Anglo-Chinese Junior College

JC2 Biology Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

BIOLOGY **9744/ 01**
Paper 1 Multiple Choice 16 September 2022
1 hour

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 Name and Index number in the Answer Sheet provided.

There are **thirty** questions in this section. 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 Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of 21 printed pages.

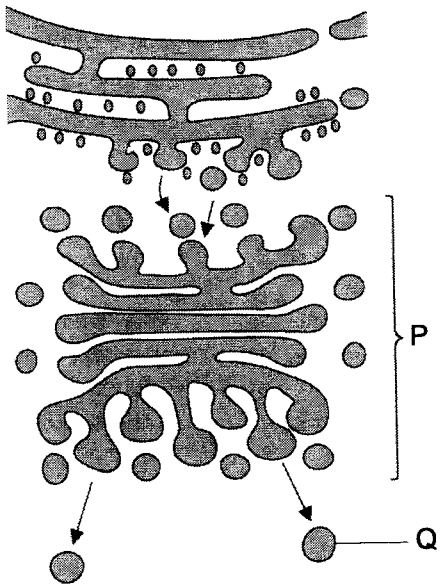
1 Different processes occur in different organelles in a plant cell.

1 transcription of circular DNA
2 movement of ions across protein channels
3 breaking of covalent bonds by hydrolysis
4 polymerisation of monomers containing nitrogen

Which processes occur in these three organelles?

	mitochondrion	chloroplast	nucleus
A	1, 2, 3, 4	1, 2, 3, 4	2, 3, 4
B	2, 4	2, 4	1, 3, 4
C	1, 3	4	2, 3
D	1	1	3, 4

2 The diagram shows some cell organelles involved in the formation and transport of trypsin.



What are the roles of organelles P and Q in the formation and transport of trypsin?

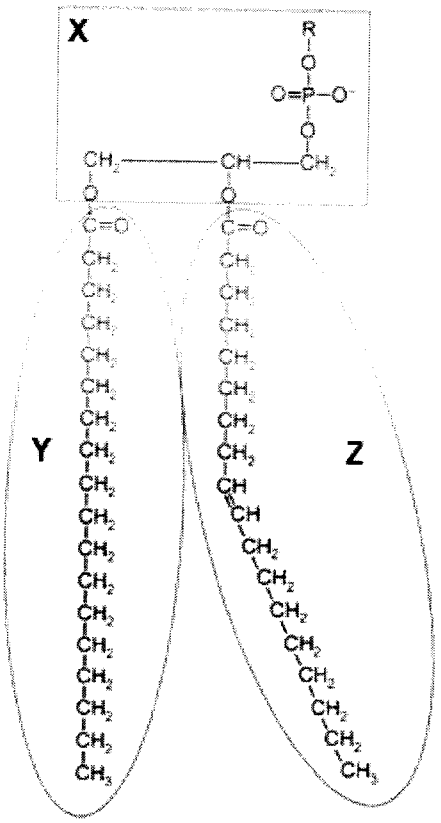
A P synthesises trypsin polypeptides on its surface and transports it from cisterna to cisterna before pinching off at the trans face as Q.

B Q has an acidic environment that prevents the activation of trypsin polypeptides modified in P, until it reaches the next organelle.

C Q transports trypsin polypeptides synthesised by free ribosomes to P for glycosylation.

D Trypsin polypeptides undergo post-translational chemical modification in the lumen of P, while Q, which contains the trypsin enzyme, fuses with the cell surface membrane.

3 The diagram shows a phospholipid molecule divided into three regions, X, Y and Z. In region X, R represents a range of possible chemical groups.

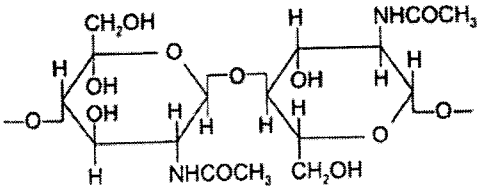


Which statements about regions X, Y and Z are correct?

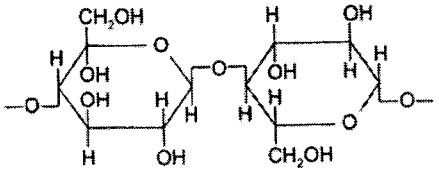
1 Regions Y and Z are linked to region X via ester bonds.
2 Regions Y and Z contain the same number of carbon atoms, resulting in a very fluid cell surface membrane.
3 R, in region X, can be a sulfhydryl group which forms disulfide bonds with other sulfhydryl groups.
4 Region Z results in the formation of a kink in the phospholipid molecule.

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

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



1



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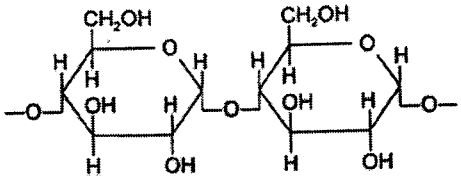

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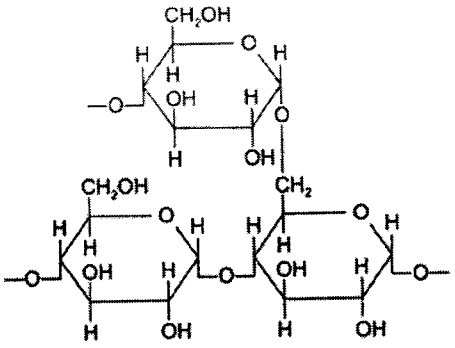


4

Which statement is correct?

A 1 is found in cellulose as β-1,4-glycosidic bond is present.

B 2 is found in amylopectin, which is a helical molecule, allowing for extensive coiling and entangling.

C 3 is found in cellulose, which is an unbranched and straight chain of β-glucose monomers.

D 4 is found in glycogen, which is made of chains of α-glucose linked by α–1,4–glycosidic bonds and α–1,6–glycosidic bonds at the branches.

5 Which comparative statements about collagen and haemoglobin are correct?

1 Collagen is more regular in structure.
2 Haemoglobin is less sensitive to changes in pH.
3 Haemoglobin is more soluble in water.
4 Collagen is more resistant to high temperatures.

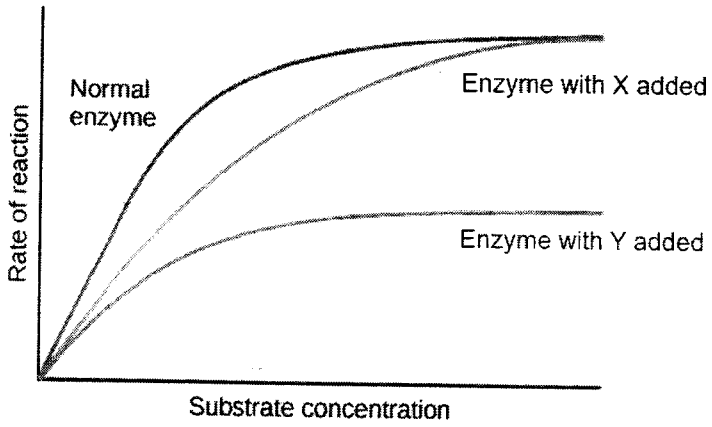
A 1, 2 and 3

B 1, 2 and 4

C 1, 3 and 4

D 2, 3 and 4

6 The effects of two different enzyme inhibitors, X and Y, were investigated.



Which statement best describes inhibitor X or Y?

A Inhibitor X could be a reversible, non-competitive inhibitor.

B In the presence of inhibitor X, V_{max} is the same as compared to without any inhibitor as X does not compete with the substrate for the active site of the enzyme.

C Inhibitor Y could be an irreversible, competitive inhibitor.

D In the presence of inhibitor Y, the rate of product formation eventually reaches zero at higher substrate concentration.

7 Which statement explains why induced pluripotent stem cells (iPSCs) are suitable for research and medical applications?

A They can be stimulated by chemical signals to express particular genes and give rise to specific cell types.

B They are specialised cells that can differentiate to give rise to almost any type of cell in the body.

C They can differentiate to a limited range of cells as they only have the genes required for a particular cell line.

D They lose genetic information as they divide, making it easy to reprogram them to differentiate into specific cell types.

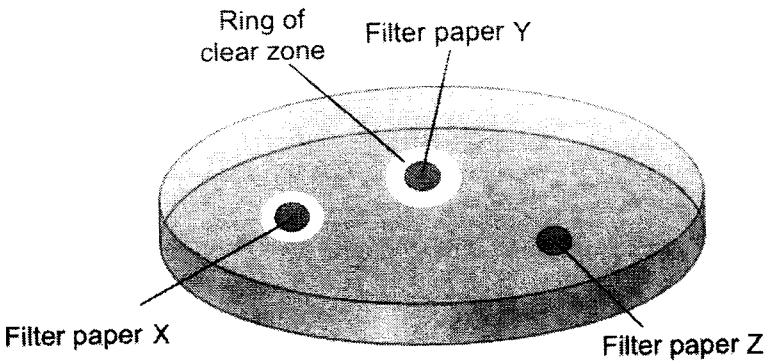
8 How many statement(s) correctly describe the lambda bacteriophage?

1 It has tail fibres that adsorb to specific proteins on bacteria.
2 The genome is made up of single-stranded DNA.
3 A phospholipid bilayer surrounds the nucleocapsid.
4 Its capsid contains a prophage.

A 0 **B** 1 **C** 2 **D** 3

9 An experiment was carried out to investigate the effect of bacteriophages and antibiotics on *E. coli*. Two strains of *E. coli* were used where one of the strains was resistant to antibiotics.

Three discs of filter papers were soaked with either temperate phages, virulent phages or antibiotics and placed on an agar plate spread with one strain of *E. coli*. The plate was then incubated at 37°C for 10 hours and rings of clear zones were observed. The diagram below shows the results.



The same experiment was repeated on a second agar plate containing the other strain of *E. coli* and there was only one ring of clear zone around filter paper Y.

Which explanation could be deduced from the experiment?

A Filter paper X was soaked with phages that did not initiate an immediate lysis of *E. coli* cells, resulting in a smaller clear zone around filter paper X than filter paper Y.

B Filter paper Y was soaked with phages that could integrate its genome into dividing *E. coli* cells, resulting in a larger clear zone around filter paper Y than filter paper X.

C Filter paper Z was soaked in antibiotics, resulting in the absence of a clear zone.

D Filter paper X was soaked in antibiotics but the strain of *E. coli* used in the second plate was resistant to antibiotics, resulting in no clear zone around filter paper X.

10 The following events occur during transcription.

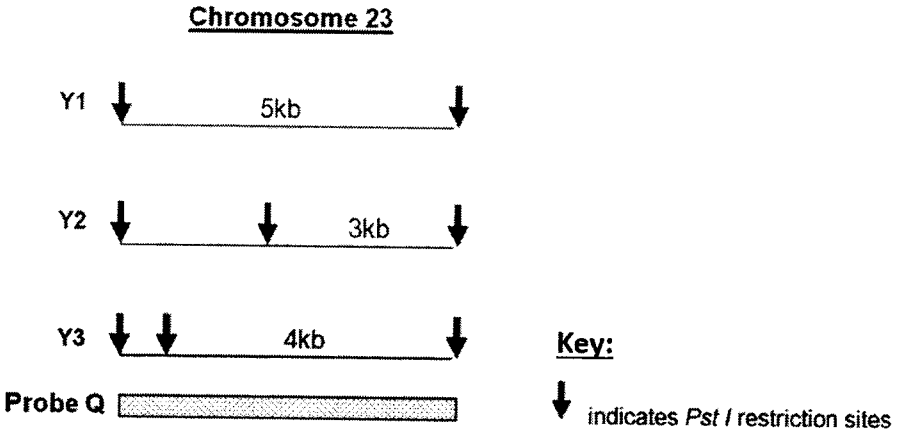
1 Bonds break between complementary bases.
2 Bonds form between complementary bases.
3 Sugar-phosphate bonds form.
4 Free nucleotides pair with complementary nucleotides.

Before the mRNA molecule leaves the nucleus, which events will have occurred twice?

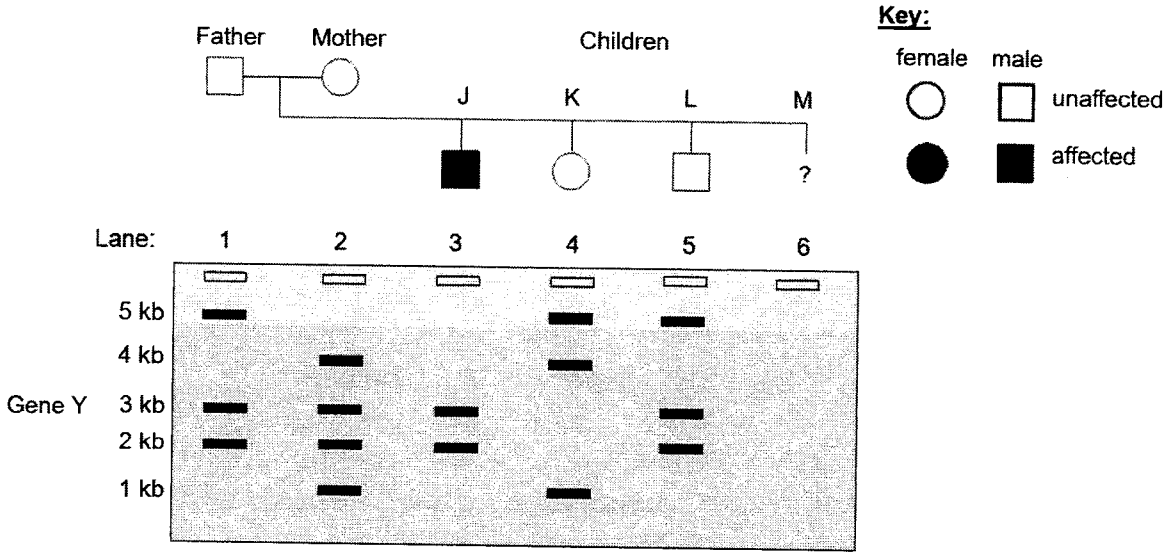
A 1, 2, 3 and 4 **B** 1, 2 and 3 only **C** 2, 3 and 4 only **D** 1 and 2 only

11 The DNA of a family affected by a rare autosomal disease was analysed using gel electrophoresis and Southern blotting. Gene Y, which is found on chromosome 23, is responsible for the disease.

Restriction enzyme *Pst* I was used to digest gene Y that has three different alleles, Y1 to Y3. Probe Q was used to identify the restriction fragments of the alleles of gene Y.



A phenotypically normal couple had three children, J, K, L, with only one of them affected by the disease. They recently gave birth to a fourth child, M.



Which conclusion could be made from the analysis?

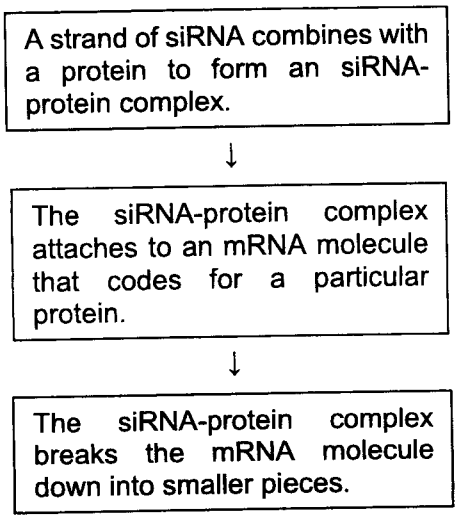
A The father is a homozygote.

B The genotype of child J is Y2Y2.

C The bands present in lane 6 could be 2 kb, 3 kb and 4 kb.

D Child M will not be affected by the disease.

12 The flowchart shows how small interfering RNA (siRNA) affects the expression of a particular target gene.



Which statements are consistent with the information provided?

1 The siRNA-protein complex attaches to an mRNA molecule coding for a particular protein because the base sequence of siRNA is complementary to the specific mRNA molecule.
2 The presence of siRNA will increase the expression of the target gene because there will be an increase in the number of mRNA molecules after the siRNA-protein complex binds to it.
3 The expression of the target gene is affected by siRNA as the complete target protein is no longer synthesised after the mRNA is cut into pieces.
4 siRNA may be useful in treating genetic diseases due to mutations because the gene will not be transcribed.

A 1, 2 and 4 **B** 1 and 3 only **C** 2 and 4 only **D** 3 and 4

13 The ends of a eukaryotic chromosome contain a special sequence of DNA called a telomere. Human telomeres consist of repeating TTAGGG sequences.

When cells undergo mitotic division, some of these repeating sequences are lost. This results in the shortening of telomeric DNA.

What is a consequence of the loss of repeating DNA sequences from the telomeres?

A The cell will begin the synthesis of different proteins.
B The cell will begin to differentiate as a result of the altered DNA.
C The number of mitotic divisions the cell can undergo will be limited.
D The production of mRNA will be reduced.

14 The life cycle of a fly includes a transition from the larval to the pupal stage. When the larva is fully grown, it changes into a pupa that does not feed. In the pupa, the tissues that made up the body of the larva are broken down. New adult tissues are formed from the substances obtained from these broken-down tissues and from substances that were stored in the body of the larva.

The table shows the mean concentration of RNA in fly pupae at different ages.

age of pupa as percentage of total time spent as a pupa	mean concentration of RNA / µg per pupa
0	20
20	15
40	12
60	17
80	33
100	20

What is a possible explanation for the change in RNA concentration in the pupa at different ages?

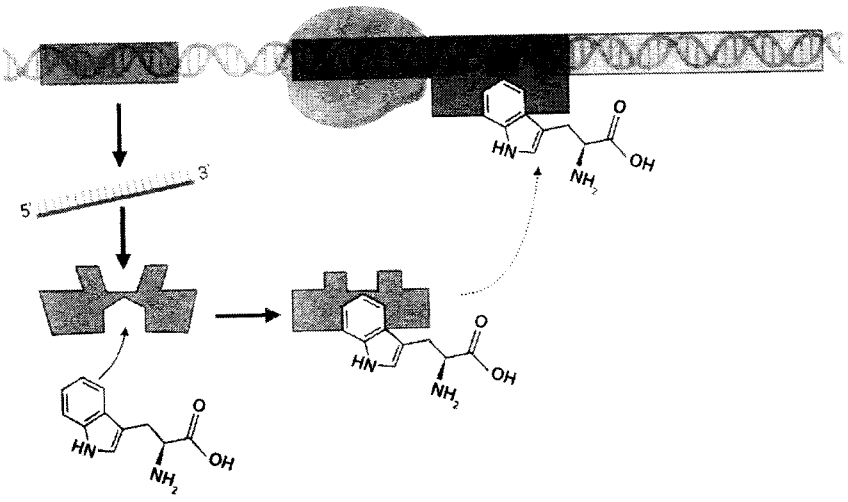
A From 0 to 40% of the time spent as a pupa, RNA concentration decreases because it is broken down together with the tissues that are broken down.

B From 0 to 100% of the time spent as a pupa, RNA concentration increases because genes are transcribed to produce more RNA for translation into proteins to form new adult tissues.

C From 60 to 80% of the time spent as a pupa, RNA concentration increases as a result of activators binding to promoters of genes that code for proteins required for the formation of new adult tissues.

D Overall concentration of RNA stayed the same throughout the time spent as a pupa because most RNAs are broken down when the pupa changes into an adult fly as no new protein needs to be synthesised.

15 The diagram shows the interaction of molecules with a segment of DNA which includes an operon.



molecule X

Which statement is **not** true?

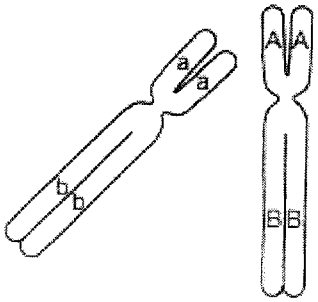
A The protein that molecule X binds to is originally inactive.

B The operon is negatively controlled by a repressor.

