise to a tripeptide.

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.....[3]

(f) Tetracycline is an example of a ribosome-targeting antibiotic which is effective only towards bacterial cells.

Suggest why tetracycline has no effect on eukaryotes.

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.....[2]

[Q2 Total: 9]

3. A study published in the *Proceedings of the National Academy of Sciences* revealed a plausible strategy to facilitate the replacement of antibiotic resistant pathogens with sensitive ones in hospitals, which faced a higher rate of evolution of antibiotic resistance.

Researchers developed and administered two different phages that target the common gut microbe *E. coli*. The first was just a standard "lytic" phage that results in the death of the bacterial cell. The second phage, called a "temperate" phage, was a little more special. The researchers engineered it to possess a well-known gene-editing system that, when injected into the host cell, both removes their antibiotic resistance genes and renders them resistant to the lytic phage at the same time.

To select for bacteria that has been successfully edited by the temperate phage, the lytic phage is added. Lytic phages only target bacteria that has not undergone gene-editing, thus selecting for successfully edited bacteria that are now antibiotic-sensitive.

Both phages designed according to this strategy are used on hospital surfaces and hand sanitizers to restore a "healthy balance" in the population of antibiotic-sensitive bacteria and antibiotic-resistant bacteria.

(a)(i) Explain how the structure of a "lytic" phage facilitates the "death of the bacterial cell."

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.....[2]

(ii) Suggest why it is important to restore a "healthy balance" in the population of antibiotic-sensitive bacteria and antibiotic-resistant bacteria in hospitals.

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.....[1]

(iii) Contrast the life cycle of the "temperate" phage and life cycle of a HIV.

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.....[1]

(b)(i) In farms, poultry are often infected with *E. coli*, some of which are resistant to antibiotics. An alternative to treating these poultry with antibiotics is to inject them with "lytic" phages. Explain how this treatment may result in the spread of antibiotic resistance in the *E.coli* that infects the poultry.

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.....[4]

(ii) The normal life cycle of the "lytic" phage did not involve homologous recombination of viral DNA genome with the host cell genome.

Suggest why homologous recombination with the host cell genome is possible in generalised transduction.

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.....[1]

(c) In another study, a mutant *E. coli* strain is engineered to have the following genotype:

***trpR*$^+$_*trpP*$^+$_*trpO*$^-$_*trpE*$^+$_*trpD*$^+$_*trpC*$^+$_*trpB*$^+$_*trpA*$^+$**

Explain how this bacteria strain will respond in the presence of tryptophan (+: wild type allele; - : loss of function allele).

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[Q3 Total: 13]

4. Fig. 4.1 shows the relationship between telomere lengths and cell divisions in somatic cells and embryonic stem cells.

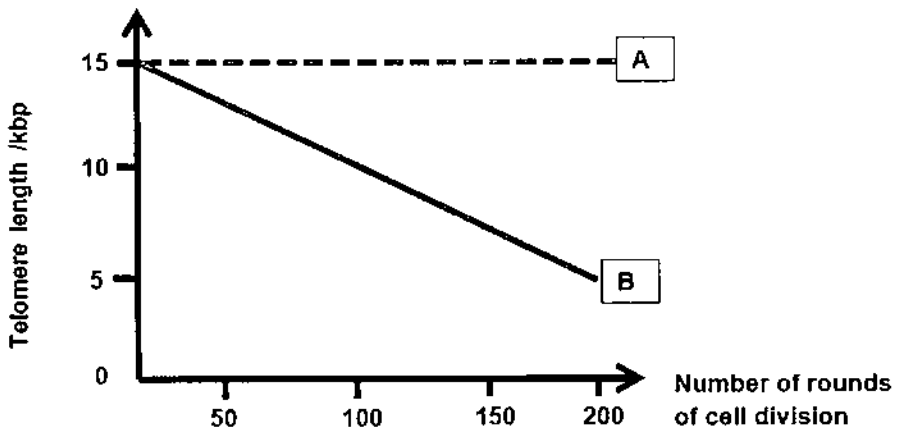

Fig. 4.1

(a) Identify the graph that represents the respective cell type. [1]

Somatic cells: Graph .....

Embryonic stem cells: Graph .....

(b) Explain your choice in **(a)**.

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.....[4]

(c) Describe a role of telomeres.

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.....[1]

The regulation of gene expression in somatic cells of eukaryotes differs from that in prokaryotic cells.

(d) Describe one difference in their gene expression at the transcriptional level.

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.....[1]

[Q4 Total: 7]

5. Coat colour in mice is determined by two gene loci, **B/b** and **D/d**.

The alleles give the following phenotypes:

B black **b** brown
D coloured **d** albino (white)

A cross between two black coat mice that are heterozygous at both gene loci produces F_1 offspring of the following phenotypes:

Black coat	675
Brown coat	225
Albino coat	300

(a) Define the term heterozygous.

.....

.....[1]

(b) Draw a genetic diagram to show the cross described. [4]

(c) Explain how the interaction between the two genes B and D gives rise to albino coat colour.

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.....[4]

A wheat breeder crossed two cultivars of wheat that varied in kernel colour – one with dark red kernel, another with white kernel (a kernel is the seed from which the wheat plant grows)

He noted that the F_1 generation was intermediate in colour (light red), but the F_2 generation ranges in colours from white to dark red.

Fig. 5.1 shows the range of kernel colour in the F_2 generation.

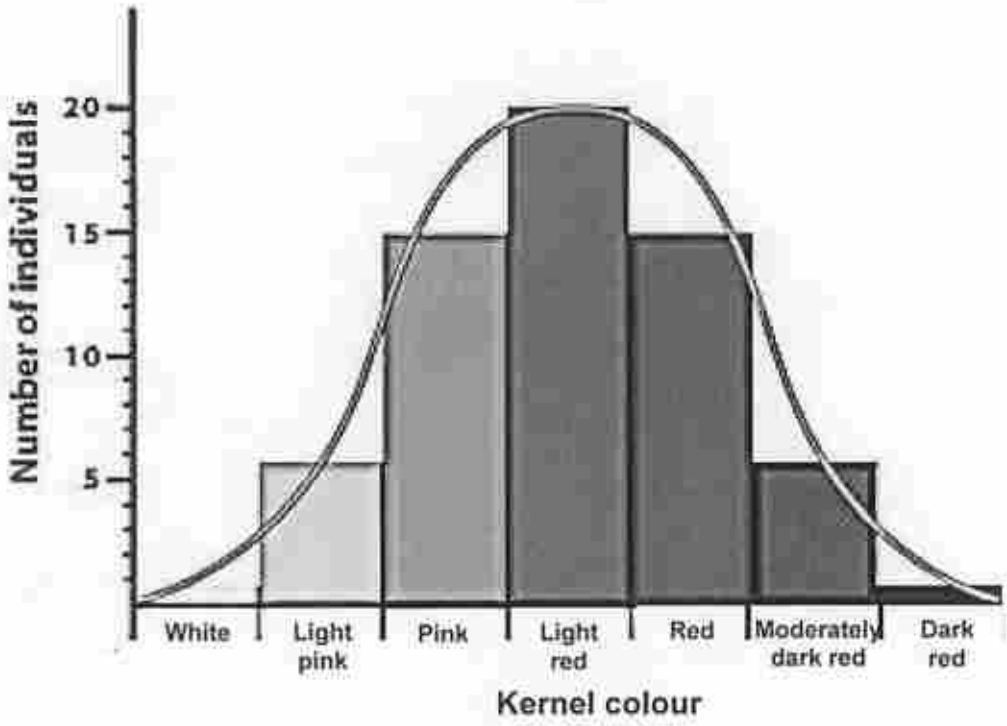

Fig. 5.1

(d) Explain the genetic basis behind the wide range of kernel colours.

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.....[2]

[Q5 Total: 11]

6. It has been hypothesized that the neurotransmitter, serotonin, plays a part in appetite control. A consistent pattern of reduction in hunger motivation is seen in human studies with a variety of drugs which induce the release of serotonin.

Patients receiving these drugs report both a lower frequency and a reduced strength of urges to eat, together with the feeling of being more in control of their eating. Such serotonergic drugs, such as Dexfenfluramine, can exert a continued suppression of appetite to bring about subsequent weight loss.

Fig 6.1 shows the diagram of a synapse at which serotonin is the neurotransmitter.

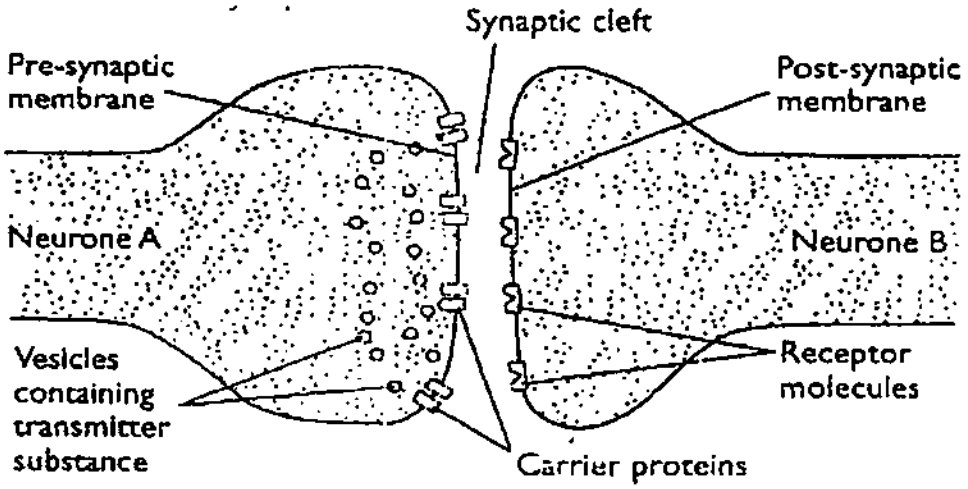

Fig 6.1

(a)(i) Describe how an impulse is initiated in Neurone B and transmitted to the brain, after the ingestion of Dexfenfluramine, to achieve the perception of fullness.

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.....[4]

Serotonin is normally rapidly reabsorbed from the synaptic cleft by carrier proteins in the pre-synaptic membrane.

(ii) Suggest one advantage of rapidly reabsorbing serotonin.

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.....[1]

(iii) Explain the effect of mitochondrial poisons, which inhibit cytochromes/electron carriers, on synaptic transmission.

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.....[2]

Serotonin receptors consist of several subtypes. In addition to ligand-gated ion channels, another subtype of serotonin receptors is shown in Fig 6.2, which participates in a transduction pathway that reduces the generation of beta amyloid, a compound involved in Alzheimer's disease. Raf, MEK and ERK are kinases.

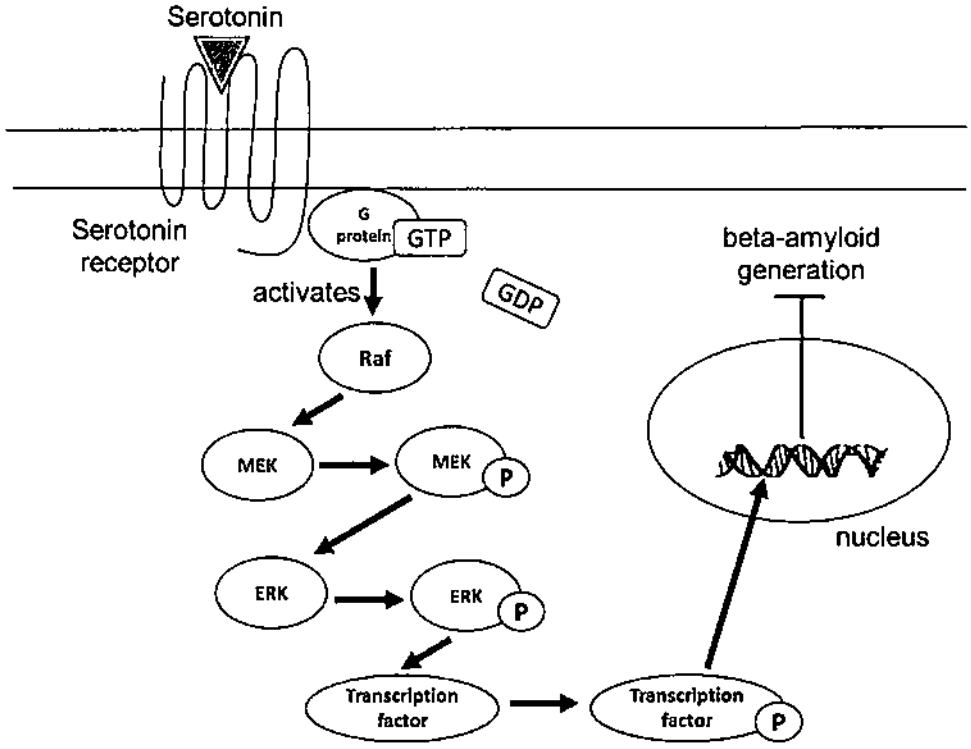

Fig. 6.2

(b)(i) Explain how the receptor in Fig.6.2 stays embedded in the plasma membrane and retains its mobility in the membrane.

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(ii) With reference to Fig. 6.2, explain how the binding of serotonin leads to a reduction in beta-amyloid generation.

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.....[4]

(c) There are reactions in plants which are crucial for its survival and growth. Explain the effect of a base addition to the gene coding for RuBisCO (Ribulose-1,5-bisphosphate carboxylase) enzyme.

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.....[3]

[Q6 Total: 17]

7. Bartesian mimicry is a type of mimicry in which a harmless organism is protected by its resemblance to another species which is avoided by predators. An example of this is the king snake, which is quite harmless. However, it has a similar colour pattern as the coral snake which is highly venomous. As a result, predators of snakes that avoid the coral snake also avoid the king snake as well.

(a)(i) Suggest an evolutionary advantage to the king snake for merely resembling a venomous coral snake instead of producing true venom.

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.....[1]

(ii) Discuss how natural selection could have led to the evolution of the colour pattern in the king snake.

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.....[4]

(b) DNA–DNA hybridisation is a technique used to determine the similarity of DNA from different species.

In this technique:

- DNA is extracted from four king snake species and cut into pieces using special enzymes;
- the DNA is heated to separate the double strands into single strands;
- single-stranded DNA from different pairs of king snake species are mixed together and cooled so that double strands of hybrid DNA form.

Fig. 7.1 shows the temperature (°C) needed to separate the hybrid DNA strands of the four king snake species, *L. getula, L. calligaster, L. triangulum and L. nigrita.*

Fig. 7.1

	L. getula	*L. calligaster*	*L. triangulum*	*L. nigrita*
L. getula	91	84	89	80
L. calligaster		90	86	87
L. triangulum			92	82
L. nigrita				90

(i) Describe and explain the difference in denaturation temperature for the *L. getula–L. triangulum* hybrid DNA and the *L. getula–L. nigrita* hybrid DNA.

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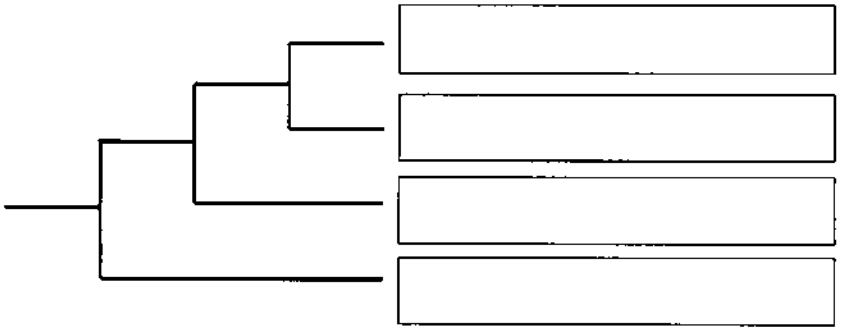
.....[3]

(ii) Using the data in Fig. 7.1, fill in phylogenetic diagram below to show the evolutionary relationship between the four species of king snakes.

.....[1]



(iii) Discuss how the neutral theory of evolution could be used to determine when two species of king snakes diverged from their common ancestor.

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.....[2]

[Q7 Total: 11]

Section B

Answer **one** question.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in sections (a), (b) etc., as indicated in the question.

8 **(a)** Explain the advantages and significance of cell signalling. [5]

(b) Secretion of glucagon plays a critical role the regulation of glucose concentration in the bloodstream.

With reference to the stages of cell signalling, describe how glucagon performs this role. [10]

(c) Discuss the differences between the cell signalling pathways of insulin and glucagon. [5]

[Total: 20]

OR

9 **(a)** Describe, using examples, how homology supports Darwin's theory of natural selection. [10]

(b) Using a named example, discuss how genetic variation may be preserved in natural population by heterozygote advantage. [10]

[Total: 20]

Civics Group	Index Number	Name (use BLOCK LETTERS)

H2

ST ANDREW'S JUNIOR COLLEGE
2016 JC2 Preliminary Examinations

H2 BIOLOGY **9648/3**

Paper 3: Applications and Planning Question

Tuesday 13th September 2016 2 hours

Additional Materials: Answer Paper
Cover Sheet for Section B

READ THESE INSTRUCTIONS FIRST

Write your civics group, index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagram, graph or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination,
1. Attach Question 5 to the **cover sheet** provided.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 3	
1	/12
2	/17
3	/11
Total	/40
4 (Planning)	/12

This document consists of **13** printed pages.

[Turn over

Answer **all** *questions.*

QUESTION 1

Tissue plasminogen activator (TPA) is a blood protein that scavenges and dissolves blood clots that may form in the final stages of the healing process. TPA is primarily used in heart patients or others suffering from poor circulation to prevent the development of clots that can be life-threatening. Hence, microbially produced TPA is in high demand.

Fig. 1.1 shows a commercially available plasmid that can be used to clone a synthetic TPA gene into *E. coli.* It contains two selectable markers which confer resistance to the antibiotics vancomycin (Van^R gene) and ampicillin (Amp^R gene) respectively.

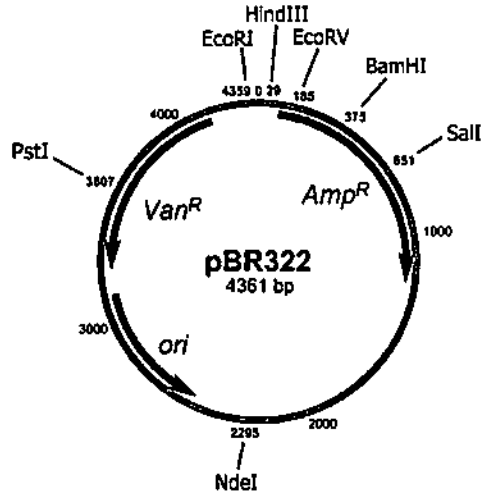

Fig. 1.1

(a)(i) Describe the natural function of restriction enzymes.

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.....[1]

(ii) *BamH1* was used to produce recombinant plasmids containing TPA gene. Describe and explain the selection procedure that would allow for selection of bacteria which contain the recombinant plasmids.

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.....[5]

(iii) The TPA gene which is inserted into the plasmid can be artificially synthesised. This synthetic TPA gene inserted into the plasmid may possess a different nucleotide sequence to the actual human gene. Explain one reason why this is so.

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.....[2]

(b) Discuss one problem of producing eukaryotic proteins using a prokaryotic host and how it can be overcome.

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.....[3]

(c) Two DNA samples of insulin gene were obtained using different methods:

1st method: reverse transcription of insulin mRNA to produce cDNA
2nd method: extraction of genomic DNA followed by selective amplification of the insulin gene using PCR

The two DNA samples were loaded into **different** wells and separated via **gel electrophoresis.** Draw the band(s) you would expect to see for the DNA sample obtained using the 2nd method in Fig 1.2.

[1]

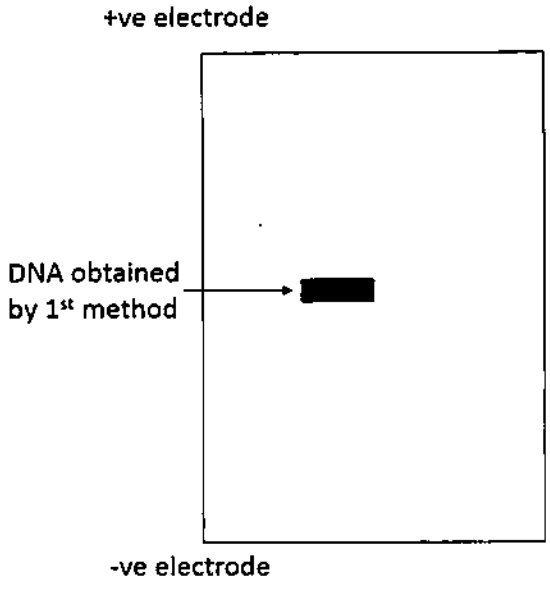

Fig. 1.2

[Q1 Total: 12]

QUESTION 2

Individuals born with severe combined immune deficiency (SCID) have no defence against common infections. This disease is caused by the possession of recessive alleles.

Fig.2.1 shows the pedigree which traces the inheritance of SCID in a family.

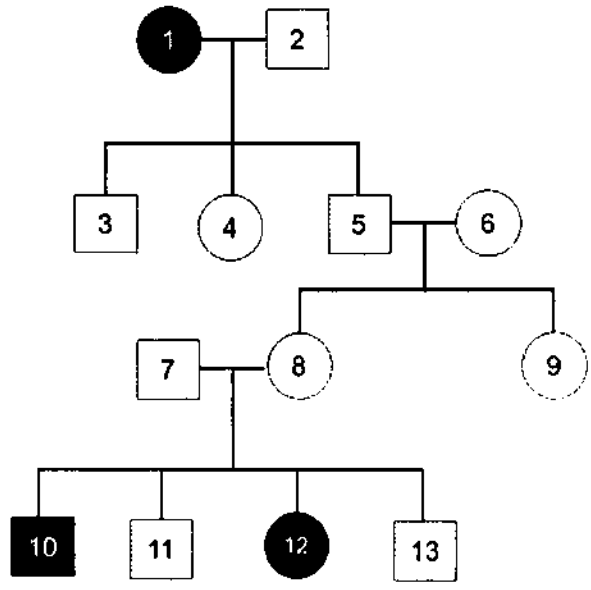

Fig. 2.1

(a)(i) Explain if the SCID tracked in Fig. 2.1 is autosomal or X-linked.

.....

.....[1]

(ii) Explain the genetic basis behind the susceptibility to common infections in this mode of SCID.

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.....

.....[3]

(iii) Explain why SCID is a suitable candidate for treatment using gene therapy.

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.....[2]

Gene therapy is carried out for individual 1 (shown in Fig.2.2). The essential steps are summarized in Fig.2.2.

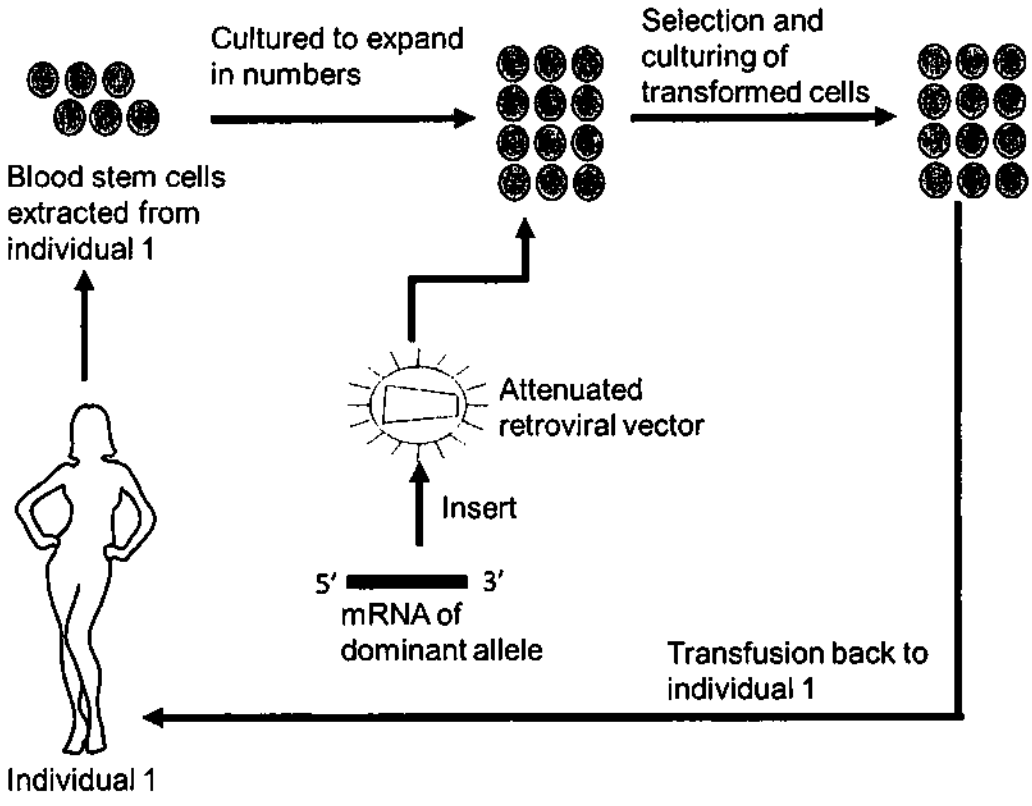

Fig.2.2

(iv) Give two reasons why blood stem cells are chosen to receive the dominant allele.

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.....[2]

(v) Suggest why the *ex vivo* method was used in this case.

.....

.....[1]

(vi) The gene therapy treatment described in Fig.2.2 turned out to be ineffective in treating individual. Suggest two reasons why.

.....

.....

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.....[2]

(vii) Explain why individuals treated **successfully** with gene therapy do not pass on the dominant allele to their children.

.....

.....[1]

(viii) Discuss two ethical considerations for the use of gene therapy.

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.....

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.....[2]

It is possible to diagnose for SCID in the individuals shown in Fig. 2.1, by detecting known RFLP regions found **within** the gene.

(ix) Explain how the Human Genome Project facilitates this process.

.....

.....[1]

In SCID, a mutation alters one base of the coding sequence, resulting in a loss of a restriction site. The gene responsible for SCID is isolated from **individual 8** of Fig. 2.1. Restriction digestion with *Msp*I enzyme results in 0.47 kb, 1.834 kb and 2.304 kb fragments.

(x) The lines in Fig. 2.3 represent the RFLP locus on the homologous chromosomes. Draw the restriction map showing the **cut sites** of *Msp*I enzyme, **using arrows**, for individual 8. The **size** of the fragments between cut sites should be indicated.

.....[1]

Fig. 2.3

A DNA probe is added which resulted in the detection of only the 1.834 kb and 2.304 kb bands.

(xi) Draw the suggested position of the probe in Fig. 2.3.

.....[1]

[Q2 Total: 17]

QUESTION 3

In Singapore, orchids of superior quality are selected for mass production through tissue culture.

Tissue culture is a collection of techniques used to grow plant cells, tissues, or organs under sterile conditions on a nutrient culture medium.

(a) Equal masses of orchid plant callus were cultured on media containing different concentrations of two plant growth regulators: auxin and cytokinin. The results are shown in Table 3.1.

treatment	concentration of plant growth regulators / mg dm^{-3}		effect of plant growth regulators on the callus
	auxin	cytokinin	
A	2.00	0.00	little or no growth
B	2.00	0.02	growth of roots
C	2.00	0.20	increased growth of callus with no differentiation
D	2.00	0.50	growth of shoots
E	0.00	0.20	little or no growth

Table 3.1

With reference to Table 3.1,

(i) describe the effects of auxin and cytokinin on the callus.

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.....[3]

(ii) suggest what treatment should be given to the shoots developed from callus in treatment D to turn them into plantlets.

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.....[1]

(b) Explain why plantlets grown from a callus in tissue culture are considered to be clones of each other.

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.....[2]

(c) Tissue culture is also used to grow genetically engineered plant cells into whole plants. An example are crops which are genetically engineered to carry the Bt toxin gene from the bacteria *Bacillus thuringiensis*.

Explain the benefit of incorporating a *Bt* gene into a crop plant.

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.....[2]

(d) The genetically modified (GM) salmon was created in 1992 by Emeritus Professor Hew Choy Leong from the department of biological sciences at the National University of Singapore.

Explain why this development of GM salmon is supported by some.

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.....[3]

[Q3 Total: 11]

4. Planning question

You are required to plan, but not carry out, an investigation into the effect of different temperatures on the rate of respiration in crickets.

Your planning must be based on the assumption that you have been provided with the following equipment and materials which you must use:

- Crickets
- Manometer with scale (internal radius of manometer is 1mm)
- Manometer fluid
- 2 rubber bungs with delivery tubes
- 2 boiling tubes
- Zinc gauze platform (to provide platform to support the crickets)
- Glass beads
- Clamps and stands
- Stop watch
- Soda lime solution
- Thermometer
- Supply of water at 50°C
- Tap water / ice
- Weighing balance
- A variety of different sized beakers, measuring cylinders, and syringes for measuring volumes

Your plan should have a clear and helpful structure to include:

- an explanation of theory to support your practical procedure,
- a description of the method used, including the scientific reasoning behind the method and any recommended safety measures,
- an explanation of dependent and independent variables involved,
- relevant and clearly labeled diagrams,
- how you will record your results and ensure they are accurate and reliable as possible,
- proposed layout of results tables and graphs with clear headings and labels,
- the correct use of technical and scientific terms.

[Q4 Total: 12]

Free-response question

Write your answer to this question on the separate answer paper provided.

Your answer:

- should be illustrated by large, clearly labeled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5 **(a)** Discuss the advantages and limitations of the Polymerase Chain Reaction. [8]

(b) Explain how gel electrophoresis is used to analyse DNA. [5]

(c) Discuss the negative implications of Genetically Modified Organisms. [7]

[Total: 20]

CANDIDATE NAME: _____ **INDEX NUMBER** _____

CG _____

SERANGOON JUNIOR COLLEGE
JC2 PRELIM EXAMINATION 2016

BIOLOGY PAPER 1
Higher 2

Thursday
22 September 2016

1 hour 15 minutes

Additional materials:
OTAS Sheet

READ THESE INSTRUCTIONS FIRST

Write your name and index number in the spaces at the top of this page and on all the work you hand in.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in this paper. Record your choice in **2B pencil** on the OTAS sheet provided.

At the end of examination, submit the question paper and MCQ OTAS sheet separately.

This question paper consists of 28 printed pages excluding this cover page.

Section A [40 marks]

Answer all questions on the OTAS provided.

1. Which of the following best accounts for the difference in structure between amylose which is helical and cellulose which is fibrous?

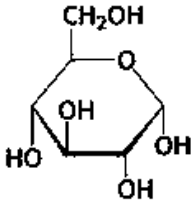
A Presence or absence of 180^{o} rotation of alternate subunits.

B Presence or absence of branching in the macromolecule

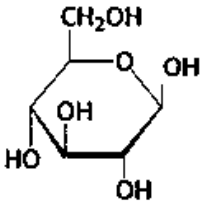
C Subunits are either monosaccharides or amino acids.

D Different tendency of macromolecule to form hydrogen bonds with water.

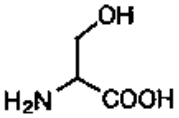
2. Which of the following combination of polymer, monomer and bond formed between monomers is correct?



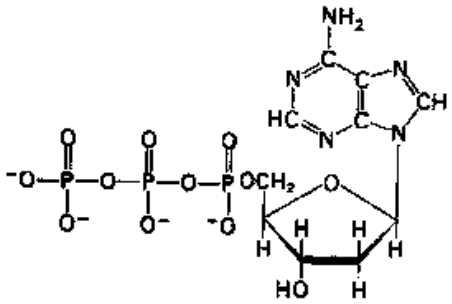
U



X



Y



Z

	starch	*cellulose*	*polypeptide*	*polynucleotide*
A	**X**, β -1,4 glycosidic bond	**U**, α -1,4 glycosidic bond	**Z**, ester linkage	**Y**, disulphide linkage
B	**U**, α -1,4 glycosidic bond	**X**, β -1,4 glycosidic bond	**Y**, peptide bond	**Z**, phosphodiester linkage
C	**Z**, peptide bond	**X**, hydrogen bond	**Z**, ionic bond	**U**, hydrogen bond
D	**X**, ionic bonds	**Y**, peptide bond	**U**, hydrogen bond	**Z**, α -1,6 glycosidic bond

3. Most wild plants contain toxins that deter animals from eating them. A scientist discovered that a toxin produced by a certain plant was also toxic to the same plant if it as applied to the roots of the plant. As the first step on finding out why the plant was not normally killed by its own toxin, he fractionated some plant cells and found that the toxin was in the fraction that contained the largest cell organelle. He also found that the toxin was no longer toxic after it was heated. Which of the following statements are consistent with the scientist's observations?

I. The toxin was stored in the central vacuole.
II. The toxin cannot cross the membrane of the organelle in which it is stored.
III. The toxin was stored in chloroplast.
IV. The toxin is likely to be lipid-soluble.
V. The toxin may be an enzyme.

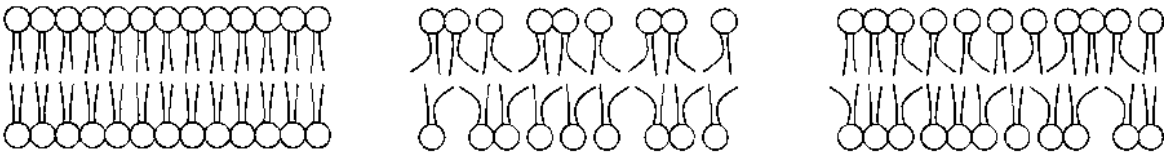
A **I, II** and **V**
B **I, IV** and **V**
C **II, III** and **IV**
D **III, IV** and **V**

4. Which of the following is/are the most likely consequence/(s) for a cell lacking functional lysosomes?

(i) The cell becomes crowded with undegraded wastes.
(ii) The cell dies because its ATP-synthesizing mechanisms are missing.
(iii) The cell dies from a lack of enzymes to catalyze metabolic reactions.
(iv) The cell is unable to reproduce itself.
(v) The cell is unable to grow to a mature size and always remains small.

A **(i)** only
B **(i)** and **(v)**
C **(ii)** and **(iv)**
D **(iii)** and **(iv)**

5. A mutated strain of the bacterium *Escherichia coli* was found to be incapable of incorporating unsaturated phospholipids into its plasma membrane. Which of the following correctly depicts and describes the membrane of such a bacteria?



Type I Type II Type III

A The membrane would appear as Type I and would be more fluid at low temperatures.

B The membrane would appear as Type I and would be less fluid at low temperatures.

C The membrane would appear as Type II and would be more fluid at low temperatures.

D The membrane would appear as Type III and would be no different from normal bacterial membranes.

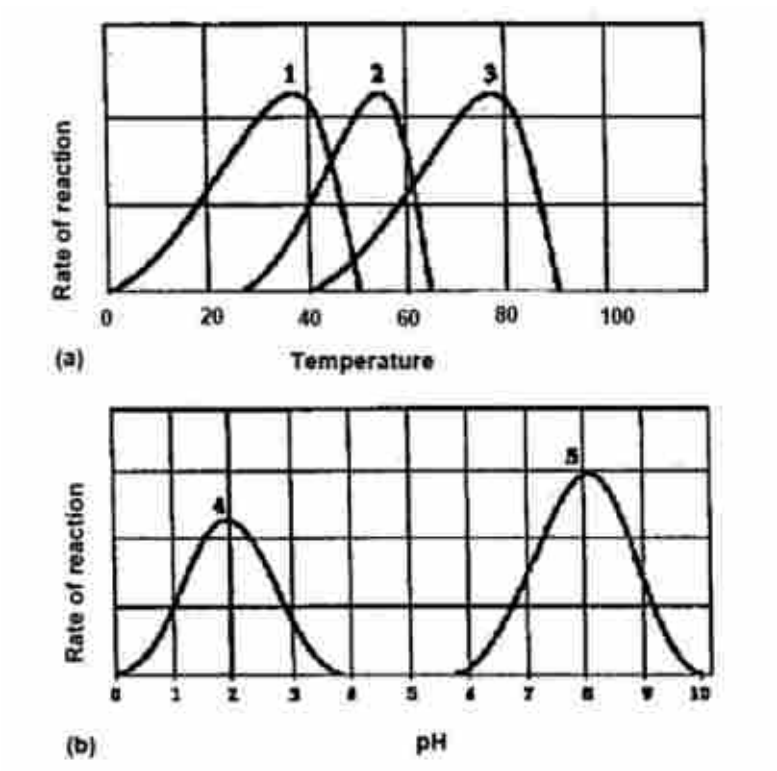
6. When mucus is secreted from a goblet cell in the trachea, these events take place.

(i) addition of carbohydrate to protein
(ii) fusion of the vesicle with the plasma membrane
(iii) secretion of a glycoprotein
(vi) separation of a vesicle from the Golgi apparatus

What is the sequence in which these events take place?

A (i), (vi), (ii), (iii)
B (i), (vi), (iii), (ii)
C (vi), (i), (ii), (iii)
D (vi), (i), (iii), (ii)

7. The following graphs show the activities of different enzymes (1-5) under different conditions:



Which statement is a correct explanation for the rate of reaction of different enzymes?

A Kinetic energy of enzyme 3 and its substrate is fastest at 75°C.

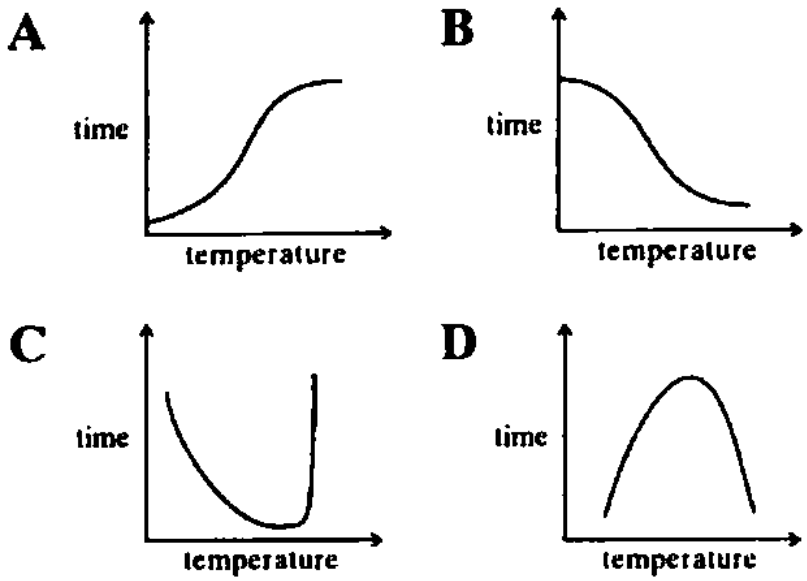
B At pH 2, most of the R groups at the active site of enzyme 4 are all negatively charged.

C At pH 8.1, substrate is bonded to the active site of enzyme 5 by hydrogen bonds only.

D At 60°C, several hydrogen bonds between R groups of enzyme 2 are broken.

8. In an investigation to determine the effect of temperature on the activity of an enzyme, the time taken for all the substrates to disappear from a standard solution was recorded. C

Which graph shows the result of this investigation?



9. Which of the following statements about meiosis is **false**?

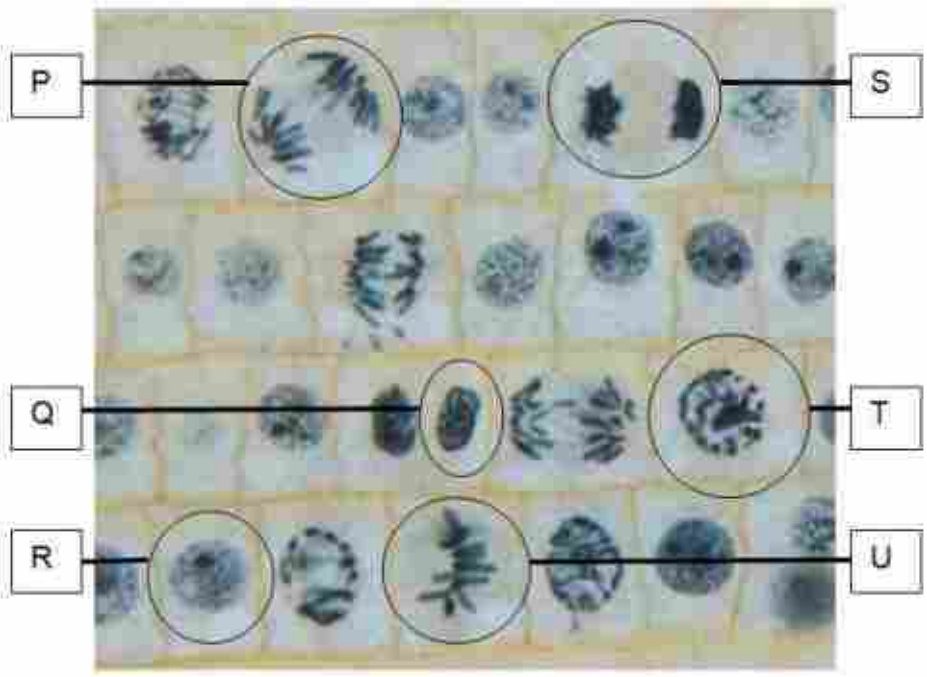
A Sister chromatids are separated at anaphase II

B Homologous chromosomes are separated in anaphase I.

C Cells at the beginning of Meiosis II are haploid

D Homologous chromosomes are paired on the metaphase plate in metaphase I.

10. The photographs below show a section of the onion root tip. The cells are at different stages of mitosis.



Which of the following shows the correct sequence of events that occurs in these cells?

A R, T, U, P, S, Q

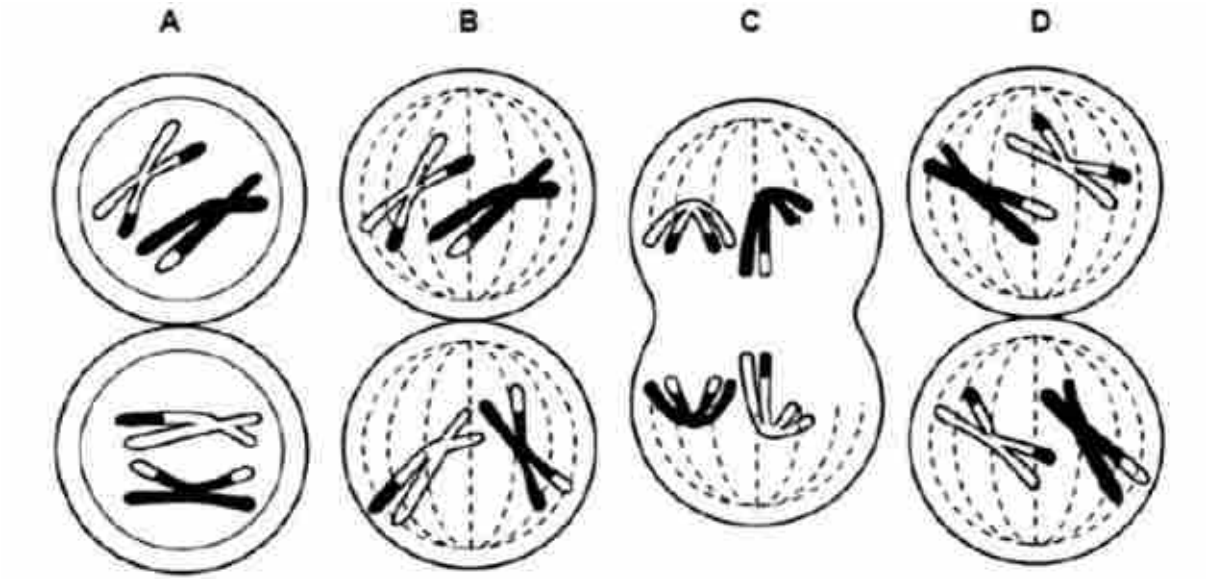
B T, U, P, S, Q, R

C Q, T, P, S, U, R

D T, R, P, S, U, Q

11. The diagram shows anaphase I of meiosis.

Which diagram shows metaphase II as meiosis continues in this cell? B



12. For a double-stranded DNA, which of the following base ratios always equals 1?

I. (A + T) / (G + C)
II. (A + G) / (C + T)
III. C / G
IV. (G + T) / (A + C)
V. A / G

A **I** and **III**

B **I**, **II** and **III**

C **II**, **III** and **IV**

D **III, IV** and **V**

13. The diagram below is a template strand of a DNA molecule.

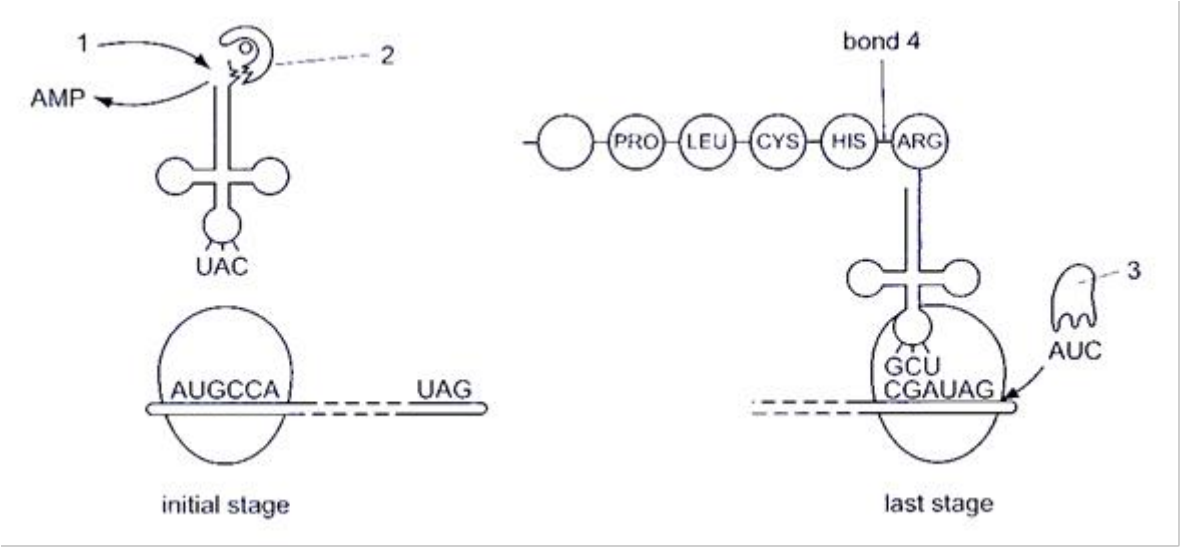
Promoter (18 nucleotides in length)	TAC	DNA sequence of 330 nucleotides	ATC

The number of amino acids in the protein coded by this template strand is

A 110 **B** 111 **C** 112 **D** 118

14. A number of molecules other than tRNA and mRNA are involved during translation.

The diagram shows some of these molecules and nucleotides in the codon and anticodon positions.



Which of the following is correct?

	1	2	3	4
A	ADP	Aminoacyl tRNA synthetase	Amino acid	Hydrogen bond
B	ADP	Amino acid	Translation releasing factor	Hydrogen bond
C	ATP	Aminoacyl tRNA synthetase	Aminoacyl tRNA	Peptide bond
D	ATP	Aminoacyl tRNA synthetase	Translation releasing factor	Peptide bond

15. With reference to a single eukaryotic gene, which of the following molecules contains the fewest number of nucleotides?

A A single strand of the original DNA segment

B A primary RNA transcript made from the original DNA segment

C A single strand of the original DNA segment after a point mutation

D A single strand of the complementary DNA (cDNA) made from the mature mRNA

16. DNA methylation is known to silence genes because it prevents transcription factors from binding. Which of the following best explains this phenomenon?

A DNA methylation modifies the shape of the transcription factor.

B DNA methylation prevents dimerization of DNA binding proteins.

C DNA methylation modifies the shape of the DNA element where the transcription factor binds.

D DNA methylation causes acetylation of histone proteins which causes heterochromatin to be formed.

17. Which of the following statements are true of the end-replication problem of linear DNA?

1. When a linear DNA molecule replicates, a gap is left at the 3' end of each new strand because DNA polymerase can only add nucleotides to a 3' end.
2. Telomerase prevents the end-replication problem from occurring.
3. Repeated rounds of replication produce shorter and shorter DNA molecules.
4. Prokaryotes do not have the end-replication problem.

A 1 and 2
B 1 and 4
C 2 and 3
D 3 and 4

18. Rhabdoviruses infect human cells. The genome of rhabdoviruses consists of a single-stranded RNA molecule whose sequence is complementary to the RNA sequence which functions as a messenger RNA. How is the "+" messenger RNA produced in such cells by rhabdovirus?

A Host cell RNA polymerase activity
B One portion of the infecting RNA is directly translated by host cell ribosomes.
C Reverse transcriptase activity
D The infecting virus particle contains an RNA-dependent RNA polymerase.

19. Some events that take place during generalized transduction are listed below.

I Bacterial host DNA is fragmented
II Bacterial DNA instead of viral DNA may be packaged in a phage capsid
III Recombination between donor DNA and recipient DNA
IV Phage infects a bacterial cell
V Phage DNA and proteins are made
VI Release of progeny virus

Which sequence of events is most accurate in describing generalized transduction?

A **IV, I, III, V,VI, II**

B **IV, I, V, II, VI,III**

C **IV, III, I, V, II,VI**

D **IV, V, I, III, II,VI**

20. A mutation that makes the regulatory gene of an inducible operon non-functional would result in

A continuous transcription of the operon's genes.
B reduced transcription of the operon's gene.
C accumulation of large quantities of a substrate for the catabolic pathway controlled by the operon.
D irreversible binding of the repressor to the promoter.

21. The coat colour of Norwegian cattle is mainly determined by the distribution of two pigments: red and black. Both pigments are the action of the enzyme tyrosinase in cells called melanocytes. A normal level of activity of the enzyme leads to the production of red pigment, whilst a high activity allows only black pigment production. The activity of the enzyme is increased by melanocyte stimulating hormone (MSH), which binds to an MSH receptor.

The receptor is coded for by the **E** locus, which has the three alleles, $\mathbf{E^D}$, $\mathbf{E^A}$ and **e**. $\mathbf{E^D}$ is insensitive to protein A which blocks MSH receptor. $\mathbf{E^A}$ is sensitive to protein A which blocks MSH receptor. No receptor is produced by the recessive allele, **e**.

The dominant allele of a second gene, the **A** locus, codes for a protein which binds to and blocks the MSH receptor coded for by $\mathbf{E^A}$, thus preventing stimulation of tyrosinase activity in a melanocyte.

What would be the coat colours of cattle with the following genotypes?

	eeAa	**E^Aeaa**	**E^DeAa**	**E^AE^AAa**
A	Red	Black	Black	Red
B	Red	Black	Red	Red
C	Black	Red	Red	Black
D	Red	Red	Black	Black

22. Two parents have a son who has blood group A and phenylketonuria. One parent has blood group O and the other has blood group AB. Neither parent has phenylketonuria. What is the probability that the second child of these parents will be a girl with blood group B who does not have phenylketonuria?

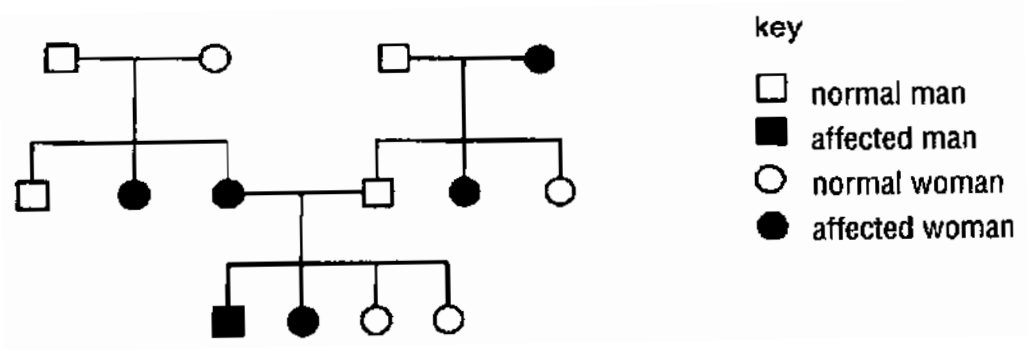
A 1 in 16

B 1 in 8

C 3 in 16

D 3 in 8

23. The family tree shows the inheritance of a skin condition.



What is the genetic basis of the skin condition?

A autosomal dominant

B sex-linked dominant

C autosomal recessive

D sex-linked recessive

24. In the board bean, a pure-breeding variety with green seeds and black hilums (the point of attached of the seed to the pod) was crossed with a pure-breeding variety with yellow seeds and white hilums. All the F_1 plants had yellow seeds and white hilums. When these were allowed to self-fertilise, the plants of the F_2 generation produced the following seeds.

Yellow seeds and white hilums	89
Yellow seeds and black hilums	28
Green seeds and white hilums	25
Green seeds and black hilums	45

A chi-squared (χ^2) test was performed to test the significance of the difference between the observed and expected results.

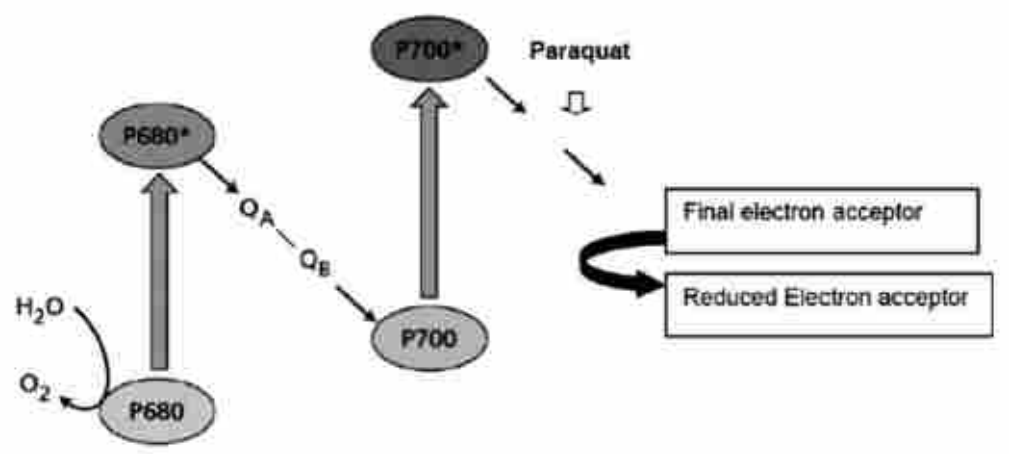
$$\chi^2 = \sum \frac{(O-E)^2}{E} \qquad \nu = c - 1$$

degrees of freedom	*p = 0.5*	*p = 0.1*	*p = 0.05*	*p = 0.01*	*p = 0.001*
1	0.46	2.71	3.84	6.64	10.83
2	1.39	4.6	5.99	9.21	13.82
3	2.37	6.25	7.82	11.34	16.27
4	3.36	7.78	9.49	13.28	18.46

Which combination correctly describes the results of the χ^2 test?

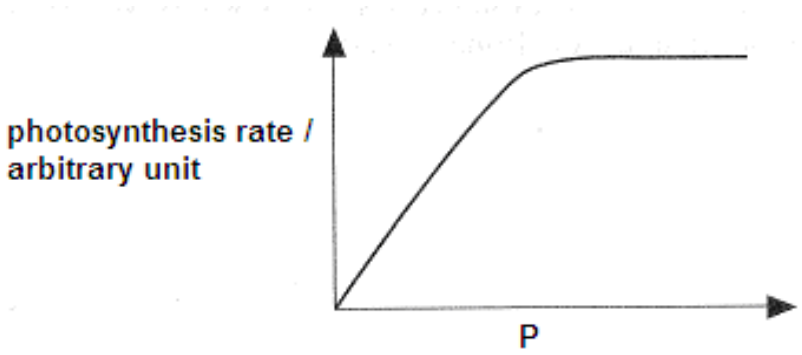
	number of degrees of freedom	*probability*	*these are two pairs of segregating alleles at two loci*
A	3	> 0.05	yes
B	3	< 0.05	no
C	4	> 0.05	yes
D	4	< 0.05	no

25. Paraquat is a poison that disrupts electron transport at the position indicated in the diagram. Paraquat was added to isolated chloroplasts. Which of the following correctly represents the outcomes in the presence of paraquat?



A Both light dependent reactions and Calvin cycle will not be able to proceed.
B Only Calvin cycle can proceed.
C Only light dependent reactions can occur.
D Both light dependent reactions and Calvin cycle can still proceed as per normal.

26. The following graph shows the relationship between the rates of photosynthesis with environmental factor **P**.

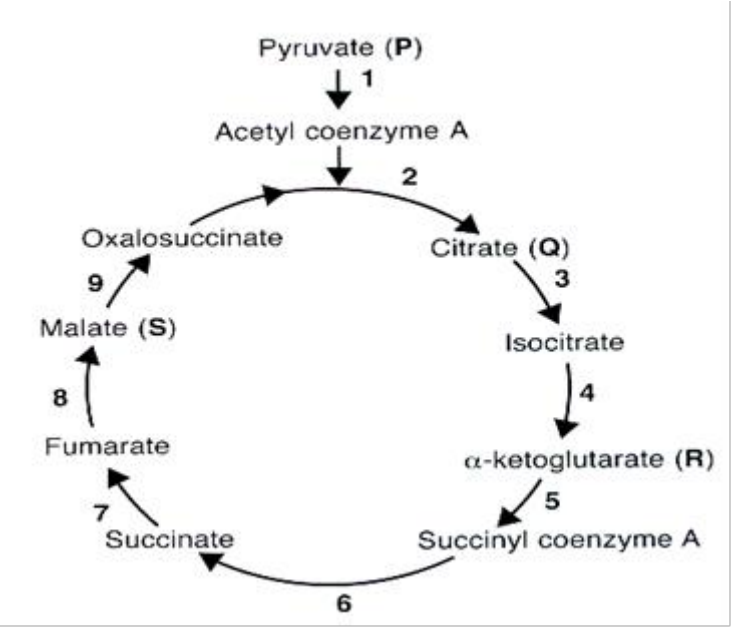


P most probably represents

1. carbon dioxide concentration.
2. oxygen concentration.
3. light intensity.
4. temperature.

A ***1*** and ***2*** **B** ***1*** and ***3*** **C** ***1*** and ***4*** **D** ***1***, ***3*** and ***4***

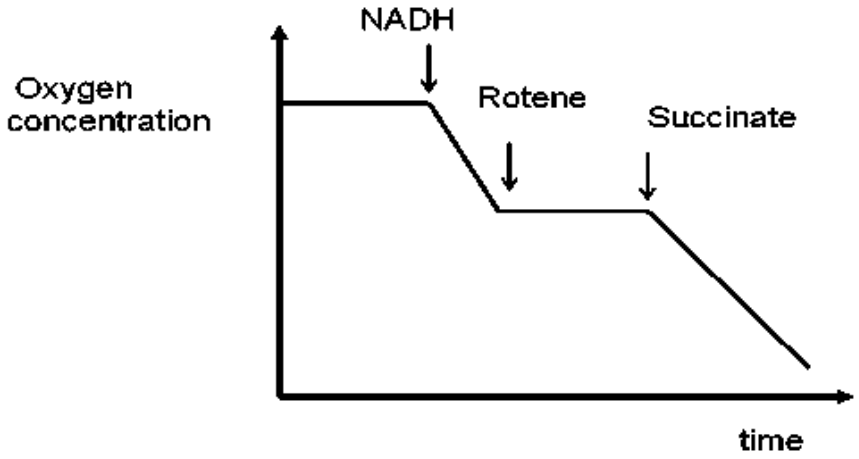
27. The diagram below shows the Krebs Cycle.



At which stages are hydrogen atoms transferred to NAD^+?

A 1, 4, 5 and 7
B 1, 4, 5 and 9
C 2, 4, 5 and 7
D 4, 5, 7 and 9

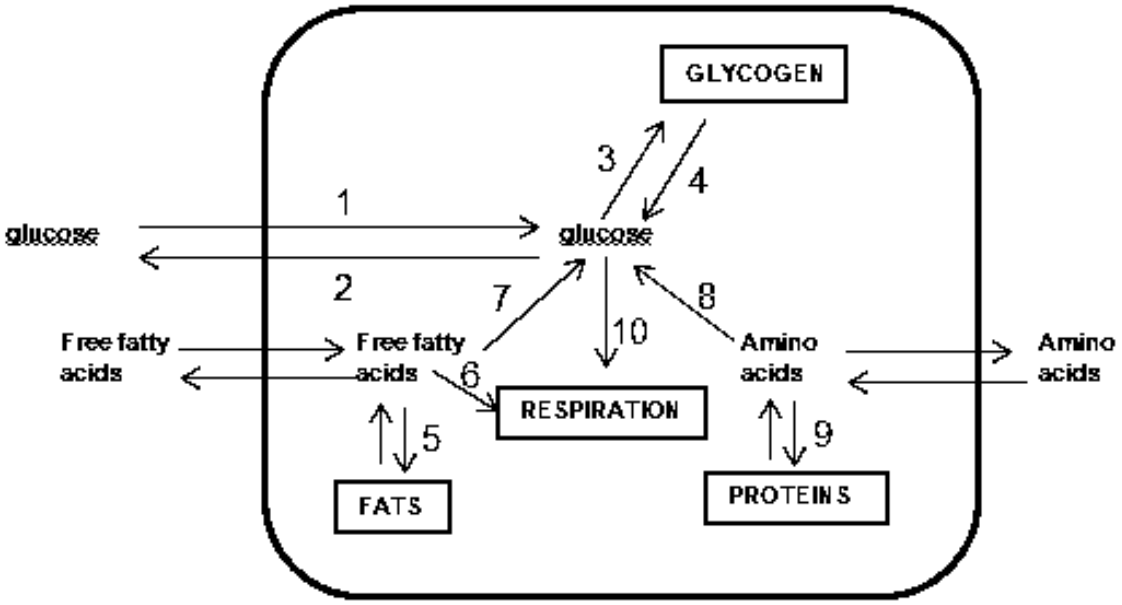
28. A suspension of mitochondria was prepared in a buffer containing ADP and inorganic phosphate (Pi). The oxygen concentration in the buffer was monitored carefully and recorded as shown below. At the times indicated, a specific reagent was added to the buffer. Throughout the experiment, the concentrations of ADP and Pi were in excess.



Which one of the following shows correctly from the highest to the lowest, the rate of ATP production after the addition of the three chemicals?

	Highest ATP production	⟶	***Lowest ATP production***
A	NADH	Succinate	Rotene
B	Succinate	NADH	Rotene
C	Rotene	NADH	Succinate
D	Rotene	Succinate	NADH

29. The diagram below shows some biochemical pathways in a liver cell. During which processes will the hormone glucagon exert an effect?



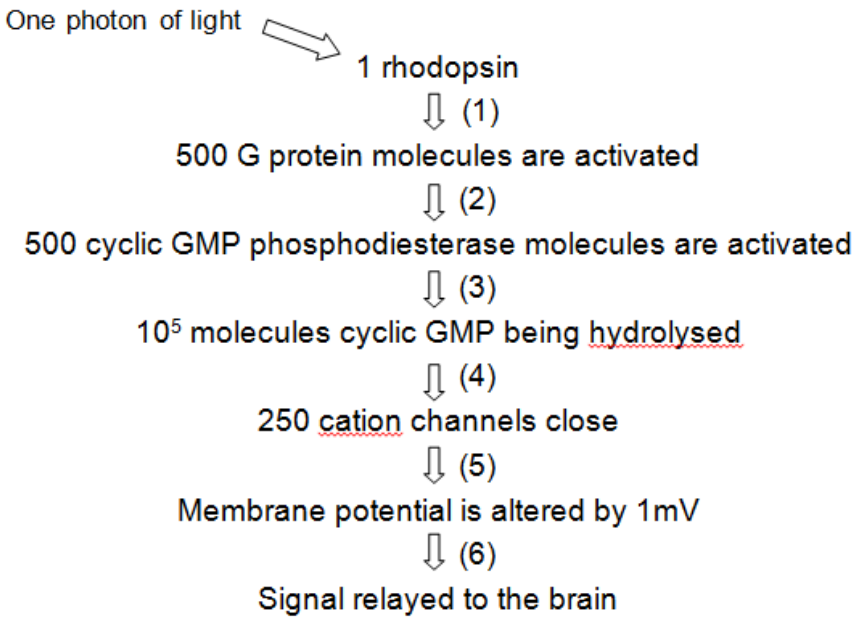
A (1), (3), (5), (9)

B (1), (4), (8), (10)

C (2), (7), (9), (10)

D (4), (6), (7), (8)

30. Rhodopsin, a light sensitive pigment that is present on the rods in the eyes. Rhodopsin is a G protein coupled receptor. The flow chart below shows how the chain of reactions that occur when rhodopsin absorbs a photon of light.



Identify the stages where *amplification* and *cellular responses* have occurred.

	Amplification	***Cellular response***
A	1, 2, 3, 4, 5	6
B	1, 3	1, 2, 3, 4, 5, 6
C	1, 3	5
D	2, 3	5

31. A neurone is undergoing relative refractory period. Which of the following statements is true?

A Membrane potential is less negative than resting potential.

B There is delayed closing of voltage-gated potassium channels.

C It is possible to initiate another action potential if a weaker stimulus is applied.

D It is impossible to initiate another action potential regardless of the stimulus strength.

32. Tetrodotoxin, a puffer fish toxin, blocks voltage-gated sodium channels. Black widow spider's venom causes the voltage-gated calcium channels to be constantly open. Crotoxin binds irreversibly to acetylcholine receptors. What will happen to the transmission of nerve impulses if each toxin is applied?

	Tetrodotoxin	**Black widow spider's venom**	**Crotoxin**
A	block action potentials along axon	reduce transmission of impulse across synapse	increase transmission of impulse across synapse
B	increase transmission of impulse across synapse	reduce transmission of impulse across synapse	block action potentials along axon
C	block action potentials along axon	increase transmission of impulse across synapse	reduce transmission of impulse across synapse
D	reduce transmission of impulse across synapse	block action potentials along axon	increase transmission of impulse across synapse

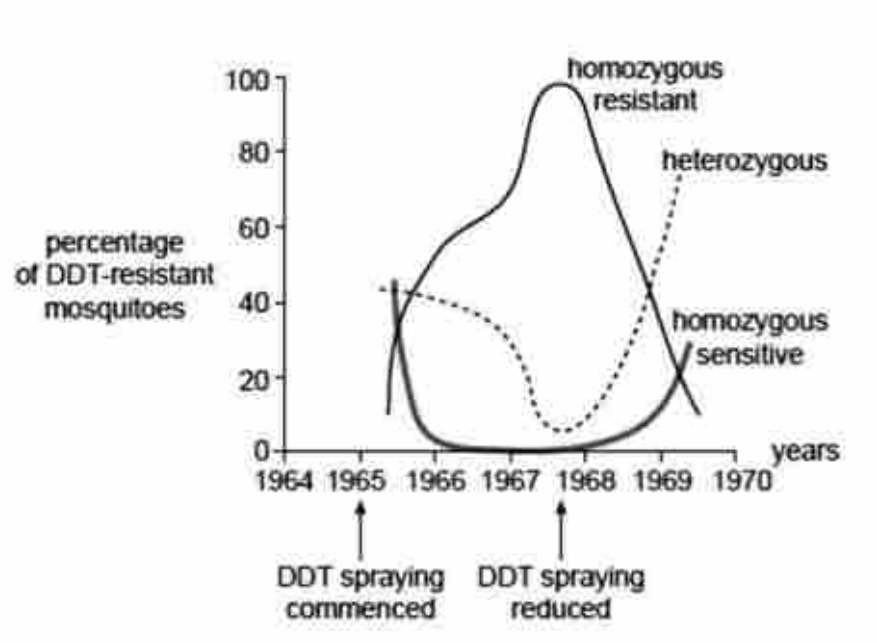
33. Members of two different species possess a similar-looking structure that they use in a similar fashion to perform the same function. Which information would best help distinguish between an explanation based on homology versus one based on convergent evolution?

A The two species live at great distance from each other.
B The two species share many proteins in common, and the nucleotide sequences that code for these proteins are almost identical.
C The sizes of the structures in adult members of both species are similar in size.
D Both species are well adapted to their particular environments.

34. In the mid-1960s, DDT was widely used as an insecticide against mosquitoes. The sensitivity to insecticide in mosquitoes is determined by a single gene that has two alleles.

allele **1** : resistant to DDT
allele **2** : sensitive to DDT

Over several years genotypic frequencies were measured in a population of mosquito larvae. The graph below shows the results.



Analysis of the graph reveals that in the population

A when spraying levels declined, heterozygous advantage occurred.

B there were no alleles for sensitivity present in the population in 1967.

C the number of alleles for resistance was equal to the number for sensitivity in 1966.

D the homozygous resistant genotype was unable to produce offspring at low spraying levels.

35. Which of the following statements is/are true of genetic drift?

(i) Genetic drift requires the presence of variation.

(ii) Genetic drift can results in the loss of beneficial alleles.

(iii) Founders effect and genetic bottleneck drive genetic drift

(iv) Genetic drift occurs in small population only

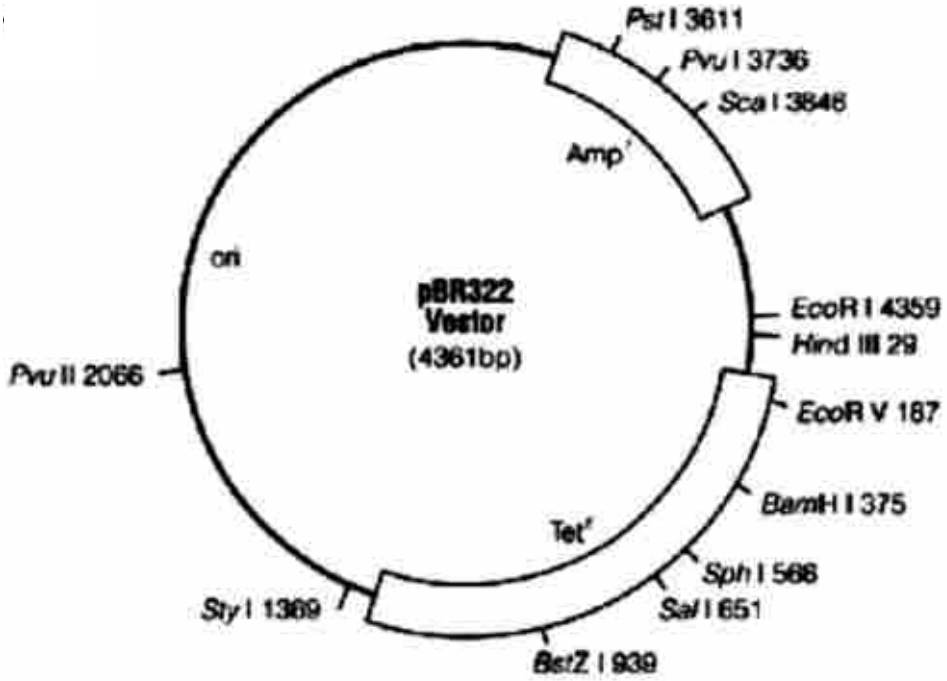
A (i) and (iv) only

B (ii) and (iii) only

C (i), (ii) and (iii) only

D (ii), (iii) and (iv) only

36. pBR322 vector is used to clone a eukaryotic gene which has been digested by the restriction endonuclease BamHI.



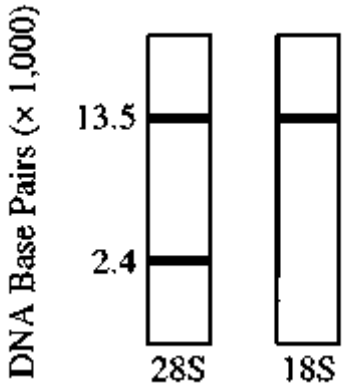
Following transformation, bacterial cells were grown in four different media, as shown below:

I nutrient broth plus ampicillin
II nutrient broth plus tetracycline
III nutrient broth plus ampicillin and tetracycline
IV nutrient broth without antibiotics

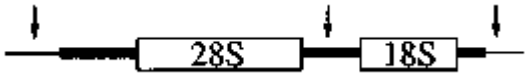
Which of the following media would bacterial cells that contain the recombinant plasmids grow in?

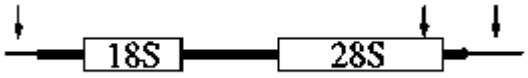
A I and II
B I and III
C I and IV
D IV only

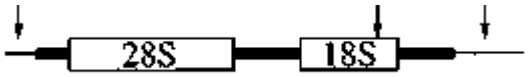
37. The autoradiograms obtained below (after electrophoresis and Southern Blotting) show human DNA digested with a specific restriction enzyme and probed with labeled rRNA. In the autoradiogram on the left, the probe was 28S rRNA; at the right, the probe was 18S rRNA.



If the arrows in the following map show the location of the restriction sites of this restriction enzyme, which map *best* explains the results shown above?

A


B


C


D


38. Which of the following statements are **true** about all stem cells?

I Stem cells can be induced to differentiate by environmental signals.
II Stem cells are easily isolated and propagated
III Stem cells are able to develop into whole organisms if implanted into the womb
IV Stem cells make more stem cells under appropriate conditions.

A I and IV

B II and III

C I, III and IV

D All of the above

39. Non -viral *ex vivo* transfer of a gene encoding coagulation factor VII was performed using fibroblast cells isolated from patients suffering from severe haemophilia A.

What is the sequence of events for the *ex vivo* transfer of the gene encoding coagulation factor VIII?

1 Transfection with plasmids containing the gene encoding coagulation factor VII

2 Implantation of cells into patients

3 Isolation of fibroblasts

4 Selection and cloning of cells expressing coagulation factor VII

A 2, 3, 1, 4

B 3, 1, 4, 2

C 3, 2, 4, 1

D 3, 4, 2, 1

40. Maize varieties are being developed in which the leaves produce proteins that are toxic to insects. The DNA coding for these toxic proteins was inserted into a maize chromosome via a bacterial plasmid. Many people are opposed to this process.

Which objection is **not** biologically valid?

A Beneficial insects may be killed if they eat genetically modified maize.

B Genes for antibiotic resistance are present in plasmids and these genes may be passed to harmful bacteria.

C Hybridisation may transfer the bacterial genes from maize to weeds, giving the weed species new and harmful characteristics.

D Mutations may be caused in cattle or humans that eat the genetically modified maize.

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CANDIDATE NAME: _____ **INDEX NUMBER** _____

CG _____

SERANGOON JUNIOR COLLEGE
JC2 PRELIM EXAMINATION 2016

BIOLOGY PAPER 1
Higher 2

Thursday
22 September 2016

1 hour 15 minutes

Additional materials:
OTAS Sheet

READ THESE INSTRUCTIONS FIRST

Write your name and index number in the spaces at the top of this page and on all the work you hand in.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in this paper. Record your choice in **2B pencil** on the OTAS sheet provided.

At the end of examination, submit the question paper and MCQ OTAS sheet separately.

This question paper consists of 28 printed pages excluding this cover page.

Section A [40 marks]

Answer all questions on the OTAS provided.

1. Which of the following best accounts for the difference in structure between amylose which is helical and cellulose which is fibrous?

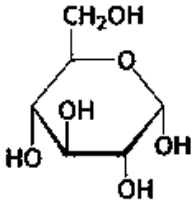
A Presence or absence of 180^{o} rotation of alternate subunits.

B Presence or absence of branching in the macromolecule

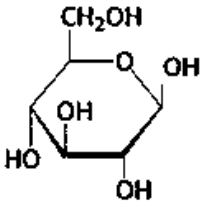
C Subunits are either monosaccharides or amino acids.

D Different tendency of macromolecule to form hydrogen bonds with water.

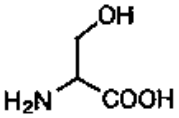
2. Which of the following combination of polymer, monomer and bond formed between monomers is correct?



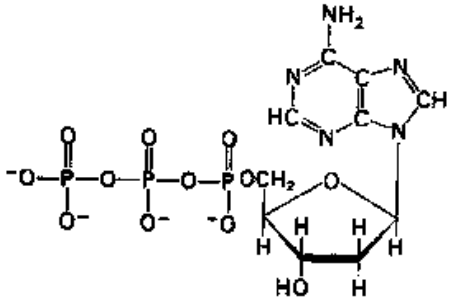
U



X



Y



Z

	starch	*cellulose*	*polypeptide*	*polynucleotide*
A	**X**, β -1,4 glycosidic bond	**U**, α -1,4 glycosidic bond	**Z**, ester linkage	**Y**, disulphide linkage
B	**U**, α -1,4 glycosidic bond	**X**, β -1,4 glycosidic bond	**Y**, peptide bond	**Z**, phosphodiester linkage
C	**Z**, peptide bond	**X**, hydrogen bond	**Z**, ionic bond	**U**, hydrogen bond
D	**X**, ionic bonds	**Y**, peptide bond	**U**, hydrogen bond	**Z**, α -1,6 glycosidic bond

3. Most wild plants contain toxins that deter animals from eating them. A scientist discovered that a toxin produced by a certain plant was also toxic to the same plant if it was applied to the roots of the plant. As the first step on finding out why the plant was not normally killed by its own toxin, he fractionated some plant cells and found that the toxin was in the fraction that contained the largest cell organelle. He also found that the toxin was no longer toxic after it was heated. Which of the following statements are consistent with the scientist's observations?

I. The toxin was stored in the central vacuole.
II. The toxin cannot cross the membrane of the organelle in which it is stored.
III. The toxin was stored in chloroplast.
IV. The toxin is likely to be lipid-soluble.
V. The toxin may be an enzyme.

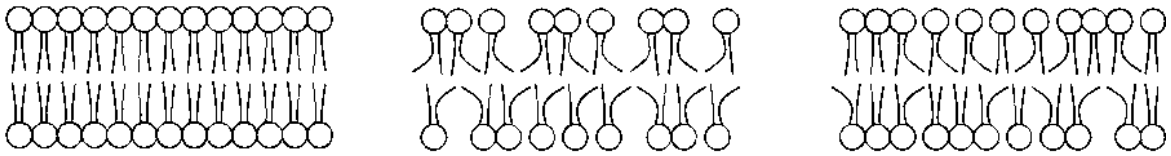
A **I, II** and **V**
B **I, IV** and **V**
C **II, III** and **IV**
D **III, IV** and **V**

4. Which of the following is/are the most likely consequence/(s) for a cell lacking functional lysosomes?

(i) The cell becomes crowded with undegraded wastes.
(ii) The cell dies because its ATP-synthesizing mechanisms are missing.
(iii) The cell dies from a lack of enzymes to catalyze metabolic reactions.
(iv) The cell is unable to reproduce itself.
(v) The cell is unable to grow to a mature size and always remains small.

