EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2022
General Certificate of Education Advanced Level
Higher 2

H2 Biology

Paper 1 Multiple Choice

9744/01

21 September 2022

60 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use paper clips, glue or correction fluid.
Write your name, civics group and registration number on the Answer Sheet in the spaces provided.

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

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

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

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Answer **all** questions.

1 Tests on four samples from a mixture of biological molecules gave the results shown in the table.

test	boiled with excess Benedict's solution	boiled with excess Benedict's solution after acid hydrolysis and neutralisation	biuret reagent	iodine solution
result	blue	red	purple	yellow

Which biological molecules were in the mixture?

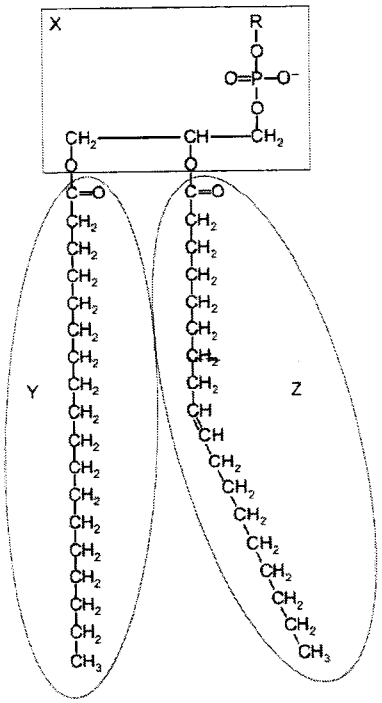
A reducing sugar and protein

B reducing sugar, non-reducing sugar and starch

C non-reducing sugar and protein

D non-reducing sugar and starch only

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



Regions X, Y and Z affect the properties of cell surface membranes in different ways.

Which row shows the effect of each region on the properties of a cell surface membrane?

	increases permeability of hydrophobic region	repels polar molecules	attracts water molecules
A	X	X	Y and Z
B	Y	Y and Z	X
C	Y and Z	X	Y and Z
D	Z	Y and Z	X

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3 Which statements could be used to describe enzyme molecules **and** antibody molecules?

1 Hydrogen bonds stabilise the structure of the protein and are important for it to function efficiently.

2 Hydrophilic R groups point in towards the centre of the molecule and cause it to curl into a spherical shape.

3 The tertiary structure of the protein molecule plays an important role in the functioning of the protein.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

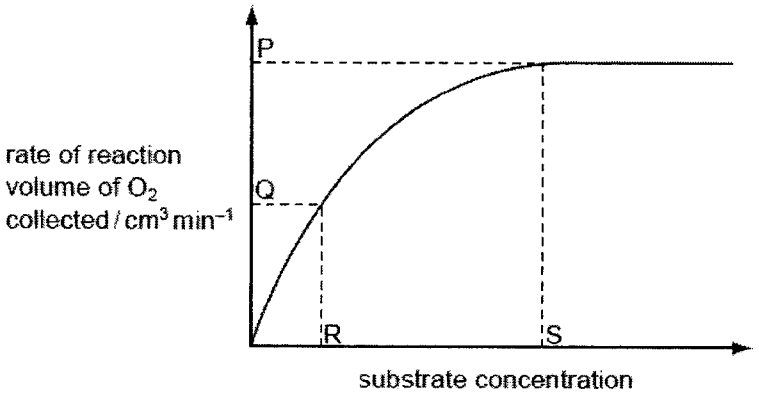
D 1, 2 and 3

4 Liver tissue produces an enzyme called catalase which breaks down hydrogen peroxide into water and oxygen.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

The rate of this reaction can be determined by measuring the volume of oxygen produced in a given length of time.

Students added small cubes of fresh liver tissue to a range of hydrogen peroxide solutions and measured the volumes of oxygen produced. Their data were used to produce the graph showing how changing the concentration of hydrogen peroxide affected the rate of oxygen production.



Which statement is correct?

1 At P, the rate of reaction is limited by the concentration of enzyme.

2 At Q, all of the enzyme active sites are occupied by substrate molecules.

3 At Q, the rate of reaction is limited by the concentration of the substrate.

4 R represents K_m where the reaction rate = V_{max} / 2.

5 At S, all of the enzyme active sites are occupied by substrate molecules.

A 2 and 3 only

B 2 and 5 only

C 1, 4 and 5 only

D 1, 3, 4 and 5 only

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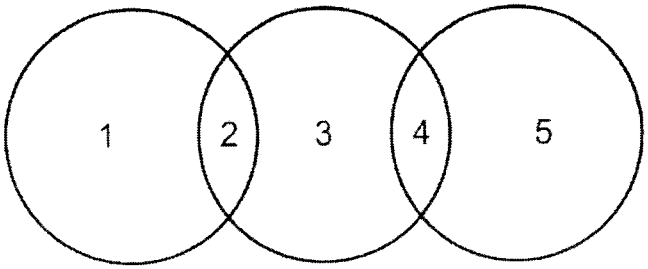
5 The diagram shows the relationship between various cells and their components.



Which row is correct?

	1	2	3	4	5
A	80S ribosome	eukaryotic cell	mitochondrion	70S ribosome	prokaryotic cell
B	chloroplast	plant cell	cell wall	prokaryotic cell	80S ribosome
C	circular DNA	nucleus	eukaryotic cell	mitochondrion	70S ribosome
D	prokaryotic cell	circular DNA	chloroplast	membrane bound	70S ribosome

6 The eyepiece lens of a microscope can be fitted with an eyepiece graticule.

Which of these statements about eyepiece graticules are correct?

1 They measure the actual length of cells in micrometres.
2 They help biologists to draw cells with correct proportions.
3 They change in size when the objective lens is changed from x10 to x40.

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

7 Liver cells contain vesicles that have proteins in their membranes which are specific for the transport of glucose.

When these cells need to take up glucose, the vesicles fuse with the cell surface membrane.

How does the uptake of glucose occur?

A Exocytosis
B Diffusion
C Endocytosis
D Facilitated diffusion

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8 A piece of a DNA molecule contains 84 base pairs. The table shows the number of adenine and cytosine bases in one or both of the DNA strands in this piece of DNA molecule.

base	strand 1	strand 2
adenine	28	23
cytosine	15	

How many guanine bases are present in this piece of DNA molecule?

A 18 **B** 33 **C** 36 **D** 41

Strand 1 has 23 T (since there are 23 A on Strand 2).
Strand 1 has 28 + 23 + 15 = 66 (A+T+C). Therefore, it has 84 - 66 = 18 G.
Strand 2 has 15 G (since there are 15 C on Strand 1).
Strand 1 and 2 has 18 + 15 = 33 G.

9 A polypeptide has the amino acid sequence glycine – arginine – lysine – serine.

The table below gives possible tRNA anticodons for each amino acid.

amino acid	**possible tRNA anticodons**	
Arginine	3' UCC 5'	3' GCG 5'
Glycine	3' CCA 5'	3' CCU 5'
Lysine	3' UUC 5'	3' UUU 5'
Serine	3' AGG 5'	3' UCG 5'

Which sequence of bases on DNA would code for the polypeptide?

A 3' CGA CGC AAG AGC 5'

B 3' CCT TCC TTC TCG 5'

C 5' GGA AGG AAA AGC 3'

D 5' GGT TGG TTG TGC 3'

Appropriate anticodons are complementary to mRNA codons which in turn are complementary to the DNA template. The anticodons thus have **similar sequence** to the DNA template strand triplet codes for the given sequence of amino acids. For glycine – arginine – lysine – serine, we have for glycine, either 3' CCA 5' or 3' CCU 5' anticodons, this corresponds to the starting triplet of option B, 3' CCT 5', further inspection would confirm the sequence given in option B to be correct for rest of the triplet codes. Note the direction of transcription of the DNA template strand (3' to 5') and the direction of translation of the mRNA strand (5' to 3').

DNA triplet codes:	3' CCT	TCC	TTC	TCG 5'
mRNA codons:	5' GGA	AGG	AAG	AGC 3'
Anticodons:	3' CCU 5'	3' UCC 5'	3' UUC 5'	3'UCG 5'

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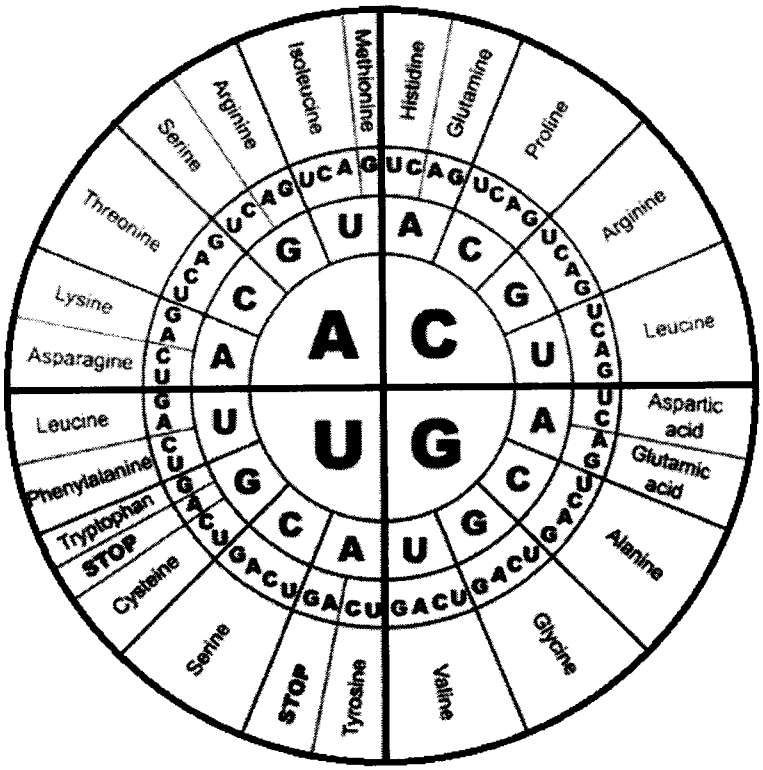
10 The mRNA codons for amino acids are shown below.



A mutagen causes the adenine in DNA to pair with cytosine during transcription.

Which tripeptide will be synthesised when the template DNA sequence **5' TAACTGCCA 3'** is used in protein synthesis in the presence of this mutagen?

A proline-valine-proline

B arginine-glutamine-proline

C tryptophan-glutamine-leucine

D threonine-valine-asparagine

Template DNA: 3' **A**CC GTC **AA**T 5'
mRNA: 5' **C**GG CAG **CC**A 3'

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11 A student observed the cells in the growing region (meristem) of an onion root and obtained the data shown.

stage	number of cells
interphase	886
prophase	73
metaphase	16
anaphase	14
telophase	11

Which percentage of cells contains chromosomes that appear as two chromatids?

A 7.3

B 8.9

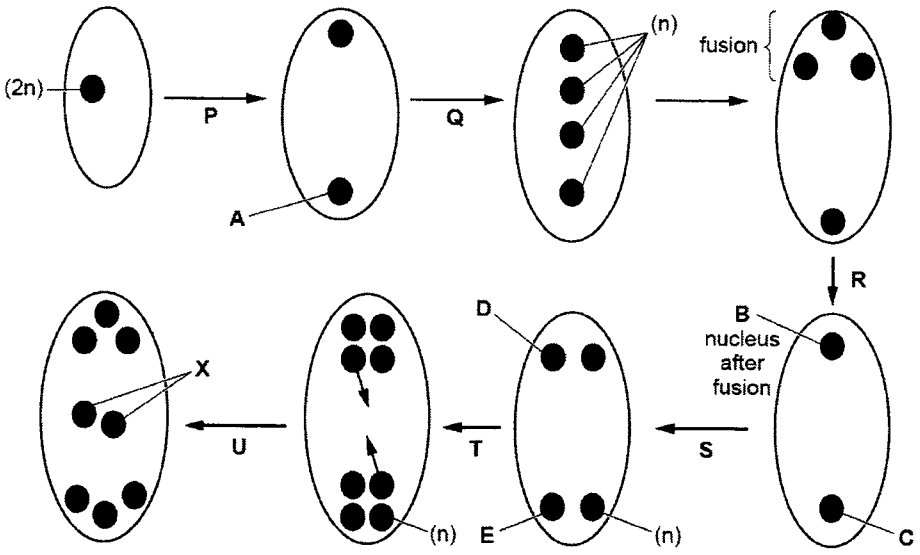
C 95.9

D 97.5

Total number of cells = 886 + 73 + 16 + 14 + 11 = 1000
Stages where cells contain **chromosomes** that appear as **two chromatids**: Prophase & Metaphase
Percentage of cells that contain **chromosomes** that appear as **two chromatids** = (73 + 16) / 1000 = 8.9%

12 The development of the embryo sac in flowering plants involves both mitosis and meiosis. Details of this development can vary in different plants.

The diagrams summarise the development of the egg cell within the embryo sac of *Lilium* sp. Some of the nuclei have been labelled to indicate the ploidy: n = haploid; 2n = diploid.



Which stage, from **P**, **Q**, **R**, and **T**, represents meiosis II?

A P **B** Q **C** R **D** T

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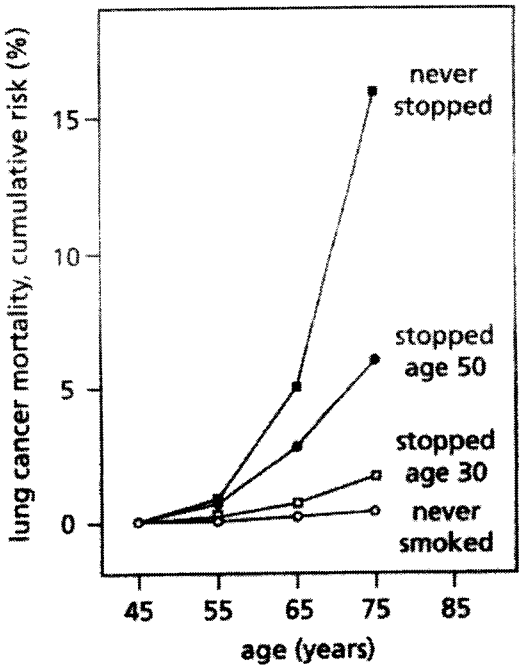
13 Mortality due to lung cancer was followed in groups of males in the United Kingdom for 50 years. The cumulative risk of dying from lung cancer as a function of age and smoking habits for four groups of males is shown in the figure.



Which of the following best explains the trends observed in the graph?

I	The slower the rate of accumulation of mutations, the lower the cumulative risk.
II	When an individual stops smoking, he will undergo a decreased rate of mutation accumulation.
III	The presence of cigarette smoke will cause the accumulation of mutations to occur at an increased rate.
IV	There is little risk of a non-smoker dying of lung cancer.

A I and IV only

B II and III only

C III and IV only

D All of the above

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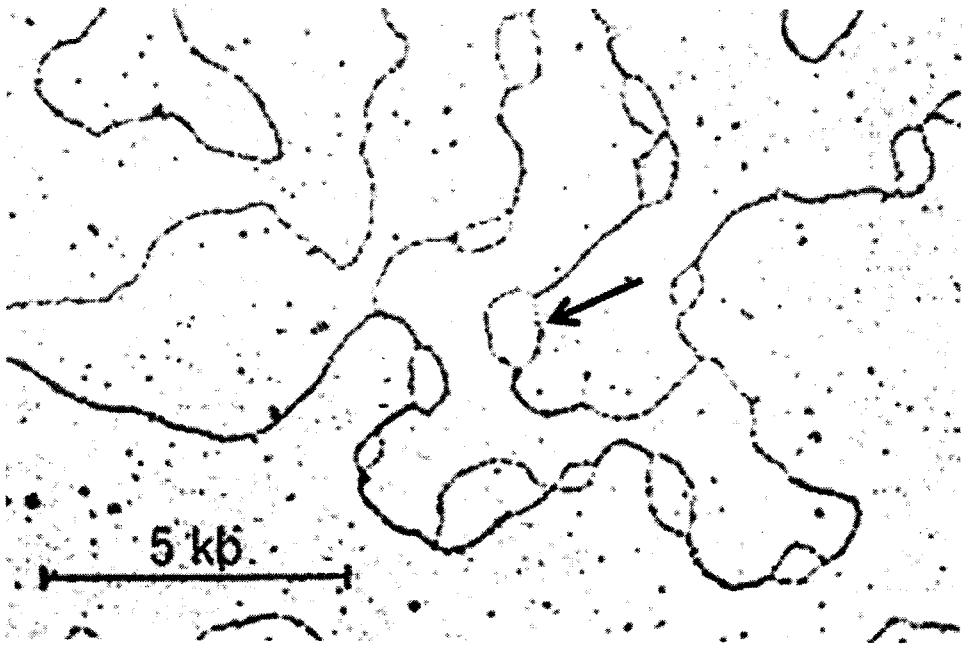
14 The figure below shows structures that are formed along a DNA molecule of a eukaryotic cell during S phase of the cell cycle.



Which statement(s) correctly describe the labelled structure and the process that is taking place?

1 Many such structures can also be found in prokaryotic DNA.

2 DNA replication requires primase to synthesize primers to provide free 3' OH for the elongation of daughter strands by RNA polymerase.

3 Eukaryotic chromosomes face the end-replication problem as they are linear. Prokaryotic chromosomes do not have the end-replication problem as they are circular.

4 The end-replication problem occurs only on the lagging strands.

A 1 and 2 only

B 1 and 3 only

C 3 only

D 3 and 4 only

Explanation:
The TEM shows the replication bubbles along the DNA of a cultured Chinese hamster cell. In each linear chromosome of eukaryotes, DNA replication begins when replication bubbles form at many sites along the giant DNA molecule. The bubble expands as replication proceeds in both directions. Eventually the bubble fuses and synthesis of the daughter strands is complete.

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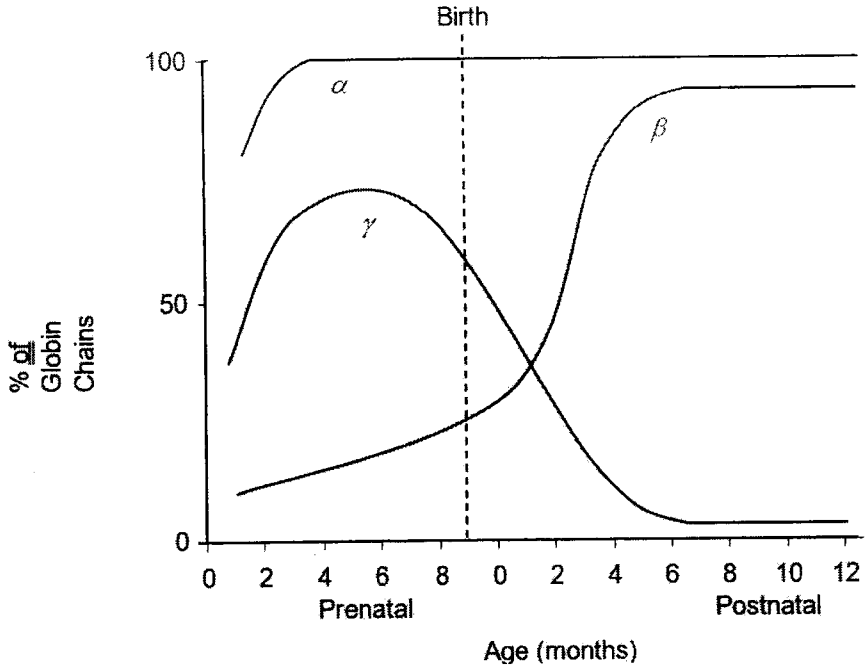
15 The globin gene family in humans consists of the α, β and γ genes. These genes code for the globin chains that make up haemoglobin and are expressed at different levels during different developmental stages.

The graph shows the expression of the various globin chains during the prenatal (fetal) and postnatal (after birth) periods.



Which of the following cannot account for the differences in the levels of expression of globin chains?

A Methyl groups are added to regulatory sequences of γ-globin genes during the postnatal period, allowing for some proteins to bind.

