



# TAMPINES MERIDIAN JUNIOR COLLEGE

## JC2 PRELIMINARY EXAMINATION

CANDIDATE  
NAME

CIVICS GROUP

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## H2 BIOLOGY

**9744/02**

Paper 2 Structured Questions

**17 September 2025**

**2 hours**

Candidates answer on the Question Paper.

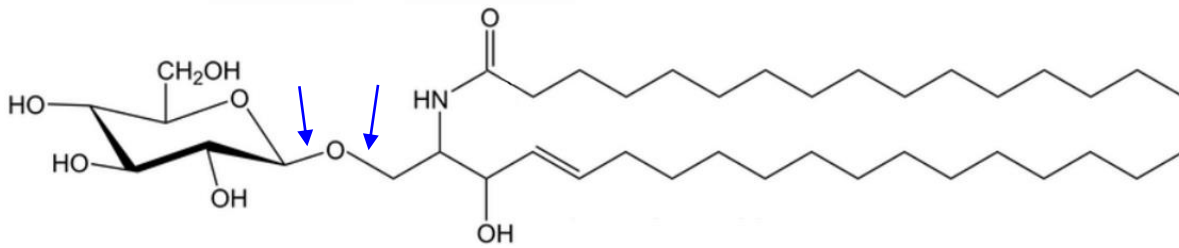
No additional materials are required.

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# SUGGESTED ANSWERS

Answer **all** questions.

1. Fig. 1.1 shows a diagram of a glycosphingolipid, a type of lipid found in the cell surface membranes of most eukaryotic organisms.



**Fig. 1.1**

- (a) Compare the structures of the glycosphingolipid and phospholipids. [2]

No.	feature	glycosphingolipid	phospholipid
1	no. of fatty acid tails / hydrocarbon chains	two	
2	head group	sugar molecule / monosaccharide	phosphate head
3	bond joining sugar / glycerol to fatty acid	ether bond / glycosidic bond	ester bond
4	elements present	C, H, O, P	C, H, O, N
5	presence of glycerol	absent	present

- (b) Suggest a role of the glycosphingolipid in the cell surface membrane. [1]

- Cell-to-cell recognition / cell-to-cell adhesion / regulate membrane fluidity

**Accept:** (precursor) to form second messenger

- (c) Glucocerebrosidase is a glycosidase enzyme that breaks down glycosphingolipids by removing the saccharide portion of the molecule. Another example of a glycosidase enzyme is maltase that breaks down maltose into glucose molecules.

Draw an **arrow** in Fig. 1.1 to show which bond glucocerebrosidase hydrolyses in the glycosphingolipid. [1]

(d) Fig. 1.2 shows the results of an experiment conducted to investigate the activity of glucocerebrosidase at various pH levels.

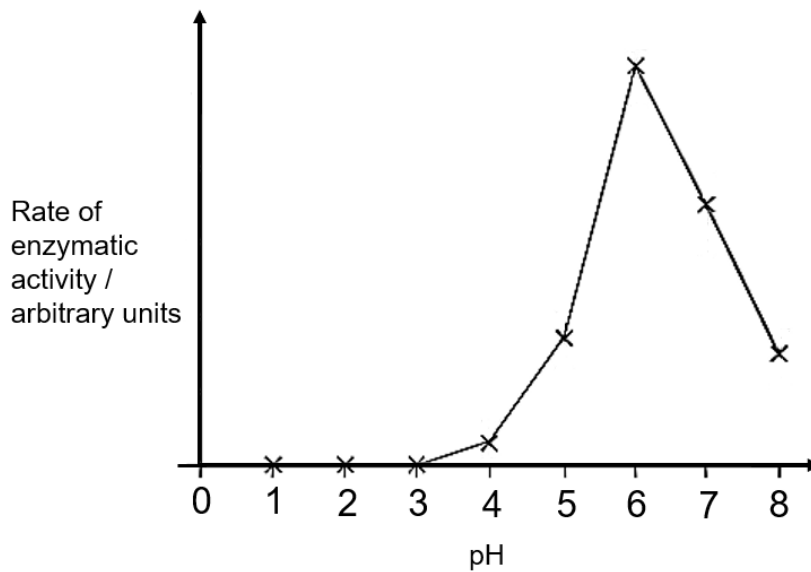


Fig. 1.2

Explain why there is no enzyme activity below pH 3.