A **(i)** only
B **(i)** and **(v)**
C **(ii)** and **(iv)**
D **(iii)** and **(iv)**

5. A mutated strain of the bacterium *Escherichia coli* was found to be incapable of incorporating unsaturated phospholipids into its plasma membrane. Which of the following correctly depicts and describes the membrane of such a bacteria?



Type I Type II Type III

A The membrane would appear as Type I and would be more fluid at low temperatures.

B The membrane would appear as Type I and would be less fluid at low temperatures.

C The membrane would appear as Type II and would be more fluid at low temperatures.

D The membrane would appear as Type III and would be no different from normal bacterial membranes.

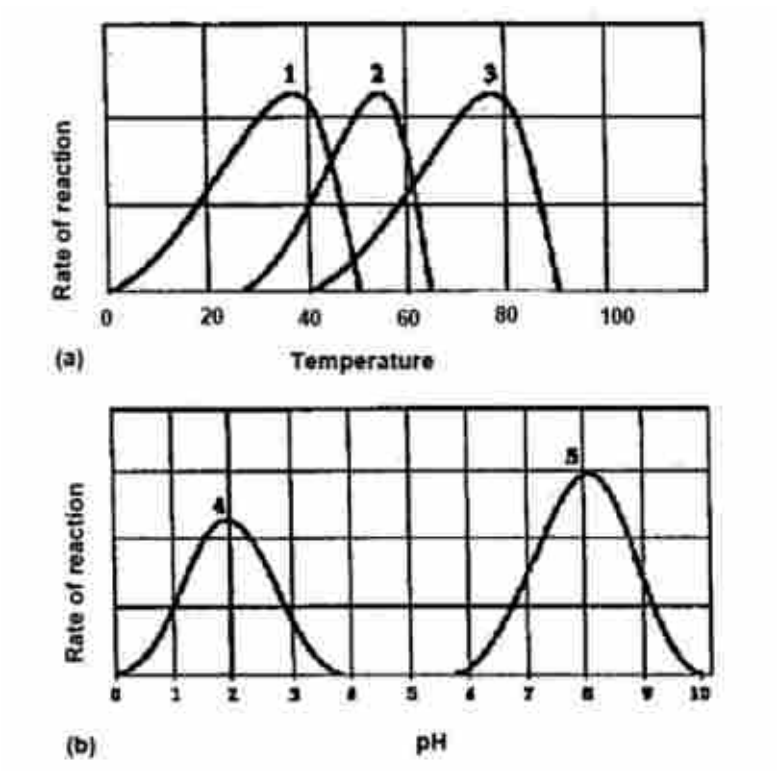
6. When mucus is secreted from a goblet cell in the trachea, these events take place.

(i) addition of carbohydrate to protein
(ii) fusion of the vesicle with the plasma membrane
(iii) secretion of a glycoprotein
(vi) separation of a vesicle from the Golgi apparatus

What is the sequence in which these events take place?

A (i), (vi), (ii), (iii)
B (i), (vi), (iii), (ii)
C (vi), (i), (ii), (iii)
D (vi), (i), (iii), (ii)

7. The following graphs show the activities of different enzymes (1-5) under different conditions:



Which statement is a correct explanation for the rate of reaction of different enzymes?

A Kinetic energy of enzyme 3 and its substrate is fastest at 75°C.

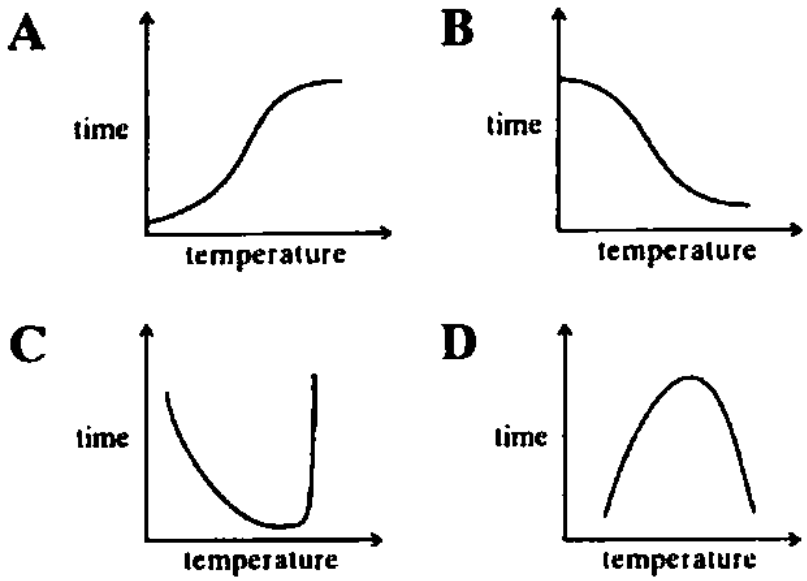
B At pH 2, most of the R groups at the active site of enzyme 4 are all negatively charged.

C At pH 8.1, substrate is bonded to the active site of enzyme 5 by hydrogen bonds only.

D At 60°C, several hydrogen bonds between R groups of enzyme 2 are broken.

8. In an investigation to determine the effect of temperature on the activity of an enzyme, the time taken for all the substrates to disappear from a standard solution was recorded.

Which graph shows the result of this investigation?



9. Which of the following statements about meiosis is **false**?

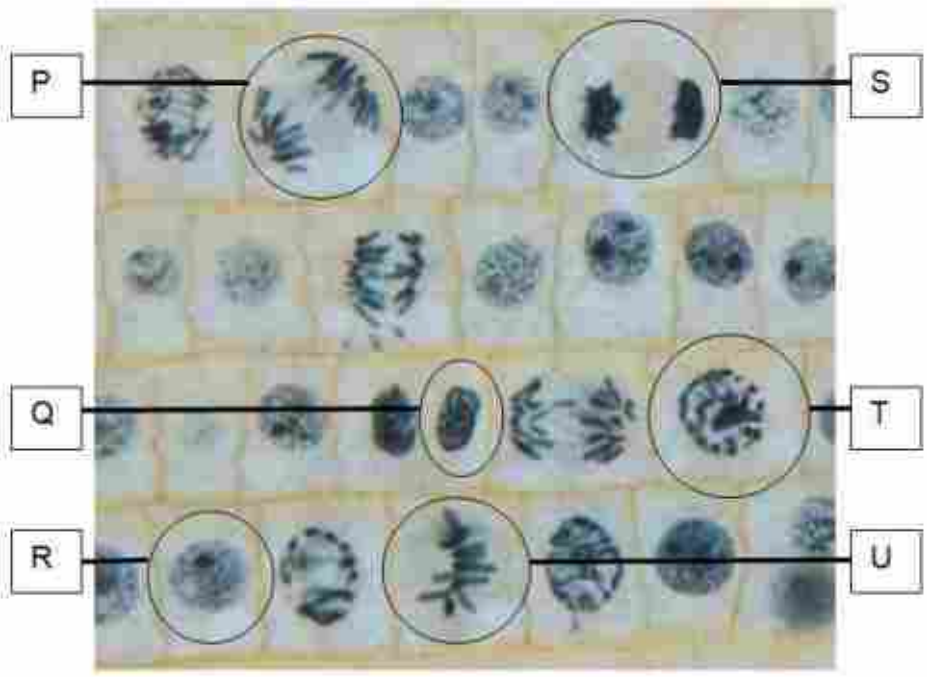
A Sister chromatids are separated at anaphase II

B Homologous chromosomes are separated in anaphase I.

C Cells at the beginning of Meiosis II are haploid

D Homologous chromosomes are paired on the metaphase plate in metaphase I.

10. The photographs below show a section of the onion root tip. The cells are at different stages of mitosis.



Which of the following shows the correct sequence of events that occurs in these cells?

A R, T, U, P, S, Q

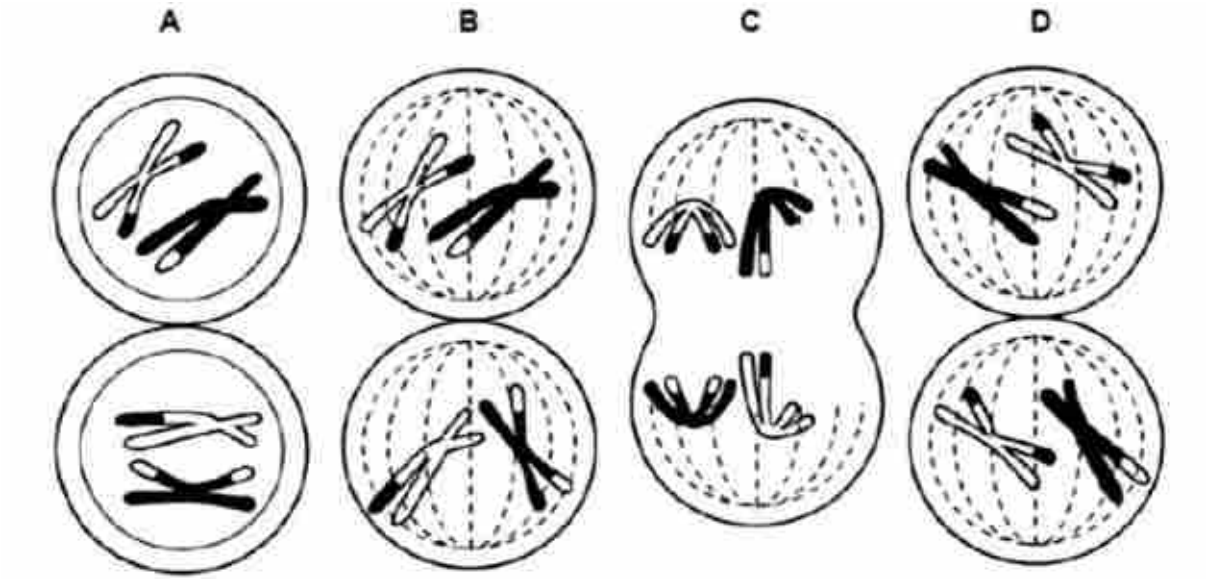
B T, U, P, S, Q, R

C Q, T, P, S, U, R

D T, R, P, S, U, Q

11. The diagram shows anaphase I of meiosis.

Which diagram shows metaphase II as meiosis continues in this cell?



12. For a double-stranded DNA, which of the following base ratios always equals 1?

I. (A + T) / (G + C)
II. (A + G) / (C + T)
III. C / G
IV. (G + T) / (A + C)
V. A / G

A **I** and **III**

B **I**, **II** and **III**

C **II**, **III** and **IV**

D **III, IV** and **V**

13. The diagram below is a template strand of a DNA molecule.

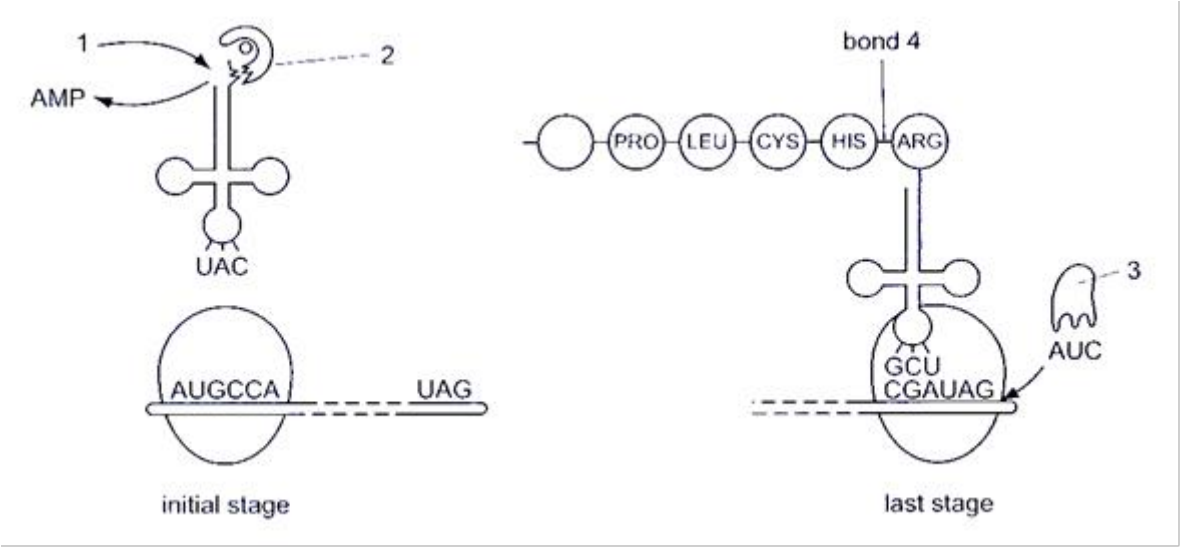
Promoter (18 nucleotides in length)	TAC	DNA sequence of 330 nucleotides	ATC

The number of amino acids in the protein coded by this template strand is

A 110 **B** 111 **C** 112 **D** 118

14. A number of molecules other than tRNA and mRNA are involved during translation.

The diagram shows some of these molecules and nucleotides in the codon and anticodon positions.



Which of the following is correct?

	1	2	3	4
A	ADP	Aminoacyl tRNA synthetase	Amino acid	Hydrogen bond
B	ADP	Amino acid	Translation releasing factor	Hydrogen bond
C	ATP	Aminoacyl tRNA synthetase	Aminoacyl tRNA	Peptide bond
D	ATP	Aminoacyl tRNA synthetase	Translation releasing factor	Peptide bond

15. With reference to a single eukaryotic gene, which of the following molecules contains the fewest number of nucleotides?

A A single strand of the original DNA segment

B A primary RNA transcript made from the original DNA segment

C A single strand of the original DNA segment after a point mutation

D A single strand of the complementary DNA (cDNA) made from the mature mRNA

16. DNA methylation is known to silence genes because it prevents transcription factors from binding. Which of the following best explains this phenomenon?

A DNA methylation modifies the shape of the transcription factor.

B DNA methylation prevents dimerization of DNA binding proteins.

C DNA methylation modifies the shape of the DNA element where the transcription factor binds.

D DNA methylation causes acetylation of histone proteins which causes heterochromatin to be formed.

17. Which of the following statements are true of the end-replication problem of linear DNA?

1. When a linear DNA molecule replicates, a gap is left at the 3' end of each new strand because DNA polymerase can only add nucleotides to a 3' end.
2. Telomerase prevents the end-replication problem from occurring.
3. Repeated rounds of replication produce shorter and shorter DNA molecules.
4. Prokaryotes do not have the end-replication problem.

A 1 and 2
B 1 and 4
C 2 and 3
D 3 and 4

18. Rhabdoviruses infect human cells. The genome of rhabdoviruses consists of a single-stranded RNA molecule whose sequence is complementary to the RNA sequence which functions as a messenger RNA. How is the "+" messenger RNA produced in such cells by rhabdovirus?

A Host cell RNA polymerase activity
B One portion of the infecting RNA is directly translated by host cell ribosomes.
C Reverse transcriptase activity
D The infecting virus particle contains an RNA-dependent RNA polymerase.

19. Some events that take place during generalized transduction are listed below.

I Bacterial host DNA is fragmented
II Bacterial DNA instead of viral DNA may be packaged in a phage capsid
III Recombination between donor DNA and recipient DNA
IV Phage infects a bacterial cell
V Phage DNA and proteins are made
VI Release of progeny virus

Which sequence of events is most accurate in describing generalized transduction?

A **IV, I, III, V,VI, II**

B **IV, I, V, II, VI,III**

C **IV, III, I, V, II,VI**

D **IV, V, I, III, II,VI**

20. A mutation that makes the regulatory gene of an inducible operon non-functional would result in

A continuous transcription of the operon's genes.
B reduced transcription of the operon's gene.
C accumulation of large quantities of a substrate for the catabolic pathway controlled by the operon.
D irreversible binding of the repressor to the promoter.

21. The coat colour of Norwegian cattle is mainly determined by the distribution of two pigments: red and black. Both pigments are made due to the action of the enzyme tyrosinase in cells called melanocytes. A normal level of activity of the enzyme leads to the production of red pigment, whilst a high activity allows only black pigment production. The activity of the enzyme is increased by melanocyte stimulating hormone (MSH), which binds to an MSH receptor.

The receptor is coded for by the **E** locus, which has the three alleles, $\mathbf{E^D}$, $\mathbf{E^A}$ and **e**. $\mathbf{E^D}$ is insensitive to protein A which blocks MSH receptor. $\mathbf{E^A}$ is sensitive to protein A which blocks MSH receptor. No receptor is produced by the recessive allele, **e**.

The dominant allele of a second gene, the **A** locus, codes for a protein which binds to and blocks the MSH receptor coded for by $\mathbf{E^A}$, thus preventing stimulation of tyrosinase activity in a melanocyte.

What would be the coat colours of cattle with the following genotypes?

	eeAa	**E^Aeaa**	**E^DeAa**	**E^AE^AAa**
A	Red	Black	Black	Red
B	Red	Black	Red	Red
C	Black	Red	Red	Black
D	Red	Red	Black	Black

22. Two parents have a son who has blood group A and phenylketonuria. One parent has blood group O and the other has blood group AB. Neither parent has phenylketonuria. What is the probability that the second child of these parents will be a girl with blood group B who does not have phenylketonuria?

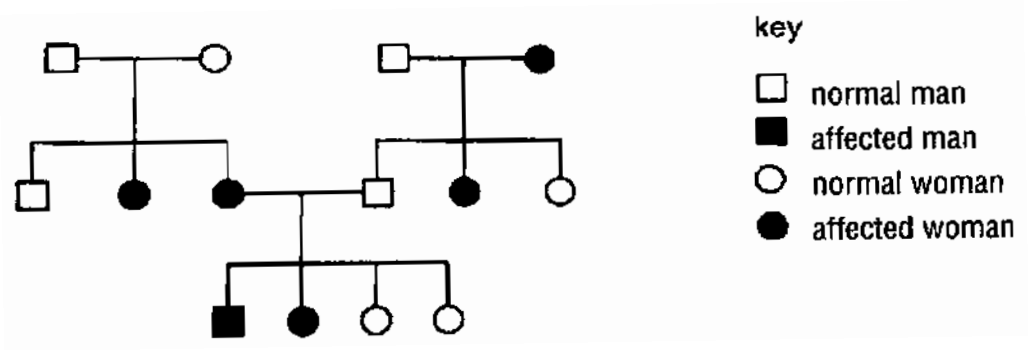
A 1 in 16

B 1 in 8

C 3 in 16

D 3 in 8

23. The family tree shows the inheritance of a skin condition.



What is the genetic basis of the skin condition?

A autosomal dominant

B sex-linked dominant

C autosomal recessive

D sex-linked recessive

24. In the board bean, a pure-breeding variety with green seeds and black hilums (the point of attached of the seed to the pod) was crossed with a pure-breeding variety with yellow seeds and white hilums. All the F_1 plants had yellow seeds and white hilums. When these were allowed to self-fertilise, the plants of the F_2 generation produced the following seeds.

Yellow seeds and white hilums	89
Yellow seeds and black hilums	28
Green seeds and white hilums	25
Green seeds and black hilums	45

A chi-squared (χ^2) test was performed to test the significance of the difference between the observed and expected results.

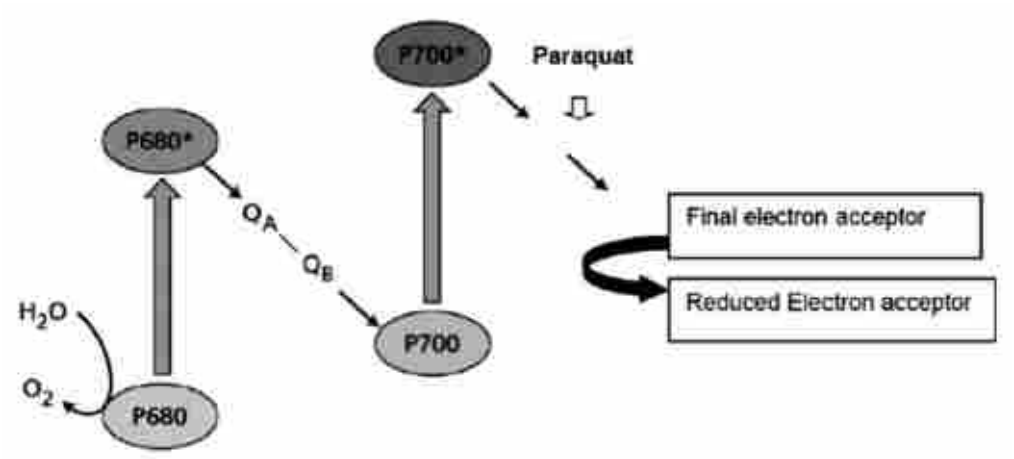
$$\chi^2 = \sum \frac{(O-E)^2}{E} \qquad \nu = c - 1$$

degrees of freedom	*p = 0.5*	*p = 0.1*	*p = 0.05*	*p = 0.01*	*p = 0.001*
1	0.46	2.71	3.84	6.64	10.83
2	1.39	4.6	5.99	9.21	13.82
3	2.37	6.25	7.82	11.34	16.27
4	3.36	7.78	9.49	13.28	18.46

Which combination correctly describes the results of the χ^2 test?

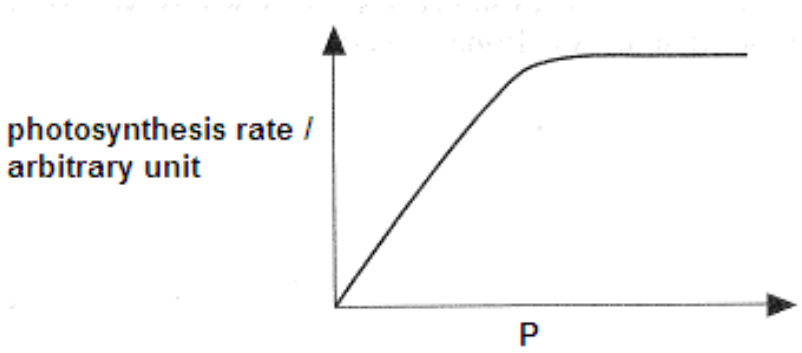
	number of degrees of freedom	*probability*	*these are two pairs of segregating alleles at two loci*
A	3	< 0.05	yes
B	3	< 0.05	no
C	4	> 0.05	yes
D	4	< 0.05	no

25. Paraquat is a poison that disrupts electron transport at the position indicated in the diagram. Paraquat was added to isolated chloroplasts. Which of the following correctly represents the outcomes in the presence of paraquat?



A Both light dependent reactions and Calvin cycle will not be able to proceed.
B Only Calvin cycle can proceed.
C Only light dependent reactions can occur.
D Both light dependent reactions and Calvin cycle can still proceed as per normal.

26. The following graph shows the relationship between the rates of photosynthesis with environmental factor **P**.

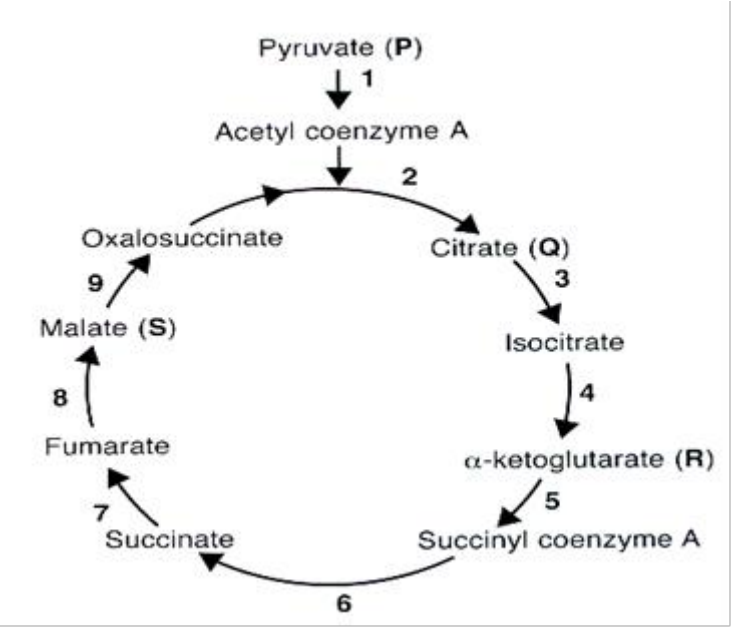


P most probably represents

1. carbon dioxide concentration.
2. oxygen concentration.
3. light intensity.
4. temperature.

A ***1*** and ***2*** **B** ***1*** and ***3*** **C** ***1*** and ***4*** **D** ***1***, ***3*** and ***4***

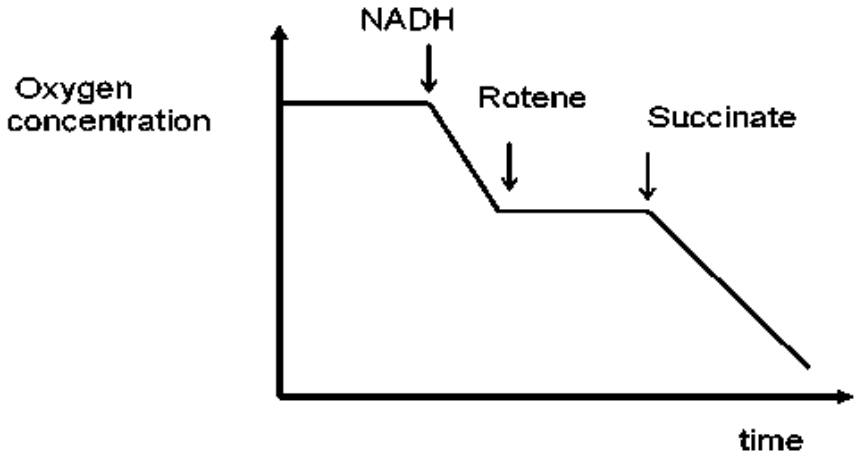
27. The diagram below shows the Krebs Cycle.



At which stages are carbon atoms removed?

A 1, 4 and 7
B 1, 4 and 5
C 2, 4 and 5
D 4, 5 and 8

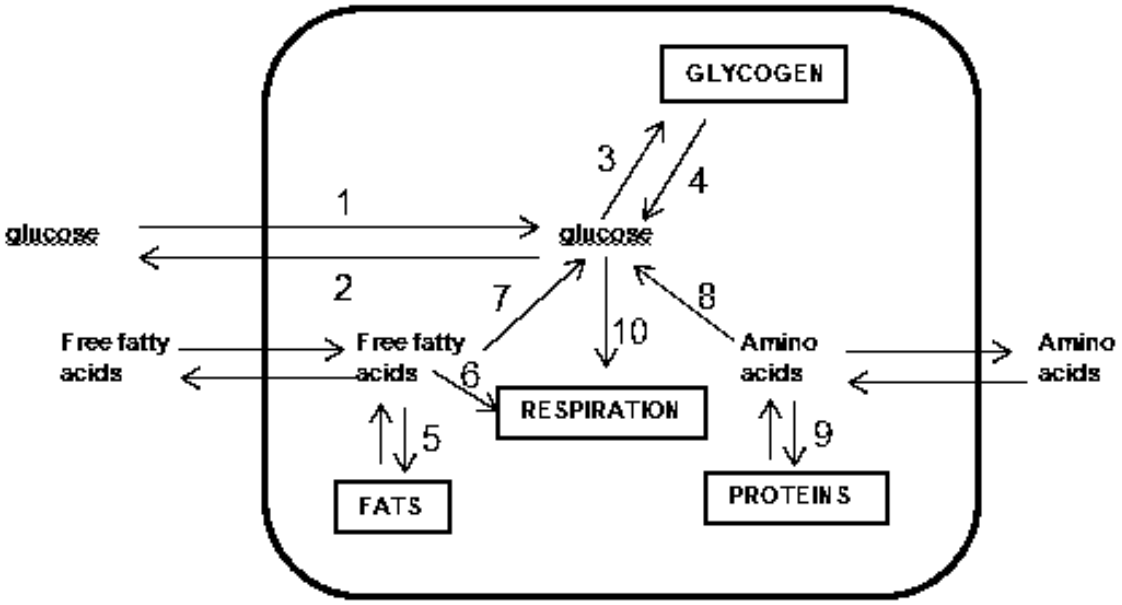
28. A suspension of mitochondria was prepared in a buffer containing ADP and inorganic phosphate (Pi). The oxygen concentration in the buffer was monitored carefully and recorded as shown below. At the times indicated, a specific reagent was added to the buffer. Throughout the experiment, the concentrations of ADP and Pi were in excess.



Which one of the following shows correctly from the highest to the lowest, the rate of ATP production after the addition of the three chemicals?

	Highest rate of ATP production	⟶	***Lowest rate of ATP production***
A	NADH	Succinate	Rotene
B	Succinate	NADH	Rotene
C	Rotene	NADH	Succinate
D	Rotene	Succinate	NADH

29. The diagram below shows some biochemical pathways in a liver cell. During which processes will the hormone glucagon exert an effect?



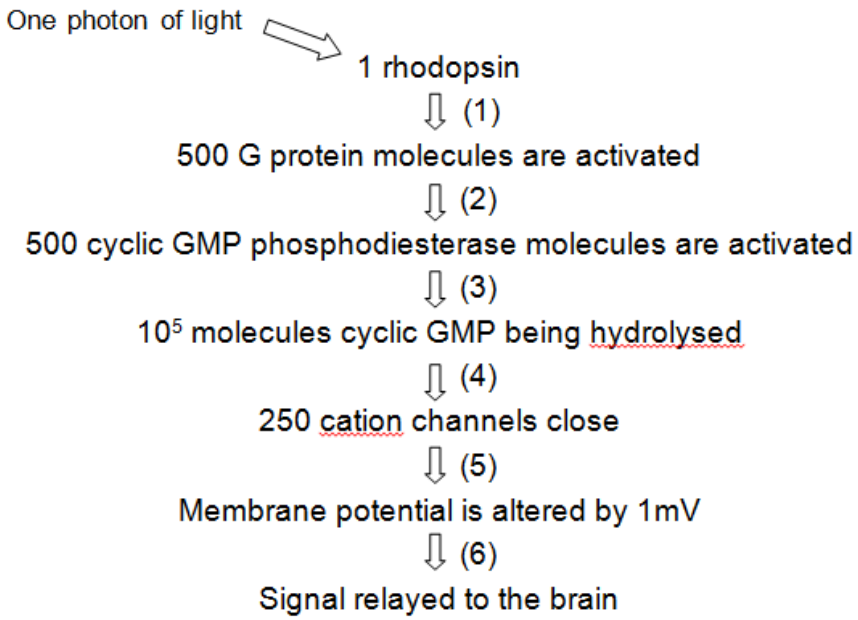
A (1), (3), (5), (9)

B (1), (4), (8), (10)

C (2), (7), (9), (10)

D (4), (6), (7), (8)

30. Rhodopsin, a light sensitive pigment that is present on the rods in the eyes. Rhodopsin is a G protein coupled receptor. The flow chart below shows how the chain of reactions that occur when rhodopsin absorbs a photon of light.



Identify the stages where *amplification* and *cellular responses* have occurred.

	Amplification	***Cellular response***
A	1, 2, 3, 4, 5	6
B	1, 3	1, 2, 3, 4, 5, 6
C	1, 3	5
D	2, 3	5

31. A neurone is undergoing relative refractory period. Which of the following statements is true?

A Membrane potential is less negative than resting potential.

B There is delayed closing of voltage-gated potassium channels.

C It is possible to initiate another action potential if a weaker stimulus is applied.

D It is impossible to initiate another action potential regardless of the stimulus strength.

32. Tetrodotoxin, a puffer fish toxin, blocks voltage-gated sodium channels. Black widow spider's venom causes the voltage-gated calcium channels to be constantly open. Crotoxin binds irreversibly to acetylcholine receptors. What will happen to the transmission of nerve impulses if each toxin is applied?

	Tetrodotoxin	**Black widow spider's venom**	**Crotoxin**
A	block action potentials along axon	reduce transmission of impulse across synapse	increase transmission of impulse across synapse
B	increase transmission of impulse across synapse	reduce transmission of impulse across synapse	block action potentials along axon
C	block action potentials along axon	increase transmission of impulse across synapse	reduce transmission of impulse across synapse
D	reduce transmission of impulse across synapse	block action potentials along axon	increase transmission of impulse across synapse

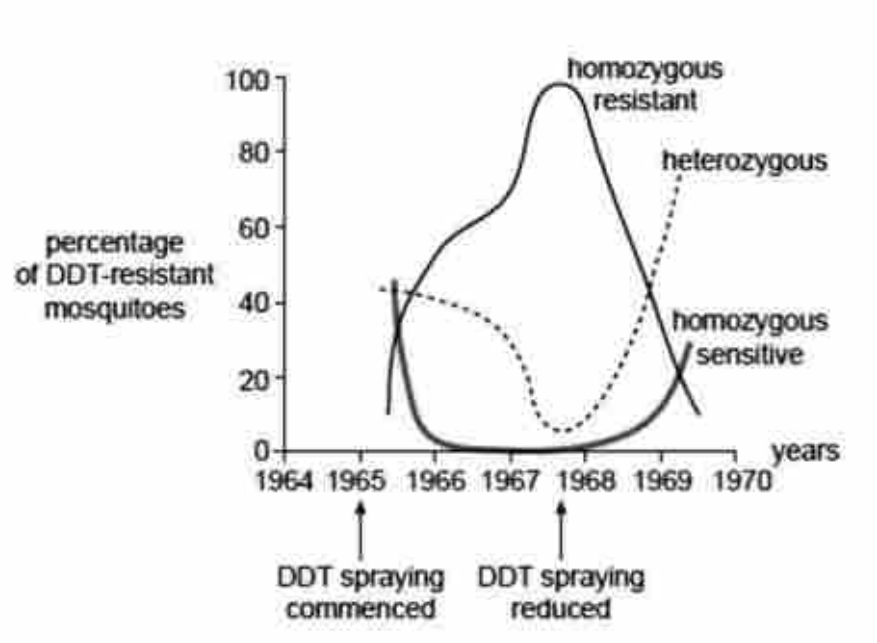
33. Members of two different species possess a similar-looking structure that they use in a similar fashion to perform the same function. Which information would best help distinguish between an explanation based on homology versus one based on convergent evolution?

A The two species live at great distance from each other.
B The two species share many proteins in common, and the nucleotide sequences that code for these proteins are almost identical.
C The sizes of the structures in adult members of both species are similar in size.
D Both species are well adapted to their particular environments.

34. In the mid-1960s, DDT was widely used as an insecticide against mosquitoes. The sensitivity to insecticide in mosquitoes is determined by a single gene that has two alleles.

allele **1** : resistant to DDT
allele **2** : sensitive to DDT

Over several years genotypic frequencies were measured in a population of mosquito larvae. The graph below shows the results.



Analysis of the graph reveals that in the population

A when spraying levels declined, heterozygous advantage occurred.

B there were no alleles for sensitivity present in the population in 1967.

C the number of alleles for resistance was equal to the number for sensitivity in 1966.

D the homozygous resistant genotype was unable to produce offspring at low spraying levels.

35. Which of the following statements is/are true of genetic drift?

(i) Genetic drift requires the presence of variation.

(ii) Genetic drift can result in the loss of beneficial alleles.

(iii) Founder effect and genetic bottleneck drive genetic drift

(iv) Genetic drift occurs in small population only

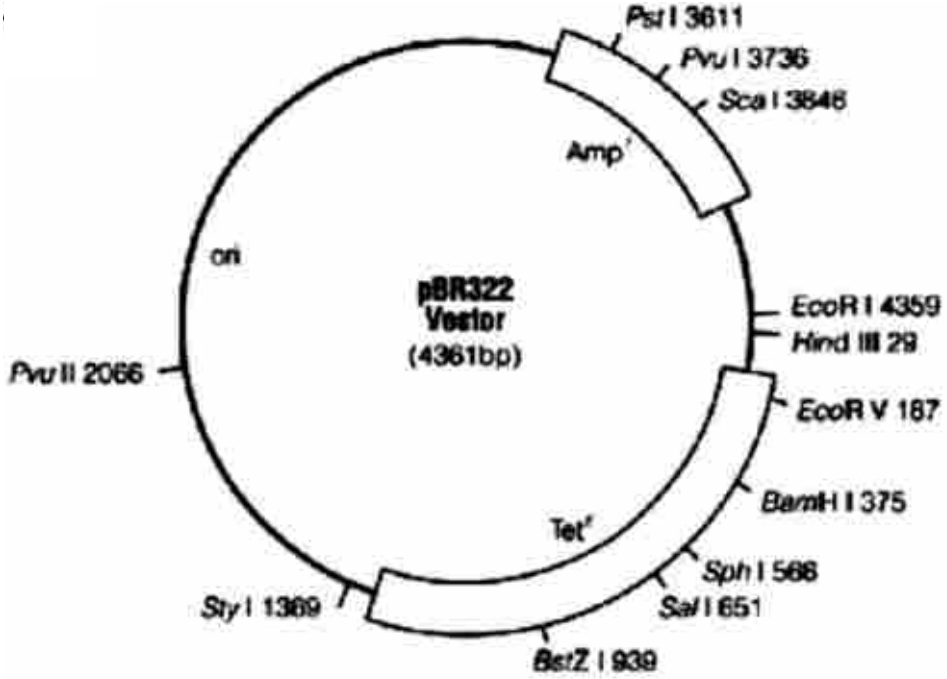
A (i) and (iv) only

B (ii) and (iii) only

C (i), (ii) and (iii) only

D (ii), (iii) and (iv) only

36. pBR322 vector is used to clone a eukaryotic gene which has been digested by the restriction endonuclease BamHI.



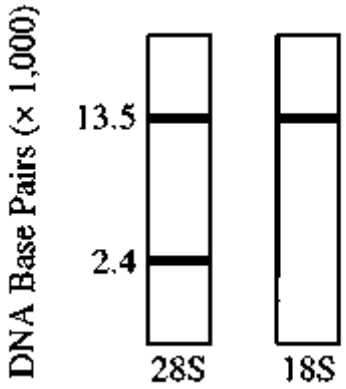
Following transformation, bacterial cells were grown in four different media, as shown below:

I nutrient broth plus ampicillin
II nutrient broth plus tetracycline
III nutrient broth plus ampicillin and tetracycline
IV nutrient broth without antibiotics

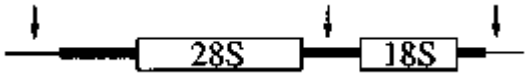
In which media would bacterial cells that contain the recombinant plasmids grow in?

A I and II
B I and III
C I and IV
D IV only

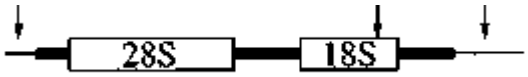
37. The autoradiograms obtained below (after electrophoresis and Southern Blotting) show human DNA digested with a specific restriction enzyme and probed with labeled rRNA. In the autoradiogram on the left, the probe was 28S rRNA; at the right, the probe was 18S rRNA.

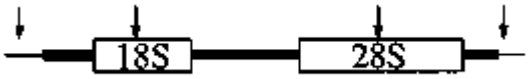


If the arrows in the following map show the location of the restriction sites of this restriction enzyme, which map *best* explains the results shown above?

A


B


C


D


38. Which of the following statements are **true** about all stem cells?

I Stem cells can be induced to differentiate by environmental signals.
II Stem cells are easily isolated and propagated
III Stem cells are able to develop into whole organisms if implanted into the womb
IV Stem cells make more stem cells under appropriate conditions.

A I and IV

B II and III

C I, III and IV

D All of the above

39. Non -viral *ex vivo* transfer of a gene encoding coagulation factor VII was performed using fibroblast cells isolated from patients suffering from severe haemophilia A.

What is the sequence of events for the *ex vivo* transfer of the gene encoding coagulation factor VIII?

1 Transfection with plasmids containing the gene encoding coagulation factor VII

2 Implantation of cells into patients

3 Isolation of fibroblasts

4 Selection and cloning of cells expressing coagulation factor VII

A 2, 3, 1, 4

B 3, 1, 4, 2

C 3, 2, 4, 1

D 3, 4, 2, 1

40. Maize varieties are being developed in which the leaves produce proteins that are toxic to insects. The DNA coding for these toxic proteins was inserted into a maize chromosome via a bacterial plasmid. Many people are opposed to this process.

Which objection is **not** biologically valid?

A Beneficial insects may be killed if they eat genetically modified maize.

B Genes for antibiotic resistance are present in plasmids and these genes may be passed to harmful bacteria.

C Hybridisation may transfer the bacterial genes from maize to weeds, giving the weed species new and harmful characteristics.

D Mutations may be caused in cattle or humans that eat the genetically modified maize.

End of Paper

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CANDIDATE NAME (CG) _____ *INDEX NUMBER* _____

SERANGOON JUNIOR COLLEGE
JC2 Preliminary Examination 2016

BIOLOGY
Higher 2

Paper 3

19th SEP 2016/ Monday
2 hours

Additional materials:
Answer paper

READ THESE INSTRUCTIONS FIRST

Write your name and index number in the spaces at the top of this page and on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in all the sections.

.

At the end of examination,
1. fasten all your work securely together

FOR EXAMINER'S USE	
1	/14
2	/14
3	/12
	/40
4	/12
5	/20
TOTAL	/72

INFORMATION FOR CANDIDATES
The intended number of marks is given in brackets [ ] at the end of each question or part question.

This question paper consists of 14 printed pages
Answer **all** questions

Question 1

The first ever gene therapy trial was initiated in 1990 by Dr William French Anderson to treat a four year old girl named Ashanthi. Ashanthi was suffering from severe combined immunodeficiency (SCID), a genetic disorder characterised by the absence of functional T-lyymphocytes.

In Ashanthi's case, the disease was caused by the absence of the enzyme adenosine deaminase (ADA-SCID). An alternative form of SCID is known as X-linked SCID.

(a) From your knowledge, contrast between the two forms of SCID mentioned in the paragraph above. [3]

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There were several *ex vivo* methods of gene therapy that were considered in Ashanthi's treatment, detailed in table 1.1. The virus vector used was a modified retrovirus.

Method	Description
A	• Normal ADA allele is introduced into viral vector • Recombinant virus is introduced into T-cells obtained from patient • Genetically modified cells are reintroduced into patient
B	• Normal ADA allele is introduced into viral vector • Recombinant virus is introduced into the cells derived from inner cell mass of blastocyst • Genetically modified cells are reintroduced into patient.
C	• Normal ADA allele is introduced into viral vector • Recombinant virus introduced into hematopoietic stem cells obtained from patient • Genetically modified cells are reintroduced into patient

Table 1.1

(b) With reference to the information presented in Table 1.1,

(i) Suggest one reason why *ex vivo* approach was utilised for gene therapy. [1]

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(ii) State the most preferred method of ex vivo gene therapy for ADA-SCID and justify the preference over the other 2 methods. [3]

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(c) Explain why the retrovirus was an efficient vector in the gene therapy of Ashanthi's condition. [2]

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Apart from diseases that plague human health, the effect of plant diseases on agriculture have also been in the spotlight. One such disease is the ringspot virus that plagues the papaya agricultural industry. Scientists have developed effective circumventive methods to tackle the problem of the ringspot virus through genetically modifying papaya. To do this, viral genes encoding capsid proteins were transferred to the papaya genome. These viral capsid proteins elicit something similar to an "immune response" from the papaya plant. Thus, the genetically modified papaya plants were resistant to infection by the papaya ringspot virus.

Figure 1.2 below depicts the comparative infection of transgenic and non-transgenic papaya in the 1995 field trail in Kapoho, Hawaii.

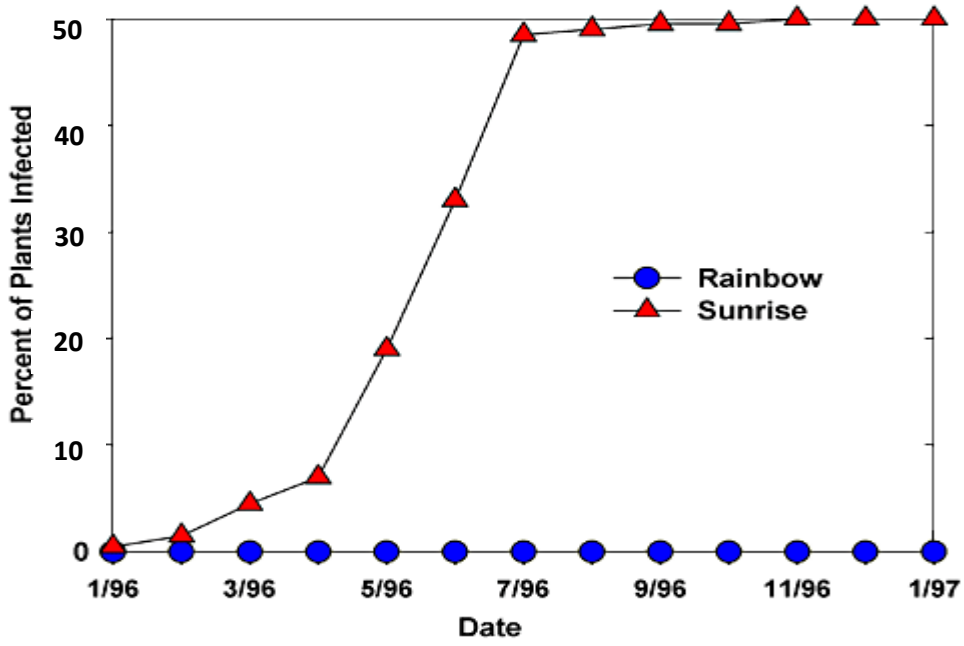

Figure 1.2

(d) With reference to Figure 1.2,

(i) Determine the identities of the transgenic and non-transgenic papaya species. [1]

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(ii) Evaluate and justify thoroughly the efficacy of the genetic intervention. [2]

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It was observed that three years later, the percentage of infected transgenic papaya species increased.

(e) Suggest and explain a possible reason for this phenomenon. [2]

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[Total: 14 marks]

Question 2

The location of the gene locus responsible for disease X was not discovered until 1985. Scientists used restriction fragment length polymorphism to discover the genetic markers associated with the disease. One such marker was a 950bp-long region known as XD15 that had been sequenced prior to 1985.

Samples of DNA were obtained from a family known to have the condition. The XD15 locus was amplified by polymerase chain reaction and mixed with *Pst*I and *Eco*RI in two separate restriction digests. The results of gel electrophoresis followed by southern blot of both restriction digests are shown in Figure. 2.1.

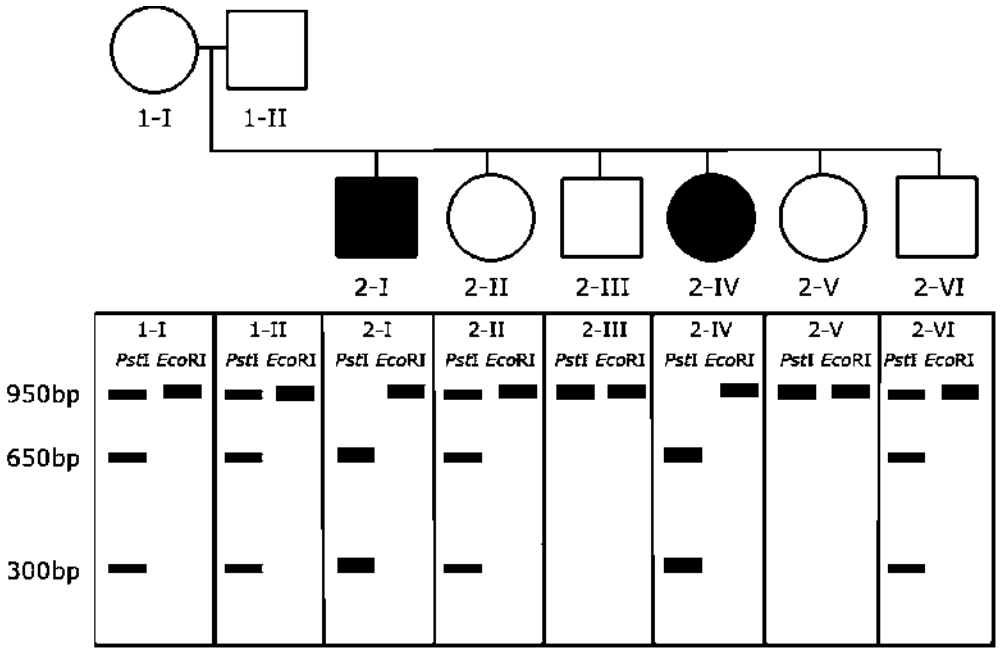

Figure. 2.1

(a) Using the information in Figure. 2.1,

(i) state and explain which restriction enzyme digest should be used to detect the XD15 genetic marker associated with disease X. [3]

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(ii) Draw a restriction map of the XD15 genetic marker that is associated with disease X.

Indicate on the restriction map the position of the radioactively-tagged probe that would enable visualization of the RFLP fragments. [2]

(b) Explain why genetic markers like XD15 can be used to detect the presence of disease-causing alleles. [2]

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The XD15 locus was amplified by polymerase chain reaction prior to gel electrophoresis and southern blot. The DNA sequence of the XD15 locus is shown in Figure. 2.2.

5' - GGATCCATCCCGATCGAAAGCTAGCTAGGATCC - 3'
3' - CCTAGGTAGGGCTAGCTTTCGATCGATCCTAGG - 5'

Figure. 2.2

(c) Design two 7-base long primers for the sequence to be amplified. [2]

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(d) Contrast between the process of PCR and DNA replication that occurs naturally in cells. [3]

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(e) Besides disease detection, RFLP analysis may be used for DNA fingerprinting as well. Explain one difference in the approach employed during RFLP analysis for both processes (disease detection and DNA fingerprinting). [2]

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[Total: 14 marks]

Question 3

(a) Plant growth regulators (PGR) such as auxin, cytokinin and ethylene are naturally produced in plants and are important in determination of the developmental pathway of plant cells.

Synthetic analogues that can be mass produced are frequently used in plant tissue culture instead of the natural PGR.

Table 3.1 summarizes the general characteristics and roles of some natural and synthetic PGR.

Type of PGR	Examples	Role
Auxins	IAA(natural) - unstable to heat & light	Promote cell division and cell growth Root initiation (when auxin:cytokinin is high)
	2,4-D(synthetic) – stable to heat & light	
Cytokinins	2iP(natural) – unstable to heat & light	Promotes cell division Shoot formation (when auxin:cytokinin is low)
	Kinetin(synthetic) - stable to heat & light	
Abscisic acid (ABA)	-	Inhibits cell division Maturation of somatic embryos Abscission (i.e. shedding) of plant leaves Seed dormancy Induces stomatal closure to reduce water loss by transpiration
Ethylene	-	Abscission (i.e. shedding) of leaves and flowers Seed and bud dormancy by growth inhibition Fruit ripening

Table 3.1

Prunus lannesiana is an early-flowering cherry (only in spring) in Japan Izu peninsula. It is commonly known as Sakura or Japanese Cherry. Researchers are keen to propagate *P. lannesiana* from sterilized explants by micropropagation due to the advantages that the technique offers. Hence, a study was made to analyse the concentration of PGR present in the *P. lannesiana* in the four seasons and the results were summarized in Table 3.2.

Conc. of PGR / arbitrary unit \ **Season**	**Spring (Mar-May)**	**Summer (June – Aug)**	**Autumn (Sep-Nov)**	**Winter (Dec – Feb)**
IAA (auxin)	15	20	25	30
2iP (cytokinin)	10	15	10	5
ABA	5	5	12	15
Ethylene	12 – 20	18	16	14

Table 3.2

Table 3.3 illustrates the physiological development of *P. lannesiana* in the various seasons.

Season	**Spring**	**Summer**	**Autumn**	**Winter**
Shoot development	Very Active	Active	Minimal	Nil
Root development	Minimal	Moderate	Active	Very Active
Leaves development	Very Active	Active	Senescence (leaves turning autumn yellow) and abscission	Nil
Flowers development	Short full bloom in early spring, followed by senescence	Nil	Nil	Buds develop but dormant in late winter
Fruit and seed development	Fruit and seed development in late spring	Seed maturation	Seed dormant	Seed dormant

Table 3.3

(i) State one economical limitation of micropropagation. [1]

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(ii) Suggest why synthetic PGR (e.g. 2,4-D and Kinetin) are used instead of natural PGR (e.g. IAA and 2iP) in plant tissue culture. [1]

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(iii) Using the information provided in Table 3.2 and Table 3.3, explain the effect of the change in the auxin:cytokinin ratio from Spring to Winter and vice versa. [4]

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(b) The Salmon Genome Project (SGP) is developed to increase knowledge of the biology of Atlantic salmon and aid agricultural breeding of the fish.

(i) Describe how the SGP serves to increase knowledge of the biology of Atlantic salmon. [2]

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In order to produce transgenic salmon expressing salmon growth hormone, sGH, the coding sequence of sGH gene is isolated from a library and cloned, using *Sac* I, into the plasmid expression vector, pBluescript II SK. The plasmid map is shown in Figure. 3.1.

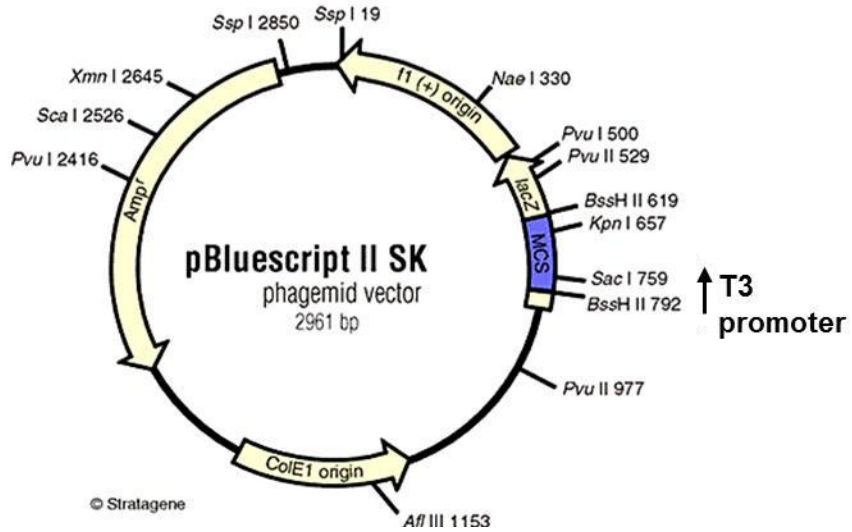

Figure 3.1

(ii) With reference to figure 3.1, describe the features of the multiple cloning site (MCS). [2]

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Subsequent to insertion of sGH gene into pBlueScript II SK, transformation into *E. coli* cells was carried out and some colonies were obtained. The plasmid DNA was extracted, digested with *Sac* I and the restriction fragments were separated in gel electrophoresis.

(iii) It was found that the recombinant plasmid with sGH gene inserted yielded no polypeptide. With reference to Fig. 3.1, state and explain a reason for this. [2]

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[Total: 12 marks]

Planning Question - Write your answers on the separate answer paper provided.

Question 4

Cefazolin is an antibiotic that disrupts the synthesis of bacterial peptidoglycan cell by preventing the formation of peptide bonds. It is bactericidal (kills bacteria) and is effective against gram-positive bacteria.

Streptococcus pneumoniae is a bacterium responsible for conditions like pneumonia and bacterial meningitis. It is a gram-positive bacterium which establishes itself as small white colonies. Discs containing cefazolin can be placed on an agar plate containing *Streptococcus pneumoniae*. If the cefazolin has been effective against *Streptococcus pneumonia,* a clear zone will be seen around the disc as shown in Figure 4.1.

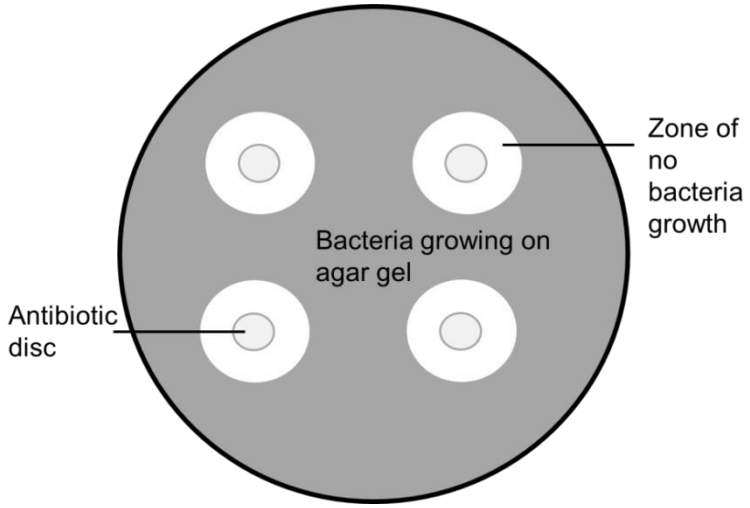


Figure 4.1

You are to plan but not carry out an experiment to investigate the effectiveness of different concentrations of cefazolin on the growth of *Streptococcus pneumoniae*.

Your plan must be based on the assumption that you have been provided with the following equipment and materials:

- Bunsen burner, to enable good aseptic conditions
- Bacterial culture in nutrient broth
- Molten nutrient agar
- Distilled water
- Sterile 90mm Petri dishes
- Sterile loops (to plate bacteria onto nutrient agar)
- $1cm^3$ pipette
- Filter paper discs
- Forceps
- Vernier calipers
- 1% cefazolin solution
- Bactericidal disinfectant for containment of used forceps and pipettes, also to clean work surfaces

Your plan should include:

- a clear and helpful structure such that the method you use is able to be repeated by anyone reading it
- an explanation of theory to support your practical procedure
- an explanation of the dependent and independent variables involved
- relevant, clearly labeled diagrams, if necessary
- proposed layout of results tables and graphs with clear headings and labels
- correct use of scientific and technical terms
- safety measures to minimise any risks associated with the proposed experiment

[Total: 12 marks]

Free-response question

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labeled diagrams, where appropriate.
Your answers must be in continuous prose where appropriate.
Your answers must be set out in sections (a), (b), etc as indicated in the question.

Question 5

(a) Discuss the advantages and evolutionary consequences of using plant tissue culture to propagate transgenic plants. [8]

(b) Outline the ethical and social implications of genetically modified organisms. [6]

(c) Explain why gene therapy is opined to have limited success in the treatment of genetic diseases. [6]

CANDIDATE NAME _____ INDEX NUMBER _____

CG _____

SERANGOON JUNIOR COLLEGE
JC2 Preliminary Examination 2016

H2 BIOLOGY
9648

Paper 2

2 Hours

MARK SCHEME

Date / Day: /

INSTRUCTIONS TO CANDIDATES
Write your name, CG and index number in the spaces at the top of this page and on all separate writing papers used.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.

Section A
Answer **all** questions.
Write your answers in spaces provided on the question paper.

Section B
Answer **only one** question out of two.
Write your answers on the separate answer paper provided.

INFORMATION FOR CANDIDATES
The intended number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINER'S USE	
Section A	
1	**/11**
2	**/**
3	**/**
4	**/13**
5	**/**
6	**/**
7	**/10**
Total	**/80**
Section B	
9 OR 10	**/20**
TOTAL	**/100**

This question paper consists of 23 printed pages and 1 blank pages

SECTION A

Answer **all** questions.

Question 1

Figure 1.1 below depicts the molecular structure of a basic unit of collagen.

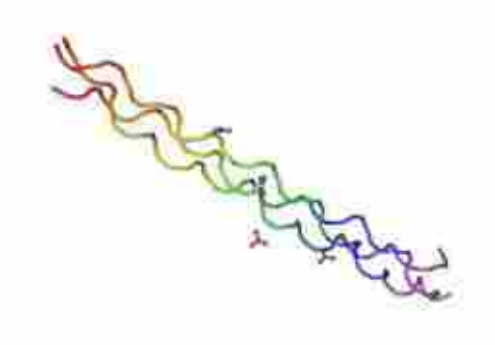


Figure 1.1

(a) State the name given to such a basic unit of collagen. [1]

- Tropocollagen.

(b) Describe how the monomers of this basic unit are joined together to achieve the final molecular configuration as shown in Figure 1.1. [3]

- Monomers are amino acids
- Join together via condensation reaction to form peptide bonds with a loss of water molecules forming a polypeptide
- Three such polypeptides join together via intermolecular hydrogen bonding between NH and CO groups to form tropocollagen

Collagen is normally found in animal connective tissue where its role is as a structural molecule. Figure 1.2 shows an electron micrograph of collagen.

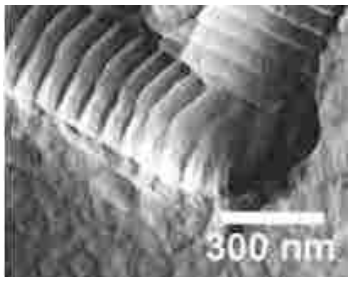


Figure 1.2

(c) Explain the banded appearance of collagen shown in Figure 1.2. [2]

- Due to **staggered arrangement/ longitudinal displacement** of tropocollagen subunits with respect to each other.
- Held by **covalent cross links** between adjacent tropocollagen subunits.

(d) Explain why collagen is able play the role of a structural molecule. [2]

- Large molecular size so insoluble.
- large **number of hydrophobic, non-polar amino acids** that face the outside of the triple helix so insoluble

  (Max 1 for solubility)

- Several tropocollagen molecules are further **covalent cross-linked** with neighbouring tropocollagen molecules running parallel to them to form a collagen fibrils/fibres giving great tensile strength.

Another common structural molecule found in nature is cellulose. Cellulose is the main structural molecule in plants.

(e) Compare the structures of cellulose and collagen. [3]

Similarities:

- Both have intermolecular hydrogen bonding
- Both associate to form fibrous structures.

Differences:

- β-glucose monomer in cellulose vs amino acid monomer in collagen
- β 1,4 Glycosidic bond in cellulose vs peptide bond in collagen.
- Cellulose is a straight chain structure while collagen is helical

[Total: 11 marks]

Question 2

The following Figure 2.1 shows an electron micrograph of several cells.

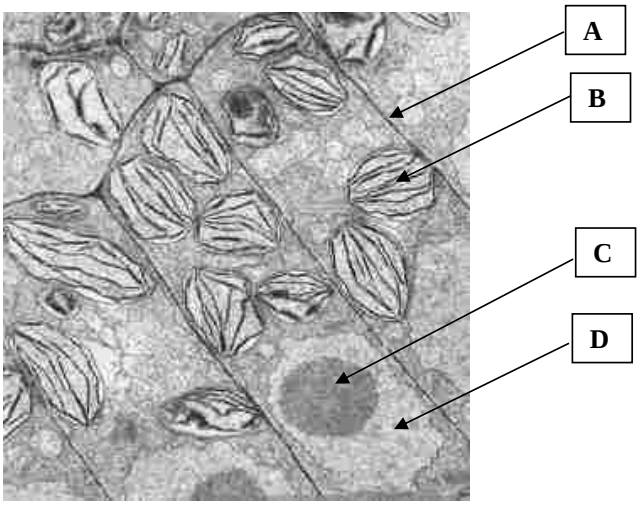


Figure 2.1

(a) Label the organelles **A – D**. [4]

A – Cell Wall

B - Chloroplast

C - Nucleolus

D – Nucleus

(b) Discuss the role of organelle C. [3]

- Contains rRNA genes
- Involved in the **synthesis of ribosomal RNA (rRNA) <u>via transcription</u>,**
- which is a constituent of **ribosomes.**
- **Also involved in the assembly of rRNA and ribosomal proteins** into **large and small subunits**

Max 3

(c) In the nucleoplasm of such cells, genetic material can be found. State the nature of this genetic material and briefly describe how this genetic material is organized. [3]

- Made up of DNA
- Organised into chromosomes
- Condensed around histone octamer and non-histone proteins

Such genetic material can take part in processes such as what is shown in **Figure 2.2**.

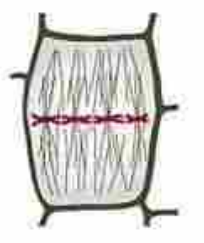


Figure 2.2

(d) With appropriate reasons, precisely identify the process shown in **Figure 2.2**. [3]

- Mitosis Metaphase
- Chromosome lined up at the equator of the cell
- No nuclear envelope visible
- Only one row and not two so not meiosis

Max 3

(e) Suggest the significance of the **next stage** of the above process. [2]

- Next stage is anaphase (no credit for stating this)
- Separates sister chromatids into individual chromosomes
- Allows each replicated chromatid/chromosome to move to the pole of the cell
- Ensures that each daughter cell will have the original chromosome number restored.
- AVP

Max 2

[Total: 15 marks]

Comment [WU1]: Just a suggestion: Can consider this question (from 2015 P2 to up the level a little, although the next question already touches on operon.. :☺

In the nucleoplasm of such cells, genetic material can be found. State 2 ways in which the organization of genes found in these cells differ from that found in bacterium. [2]

Suggest one advantage of this organization in bacterium. [1]

Question 3

A set of abundant nucleoid-associated proteins (NAPs) play key functions in organizing the bacterial chromosome and regulating gene transcription globally. Histone-like nucleoid structuring protein (H-NS) is representative of a family of NAPs that are widespread across bacterial species. They have drawn extensive attention due to their crucial function in gene silencing in bacterial pathogens. Figure 3.1 illustrates how H-NS is able to silence genes of bacterial pathogens. *(Information obtained from Biophysical Journal Oct 2015, 109(7))*

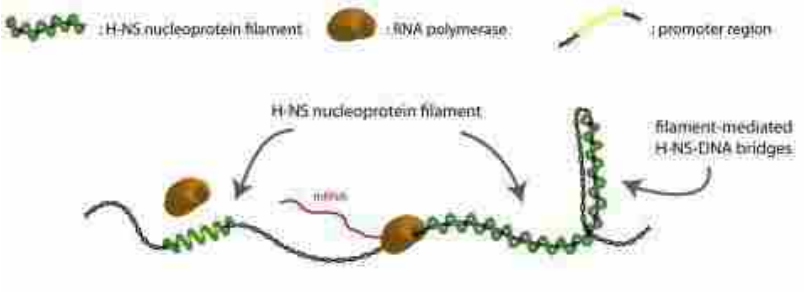


Figure 3.1

(a) State the name of one bacterial pathogen. [1]

- Bacteriophage

(b) Explain the role of RNA polymerase in a bacterial cell. [3]

- Involved in transcription, leading to the production of messenger RNA.
- Messenger RNA acts as a template for translation into proteins at ribosomes.
- Binds to promoter of gene, bringing ribonucleotides together, joining them via phosphodiester bonds

(c) Using the information from Figure 3.1, suggest how H-NS is able to silence genes. [2]

- Inhibits binding of RNA polymerase to the promoter region
- Blocks the movement of RNA polymerase along the gene

The following figure shows regulation of transcription in the trp operon of a bacterial cell.

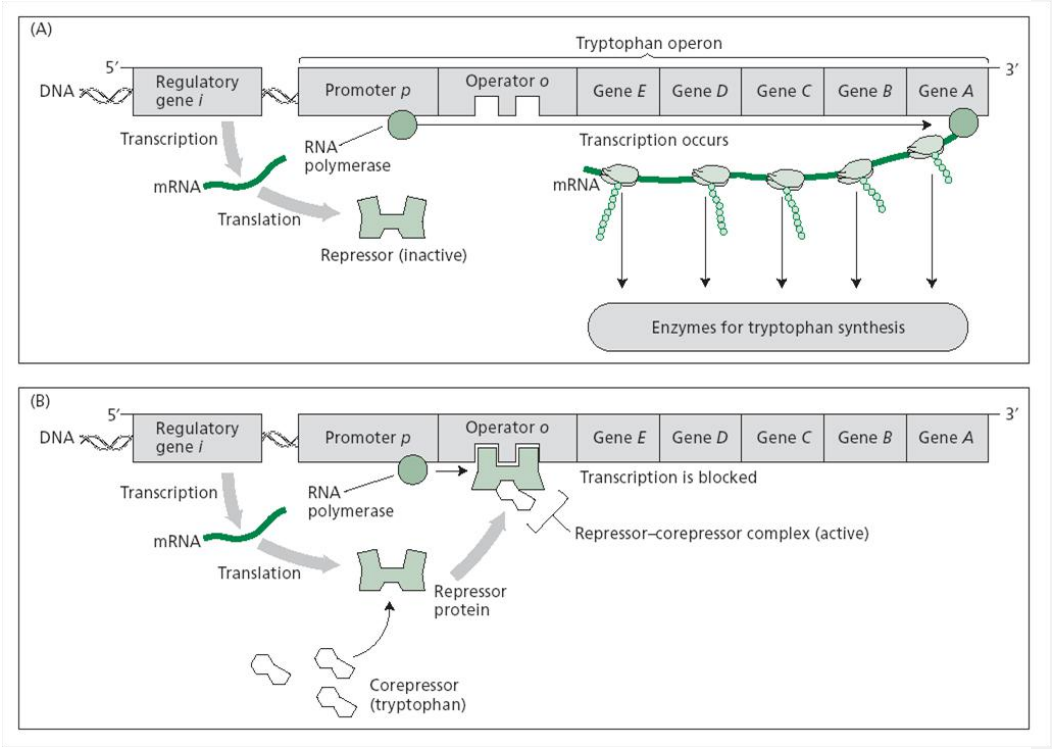


Figure 3.2

(d) Using the information in figure 3.2, describe the process of negative regulation in bacterial operons. [4]

- Involves the use of a repressor molecule
- In the trp operon example, repressor is made in the inactive form, operon default on/transcription occurs.
- In the presence of co-repressor tryptophan, repressor is activated = repressor-corepressor complex.
- repressor-corepressor complex binds to operator, block RNA polymerase and operon is switched off/transcription does not occur.

(e) Suggest why tryptophan is the ideal co-repressor for this operon. [2]

- Enzymes produced by operon result in the synthesis of tryptophan.
- Tryptophan thus inhibits its own production when it is in excess.
- Acts as an end product inhibitor

Max 2

(f) The lac operon is an example of an inducible operon system. Contrast negative regulation of the lac operon with that of the trp operon. [2]

Lac operon	**Trp operon**
Repressor produced in the active form	Repressor produced in the inactive form
Requires allolactose as an inducer	Requires tryptophan as a co-repressor

Question 4

The diagram shows the chromosome from a plant cell in which 2n = 4. The dominant allele **A** of a gene results in red flower and pink spines on the fruit. The recessive allele, **a**, gives yellow flower and green spines. The dominant allele **B** intensifies the colour of the pink spines to red. The plant is heterozygous as shown below:

(a) The plant was selfed. Give the phenotypic ratio of the offspring. Explain your answer. [3]

1. 9 red flower and red spines on the fruit : 3 red flower with pink spines on the fruit : 4 yellow flower with green spines on the fruit;
2. Due to epistasis;
3. Offspring with genotype aa and B/b alleles will have yellow flower and green spines on the fruit as pink is not expressed so the colour cannot be intensify even in the presence of B allele/ recessive alleles a **mask** the dominant allele B;

The plant is also heterozygous for another characteristic, the height of the plant. Allele T = tall is dominant to allele t = dwarf. A cross was made between the tall, red-flowered plant with a dwarf, yellow-flowered plant and produced a large number of offspring. **Table 4.1** shows the results.

Table 4.1

Phenotype	**Number of offspring**
Tall, red-flowered plant	35
Tall, yellow-flowered plant	14
Dwarf, red-flowered plant	16
Dwarf, yellow-flowered plant	33

(b) The ratio of phenotypes expected in a cross such as this is 1:1:1:1. Chi-squared test was performed on these data giving a calculated value of X^2 of 14.64.

Table 4.2: Distribution of X^2

Degrees of freedom	Probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(i) Use the calculated value of X^2 and the table of probability provided in **Table 4.2** to find the probability of the results of the cross is due to chance. [1]

1. Probability: $0.001 < p < 0.01$

(ii) State what conclusions may be drawn from the probability found in (b)(i). [2]

1. There is significant difference between expected results and actual results/ Probability of the actual results deviating from the expected results due to chance is low since it is less than 0.05
2. Inheritance pattern does not conform to the 1:1:1:1 ratio

(iii) Explain the difference between the expected and actual results of the test cross. [3]

1. Difference is due to the two genes being linked together
2. Tendency for these two genotypes (AT and at) of the gametes to be produced → more tall, red-flowered plant and dwarf, yellow-flowered plants are produced
3. Due to crossing over during Prophase I of meiosis, new recombinants where A is linked to t and a is linked to T are produced, resulting in tall, yellow-flowered plants and dwarf, red-flowered plants.

(c) Briefly explain how another factor, besides crossing over, can bring about genetic variation in the offspring produced by a sexually reproducing organism (Exclude mutation from your answer). [1]

1. Independent assortment of homologous chromosomes during meiosis 1results in different combination of alleles into the gametes / 2^n possible combinations where n is the number of homologous pairs. (Rej: independent assortment without any sufficient elaboration)

OR

2. random fertilization/ fusion of gametes results in different genotypes/ combination of alleles in the offspring/ results from each gamete having different sets of chromosomes

In another completely different cross involving humans, the following results were obtained.

Phenotypes	Genotypes	Color of skin
Extremely dark	PPQQRR	6
Very dark	PpQQRR	5
Dark	PpQqRR	4
Intermediate	PpQqRr	3
Light	ppQqRr	2
Very light	ppqqRr	1
Extremely light	ppqqrr	0

(d) What is the term used to describe the range of phenotypes in the above example? [1]

1. Continuous Variation (Rej: Polygenic inheritance)

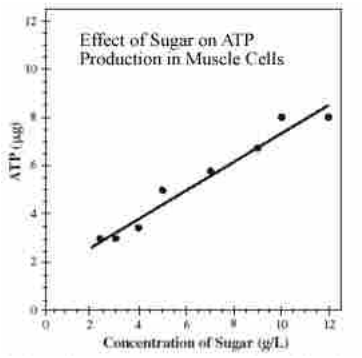
(e) Explain the genetic basis for the range of phenotypes seen. [2]

1. Human skin colour is controlled by **3 pairs/many** of independent genes. (rej: multiple alleles)
2. Cumulative/additive effect on the trait without complete dominance.

[Total: 13 marks]

Question 5

The following figure shows the effect of sugar levels on muscle cells.



(a) Describe and explain the effect of sugar on ATP production in muscle cells. [3]

1. As concentration of sugar increases from 2 to 12g/L ATP production increases from 2.5 to 8.5ug.
2. Sugar (Glucose) used in mitochondria of muscle cells in aerobic respiration/ description of stages of respiration **apart from only glycolysis**
3. Aerobic respiration produces ATP

(b) Suggest and explain what will happen to ATP production if the concentration of sugar continued to increase. [2]

1. It will plateau off
2. Possible limiting factors with example = rate of sugar uptake into muscle cell/ respiratory enzyme conc/ oxygen concentration AVP (Rej: limited number of cells or mitochondria)

The coenzyme cytochrome *c* oxidoreductase, is the third complex in the electron transport chain, playing a critical role in biochemical generation of ATP (oxidative phosphorylation).

(c) Explain how the coenzyme cytochrome c oxidoreductase may aid in the production of ATP in the electron transport chain. [3]

1. Serves as an electron carrier
2. Energy released when passing electrons used to pump/ actively transport H+ into intermembrane space/ create proton gradient
3. H+ then moves down a conc gradient through the stalked particle/ ATP synthase complex to make ATP from ADP and Pi.
4. AVP

(d) Actimycin A is known to inhibit the coenzyme cytochrome c oxidoreductase. Predict the effect actimycin A would have on the aerobic respiratory process. [2]

1. Electrons cannot move down the chain, ATP not made
2. NAD+ and FAD not regenerated
3. hence Krebs cycle and link reaction shut down, aerobic respiration shut down
4. AVP

Rej: inhibit ATP production unless accompanied by valid explanation.

Any 2

[Total: 10 marks]

Question 6

The following Figure 6.1 shows the synaptic knob of a synapse found in the sympathetic ganglion of frogs. Such synapses are unique as they contain receptors to the neurotransmitter noradrenaline (NE) on the pre-synaptic membrane itself. These are known as autoreceptors.

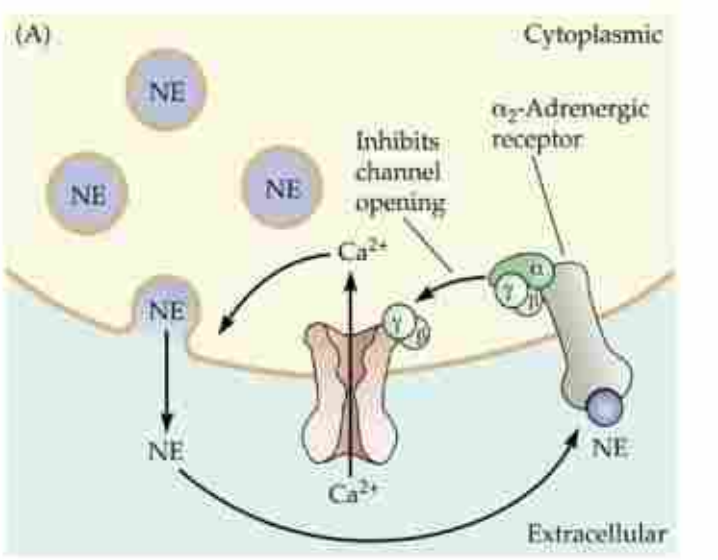


Figure 6.1

(a) State the name given to synapses that use noradrenaline as the neurotransmitter. [1]

- Adrenergic synapse

(b) Using the information given in Figure 6.1, explain how the release of noradrenaline at the pre-synaptic membrane may eventually inhibit the synapse itself. [3]

- Noradrenaline binds to α_2-Adrenegic receptor.
- Leads to the β & ϒ subunits moving to and binding with the Ca^{2+} channel thus inhibiting opening of Ca^{2+} channel, preventing Ca^{2+} influx.
- Prevents fusion of synaptic vesicles with presynaptic membrane.

(c) Suggest the significance of this self-inhibitory effect. [1]

- Rapid self-regulation of neurotransmitter release.
- AVP

(d) Explain one function of synapses. [2]

1. Ensure **one-way transmission of nerve impulses**. As only the presynaptic membrane can release neurotransmitter and only postsynaptic membrane has receptors that trigger an action potential.