B Alternative splicing occurs in the mature mRNA of the α-globin and β-globin genes, resulting in differences in the rate of expression of globin chains during the prenatal period.

C A growth factor triggers the expression of a transcription factor that increases the rate of β-globin gene expression during the postnatal period.

D The shortening of poly(A) tail in the mRNA of γ -globin genes reduces its stability, resulting in a decrease in the rate of expression of γ-globin chains during the postnatal period.

Explanation:
Alternative splicing does not change the rate of gene expression

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16 One hypothesis about the origin of viruses is that they existed before cellular life forms, later evolving into parasites of cellular organisms. Groups with an ancient, common origin tend to share conserved sequences of DNA or RNA.

Which observation about virus genomes supports the view that viruses existed before cellular life forms and only much later evolved into parasites?

A All viruses have genes that code for capsid components.

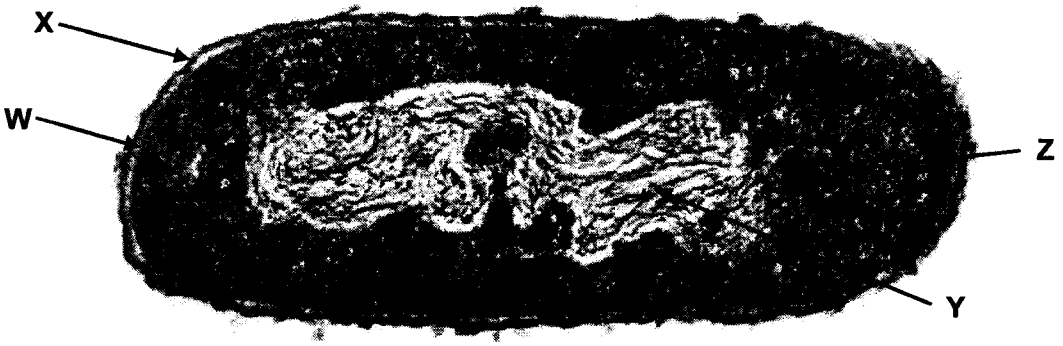
B Introns of eukaryotic genes have common features with viral genomes.

C Large virus genomes have genes that originate in host cells.

D Viral genomes have conserved genes not found in any other genomes.

Explanation
The observation that all viruses share conserved genes that are not found in any other genomes suggests that viruses existed before other life forms evolved.

17 The diagram shows an electron micrograph of a bacterial cell.



Which of the following correctly identifies the functions of structures **W**, **X**, **Y** and **Z**?

	W	X	Y	Z
A	maintains shape of bacterial cell	protects bacterial cell against desiccation	contains antibiotic resistance genes which may be beneficial to the bacterial cell	serves as the site of protein synthesis
B	controls the passage of substances into and out of the cell	maintains shape of bacterial cell	contains genetic information which is essential to the survival of bacterial cell	serves as the site of translation of mRNA
C	controls the passage of substances into and out of the cell	maintains shape of bacterial cell	contains antibiotic resistance genes which may be beneficial to the bacterial cell	protects bacterial cell against desiccation
D	protects bacterial cell against desiccation	protects bacterial cell from the action of phagocytes	contains genetic information which is essential to the survival of bacterial cell	maintains shape of bacterial cell

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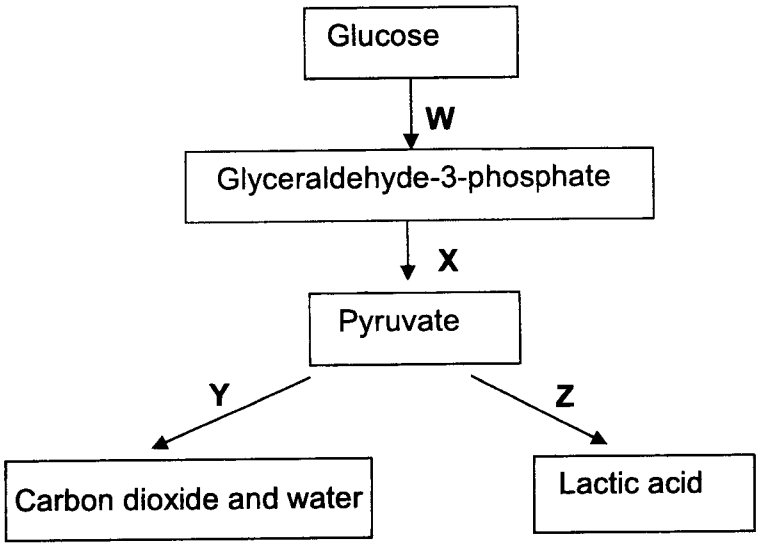
18 Which option shows the correct match of processes **W, X, Y and Z** to statements **(1), (2) and (3)**?



(1) NAD is regenerated without the use of the electron transport system.

(2) ATP is synthesised via substrate level phosphorylation.

(3) It can take place under anaerobic conditions.

	(1)	(2)	(3)
A	Z only	X only	W, X, Z only
B	Z only	X, Y only	W, X, Z only
C	Y, Z only	X only	W, X, Y, Z
D	Y, Z only	X, Y only	W, X, Y, Z

19 Dinitrophenol is a compound that can lodge within the thylakoid membranes of chloroplasts. Its presence provides an alternative route for H^+ ions to diffuse across the thylakoid membranes.

In what way would the Calvin cycle be affected in chloroplasts poisoned with dinitrophenol?

A No effect since Calvin cycle is an enzyme-controlled process.

B The rate of Calvin cycle would increase as pH in the stroma decreases.

C The rate of Calvin cycle would decrease with the accumulation of glycerate-3-phosphate.

D The rate of Calvin cycle would decrease with the accumulation of glyceraldehyde–3-phosphate.

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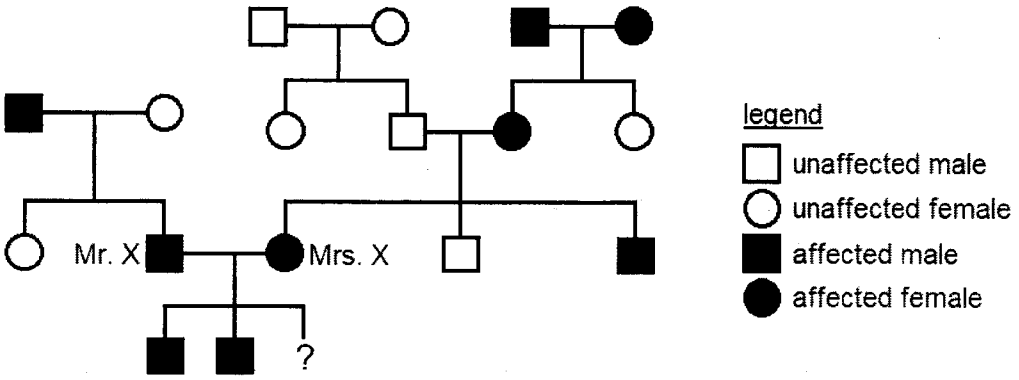
20 The family tree below shows the inheritance of a heart disease due to hypercholesterolaemia.



Mrs. X is expecting a third child. If the child is a son, what is the percentage probability that he will be unaffected?

A 0 %

B 12.5 %

C 25 %

D 50 %

21 Coat colour in horse has three possible phenotypes, grey, black and chestnut, which is due to the interaction of two genes.

Gene ***G/g*** has two alleles: ***G*** resulting in grey coat and ***g*** resulting in non-grey coat.

Gene ***E/e*** has two alleles: ***E*** resulting in black coat and ***e*** resulting in chestnut coat.

The following crosses were carried out.

cross	parental phenotypes	offspring phenotypes
1	grey x grey	grey, black, chestnut
2	black x black	black
3	grey x black	grey, black, chestnut

Which row shows the genotypes of the parents?

	1	2	3
A	GgEe x GgEE	ggEE x ggEE	GgEe x ggEe
B	GgEe x Ggee	ggEe x ggEe	GGEe x ggEe
C	GgEe x GgEe	ggEE x ggEE	GGEe x ggEE
D	GgEe x GgEe	ggEE x ggEe	GgEe x ggEe

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22 Two pure-breeding varieties of plants, one producing short leaves and one producing long leaves, were crossed. The resultant seeds were planted in two different locations, and the lengths of the leaves were measured.

	Location A	Location B
Number of leaves measured	5	5
Mean length / cm	12.1	6.9
Standard deviation	1	1

The formula used for *t*-test is:

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

$\bar{x}$ = mean of samples
s = standard deviation
n = number of samples

Degree of freedom	Probability				
	0.20	0.10	0.05	0.02	0.01
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169

Which conclusion is correct?

	t value	Conclusion
A	6.544	Differences in lengths of leaves due to different genotypes
B	8.222	Differences in lengths of leaves due to random chance
C	8.222	Differences in lengths of leaves due to effects of different environments
D	6.544	Differences in lengths of leaves due to effects of different environments

23 Which of the following correctly matches the step involved in gel electrophoresis to its purpose?

	Step	Purpose
A	Adding buffer solution into electrophoresis gel box	To separate the two complementary strands of double-stranded DNA fragments
B	Adding loading dye	To bind to all DNA fragments to monitor progress of electrophoresis
C	Electrophoresis	To separate DNA fragments based on the amount of negative charges they have
D	Soaking gel in ethidium bromide	To bind to all DNA fragments for visualisation of the DNA bands

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24 *Dolly The Sheep* was the first mammal to be cloned from an adult cell. The success of this cloning experiment is consistent with the view that

A differentiated cells retain all the genes of the zygote.

B genes are lost during differentiation.

C the differentiated state is normally very unstable.

D cells can be easily reprogrammed to differentiate and develop into another kind of cell.

25 Which of the following statements about insulin receptor are **false**?

1. It dimerises when insulin molecules bind to each of the 2 receptor subunits.
2. It exhibits enzymatic activity.
3. It has a 7-pass transmembrane domain.
4. It is secreted by β-cells of islets of Langerhans.

A 1 and 4

B 2 and 3

C 1, 3 and 4

D 2, 3 and 4

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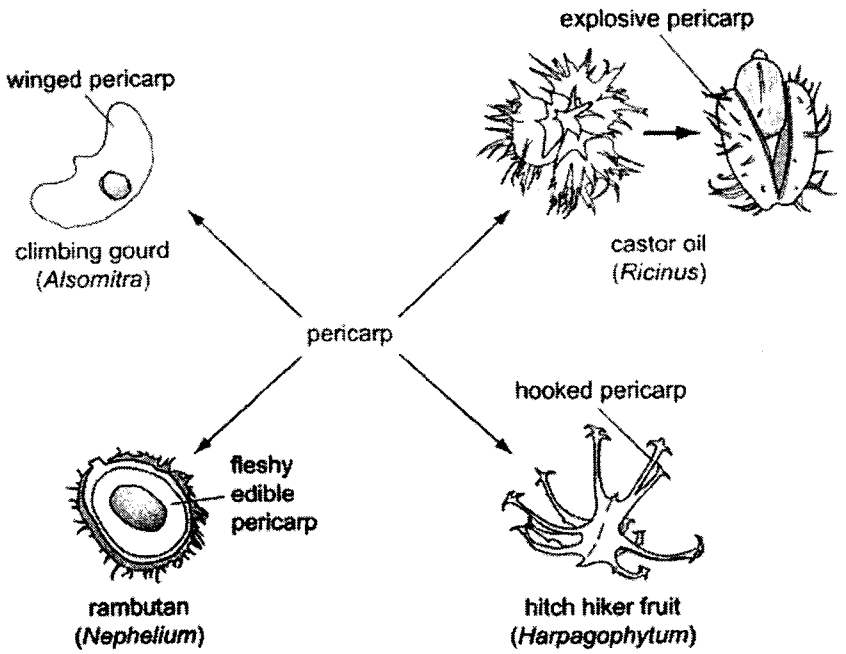
26 The diagram illustrates variation in the pericarp (fruit wall) for a variety of methods used in seed dispersal.



What do these examples illustrate?

A The adaptive radiation of analogous structures showing convergent evolution.

B The adaptive radiation of analogous structures showing divergent evolution.

C The adaptive radiation of homologous structures showing convergent evolution.

D The adaptive radiation of homologous structures showing divergent evolution.

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27 The α, β and γ globin chains of human, chimpanzee, gorilla and gibbon haemoglobin were analysed. The number of differences in the amino acid sequences in comparison with the human molecules is shown in the table.

species	number of differences in amino acid sequence from human molecules		
	α globin	β globin	γ globin
chimpanzee	0	0	1
gorilla	1	1	1
gibbon	3	3	2

What do the differences suggest?

A Humans and gorillas shared a common ancestor more recently than humans and gibbons.

B Humans and gibbons shared a common ancestor more recently that humans and chimpanzees.

C Humans evolved from chimpanzees.

D Humans and gorillas do not share a common ancestor.

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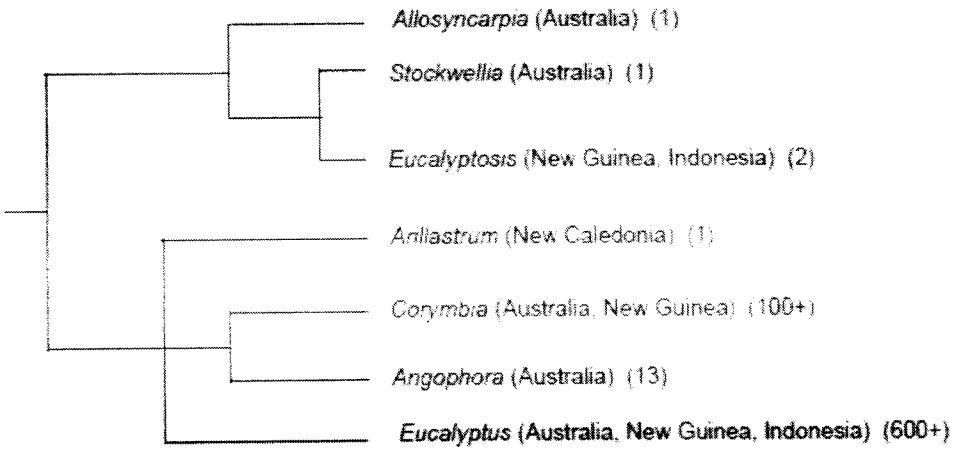
28 A proposed phylogeny for the seven genera of plants is shown in the diagram below, along with the countries in which they are found.



Key Numbers in brackets ( ) refer to the numbers of species in the genus.

It would be reasonable to conclude that

A DNA sequences in *Eucalyptosis* would be more similar to those in *Allosyncarpia* than to those in *Stockwellia*.

B speciation in *Eucalyptus* was assisted by different selection pressures.

C the greater the number of species in a genus, the younger the genus.

D the genus that evolved most recently was *Angophora*.

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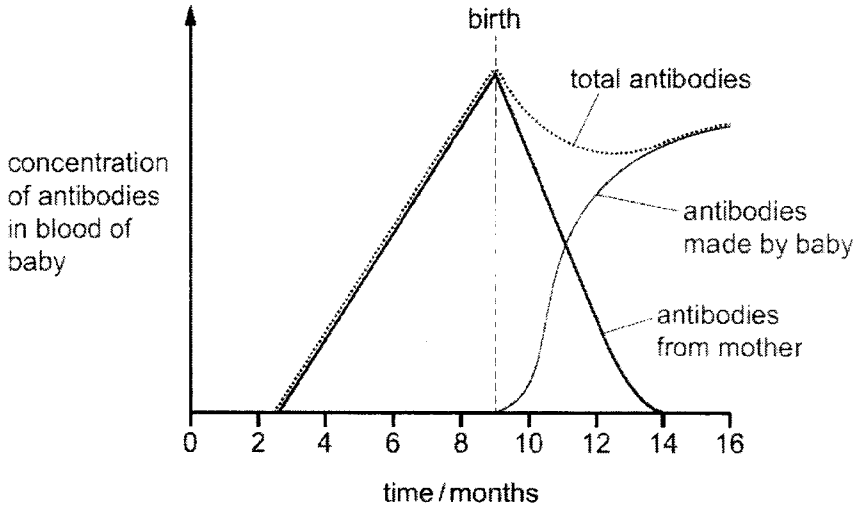
29 The graph shows the changes that occur in the concentration of antibodies in the blood of a baby before birth and during the first few months after birth.



Which description about the changes in immunity during the first few months after birth is correct?

A active artificial immunity decreases, active natural immunity increases

B active natural immunity decreases, active artificial immunity increases

C passive artificial immunity decreases, active natural immunity increases

D passive natural immunity decreases, active natural immunity increases

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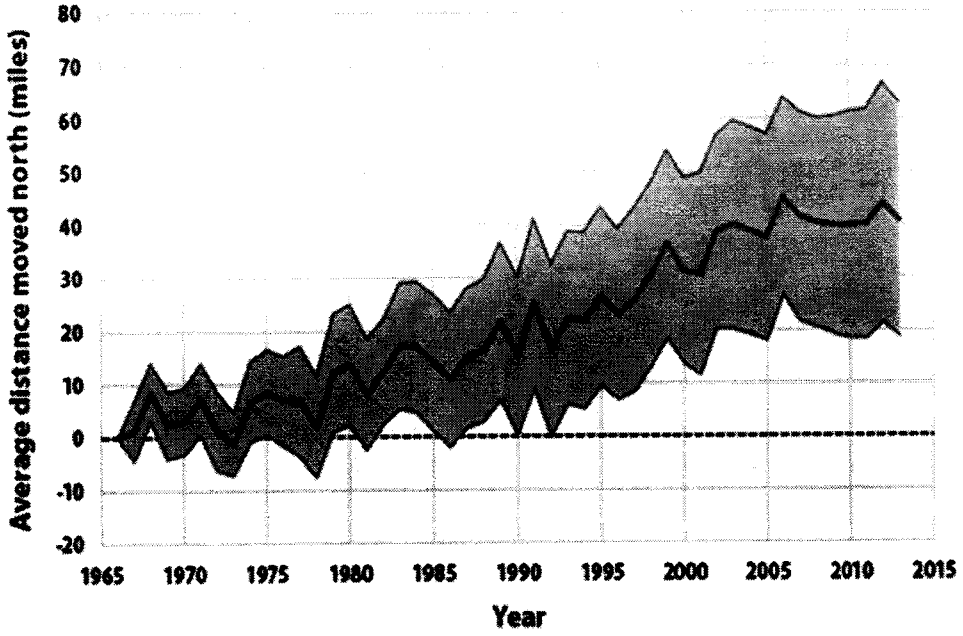
30 Warmer temperatures are forcing birds in pine forests to breed farther north. Many species once found farther south are also expanding their ranges.

The graph below shows the average latitude occupied by 305 bird species in North America during the winters of 1966 to 2013. The shaded band shows the range of latitudes occupied by the birds.



What could explain the observation?

1 Seasonal birds begin their migration earlier, and lay eggs earlier, in response to warming forest climate.

2 Birds are mobile, thus do not need to adapt and can switch their home ranges and habitat to find more suitable breeding grounds.

3 As temperature rises, hardwood forests in the north lose their advantage, and pine forests found in the south now cover the northern region.

4 As temperature rises, birds experience warmer winters that increases their reproductivity, resulting in larger bird populations.

A 2 only

B 2 and 3 only

C 1, 2 and 4 only

D 1, 3 and 4 only

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EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2022
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	**ANSWER KEY**							
CIVICS GROUP	**2**	**1**	**-**			REGISTRATION NUMBER		

H2 Biology

9744/02

Paper 2 Structured Questions

14 September 2022

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration 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, highlighters, glue or correction fluid/tape.

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 Examiner's Use	
1	
2	
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8	
9	
10	
11	
Total	/100

This document consists of **30** printed pages and **2** blank pages.

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Answer **all** questions.

1 The Golgi body, rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER) form part of the internal membrane system of a cell. The membranes have a fluid mosaic structure.

Fig. 1.1 is a transmission electron micrograph of one area of a liver cell showing a region with RER and a region with SER. Mitochondria are also visible in the image.

