

**Anglo-Chinese Junior College**  
JC2 Biology Preliminary Examination  
Higher 2



A Methodist Institution  
(Founded 1886)

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**BIOLOGY**

Paper 1 Multiple Choice

**9744/ 01**

16 September 2022

1 hour

Additional Materials: Multiple Choice Answer Sheet

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**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.

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**This document consists of 20 printed pages.**

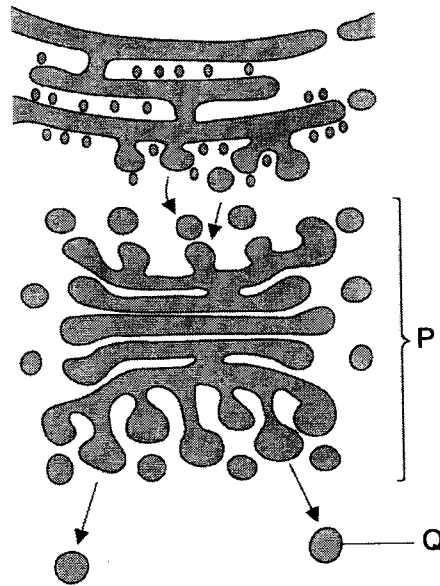
1 Different processes occur in different organelles in a plant cell.

- 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
<b>A</b>	1, 2, 3, 4	1, 2, 3, 4	2, 3, 4
<b>B</b>	2, 4	2, 4	1, 3, 4
<b>C</b>	1, 3	4	2, 3
<b>D</b>	1	1	3, 4

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

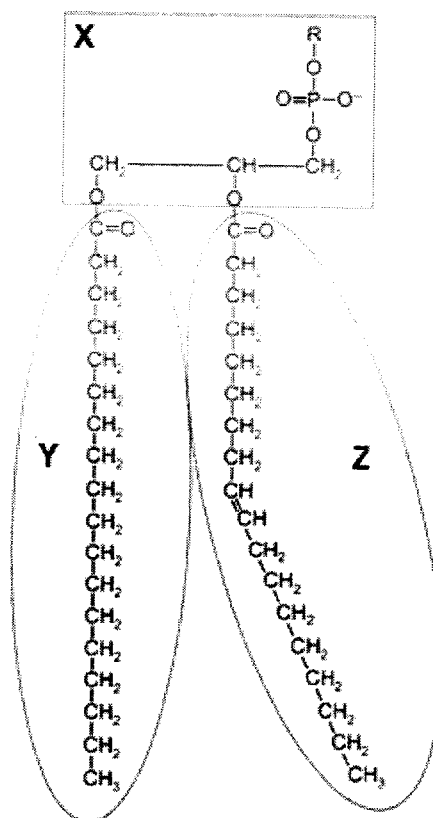


What are the roles of organelles P and Q in the formation and transport of trypsin?

- 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

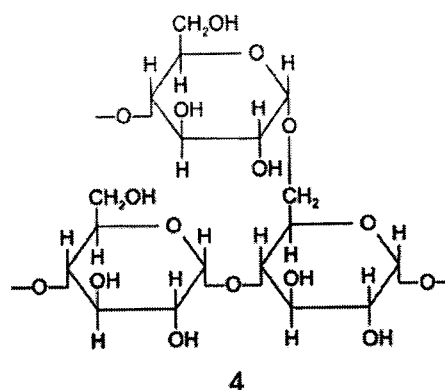
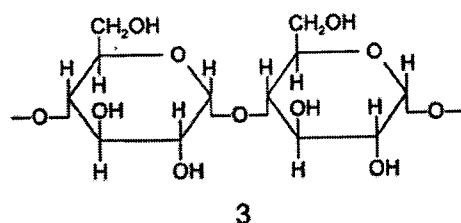
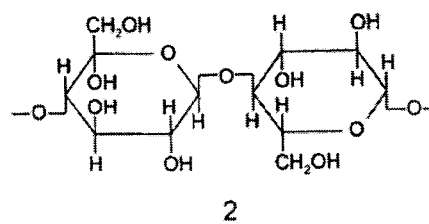
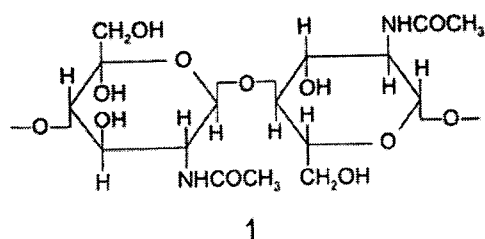
- 3 The diagram shows a phospholipid molecule divided into three regions, X, Y and Z. In region X, R represents a range of possible chemical groups.



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

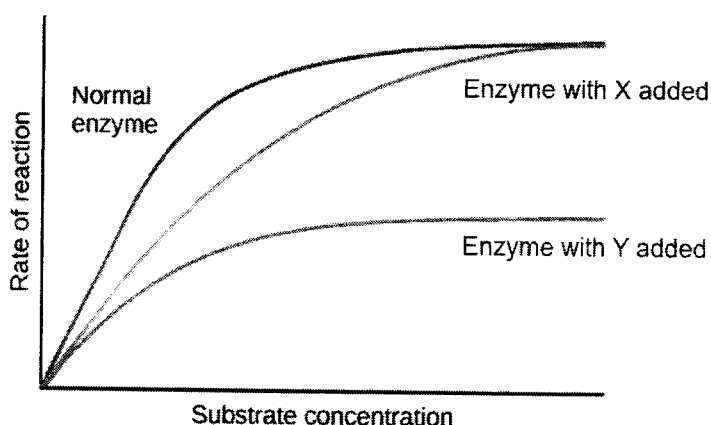
- 4 The diagrams show short sections of some common and modified polysaccharides.



Which statement is correct?

- A** 1 is found in cellulose as  $\beta$ -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  $\beta$ -glucose monomers.
- D** 4 is found in glycogen, which is made of chains of  $\alpha$ -glucose linked by  $\alpha$ -1,4-glycosidic bonds and  $\alpha$ -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

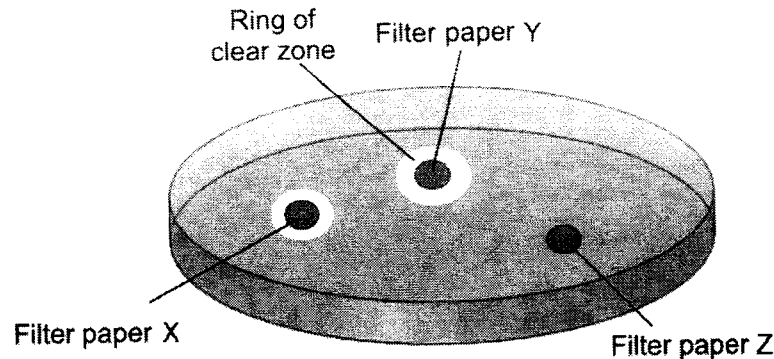
**C** 2

**D** 3

[Turn over

- 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?

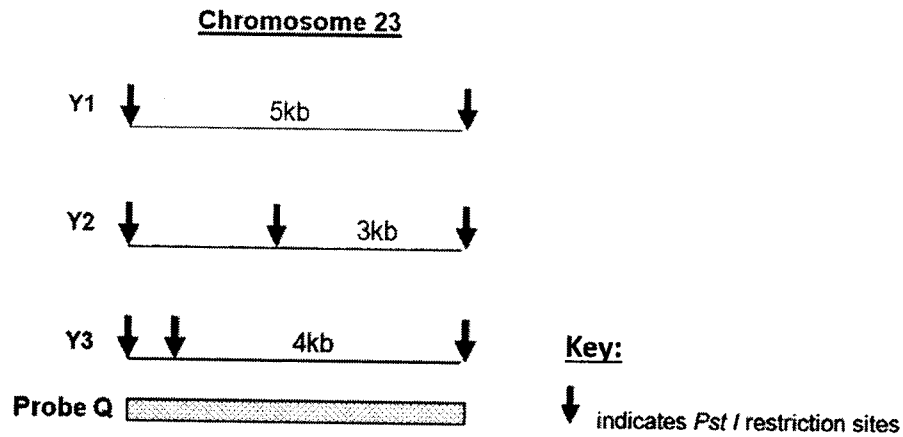
- A Filter paper X was soaked with phages that did not initiate an immediate lysis of *E. coli* cells, resulting in a smaller clear zone around filter paper X than filter paper Y.
  - B Filter paper Y was soaked with phages that could integrate its genome into dividing *E. coli* cells, resulting in a 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?

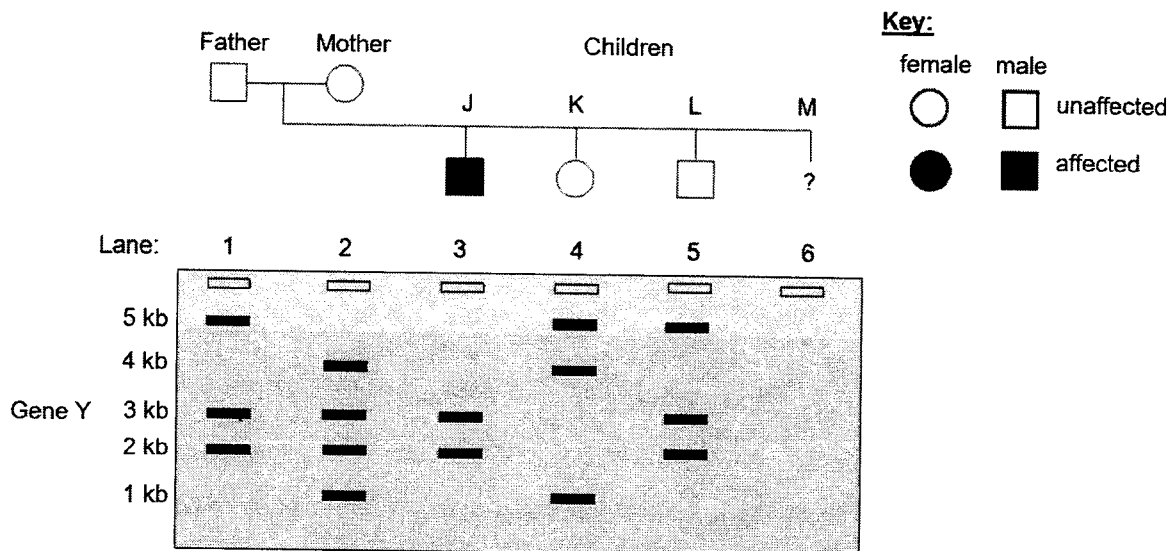
- A 1, 2, 3 and 4      B 1, 2 and 3 only      C 2, 3 and 4 only      D 1 and 2 only

- 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.