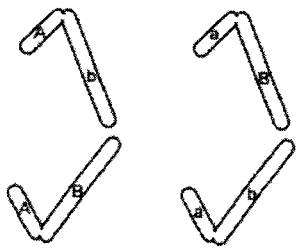
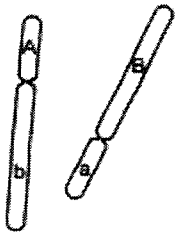
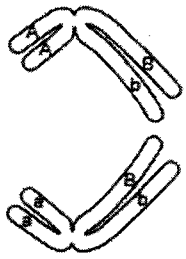
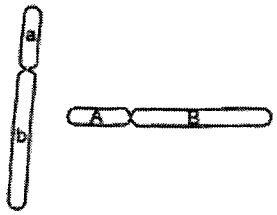
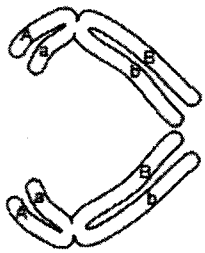
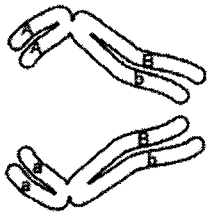
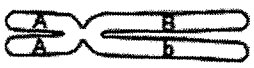
C This metabolic pathway is regulated by the process of feedback inhibition.

D The absence of molecule X allows the synthesis of proteins involved in catabolism.

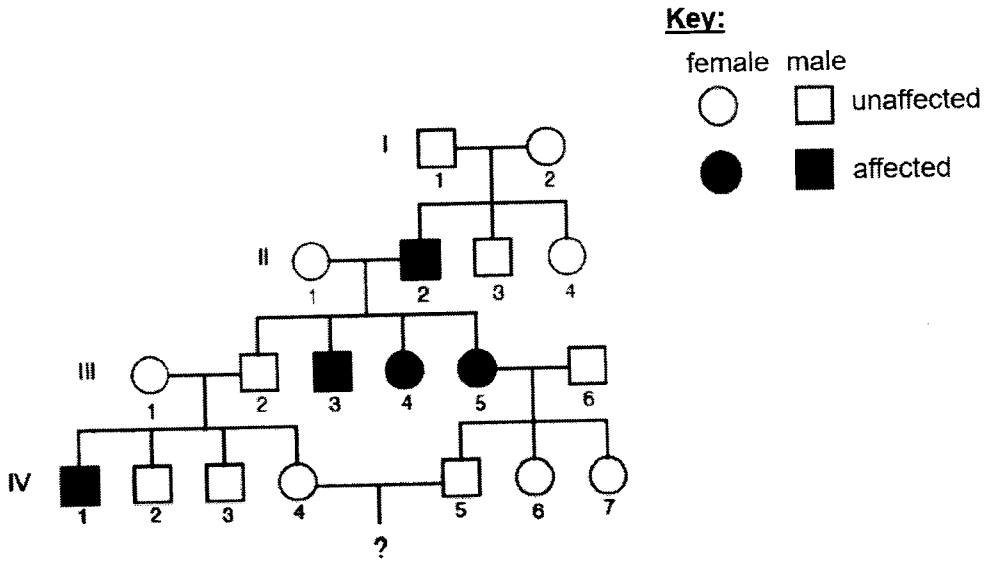
16 The figure shows the location of two genes, A/a and B/b, on two homologous chromosomes in early prophase I of meiosis in an animal cell.



Which row is a possible representation of these chromosomes as they progress from anaphase I to prophase II?

	anaphase I	prophase II
A		
B		
C		
D		

17 The pedigree shows the inheritance of a trait over three generations in an extended family.



What is the probability that individuals IV–4 and IV–5 have a son who has the trait?

A 1 in 4 **B** 1 in 6 **C** 1 in 8 **D** 1 in 12

18 In the inheritance of feather colour in chickens, individuals carrying the dominant allele, W, have white plumage even if they also carry the dominant allele, C, for coloured plumage.

White Leghorn chickens have the genotype WWCC and white Wyandotte chickens have the genotype wwcc. A white Leghorn is crossed with a white Wyandotte and the F2 generation yielded 27 chickens with white plumage and 7 chickens with coloured plumage. The expected ratio for this cross was 13 : 3.

A chi-squared test was performed to test the significance of the difference between the observed and expected results. It was found that there was no significant difference, at a 95% confidence level, between the observed and expected results.

table of chi-squared values					
degrees of freedom	probability P (%)				
	95	80	50	20	5
1	0.00393	0.0642	0.455	1.642	3.841
2	0.103	0.446	1.386	3.219	5.991
3	0.352	1.005	2.366	4.642	7.816

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

O = observed result
E = expected result
v = n–1

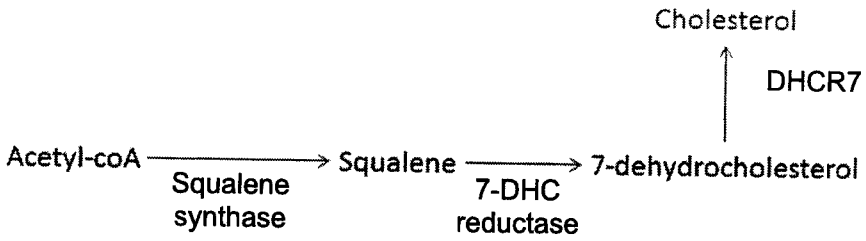
Using the equation and table above, which value would be close to the calculated chi-square value for this experiment?

A 0.098 **B** 3.34 **C** 3.88 **D** 7.52

19 A gene found on chromosome 11 codes for an enzyme called 7-dehydrocholesterol reductase (DHCR7). This enzyme is involved in the biosynthesis of cholesterol. Inheritance of two mutated alleles results in a disease known as Smith-Lemli-Opitz syndrome, which is characterised by a reduced level of cholesterol.

Another gene found on this chromosome codes for the protein alpha-tectorin (TECTα), which is a major component of the tectorial membrane in the inner ear. A dominant mutation results in a disease known as non-syndromic deafness.

Apart from DHCR7, other enzymes required in the biosynthesis of cholesterol are squalene synthase and 7-DHC reductase which are coded for by genes found on other chromosomes.



Which statement cannot be concluded?

A The *DHCR7* gene and *TECTα* gene do not assort independently.

B A person who is heterozygous for both *DHCR7* and *TECTα* genes suffers from non-syndromic deafness but not Smith-Lemli-Opitz syndrome.

C The production of cholesterol from acetyl-CoA is influenced by gene interactions.

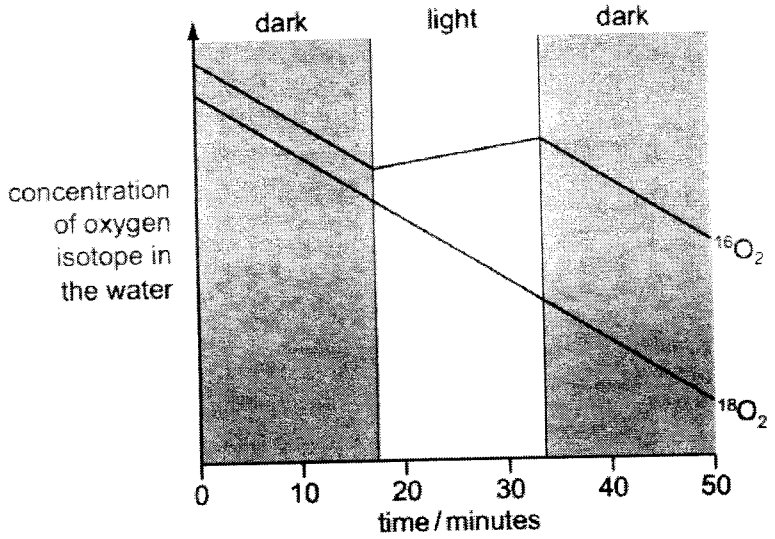
D The amount of cholesterol that can be produced shows discontinuous variation.

20 An aqueous suspension of isolated chloroplasts will produce oxygen if illuminated in the presence of a certain type of compound.

Which type of compound and which colours of light are required for maximum oxygen production?

	type of compound	colours of light
A	electron acceptor	blue and green
B	electron acceptor	blue and red
C	electron donor	blue and green
D	electron donor	blue and red

21 The common isotope of oxygen is ^{16}O. Air containing $^{16}O_2$ and $^{18}O_2$ was bubbled through a suspension of algae for a limited period. After this, the concentration of these two isotopes of oxygen in the water was monitored for the next 50 minutes whilst the algae were subjected to periods of dark and light. The results are shown in the diagram.



What is the best explanation for these results?

A Both isotopes of oxygen are used by the algae in the dark in respiration, but in the light oxygen is produced from water in photorespiration.

B The algae can distinguish chemically between the two isotopes.

C The algae produce oxygen from the water during photosynthesis, but only in the light.

D The two isotopes have different rates of diffusion.

22 Different types of reactions occur in the Calvin cycle.

Which statement correctly describes Calvin cycle?

A Carboxylation occurs in the conversion of triose phosphate to ribulose bisphosphate.

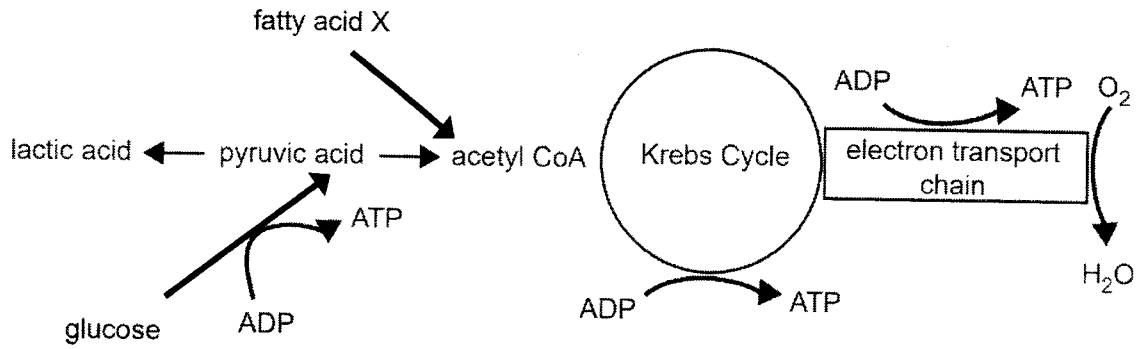
B Decarboxylation occurs in the conversion of ribulose bisphosphate to 3-phosphoglycerate.

C Phosphorylation occurs in the conversion of ribulose bisphosphate to 3-phosphoglycerate.

D Reduction occurs in the conversion of 3-phosphoglycerate to glyceraldehyde-3-phosphate.

23 If there is insufficient glucose for cellular respiration, fatty acids can be converted to acetyl CoA.

The diagram summarises the pathways for the breakdown of fatty acid X and glucose molecules. Each molecule of fatty acid X produces eight molecules of acetyl CoA.



Which statement is correct?

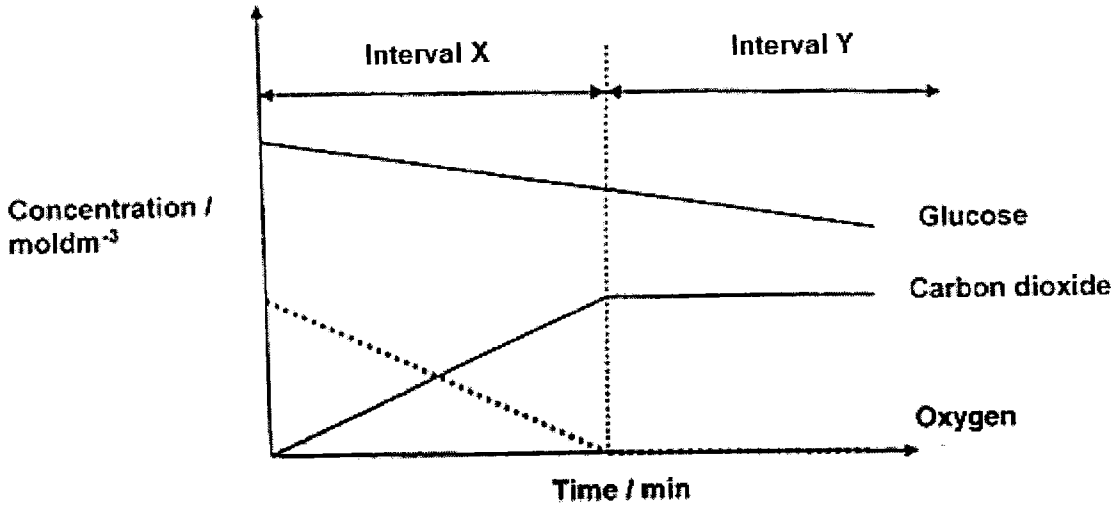
A For every glucose molecule oxidised, more ATP is made in the Krebs cycle than in glycolysis.

B Under aerobic conditions, one molecule of fatty acid X produces more ATP than one glucose molecule.

C Under anaerobic conditions, fatty acids are preferred over glucose as respiratory substrates.

D Oxygen plays a more important role as the final electron and proton acceptor when glucose molecules are oxidised as compared to the oxidation of fatty acids.

24 In an experiment, metabolically active cells were introduced to a sealed container of nutrient solution. The graph of the concentrations of glucose, carbon dioxide and oxygen were then analysed over time.



Which row identifies the processes happening at intervals X and Y?

	Interval X	Interval Y
A	Aerobic respiration	Lactic acid fermentation
B	Aerobic respiration	Alcoholic fermentation
C	Lactic acid fermentation	Aerobic respiration
D	Alcoholic fermentation	Aerobic respiration

25 The processes following an increase in blood glucose level are listed. The processes are **not** listed in the correct sequence.

- Activated protein kinase A phosphorylates and activates glycogen phosphorylase, which catalyses the breakdown of glycogen to glucose.
- Activated receptor binds to and activates a specific G protein located on the cytoplasmic side of the plasma membrane.
- Activated G protein then activates a membrane-bound enzyme.
- Activated adenyl cyclase converts ATP to cAMP, leading to an increase in concentration of cAMP.
- Binding of glucagon to a G-protein linked receptor causes the receptor to change 3D conformation.
- GTP nucleotide replaces the GDP bound to the G protein.
- cAMP acts as a second messenger and binds to and activates protein kinase A.

What is the consequence when the fourth step in the correct sequence of steps does not occur?

A ATP will be hydrolysed to ADP.

B Adenyl cyclase will be hyperactive.

C Protein kinase A will remain inactive.

D G protein will remain bound with GDP.

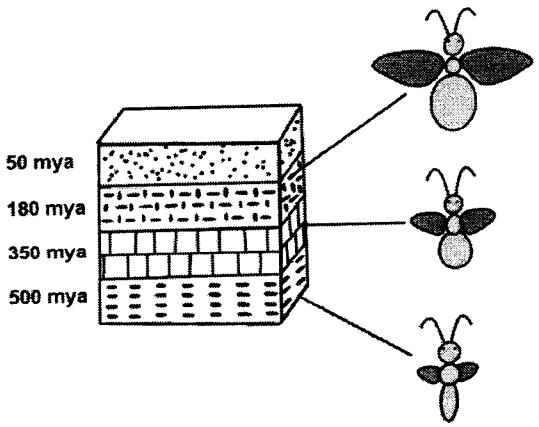
26 Several closely related frog species of the genus *Rana* are found in the forests of the South-eastern United States. The species boundaries are maintained by reproductive barriers. The statements below describe the different type of reproductive barriers that exist between the different species.

1 Males of one species sing only when its predators are absent; males of another species sing only when its predators are present.
2 One species mate at the season when daylight is increasing from 13 hours to 13 hours and 15 minutes; another species mate at the season when daylight is increasing from 14 hours to 14 hours and 15 minutes.
3 Two species of frogs belonging to the same genus occasionally mate, but the offspring fail to develop and hatch.

Which row correctly matches the statement to the type of reproductive barrier that is described?

	1	2	3
A	temporal	behavioural	hybrid inviability
B	seasonal	geographical	hybrid sterility
C	sympatric	temporal	gamete incompatibility
D	behavioural	temporal	hybrid inviability

27 A team of palaeontologists discovered the remains of an insect-like organism trapped in amber, which was found in rock layers believed to be about 180 million years old. As they dug deeper into the older layers of rock, they made several further discoveries. The diagram shows their findings.



Key:

mya: million years ago

Which statement can be concluded from the information provided?

A Speciation occurred gradually, with many small changes accumulating over a long period of time.

B The changes observed in these populations occurred gradually from 500 million years ago until 180 million years ago.

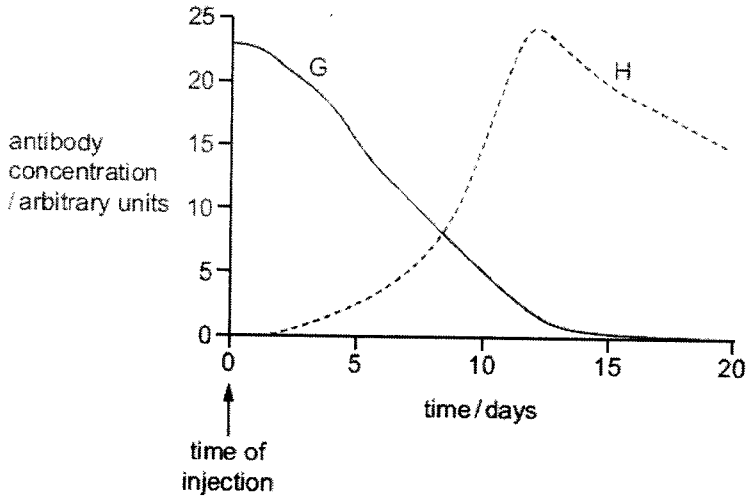
C The original population changed dramatically over time which lead to several different species forming.

D There were several large speciation events that occurred within a short period of time within these populations.

28 Tetanus is a bacterial infection.

The graph shows the blood antibody concentration of two people.

On day 0, person G was injected with antibodies to the tetanus toxin and person H was injected with the vaccine for tetanus.



What could be the result if G and H were infected with the tetanus bacteria on day 20?

A A second antibody peak would occur in person H that would be lower than the first peak.

B Tetanus antibodies would not be produced in person G.

C Antibody concentration would stay constant in person H.

D Antibody production would peak after day 32 in person G.

29 Some animals have genes that code for small peptides called cathelicidins. These peptides kill a wide range of bacteria by attaching to lipids in the bacterial membranes to weaken or disrupt them.

Scientists have produced a synthetic version of cathelicidin that kills bacteria which are resistant to a number of antibiotics such as tetracycline.

Which pair of statements explain how this synthetic cathelicidin might counter the problem of antibiotic resistance?

1 It is synthetic so bacteria can never become resistant to it.
2 It could be used instead of tetracycline, allowing tetracycline resistance to be reduced.
3 The only way a bacterium could develop resistance to it is by altering all the lipids in its membrane.
4 It could be used to kill multidrug-resistant strains of bacteria for which there is no effective antibiotic.

A 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

30 The speckled wood butterfly (*Pararge aegeria*) is commonly found in woodland in southern parts of Britain. In the last 40 years, *P. aegeria* has significantly increased both its abundance and its ecological range in Britain. This is thought to be due to climate change, allowing the species to survive in more northerly habitats.

What impact would the increased ecological range of *P. aegeria* have on other species?

1 There could be increased food sources for birds.
2 More plants could be damaged by caterpillars.
3 There could be more pollination of flowers.
4 There could be increased competition with butterflies of other species.

A 1, 2, 3 and 4 **B** 1 and 4 only **C** 2 and 3 only **D** 2 and 4 only

Answers

1	A	**16**	D
2	D	**17**	D
3	C	**18**	A
4	D	**19**	D
5	C	**20**	B
6	C	**21**	C
7	A	**22**	D
8	B	**23**	B
9	D	**24**	A
10	B	**25**	C
11	B	**26**	D
12	B	**27**	B
13	C	**28**	D
14	A	**29**	D
15	D	**30**	A

Anglo-Chinese Junior College

JC2 Biology Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		FORM CLASS	
TUTORIAL CLASS		INDEX NUMBER	

BIOLOGY
Paper 2 Structured Questions

9744/02
25 August 2022
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Name, Class and Index number in the spaces at the top of this page.
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.