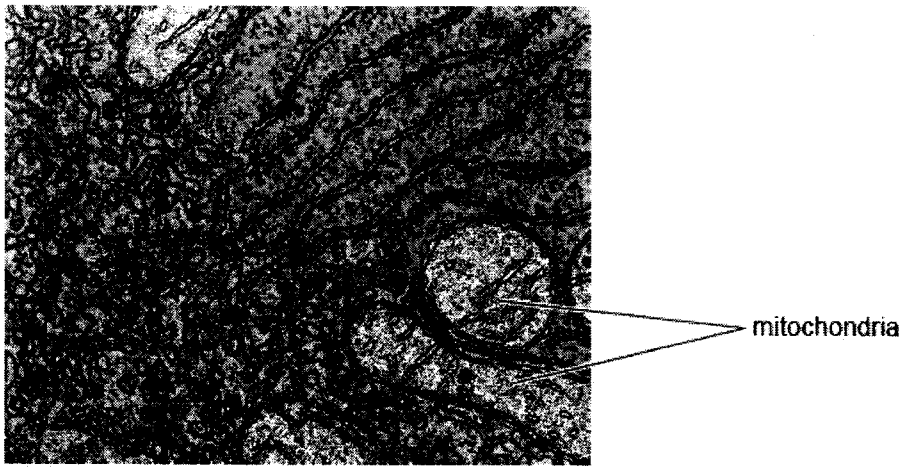

Fig. 1.1

(a) Describe **one** difference between RER and SER. [2]

Structure (any 1)

1. RER has **ribosomes** attached to its surface but SER has **no** ribosomes attached;
2. RER has **flattened sacs** / **cisternae** but SER is **tubular**;
3. RER is continuous with **outer membrane of nucleus** (R: nuclear envelope) but SER is not connected to the nucleus;
4. AVP e.g. RER has **regular** / **layered** arrangement compared to SER which has **irregular** / **disorganised** arrangement;

Function

5. RER **produces** / **transports**, **proteins** / glycoproteins / polypeptides while SER **produces lipids** / cholesterol / steroids; (A: detoxification)

(b) Phospholipids are one of the main components of membranes.

Describe the structure of a phospholipid molecule. [2]

1. A phospholipid consists of **1 phosphoric acid / phosphate group** and **2 fatty acids** combined with **1 glycerol**; (R: if quantity of components not stated)
2. Each fatty acid forms an **ester bond** with glycerol (total of 2 ester bonds) and phosphoric acid forms a **phosphoester bond** with glycerol; (NOTE: glycerol for point 1 can be marked here if student wrote phosphate head and 2 fatty acid tails but did not mention glycerol as part of the structure)
3. AVP e.g. Choline portion attached;
4. AVP e.g. Saturated / unsaturated fatty acid tails;

Point 1 must be present for full credit.

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(c) One function of a Golgi body is to package molecules into Golgi vesicles.

(i) A Golgi body and Golgi vesicles are **not** visible in Fig. 1.1.

Describe the features, **other than** the presence of Golgi vesicles, that would help you identify a Golgi body in a transmission electron micrograph of another area of the same liver cell. [2]

1. **Stack of flattened membrane-bound sacs** called **cisternae**;
2. Each cisterna in stack is **not interconnected / separate**;
3. Has a single membrane;
4. Two distinct faces (**cis and trans**);
5. Two ends of cisternae are swollen / enlarged; (max 2)

Point 5 is not recommended (not technical).

(ii) Some Golgi vesicles contain secretory proteins for release from the cell.

Describe the sequence of events that occurs following the packaging of a secretory protein into a Golgi vesicle to its release from the cell. [3]

1. In Golgi apparatus, secretory proteins leave via **secretory vesicles / Golgi vesicles** by **budding** from ***trans*** face of Golgi;
2. Secretory vesicles / Golgi vesicles containing secretory proteins **fuse with cell surface membrane;**
3. and **release** secretory proteins via **exocytosis**; (R?: proteins *exit/leave* cell) (I: all events before packaging of secretory protein into Golgi vesicle)

(iii) Some Golgi vesicles contain glycoproteins or glycolipids to be added to the cell surface membrane.

State a role of **glycolipids** in the cell surface membrane. [1]

1. Acts as a **self-antigen / recognition site** / for **cell-cell recognition**;
2. Acts as a **receptor**;
3. For **membrane stability**;
4. For **cell-cell adhesion**; (any 1)

[Total: 10]

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2 Fig. 2.1**A** shows a polypeptide molecule during protein synthesis. A molecule of glycine is shown just before it is added to the polypeptide.

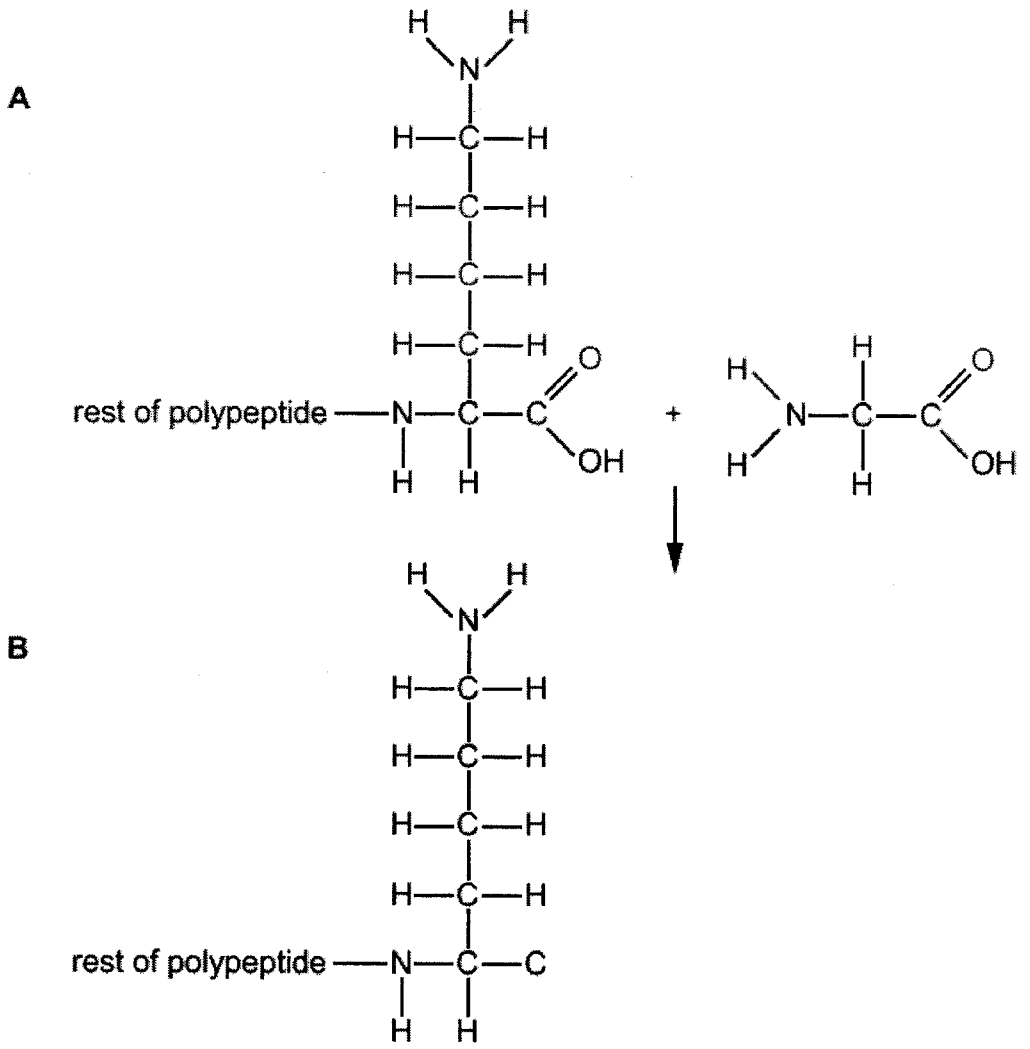

Fig. 2.1

(a) Complete Fig. 2.1**B** to show the molecule of glycine added to the end of the polypeptide. [2]

1. **Product** (R: R used instead of H for glycine) + release of **water** molecule
2. Peptide **bond**: correct identification + labelling

(Not marked for but should include: condensation **reaction**)

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The feet of elephants are protected by structures under the skin known as cushions, as shown in Fig. 2.2.

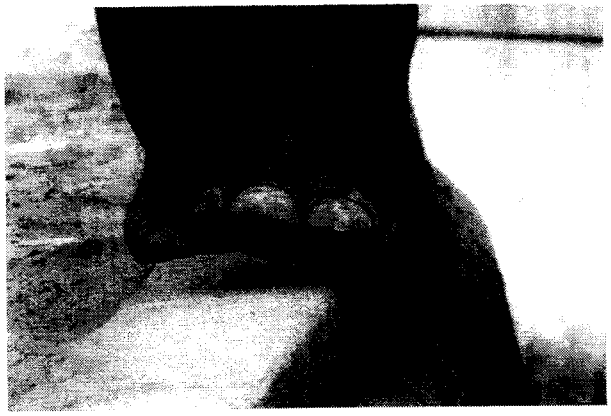

Fig. 2.2

The cushions are made up of a large number of cells surrounded by connective tissue containing many fibres of collagen. The fibres help to maintain the structure of the cushion.

The collagen fibres are made of collagen molecules.

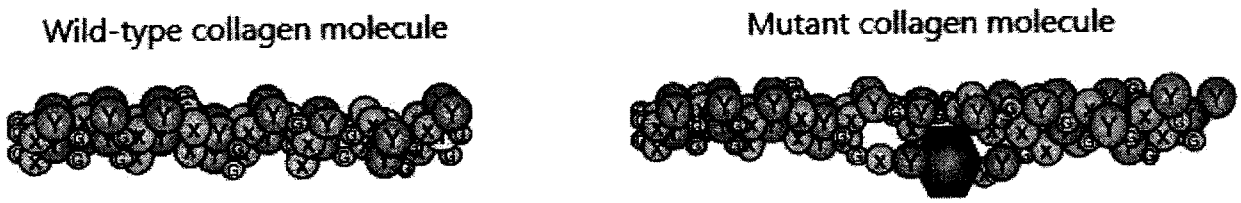

Fig. 2.3

With reference to Fig. 2.3,

(i) describe the structure of a wild-type collagen molecule. [4]

1. **Three polypeptide chains coil around each other** to form a **tight/compact <u>triple helix</u>**;
2. **Each polypeptide chain** consists of **repeating tripeptide units: G-X-Y**, where **G** is glycine, **X** is usually proline and **Y** is usually hydroxyproline; (glycine is every third amino acid in the polypeptide chain) (R: just glycine, proline, hydroxyproline)
3. **<u>Hydrogen bonds</u>** are formed **between adjacent polypeptide chains**, specifically between peptide bond **<u>N-H group</u>** of **<u>glycine</u>** and **<u>C=O group</u>** of **<u>proline</u>**
4. **<u>G</u>** is **smaller than <u>X</u> and <u>Y</u>**, which are **bulkier and less flexible**

(ii) Osteogenesis imperfecta (OI), commonly known as "brittle bone disease", is a disorder characterized by bone fragility and abnormalities of connective tissue. Vast majority of affected individuals have mutations in the genes encoding the polypeptide chains of collagen, which result in substitution of amino acid residues.

Suggest the effect of such mutations on the structure of collagen fibre. [2]

1. **<u>G</u>** is substituted with a **much larger amino acid residue** which **disrupts the close/compact packing of triple helix / three polypeptides** ; (R: no collagen molecule/tropocollagen formed) [compulsory]

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2. **Less/no covalent cross-links between adjacent collagen molecules, reducing formation of collagen fibrils**, and disrupting structure of collagen fibre formed from staggered arrangement of collagen fibrils;

Collagen is a water-insoluble fibrous protein that can be prone to swelling. Collagen swelling occurs when water fills up the gaps between collagen molecules.

Fig. 2.4 shows the effect of pH on swelling ratio of collagen. Swelling ratio is defined as the percentage increase in the weight of collagen due to water absorption.

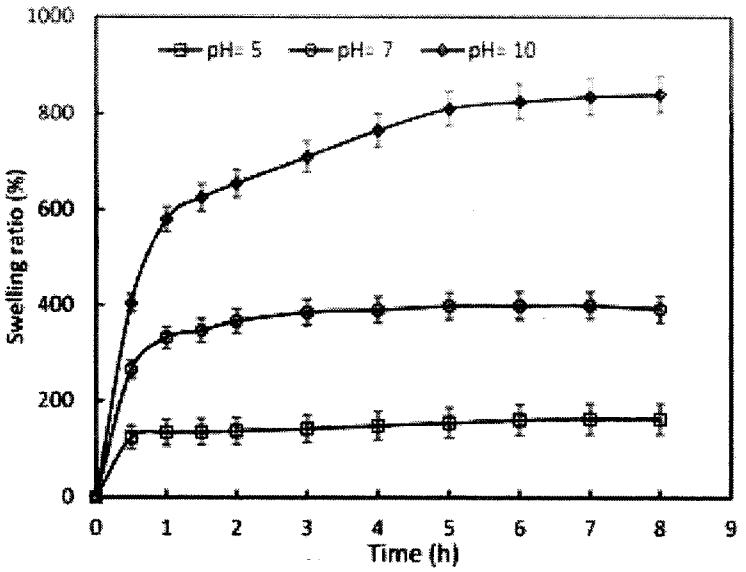

Fig. 2.4

(iii) With reference to Fig. 2.4, describe and explain the effect of pH on collagen. [2]

1. As pH increases from **pH 5** to pH 7 to **pH 10**, the **swelling ratio** of collagen **increases** from around **150%** to 400% to **850%** by end of 8 hours;
2. **Excess OH^- ions at high pH neutralise** the **positively charged R group** of **amino acids**, breaking the **ionic bonds and hydrogen bonds**, creating **larger / more gaps** between collagen molecules, resulting in higher swelling ratio;

[Total: 10]

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3 **(a)** Fig. 3.1 is a photomicrograph of root tip cells at different stages in the cell cycle. A cell cycle in interphase is labelled.

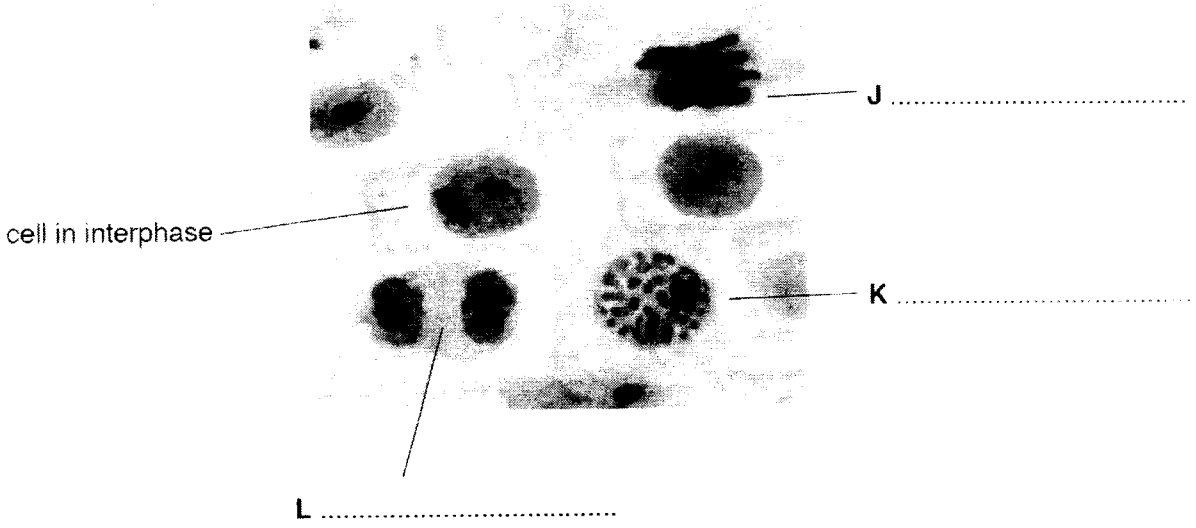

Fig. 3.1

(i) Name the stage of mitosis shown in each of the cells **J**, **K** and **L** in Fig. 3.1.

Write your answer in the space next to each letter on Fig. 3.1. [2]

1. **J** metaphase; **K** prophase; **L** telophase
   [3 correct: 2 marks; 1 – 2 correct: 1 mark]

(ii) Explain how it is possible to deduce that the labelled cell in interphase shown in Fig. 3.1 is in late, rather than early, interphase. [1]

1. The size of the cell is the same size as cells in mitosis (OWTTE)

(iii) Suggest one advantage of using a light microscope, rather than an electron microscope, to study cell division. [1]

1. Light microscope can be used to observe living cells
2. the process of mitosis can be seen happening (OWTTE) (**R** easier to see mitosis happening **I** to study cell division)
3. The light microscope is easier to use (OWTTE) A: qualified personnel needed for use of electron microscope.
4. AVP

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(b) Mutations in human body cells can sometimes result in a tumour. Some tumours are cancerous.

(i) Outline how tumour development is a multistep process. [3]

1. A single normal cell first undergoes a **loss-of-function mutation** in **both alleles of the tumour suppressor gene,** leading to **increased cell proliferation/excessive cell division;**
2. Following this, the cell accumulates another **gain-of-function mutation** of the **proto-oncogene** to form **oncogene**,
3. Coupled with other **accumulated mutations** in other cancer critical genes (e.g. proto-oncogenes and telomerase genes), they lead to **uncontrolled cell division** and the development of tumour.
4. AVP: **Dysregulation of cell cycle checkpoints** due to **mutations**.

(ii) Tumour cells have antigens on their cell surface that are not present on non-tumour cells.

These antigens are the result of gene mutations and are known as tumour specific antigens (TSA).

One type of TSA differs in structure from the protein found on the cell surface of non-tumour cells by a single amino acid.

Explain how a gene mutation could result in the production of this TSA. [2]

1. It is due to a **single base substitution** mutation, which results in a **different** mRNA **codon** that codes for **different amino acid**. (A: description of single base mutation, e.g. point mutation)
2. Thus, the resulting protein will have a **different primary structure** / the **sequence of amino acids is changed**. Subsequently changing the secondary and tertiary structure, causing polypeptide to **fold** into a **different 3D conformation** (A: tertiary structure).

(c) Immunotherapy is a form of treatment for cancer which aims to stimulate the immune system to destroy tumour cells.

One form of immunotherapy for cancer uses a vaccine which contains one specific type of TSA.

Suggest how vaccination with a specific type of TSA could lead to the destruction of tumour cells by T-lymphocytes in the body. [1]

1. **Activated T-lymphocytes** will **only recognize** one specific type of **TSA on tumour cells** and destroy tumour cells only. (OWTTE)

I: antigen presentation, antibody production

[Total: 10]

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4 Lactate dehydrogenase (LDH) is an enzyme found in many organisms. Within the same organism, it can be found in different forms, called isoenzymes. The isoenzymes are structurally different but all catalyse the same reaction.

Lactate dehydrogenase isoenzymes are globular proteins, each consisting of four polypeptides.

Lactate dehydrogenase isoenzymes are made up of two types of polypeptide: polypeptide M, which is coded for by the LDH-A gene and polypeptide H, which is coded for by the LDH-B gene.

Table 4.1 shows the composition of different human lactate dehydrogenase isoenzymes and examples of tissues and organs where each can be found.