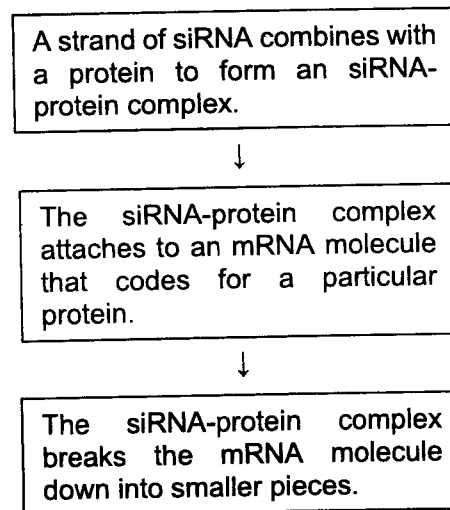


Which conclusion could be made from the analysis?

- 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.

[Turn over

- 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.

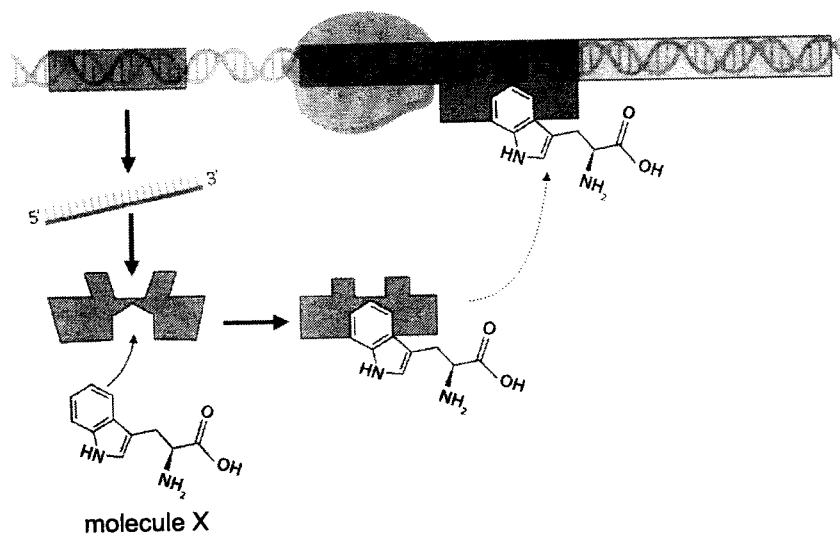
age of pupa as percentage of total time spent as a pupa	mean concentration of RNA / $\mu\text{g}$ per pupa
0	20
20	15
40	12
60	17
80	33
100	20

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.

[Turn over

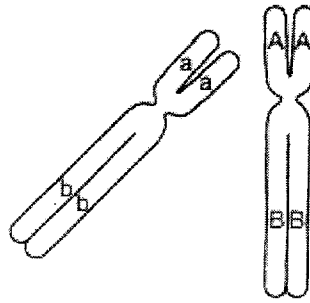
- 15 The diagram shows the interaction of molecules with a segment of DNA which includes an operon.



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.

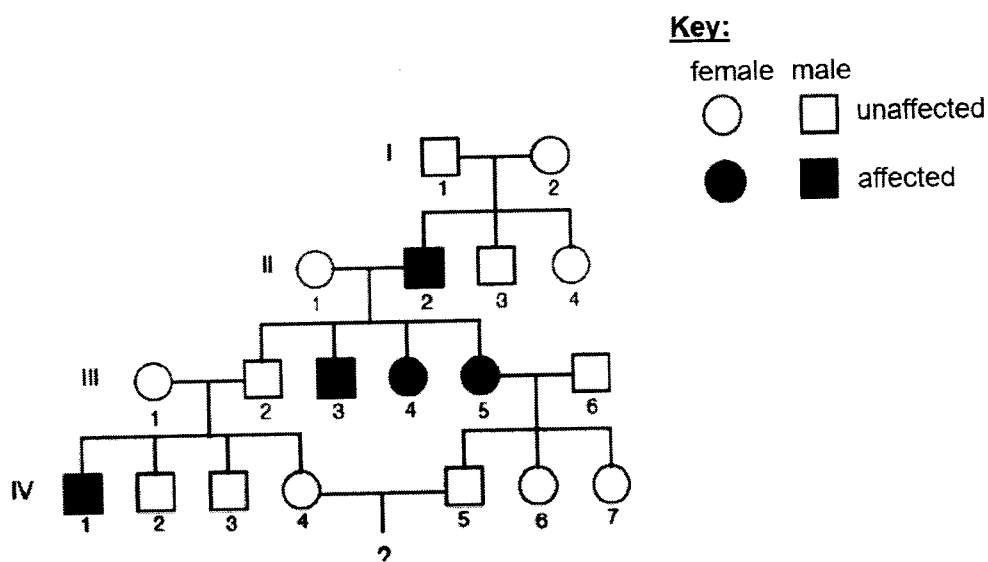


Which row is a possible representation of these chromosomes as they progress from anaphase I to prophase II?

	anaphase I	prophase II
A		
B		
C		
D		

[Turn over

- 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 F<sub>2</sub> 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

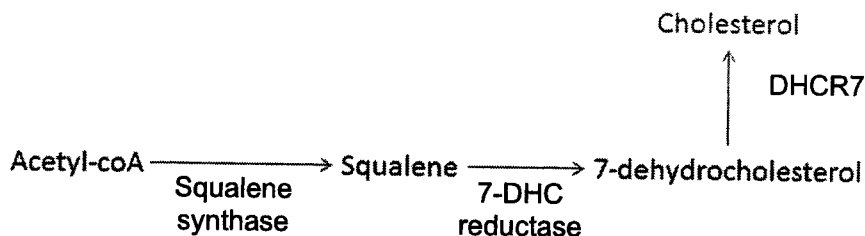
Using the equation and table above, which value would be close to the calculated chi-square value for this experiment?

- 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 (TECT $\alpha$ ), 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.

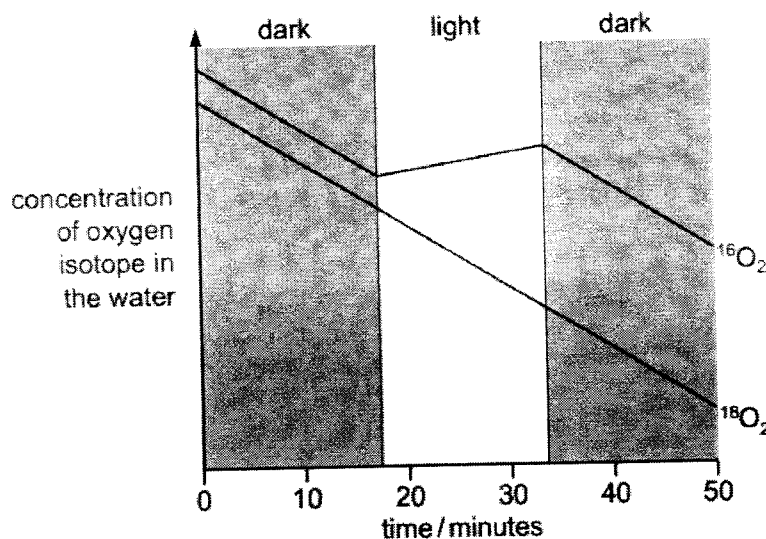


- Which statement cannot be concluded?
- A The *DHCR7* gene and *TECT $\alpha$*  gene do not assort independently.
- B A person who is heterozygous for both *DHCR7* and *TECT $\alpha$*  genes suffers from non-syndromic deafness but not Smith-Lemli-Opitz syndrome.
- C The production of cholesterol from 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  $^{16}\text{O}$ . Air containing  $^{16}\text{O}_2$  and  $^{18}\text{O}_2$  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?

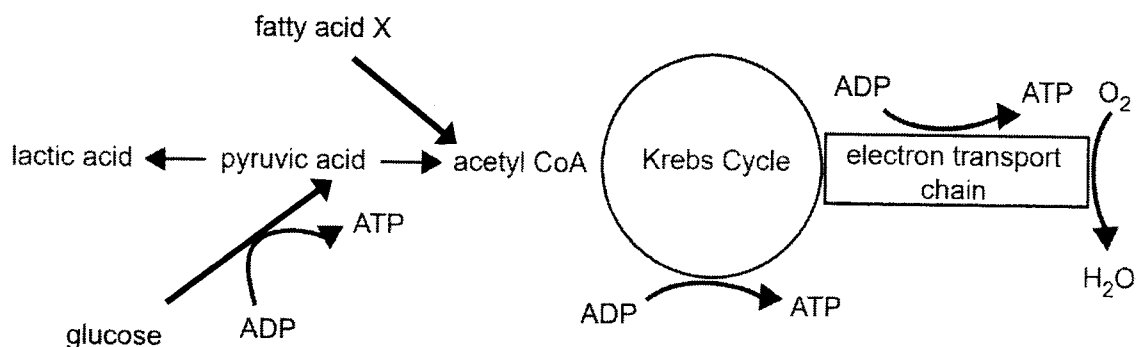
- A Both isotopes of oxygen are used by the algae in the dark in respiration, but in the light oxygen is produced from water in photorespiration.
  - B The algae can distinguish chemically between the two isotopes.
  - C The algae produce oxygen from the water during photosynthesis, but only in the light.
  - 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.

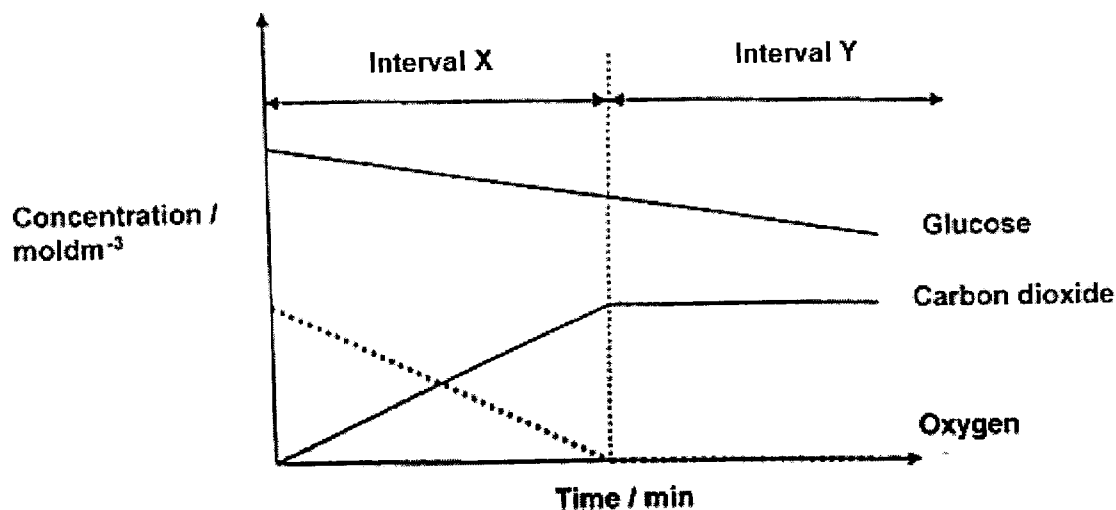
The diagram summarises the pathways for the breakdown of fatty acid X and glucose molecules. Each molecule of fatty acid X produces eight molecules of acetyl CoA.