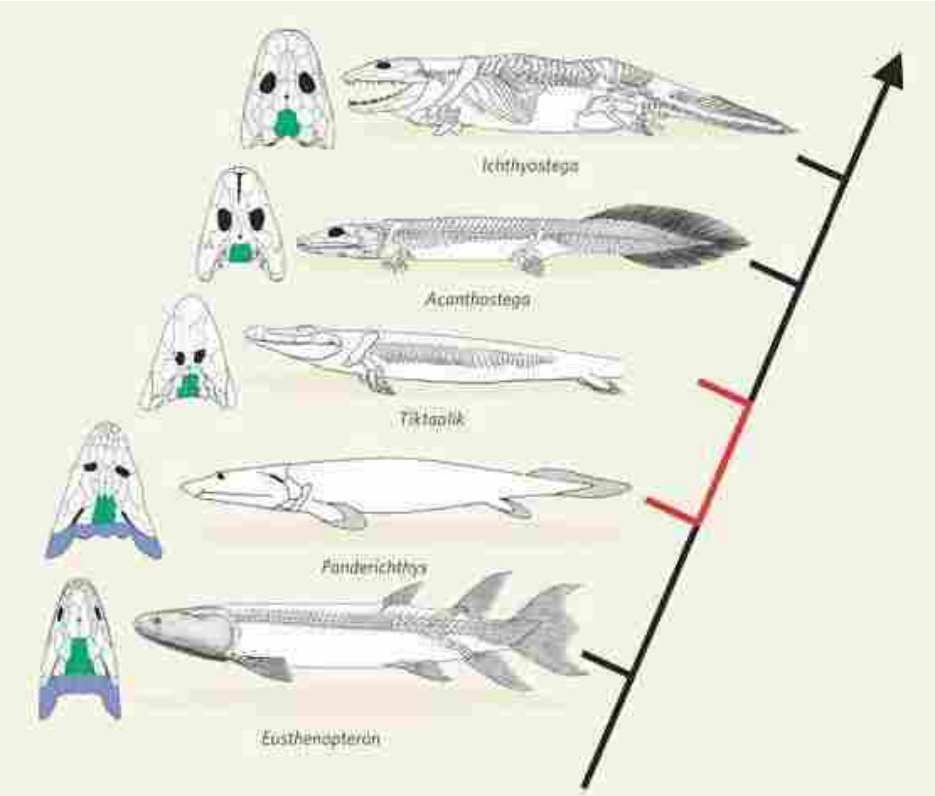
2. The post-synaptic neurone and synapses act as **a junction for the integration of stimuli** from **various sources** to **produce a co-ordinated response**. (Allow for alternative point on inhibition)

3. **Filter out** low-level stimuli that are of no significance, i.e. remove “background noise” from the body’s nervous system as all neurotransmitter will have been released but stimuli continues = adaptation

[Total: 7 marks]

Question 7

Figure 7.1 shows a series of fossils. This series depicts how land-based amphibians could have evolved from fishes. Tiktaalik hails from the Late Devonian period, about 360 million years ago, and is both chronologically and morphologically intermediate between two other major fossils in this series, the more fish-like *Panderichthys* and the more tetrapod-like *Acanthostega*.



(a) State the name given to fossils such as *Tiktaalik* that have characteristics from two seemingly diverse groups of organisms. [1]

- Transitional forms

(b) Explain how such fossil records can actually support Darwin's theory of evolution. [4]

- Similarities amongst group of organisms
- Suggests a common ancestor
- Differences amongst group of organisms
- Suggests modification due to natural selection
- Evidence for descent with modification.

In most respects *Tiktaalik's* body is fish-like: it has fins and gill arches, just like a fish. However, its skull and especially its limbs mark it as a tetrapod ancestor. Species such as *Panderichthys* had true fins, similar to those of modern ray-finned fishes, consisting of an array of long, thin, spindly bones unsuitable for bearing weight. On the other side of the gap

is *Acanthostega*, with true limbs – each containing a radius and an ulna, just like our arms, and outfitted with eight true toes.

(c) State the name given to similar structures such as the limbs of *Acanthostega* and *Tiktaalik*.

- Homology / Homologous structures

(d) It was believed that the environment *Tiktaalik* evolved in was filled with swampy, silty lagoons. These dirty, unclear water masses also tended to have algae covering its surface. Using this information, describe how the amphibian-like *Acanthostega* could have evolved from the species *Tiktaalik*. [4]

- Variation existed within the *Tiktaalik* population; some individuals had the beginnings of true limbs.
- Formed two sub-populations, one on land and one in the swamps (those with fins and gill arches)
- These individuals within the swamps were selected against as the silty water and algae made survival more difficult, eg difficulty breathing. OWTTE/ Those on land selected for as easier to breathe/more food options OWTTE
- Alleles for true limbs passed down to next generation.
- No interbreeding/genetic isolation/reproductive isolation existed between the two sub-populations

Stimulus information adapted from:
http://www.patheos.com/blogs/daylightatheism/2006/04/hello-beautiful/ &
https://sciencenotes.wordpress.com/tag/

Section B

Question 8

(a) Explain the eukaryotic processing of pre-mRNA. [6]

1. Capping changes 5' end with the addition of 7-methylguanosine group;
2. Protects mRNA from degradation by 5' exonucleases / confers stability / assists in ribosomal binding;
3. Splicing removes introns and ligates exons to produce a mature mRNA;
4. Alternative splicing may occur, resulting in different combinations mature mRNA from a gene;
5. Addition of poly-A tail to 3' end of mRNA;
6. Allows slower degradation by 3' exonucleases / longer poly(A) tail implies longer half-life of mRNA / facilitates transport of mRNA from nucleus to cytoplasm;

(b) Compare and contrast between prokaryotic and eukaryotic control of gene expression at the translational and post-translation level. [9]

Feature	Eukaryotic	Prokaryotic
Initiation of translation	Initiated by recognition of AUG sites by small ribosomal subunit;	
	First amino acid methionine	First amino acid N-formyl-methionine;
Translational repressors	Translational repressors bind at 5' UTR to prevent translation initiation;	
Stability of mRNA	Eukaryotic mRNA more stable / present in cytoplasm for longer period of time, due to 5' cap and poly A tail	Prokaryotic mRNA has no poly A tail or 5' cap, so less stable / have shorter half-life;
Biochemical Modification	Addition of biochemical groups to proteins → activate protein;	Biochemical modification not as significant due to lack organelles such as ER & GA;
Protein degradation	Unwanted / misfolded proteins can be degraded by proteasomes / lysosomal degradation	Lack lysosomes / proteasomes but possess other mechanism of degrading proteins;
Feedback inhibition	Feedback mechanism present to control gene expression;	

(c) Describe the significance of gene amplification. [5]

1. Definition – selective increase in number of copies of a particular gene without a proportional increase in other genes;
2. Meet the needs of cells resulting in higher level of mRNA and polypeptide synthesis at different development stages of cells;
3. Specific example
4. May cause diseases like cancer due to over-expression of proteins leading to development of malignant tumours ;
5. May confer drug resistance, ref to example of methotrexate;
6. May confer selective advantage which allow organisms to survive in a particular environment;
7. May contribute to evolution of genome, ref to homologous genes;

Question 9

(a) With reference to the three different stages of cell signaling, describe in detail the sequence of events when a glucagon molecule reaches the liver cell. [10]

Signal reception
The hormone, glucagon acts the "first messenger" or a ligand, binding specifically to a G-protein-linked receptor located on the outside surface of the plasma membrane of the target cell.
Forming a hormone receptor complex
activates the G protein → displacement by GTP of GDP
The activated G protein moves to and then activates the enzyme adenylyl cyclase,
Adenylyl cyclase catalyses the formation of cAMP from ATP.

Signal transduction
cAMP acts as a second messenger
moves within the cell to activate enzymes
such as protein kinases.
Protein kinases then activate other enzymes by phosphorylating them.
In a cascade reaction
Signal is amplified

Cellular response
regulate cellular activities in the cytoplasm by increasing the blood glucose level to 90mg glucose/100ml blood
regulate transcription in the nucleus
by synthesis of enzymes or other proteins from genes
eg. activating enzymes required for increasing blood glucose level
such as glycogenolysis – breakdown of glycogen to give glucose,
gluconeogenesis – synthesis of glucose from sources other than carbohydrates, etc

(b) Discuss roles played by proteins in maintaining the potential differences across membranes and in the transmission of nerve impulses along an axon [7]

1. Na+/K+ pump on axon membrane;
2. to maintain membrane potential (potential difference across membranes);
3. via active transport requiring ATP;
4. for every 3 Na+ out, 2 K+ in;
5. to maintain a electrochemical gradient of Na+ and K+ across axon membrane
6. non-gated K and Na ion leakage channels;
7. based on facilitated diffusion controlling movement of Na+ & K+ in and out of axoplasm down electrochemical gradient;
8. there are 20x more K+ leakage channels in the axon membrane than Na+ channels
9. Both Na+/K+ pump and leakage channels are responsible for the resting potential of the nerve cell
10. voltage gated Na+ and K+ ion channels;
11. nec for depolarisation and repolarisation of axon membrane
12. arrival of stimulus or initial depolarisation → opening of Na+ channels,
13. entry of Na+ into axoplasm causing depolarization of membrane
14. A.P. generated when threshold potential exceeded;
15. A.P. transmitted/propagated to adjacent region of axon by closure of Na+ gates so that Na+ must move to region ahead and not out of nerve cell;
16. efflux of K+ out of axoplasm as Na+ channels close & K+ channels open;
17. repolarisation occurs;

(c) Explain how loss of myelination, which happens in the demyelinating disease multiple sclerosis, disrupts signal transmission in the nervous system. [3]

Myelin sheath made of lipids is important in electrical insulation
limiting the APs to the node of Ranviers allowing the A.P to jump from node to node increasing the speed of transmission
Loss of myelination leads to more AP generated → Decreasing/slow speed of transmission

Accept the reverse explanation.

CANDIDATE NAME _____ **INDEX NUMBER** _____

CG _____

SERANGOON JUNIOR COLLEGE
JC2 Preliminary Examination 2016

H2 BIOLOGY
9648

Paper 2

2 Hours

Additional materials:
Writing papers

Date / Day: 13th September 2016/Tuesday

INSTRUCTIONS TO CANDIDATES
Write your name, CG and index number in the spaces at the top of this page and on all separate writing papers used.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.

Section A
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3	**/14**
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5	**/10**
6	**/7**
7	**/10**
Total	**/80**
Section B	
9 OR 10	**/20**
TOTAL	**/100**

This question paper consists of 18 printed pages

SECTION A

Answer **all** questions.

Question 1

Figure 1.1 below depicts the molecular structure of a basic unit of collagen.

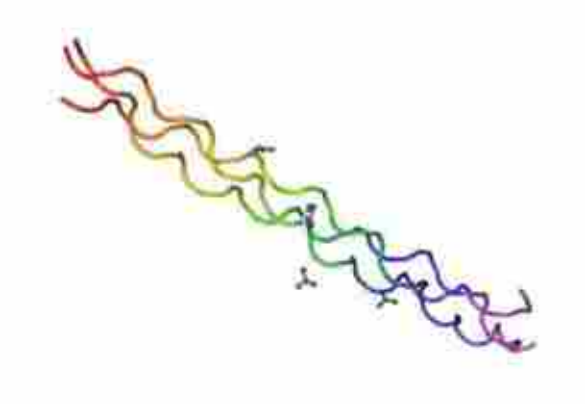

Figure 1.1

(a) State the name given to such a basic unit of collagen. [1]

……

(b) Describe how the monomers of this basic unit are joined together to achieve the final molecular configuration as shown in **Figure 1.1**. [3]

……

……

……

……

……

……

……

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Collagen is normally found in animal connective tissue where its role is as a structural molecule. Figure 1.2 shows an electron micrograph of collagen.

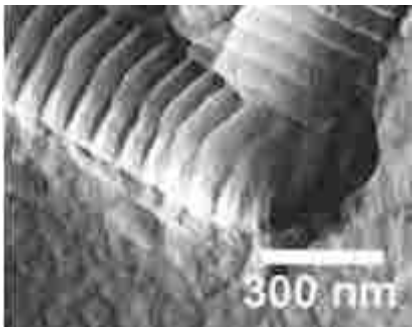

Figure 1.2

(c) Explain the banded appearance of collagen shown in **Figure 1.2**. [2]

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(d) Explain why collagen is able play the role of a structural molecule. [2]

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Another common structural molecule found in nature is cellulose. Cellulose is the main structural molecule in plants.

(e) Compare the structures of cellulose and collagen. [3]

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[Total: 11 marks]

Question 2

The following Figure 2.1 shows an electron micrograph of several cells.

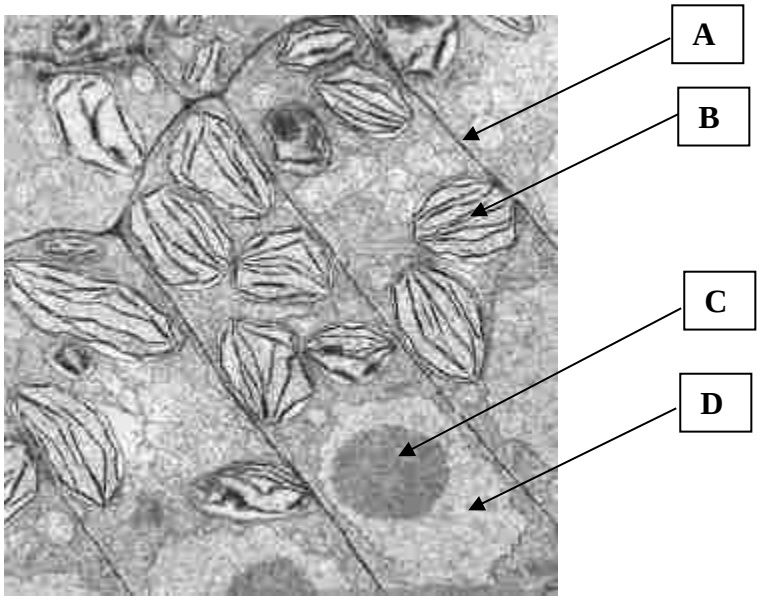

Figure 2.1

(a) Label the organelles **A – D**. [4]

A - ……...

B - ……...

C - ……...

D - ……...

(b) Discuss the role of organelle C. [3]

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(c) In the nucleoplasm of such cells, genetic material can be found. State the nature of this genetic material and briefly describe how this genetic material is organized. [3]

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Such genetic material can take part in processes such as what is shown in **Figure 2.2**.

Figure 2.2

(d) With appropriate reasons, precisely identify the process shown in **Figure 2.2**. [3]

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(e) Suggest the significance of the **next stage** of the above process. [2]

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[Total: 15 marks]

Question 3

A set of abundant nucleoid-associated proteins (NAPs) play key functions in organizing the bacterial chromosome and regulating gene transcription globally. Histone-like nucleoid structuring protein (H-NS) is representative of a family of NAPs that are widespread across bacterial species. They have drawn extensive attention due to their crucial function in gene silencing in bacterial pathogens. Figure 3.1 illustrates how H-NS is able to silence genes of bacterial pathogens. *(Information obtained from Biophysical Journal Oct 2015, 109(7))*

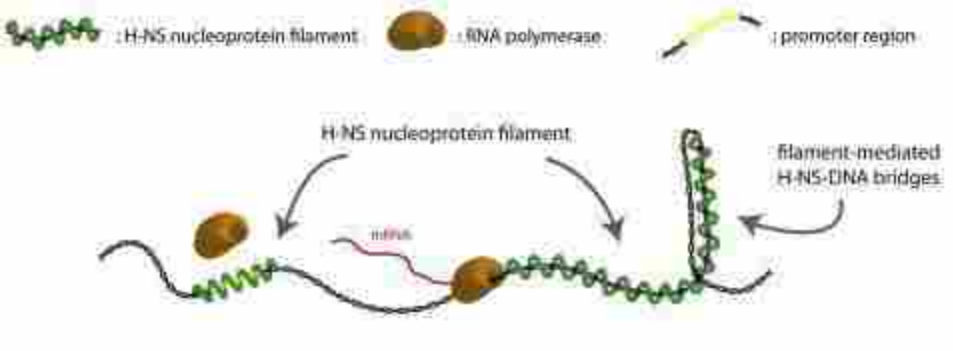

Figure 3.1

(a) State the name of one bacterial pathogen. [1]

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(b) Explain the role of RNA polymerase in a bacterial cell. [3]

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(c) Using the information from **Figure 3.1**, suggest how H-NS is able to silence genes. [2]

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The following figure shows regulation of transcription in the trp operon of a bacterial cell.

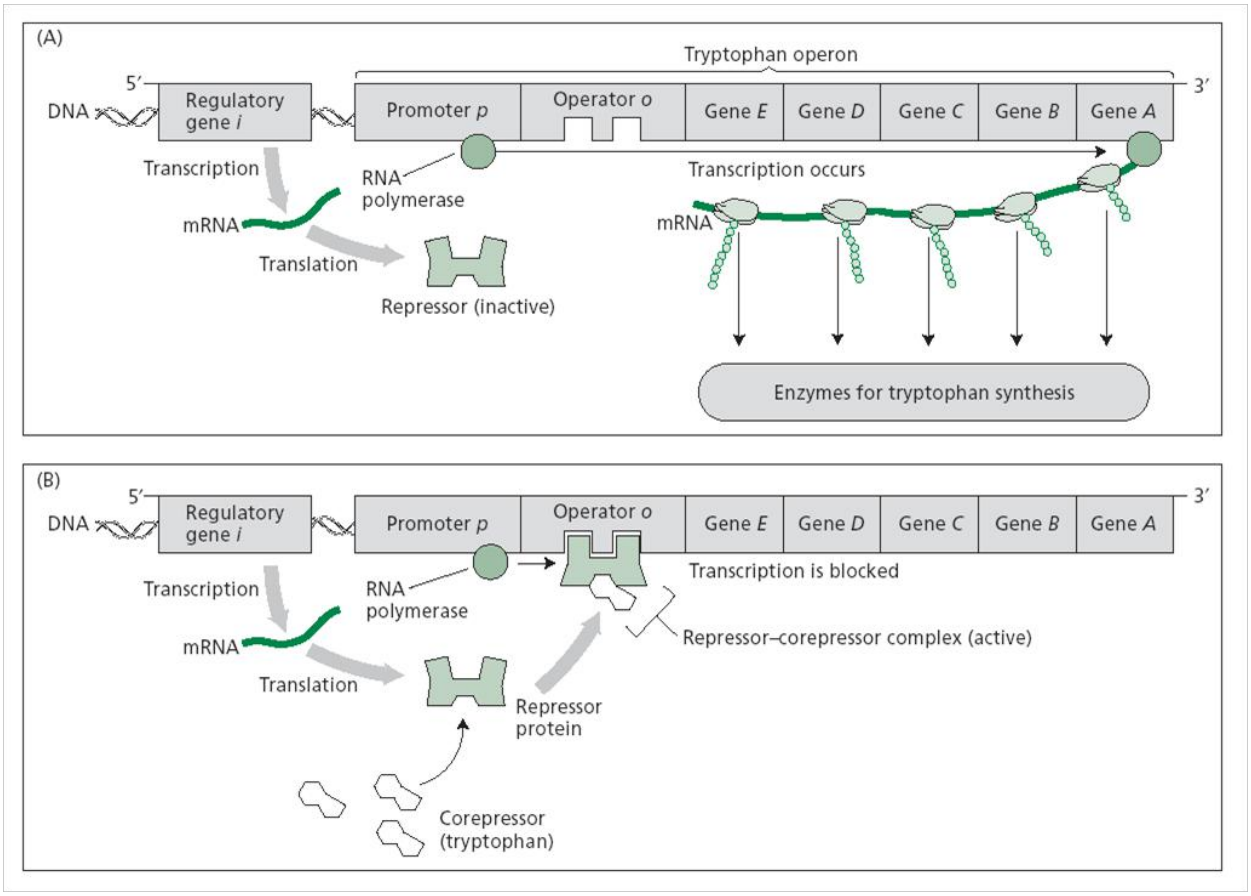

Figure 3.2

(d) Using the information in **figure 3.2**, describe the process of negative regulation in bacterial operons. [4]

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(e) Suggest why tryptophan is the ideal co-repressor for this operon. [2]

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(f) The lac operon is an example of an inducible operon system. Contrast negative regulation of the lac operon with that of the trp operon. [2]

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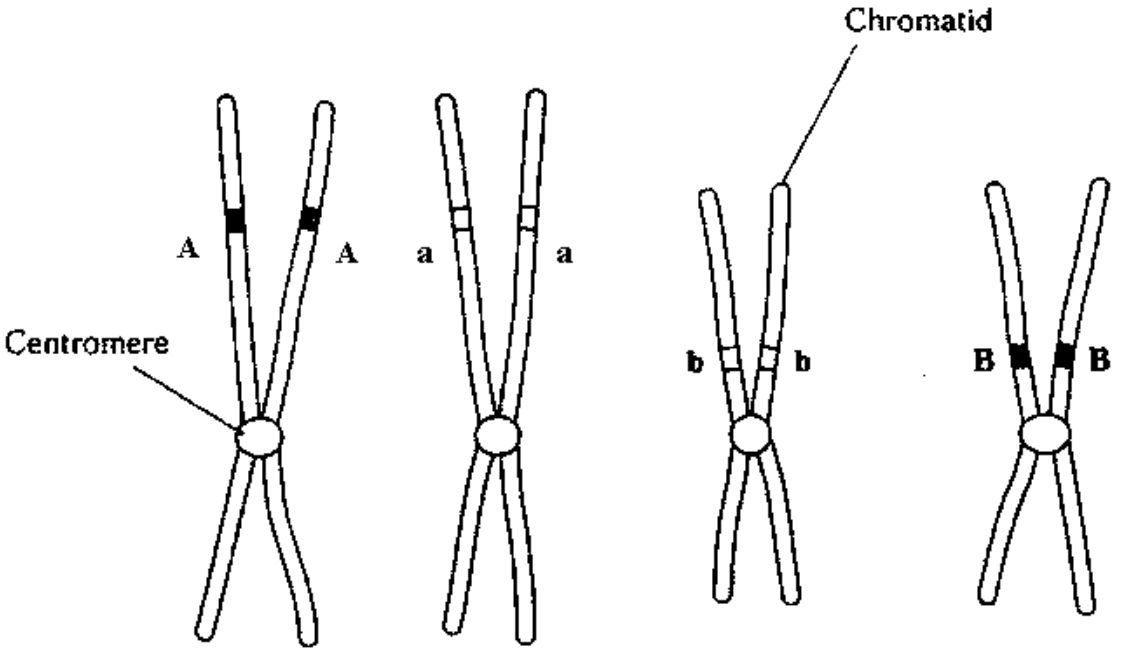
[Total: 14 marks]

Question 4

The diagram shows the chromosome from a plant cell in which 2n = 4. The dominant allele **A** of a gene results in red flower and pink spines on the fruit. The recessive allele, **a**, gives yellow flower and green spines. The dominant allele **B** intensifies the colour of the pink spines to red. The plant is heterozygous as shown below:



(a) The plant was selfed. Give the phenotypic ratio of the offspring. Explain your answer. [3]

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The plant is also heterozygous for another characteristic, the height of the plant. Allele T = tall is dominant to allele t = dwarf. A cross was made between the tall, red-flowered plant with a dwarf, yellow-flowered plant and produced a large number of offspring. **Table 4.1** shows the results.

Table 4.1

Phenotype	**Number of offspring**
Tall, red-flowered plant	35
Tall, yellow-flowered plant	14
Dwarf, red-flowered plant	16
Dwarf, yellow-flowered plant	33

(b) The ratio of phenotypes expected in a cross such as this is 1:1:1:1. Chi-squared test was performed on these data giving a calculated value of X^2 of 14.64.

Table 4.2: Distribution of X^2

Degrees of freedom	Probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(i) Use the calculated value of X^2 and the table of probability provided in **Table 4.2** to find the probability of the results of the cross is due to chance. [1]

Probability ……

(ii) State what conclusions may be drawn from the probability found in (b)(i). [2]

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(iii) Explain the difference between the expected and actual results of the test cross. [3]

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(c) Briefly explain how another factor, besides crossing over, can bring about genetic variation in the offspring produced by a sexually reproducing organism (Exclude mutation from your answer). [1]

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In another completely different cross involving humans, the following results were obtained.

Phenotypes	Genotypes	Color of skin
Extremely dark	PPQQRR	6
Very dark	PpQQRR	5
Dark	PpQqRR	4
Intermediate	PpQqRr	3
Light	ppQqRr	2
Very light	ppqqRr	1
Extremely light	ppqqrr	0

(d) What is the term used to describe the range of phenotypes in the above example? [1]

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(e) Explain the genetic basis for the range of phenotypes seen. [2]

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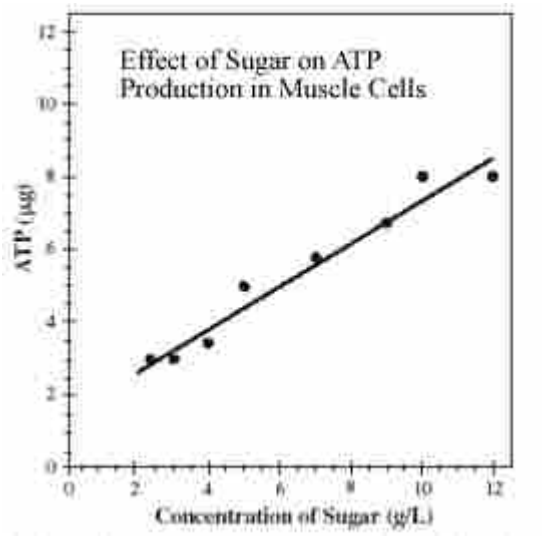
[Total: 13 marks]

Question 5

The following figure shows the effect of sugar levels on muscle cells.



(a) Describe and explain the effect of sugar on ATP production in muscle cells. [3]

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(b) Suggest and explain what will happen to ATP production if the concentration of sugar continued to increase. [2]

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The coenzyme cytochrome *c* oxidoreductase, is the third complex in the electron transport chain, playing a critical role in biochemical generation of ATP (oxidative phosphorylation).

(c) Explain how the coenzyme cytochrome c oxidoreductase may aid in the production of ATP in the electron transport chain. [3]

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(d) Actimycin A is known to inhibit the coenzyme cytochrome c oxidoreductase. Predict the effect actimycin A would have on the aerobic respiratory process. [2]

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[Total: 10 marks]

Question 6

The following Figure 6.1 shows the synaptic knob of a synapse found in the sympathetic ganglion of frogs. Such synapses are unique as they contain receptors to the neurotransmitter noradrenaline (NE) on the pre-synaptic membrane itself. These are known as autoreceptors.

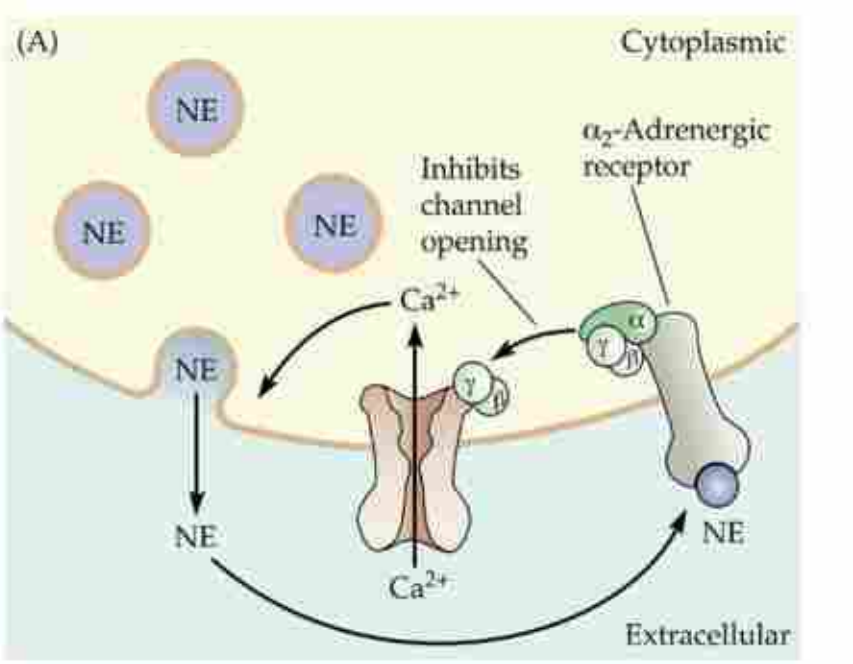

Figure 6.1

(a) State the name given to synapses that use noradrenaline as the neurotransmitter. [1]

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(b) Using the information given in Figure 6.1, explain how the release of noradrenaline at the pre-synaptic membrane may eventually inhibit the synapse itself. [3]

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(c) Suggest the significance of this self-inhibitory effect. [1]

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(d) Describe two functions of synapses. [2]

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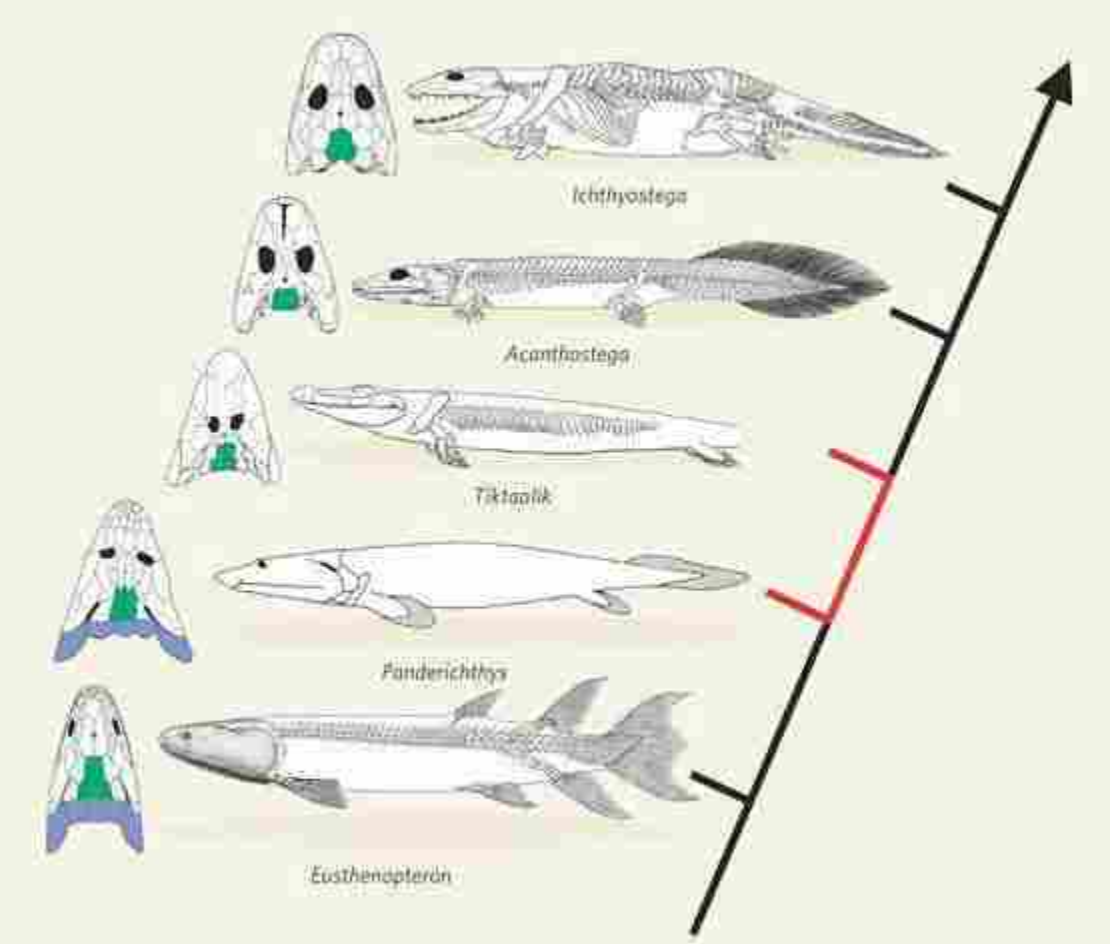
[Total: 7 marks]

Question 7

Figure 7.1 shows a series of fossils. This series depicts how land-based amphibians could have evolved from fishes. Tiktaalik hails from the Late Devonian period, about 360 million years ago, and is both chronologically and morphologically intermediate between two other major fossils in this series, the more fish-like *Panderichthys* and the more tetrapod-like *Acanthostega*.



(a) State the name given to fossils such as *Tiktaalik* that have characteristics from two seemingly diverse groups of organisms. [1]

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(b) Explain how such fossil records can actually support Darwin's theory of evolution. [4]

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In most respects *Tiktaalik's* body is fish-like: it has fins and gill arches, just like a fish. However, its skull and especially its limbs mark it as a tetrapod ancestor. Species such as *Panderichthys* had true fins, similar to those of modern ray-finned fishes, consisting of an array of long, thin, spindly bones unsuitable for bearing weight. On the other side of the gap is *Acanthostega*, with true limbs – each containing a radius and an ulna, just like our arms, and outfitted with eight true toes.

(c) State the name given to similar structures such as the limbs of *Acanthostega* and *Tiktaalik*. [1]

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(d) It was believed that the environment *Tiktaalik* evolved in was filled with swampy, silty lagoons. These dirty, unclear water masses also tended to have algae covering its surface. Using this information, describe how the amphibian-like *Acanthostega* could have evolved from the species *Tiktaalik*. [4]

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Stimulus information adapted from: http://www.patheos.com/blogs/daylightatheism/2006/04/hello-beautiful/ & https://sciencenotes.wordpress.com/tag/

[Total: 10 marks]

Section B

Answer **one** question

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labeled diagrams, where appropriate.
Your answers must be in continuous prose where appropriate.
Your answers must be set out in sections (a), (b), etc as indicated in the question.

Question 8

(a) Explain the eukaryotic processing of pre-mRNA. [6]

(b) Compare and contrast between prokaryotic and eukaryotic control of gene expression at the translational and post-translation level. [9]

(c) Describe the significance of gene amplification. [5]

Question 9

(a) With reference to the three different stages of cell signaling, describe in detail the sequence of events when a glucagon molecule reaches the liver cell. [10]

(b) Discuss roles played by proteins in maintaining the potential differences across membranes and in the transmission of nerve impulses along an axon. [7]

(c) Explain how loss of myelination, which happens in the demyelinating disease multiple sclerosis, disrupts signal transmission in the nervous system. [3]

CANDIDATE NAME (CG) _____ *INDEX NUMBER* _____

SERANGOON JUNIOR COLLEGE
JC2 Preliminary Examination 2016

BIOLOGY
Higher 2

Paper 3

19th SEP 2016/ Monday
2 hours

MARK SCHEME

READ THESE INSTRUCTIONS FIRST

Write your name and index number in the spaces at the top of this page and on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in all the sections.

.

At the end of examination,
1. fasten all your work securely together

FOR EXAMINER'S USE	
1	/14
2	/14
3	/12
	/40
4	/12
5	/20
TOTAL	/72

INFORMATION FOR CANDIDATES
The intended number of marks is given in brackets [ ] at the end of each question or part question.

This question paper consists of 17 printed pages and 1 blank page

Answer **all** questions

Question 1

The first ever gene therapy trial was initiated in 1990 by Dr William French Anderson to treat a four year old girl named Ashanthi. Ashanthi was suffering from severe combined immunodeficiency (SCID), a genetic disorder characterised by the absence of functional T-lyymphocytes.

In Ashanthi's case, the disease was caused by the absence of the enzyme adenosine deaminase (ADA-SCID). An alternative form of SCID is known as X-linked SCID.

(a) From your knowledge, contrast between the two forms of SCID mentioned in the paragraph above. [3]

	X-linked SCID	**ADA-SCID**	
Gene involved	• Gene coding for **interleukin 2 receptor gamma**	• Gene coding for **adenosine deaminase**	1m
Chromosome on which the gene is found	• **X chromosome**	• **Chromosome 20**	1m
Effect of mutation leading to SCID	• Results in production of **defective interleukin receptor**	• Mutation results in non-functional enzyme that is **defective in purine metabolism / cannot break down purines**	1m
	• Leading to **defective signalling pathway** which **prevents proper development** of T-lymphocytes	• Leading to the **accumulation of deoxyadenosine** which is **toxic** to immature lymphoid cell	1m

[max 3]

There were several *ex vivo* methods of gene therapy that were considered in Ashanthi's treatment, detailed in Table 1.1. The virus vector used was a modified retrovirus.

Method	Description
A	• Normal ADA allele is introduced into viral vector • Recombinant virus is introduced into T-cells obtained from patient • Genetically modified cells are reintroduced into patient
B	• Normal ADA allele is introduced into viral vector • Recombinant virus is introduced into the cells derived from inner cell mass of blastocyst • Genetically modified cells are reintroduced into patient.
C	• Normal ADA allele is introduced into viral vector • Recombinant virus introduced into hematopoietic stem cells obtained from patient • Genetically modified cells are reintroduced into patient

Table 1.1

(b) With reference to the information presented in Table 1.1,

(i) Suggest one reason why *ex vivo* approach was utilised for gene therapy. [1]

- Allows specific **identification of target cells** with therapeutic gene (OWTTE).
- Allows **monitoring of gene expression before reintroduction** as success rate is very low.
- Safer because can **monitor for cancer cells** caused by the **random integration of DNA / insertional mutagenesis by retrovirus** which can knock out tumour suppressor genes or activate proto-oncogenes.

[any 1]

(ii) State the most preferred method of ex vivo gene therapy for ADA-SCID and justify the preference over the other 2 methods. [3]

- Method C.
- **Hematopoietic stem cells** are capable of **long term self renewal**, making the treatment **more permanent** as compared to using **differentiated T-cells** in **method A**.
- **Hematopoietic stem cells** are derived from the patient **will not trigger any immune response** when returned to patient, as compared to using **embryonic stem cells** from another source in **method B**.

(c) Explain why the retrovirus was an efficient vector in the gene therapy of Ashanthi's condition. [2]

- It contains surface **glycoproteins** which are **specific** to the cell-surface receptors on T-**lymphocytes**, thus **increasing the efficiency** of gene delivery to the **specific target cell**.
- It contains the enzyme **integrase**, allowing the **integration** of the **normal ADA allele** into the **genome** of the target cell.

Apart from diseases that plague human health, the effect of plant diseases on agriculture have also been in the spotlight. One such disease is the ringspot virus that plagues the papaya agricultural industry. Scientists have developed effective circumventive methods to tackle the problem of the ringspot virus through genetically modifying papaya. To do this, viral genes encoding capsid proteins were transferred to the papaya genome. These viral capsid proteins elicit something similar to an "immune response" from the papaya plant. Thus, the genetically modified papaya plants were resistant to infection by the papaya ringspot virus.

Figure 1.2 below depicts the comparative infection of transgenic and non-transgenic papaya in the 1995 field trail in Kapoho, Hawaii.

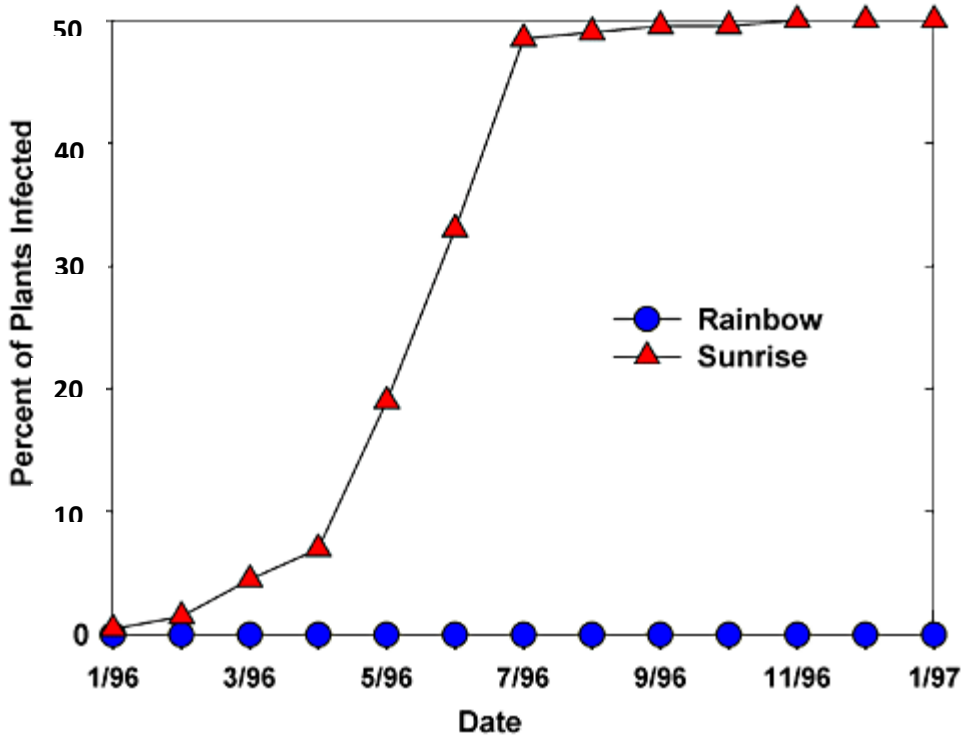


Figure 1.2

(d) With reference to Figure 1.2,

(i) Determine the identities of the transgenic and non-transgenic papaya species. [1]

- Transgenic species: Rainbow + Non-transgenic species: Sunrise.

(ii) Evaluate and justify thoroughly the efficacy of the genetic intervention. [2]

- Highly effective
- Quote values:

The percentage of infected Sunrise papaya species increased to from **0% to 16% by April'96**, followed by a sharp increase from **16% to 98% by July'96** and **reached 100% by Nov'96**, as compared to the percentage of infected Rainbow species which **remained at 0%** throughout the year.

It was observed that three years later, the percentage of infected transgenic papaya species increased.

(e) Suggest and explain a possible reason for this phenomenon. [2]

- **Mutation** in the ringspot virus **genome** had occurred,
- Enables ringspot virus to **make new surface glycoproteins** that GM papaya is no longer resistant to as **immune response is no longer triggered** by infection with the ringspot virus.
- AVP+ explanation

[Total: 14 marks]

Question 2

The location of the gene locus responsible for disease X was not discovered until 1985. Scientists used restriction fragment length polymorphism to discover the genetic markers associated with the disease. One such marker was a 950bp-long region known as XD15 that had been sequenced prior to 1985.

Samples of DNA were obtained from a family known to have the condition. The XD15 locus was amplified by polymerase chain reaction and mixed with *Pst*I and *Eco*RI in two separate restriction digests. The results of gel electrophoresis followed by southern blot of both restriction digests are shown in Fig. 2.1.

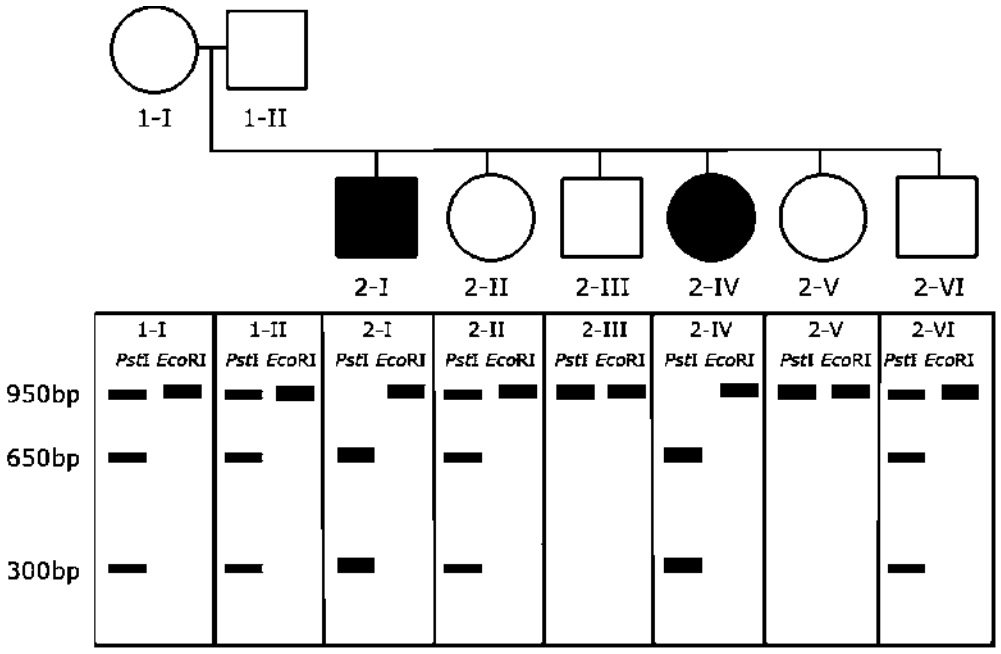


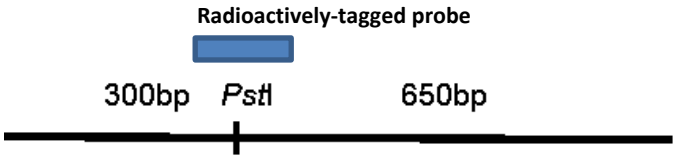
Fig. 2.1

(a) Using the information in Fig. 2.1,

(i) state and explain which restriction enzyme digest should be used to detect the XD15 genetic marker associated with disease X.[3]

- ***Pst*I**
- Digestion with *Pst*I produced **two bands** of **300bp and 650bp** in **affected individuals** but **unaffected individuals** showed either a **single band of 950bp** or **three bands of 950bp, 650bp and 300bp**.
- But after digestion with *Eco*RI, **all individuals** had **single 950bp fragments** and the affected and unaffected individuals are not differentiated.

(ii) draw a restriction map of the XD15 genetic marker that is associated with disease X. Indicate on the restriction map the position of the radioactively-tagged probe that would enable visualization of the RFLP fragments. [2]



- [Size of fragment + labelling of restriction site] -1m
- [Position of probe + label of probe] -1m

(b) Explain why genetic markers like XD15 can be used to detect the presence of disease-causing alleles. [2]

- These genetic markers are easily **identifiable** because they are **highly polymorphic**
- They are **closely/ tightly linked** to the disease-causing alleles on the same chromosome, thus **unlikely that crossing over will occur** /are likely to be **inherited together** as one unit with the disease-causing allele

The XD15 locus was amplified by polymerase chain reaction prior to gel electrophoresis and southern blot. The DNA sequence of the XD15 locus is shown in Fig. 2.2.

5' - GGATCCATCCCGATCGAAAGCTAGCTAGGATCC - 3'
3' - CCTAGGTAGGGCTAGCTTTCGATCGATCCTAGG - 5'

Fig. 2.2

(c) Design two 7-base long primers for the sequence to be amplified. [2]

Primer 1: 5' – GGATCCA – 3'
Primer 2: 3' – TCCTAGG – 5'

- 5' and 3' indicated correctly on both primers- 1m
- Correct sequence of both primers – 1m
- 1m awarded if one of the primer has correct sequence and direction indicated.

(d) Contrast between the process of PCR and DNA replication that occurs naturally in cells. [3]

Basis of comparison)	**Differences**

1. Nature of primers	DNA replication involves RNA primers while PCR requires DNA primers.
2. Location	DNA replication takes place in the nucleus of the cell while PCR is automated/takes place in a thermocycler.
3. Enzymes involved	DNA replication involves DNA polymerase while PCR involves the enzyme *Taq* polymerase.
4. Proof-reading	In DNA replication, the daughter strands are proofread by DNA polymerase I but there is no proofreading of daughter strands in PCR by *Taq* polymerase.
5. Unzipping of template DNA	In PCR, high temperatures are required for denaturing the strands while in DNA replications, the enzyme helicase unwinds the strands.
6. Synthesis of primers	In DNA replication, primase synthesises the RNA primers, but in PCR, the primers are added in/primase is not involved.

[max 3]

(e) Besides disease detection, RFLP analysis may be used for DNA fingerprinting as well. Explain one difference in the approach employed during RFLP analysis for both processes (disease detection and DNA fingerprinting). [2]

	Disease detection	**DNA fingerprinting**
Number of DNA probes used	One probe;	Multiple probes;
➔Reason	Only one loci is analysed in disease detection;	multiple loci are analysed in the creation of a DNA fingerprint;
Location where restriction enzymes cut	Restriction enzymes cut **within** the gene locus	Restriction enzymes cut **outside** the Variable number of tandem repeat (VNTR) loci
➔ Reason	Changes in base sequence changes restriction sites that result in different sized restriction fragments being released when cut with the restriction enzyme.	The DNA polymorphism for this loci arises due to different number of tandem repeats of a particular sequence. Cutting outside the VNTR loci releases fragments of different lengths for each allele. Gel electrophoresis can then separate the different alleles by size.

[max 2: state difference 1m + explanation 1m]

[Total: 14 marks]

Question 3

(a) Plant growth regulators (PGR) such as auxin, cytokinin and ethylene are naturally produced in plants and are important in determination of the developmental pathway of plant cells.

Synthetic analogues that can be mass produced are frequently used in plant tissue culture instead of the natural PGR.

Table 3.1 summarizes the general characteristics and roles of some natural and synthetic PGR.

Type of PGR	Examples	Role
Auxins	IAA(natural) - unstable to heat & light	Promote cell division and cell growth Root initiation (when auxin:cytokinin is high)
	2,4-D(synthetic) – stable to heat & light	
Cytokinins	2iP(natural) – unstable to heat & light	Promotes cell division Shoot formation (when auxin:cytokinin is low)
	Kinetin(synthetic) - stable to heat & light	
Abscisic acid (ABA)	-	Inhibits cell division Maturation of somatic embryos Abscission (i.e. shedding) of plant leaves Seed dormancy Induces stomatal closure to reduce water loss by transpiration
Ethylene	-	Abscission (i.e. shedding) of leaves and flowers Seed and bud dormancy by growth inhibition Fruit ripening

Table 3.1

Prunus lannesiana is an early-flowering cherry (only in spring) in Japan Izu peninsula. It is commonly known as Sakura or Japanese Cherry. Researchers are keen to propagate *P. lannesiana* from sterilized explants by micropropagation due to the advantages that the technique offers. Hence, a study was made to analyse the concentration of PGR present in the *P. lannesiana* in the four seasons and the results were summarized in Table 3.2.

Conc. of PGR / arbitrary unit \ Season	Spring (Mar-May)	Summer (June – Aug)	Autumn (Sep-Nov)	Winter (Dec – Feb)
IAA (auxin)	15	20	25	30
2iP (cytokinin)	10	15	10	5
ABA	5	5	12	15
Ethylene	12 – 20	18	16	14

Table 3.2

Table 3.3 illustrates the physiological development of *P. lannesiana* in the various seasons.

Season	Spring	Summer	Autumn	Winter
Shoot development	Very Active	Active	Minimal	Nil
Root development	Minimal	Moderate	Active	Very Active
Leaves development	Very Active	Active	Senescence (leaves turning autumn yellow) and abscission	Nil
Flowers development	Short full bloom in early spring, followed by senescence	Nil	Nil	Buds develop but dormant in late winter
Fruit and seed development	Fruit and seed development in late spring	Seed maturation	Seed dormant	Seed dormant

Table 3.3

(i) State one economical limitation of micropropagation. [1]

1. Micropropagation **requires sophisticated facilities, sterile laboratory conditions and special nutrient media – high cost to maintain**
2. It also **requires trained personnel** with specialised skills / **technical expertise – high cost to train**;
3. AVP

(ii) Suggest why synthetic PGR (e.g. 2,4-D and Kinetin) are used instead of natural PGR (e.g. IAA and 2iP) in plant tissue culture. [1]

1. **Lower Cost due to mass production**;
2. **More stable to heat** and **light**;

(iii) Using the information provided in Table 3.2 and Table 3.3, explain the effect of the change in the auxin:cytokinin ratio from Spring to Winter and vice versa. [4]

1. When season change from Spring to Winter, the **auxin:cytokinin ratio generally increased from 3:2 in spring to 6:1 in winter / by four fold**;
2. which **promotes root growth in winter** to **improve absorption of nutrients and water** to sustain the survival of plant;
3. When season change from Winter to Spring, the **auxin:cytokinin ratio decreased from 6:1 in winter to 3:2 in spring / by four fold**;
4. which **promotes shoot development in spring**, allowing for **full bloom of *Prunus lannesiana* in spring for pollination / for photosynthesis for maximal growth / for regeneration of leaves for photosynthesis**;

(b) The Salmon Genome Project (SGP) is developed to increase knowledge of the biology of Atlantic salmon and aid agricultural breeding of the fish.

(i) Describe how the SGP serves to increase knowledge of the biology of Atlantic salmon. [2]

1. To **generate the genomic map** of the Atlantic Salmon;

2. To identify, locate and analyse genes and their regulatory sequences;
3. To study patterns of inheritance of these genes;
4. To establish possible evolutionary relationships with other organisms;

In order to produce transgenic salmon expressing salmon growth hormone, sGH, the coding sequence of sGH gene is isolated from a library and cloned, using *Sac* I, into the plasmid expression vector, pBluescript II SK. The plasmid map is shown in **Fig. 3.1**.

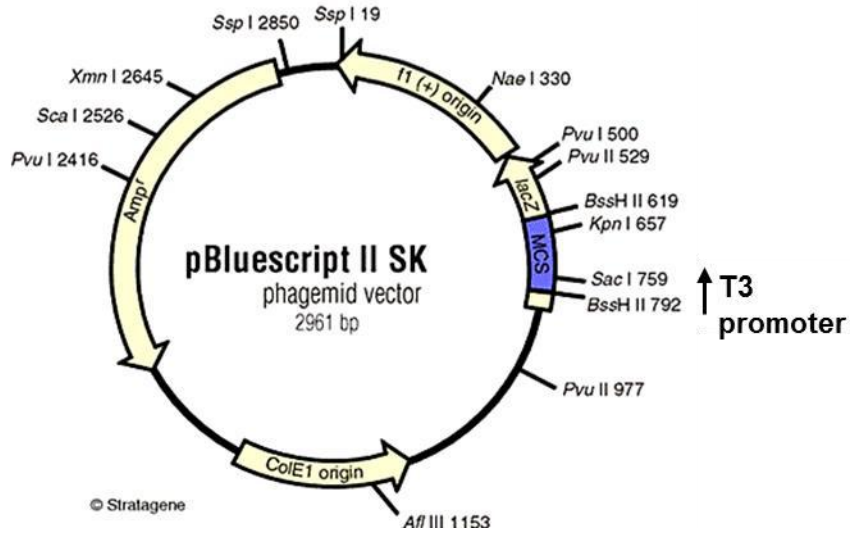


Figure 3.1

(ii) With reference to figure 3.1, describe the features of the multiple cloning site (MCS). [2]

1. Consists of a **variety** of **restriction enzyme sites** / **recognition sites** for **different** restriction enzymes such as *BssH* II, *Sac* I and *Kpn* I;
2. **Found within** the selection marker ***lacZ* gene**;
3. There is only **one / unique recognition site** for **each restriction enzyme** for the insertion of the gene of interest (GOI) into the vector;

Subsequent to insertion of sGH gene into pBlueScript II SK, transformation into *E. coli* cells was carried out and some colonies were obtained. The plasmid DNA was extracted, digested with *Sac* I and the restriction fragments were separated in gel electrophoresis.

(iii) It was found that the recombinant plasmid with sGH gene inserted yielded no polypeptide. With reference to Fig. 3.1, state and explain a reason for this. [2]

Either:
1. Since ***Sac* I restriction site is within / near T3 promoter**, sGH gene inserted may **disrupt the promoter sequence**;
2. This results in **no expression** / transcription & translation of gene & thus **no polypeptide** is produced;

OR:
3. sGH inserted in the **wrong orientation,** hence **sequence of gene is reversed**;

4. So even though a protein is expressed under the control of T3 promoter, the amino acid sequence and hence the **3D conformation of polypeptide** is **different** from original;

[Total: 12 marks]

Question 4

Cefazolin is an antibiotic that disrupts the synthesis of bacterial peptidoglycan cell by preventing the formation of peptide bonds. It is bactericidal (kills bacteria) and is effective against gram-positive bacteria.

Streptococcus pneumoniae is a bacterium responsible for conditions like pneumonia and bacterial meningitis. It is a gram-positive bacterium which establishes itself as small white colonies. Discs containing cefazolin can be placed on an agar plate containing *Streptococcus pneumoniae*. If the cefazolin has been effective against *Streptococcus pneumonia,* a clear zone will be seen around the disc as shown in **Figure 4.1**.

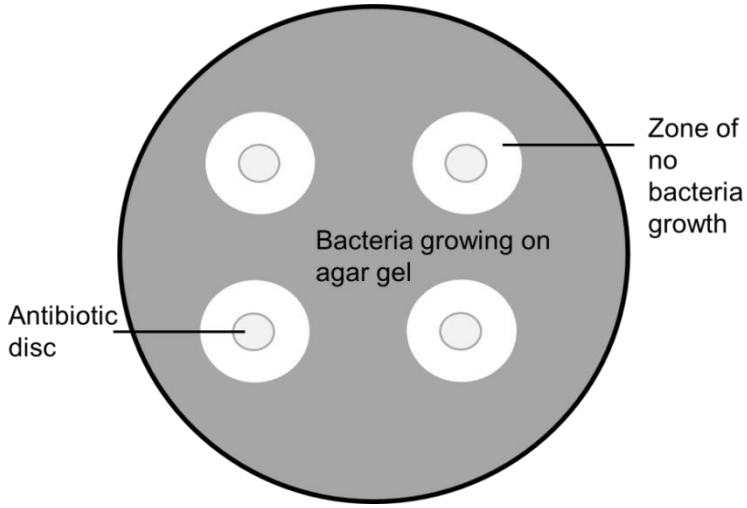


Figure 4.1

You are to plan but not carry out an experiment to investigate the effectiveness of different concentrations of cefazolin on the growth of *Streptococcus pneumoniae*.

Your plan must be based on the assumption that you have been provided with the following equipment and materials:

- Bunsen burner, to enable good aseptic conditions
- Bacterial culture in nutrient broth
- Molten nutrient agar
- Distilled water
- Sterile 90mm Petri dishes
- Sterile loops (to plate bacteria onto nutrient agar)
- $1cm^3$ pipette
- Filter paper discs
- Forceps
- Vernier calipers
- 1% cefazolin solution
- Bactericidal disinfectant for containment of used forceps and pipettes, also to clean work surfaces

- Your plan should include:
- a clear and helpful structure such that the method you use is able to be repeated by anyone reading it
- an explanation of theory to support your practical procedure
- an explanation of the dependent and independent variables involved
- relevant, clearly labeled diagrams, if necessary
- proposed layout of results tables and graphs with clear headings and labels
- correct use of scientific and technical terms
- safety measures to minimise any risks associated with the proposed experiment

Total: [12 marks]

Question 4: Planning Answer

<table>
<tr>
<td>Theory</td>
<td>

Cefazolin is an antibiotic that interferes with the synthesis of peptidoglycan in bacterial cell wall by disrupting peptide bond formation.
This greatly weakens the cell wall and causes the bacterium to lyse or burst open, because of osmotic pressure. As a result, this directly kills the bacteria.
cefazolin is placed in the form of antibiotic discs on the agar gel plated with Streptococcus pneumoniae. The size of the clear zone formed after incubation is a measure of the effectiveness of the cefazolin. Increasing concentration of cafazolin will increase the diameter of the clear zone.

</td>
<td>✓ description of scientific reasoning and theory of the method used to measure effectiveness of cefazolin</td>
</tr>
<tr>
<td>Variables</td>
<td>Independent variables: 5 concentrations of cefazolin solution (0.2, 0.4, 0.6, 0.8, 1.0 %) prepared by simple dilution.

Dependent variables: Diameter of clear zone / mm

Controlled variables (any 2):

Concentration and volume of bacterial culture
Concentration and volume of agar used
Size of filter paper disc
Weight of filter paper

</td>
<td>✓ independent, dependent variables and controlled variables</td>
</tr>
<tr>
<td>Procedure</td>
<td>
1. Add 10cm^3 of molten nutrient agar to the petri dish using aseptic technique and leave to set.
2. Prepare cefazolin solutions of 5 different concentrations using simple dilution according to the table below. Label the beakers accordingly.
<table>
<tr><th>Concentration of cefazolin solution / %</th><th>Volume of 1% cefazolin stock solution / cm^3</th><th>Volume of distilled water / cm^3</th><th>Total volume / cm^3</th></tr>
<tr><td>1.0</td><td>10</td><td>0</td><td>10</td></tr>
<tr><td>0.8</td><td>8.0</td><td>2.0</td><td>10</td></tr>
<tr><td>0.6</td><td>6.0</td><td>4.0</td><td>10</td></tr>
<tr><td>0.4</td><td>4.0</td><td>6.0</td><td>10</td></tr>
<tr><td>0.2</td><td>2.0</td><td>8.0</td><td>10</td></tr>
</table>
3. Draw lines on the base of the petri dish so that the base is divided into 6 equal parts. Label the sections 1 to 6.
4. When the gel is cast on the petri dish, use a sterile loop to plate the nutrient broth containing Streptococcus pneumoniae onto the agar gel.
5. Prepare a control disc by soaking a sterile disc in distilled water.
</td>
<td>✓ dilution method

✓ control

✓ method-</td>
</tr>
</table>

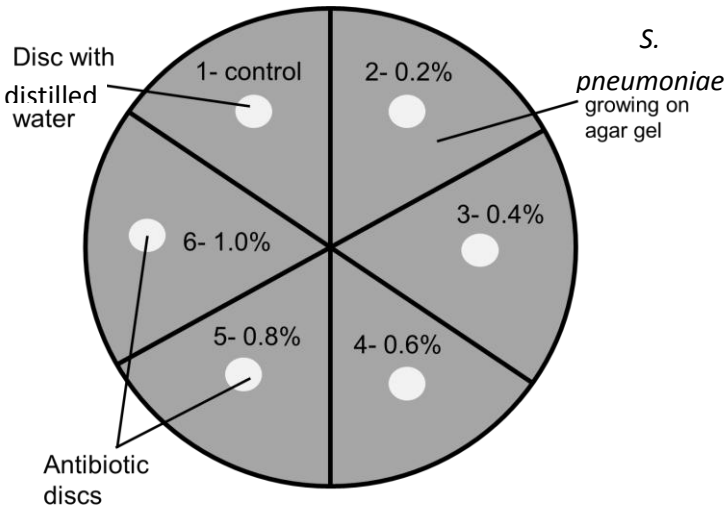
	6. Using the Bunsen burner, flame and cool forceps to sterilize them. 7. Use sterile forceps to place the control disc in the centre of section 1 8. Prepare the 5 cefazolin discs containing 5 different cefazolin concentrations by soaking each of the discs into the 5 different concentrations of cefazolin solutions prepared from simple dilution. 9. Using flamed and cooled forceps place the disc containing the 5 concentrations into the other 5 labeled sections. 10. The setup of the petri dish in the experiment is as shown below:  11. Conduct 3 replicates from steps 1-8 and 2 repeats for all prepared concentration of cefazolin. 12. Seal the petri dish and incubate the petri dish at 30°C for 2 days. 13. Without opening the lid measure the diameter of the clear zone around each disc using vernier calipers. 14. Tabulate the results to show the effect of different cefazolin concentrations on *Streptococcus pneumoniae* growth.	setup ✓ relevant diagram ✓ 3 replicates, 2 repeats ✓ fixed incubation time

Table showing the effect of different concentration of cefazolin/% on the diameter of clear zone /mm

Conc. of cefazolin	Diameter of clear zone /mm			
	Reading 1	Reading 2	Reading 3	Average
1.0				
0.8				
0.6				
0.4				
0.2				
0.0 (Control)				

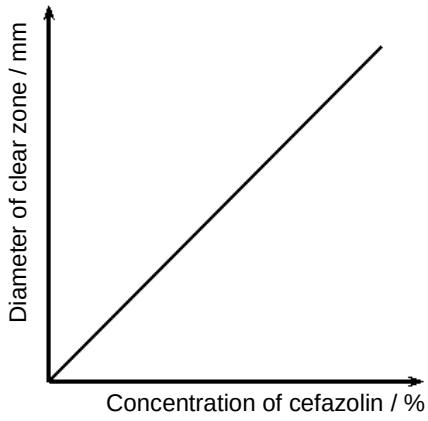
Average = $\frac{\text{reading 1 + reading 2 + reading 3}}{3}$

✓ method to calculate growth of bacteria

15. Plot a graph of diameter of clear zone /mm produced against the concentration of cefazolin /%.

Graph of diameter of clear zone /mm produced against the concentration of cefazolin /%.

✓ appropriate table and graph



The increase in the diameter of the clear zones should be directly proportional to the concentration of cefazolin.

✓ expected relationship between [penicillin] and diameter of clear zone

Risk and precaution

To prevent infection or growth of harmful microorganisms:

- Cover all cut or broken skin with a waterproof dressing
- Wear tightly fitting disposable gloves and clean laboratory coat
- Clean the bench surface with bactericidal disinfectant and use a bunsen burner which creates a sterile environment. Students should work as close as possible to the flame.
- Swap any spillages with bactericidal disinfectant.
- Proper disposal / treatment of contaminated materials or equipment using sterilizer/autoclave

✓ Safety (Any 1)

Question 5

Free-response question

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labeled diagrams, where appropriate.
Your answers must be in continuous prose where appropriate.
Your answers must be set out in sections (a), (b), etc as indicated in the question.

(a) Discuss the advantages and evolutionary consequences of using plant tissue culture to propagate transgenic plants. [8]

(b) Outline the ethical and social implications of genetically modified organisms. [6]

(c) Explain why gene therapy is opined to have limited success in the treatment of genetic diseases. [6]

Question 5

(a) Discuss the advantages and evolutionary consequences of using plant tissue culture to propagate transgenic plants. [8]

Advantages [MAX = 5]:

1. **All** transgenic plants **contain the desired gene** - Using plant tissue culture of a genetically engineered plant cell will give rise to **whole transgenic plants** that are **genetically identical**

2. **Rapid production** - allows **large numbers** of transgenic plants to be grown from just one or a **few stock plants** can be achieved; through asexual means;

3. Plant diseases can be avoided - Production of bacteria or virus-free plants; since only **meristematic tissue** of the transgenic plant is used for propagation OR plant cloning method uses **dilute sodium hypochlorite** for surface sterilization, ensuring bacteria or virus-free plants

4. Transgenic plants can be produced at **any time of the year**/ not subject to seasonal change; thus plants can be produced out of season and people can buy plants at lower prices than usual;

5. **Reliability**; and **quality control** can be achieved - since growing conditions are standardized and optimized

6. Land area needed to grow these transgenic plants through tissue culture is much less; **save space**;

7. Prevents "loss" of transgene due to sexual reproduction / through gamete formation; maintenance of transgene within entire crop;

Evolutionary Consequences [MAX = 3]:

7. Desirable / beneficial genes are quickly passed on to subsequent generations / ensures integrity and **maintenance of genetic composition** as the transgenic plants can propagate rapidly under favourable environment;

8. **Lack of genetic variation** poses a **problem to the survival** of a species / unable to respond to unfavourable changes in selection pressure as a result of changing environment;

9. **Low evolutionary potential** thus no speciation / natural selection cannot occur without variation;

10. Thus there is a **high risk of extinction** of that species as all individuals are genetically

identical, thus equally susceptible to pathogens / succumb to outbreak of epidemics / disease;

11. When transgenic plants are reintroduced into the wild, might cross- pollinate and these might cause production of pesticide/herbicide resistance / generating "**superweeds**" that will disrupt the ecological balance / ecosystem.

Note: Ans must make reference to transgenic plants, not a generic propagation of plants by plant cloning,

(b) Outline the ethical and social implications of genetically modified organisms. [6]

Definition of GMO – 1m

Organism that has acquired one or more genes by **recombinant DNA technology**. The genes may or may not be from the same species.

Ethical concerns (Max 3):

1. Exploitation of animals for food (+ any 1 elaborated point)
   A. **Increased use of growth hormone has harmful effect**s on the health of animals. Eg the use of bovine somatotrophin in dairy cattle increases the risk of mastitis
   B. Concern whether the animals are **biologically capable of withstanding additional stress** of increased production of milk, meat and other products

2. Exploitation of animals for medical research (+ elaboration)
   A. Medical experiments may **cause suffering** in animals and there are **concerns of violations of animals' rights**. (eg. Oncomouse)

3. Religious concerns or dietary restrictions (+ any 1 elaborated point)
   A. Eg. Religious groups are concerned that GM foods might contain genes from animals prohibited by their religion
   B. Eg. Objections to consumption of plants that have been modified to carry animal genes or vice versa by vegetarians.

4. There is concern about the **rights of patenting** a genetically modified animal or plant. (+ elaboration)
   A. Companies have sought to patent the transgenic animals or plants that they have developed, however, people argue that patenting animals is unethical as it **reduces them to the level of objects**.

5. **Labelling of products** on sale to indicate that genetic engineering was involved in their production is **not mandatory** in some countries (+elaboration)
   A. this deprives consumers from making an informed choice based on their religious, medical (allergies), personal (vegetarians) backgrounds.

Social Concerns (max 3)

1. Release (accidental or otherwise) of GM animals into the wild may result in GM animals

outcompeting wild types such that **ecological balance is disrupted**/severe impacts on the food-chain.

2. Introduction of foreign gene(s) may result in production of secondary metabolites that may be **toxic** to animals themselves and/or livestock/humans that consume them.

3. New proteins in GM animals may be potentially **allergenic** to humans that consume them.

4. **Antibiotic resistance genes** may be transferred to bacteria in the gut, increasing the resistance of such bacteria to medicinal antibiotics.

5. E.g., larger transgenic salmon may be preferably selected as mates over smaller wild types, thus **destabilises ecosystem** and hence **threatens biodiversity**;

(c) Explain why gene therapy is opined to have limited success in the treatment of genetic diseases. [6]

1. Short-lived nature
   - Many vectors **do not** allow for the **integration of the normal allele into the target cell genome / the rapidly dividing nature of many cells** (i.e. new cells need to be targeted) prevents the effects of gene therapy from being long-lived and stable**.**
   - As a result, patients have to undergo **multiple rounds of gene therapy**.

2. Immune response
   - The **vector** that is introduced into the tissue might be recognised by the immune system as a **foreign** particle (e.g. due to previous infection) and elicit an **immune response**.
   - As a result, the effectiveness of the therapy is reduced as the vectors are **destroyed**.

3. Viral vector may regain virulence
   - Even though the in the viral vector is modified to be safe/disease-causing viral gene is removed, the viral vector may **regain** or **develop virulence.**
   - This causes **harm** in the patient body.

4. Insertional mutagenesis
   - For some viral vectors (e.g. retrovirus), the **integration of normal allele into host genome** is **random** and may **disrupt host's gene** or regulatory gene sequences/control elements.
   - Disruption of tumour suppressor gene/ conversion of proto-oncogene to oncogene **(one named e.g.)** may cause **cancer**.

5. Multi-gene disorders/disease
   - Many common **diseases** (**one named e.g.** heart disease/high blood pressure/ Alzheimer's disease/diabetes), are caused by the combined effects of **multiple genes**.
   - Gene therapy is not effective as it is **impossible to introduce many normal alleles** into target cells at the same time.

6. Large genes

- There may be a **problem finding a suitable vector** if the **normal allele** that needs to be delivered into the target cells is **large** (e.g. viral vectors can only accept genetic material of a certain size).

7. Non-dividing target cells
   - Some viral vectors may **not be able to infect non-dividing cells** (eg. retrovirus). Hence gene therapy may not be suitable for diseases involving some cell types.
     OR
     If the modified target cell (with the normal functional allele) does not divide and multiply, the introduced gene is lost when the cell dies.

8. Diseases caused by presence of a dominant allele
   - Gene therapy is ineffective when the **mutated defective allele** is **dominant** and the **normal allele is recessive.**
   - The expression of the normal allele will still be **masked** by the dominant defective allele even after being introduced into the target cell genome

9. Problem with controlling the activity of gene expression
   - Modified cells **may not synthesize sufficient** functional **proteins** to bring about an improvement.
   - Due to (**any valid reason**): e.g. not all cells taking up the normal allele / cells not expressing the proteins at the right time (eg. in thalassemia disease) / normal allele not expressed because they are integrated into a heterochromatic region of the host cell genome.

10. AVP

[1 mark for each well-elaborated point]

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VICTORIA JUNIOR COLLEGE
BIOLOGY DEPARTMENT
JC2 PRELIMINARY EXAMINATIONS 2016
Higher 2

CANDIDATE NAME

CLASS

BIOLOGY 9648/01

Paper 1 Multiple Choice **22 September 2016**

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Booklet

READ THESE INSTRUCTIONS FIRST

Write in a soft pencil.
Do not use any staples, paper clips, highlighters, glue or correction fluid.
Write your name, Centre number and candidate number on the Answer Sheet in the spaces provided.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

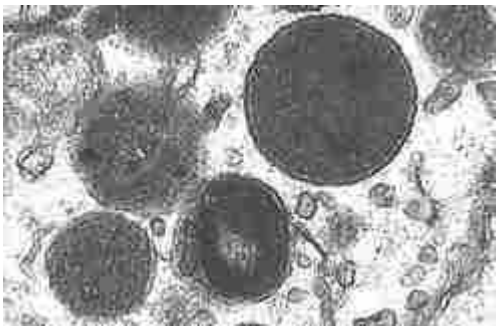
Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deduced for a wrong answer.
Any rough working should be done in this booklet

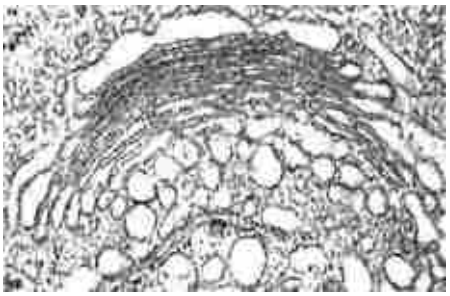
This paper consists of **25** printed pages.

1. The electron micrographs of several structures of a liver cell are shown below.

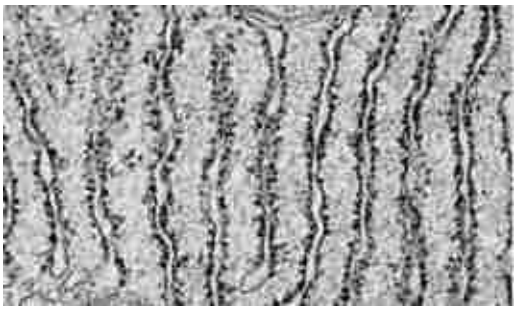
1



2



3



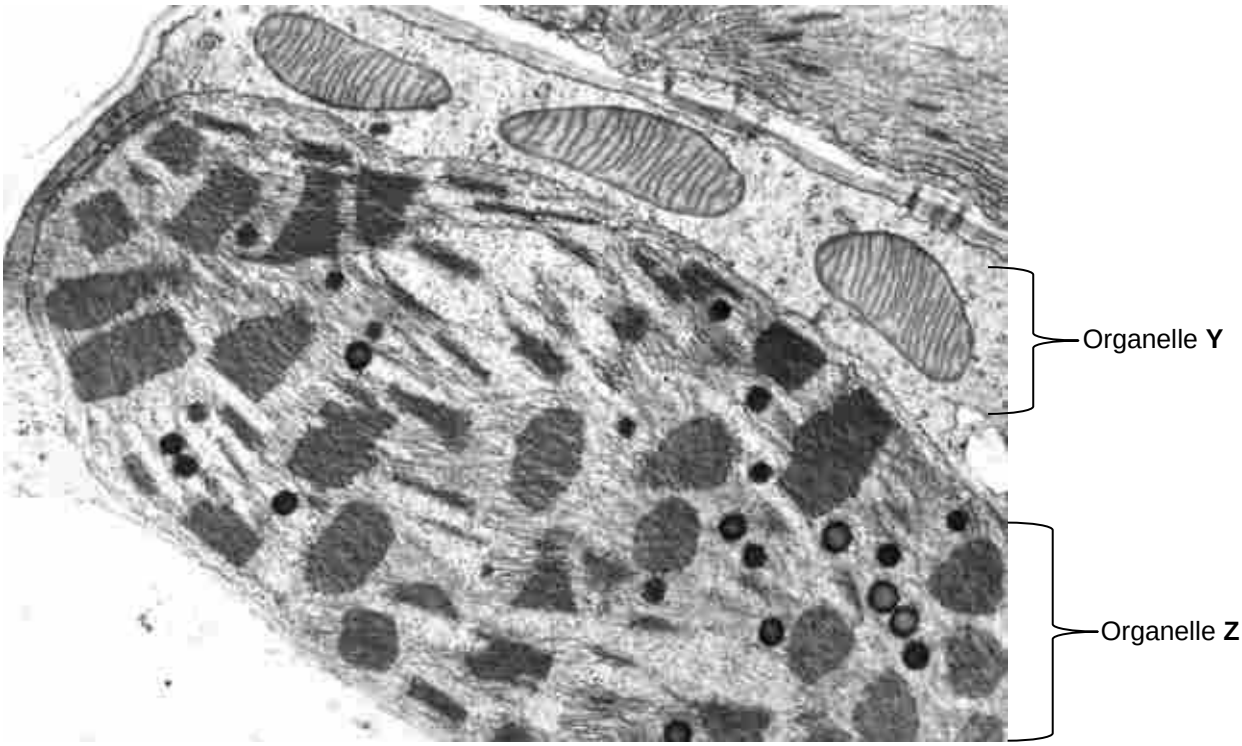
4

Radioactive amino acids were introduced into the cell to trace the path taken in the formation of hydrolytic enzymes.

Which of the following options correctly show the time taken, in minutes, for radioactivity to be detected in the structures **1 – 4**.

	Time taken, in minutes, for radioactivity to be detected in structure			
	1	**2**	**3**	**4**
A	3	10	20	30
B	30	20	3	-
C	10	20	30	3
D	20	10	3	30

2. The electron micrograph below shows two organelles **Y** and **Z** in a leaf mesophyll cell of a plant.



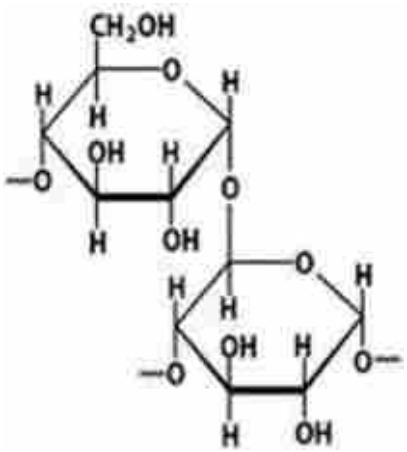
Which of the following statements are **not** true about organelles **Y** and **Z**?