[3]

1. Below pH 3, charged and/or polar R-groups of amino acids in the enzyme are neutralised.
2. Ionic and hydrogen bonds (ecf from point 1) between amino acids are disrupted.
3. There is a change in 3D conformation of the enzyme, hence the active site is no longer complementary to the substrate
4. No enzyme-substrate complex can be formed to catalyse the hydrolysis of the bond.  
Accept: less

- (e) Another experiment was conducted to investigate the effect of substrate concentration on the activity of glucocerebrosidase, with and without a chemical called isofagomine.

The results are shown in Fig. 1.3.

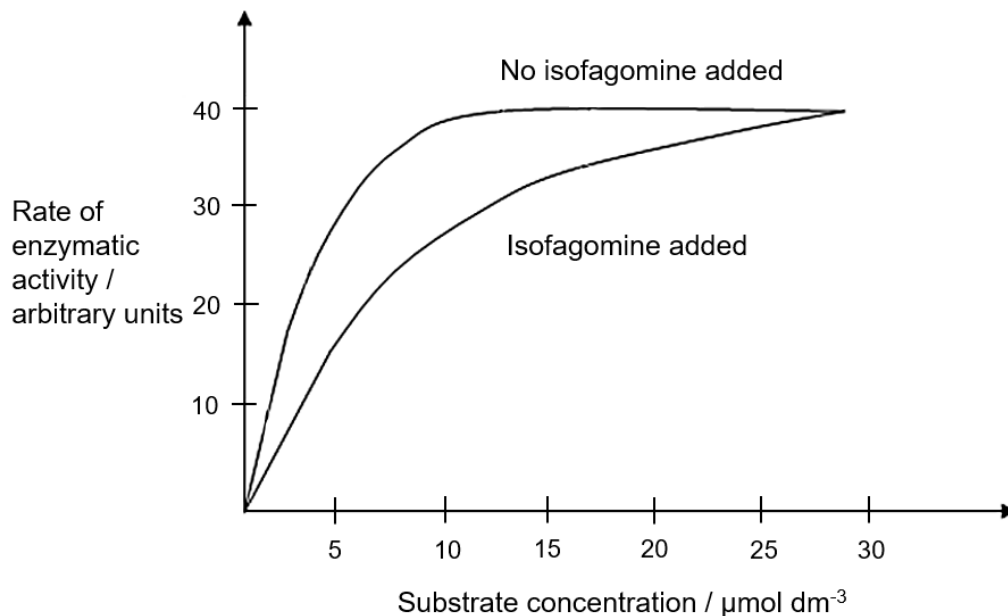


Fig. 1.3

- (i) Describe and explain the results of the experiment at substrate concentrations above 10  $\mu\text{mol dm}^{-3}$  for the reaction without isofagomine. [2]

**[Describe]**

1. Above 10  $\mu\text{mol dm}^{-3}$ , rate of reaction remains constant/plateaus at 40 a.u.

**[Explain]**

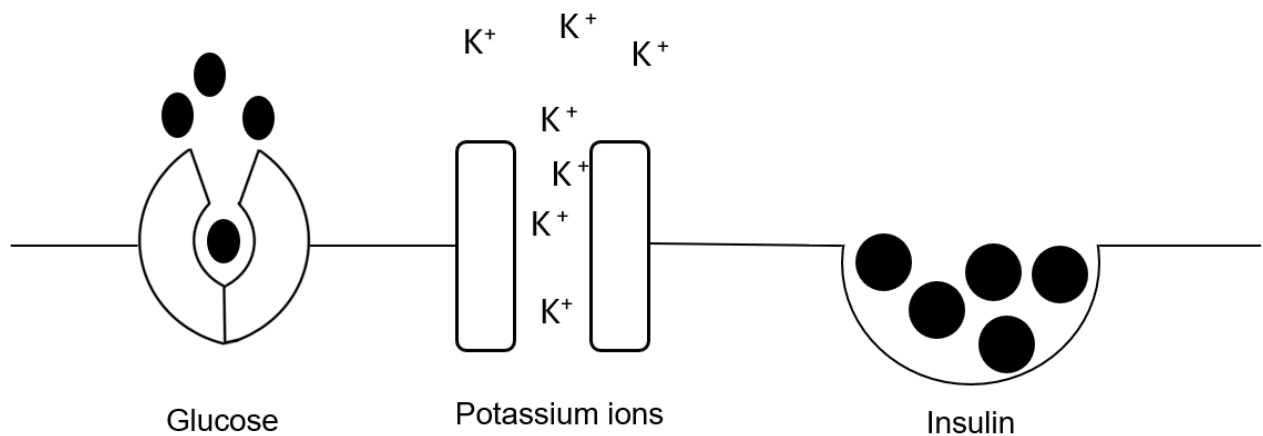
2. All active sites of enzyme molecules are saturated with substrates / Enzyme concentration is the limiting factor.