Table 4.1

isoenzyme	polypeptide composition of enzyme	example of isoenzyme location
LDH-1	HHHH	heart red blood cells
LDH-2	HHHM	heart red blood cells
LDH-3	HHMM	brain lungs
LDH-4	HMMM	kidneys placenta
LDH-5	MMMM	liver skeletal muscles

(a) With reference to Table 4.1, suggest how different cells of the same individual can produce different isoenzymes. [2]

1. Due to **differential gene expression** / WTTE of **LDH-A and LDH-B** genes **expressed** in **different** cells; (A: Appropriate reference to mRNA half-life of LDH-A and LDH-B mRNA products)

   (R: reference to alternative splicing since there are only two genes given, each gene only codes for one polypeptide – LDH-A gene for polypeptide M and LDH-B for polypeptide H, hence not likely to have alternative splicing)

2. **Cite appropriate pair of data** from Table 4.1 e.g. **LDH-1** isozyme from **heart and red blood cells** have **only** H polypeptide chains suggesting only **LDH-B gene expressed** but **LDH-5** isozyme in **liver and skeletal muscles** only has 4 M polypeptide chains, suggesting that only **LDH-A** gene **expressed**;
   (LDH-1 and LDH-5 is a straightforward pair for use to compare)

   Explanation given must match data cited e.g. genes being switched off cannot be used to account for presence of LDH-2 to LDH-4 isoenzymes as both the LDH-A and LDH-B would be expressed (they contain mixture of H and M polypeptides).

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(b) The base sequences of the LDH-A and LDH-B genes and the sequences of the amino acids encoded by these genes were determined.

Fig. 4.1 shows the first ten amino acids of polypeptides M and H and the corresponding base sequences of one of the DNA strands of each gene.

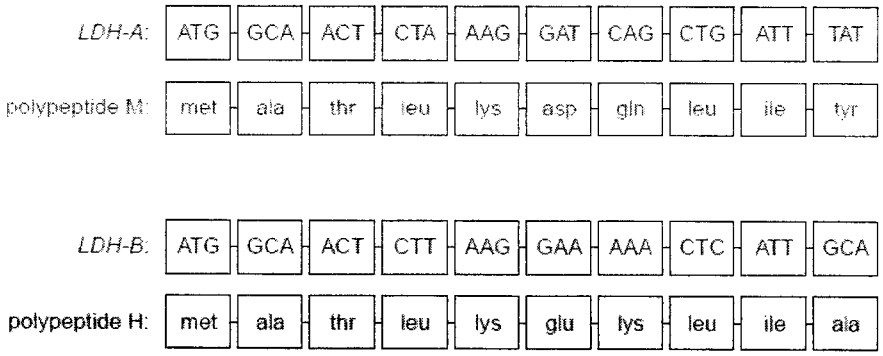

Fig. 4.1

Table 4.2 shows the genetic code (mRNA codons).

Table 4.2

first position	second position				third position
	U	C	A	G	
U	phe	ser	tyr	cys	U
	phe	ser	tyr	cys	C
	leu	ser	STOP	STOP	A
	leu	ser	STOP	trp	G
C	leu	pro	his	arg	U
	leu	pro	his	arg	C
	leu	pro	gln	arg	A
	leu	pro	gln	arg	G
A	ile	thr	asn	ser	U
	ile	thr	asn	ser	C
	ile	thr	lys	arg	A
	met	thr	lys	arg	G
G	val	ala	asp	gly	U
	val	ala	asp	gly	C
	val	ala	glu	gly	A
	val	ala	glu	gly	G

With reference to Fig. 4.1 and Table 4.2,

(i) state if both the base sequences of LDH-A and LDH-B genes are the template strand or non-template strand of DNA. [1]

Non-template strand(s);

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(ii) explain your answer to **(b)(i)**. [2]

1. mRNA is equivalent to DNA strand shown except U replaces T / is <u>complementary copy</u> of <u>transcribed strand of DNA</u>;
2. e.g. Methionine start amino acid thus AUG is mRNA codon, so transcribed DNA would be TAC, instead of ATG;

(iii) Fig. 4.2 shows the process of polypeptide synthesis.

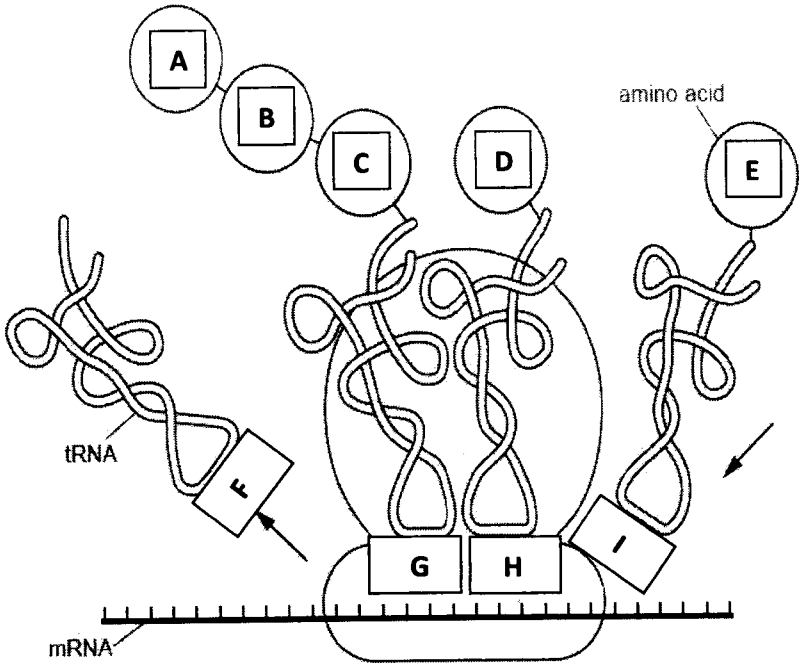

Fig. 4.2

Fill in the following spaces with the relevant information for the synthesis of the first five amino acids for the LDH-A polypeptide chain.

Amino acids: **A** met **B** ala **C** thr **D** leu **E** lys [1]

Anticodons: **F** CGA **G** UGA **H** GAA **I** UUU [1]

CGG	UGG	GAG	UUC
CGU	UGU	GAU	
CGC	UGC	GAC	

1 mark for each group (all or none for each group)

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(iv) Compare the structures of mRNA and tRNA. [3]

Answer to be written in prose. Following table for ease of answer presentation.

mRNA	tRNA
Similarity	
1. Both are **single stranded polynucleotide** chain; *2.* Both are made of **ribonucleotides**; *3.* Both contain **uracil** in place of thymine; *4.* AVP; Nucleotides joined by **phosphodiester** bonds; (max 2)	
Difference	
1. Single strand not folded	*1.* Single strand folded into a clover-leaf structure
2. Absence of hydrogen bonds within molecule	*2.* Hydrogen bonds between complementary base pairs within molecule
3. The 3' end does not have a fixed codon	*3.* The 3' end of the tRNA strand always end with the CCA codon
4. No anticodon	*4.* Anticodon present
5. Does not have amino acid attached	*5.* Can have amino acid attached
6. AVP	*6.* AVP (Max 2)

[Total: 10]

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5 In multicellular eukaryotes, gene regulation is important in development. Different sets of genes need to be expressed in different cells, at the right times, and in the right sequence for organisms to develop correctly.

In eukaryotes, a specific transcription factor or activator binds to an enhancer to regulate the expression of genes coding for specific proteins in different tissues.

(a) (i) Explain the meaning of the term 'enhancer'. [1]

1. Enhancers are **non-coding DNA sequences / distal control elements** where **activators bind** to, which **increase** the **rate of transcription**;

('Activators bind to' already suggested in the question stem, but no need to mark for it)

(ii) Using the information given, suggest a reason why activators are referred to as 'specific' transcription factors. [1]

1. Specific cell types in the body may have specific types of activator molecules (that are not present in other cell types);
2. AVP; Not found in all eukaryotic species; Only present in specific developmental stage

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(b) The *PITX1* gene codes for a protein that plays a role in the development of pelvic spines of fishes like the three-spine stickleback, *Gasterosteus aculeatus*. *PITX1* also plays critical roles in controlling the development of the fish body like the formation of the jaws, pelvis and pituitary glands.

Fig. 5.1 shows a diagram of the *PITX1* gene and the associated regions.

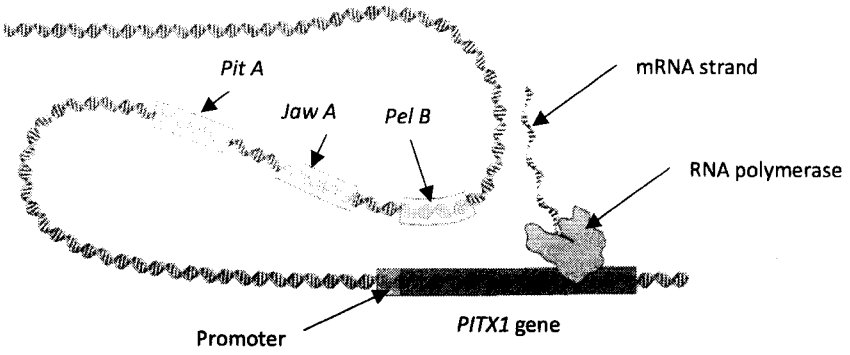

Fig. 5.1

(i) The three regions, *Pel B*, *Jaw A*, *Pit A* are important for the expression of the *PITX1* gene.

Describe how the binding of an activator like Pel B at the *Pel B* region can affect gene expression. [2]

1. Binding of activator to enhancer causes **bending of spacer DNA** allows **direct interaction** of activators with **RNA polymerase** and **general transcription factors** at the promoter;
2. Promoting the assembly of **transcription initiation complex**, thus **increasing rate of transcription**;

(ii) Explain how the structure of the Pel B activator enables it to bind to the *Pel B* region. [1]

1. Pel B activator protein has a **DNA-binding site** that is **complementary** to the **conformation** of the Pel B **enhancer / sequence**;

(iii) Assuming that cells in the pelvis and eyes of the stickleback contain the same *PITX1* gene and the same three regions as shown in Fig. 5.1, explain why eyes of the stickleback do not have spines. [2]

1. In the **eye cells**, there are **no activator proteins** like Pel B, Jaw A, Pit A that can bind to the Pel B, Jaw A and Pit A enhancer regions;
   OR
   Genes for activator proteins Pel B / Jaw A / Pit A are silenced;
   OR
   Chromatin modification (e.g. DNA methylation)
2. Thus, the **PITX1 gene** in the cells of the eyes is **not expressed** and **no spines** are produced in the eyes;

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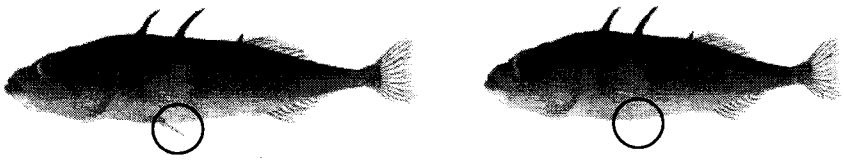
(c) Scientists researching on different species of sticklebacks living in the marine environments and in freshwater lakes found that they differed in the presence or absence of the pelvic spines as shown in Fig. 5.2.

Molecular genetic analysis found that these two groups of fishes exhibited very different levels of expression for the *PITX1* gene. Fig. 5.3 shows the level of expression (in arbitrary units or A.U.) of the *PITX1* gene in the pelvic regions for the fishes from both habitats.



Marine stickleback Freshwater stickleback

Fig. 5.2

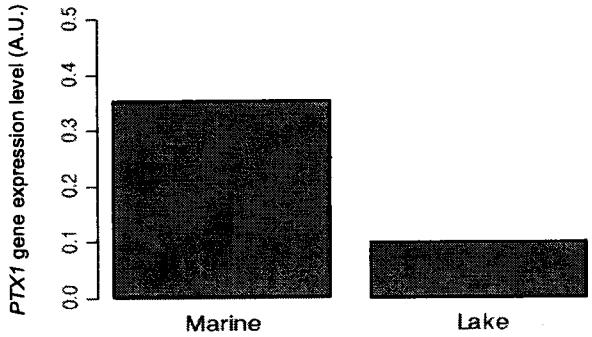


Fig. 5.3

(i) With reference to Fig. 5.3, suggest a reason for the absence of pelvic spines in freshwater stickleback. [2]

1. Gene expression of **0.35 A.U.** in lake/freshwater fishes compared to **0.10 A.U.** in marine fishes; (A: 3.5 times gene expression level)
2. Not enough gene expression of PITX1 gene, need to reach threshold/minimum level (OWTTE);

(ii) In freshwater habitats, dragonfly larva are much larger in size than young sticklebacks. They predate on the young sticklebacks by grabbing on to protruding parts of the fish.

Suggest how the absence of pelvic spines aids in the survival of the young sticklebacks. [1]

1. It makes it **harder** for dragonfly larva to grab and eat the young fish due to **less** of protruding spines (OWTTE);

[Total: 10]

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6 The patty pan squash plant, *Cucurbita pepo*, produces edible fruits that vary in colour.

(a) The colour of the fruits is controlled by two genes, **A/a** and **B/b**, that occur on different chromosomes.

- Allele **A** produces a white fruit colour.
- Allele **a** does not produce a colour by itself but allows the colours coded by gene **B/b** to show in the phenotype.
- Allele **B** produces a yellow fruit colour.
- Allele **b** produces a green fruit colour.

In a dihybrid cross, a pure-breeding white parent plant was crossed with another pure-breeding green parent plant. All the resulting F_1 plants produced white fruits.

The F_1 plants were then crossed with each other to obtain the F_2 generation.

(i) State the name for this type of gene interaction. [1]

Epistasis / Dominant epistasis;

(ii) Draw a genetic diagram to show the cross of the F1 plants to obtain the F2 generation.

F_1 Phenotypes	white squash	X	white squash
F_1 Genotypes	AaBb	X	AaBb
Meiosis Gametes	AB Ab aB ab		AB Ab aB ab

Random Fertilisation

	AB	Ab	aB	ab
AB	AABB white	AABb white	AaBB white	AaBb white
Ab	AABb white	AAbb white	AaBb white	Aabb white
aB	AaBB white	AaBb white	aaBB yellow	aaBb yellow
ab	AaBb white	Aabb white	aaBb yellow	aabb green

F_2 Genotypic Ratio: 12 A_B_ , A_bb : 3 aaB_ : 1 aabb

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F_2 Phenotypic Ratio	12 white : 3 yellow : 1 green

F_1 Phenotype **and** Genotype; 1 m
Gametes; 1m (R: if not circled)
Punnet Square with genotypes **and** phenotypes; 1m
F_2 Genotypic and Phenotypic Ratios; 1 m

[4]

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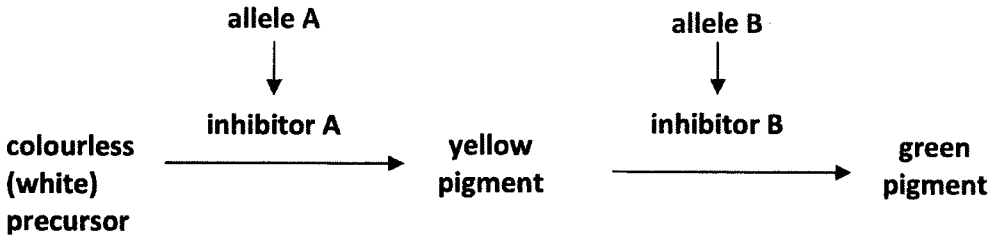
(b) Explain how different genotypes give rise to a white phenotype. [3]

1. Both alleles A and B code for **functional inhibitors** A and B respectively;
2. Inhibitor A **inhibits** the enzyme that **converts a colourless/white precursor to yellow** pigment, while inhibitor B **inhibits** the enzyme that **converts the yellow pigment to a green pigment;**
3. Thus a genotype **with one dominant A allele or with at least one dominant A and at least one dominant B allele** will give a **white phenotype** (A_bb, A_B_);

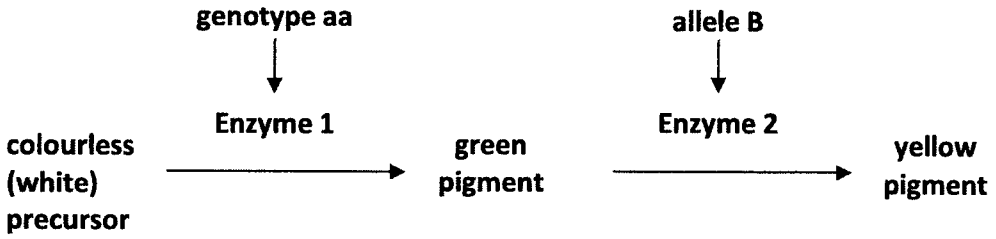
Note: The squash is only **yellow** if the genotype is **aaB_** / The squash is green if the genotype is **aabb** / OWTTE;



Accepted Alternative Answer:

1. **Allele A** will result in a **non-functional enzyme** 1;
2. Non-functional enzyme 1 **cannot convert colourless/white precursor** to **green** pigment, hence a **white phenotype** (A_bb, A_B_);
3. **Genotype aa** code for a **functional enzyme** 1, it converts **colourless/white precursor** to **green** pigment (aabb);

(Note: Genotype of aaB_ will result in yellow phenotype)



(c) Explain how you would determine if the genotype of a white squash was homozygous dominant or homozygous recessive at gene locus **B**, assuming that it is heterozygous at gene locus **A**. [2]

1. **Test cross** with a plant that is/has **double homozygous recessive** / **genotype aabb** / **green** squash;
2. If we see **half** of the offspring are **white** and **half** of the offspring are **yellow**, the B locus is homozygous dominant, Aa**BB**, but if **half white** and **half green**, then the B locus is homozygous recessive, Aa**bb**;

AaBB x aabb → AaBb (white) : aaBb (yellow)
Aa[redacted] x aabb → Aabb (white) : [redacted] (green)

[Total: 10]

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7 **(a)** Chemiosmosis is the term used to describe the synthesis of ATP using a proton gradient across a membrane in a mitochondrion or chloroplast. It was first demonstrated by Peter Mitchell in 1961.

- In some of his experiments, Peter Mitchell used mitochondria that had been isolated from cells.
- The mitochondria were kept in liquid, in glass dishes, to which ADP, Pi and other substances were added.
- The outer mitochondrial membrane is freely permeable to proton entry.
- The temperature, pH and water potential were kept constant.
- After a period of time, he checked for the presence of ATP.

The contents of some of the dishes are shown in the table below.

Complete the table using a tick (✓) if ATP was produced, and a cross (✗) if no ATP was produced. [2]

dish contents	ATP produced
mitochondria + ADP + Pi + acetyl CoA + oxygen	✓
mitochondria + ADP + Pi + acetyl CoA	✗
mitochondria + ADP + Pi + low concentration of protons (H^+)	✗
mitochondria + ADP + Pi + high concentration of protons (H^+)	✓

0 or 1 correct = 0 mark
2 or 3 correct = 1 mark
4 correct = 2 marks

(b) Explain the consequences to a mitochondrion if the water potential of the liquid in the dishes is higher than the water potential of the mitochondrial matrix. [2]

1. Water would enter the mitochondrion via **osmosis down the water potential gradient**;
2. **Mitochondrion burst / membranes rupture**;

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(c) Fig. 7.1 is a transmission electron micrograph of a chloroplast.

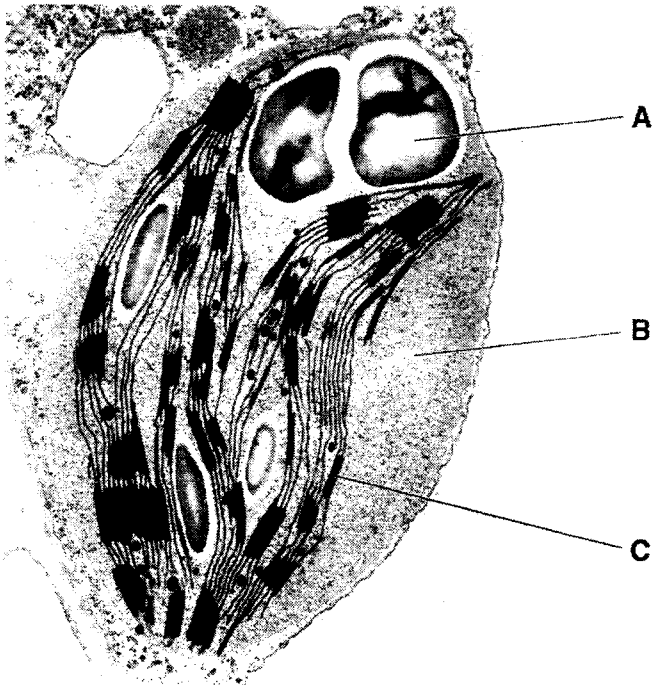

Fig. 7.1

Many compounds and structures involved in photosynthesis are located in a chloroplast.