Answer **all** questions in the spaces provided on the Question Paper.

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.

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

For Examiners' use only	
1	/ 9
2	/ 10
3	/ 11
4	/ 9
5	/ 10
6	/ 10
7	/ 10
8	/ 10
9	/ 10
10	/ 6
11	/ 5
Total	/ 100

This document consists of 31 printed pages.

[Turn over

For Examiner Use

Answer **all** questions.

1 Fig. 1.1 shows *Mycobacterium tuberculosis* infecting an alveolar cell in the lungs.

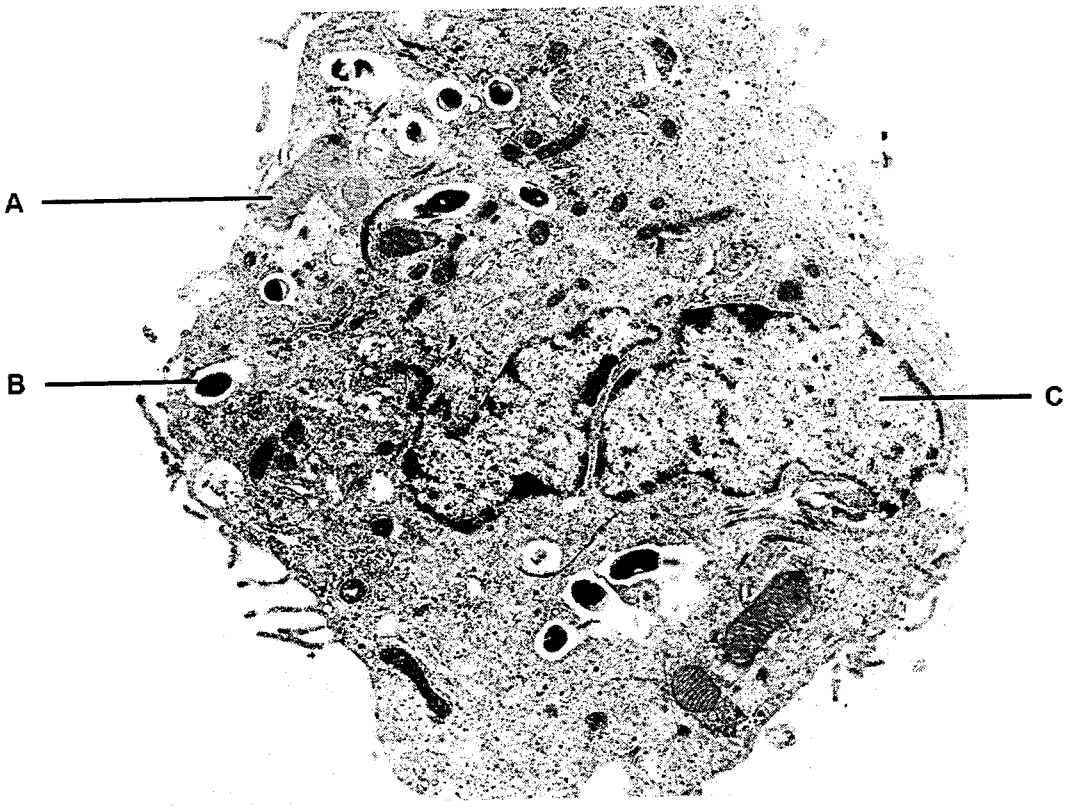


Fig. 1.1

(a) **(i)** Using the letters **A** to **C**, identify the mitochondrion.

A;

..... [1]

(ii) Justify your answer to **(a)(i)**.

1. **Double membrane-bound;**
2. **Highly folded inner membrane;**
3. **Rod-shaped;**

max 2m

..... [2]

(b) Compare the structures of *M. tuberculosis* and a mitochondrion.

Similarity:

1. **Both contain circular DNA;**
2. **Both contain 70S ribosomes;**

Difference:

3. ***M. tuberculosis* / bacterial cells is bound by a single membrane, while a mitochondrion is bound by a double membrane;**
4. ***M. tuberculosis* has a peptidoglycan cell wall, while mitochondrion does not have a cell wall;**

At least one similarity and one difference

..... [3]

(c) Explain how the structure of organelle **C** allows it to serve its functions.

1. **Presence of a <u>nuclear envelope</u> / bound by <u>double membrane</u>, which allows nucleus to protect the DNA / chromatin from reactions in the cytoplasm;**
2. **Presence of <u>nuclear pores</u> which allow the export of mRNA/ribosomal subunits for translation in the cytoplasm / import of ribosomal proteins for assembly of ribosomal subunits / import of nucleotides for DNA replication or transcription;**
3. **Presence of <u>enzymes</u> in the nucleoplasm which allows <u>DNA replication / transcription</u> / post-transcriptional modification to occur;**
4. **Presence of <u>nucleolus</u> which allows the synthesis of rRNA / assembly of ribosomal subunits;**

max 3m

..... [3]

[Total: 9]

2 The rate of carbon dioxide uptake at a range of carbon dioxide concentrations by barley and sugar cane were compared at two temperatures using the apparatus shown in Fig. 2.1.

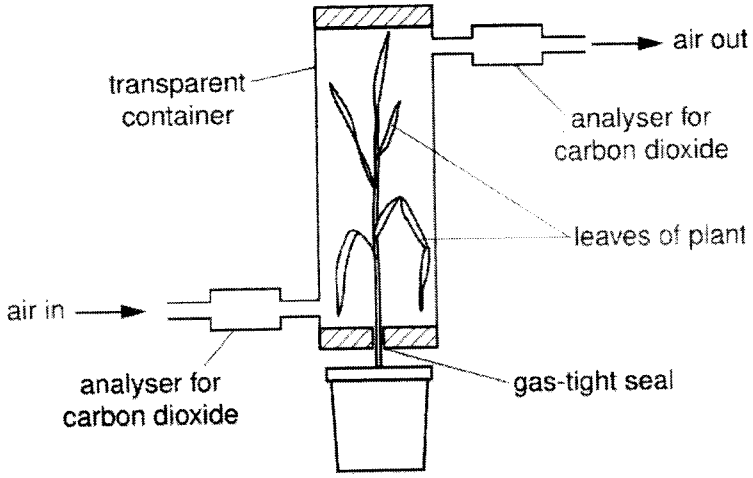


Fig. 2.1

The results of the experiment are presented in Fig. 2.2.

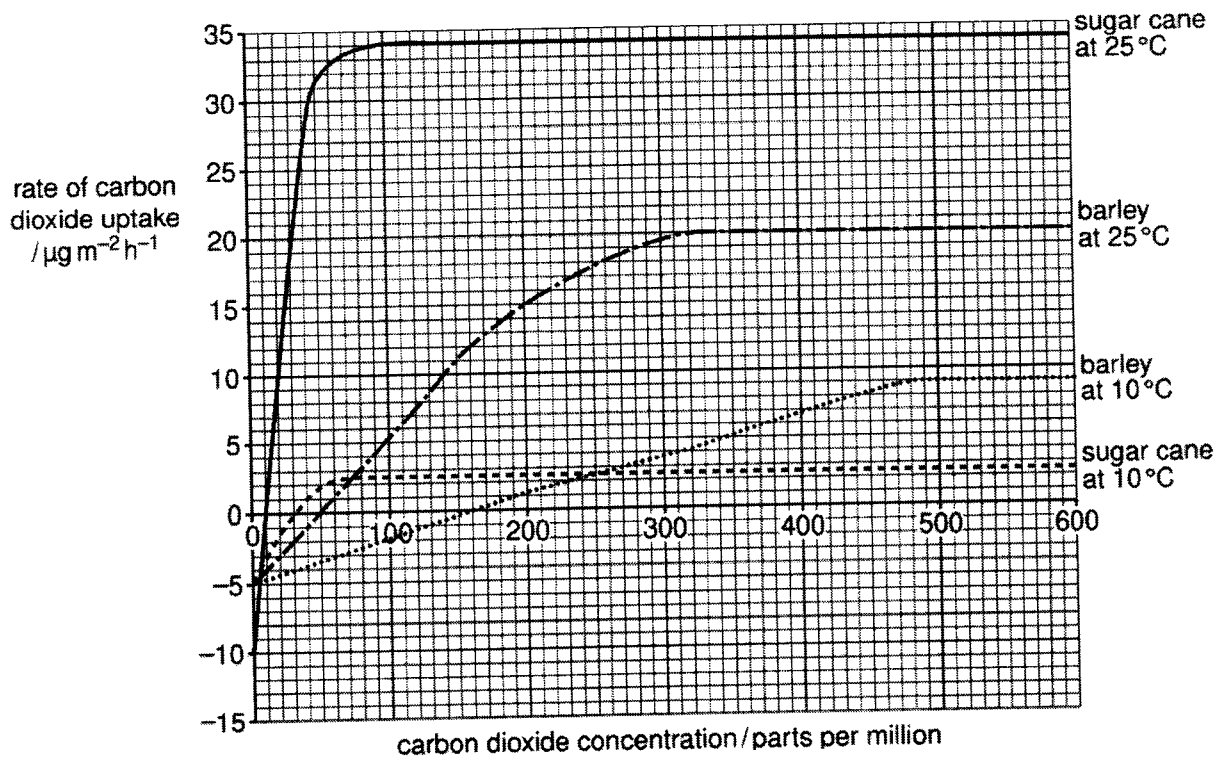


Fig. 2.2

For Examiner Use

(a) (i) With reference to Fig. 2.2, describe the differences in rates of carbon dioxide uptake by barley and sugar cane in response to increasing carbon dioxide concentrations at 25°C.

1. **Sugar cane reaches maximum rate of CO_2 uptake at lower CO_2 concentration / barley reaches maximum rate of CO_2 uptake at higher CO_2 concentration;**
2. **Quote data: maximum rate for sugar cane is reached at 100ppm vs barley at 320ppm at 25°C;**
3. **Sugar cane reaches a higher maximum rate of carbon dioxide uptake than barley;**
4. **Quote data: 34 μg m^{-2} h^{-1} for sugar cane vs 20 μg m^{-2} h^{-1} for barley;**
5. **The rate of CO_2 uptake by sugar cane increases faster than the rate of CO_2 uptake by barley as CO_2 concentration increases;**
6. **Rate of CO_2 uptake by sugar cane increases faster from 0 to 34 μg m^{-2} h^{-1} compared to that by barley from 0 to 5.5 μg m^{-2} h^{-1} as CO_2 concentration increases from 0ppm to 100pm;**
7. **Sugar cane has a lower CO_2 compensation point than barley;**
8. **CO_2 compensation point for sugar cane is 10ppm vs. barley at 50ppm at 25°C;**

2 trends + corresponding data, max 4m

..... [4]

(ii) Barley and sugar cane thrive in different climatic conditions. Complete Table 2.1 to show where these plants are likely to be found.

Table 2.1

climatic conditions	plant
tropical, warm climate	**sugar cane**
temperate, cool climate	**barley;**

[1]

Sugar cane is a cash crop which produces a high concentration of sucrose. Invertase found in the sugar cane hydrolyses sucrose into glucose and fructose, resulting in post-harvest loss of sucrose.

(b) Explain why a non-competitive inhibitor of invertase can potentially be used to reduce such losses.

1. **A non-competitive inhibitor binds to a site other than the active site of invertase;**
2. **change the 3D conformation of invertase such that it is no longer complementary to sucrose does not bind to sucrose/ sucrose hydrolysis is prevented;**

..... [2]

Starch is also found in sugar cane as a storage polysaccharide.

(c) **(i)** Describe the advantages to a plant of condensing glucose molecules into starch.

1. **starch is more compact, making it a better energy storage molecule;**
2. **starch is insoluble in water/ osmotically inactive or inert/ does not affect osmotic potential in cells, thus a better storage molecule;**

function as "storage molecule" to be stated at least once in MP1 or MP2

..... [2]

(ii) Suggest why mammals store glucose as glycogen rather than as starch.

1. **glycogen has more branching points than amylopectin in starch, which allow for fast mobilisation of glucose when needed/ can be compacted further for energy storage purposes;**
2. **absence of enzymes in mammals that can polymerise glucose to form starch;**

max 1m

..... [1]

[Total: 10]

3 Table 3.1 shows the telomerase activity and change in telomere length over time in different human stem cells.

Table 3.1

type of stem cell	telomerase activity	telomere length over time
germline	high	maintained
zygotic	high	maintained
embryonic	high	maintained
blood	low	shortened
skin	low	shortened
intestinal	low	shortened

(a) (i) With the exception of germline stem cells, explain how the potency of stem cells is related to the telomere length in these cells.

1. **Totipotent and pluripotent stem cells exhibit high telomerase activity, while multipotent stem cells exhibit low telomerase activity;**
2. **Telomere lengths are only maintained in cells where telomerase activity is high / will shorten over time in cells where telomerase activity is low;**
3. **With each round of DNA replication, the 5' end of daughter DNA strands is shortened due to the end-replication problem;**
4. **Telomerase synthesises multiple DNA repeats at the 3' end of DNA to lengthen the telomere;**

..... [4]

(ii) Germline stem cells are the diploid cells that can only give rise to gametes, hence are considered unipotent.

Suggest why telomerase activity is high in germline stem cells.

To maintain the length of telomeres over successive generations of a species / To preserve genetic integrity in the offspring/descendants;

..... [1]

(iii) Like telomeres, the centromere is an example of a non-coding DNA.

Compare the structures of telomeres and centromeres.

Similarity:

1. **Both are made of DNA repeats / repetitive sequences of DNA / tandem repeats;**

Differences

2. **Telomere is found at the ends of linear chromosomes unlike centromere/ while centromeres are found at a point along the chromosomes/ not at the ends of chromosomes;**
3. **Telomeres occur in two regions on a chromosome while centromere occurs at one region on a chromosome;**
4. **Centromeres contain binding site complementary to kinetochore proteins while telomeres do not have such binding sites;**
5. **Telomeres can form loops while centromeres do not;**

At least one similarity and one difference

..... [2]

The Hayflick limit is the number of times a cell population can divide before cell division stops, assuming an absence of telomerase activity.

Healthy human cells start off with an average telomere length of 10 kilobases (kb). Telomeres shorten at rates of 140 to 210 bases per replication prior to each cell division. It is estimated that when telomere lengths reach the threshold of 1.6 kb, the cells become senescent.

(b) (i) Using the information provided, calculate the range of values for the Hayflick limit.

Lower range of the Hayflick limit = (10,000 – 1600) / 210 = 40 divisions
Upper range of the Hayflick limit = (10,000 – 1600) / 140 = 60 divisions

1. **Complete workings shown – 1m**
2. **Correct answer – 1m**

..... to ..... divisions [2]

(ii) Describe two possible deleterious effects on DNA when telomeres are depleted.

1. **Genes near / at the ends of DNA may become eroded;**
2. **DNA ends / chromosomal ends may undergo end-to-end fusions;**
3. **DNA ends / chromosomal ends may be degraded by exonucleases;**

R! replicative senescence and apoptosis

max 2m

..... [2]

[Total: 11]

For Examiner Use

4 One of the three tenets of the cell theory states that all living organisms are composed of one or more cells. Viruses challenge this tenet as they possess both living and non-living characteristics.

Giant viruses such as mimiviruses have been discovered recently. It is debatable whether such viruses are considered as living organisms or non-living entities. Mimivirus contains a DNA genome which is significantly larger than the genomes of any other known virus and is comparable to that of a cell. Like other viruses, it is dependent on its host for translation.

Fig. 4.1 shows the structure of Mimivirus.

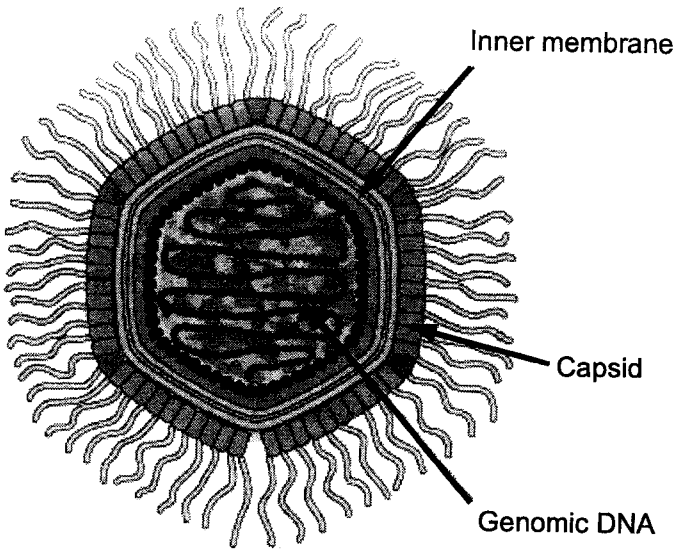


Fig. 4.1

(a) With reference to the information provided, discuss if the discovery of mimivirus justify the classification of viruses as living.

Classify as living organisms:

1. **It has <u>genes/ genetic material</u> which codes for proteins;**

Classify as not living organisms:

2. **It does not have ribosomes/ cannot synthesise proteins to replicate itself independently of the host cell/ still require host to reproduce/ not free-living;**
3. **According to Fig. 4.1, it does not have organelles;**

..... [3]

Fig. 4.2 shows the structure of an influenza virus.

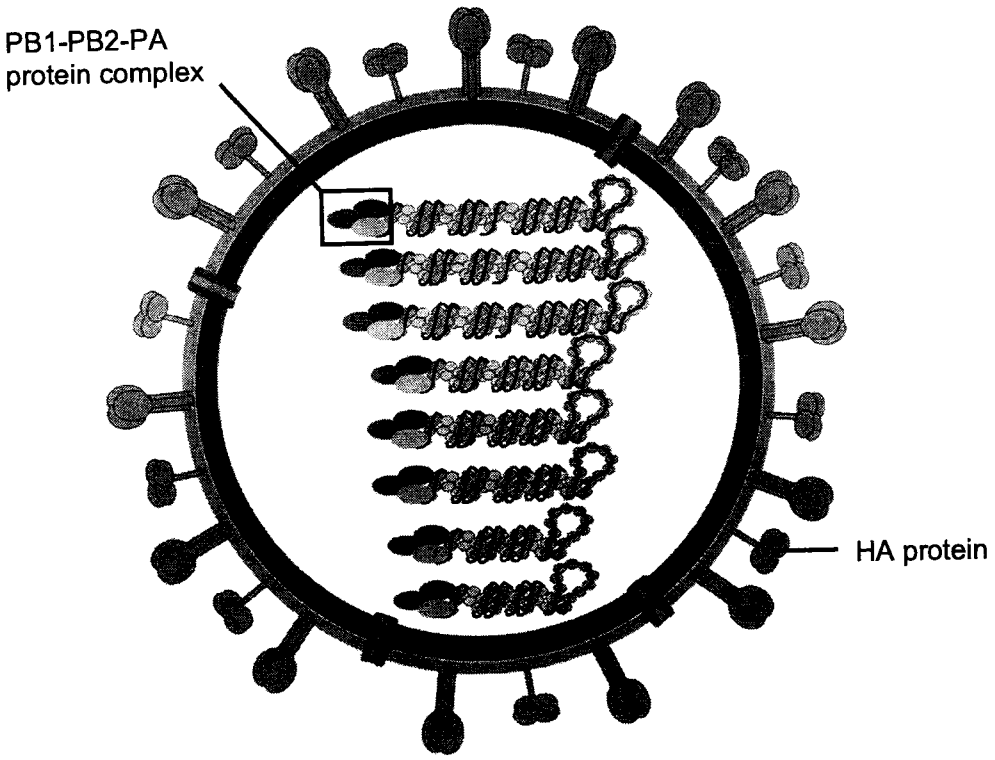


Fig. 4.2

(b) Describe the role of the following components labelled in Fig. 4.2 in the viral reproductive cycle:

(i) PB1-PB2-PA protein complex.