- (ii) With reference to Fig. 1.3, explain the effect of isofagomine on the rate of enzymatic activity. **[HI-2]** [4]

1. Isofagomine is a competitive inhibitor.
2. Isofagomine is structurally similar to glycosphingolipids.
3. Isofagomine competes with glycosphingolipids to bind to the active site of the glucocerebrosidase enzyme, forming an enzyme-inhibitor complex / is complementary in shape to the active site of glucocerebrosidase.
4. The glycosphingolipids cannot bind to glucocerebrosidase, fewer enzyme-substrate complexes are formed per unit time, hence rate of reaction decreases.
5. With isofagomine added, the rate of reaction reaches  $V_{\text{max}}$  at 10  $\mu\text{mol dm}^{-3}$  substrate concentration.

[Total: 13]

2. Fig. 2.1 shows the movement of three different substances across a cell surface membrane.



**Fig. 2.1**

(a) Explain why transmembrane proteins are needed to transport glucose and potassium ions across the cell surface membrane. [3]

1. Glucose is polar and potassium ions are charged.
2. Polar and charged molecules cannot pass through the hydrophobic fatty acid core of the cell surface membrane.
3. Transmembrane proteins provide a hydrophilic channel/pathway/passage for glucose and potassium ions to pass through the cell surface membrane.

(b) Describe **one** difference between the mechanism of transport of glucose and potassium ions across the cell surface membrane. [1]

1. Idea of conformational change in glucose carrier but not potassium ion channel.
2. Only one molecule of glucose can be transported across the cell surface membrane at a time while multiple potassium ions can be transported across the cell surface membrane together.

(c) Fig. 2.1 shows insulin being released out of the cell via exocytosis.

Describe how insulin synthesised by ribosomes is transported to the cell surface membrane. [3]

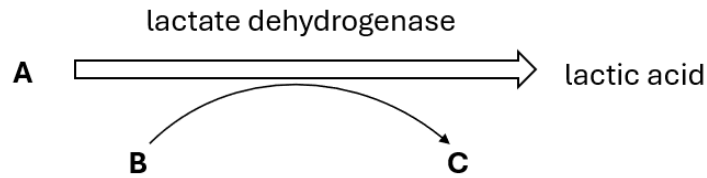
1. Insulin molecules synthesised in the rough endoplasmic reticulum bud off from the rER in ER vesicles.
2. ER vesicles move to and fuse with the cis face of the Golgi apparatus
3. Insulin is sorted and packaged into secretory vesicles and buds off at the trans face of the Golgi body.
4. *Ref to* movement of vesicles along microtubules within the cell.

**[Total: 7]**

3. When there is insufficient oxygen in the cell, ATP is synthesised via anaerobic respiration.

Fig. 3.1 shows one of the reactions occurring during anaerobic respiration in humans.

This reaction is catalysed by lactate dehydrogenase.



**Fig. 3.1**

- (a) Identify

(i) molecule **A** [1]

pyruvate / pyruvic acid

(ii) molecules **B** and **C** [1]

**B** NADH

**C** NAD<sup>+</sup>

(b) State the location in the cell where this reaction occurs. [1]