Using the labels **A**, **B** or **C**, complete Table 7.1 to show the location of four of these compounds or structures.

You may use each of the letters **A**, **B** and **C** once, more than once, or not at all.

Table 7.1

compound or structure	location
ATP synthase	**C**
rubisco	**B**
starch grain	**A**
phospholipid bilayer	**C**

0 or 1 correct = 0 mark
2 or 3 correct = 1 mark
4 correct = 2 marks

[2]

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(d) The light dependent stage of photosynthesis in a suspension of isolated chloroplasts can be investigated using the Hill reaction.

Dichlorophenolindophenol (DCPIP) can be used to follow the process. DCPIP is a blue dye which turns colourless when it is reduced by accepting hydrogen and electrons.

oxidised DCPIP ⟶ reduced DCPIP

blue ⟶ colourless

(i) DCPIP is an artificial hydrogen acceptor that can be used in the Hill reaction.

Name the natural hydrogen acceptor found in chloroplasts that is replaced by DCPIP in the Hill reaction. [1]

$NADP^+$

(ii) Outline the way in which hydrogen is made available to reduce the hydrogen acceptor in the light dependent stage of photosynthesis. [2]

1. **Photolysis** of **water** occurs to **split water molecule into hydrogen ions and oxygen atom** in **photosystem II**
2. NADP reductase / enzyme **combines $NADP^+$** with **hydrogen ions and electrons** to **reduce** it to **NADPH**.

(iii) Predict **and** explain the effect on the concentration of RuBP in the chloroplasts if DCPIP becomes reduced instead of the natural hydrogen acceptor. [1]

1. RuBP concentration will **decrease** as it is **used up in carbon fixation** but **not regenerated**.

[Total: 10]

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8 Sickle cell anaemia is an autosomal recessive inherited disorder.

- The Hb^A allele codes for the normal β-globin polypeptide of haemoglobin.
- The Hb^S allele, caused by a base substitution mutation, codes for an abnormal β-globin polypeptide.
- The base substitution results in the amino acid glutamate, which has a charged R group, to be replaced by valine, which has a non-polar R group, in the polypeptide.

The abnormal haemoglobin molecules (HbS) form fibres in low partial pressures of oxygen (*p*O2). The fibres cause red blood cells to become sickle shaped and the cells can block blood capillaries.

Individuals with adult haemoglobin molecules that are all abnormal (HbS) have sickle cell anaemia. This is a painful chronic condition that can be life-threatening.

(a) Explain why this mutation causes the HbS to form fibres. [2]

1. The **R group** of **valine** is **non-polar** and **hydrophobic** while the R group of glutamate is charged and hydrophilic. (no need 2nd part because not about HOW)
2. **HbS polymerise** to form fibres due to **hydrophobic interactions** between exposed hydrophobic regions on β-globin polypeptides of adjacent haemoglobin molecules (R: *without idea of between haemoglobin*) in low partial pressures of oxygen (*p*O2)

(b) People who are heterozygous (Hb^A Hb^S) have sickle cell trait (SCT). For a child to inherit sickle cell anaemia (Hb^S Hb^S), both parents must have SCT. A genetic screening program is available for sickle cell anaemia and SCT.

(i) To test for the presence of Hb^S, DNA is extracted and the polymerase chain reaction (PCR) is carried out with two specific sets of primers. One set of primers (normal-specific primers) detects Hb^A allele while the other set of primers (mutant-specific primers) detects Hb^S allele.

Explain:

- why primers are used in PCR
- how the use of two specific sets of primers allows the amplification of the normal, sickle cell anaemia and SCT genotypes. [2]

1. Primers **anneal/bind to normal or mutated codon** to **provide free 3' OH group** for **Taq polymerase** to **extend/replicate/amplify DNA**;
2. Binding of **normal-specific primer only** indicates **Hb^A Hb^A** (normal genotype), binding of **mutant-specific primer only** indicates **Hb^S Hb^S** (sickle cell anaemia genotype), while binding of **both normal-specific and mutant-specific primers** indicate **Hb^A Hb^S** (SCT genotype)

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(ii) Gel electrophoresis is carried out on the products of the PCRs.

Fig. 8.1 includes the results for two individuals, **A** and **B**, tested for the sickle cell allele.

- Each lane has an 860 base pair (bp) band to indicate the test is valid.
- Lane 1 is a control lane with a 207bp band for an individual with known normal phenotype.
- Lane 2 is a control lane with a 207bp band for an individual with known sickle cell anaemia phenotype.
- Lanes 1, 3 and 5 contain DNA from the PCR that used normal-specific set of primers.
- Lanes 2, 4 and 6 contain DNA from the PCR that used mutant-specific set of primers.

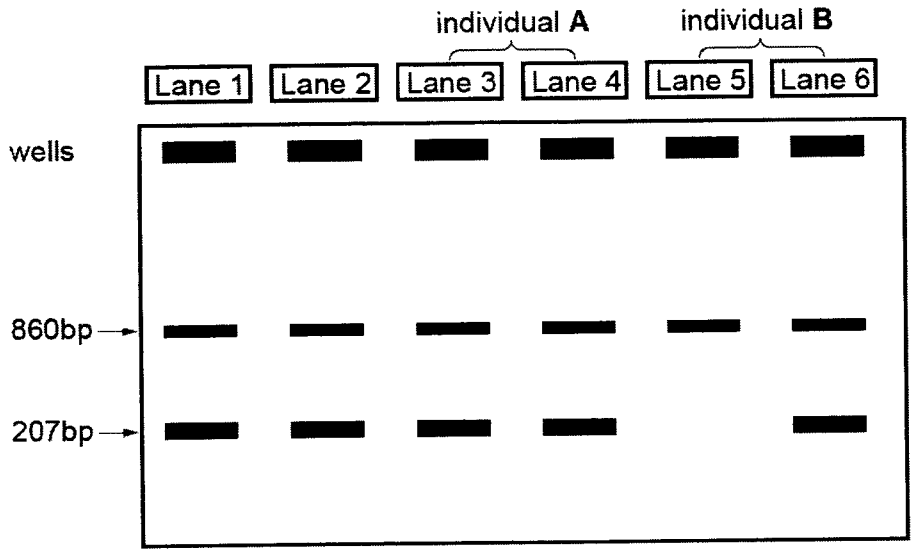

Fig. 8.1

Deduce the genotypes and phenotypes of individuals **A** and **B** in Fig. 4.1. [2]

A: Hb^A Hb^S SCT

B: Hb^S Hb^S Sickle cell anaemia

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(c) Genetically modified stem cell transplant is a common form of gene therapy used to treat sickle cell anaemia. It involves the following steps:

1. Removing haematopoietic stem cells (HSCs) from the patient
2. Genetically modifying the genome of the HSCs by inserting normal Hb^A allele
3. Reintroducing the modified stem cells back into the patient.

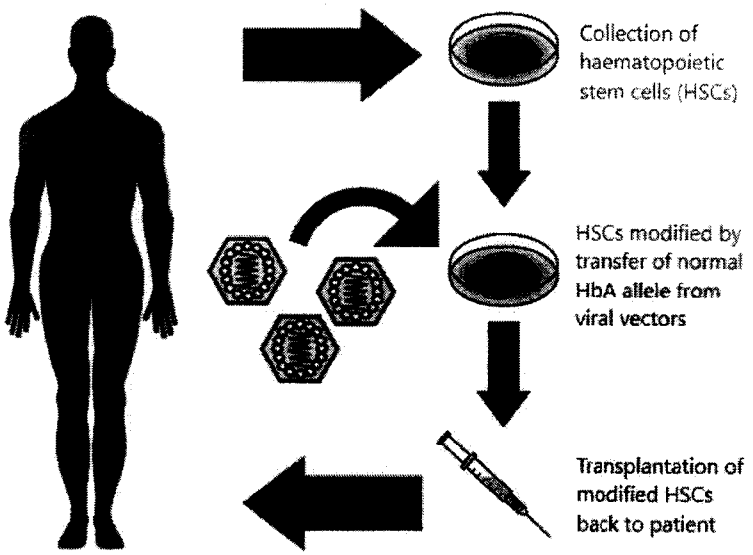

Fig. 8.2

(i) Describe the characteristics of haematopoietic stem cells that enable them to be used for stem cell therapy. [3]

1. Haematopoietic stem cells are **multipotent** with the ability to **differentiate** into **several blood cell types**. (several related cell types but is restricted to blood cells only);
2. Hence, they are able to **replace sickled red blood cells** (R: diseased tissues) (or **replenish blood cells lost through disease**);
3. They are capable of **self-renewal** and **extensive proliferation** to form more haematopoietic stem cells;

(ii) Suggest an advantage of the specific type of stem cell therapy shown in Fig. 8.2. [1]

1. As the haematopoietic stem cells are taken from the patient's own body, the cells are **genetically identical** to that of the patient, **avoiding the problem of immune rejection** (or lower chance);
2. AVP (no need to wait for stem cells from healthy donor, no need to find a genetically-compatible stem cell donor)

[Total: 10]

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9 Different signalling pathways generate calcium (Ca^{2+}) signals which regulate many cellular functions, e.g. smooth muscle contraction.

Fig. 9.1 shows the inositol trisphosphate/calcium (IP_3/Ca^{2+}) signalling pathway. Phosphatidyl inositol-bisphosphate (PIP_2) is hydrolysed into IP_3 and diacylglycerol (DAG) by phospholipase C.

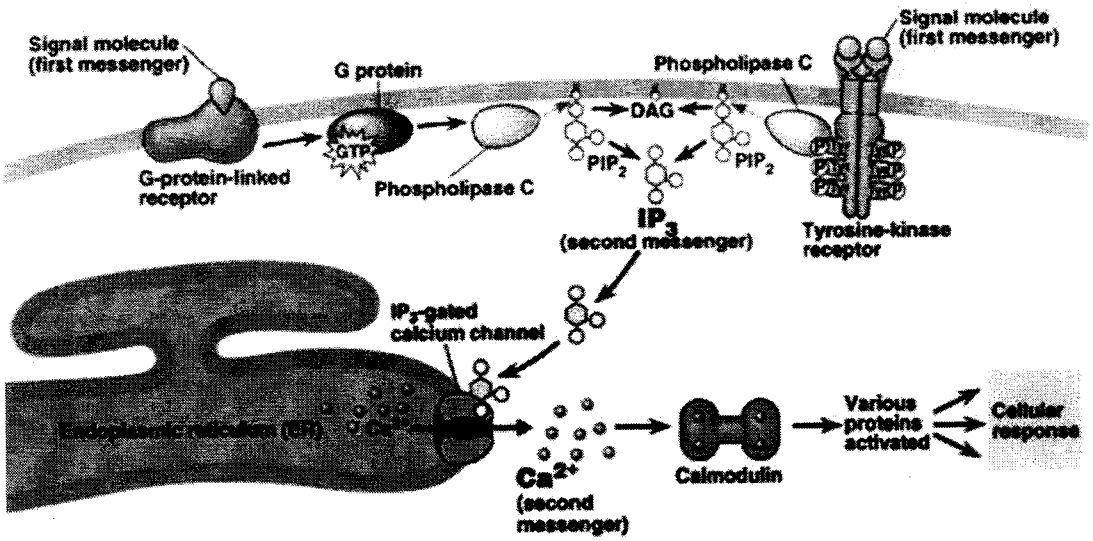

Fig. 9.1

(a) With reference to Fig. 9.1,

(i) describe the structural differences of the two receptors. [2]

1. **One protein** vs **two protein subunits** (dimer)
2. **Different ligand-binding sites** complementary in **conformation** (and charge) to **different ligands (A: different conformation of ligand-binding sites)**
3. **Different binding sites for G protein vs phospholipase C in intracellular domain**

(ii) define second messengers and explain their role in signal transduction. [2]

define: **Small, non-protein, water-soluble molecules/ions**

role: **Bind, induce change in conformation** and **activate** ...
(e.g. **IP_3 binds and induces change in conformation** in **IP_3-gated calcium channel, activating the IP_3-gated calcium channel**
OR **Ca^{2+} binds and induces change in conformation** in **calmodulin, activating the calmodulin**)

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(iii) outline two stages where signal amplification may occur. [2]

1. **Each <u>tyrosine kinase receptor</u>** activating **many <u>phospholipase C</u>**, where each binds to a phosphorylated tyrosine residue
2. **Each <u>phospholipase C</u>** producing **many <u>IP_3</u>**
3. **Each <u>IP_3</u>** activating a IP_3-gated calcium channel and releasing **many <u>Ca^{2+}</u>**

(iv) Dysregulation of the IP_3/Ca^{2+} signalling pathway can lead to many different possible human diseases. Hypertension is caused by increased smooth muscle contraction due to enhanced IP_3/Ca^{2+} signalling.

Suggest the type of mutation in phospholipase C that could lead to hypertension. [2]

1. **<u>Gain-in-function mutation</u>** in **gene coding for phospholipase C**, causing **phospholipase C** to be **constitutively active** / have **high rate of hydrolysis of PIP2**
2. Resulting in **constitutive signal transduction**, thus **high concentration of Ca^{2+}** leading to **increasing smooth muscle contraction / hypertension**

(b) Calcium binding by calmodulin exhibits considerable cooperativity, making calmodulin an unusual example of a monomeric (single-chain) cooperative-binding protein with four calcium-binding sites.

Fig. 9.2 shows calmodulin without calcium (left), and calmodulin with calcium (right). Sites that bind target proteins are indicated by the stars (*).

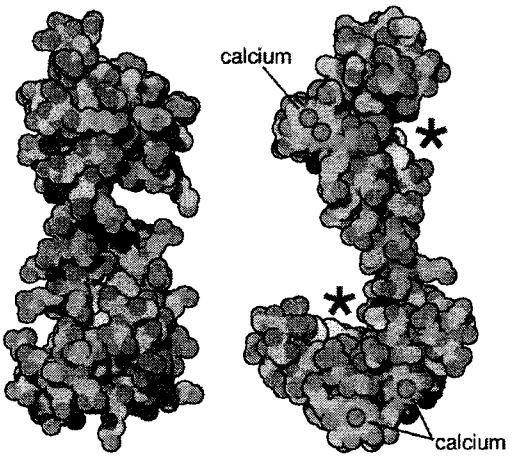

Fig. 9.2

With reference to Fig. 9.2, suggest how cooperative binding of Ca^{2+} ions to calmodulin is necessary for calmodulin activity. [2]

1. [Cooperative binding] Binding of **<u>one</u> <u>Ca^{2+}</u> ion** to **<u>one</u> <u>calcium-binding site</u>** of calmodulin induces **<u>conformational change</u>** in the **other <u>three</u> <u>calcium-binding sites</u>**.
2. This leads to an **increase in the affinity of calcium-binding sites for Ca^{2+}** and causes the **binding site for target protein** to be **exposed**.

[Total: 10]

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10 (a) Fig. 10.1 is a diagram that shows the structure of an antibody molecule.

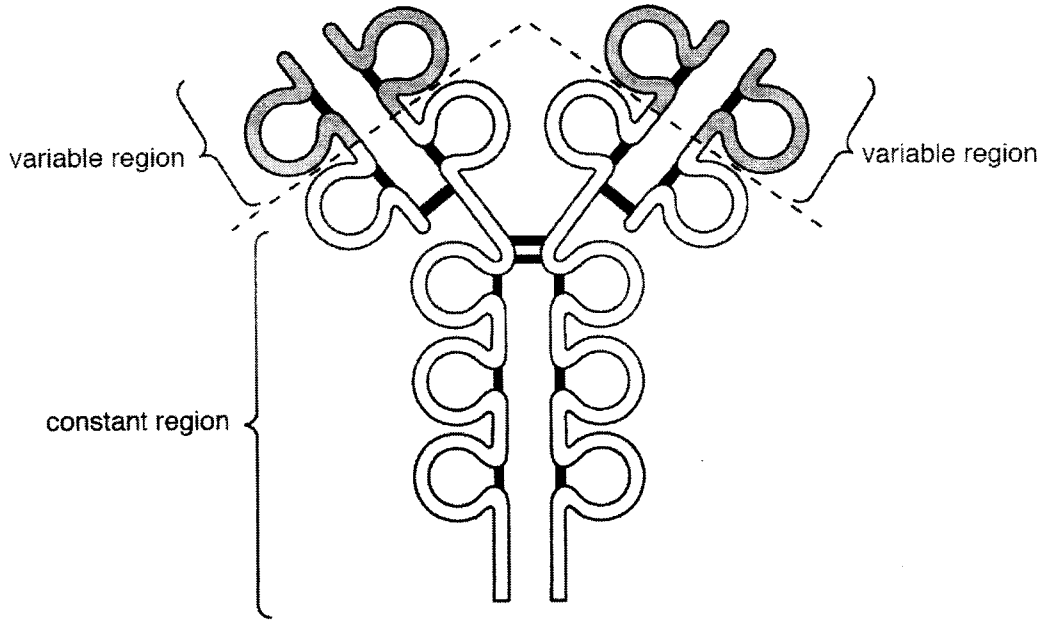

Fig. 10.1

Use Fig. 10.1 to explain how the structure of the variable region of an antibody molecule is related to its function. [2]

1. It has **two antigen-binding sites** that are **complementary in conformation and charge** to (epitope of) antigen; (R: active site)
2. Both **light chain** and **heavy chain** (polypeptide chain) undergo **folding** (A: intramolecular interactions between R groups of amino acids) to give rise to the **specific 3D conformation**;
3. **Preventing pathogen from binding to host cell receptors** and infecting host cells, thus **neutralizing** pathogen.

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(b) Fig. 10.2 shows a process that occurs to heavy chain gene on human chromosome 14.

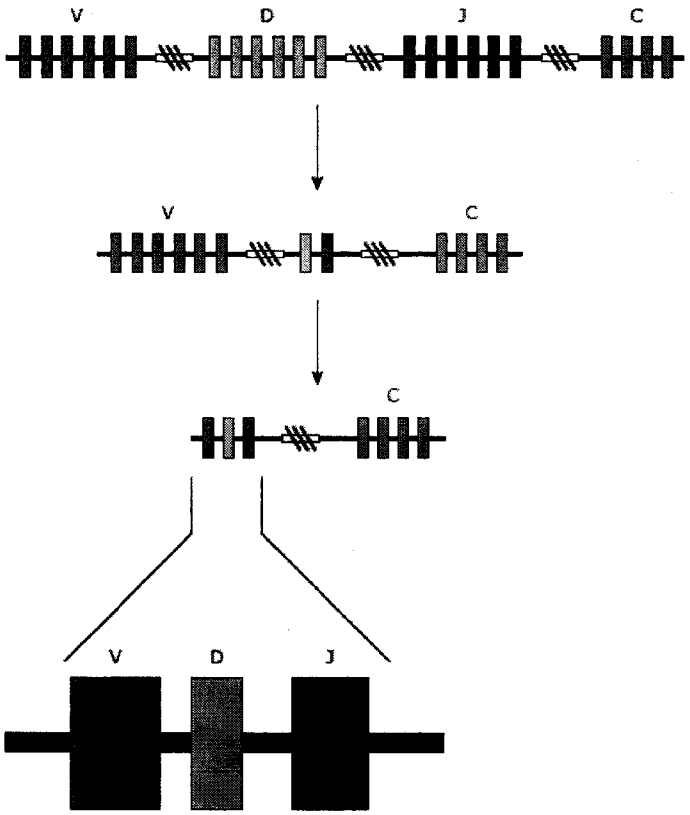

Fig. 10.2

(i) Outline the process shown in Fig. 10.2. [2]

1. **Rearrangement** of **a** D gene **segment** with **a** J gene **segment** to form **a DJ rearrangement**
2. **Rearrangement** of **a** V gene **segment** with the DJ rearrangement to form **VDJ rearrangement**

(R: plural)

(ii) Explain the significance of the above process. [1]

1. Help to generate a **variety** of **heavy chain** of antibodies after transcription, splicing and translation

[Total: 5]

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11 Fig. 11.1 shows the relationship between the density of coral skeletons and the rate of precipitation of key minerals for the coral skeleton. The different shapes represent coral samples obtained from different locations in the world.