1. **PB1, PB2 and PA form the viral RNA-dependent RNA polymerase/ RNA replicase;**
2. **which transcribes the (-)-sense RNA genome to form complementary (+)-sense mRNA;**
3. **These (+)-sense mRNA can be translated to form viral proteins/ used as templates to make new copies of the (-)-sense RNA genome;**

max 2m

..... [2]

(ii) HA protein.

1. **HA protein is haemagglutinin which binds to specific sialic acid receptors on the cell surface of the epithelial cells lining the respiratory tract;**
2. **allows virus to be taken into cells via receptor-mediated endocytosis;**

..... [2]

Oseltamivir is an orally administered antiviral medication that is recommended for patients infected with influenza virus. Fig. 4.3a shows the mechanism of action of oseltamivir and Fig. 4.3b shows its molecular structure as compared to that of sialic acid.

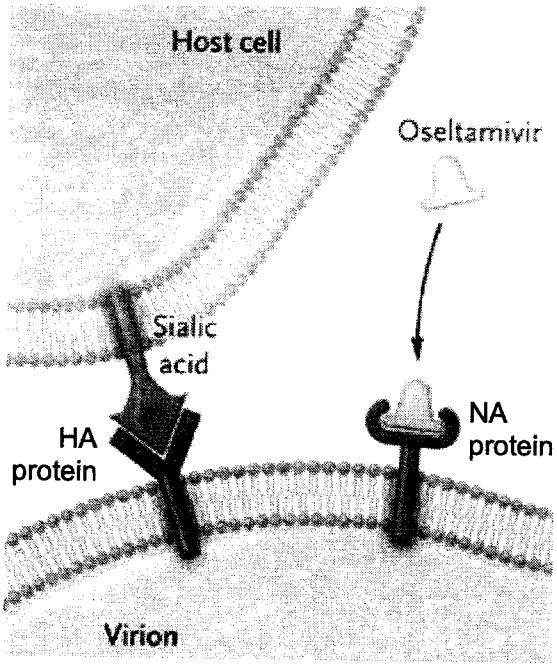


Fig. 4.3a

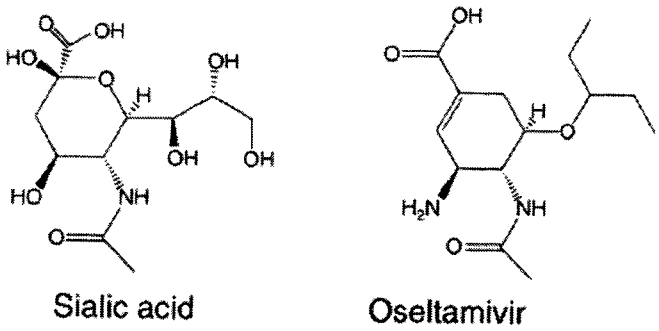


Fig. 4.3b

(c) Explain how oseltamivir affects the reproductive cycle of H1N1 virus.

1. **Oseltamivir has similar 3D conformation as sialic acid and is able to bind to the <u>active site</u> of <u>neuraminidase</u>;**
2. **Prevents neuraminidase from cleaving sialic acid so that virion cannot be released via budding to infect other cells;**

..... [2]

[Total: 9]

5 Fig. 5.1 shows the expression of the *lac* operon.

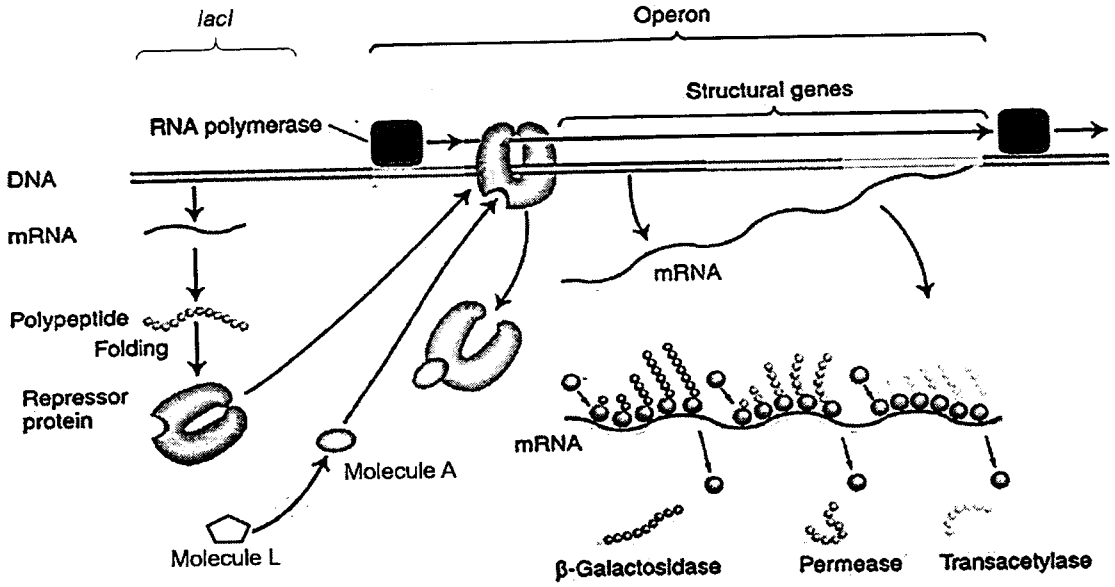


Fig. 5.1

(a) With reference to Fig. 5.1, identify molecule **A**.

Allolactose; R! lactose

..... [1]

An investigation was conducted to find out more about the *lac* operon. Bacteria were grown in a medium containing 2% glucose and 2% lactose. Three different experiments were conducted.

- experiment **A** – Wild type bacteria.
- experiment **B** – Bacteria with a mutation.
- experiment **C** – Wild type bacteria with IPTG added. IPTG is a molecular mimic of allolactose.

Fig. 5.2 shows the results of the investigation.

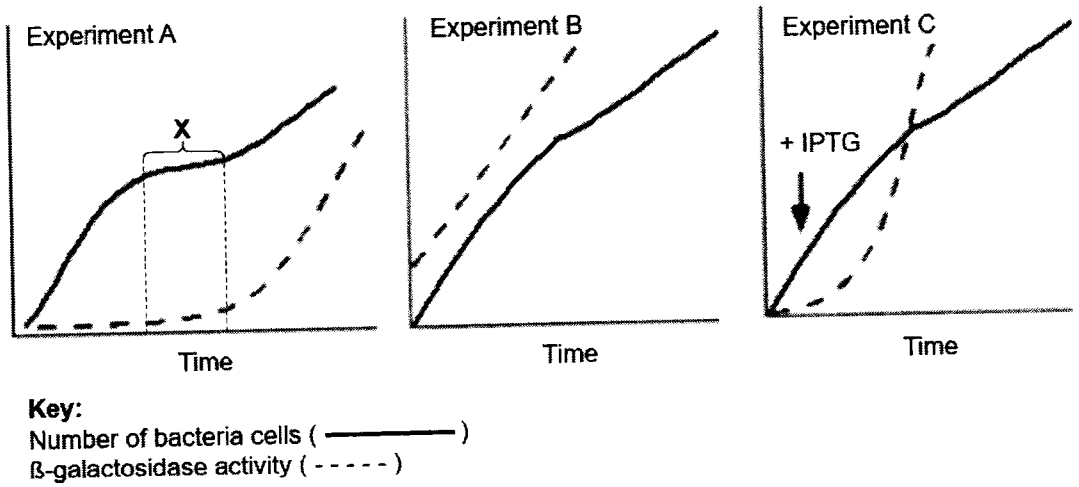


Fig. 5.2

(b) (i) Explain the bacterial growth during period **X** in experiment **A**.

1. ***Number of bacteria remains constant as <u>glucose</u> has been used up;**
2. **Time is needed for the activation of <u>adenyl cyclase</u> at low glucose concentration to increase <u>cAMP</u> level;**
3. **cAMP then binds and activate <u>CAP</u> to stimulate the transcription of the lac operon to produce more ß-galactosidase to metabolise more lactose;**

***MP1 compulsory, max 2m**

..... [2]

(ii) Suggest what mutation might have occurred in the bacteria used in experiment **B**.

1. **Loss of function mutation in <u>lacI gene</u> coding for lac repressor;**
2. **Resulting in the production of non-functional/ inactive <u>lac repressor</u>, unable to bind to operator;**
3. **Mutation of <u>operator</u> sequence of lac operon;**
4. **Resulting in active <u>lac repressor</u> unable to bind to operator;**

***MP1 + MP2 OR MP3 + MP4**

..... [2]

(iii) Explain the effect of IPTG in experiment **C**.

1. **Acts as inducer which binds to allosteric site of active lac repressor to inactivate it;**
2. **repressor unable to bind to <u>operator,</u> resulting in transcription of lac operon/ ß-galactosidase gene;**

..... [2]

(c) Explain how bacteriophages could enable more bacteria in a population to metabolise lactose.

1. **In <u>generalised transduction</u>, a random segment/ fragment of the infected bacteria cell's degraded DNA containing the <u>*lacZ* gene / *lac* operon</u>* (R! bacterial chromosome/ genome) is <u>mistakenly packaged</u> into a phage;**
   OR
   In <u>specialised transduction</u>, when prophage leaves bacterial chromosome, <u>prophage/ viral DNA</u> may be improperly excised, a specific segment/ fragment of bacterial DNA containing the <u>*lacZ* gene / *lac* operon</u>* that is adjacent to prophage is excised with it;
2. **Upon its release from the lysed host/ bacteria cell, the <u>phage</u> can infect/ attach to another bacterium (recipient) and inject/ transfer the piece of bacterial DNA (R! bacterial chromosome/ genome, viral genome/ DNA) acquired from the donor;**
3. **DNA of donor cell can subsequently replace homologous region of chromosome of recipient cell via <u>homologous recombination</u> (for both generalised and specialised transduction)/ incorporated into host chromosome via <u>integration</u> (for specialised transduction);**

*** Must have mention of *lacZ* / *lac* operon in answer**

..... [3]

[Total: 10]

For Examiner Use

6 Cancer is a disease in which genetic alterations, most frequently chromosomal aberrations, are acquired in somatic cells. Fig. 6.1 shows a karyotype from a patient diagnosed with leukemia.

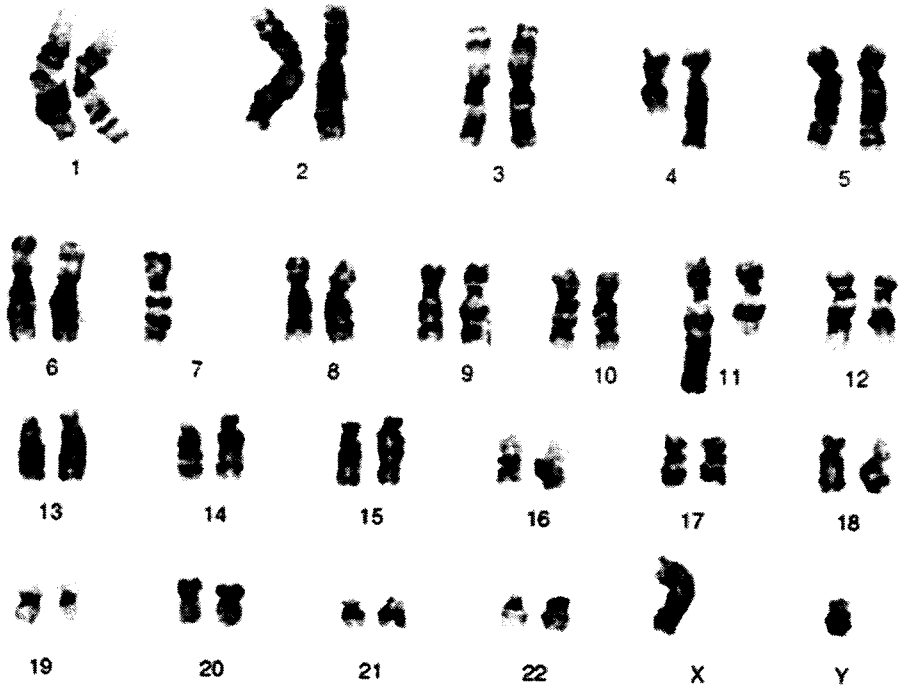


Fig. 6.1

(a) **(i)** Describe two types of chromosomal aberrations evident in Fig. 6.1.

1. **Aneuploidy resulting from the loss of one chromosome 7;**
2. **Translocation of a segment of chromosome 4 to chromosome 11;**

..... [2]

(ii) Acquired chromosome aberrations affecting specific genes are found to be associated with specific types of cancer, such as leukemia.

Explain how the chromosomal aberrations identified in **(a)(i)** could have resulted in uncontrolled division of cells in a leukemia patient.

1. **Aneuploidy may have led to a loss of tumour suppressor genes / translocation may have led to a disruption of tumour suppressor genes, such that tumour suppressor proteins are not produced/ are non-functional;**
2. **cells with damaged DNA bypass cell cycle checkpoints/ cannot undergo DNA repair/ apoptosis;**
3. **translocation may have brought a proto-oncogene under the control of a strong promoter such that excess proteins are produced/ formation of an oncogene which codes for a hyperactive protein;**
4. **resulting in cell cycle progression despite a lack of growth signals;**

..... [4]

The effect of papaya peel extract on the ability of human tumour cells to divide was investigated. Different concentrations of papaya peel extract were added to cultures of human liver tumour cells, which were then incubated at 37°C. Table 6.1 shows the percentage of tumour cells that are still able to divide after incubation for 48 hours.

Table 6.1

papaya peel extract concentration/ μg cm^{-3}	percentage of tumour cells that are able to divide
0	100
5	63
10	58
20	46
40	40
80	37

(b) (i) Suggest how the papaya peel extract could prevent the tumour cells from dividing by targeting specific phases of mitosis.

Extract may contain enzymes inhibitors/ proteins which	**E.g. possible mechanism**
1. Inhibit prophase;	**2. by preventing chromatin condensation/ nuclear envelope disintegration;**
3. Inhibit metaphase;	**4. by preventing spindle fibres attachment to kinetochore complex at the centromere of chromosomes;**
5. Inhibit anaphase;	**6. by preventing separation of sister-chromatids to opposite poles of the cell;**
7. Inhibit telophase;	**8. by preventing formation of nuclear envelope;**

Max 1m for named stage + 1m for corresponding mechanism

..... [2]

(ii) A student stated that 80 μg cm^{-3} of papaya peel extract would be suitable as a treatment for skin tumours in humans.

State the reasons why this statement is **not** supported by this study.

1. **<u>37%</u> of cancer cells are still able to divide;**
2. **study is done on liver cancer cells, not on skin cancer cells, so effectiveness of extract on skin cancer cells is unknown;**
3. **unknown side effects;**
4. **effects *in vivo* are unknown;**
5. **skin may not be permeable to extract if applied topically/ unknown concentration arrives at cells if extract is ingested;**

max 2m

..... [2]

[Total: 10]

7 Watermelon is a popular fruit crop. The colour intensity of watermelon flesh is a characteristic that some consumers look out for, as there is a perceived positive correlation of flesh colour intensity with sweetness.

Flesh colour intensity is controlled by gene **R/r**, in which allele **R** gives rise to scarlet red flesh (darker shade), while allele **r** gives rise to coral red flesh (lighter shade). Analysing the sequence of the alleles showed that allele **R** had a restriction site for the restriction enzyme *Hpa*II. This restriction site is absent in allele **r** due to a single nucleotide substitution.

Gene **T/t** codes for a sugar transporter which is responsible for different sweetness levels in the different cultivars.

The scientists then carried out an analysis of three generations of watermelon plants (I to III). The fruits produced by each plant were assessed for two features:

- the presence or absence of the *Hpa*II restriction site
- sweetness (the fruits were classified "sweet" or "not as sweet")

Fig. 7.1 shows the pedigree of the three different generations of watermelon plants.

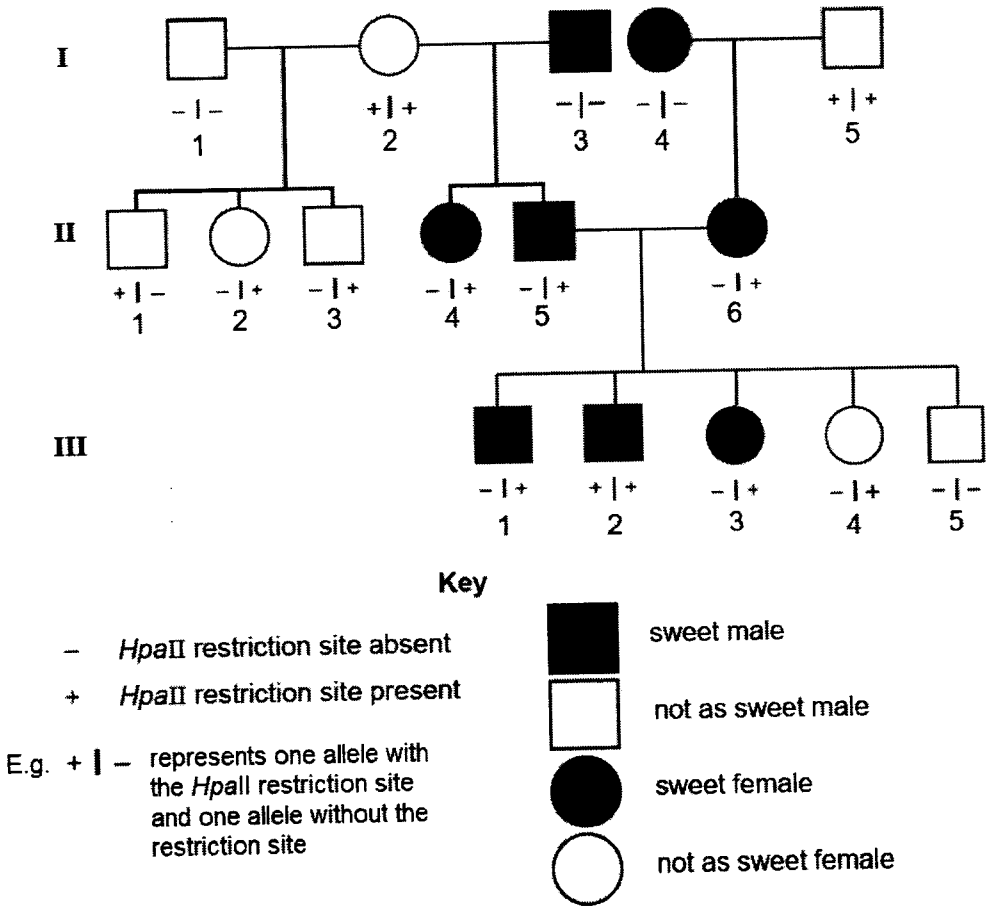


Fig. 7.1

(a) With reference to Fig. 7.1, identify an evidence that supports these statements:

(i) the sweet phenotype is due to a dominant allele.

Individuals II-5 and II-6 are both sweet, but they give rise to offspring which are sweet and not so sweet, hence indicating that II-5 and II-6 are heterozygotes (and the not-so-sweet phenotype will only be phenotypically expressed in homozygous recessive individuals);

..... [1]

(ii) the gene **R/r** is located on an autosome.

1. **All individuals have two alleles (which can be seen from having -/-, -/+ or +/+ in all individuals;**
2. **Phenotype of male offspring is not determined only by the female parent/mother e.g. III-5 from II-6, homozygous recessive phenotype due to inheritance from both parents;**

max 1m

..... [1]

(b) The perceived positive correlation of flesh colour intensity and sweetness could be due to complete linkage between genes **R/r** and **T/t**. Using the symbols provided, draw a genetic diagram to show the expected phenotypic ratio for the cross between individuals II-5 and II-6 if genes **R/r** and **T/t** are completely linked.