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
<b>A</b>	Aerobic respiration	Lactic acid fermentation
<b>B</b>	Aerobic respiration	Alcoholic fermentation
<b>C</b>	Lactic acid fermentation	Aerobic respiration
<b>D</b>	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 adenylyl 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** Adenylyl cyclase will be hyperactive.
- C** Protein kinase A will remain inactive.
- D** G protein will remain bound with GDP.

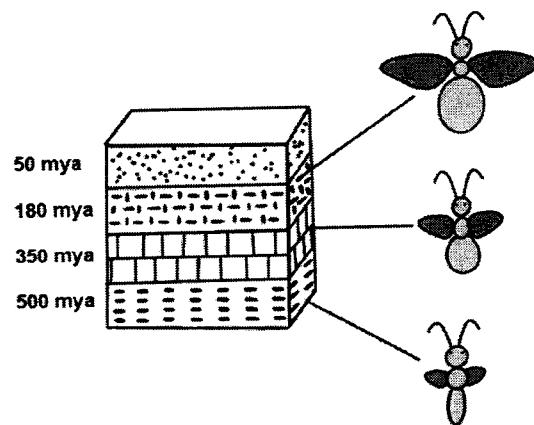
26 Several closely related frog species of the genus *Rana* are found in the forests of the South-eastern United States. The species boundaries are maintained by reproductive barriers. The statements below describe the different type of reproductive barriers that exist between the different species.

- 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

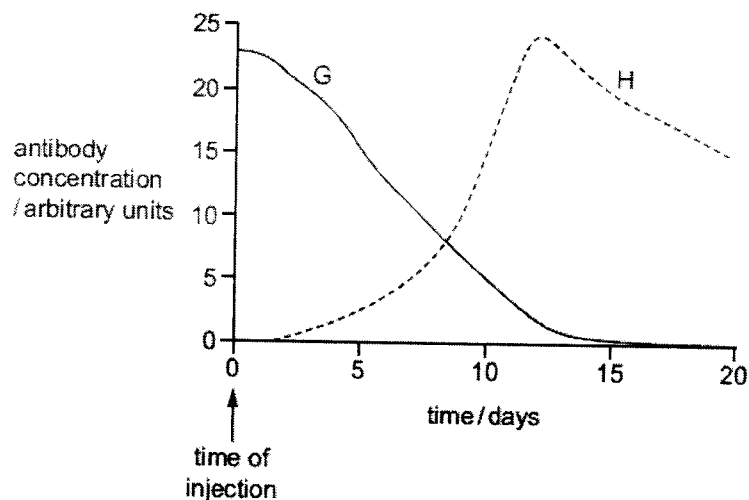
Which statement can be concluded from the information provided?

- 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



**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
<b>Total</b>	<b>/ 100</b>

This document consists of 32 printed pages.

[Turn over

Answer all questions.

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

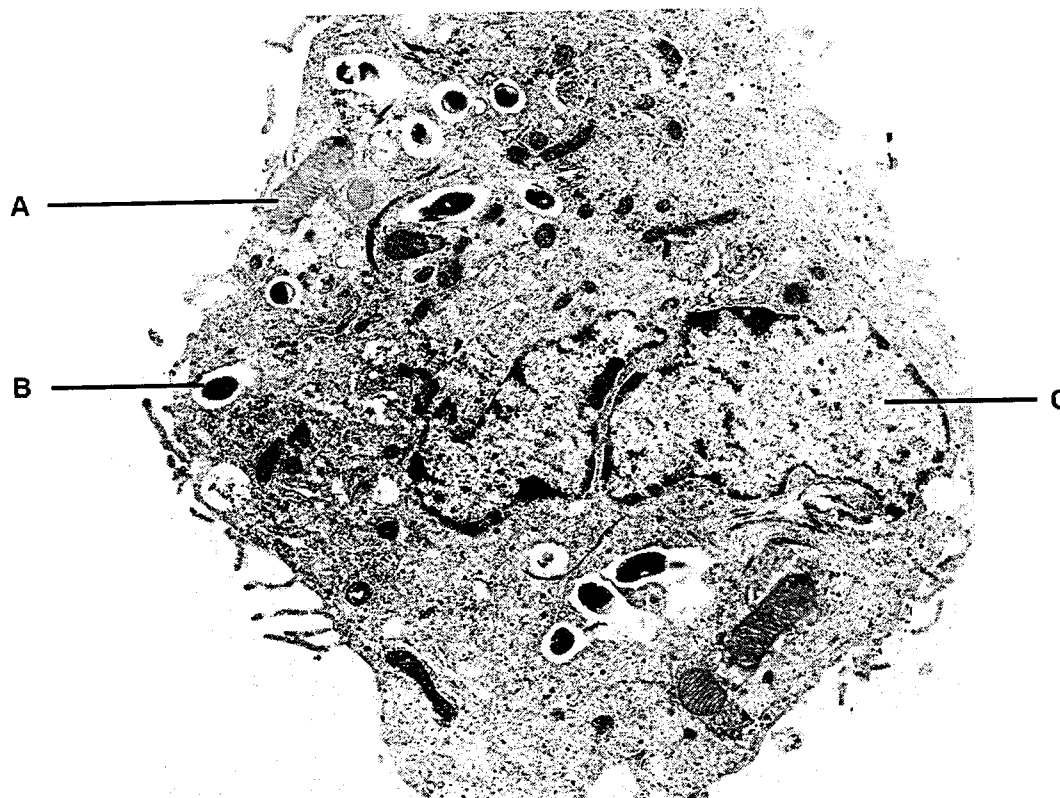


Fig. 1.1

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

..... [1]

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

.....  
.....  
.....  
.....  
..... [2]

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

.....  
.....  
.....  
.....  
.....  
.....  
..... [3]

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

.....  
.....  
.....  
.....  
.....  
.....  
..... [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.

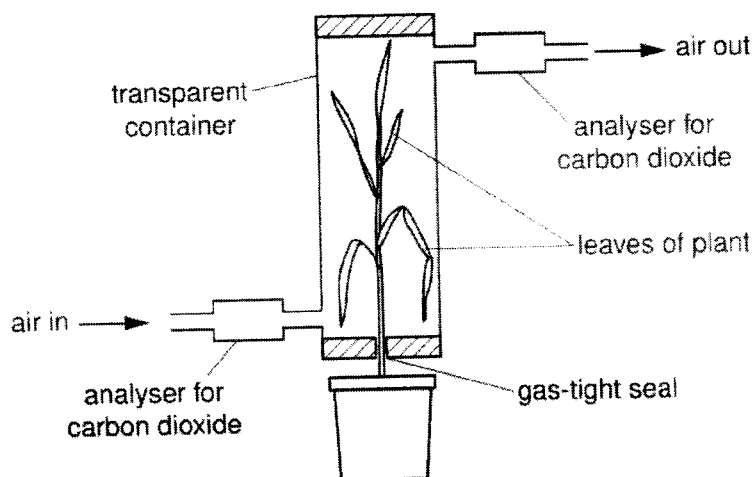


Fig. 2.1

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

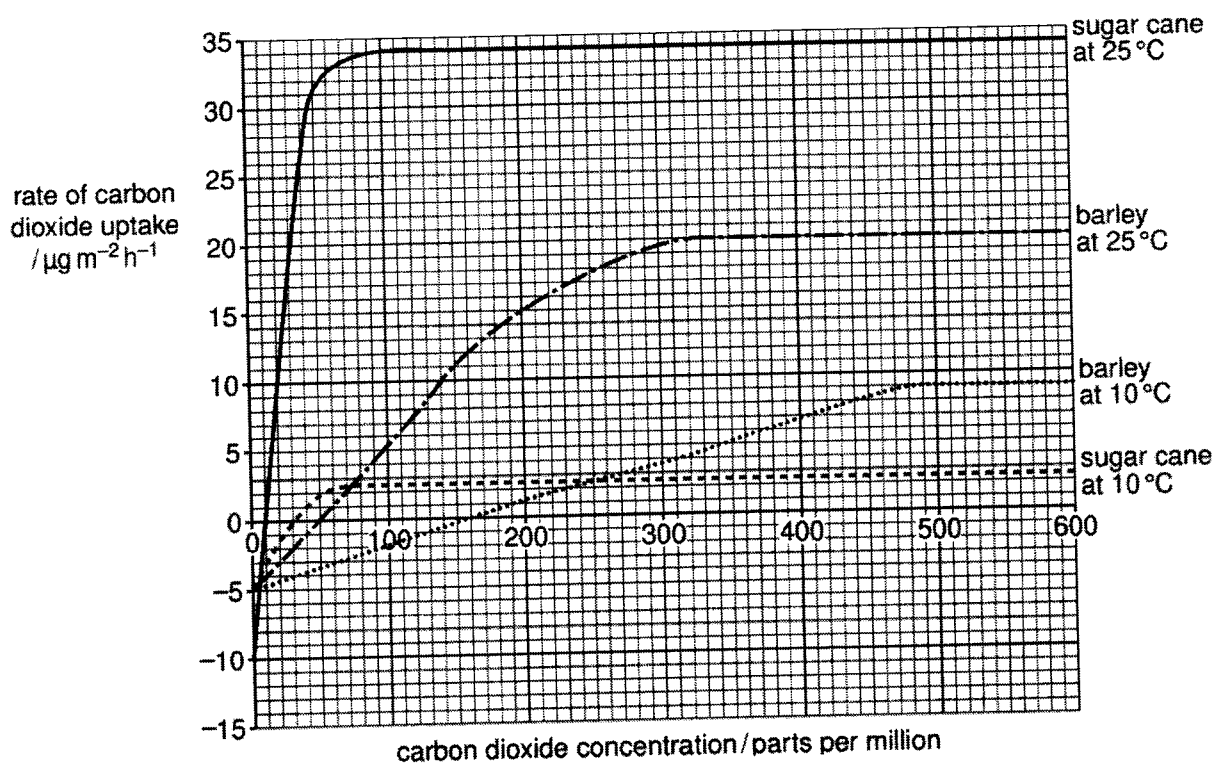


Fig. 2.2



- (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.