1 Organelle **Z** utilises transporters to export ATP to organelle **Y** to drive cellular activities.
2 Oxygen released by organelle **Z** is used in organelle **Y** during glycolysis.
3 Transcription and translation occurs in both organelles.
4 Organelle **Y** has electron transport chain proteins but organelle **Z** does not.

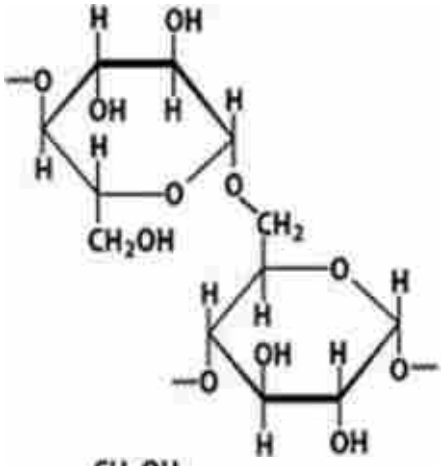
A 1 and 2 only
B 3 and 4 only
C 1, 2 and 4
D All of the above

3. Which of the following correctly shows an α 1,6 glycosidic bond found in amylopectin?

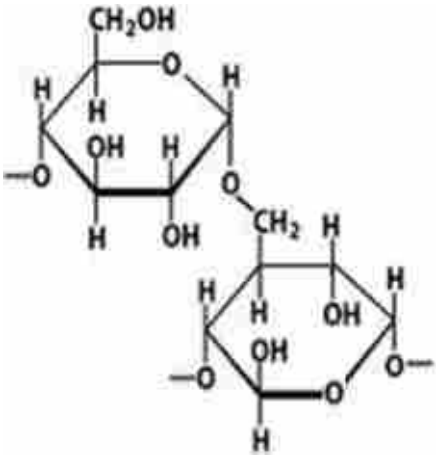
A



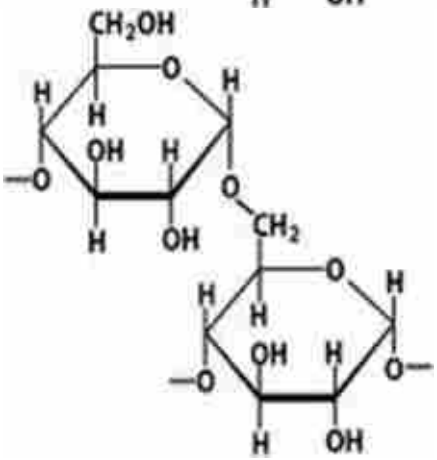
B



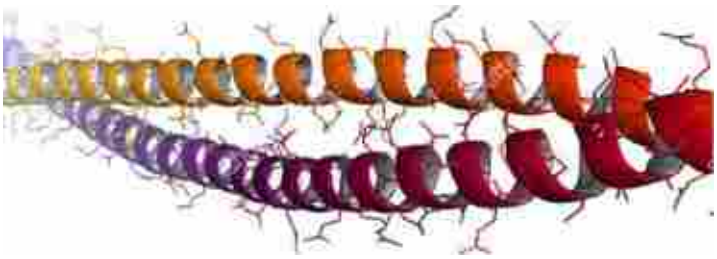
C



D



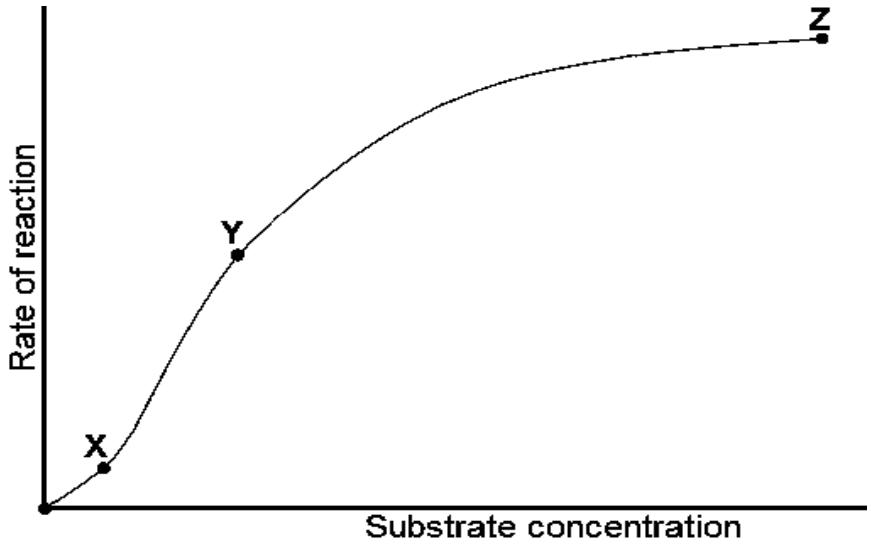
4. The diagram below shows the structure of a protein found in the hair, claws and horns of many animals.



Which of the following is true about the protein?

A The polypeptides are arranged in a staggered manner to increase in stability.
B The protein is insoluble in water due to hydrophobic R groups on the exterior.
C The secondary structure of the protein is maintained by hydrogen bonds between R groups.
D Every third amino acid is a proline.

5. The graph below shows the effect of increasing substrate concentrations on the activity of an allosteric enzyme under optimum conditions.



Which of the following statements is correct?

A There is low kinetic energy at **X** to overcome the activation energy, thus resulting in a low rate of reaction.
B Rate of reaction increases at a faster rate at **Y** as the allosteric activator outcompetes the allosteric inhibitor to bind to the allosteric site.
C At **Z**, enzyme molecules are in the active state and active sites are saturated.
D Substrate concentration is the limiting factor at **X** and **Y** but temperature is the limiting factor at **Z**.

6. Which of following statements regarding the fluid mosaic model are correct?

1 Fluidity of the membrane is a result of hydrophilic and hydrophobic interactions between components of the membrane.
2 Cholesterol maintains the fluidity of membrane by preventing the two layers of phospholipids from moving too far away from each other.
3 The attachment of different carbohydrates to the components of the membrane gives the look of a mosaic.
4 Fluidity of the membrane allows for the entry and release of influenza viruses.
5 Cholesterol increases membrane fluidity by binding to the phospholipid tails which causes the tails to bend.

A 1 and 4
B 2 and 3
C 1, 4 and 5
D 3 and 5

7. An experiment was conducted to determine the mode of entry of a drug into

animal cells. Cells which did not contain the drug were placed into separate containers with different concentrations of the drug. The concentrations of the drug inside the cells at the end of 10 minutes were obtained. The experiment was conducted in 2 different temperatures. The results are shown in the tables below.

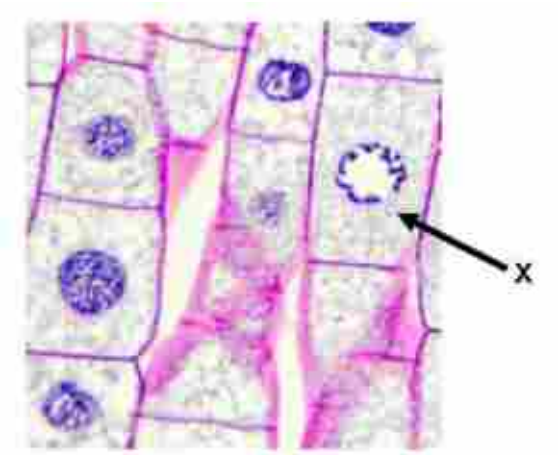
Experiment conducted in 20^{o}C	
Concentration of drug in the container / moldm^{-3}	**Concentration of drug inside the cells after 10 minutes / moldm^{-3}**
0	0
10	4
20	7
30	11
40	13
50	13
60	13

Experiment conducted in 30^{o}C	
Concentration of drug in the container / moldm^{-3}	**Concentration of drug inside the cells after 10 minutes / moldm^{-3}**
0	0
10	5
20	9
30	14
40	20
50	20
60	20

Which of the following statements is incorrect?

A The drug molecule is hydrophilic and water-soluble.
B A drastic change in extracellular pH will decrease rate of drug entry.
C No ATP is required for the entry of the drug.
D Increasing membrane fluidity results in faster drug entry.

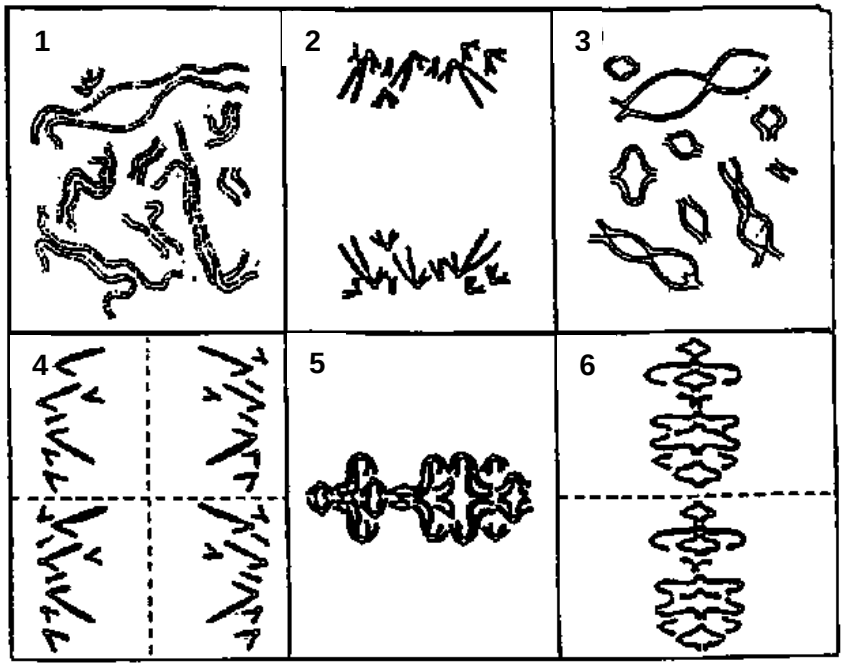
8. X shows a cell at a particular stage of cell division.



For the next stage in this nuclear division, what would be correct?

	Centrioles	Nuclear envelope	Paired chromatids
A	present	breaking down	absent
B	absent	reforming	present
C	present	absent	present
D	absent	absent	absent

9. The figure below shows 6 stages of the process of meiosis occurring in a plant cell. (2n = 18)



What is the correct order of these 6 stages?

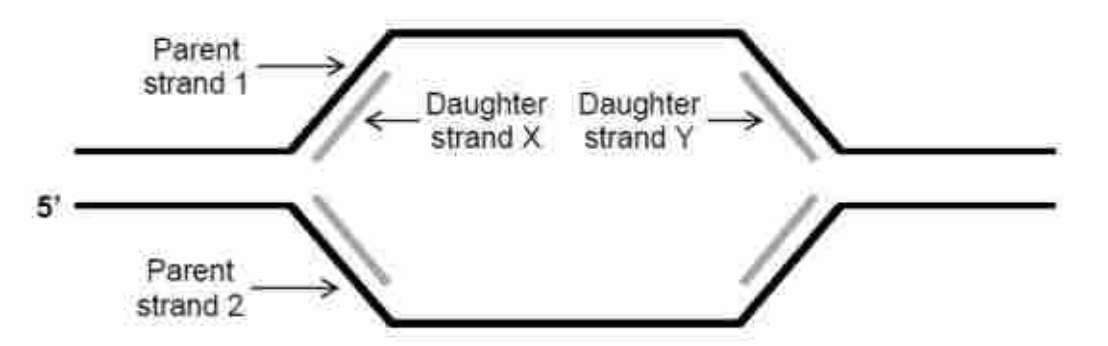
A 3, 5, 2, 6, 4, 1
B 3, 1, 5, 2, 6, 4
C 2, 3, 1, 5, 6, 4
D 1, 3, 5, 2, 6, 4

10. The table below shows the events that occur at different stages of the cell

cycle. Which row shows the correct event for the respective stages?

	Late interphase	Prophase I	Metaphase I	Anaphase II
A	DNA replication	condensation of chromosomes	alignment of chromosomes at the equator	separation of chromosomes
B	DNA replication	pairing of bivalents	alignment of bivalents at the equator	separation of sister chromatids
C	protein synthesis	crossing over	alignment of bivalents at the equator	separation of sister chromatids
D	replication of organelles	pairing of bivalents	alignment of chromosomes at the equator	separation of chromosomes

11. A simplified representation of a replication bubble is shown in the figure below. Parental strands 1 and 2 and the growing daughter strands X and Y are indicated.



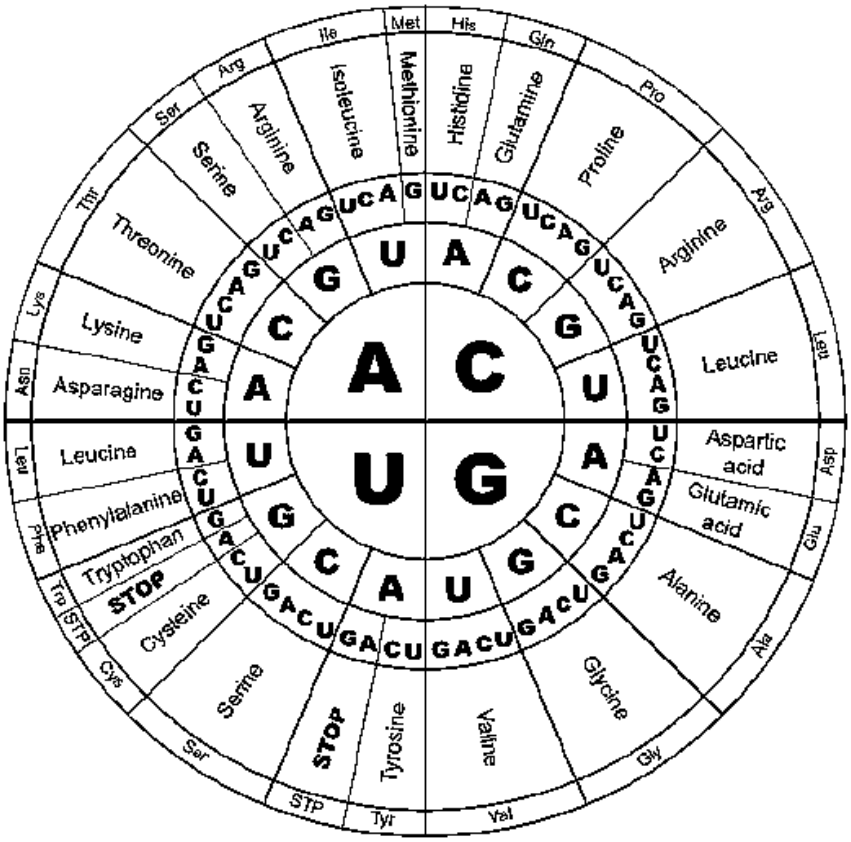
Which of the following statements about the syntheses of daughter strands X and Y is correct?

A Daughter strands X and Y are synthesised away from their respective replication forks.
B Daughter strand X is synthesised continuously while daughter strand Y is synthesised in the form of Okazaki fragments.
C Daughter strand X is synthesised in the 5' → 3' direction while daughter strand Y is synthesised in the 3' → 5' direction.
D DNA ligase will eventually catalyse the fusion of daughter strand X with daughter strand Y.

12. The first five DNA triplets that code for a particular protein is shown below:

3’ CAC GGA AGC CCA GAA 5’

The genetic information in the sequence above is eventually converted into a specific amino acid sequence according to the figure below.

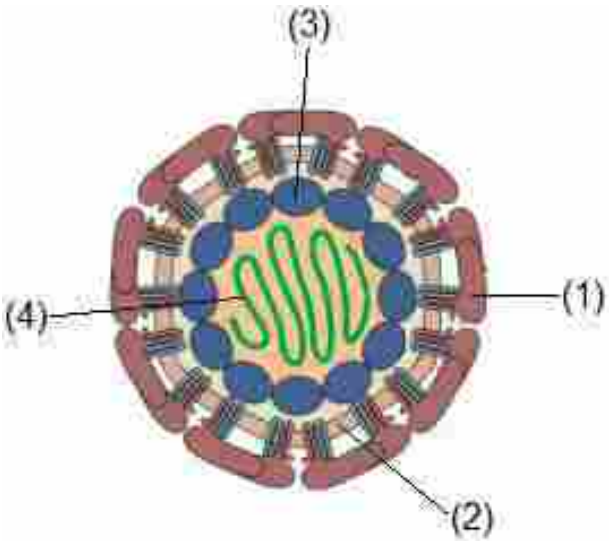


With the aid of figure, what is the sequence of the protein encoded by the DNA sequence above?

A His – Gly – Ser – Pro – Glu
B Val – Pro – Ser – Gly – Leu
C Lys – Thr – Arg – Arg – His
D Phe – Try – Ala – Ser – Val

13. Zika virus, formerly a neglected pathogen, has recently been associated with microcephaly in foetuses, and with Guillian–Barré syndrome in adults. Recent research into its structures and replication cycle has aided medical scientists in designing potential vaccines against the virus.

The diagram below shows the structure of Zika virus.



Which of the following shows correctly the components of each labelled structure in the diagram?

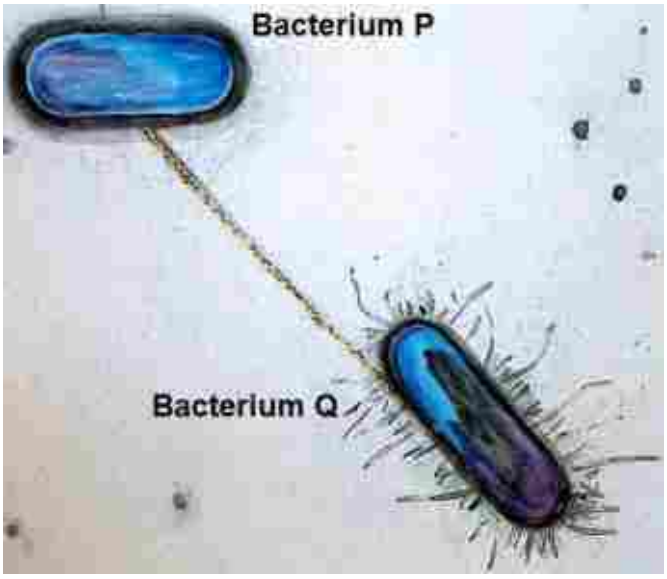
	(1)	(2)	(3)	(4)
A	Lipids	Phospholipids	Protein	DNA
B	Protein and carbohydrates	Phospholipids and cholesterol	Protein and carbohydrates	DNA
C	Protein and carbohydrates	Phospholipids and cholesterol	Protein	RNA
D	Carbohydrates	Phospholipids	Protein and carbohydrates	RNA

14. Which of the following are valid comparison between the replication cycles of a lambda phage and HIV?

1 Both replication cycles involve uncoating to release viral genome into the cytoplasm.
2 The protein involved in receptor binding for HIV is attached with short carbohydrate chains but not lambda phage.
3 The synthesis of viral proteins in both viruses involves transcription of viral DNA and translation.
4 Both involve the insertion of viral DNA into host genome and may cause insertional mutagenesis leading to uncontrolled cell division.
5 The replication cycle of HIV involves enzymes not coded by the host genome but not lambda phage.

A 1 and 4
B 2 and 3
C 2, 4 and 5
D 1, 3, and 5

15. The following shows a process taking place among prokaryotic cells.



Which of the following is false regarding the process?

A The ability of a bacterium to carry out the process is conferred by genes present on a plasmid.
B RNA primers are needed to provide free 3' OH ends for DNA replication in both bacteria.
C The DNA is linear as it is being transferred between the two bacteria via the cytoplasmic bridge.
D Genes transferred from bacterium P to bacterium Q are not essential for survival normally but are beneficial under stressful conditions.

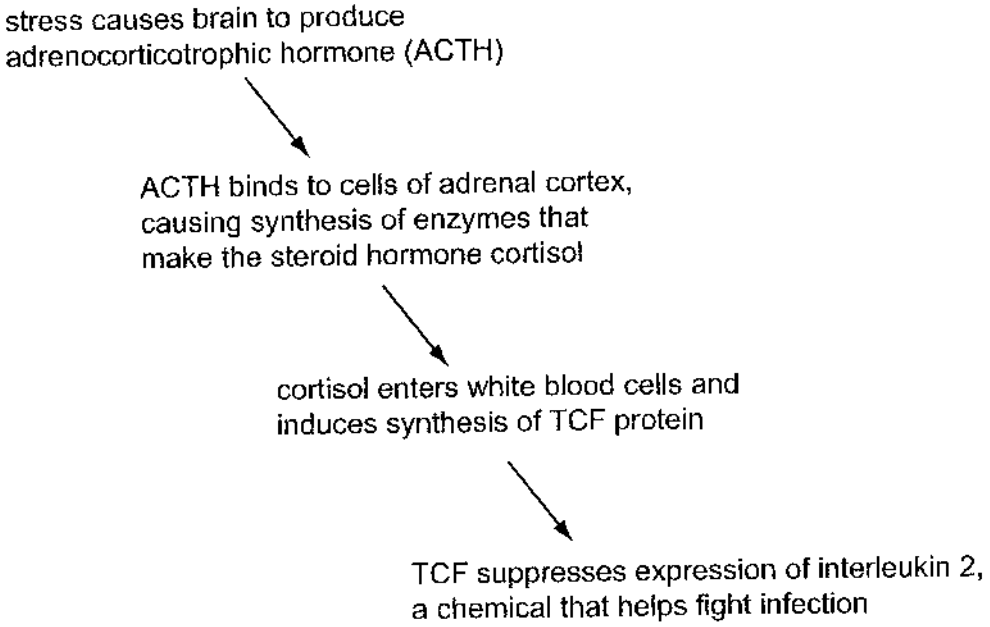
16 Some steps involved in bacterial binary fission are listed below.

1 Breaking of hydrogen bonds in DNA
2 Formation of cell membrane and cell wall between DNA
3 Attachment of DNA to mesosome
4 Bidirectional DNA replication
5 Separation of DNA due to cell elongation

Which of the following shows the correct sequence of events in binary fission?

A 3 → 1 → 4 → 5 → 2
B 3 → 4 → 5 → 1 → 2
C 1 → 4 → 3 → 5 → 2
D 1 → 3 → 5 → 4 → 2

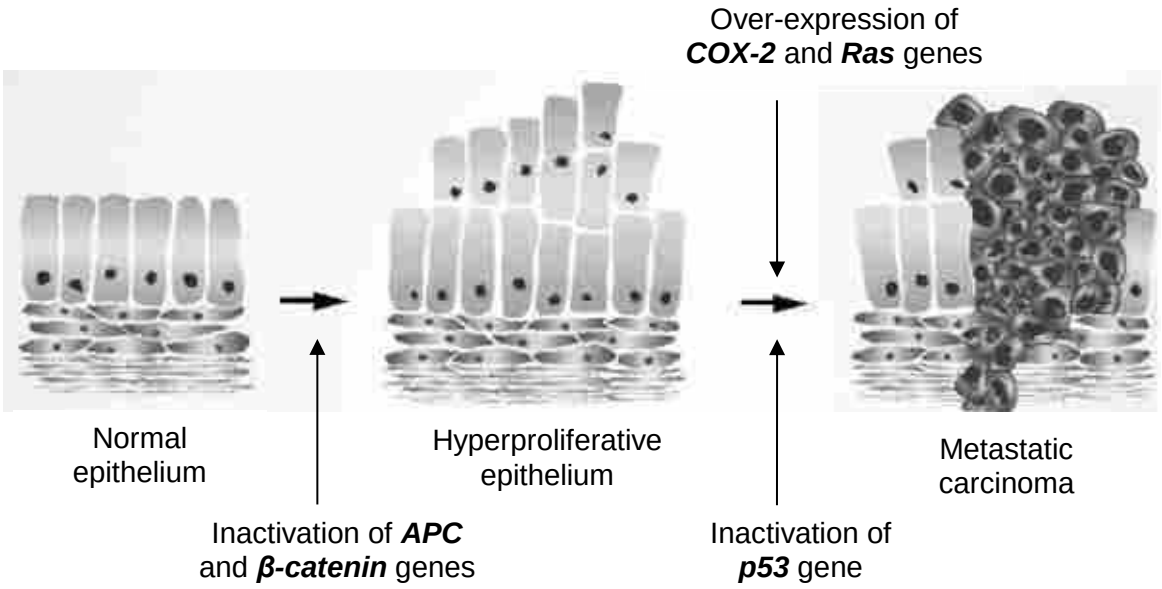
17. When a person undergoes a stressful experience, their immune system can be depressed and they become more susceptible to infection. Some of the elements involved in this chain of events are shown in the diagram below.



Which combination correctly shows the genes that are likely to have transcription-enhancing factors bound to their control elements during the above sequence of events?

	Gene for ACTH	Gene for TCF	Gene for interleukin 2
A		X	X
B	X		
C			X
D	X	X	

18. The diagram below illustrates the development of colorectal cancers.



Which of these statements can be inferred from this multistep model of carcinogenesis?

1 Cells whose *APC* and *β-catenin* genes are inactivated have lost contact inhibition and can form a tumour mass.
2 *APC* and *β-catenin* genes are tumour suppressor genes
3 High levels of *Ras* protein are produced only when both copies of *Ras* gene are mutated.
4 Two copies of normal *p53* alleles must be present to inhibit cell division
5 Gain-of-function mutation in *COX-2* gene is a pre-requisite for the formation of metastatic carcinoma.

A 1 and 3
B 2, 3 and 4
C 1, 2 and 5
D 2, 3 and 5

19. Which of the following **do not** provide a possible mechanism for the production of a wide number of types of antibody proteins from a small number of genes?

1 gene amplification
2 alternative splicing
3 crossing over and random segregation
4 deletions and random translocation of DNA segments

A 2 only
B 1 and 4
C 2 and 4
D 1, 3 and 4

20. The fur colour of hamsters is controlled by a gene with 3 alleles. The phenotypes are black, brown and white fur. 4 crosses were repeated many times. The crosses and the outcomes of these crosses are shown in the table below.

Cross	Parents	Offspring phenotype and ratio
1	black x black	3 black : 1 white
2	brown x white	1 brown : 1 white
3	black x black	3 black : 1 brown
4	white x white	all white

From the data, it is possible to conclude that

A brown fur is recessive to white fur.

B all of the white fur offspring are heterozygous.

C two thirds of the black fur offspring in cross **3** are heterozygous.

D the black fur parents in cross **1** have the same genotype as the black fur parents in cross **3**.

21. Fruit flies *Drosophila* homozygous for long wings, were crossed with flies homozygous for vestigial wings. The F_1 and F_2 generations were raised at three different temperatures.

At each temperature, the F_1 generation all had long wings.

The table below shows the results in the F_2 generation.

Temperature	***Result***
21°C	¾ long wings, ¼ vestigial wings
26°C	¾ long wings, ¼ intermediate wing length
31°C	all long wings

Which statement explains these results?

A Wing length is under polygenic control.
B Long wing and vestigial wing illustrate codominance at 26°C.
C Heterozygous flies have vestigial wings only at 21°C or below but have long wings at 31°C or above.
D Vestigial wing allele is recessive but causes a vestigial wing phenotype only at lower temperatures.

22. In cattle, the gene responsible for normal development of hair and teeth, ectodysplasin 1 (*ED1*) is located on the X chromosome. Mutations in the *ED1* gene result in a rare genetic disorder, anhidrotic ectodermal dysplasia. Another character, the presence of horns, is determined by a gene on an autosome. The allele for the absence of horns (**H**) is dominant and the allele for the presence of horns (**h**) is recessive.

A horned bull with anhidrotic ectodermal dysplasia was mated on several occasions to the same female. A large number of offspring consisting of males and females in equal numbers in all combinations of phenotypes are shown in the table.

Offspring phenotypes
No anhidrotic ectodermal dysplasia, horns present
No anhidrotic ectodermal dysplasia, horns absent
Anhidrotic ectodermal dysplasia, horns present
Anhidrotic ectodermal dysplasia, horns absent

If $\mathbf{X^E}$ represents an X chromosome carrying the normal *ED1* allele and $\mathbf{X^e}$ represents an X chromosome carrying the *ED1* allele for anhidrotic ectodermal dysplasia, what is the genotype of the female parent?

A $\mathbf{X^EX^EHH}$

B $\mathbf{X^EX^EHh}$

C $\mathbf{X^EX^eHH}$

D $\mathbf{X^EX^eHh}$

23. Which of the following statements are true?

1 Continuous variation is controlled by the additive effects of polygenes.

2 Continuous variation is always affected by the environment.

3 Discontinuous variation is sometimes affected by the environment.

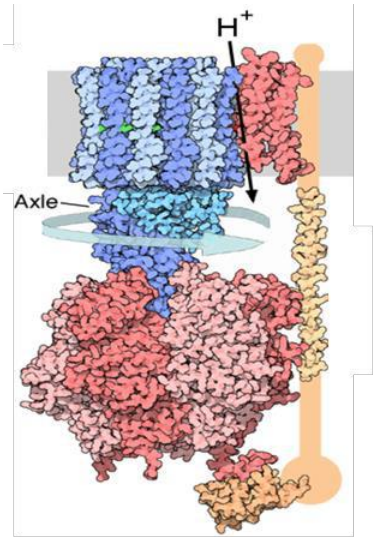
4 Discontinuous variation exhibits a normal distribution curve.

A 1 and 2
B 1 and 3
C 3 and 4
D 1, 2 and 3

24. A man and a woman, both with normal colour vision, have a colour-blind boy together. The woman is pregnant for a second time, and the doctor tells her she is carrying twins of one boy and one girl. What is the chance that both twins will have normal colour vision?

A 0%
B 25%
C 50%
D 100%

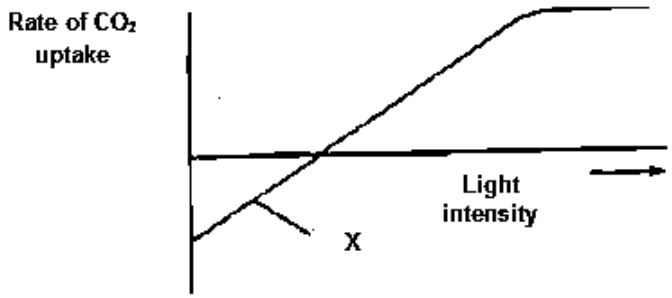
25. The diagram below shows a transmembrane protein that is involved in photophosphorylation



Which of the following statements are true

A It utilises the energy of ATP to do work.
B Its activation results directly in the production of water
C It carries out an oxidation reaction
D It transports ions through it via facilitated diffusion

26. In the graph below, the rate of CO_2 uptake by green algae cells is shown to vary with increasing light intensity.



Which of the following is true at point **X**?

A The algae cells are photosynthesising.
B Rate of carbon fixation by the calvin cycle equals rate of respiration.
C CO_2 is a limiting factor.
D There is not enough light for photosynthesis to have commenced.

27. A mitochondria suspension obtained from liver cells is prepared for investigations of the products of respiration. Acetyl-CoA is added to the suspension.

Which of the following correctly matched the products of Krebs cycle for every oxidation of one glucose molecule in this mitochondria suspension?

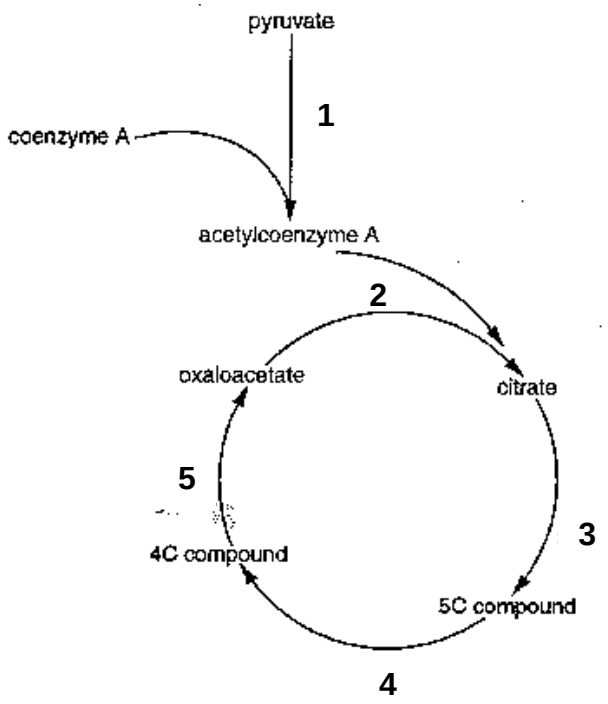
	Product	**Krebs cycle / glucose**
A	ATP	1
	Reduced NAD	3
	Reduced FAD	1
	CO_2	2

	Product	**Krebs cycle / glucose**
B	ATP	2
	Reduced NAD	6
	Reduced FAD	2
	CO_2	4

	Product	**Krebs cycle / glucose**
C	ATP	4
	Reduced NAD	4
	Reduced FAD	2
	CO_2	2

	Product	**Krebs cycle / glucose**
D	ATP	4
	Reduced NAD	6
	Reduced FAD	2
	CO_2	4

28. The diagram shows a process in a cell.



At which numbered stages does decarboxylation take place?

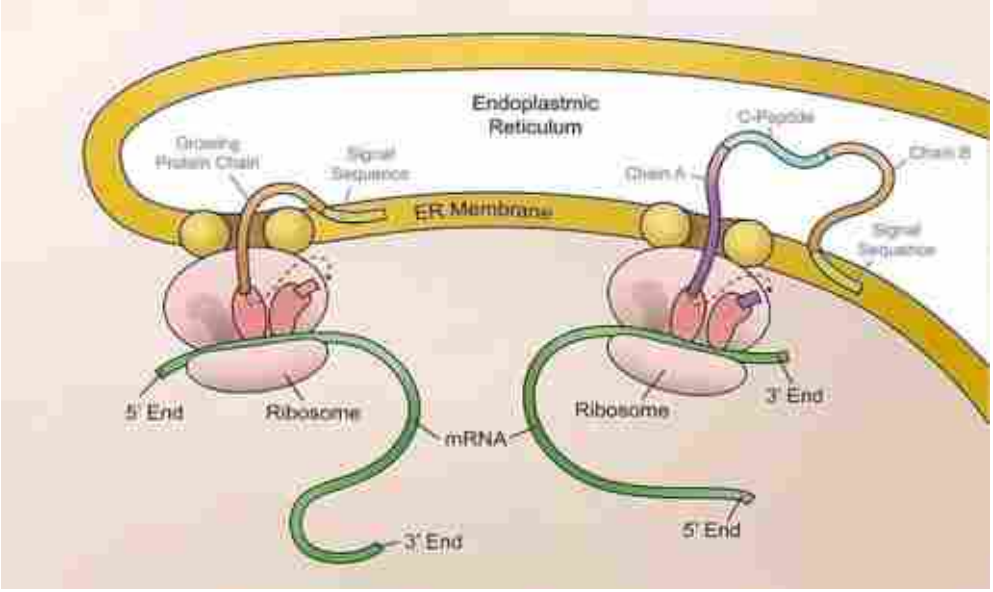
A 1 and 3
B 1, 3 and 4
C 2, 3 and 4
D 3, 4 and 5

29. Tetrodotoxin, a puffer fish toxin, blocks voltage-gated sodium channels. Black widow spider's venom causes the voltage-gated calcium channels to be constantly open. Crotoxin binds irreversibly to acetylcholine receptors.

What will happen to the nerve transmission if each toxin is applied?

	Tetrodotoxin	**Black widow spider's venom**	**Crotoxin**
A	block action potentials along axon	reduce transmission of impulse across synapse	increase transmission of impulse across synapse
B	increase transmission of impulse across synapse	reduce transmission of impulse across synapse	block action potentials along axon
C	block action potentials along axon	increase transmission of impulse across synapse	reduce transmission of impulse across synapse
D	reduce transmission of impulse across synapse	block action potentials along axon	increase transmission of impulse across synapse

30. The diagram below shows part of the insulin synthesis pathway in the pancreas.



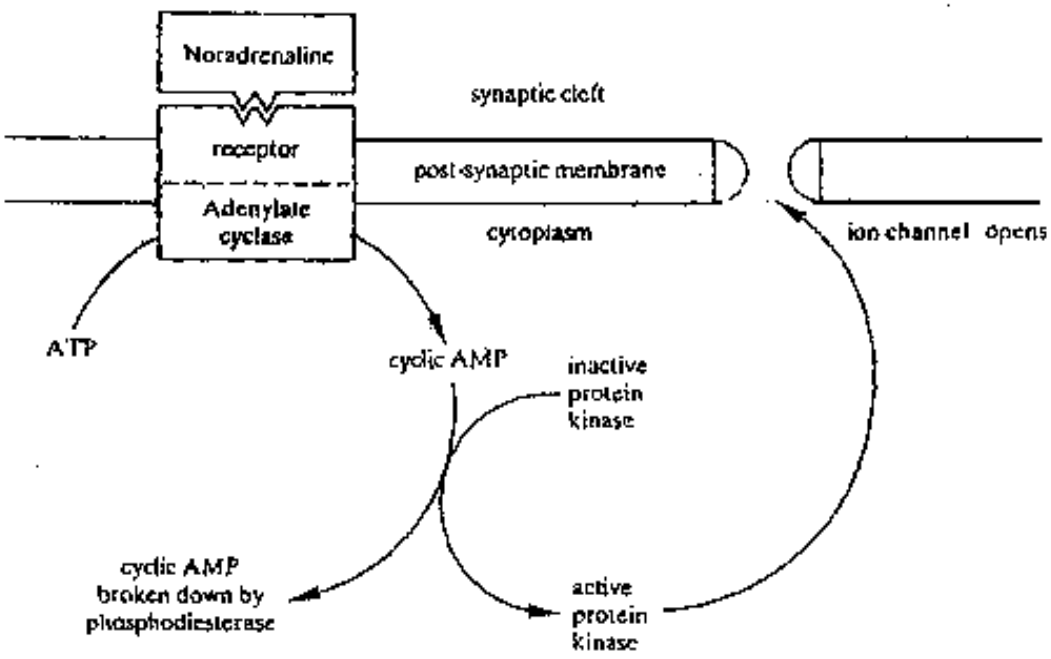
Which of the following statements is correct?

1 The islets of Langerhans are the effector cells in the regulation of blood glucose levels.
2 The signal peptide sequence (in the diagram above) that is synthesised in beta cells is made up of many amino acids with hydrophobic R groups.
3 The functional insulin hormone, made up of an A chain and a B chain held together by disulfide bonds, is formed in the rER lumen.
4 In the beta cells, pro-insulin will be converted to insulin after proteolytic cleavage of the C peptide from pro-insulin and the A and B chains are joined in the correct conformation.
5 Two separate ribosomes synthesise the A chain and the B chain in the above beta cell.
6 Negative feedback to prevent further synthesis of insulin occurs when blood glucose levels rise above norm.

A 1, 2 and 6
B 1, 3, and 4
C 2, 3 and 4
D 3, 5 and 6

31. Noradrenaline stimulates the activity of an enzyme adenylate cyclase located on

the post-synaptic membrane of a neurone. This initiates the sequence of reactions shown in the diagram, causing the opening of channels in the membrane through which ions can pass

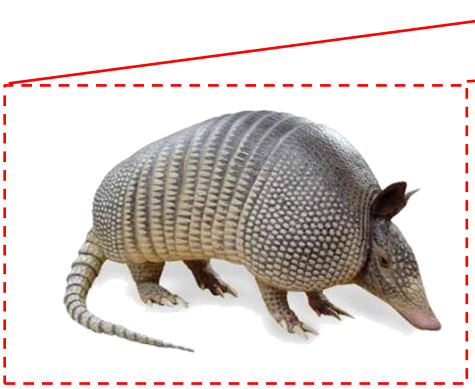


Caffeine causes the ion channels to remain open. A possible explanation is the inhibition of

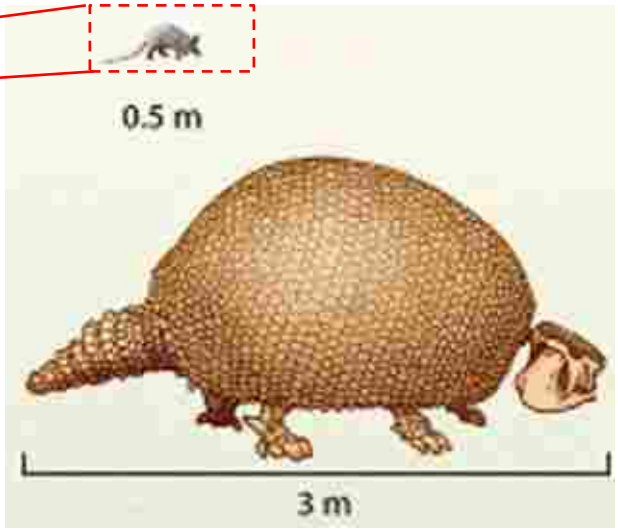
A ATP production
B phosphodiesterase
C cyclic AMP production
D adenylate cyclase

32. Armadillos are medium-sized mammals with tough bony covering that

protects the body. When harassed, armadillos will coil under their shield to minimise the amount of exposed flesh. They are insectivores, feeding on adult and larval forms of ants and termites. Once the prey is detected, armadillos use their claws to dig rapidly to tear into the ant and termite mounds. Their sticky tongues effectively lap up the scurrying insects. Fossils of a recent extinct species of giant armadillo were found to be similar to another smaller species of armadillo presently inhabiting the same region where it is discovered.



Living armadillo



Extinct armadillo

Which of the following statement supports the theory of natural selection?

A Some environmental conditions remained similar whereas other conditions changed between the past and the present.
B The similar characteristics of both species are due to the result of divergent evolution.
C The difference in size of both species is due to the result of constant rate of mutation of a particular gene affecting the growth rate.
D The extinction of the larger armadillo species was due to a chance event.

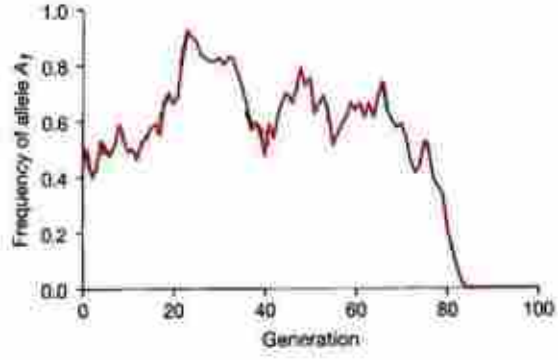
33. Cabbage, *Brassica oleracea* (2n = 20), and radish, *Raphanus sativus* (2n = 18), are different species of the Brassicaceae family. When these plants are crossed, a hybrid is produced. Two cells from the hybrid plant are fused to form a single cell which is propagated using tissue culture technique.

Which of the following is true?

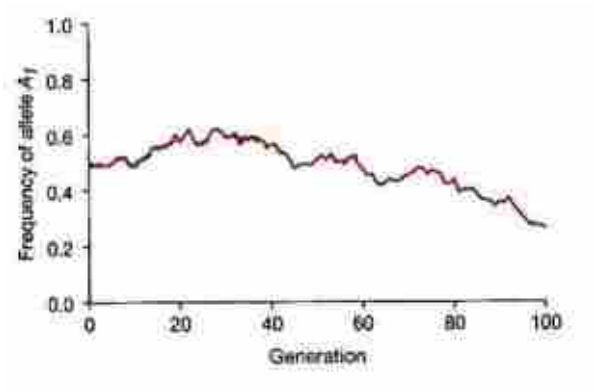
A The hybrid plant is a polyploid.
B The hybrid plant can produce gametes.
C The single fusion cell may eventually result in a new plant species.
D The plant that arises from the cultured cell may be crossed with either *Brassica oleracea* or *Raphanus sativus* to produce a viable and fertile offspring.

34. The graphs show the frequency of allele A1 of two fruit fly populations on an island and on a nearby mainland over time.

Island population size: 40



Mainland population size: 400,000



Based on the information, which of the statement(s) is/are true?

1 Selective pressures for gene A in the mainland changed over time.
2 Genetic drift and natural selection contributed to the change in frequency of allele A1 in the mainland population.
3 The loss of allele A1 from the island population could be due to a spontaneous mutation in the allele sequence.
4 Random chance could result in the fixation or loss of allele A1 in the island population.

A 3 only
B 3 and 4
C 1, 2 and 4
D 1, 2, 3 and 4

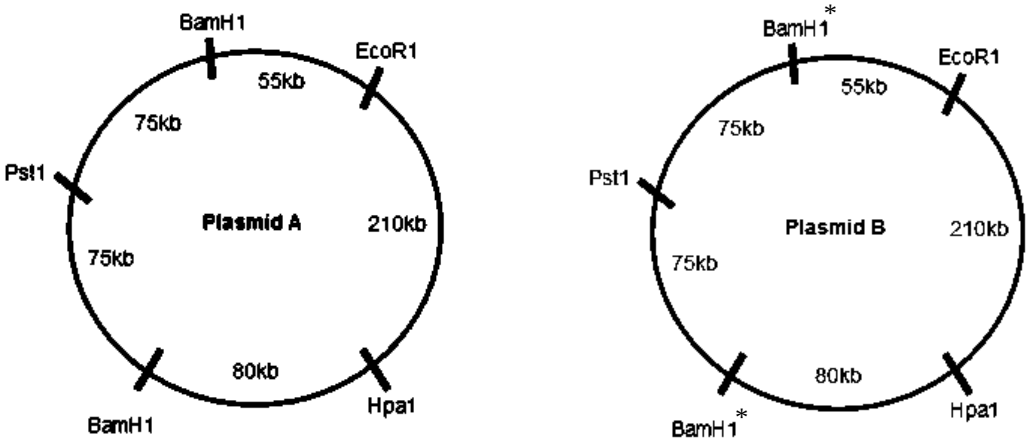
35. Which of the following statements are true for DNA libraries in cancer research?

1 The amino acid sequence of a mutated p53 protein can be determined from only a genomic DNA library.
2 Only a genomic DNA library can be used for the study of a strong enhancer sequence of a proto-oncogene.
3 The expression of specific proto-oncogenes and tumour suppressor genes in a type of cancer can only be determined from a cDNA library.
4 The identity of a specific regulatory protein affecting the expression of a tumour suppressor gene in a type of cancer can only be determined from a cDNA library.

A 1 and 2
B 3 and 4
C 1, 2 and 3
D 2, 3 and 4

36. The figure below shows 2 plasmids (A and B) and the respective restriction sites of various restriction enzymes.

In plasmid B, mutations were deliberately introduced and affected restriction sites are denoted by *****. The lengths of the plasmid DNA between consecutive restriction sites are also indicated.



A scientist carried out a series of 2 experiments by adding different restriction enzymes to the plasmids. Each tube was then left to incubate at 37ºC for about 60 minutes (sufficient time for complete digestion to take place). The results are shown in the table below.

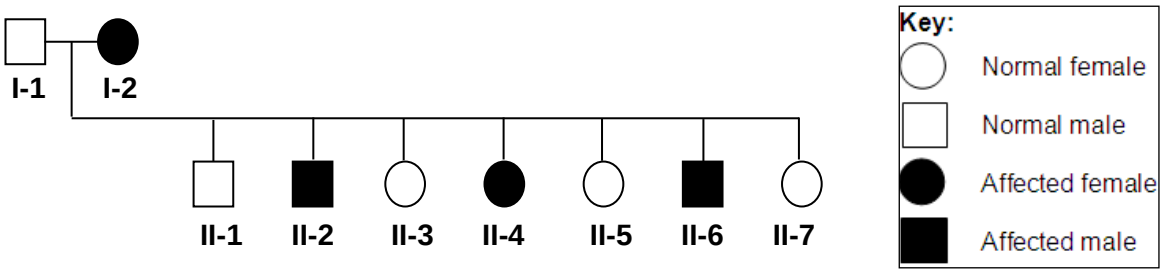
Tube number	Components	Fragment sizes/ kb
1	Plasmid A + 2 restriction enzymes	80, 150, 265
2	Plasmid B + 2 restriction enzymes	155, 340

Identify the enzymes that were added to tubes 1 and 2.

	Tube number	Restriction enzymes
A	1	HpaI , EcoRI
	2	EcoRI , HpaI
B	1	BamHI , PstI
	2	PstI , EcoRI
C	1	BamHI , HpaI
	2	HpaI , PstI
D	1	BamHI , EcoRI
	2	HpaI , BamHI

37. Use the information below for Questions 37 and 38.

Adult polycystic kidney disease (APKD) is inherited in an autosomal dominant manner. In an investigation to determine the chromosomal locus of APKD, linkage analysis of the APKD gene was carried out on members of one family. Three RFLP loci, **P**, **Q** and **R**, located on the non-coding regions of three different chromosomes, were used. The results of the linkage analysis are shown in the figure.



	RFLP alleles present at various individuals' RFLP loci								
	I-1	**I-2**	**II-1**	**II-2**	**II-3**	**II-4**	**II-5**	**II-6**	**II-7**
RFLP locus P	2 , 6	1 , 6	1 , 2	2 , 6	1 , 6	6 , 6	1 , 2	6 , 6	1 , 6
RFLP locus Q	1 , 5	2 , 7	5 , 7	2 , 5	1 , 7	1 , 2	5 , 7	1 , 2	1 , 7
RFLP locus R	4 , 8	5 , 8	5 , 8	8 , 8	5 , 8	4 , 8	5 , 8	4 , 8	5 , 8

Based on the information, which RFLP allele(s) will reveal if an individual has APKD?

	RFLP locus P	**RFLP locus Q**	**RFLP locus R**
A	-	2	-
B	6	2	8
C	-	1 , 2 , 5 , 7	-
D	1 , 2 , 6	1 , 2 , 5 , 7	4 , 5 , 8

38. Once the RFLP allele(s) associated with the disease allele is/are identified and sequence is determined, how could one check if a child may be suffering from APKD? Assume the sequence of APKD is not known.

1 Obtain genomic DNA → restriction digestion → gel electrophoresis → ethidium bromide staining
2 Obtain genomic DNA → restriction digest → gel electrophoresis → southern blot → autoradiography
3 Obtain genomic DNA → PCR → restriction digestion → gel electrophoresis → ethidium bromide staining
4 Obtain mRNA → cDNA → restriction digestion → gel electrophoresis → ethidium bromide staining

A 2 only
B 2 and 3
C 2, 3 and 4
D 1, 2, 3 and 4

39. Which of the following correctly describes the role of stem cells in adult tissues and organs?

A Stem cells are undifferentiated cells found amongst differentiated cells and they take over the function of the tissue when the overlying cells become damaged or worn out.
B Stem cells are embryonic cells that persist in the adult, and can give rise to all of the cell types in the body.
C Stem cells are partially differentiated cells that have yet to express the genes and proteins characteristic of their differentiated state, and do so when needed for repair of tissues and organs.
D Stem cells are undifferentiated cells that can divide asymmetrically, giving rise to one daughter cell that remains a stem cell and one daughter cell that will differentiate to replace damaged and worn out cells in the adult tissue or organ.

40. What are the arguments against the use of genetically modified organisms (GMOs)?

1 Insufficient testing of genetically modified crop for their side effects
2 Unforeseen long-term effects of genetic manipulation
3 Accidental genetic recombination in gut bacteria as a result of consuming food derived from GMOs
4 Control of food supply by a small number of companies that have access to genetic engineering technology

A 1 and 2 only
B 2 and 3 only
C 1, 2 and 3 only

D All of the above

ANSWERS

1	B	**11**	D	**21**	D	**31**	B
2	C	**12**	B	**22**	D	**32**	A
3	D	**13**	C	**23**	B	**33**	C
4	B	**14**	B	**24**	C	**34**	C
5	C	**15**	D	**25**	D	**35**	D
6	A	**16**	A	**26**	A	**36**	C
7	D	**17**	C	**27**	B	**37**	A
8	D	**18**	C	**28**	B	**38**	B
9	D	**19**	D	**29**	C	**39**	D
10	C	**20**	C	**30**	C	**40**	D

VICTORIA JUNIOR COLLEGE
BIOLOGY DEPARTMENT
JC2 PRELIMINARY EXAMINATIONS 2016
Higher 2

CANDIDATE NAME

CLASS	1	5	S		

EXAM NUMBER								

BIOLOGY 9648/02

Paper 2 Core Paper **14 September 2016**

Additional Materials: Answer Paper **2 hours**

READ THESE INSTRUCTIONS FIRST

Write your Class, exam number and name on all the work you hand in.
Write in dark blue or blue pen.
You may use a soft pencil for any diagrams or graphs.
Do not use any staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions in the spaces provided on the question paper.

Section B
Answer any **one** question on the writing paper provided.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use the appropriate units.

At the end of the examination,
1. hand in sections A and B separately;
2. fasten all your work securely;
3. enter the question number of section B that you have answered in the grid opposite.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
8	
Section B	
Total	

This paper consists of **20** printed pages.

Section A: Structured questions
Answer **all** the questions. All answers must be written on the spaces provided and nowhere else.

1 (a) **Fig. 1.1** shows the electro-micrograph of a T-helper cell found in the bloodstream of a healthy individual. **Fig 1.2** shows the how a region of the T-helper cell looks like when magnified.

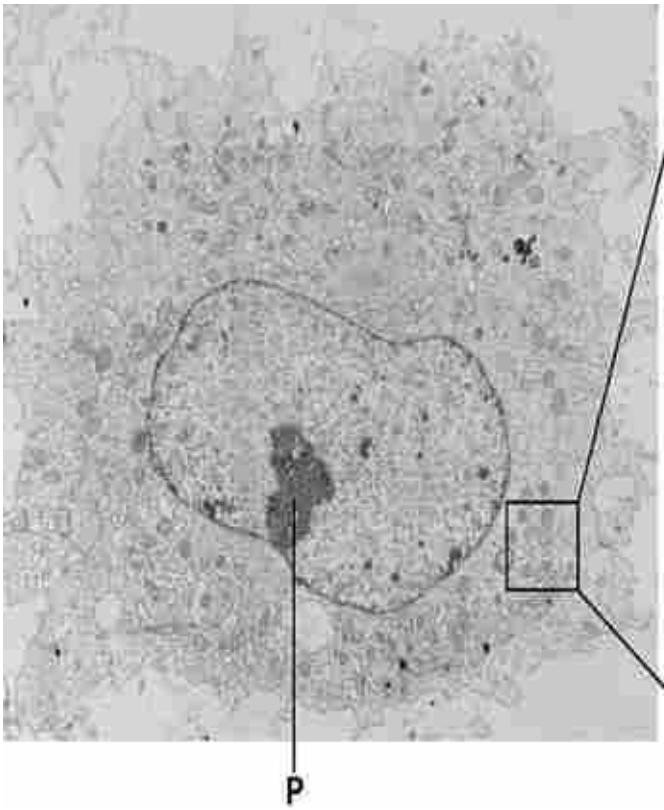


Fig. 1.1 EM of T helper cell

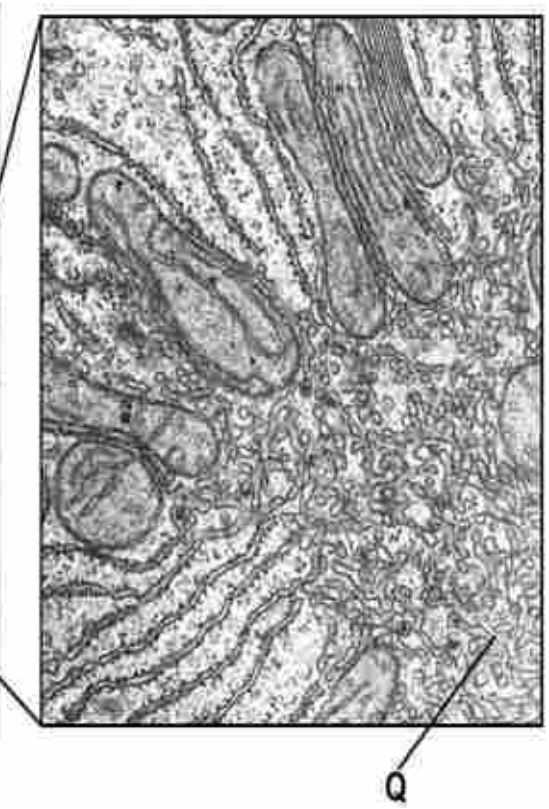


Fig. 1.2 Magnified region of a part of the T helper cell

(i) Identify structures **P** and **Q** and describe briefly their functions.

[3]

(ii) Contrast the structure of a lysosome with structure **P**.

[2]

(b) The cytoplasm of T-helper cells contains different proteins and enzymes, one of which is phosphofructokinase involved in the metabolism of glucose to produce energy necessary for cell survival and functions. In order to ensure a constant supply of energy, most organisms have evolved the use of storage molecules to store excess glucose.

(i) Name a carbohydrate that functions as a storage molecule for T-helper cells.

[1]

(ii) Describe **three** structural differences between the carbohydrate named in **(b) (i)**. and cellulose.

[3]

(iii) Explain how the presence of two types of bonds in amylopectin enables it to carry out its function.

[3]

(c) Phosphofructokinase is an allosteric enzyme. Explain how the presence of an allosteric inhibitor affects the enzymatic activity of an allosteric enzyme.

[2]

[Total: 14]

2 The Fig. 2.1 shows an enzyme involved in the activation of tRNA for translation in prokaryotes.

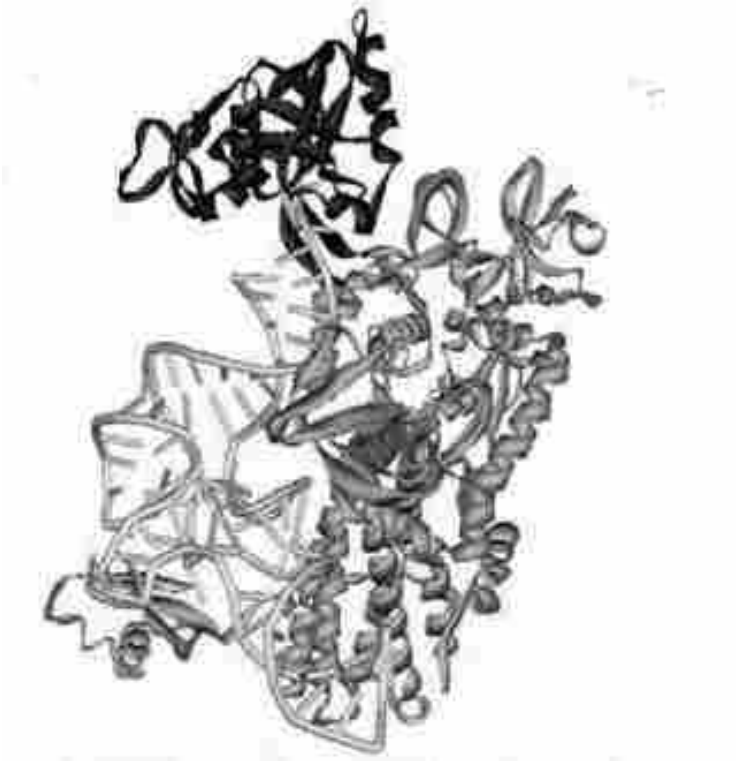


Fig 2.1

(a) (i) Explain the mode of action of this enzyme.

[3]

(ii) Explain the significance of having more than one type of the enzyme named in **(a) (i)** in the cell.

[2]

(b) How does the order of nucleotides in a gene encode the information that specifies the primary structure of a polypeptide? Include two features of the genetic code in your answer.

[3]

(c) Explain how different polypeptides can be synthesised simultaneously from a single mRNA is produced from an operon in prokaryotes.

[2]

[Total: 10]

3 Fig. 3.1 shows the *arg* operon found in *Escherichia coli*. In the absence of arginine, the operon is in the active state. In the presence of arginine, the expression of the structural genes decreases.

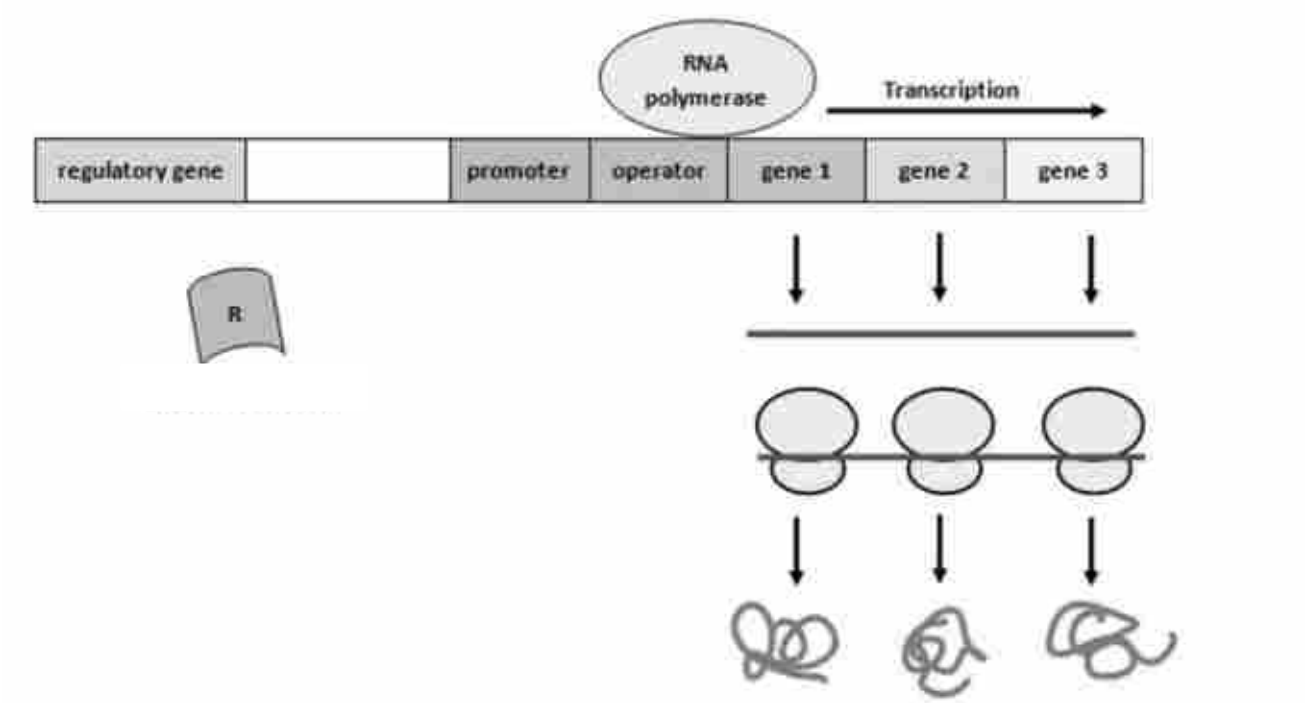


Fig 3.1

(a) Using **Fig 3.1** explain the mode of control of the Arg operon.

[2]

(b) Explain why it is useful for a bacterial cell to decrease expression of the structural genes when arginine is present.

[2]

Besides having operons, bacteria can have other means to enhance their adaptability to the changing environment through gene transfer. Fig. 3.2 shows one way in which bacteria can acquire new genetic material.

Fig. 3.2

(c) Name and describe the process which can result in this population of bacteria acquiring the same allele needed to increase their likelihood of survival.

[3]

Fig. 3.3 shows a classic experiment used to show that physical contact between bacterial cell is necessary in order for conjugation to happen

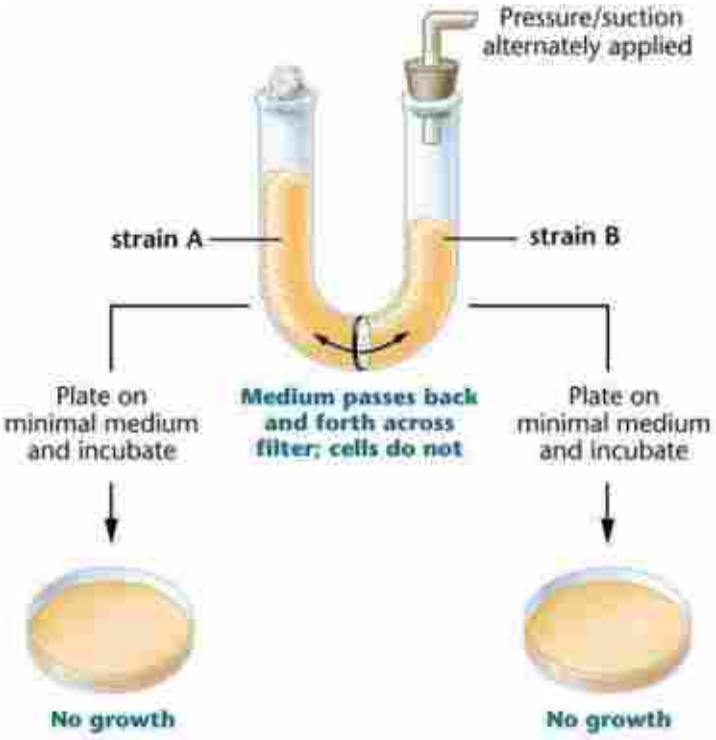


Fig. 3.3

(d) A student tried to replicate the experiment but did not get the result shown in Fig. 3.3. Instead, he observed a few bacterial colonies which are hybrids of strains A and B. He later realized that he had accidentally forgot to add in DNAase when carrying out the experiment.

(i) Briefly describe the role of DNAase in this experiment

[1]

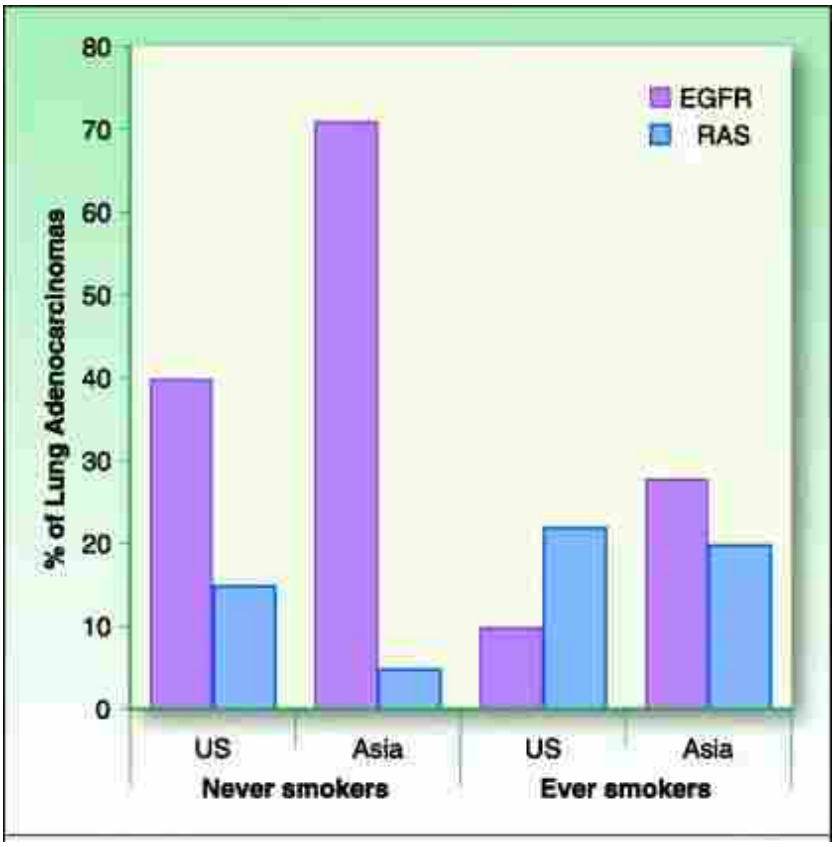
(ii) How does the lack of DNAase in the experiment result in the growth of the hybrid bacterial colonies?

[2]

[Total: 10]

4 The majority of lung cancers are caused by long term exposure to the several classes of carcinogens present in tobacco smoke. However there are instances of lung cancers arising in the absence of detectable tobacco exposure. Analysis of the different mutations in individuals who smoked (ever-smokers) and those who did not (never-smokers) suggest that lung cancers in never smokers may follow a very different cellular and molecular pathway of malignant transformation.

The Fig. 4.1 shows the differential frequencies of gene mutations of the epidermal growth factor receptor (EGFR) and Ras reported in lung adenocarcinomas in Asia versus United States, in never-smokers and ever-smokers.



http://clincancerres.aacrjournals.org/content/15/18/5646

Fig. 4.1

With reference to Fig. 4.1,

(a) (i) describe the effect of Ras and EGFR mutations on the development of lung cancer in never-smokers and ever –smokers in Asia.

.....

[1]

.....

(ii) Suggest the molecular basis behind why never-smokers in Asia develop lung cancer.

[2]

Data emerging over the past several years show that activating mutations in the epidermal growth factor receptor (EGFR) gene may underscore the development of a distinct class of lung cancers. EGFR signalling is triggered by the binding of growth factors resulting in the dimerization of EGFR.

(b) Suggest the role of the *EGFR* gene in relation to the development of cancer.

[3]

(c) Small molecule inhibitors of the tyrosine kinase enzymatic activity to inhibit cross-phosphorylation and signalling of the EGFR have been used in clinical treatment in the United States. Results found that the success of treatment of lung cancers is higher for never-smokers than ever-smokers. Based on Fig. 4.1 suggest why this is so.

[2]

(d) 50% of never-smokers with lung cancer also have mutations in the p53 gene. Explain how mutations in the *p53* gene may lead to the development of lung cancer.

[3]

[Total: 11]

5 In the Korean clover plant, the development of petals is determined by two genes on separate autosomes. Gene A has two alleles - the dominant allele **A** results in the development of normal petals, while the recessive allele, **a**, results in small petals. On another chromosome, the dominant allele **B** of another gene has no effect on petal development. However, allele **b** hinders petal development and so results in the formation of fused petals regardless of the nature of the allele at gene A.

A Korean clover plant was self-pollinated and obtained the following offspring:

Normal petals	46
Small petals	14
Fused petals	20

(a) (i) State the genotype and phenotype of the clover plant that was self-pollinated.

Genotype:

Phenotype: [1]

(a) (ii) Use a genetic diagram to illustrate the phenotypic ratio of the offspring from this cross.

[3]

(b) A scientist decided to study the inheritance of flower colour and plant height in another plant species. The alleles for these traits are shown below.

T: Allele for tall plants **t:** allele for dwarf plants

Y: allele for yellow flowers **y:** allele for white flowers

He carried out a cross between a heterozygous tall, yellow-flowered plant with a homozygous recessive dwarf, white-flowered plant and obtained a large number of offspring. Table 5.1 shows the results.

Phenotype	**Number of offspring**
Tall, yellow-flowered plant	78
Tall, white-flowered plant	22
Dwarf, yellow-flowered plant	20
Dwarf, white-flowered plant	80

Table 5.1

(i) State the expected phenotypic ratio of the offspring in Table 5.1.

[1]

(ii) Use the chi-squared (X^2) test and the table of probabilities shown in Table 5.2 to find the probability of the results of this cross departing significantly by chance from expectation. Show your working. [2]

$$\chi^2 = \sum \frac{(\text{Observed Value} - \text{Expected Value})^2}{(\text{Expected Value})}$$

Key to symbols

s = standard deviation	n = sample size (number of observations)	E = expected 'value'
Σ = 'sum of'	v = degrees of freedom	
x = observation	c = number of classes	
$\bar{x}$ = mean	O = observed 'value'	

Distribution of X^2

	probability, p				
degrees of freedom	**0.10**	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

Table 5.2

X^2 value = ...

number of degrees of freedom = ...

probability = ...

(iii) State what conclusions may be drawn from the probability found in (b) (ii).

.....

.....

.....

[2]

(iv) Explain the observed phenotypic ratio in Table 5.1.

.....

.....

.....

[2]

[Total: 11]

6 Myasthenia gravis is a disease of the neuromuscular junctions which causes muscular weakness. It develops because the muscle's response to repeated nerve signals declines with time, and the muscles become weak and tired.

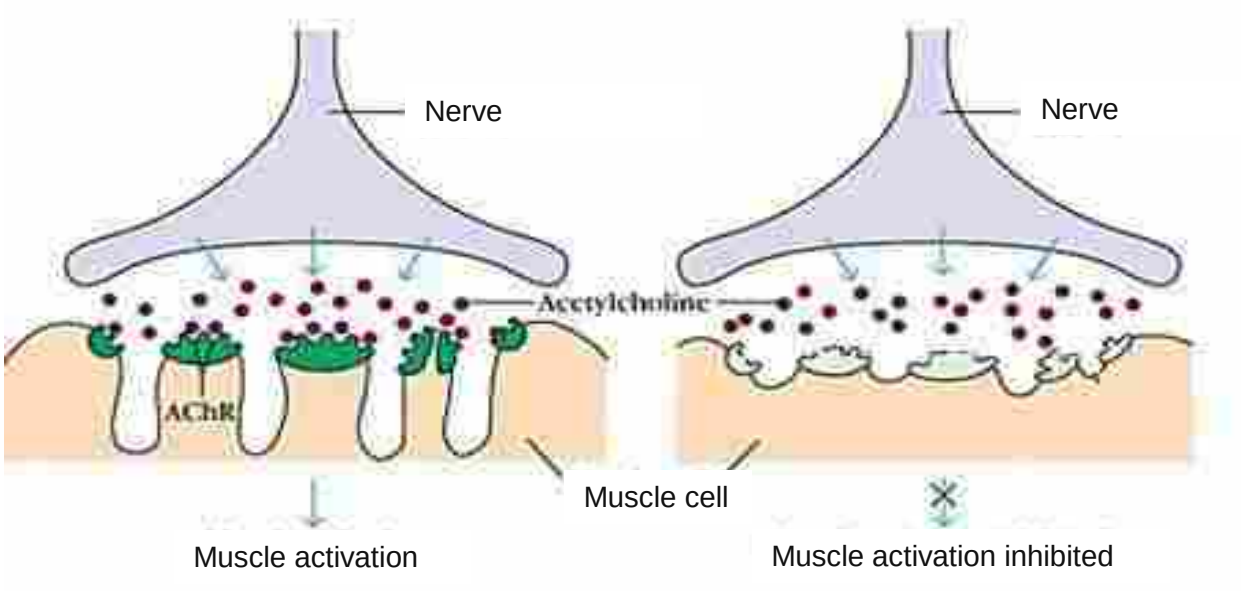


Fig. 6.1: Normal neuromuscular junction

Fig. 6.2: Myasthenic neuromuscular junction

(a) (i) State one similarity in the structure of a normal and myasthenic neuromuscular junction as seen in Fig. 6.1 and 6.2 and explain how it aids in synaptic transmission.

[2]

(ii) State one difference in the structure as seen in Fig. 6.1 and 6.2 and explain how it affects synaptic transmission.

[2]

(b) Describe the mechanism that ensures unidirectional movement of nerve impulses along the axon of a neurone.

[2]

(c) Fig. 6.3 shows action potentials generated along an axon over a fixed time, X.

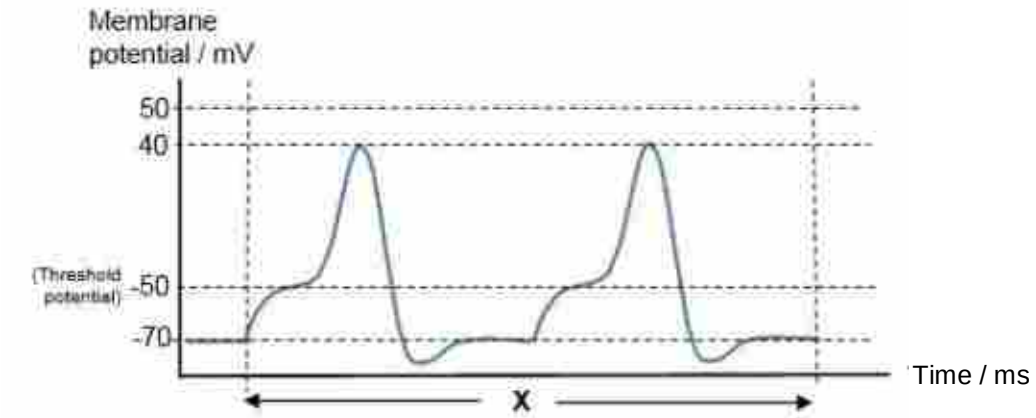
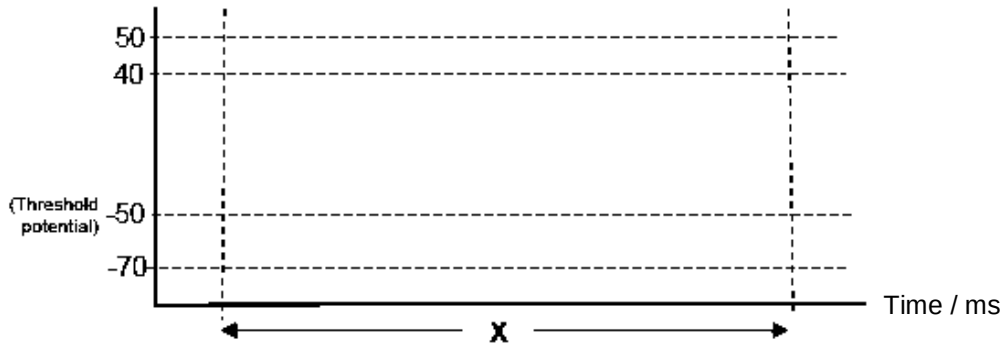


Fig 6.3

In the space provided, draw the action potentials generated over the same time period X if the stimulus is more intense. [2]



[Total: 8]

7 Glucagon plays a critical role in maintaining glucose homeostasis. The molecular mechanisms for glucagon-mediated glucose regulation are shown in Fig. 7.1.