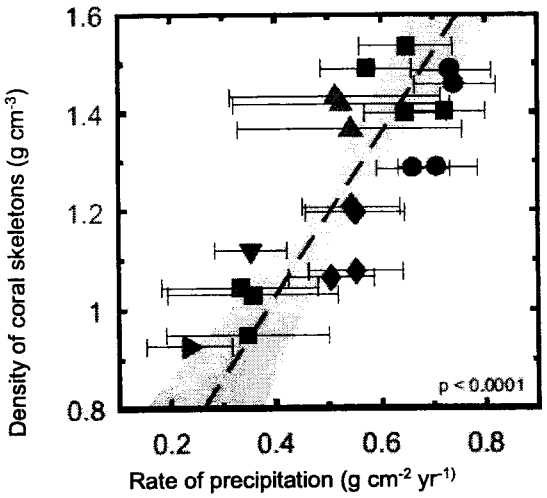

Fig. 11.1

(a) (i) Describe the general relationship between density of coral skeletons and rate of precipitation of key minerals for the coral skeleton. [1]

1. **Increased rate of precipitation correlates / directly proportional** to the **increase** in **density of coral skeletons**

(ii) An increase in carbon dioxide concentration in the atmosphere has resulted in higher concentrations of carbon dioxide in the ocean. This has caused a decrease in the pH of the ocean and has resulted in ocean acidification.

Explain how ocean acidification has affected corals. [1]

1. Ocean acidification has **reduced** quantity of **carbonate ions / calcium carbonate** in the oceans that are required for building corals leading to **lower density** of the coral skeleton and **slower growth / slower rebuilding;**

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(b) Scientists are studying seaweeds such as *Laminaria hyperborea* because they absorb a large quantity of carbon dioxide during photosynthesis. This may help to increase the pH of the ocean and reverse ocean acidification.

In the laboratory, *Laminaria hyperborea* was grown in water with different pH values. All other variables, including temperature and light, were standardised.

The mean rate of photosynthesis was calculated over a 24 hour period for each pH value.

The results are shown in Fig. 11.2.

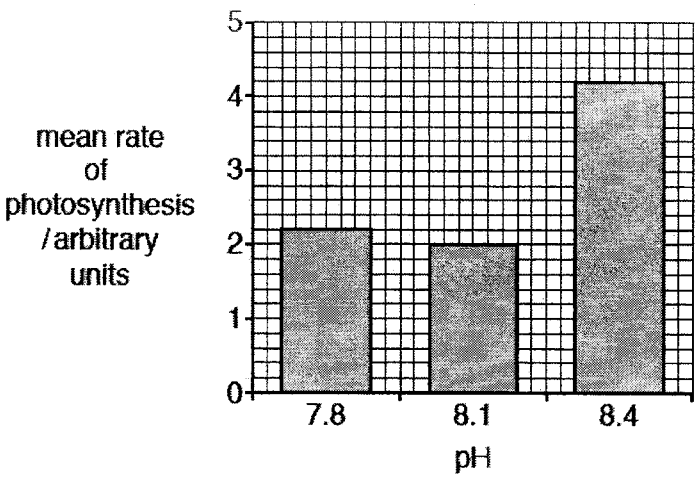

Fig. 11.2

The lower pH values on Fig. 11.2 represent ocean acidification.

With reference to Fig. 11.2, suggest why the results for the lower pH values do **not** fully support the idea that seaweeds can help to reduce ocean acidification. [3]

1. At lower pH of **7.8** / **8.1**, mean rate of photosynthesis was **2.2 units** / **2.0 units**;
2. This is 2.0 units / 2.2 units **lower/less** compared to **rate of photosynthesis** at pH **8.4** / OWTTE
3. Thus the seaweeds can **absorb less carbon dioxide** at **lower pH**, which does not fully support idea they can help reduce ocean acidification;

[Total: 5]

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H2 Biology

9744/03

Paper 3 Structured & Free Response Questions

19 September 2022

2 hours

Candidates answer **Section A** on the Question Paper and **Section B** on the Answer Booklet.

Additional Materials: 12-page Answer Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue or correction fluid/tape.

Section A
Answer **all** questions.

Section B
Answer **one** question on the **12-page Answer Booklet**.
Write your answer to each part of the question on a fresh sheet of paper.

The use of an approved scientific calculator is expected, where appropriate.

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

At the end of the examination, ensure that you submit both the question paper and answer booklets.

For Examiner's Use	
Section A	
1	
2	
3	
Section C	
4 OR 5	
Total	/75

This document consists of 24 printed pages and 1 blank page.

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Section A

1 **(a)** Influenza causes occasional pandemics that have claimed the lives of millions of people.

Different strains of influenza are named in terms of 'H' and 'N'. For example, avian influenza is named H5N1.

Fig. 1.1 shows the main structural features of the H5N1 influenza virus.

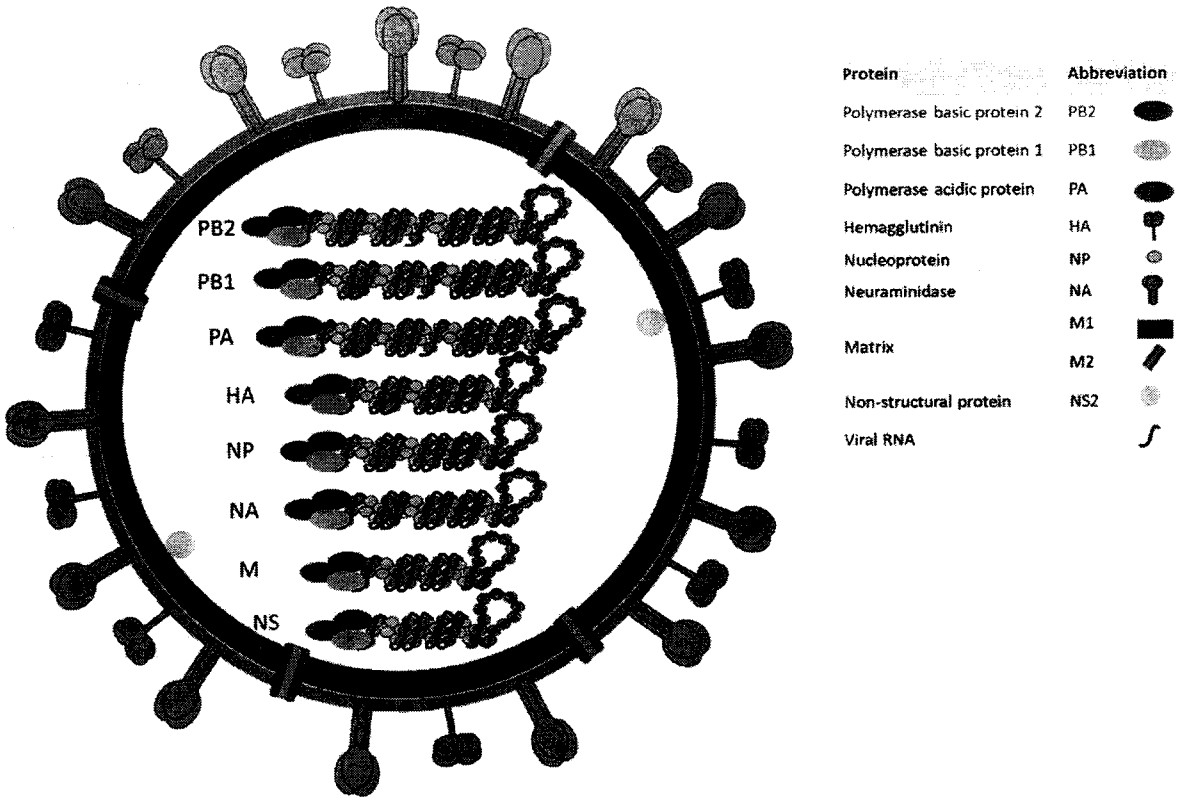

Fig. 1.1

(i) Explain the functions of haemagglutinin and neuraminidase in an enveloped virus, such as H5N1.

Haemagglutinin

.....

..... [1]

1. **Haemagglutinin <u>binds</u>** to **<u>sialic acid</u>** receptor on host cell membrane, facilitates entry into host cell by **<u>endocytosis</u>**.

Neuraminidase

.....

..... [1]

2. **Neuraminidase <u>cleaves</u>** the **<u>sialic acid</u>** to facilitate **release / budding** of the viruses from the infected cells.

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(ii) Other than components stated in Fig. 1.1, name two other components of the envelope of a virus, such as H5N1.

..... [1]

1. **Phospholipids** and **cholesterol.**

(iii) The emergence of new strains of influenza continues to pose challenges to public health and the scientific communities.

Fig. 1.2 shows various ways that new strains of influenza, such as H5N1, may arise.

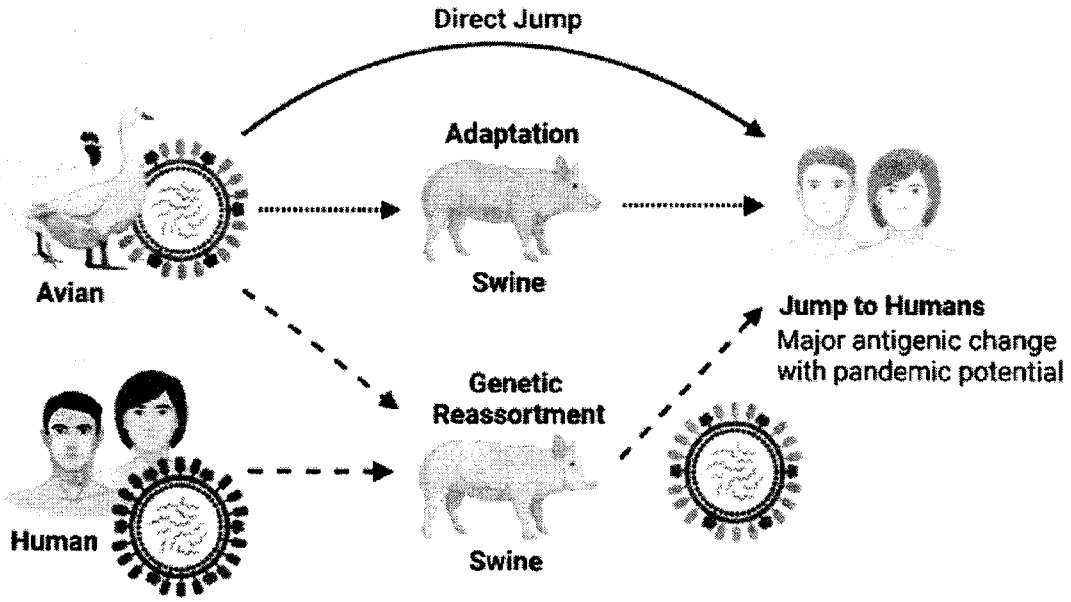

Fig. 1.2

Outline how a new strain may arise due to genetic reassortment.

.....

.....

.....

.....

.....

..... [3]

1. New viral strains are also formed when **two or more strains** of influenza viruses from **avian and human infect a swine host** where
2. **reassortment** of the different **RNA segments** occur resulting in a **new combination of RNA segments** in a **virion**, giving rise to **antigenic shift**.
3. **New combination of hemagglutinin and neuraminidases** at the viral envelope.

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(iv) Suggest how adaptation of influenza virus in swine, as seen in Fig. 1.2, may have occur.

.....

.....

.....

..... [2]

1. There are **accumulation of mutations** of the **viral genome** leading to the changes in the ribonucleotide sequence (I: antigenic shift)
2. as a result of the **lack of proofreading** ability of **RNA-dependent RNA polymerase** and the **fast/high rate of replication** of the virus.

(v) An individual's immune responses can change throughout their lifetime.

Fig. 1.3 shows one person's immune response to the influenza virus when they were first infected and when they were infected two years later by a new, mutated strain of the virus.

The influenza virus has many antigens to which the immune system can respond. Fig. 1.3 shows the response to four of these antigens (A–D).

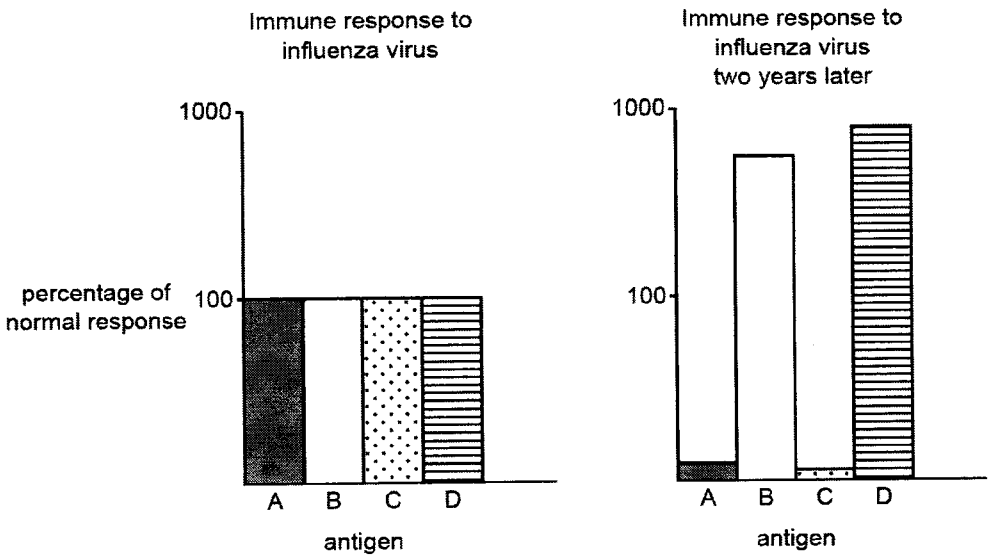

Fig. 1.3

Explain the differences in the person's initial immune response to the influenza virus with their immune response two years later.

.....

.....

.....

..... [2]

1. **Memory cells** produce a **stronger / larger response** to **antigens B and D**. NOTE: context is generally immune response, no need to specify memory B or T cells.
2. **Mutated virus** has **less of / no longer has antigens A and C**.

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(b) Tuberculosis (TB) is another respiratory infectious disease that affects human.

The vaccine used to control TB is known as Bacillus Calmette-Guérin (BCG). The vaccine contains live bacteria that have been selected so that they do not cause disease in humans.

Fig. 1.4 shows a macrophage that is in the process of engulfing the bacteria in the vaccine.

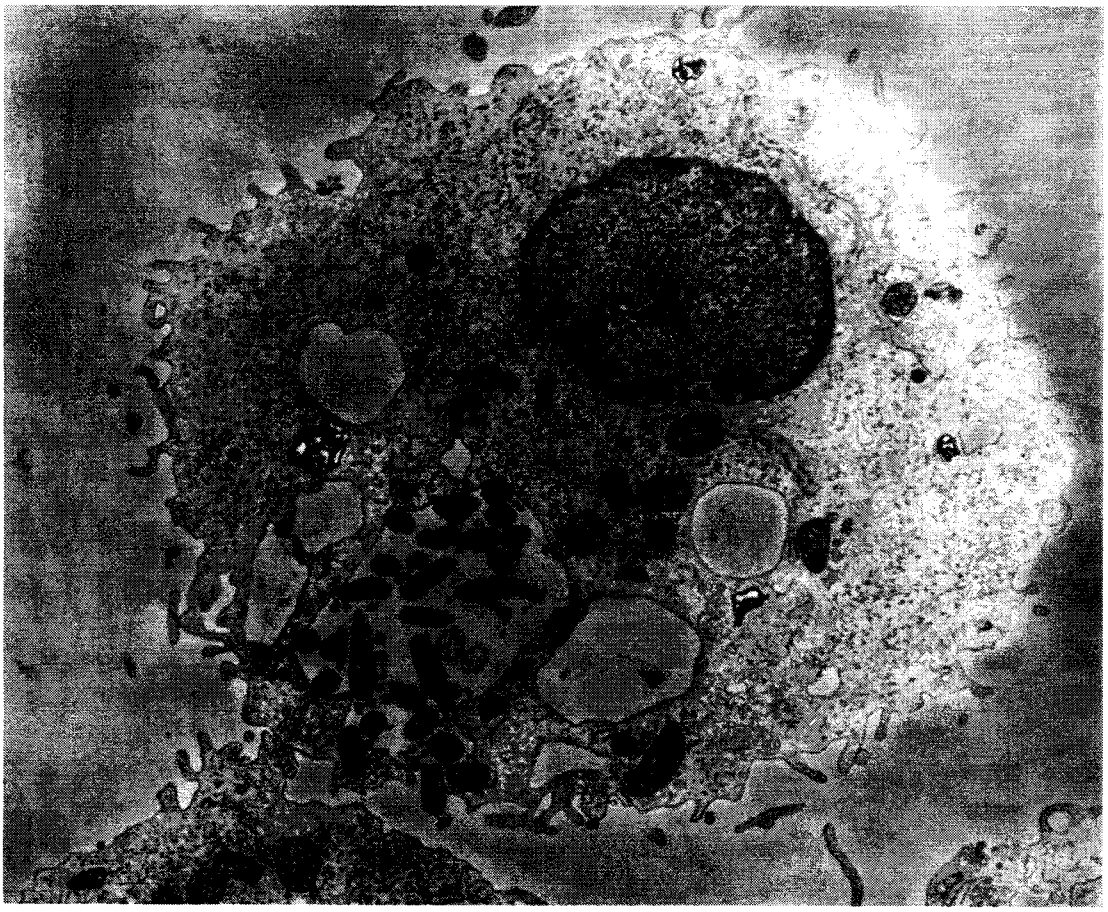

Fig. 1.4

(i) Name the pathogen that causes TB.

..... [1]

1. ***Mycobacterium tuberculosis*** (A: without underline)

(ii) Describe how this pathogen is transmitted.

.....

.....

.....

..... [2]

1. When an **infected** person with the active TB disease **sneezes or coughs**,
2. and an **uninfected** person **inhales** the **fine, droplets** containing the bacteria.

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(iii) Outline the events that occur in the body after the macrophage has engulfed the bacteria until the production of antibodies in response to the BCG vaccine.

.....

.....

.....

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.....

.....

.....

..... [5]

1. **Fusion** of phagocytic **vesicle with lysosomes**, **hydrolysis of bacteria** by hydrolytic enzymes
2. **Processing antigens** to form **antigen-MHC complex** to be presented on cell surface membrane to become **antigen presenting cell** (APC).
3. Binding of APC to **naïve T cell** results in **secretion of cytokines** that will **activate** the naïve **T cells** which will undergo clonal expansion and differentiation to form effector and memory T cells. (A: T helper cells)
4. **Naïve B cells** encounters vaccine/bacteria and also **present the antigen** on its cell surface membrane, which is **recognised** and bound by antigen-specific **T helper cell**.
5. **T helper cells** secrete cytokines that **stimulate / activate** specific **naïve B cells** to become **antibody-secreting plasma cells**.

(iv) The treatment for people with active TB lasts six months and involves a combination of antibiotics. This is usually very effective if the person has a susceptible (non-resistant) strain of the bacteria.

Table 1.1 summarises one recommended treatment strategy that involves a combination of antibiotics.

Table 1.1

antibiotic	length of treatment	mode of action of antibiotic
rifampicin (R)	6 months	enters bacterial cells and inhibits protein synthesis
isoniazid (H)	6 months	prevents the synthesis of cell wall components known as mycolic acids
ethambutol (E)	first two months	prevents mycolic acids from being added to the cell wall
pyrazinamide (Z)	first two months	prevents the synthesis of fatty acids

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Susceptible strains of the bacteria will be killed using any one of the antibiotics listed in Table 1.1. However, combination treatment is preferred as it is one method that can be used to reduce the impact to society of antibiotic resistance.