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..... [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	
temperate, cool climate	

[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.

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..... [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.

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..... [2]

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

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..... [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.

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..... [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.

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..... [1]

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

Compare the structures of telomeres and centromeres.

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..... [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.

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

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

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..... [2]

[Total: 11]

- 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.

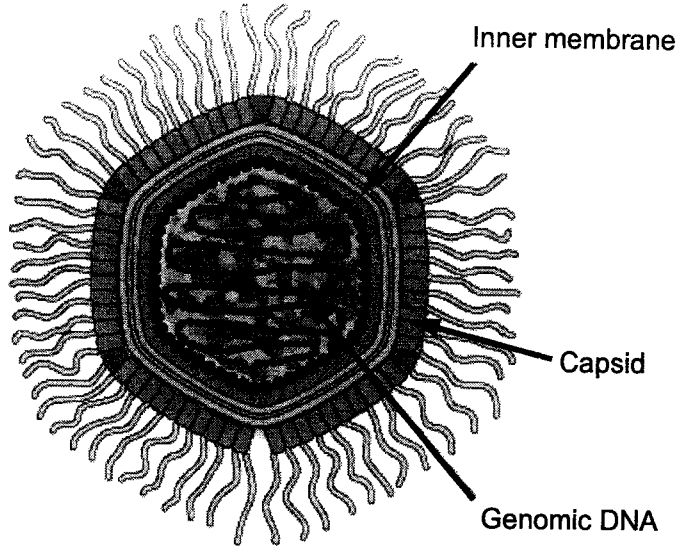


Fig. 4.1

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

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..... [3]

[Turn over

Fig. 4.2 shows the structure of an influenza virus.

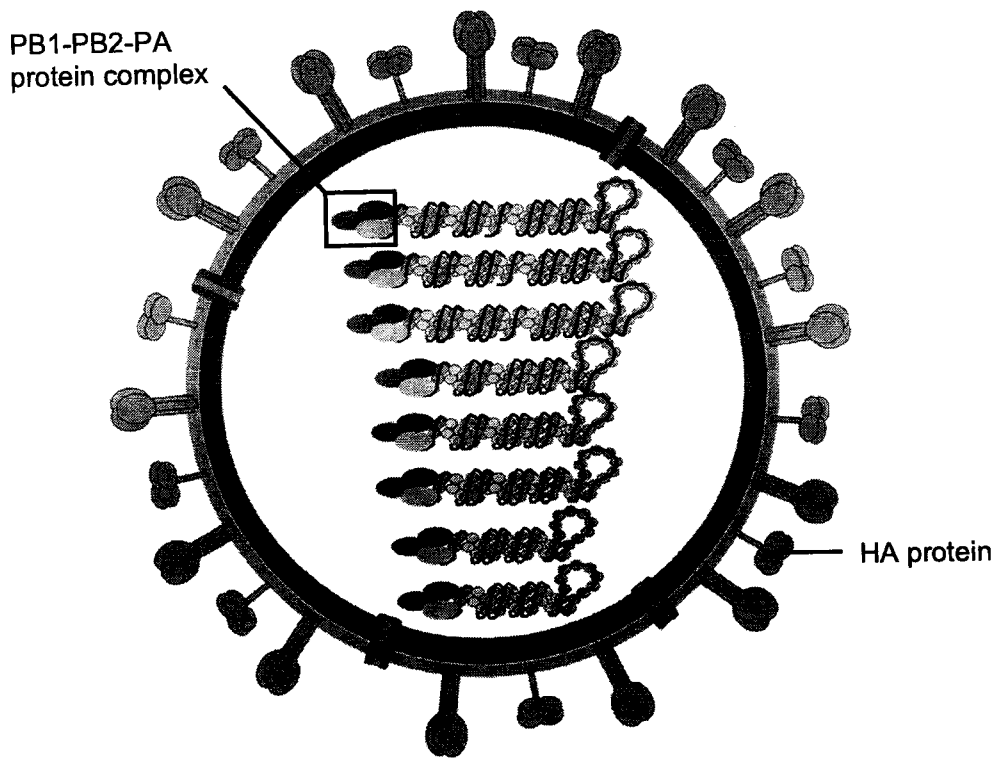


Fig. 4.2

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

(i) PB1-PB2-PA protein complex.

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..... [2]

(ii) HA protein.

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.....  
..... [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.

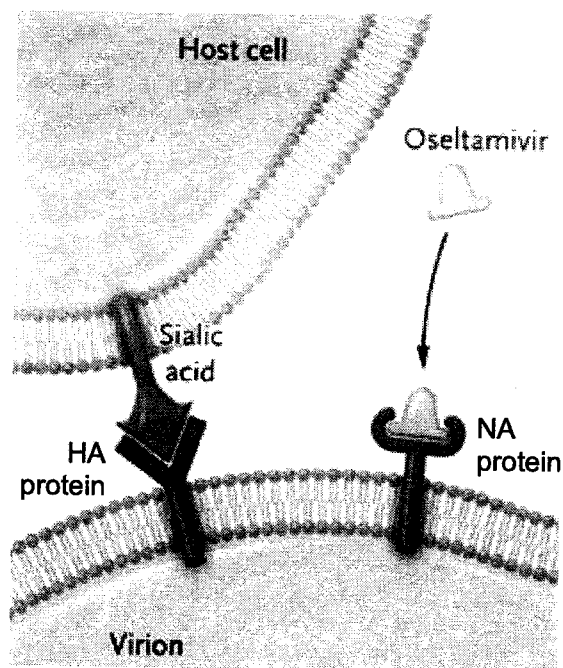


Fig. 4.3a

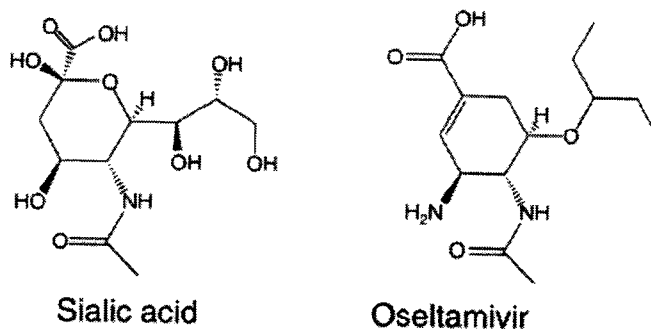


Fig. 4.3b

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

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..... [2]

[Total: 9]

[Turn over

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

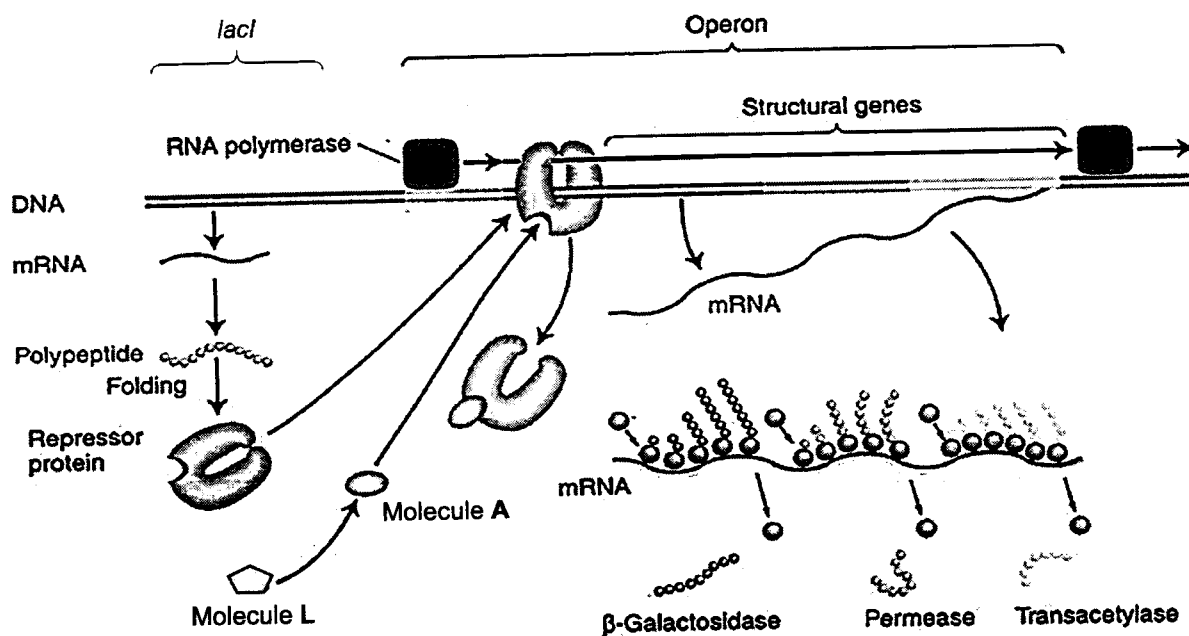


Fig. 5.1

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

..... [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.

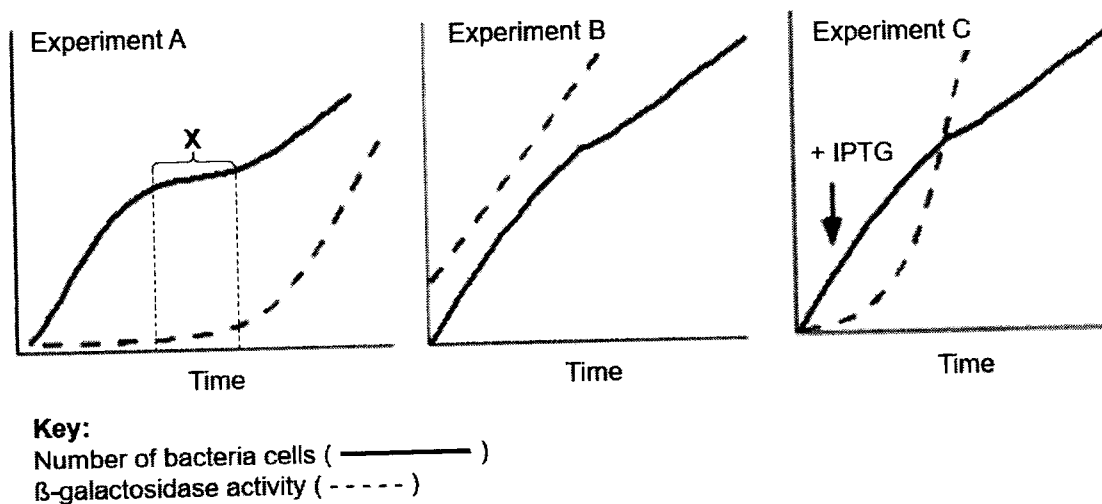


Fig. 5.2



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

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.....  
..... [2]

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

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..... [2]

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

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..... [2]

**[Turn over**

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

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[3]

[Total: 10]

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.