Parental phenotype **Scarlet Red, Sweet** **x** **Scarlet Red, Sweet**
Parental genotype **(Rt)(rT)** **x** **(Rt)(rT)** ;

Gametes (Rt) (rT) (Rt) (rT) ;

	(Rt)	(rT)
(Rt)	(Rt)(Rt) **Scarlet red, Not so sweet**	(Rt)(rT) **Scarlet red, Sweet**
(rT)	(rT)(Rt) **Scarlet red, Sweet**	(rT)(rT) **Coral red, Sweet**

Correct genotype;
Correct phenotype;

Offspring phenotypic ratio
1 Scarlet red, Not so sweet : 2 Scarlet red, Sweet : 1 Coral red, Sweet ;

[5]

(c) State the expected phenotypic ratio for the cross between individuals II-5 and II-6, if genes **R/r** and **T/t** segregate independently.

9 scarlet red flesh and sweet : 3 scarlet red flesh and not so sweet : 3 coral red flesh and sweet : 1 coral red flesh and not so sweet;

***compulsory to see phenotypes, not just the numbers**

..... [1]

(d) The scientists aim to verify if there is a positive correlation between flesh colour intensity and sweetness.

A cross is carried out between two individuals which are heterozygous for both the genes **R/r** and **T/t**.

State the null hypothesis and statistical test that would need to be carried out in order to verify the correlation.

Null hypothesis:

The expected ratio of the cross follows a Mendelian inheritance (9:3:3:1), hence the difference between the observed and expected numbers is due to chance / not significant;

Statistical test:

Chi-Squared test;

..... [2]

[Total: 10]

For Examiner Use

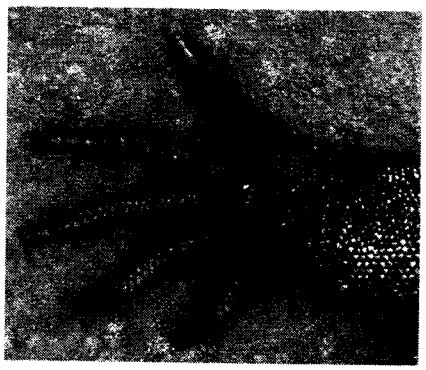
8 The Galapagos marine iguanas (*Amblyrhynchus cristatus*) inhabit the coastlines of islands throughout the Galapagos archipelago. They mainly live in colonies on rocky shores, where they bask after foraging for underwater algae and seaweed in the relatively cold waters. The rocks on which they bask on are occasionally exposed to heavy waves. Like other reptiles, they are ectotherms with limited physiological means of keeping their body temperature constant and often rely on external sources of heat.

Morphological and genetic data have revealed that the closest relative of *Amblyrhynchus* is the genus of terrestrial iguanas, *Conolophus*, which is also endemic to the Galapagos.

Fig. 8.1 shows the overall morphology of the marine and terrestrial iguanas, as well as their claw structures.

Marine iguana

Terrestrial iguana



Marine iguana

Terrestrial iguana

Fig 8.1

(a) Based on the information provided, explain how marine iguanas are better adapted to the marine environment compared to terrestrial iguanas.

1. **They have darker skin tone and longer/sharper claws (compared to the terrestrial iguana counterparts);**
2. **Dark skin tones allow the iguanas to rapidly absorb heat (from sunlight) after losing body heat to the cold waters;**
3. **Their claws are long / sharp for clinging to rocks on shore exposed to strong waves;**

..... [3]

Scientists have observed 17 populations of the Galapagos marine iguanas, all belonging to the same species, on the different islands in the archipelago.

The *cytochrome b* (*cytb*) gene of the mitochondrial genome was analysed and compared across the 17 iguana populations. Based on the analysis, scientists were able to identify three major clades as shown in the phylogenetic diagram in Fig. 8.2.

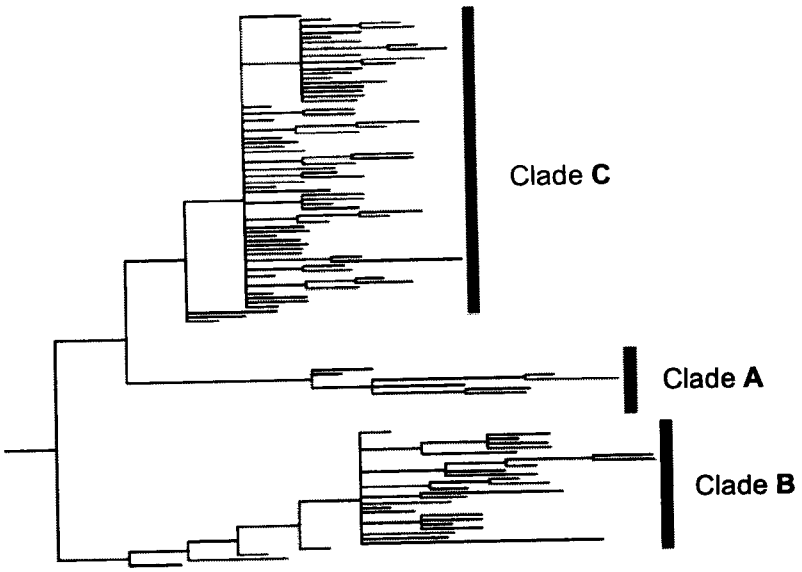


Fig. 8.2

(b) **(i)** Define what is meant by a "clade" as shown in Fig. 8.2.

A group consisting of a single common ancestor and all its descendants, (where all members of the clade share similarities in DNA sequences of the *cytb* gene);
R! ref. to species

..... [1]

(ii) Explain what the branch lengths of the phylogenetic diagram in Fig. 8.2 represent.

1. **Branch lengths show the number of differences in base sequence of DNA between descendants;**
2. **Which arose due to mutations accumulated since divergence from the last common ancestor;**

..... [2]

Fig. 8.3 maps the phylogeographic distribution of the three clades on the Galapagos islands, where the circles represent the proportion of the different clades of marine iguanas on each island.

It is known that the volcanic islands of Galapagos did not emerge at the same time, but progressively over a period of three million years. The map indicates the age of each island in mya (million years ago). The nearest mainland country, Ecuador, is 900 km east of these islands.

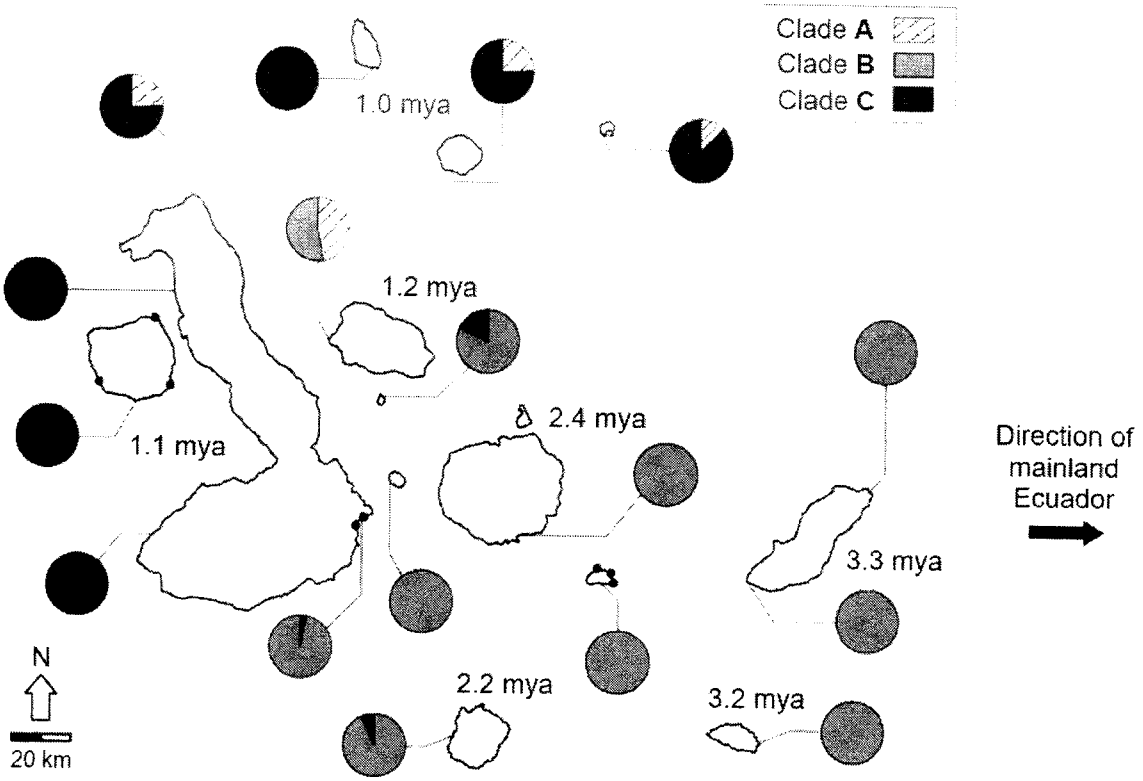


Fig. 8.3

(c) (i) With reference to Fig. 8.3, describe how the phylogeographic distribution of marine iguanas (*A. cristatus*) belonging to clades **B** and **C** differ.

Iguanas belonging to <u>clade B</u> are found predominantly on the islands in the East and South while iguanas belonging to <u>clade C</u> mainly inhabit the islands in the West and North / North-West;

..... [1]

(ii) Suggest an explanation for the difference in phylogeographic distribution described in (c)(i).

1. **The Eastern islands formed earlier between 3.2 to 3.3 mya, followed by the West /Northern islands which are formed between 1.0 to 1.2 mya;**
2. **The ancestral population could have colonised the Eastern islands from mainland Ecuador;**
3. **New clades may be formed due to geographical isolation by the water bodies, which limited gene flow between populations on different islands;**
4. **Genetically similar/related populations tend to be found on islands in geographical proximity;**
5. **Different islands may have varying environmental conditions which exert different selection pressures;**
6. **Hence different clades may experience different reproductive success on each island, resulting in the different proportions of iguanas from each clade;**

max 3m

..... [3]

[Total: 10]

9 Glucose is an important substrate in cellular respiration. Fig. 9.1 shows the mTOR signalling pathway that drives cell growth by greatly stimulating glucose uptake and utilisation in a normal cell.

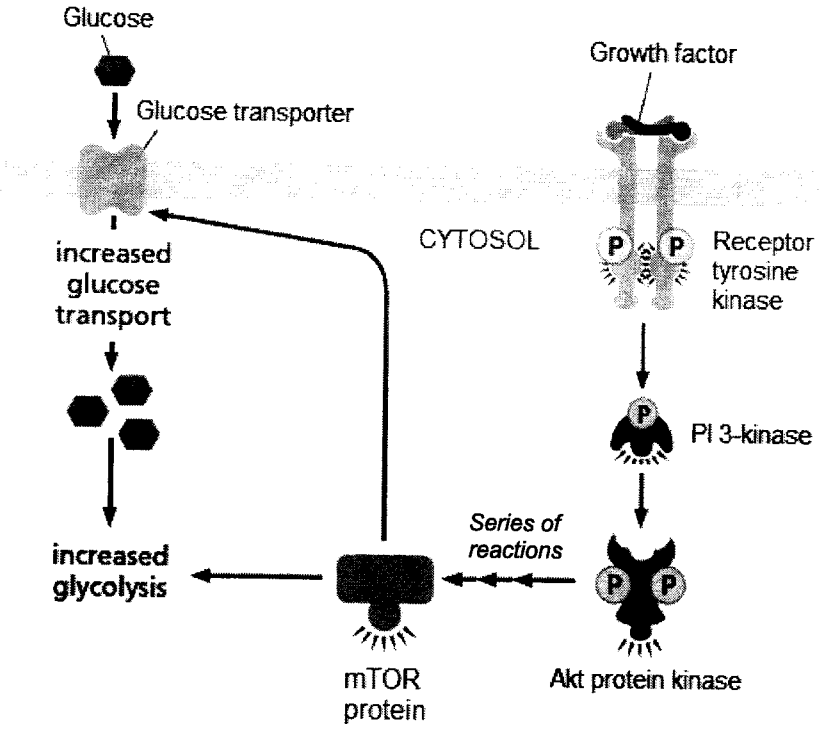


Fig. 9.1

(a) **(i)** State one chemical property of the growth factor.

It is hydrophilic / polar / charged;

..... [1]

(ii) Describe how the binding of PI 3-kinase to the receptor tyrosine kinase leads to the cellular responses in Fig. 9.1.

1. **PI 3-kinase binds to specific phosphorylated tyrosine residues on the receptor and becomes <u>phosphorylated</u> and <u>activated</u>;**
2. **PI 3-kinase binds to <u>Akt protein kinase</u>, <u>phosphorylating</u> and <u>activating</u> it, which in turn activates other protein kinases via a <u>phosphorylation cascade</u>;**
3. **Last protein kinase / relay protein in the phosphorylation cascade <u>activates mTOR protein</u>, increasing glucose transport / glycolysis;**
4. **This is due to translocation of glucose transporters to the cell surface membrane, increasing permeability of cell to glucose / activation of enzymes which carry out glycolysis;**

max 3m

..... [3]

The abnormal growth of cancer cells is highly dependent on increased glucose uptake and reliance on glycolysis for ATP production.

Recently, it has been suggested that having a ketogenic diet may be more inexpensive and easier to adopt than certain traditional anti-cancer therapies. A ketogenic diet is characterised by a high-fat and low-carbohydrate intake which is expected to decrease blood glucose levels and conversely increase ketone body levels. It is found that ketone bodies cannot be utilised by cancer cells.

Fig. 9.2 shows the effect of a ketogenic diet on a normal cell, where the decrease in glucose availability prevents some cellular processes from occurring.

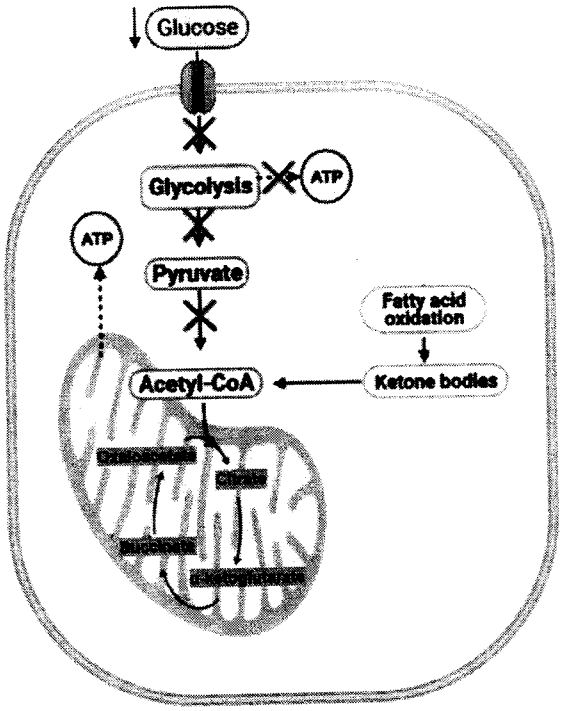


Fig. 9.2

(b) (i) Describe how a ketogenic diet could act as a possible anti-cancer treatment.

1. **Cancer cells would not be able to synthesise acetyl-CoA due to lack of glucose and inability to utilise ketone bodies;**
2. **ATP cannot be produced by substrate level phosphorylation during glycolysis, which cancer cells are reliant on;**
3. **ATP cannot be produced by substrate level phosphorylation during Krebs cycle (as acetyl-CoA is not produced);**
4. **ATP cannot be produced by oxidative phosphorylation due to the lack of NADH and $FADH_2$ molecules (as Krebs cycle does not occur);**
5. **No ATP is available for the growth and proliferation of cancer cells;**

max 4m

..... [4]

For Examiner Use

(ii) While ketogenic diets show promise in limiting cancer cell proliferation, there are also concerns regarding its usage over a longer period of time.

Suggest the possible implications of having a ketogenic diet in the long term.

1. **There is a need to evaluate effect of different fatty acids as certain fats are not healthy;**
2. **A diet high in fat may lead to other health complications such as obesity;**
3. **Nutrient deficiencies could develop depending on what kinds of food are part of the diet (e.g. consuming less staple food such as rice and noodles);**
4. **Not all cell types in the body may be able to utilise fatty acids as a source of energy;**

max 2m

..... [2]

[Total: 10]

For Examiner Use

10 One distinctive feature of the adaptive immune system is the ability to generate millions of different antibody molecules to specifically target different foreign antigens.

(a) Fig. 10.1 shows the structure of a typical antibody, where two major segments of the antibody have been labelled with blank boxes.

Using the letters '**S**' to represent somatic recombination, '**H**' to represent hyper-mutation, and '**C**' to represent class switching, indicate in the blank boxes which segment of the antibody is affected by each of the three processes (each box may be filled by more than one symbol).

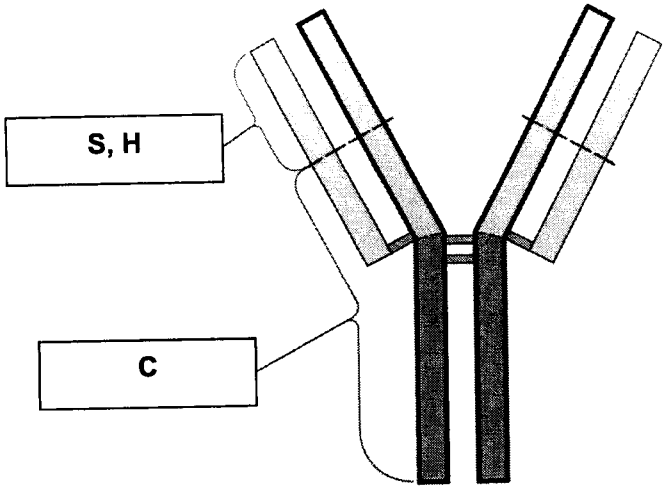


Fig. 10.1

[3]

Fig. 10.2 shows the concentrations of different antibody types following an initial exposure to a specific antigen and a repeated exposure to the same antigen.

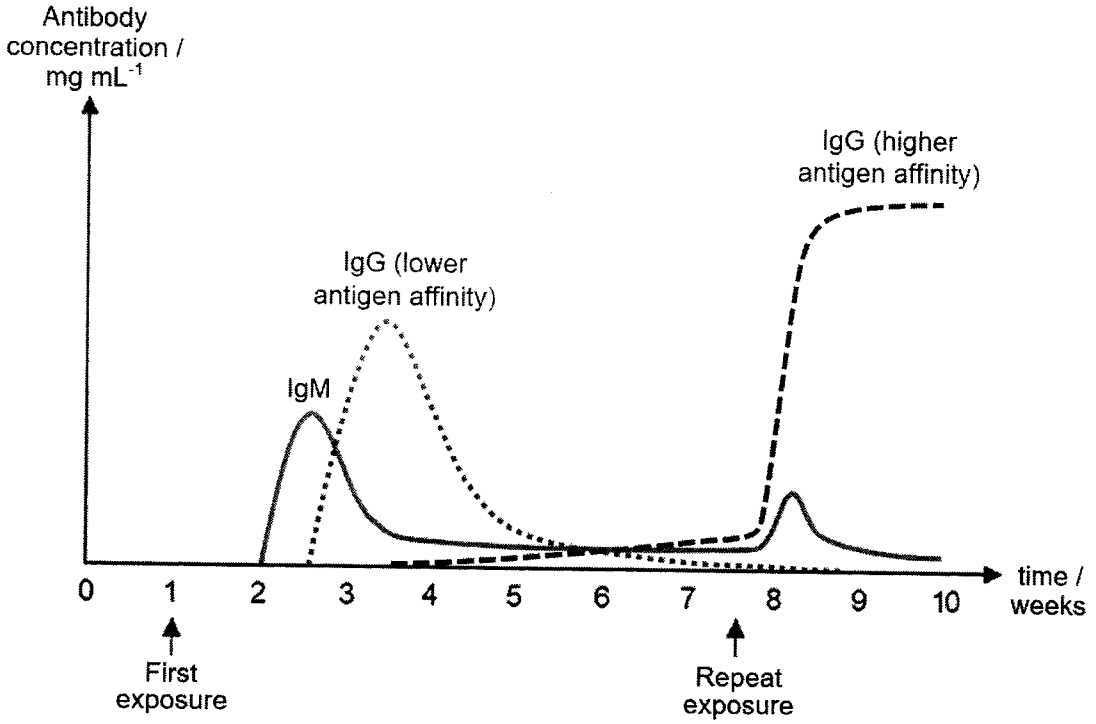


Fig. 10.2

(b) With reference to Fig. 10.2, explain how the type of antibody secreted by B cells changes during the primary immune response.