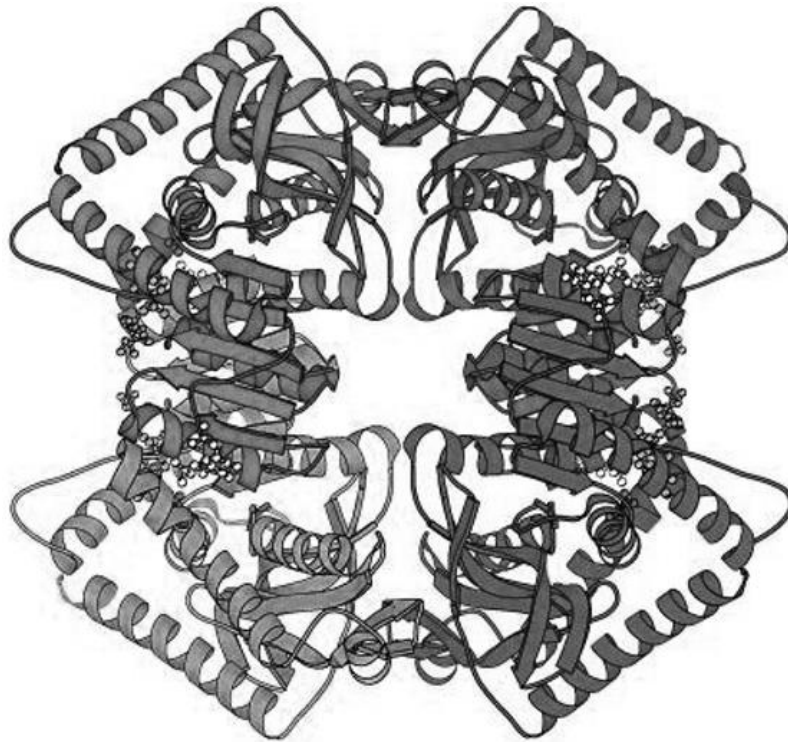
cytosol / cytoplasm

(c) Explain the importance of this reaction in the production of ATP. [2]

1. To regenerate NAD<sup>+</sup> for glycolysis.

2. Net 2 molecules of ATP are produced via substrate level phosphorylation during glycolysis.

(d) Fig. 3.2 shows the structure of lactate dehydrogenase 3 (LDH-3), which is found in the lungs.



**Fig. 3.2**

With reference to Fig. 3.1 and Fig. 3.2, describe the structural differences between LDH-3 and haemoglobin. [2]

No.	feature	LDH-3	haemoglobin
1.	secondary structure	$\alpha$ -helices and $\beta$ -pleated sheets	only $\alpha$ -helices and $\beta$ -pleated sheets
2.	cofactor bound to the enzyme	NADH	heme group
3.	type of binding site	active site	oxygen binding site

(e) Lactate dehydrogenase is an allosteric enzyme.

Explain how allosteric activators increase the rate of enzymatic activity in lactate dehydrogenase. [2]

1. Allosteric activators bind to an allosteric site / site away from active site on one subunit of lactate dehydrogenase.
2. *Idea of* conformational change in (all) subunits into active form.

[Total: 9]

4. Meristematic tissue is found in the growing region of plants, such as root tips.

Fig. 4.1 shows a section through the meristematic region of a root tip of onion, *Allium cepa*.