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..... [2]



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/ $\mu\text{g cm}^{-3}$	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.

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..... [2]

- (ii) A student stated that  $80 \mu\text{g cm}^{-3}$  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.

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..... [2]

[Total: 10]

[Turn over

- 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.

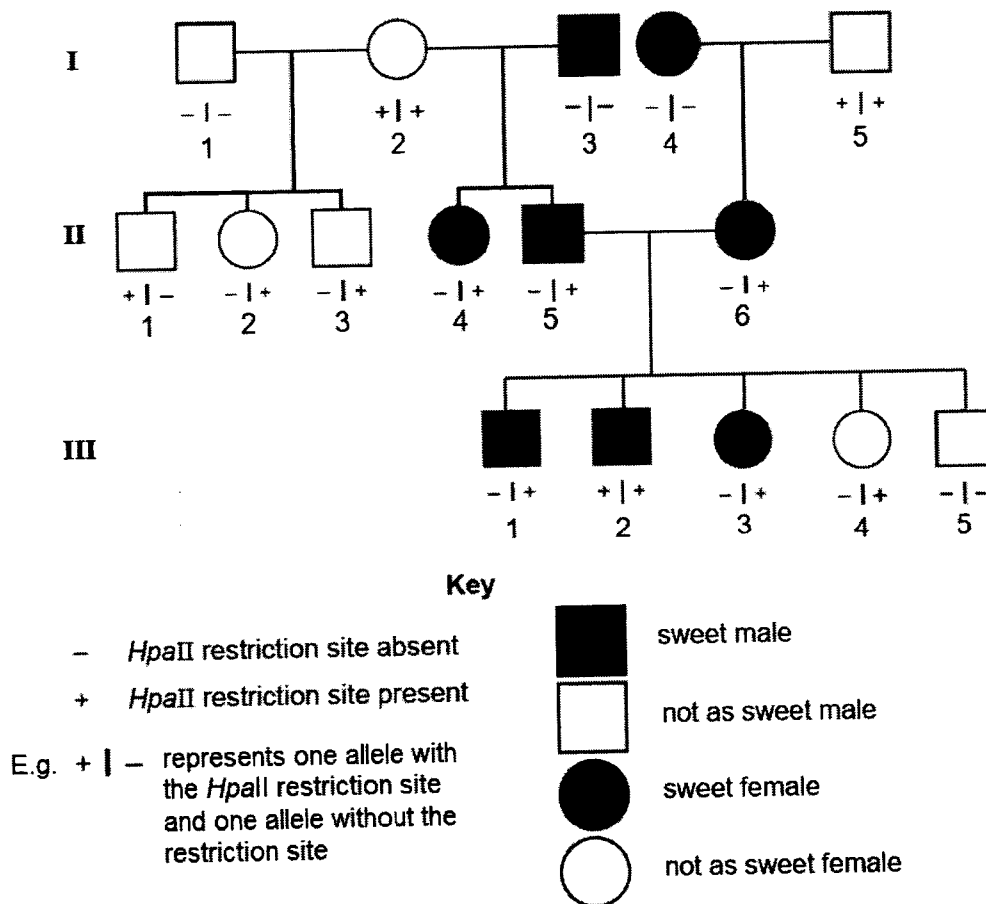


Fig. 7.1

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

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

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.....  
..... [1]

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

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.....  
..... [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.

[5]

[Turn over

(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.

.....  
..... [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: .....  
.....

Statistical test: ..... [2]

[Total: 10]



**Question 8 starts on Page 22**

**[Turn over**

- 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.

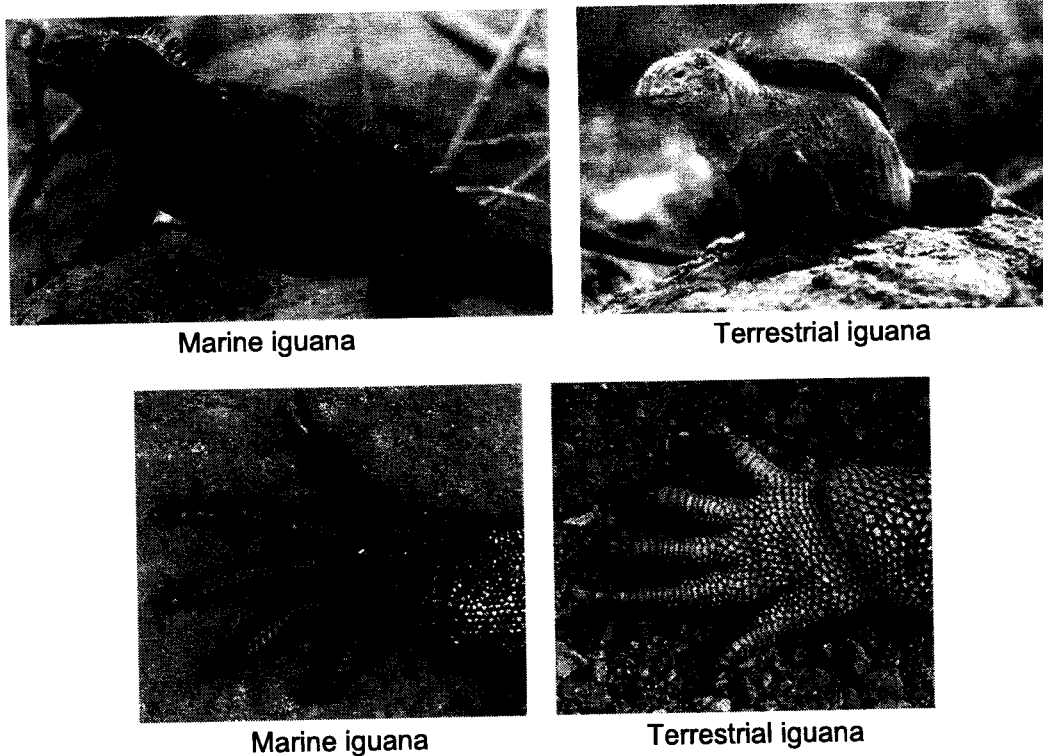


Fig 8.1

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

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..... [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.

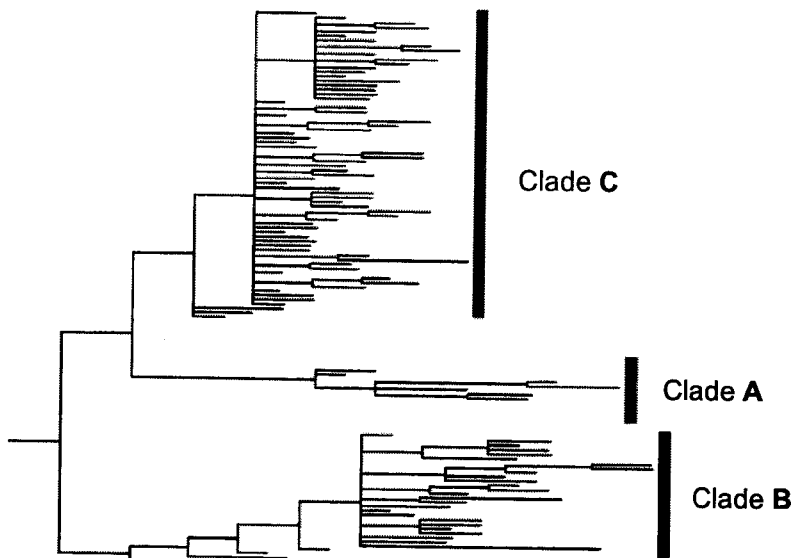


Fig. 8.2

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

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 ..... [1]

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

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 .....  
 .....  
 .....  
 ..... [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.

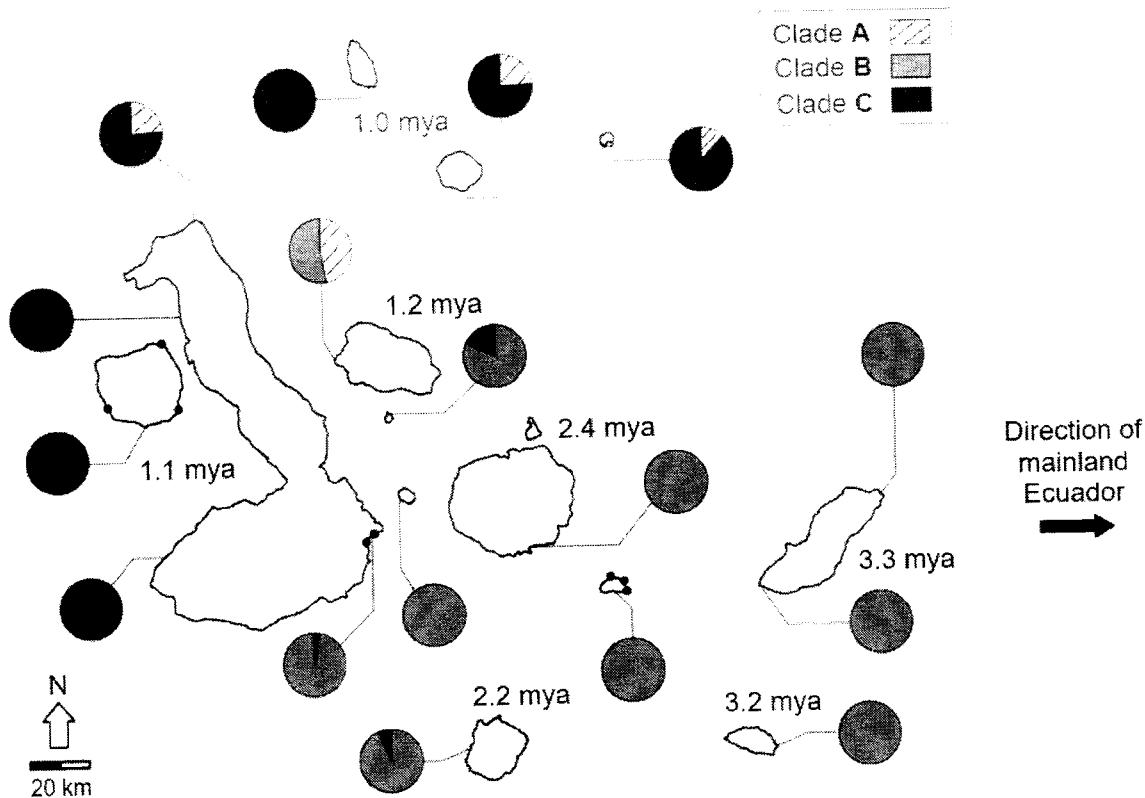


Fig. 8.3

(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.