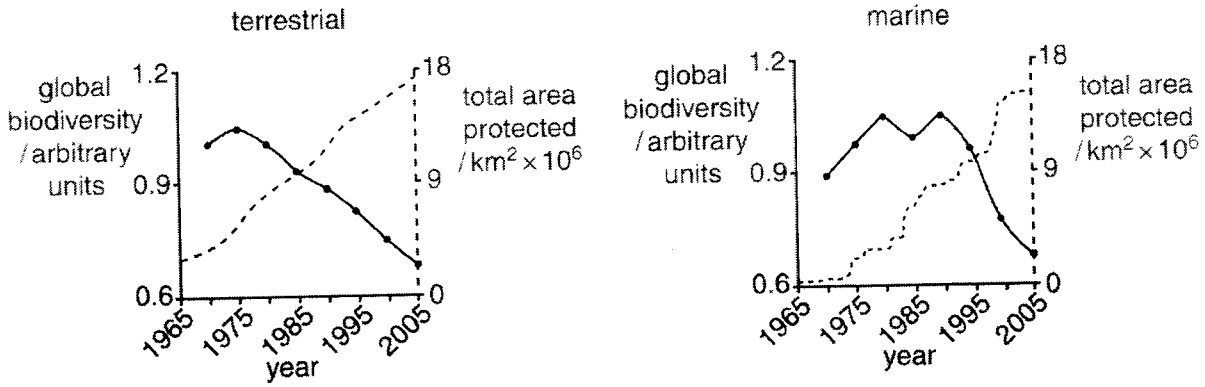
1. **IgM is the first class of antibody to be secreted by B cells, with secretion starting at week 2 / peaking at week 2.5;**
2. **IgG secretion occurs later only after class switching has taken place, with secretion starting at week 2.5 / peaking at week 3.5;**
3. **IgG of higher binding affinity to antigen is only secreted after somatic hypermutation / affinity maturation has taken place, with a low concentration secreted starting at week 3.5 during the primary immune response;**

..... [3]

[Total: 6]

11 Biodiversity refers to the wide variety of species found in various habitats. To reduce the loss of global biodiversity, large areas of habitat have been protected.

Fig. 11.1 shows the changes in global biodiversity and in the total area protected from 1965 to 2005, in terrestrial and marine habitats.



key:

——— global biodiversity

------ total area protected

Fig. 11.1

(a) (i) Compare the relationship between total area protected and global biodiversity in marine habitats:

- between 1970 and 1990, and
- between 1990 and 2005.

1. **Between 1970 and 1990, as total protected areas increased, global biodiversity increased;**
2. **As total protected areas increased from 0 km² x 10⁶ in 1970 to 8 km² x 10⁶ in 1990, global biodiversity increased from 0.9 arbitrary units to 1.05 arbitrary units;**
3. **exceptions; e.g. dip from 1980 till 1985;**
4. **Between 1990 and 2005, as total area protected increases, global biodiversity decreases;**
5. **As total protected areas increased from 8 km² x 10⁶ in 1990 to 16 km² x 10⁶ in 1990, global biodiversity decreased from 1.05 arbitrary units to 0.7 arbitrary units;**

A! a.u. after defining once
max 4m

..... [4]

For Examiner Use

(ii) Suggest why a smaller area of marine habitats has been protected than of terrestrial habitats.

1. **marine environments are difficult to patrol/ monitor;**
2. **lack of public, awareness / interest;**
3. **International ownership issues; A! example**
4. **difficult to, set /mark / recognise, boundaries;**
5. **AVP; e.g. problem of mobile populations thus difficult to decide on area to protect;**

max 1m

..... [1]

[Total: 5]

Anglo-Chinese Junior College

JC2 Biology Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		FORM CLASS	
TUTORIAL CLASS		INDEX NUMBER	

BIOLOGY
Paper 3 Long Structured and Free-response Questions

9744/03
30 August 2022
2 hours

Candidates answer on the Question Paper.
Additional Materials: Writing paper(s)

READ THESE INSTRUCTIONS FIRST

Write your Name, Class and Index number in the spaces at the top of this page.
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.

Section A
Answer **all** questions.

Section B
Answer any **one** question on the separate writing paper(s) 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.

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 the writing paper(s) used securely together.

For Examiners' use only	
Section A	
1	/ 30
2	/ 10
3	/ 10
Section B	
4 or 5	/ 25
Total	/ 75

This document consists of 19 printed pages.

[Turn over

For Examiner's Use

Section A

Answer **all** the questions in this section.

1 The Human Immunodeficiency Virus (HIV) is an enveloped virus that consists of glycoproteins on its surfaces. Fig. 1.1 shows the structure of an Env glycoprotein on HIV.

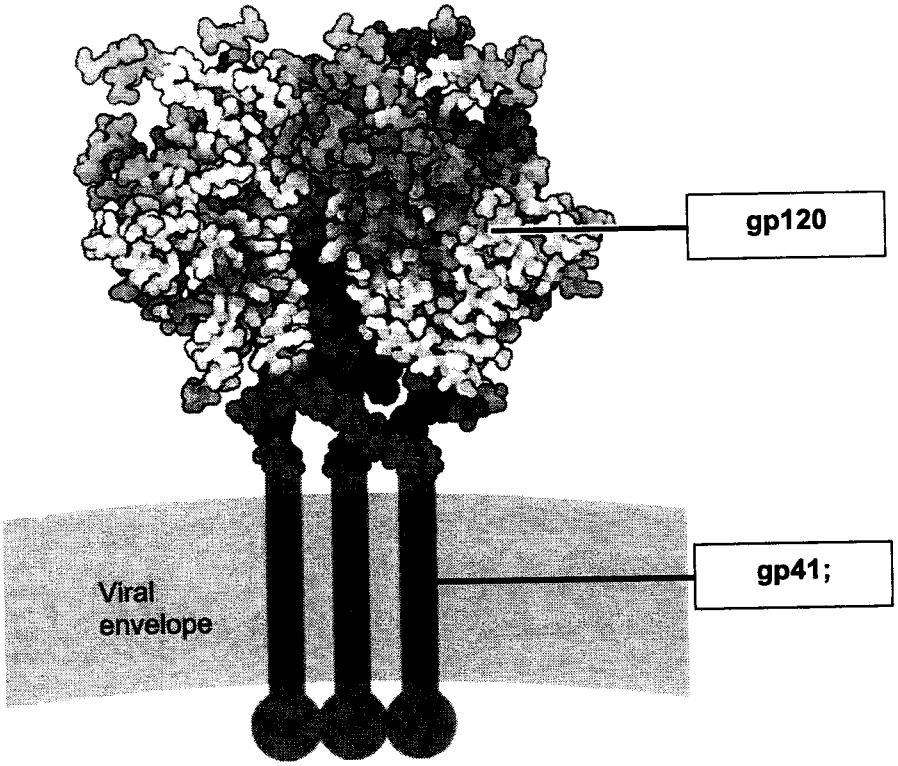


Fig. 1.1

(a) (i) The Env glycoprotein is made up of two associated subunits.

In the boxes in Fig. 1.1, state the name of these two subunits.

@1m for correctly labelled gp120 and gp41 [1]

(ii) Describe how the glycoprotein interacts with the viral envelope.

1. **The glycoprotein contains amino acid residues with <u>hydrophobic/ non-polar R groups</u> which can interact with the <u>hydrophobic hydrocarbon tails/ fatty acid chains</u> of the viral envelope;**

.....

2. **Forming weak <u>hydrophobic interactions</u>;**

.....

@1m each

..... [2]

For Examiner's Use

(iii) HIV envelope proteins are glycosylated by host cell enzymes as HIV genome does not encode gene products capable of synthesising carbohydrates.

Suggest how glycosylation of HIV envelope proteins may impair the host immune response to HIV infection.

1. **The carbohydrates are added by host enzymes thus are 'self' glycans/ disguised HIV envelope proteins as 'self'/ self-antigens/ not foreign;**
   OR
   carbohydrates added are able to shield HIV surface proteins/ result in a change in the conformation of glycoproteins;

.....

2. **prevent recognition/ binding by the immune cells or antibodies/ evades detection by immune system;**

.....

@1m each

..... [2]

(b) Describe the interactions between HIV and the host cell to enable the entry of the virus into the cell.

1. **<u>gp120</u> on the envelope of HIV binds to the <u>CD4 receptor</u> and a <u>co-receptor</u> on the helper T cell/ host cell;**

.....

2. **This binding triggers an allosteric/ conformation change in <u>gp41</u>, which penetrates the host cell surface membrane;**

.....

3. **The envelope membrane of the virus <u>fuses</u> with the host cell surface membrane;**

.....

4. **The nucleocapsid is released into the cytoplasm, the capsid is degraded and the HIV genome and enzymes are released;**

.....

@1m each, max 3m

..... [3]

For Examiner's Use

Upon entry into the host cell, HIV uses the enzyme reverse transcriptase to reverse transcribe its RNA genome into double-stranded DNA for integration into the host genome.

Reverse transcriptase is made up of two subunits, forming two different active sites that are essential for its function. Fig. 1.2 shows the location of these active sites on the enzyme with its newly formed double-stranded DNA.

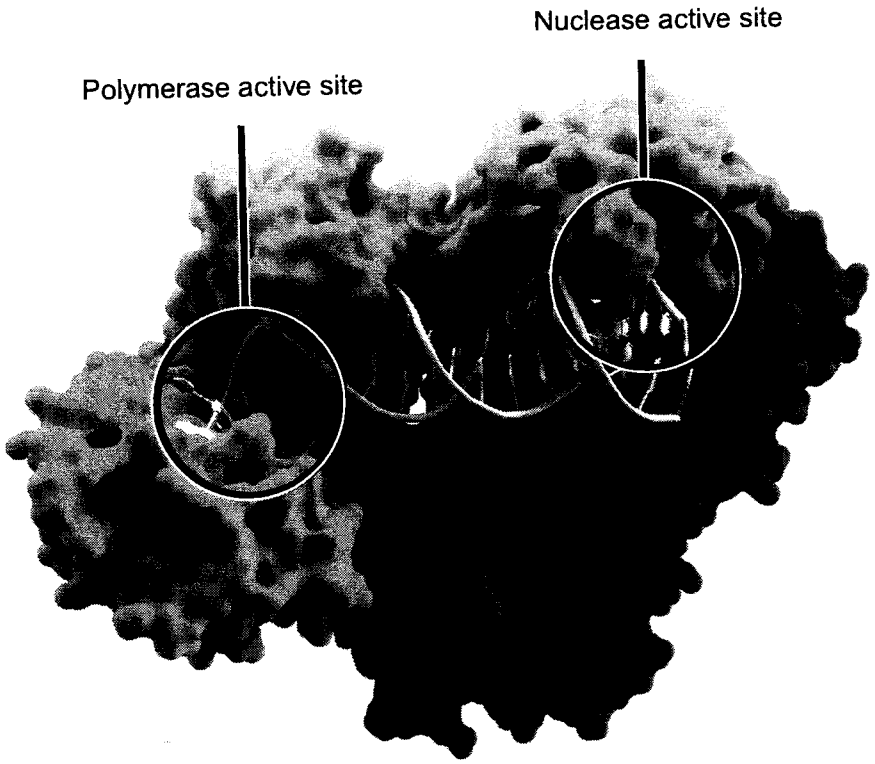


Fig. 1.2

(c) (i) Explain what determines the precise positions of these two active sites in the structure of reverse transcriptase.

1. **Primary structure consisting of unique/specific number and sequence of amino acids linked by peptide bonds;**

.....

2. **folded into α-helices and β-pleated sheets that make up secondary structure maintained by hydrogen bonds between the –CO group and the –NH group of the polypeptide backbone;**

.....

3. **Further folding results in 3D conformation/ globular protein/ tertiary structure maintained by hydrogen bonds, ionic bonds, disulfide bonds, and hydrophobic interactions (any 2 bonds) between the R groups of amino acids, forming active sites;**

.....

4. **Association of two subunits by hydrogen bonds, ionic bonds, disulfide bonds, and hydrophobic interactions (any 2 bonds) between the R groups of amino acids in the quaternary structure, forming active sites;**

.....

For Examiner's Use

@1m each

..... [4]

(ii) Compare the structures of reverse transcriptase and DNA.

Similarity:

1. **Both are (two) polymers formed by condensation reactions;**
2. **Both are held by <u>hydrogen bonds</u> / <u>hydrophobic interactions</u>;**

.....

Differences:

2. **Reverse transcriptase is made up of <u>amino acids</u> while DNA is made up of <u>deoxyribonucleotides</u>;**
3. **Reverse transcriptase can be made up of 20 common types of amino acids while DNA can be made up of 4 types of nitrogenous bases;**
4. **Monomers in reverse transcriptase are held by <u>peptide bonds</u> while monomers in DNA are held by <u>phosphodiester bonds</u>;**
5. **Polypeptides in reverse transcriptase are held by <u>ionic bonds</u>, hydrogen bonds, hydrophobic interactions while polynucleotides in DNA are only held by hydrogen bonds, hydrophobic interactions;**
6. **Reverse transcriptase has a <u>globular</u> structure while DNA is <u>helical</u>;**

.....

.

.....

@1m each, 1m for similarity and 1m for difference

..... [2]

For Examiner's Use

One application of reverse transcriptase in research is in a technique called reverse transcription-polymerase chain reaction (RT-PCR). The classical PCR technique can only be applied to DNA strands, whereas RT-PCR allows the application of PCR technique to an RNA template. A potential use of RT-PCR is in the study of gene expression.

Fig. 1.3 illustrates the process of RT-PCR using mRNA as a template. Oligo dT primers, which are single-stranded sequences of repeating deoxythymine, are added to the reaction mixture.

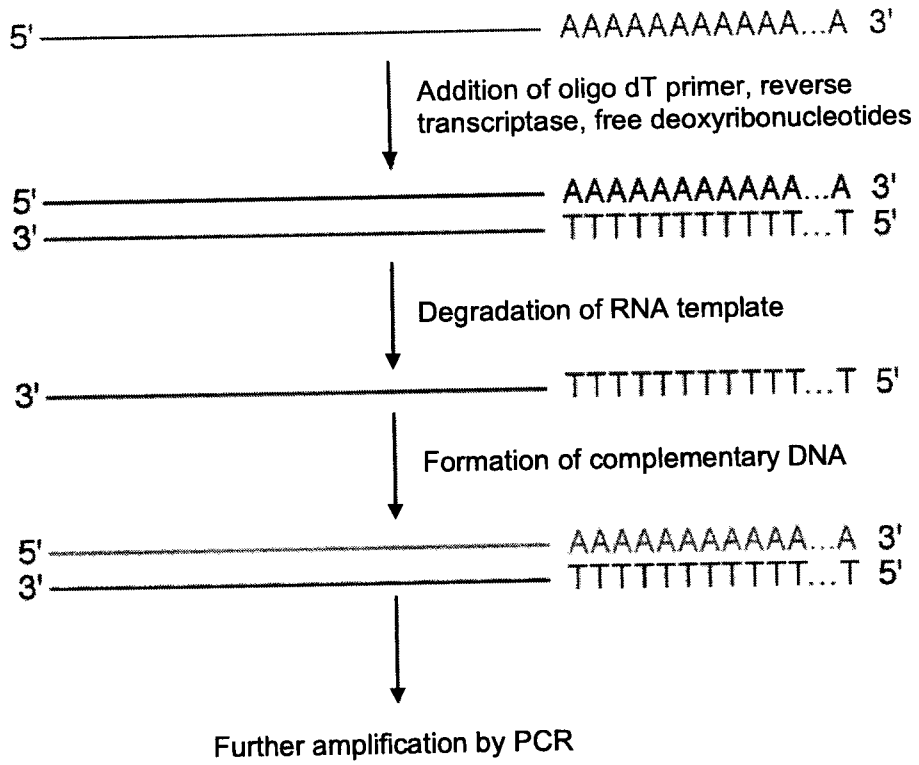


Fig. 1.3

(d) (i) With reference to Fig. 1.2 and Fig. 1.3, explain how reverse transcriptase and oligo dT primers can be used in RT-PCR to study gene expression.

1. ***Oligo dT primers bind to poly-A tail of mRNA via complementary base pairing;**
2. ***Presence of mRNA / formation of cDNA / amplification will indicate that the gene has been transcribed;**

.....

3. **Reverse transcriptase catalyse the synthesis of a DNA strand complementary to mRNA template at its polymerase active site;**

.....

4. **Hydrolysis/ degradation of the RNA strand the occurs at its nuclease active site;**

.....

5. **Reverse transcriptase then catalyses synthesis of a second DNA strand complementary to the first at its polymerase active site;**

For Examiner's Use

@1m each, mp1 or 2 compulsory, max 3m

..... [3]

The relative activity of reverse transcriptase at different temperatures can be investigated using the SYPRO orange fluorescence assay. The reverse transcriptase is incubated with a fluorescent chemical known as SYPRO orange and the temperature is gradually increased. SYPRO orange interacts with the hydrophobic regions in an enzyme which are normally not exposed. The amount of SYPRO orange which binds to an enzyme can be detected by measuring the intensity of the fluorescence.

Fig. 1.4 shows the results of the SYPRO orange fluorescence assay on two types of reverse transcriptase.

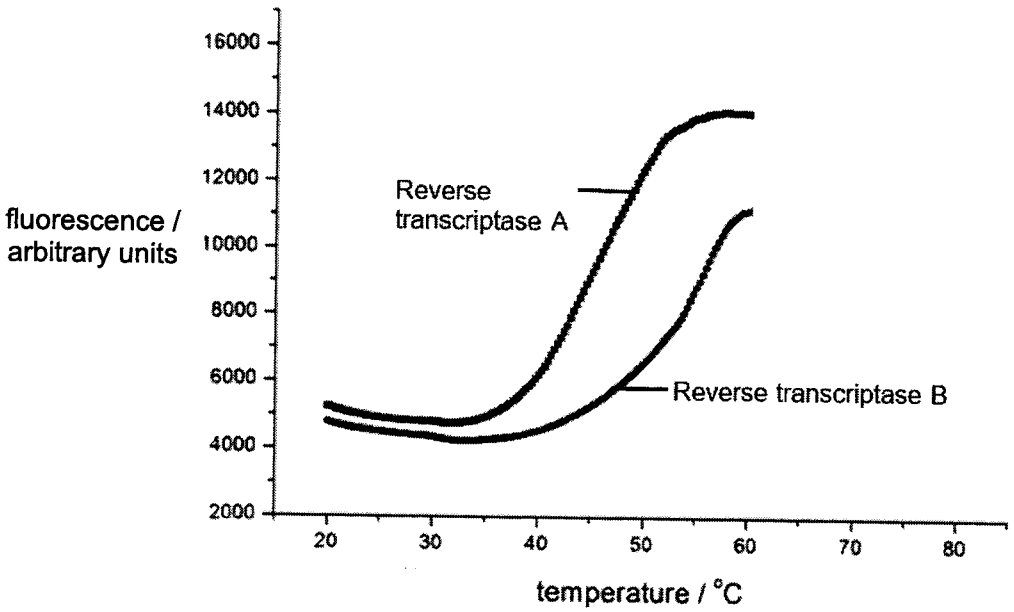


Fig. 1.4

(ii) During RT-PCR, a high incubation temperature may be used.

Suggest and explain which reverse transcriptase is more suitable to be used for RT-PCR.

1. **Reverse transcriptase B;**

.....

2. **As temperature increases, the enzymes denatures/ unfolds, exposing the hydrophobic regions for the binding of SYPRO orange, resulting in an increase in fluorescence intensity;**

.....

3. **At all temperatures from <u>20 to 60°C</u>, fluorescence level of reverse transcriptase B is lower than that of reverse transcriptase A;**

.....