With reference to Table 1.1, explain how combination treatment for TB can help to reduce the impact of antibiotic resistance compared to single antibiotic treatment.

.....

.....

.....

..... [2]

Combination treatment:
1. **acts on different targets** / have **different modes of actions** to **kill all** the bacteria.
2. **resistance / mutation unlikely to occur on all antibiotics** at the same time, hence there will be some antibiotics that are **still effective** (OWTTE).
3. **longer treatment time increases chance of killing all** bacteria
4. **likely to eliminate bacteria more quickly** so less resistance can occur
5. AVP

[Any two]

(v) Rifampicin binds tightly to an RNA polymerase molecule close to its active site. This affects the activity of the enzyme.

During the formation of RNA, a number of events occur that involve the action of RNA polymerase.

Suggest two ways in which rifampicin can affect the activity of RNA polymerase.

.....

.....

.....

..... [2]

1. It **alters the <u>conformation</u>** of the **<u>active site</u>**, resulting in **substrate / nucleotides not able to bind** to active site. (I: non-competitive inhibitor / allosteric inhibitor) (R: competitive inhibitor) NOTE: close to, not at active site.
2. **<u>Complementary base pairing</u> between DNA and RNA cannot / less easily formed.**
3. It **prevents / reduces frequency of <u>attachment to promoter</u>**, and **no / less likely to <u>initiate</u> transcription.** (A: description of transcription initiation)
4. It **prevents / reduces frequency of mRNA elongation** due to **no / less likely for phosphodiester bonds to form.**
5. **AVP**

[Any two]

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(vi) Countries are classified by the World Bank into one of four income groups.

Table 1.2 shows the estimated incidence of TB for 2012 to 2016 for these income groups.

The incidence represents the number of new cases of TB occurring per 100 000 people in one year. The new cases include the number of cases that have occurred again after a period of recovery (relapse TB).

Table 1.2

	incidence per 100 000 people				
year / income group	2012	2013	2014	2015	2016
low	253	244	238	231	224
lower middle	244	240	236	232	227
upper middle	84	81	78	76	74
high	14	13	13	12	12

Describe the patterns and trends shown in Table 1.2.

.....

.....

.....

..... [2]

1. There is a **decrease in incidence over time** for **all groups** e.g., in low income group from 253 in 2012 to 224 in 2016 (A: any relevant data from 2012 to 2016).
2. **Similar incidence rate** between **low and lower middle income** group e.g., 224 in low and 227 in lower middle in 2016 (A: any relevant data from 2012 to 2016).
3. There is a **lower incidence rate in upper middle / high** income group than **low / lower middle** income group (ORA), e.g., 74 in upper middle and 227 in lower middle in 2016 (A: any relevant data from 2012 to 2016).
4. There is a general decrease in incidence rate with increase in income group e.g., 253 in low to 14 in high in 2012 (A: any relevant data from 2012 to 2016).
5. AVP

[Any two]

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(vii) In general, the countries that do not have a BCG vaccination programme are high-income countries that have a low number of cases of TB. In most of these countries, the vaccine is given only to babies and children at high risk of developing TB.

Suggest **one** reason why a child in a country with a low number of cases of the disease could be at a high risk of developing TB.

.....

..... [1]

1. Children with **compromised immune system** which makes them more susceptible to infection (OWTTE).
2. They have family members that are from a country that has high TB incidences (OWTTE)
3. They are travelling to / recently returned from countries that have high incidences of TB.
4. They live in an area that has outbreak of TB.
5. AVP

[Any one]

NOTE: the question is asking why babies who live in low incidence rate country could be at **high risk** of developing TB. It's not referring to general population, hence herd immunity is not relevant in this question.

(c) Sucrose phosphorylase is an enzyme found in some species of bacteria. One function of this enzyme is for the production of compounds that help to protect the cell from harmful osmotic changes in the external environment.

(i) Fig. 1.5 shows the reversible reaction that takes place within the bacterial cell.

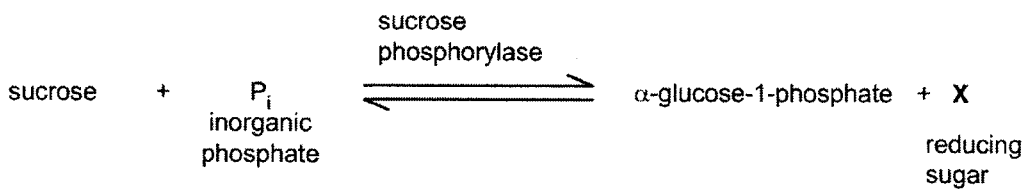

Fig. 1.5

Name reducing sugar **X** in Fig. 1.5.

..... [1]

1. **Fructose**

(ii) In the absence of sucrose phosphorylase as a catalyst, the reaction shown in Fig. 1.5 would take too long to occur to allow the bacterial cell to function efficiently.

Explain why the reaction shown in Fig. 1.5 proceeds at a much faster rate in the presence of the enzyme.

.....

..... [1]

1. Enzyme **lowers the activation energy** of the reaction by... (mechanism)...

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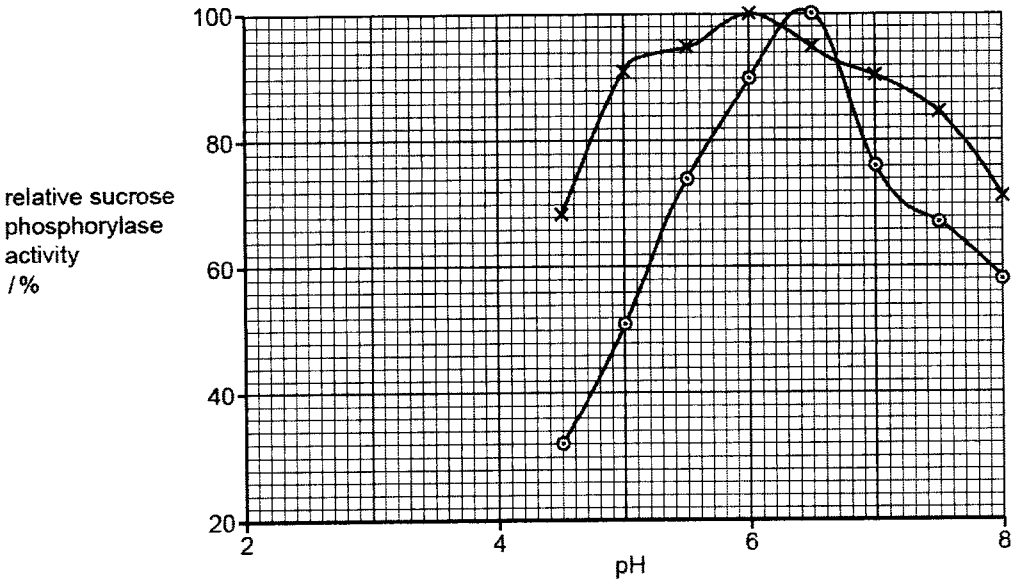
(iii) An enzyme that catalyses a reaction of commercial interest needs to be investigated to see if it is suitable for use in industry.
For example:

- immobilised enzymes may be used as they have a longer shelf-life than the enzyme free in solution
- many industrial reactions are carried out at higher temperatures to minimize contamination of products by microorganisms.

Fig. 1.6 shows the results of an investigation to compare the activity of sucrose phosphorylase free in solution (free enzyme) with immobilised sucrose phosphorylase (immobilised enzyme) at different pHs.

Fig. 1.7 shows the activity of the free enzyme and immobilised enzyme at different temperatures.



Key

⊙ free enzyme
× immobilised enzyme

Fig. 1.6

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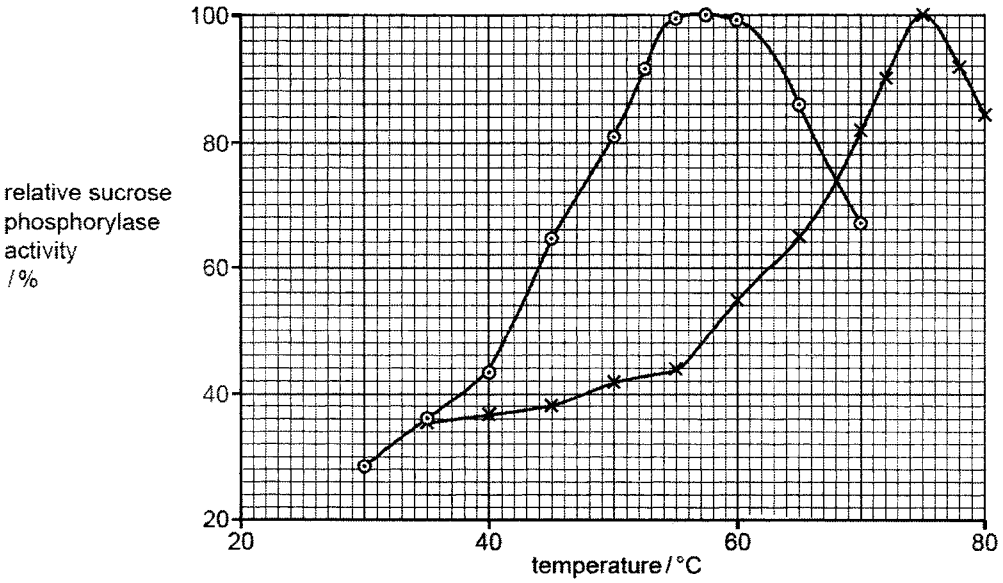

Fig. 1.7

With reference to the results shown in Fig. 1.6 and Fig. 1.7, discuss why **immobilised** sucrose phosphorylase enzyme could be better for use in industrial reactions.

.....

.....

.....

.....

.....

..... [3]

1. It has a **higher optimum temperature** hence more **suitable for reactions that require higher temperatures / thermostable / have a longer shelf-life (enzymes can be reused more often) / less microbial contamination due to high heat** (OWTTE).
2. In the same pH range, it has a **greater range of pH with higher activity / greater stability** hence **less affected by pH changes** on its enzyme activity (OWTTE) (A: resists changes in pH)
3. Data citation: 1 set of relevant data for temperature and pH (e.g. **75 °C vs 56 – 58 °C / 17°C higher** and **68% activity or higher between pH 5 to 8**)

[Total: 30]

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2 Researchers investigated the extent to which the founder effect and natural selection affected evolutionary change.

Fig. 2.1 shows the brown anole lizard, *Anolis sagrei*. These lizards live on a number of Caribbean islands and feed on a variety of invertebrates and other small animals.

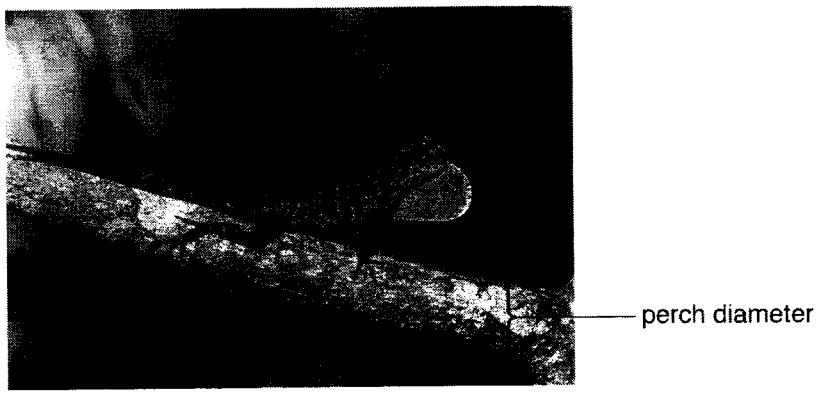

Fig. 2.1

A. sagrei spends a lot of time perching (resting) on, or moving along, branches of shrubs and trees. The width of the branch that *A. sagrei* perches on is known as the perch diameter, as labelled in Fig. 2.1.

There is a positive correlation between perch diameter and hind limb length of *A. sagrei*.

- Longer hind limbs allow *A. sagrei* to run faster on vegetation with a larger diameter.
- Shorter hind limbs are needed to provide stability on vegetation of a smaller diameter.

In 2004, a hurricane caused the death of all the *A. sagrei* lizards on seven islands.

In 2005, the researchers randomly collected seven male and seven female lizards from a source population on a nearby island. For each of the seven islands affected by the hurricane, a male and female lizard were mated and placed on each island. These islands formed the experimental founder islands where new populations of *A. sagrei* were successfully established from each founding pair.

Fig. 2.2 shows the difference in vegetation between the source island and the seven experimental founder islands.

Fig. 2.2

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(a) (i) Predict the effect of natural selection on mean hind limb length of *A. sagrei* on the seven experimental founder islands.

.....

..... [1]

1. (mean hind limb length) should **decrease** / legs get **shorter**.

(ii) Predict how collecting individuals at random for the seven founding pairs affects the mean hind limb length of *A. sagrei* on the different islands.

.....

..... [1]

1. (mean hind limb length) will **vary;**

(b) Many generations of *A. sagrei* were produced over the four years after the introduction of the founding pairs.

Fig. 2.3 shows how the mean hind limb length of *A. sagrei* changed on the seven experimental islands and on the source island.

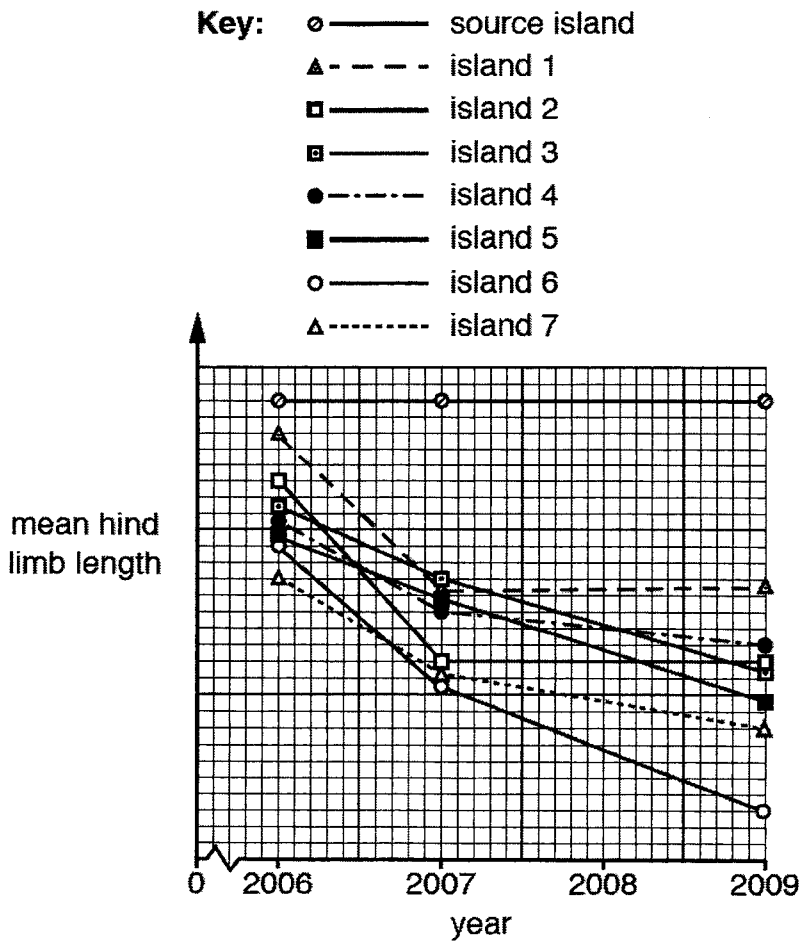

Fig. 2.3

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With reference to Fig. 2.2 and Fig. 2.3, describe **and** suggest explanations for the results for the islands.

.....

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.....

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..... [5]

1. There is **directional selection** as the **hind limb length decreased** in **all / seven <u>experimental</u> / <u>founder</u> islands**. (R: <u>all islands</u>, because data includes source island, which is *does not* have decreased hind limb length)
2. There is **stabilising selection** as the **hind limb length stayed the same** on **<u>source</u> island**.
3. [Selection pressure] The **selection pressure** is **reduced / thinner perch diameter** (A: branch / perch).
4. [Selective Advantage & Example] Individuals with favourable traits such as **<u>shorter limbs</u>** have a **<u>selective advantage</u>** and are **<u>selected for</u>** (R: favourable alleles are selected for') because there is **increased stability**.
5. [Differential survival & reproduction] Individuals with shorter limbs were selected for and so **<u>survived and reproduced to produce fertile, viable offspring</u>; Favorable alleles were passed to offspring** resulting in **<u>higher frequencies of the alleles</u> in the descendent population over time**. (R: 'passing favourable traits')

NOTE: point on variation not important in this context since it is founder effect.

(c) In the investigation, one population of *A. sagrei* was established on each experimental founder island.

Outline how speciation may occur on the seven experimental founder islands.

.....

.....

.....

.....

.....

..... [3]

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1. There is **allopatric speciation.**
2. ~~The~~ **islands** are **geographically isolated** as they are surrounded by water that acts as a physical barrier preventing interbreeding. This results in the **disruption of gene flow;**
3. Over **many generations,** each population of *A. sagrei* **evolve independently on different islands** (with change in allele frequencies due to natural selection, genetic drift and accumulation of genetic mutations), became **reproductively isolated** and can no longer interbreed to produce viable, fertile offspring.

Accept other points:

4. **Different mutations** may occur to the populations in the seven islands, resulting in **different variation**.
5. Different islands will present **different selection pressures** and individuals best adapted to the environment (or individuals with favourable trait) will have a **selective advantage** will be **selected for** (they survive to reproduce) and **favourable alleles will be passed on to the next generation** and so the **frequency of favourable alleles will increase.**

[Total: 10]

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3 **(a)** Fig. 3.1 shows the structure of a prokaryotic cell.

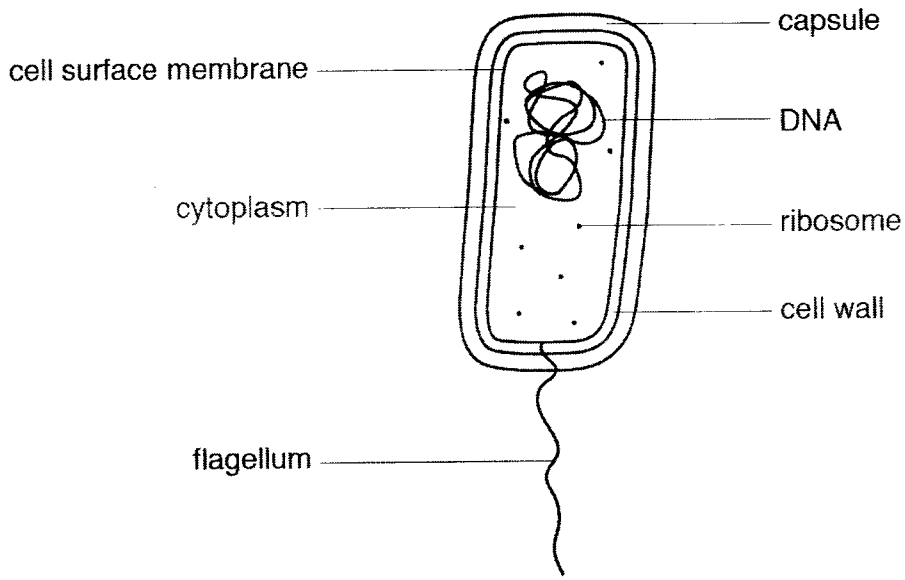

Fig. 3.1

Fig. 3.1 has not been fully labelled to confirm that the cell is prokaryotic.

State what other information could be added to two of the labels to confirm that this cell is prokaryotic and not eukaryotic.

.....

.....