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..... [1]

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

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[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.

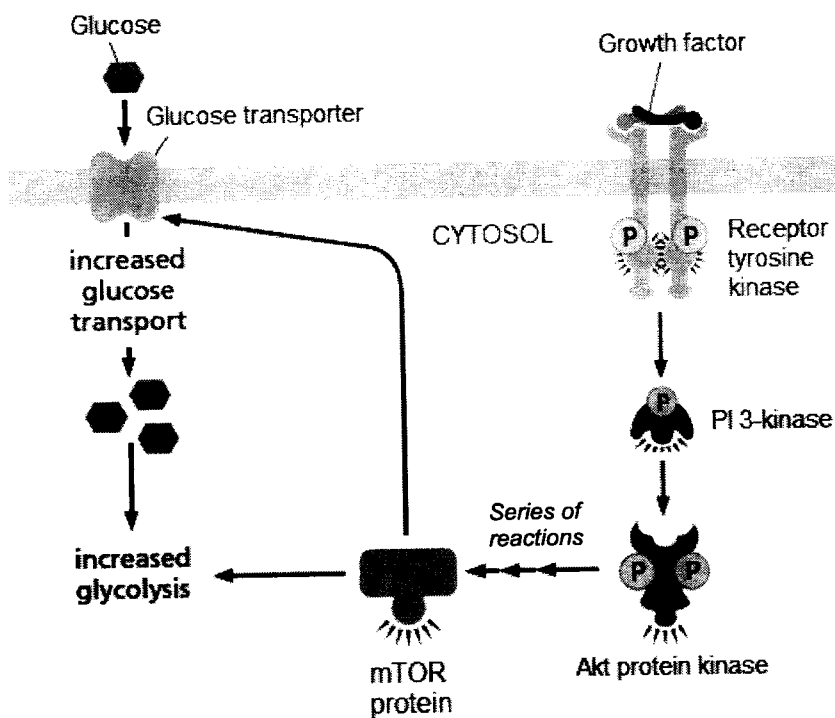


Fig. 9.1

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

..... [1]

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

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..... [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.

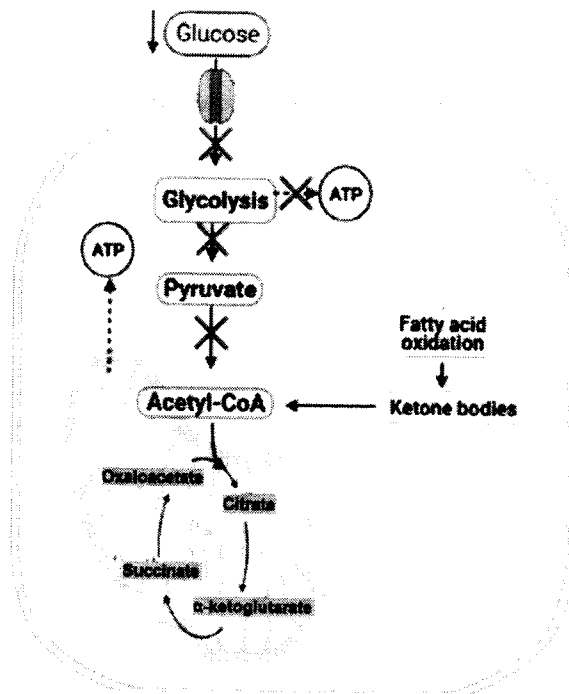


Fig. 9.2

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

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..... [4]

[Turn over

- (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.

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..... [2]

[Total: 10]



- 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).

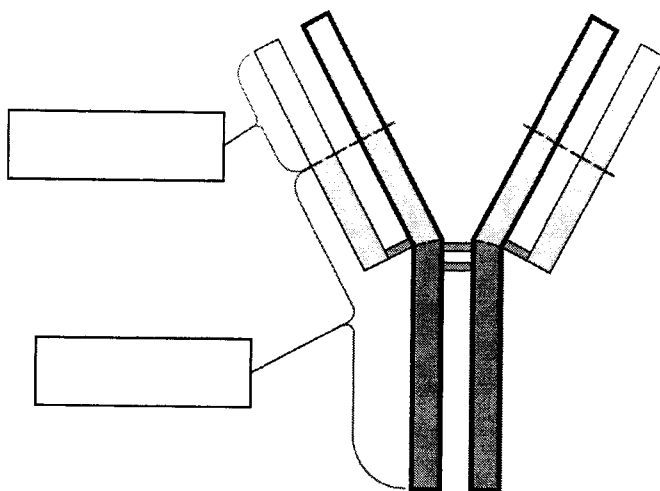


Fig. 10.1

[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.

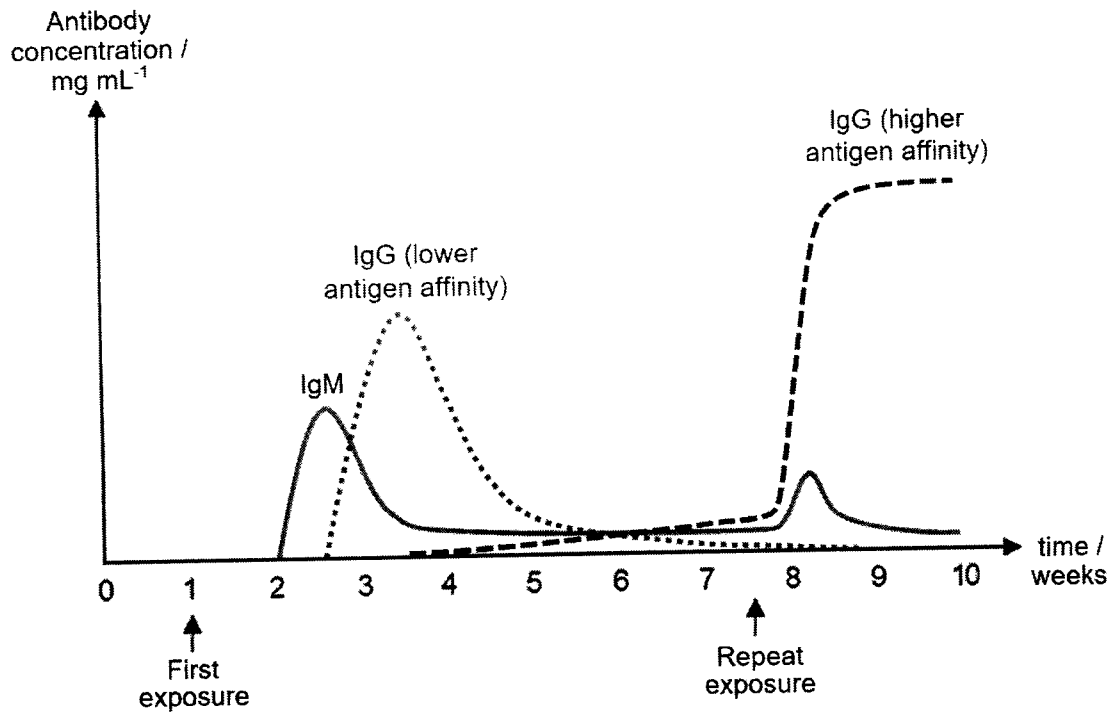


Fig. 10.2

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

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..... [3]

[Total: 6]



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

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..... [1]

[Total: 5]



**Anglo-Chinese Junior College**  
 JC2 Biology Preliminary Examination  
 Higher 2



A Methodist Institution  
 (Founded 1885)

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 in the spaces provided in the question paper.

**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	
<b>Section A</b>	
1	/ 30
2	/ 10
3	/ 10
<b>Section B</b>	
4 or 5	/ 25
<b>Total</b>	<b>/ 75</b>

This document consists of 19 printed pages.

[Turn over

## 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.

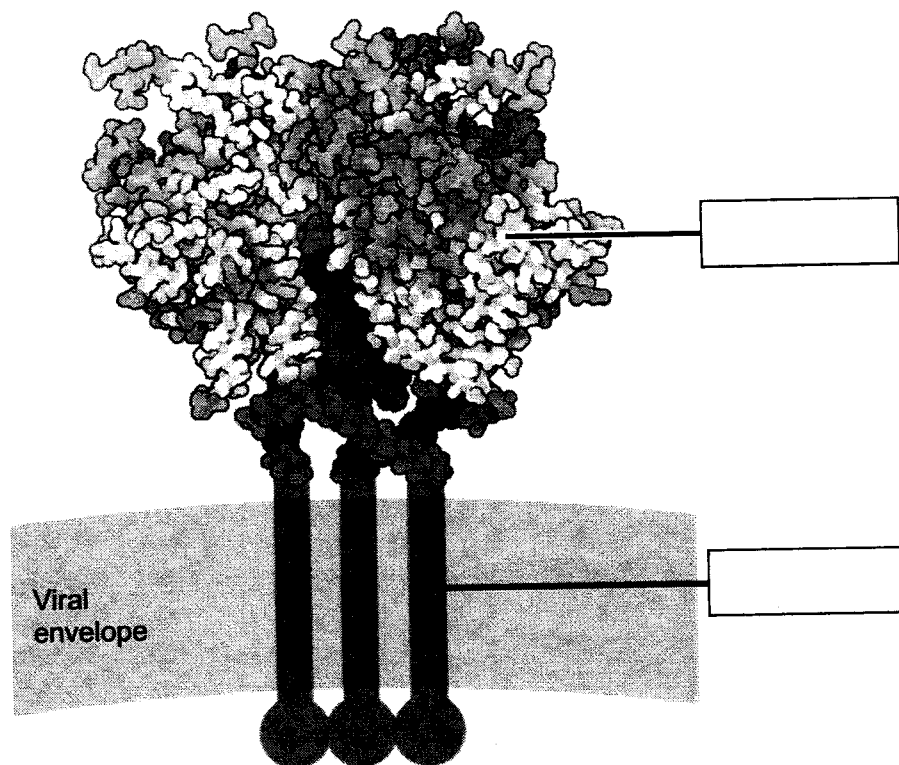


Fig. 1.1

- (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.

[1]

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

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..... [2]

(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.

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[2]

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

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[3]

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.