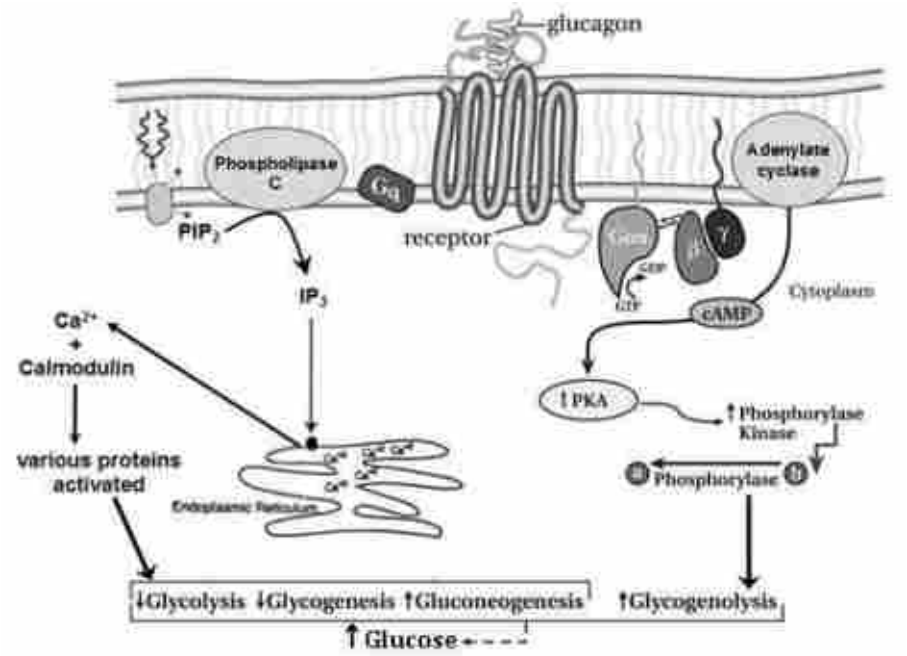


Fig. 7.1

(a) State the type of receptor that glucagon binds to and explain how this receptor is fully activated.

[2]

(b) With reference to Fig. 7.1, briefly explain how cAMP can lead to an increase in blood glucose concentration.

[3]

[Total: 5]

8 Members of the family Rhopalidae include the soapberry bugs which are brightly-coloured fruit-eaters, comprising of three genera and about 65 species. These bugs are specialists on plants in the soapberry family (Sapindaceae) in which they obtain the nutrients from the fruits by piercing the skin using their sharp beaks.

Fig. 8.1: A soapberry bug feeding on a fruit

Jadera haematoloma is a soapberry bug found in Florida following the introduction of a non-native soapberry plant in the 1920s which out-competed the native plant in some locations. At such locations, measurement of the beak length of individual bugs was also carried out (Fig. 8.2). Analysis of the fruit of the non-native plant also showed that it has thinner skin as compared to the fruit of the native plant.

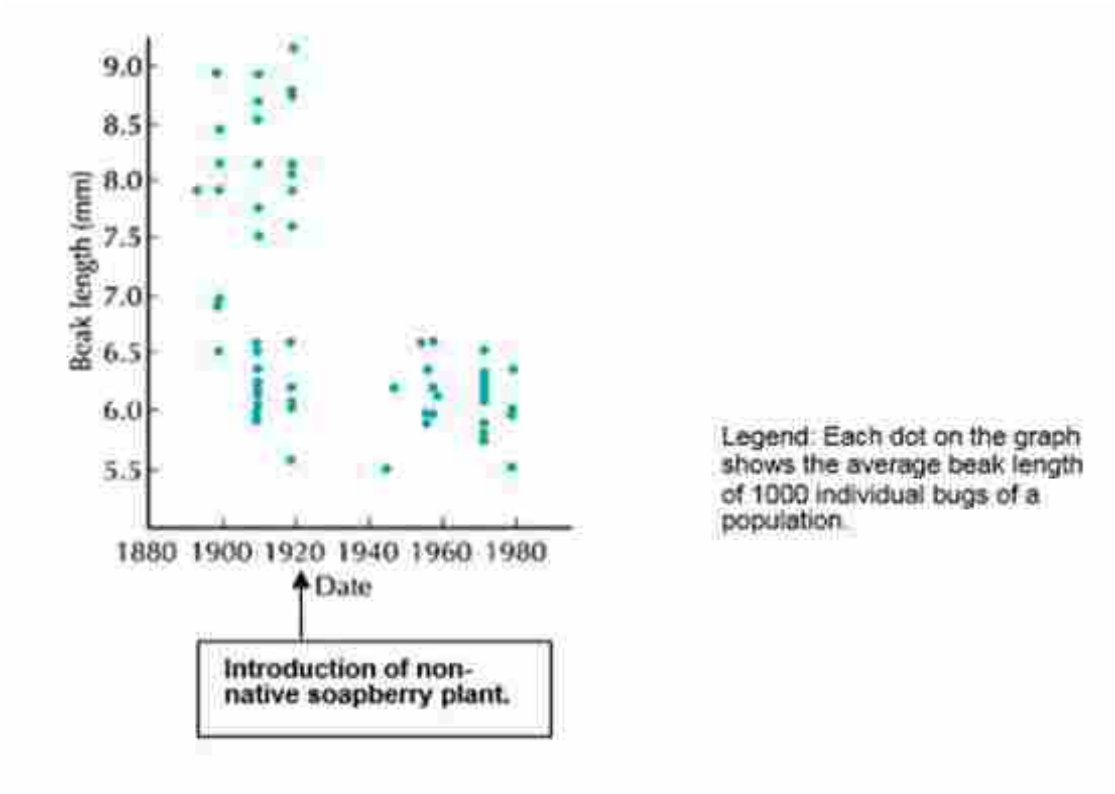


Fig. 8.2: Beak lengths of soapberry bugs (1880-1980)

(a) Explain why the evolution of *Jadera haematoloma* after the introduction of a non-native soapberry plant in the 1920s is not considered a form of divergent evolution.

.....

[1]

.....

(b) Account for the beak lengths over time.

[4]

(c) In 1980, 4000 soapberry bugs at one sampling site were caught and transported to island X with a variety of soapberry plants with thick and thin skinned fruits. The bugs were allowed to populate the island in the absence of predator. In 1990, the beak lengths of bugs were measured and showed a wide variety of beak lengths.
At the same time in 1980, 40 individuals were taken and released to an isolated island Y with the same conditions as island X. In 1990, the beak lengths of bugs in both islands were also measured but the beak lengths were all short (below 6mm) although both islands were similar to each other.

(i) Suggest a likely explanation for the result seen in island Y.

[2]

(ii) In 2000, both islands were invaded by a plant viral disease that destroyed the soapberry plants with thin-skinned fruits. The outcome of/effect on the bugs in both islands in terms of the beak length variety and total number of bugs over time are shown in Fig. 8.4.

Island	**X**	**Y**
Total number of bugs	Remains about the same	Nil (extinction)
Variety of beak length	Only long beaks	-

Fig.8.4

Explain the results in Fig. 8.4.

.....

.....

.....

[2]

(c) Analysis of the DNA sequences of the soapberry bugs in both islands before the viral invasion revealed differences that could not be explained by the theory of natural selection. How may the neutral theory of molecular evolution account for the differences?

.....

.....

.....

[2]

[Total: 11]

Section B

Answer **one** question.

Write your answers on separate writing paper.

Your answer should be illustrated by large, clearly labeled diagrams, where appropriate.

Your answer must in continuous prose, where appropriate.

Your answers must be set out in sections (a), (b) etc., as indicated in the question.

Begin your answers to each part (a), (b) and (c) on a new sheet of writing paper.

9 **(a)** Explain how molecular and anatomical homology supports Darwin's theory of natural selection [6]

(b) Describe the response of the muscle cell to insulin with respect to cell signaling [8]

(c) Define control elements and explain how they interact with other factors to influence transcription [6]

10 **(a)** Explain how recessive alleles may be preserved in a natural population [6]

(b) Explain the advantages and significance of having a cell signaling system [6]

(c) Describe binary fission and explain how it differs from bacterial conjugation. [8]

[20]

VICTORIA JUNIOR COLLEGE
BIOLOGY DEPARTMENT
JC2 PRELIMINARY EXAMINATIONS 2016
Higher 2

BIOLOGY 9648/02

Paper 2 Core Paper Answers **14 September 2016**

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1 (a)

(i) Identify structures **P** and **Q** and describe briefing their functions. [3]

- P – Nucleolus [1/2]
- Transcription of ribosomal RNA [1/2]
- Site of ribosome assembly [1/2]
- Q – Smooth endoplasmic reticulum [1/2]
- Site of synthesis of lipids [1/2]
- Detoxification of drugs and poisons [1/2]
- Stores calcium ions required for contraction in muscle cells [1/2]

(ii) Contrast the structure of a lysosome with structure **P**. [2]

Lysosome	P (Nucleolus)
• Membrane-bound [1/2]	• Not membrane-bound [1/2]
• Contains hydrolytic enzymes [1/2]	• Contains DNA coding for rRNA [1/2]

(b)

(i) Name a carbohydrate that functions as a storage molecule for T-helper cells.

- Glycogen [1]

(ii) Describe **three** structural differences between cellulose and the carbohydrate in **(bi)**. [3]

Cellulose	Glycogen
• Made up of β-glucose	• Made up of α-glucose
• Joined by β 1,4 glycosidic bonds	• Joined by α 1,4 glycosidic bonds and α 1,6 glycosidic bonds
• Unbranched, straight chains	• Branched brush-shaped
• Alternate subunits rotated 180^{o}	• Alternate subunits in the same orientation
• Inter-chain hydrogen bonds present	• No cross-linkages between adjacent chains

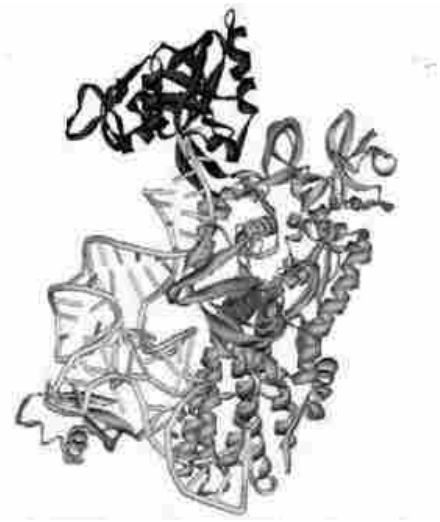
(iii) Explain how the presence of two types of bonds in amylopectin enables it to carry out its function. [2]

- α 1,4 glycosidic bonds between subunits within a branch [1/2]
- α 1,6 glycosidic bonds at branch points [1/2]
- form branched helical structure
- compact for storage function
- Both bonds can be broken enzymatically to release α glucose for respiration [1/2]
- Hydrolysis of α 1,6 glycosidic bonds breaks up amylopectin into many branches for more efficient breakdown [1/2]

(c) Phosphofructokinase is an allosteric enzyme. Explain how the presence of an allosteric inhibitor affects the enzymatic activity of an allosteric enzyme. [2]

- Allosteric inhibitor binds to allosteric site [1/2]
- Causes the enzyme conformation to change to inactive state [1/2]
- Active site not complementary to substrate [1/2]
- Prevent effective collision and formation of enzyme-substrate complex [1/2]

2. The diagram below shows an enzyme involved in the activation of tRNA for translation in prokaryotes.



(a) (i) Explain the mode of action of this enzyme [3]

- amino-acyl tRNA synthetase;
- has a specific active site that is
- complementary to specific tRNA anticodons and a specific amino acid
- Ref. to induced fit theory
- catalyses the attachment of a specific amino acid to the 3' stem of the tRNA in the formation of the amino-acyl tRNA complex
- by lowering the activation energy of the reaction
- through the formation of an enzyme structure complex

(ii) Explain the significance of having more than one type of the enzyme named in (ai) in the cell [2]

- There are 20 different amino acids and hence 20 different amino-acy-tRNA synthethases are needed
- This ensures that each of the 20 amino acids are correctly linked to their tRNAs/ ref to specificity of enzyme for substrate
- As the anticodons of the tRNA bind by complementary base pairing to the condons in the P and A site of the ribosome
- When an amino acid has been linked to a tRNA, it will be incorporated into a growing polypeptide chain at a position dictated by the codon of the mRNA.
- Allowing the primary structure of the polypeptide to be synthesised correctly according to the codons of the mRNA that is being translated

(b) How does the order of nucleotides in a gene encode the information that specifies the primary structure of a polypeptide? Include two features of the genetic code in your answer.[3]

- Transcription of the gene by RNA polymerase produces a complementary sequence of mRNA;
- Three consecutive nucleotides on mRNA make one codon;
- One codon codes for one amino acid;
- Although more than one codon can code for the same amino acid due to the degenerate nature of the genetic code;
- The ribosome read the codons one after another with no space between codons as the genetic code is non-overlapping.
- The ribosome thus joins the amino acids in the correct sequence as coded for by the codon sequence to form the polypeptide's primary structure/ the codon sequences hence determine the number, type and sequence of amino acids of the polypeptide synthesized by the ribosome
- As the genetic code is punctuated where 3 codons do not code for amino acids but function as stop codons that mark the end of translation. The ribosome stops polypeptide synthesis when a stop codon is located in the ribosome A site as a release factor enters the site to release the completed polypeptide.

(c) Explain how different polypeptides can be synthesised simultaneously from a single mRNA in prokaryotes. [2]

- A prokaryotic mRNA is a polycistronic mRNA;
- And contains the coding sequence for more than one polypeptide/ structural gene product involved in a related metabolic pathway;
- Each coding sequence has its own start and stop codon;
- Allows more than one ribosome to bind to the polycistronic mRNA and start simultaneous translation beginning at the start codon
- more than one translation initiation complex can be formed at a time;
- Translation of each polypeptide stops when the ribosomes read the stop codon for the coding sequence

3

(a) Using Fig 3.1, explain the mode of control of the Arg operon. [2]

- Negative control of arg operon;
- as the repressor (activated by arginine) is required to switch / turn off gene expression;

(b) Explain why it is useful for a bacterial cell to decrease expression of the structural genes when arginine is present. [2]

- Trp genes code for enzymes (involved in / necessary for) (anabolism / synthesis) of tryptophan
- Decreased expression helps to conserve resources that could be diverted for other uses /preventing wastage of resources

(c) Name and describe the process which can result in a population of bacteria acquiring the same allele needed to increase their likelihood of survival.

- **specialised transduction;;**
- Viral DNA **integrates** into a **specific location**;
- When it excises as the cell enters the **lytic cycle**;
- The bacterial DNA removed along with the **excision** of the viral DNA;
- will be those that are **near to the prophage** on the bacterial chromosome;
- DNA transferred will therefore be about the same;

(d)(i) Briefly describe the role of DNAase in this experiment.

- Digest naked DNA fragments

(ii) How does the lack of DNAase in the experiment result in the growth of the hybrid bacterial colonies?

- Without the DNAase, the naked DNA fragments from bacteria which have died may be taken up by the other strain via transformation
- DNA fragment will be small enough to cross over the filter

4.

With reference to Fig. 4.1

(a) (i) describe the effect of the 2 gene mutations on the occurrence of cancer in Asians. [1]

- 70% of never smokers with lung cancer have mutations in EGFR gene compared to 27% of ever smokers with lung cancer;
- While 4 % of never smokers with lung cancer have mutations in Ras gene compared to 20% of ever smokers with lung cancer;

(ii) suggest how never smokers in Asia developed lung cancer [2]

- never smokers who get lung cancer could have inherited a dominant mutation in the EGFR gene and experienced a loss of heterozygosity for two or more tumour suppressor genes;;
- as seen from the high percentage of never smokers having the mutation in the EGFR gene compared to ever smokers suggesting the never smokers inherited an increased disposition to acquiring lung cancer;
- even in the absence of exposure to chemical carcinogens such as tar in cigarette smoke

(b) Suggest the role of the *EGFR* gene in relation to the development of cancer. [2]

- *EGFR* gene is a proto-oncogene;
- That codes for the production of growth factor receptor involved in the signalling pathway for cell division;
- Gain-of-function mutation converts EGFR gene into an oncogene;
- The hyperactive/ constitutively dimerised EGFR protein/ receptor constantly stimulates cell division/ results in abnormally active signalling to initiate cell division
- The cell is able to proliferate in the absence of growth factors
- The excessive/ uncontrolled cell proliferation leads to formation of cancerous tissue / tumor.

(c) Small molecule inhibitors of the tyrosine kinase enzymatic activity to inhibit autophosphorylation and signalling of the EGFR have been used in clinical treatment in the United States. Results found that the success of treatment of lung cancers is higher for never-smokers than ever-smokers. Based on Fig. 4.111, suggest why this is so. [2]

- Mutations in EGFR is causal to development of cancer in 40% of never-smokers compared to 10% of ever-smokers;
- Hence inhibiting the EGFR is 4 times more likely to lead to success in treatment in never-smokers;
- A higher percentage of ever-smokers (22% compared to 14%) have mutations in Ras;
- Ras acts downstream of the EGFR / involved in another cell signalling pathway;
- A EGFR inhibitor will have no effect as a hyperactive Ras can signal of excessive cell division even in the absence of signalling from the growth factor receptor;

(d) 50% of never smokers with lung cancer also have mutations in the p53 gene. Explain how mutations in the *p53* gene may lead to the development of lung cancer. [3]

- p53 is a tumor suppressor gene that serves to restraint cell division;
- ref. Loss-of-function mutations
- ref. in both alleles of the *p53* gene
- ref. p53 protein is a transcription factor
- When there is DNA damage,the mutated p53 protein is unable to activate:
  - DNA repair genes to repair the DNA damage
  - P21 gene stop the cell cycle to allow time to repair DNA
  - genes controlling apoptosis that cause the (lung epithelial) cell to die when there is excessive DNA damage
- thus allowing accumulation of mutations to occur.

5.

(a) (i) State the genotype and phenotype of the clover plant that was self-pollinated.

Genotype: AaBb (1/2)

Phenotype: Normal petals **(1/2)** [1]

(a) (ii) Use a genetic diagram to illustrate the phenotypic ratio of the offspring from this cross.

Phenotype of parents: normal petals x normal petals

Genotypes of Parents: AaBb x AaBb

F1 Gametes **AB** **Ab** **aB** **ab** ; **1 m for gametes;**

F1 Genotypes and Phenotypes:

Gametes	**AB**	**Ab**	**aB**	**ab**
AB	**AABB normal**	**AABb normal**	**AaBB normal**	**AaBb normal**
Ab	**AABb normal**	**AAbb fused**	**AaBb normal**	**Aabb fused**
aB	**AaBB normal**	**AaBb normal**	**aaBB small**	**aaBb small**

ab	AaBb normal	Aabb fused	aaBb small	aabb fused

1 m for all correct F1 genotypes;

1 m for all correct corresponding phenotypes;

F1 Phenotypic Ratios: normal : small : fused

9 : 3 : 4 ; **1 m for correct ratio;** [3]

(b) (i) State the expected phenotypic ratio of the offspring in Table 5.1.

1:1:1:1 [1]

(ii) A X^2 (chi-squared) test was conducted on the results. Using the formula and table of probabilities given below, calculate the X^2 value and give the conclusion that may be drawn from it.

$$\chi^2 = \sum \frac{(\text{Observed Value} - \text{Expected Value})^2}{(\text{Expected Value})}$$

Calculated X^2 value = 67.36 **[1/2]**

Degree of freedom = 3

Probability = < 0.001

Distribution of X^2

	probability, p				
degrees of freedom	**0.10**	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

Conclusion:
Since p<0.001

Difference between expected and observed phenotypic ratio is significant and not due to chance;

Observed ratio does not follow expected ratio of 1:1:1: [2]

(b) (iii) Explain the observed phenotypic ratio in Table 5.1.

- Linked genes
- Allele **T** is linked to allele **Y** and allele **t** is linked to allele **y**;
- If crossing over occurs, linkage between alleles is broken / new allele linkages will be formed;
- Such that recombinant gametes/chromosomes (**Ty** and **tY**) are formed ;
- Large no. of tall, yellow-flowered and dwarf, white-flowered / offspring with parental phenotypes OR small no. of dwarf, yellow-flowered and tall, white-flowered / offspring with recombinants phenotypes; [Max 2]

6 **(a)** Myasthenia gravis is a disease of the neuromuscular junctions which causes muscular weakness. It develops because the muscle's response to repeated nerve signals declines with time, and the muscles become weak and tired.

(i) State one similarity in the structure of a normal and myasthenic neuromuscular junction as seen in Fig. 6.1a and 6.1b and explain how it aids in synaptic transmission. [2]

Any one:

- Pre-synaptic neurones are able to secrete acetylcholine. [1/2]
- Acetylcholine diffuses across the synaptic cleft [1/2] and bind to the acetylcholine receptors [1/2] present on the post-synaptic membrane [1/2] / muscle cell → membrane depolarisation [1/2]

Or

- Acetylcholine receptors [1/2] present on the post-synaptic membrane [1/2] / muscle cell.
- Upon binding with acetylcholine, ligand / chemical / Na^+-gated channel opens [1/2] → influx of Na^+ [1/2]→ membrane depolarisation [1/2]

(ii) State one difference in the structure as seen in Fig. 6.1a and 6.1b and explain how it affects synaptic transmission. [2]

Any one:

- Unlike normal muscle cell which is deeply folded [1/2], Myasthenic neuromuscular junction has less shallow in-folding [1/2] of the post-synaptic membrane / muscle cell
- Affects the number of acetylcholine receptor [1/2] (or AChR) embedded on the membrane available to bind to acetylcholine

- Abnormal acetylcholine receptor (or fewer normal acetylcholine receptors present) [1/2] present on the post-synaptic membrane / muscle cell
- Cannot bind to acetylcholine [1/2] / bind to auto-antibodies

- Hence, acetylcholine cannot bind [1/2]
- No post-synaptic depolarisation possible [1/2] → no action potential

(b) Describe the mechanism that ensures unidirectional movement of nerve impulses along the axon of a neurone and no overstimulation of the neurone. [2]

- Refractory period [1/2] – short time immediately after an action potential in which the neurone cannot respond to another stimulus [1/2]

<u>Absolute refractory period</u>

- Voltage-gated Na^+ channels are either already opened (during depolarisation phase) or are inactivated (during repolarisation phase) [1/2]
- Cannot initiate an action potential no matter how strong is the stimulus [1/2]

<u>Relative refractory period</u>

- Voltage-gated K^+ channels are open and membrane is hyperpolarised / during hyperpolarisation phase) [1/2]
- An action potential can only be initiated if the stimulus is stronger than usual [1/2]

- Correct mention of both absolute and relative refractory period [1/2]

(c) The diagram shows the action potentials generated over a fixed time, X.

In the space provided, draw the action potentials generated over the same time period if the stimulus is more intense. [1]

- more AP within period X

7

(a) State the type of receptor that glucagon binds to and explain how this receptor is the fully activated. [2]

- **G-protein linked/coupled receptor**
- Binding of glucagon to complementary binding site on receptor cause a **change in conformation** of the receptor which can now bind G-protein

(b) With reference to fig 7.1, briefly explain how cAMP can lead to an increase in blood glucose concentration. [3]

- cAMP is a **second messenger** in the **signal transduction pathway** of glucagon
- cAMP triggers different signal pathways leading to **different cellular responses** such as glycogenolysis and gluconeogenesis
- cAMP activates the **protein kinase A** which phosphorylates and activates the enzymes needed for the glycogenolysis/the breakdown of glycogen to glucose-1-phosphate and glucose
- Gluconeogenesis which is stimulated results in the generation of glucose from non-carbohydrate carbon substrates such as pyruvate and lactate in the liver.
- Inhibition of the enzymes (e.g. glycogen synthase) needed for the formation of glycogen from glucose
- The glucose is then released by facilitated diffusion through glucose carriers on the surface of the liver cells to raise blood glucose concentration

8 (i) Explain why the evolution of *Jadera haematoloma* after the introduction of a non-native soapberry plant in the 1920s is not considered a form of divergent evolution. [1]

- It did not involve the an inherited characteristics / homologous structure (e.g. sharp beak) undergoing modification to perform different functions [1/2]
- nor did it involve speciation to become two or more different species [1/2]
  or
- There is actually a decrease in phenotypic variation [1/2]
- Q.V [1/2]

(ii) With reference to the information and Fig. 7.2, account for the beak lengths over time. [4]

<u>Description of trend</u>

- Variation of beak lengths prior 1920 / before introduction of the non-native soapberry plant / prior 1920 [1/2]
- QV: 5.5 to 9.1mm [1/2]
- Reduction of beak lengths from 1920 onwards / after introduction of non-native plant [1/2]
- QV: 5.5 to 6.5mm [1/2]

Explanation

- Thinner skin of the non-native fruit provides a selective pressure favouring shorter beak / shorter beak bugs are selected for [1/2]

- Possible reason – same access to nutrients / food as the longer beak bugs but able to survive longer than the longer beak bugs since they do not need to channel additional resources to develop a longer beak [1/2]

- Higher reproductive success [1/2]
- pass favourable alleles to the offspring [1/2]
- Higher proportional of alleles coding for shorter beaks in the gene pool over time [1/2]

(ci) Suggest a likely explanation for the results seen in island Y.

- Ref to genetic drift affected the outcome [1/2]

- Since only 40 individuals (or idea of small population) [1/2] were initially taken to the laboratory, by random chance none of the individual carried the alleles coding for the longer beak. [1/2]

Also accept: By random chance, the individuals carrying the alleles coding for the longer beak in the initial population failed to reproduce successfully after one or few generations in the laboratory and so the alleles were removed in the gene pool [1/2]

- Ref to alleles coding for short beak were fixed in the gene pool [1/2]

(ii) Explain the results in Fig 8.4. [2]

- Bug population in island Y suffered from a low variation of alleles for beak length / only have alleles for short beak length [1/2]
- No natural selection [1/2]
- When only thick-skinned fruits were available, the short beaks could not penetrate the skin to obtain the nutrients so entire population became extinct [1/2]

- Bug population in island X had a greater variety of alleles for beak length [1/2]
- When only thick-skinned fruits were available, the bugs with longer beaks could penetrate the skin to obtain the nutrients and are favoured by natural selection and so increase in number over time [1/2]

(c) Analysis of the DNA sequences of the soapberry bugs in both islands before the viral invasion revealed differences that could not be explained by the theory of natural selection alone. How may the neutral theory of molecular evolution and the genetic code account for the differences? [2]

- Neutral mutations [1/2] occurred but did not affect the fitness / reproductive success of the individuals [1/2]

- Mutations occurred in the non-coding regions which comprise a large proportion of the genome did not affect the phenotype [1/2]

- Mutations occurred in the coding regions could still give rise to the same phenotype because:

  - different codons may code for the same amino acid / degenerate nature of the code [1/2]
  - different codon codes for a different amino acid but retained similar property as the amino acid coded by the original codon [1/2]

2016 H2 BIOLOGY PRELIM PAPER 2 ESQ answers

9 (a) Explain how molecular and anatomical homology supports Darwin's theory of natural selection. [6]

Darwin's theory of natural selection

- It is based on **descent with modifications** [1/2] where different species are **related by descent / share common ancestors** [1/2]

- Heritable traits underwent modifications which resulted in the **differences between present species and the ancestral species** [1/2]

Anatomical homology

- Different but related species would share a basic anatomical plan which they inherited from their common ancestor.

- Named example 1: **Pentadactyl limb** [1/2]
- The **limbs** of all mammals / air-breathing vertebrates share a **basic bone arrangement plan** [1/2]
- Modified differently amongst the descendent species → **locomotion** [1/2]
- As adaptation to the **particular environment / selective pressure** [1/2]
- At least **2 examples** [1/2]: Human forelimbs – manipulation; whales – swimming; bats – flying; AVP
- Named example 2: **Vestigial structure** [1/2]
- **Reduced and may be non-functional** in some species but **functional in other species** [1/2]
- Degeneration of structure due to the **absence of selective pressure** which used to be present [1/2]
- At least **1 example** [1/2]: Limbs in snakes – no longer needed / beneficial for locomotion; Hind-limbs in whales – not needed for swimming / ancestor was a land mammal; AVP

Molecular homology

- Similarities in **genetic language of DNA and RNA** [1/2]
- **Universal genetic code** [1/2] among all species

- **Similarities in DNA / RNA / amino acid sequences** in **homologous genes or proteins** [1/2]
- Known **closely related species or members of the same species** sharing a more recent common ancestor have **greater similarity** than **less related species** [1/2]

10b) Explain the significance of mutations and genetic drift in the neutral theory of molecular evolution [6]

- Evolutionary change at the molecular level occurs primarily through neutral mutations [1/2] which do not affect the phenotype of the organism [1/2]
- According to the theory, most of the genetic variation in populations is the result of mutation and genetic drift and not selection [1/2]
- Mutations result in the creation of new alleles [1/2]
- May or may not affect the biological fitness of the individual [1/2]
- However, many mutations which are neutral
- Reasons:
    - Mutations occurred in the non-coding region of the genome [1/2]
- since non-coding sequences make up the majority of the eukaryotic genome [1/2]
    - Mutations in the coding region may not affect the phenotype
- due to the degenerate code where one amino acid may be coded by more than one codon [1/2]
- If mutations in the coding region result in a slightly different protein, it may also not affect the fitness of the individual (i.e. neither detrimental or adaptative) [1/2]

- In subsequent generations, the frequency of the neutral alleles changes due to genetic drift [1/2] which is the random change of allele frequencies in the gene pool of a (especially small) population from one generation to the next [1/2] Through genetic drift, some of the neutral alleles may be over or under represented [1/2] or lost or become fixed [1/2] in the gene pool. The evolutionary change in the population or species is more pronounced if it is small [1/2]
- Ref to small size due to Founder Effect or Bottleneck Effect [1/2]
- Founder effect – when a few individuals become isolated from a larger population and establishes a new population [1/2]
- Bottleneck effect – when sudden change in environment (e.g. any named natural disaster or over-hunting/over-predation) led to drastic reduction in population size [1/2]
- Hence, only neutral mutations and genetic drift are significant to the theory [1/2]

9b)Describe how the response of muscle cells to insulin with respect to cell signalling. [8]

- Insulin is released from the **β cells of the islets of Langerhans** in the pancreas;

- in response to a rise in blood glucose level **above the norm** of 100mg /100cm^3 blood;
- Before the insulin (ligand) binds, the insulin receptors exist as two individual polypeptides **subunits**;
- The insulin is carried by the blood and **binds to insulin receptor** on the target cell to form a hormone-receptor complex;
- The ligand binding causes two receptor subunits to associate closely with each other forming a dimer (ref . to **dimerization**);
- Dimerization **activates the tyrosine kinase** region of each polypeptide;
- Each tyrosine kinase adds a phosphate from an ATP molecule to a tyrosine on the tail of the other polypeptide (ref. to **cross phosphorylation**);
- The fully-activated receptor protein is now recognized by specific **relay proteins** inside the cell;
- Each relay protein will bind to specific phosphorylated tyrosine residues and will undergo a resultant conformation change that activates it;
- Each activated relay proteins triggers a **specific transduction pathway**;
- leading to a **cellular response**;
- As a result of the activation of **different** relay molecules by **one** activated RTK, ligand binding to a RTK may results in **multiple transduction pathways and cellular responses** (see examples below);
- Ref. to **phosphorylation cascade**, in which a series of different proteins in a pathway are phosphorylated sequentially;
- Ref. to **signal amplification** as one ligand can result in many different downstream proteins being activated
- These cellular responses help bring blood glucose levels back to the norm of 100 mg/100 ml blood. Once the norm level is reached, the **negative feedback mechanism** prevents the further release of insulin from the β cells.

Examples of cellular responses:

- Insulin facilitates the transport of glucose into cells by **increasing the number** of **glucose carriers** at the membranes of the cells;
- Upon activation of the insulin receptor, a signal transduction pathway is activated that causes vesicles in the cytoplasm that contain glucose carrier proteins to **move and fuse to the cell membrane**;
- Increase in glucose carrier proteins, **increase in facilitated diffusion of glucose** into cells;
- Stimulate **glycogenesis** - Activates enzymes involved in glycogen synthesis e.g. glycogen synthase which polymerises glucose-1- phosphate (formed from G6P) to glycogen;

9c) Define control elements and explain how they interact with other factors to influence transcription. [6]

Control elements

- Non-coding regions of the genome that function as binding sites of transcription factors [1/2]
- To control the rate of transcription of genes [1/2]
- Include promoters, enhancers and silencers [1/2]

Promoter

- Proximally upstream of the gene it controls [1/2]
- Contains TATA box [1/2]
- Recognised and bound by general transcription factors [1/2]
- Which recruit RNA polymerase to form transcription initiation complex in order to turn on transcription [1/2]

Enhancer

- Recognised and bound by activators [1/2]
- DNA bending protein causes DNA to bend, bringing the bound activator close to the promoter [1/2]
- Bound activator interacts with the transcription initiation complex to increase transcription [1/2]

Silencer

- Recognised and bound by repressors [1/2]
- Bound repressor interacts with the transcription initiation complex to decrease transcription, prevent activator binding or function, as well as causing DNA to be tightly coiled [1/2]

- Ref. to enhancers and silencers being distal to genes they control [1/2]
- Ref. to transcription factors being able to bind to the control elements when DNA is less tightly coiled / in euchromatin form [1/2]
- Due to histone acetylation and lack of DNA methylation [1/2]

10 (a) Explain how recessive alleles may be preserved in a natural population. [6]

D1. Diploidy – eukaryotes are diploid / have two copies of alleles present for each locus; (each gene can have more than 2 alleles but at any one time, a diploid organism can only have 2.)

D2. Recessive alleles carried by heterozygotes; not subjected to natural selection (hidden from selective effect);

D3. Heterozygotes express dominant trait;

D4. Through masking of recessive allele by the dominant allele of the gene;

D5. (Ref. to effect of natural selection) dominant trait selected for;

D6. Variation only exposed to selection in rare occasion when both parents carry recessive allele, and both copies ending in the same zygote (recessive trait selected against);

D7. Recessive alleles being passed on to the offspring when heterozygotes propagate;

B1. Balancing selection;

B2. When natural selection maintains 2 or more forms in population; (Note: each form is a result of a particular genotype i.e. combination of alleles)

B3. Heterozygote advantage;

B4. When heterozygotes have greater fitness / selective advantage over both kinds of homozygotes;

B5. The recessive allele (in heterozygotes) will be maintained by natural selection / natural selection favours recessive alleles;

B6. Frequency-dependent selection;

B7. When fitness of a phenotype declines if it becomes too common in the population;

B8. The different alleles (including recessive alleles) can be maintained within the population; or frequency of different alleles oscillates over time;

N1. Neutral variation;

N2. Mutation resulting in recessive allele ultimately has no effect on survival or reproductive fitness of individual; not selected against/ selectively neutral;

10 (b) Explain the advantages and significance of having a cell signalling system. [6]

- Cell signalling system comprise of 3 stages: signal reception, signal transduction and cellular response;
- Helps ensure crucial activities/reactions occur in the right cells, at the right time and in proper coordination with other cells of the organism;;
- (At signal reception stage) Specific cells detect specific ligands/signalling molecules; (e.g. hormone glucagon binds to receptor on alpha-cells of islets of Langerhans)

- Ligand shape is complementary to receptor found on/within target cell;
- (Signal transduction stage) Ligand binding causes conformation of receptor protein to change; triggering transduction/signal transduction/multi-step pathway; that involves a sequence of changes in a series of different molecules; such as relay proteins and second messengers (e.g. glucagon biding to GCPR causes it to underdo conformational change, in turn activating G protein, which in turn activates adenylyl cyclase, causing increased production of cAMP (second messenger), which in turn activates protein kinase, and triggers phosphorylation cascade)
- (Cellular response stage) Specific cellular response elicited;

Advantages of multistep pathway:

- Signal amplification; some of the molecules in the pathway transmit the signal to numerous molecules at the next step of the series resulting in a large number of activated molecules at the end of the pathway; (e.g. phosphorylation cascade mentioned above)
- Regulation allows for fine tuning and control of cellular response;
- Numerous cellular responses can be elicited from a single ligand molecule; (e.g. activation of numerous transcription factors and consequently genes, like glycogen phosphorylase and glycogen synthase, which catalyse various reactions that ultimately bring blood glucose levels up to the norm)

10c) Describe binary fission and explain how it differs from bacterial conjugation [8]

- First the circular DNA attaches itself to the cell membrane;
- Duplication starts at the origin of replication; and occurs bidirectionally;
- DNA replicates semi-conservatively;
- When the cell divides, the duplicated DNA is separated and the cell membrane folds inwards to form a double layer across the long axis of the cell.
- New cell wall layers are secreted within the membrane layers.
- This divides the cell into two smaller, identical cells;

	Binary fission	Bacterial conjugation
Purpose of process	Form of asexual reproduction to form genetically identical offspring	Way in which bacteria acquire new genetic material
Number of bacterium involved	Involves one parent bacterium only	Involves 2 bacteria (one F+ /donor cell and one F- /recipient cell)
Type of genetic material replicated	The bacterial chromosomes (and plasmids) of the cell is	The F plasmid is copied and transferred to the recipient

and how it is transferred to recipient (conjugation) or progeny (binary fission)	copied and the cell divides to allow each cell to have one copy.	using a cytoplasmic bridge.
Change in size of bacteria/Fate of bacteria after the process	The parent cell enlarges before dividing equally into two/ Parent cell becomes 2 daughter cells	No change in size of the bacteria involved
Length of time needed for process	Takes a longer time as all genetic material and cellular structures like ribosomes have to be duplicated, as well as the synthesis of a new cell wall to divide the bacterium into two	Takes a shorter time as only time needed for the construction of a cytoplasmic bridge and the transferring of the small F plasmid
What is synthesised in the process	Involves duplication of all genetic material, bacterial ribosomes and new cell wall layers	Involves the synthesis of a cytoplasmic bridge for transfer of the F factor from donor to recipient

VICTORIA JUNIOR COLLEGE
BIOLOGY DEPARTMENT
JC2 PRELIMINARY EXAMINATIONS 2016
Higher 2

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BIOLOGY 9648/03

Paper 3 **19 September 2016**

Additional Materials: Answer Booklet/ Paper **2 Hours**

READ THESE INSTRUCTIONS FIRST

Write your CT GP/ INDEX NO. and name on all the work you hand in.
Write in dark blue or blue pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use any staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.

The intended number of marks is given in brackets [ ] at the end of each question.

For Examiner's Use	
Section A	
1	
2	
3	
Planning Question	
5	
Total	

This document consists of **16** printed pages.

Answer **all** questions

Question 1

(a) The bacterial plasmid, pBR322, was used as a vector for Gene X as shown in Fig. 1.1 below.

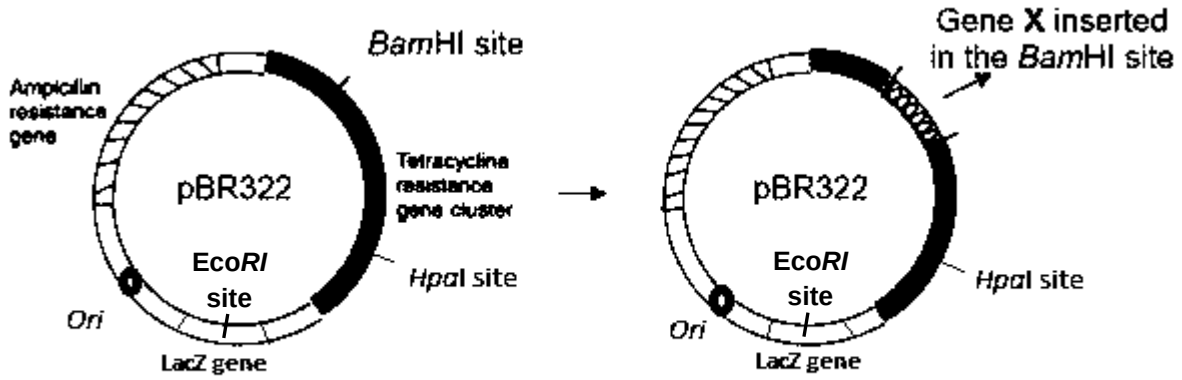

Fig. 1.1

Gene X was inserted in the *Bam*HI restriction site. pBR322 also contain the *Eco*RI and *Hpa*I restriction sites. The target sites for these restriction enzymes are shown in the table below. The lines drawn in each sequence show where the enzyme cuts the DNA molecule.

restriction enzyme	specific target base sequence of DNA
EcoRI	G | A A T T C C T T A A | G
BamHI	G | G A T C C C C T A G | G
HpaI	G T T | A A C C A A | T T G

(i) With reference to Fig. 1.1, explain how two properties of plasmid pBR322 allow it to be used as a vector.

……..

……..

……..

…… [2]

(ii) Outline the steps taken to produce the recombinant plasmid shown in Fig. 1.1.

……..

……..

……..

…… [2]

(iii) Explain the disadvantage that would arise if gene X was to be inserted into the *Hpa*I restriction site instead of the *Bam*HI site.

……..

……..

……..

…… [2]

(b) Calcium chloride heat shock treatment was then used to introduce the recombinant plasmid into *Escherichia coli*. However, the process of creating recombinant plasmids is typically not 100% efficient. Often, a mixture of re-annealed plasmid and re-annealed DNA is produced along with the recombinant plasmid. These may be taken up by the bacteria as well. This necessitates the process of selecting for the bacteria that have successfully taken up the recombinant plasmid. As such, the bacteria was first plated onto a nutrient agar plate containing ampicillin. Replica plating was subsequently carried out onto a nutrient agar plate containing tetracycline. Bacterial growth on both plates is shown in Fig. 1.2.

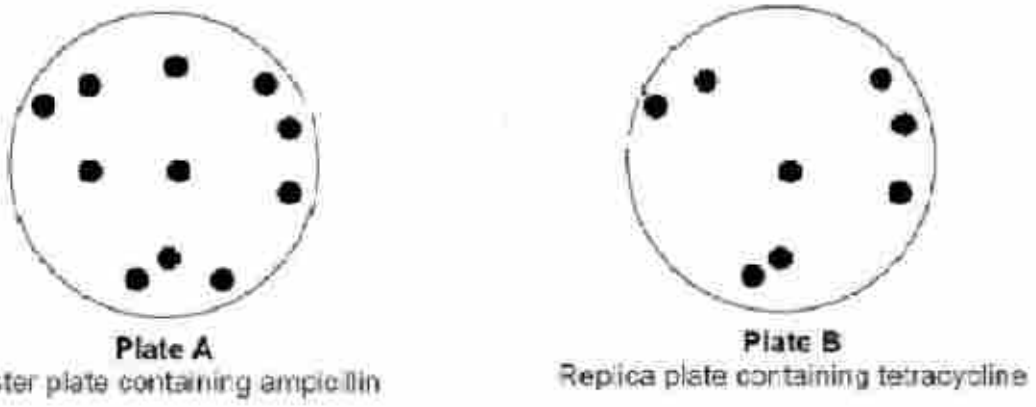

Fig. 1.2

With reference to Fig 1.2,

(i) Circle the colonies that were successfully transformed with the recombinant plasmid.

[1]

(ii) Account for the difference in colony numbers in Plate A and B.

……..

……..

……..

……..

……..

……..

…… [3]

(c) In a separate cloning experiment, the same plasmid pBR322 was used to introduce another gene, Gene Y, into a batch of E.coli cells. Fig. 1.3 shows the results of plating the transformed E.coli cells onto an agar plate with the appropriate substances.

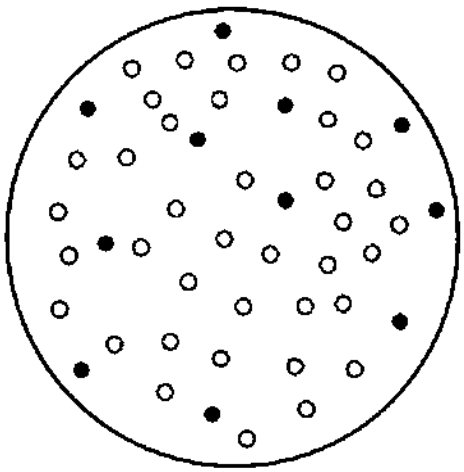

Fig. 1.3

(i) Explain why the colonies differ in colours in Fig. 1.3.

……..

……..

……..

……..

……..

……..

……..

…… [4]

(ii) Suggest why replica plating was not necessary in this experiment.

……..

…… [1]

(d) In another cloning experiment, another plasmid pBR33 was used to introduce Gene Z into a different strain of *E.coli* bacteria. Gene Z was inserted into one of the three selection markers found in pBR33 – neomycin resistance gene, kanamycin resistance gene and streptomycin resistance gene.

The bacteria were then plated onto nutrient agar plate containing neomycin. Replica plating was subsequently carried out onto nutrient agar plate containing streptomycin. Bacterial growth on the two plates is shown in Fig. 1.4 below.

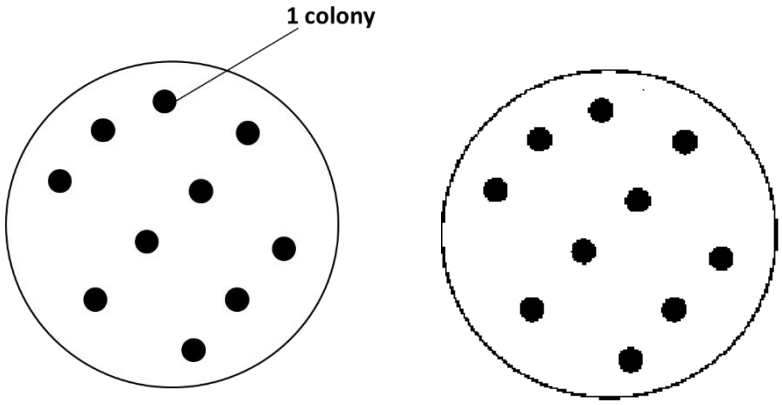

Fig. 1.4

Account for the results obtained in Fig. 1.4.

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…… [3]

[Total 18]

Question 2

Explain why two primers are used for polymerase chain reaction.

……...

……...

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…… [2]

Duchenne muscular dystrophy is a genetic disease in which there is a progressive loss of muscle mass, leading to physical weakness, difficulty in standing and walking, and eventually paralysis and death. Early symptoms of the disease can only be observed between the ages of 2 and 3 in most patients. A group of doctors and medical biologists discovered a RFLP marker, found on the same chromosome as the disease gene, which can be used in the screening of the disease during pregnancy.

To investigate the effective of the RFLP marker in disease screening, samples of DNA were obtained from a family known to have the disease. The RFLP locus was isolated and amplified using polymerase chain reaction, which was then mixed with *Bam*HI restriction enzymes. The pedigree tree of the family and results of gel electrophoresis are shown in Fig. 2.1.

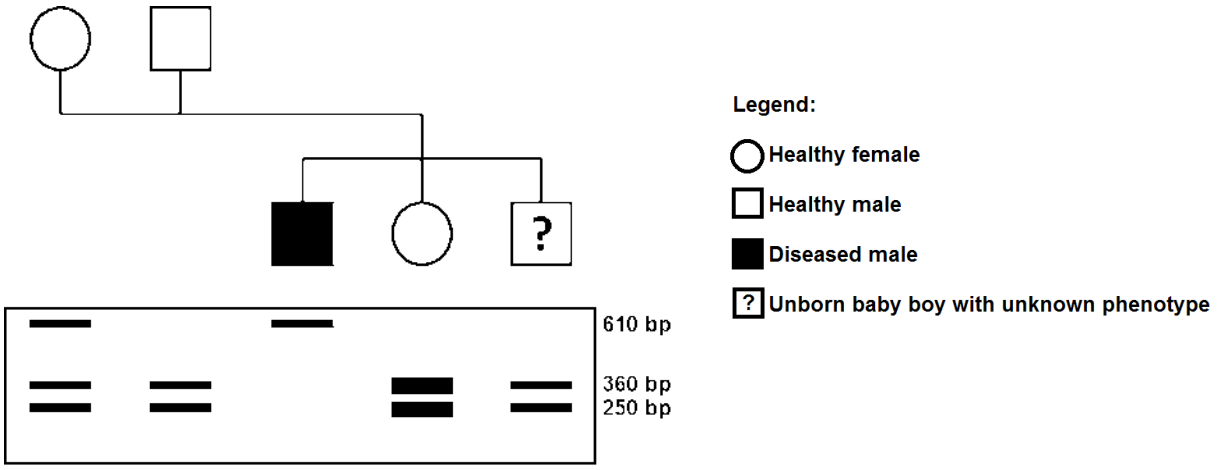

Fig. 2.1

(a) With reference to Fig. 2.1,

(i) state the mode of inheritance of the Duchenne muscular dystrophy.

…… [1]

(ii) explain why there are different fragment lengths after restriction digest.

……...

……...

……...

……...

…… [3]

(iii) Explain the difference in the band patterns between the father and the daughter.

……...

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……...

…… [3]

(b) Some years later, the baby boy with unknown phenotype is born and has reached two years of age. Clinical diagnosis reveals that he too suffers from Duchenne muscular dystrophy.

(i) Explain why the band pattern of the baby boy is different from that of his older brother even though both are with the disease. Assume no new mutations occurred in the disease gene or RFLP locus.

……...

……...

……...

…… [2]

(ii) Suggest an ethical implication that may arise due to the use of this RFLP marker to screen for Duchenne muscular dystrophy.

……...

……. [1]

[Total: 12]

Question 3

(a) Patients with severe combined immunodeficiency disorder (SCID) are vulnerable to serious infections and death. There are two main types of SCID, X-SCID and ADA-SCID. Besides the location and difference in their modes of inheritance, give two differences between the two types of SCID.

Difference	X-SCID	ADA-SCID
1		
2		

[2]

(b) Gene therapy can be used to treat SCID by introducing retrovirus containing the normal gene into hematopoietic stem cells (HSCs). The HSCs are then infused into the patient.

Explain how this choice of vector and target cells may theoretically lead to long term treatment of the disease.

……...

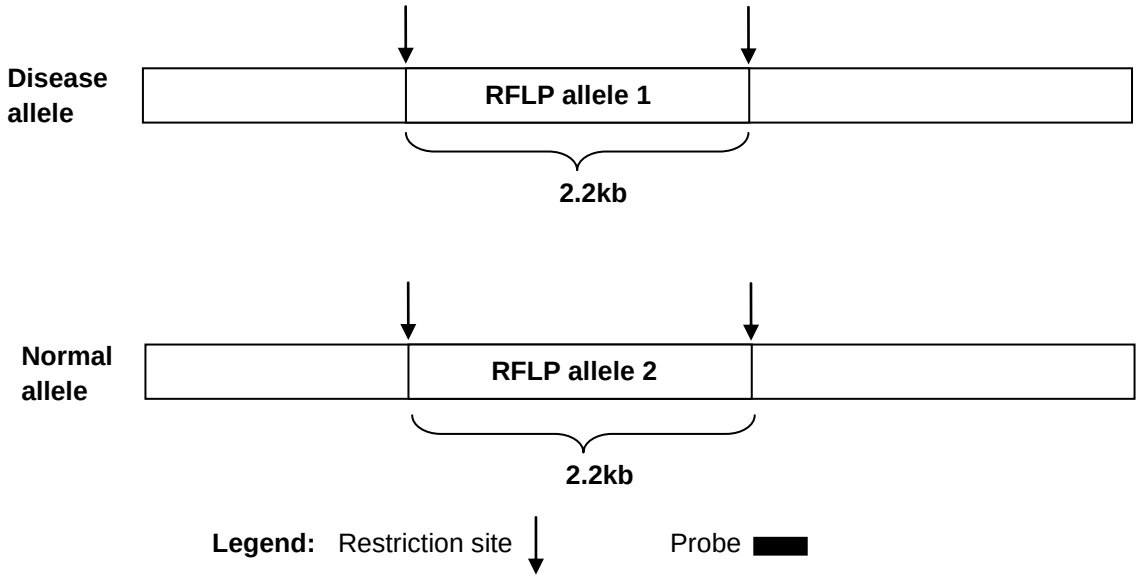
……...

……. [2]

(c) In one attempt to treat ADA-SCID, hematopoietic stem cells (HSCs) from the bone marrow of baby X patient were collected and treated with retrovirus containing the ADA gene before infusing them back.

Genomic DNA from the T lymphocyte cells of baby X was later extracted. The extracted DNA was digested with a restriction enzyme and subjected to Southern blot analysis using a specific probe that binds to a known RFLP marker found within the gene associated with the disease.

The RFLP allele 1 associated with the disease allele gives rise to a 0.8kb band while the RFLP allele 2 associated with the normal allele gives rise to a 2.2kb band.



(i) With the information provided, draw to indicate the position of another restriction site and the position where the probe binds to. You should also indicate the length of the restriction fragments that would be produced. [1]

The RFLP band patterns from baby X's normal brothers, Tom and John, are shown in Fig. 3.1.

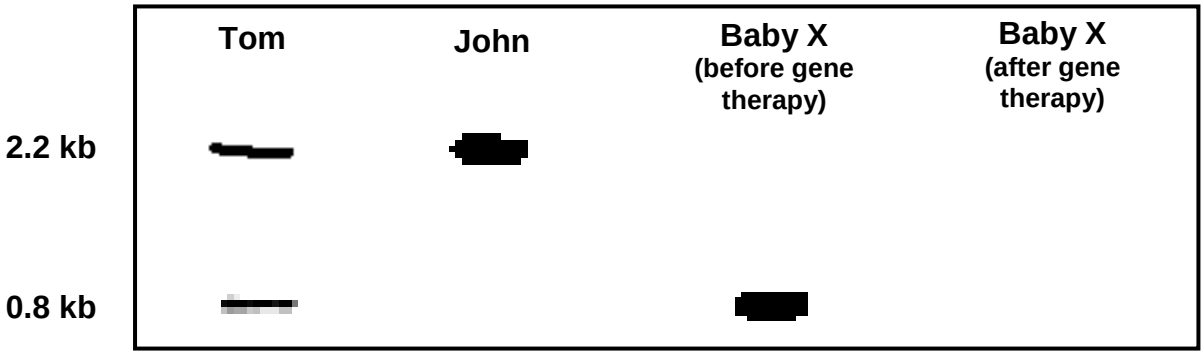


Fig 3.1: Results of Southern Blot analysis of DNA extracted from T lymphocytes

(ii) With reference to Fig 3.1, explain the difference in the band pattern of Tom and John.

……...

……...

……...

…… [2]

(iii) Draw the expected band pattern of baby X after gene therapy treatment. [1]

Over the next 360 days after infusion, the total number of various blood cells (e.g. red blood cells and white blood cells) of baby X were recorded at regular intervals.

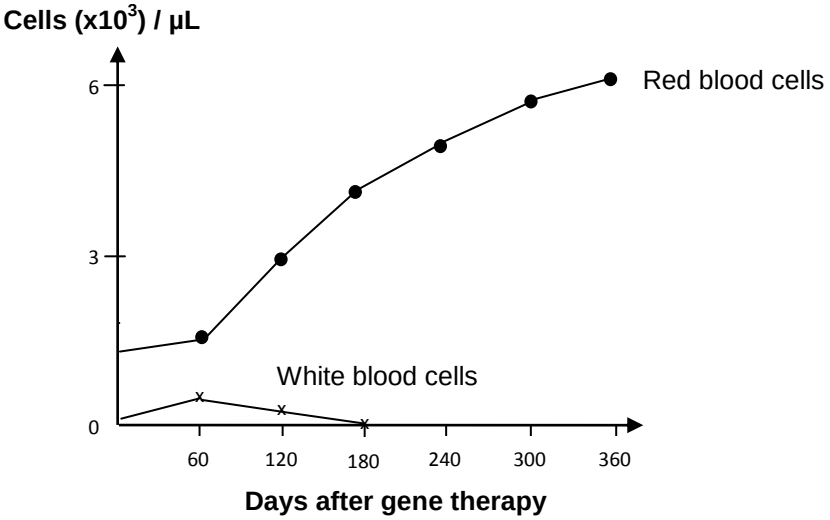


Fig 3.2

(iv) With reference to Fig 3.2, describe the effectiveness of the treatment in baby X.

……...

…… [1]

(v) Suggest a reason for your answer. [1]

……...

…… [1]

[Total 10]

Planning Question

4. An orange plantation owner wants to find out the amount of ascorbic acid (vitamin C) that his breed of oranges produces. He believes that his oranges produce the most vitamin c compared to the standard orange breeds which typically contain 0.8 to 1.6 $mmolL^{-1}$.

The amount of ascorbic acid present in a sample can be determined using a bioassay method. At pH 8, ascorbic acid reduces solutions of the dye dichlorophenol indophenol (DCPIP) from blue to colourless. For the bioassay to work, the pH of the samples must be adjusted to pH 8. Ascorbic acid does not chemically change when neutralised by sodium hydroxide, or when boiled.

Using this information and your own knowledge, design an experiment to determine the validity of the plantation owner's claim that orange juice from his plantation contains higher concentrations of ascorbic acid.

Your planning must be based on the assumption that you have been provided with the following equipment and materials which you must use:

- 100 cm^3 of 5.0 $mmolL^{-1}$ stock solution of ascorbic acid, adjusted to pH 7
- 100 cm^3 distilled water
- 100 cm^3 molten agar containing DCPIP
- Sterile petri dishes
- 1ml syringe
- plastic straw to create wells in the agar plate
- Ruler / 2mm graph paper
- Labels
- Timer, e.g. stopwatch
- Bunsen burner
- Normal laboratory glassware e.g. test tubes, beakers, graduated pipettes, droppers, glass rods etc
- 10 cm^3 orange juice, supplied by the plantation owner
- 10% sodium hydroxide solution
- pH indicator paper to indicate alkaline pH

Your plan should:
- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variable,
- describe the method with the scientific reasoning used to decide the method so that results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of tables and graphs,
- use correct technical and scientific terms,
- include references to safety measures to minimize any risk associated with the proposed experiment.

[Total: 12]

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Free-response question

Write your answers to this question on the separate paper provided.

Your answer:

- should be illustrated by large, clearly labelled diagrams, where appropriate.
- must be in continuous prose, where appropriate.
- must be set out in section (a), (b), etc., as indicated in the question.

5 **(a)** Outline the procedure for the production of human growth hormone by genetic engineering techniques. [8]

(b) Describe the benefits of the Human Genome Project. [8]

(c) Discuss the ethical concerns that have arisen from genetically modified organisms. [4]

[Total: 20]

Question 1

(a) The bacterial plasmid, pBR322, was used as a vector for Gene X as shown in Fig. 1.1 below.

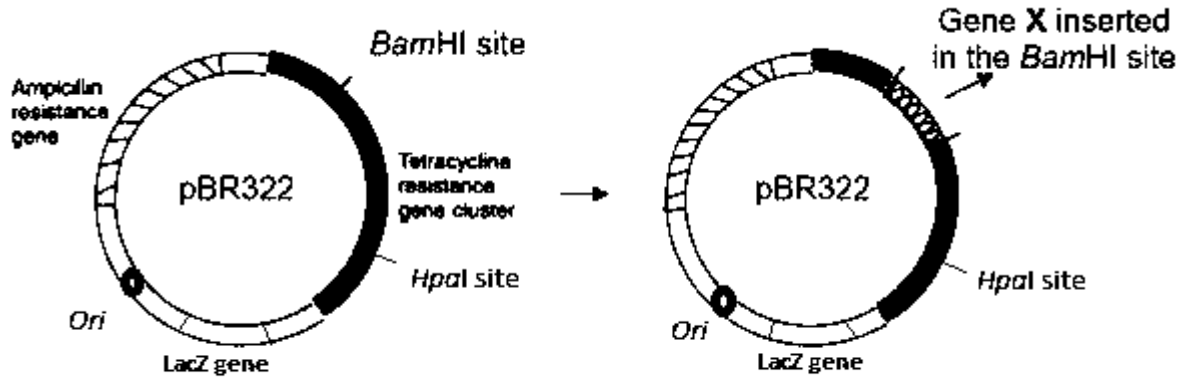


Fig. 1.1

Gene X was inserted in the *Bam*HI restriction site. pBR322 also contain the *Eco*RI and *Hpa*I restriction sites. The target sites for these restriction enzymes are shown in the table below. The lines drawn in each sequence show where the enzyme cuts the DNA molecule.

restriction enzyme	specific target base sequence of DNA
EcoRI	G | A A T T C C T T A A | G
BamHI	G | G A T C C C C T A G | G
HpaI	G T T | A A C C A A | T T G

(i) With reference to Fig. 1.1, explain how two properties of plasmid pBR322 allow it to be used as a vector. [2]

- Presence of origin of replication; so inserted gene can be replicated;
- Has ampicillin and tetracycline resistance genes; as selection markers / allow identification of host cells that have successfully taken up the recombinant plasmid

(ii) Outline the steps taken to produce the recombinant plasmid shown in Fig. 1.1. [2]

- Cut plasmid and gene X with BamHI restriction enzyme;
- "Sticky ends" generated;
- Allow plasmid and gene to anneal with ref. complementary base pairing;

- Add ligase to seal the nicks in the sugar-phosphate backbone / form phosphodiester bonds between the ends of the cut plasmid and gene;

(iii) Explain the disadvantage that would arise if gene X was to be inserted into the *Hpa*I restriction site instead of the *Bam*HI site. [2]

- HpaI generates “blunt ends”;
- No hydrogen bonds to hold the cut plasmid and gene together;
- Ref. extra step that will require linker;
- To generate “sticky ends”

(b) Calcium chloride heat shock treatment was then used to introduce the recombinant plasmid into *Escherichia coli*. However, the process of creating recombinant plasmids is typically not 100% efficient. Often, a mixture of re-annealed plasmid and re-annealed DNA is produced along with the recombinant plasmid. These may be taken up by the bacteria as well. This necessitates the process of selecting for the bacteria that have successfully taken up the recombinant plasmid. As such, the bacteria was first plated onto a nutrient agar plate containing ampicillin. Replica plating was subsequently carried out onto a nutrient agar plate containing tetracycline. Bacterial growth on both plates is shown in **Fig. 1.2**.

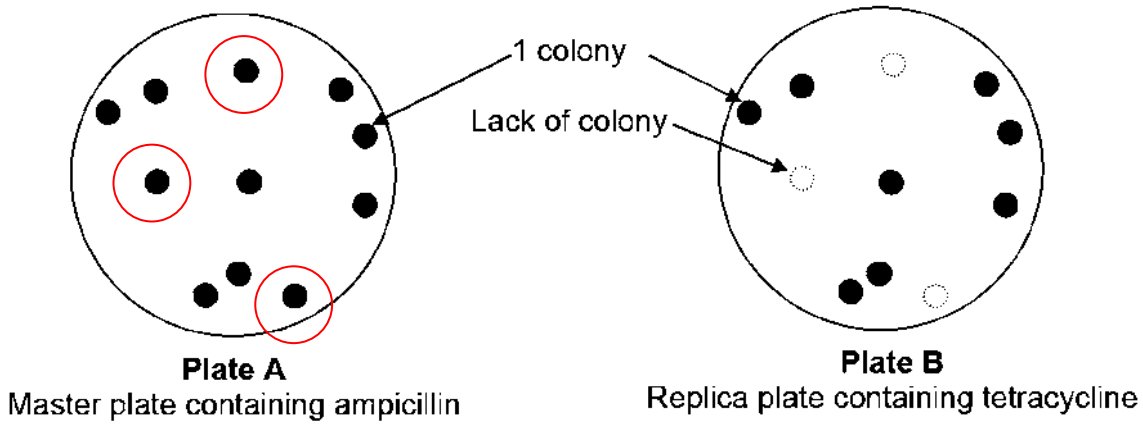


Fig. 1.2

With reference to Fig 1.2,

(i) Circle the colonies that were successfully transformed with the recombinant plasmid. [1]

(ii) Account for the difference in colony numbers in Plate A and B. [3]

- Plate A selects for all successfully transformed cells/ taken up plasmid with ampicillin gene; (maybe recombinant plasmid or re-annealed plasmid);
- Selected against / killed off cells which took up re-annealed DNA;
- Plate B contain 3 fewer colonies compared to Plate A;
- Missing colonies had successfully taken up the recombinant plasmid;
- where gene X had been inserted into tetracycline gene and disrupted it (ref. to insertional inactivation) / colonies lost tetracycline resistance and died;

- Therefore comparing the difference in colony numbers between Plate A and B will allow us to identify recombinant cells/ colonies;

(c) In a separate cloning experiment, *E.coli* cells were transformed with another type of plasmid carrying a different selectable marker. Fig. 1.3 shows the results of plating the transformed *E.coli* cells onto an agar plate with the appropriate substances.

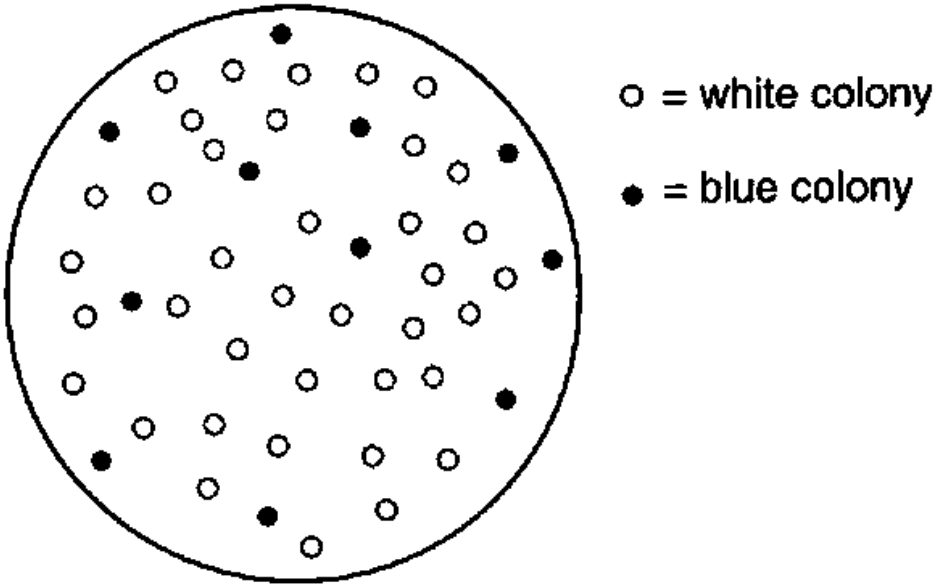


Fig. 1.3

(i) Explain why some colonies appeared white while others appeared blue. [4]

- The cells must have been transformed by plasmids containing intact lacZ gene as the selectable marker;
- The agar plate must have contained X-gal and IPTG;

- lacZ gene codes for β-galactosidase enzyme;
- β-galactosidase enzyme catalyses the conversion of X-gal in the agar from colourless to blue;
- Hence, colonies that contain the reannealed / non-recombinant plasmids appeared blue.

- Should the lacZ gene in the plasmid be disrupted as a result of insertion of foreign DNA / gene, ref. to insertional inactivation of lacZ gene;
- no functional β-galactosidase enzyme will be produced and thus no blue product is formed;

- Hence, colonies that contain the recombinant plasmids appeared white.

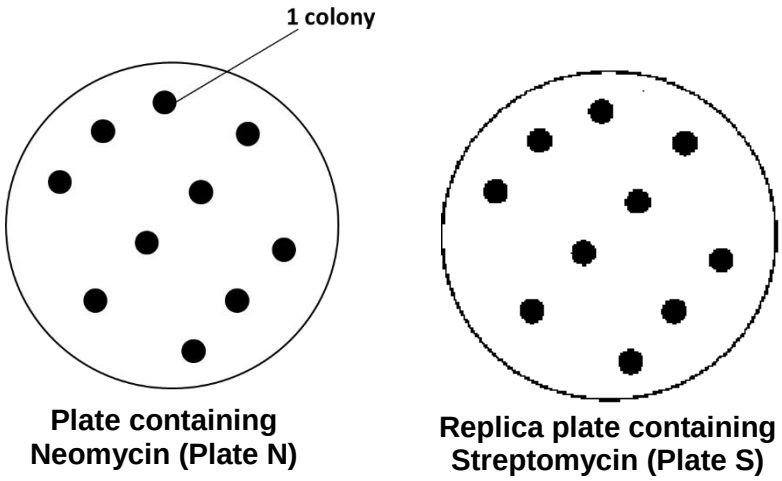
(ii) Suggest why replica plating was not necessary in this experiment. [1]

- By their colours, colonies that contain the recombinant plasmids (appeared white) can be differentiated from those that do not (appeared blue);
- Replica plating is necessary only when the selection process kills off the desired colonies.

- In the case of using two antibiotic resistance genes as the selection markers, the insertion of foreign DNA / gene disrupts only one of the two antibiotic resistance genes in the plasmid.
- To identify colonies that contain the recombinant plasmids, the colonies must be treated with two types of antibiotics.
- Those that survived one antibiotic treatment but not the other would be the desired colonies.
- However, adding both antibiotics to the same agar plate would kill off the desired colonies.
- To get living cells that contain the recombinant plasmids, replica plating must be done.)

d) In a separate cloning experiment, another plasmid pBR33 was used to introduce Gene Z into a different strain of *E.coli* bacteria. Gene Z was inserted into one of the three genetic markers found in pBR33 – neomycin resistance gene, kanamycin resistance gene and streptomycin resistance gene.

The bacteria were then plated onto nutrient agar plate containing neomycin. Replica plating was subsequently carried out onto nutrient agar plate containing streptomycin. Bacterial growth on the two plates is shown in Fig. 1.4 below.



Account for the results obtained in Fig. 1.4. [3]

- Gene Z inserted in kanamycin-resistant gene;
- Insertional inactivation;
- 3 functional genes in re-annealed/non-recombinant plasmids vs 2 functional genes is recombinant;

- Bacteria with recombinant plasmid can survive in presence of neomycin and streptomycin
- Bacteria with re-annealed plasmid can survive in all 3 antibiotics
- Both plates have same number; and position; of colonies; QV: 10 colonies
- Both plates do not contain any non-transformed bacteria; consists of transformed cells with recombinant and non-recombinant plasmid

Alternative:

- Gene Z inserted neomycin-resistant gene;
- So plate N has killed off all bacteria with recombinant plasmids and non-transformed bacteria
- So when is done on from Plate N to plate S, only the bacteria that survive (i.e. the recombinant bacteria) are picked up by the nitrocellulose membrane and transported to plate S;

[Total: 18]

Question 2

Explain why two primers are used for polymerase chain reaction. [2]

- Ref. to the 2 primers as **forward and reverse primers** [1/2]
- **Flank the targeted sequence** to be amplified [1/2]
- **Amplify large quantities of a specific sequence** of DNA in a short period of time [1/2]
- **1 primer anneals to 1 of the separated DNA strands** after denaturation [1/2]
- **Provide free 3' OH for *Taq* polymerase** to elongate the complementary strands of **both templates** to produce 2 DNA molecules [1/2]

Duchenne muscular dystrophy is a genetic disease in which there is a progressive loss of muscle mass, leading to physical weakness, difficulty in standing and walking, and eventually paralysis and death. Early symptoms of the disease can only be observed between the ages of 2 and 3 in most patients. A group of doctors and medical biologists discovered a RFLP marker, found on the same chromosome as the disease gene, which can be used in the screening of the disease during pregnancy.

To investigate the effective of the RFLP marker in disease screening, samples of DNA were obtained from a family known to have the disease. The RFLP locus was isolated and amplified using polymerase chain reaction, which was then mixed with *Bam*HI restriction enzymes. The pedigree tree of the family and results of gel electrophoresis are shown in Fig. 2.1.

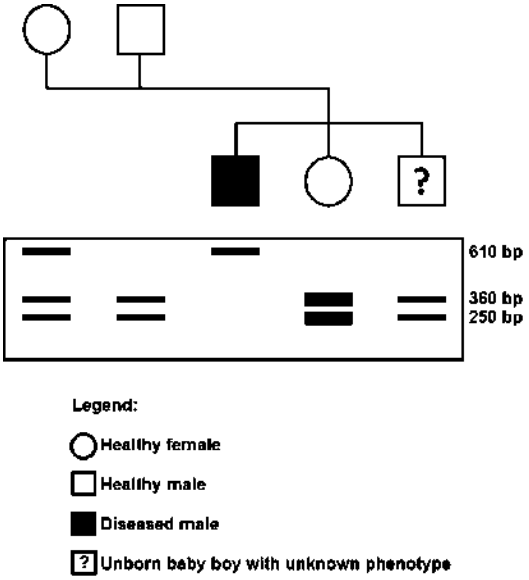


Fig. 2.1

(a) With reference to Fig. 2.1,

(i) state the mode of inheritance of the Duchenne muscular dystrophy. [1]

- Sex-linked recessive [1]

(ii) explain why there are different fragment lengths after restriction digest. [3]

- Ref. to the RFLP marker having **2 alleles** [1/2]
- 1 allele contains a ***Bam*HI restriction site** while the other does not [1/2]
  - Variation due to a **mutation** [1/2]
- Allele with restriction site produces 2 RFLP fragments of 360 bp and 250 bp [1/2]
  - Due to digestion by *Bam*HI restriction enzyme [1/2]
- Allele without restriction site produces 1 RFLP fragment of 610 bp [1/2]
  - *Bam*HI restriction enzyme **cannot recognise the mutated sequence** resulting in no restriction digest [1/2]

(iii) Explain the difference in the band patterns between the father and the daughter. [3]

- The daughter has **thicker bands** than the father corresponding to the same sizes [1/2]
  - 360 and 250 bp [1/2]
  - **Twice** as thick [1/2]
- The RFLP marker is **found on the X chromosome** [1/2]
  - Father has only 1 X chromosome thus 1 copy of the allele of the RFLP marker [1/2]
  - Daughter has 2 X chromosomes thus 2 copies of the allele of the RFLP marker [1/2]
- Ref. to thickness of the bands due to amount of RFLP fragments [1/2]

(b) Some years later, the baby boy with unknown phenotype is born and has reached 2 years of age. Clinical diagnosis reveals that he too suffers from Duchenne muscular dystrophy.

(i) Explain why the band pattern of the baby boy is different from that of his older brother even though both are with the disease. Assume no new mutations occurred in the disease gene or RFLP locus. [2]

- **Crossing over** occurred during gamete formation in the mother [1/2]
- Between the disease gene and RFLP locus [1/2]
- Giving rise to gametes with a X chromosome with **different combinations of alleles** [1/2]
  - X chromosome inherited by older brother has RFLP allele producing 610 bp fragment linked to the disease allele [1/2]
  - X chromosome inherited by baby boy has RFLP allele producing 360 bp and 250 bp fragments linked to the disease allele [1/2]

(ii) Suggest an ethical implication that may arise due to the use of this RFLP marker to screen for Duchenne muscular dystrophy. [1]

Any 1:

- **Stigmatisation** of the parents and child even **before the onset** of the disease
- Parents may want to **terminate the pregnancy** if the unborn baby is diagnosed with the disease
- Parents may have to pay a **higher premium for child insurance** even **before the onset** of the disease
- AVP

[Total: 12]

Question 3

(a) Patients with severe combined immunodeficiency disorder (SCID) are vulnerable to serious infections and death. There are two main types of SCID, X-SCID and ADA-SCID. Besides the location and difference in their modes of inheritance, give two differences between the two types of SCID.

Difference	X-SCID	ADA-SCID
1 (Name of gene; Idea of what the gene codes for / function of normal protein)	Mutation of **IL2RG (interleukin-2 receptor gamma) gene** that codes for **gamma chain** on **lymphocyte receptor**	Mutation of gene coding for **adenosine deaminase (ADA)** involved in **purine metabolism / breakdown of deoxyadenosine**
2 (Consequence)	**Defective receptor** unable to activate **cell signal pathways** leading to **normal development of specific white blood**	Hence, **ADA deficiency** leads to the **accumulation of deoxyadenosine** which **kill developing white blood cells**

[2]

(b) Gene therapy can be used to treat SCID by introducing retrovirus containing the normal gene into hematopoietic stem cells (HSCs). The HSCs are then infused into the patient. Explain how this choice of vector and target cells may theoretically lead to long term treatment of the disease. [2]

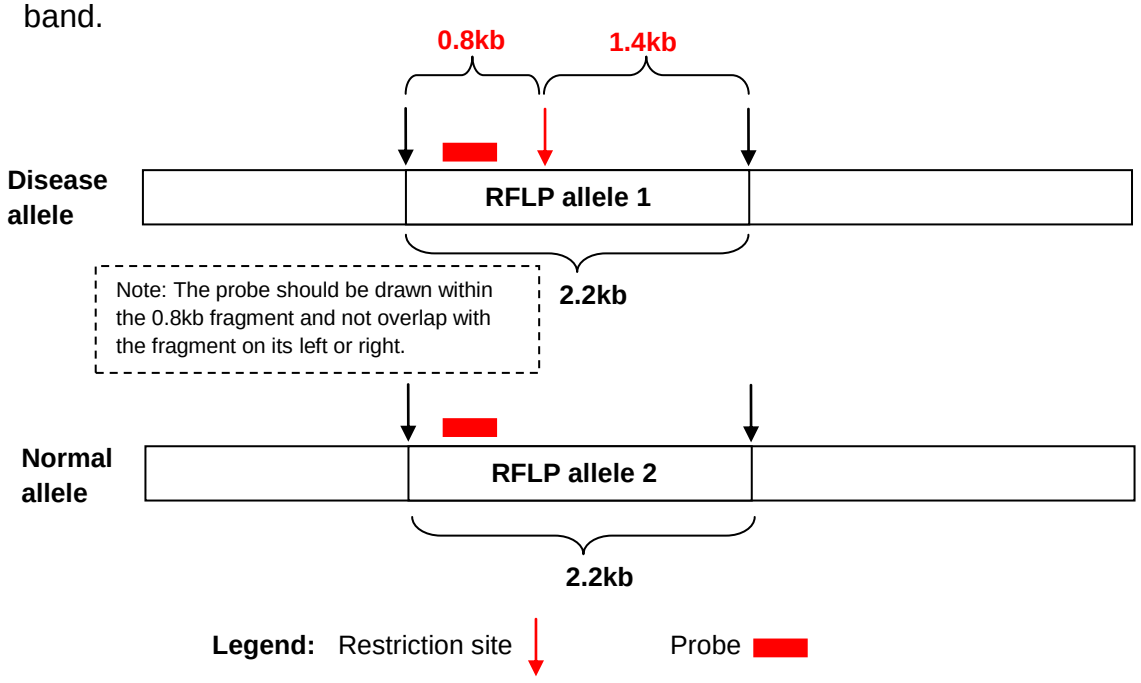
Retroviral vectors are able to **integrate** the **normal gene into the chromosome** [1/2]. The HSCs are able to undergo **long term self-renewal** by **mitotic cell divisions** [1/2]

Hence, patient will have the normal gene in his/her white blood cells since the **normal gene would be replicated and passed to the daughter cells** [1/2] When the HSCs **differentiate into white blood cells** [1/2], the normal **gene can be expressed** and produce the **normal enzyme** [1/2]

(c) In one attempt to treat ADA-SCID, hematopoietic stem cells (HSCs) from the bone marrow of baby X patient were collected and treated with retrovirus containing the ADA gene before infusing them back.