4. **which shows that reverse transcriptase B is <u>more</u> thermostable/ <u>more</u> heatstable/ withstand high temperature/ denature to <u>smaller</u> extent/ denature at <u>higher</u> temperature and likely to remain active during the reaction;**

[Turn over

For Examiner's Use

@1m each

..... [4]

Infections by some viruses are known to increase the risk of cancer development. The HIV weakens the immune system and increases the susceptibility of the body to infections which cause cancer. Other viruses like the human papillomavirus (HPV) can integrate its genome into the host genome and produce highly carcinogenic proteins.

Fig. 1.5 shows how a HPV infection which persists for many years can lead to cellular changes that, if untreated, may result in the formation of a malignant tumour.

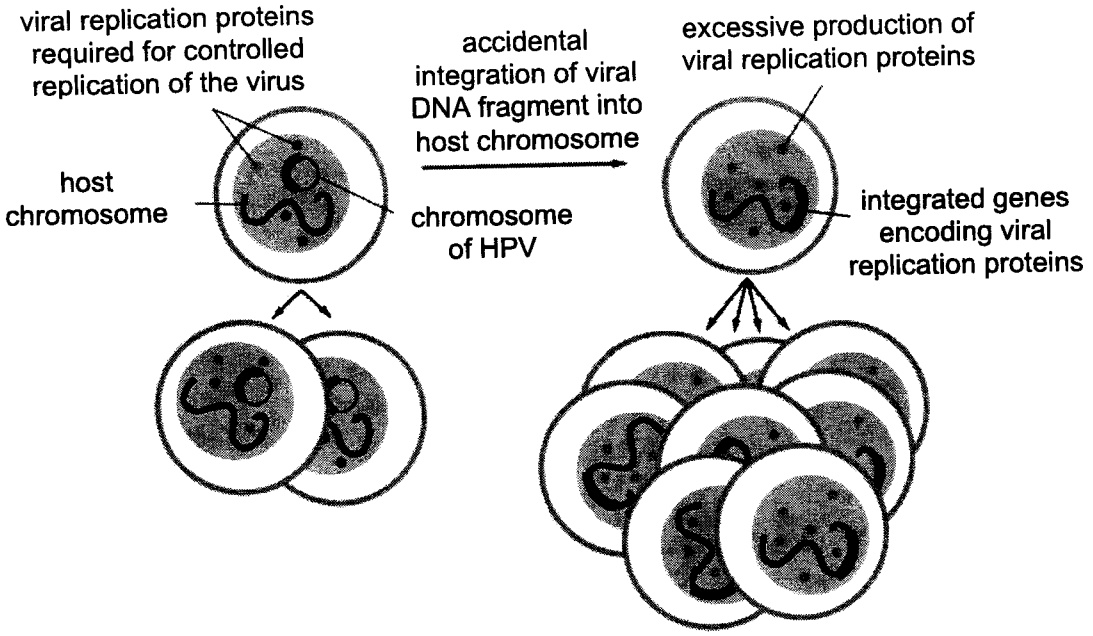


Fig. 1.5

Fig. 1.6(a) shows how proteins regulating the cell cycle checkpoints, such as p53 and Rb protein, keep the cell cycle in check and prevent cell proliferation in a normal cell. Fig. 1.6(b) shows an example of two viral replication proteins, E6 and E7, interfering with p53 and Rb protein function and resulting in excessive cell proliferation.

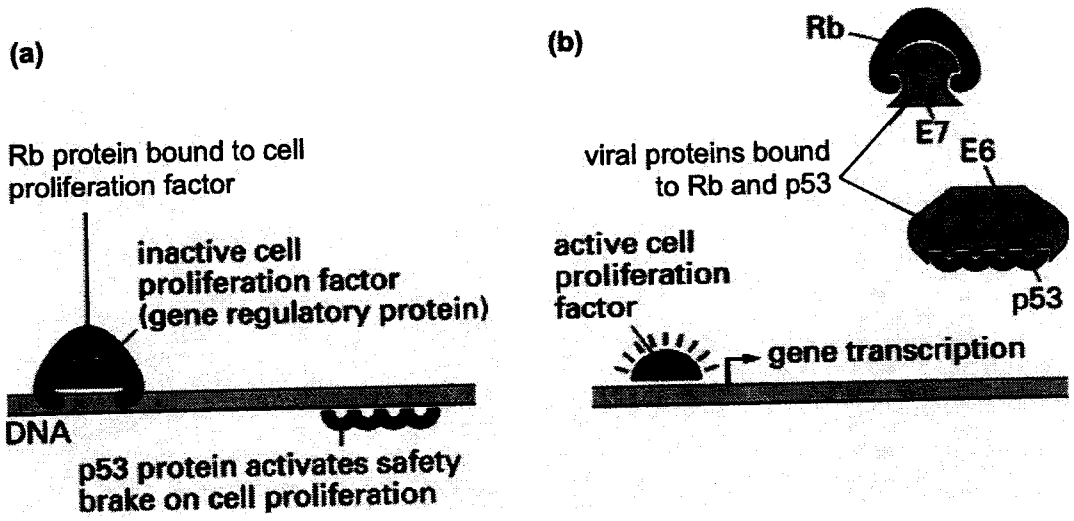


Fig. 1.6

For Examiner's Use

(e) (i) With reference to Fig. 1.5 and Fig 1.6, suggest and explain how a tumour can be formed in patients with HPV infection persisting for many years.

1. **Integration of viral DNA fragment containing genes coding for viral replication proteins into the host cell's genome;**

.....

2. **under the control of an active promoter resulting in excess production of viral replication proteins;**

.....

3. **E6 binds complementary to and sequester p53, prevent cell cycle arrest;**

.....

4. **E7 binds complementary to and sequester Rb protein, prevent inhibition/ results in activation of cell proliferation factor;**

.....

5. **Decreases fidelity of cell cycle checkpoints such that cells with DNA damage can continue to divide uncontrollably;**

.....

@1m each, max 4m

..... [4]

(ii) Suggest a reason why it may take 10 to 20 years for HPV-infected cells to become cancerous.

1. **HPV-infected cells may be detected and removed by immune cells / antibodies;**

.....

2. **Time is required for accumulation of mutations in several tumour suppressor genes / at least one proto-oncogene / genes involved in carcinogenesis/angiogenesis/metastasis etc.;**

.....

3. **Integration of HPV genome only occurs by chance/ is accidental (according to Fig. 15);**

.....

4. **HPVs may remain in latency within the host cell and viral proteins are not produced;**

.....

@1m each, max 1m

..... [1]

[Turn over

For Examiner's Use

HPVs spread easily through direct sexual contact, including vaginal, oral, and anal sex. Fig. 1.7 shows the HPV-associated cancer incidence in the United States between 2008 and 2012.

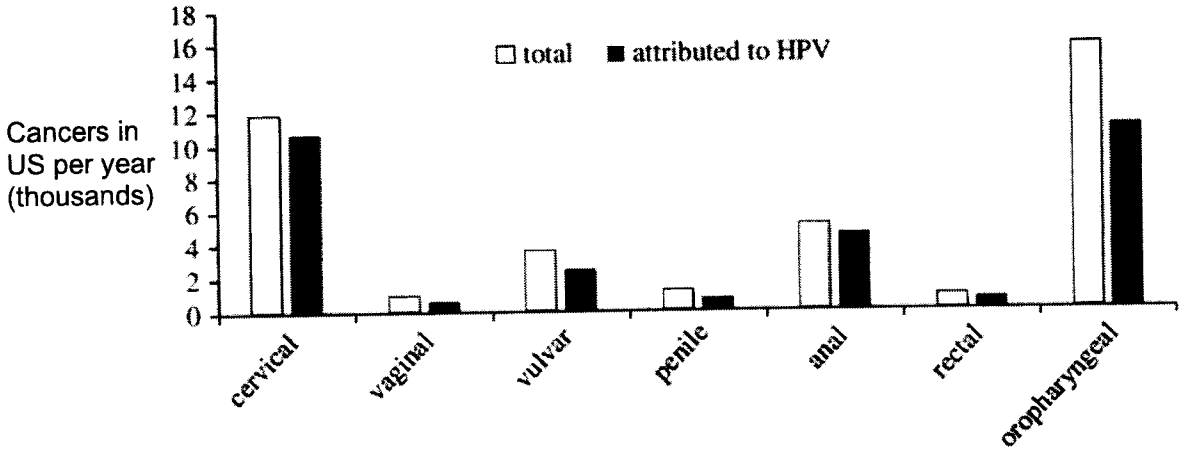


Fig. 1.7

The HPV vaccine was first introduced in 2006, with a recommendation to vaccinate females of ages 11 to 26. With growing evidence supporting the expansion of the vaccine, many countries are extending its coverage to males.

Fig. 1.8 shows the numbers of cancers caused by HPV and the gender distribution for each type of cancer in the United States each year.

Fig. 1.9 shows the estimated effect of HPV vaccination on oral HPV infections among individuals from 18 to 33 years of age in the United States population. Results are presented as the total number of infections in the absence of HPV vaccination, the number of preventable infections at 100% vaccination levels, and the number of potentially vaccine-prevented infections at current HPV vaccination levels in the population.

Fig. 1.10 shows the rates of HPV-associated cancers and age at diagnosis among men in the United States per year.

For Examiner's Use

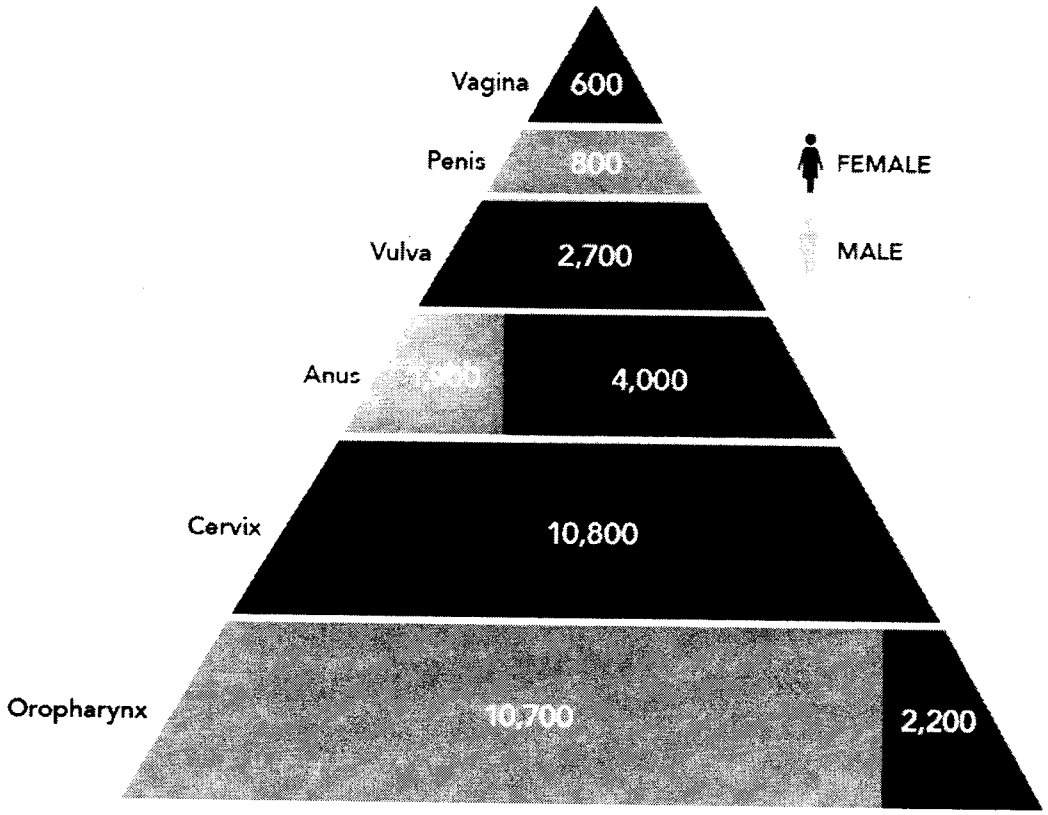


Fig. 1.8

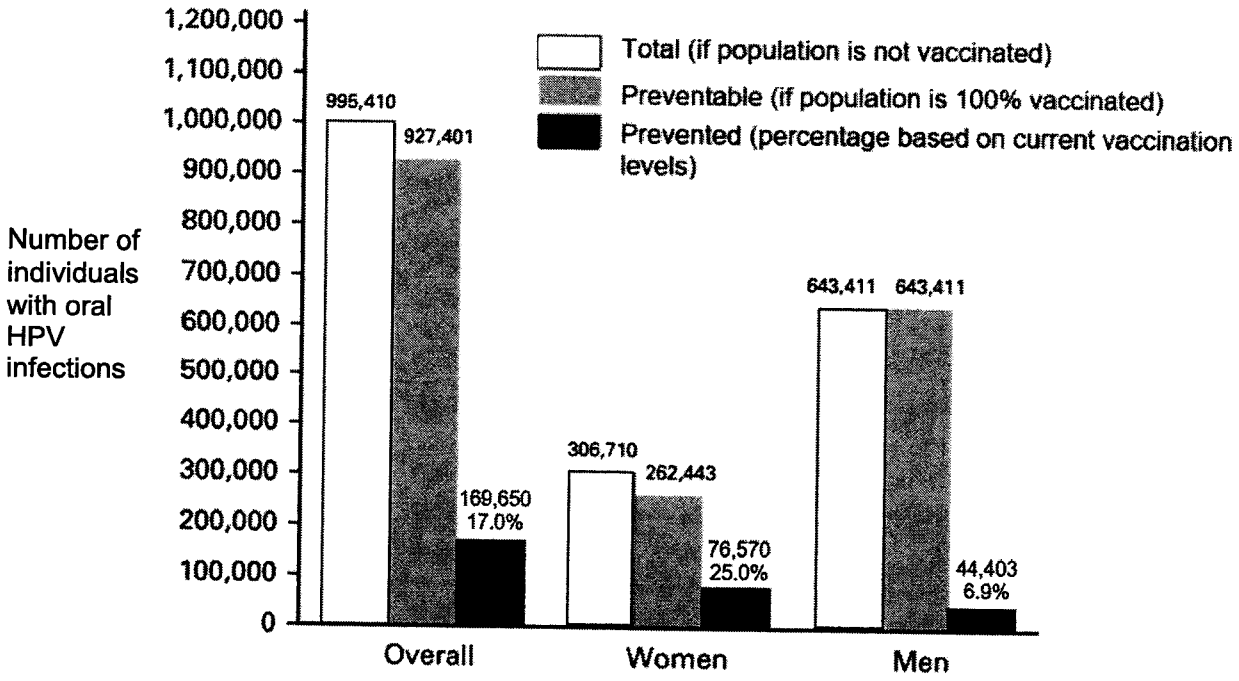


Fig. 1.9

[Turn over

For Examiner's Use

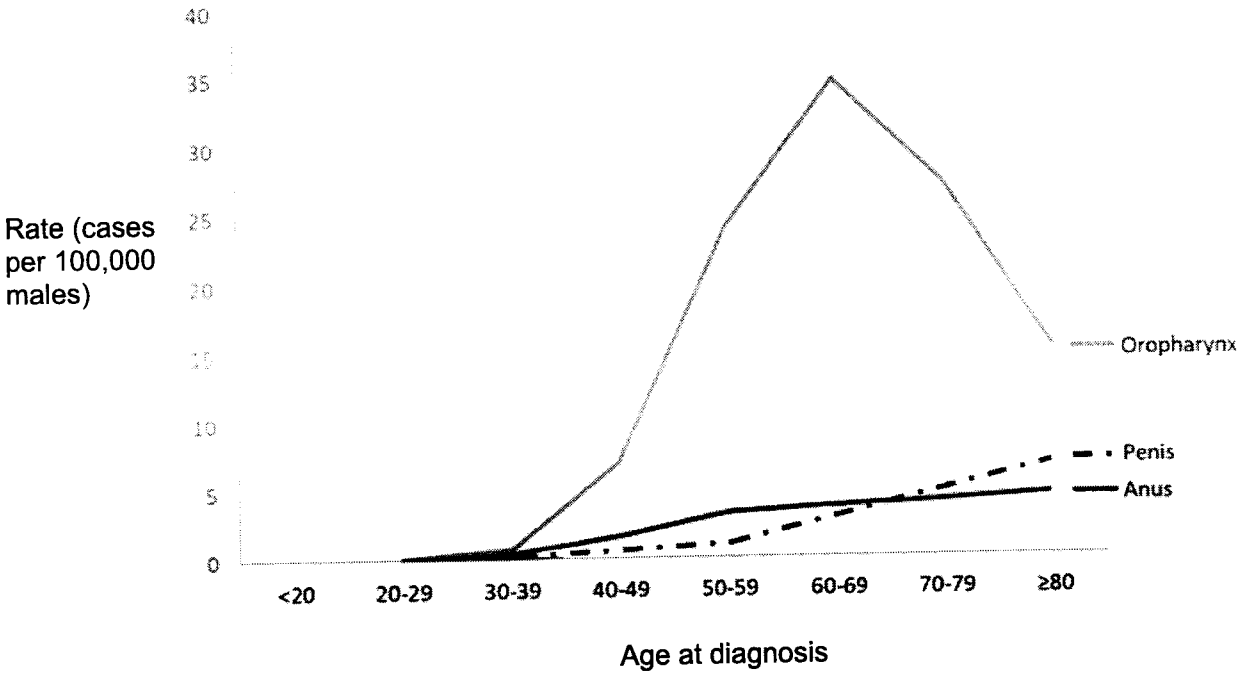


Fig. 1.10

(f) With reference to Fig. 1.7, Fig. 1.8, Fig. 1.9 and Fig. 1.10, discuss why HPV vaccination should be encouraged in young males less than 20 years old in the United States population to reduce the risk of HPV-associated oropharyngeal cancer.

1. **From Fig. 1.7, majority of oropharyngeal cancer, 11 thousands out of 16 thousands cancers in US per year, is attributed to HPV infection;**

.....

2. **From Fig. 1.8, as many as 10700 cases of HPV-associated oropharyngeal cancer affect males, more so than females at 2200 cases;**

.....

3. **From Fig. 1.9, number of infections prevented by current level of vaccination is low at 6.9%, which implies that current vaccination effort is insufficient;**

.....

4. **From Fig. 1.9, vaccination can prevent 100% of oral HPV infections in men;**

.....

5. **From Fig. 1.10, vaccination should be given earlier than 20 years old as a preventive strategy as the youngest males diagnosed with oropharyngeal cancer is between 20-29 years old/ males are beginning to be diagnosed with oropharyngeal cancer from 20 years old onwards;**

.....

@1m each, max 4m

..... [4]

[Total: 30]

For Examiner's Use

2 The venom of a snake contains many protein toxins which can damage the tissues of a victim who has been bitten. The snake bite can lead to significant disability or death within hours, and an antivenom would be necessary for treatment. The following steps describe how an antivenom is traditionally produced.

- The venom of a snake is collected.
- An animal, often a horse, is injected with a controlled quantity of the venom.
- The horse's blood is withdrawn and the antibodies produced in response to the protein toxins are isolated.
- The isolated antibodies are purified and formulated as an injection.

The antivenom produced is effective only against the species of snake from which the venom is obtained.

(a) (i) State the type of immunity that is conferred by the antivenom when administered to the snake-bite victim.

Artificially-acquired, passive immunity;

..... [1]

(ii) Describe how antibodies in the antivenom may reduce the harmful effects of toxins in the snake venom.

1. **Through neutralisation where the binding of antibodies to the toxin prevents the toxin from binding to host cell receptors;**
2. **Through opsonisation, where the binding of the antibodies mark the toxin for phagocytosis by macrophages;**
3. **Through the activation of complement proteins, triggers the formation of pores in the cell surface membrane/ osmotic lysis of the targeted cell;**

.....

max 1m

..... [1]

(iii) Explain why a particular antivenom is effective only against a specific species of snake.

1. **Venom from different species of snake contain different protein toxins;**

.....

2. **During the production of the antivenom, only B lymphocytes with receptors that have a binding site with a 3D conformation complementary to the protein toxins undergo clonal selection;**
   OR
   The antibodies produced in response to the venom have antigen binding sites / variable domains that have a 3D conformation complementary to the protein toxins;

.....