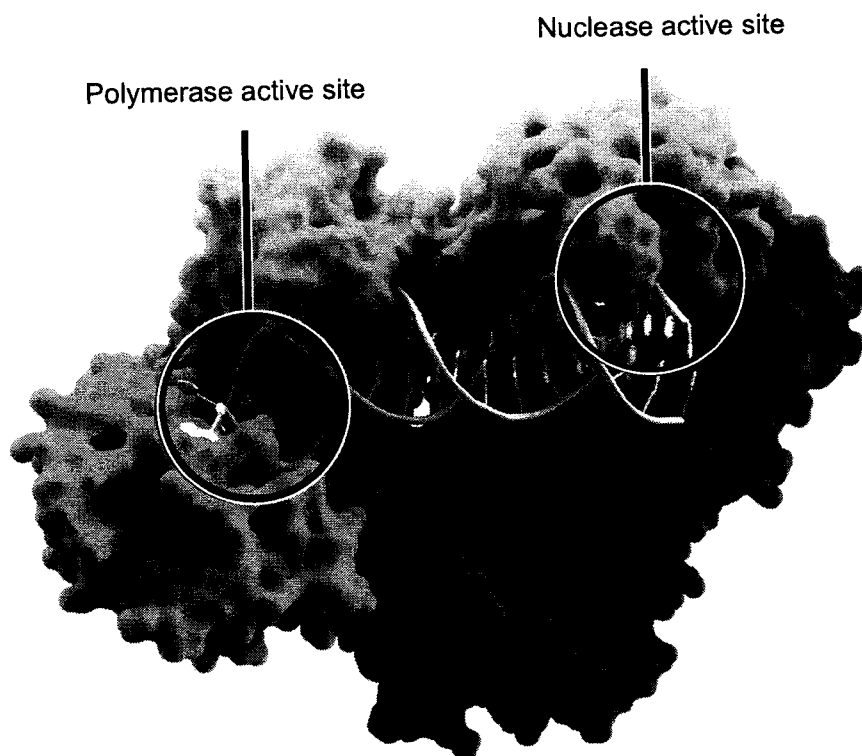


Fig. 1.2



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

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..... [4]

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

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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.

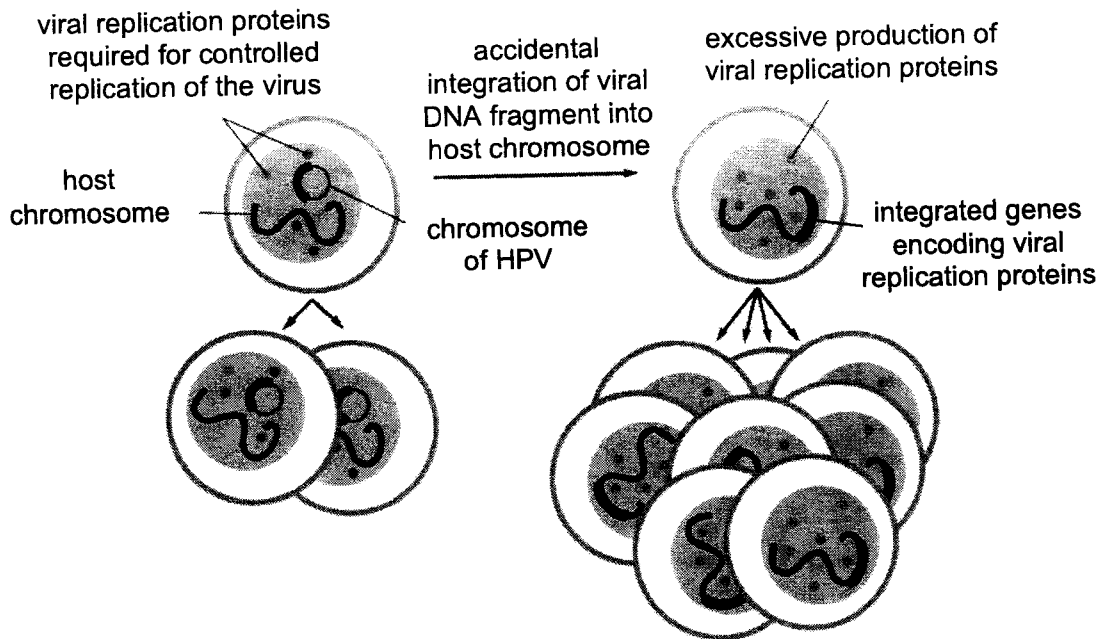


Fig. 1.5

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.

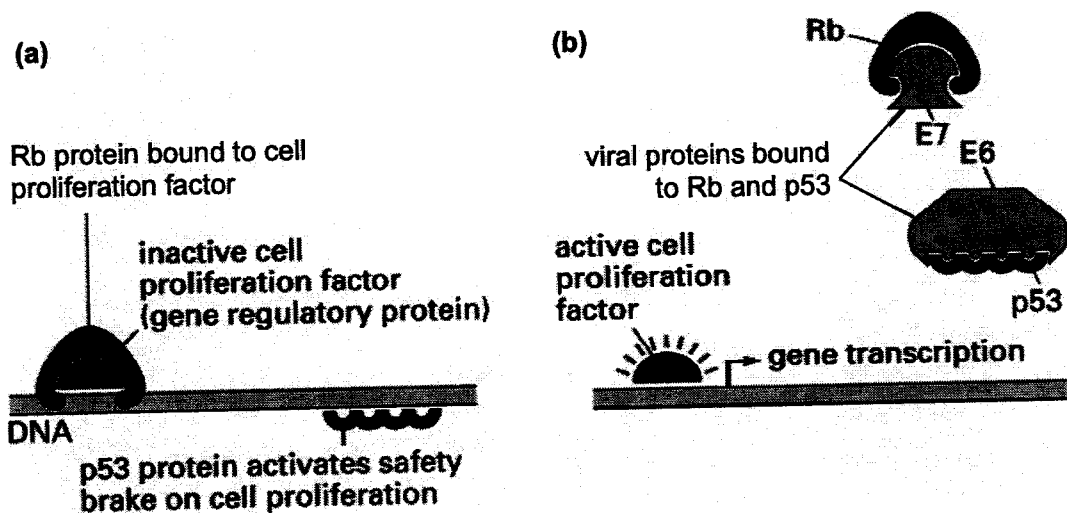


Fig. 1.6

(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.

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..... [4]

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

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..... [1]

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.

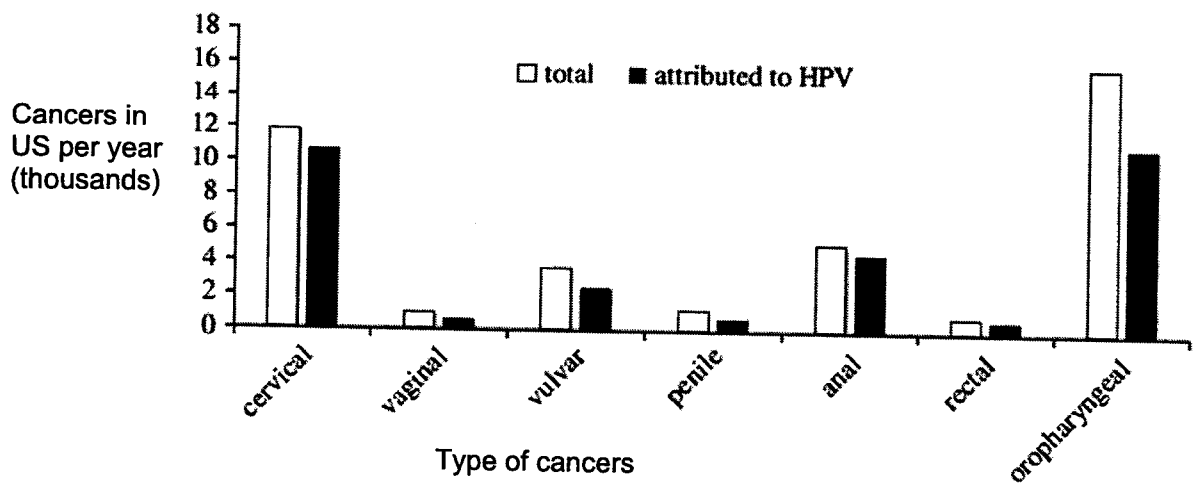


Fig. 1.7

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.