Genomic DNA from the T lymphocyte cells of baby X was later extracted. The extracted DNA was digested with a restriction enzyme and subjected to Southern blot analysis using a specific probe that binds to a known RFLP marker found within the gene associated with the disease.

The RFLP allele 1 associated with the disease allele gives rise to a 0.8kb band while the RFLP allele 2 associated with the normal allele gives rise to a 2.2kb band.



(i) With the information provided, draw to indicate the position of another restriction site and the position where the probe binds to. You should also indicate the length of the restriction fragments that would be produced. [1]

The RFLP band patterns from baby X's normal brothers, Tom and John, are shown in Fig. 3.1.

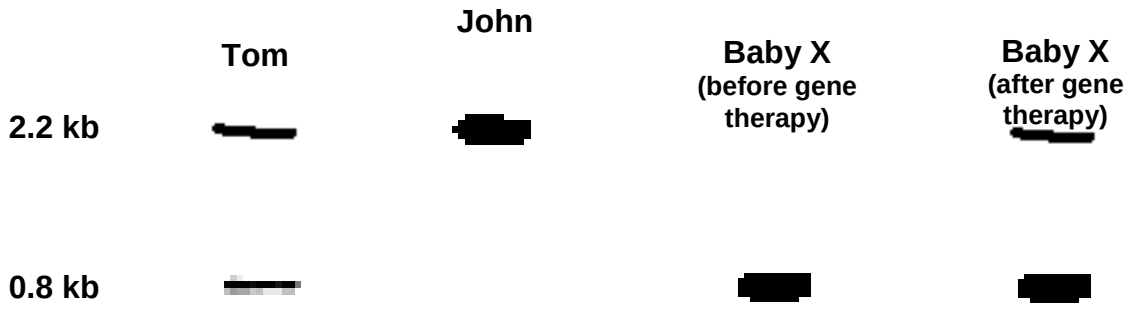


Fig 3.1: Results of Southern Blot analysis of DNA extracted from T lymphocytes

(ii) With reference to Fig 3.1, explain the difference in the band pattern of Tom and John. [2]

ADA-SCID is an **autosomal recessive condition**. [1/2]
Tom has **one copy of the recessive and one copy of the dominant allele / heterozygous**. [1/2]
Ref to **two bands** of **2.2kb and 0.8kb** [1/2]

John has **two copies of the normal dominant allele / homozygous dominant** [1/2]
Ref to **one thicker band of 2.2kb** [1/2]

(iii) Draw the expected band pattern of baby X after gene therapy treatment. [1]

Over the next 360 days after infusion, the total number of various blood cells (e.g. red blood cells and white blood cells) of baby X were recorded at regular intervals.

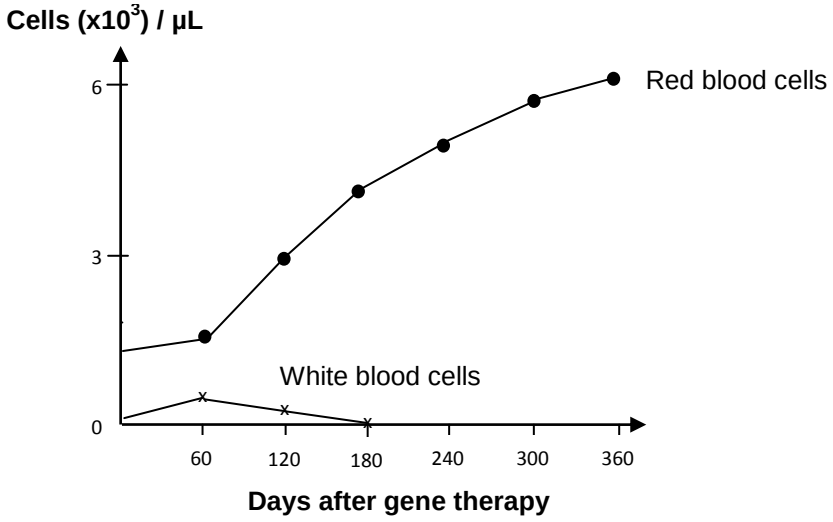


Fig 3.2

(iv) With reference to Fig 3.2, describe the effectiveness of the treatment in Baby X. [1]

The treatment was **ineffective / effective only for a short term** [1/2]
Decline of the white blood cells / QV: from about **0.5 x10^3 /µL in day 60 to 0 by day 180** [1/2]

(v) Suggest a reason for your answer. [1]
Any one:
The gene inserted into the chromosome **could not be expressed**
The inserted gene was **mutated** and so **could not produce a functional enzyme**

[Total: 10]

(4) An orange plantation owner wants to find out the amount of ascorbic acid (vitamin C) that his breed of oranges produces. He believes that his oranges produce the most vitamin c compared to the standard orange breeds which typically contain 0.8 to 1.6 $mmolL^{-1}$.

The amount of ascorbic acid present in a sample can be determined using a bioassay method. At pH 7 and above, ascorbic acid reduces solutions of the dye dichlorophenol indophenol (DCPIP) from blue to colourless. For the bioassay to work, the pH of the samples must be adjusted to pH7 - 9. Ascorbic acid does not chemically change when neutralised by sodium hydroxide or when boiled.

Using this information and your own knowledge, design an experiment to determine the validity of the plantation owner's claim that orange juice from his plantation contains higher concentrations of ascorbic acid.

Your planning must be based on the assumption that you have been provided with the following equipment and materials which you must use:

- 100 cm^3 of 5.0 $mmolL^{-1}$ stock solution of ascorbic acid, adjusted to pH 7
- 100 cm^3 distilled water
- 100 cm^3 molten agar containing DCPIP
- Sterile petri dishes
- 1ml syringe
- plastic straw to create wells in the agar plate
- Ruler / 2mm graph paper
- Labels
- Timer , e.g. stopwatch
- Forceps
- Bunsen burner
- Normal laboratory glassware e.g. test tubes, beakers, graduated pipettes, droppers, glass rods etc
- 10 cm^3 orange juice, supplied by the plantation owner
- 10% sodium hydroxide solution
- pH indicator paper to indicate alkaline pH

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variable,
- describe the method with the scientific reasoning used to decide the method so that results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of tables and graphs,
- use correct technical and scientific terms,
- include references to safety measures to minimize any risk associated with the proposed experiment.

[Total: 12]

Proposed answer

Introduction

- Ascorbic acid reduces blue DCPIP to colourless. .
- Increase in concentration of ascorbic acid will increase the rate of decolourisation of DCPIP
- Different concentrations of ascorbic acid can be created from the stock solution. A standard curve of the amount of decolourisation of DCPIP by the different concentrations of ascorbic acid can be created. The amount of ascorbic acid in orange can be determined by reading off the standard curve

Explain how to determine concentration of ascorbic acid in oranges using the standard curve [1m]

Procedure

1. Obtain 10cm^3 of different concentrations of ascorbic acid solution by dilution.

Describe how to obtain different concentrations of ascorbic acid [1m]

Concentration of ascorbic acid solution / mmolL-1	Volume of 5.0 mmolL-1 ascorbic acid solution / cm^3	Volume of distilled water / cm^3
5	10	0
4	8	2
3	6	4
2	4	6
1	2	8
0	0	10

1. Pour the molten agar containing DCPIP into the petri dishes and allow the agar to cool.
2. Once the agar is cooled, use the plastic straw to make eight equal sized wells in the agar gel plate. Ensure that the wells are well-spaced.

Describe the settling up of the DCPIP agar plates and wells in the plates[1m]

3. Prepare a control experiment using boiled and cooled orange juice, following the same experimental procedures and conditions, to show that the decolourisation of DCPIP is due to the action of ascorbic acid and not due to the action of any enzymes in the juice.

Describe control to prove reaction is due to ascorbic acid in the orange juice and is not enzyme catalysed [1m]

4. Add 10% sodium hydroxide solution to the boiled and cooled orange juice, drop by drop with a dropper, until the pH is between 7 to 9. Check the pH by removing a drop of solution with a clean glass rod and placing it on indicator paper.
5. Neutralise the fresh orange juice in the same manner as described in step 4.

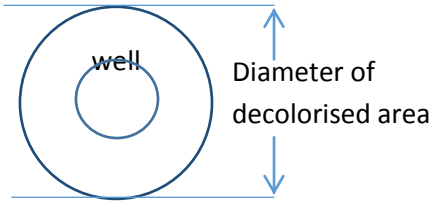
Describe neutralisation of fresh orange juice.[1m]

6. Using the 1 ml syringe, place 0.2 ml of each of the ascorbic acid solutions prepared according to the dilution table, 0.2 ml of orange juice and 0.2 ml of boiled and neutralised orange juice into one well each. Label the wells.

State appropriate volumes scorbic acid [1m]

7. Replace the lid of the petri dish and leave the plates on the table for one hour.
8. After one hour, place the dish on the graph paper and measure the diameter of each of the rings where the blue DCPIP has been decolourised
9. Repeat step 1 to 7 three times.

Describe the measurement of ring of decolourisation [1m]
Describe repeats [1m]

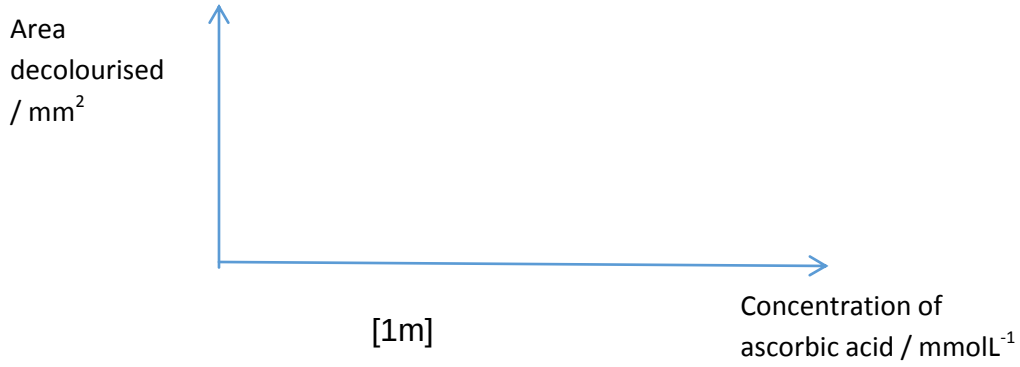


Draw a labelled diagram [1m]

10. Record the results in the table below and calculate the area of decolorisation

Concentration of ascorbic acid	Diameter of ring of decolourisation / mm				Area decolourised/ mm^2
	Experiment 1	Experiment 2	Experiment 3	Average	
5					
4					
3					
2					
1					
0					
Sample of neutralised orange juice					
Sample of boiled and cooled orange juice which has been neutralised					

[1m]



[1m]

From the standard curve drawn, calculate the concentration of ascorbic acid found in the sample of orange juice from the area of decolorisation obtained from the experiment

with the sample of orange juice. If the concentration is higher than 0.8 to 1.6 mmolL^{-1}, the plantation owner's claim of his breed producing a higher concentration of Vitamin C than standard orange breeds is valid. [1m]

Safety
Sodium hydroxide and ascorbic acid may cause irritation when in contact with skin. Wear gloves when handling these reagents. [1m]

Question 1

(a) Outline the procedure for the production of human growth hormone by genetic engineering techniques. [8]

(b) Describe the benefits of the Human Genome Project. [8]

(c) Discuss the ethical concerns that have arisen from genetically modified organisms. [4]

Question 5

(a) Outline the procedure for the production of human growth hormone by genetic engineering techniques. [8]

Isolation of human growth hormone - max 2
- **Human growth hormone mRNA** (1/2)
- extracted from **anterior pituitary gland** is used (1/2)
- as template to synthesize **complementary DNA** (**cDNA**) (1/2)
- Using the enzyme **reverse transcriptase** (1/2)
- Reason: ***E.coli*****,** being **prokaryotes** → **lack mRNA processing machinery** (1/2)
- **Introns** are **not excised** and **exons spliced** (1/2)
- Therefore, **no mature mRNA** can be formed from the **eukaryotic gene** (1/2)
- Ref to use of **DNA polymerase** → double stranded DNA (1/2)

Formation of recombinant DNA – max 2
- Both **plasmid vector and cDNA** are cut with **restriction enzyme** that produces **blunt ends** [1]
- (In separate reactions) **terminal transferase** (1/2)
- is used to add **extra guanines to vector** and **extra cytosines to the cDNA** *(or vice-versa*) [1]
- To create **complementary sticky ends** (1/2)

Or
- Both **plasmid vector and cDNA** are cut with **same** restriction enzyme (1/2)
- Any e.g. of appropriate restriction enzyme (**HindIII, BamHI**, etc) (1/2)
- To create **complementary sticky ends** (1/2)

- **DNA ligase** is used to facilitate the joining of cDNA to vector to form **recombinant DNA** (1/2)
- By forming **phosphodiester bond** between the sugar and the phosphate group / nucleotides (1/2)

Transfer of recombinant DNA to bacteria host followed by screening – max 3

- **Bacteria** (e.g. *E.coli*) is **transformed** with recombinant DNA (1/2)
- By **$CaCl_2$ heat-shock** method (1/2)
- **Transformed bacteria** with the recombinant DNA are **selected** (1/2)
- In the presence selection markers E.g. **antibiotics resistance genes** – transformed cells survive in the presence of antibiotics (1/2)

- Identification of **correct transformed colonies** with **recombinant plasmid** from transformed colonies with re-annealed vector only by *(either one)* ***b*lue-white screening** or **replica plating** (1/2)
- Elaboration of either method:

1. **Replica plating**
   - Bacterial cells are plated on a nutrient plate with **one antibiotics** and then replica plated on **another plate with another antibiotics** or idea of 2 plates (each with an antibiotics) are used (1/2)
   - Colonies with re-annealed vector only are **resistant to both antibiotics** because both antibiotic resistant genes are intact. (1/2)
   - **Colonies with correct recombinant DNA** are **resistant to one antibiotics** but **susceptible to another** because the corresponding **antibiotic resistant gene is disrupted** during **insertion of the gene** (or ref to **insertional inactivation**) (1/2)
   - Hence **comparing the position of the colonies on both plates** help to identify correct colonies (1/2)

Or

2. **Blue-white screening**
   - Bacteria cells are plated on a nutrient plate containing an **antibiotics** and the substrate **X-gal** (1/2)
   - Colonies with re-annealed vector only are resistant to **antibiotics** / contain antibiotics resistance gene and **intact / functional β-galactosidase / Lac Z gene**. (1/2)
   - **β-galactosidase enzyme** that act on X-gal resulting in **blue** colonies (1/2)
   - Colonies with correct recombinant DNA will appear **white** because the β-galactosidase / Lac Z gene is **disrupted** during **insertion of the gene** (or ref to **insertional inactivation**) (1/2)

Culture of correct transformed cells and extraction and purification of insulin - max 1

- And **cultured** in a **nutrient / growth medium / fermenter** (1/2)
- Ref to **prokaryotic promoter** inserted next to eukaryotic gene (1/2)
- The eukaryotic **gene** is **expressed** in the bacteria (1/2)
- The protein is **extracted** and **purified** for use (1/2)

(b) Discuss the benefits of the Human Genome Project. [8]

A. Molecular medicine (no marks for heading; max 2 mks, @ 1 mk)
1 Earlier diagnosis/detection of genetic diseases;
2 Gene therapy;
3 Rational drug design/control systems for drugs/rational drug design/pharmacogenomics & custom drugs;

B. Energy and Environmental Applications (max 1 mk, @ 1 mk)
4 Use microbial genomics research to create new energy sources (biofuels);
5 Use microbial genomics research to develop environmental monitoring techniques to detect pollutants ;
6 Use microbial genomics research for safe, efficient environmental remediation;

C. DNA Forensics (max 3 mk, @ 1 mk)
7 Identify potential suspects whose DNA may match evidence left at crime scenes;
8 Exonerate persons wrongly accused of crimes;
9 Identify crime and catastrophe victims;
10 Establish paternity and other family relationships;
11 Identify endangered and protected species as an aid to wildlife officials (could be used for prosecuting poachers);
12 Detect bacteria and other organisms that may pollute air, water, soil, and food;
13 Match organ donors with recipients in transplant programs;
14 Determine pedigree for seed or livestock breeds;
15 Authenticate consumables such as caviar and wine;

D. Agriculture, Livestock Breeding, and Bioprocessing (max 1 mk, @ 1 mk)
16 Healthier, more productive, disease-resistant crops/ farm animals / higher yield;
17 More nutritious produce ;
18 Edible vaccines incorporated into food products;
19 New environmental cleanup uses for plants like tobacco;

E. Bioarchaeology, anthropology, evolution and human migration (max 1 mk, @ 1 mk)
20 Study human evolution (through germline mutations in lineages);
21 Study of migration of diff pop groups based on female genetic inheritance/lineage and migration of males via Y chromosomes;
22 Compare breakpoints in the evolution of mutations with ages of populations and historical events;

F. Risk assessment (@ 1 mk)
23 Assess health damage and risks caused by radiation exposure/mutagenic chemicals/ cancer-causing toxins;

Total max: 8 mk

(c) Discuss the ethical concerns that have arisen from genetically modified organisms. [4]

Ethical (deals with right or wrong; equity; fairness)

- Genetic manipulation of plants may not be acceptable by some as it involves altering the genetic makeup of the plants which can be seen as tampering with nature;;
- Religious groups with strong dietary restrictions may not be informed about the genetic content of the food they are eating and may unknowingly consumed GM food with genes from unacceptable sources;; (example to illustrate)
- Patenting of the transgenic crops is viewed as unethical as it promotes the treatment of living things as mere objects or commodities to be owned and redesigned at will;
- Patenting of the transgenic crops by companies in order to ensure they profit from the technique may end up causing farmers to be dependent on them;; (Use example of the patent for the genetically engineered seeds)
- Companies with the patents become very rich at the expense of the farmers or consumers who have to pay for the high cost of the seeds or plants;;
- World food production may be controlled/ dominated by a small number of large biotechnology companies with the technical know-how;;

Name	NRIC Number	CTG

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION 2016

BIOLOGY **9648/01**

HIGHER 2 **29 AUGUST 2016**
MONDAY 0800 – 0915

Paper 1 Multiple Choice **1 hour 15 minutes**

Additional material:
Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil (type B or HB is recommended).
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, full NRIC number and CTG on the Multiple Choice Answer Sheet and question paper in the spaces provided.

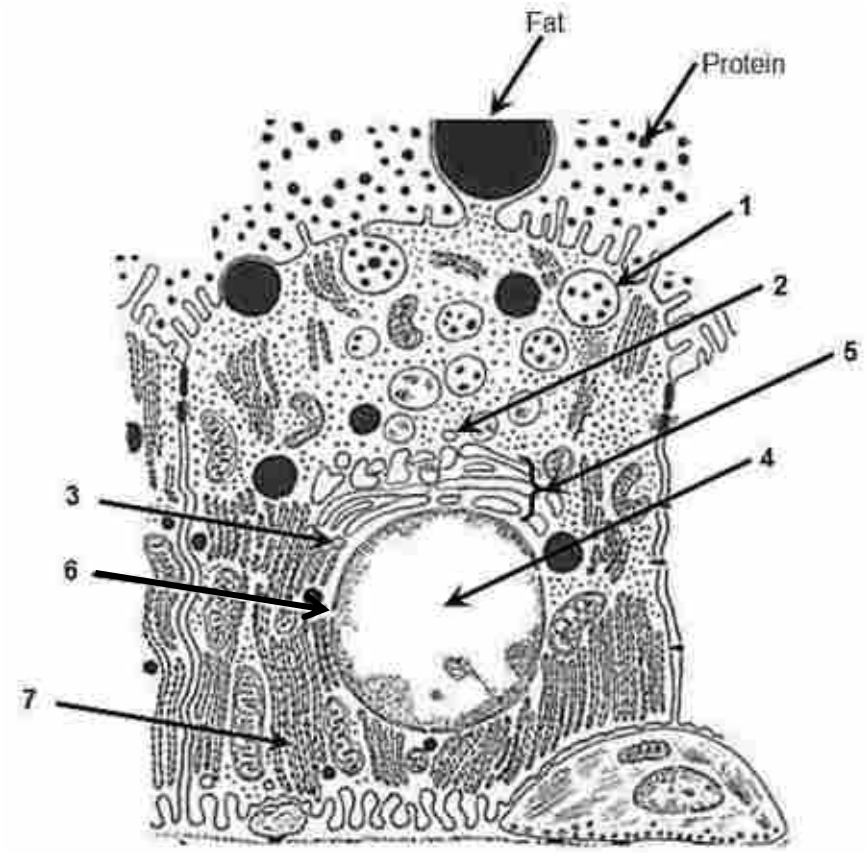
There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet.

Calculators may be used.

This question paper consists of **21** printed pages.

1 The diagram below shows a lactating mammary secretory cell. In this cell, milk proteins, such as casein, are transcribed and translated, and eventually secreted into the lumen of the mammary gland.



Which of the following shows the most likely sequence of locations involved in this process?

	start →						finish
A	6	3	4	7	2	5	1
B	6	4	3	7	5	2	1
C	4	6	7	3	5	2	1
D	4	3	7	6	2	5	1

2 The table gives description of four membranous structures in a cell.

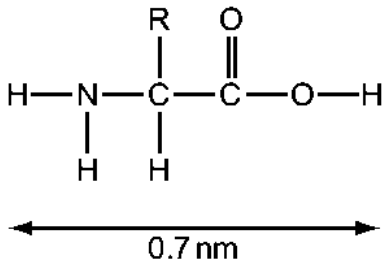
Which structure is correctly matched to its function?

	Structure	Function
A	an extensive network of tubes and sacs; each tube and sac bounded by a single membrane	Lipid synthesis
B	a spherical sac bounded by a single membrane	Protein synthesis
C	a sac bounded by two membranes, the inner highly folded	Packaging of proteins
D	a stack of elongated, curved sacs; each sac bounded by a single membrane	Photosynthesis

3 The diameters of some atoms when they form bonds are given in the table.

Atom	Single bond / nm	Double bond / nm
H	0.060	-
O	0.132	0.110
N	0.140	0.120
C	0.154	0.134

The approximate length of the amino acid shown below was estimated using the figures in the table.



What will be the approximate length of a dipeptide formed using this amino acid?

A 0.8 nm **B** 1.2 nm **C** 1.5 nm **D** 1.9 nm

4 During the production of fruit juice, enzymes are used to break down the components of cell walls. Which carbohydrate will be produced by this hydrolysis?

A Sucrose **B** Maltose **C** α – glucose **D** β – glucose

5 The enzyme phosphofructokinase is involved in phosphorylation of hexose phosphate sugars during glycolysis. It is involved in control of the rate of glycolysis and thus respiration, by end-product inhibition.

Deduce which of the following is a description of this enzyme.

	Shape of binding site(s)	Substrate	Product
A	no allosteric site, active site complementary to ATP and hexose	hexose	hexose phosphate
B	allosteric site complementary to glucose, active site complementary to hexose phosphate	hexose phosphate	hexose phosphate
C	allosteric site complementary to ATP, active site complementary to ATP and hexose phosphate	hexose phosphate	hexose bisphosphate
D	no allosteric site, active site complementary to hexose bisphosphate	hexose bisphosphate	two triose phosphate

6 A cell in the G1 phase has two homologous pairs of chromosomes. It then undergoes a mitotic division, followed by meiosis. At the end of meiosis II, what is the total number of chromosomes and gene loci found in all the daughter cells formed?

A 8 chromosomes and 4 times as many gene loci as the original parent cell

B 8 chromosomes and 8 times as many gene loci as the original parent cell

C 16 chromosomes and 4 times as many gene loci as the original parent cell

D 16 chromosomes and 8 times as many gene loci as the original parent cell

7 For organisms undergoing sexual reproduction, a reduction division occurs before fertilisation.

Which reason(s) explain why this is necessary?

1 increase genetic variation
2 prevent doubling of the chromosome number
3 reduce the chances of mutation

A 1 only **B** 2 only **C** 1 and 2 only **D** 1, 2 and 3

8 One complete turn of the double helix of DNA contains 10 pairs of bases and is 3.4nm long. What is the approximate number of amino acids in an enzyme coded by a 132 nm length of DNA?

A 38

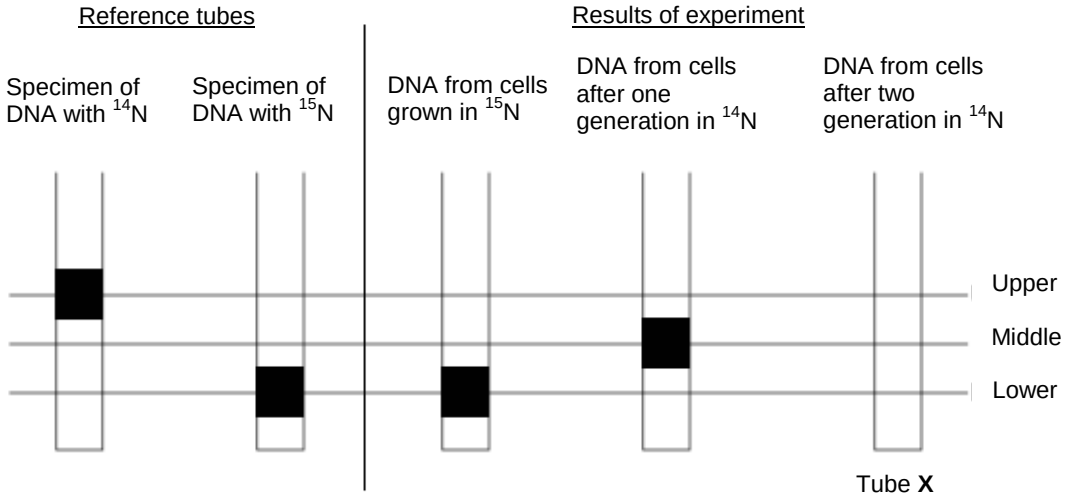
B 129

C 150

D 388

9 Cells of the bacterium E. coli were grown for many generations on a medium containing only the heavy isotope of nitrogen, ^{15}N. The cells were then transferred to a medium containing only ^{14}N and allowed to grow. Samples of the bacteria were removed from the culture after one generation and after two generations. The DNA from each sample was extracted and centrifuged.

The figure below shows two reference tubes and the results of this experiment.



What are the positions and relative proportions of the bands in Tube **X**?

	Upper	**Middle**	**Lower**
A	50%	50%	0%
B	0%	50%	50%
C	50%	0%	50%
D	25%	50%	25%

10 A student obtained a sample of DNA and an mRNA was transcribed from this DNA. The samples were subsequently purified. He then separated the two strands of the DNA sample.

The base compositions of each strand and that of the mRNA were analysed. The results of the analysis are shown in the table below.

	A	G	C	T	U
DNA strand 1	19.1	26.0	31.0	23.9	0.0
DNA strand 2	24.2	30.8	25.7	19.3	0.0
DNA strand 3	20.5	25.2	29.8	24.5	0.0
mRNA	19.0	25.9	30.8	0.0	24.3

A Strand **1**

B Strand **2**

C Strand **3**

D None of the above

11 Which of the following occurs in the life cycle of an influenza virus but **not** in the life cycle of HIV?

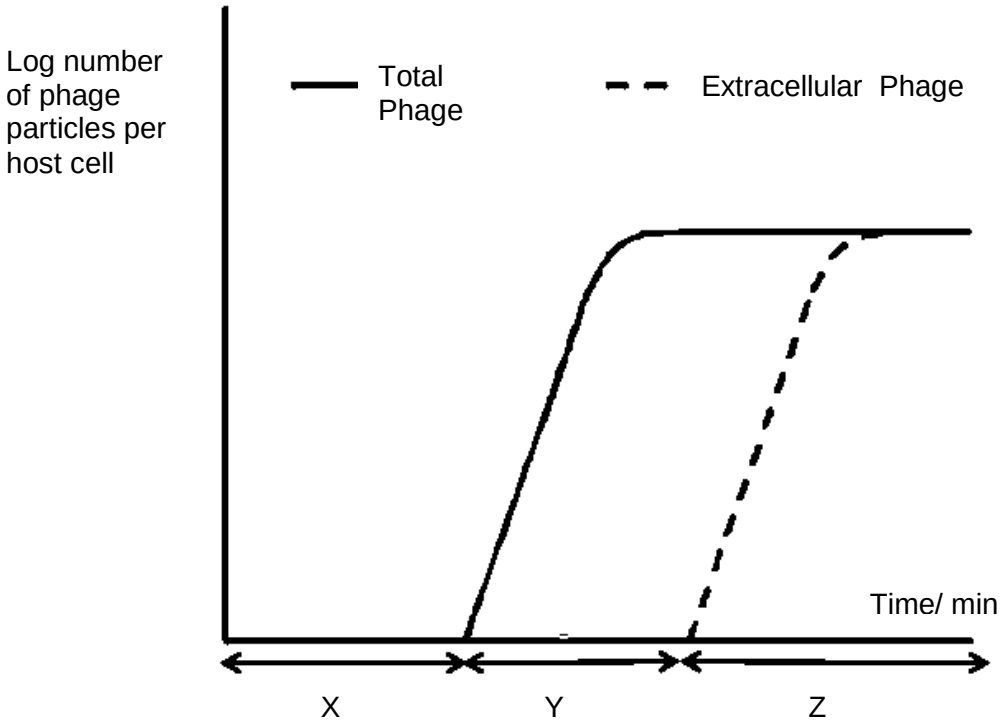
A Synthesis of double stranded complementary DNA.

B Integration of DNA into host genome.

C Binding to specific surface receptors followed by fusion of membrane.

D Removal of specific surface receptors during release.

12 The figure below shows a growth cycle of a T4 phage.



Which of the following statements about X, Y and Z of the growth cycle is correct?

A X is the eclipse period where the phage's tail fibers attach to specific receptors on the bacterial cell.

B Period Z will correspond to the death of host cells.

C X corresponds to the period where the phage exists as a prophage

D Y is the period where there is just active viral DNA replication and protein production.

13 Which statement correctly describes the control of transcription of the genes involved in the synthesis of tryptophan in Escherichia coli?

A A repressor protein is inactive and does not bind to the operator, switching on the genes.

B A repressor protein is active and does not bind to the operator, switching off the genes.

C A repressor protein is active and binds to the promoter, switching on the genes.

D A repressor protein is inactive and does not bind to the promoter, switching off the genes.

14 A similarity between transformation and conjugation in bacteria is that they

A both involve double-stranded DNA passing into the cell whereby one strand is degraded by nucleases.

B both involves homologous recombination where nucleotide sequences are exchanged.

C both involves the formation of sex pili in order for the DNA to enter.

D both involve recombination and forming new plasmids.

15 Some events that take place during generalised transduction are listed below.

1 Bacterial host DNA is fragmented
2 Bacterial DNA may be packaged in a phage capsid
3 Recombination between donor bacterial DNA and recipient bacterial DNA
4 Phage infects a bacterial cell
5 Phage DNA and proteins are made

Which sequence of events is correct?

A 4 1 5 2 3

B 4 1 3 5 2

C 4 3 1 5 2

D 4 5 1 3 2

16 The following are all levels of control of gene expression.

1 Transcriptional
2 Post-transcriptional
3 Translational
4 Post-translational

Which sequence of events is correct?

A 1, 2, 3 and 4

B 1 and 2 only

C 2 and 4 only

D 3 and 4 only

17 Which statement correctly describes a role of histone proteins?

A All eukaryotic genes are transcribed continuously because they are not packaged by histones.

B DNA must be selectively released from its histone packaging before transcription can occur in bacteria.

C Histones package prokaryote chromatin into the nucleosomes that form the bulk of the chromosome.

D The organisation of DNA by histones in eukaryotes allows some gene control sequences to be thousands of base pairs away from the gene concerned.

18 Four different genes are regulated in different ways.

1 Gene 1 undergoes tissue-specific patterns of alternative splicing

2 Gene 2 is part of a group of structural genes controlled by the same regulatory sequences

3 Gene 3 is in some circumstances subject to methylation

4 Gene 4 codes for a repressor protein which acts at an operator site close by

Which combination correctly identifies the gene regulatory steps involving prokaryotes and eukaryotes?

	prokaryotic	eukaryotic
A	1 and 2	3 and 4
B	1 and 3	2 and 4
C	2 and 3	1 and 4
D	2 and 4	1 and 3

19 Ras protein is a G-protein involved in a cell-signalling pathway. This protein is coded for by a proto-oncogene. Which of the following would lead to the cell undergoing uncontrolled cell division?

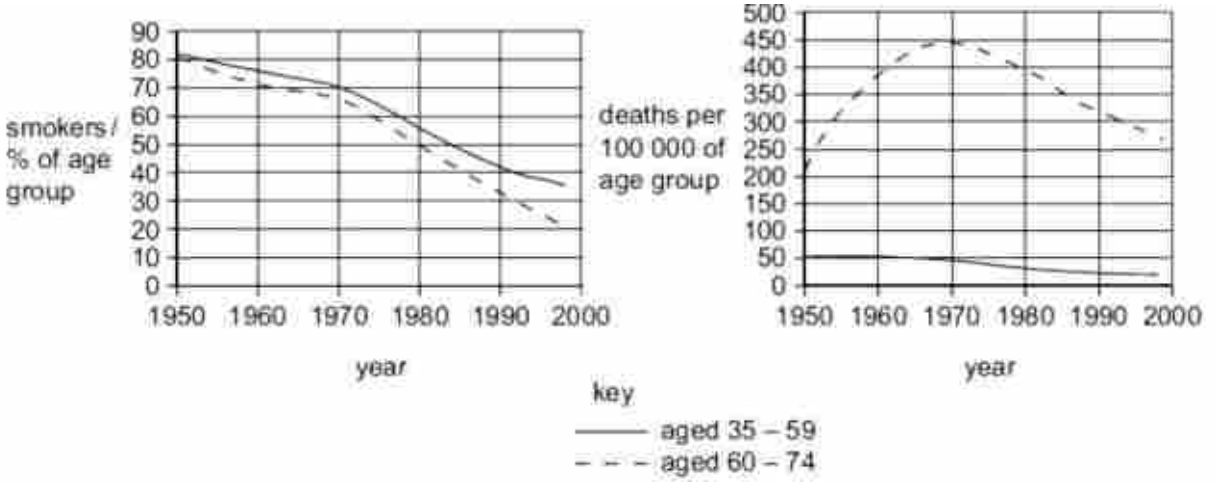
A Point mutation within the proto-oncogene, forming mutant Ras which is constitutively active.

B Formation of multiple copies of the Ras proto-oncogene resulting in mutant Ras proteins.

C Duplication of the Ras promoter that controls the proto-oncogene.

D Translocation of the proto-oncogene upstream of a hyperactive promoter.

20 Some studies suggest that smoking increases the risk of developing lung cancer. The two graphs show the percentage of smokers and the deaths from lung cancer in men of two age groups between 1950 and 1998.



Which statement is **not** supported by the data in the graphs?

A Deaths from lung cancer in men 35-59 decreased by 50 % over the period of the study.

B Deaths from lung cancer in men 60-74 increased up to 1970.

C The data for men 60-74 between 1950 to 1970 suggests that lung cancer takes up to 20 years to develop.

D The number of men aged 35-59 who were smokers decreased by approximately 70 % over the period of the study.

21 A parent organism of unknown genotype is mated in a test cross. Half of the offspring have the same phenotype as the parent.

What can be concluded from this result?

A The parent is heterozygous for the trait.

B The parent is homozygous dominant for the trait.

C The parent is homozygous recessive for the trait.

D The trait being inherited is polygenic.

22 The table shows the results of a series of crosses in a species of small mammal.

coat colour phenotype		
male parent	female parent	offspring
dark grey	light grey	dark grey, light grey, albino
light grey	albino	light grey, white with black patches
dark grey	white with black patches	dark grey, light grey
light grey	dark grey	dark grey, light grey, white with black patches

What explains the inheritance of the range of phenotypes shown by these crosses?

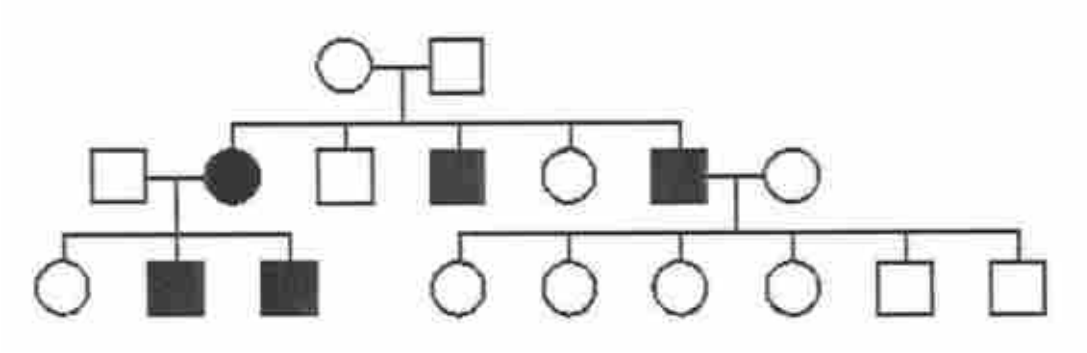
A one gene with a pair of co-dominant alleles

B one gene with multiple alleles

C sex linkage of the allele for grey coat colour

D two genes, each with a dominant and recessive allele

23 The following pedigree depicts the inheritance of a rare hereditary disease affecting muscles.



What is the mode of inheritance of this disease?

A autosomal dominant

B autosomal recessive

C X-linked dominant

D X-linked recessive

24 The statements are descriptions of aspects of genetics.

1 The phenotype is affected by both alleles at the same locus of a heterozygous individual.

2 The combined effects of alleles at two or more gene loci equal the sum of their individual effects.

3 Many different alleles present in a gene pool can occupy the same gene locus.

4 Alleles of one gene mask the effects of the alleles of another gene at a different locus.

Which of the following correctly describes the statements?

	Codominant alleles	Epistatic alleles	Multiple alleles	Additive genes
A	1	4	2	3
B	1	4	3	2
C	2	1	4	3
D	3	1	4	2

25 In cats, the genes controlling coat-colour are co-dominant and carried on the X chromosomes. When a black female was mated with a ginger male the resulting litter consisted of black male and tortoise-shell female kittens.

What phenotypic ratio would be expected in the F2 generation?

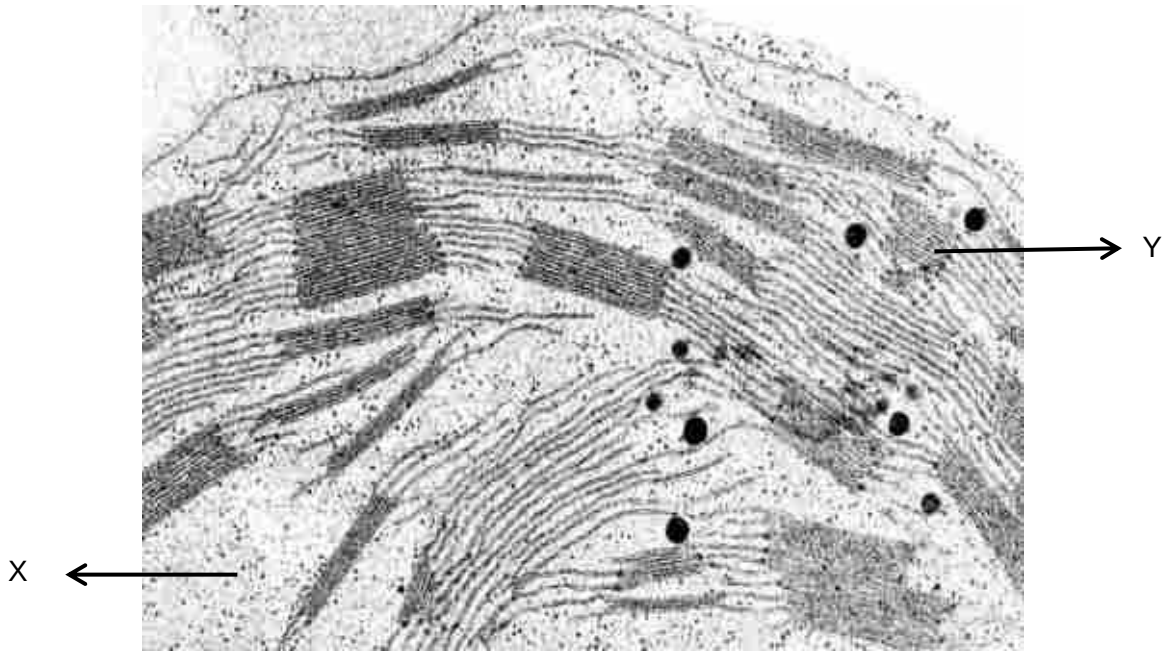
A 1 black male : 1 ginger male : 2 tortoise-shell females

B 1 black male : 1 ginger male : 1 tortoise-shell female : 1 black female

C 2 black males : 1 tortoise-shell female : 1 ginger female

D 2 black males : 1 tortoise-shell female : 1 black female

26 The electron micrograph shows a chloroplast of a plant cell with structures X and Y labelled.



Which of the following statements is correct?

A There is production of NADH and ATP within structure Y.

B There are photosynthetic pigments present in structure X which harnesses chemical energy

C Structure Y is the location in which triose phosphate is produced.

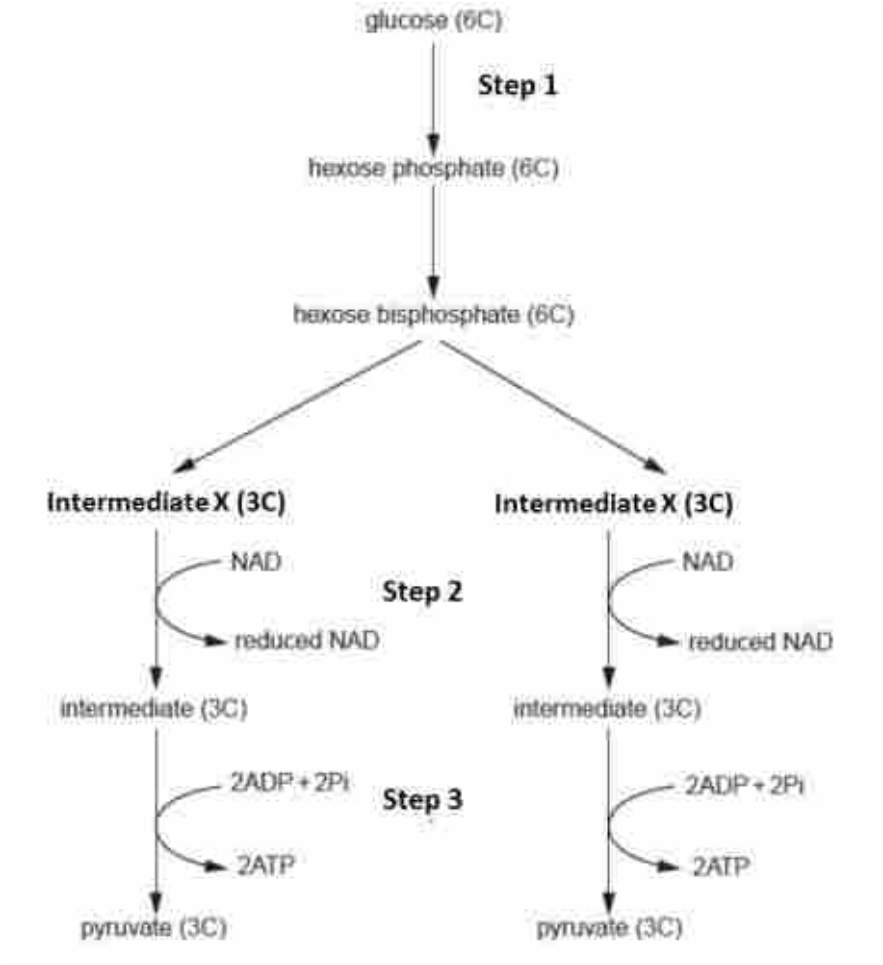
D Structure Y contains proteins involved in the phosphorylation of ADP.

27 2,4-dinitrophenol (DNP) is a chemical and was used for weight loss. However, the prolonged overdose of DNP leads to toxicity including the potential for hyperthermia and death. DNP targets the inner mitochondrial membrane to uncouple oxidative phosphorylation from electron transport. It allows protons to cross the inner mitochondrial membrane and thus dissipates the proton gradient. It also increases tissue metabolism.

Which of the following is true of a cell treated with 2,4-dinitrophenol?

	Ability to use oxygen	**Ability to produce carbon dioxide**	**ATP yield**
A	Yes	No	Decreases
B	Yes	Yes	Decreases
C	No	Yes	Increases
D	Yes	No	Increases

28 During glycolysis, glucose is converted by a series of steps into two molecules of pyruvate.



Which of the following correctly labels intermediate X, steps 1 – 3 and the location where step 3 occurs at?

	Location	**Intermediate X**	**Step 1**	**Step 2**	**Step 3**
A	Cytosol	Glyceraldehyde-3-phosphate	Reduction	Oxidation	Oxidative phosphorylation
B	Cytosol	Triose phosphate	Phosphorylation	Oxidation	Substrate level phosphorylation
C	Mitochondrial matrix	Glycerate-3-phosphate	Reduction	Reduction	Substrate level phosphorylation
D	Cytosol	Triose phosphate	Phosphorylation	Reduction	Substrate level phosphorylation

29 A scientist is investigating the effects of Poison T on the cell signalling pathway of glucagon. It is found that Poison T diminishes the effect of glucagon.

The table below shows the different components of the cell signalling pathway of glucagon and their statuses.

Component	Status
G Protein Coupled Receptor (GPCR)	Configuration can be changed
G protein	Can exchange GDP for GTP
cAMP levels	low
Protein Kinase A	Inactivated

Which of the following statements can be concluded from the results?

1 Poison T interferes with reception.

2 Poison T prevents G protein from hydrolysing GTP.

3 Poison T inactivates the enzyme adenylate cyclase.

4 Poison T stops the relaying of message down the phosphorylation.

A 1 and 2

B 2 and 3

C 2 and 4

D 3 and 4

30 Impulses travel very rapidly along nerves from the leg muscles of a mammal because

A there is a high concentration of Na+ ions inside the axons.

B the nerves contain myelinated fibres.

C there is a potential difference across the axon membranes

D a nerve impulse is an all-or-nothing phenomenon.

31 As adults, certain species of whales possess baleen instead of teeth. Baleen is used to filter the whales' diet of planktonic animals from seawater. As embryos, baleen whales possess teeth, which are later replaced by baleen. The teeth of embryonic baleen whales are evidence that

A All whales are descendants of terrestrial mammals.

B Baleen whales are descendants of toothed whales.

C Baleen embryos pass through a stage when they resemble adult toothed whales.

D Among ancient whales, baleen evolved before teeth.

32 Which of the following increases the number of different alleles in a population?

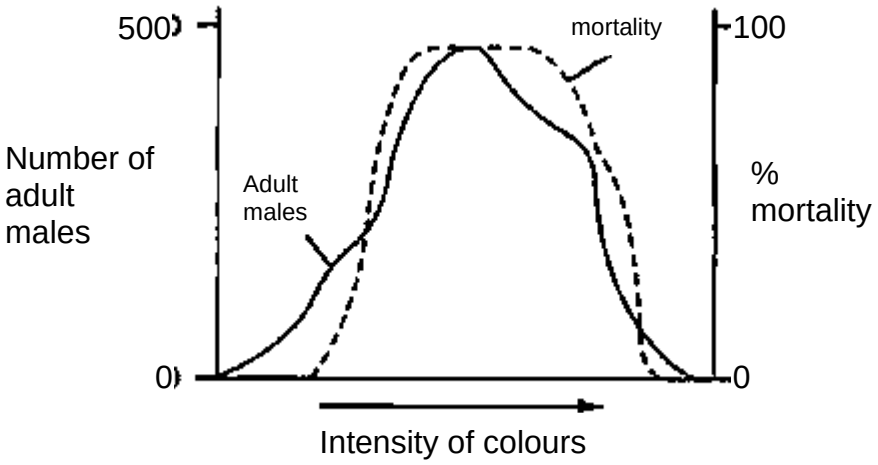
A crossing over

B gene mutation

C random fusion of gametes

D random assortment of chromosomes in meiosis

33 The graph below shows data on a population of a species of moth which shows considerable variation in colour intensity. Which conclusion can be made from this graph?



A Colour variation is environmentally induced.

B Colour variation is genetically determined.

C Extreme forms are favoured by natural selection.

D The species shows discontinuous variation with respect to colour.

34 Which uses of the information from the human genome project are generally considered to be unethical?

1 an insurance company only giving cheap rates to people with genetic predispositions to fewer diseases

2 genetic archaeologists identifying the earliest forms of genes to show evolutionary relationships

3 cytologists developing tests for only some defective genes

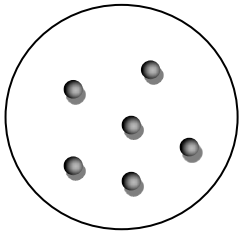
4 doctors only giving specific drugs to block the actions of faulty genes to carriers of those genes

5 genetic counsellors giving specific lifestyle information only to people genetically predisposed to risks

6 parents choosing embryos for implantation only after ante-natal tests for acceptable genes

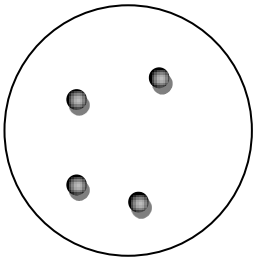
A 1 and 3 **B** 1 and 6 **C** 2 and 5 **D** 3 and 4

35 The insulin gene and a plasmid with ampicillin and tetracycline resistant genes were cut using the same restriction enzyme, EcoRI. The cut plasmid and insulin gene was mixed together and DNA ligase was allowed to react. Subsequently the mixture was heat shocked at 42 degrees with E. coli. The mixture was then plated on nutrient agar to obtain a master plate with colonies shown below.

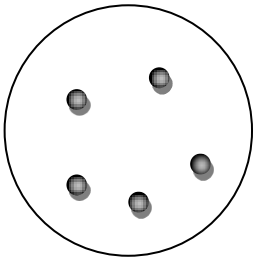


Master plate (nutrient agar)

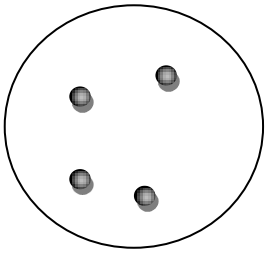
Three replica plates containing different antibiotics were obtained from the master plate. The diagram below shows the results of the replica plates.



Nutrient agar with ampicillin



Nutrient agar with tetracycline



Nutrient agar with tetracycline and ampicillin

Which of the following can be concluded from the results obtained?

A The ampicillin resistant gene is inactivated by insertion of the insulin gene

B The tetracycline resistant gene is inactivated by insertion of the insulin gene.

C The tetracycline resistant gene does not act as a selectable marker

D The ampicillin resistant gene does not act as a selectable marker.

36 Which of the following is the most powerful way of increasing the specificity of a DNA profile analysis?

A Repeat the analysis multiple times.

B Increase the number of markers used.

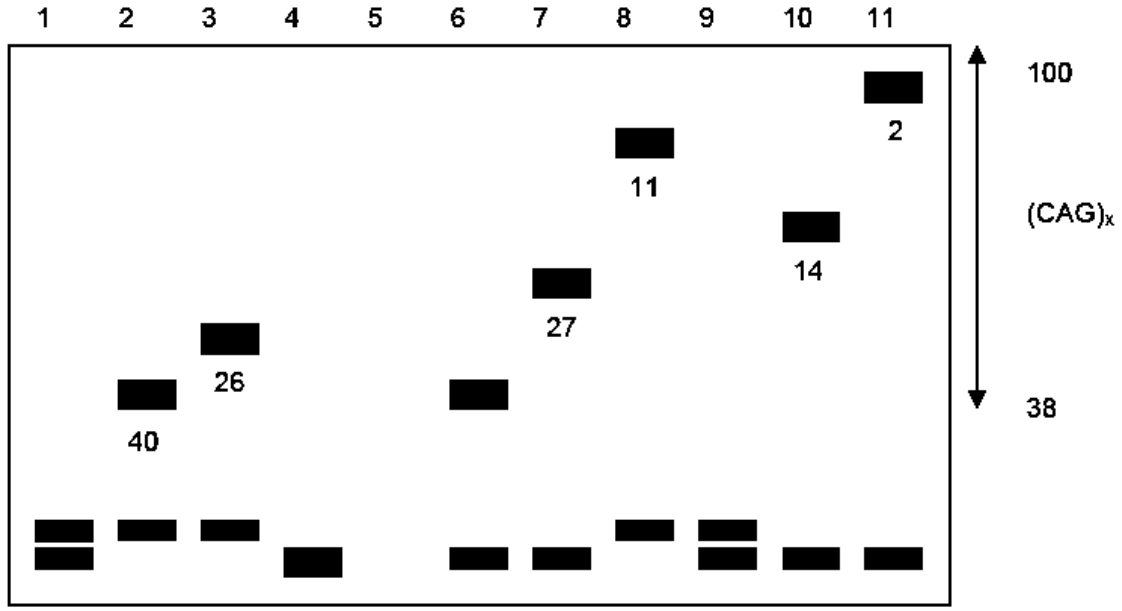
C Analyse each marker by PCR rather than RFLP analysis.

D Select markers present on the sex chromosomes rather than on the autosomes.

37 The data below shows the results of electrophoresis of PCR fragments amplified using primers for the site that has been shown to be altered in Huntington's disease.

The inherited mutation in the Huntington's disease gene abnormally repeats the nucleotide sequence CAG from 36 up to more than 120 times of that. The male parent, shown as individual 2, had the onset of Huntington's disease when he was 40 years old.

Six of his children (individuals 3, 5, 7, 8, 10, 11) suffer from Huntington's disease, and the age at which the symptoms first began is shown by the number below the band from the PCR fragment.



What is the likely outcome for the normal individuals 4, 6, and 9?

A Individuals 4 and 9 do not have the trait, and will not get Huntington's disease, but individual 6 is likely to start the disease when he reaches his father's age of 40.

B Individuals 4, 6, and 9 have not inherited the defect causing Huntington's disease.

C Individuals 4, 6, and 9 will still develop Huntington's disease at some point in their lives, since the disease is inherited as a dominant trait.

D Two of the three will develop the disease, since it is inherited as a dominant trait, but the data does not allow you to predict which two.

38 Which of the following statements are true about adult stem cells?

1 They can undergo self-renewal

2 They can be totipotent, pluripotent or multipotent.

3 They can differentiate into almost any cell type.

4 They can give rise to specialised cells.

A 1 and 2 **B** 1 and 4 **C** 2 and 3 **D** 3 and 4

39 Which of the following methods can be used to introduce a foreign gene into a plant cell?

1 By Agrobacterium-mediated transfection

2 By microinjection of naked DNA

3 Using a phage delivery vector

4 Using a gene gun

A 1 and 3 only

B 1, 2 and 4 only

C 1, 3 and 4 only

D All of the above

40 Developing fish eggs can be treated to produce a diploid egg. In salmon, such eggs have been fused with haploid salmon sperm to give infertile triploid salmon.

Reproductive organ tissue from diploid trout was transplanted into newly hatched triploid salmon. This tissue matured as the fish grew and the salmon successfully produced viable trout sperm or eggs which resulted in young trout.

Which fish could be seen as genetically modified?

A salmon providing eggs for treatment

B trout providing reproductive organ tissue

C young triploid salmon

D young trout

Name	**NRIC Number**	**CTG**

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION 2016

BIOLOGY **9648/01**

HIGHER 2 **28 AUGUST 2016**
MONDAY 0800 – 0915

Paper 1 Multiple Choice **1 hour 15 minutes**

Additional material:
Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil (type B or HB is recommended).
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, full NRIC number and CTG on the Multiple Choice Answer Sheet and question paper in the spaces provided.

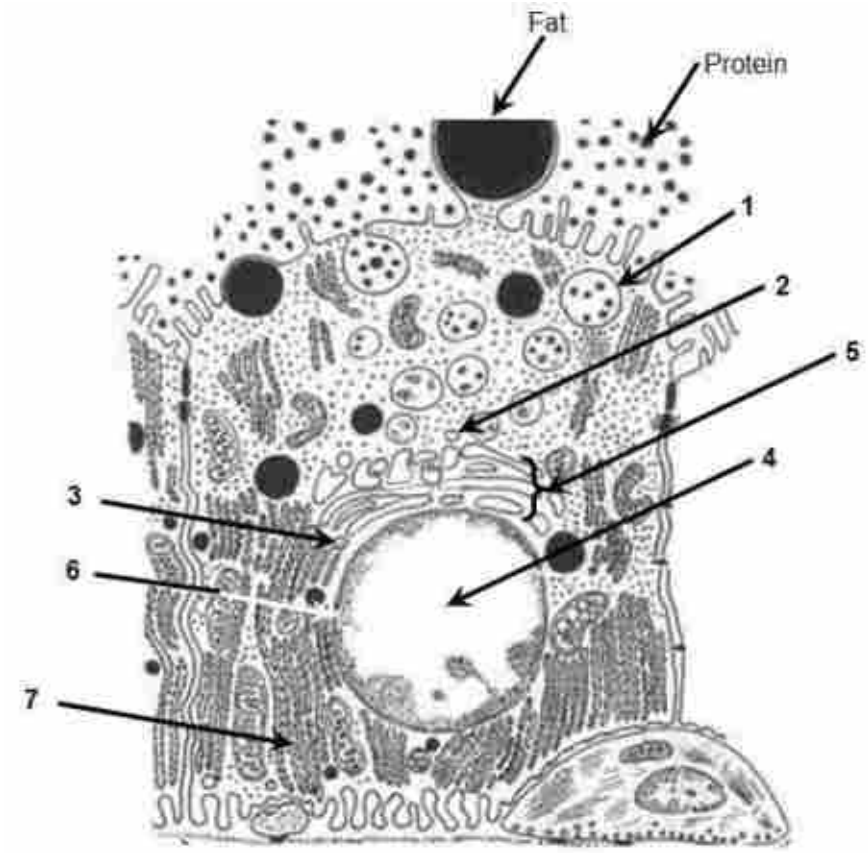
There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet.

Calculators may be used.

This question paper consists of **21** printed pages.

1 The diagram below shows a lactating mammary secretory cell. In this cell, milk proteins, such as casein, are transcribed and translated, and eventually secreted into the lumen of the mammary gland.



Which of the following shows the most likely sequence of locations involved in this process?

	start →						finish
A	6	3	4	7	2	5	1
B	6	4	3	7	5	2	1
C	4	6	7	3	5	2	1
D	4	3	7	6	2	5	1

Reasoning: Transcription occurs in the nucleus (4) → mRNA exported out through nuclear envelope (6) → translation occurs in the RER (7) → transport vesicle to GA (3) → protein modification at GA (5) → transport vesicle bud from GA (2) → transport to CSM (1)

2 The table gives description of four membranous structures in a cell.

Which structure is correctly matched to its function?

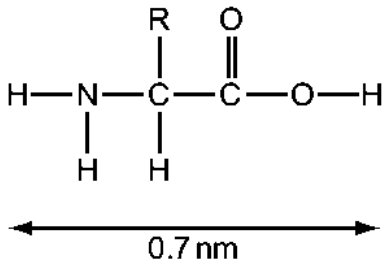
	Structure	Function
A	an extensive network of tubes and sacs; each tube and sac bounded by a single membrane	Lipid synthesis
B	a spherical sac bounded by a single membrane	Protein synthesis
C	a sac bounded by two membranes, the inner highly folded	Packaging of proteins
D	a stack of elongated, curved sacs; each sac bounded by a single membrane	Photosynthesis

Reasoning: option B structure is a vesicle therefore mismatch function; option C structure is mitochondrion therefore mismatch function; option D structure is GA therefore mismatch function.

3 The diameters of some atoms when they form bonds are given in the table.

Atom	Single bond / nm	Double bond / nm
H	0.060	-
O	0.132	0.110
N	0.140	0.120
C	0.154	0.134

The approximate length of the amino acid shown below was estimated using the figures in the table.



What would be the approximate length of a dipeptide formed using this amino acid?

A 0.8 nm **B** 1.2 nm **C** 1.5 nm **D** 1.9 nm

Reasoning: Original amino acid length = 0.060 + 0.140 + 0.0154 + 0.154 + 0.132 + 0.060 = 0.7 nm. Therefore, dipeptide length = (0.060 + 0.140 + 0.0154 + 0.154) + (0.140 + 0.0154 + 0.154 + 0.132 + 0.060) = 1.268 nm. Therefore, approximately 1.2 nm.

4 During the production of fruit juice, enzymes are used to break down the components of cell walls. Which carbohydrate will be produced by this hydrolysis?

A Sucrose **B** Maltose **C** α – glucose **D** β – glucose

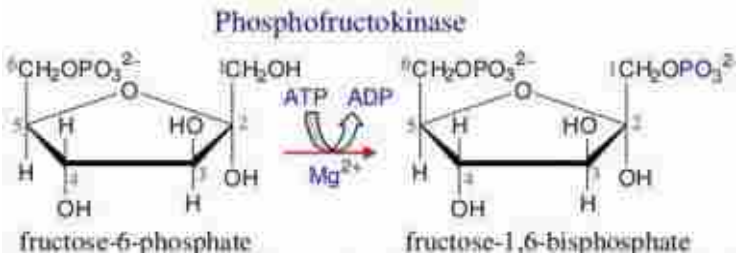
Reasoning: Cell wall is made up of beta-glucose.

5 The enzyme phosphofructokinase is involved in phosphorylation of hexose phosphate sugars during glycolysis. It is involved in control of the rate of glycolysis and thus respiration, by end-product inhibition.

Deduce which of the following is a description of this enzyme.

	Shape of binding site(s)	Substrate	Product
A	no allosteric site, active site complementary to ATP and hexose	hexose	hexose phosphate
B	allosteric site complementary to glucose, active site complementary to hexose phosphate	hexose phosphate	hexose phosphate
C	allosteric site complementary to ATP, active site complementary to ATP and hexose phosphate	hexose phosphate	hexose bisphosphate
D	no allosteric site, active site complementary to hexose bisphosphate	hexose bisphosphate	two triose phosphate

Explanation



PFK is the key regulatory enzyme for glycolysis. When ATP levels are high in the cell, the cell no longer needs metabolic energy production to occur. In this case, PFK's activity is inhibited by allosteric regulation by ATP itself. Allosteric regulators bind to a different site on the enzyme than the active (catalytic) site. Thus ATP binds in two places on PFK: in the active site as a substrate and in the regulatory site

6 A cell in the G1 phase has two homologous pairs of chromosomes. It then undergoes a mitotic division, followed by meiosis. At the end of meiosis II, what is the total number of chromosomes and gene loci found in all the daughter cells formed?

A 8 chromosomes and 4 times as many gene loci as the original parent cell

B 8 chromosomes and 8 times as many gene loci as the original parent cell

C 16 chromosomes and 4 times as many gene loci as the original parent cell

D 16 chromosomes and 8 times as many gene loci as the original parent cell

Reasoning: draw to visualise

7 For organisms undergoing sexual reproduction, a reduction division occurs before fertilisation.

Which reason(s) explain why this is necessary?

1 increase genetic variation
2 prevent doubling of the chromosome number
3 reduce the chances of mutation

A 1 only **B** 2 only **C** 1 and 2 only **D** 1, 2 and 3

Reasoning: reductive division is to reduce the number of chromosomes to haploid number, therefore statement 1 and 3 are not the best explanation why this was necessary.

8 One complete turn of the double helix of DNA contains 10 pairs of bases and is 3.4nm long. What is the approximate number of amino acids in an enzyme coded by a 132 nm length of DNA?

A **38**

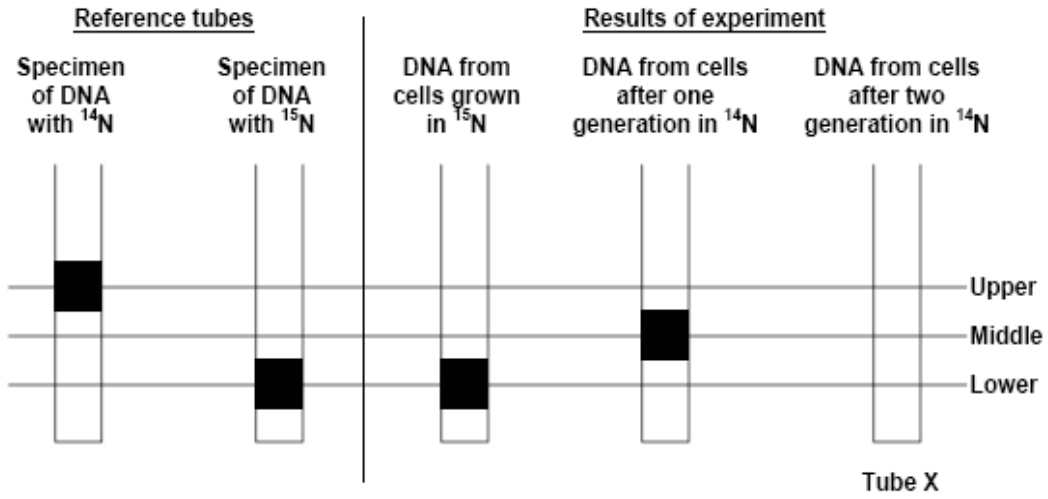
B **129**

C **150**

D **388**

9 Cells of the bacterium E. coli were grown for many generations on a medium containing only the heavy isotope of nitrogen, ^{15}N. The cells were then transferred to a medium containing only ^{14}N and allowed to grow. Samples of the bacteria were removed from the culture after one generation and after two generations. The DNA from each sample was extracted and centrifuged.

The figure below shows two reference tubes and the results of this experiment.



What are the positions and relative proportions of the bands in Tube **X**?

	Upper	Middle	Lower
A	50%	50%	0%
B	0%	50%	50%
C	50%	0%	50%
D	25%	50%	25%

10 A student obtained a sample of DNA and an mRNA was transcribed from this DNA. The samples were subsequently purified. He then separated the two strands of the DNA sample.
The base compositions of each strand and that of the mRNA were analysed. The results of the analysis are shown in the table below.

	A	G	C	T	U
DNA strand 1	19.1	26.0	31.0	23.9	0.0
DNA strand 2	24.2	30.8	25.7	19.3	0.0
DNA strand 3	20.5	25.2	29.8	24.5	0.0
mRNA	19.0	25.9	30.8	0.0	24.3

A Strand **1**

B Strand **2**

C Strand **3**

D None of the above

11 Which of the following occurs in the life cycle of an influenza virus but **not** in the life cycle of HIV?

A Binding to specific surface receptors followed by fusion of membrane

B Integration of DNA into host genome

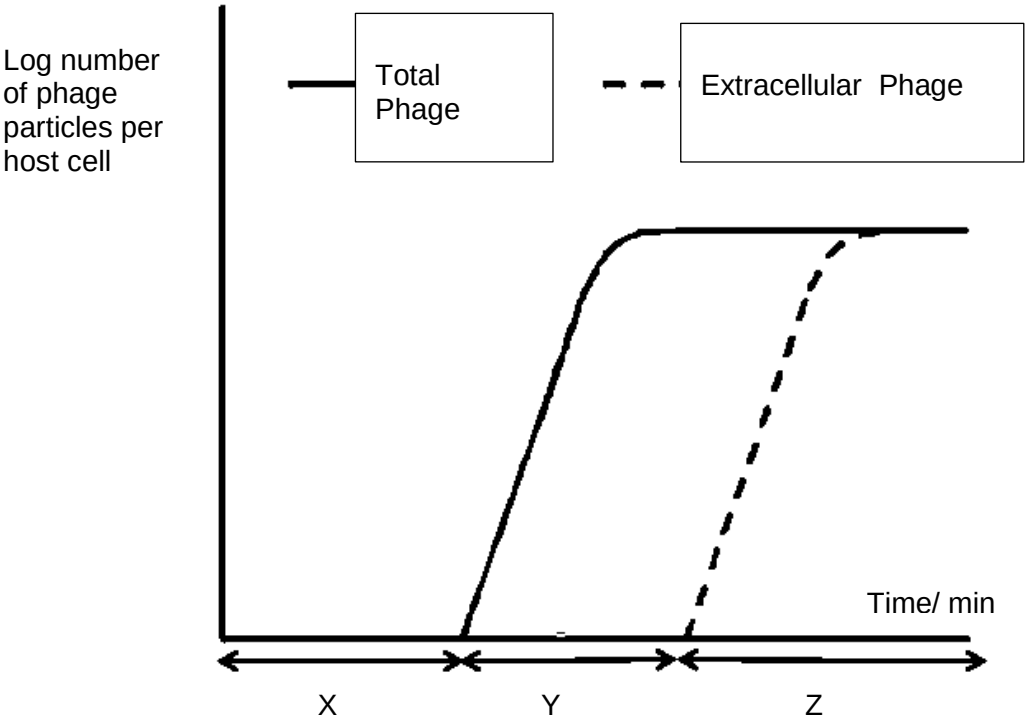
C Removal of specific surface receptors during release

D membraneSynthesis of double stranded complementary DNA

Explanation

Option A, B and D - occurs in HIV and not influenza

12 The figure below shows a growth cycle of a T4 phage.



Which of the following statements about X, Y and Z of the growth cycle is **correct**?

A X is the eclipse period where the phage's tail fibers attach to specific receptors on the bacterial cell.

B Period Z will correspond to the death of host cells.

C X corresponds to the period where the phage exists as a prophage

D Y is the period where there is just active viral DNA replication and protein production.

Explanation
http://www.microbiologybook.org/mayer/phage.htm

X : During the **eclipse phase**, no infectious phage particles can be found either inside or outside the bacterial cell. The phage nucleic acid takes over the host biosynthetic machinery and phage specified m-RNA's and proteins are made.

Y : Intracellular Accumulation Phase
In this phase the nucleic acid and structural proteins that have been made are assembled and infectious phage particles accumulate within the cell.

Z : Lysis and Release Phase
After a while the bacteria begin to lyse due to the accumulation of the phage lysis protein and intracellular phage are released into the medium. The number of particles released per infected bacteria may be as high as 1000.

13 Which statement correctly describes the control of transcription of the genes involved in the synthesis of tryptophan in Escherichia coli?

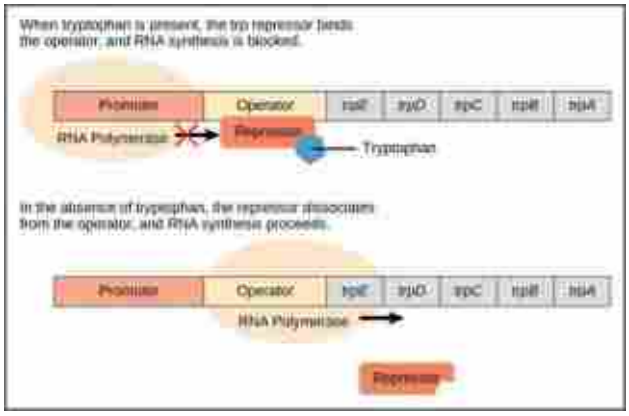
A A repressor protein is inactive and does not bind to the operator, switching on the genes.

B A repressor protein is active and does not bind to the operator, switching off the genes.

C A repressor protein is active and binds to the promoter, switching on the genes.

D A repressor protein is inactive and does not bind to the promoter, switching off the genes.

Explanation



Trp repressor (without tryptophan attached) is inactive and can't bind to the operator of the DNA, allowing transcription to continue.

14 A similarity between transformation and conjugation in bacteria is that they

A both involve double-stranded DNA passing into the cell whereby one strand is degraded by nucleases.

B both involves homologous recombination where nucleotide sequences are exchanged.

C both involves the formation of sex pili in order for the DNA to enter.

D both involve recombination and forming new plasmids.

15 Some events that take place during generalised transduction are listed below.

1 Bacterial host DNA is fragmented
2 Bacterial DNA may be packaged in a phage capsid
3 Recombination between donor bacterial DNA and recipient bacterial DNA
4 Phage infects a bacterial cell
5 Phage DNA and proteins are made

Which sequence of events is correct?

A 4 1 5 2 3

B 4 1 3 5 2

C 4 3 1 5 2

D 4 5 1 3 2

16 The following are all levels of control of gene expression.

1 Transcriptional
2 Post-transcriptional
3 Translational
4 Post-translational

Which sequence of events is correct?

A 1, 2, 3 and 4

B 1 and 2 only

C 2 and 4 only

D 3 and 4 only

17 Which statement correctly describes a role of histone proteins?

A All eukaryotic genes are transcribed continuously because they are not packaged by histones.

B DNA must be selectively released from its histone packaging before transcription can occur in bacteria.

C Histones package prokaryote chromatin into the nucleosomes that form the bulk of the chromosome.

D The organisation of DNA by histones in eukaryotes allows some gene control sequences to be thousands of base pairs away from the gene concerned.

18 Four different genes are regulated in different ways.

Gene **1** undergoes tissue-specific patterns of alternative splicing
Gene **2** is part of a group of structural genes controlled by the same regulatory sequences
Gene **3** is in some circumstances subject to methylation
Gene **4** codes for a repressor protein which acts at an operator site close by

Which combination correctly identifies the gene regulatory steps involving prokaryotes and eukaryotes?

	prokaryotic	eukaryotic
A	**1** and **2**	**3** and **4**
B	**1** and **3**	**2** and **4**
C	**2** and **3**	**1** and **4**
D	**2** and **4**	**1** and **3**

19 Ras protein is a G-protein involved in a cell-signalling pathway. This protein is coded for by a proto-oncogene. Which of the following would lead to the cell undergoing uncontrolled cell division?

A Point mutation within the proto-oncogene, forming mutant Ras which is constitutively active.

B Formation of multiple copies of the Ras proto-oncogene resulting in mutant Ras proteins.

C Duplication of the Ras promoter that controls the proto-oncogene.

D Translocation of the proto-oncogene upstream of a hyperactive promoter.

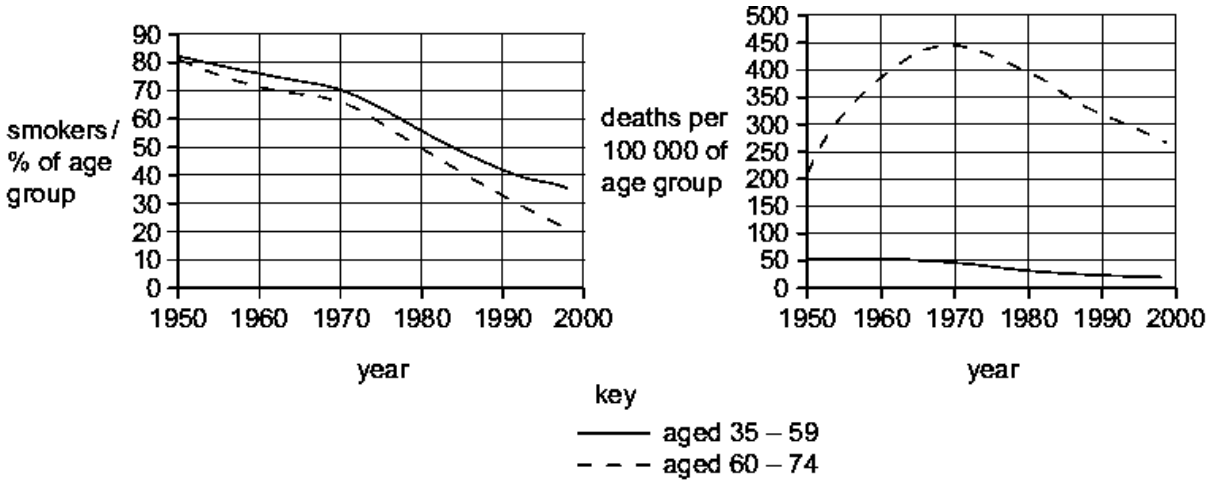
Explanation

Option A -An oncogene formed by point mutation encodes an oncoprotein that differs slightly from the normal protein encoded by the corresponding proto-oncogene.

Amplication or translocation next to an active promoter generates protein products that are identical with the normal proteins; their oncogenic effect is due to their being expressed at higher-than-normal levels or in cells where they normally are not expressed.

Option D – not correct as gene is in front of promoter

20 Some studies suggest that smoking increases the risk of developing lung cancer. The two graphs show the percentage of smokers and the deaths from lung cancer in men of two age groups between 1950 and 1998.



Which statement is **not** supported by the data in the graphs?

A Deaths from lung cancer in men 35-59 decreased by 50 % over the period of the study.

B Deaths from lung cancer in men 60-74 increased up to 1970.

C The data for men 60-74 between 1950 to 1970 suggests that lung cancer takes up to 20 years to develop.

D The number of men aged 35-59 who were smokers decreased by approximately 70 % over the period of the study.

21 A parent organism of unknown genotype is mated in a test cross. Half of the offspring have the same phenotype as the parent.

What can be concluded from this result?

A The parent is heterozygous for the trait.

B The parent is homozygous dominant for the trait.

C The parent is homozygous recessive for the trait.

D The trait being inherited is polygenic.

Reasoning: Since half of the offspring has the same phenotype as the parent, the other half is assumed to have phenotype different from parent. This will work out to be in a 1: 1 ratio. Therefore, parent must be heterozygous which when cross with homozygous recessive produced a 1: 1 ratio.

22 The table shows the results of a series of crosses in a species of small mammal.

coat colour phenotype		
male parent	female parent	offspring
dark grey	light grey	dark grey, light grey, albino
light grey	albino	light grey, white with black patches
dark grey	white with black patches	dark grey, light grey
light grey	dark grey	dark grey, light grey, white with black patches

What explains the inheritance of the range of phenotypes shown by these crosses?