@1m each

[Turn over

For Examiner's Use

..... [2]

(iv) Suggest why injection with vaccines containing inactivated protein toxins is not an effective treatment for a snake-bite victim.

1. **Vaccines requires several days to take effect, but a snake-bite victim requires immediate treatment;**
   OR
   Vaccination is only effective if administered several days before the bite;

.....

2. **Time is required for antigen presentation/ activation of T and B lymphocytes/ differentiation of B lymphocytes into plasma cells/ synthesis or secretion of antibodies;**

.....

.....

@1m each

..... [2]

Fig. 2.1 shows how the blood withdrawn from the horse is centrifuged to obtain three distinct layers – the blood plasma, a layer of white blood cells, and a layer of red blood cells.

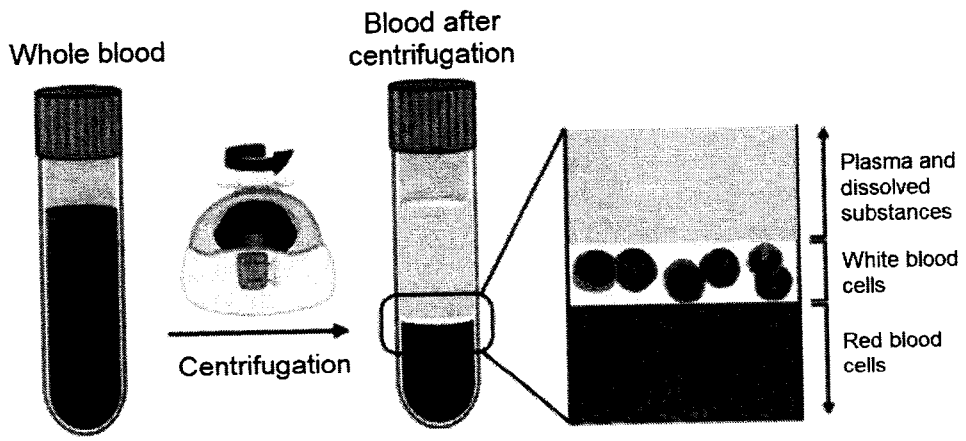


Fig. 2.1

(b) State the layer which the antivenom antibodies would be found in and explain your answer.

1. **Blood <u>plasma</u> / <u>Plasma and dissolved substances</u>;**

.....

2. **Antibodies are <u>secreted/ released</u> by plasma cells into the extracellular compartment, and are globular proteins hence soluble in water/ less dense than cells**

@1m each

..... [2]

For Examiner's Use

Due to a global shortage in supply of antivenoms, scientists are exploring the use of genetically modified *Escherichia coli* to mass produce antivenom antibodies. The genes coding for the antibodies can be inserted into *E. coli* by transformation.

(c) Suggest one advantage and one challenge of using *E. coli* for antivenom production over the traditional method.

Advantage:

1. **More ethically acceptable as no animals have to be exposed to the venom;**
2. **Faster rate of antibody synthesis (due to faster rate of growth and cell division);**
3. **Less space required for production of antibodies/ more economical;**

.....

Challenge:

4. **Method requires the sequence coding for the specific antibody to be known; OR**
5. **Efficiency of inserting the genes by transformation is low; OR**
6. **Bacteria cannot carry out post-transcriptional modification / excision of introns from mRNA; OR**
7. **Bacteria cannot carry out post-translational chemical modification required for antibody synthesis (due to lack of RER & GA);**

.....

.....

@1m max for advantage and @1m max for challenge, max 2m

..... [2]

[Total: 10]

For Examiner's Use

3 Malaria is a mosquito-borne disease caused by a unicellular parasite, *Plasmodium*, which spends a part of its life cycle in a mosquito and a part of it in a human. The mosquito transmits the *Plasmodium* to a human when it feeds on human blood. In the low-lying coastal country of Belize, where malaria is a serious problem, studies have been made to determine the environmental factors which affect the incidence of the disease.

156 villages were studied over a ten-year period. Fig. 3.1 highlights the incidence of malaria in the different districts of Belize.

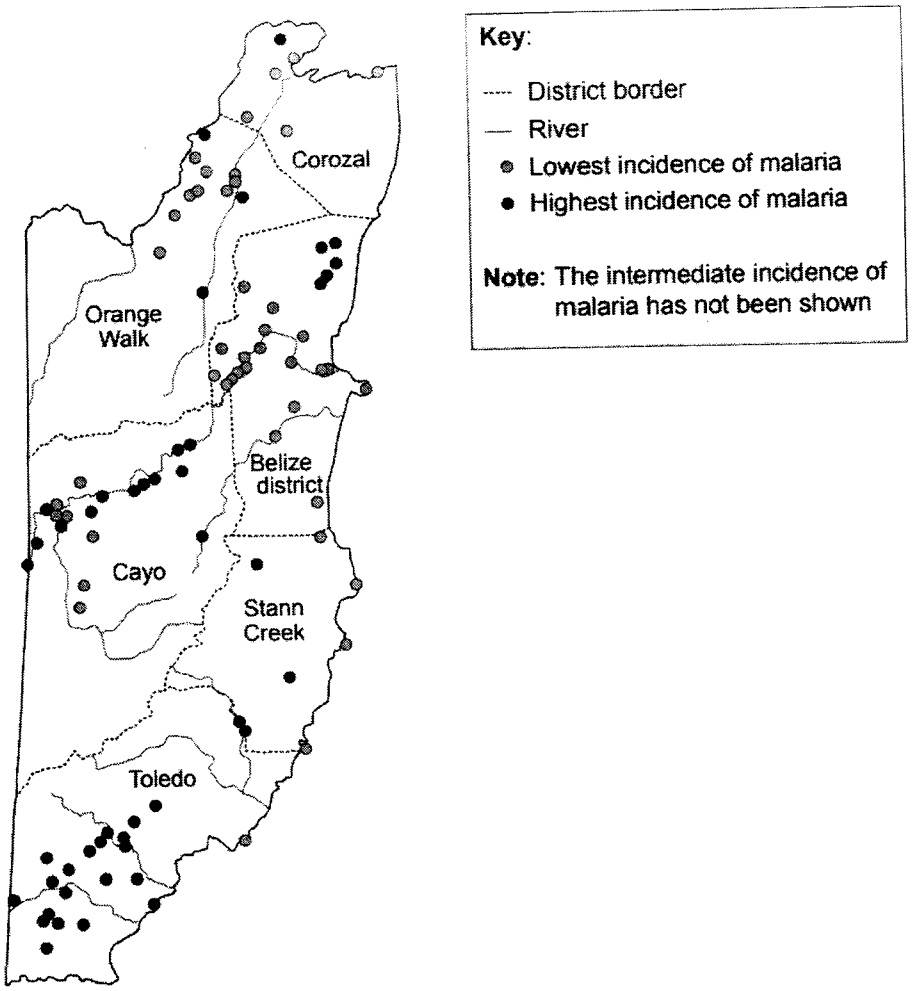


Fig. 3.1

(a) (i) Based on the studies conducted, explain why the association of rivers with a high incidence of malaria is inconclusive.

1. **Although high incidence of malaria can be found near rivers such as in Cayo/ Toldedo/ Orange Walk/ Stann Creek;**
2. **There are rivers with a low incidence of malaria along them such as the river in the Belize District;**
3. **There are rivers with a mixture of high and low incidence of malaria e.g. the river in Cayo;**

.....

4. **Along one river in Toledo/Orange Walk, there is no incidence of malaria recorded at all;**

.....

For Examiner's Use

5. **There is high incidence of malaria found away from rivers such as in the Belize district/Toledo;**

@1m each, max 2m

..... [2]

(ii) Suggest possible factors why the incidence of malaria is low in Corozal compared to other districts.

1. **It has less rainfall hence less stagnant pools of water present, preventing mosquitoes from breeding;**

.....

2. **It experiences higher rainfall hence faster flowing rivers made conditions unfavourable for mosquito breeding;**

.....

3. **More active predators present (such as amphibians) which prey on mosquitoes, reducing their numbers;**

.....

4. **Inhabitants are more aware and practice methods (name/ describe a method) which keep the number of mosquitoes low;**

.....

5. **The district has a smaller population hence the disease does not spread as fast;**
6. **AVP;**

@1m each, max 2m

..... [2]

Table 3.1 shows the total surface area for different types of land use in the country of Belize.

Table 3.1

Land Use		Thousands of hectare
Agricultural	Arable land (suitable for growing crops)	70
	Permanent crops	32
	Pastures	50
Non-agricultural	Forest area	1412
	Other lands	717

(b) **(i)** Calculate the percentage of land used for agricultural purposes in Belize.

1. **Total land used for agriculture = 70 + 32 + 50 = 152 thousands of hectare**
   Total land area in Belize = 70 + 32+ 50 + 1412 + 717 = 2281 thousands of hectare;

2. **152/2281 x 100% = 6.66% (3 sf);**

@1m each

[Turn over

For Examiner's Use

Percentage of land used for agriculture = **6.66** [2]

Climate change is affecting agricultural production and productivity in Belize. Mean annual temperatures have increased at an average rate of 0.1°C per decade since 1960 and climate projections suggest that temperatures could rise by another 1.8°C by 2050. Rainfall is likely to fall throughout the country, with decreases ranging from 7% in the northern zone to 10% in the southern zone. It has also been reported that some farmlands in the southern zone have a high incidence of malaria and pests.

(ii) Explain why converting some of the forests to farmland will worsen the effects of climate change.

1. **Burning trees will release carbon dioxide into the atmosphere;**
   OR
   Burning trees will remove carbon sinks as crops that are planted are less effective carbon sinks than trees;
   OR
   Disturbances during deforestation releases stored carbon in the soil, leading to further carbon emission into the atmosphere;

.....

2. **Increase in greenhouse gas emission which further traps longwave radiation/ heat, worsening the effects of climate change;**

.....

@1m each

..... [2]

(iii) Suggest changes Belize can adopt in its agricultural practices to improve agricultural productivity amidst climate change.

1. **Grow drought-tolerant/heat-tolerant crops;**

.....

2. **Improve water irrigation systems;**
3. **Adjustment of crop planting dates to match rainfall patterns;**

.....

4. **Focus the agricultural practices in the northern areas which do not have high incidence of pests;**
5. **Improve pest-management practices so that crops are not easily eaten by pests;**
6. **AVP;**

.....

@1m each, max 2m

..... [2]

[Total: 10]

For Examiner's Use

Section B

Answer **one** question in this section.

Write your answers on the separate 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 parts **(a)** and **(b)**, as indicated in the question.

4 **(a)** Explain how the structure of proteins that bind to mRNA is linked to their roles in the regulation of eukaryotic gene expression at post-transcriptional and translational levels. [15]

(b) Explain the significance of bond formation in the process of DNA replication and describe how the end-replication problem arises in eukaryotes. [10]

[Total: 25]

5 **(a)** Describe how eukaryotic ribosomes are formed and explain the role of ribosomes in translation. [15]

(b) It is known that the first eukaryotic cells were unicellular and had evolved from a prokaryotic ancestor.

Explain the functions of telomeres and suggest how telomeres may have originated and evolved in early eukaryotes. [10]

[Total: 25]

For Examiner's Use

4 (a) Explain how the structure of proteins that bind to mRNA is linked to their roles in the regulation of eukaryotic gene expression at post-transcriptional and translational levels. [15]

Structure of RNA binding proteins

1. **Enzyme is specific as the active site has a 3D conformation that is complementary to specific sequences it bind to on mRNA;**
2. **The RNA-binding site on proteins has a 3D conformation which is complementary to specific sequences on mRNA, allowing them to bind;**

Roles at post-transcriptional level (max 8m)

3. **Spliceosome recognises splice sites at introns;**
4. **They excise introns and join together exons in RNA splicing;**
5. **They are involved in alternative splicing resulting in synthesis of more than 1 type of polypeptide from the same pre-mRNA / different combinations of exons;**

6. **Poly(A) polymerase / enzyme recognises the 3' end of pre-mRNA;**
7. **Adds (50-250) adenine nucleotides to it, forming the poly A tail;**
8. **Poly(A) binding proteins recognise the 3' poly A tail;**
9. **Bind to it and slow down the degradation of the 3' end of mRNA by exonucleases / promote export of the mRNA from the nucleus / facilitate the initiation of translation;**

9a. **A longer poly A tail increases the stability of the mRNA;**

10. **Enzymes recognise the 5' end of pre-mRNA;**
11. **and add the modified guanosine cap to it;**
12. **Nuclear export proteins recognise the mature mRNA;**
13. **and help direct it to the nuclear pores for export to the cytoplasm/ slow down the degradation of mRNA by exonucleases/ facilitate the initiation of translation;**

Roles at translational level (max 8m)

14. **Deadenylase / enzyme recognises the mRNA poly (A) tail;**
15. **and shortens it;**
16. **triggering enzymes to remove the 5' modified guanosine cap;**
17. **Once the cap is removed, exonucleases rapidly degrade/ shorten half-life of mRNA;**

18. **Specific proteins recognise and bind to the 3' UTR of the mRNA,**
19. **increasing or decreasing the rate of poly-A tail shortening;**

20. **Translation initiation factors facilitate the binding of the small ribosomal subunit to mRNA / recruit the initiator tRNA, Met-tRNA, to the start codon, AUG;**
21. **When activated or inactivated, translation initiation factors will affect translation of all the mRNAs in a cell;**

22. **Translation repressor proteins recognise and bind to the mRNA at the 5' UTR,**
23. **preventing the small subunit of the ribosome from binding / ribosome assembly;**

24. **Poly(A) polymerase / enzyme (in the cytoplasm) recognises mRNAs with poly A tails of insufficient length;**
25. **adds more adenine nucleotides to it, allowing translation of these mRNAs to begin;**

26. QWC: At least 1 correct point from the structure + 1 correct role in post-transcriptional + 1 correct role in translational;

For Examiner's Use

For Examiner's Use

4

(b) Explain the significance of bond formation in the process of DNA replication and describe how the end-replication problem arises in eukaryotes. [10]

Significance of bond formation (max 7m)

1. **Formation of temporary bonds such as hydrogen bonds, ionic bonds, hydrophobic interactions (any 2) is required for protein/enzyme binding to DNA;**

2. **Binding of helicase to the origin of replication to cause the DNA molecule to unwind and unzip / allow formation of the replication bubble;**
3. **Binding of topoisomerase ahead of the replication fork to make a transient double-stranded break / to prevent the formation of supercoils;**
4. **Binding of single-stranded DNA binding proteins to separated parental DNA strands to prevent reannealing;**
5. **Binding of primase to the template DNA strand to synthesise a short RNA primer;**
6. **Binding of DNA polymerase III to the 3'OH group of an elongating DNA strand for the addition of new deoxyribonucleotides;**
7. **Binding of DNA polymerase I to the RNA primer to remove the primer and replace it with deoxyribonucleotides;**
8. **Binding of DNA ligase to the gap between two Okazaki fragments to form a phosphodiester bond between them;**

MP2 to MP8: max 2m

9. **Formation of hydrogen bonds required for complementary base pairing of nucleotides;**
10. **where adenine pairs with thymine and guanine pairs with cytosine;**
11. **To allow the DNA to be replicated accurately with the correct sequence;**
12. **To allow repair of DNA as proofreading of the sequence is carried out;**
13. **To allow the DNA strands to rewind at the end of DNA replication;**

14. **Formation of phosphodiester bonds between the 3'OH group of one nucleotide and the 5' phosphate of an adjacent nucleotide;**
15. **To allow the formation of a polymer / polynucleotide;**

16. **Hydrophobic interactions between stacked bases;**
17. **To stabilise the DNA structure;**

End replication problem

18. **When the lagging DNA strand is synthesised, many Okazaki fragments are formed, where each fragment has an RNA primer made by primase;**
19. **DNA polymerase I removes the primers and fills the gap with complementary deoxyribonucleotides;**
20. **However, DNA polymerase I cannot fill the gap / there is an absence of an existing 3' OH end at the 5' end of lagging strand / newly synthesised strand / daughter strand;**
21. **Repeated rounds of replication produce shorter and shorter DNA molecules;**

22. **QWC: At least 1m from significance of bond formation + At least 1m from end replication problem;**

5

For Examiner's Use

(a) Describe how eukaryotic ribosomes are formed and explain the role of ribosomes in translation. [15]

Formation of ribosomes

1. **Ribosomes are made up of rRNA and ribosomal proteins;**
2. **rRNA genes/ DNA coding for rRNA undergo transcription in the nucleolus, forming rRNA;**
3. **Genes coding for ribosomal proteins are transcribed in the nucleus to form pre-mRNAs/primary mRNA transcript/mRNA;**
4. **The pre-mRNAs/ primary mRNA transcript undergo post-transcriptional modifications, forming mature mRNAs before they exit the nucleus via nuclear pores;**
5. **They undergo translation in the cytoplasm to form ribosomal proteins;**
6. **Ribosomal proteins are transported from the cytoplasm back into the nucleus;**
7. **rRNA and ribosomal proteins are assembled into the large/ 60S and small/ 40S ribosomal subunits in the nucleolus;**
8. **The ribosomal subunits are then transported to the cytoplasm where they remain separated;**
9. **Assembly of large and small subunits to form 80S ribosomes when translation is initiated;**

Role of ribosomes

10. **Site of polypeptide synthesis/translation;**
11. **Where the mRNA sequence is translated to a sequence of amino acids in a polypeptide;**
12. **Small subunit recognises and binds to the 5' end of the mRNA / near the start codon;**
13. **Large subunit contains the E, P A sites;**
14. **P site – holds the peptidyl-tRNA, which transfers its amino acid(s) to the aminoacyl-tRNA in the A site / the site for the growing polypeptide chain;**
15. **A site – holds the incoming aminoacyl-tRNA, (which accepts the earlier amino acid to form a peptidyl-tRNA);**
16. **A site – also receives the release factor which signals the end of translation;**
17. **Contains peptidyl transferase – the enzyme which catalyses the formation of peptide bonds between adjacent amino acids;**
18. **E site – site where tRNA leaves the ribosome;**
19. **Aligns mRNA in the ribosome, so that anticodons of incoming aminoacyl-tRNA molecules can form hydrogen bonds with mRNA codons via complementary base pairing;**

20. **QWC: At least two correct points for the formation and two correct points for roles of ribosomes;**

For Examiner's Use

5 (b) It is known that the first eukaryotic cells were unicellular and had evolved from a prokaryotic ancestor.

Explain the functions of telomeres and suggest how telomeres may have originated and evolved in early eukaryotes. [10]

Functions of telomeres

1. **Telomeres protect genes at the ends of chromosomes from being eroded during semi-conservative DNA replication due to the end-replication problem;**

2. **Part of the telomeres forms loops at the ends of chromosomes and these loops bind to proteins to protect the ends of chromosomes;**
3. **Telomeres prevent chromosomal end-to-end fusions;**
4. **which can lead to chromosomal aberrations;**
5. **Telomeres protect chromosomal ends from inappropriate degradation by exonucleases;**

6. **Telomere shortening to a critical length also act as signals for cells to enter replicative senescence;**
7. **where the cell cycle is arrested / the cell may undergo apoptosis;**

Evolution of telomeres

8. **There was a change in the structure of DNA molecule from circular to linear form (at one point in the past);**

9. **Variation in presence of non-coding DNA at the ends of DNA molecules occurred in the population of eukaryotic cells due to spontaneous mutation;**
10. **Linear DNA molecules were susceptible to shortening due to the end-replication problem / any other deleterious effect due to lack of telomeres, which acted as a selection pressure;**
11. **Cells with non-coding DNA at the ends of DNA molecules are selected for;**
12. **These cells are more likely to survive and reproduce / have a higher reproductive success, passing on the presence of the telomere to daughter cells;**
13. **Over time, there is an increase in frequency of *cells* having telomeres in the gene pool of the cell population;**

14. **QWC: At least 2m for the function of telomeres + 1m for the evolution of telomeres;**