..... [1]

1. **70S** ribosomes
2. **Circular** DNA / **non-histone** DNA / DNA not **enclosed in nucleus**
3. **Peptidoglycan** cell wall
4. AVP

   [Any two points]

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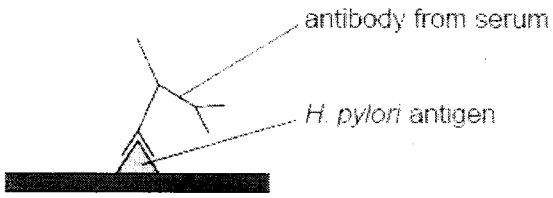
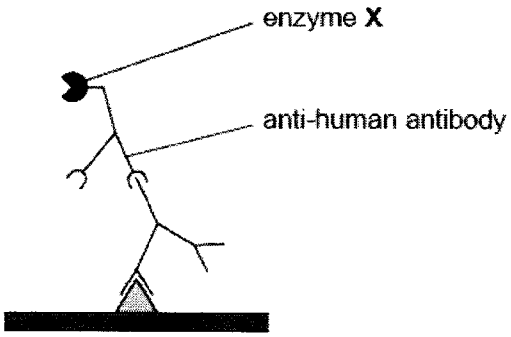
(b) The bacterium *Helicobacter pylori* has been associated with diseases such as gastric ulcers and stomach cancer.

An infection with *H. pylori* can be diagnosed by testing for the antibodies produced in response to *H. pylori* antigens, as shown in Fig. 3.2.

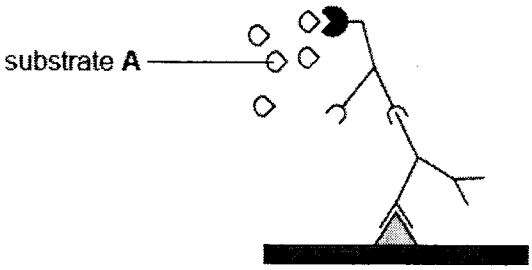
step 1
add blood serum samples to antigens of *H. pylori* attached to wells in a testing plate



step 2
rinse the testing plate and add anti-human (secondary) antibody linked to enzyme **X**



step 3
rinse the testing plate and add substrate **A**, which is converted to a coloured product by enzyme **X**



step 4
reaction stopped and colour noted

Fig. 3.2

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With reference to Fig. 3.2, explain the importance of the following in this test:

(i) the *H. pylori* antigen.

.....

..... [1]

1. the **antigen** is **specific** to the **antibody from the serum** and can be used to **detect** the presence of ***H. pylori*** in the patient.

(ii) the use of enzyme **X**

.....

..... [1]

1. it is able to **catalyse a coloured product** to help **visualize** the presence of antibodies produced in response to *H. pylori*.

(c) Amoxicillin is an antibiotic that is commonly used to treat *H. pylori*, it is similar to penicillin.

Suggest the mode of action of amoxicillin.

.....

.....

.....

..... [2]

1. it is a **competitive inhibitor** to **enzymes** involved in **peptidoglycan synthesis** (I: transacetylase and A: transacetylase as substitute for idea of enzyme).
2. As a result, there is **inhibition to the formation of cross-links between adjacent chains** of peptidogylcan.
3. Bacterial **cell wall becomes weakened** when bacterial **cells** carry out **division**.
4. When bacteria **take in water by osmosis**, the **increased turgor pressure** against the weakened cell wall causes the bacteria to swell and **lyse**.

[Any two]

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(d) In some people, *H. pylori* infection can be difficult to treat because, over time, new strains of bacteria arise that have resistance to commonly used antibiotics. The resistance to antibiotics has been found to spread without the need of a vector or bacterium.

Explain how resistance to antibiotics is spread in a population of *H. pylori*.

.....

.....

.....

.....

.....

..... [3]

1. It is via the process of bacterial **transformation**.
2. **Fragments** of **DNA** containing **antibiotic resistance gene** (from lysed bacterial cells) in the surrounding medium are taken up by a **competent bacterial cell** via **surface proteins**.
3. The DNA containing the antibiotic resistance gene is **incorporated into the bacterial chromosome/DNA** via **homologous recombination**.

(e) *H. pylori* has an operon that is involved in synthesis of an amino acid, **X**. Fig 3.3 shows the operon and how it is being regulated.

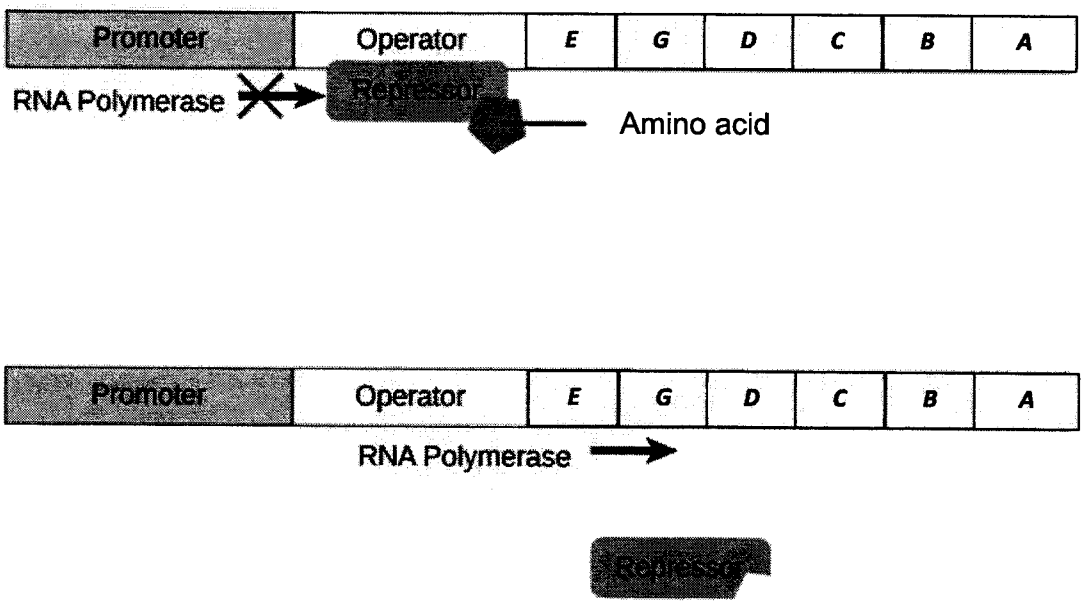

Fig. 3.3

(i) identify the type of operon.

..... [1]

1. **Repressible** operon

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(ii) predict the effect of an insertional mutation in the regulatory gene that codes for the repressor.

.....

..... [1]

1. [Loss-of-function mutation] **Repressor** will be **non-functional** and there will be **constitutive expression** of the operon.
   OR
2. [Gain-of-function mutation] **Repressor** will be **hyperactive/constitutively bound** and the operon is **not expressed**.

[Total: 10]

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Section B

Answer **one** question in this section.

Write your answers in the **12-page Answer Booklet** provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in section **(a)** and **(b)**, as indicated in the question.

4 **(a)** Molecular biology techniques are common methods used in molecular biology, biochemistry, and genetics which generally involve manipulation and analysis of DNA.

Outline the principles of techniques used to analyse DNA. [10]

A. Reasons for Analysing DNA (Brief description) [1]
1. Genetics / Forensics / Mutation and disease detection / Evolutionary studies etc;
2. AVP – e.g. identifying and comparing band patterns between individuals with mutated gene sequences and normal individuals;

B. DNA Extraction (Needed for all techniques) [1]*
3. **DNA** extracted from **blood or saliva** of subject/scene of crime/organisms/fossils etc;

C. Polymerase Chain Reaction [max 1]
4. **Sequence gene/sequence** to identify sequence of interest /gene of interest / mutation etc;
5. **Amplification** of DNA via **polymerase chain reaction;**
6. Use of forward and reverse **primers** to flank the target gene/sequence;
7. Production of **many** copies of gene/sequence of interest for analysis, from **initial small amounts**;

D. Restriction Enzymes [1]*
8. The amplified DNA samples are **digested / cut / hydrolysed** using **restriction enzymes** that cleave at **specific restriction sites**, producing **different fragments**;

E. Gel Electrophoresis [max 4]
9. Different DNA fragments of different sizes are loaded onto an agarose **gel** and subjected to an **electric field**;
10. **Negatively charged** DNA will move towards the **positive electrode / anode**;
11. **Meshwork of polymer fibres** that makes up agarose gel **impedes movement** of the DNA fragments, affecting the **longer fragments more than shorter ones**;
12. **Shorter DNA fragments migrate faster** than the **larger DNA fragments** towards the positive electrode;
13. **Separate** a mixture of DNA fragments of different lengths;
14. To visualise the bands, gel slab is next stained with a DNA-binding / **DNA-staining dye**, usually **ethidium bromide**;
15. When the gel is placed under **UV light** afterwards, **DNA bands** will be revealed as the dye bound to the DNA **fluoresces**;
16. Electrophoresis helps to estimate **fragment length/size** – by comparing position of the band relative to bands of the DNA ladder and **relative amount** of DNA;

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F. Southern Blotting / Nucleic Acid Hybridisation [max 3]

17. DNA fragments are transferred from the agarose gel slab to a **nitrocellulose membrane**;
18. The bands of DNA fragments bind to the membrane in exactly the **same position** as they were in the gel;
19. The target DNA bands on the membrane can then be **selectively visualised** by using **radioactive probes** to detect **specific DNA sequences**;
20. **Single stranded** DNA probes **hybridise** to specific sequences by **complementary base pairing**;
21. **Autoradiography** is performed by placing an **X-ray film** over the membrane;
22. The radioactivity of the bound probes exposes the film to form an image corresponding to the bands that have base-paired to the probe;

G. AVP e.g. Restriction Fragment Length Polymorphism;

*Required for full credit.

(b) Cycles play important roles in both natural and man-made biological processes.

Write an essay about cycles in biology. [15]

A. Cell Cycle [max 5]

1. The cell cycle is the **sequence of events** which occurs **between the formation of a cell and its division into daughter cells**;
2. Three main stages: **interphase, nuclear division, cytokinesis**;
3. During interphase - Cell produces many materials and or organelles required for carrying out all its functions;
4. Cell **replicates its DNA** (during **S phase of interphase**) to prepare for nuclear division;
5. Nuclear division – **mitosis** – forming **identical** cells for **growth / repair / asexual reproduction** AND **meiosis** – forming **gametes**;
6. Cytokinesis - Division of **cytoplasmic contents** into **2 daughter cells**;
7. **Fusion** of a **haploid** sperm and **haploid** egg during **fertilisation** results in the formation of a **diploid zygote**;
8. After fertilisation, the zygote undergoes a process of nuclear division **(mitosis)**; (This generates cells that are **genetically identical** to the original zygote)

B. Krebs Cycle [max 5]

9. **Pyruvate** from glycolysis is converted to **acetyl-CoA** via **oxidative decarboxylation**;
10. Krebs cycle involves 3 main stages:
11. Acetyl CoA (2C) joins the cycle by combining with **oxaloacetate** (4C) to form **citrate** (6C);
12. Citrate is **decarboxylated** and **oxidised by dehydrogenation** to form **α-ketoglutarate** (5C) and **NADH;**

This process is also an **oxidative decarboxylation** reaction;

13. **Oxaloacetate** (4C) is regenerated;
14. Krebs cycle involves multiple reactions, including 1 substrate-level phosphorylation, 1 decarboxylation, and 3 dehydrogenation reactions;
15. As a result 1 ATP, 1 CO_2, 2 NADH, and 1 $FADH_2$ are produced per molecule of α-ketoglutarate;
16. For **each** molecule of glucose, glycolysis yields **2 molecules of pyruvate**, and hence **2 molecules of acetyl CoA**. As such, **two rounds of Krebs cycle** are needed to **completely oxidise one molecule of glucose**;

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17. All 6 carbon atoms in glucose are lost as 6 CO_2;
18. For each 6C glucose molecule, **2 CO_2** are released via **link reaction**, and **4 CO_2** are released via **Krebs cycle;**
19. The mobile electron carriers (**NADH and $FADH_2$**) with their reducing power will next be transported to the **electron transport chain**, where the bulk of **ATP** is generated;

C. Electron Transport Chain and Cyclic Photophosphorylation [max 5]

20. The photo-excited **electron from P700** is captured by the **PS I primary electron acceptor;**
21. and then passed on to the middle part of the **first electron transport chain (ETC);**
22. As the photo-excited electron travels down the ETC, which consists of **electron carriers** of **progressively lower energy levels**, energy lost is **coupled to the formation of ATP via chemiosmosis;**
23. This way of synthesizing ATP using light energy is called **cyclic photophosphorylation** (This electron eventually fills the electron "hole" left in P700, completing the cycle);
24. **No NADPH** is produced but passing the excited electrons to the second electron transport chain as in the non-cyclic light-dependent reaction, they are transferred to the first electron transport chain;
25. **No O_2** is produced as there is **no photolysis of water;**
26. Hence, **only ATP** is produced by **cyclic light-dependent reaction;**

D. Calvin Cycle [max 5]

Calvin cycle is a pathway that reduces carbon dioxide to produce carbohydrates. It comprises of 3 phases:

27. Carbon fixation - This step involves **carbon dioxide** combining with **RuBP** (ribulose bisphosphate, a 5C sugar);
28. Product is an unstable 6C intermediate that will immediately split to form 2 molecules of **glycerate phosphate** (for every one molecule of CO_2);
29. PGA reduction - **GP is reduced (gains electrons)** to form a 3C compound, **glyceraldehyde-3-phosphate (G3P);**
30. This reaction requires the reducing power of **NADPH** and energy of **ATP** (products of non-cyclic light-dependent reaction);
31. RuBP regeneration - G3P has to be used to regenerate **RuBP;**
32. **5** molecules of **G3P** (a 3C molecule; total 15C) used to regenerate **3 RuBP** (a 5C molecule; total 15C);
33. **3 ATP** from the light-dependent reaction is used;

E. Polymerase Chain Reaction (PCR) [max 5]

34. A brief heat treatment (up to **95°C**) to **denature / unzip and separate** the two strands of DNA double helix;
35. This exposes the bases for complementary base pairing required in subsequent steps;
36. Cooling of the DNA (to **~60°C**) in presence of a large excess of **DNA primers** allows their specific **annealing** to complementary sequences at the 3' ends of each of the template DNA strand;
37. *Taq* polymerase **synthesises** the complementary DNA strand by catalysing the formation of **phosphodiester bonds** between dNTPs at an optimum **72°C**;

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38. **Chain extension** occurs from 3' end of DNA primer which provides free 3' OH group required by *Taq* polymerase;
39. When the above elongation is completed, the primer has been lengthened into a **new complementary strand** of the single-stranded DNA fragment;
40. Because both separated DNA strands are used as templates, there are now **two copies of the original fragment** (each DNA molecule becomes two);
41. Each cycle results in a **doubling** in number of DNA molecules being replicated;
42. The amount of desired sequence hence **increases exponentially** after **multiple cycles**;

QWC: At least 3 accounts of relevant cycles, clearly indicating the cyclical nature, importance or significance of the cycle.

Possible AVPs:

Feedback cycle / Enzyme feedback inhibition

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5 **(a)** Explain how anatomical and molecular homology support Darwin's theory of evolution on descent with modification. [10]

DEFINITION

1. **Homology** refers to **similar characteristics** (anatomical or molecular) found in **different species** due to **common ancestry**;

ANATOMICAL HOMOLOGY (max 7m)

2. Organisms with **anatomical homology** have **anatomical (A: morphological) structures** such as bones, organs and gross structural features that they **share with a common ancestor** and thus supports Darwin's theory of descent with modification;
3. Named e.g.: ***pentadactyl limb**** structure in forelimbs;
4. of all **tetrapods/humans, cats, whales** (or any valid e.g. where they state a few organisms or a group of organisms);
5. Forelimbs have **same arrangement of bones** but have **different functions** and superficially look different;
6. e.g. **legs for walking** in cats, **flippers for swimming** in whales (any two e.g.);
7. 5 digit pentadactyl limb structure in common ancestor was altered by **natural selection/different selection pressures** in different organisms to suit **specialised functions/environments**, resulting in variations of the pentadactyl limb structure;
8. Anatomically homologous structures that are **greatly reduced in size / have little to no function** as they were **selected against**;
9. are called ***vestigial structures****;
10. Organisms with vestigial structures **share common ancestry** with organisms in which the **structure is still functional** and thus supports Darwin's theory of descent with modification.
11. Named e.g.
    Hind limbs (femur) / hips (pelvic bones) in whales are reduced to **small bones** (i.e. vestigial structures) as they are no longer beneficial to whales which swim. However, their presence in whales **suggest common ancestry with tetrapods (terrestrial ancestors with four legs)**;
    Appendix in humans is also a vestigial structure as it is **reduced** from cecum of its **primate ancestors** which was involved in digestion of plant material. Thus, presence of appendix in humans, **suggests common ancestry with primates**;
    Fossil records: modification of homologous structures with time

MOLECULAR HOMOLOGY

12. Organisms with **molecular homology** have **similar *DNA, RNA & amino acid**** **sequences** as they **share a common ancestor** that had these molecules;
13. Named e.g. **cytochrome C/ p53 / haemoglobin** are homologous genes;
14. **Homologous genes** share significant **sequence homology** and when expressed, produce **proteins** that have **same function** in all organisms that possess them and thus supports Darwin's theory of descent with modification;
15. **Nucleotide sequences** in ancestral genes were modified due to **accumulation of mutations** that occurred over many generations that were selected for;
16. The **greater the sequence similarity** between homologous genes, the **more closely related** the 2 species are;

QWC 1 anatomical and 1 molecular homology

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(b) Explain the significance of different biomolecular composition in membranes of different cells and different organelles. [15]

Biomolecules in membrane:
Phospholipids, proteins, glycolipids, glycoproteins, cholesterol

Significance of different biomolecular composition in membrane:
In different organelles (max **10m**)

1. **Mitochondria** and **chloroplasts**: require **proteins**, such as **electron carriers** and **ATP synthase**, to be arranged in order
2. To facilitate **electron transfer along electron transport chain** and for **chemiosmosis** to be carried out for **ATP synthesis**;
3. Ref. to **oxidative phosphorylation** and **photophosphorylation**
4. **Chloroplasts**: **photosystems / photosynthetic pigments** on thylakoid membrane for **absorption of light**;
5. **Nucleus**: require opening such as **nuclear pores** to be present in the membrane for e.g. transport of RNA out of nucleus (at least one e.g.);
6. **Rough endoplasmic reticulum (RER)**: more **channel proteins** for newly synthesized **proteins** to **enter lumen**;
7. **Smooth endoplasmic reticulum (SER)**: more **Ca^{2+} channel proteins** for release of Ca^{2+} into cytosol;
8. **Lysosome**; more **proton pumps** to maintain acidic internal environments;
9. AVP

In different cells (max **10m**)

10. Different cell types contain different **amount** and **types** of **glycoproteins** and **glycolipids** at **cell surface membrane**;
11. For **cell-cell recognition/communication** and **cell-cell adhesion** to form **tissues**
12. Different cells require **specific receptor proteins** to be present on **cell surface membrane**;
13. To allow **specific ligand** (signalling molecule) to recognize and **bind**;
14. For **e.g.** muscle cell with glucagon receptor;
15. Cells that **produce hydrophilic molecules for extracellular use** contains more **transport/channel/carrier proteins** on the **cell surface membrane**;
16. For e.g. ???
17. **Cell surface membrane** of **immune cells**, for eg. **B cell / macrophage / T helper cell**, contain **specific receptor** eg. **BCR** with specific antigen binding sites;
18. That enable it to bind to specific **antigen**;
19. Cells in organisms living in areas of **higher temperatures** have **cell surface membrane** with **lower percentage of unsaturated fatty acids** (A: higher percentage of saturated fatty acids) **in phospholipids / phospholipid bilayer**; (A: reverse for lower temperatures)
20. For **lower membrane fluidity** and **greater membrane stability**; (A: reverse for lower temperatures)
21. **Cell surface membrane** with **varying amounts** of **cholesterol** that help to **regulate membrane fluidity**
22. AVP

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