A one gene with a pair of co-dominant alleles

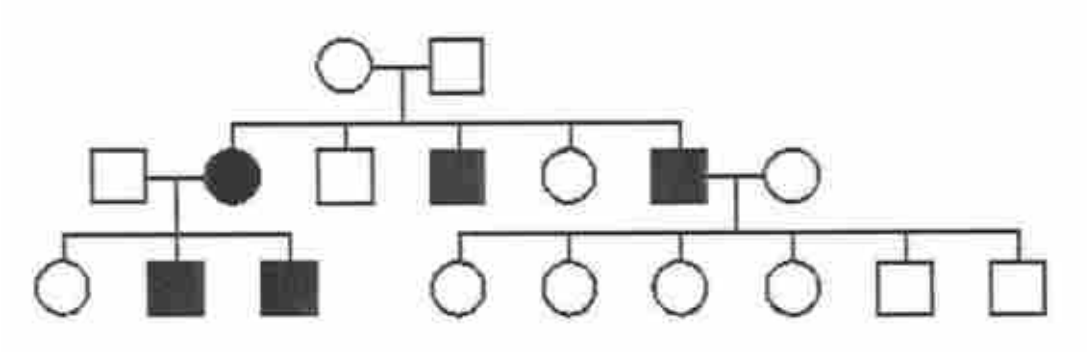
B one gene with multiple alleles

C sex linkage of the allele for grey coat colour

D two genes, each with a dominant and recessive allele

Reasoning: cross 1 produces a third phenotype from parent implies that there is a hidden recessive allele in both dark grey male and light grey female. This is substantiated by cross 2 where the albino phenotype disappeared in the cross when cross with light grey. However, we observe an appearance of another phenotype white with black patches, thus implying that there could be another allele hidden as recessive in light grey male in cross 2. This is substantiated in cross 3 whereby the phenotype disappears when cross with dark grey male, implying that white with black patches is recessive towards dark grey and we observe the appearance of light grey indicating that light grey is also recessive and hidden in the dark grey male in cross 3. Thus, we can conclude the presence of multiple alleles.

23 The following pedigree depicts the inheritance of a rare hereditary disease affecting muscles.



What is the mode of inheritance of this disease?

A autosomal dominant

B autosomal recessive

C X-linked dominant

D X-linked recessive

Reasoning: students who do not analyse the questions carefully will be inclined to choose D due to more males affected than females. However, careful analysis will reveal that in order for the disease to be classified as X-linked recessive, affected female in generation 2 must have an affected male in generation 1 so that she can inherit both recessive X-chromosome. However, this is not the case as the male in generation 1 is normal. Thus the only logical explanation is that both male and female in generation is carriers, thus able to produce affected children in generation 2.

24 The statements are descriptions of aspects of genetics.

1 The phenotype is affected by both alleles at the same locus of a heterozygous individual.

2 The combined effects of alleles at two or more gene loci equal the sum of their individual effects.

3 Many different alleles present in a gene pool can occupy the same gene locus.

4 Alleles of one gene mask the effects of the alleles of another gene at a different locus.

Which of the following correctly describes the statements?

	Codominant alleles	Epistatic alleles	Multiple alleles	Additive genes
A	1	4	2	3
B	1	4	3	2
C	2	1	4	3
D	3	1	4	2

Reasoning: Factual.

25 In cats, the genes controlling coat-colour are co-dominant and carried on the X chromosomes. When a black female was mated with a ginger male the resulting litter consisted of black male and tortoise-shell female kittens.

What phenotypic ratio would be expected in the F2 generation?

A 1 black male : 1 ginger male : 2 tortoise-shell females

B 1 black male : 1 ginger male : 1 tortoise-shell female : 1 black female

C 2 black males : 1 tortoise-shell female : 1 ginger female

D 2 black males : 1 tortoise-shell female : 1 black female

Reasoning: do the cross to visualise the answer.

26 2,4-dinitrophenol (DNP) is a chemical and was used for weight loss. However, the prolonged overdose of DNP leads to toxicity including the potential for hyperthermia and death. DNP targets the inner mitochondrial membrane to uncouple oxidative phosphorylation from electron transport. It allows protons to cross the inner mitochondrial membrane and thus dissipates the proton gradient. It also increases tissue metabolism.

Which of the following is true of a cell treated with 2,4-dinitrophenol?

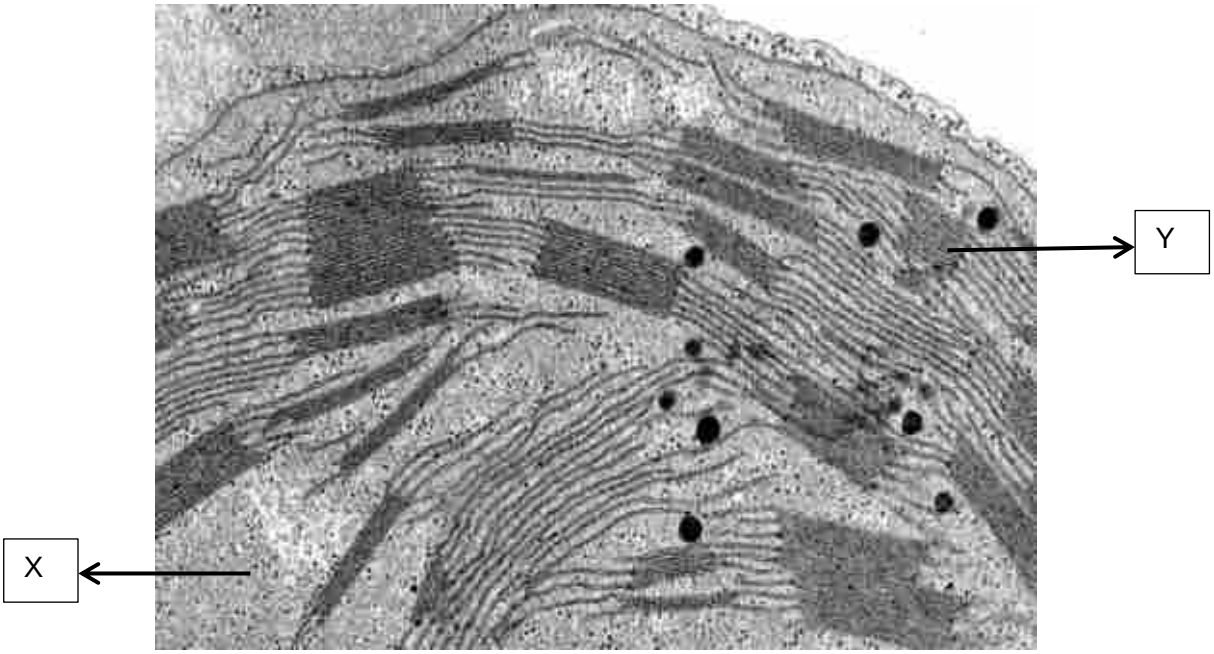
	Ability to use oxygen	**Ability to produce carbon dioxide**	**ATP yield**
A	Yes	No	Decreases
B	Yes	Yes	Decreases
C	No	Yes	Increases
D	Yes	No	Increases

Explanation

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3550200/

ATP should decrease as proton gradient is disrupted with potential energy decreased, leading to less ATP. Oxygen still acts as last electron acceptor to form water. Metabolism increases as lowered level of ATP formed.

27 The electron micrograph shows a chloroplast of a plant cell with structures X and Y labelled.



Which of the following statements is correct?

A There is production of NADH and ATP within structure Y.

B There are photosynthetic pigments present in structure X which harnesses chemical energy

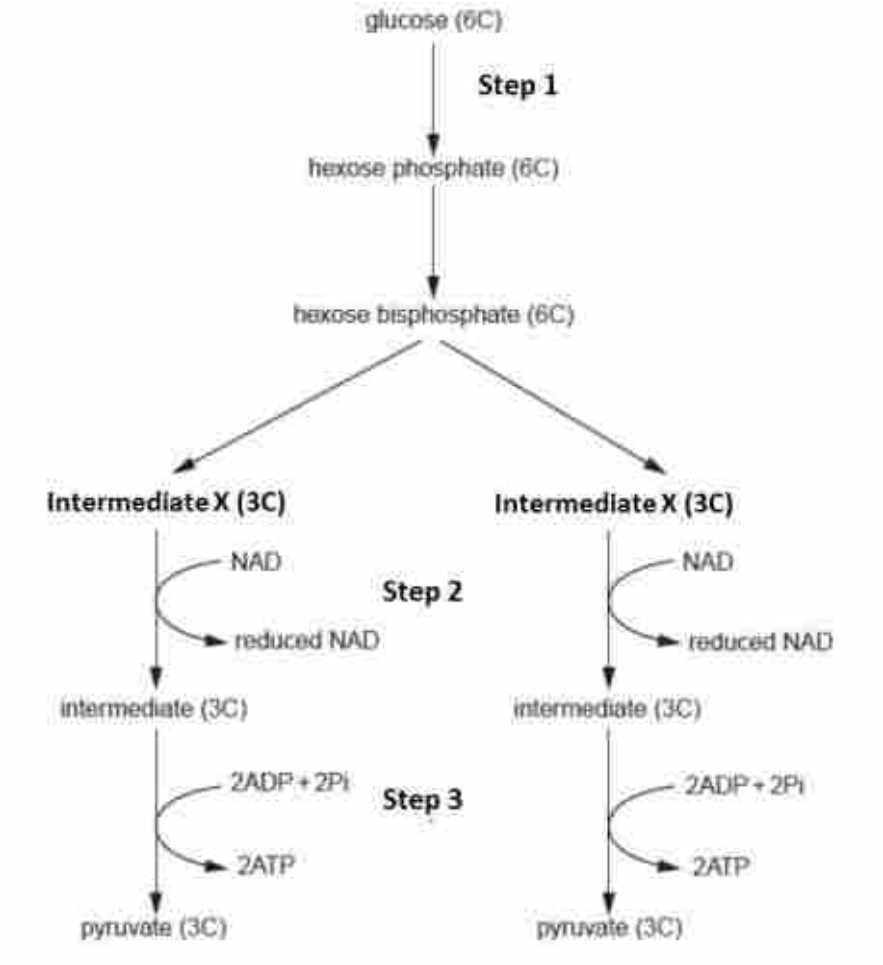
C Structure Y is the location in which triose phosphate is produced.

D Structure Y contains proteins involved in the phosphorylation of ADP.

Explanation

Y – grana – light dependent reactions → form NADPH and ATP
X –stroma – light independent reactions → form glucose

28 During glycolysis, glucose is converted by a series of steps into two molecules of pyruvate.



Which of the following correctly labels intermediate X, steps 1 – 3 and the location where step 3 occurs at?

	Location	Intermediate X	Step 1	Step 2	Step 3
A	Cytosol	Glyceraldehyde-3-phosphate	Reduction	Oxidation	Oxidative phosphorylation
B	Cytosol	Triose phosphate	Phosphorylation	Oxidation	Substrate level phosphorylation
C	Mitochondrial matrix	Glycerate-3-phosphate	Reduction	Reduction	Substrate level phosphorylation
D	Cytosol	Triose phosphate	Phosphorylation	Reduction	Substrate level phosphorylation

29 A scientist is investigating the effects of Poison T on the cell signalling pathway of glucagon. It is found that Poison T diminishes the effect of glucagon.

The table below shows the different components of the cell signalling pathway of glucagon and their statuses.

Component	Status
G Protein Coupled Receptor (GPCR)	Configuration can be changed
G protein	Can exchange GDP for GTP
cAMP levels	low
Protein Kinase A	Inactivated

Which of the following statements can be concluded from the results?

1 Poison T interferes with reception.

2 Poison T prevents G protein from hydrolysing GTP.

3 Poison T inactivates the enzyme adenylate cyclase.

4 Poison T stops the relaying of message down the phosphorylation.

A **I** and **II**

B **II** and **III**

C **II** and **IV**

D **III** and **IV**

30 Impulses travel very rapidly along nerves from the leg muscles of a mammal because

A there is a high concentration of Na+ ions inside the axons.

B the nerves contain myelinated fibres.

C there is a potential difference across the axon membranes

D a nerve impulse is an all-or-nothing phenomenon.

31 As adults, certain species of whales possess baleen instead of teeth. Baleen is used to filter the whales' diet of planktonic animals from seawater. As embryos, baleen whales possess teeth, which are later replaced by baleen. The teeth of embryonic baleen whales are evidence that

A All whales are descendants of terrestrial mammals.

B Among ancient whales, baleen evolved before teeth.

C Baleen whales are descendants of toothed whales.

D Baleen embryos pass through a stage when they resemble adult toothed whales.

Reasoning: since the characteristic (having teeth) appeared in the embryos of baleen whales, this implies embryological homology with the other whales having teeth. Thus it can be deduced that having baleen is due to descent with modification, hence baleen whales are descendants of the toothed whales.

32 Which of the following increases the number of different alleles in a population?

A crossing over

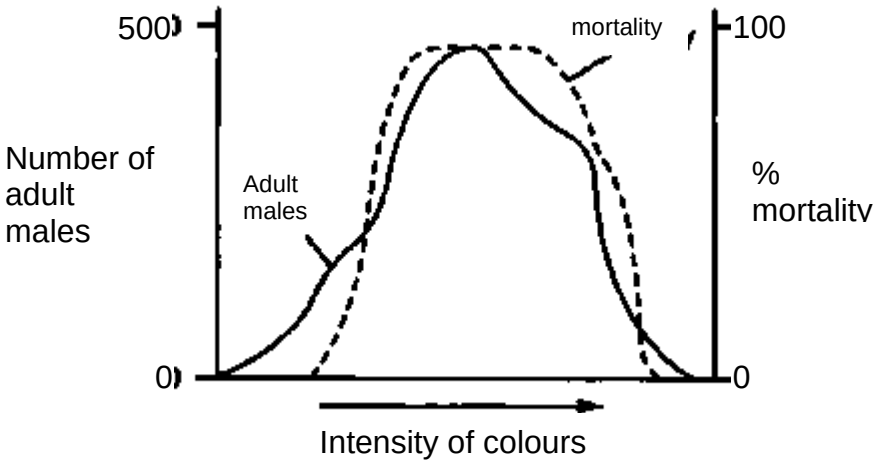
B gene mutation

C random fusion of gametes

D random assortment of chromosomes in meiosis

Reasoning: Factual. Mutation is the only process that can produce a new allele.

33 The graph below shows data on a population of a species of moth which shows considerable variation in colour intensity. Which conclusion can be made from this graph?



A Colour variation is environmentally induced.

B Colour variation is genetically determined.

C Extreme forms are favoured by natural selection.

D The species shows discontinuous variation with respect to colour.

Reasoning: students should interpret as mortality as death. Therefore, able to deduce that intermediate colour have highest death while extreme colours have lowest death.

34 Which uses of the information from the human genome project are generally considered to be unethical?

1. an insurance company only giving cheap rates to people with genetic predispositions to fewer diseases
2. genetic archaeologists identifying the earliest forms of genes to show evolutionary relationships
3. cytologists developing tests for only some defective genes
4. doctors only giving specific drugs to block the actions of faulty genes to carriers of those genes
5. genetic counsellors giving specific lifestyle information only to people genetically predisposed to risks
6. parents choosing embryos for implantation only after ante-natal tests for acceptable genes

A 1 and 3 **B** 1 and 6 **C** 2 and 5 **D** 3 and 4

Reasoning: 2, 3, 4 and 5 are neutral statements.

35 Which of the following is the most powerful way of increasing the specificity of a DNA profile analysis?

A Repeat the analysis multiple times.

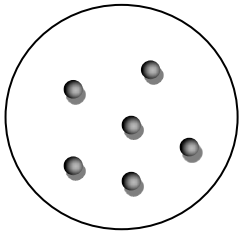
B Increase the number of markers used.

C Analyse each marker by PCR rather than RFLP analysis.

D Select markers present on the sex chromosomes rather than on the autosomes.

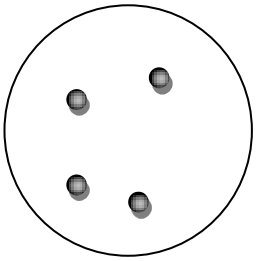
Reasoning: option A is increasing reliability. Option C and D are not relevant to the question about increasing specificity..

36 The insulin gene and a plasmid with ampicillin and tetracycline resistant genes were cut using the same restriction enzyme, EcoRI. The cut plasmid and insulin gene was mixed together and DNA ligase was allowed to react. Subsequently the mixture was heat shocked at 42 degrees with E. coli. The mixture was then plated on nutrient agar to obtain a master plate with colonies shown below.

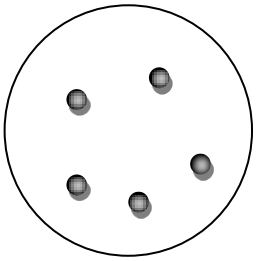


Master plate (nutrient agar)

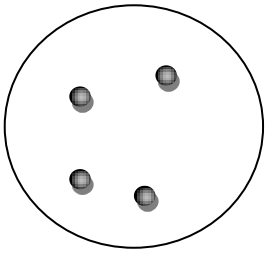
Three replica plates containing different antibiotics were obtained from the master plate. The diagram below shows the results of the replica plates.



Nutrient agar with ampicillin



Nutrient agar with tetracycline



Nutrient agar with tetracycline and ampicillin

Which of the following can be concluded from the results obtained?

A The ampicillin resistant gene is inactivated by insertion of the insulin gene

B The tetracycline resistant gene is inactivated by insertion of the insulin gene.

C The tetracycline resistant gene does not act as a selectable marker

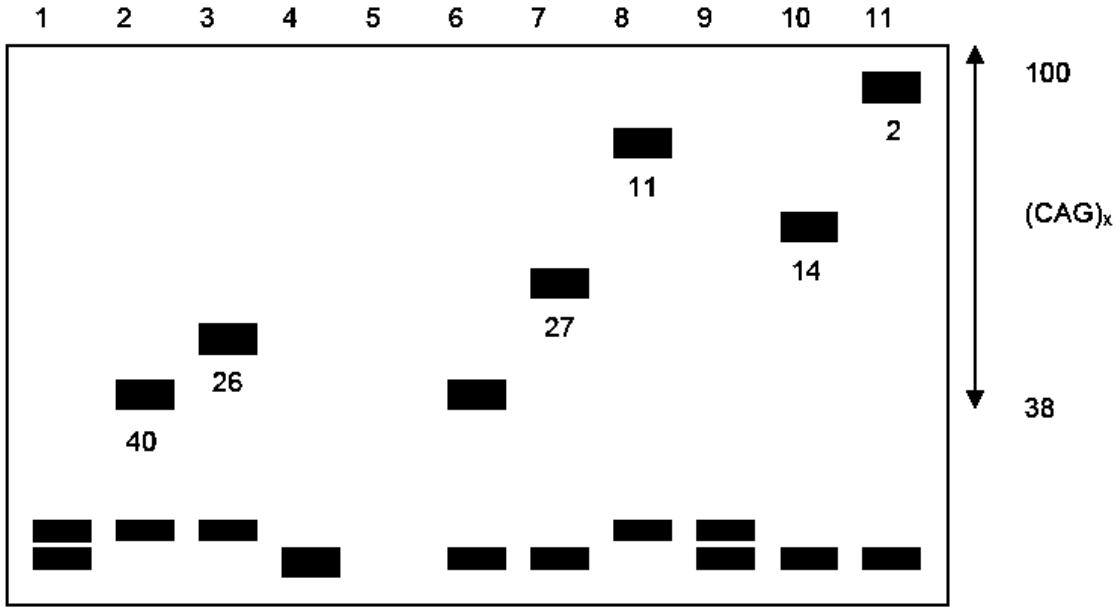
D The ampicillin resistant gene does not act as a selectable marker.

Reasoning: the colony on the extreme right is not found on ampicillin plates.

37 The data below shows the results of electrophoresis of PCR fragments amplified using primers for the site that has been shown to be altered in Huntington's disease.

The inherited mutation in the Huntington's disease gene abnormally repeats the nucleotide sequence CAG from 36 up to more than 120 times of that. The male parent, shown as individual 2, had the onset of Huntington's disease when he was 40 years old.

Six of his children (individuals 3, 5, 7, 8, 10, 11) suffer from Huntington's disease, and the age at which the symptoms first began is shown by the number below the band from the PCR fragment.



What is the likely outcome for the normal individuals 4, 6, and 9?

A Individuals 4 and 9 do not have the trait, and will not get Huntington's disease, but individual 6 is likely to start the disease when he reaches his father's age of 40.

B Individuals 4, 6, and 9 have not inherited the defect causing Huntington's disease.

C Individuals 4, 6, and 9 will still develop Huntington's disease at some point in their lives, since the disease is inherited as a dominant trait.

D Two of the three will develop the disease, since it is inherited as a dominant trait, but the data does not allow you to predict which two.

Reasoning: individual 4 and 9 do not have CAG repeat sequence in the risk zone thus will not develop the disease (eliminate option C and D). Individual 4 has the CAG repeat sequence in the risk zone, same as individual 2, thus likely to develop the disease.

38 Which of the following statements are true about adult stem cells?

1 They can undergo self-renewal

2 They can be totipotent, pluripotent or multipotent.

3 They can differentiate into almost any cell type.

4 They can give rise to specialised cells.

A 1 and 2 **B** 1 and 4 **C** 2 and 3 **D** 3 and 4

Reasoning: adult stem cells are multipotent and can only differentiate into a specific lineage.

39 Which of the following methods can be used to introduce a foreign gene into a plant cell?

1 By Agrobacterium-mediated transfection

2 By microinjection of naked DNA

3 Using a phage delivery vector

4 Using a gene gun

A **1** and **3** only.

B **1, 2** and **4** only.

C **1, 3** and **4** only.

D All of the above.

40 Developing fish eggs can be treated to produce a diploid egg. In salmon, such eggs have been fused with haploid salmon sperm to give infertile triploid salmon.

Reproductive organ tissue from diploid trout was transplanted into newly hatched triploid salmon. This tissue matured as the fish grew and the salmon successfully produced viable trout sperm or eggs which resulted in young trout.

Which fish could be seen as genetically modified?

A salmon providing eggs for treatment

B trout providing reproductive organ tissue

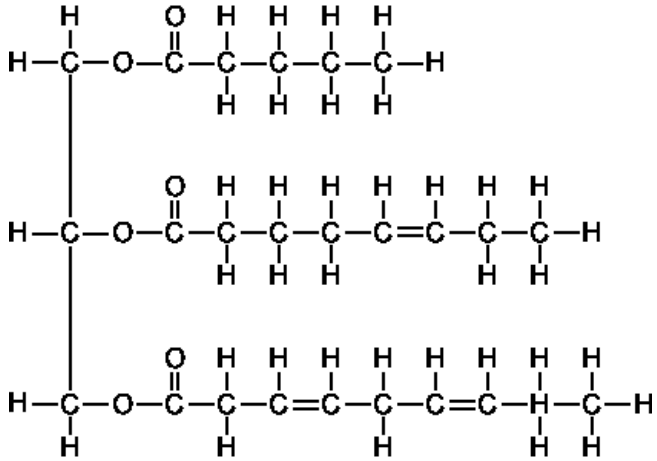
C young triploid salmon

D young trout

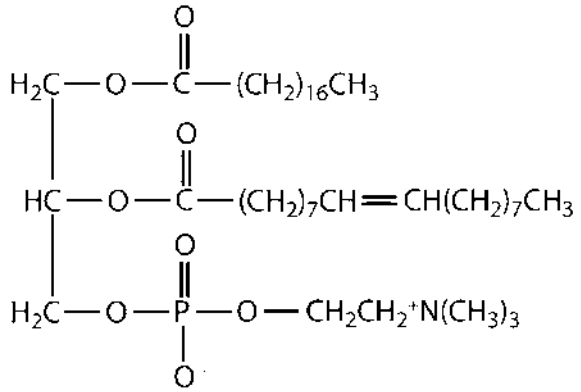
Section A

Answer **all** the questions in this section.

1 Fig. 1.1 shows the structure of two lipid molecules, **X** and **Y**.



X



Y

Fig. 1.1

(a) With reference to Fig. 1.1,

(i) describe **two** structural features which are similar between molecules **X** and **Y**.

_____

_____

_____

_____ [2]

(ii) explain how the structure of molecule **Y** is related to bilayer arrangement in cell membrane.

_____

_____

_____

_____

_____

_____[3]

Other than lipids, proteins are also the building blocks of life. Every cell in the human body contains protein. The basic structure of protein is a chain of amino acids.

(b) Describe how a dipeptide is formed from two amino acids.

_____

_____

_____

_____[2]

One of the important protein molecules in the human body is collagen. Collagen is the main structural protein. It strengthens the tendons and supports the skin and internal organs. Bones and teeth are made by adding mineral crystals to collagen. Collagen is made up of many tropocollagen subunits. Each tropocollagen subunit is composed of three polypeptide chains, wound together in a tight triple helix. Fig. 1.2 shows only a segment of the collagen.

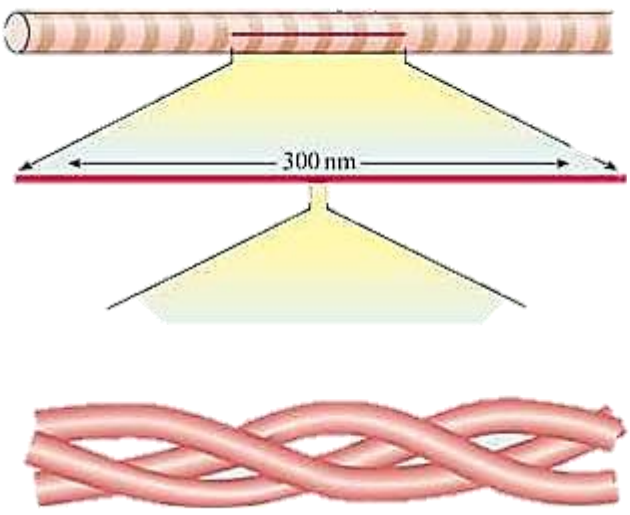


Fig. 1.2

(c) Explain why collagen is described as a fibrous protein.

_____

_____

_____

_____[2]

Cellulose is an important structural component of the primary cell wall of green plants while collagen is the main structural protein in the extracellular space in the various connective tissues in animal bodies.

(d) Describe **two** structural differences between collagen and cellulose.

_____

_____

_____

_____ [2]

[Total: 11]

2 DNA is found mostly in the cell nucleus, but another type of nucleic acid, RNA, is common in the cytoplasm. Watson and Crick proposed that RNA must copy the *template* found in the nucleus and carry it out to the cytoplasm, where proteins are synthesized. Crick also predicted the existence of an "adaptor" molecule that reads the genetic code and selects the appropriate amino acids to add to a growing polypeptide chain. This proposed flow of genetic information is known as the "Central Dogma".

As it turned out, several types of RNA are involved in the utilization of genetic information. In the nucleus, the code is "transcribed," or copied, into a messenger RNA (mRNA) molecule. In the cytoplasm, the mRNA code is "translated" into amino acids. Translation is orchestrated at the ribosome, itself partly composed of RNA, with transfer RNA playing the role of adaptor.

RNA is an intermediary between DNA and protein. (n.d.). Retrieved July 03, 2016, from http://www.dnaftb.org/21

(a) Describe the functions of the nuclear envelope that encloses the nucleus.

_____

_____

_____

_____[2]

(b) With reference to the information given above,

(i) suggest how the structure of the adaptor molecule is suitable for its role.

_____

_____

_____

_____[2]

(ii) explain what is meant by the term *template*.

_____

_____

_____

_____

_____

_____[3]

(c) Explain why the unwinding of the DNA double helix promotes transcription.

_____

_____[1]

[Total: 8]

3 Fig. 3.1 shows the course of a human immunodeficiency virus (HIV) infection. The graph shows HIV RNA copies and $CD4^+$ T lymphocytes counts over course of the infection.

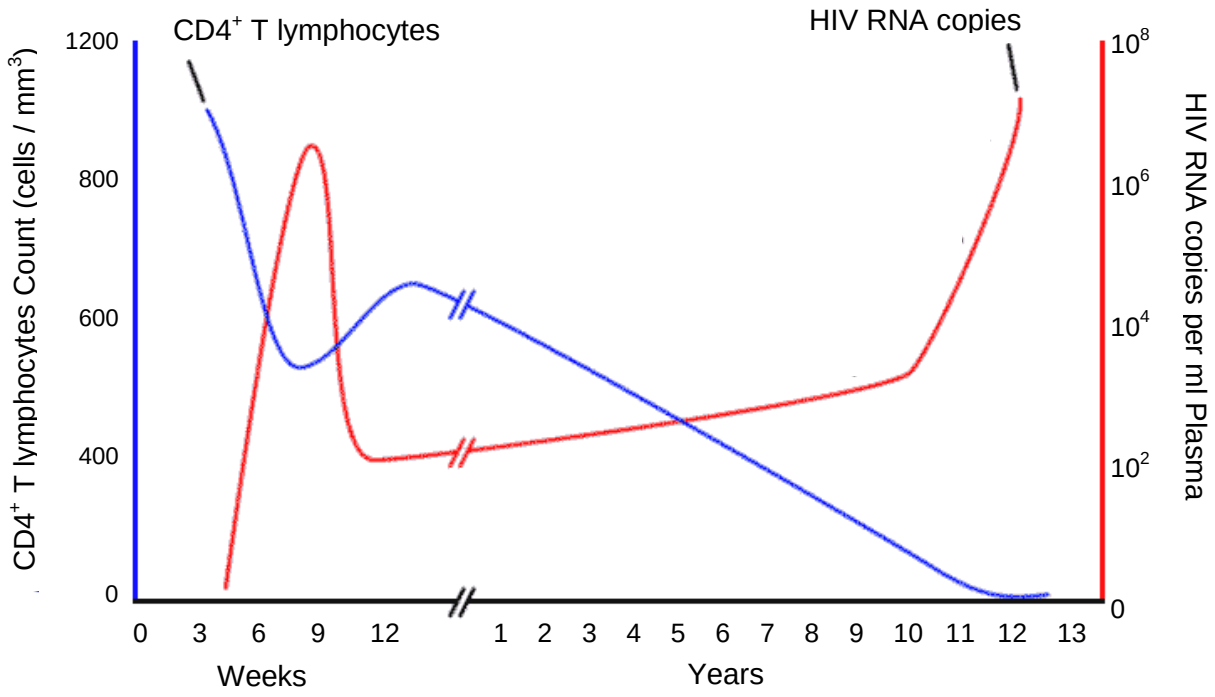


Fig. 3.1

(a) **(i)** Outline how HIV infects the cell.

[4]

(ii) With reference to Fig. 3.1, explain the course of HIV infection from week 1 to week 12.

_____

_____

_____

_____ [2]

(b) Fig. 3.2 shows how a defective lambda phage could be formed.

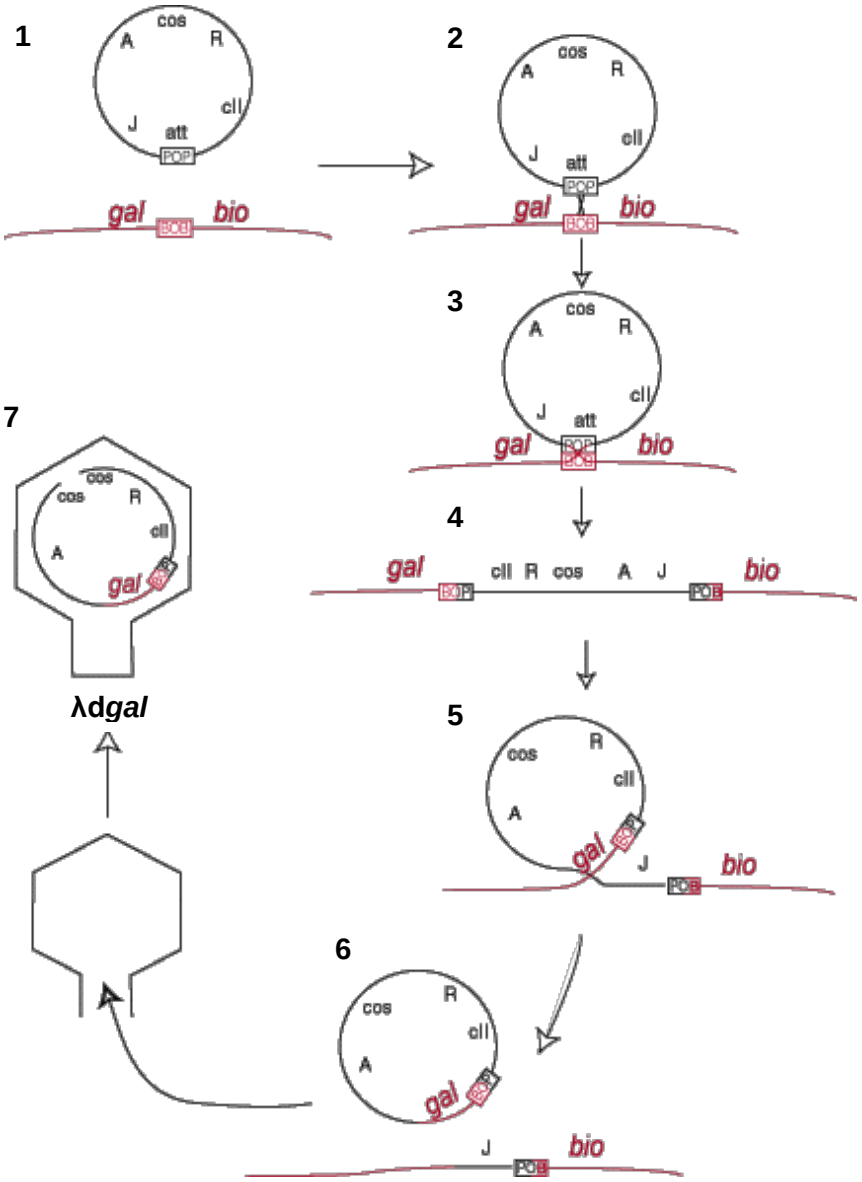


Fig. 3.2

(i) What is a lambda (λ) phage?

_____

_____ [1]

(ii) Name **two** important requirements necessary for the DNA of lambda phage to be integrated into the host's DNA as shown in stages 2 to 4.

_____

_____

_____

_____ [2]

(iii) With reference to Fig. 3.2, suggest and explain a possible outcome of the host DNA from this infection when the defective phage shown in stage 7 infects another host cell with *gal* ⁻ allele.

_____

_____

_____

_____ [2]

[Total: 11]

4 The TATA box binding protein (TBP) attaches to a specific DNA sequence found in the regulatory region upstream of the insulin gene. TBP, along with a variety of TBP-associated factors, form the transcription initiation complex.

Fig. 4.1 shows TBP attached to DNA.

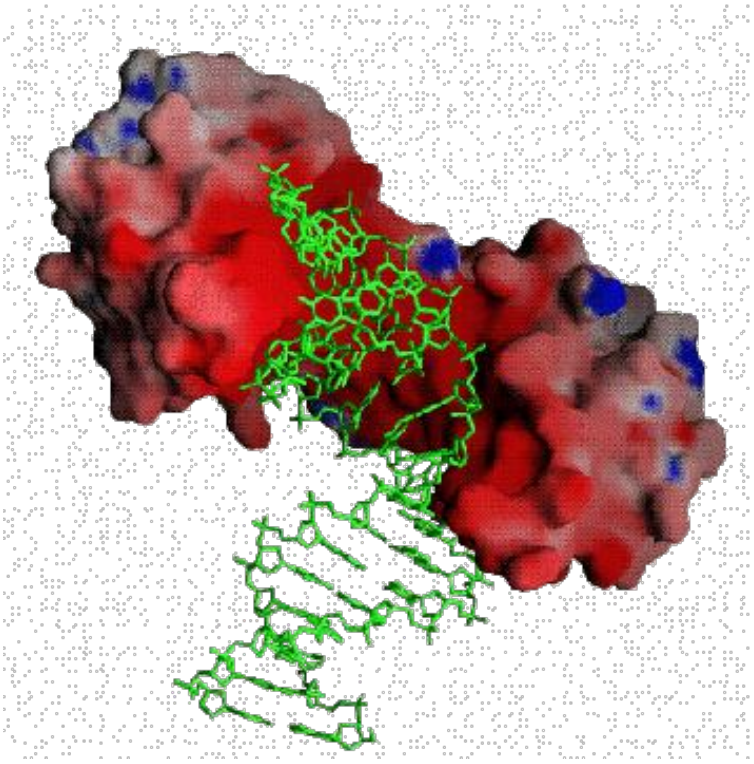


Fig. 4.1

TBP. (n.d.). Retrieved July 03, 2016, from https://ghr.nlm.nih.gov/gene/TBP

(a) With reference to the information given and Fig. 4.1,

(i) state the name of the *regulatory region of DNA.*

_____ [1]

(ii) suggest how TBP will bind to this *regulatory region.*

_____

_____ [1]

(iii) suggest how TBP will initiate transcription.

_____

_____ [1]

Fig. 4.2 shows how a mature insulin mRNA is synthesised via post-transcriptional modification processes.

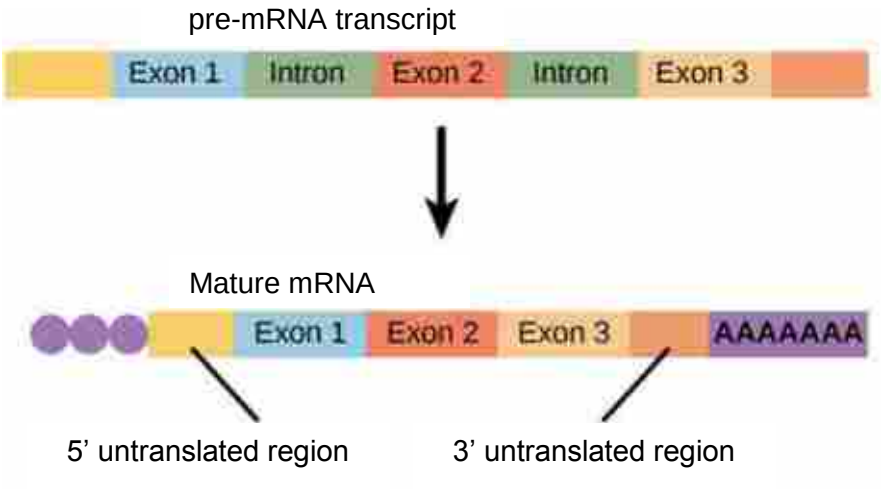


Fig. 4.2

(b) Explain why these post-transcriptional modifications are necessary.

_____

_____

_____

_____

_____

_____[3]

(c) The mature insulin is translated to form a preproinsulin which is an inactive precursor.

Describe one specific post-translational modification that converts it to its active form.

_____

_____

_____

_____[2]

[Total: 8]

5 A transcription factor is a protein that promotes transcription at a particular locus. The gene *Ets 2* codes for a transcription factor, and is located on human chromosome 21. The gene is expressed in cartilage and bone tissues during development. In mice, *Ets 2* is located on chromosome 16 and mice with trisomy 16 show similar skeletal abnormalities to humans with Down's syndrome.

(a) (i) Explain the genetic basis of Down's syndrome in humans.

_____

_____

_____

_____ [2]

(ii) Explain how a trisomy, such as trisomy 16 in mice, can occur in a zygote.

_____

_____

_____

_____

_____

_____ [3]

In order to investigate the possible role of *Ets 2* in Down's syndrome, transgenic mice have been produced which carry an extra copy of mouse *Ets 2*. These mice show similar skeletal abnormalities to mice with trisomy 16. Tissues from the transgenic mice produced up to 1.8 times more *Ets 2* messenger RNA than control mice.

(iii) Suggest why these transgenic mice and mice with trisomy 16 show similar abnormalities.

_____

_____

_____

_____ [2]

Besides chromosomal mutations, gene mutations also occur in humans. Haemophilia A is characterized by deficiency in coagulation factor VIII, which results in prolonged oozing after injuries, tooth extractions, or surgery and renewed bleeding after initial bleeding has stopped. *F8* gene codes for the coagulation factor VIII.

In severe haemophilia A, spontaneous joint bleeding is the most frequent symptom. Serious complications can result from bleeding into the joints, muscles, brain, or other internal organs. Severity of symptoms can vary.

(b) Explain how substitution of bases in the *F8* gene could cause different levels of severity of symptoms in Haemophilia A.

_____

_____

_____

_____

_____

_____[3]

[Total: 10]

6 In summer squash, there are two pairs of alleles that determine fruit colour. The two genes are known to assort and segregate independently.

Two white-fruited plants are crossed. Both parents are known to be heterozygous for both genes. The cross produces the following offspring: 20 green-fruited plants, 58 yellow-fruited plants, and 218 white-fruited plants.

(a) State the name for this type of interaction between the two genes.

_____[1]

(b) Using the symbols D, d and E, e to draw a genetic diagram to explain the results given in the above information.

[4]

(c) Using enzyme production as a biochemical basis for the fruit colour in squash, explain how the two genes interact to produce the various phenotypes.

_____

_____

_____

_____

_____

_____[3]

A chi-squared test was carried out on the results of the cross.

Phenotype	Observed (*O*)	Expected (*E*)	$\frac{(O-E)^2}{E}$
green-fruited plants	20	19	0.1216
yellow-fruited plants	58	56	0.1126
white-fruited plants	218	222	0.0721
			$X^2 = 0.306$

Part of the critical values of the chi-squared distribution is shown below.

Degree of freedom	Probability								
	0.995	0.99	0.975	0.95	0.90	0.10	0.05	0.025	0.01
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345

(d) Explain how the chi-squared calculated value of 0.306 supports the hypothesis that the two genes assorted and segregated independently.

_____

_____

_____

_____

_____

_____[3]

[Total: 11]

7 It is important that the body's internal environment is controlled to maintain relative constancy of the internal environment despite external environmental changes. Maintaining a constant internal environment is called homeostasis. The nervous and endocrine systems both work to bring about this but their response patterns are different. Both the systems use chemical messengers to signal cells, but the speed at which these messages are transmitted is different.

(a) Outline how the body receives information from the external environment to bring about a response. [3]

_____

_____

_____

_____

_____

_____[3]

Fig. 7.1 is a schematic diagram of the interaction between the different systems with the external environment.

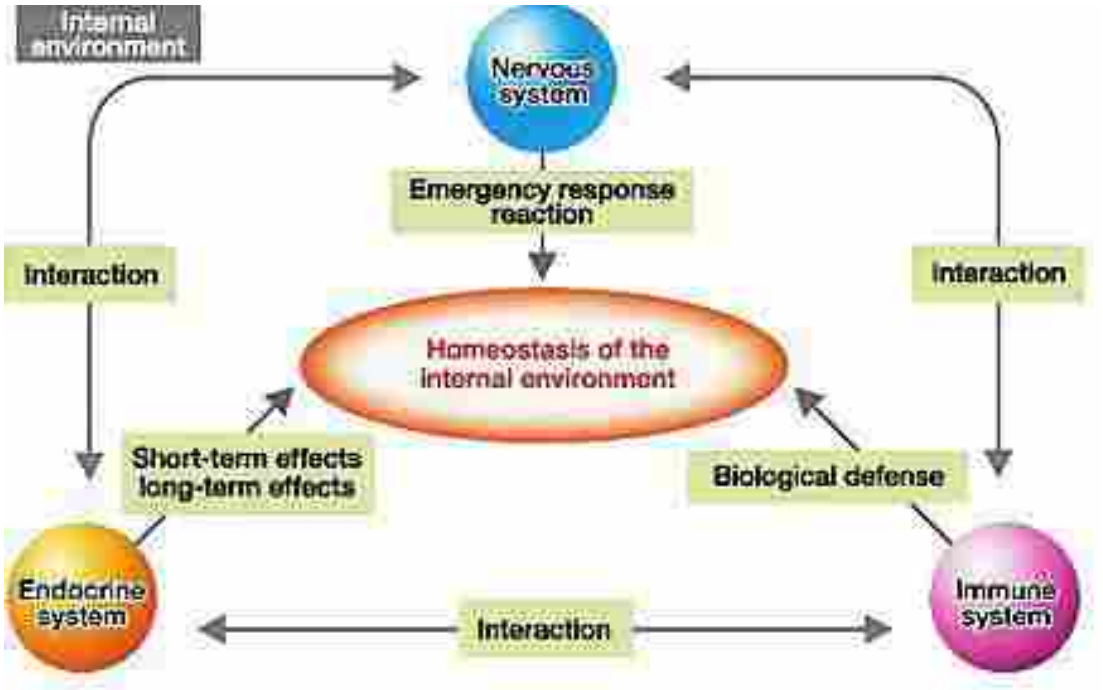


Fig. 7.1

(b) With reference to Fig. 7.1, describe the important differences between endocrine and nervous systems.

_____

_____

_____

_____[2]

Fig. 7.2 shows the steps needed to transmit a signal across a junction known as a synapse between two neurones.

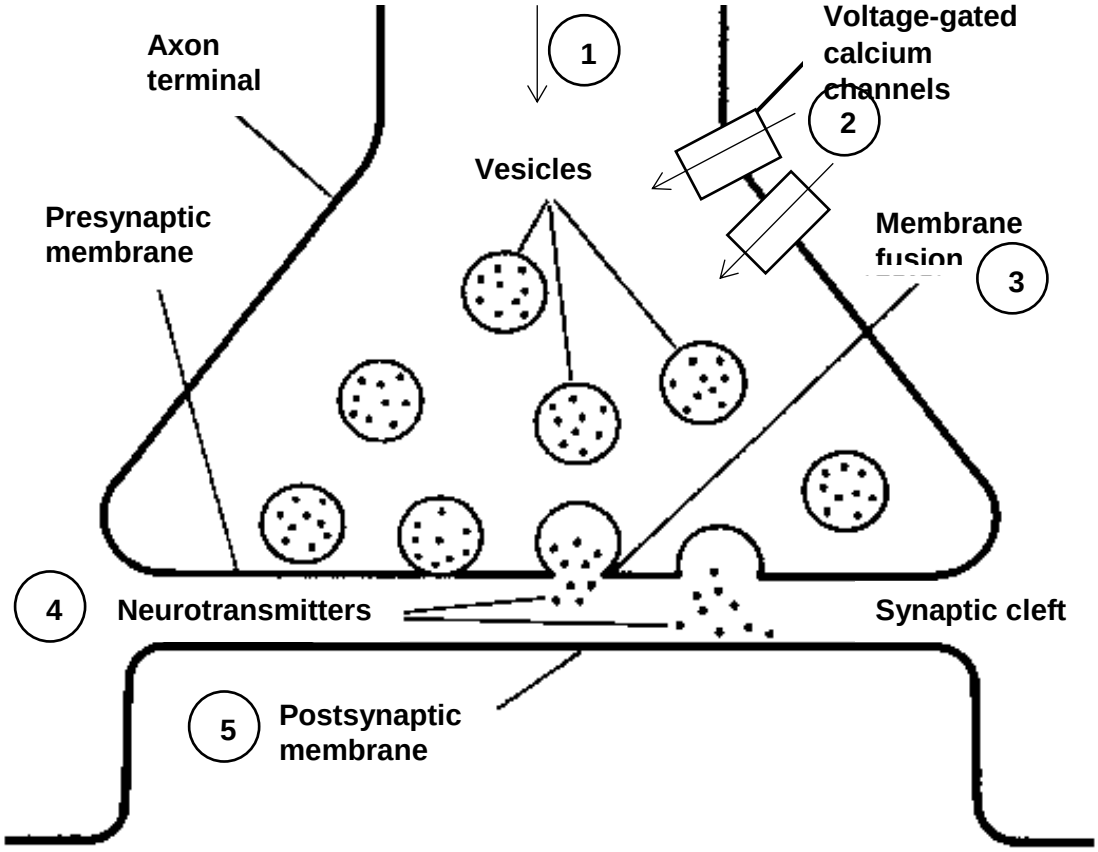


Fig. 7.2

(c) **(i)** Explain which steps shown in Fig. 7.2 will result in synaptic delay.

_____

_____

_____

_____[2]

(ii) Describe the roles of calcium ions in signal transmission across the synapse.

_____

_____

_____

_____[2]

The synaptic knob releases a chemical transmitter, acetylcholine. Nerve gas prevents the breakdown of this chemical.

(d) Suggest and explain one effect of nerve gas on the transmission of nerve impulse across the synapse.

_____

_____[1]

[Total: 10]

8 Anoles are small, colour-changing lizards that are abundant in the Caribbean Islands. Hundreds of species live on the six islands of the Caribbean. Biologist Jonathan Losos has discovered the traits that enable dozens of anole species to adapt to different vertical niches in the forest of the islands.

While differences in limb length, body shape, and toepad size allow different species to flourish on the ground, on thin branches, or high in the canopy, changes in other characters, such as their colourful dewlaps, have played a key role in reproductive isolation and the formation of new species.

Fig. 8.1 shows a picture of *Anolis grahami*, commonly called Graham's anole. This is a species originally native to the island of Jamaica. Jamaica, part of the Caribbean islands, has a lush topography of mountains, rainforests and reef-lined beaches. Graham's anole is one of eight anole species found on Jamaica.

Fig. 8.1

(a) Complete Table 8.1 to show the classification of *Anolis grahami*.

Kingdom	
	Chordata
	Reptilia
	Squamata
Family	Polychrotidae
Genus	
Species	*Anolis grahami*

[3]

Differences in the DNA sequences that encode cytochrome *b* in the eight species of Jamaican anoles have been measured.

(b) Suggest why the cytochrome *b* gene is used to measure changes in DNA sequences in closely related species.

[2]

Fig. 8.2 shows differences in cytochrome *b* DNA plotted against time since colonisation (My).

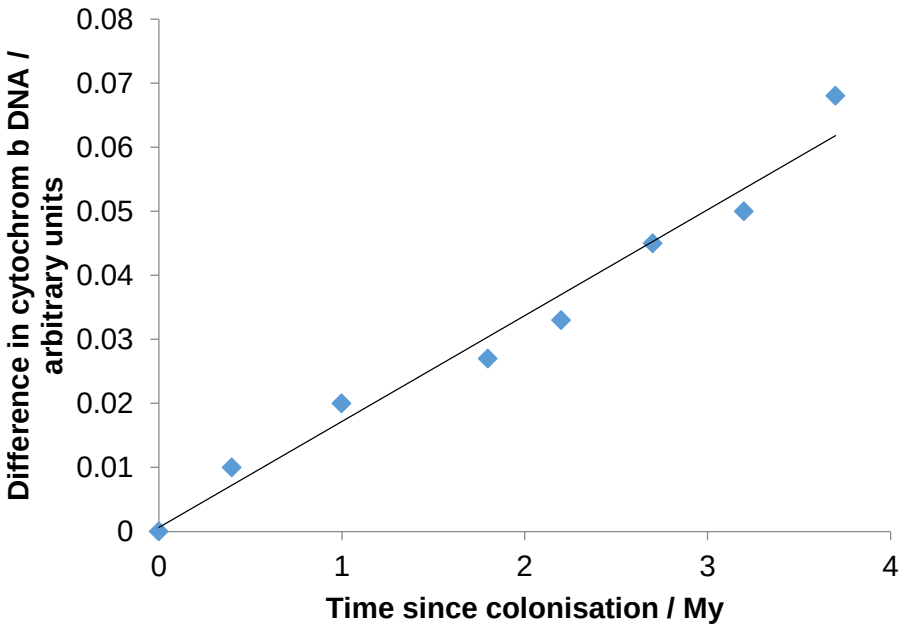


Fig. 8.2

(c) Describe how these changes in DNA sequence of cytochrome *b* supports the neutral theory of evolution.

[3]

Using similarities in the banding of their chromosomes, it is possible to construct a phylogenetic tree for the evolution of these *Anolis* lizards.

Fig. 8.3 shows the phylogenetic tree for eight species of the *Anolis* lizards.

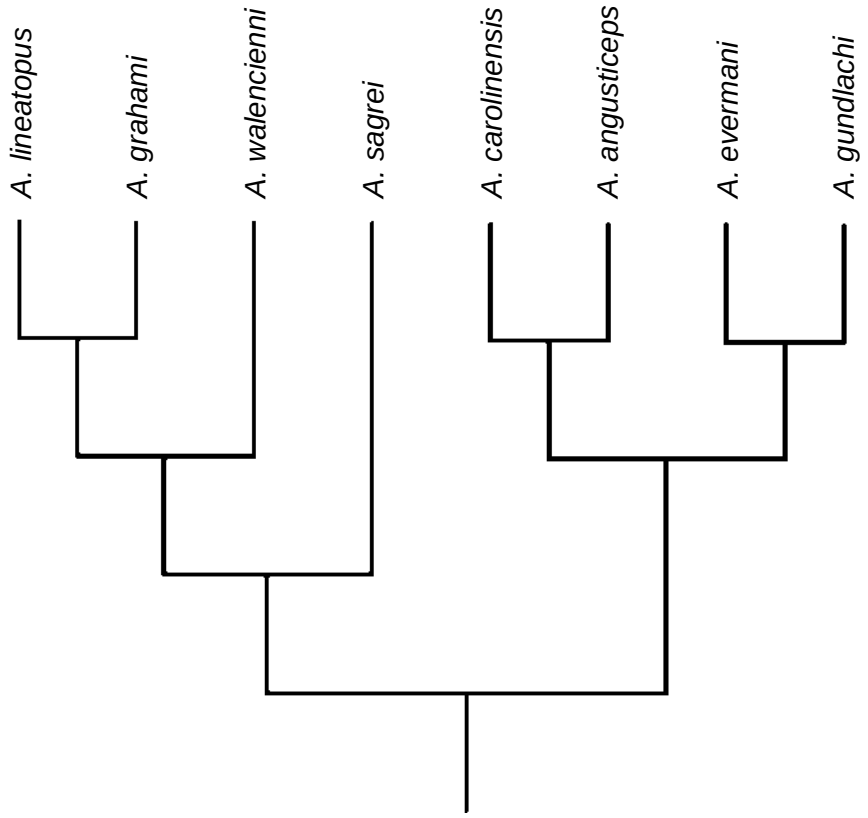


Fig. 8.3

(d) Explain the relationship between classification and phylogeny.

_____

_____

_____

_____

_____

_____[3]

[Total: 11]

Section B

Answer **one** question.

Write your answers on the separate answer paper provided.

Your answer should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

9 **(a)** Outline the three phases of the Calvin cycle. [6]

(b) Explain the need for the production of genetically identical cells and fine control of replication. [8]

(c) Describe the roles of NAD^+ in aerobic respiration. [6]

[Total: 20]

10 **(a)** Outline the process of binary fission in bacteria. [6]

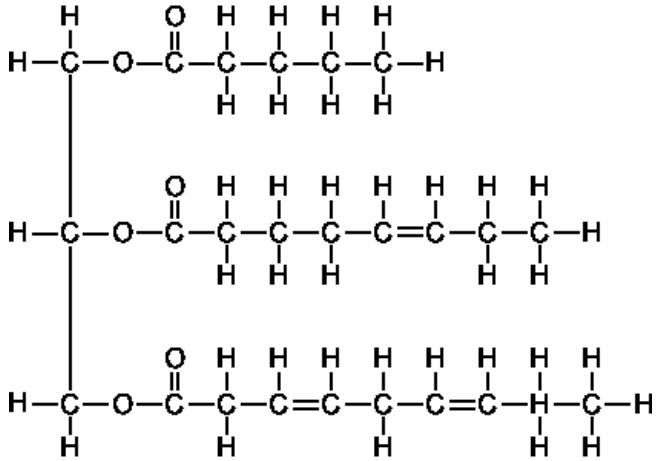
(b) Explain the effects of competitive and non-competitive inhibitors on the rate of enzyme activity. [6]

(c) Describe the causes of genetic variation in a population. [8]

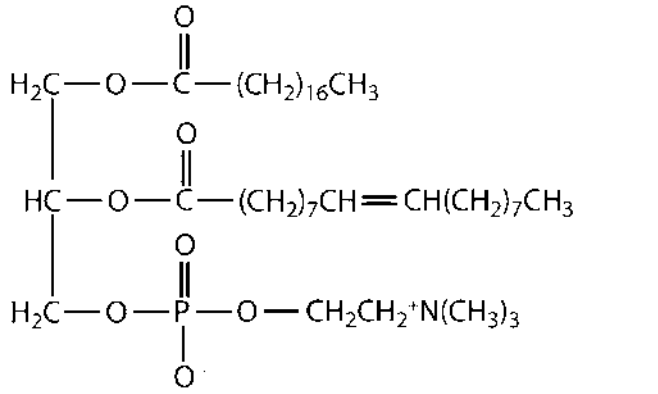
[Total: 20]

Suggested Answers with marking feedback

1 Fig. 1.1 shows the structure of two lipid molecules, **X** and **Y**.



X



Y

Fig. 1.1

(a) With reference to Fig. 1.1,

(i) describe **two** structural features which are similar between molecules **X** and **Y**.

1. Both molecule X (triglyceride) and molecule (phospholipid) contains a **glycerol molecule**.

2. Both molecules contain **at least 1 ester bond**. (Reject if student write three ester bonds as phospholipid only has 2 ester bond.)

3. Both molecules contain **at least 1 chain of hydrocarbon**. (Reject if student write three hydrocarbon chains as phospholipid only has 2 ester bond.)

4. Both molecules contain **1 chain of unsaturated hydrocarbon**.

5. Both molecules contain **carbon, oxygen and hydrogen atoms**.

Any **2**

(ii) explain how the structure of molecule **Y** is related to bilayer arrangement in cell membrane.

1. The phosphate head is polar / hydrophilic thus able to form hydrogen bonds with water molecules in the aqueous environment.

2. The fatty acid chains are long and non-polar / hydrophobic thus resulting them facing away from the aqueous environment to form the hydrophobic core.

3. Unsaturated fatty acid chains contains carbon-carbon double bonds (C=C), resulting in the formation of kinks that prevents the close packing of phospholipids.

Other than lipids, proteins are also the building blocks of life. Every cell in the human body contains protein. The basic structure of protein is a chain of amino acids.

(b) Describe how a dipeptide is formed from two amino acids.

1. The carboxyl group (-COOH) of one amino acid is linked to the amino group ($-NH_2$) of another amino acid through condensation / removal of a molecule of water.

2. A peptide bond (accept amide linkage) (-CONH-) is formed between the two amino acids.

One of the important protein molecules in the human body is collagen. Collagen is the main structural protein. It strengthens the tendons and supports the skin and internal organs. Bones and teeth are made by adding mineral crystals to collagen. Collagen is made up of many tropocollagen subunits. Each tropocollagen subunit is composed of three polypeptide chains, wound together in a tight triple helix. Fig. 1.2 shows only a segment of the collagen.

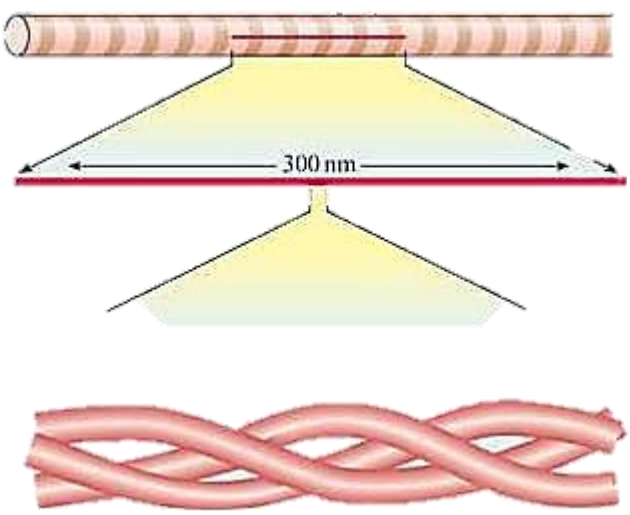


Fig. 1.2

(d) Explain why collagen is described as a fibrous protein.

1. Each polypeptide chain comprises of a primary structure of <u>regular repetitive sequences of proline-hydroxylproline-glycine</u>.

2. Each polypeptide chain has a <u>predominantly secondary helical structure</u>.

3. Three polypeptide chains wound around each other to form <u>a triple helix</u> / tropocollagen.

4. This allows the tropcollagen to form long fibres which may run parallel to one another, linked by <u>cross-bridges</u>.

5. Tropocollagen <u>is insoluble</u> in water because there are no free polar groups to form hydrogen bonds with water molecules OR all the –NH groups on glycine residue and all the –CO groups of proline resides are involved in hydrogen bonding to stabilise the triple helix OR proline and glycine have non-polar R groups that unable to interact with water molecules.

Cellulose is an important structural component of the primary cell wall of green plants while collagen is the main structural protein in the extracellular space in the various connective tissues in animal bodies.

(d) Describe **two** structural differences between collagen and cellulose.

Cellulose	Collagen
Cellulose is a polymeric unit made up of **glucose**.	Collagen is a polymeric unit made up of **amino acids.**
Compose of **one repeat unit** of glucose. (only β-glucose)	Compose of **three repeat units** of amino acids (Gly-Pro-X).
Monomers of cellulose (glucose) are linked via **glycosidic bonds**.	Monomers of collagen (amino acids) are linked via **peptide bonds**.
Cellulose fiber is made up of **a single straight and unbranched chain** of glucose polymer.	Collagen fiber is a composed of **three helical polypeptide chain** twisted together to form a triple helix.
H-bonding maintains the bundles of fiber of cellulose. H bonding is between **OH groups** of the beta glucose.	H-bonding maintains the bundles of fiber of collagen. H bonding is between **C=O and H-N** groups of the amino acids.
Comparing it with the bundle of fibres in cellulose, there are **no covalent cross-links** between the fibres.	Within the tropocollagen, some **covalent bonds** are present to maintain the triple helix structure.

Accept any other valid answers such as rotation of beta-glucose and no rotation of amino acids.

Any two rows; students' answer must be point-to-point comparison to be awarded credit.

[Total: 11]

2 DNA is found mostly in the cell nucleus, but another type of nucleic acid, RNA, is common in the cytoplasm. Watson and Crick proposed that RNA must copy the *template* found in the nucleus and carry it out to the cytoplasm, where proteins are synthesized. Crick also predicted the existence of an "adaptor" molecule that reads the genetic code and selects the appropriate amino acids to add to a growing polypeptide chain. This proposed flow of genetic information is known as the "Central Dogma."

As it turned out, several types of RNA are involved in the utilization of genetic information. In the nucleus, the code is "transcribed," or copied, into a messenger RNA (mRNA) molecule. In the cytoplasm, the mRNA code is "translated" into amino acids. Translation is orchestrated at the ribosome, itself partly composed of RNA, with transfer RNA playing the role of adaptor.

RNA is an intermediary between DNA and protein. (n.d.). Retrieved July 03, 2016, from http://www.dnaftb.org/21

(a) Describe the function**s** of the nuclear envelope that encloses the nucleus. [2]

(1) To **separate nucleoplasm from cytoplasm/ compartmentalisation/ served as a barrier** to provide a **localised and optimum environment** in the nucleus for processes such as transcription that occur in the nucleus

A: creates an **enclosed environment**; contained within the nucleus **to prevent DNases/endonucleases/exonucleases** from breaking down the DNA.

R: suitable environment for cellular activity/ compartmentalisation of the nucleolus/ work more efficiently **without stating** optimum/localised environment; the simple stating down of preventing DNA from being degraded/digested **without stating** that it is the action of relevant enzymes and etc

(2) To **regulate/control movement of materials** between **nucleus and cytoplasm** into the cytoplasm or ribosomal subunits and nucleotides into the nucleoplasm, e.g. movement of mRNA

A: have pores to allow the movement of / allows **only certain molecules** to pass through such as mRNA or small molecules into the cytoplasm for translation (taught in DNA and Genomics)

R: allows **only small molecules (concept is certain molecules or specific molecules)** to pass through; allows only certain molecules to pass through **without the mention of nuclear pores or selectively permeable**.

R: separates the process of transcription and translation; there must be the concept that **this only occurs in eukaryotic cells. So if students did not state clearly that this occurs in eukaryotic cells only, no marks will be given**

(b) With reference to the information given above,

(i) suggest how the structure of the adaptor molecule is suitable for its role.

3' CCA end/stem that the specific **amino acid** will be binded to the other end of the tRNA is made up of **three bases known as an anticodon** that is **complementary/binds to the codons of the mRNA**

R: do not accept CCA only without the 3'/ 3' OH end

(ii) explain what is meant by the term *template*.

(1) In the synthesis of RNA molecules, the template used is **DNA/ antisense/ non-coding DNA** .

R: sense/coding strand of DNA (this strand is not used)

(2) The DNA base sequence is used to form **complementary base pair** using **free ribonucleotides/ encode for the ribonucleotide seqduence.**

(3) The template serves to ensure that the **same genetic information** is passed to **amino acid sequence** every time a gene is **transcribed and translated**.

Or:

This ensure that the **genetic code is passed down** to **mRNA/sequence of mRNA through transcription** and to the **amino acid sequence** (reject protein sequence) through **translation.**

(c) Explain why the unwinding of the DNA double helix promotes transcription.

RNA polymerase/ can bind to the **promoter region**. Or **the transcription factors** can bind to the **TATA box**.

3 Fig. 3.1 shows the course of an HIV infection. The graph shows HIV copies and CD4 counts over course of a typical HIV infection

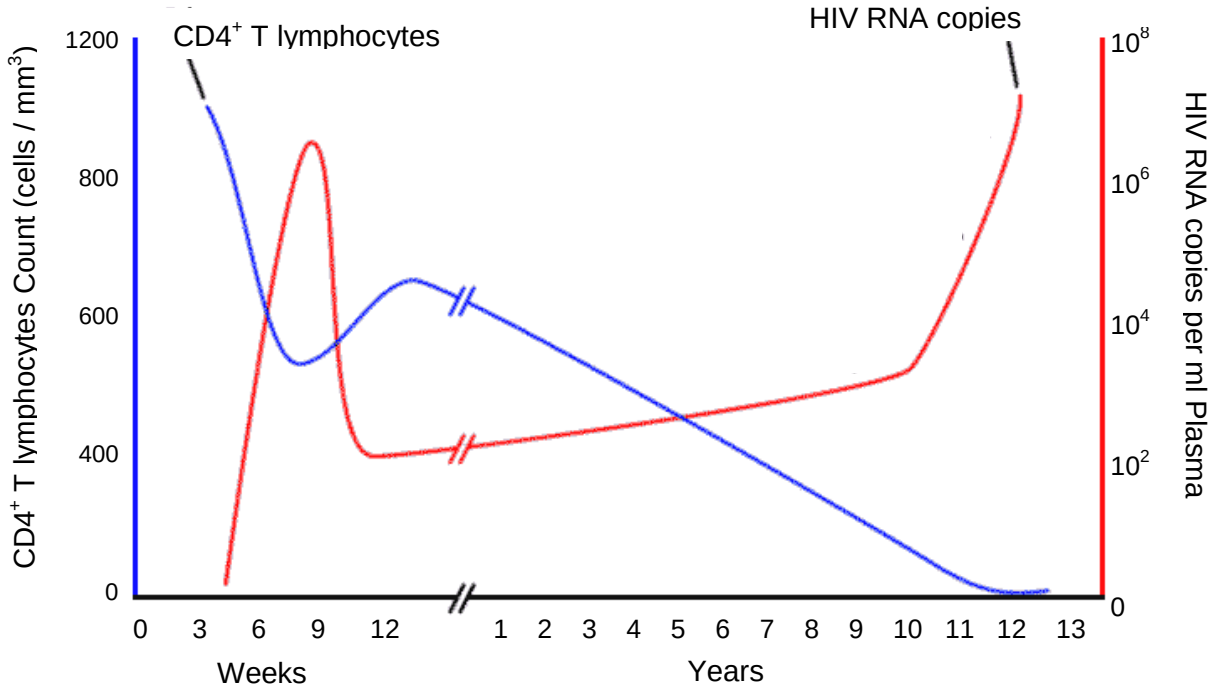


Fig. 3.1

(a) (i) Outline how the human immunodeficiency virus infects the cell.

1. Complementary binding of the virus spikes /gp 120 to specific host receptors on the $CD4^+$ T cells and HIV envelope fuses with the host cell membrane envelope

2. RNA released into cytoplasm where reverse transcriptase uses viral + sense RNA as template to synthesise a strand of cDNA and then form a double stranded viral DNA.

3. The DNA enters the nucleus and integrase catalyses the integration into the chromosome DNA to form a provirus

4. The provirus DNA is transcribed to form viral mRNA and also viral mRNA can be used as template for translation to viral proteins

5. The HIV protease cleaves the long chains of polyproteins and assembly of new HIV with the viral genome and proteins before budding out of host cells.

(ii) With reference to Fig. 3.1, explain the course of an HIV infection from week 1 to week 12.

1 From 3 to 8 weeks, HIV RNA copies increase to 10^7 copies per ml while CD4 T cells dropped to 550 cells/mm^3. This is because the virus replicating rapidly and the number of T cells in the blood decreases as the infected cells destroyed after a couple of days.

2 From 8 weeks to 12 weeks, HIV RNA copies decrease to 10^2 copies per ml while CD4 T cells increase to 620 cells/mm^3. This is because the body's natural response to an infection is to fight infected cells, Virus are killed by the immune system/antibodies and the CD4 cells lost are replaced.

(b) Fig. 3.2 shows how a defective lambda phage could be formed.

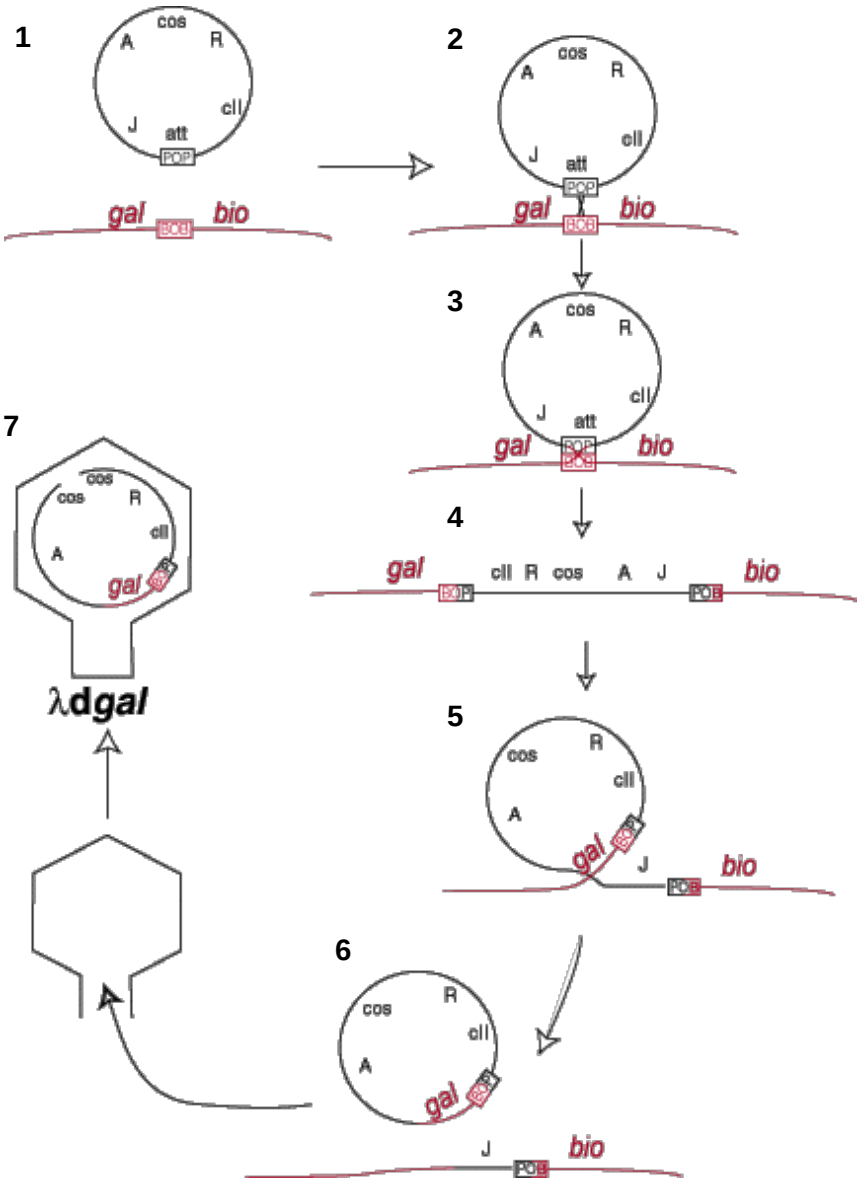


Fig. 3.2

(i) What is a lambda (λ) phage?

It is a temperate phage as it is able to go through a **lytic cycle** and destroy host cell or enter a **lysogenic stage** where the viral integrates into the bacteria's DNA as a prophage. [1]

(ii) Name **two** important requirements necessary for the DNA of lambda phage to be integrated into the host's DNA as shown in stages 2 to 4.

1 repression of all lytic functions by lambda repressor
2 requires enzymes , lambda integrase to allow integration
3 a special site /site-specific recombination) in the phage DNA and host DNA. The site is called *att* (*att*achment site)

[any 2]

(iii) With reference to Fig. 3.2, suggest and explain a possible outcome of the host DNA from this infection when the defective phage shown in stage 7 infects another host cell with *gal* $^-$ allele.

1 The gal allele from the defective phage can be incorporated into the host chromosome by **homologous recombination** due to crossover between the phage allele and chromosome allele.

2 The crossover involves **Host's gal $^-$ allele in exchange for the phage gal$^+$ allele → result in** recipient converted to gal$^+$ by specialized transduction.

[Total: 11]

4 The TATA box binding protein (TBP) attaches to a specific DNA sequence found in the regulatory region upstream of the insulin gene. TBP, along with a variety of TBP-associated factors, form the transcription initiation complex.

Fig. 4.1 shows TBP attached to DNA.

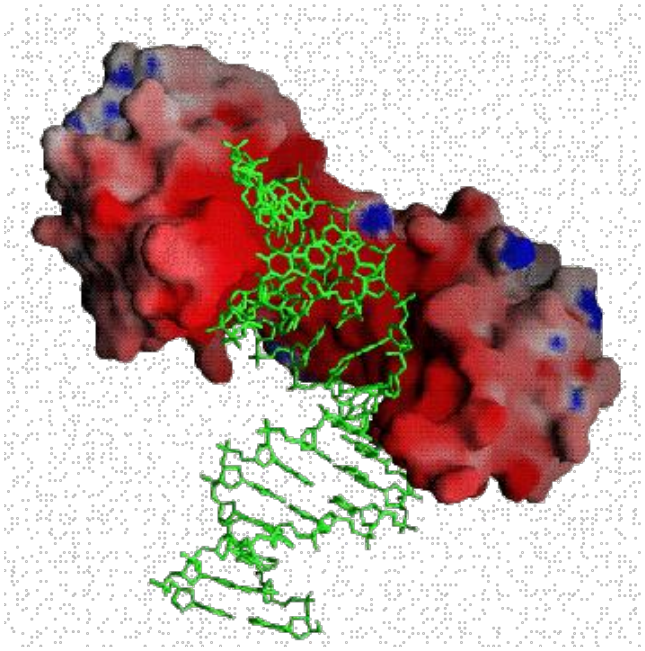


Fig. 4.1

TBP. (n.d.). Retrieved July 03, 2016, from https://ghr.nlm.nih.gov/gene/TBP

(a) With reference to the information given and Fig. 4.1,

(i) state the name of the *regulatory region.*

Promoter; **reject TATA box** (read the question, TATA box can only be PART of the regulatory region indicating that the regulatory region must be the promoter region)

(iii) suggest how TBP will bind to this *regulatory region.*

The **binding site** of the TBP is c**omplementary to the specific base sequence/ sequence**, being TATA box of the promoter region. [1]

R: active site of TBP; it is not an enzyme.

R: complementary to DNA or DNA structure, it must be complimentary to the regulatory sequence only, or else the proteins can bind to all parts of the DNA instead.

(iv) suggest how TBP initiates transcription.

When TBP binds to a TATA box, it **distorts the DNA/ place strain on the two DNA strands** and **partially unwinds** the DNA double helix.
(**best answer because this can be seen from the diagram**)

Fig. 4.2 shows how a mature insulin mRNA is synthesised via post-transcriptional modification processes.

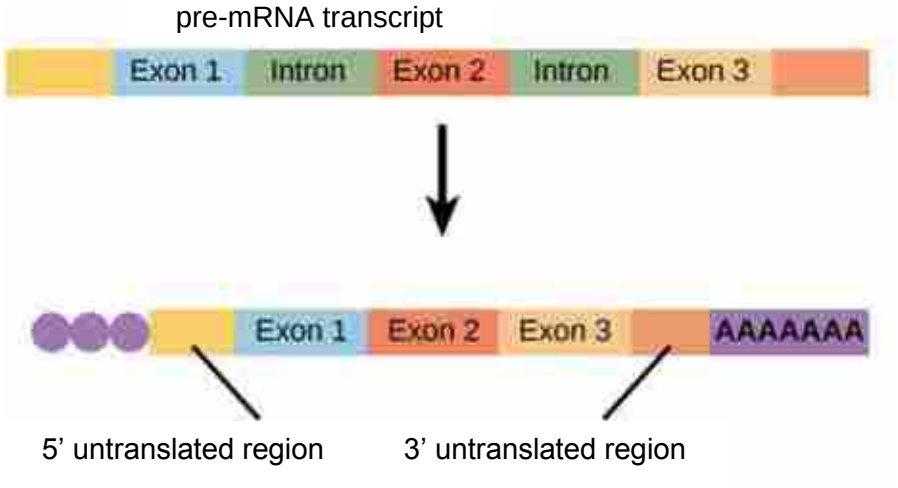


Fig. 4.2

(b) **Explain** why the post-transcriptional modifications are necessary.

RNA **splicing**	**Removal of introns sequences** and **splice of exons** together. R: removal of introns only; reject non coding regions are excised and coding regions are spliced, The specific terms are introns and exons. The word splice must be present. If RNA splicing is not specifically stated, the student must state that exons are spliced together. *Note that the picture did not show alternative splicing so any reference to more than one kind of polypeptide produced will not be awarded marks. But marks are given if the student stated that introns are excised.*
the **5' end** of the new RNA molecule is modified by addition of a **7-methyl guanosine cap** **R: 5' cap, 7-methyl guanosine cap without mention to the 5' end**	Any one of the below: **1.** It helps to **protect the growing pre-mRNA chain from degradation by ribonucleases/exonuclease/enzymes**. **2.** It facilitates the export of mature mRNA from the nucleus to the cytoplasm. **3.** It is important for **recognition of the mature mRNA by ribosomes** to initiate translation.
Polyadenylation: The **addition of a long sequence of adenine nucleotides at the 3'end** of pre-mRNA to form a **poly(A) tail.** **R: poly A tail without mention to the 3' end**	***R: The poly(A) tail confers stability on mRNAs without any reason stated.*** Any one of the below: **1.** The poly(A) tail confers stability on many mRNAs, **increasing the time** during which the **mRNA remains intact and available for translation** before it is **degraded by cellular enzymes**. Or The poly(A) tail **protects mature mRNA from being degraded by RNases**. **2.** It **facilitates the export of mRNA from the nucleus** to the cytoplasm. **3.** It **facilitates the attachment of ribosomes to the mature mRNA**.