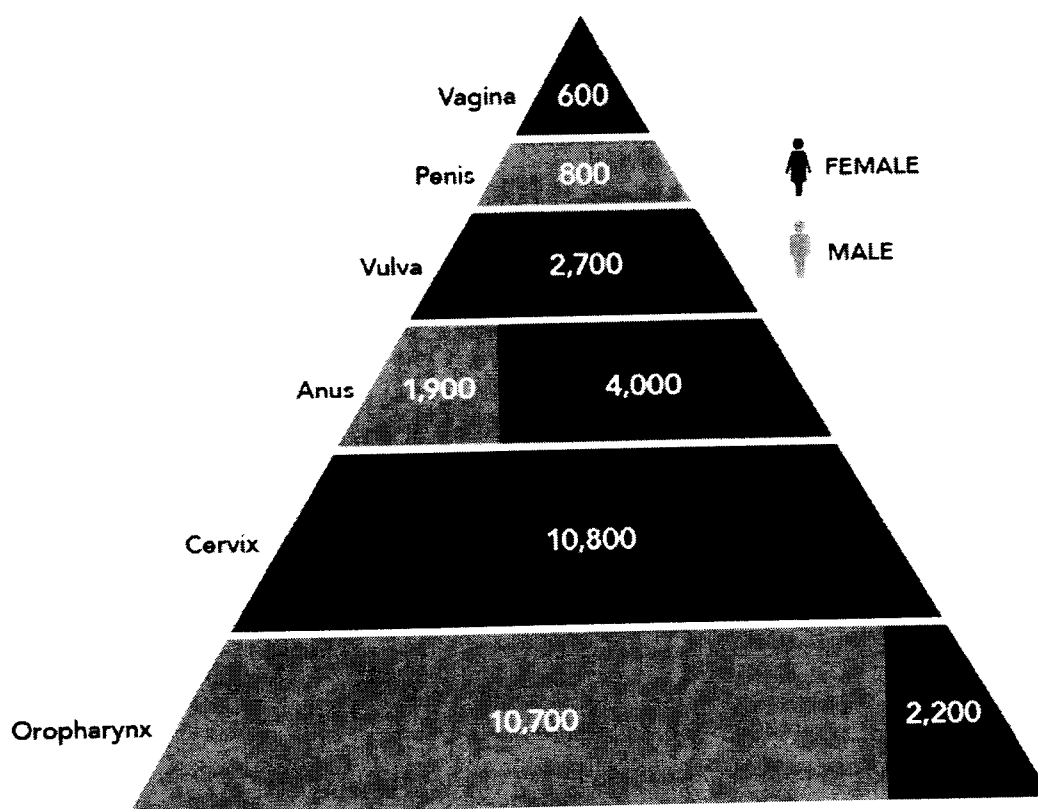


Fig. 1.8

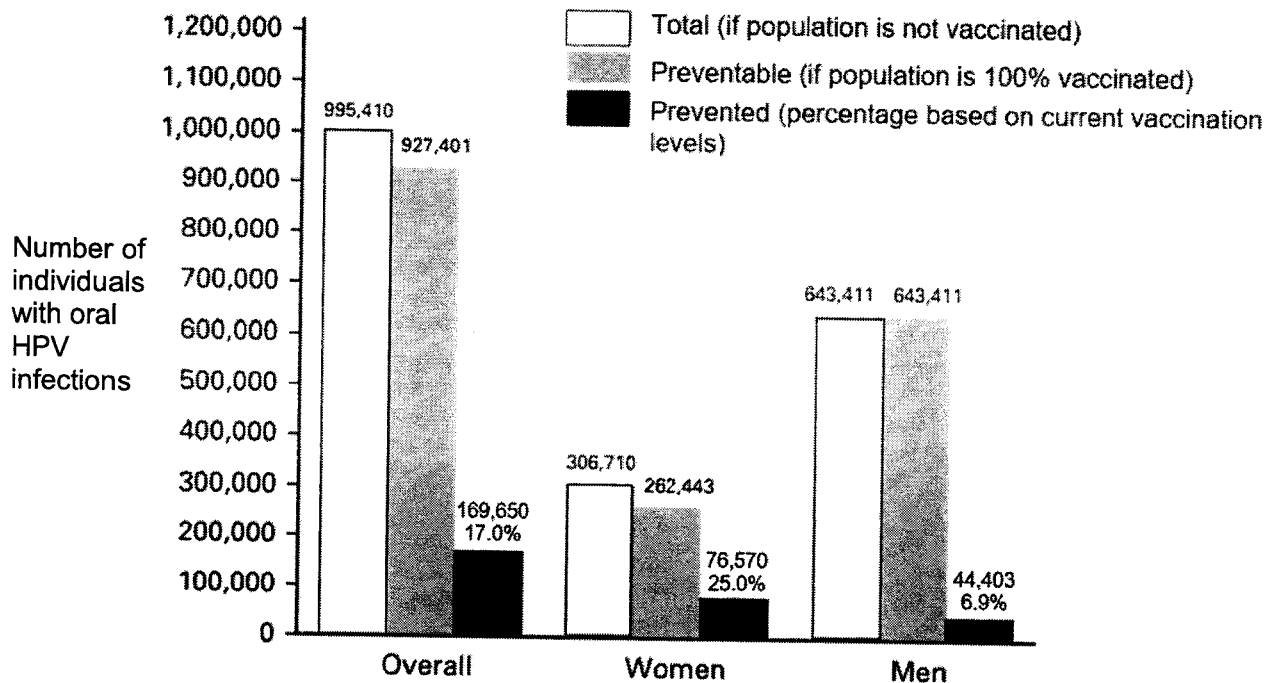


Fig. 1.9

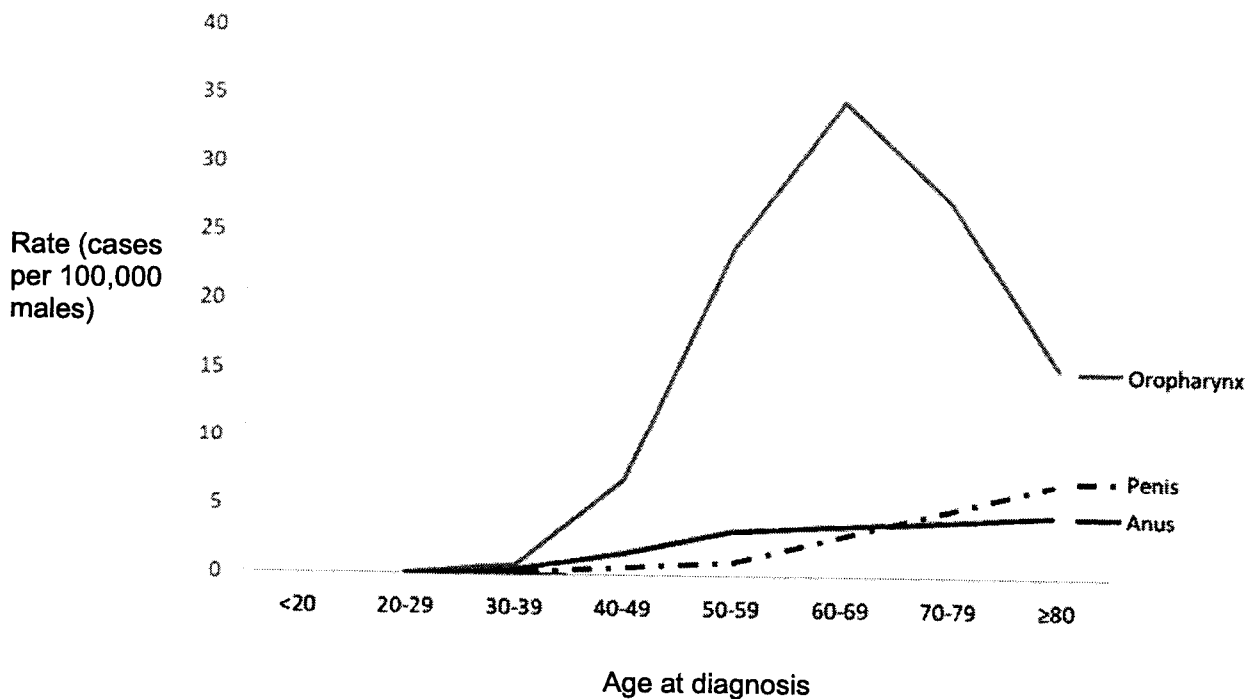


Fig. 1.10

- (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.

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..... [4]

[Total: 30]



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.

..... [1]

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

.....  
..... [1]

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

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.....  
..... [2]

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

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..... [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.

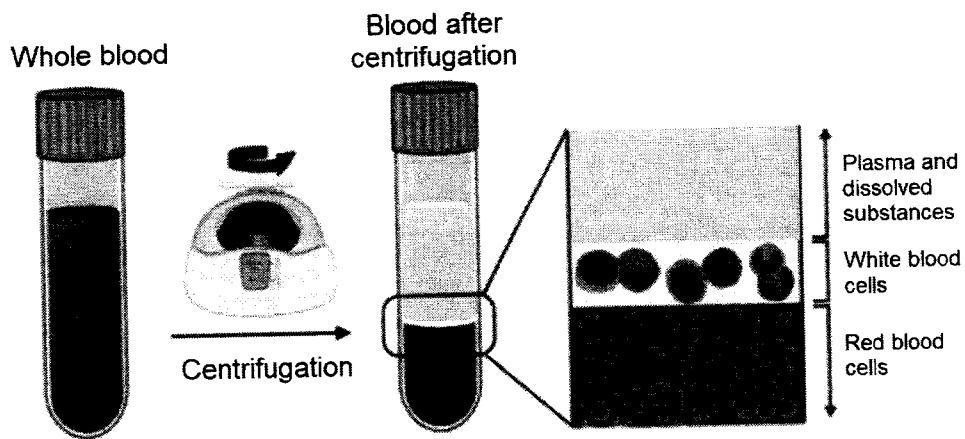


Fig. 2.1

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

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..... [2]

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* .....

.....

*Challenge* .....

..... [2]

[Total: 10]

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.

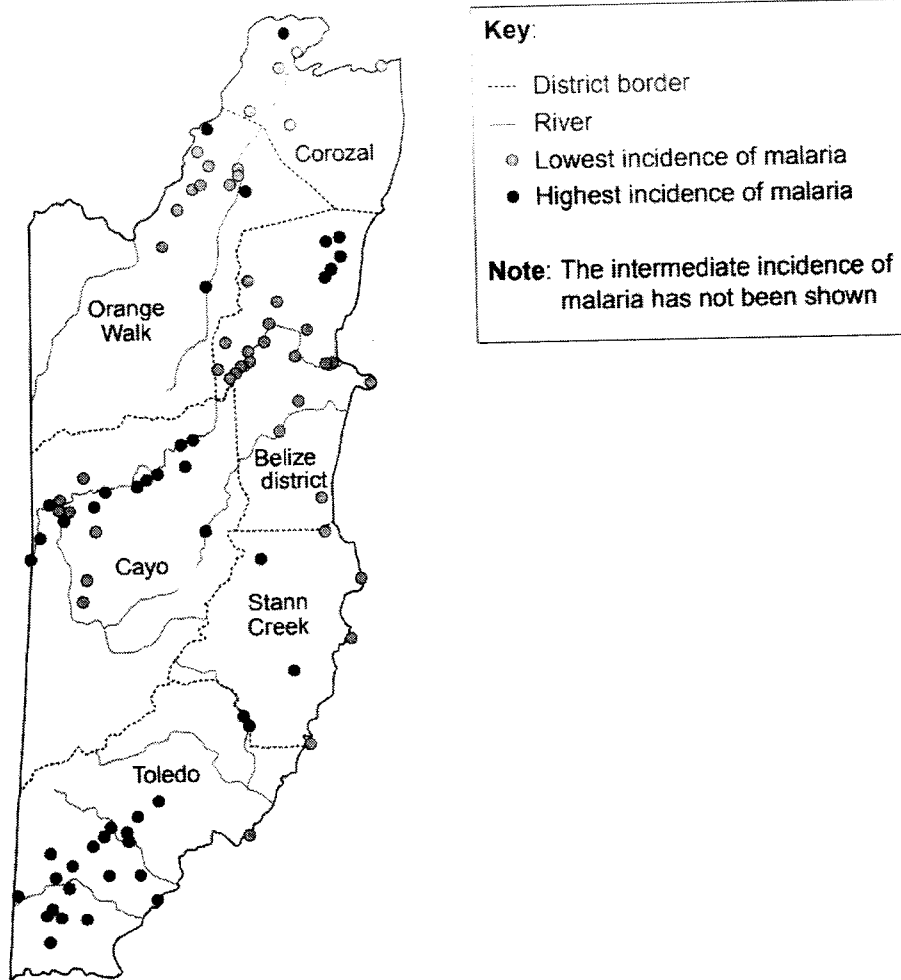


Fig. 3.1

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

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..... [2]

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

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..... [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.

Percentage of land used for agriculture = \_\_\_\_\_ [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.

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..... [2]

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

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..... [2]

[Total: 10]

**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]