(c)

The mature insulin mRNA is translated to form a preproinsulin which is an inactive precursor. Describe one specific post-translational modification that converts it to its active form. [2]

Covalent modification such **cleavage of a polypeptide chain** in insulin [1], **polypeptide C is cleaved** and **chain A is connected to chain B** [1]

Or

Covalent modification such as **the formation of covalent bonds** in the polypeptide [1]
The formation of **two disulfide bonds** between **chain A and B** [1]

[Total: 8]

5 A transcription factor is a protein that promotes transcription at a particular locus. The gene *Ets 2* codes for a transcription factor, and is located on human chromosome 21. The gene is expressed in cartilage and bone tissues during development. In mice, *Ets 2* is located in chromosome 16 and mice with trisomy 16 show similar skeletal abnormalities to humans with Down's syndrome.

(a) (i) Explain the genetic basis of Down's syndrome in humans.

1 Presence of an extra copy of chromosome of 21/ 2n +1;

2 Due to translocation fragment 21 on to another chromosome/non-disjunction during meiosis;

(ii) Explain how a trisomy, such as trisomy 16 in mice, can occur in a zygote.

1 homologous chromosomes fail to separate at anaphase 1 /meiosis 1;

2 in oogenesis/formation of gametes in the mother where gamete has both homologous pair of chromosomes;

3 third chromosome added(from sperm) at fertilisation;

In order to investigate the possible role of *Ets 2* in Down's syndrome, transgenic mice have been produced which carry an extra copy of mouse *Ets 2*. These mice show similar skeletal abnormalities to mice with trisomy 16. Tissues from the transgenic mice produced up to 1.8 times more *Ets 2* messenger RNA than control mice.

(iii) Suggest why these transgenic mice and mice with trisomy 16 show similar abnormalities.

1 both have, three/an extra copy of Ets 2;
2 both produce more Ets 2 messenger RNA than normal;
3 both have more transcription factor than normal

Max 2

Besides chromosomal mutations, gene mutations also occur in humans. Haemophilia A is characterized by deficiency in coagulation factor VIII, which results in prolonged oozing after injuries, tooth extractions, or surgery and renewed bleeding after initial bleeding has stopped. *F8* gene codes for the coagulation factor VIII.

In severe haemophilia A, spontaneous joint bleeding is the most frequent symptom. Serious complications can result from bleeding into the joints, muscles, brain, or other internal organs. Severity of symptoms can vary.

(b) Explain how substitution of bases in the *F8* gene could cause different levels of severity of symptoms in Haemophilia A.

1 Mutations involving substitutions of nucleotides in the F8 gene lead to change in amino acid sequences, change in R groups, change in bonds formed and change in 3-D conformation and then the production of an abnormal/non-functional coagulation factor VIII

2 Depends where the mutation is. If altered protein effectiveness in the blood clotting process reduce but do not eliminate the activity of these proteins, which usually causes mild or moderate haemophilia.

3 Some mutations at essential sites → almost completely eliminate the activity of coagulation factor VIII i.e. the protein does not work at all → , resulting in severe haemophilia.

[Total: 10]

6 In summer squash, there are two pairs of alleles that determine fruit colour. The two genes are known to assort and segregate independently.

Two white-fruited plants are crossed. Both parents are known to be heterozygous for both genes. The cross produces the following offspring: 20 green-fruited plants, 58 yellow-fruited plants, and 218 white-fruited plants.

(a) State the name for this type of interaction between the two genes.

Epistasis (Accept: dominant epistasis; Reject: Recessive epistasis) [1]

(b) Using the symbols D, d and E, e to draw a genetic diagram to explain the results given in the above information.

Parental phenotype	White-fruited plant	X	White-fruited plant
Parental genotype	DdEe	X	DdEe
Gametes	(DE) (dE) (De) (de)		(DE) (dE) (De) (de)

Gametes must be circled.

Punnet Square (with associated genotype)

	(DE)	(dE)	(De)	(de)
(DE)	DDEE White	DdEE White	DDEe White	DdEe White
(dE)	DdEE White	ddEE Yellow	DdEe White	ddEe Yellow
(De)	DDEe White	DdEe White	DDee White	Ddee White
(de)	DdEe White	ddEe Yellow	Ddee White	ddee Green

Phenotypic ratio	White-fruited plant	Yellow-fruited plant	Green-fruited plant
	12	3	1

[4]

(c) Using enzyme production as a biochemical basis for fruit colour in squash, explain how the two genes interacted to produce the various phenotypes.

i. Each gene codes for an enzyme that is involved in a **single biochemical pathway that regulates the pigmentation in fruits of the squash plant**.

ii. The dominant allele, **D**, codes for an enzyme that will suppress / inhibit the action of the second enzyme thus result in no pigmentation of the fruits despite the nature of the gene (**E/e**).

iii. The second gene (which has two alleles, **E** and **e**) codes for an enzyme that catalyse the production of either yellow pigments or green pigments that will be deposited in the fruits in the presence of recessive allele, **d**.

[OWTTE: Students are expected to write in their own words to show understanding of the concept of epistasis.]

A chi-squared test was carried out on the results of the cross.

Phenotype	Observed (*O*)	Expected (*E*)	$\frac{(O-E)^2}{E}$
green-fruited plants	20	19	0.1216
yellow-fruited plants	58	56	0.1126
white-fruited plants	218	222	0.0721
			$X^2 = 0.306$

Part of the critical values of the chi-squared distribution is shown below.

Degree of freedom	Probability								
	0.995	0.99	0.975	0.95	0.90	0.10	0.05	0.025	0.01
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345

(d) Explain how the chi-squared calculated value of 0.306 supports the hypothesis that the two genes assorted and segregated independently.

i. At **p = 0.05** and at degree of freedom 2, the **χ2 value is 0.306 is less than the critical value of 5.991** OR χ2 = 0.306 gives a **probability that is between 0.10 and 0.90 which is greater than p = 0.05**.

ii. There is **no significant difference** between the observed data and the expected numbers and any **deviations** of observed data from expected data are **due to chance**.

iii. The hypothesis that the two pairs of alleles assorted and segregated independently is **not rejected**.

[Total: 11]

7 It is important that the body's internal environment is controlled to maintain relative constancy of the internal environment despite external environmental changes. Maintaining a constant internal environment is called homeostasis. The nervous and endocrine systems both work to bring about this but their response patterns are different. Both the systems use chemical messengers to signal cells, but the speed at which these messages are transmitted is different.

(a) Outline how the body receives information from the external environment to bring about a response. [3]

A **receptor detects changes** in the internal or external environment.

The **control centre receives information** from the receptors and initiates the response to maintain homeostasis.

An **effector is any organ or tissue** that receives information from the integrating center and acts to **bring about the changes** needed to maintain homeostasis.

Fig. 7.1 is a schematic diagram of the interaction between the different systems with the external environment.

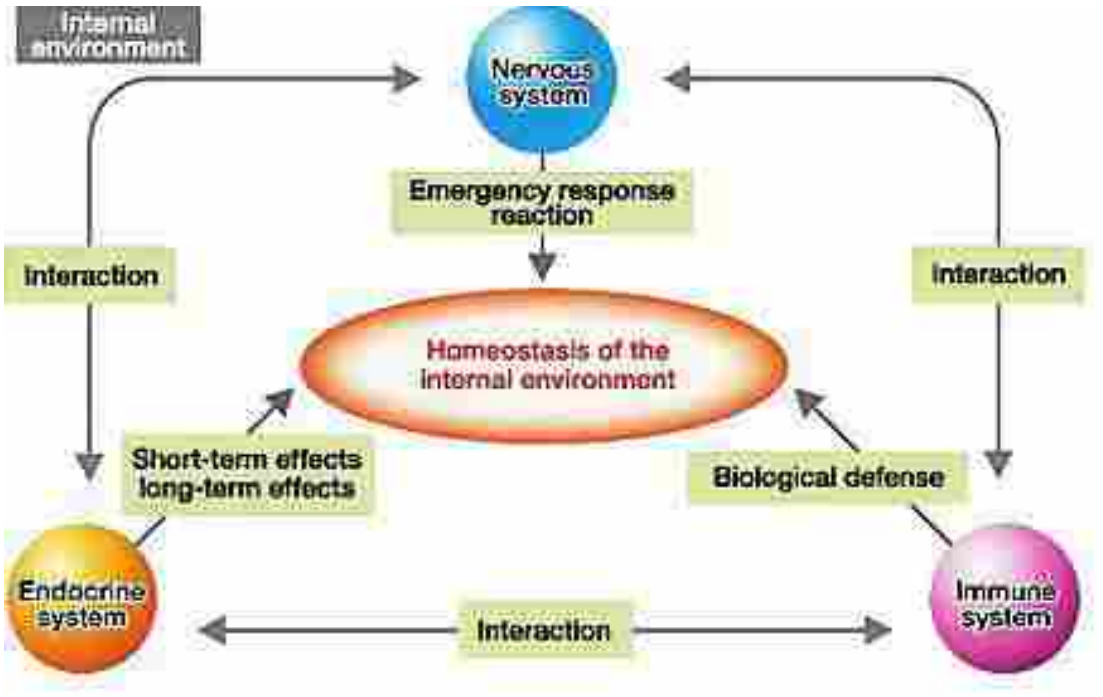


Fig. 7.1

(b) With reference to Fig. 7.1, describe the important differences between endocrine and nervous systems.

1 The nervous system responds to stimuli **quickly / almost instantaneously** by **sending electrical action potentials along neurons**, which in turn transmit these action potentials to their target cells using **neurotransmitters**/ **electrical impulses**

2 The endocrine system responds to stimuli **significantly slower**, as **hormones** must first be synthesized, **transported to their target cell**, and enter or signal the cell. / The target cell must go through the process of transcription, translation, and protein synthesis before the intended action of the hormone is seen.

3 Although hormones act more slowly than a nervous impulse, their effects are **long lasting or short term**. The nervous system breaks down the neurotransmitter rapidly, the chemical messenger of the nervous system. This response to stimuli is **are short lived**.

Fig. 7.2 showed the steps needed to transmit a signal across a junction known as a synapse between two neurones.

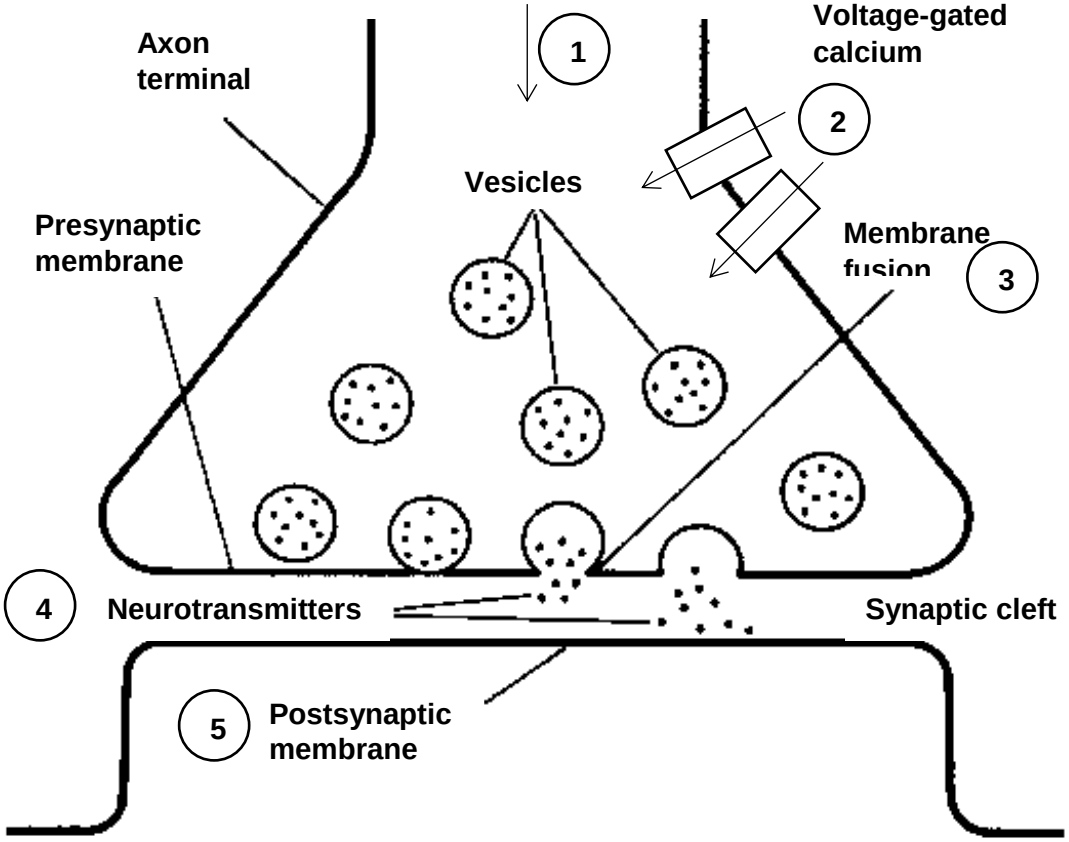


Fig. 7.2

(c) (i) Explain which steps shown in Fig. 7.2 will result in synaptic delay.

Step 3: the **release of the neurotransmitters** bounded in **vesicles** via **exocytosis/fusion** with the presynaptic cell surface membrane requires time as **movement to the CSM and the membrane fusion require time**.
Step 4: the **diffusion of the acetylcholine** through the **synaptic cleft**
Step 5: the **configuration change of receptor** after the **binding/the binding of the acetylcholine to the receptor requires time**.

(ii) Describe the roles of calcium ions in signal transmission across the synapse.

In this way, **calcium influx** during **depolarization of the membrane of the presynaptic neurone** regulates the presynaptic release of neurotransmitter substances.

This resulted in the **movement of vesicles containing acetylcholine toward the presynaptic membrane**. The vesicles then eject neurotransmitter into the synaptic cleft.

The synaptic knob releases a chemical transmitter, acetylcholine. Nerve gas prevents the breakdown of this chemical.

(d) Suggest and explain one effect of nerve gas on the transmission of nerve impulse across the synapse.

The acetylcholine **remains bounded to the receptor** for extended period of time and the **postsynaptic membrane will remain depolarised for an extended period**, prolonging the effects.

Or

The acetylcholine **cannot be broken down and recycled to the presynaptic cell** will not be able to pass any chemical signals across the synapse due to this. There will be **no action potential triggered in the postsynaptic cell /depolarisation of the postsynaptic membrane**. [1]

8 Anoles are small, colour-changing lizards that are abundant in the Caribbean Islands. Hundreds of species live on the six islands of the Caribbean. Biologist Jonathan Losos has discovered the traits that enable dozens of anole species to adapt to different vertical niches in the forest of the islands.

While differences in limb length, body shape, and toepad size allow different species to flourish on the ground, on thin branches, or high in the canopy, changes in other characters, such as their colourful dewlaps, have played a key role in reproductive isolation and the formation of new species.

Fig. 8.1 shows a picture of *Anolis grahami*, commonly called Graham's anole. This is a species originally native to the island of Jamaica. Jamaica, part of the Caribbean islands, has a lush topography of mountains, rainforests and reef-lined beaches. Graham's anole is one of eight anole species found on Jamaica.

Fig. 8.1

(a) Complete Table 8.1 to show the classification of *Anolis grahami*.

Kingdom	**Animalia**
Phylum	Chordata
Class	Reptilia
Order	Squamata
Family	Polychrotidae
Genus	***Anolis***
Species	*Anolis grahami*

[3]

Differences in the DNA sequences that encode cytochrome *b* in the eight species of Jamaican anoles have been measured.

(b) Suggest why the cytochrome *b* gene is used to measure changes in DNA sequences in closely related species.

i. Cytochrome b gene is **present in all the eight species** and thus serves as a good basis for comparison in monitoring DNA changes across the eight different species;

ii. Cytochrome b gene sequence changes very **slowly** OR most mutations in cytochrome b gene are **silent** as cytochrome b gene encodes for the cytochrome b complex that is essential for aerobic respiration. (Accept: highly conserved as it suggested that the change is slow / silent)

iii. Changes in the cytochrome b DNA are also **passed down the maternal line** via mitochondrial DNA, thus **no recombination occurs** and any difference in DNA sequence between species is solely the result of mutations.

Fig. 8.2 shows differences in cytochrome *b* DNA plotted against time since colonisation (My).

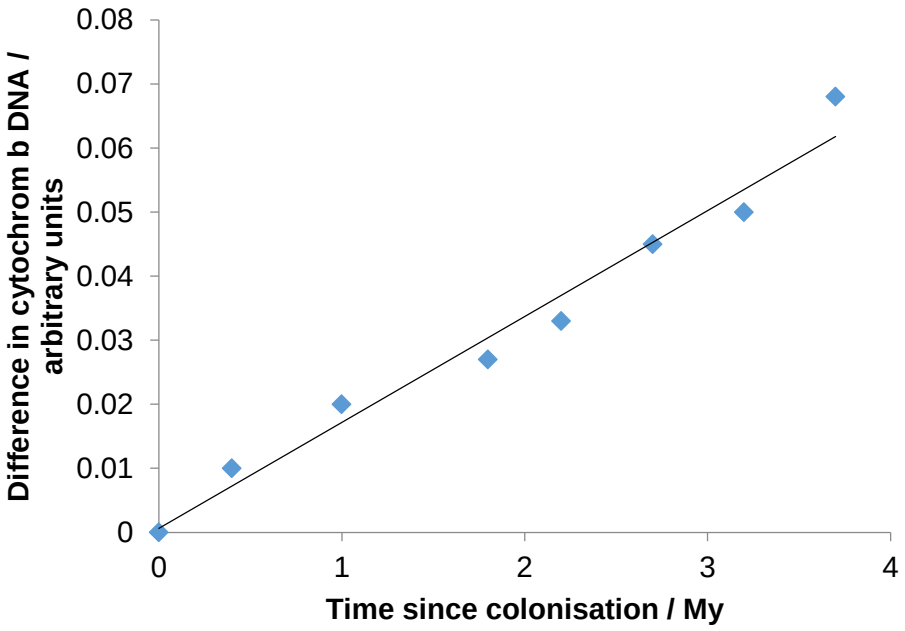


Fig. 8.2

(c) Describe how these changes in DNA sequence of cytochrome *b* supports the neutral theory of evolution.

i. Neutral theory of molecular evolution states that there is no selective advantage or disadvantage involved with changes on certain sets of DNA sequences, and there is no effect on the phenotype. (OWTTE such as does not affect Darwinian fitness / does not affect fitness)

ii. Mutations are silent; and there are a small number of changes that are not often observed in the phenotype. (Accept degeneracy of genetic code that allow mutations to be silent)

iii. The graph shown in Fig. 8.2 shows a straight line which reflects that the rate of mutation in cytochrome b gene sequences is steady / constant.

Using similarities in the banding of their chromosomes, it is possible to construct a phylogenetic tree for the evolution of these *Anolis* lizards.

Fig. 8.3 shows the phylogenetic tree for eight species of the *Anolis* lizards.

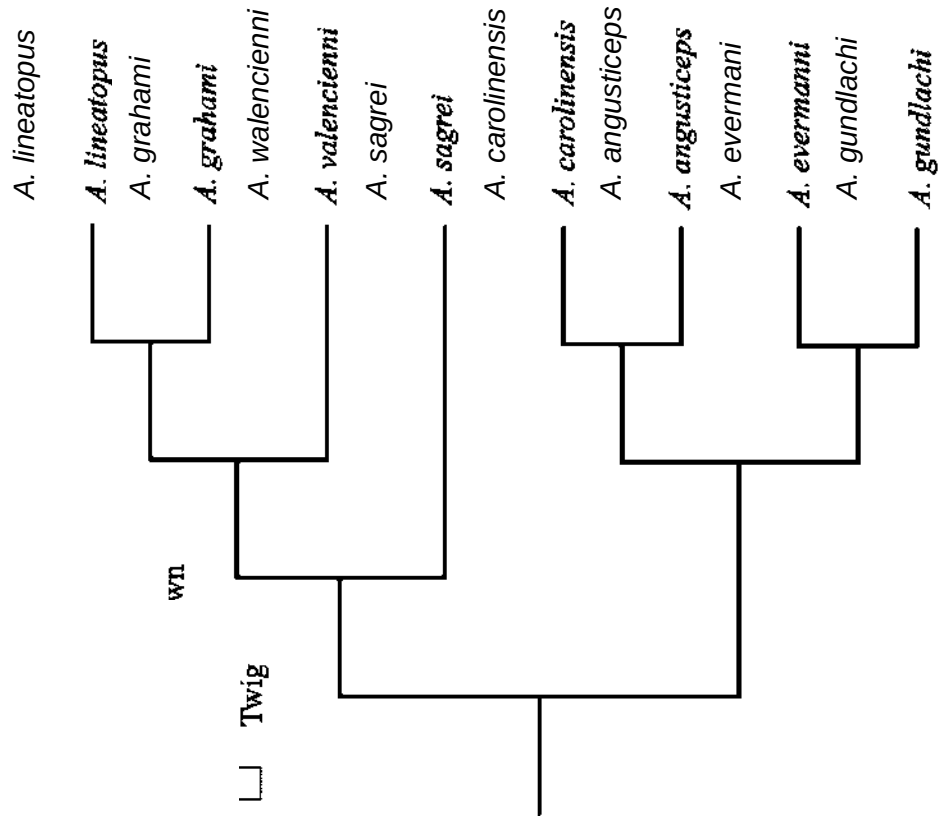


Fig. 8.3

(d) Explain the relationship between classification and phylogeny.

Classification is the organisation of species according to particular characteristics.

Classification may not take into consideration the evolutionary relationship between the species.

Phylogeny is the organisation of species according to particular characteristics which takes into consideration the evolutionary relationship between the species.

[Total : 11]

9 (a) Outline the three phases of the Calvin cycle [6]

Phase 1 (CO_2 fixation) /carboxylation

1. **Carbon dioxide acceptor is** ribulose bisphosphate **(RuBP), a five-carbon sugar.**
2. **This is process is known as** carboxylation **/ Carboxylation is catalysed by the enzyme** RuBP carboxylase (RUBISCO)**.**

3. **The intermediate six-carbon product is** unstable**/This intermediate six-carbon product will be broken down to two molecules of** glycerate 3-phosphate **(GP) / 3-phosphoglycerate, a three-carbon organic acid.**

Phase 2 (Reduction)

4. **Glycerate-3-phosphate is** phosphorylated **by** ATP **to form** 1, 3-bisphosphoglycerate**.**
5. 1, 3-bisphosphoglycerate is reduced by NADPH to form glyceraldehyde 3-phosphate (G3P) / triose phosphate (TP).

Phase 3 (Regeneration of CO_2 acceptor RuBP)

6. Glyceraldehyde 3-phosphate **(G3P) / triose phosphate has to be used to regenerate the RuBP.**
7. ATPs **are used to form glucose. Therefore, more ATPs are used in total compared to NADPH in Calvin cycle.**
8. **To form a** glucose molecule **(6-carbon),** two G3P **(3-carbon) are combined together.**

(b) Explain the need for the production of genetically identical cells and fine control of replication. [7]

1 To ensure **genetic stability** as cell replicates via mitosis
New daughter cells contain the **full set of chromosomes** and **identical hereditary information** as those of the parent cell.
There is no variation in genetic information and the chromosome number

2 Asexuel reproduction / vegetative propagation
Mitotic division is the means for some plant and animal to produce asexually

3 Growth
The number of cells within an organism increases by mitosis.
This is the basis of growth in multicellular organisms which originated from a single diploid zygote.

4 Cell replacement
Cells in the skin, vaginal and oesophageal lining are constantly sloughed off, dying and being replaced by new ones.
When damaged tissues are repaired, the new cells must be exact copies of the cells being replaced so as to retain normal functions of cells.

5 Regeneration
Some animals are able to regenerate whole parts of the body, such as legs in crustaceans and arms in starfish.

Max 3

1. Cell cycle can be out on hold at specific checkpoints. Allows cycle to be assayed for accuracy and can be halted if there are errors for repair or trigger apoptosis to occur.

2. Three main checkpoints (G1, G2 and M) act as control points where stop and go-ahead signals can **regulate the cell cycle. /**whereby there are sensitive mechanisms to detect internal state of the cell. Example nutritional state , DNA damage, cell size, DNA replication , chromosome attachment

3. A tumour suppressor gene called p53 gene produces a stop signal and plays key role in monitoring the integrity of DNA, producing proteins that halt cell cycle by regulating cyclin and cyclin dependent kinases interaction.

4. Mutation of the gene can cause dysregulation of the cyclin and cyclin dependent kinases interaction that interrupt the fine control of the checkpoints can lead to uncontrolled cell division.

5. This is because there is no detection of the presence of unreplicated or damaged DNA and hence lead to unrestrained proliferation of cells that could have DNA damage→ cancer cells. Hence, need for fine control of replication of DNA and cells for genetic stability and normal growth.

6. Ensured that replication occurs only when required in situations of growth , cell replacement so as to avoid wastage of resources and energy to replicate when not necessary .
And other AVP

Max 4

(c) Describe the role of NAD+ in aerobic respiration. [7]

1. NAD^+ is **a coenzyme** involved in redox reactions and functions as
2. a **mobile electron (and proton) carrier** to carry high energy electrons and H^+ from organic molecules to the electron transport chain on the cristae of mitochondria;
3. **Organic molecules are oxidized** during glycolysis, link reaction and Krebs cycle and the **electrons and H^+** from the oxidation process are **transferred to NAD^+ to form NADH;**
4. The electrons in NADH are used to **reduce the electron acceptors** of the electron transport chain, while **NADH itself gets re-oxidised**;
5. As electrons pass down the chain, the release of energy in a series of redox reactions is coupled to the **phosphorylation of ADP to form ATP**;
6. The protons released in the oxidation of NADH is used to **establish the proton gradient** necessary for ATP synthesis; (accept chemiomosis in place of proton gradient)
7. **1 NADH yields 2.5 ATP**
8. and **reoxidation of NADH** allows the **regeneration of the coenzyme NAD^+**, allowing it to pick up more protons and electrons from the Krebs cycle, link reaction and glycolysis so that these reactions can continue.

10 (a) Outline the process of binary fission in bacteria. [6]

Ref to Genetics of Bacteria Lecture Notes

1. The bacterial chromosome begins its replication at a specific point called the **origin of replication**, made up of a particular sequence of nucleotide bases.

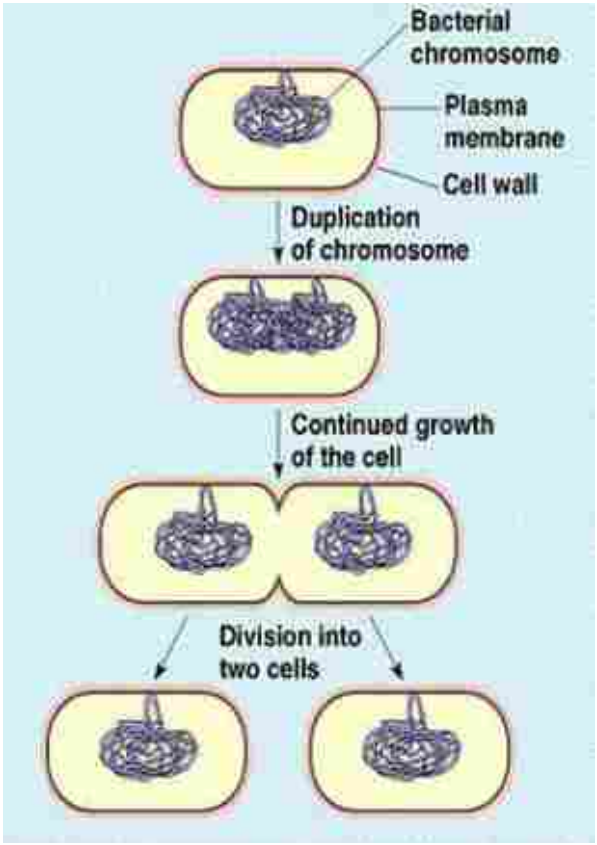
2. The double helix unwinds to form two separate strands and the overall direction of replication is outward from the origin, in both directions (i.e. **bidirectional**) resulting in an **interlocking structure** made up of 2 daughter molecules is formed.

3. **Topioisomerase** is needed to cut, separate and reseal the two DNA molecules and the duplicated DNA molecules are attached to the plasma membrane.

4. The cell **elongates** in preparation for cell division (to approximately two times its size).

5. When the cell divides, it separates the duplicated DNA and the cell membrane folds inwards (**invaginates**) to form a double layer across the long axis of the cell. (Reject: cell wall inviaginate, cell invaginate)

6. **New cell wall** layers are formed within the membrane layers and this divides the cell into two smaller identical cells that may stay together or separated (dividing cells).



(b) Explain the effects of competitive and non-competitive inhibitors on the rate of enzyme activity. [6]

Ref to Enzymes tutorial answers

Competitive inhibitor

1. It has close structural resemblance to the substrate, thus it competes with substrate molecule for active site of enzyme.

2. It binds to active site of the enzyme hence the rate of reaction/enzymatic activity is reduced as inhibitor excludes substrate molecules from binding.

3. The effect of competitive inhibitor can be reduced by increasing the substrate concentration which increases the probability of enzyme-substrate collision rather than enzyme-inhibitor collision.

4. Therefore, the rate of reaction increased and the effect of inhibitor is negligible. Rate of reaction will reach maximum velocity.

Max **3-**

Non-competitive inhibitor

1. Non-competitive inhibitor has no close structural resemblance to the substrate thus it binds to a site other than the active site.

2. Attachment of inhibitor either inhibits attachment of substrate to active site by changing the shape of the active site or prevents catalysis after substrate is bound to the enzyme.

3. Inhibition cannot be overcome by high substrate concentration; therefore probability of enzyme-substrate collision remains low.

4. Therefore, the rate of reaction decreased and will not reach maximum velocity; the effect of inhibitor cannot be reduced.

Max **3**

(c) Describe the causes of genetic variation in a population. [8]

1. **Independent assortment** and **segregation of homologous chromosomes** occurs during **metaphase I and anaphase I**, **respectively**.

2. During **metaphase I**, the **homologous chromosomes**, each consisting of one maternal and one paternal chromosome are **randomly arranged at the equator** OR the arrangement of one pair of homologous chromosomes at the equator is **independent of the other pairs of homologous chromosomes**.

3. During **anaphase I,** the chromosomes of one homologous pair will **separate independently** of the other pairs that result **in different combinations of** chromosomes in the **daughter cells** at the end of meiosis I.

4. **Crossing over of segments of non-sister chromatids in propase (I)** of homologous chromosomes at prophase I will lead to **new combinations of alleles** (REJECT: genes) on chromosomes of the gametes.

5. The 2 replicated **homologous chromosomes** form **synapsis / pair up** during prophase I of meiosis whereby they are joined at several points along their length such that **non-sister chromatids overlap and intersect**.

6. **Breakage of segments of non-sister chromatids** and **subsequent recombination of segments of non-sister chromatids** of homologous chromosomes at each chiasma allows mutual exchange of corresponding segments of alleles.
7. During **sexual reproduction**, **random fertilisation of gametes** occurs whereby a random sperm will fertilise the ovum resulting in further variation within a population.

8. **Mutations in the genes** in gametes immediately results in the **formation of new alleles** thus changes the gene pool of a population by substituting one allele for another.

Answer **all** questions.

1 A DNA library is a collection of DNA fragments that have been cloned into vectors so that researchers can identify and isolate the DNA fragments that interest them for further study. There are basically two kinds of libraries: genomic DNA and cDNA libraries.

(a) Outline how a cDNA library is produced.

_____

_____

_____

_____ [2]

(b) Explain why the cDNA library is preferred over the genomic library by the researchers.

_____

_____

_____

_____

_____

_____ [3]

The presence and absence of the restriction site generates a restriction fragment length polymorphism (RFLP). RFLP can be a useful biological tool, for example as a marker in chromosomal mapping.

(c) State **one** other ways in which RFLP can be used as a biological tool.

_____ [1]

(d) Outline how the relative positions between the particular gene and the two RFLP markers can be determined.

_____

_____

_____

_____

_____

_____ [3]

RFLP analysis is often applied to genomic DNA after digesting with restriction enzymes and separating the DNA by gel electrophoresis. Gel electrophoresis of this DNA produces a smear of DNA, rather than distinct bands.

For a smear of digested DNA, additional steps involving DNA hybridisation are needed to analyse the RFLP pattern for a particular gene.

(e) Outline the process of DNA hybridisation that allows the RFLP pattern for a particular gene to be visualised.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ [5]

[Total: 14]

2 Telomere length regulates the life span of a cell, in which the numbers of cell cycles are limited before the cell undergoes cell senescence. Thus, telomeres limit the capacity of a cell to divide. Fig. 2.1 shows the relationship between telomere length and the number of cell cycles for the different types of cells in the body.

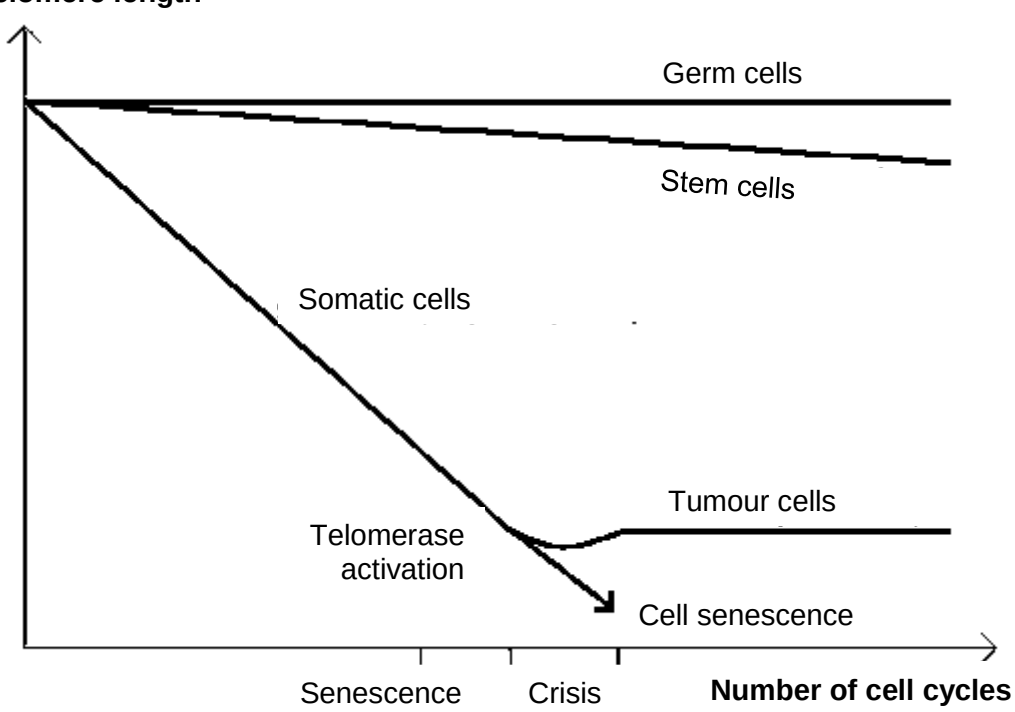


Fig. 2.1

With reference to Fig. 2.1,

(a) state one similarity in the relationship between telomere length and the number of cell cycles in stem cells and tumour cells.

_____

_____ [1]

(b) explain how the relationship between telomere length and the number of cell cycles support one of the properties of stem cells.

_____

_____

_____

_____ [2]

Cytokines bind Type I/II cytokine receptors that have a common receptor subunit called the common gamma-C chain (γc). Mutations of *γc* gene underlie X-linked severe combined immunodeficiency (X-SCID) and account for roughly half of all known cases of SCID. Fig 2.2 shows that the deficiency of γc protein blocks signalling by IL-7 and IL-15 which is required for haematopoietic stem cells to develop into natural killer (NK) cells and T cells. NK cells and T cells are lymphocytes that play critical roles in the immune system.

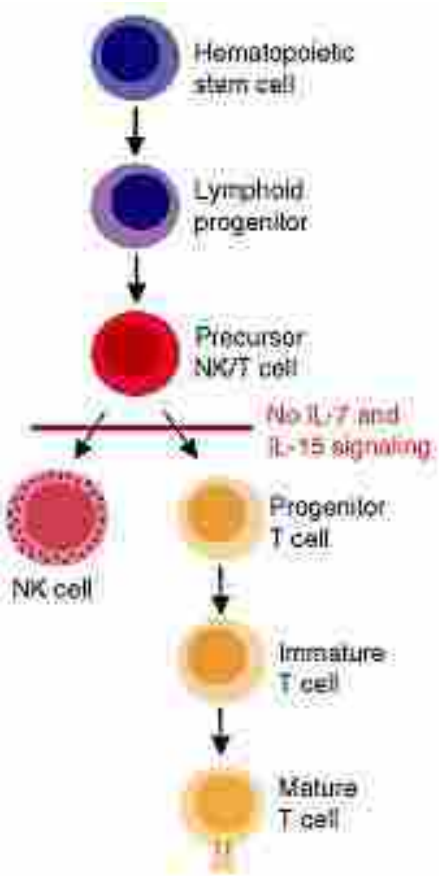


Fig. 2.2

(c) With reference to the information given and Fig. 2.2, explain why individuals with X-linked SCID have high mortality.

_____

_____

_____

_____ [2]

Gene therapy has been used to treat patients with X-linked SCID. X-linked SCID is a recessive disease. Gene therapy uses a vector to deliver a normal copy of a γc gene to the cells where it is needed.

(d) Describe **one** non-viral gene delivery system that could have been used to insert normal copy of a γc gene into stem cells.

_____

_____

_____

_____

_____

_____

_____

_____ [4]

(e) Explain why it is sufficient to insert a single normal copy of a γc gene into stem cells for gene therapy.

_____

_____

_____

_____ [2]

[Total: 11]

3 The *Aedes aegypti* mosquito is the main vector that transmits the viruses that cause dengue. Brazil is one of the first few countries to attempt to reduce the numbers of *A. aegypti* by using genetically modified (GM) male mosquitoes. This project was initiated a year after an epidemic of dengue fever that caused more than 1.5 million cases in Brazil.

The male *A. aegypti* mosquitoes are genetically engineered to contain a *t*TA gene that produces a protein called *t*TA. When they are released into the environment and mated with the female mosquitoes, the *t*TA gene is passed to the offspring, causing death. This will bring down the population numbers.

A heritable, fluorescent marker (GFP) gene was also introduced into the engineered mosquitoes to distinguish them from native pest insects and to help scientists with the management of pest control programmes.

(a) Explain why, in many examples of gene technology, fluorescent markers are used in preference to antibiotic resistance genes.

_____

_____ [1]

Fig. 3.1 shows the transgene that has been added to the GM mosquito.

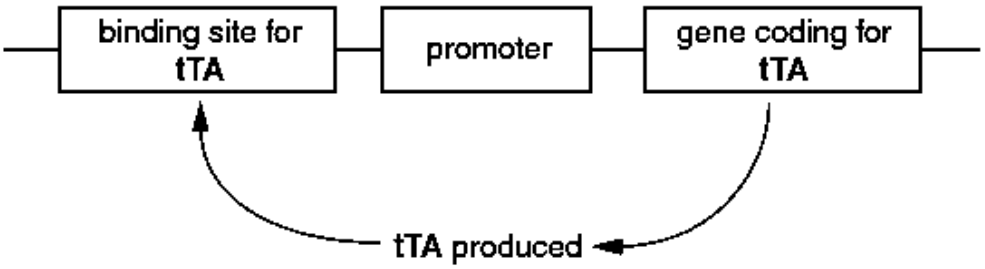


Fig. 3.1

(b) With reference to Fig. 3.1, explain why a promoter needs to be transferred along with the tTA gene.

_____

_____

_____

_____ [2]

In addition to GM mosquitoes, there are experiments using mosquitoes infected with a bacterium, *Wolbachia that* seems to prevent them from spreading diseases.

The National Environmental Agency (NEA) of Singapore is conducting studies on the feasibility of using bacteria, *Wolbachia*. The bacterium is found naturally and used in the laboratory to infect male *A. aegypti* mosquitoes.

Wolbachia-infected male *A. aegypti* mosquitoes are released to mate with the females and their eggs do not hatch. This helps to suppress the Aedes mosquito population in Singapore.

(c) Describe reasons why some members of the public will prefer to use mosquitoes infected *Wolbachia,* instead of using genetically modified mosquitoes to decrease the population of Aedes mosquito.

_____

_____

_____

_____ [2]

(d) The two methods of controlling mosquito population have some disadvantages. Suggest one disadvantage.

_____

_____

_____

_____ [2]

Genetic engineering can also be used to make transgenic plants that increase the yield of cash crops. In 1907, scientists found that a common plant tumour was caused by the invasion of a bacterium called *Agrobacterium tumefaciens*. They discovered that the tumour was caused when plasmids from the bacteria were taken into the DNA of the host plant's cells and expressed. By 1983, biotechnologists were able to introduce genes into plant cells using modified plasmids that do not result in tumour formation. Fig. 3.2 shows the procedure of transforming *Brassica* using this method.

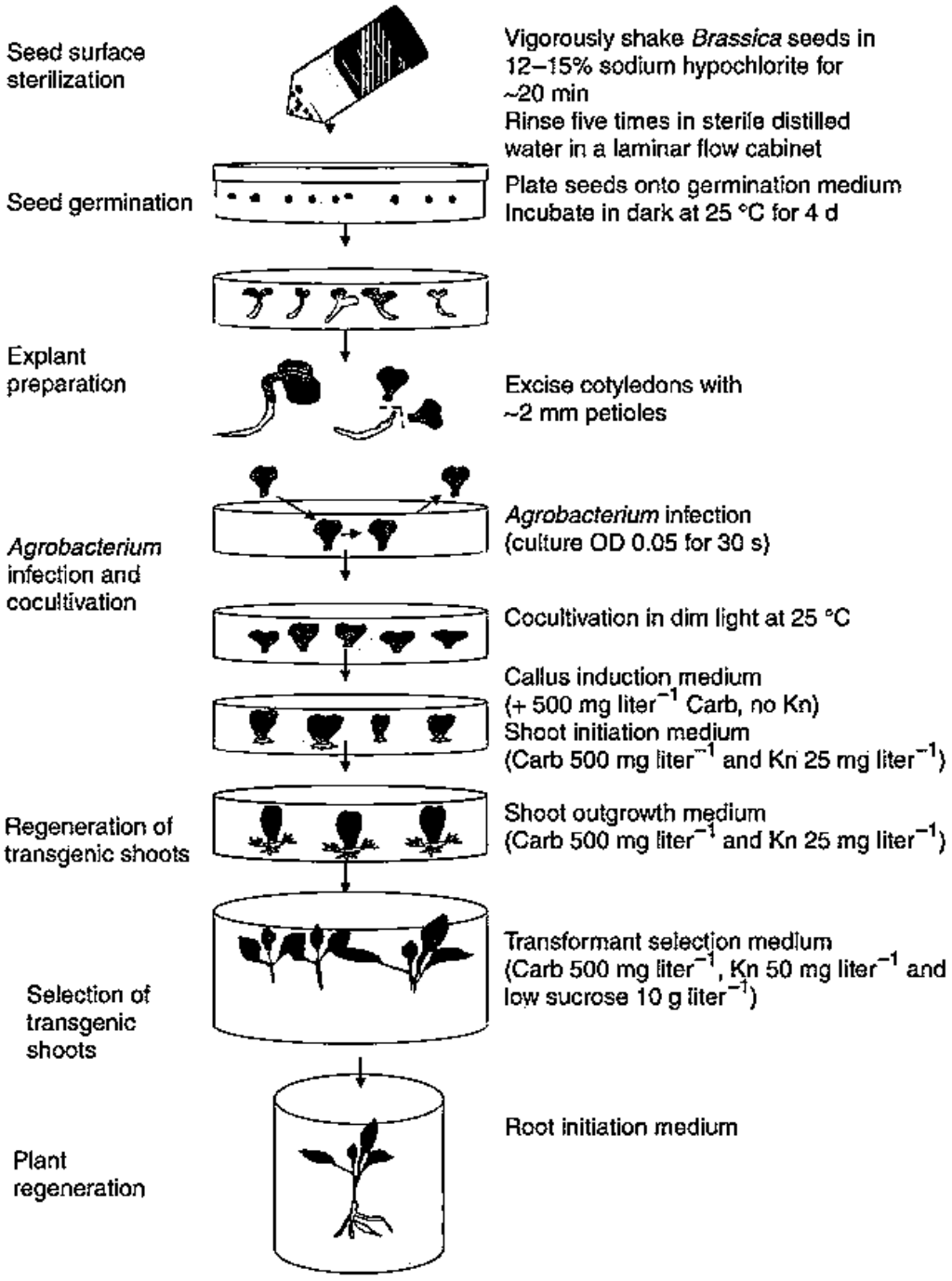


Fig. 3.2

(e) With reference to Fig. 3.2, explain why carbenicillin and kanamycin were added in the various media.

_____

_____

_____

_____

_____

_____ [3]

(f) Explain why plant tissue culture technique is used to regenerate the transformed plants.

_____

_____

_____

_____ [2]

(g) State the difference in composition between the root initiation medium and the shoot outgrowth medium.

_____

_____ [1]

(h) Explain the significance of genetic engineering in improving the quality and yield of crop plants and animals using **named examples**.

_____

_____

_____

_____ [2]

[Total: 15]

4 Planning Question

Enzymes such as catalase are protein molecules which are found in living cells. They are used to speed up specific reactions in the cells. They are all very specific as each enzyme just performs one particular reaction.

Catalase is an enzyme found in food such as potato and liver. It is used for removing hydrogen peroxide (H_2O_2) from the cells. Hydrogen Peroxide is the poisonous by-product of metabolism. Catalase speeds up the decomposition of Hydrogen Peroxide into water and oxygen.

Your planning is to investigate how the concentration of the enzyme affects the rate of reaction of the enzyme catalase on the decomposition of hydrogen peroxide. Rate of oxygen can be measured using a gas pressure sensor that is connected to an interface that translates sensor data. It is possible to measure the pressure of oxygen gas formed as H_2O_2 is destroyed. At the start of the reaction, there is no product, and the pressure is the same as the atmospheric pressure, being 101kPa.

Your planning must be based on the assumption that you have been provided with the following apparatus and materials, as well as other appropriate apparatus and equipment found in the school laboratory.

- 1 potato
- 1 electric blender
- cheese cloth
- Filter funnel
- 3% hydrogen peroxide
- pH Buffers
- Glass rods
- Knife
- Test tubes
- Stopwatch
- Access to water bath
- Gas Pressure sensor
- Interface and software
- Tubings with valves
- Other measuring instruments (measuring cylinder, syringes, etc.) and apparatus (beakers, test-tube, etc.)

Your plan should have a clear and helpful structure to include:

- Have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it, including scientific reasoning behind procedure.
- Be illustrated by relevant diagram(s) to show, for example, the arrangement of apparatus used.
- Include the layout of result tables and graphs with clear headings and labels.
- Include full details and explanations of the procedures that you would adopt to ensure that the results obtained were as quantitative, precise and reliable as possible.
- Include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

5 Free response question

Write your answers to this question on the separate answer paper provided.

Your answers:
- should be illustrated by large, clearly labelled diagrams, where appropriate,
- must be in continuous prose, where appropriate,
- must be set in sections **(a)**, **(b)** etc., as indicated in the question.

(a) Explain the problems associated with the expression of eukaryotic genes in prokaryotes and how these problems are overcome. [6]

(b) Explain the steps in gel electrophoresis. [7]

(c) Discuss the goals and benefits of the Human Genome Project. [7]

[Total: 20]

Marking Scheme

1 A DNA library is a collection of DNA fragments that have been cloned into vectors so that researchers can identify and isolate the DNA fragments that interest them for further study. There are basically two kinds of libraries: genomic DNA and cDNA libraries.

(a) Outline how a cDNA library is produced.[2]

Reverse transcriptase uses the mRNA isolated from a specific tissue as a template to reverse transcribe to form a single-stranded cDNA copy;

RNaseH is added to partially digest the mRNA strand and DNA polymerase is used to initiate synthesis of a complementary cDNA strand;

Terminal transferase adds linkers to the resultant double-stranded cDNA to allow the cDNAs are inserted into plasmids.

Recombinant plasmids are then introduced into competent bacterial host cells to be stored to form the library;

(b) Explain why the cDNA library is preferred over the genomic library by the researchers. [3]

The cDNA library is smaller OR more compact as it only contains only the coding sections of DNA OR exons;

Introns removed OR no junk DNA present (Reject: non-coding genes absent) thus it is easier to find desired gene

Genes present in clones are those that are being expressed OR reflects proteins actually represented in the cells;

AVP;

The presence and absence of the restriction site generates a restriction fragment length polymorphism (RFLP). RFLP can be a useful biological tool, for example as a marker in chromosomal mapping.

(c) State **one** other ways in which RFLP can be used as a biological tool.[1]

Disease detection OR DNA fingerprinting

A: paternity testing / family tracing as these are subcategories for DNA fingerprinting
R: forensics (vague)

(d) Outline how the relative positions between the particular gene and the two RFLP markers can be determined.[3]

The order and the relative distances between the RFLP markers and the disease gene on a linkage map are based on recombination frequencies obtained.

The recombination frequency is a measure of genetic distance between two loci on a DNA molecule / OWTTE

The closeness of the RFLP marker A, B and the disease gene can be measured by:

- The frequency at which two RFLP markers (A and B) are inherited together OR
- The frequency at which the disease gene and RFLP marker A are inherited together OR
- The frequency at which the disease gene and RFLP marker B are inherited together

RFLP analysis is often applied to genomic DNA after digesting with restriction enzymes and separating the DNA by gel electrophoresis. Gel electrophoresis of this DNA produces a smear of DNA, rather than distinct bands.

For a smear of digested DNA, additional steps involving DNA hybridisation are needed to analyse the RFLP pattern for a particular gene.

(e) Outline the process of DNA hybridisation that allows the RFLP pattern for a particular gene to be visualised.[5]

The double helix structure of the DNA is drawn from the gel onto a nitrocellulose membrane by a blotting process.

The double stranded DNA on the nitrocellulose membrane is then split by the addition of an alkali, e.g. NaOH.

Radioactively-labelled / fluorescence-labelled probes are added.

Thus the probe will bind to the complementary sequence of single-stranded DNA on the nitrocellulose membrane.

The membrane is then placed next to a photographic film and the genetic fingerprint can be seen when the film is developed. [for radioactive probe] / The membrane is then placed under a UV lamp and the genetic fingerprint can be seen. [for fluorescence probe]

[Total: 14]

2 Telomere length regulates the life span of a cell, in which the numbers of cell cycles are limited before the cell undergoes cell senescence. Thus, telomeres limit the capacity of a cell to divide. Fig. 2.1 shows the relationship between telomere length and the number of cell cycles for the different types of cells in the body.

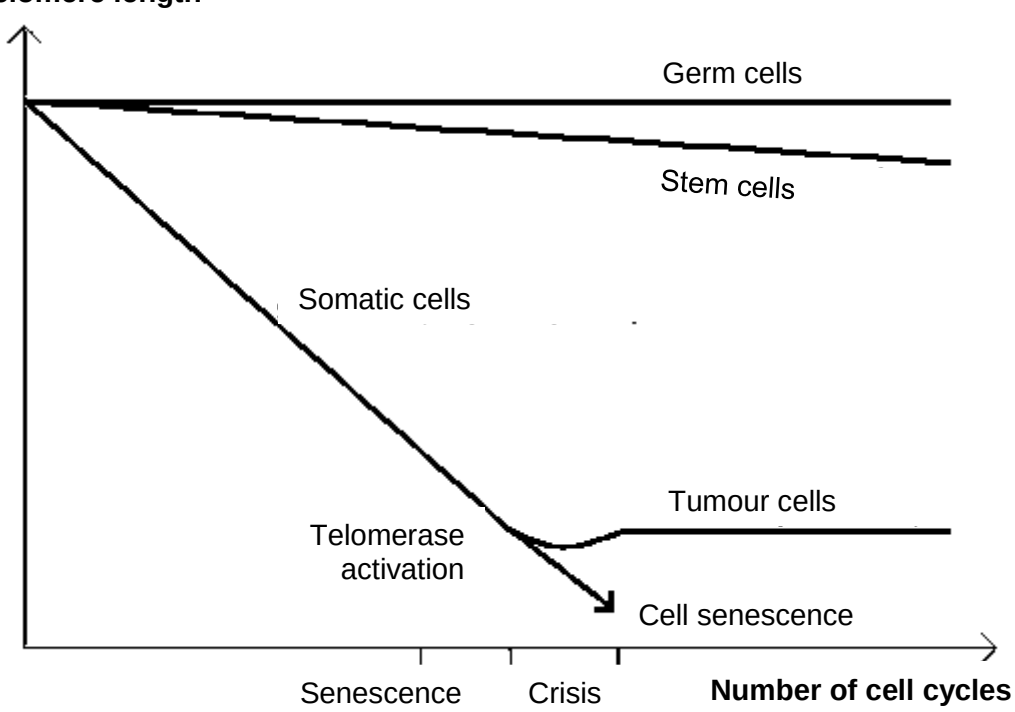


Fig. 2.1

With reference to Fig. 2.1,

(a) state one similarity in the relationship between telomere length and the number of cell cycles in stem cells and tumour cells. [1]

Both stem cells and tumour cells can divide by mitosis **many times as telomere length is longer than hayflick limit / critical length**. / OWTTE

A: higher number of cell cycles, telomere length remains constant for both types of cells.

(b) explain how the relationship between telomere length and the number of cell cycles support one of the properties of stem cells. [2]

This is because the telomere length in stem cells **decreases slowly / erodes at a relatively slower rate / is maintained at a relatively constant length** thus allowing them to replicate many times to produce more daughter stem cells.

Hence, stem cells are able to **self-renew / self-regenerate / divide continuously by mitosis** for a longer period.

Cytokines bind Type I/II cytokine receptors that have a common receptor subunit called the common gamma-C chain (γc). Mutations of *γc* gene underlie X-linked severe combined immunodeficiency (X-SCID) and account for roughly half of all known cases of SCID. Fig 2.2 shows that the deficiency of γc protein blocks signalling by IL-7 and IL-15 which is required for haematopoietic stem cells to develop into natural killer (NK) cells and T cells. NK cells and T cells are lymphocytes that play critical roles in the immune system.

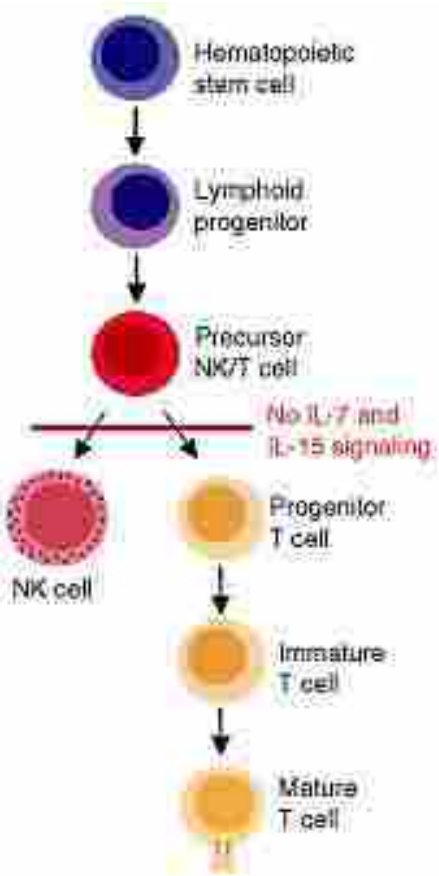


Fig. 2.2

(c) With reference to the information given and Fig. 2.2, explain why individuals with X-linked SCID have high mortality. [2]

Individuals with X-linked SCID are **unable to express gamma-C chain gene** to produce function IL-7 and IL-15 thus **signalling by IL-7 and IL-15 is blocked**.

This **prevents the differentiation of precursor NK/T cell** into functional / mature NK and/or T-cells, thus individuals have weaker immune system which makes them **susceptible to many infections that can cause death**.

Gene therapy has been used to treat patients with X-linked SCID. X-linked SCID is a recessive disease. Gene therapy uses a vector to deliver a normal copy of a γc gene to the cells where it is needed.

(d) Describe **one** non-viral gene delivery system that could have been used to insert normal copy of a γc gene into stem cells. [4]

1. Use an appropriate **restriction enzyme** to excise the **normal allele** that codes for gamma-c and to l**inearise** an appropriate bacteria plasmid. Use DNA **ligase** to form the **phosphodiester bonds between adjacent nucleotide sequences** to form the recombinant plasmid;

2. Insert the recombinant plasmid into a **liposome** that is coated with specific receptors, such that the liposome will identify and adhere to the stem cells;

3. Allow the plasmid-containing liposome to get in **contact** in-vitro with the stem cells to be treated;

4. Upon **membrane fusion** between the phospholipid bilayers of the liposome and stem cell surface membranes (**A: receptor-mediated endocytosis)**, the recombinant plasmid will be released into the nucleus for the stem cell genome to take up the normal gamma-c allele via **homologous recombination**;

A: gene gun (if student is able to elaborate)

1. Use an appropriate **restriction enzyme** to excise the **normal allele** that codes for gamma-c and to l**inearise** an appropriate bacteria plasmid. Use DNA **ligase** to form the **phosphodiester bonds between adjacent nucleotide sequences** to form the recombinant plasmid**.**

2. **Gold or tungsten spherical particles** are coated with plasmid DNA.

3. Metal particles are **accelerated to high speed by pressurised gas in the gene gun** into stem cells.

4. The recombinant plasmid will be in the nucleus for the stem cell genome to take up the normal gamma-c allele via **homologous recombination**;

(e) Explain why it is sufficient to insert a single normal copy of a γc gene into stem cells for gene therapy.[2]

The normal gamma-C allele is dominant;

Hence one copy of the dominant allele is sufficient to produce functional protein products;

[Total: 11]

3 The *Aedes aegypti* mosquito is the main vector that transmits the viruses that cause dengue. Brazil is one of the first few countries to attempt to reduce the numbers of *A. aegypti* by using genetically modified (GM) male mosquitoes. This project was initiated a year after an epidemic of dengue fever that caused more than 1.5 million cases in Brazil.

The male *A. aegypti* mosquitoes are genetically engineered to contain a *t*TA gene that produces a protein called *t*TA. When they are released into the environment and mated with the female mosquitoes, the *t*TA gene is passed to the offspring, causing death. This will bring down the population numbers.

A heritable, fluorescent marker (GFP) gene was also introduced into the engineered mosquitoes to distinguish them from native pest insects and to help scientists with the management of pest control programmes.

(a) Explain why, in many examples of gene technology, fluorescent markers are used in preference to antibiotic resistance genes.

- easier to, identify/screen for transformed cells as only U.V light is required.
- more economical/time saving/labour saving with an reasonable explanation like no need to replica plate
- resistance gene(s) can be passed to other bacteria;
- idea of antibiotics no longer effective
  OR
  requiring development of new, antibiotics/treatments; [1]

Fig. 3.1 shows the transgene that has been added to the GM mosquito.

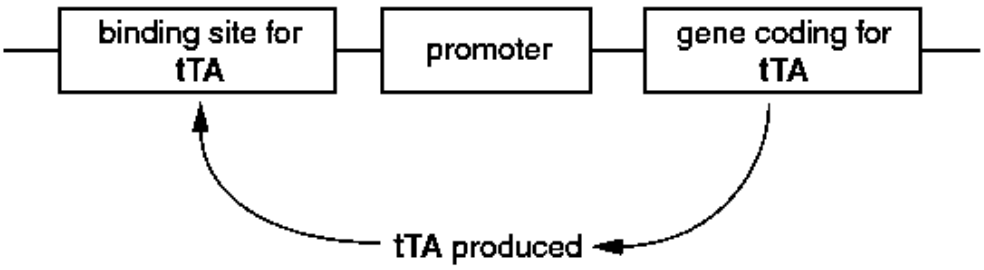


Fig. 3.1

(b) With reference to Fig. 3.1, explain why a promoter needs to be transferred along with the tTA gene.

RNA polymerase and general transcription factors bind at the promoter to initiate transcription / switch on gene expression;

If the promoter is not transferred along with the desired gene, the gene has to be inserted near an existing promoter**,** this may disrupt expression of existing gene**;**

in eukaryotes precise position of promoter is important for gene expression**;** [2]

In addition to GM mosquitoes, there are experiments using mosquitoes infected with a bacterium, *Wolbachia,* that seems to prevent them from spreading diseases.

The National Environmental Agency (NEA) of Singapore is conducting studies on the feasibility of using bacteria, *Wolbachia*. The bacterium is found naturally and used in the laboratory to infect male *A. aegypti* mosquitoes.

Wolbachia-infected male *A. aegypti* mosquitoes are released to mate with the females and their eggs do not hatch. This helps to suppress the Aedes mosquito population in Singapore.

(c) Describe reasons why some members of the public will prefer to use mosquitoes infected *Wolbachia,* instead of using genetically modified mosquitoes to decrease the population of Aedes mosquito.

Not genetically modified, thus the use of infected mosquitoes will not have the concern of foreign genes inserted into another species.

Tampering with the genome of another species is going against nature (accept alternative words)

The bacteria is found naturally, there is no worry of the introducing novel genes into the environment.

With the equipment and specialised skills required for transgenic technology, the cost of genetically modifying the mosquito may be more expensive than infecting the mosquitos with a bacteria that is found naturally. [2]

(d) The two methods of controlling mosquito population have some disadvantages. Suggest one disadvantage.

Both methods will involve the continuous/repeated release of modified males because the genetically modified or the infected males will not leave any viable offspring to reproduce; costly/dependent on the company/ lock in with company for long periods.

Both methods will involve the release of large numbers of modified mosquitoes as the chances of a female mating with a modified male must be higher for this method to work; costly.

Genetic engineering can also be used to make transgenic plants that increase the yield of cash crops. Fig. 3.2 shows the procedure of transforming *Brassica* using this method.

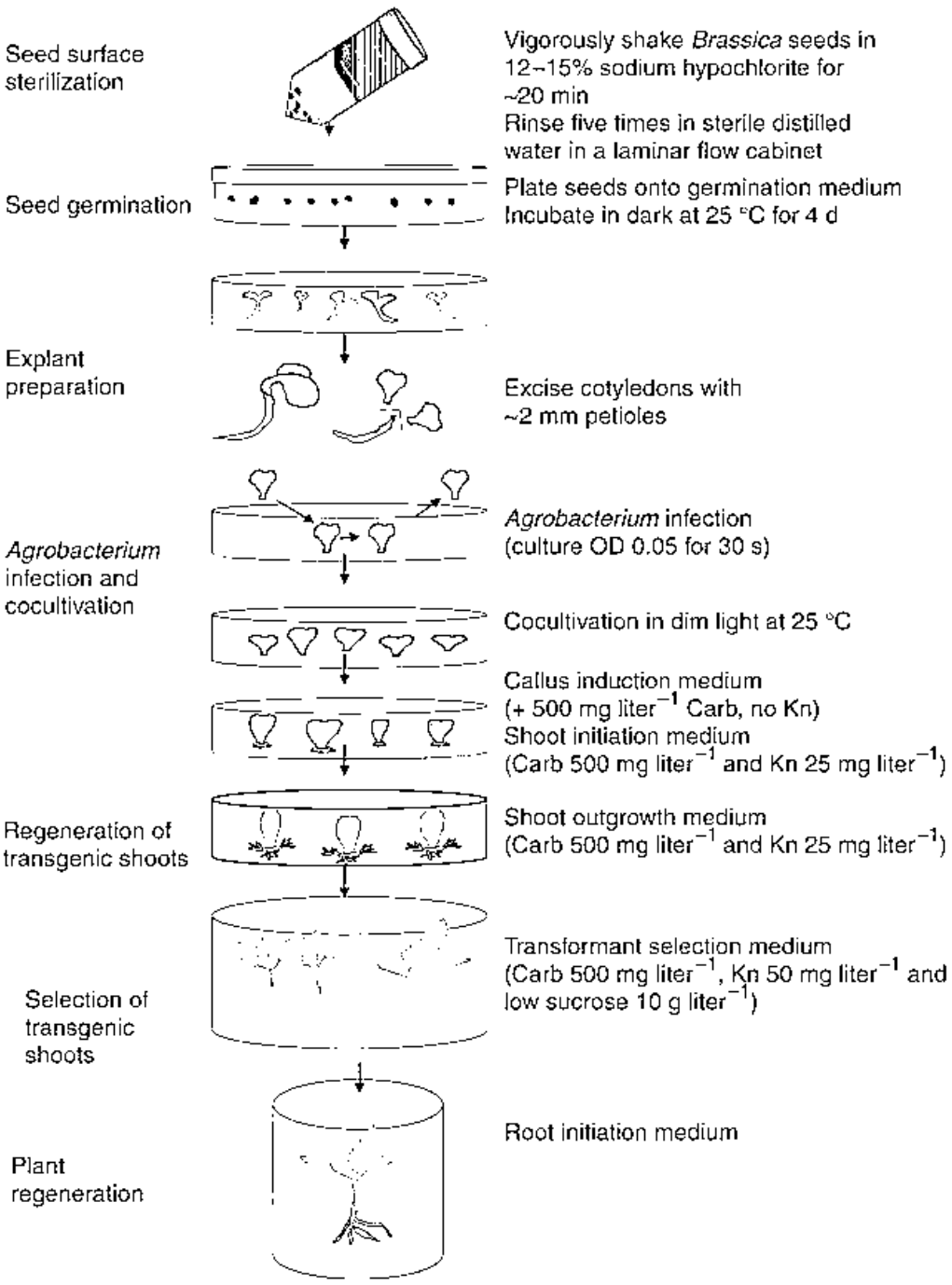


Fig. 3.2

(e) With reference to Fig. 3.2, explain why carbenicillin and kanamycin were added in the various media.

- Carbenicillin and kanamycin are antibiotics, which were added to select for the growth of transformed Brassica;
- OR
- Carbenicillin and kanamycin are antibiotics; carbenicillin is added to inhibit the growth of *A. tumefaciens* attached to the explants and kanamycin added subsequently to select for the growth of transformed Brassica;
- The genetic markers on the plasmid are therefore genes encoding for resistance to carbenicillin and kanamycin;
- Only successfully transformed cells/ plantlets will survive in culture; [3]

(f) Explain why plant tissue culture technique is used to regenerate the transformed plants.

- They have the advantage of being free from fungal or bacterial infections because the PTC is done in a sterile/pathogen free environment;
- Quick production of mature plants;
- Regeneration of whole plants from genetically modified explants;
- Many Genetically modified plants can be grown from one a few plant cells
  Amount of space required for field trials to determine which plants have desirable traits is reduced; [2]

(g) State the difference in composition between the root initiation medium and the shoot outgrowth medium.

Root initiation medium: high auxin:cytokinin whereas;
Shoot outgrowth medium: high cytokinin:auxin [1]

(h) Explain the significance of genetic engineering in improving the quality and yield of crop plants and animals using **named examples**.

Must include one example of plant and animal each to get the full mark, if both examples are of plants/animals, a max of 1 mk is given

Golden Rice can help to **alleviate vitamin A deficiency** due to the insertion of a gene that encodes for **beta carotene (precursor to Vitamin A)**. rice becomes **more nutritious (increase in quality)** → decreased malnutrition in underdeveloped countries.

Bt corn/ cotton contains **a gene from a naturally occurring soil-borne bacterium**, ***Bacillus thuringiensis*** that can kill **insect pests that feed on the plants**. This reduced reliance on chemical insecticides → in turn reducing cost, labour to employ staff to spray chemical insecticides, environmental damage (Bt toxin breaks down rapidly in the environment)/ Higher yield → due to reduced crop losses

Transgenic salmon carries a **gene that codes for the production of Chinook salmon growth hormone, thus increasing their growth greatly. Antifreeze proteins (AFPs)** function to lower the freezing temperatures of fish blood and extracellular fluids to protect fish from freezing in frigid marine waters. •
Faster growth rate means salmon farmers are able to market their fish earlier, and this means increased overall production and profits due to a faster production cycle.

Other revelant NAMED examples. [2]

[Total: 15]

Suggested answers

Background theory: max 3 marks

- In excess substrate, hydrogen peroxide, as catalase enzyme concentration increases, **more active sites are available**.-->More enzyme-substrate complexes are formed. Hence higher rate of reaction. Result in higher production of oxygen from decomposition of hydrogen peroxide.
- At high concentration of catalase , **not enough substrate molecules to occupy all the active sites** of the enzyme molecules.
- Rate of reaction limited by enzyme concentration**/** A point is reach when further increase in enzyme concentration **does not increase** the rate of reaction.--> **plateau** in rate of reaction.
- Increase in oxygen produced measured by change in pressure and can be read from a pressure sensor

Variables

Dependable variable : The change in pressure in kPa over 1 min to obtain initial rate in kPa min^{-1} / 30 s to obtain kPa s^{-1}

Independent variable : enzyme concentration in % /mol dm^{-3} (5 ranges)

Fixed variable : Volume and concentration of hydrogen peroxide. Temperature , pH , mass of potato AVP (state at least 3)

Methodology:

- **Preparation of catalase concentrations**

1. Potato peeled, cut , grind with buffer, filter with cheese cloth to obtain potato liquid containing catalase
2. Prepare 5 different concentrations of catalases solutions according to the dilution table shown below. The volume of each concentration will be the same eg 10 cm^3.

Concentration of catalase (%)	Volume of stock catalase solution (cm^3)	Volume of distilled water (cm^3)
10.0	10.0	0.0
8.0	8.0	2.0
6.0	6.0	4.0
4.0	4.0	6.0
2.0	2.0	8.0
0.0	0.0	10.0

[2]

Procedure

1. Pilot test*Conduct a pilot experiment to determine suitability of apparatus, suitability of range of independent variable (e.g. enzyme range), optimum conditions, amount of materials used (number of pieces of potatoes, volume of distilled water)
2. Place 5 test tubes in a rack and label 1, 2 etc
3. Fill each test tube with 5 cm^3 of 3.0% H_2O_2
4. Place all tubes in water bath of 38-42°C water bath for 2 min
5. Acclimatize the catalase solutions separately, in a 38-42°C water bath for 2 min.
6. After 2 min, using a clean syringe, add 0.5 cm^3 of enzyme suspension (10%) to test tube 1.
7. Mix well by stirring and connect the Gas pressure Sensor to the computer interface. Start time. Click to begin data collection.

   Allow the reaction to take place for 1 minute/ 30 s

8. Immediately after 1 minute, read the pressure of the oxygen gas formed and obtain change of pressure.

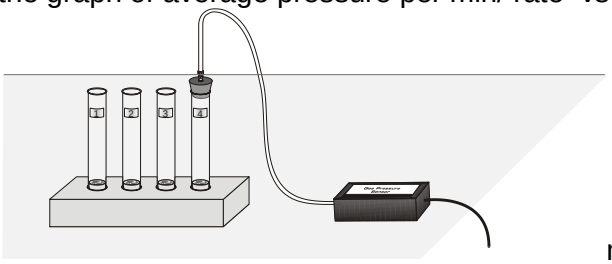
9. Collect data for test tubes 2 and 3 till 5 for the different catalase concentrations.

10. **Repeat Steps 2–10** 3 times to obtain replicates in order to obtain **average readings** and ensure no anomalies.

11. Repeat **preparation of catalase suspension and dilution** and **repeat steps 1 to 11** at least 2 times to ensure reproducibility

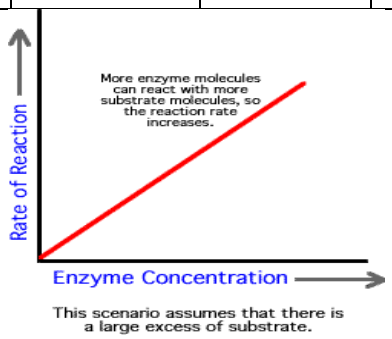
12. **Control: Replace catalase with distilled water and add hydrogen peroxide.**
Purpose: To show that any production of oxygen still due to the presence of catalase which cause decomposition of hydrogen peroxide, and hence the results obtained due to presence of catalase [1]

13. Obtain the graph of average pressure per min/ rate vs enzyme concentration



must annotate correctly

Concentration of catalase / %	Rate / kPa min^{-1}			
	Replicate 1	Replicate 2	Replicate 3	Average
10.0				
8.0				
6.0				
4.0				
2.0				
0.0				



Risk assessment [1] at least 2 correct

Risk	**Precaution**
Glassware	Breakage → clean up carefully to avoid cuts
Use of electric blender	Ensure hands dry when switching on the power to prevent electrocution
Hydrogen peroxide	Corrosive – wear goggles and gloves

5 Free response question

Write your answers to this question on the separate answer paper provided.

Your answers:
- should be illustrated by large, clearly labelled diagrams, where appropriate,
- must be in continuous prose, where appropriate,
- must be set in sections **(a)**, **(b)** etc., as indicated in the question.

(a) Explain the problems associated with the expression of eukaryotic genes in prokaryotes and how these problems are overcome. [6]

1. Prokaryotes (bacteria) lack: ability to perform post-transcriptional modifications → they lack the RNA splicing machinery, thus they are unable to remove the introns of an eukaryotic gene.

2. Also, with introns, the eukaryotic gene can be too long to be incorporated into the plasmid.

3. mRNA with introns removed are used– using reverse transcriptase → form cDNA complementary to RNA in 5' → 3' direction.

4. Then mRNA is removed and another complementary DNA is synthesised by DNA polymerase using the single stranded DNA.--> blunt ends DNA being the eukaryotic gene. Then form recombinant DNA to transform into bacteria to clone the gene when bacteria undergo binary fission.

5. Prokaryotes (bacteria) lack: ability to perform many post-translational modifications → they cannot produce a functional protein and any example add disulphide bridges to join polypeptide A and B in insulin → unable to fold into 3-D configuration that is functional;

6. form artificial gene for each polypeptide and form recombinant DNA separately. Transform into bacteria and form fusion proteins separately. Extract, purify and to allow formation of bonds in-vitro

7. Prokaryotes (bacteria) lack ability to recognise eukaryote's promoter → to express eukaryotic genes in the bacteria

8. thus, a strong lac promoter is inserted next to an eukaryotic gene so that the bacteria transcription machineries , RNA polymerase can recognise and bind;

(b) Explain the steps in gel electrophoresis [7]

Agarose gel electrophoresis Is used for **resolving or separating DNA molecules** on the basis of **different molecular lengths or masses**

1. The gel is inserted into the electrophoresis chamber, and covered with an **electrophoretic buffer** which provide ions to support conductivity.

2. A **loading buffer with a tracking / marker dye** added to the DNA samples before loading into the sample wells. This serves to allow tracking of DNA that is colourless and allows visual monitoring of how far the electrophoresis has proceed.

3. The loading buffer contains glycerol, a dense liquid which helps the DNA sample to sink to bottom of well as denser.

4. Because of its phosphate groups, DNA is **negatively charged** at physiological / neutral pH. When electric current applied across the gel, opposite charges attract, DNA molecules must travel to reach the **positive electrode (anode)**.

5. The agarose comprises of a complex network of pores act like a sieve that separates molecules by molecular size→ hence the migration distance is **inversely proportional** to the molecular size of a DNA fragment.

6. **DNA fragments (not visible in gel) are visualized by staining with ethidium bromide.** This fluorescent dye **intercalates** (penetrates) between the bases and when exposed to ultraviolet light, DNA fragments will appear as **discrete bands** on the gel.

7. **DNA markers** are loaded. The DNA markers serve as **"ladders" of fragments of known sizes** which is used to determine the size of DNA molecule studied.

(c) Discuss the goals and benefits of the Human Genome Project. [7]

Goals

1. To identify all the approximate 20,000-25,000 genes in human DNA;
2. To determine the complete nucleotide sequence of the 3 billion chemical base pairs that make up entire human DNA;
3. To store this information in databases accessible to public;
4. To improve tools for data analysis;
5. To transfer related technologies for the private sector;
6. To address the ethical, legal and social issues that may arise from the project;

Benefits

Molecular medicine

1 Construct a detailed physical map of the entire genome to allow elucidation of genes associated with human diseases OR understanding the genetic basis of diseases;
2 Allows **early diagnosis** OR detection of genetic diseases; E.g. risk of breast cancer, diabetes and colon cancer;
3 Enhances research on pharmacogenomics: design customized drugs based on genetic profile. Drug design OR pharmacogenomics: 'custom drugs' → knowing about which genes affect a person's response to a drug OR genetic differences affect the way we react to a drug → possibility of tailoring drugs prescribed to fit a patient's pharmacogenomics profile for greater efficacy / to avoid dangerous side effects OR design of the most effective drug therapy and treatment strategies based on the specific genetic profile of a patient;
4 Pharmaceutical products such as medicine can be synthesized using readily available gene sequences, e.g. humulin or tissue plasminogen activator (TPA) given to after heart attack to dissolve blood clots.
5 Enables novel treatment through gene therapy as gene sequences are now readily available.
6 Allows genetic testing for the presence of a faulty gene for a condition that may not develop for some years, including having presymptomatic genetic testing for Huntington disease and predictive testing for young-onset forms of Alzheimer disease;
7 Allows large scale studies on genetically homogenous populations to identify alleles linked to certain disease conditions;

A. DNA Forensics
8 Identify potential suspects whose DNA may match evidence left at crime scenes;
9 Exonerate persons wrongly accused of crimes; /Identify crime and catastrophe victims
10 Establish paternity and other family relationships;
11 Match organ donors with recipients in transplant programs;

B. Bioarchaeology, anthropology, evolution and human migration
12 Study human evolution (through germline mutations in lineages);
13 Study of migration of different population groups based on female genetic inheritance OR lineage and migration of males via Y chromosomes;

C. Risk assessment

14 Provides a means of risk assessment to evaluate health risks of individuals who may be exposed to radiation or carcinogens