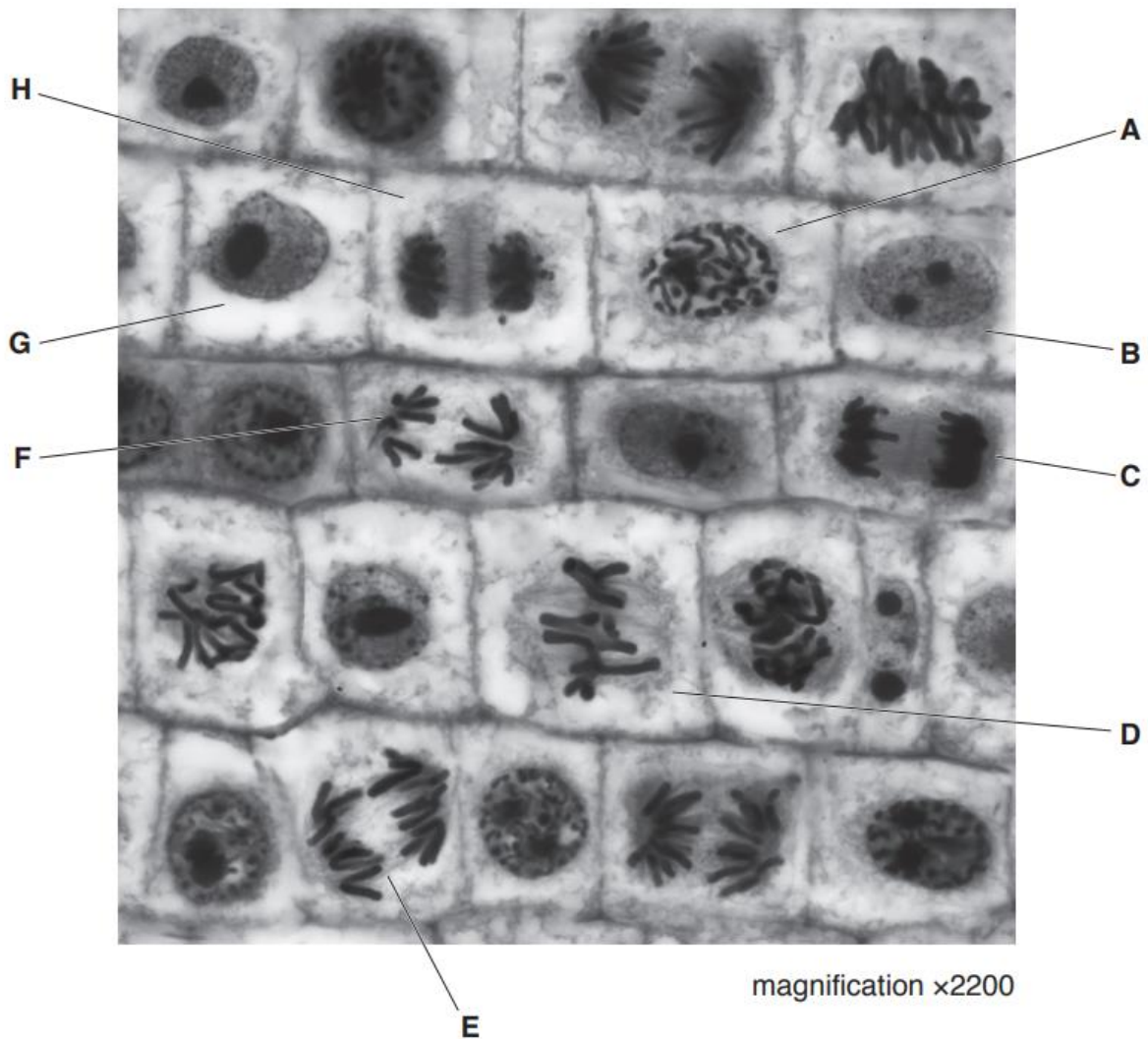


Fig. 4.1



Table 4.1 shows the numbers of cells in different stages of the cell cycle that were observed in sections of the meristematic regions of root tips of *A. cepa*.

**Table 4.1**

stage of cell cycle	one example of cell from Fig. 4.1	number of cells counted in each stage			
		replicate 1	replicate 2	replicate 3	mean
interphase	<b>B</b>	4686	4709	4808	4734
prophase	<b>A</b>	148	159	155	154
metaphase	<b>D</b>	38	47	40	42
anaphase	<b>E/F/C</b>	25	33	28	29
telophase	<b>C/H</b> <i>Reject C if stated for anaphase</i>	38	47	39	41
				total	5000

- (a) Complete Table 4.1 by using the letters **A** to **H** from Fig. 4.1 to identify **one** cell in each stage of the cell cycle. The first example has been completed for you. [2]

1 mark for any two correct

- (b) The total length of time taken for meristematic cells of *A. cepa* to complete one cell cycle at 25°C is 12 hours.

Using sections similar to the one in Fig. 4.1, the length of time spent in each stage of the cell cycle can be estimated.

To obtain the estimate, the percentage of cells in that stage is calculated.

Using the data in Table 4.1, calculate:

- the percentage of cells in anaphase
- the mean length of time for anaphase in minutes.

Show your working.

[2]

- $29/5000 \times 100\% = 0.58\% / 0.6\%$ ;
- $58\% \times 12 \text{ hours} = 0.0696 \text{ hr}$   
 $0.0696 \times 60 = 4 / 4.2 / 4.18 \text{ min ; allow ecf}$

percentage of cells in anaphase = ..... %

mean length of time in anaphase = ..... min

(c) Describe how the spindle is involved during the process of mitosis. [3]

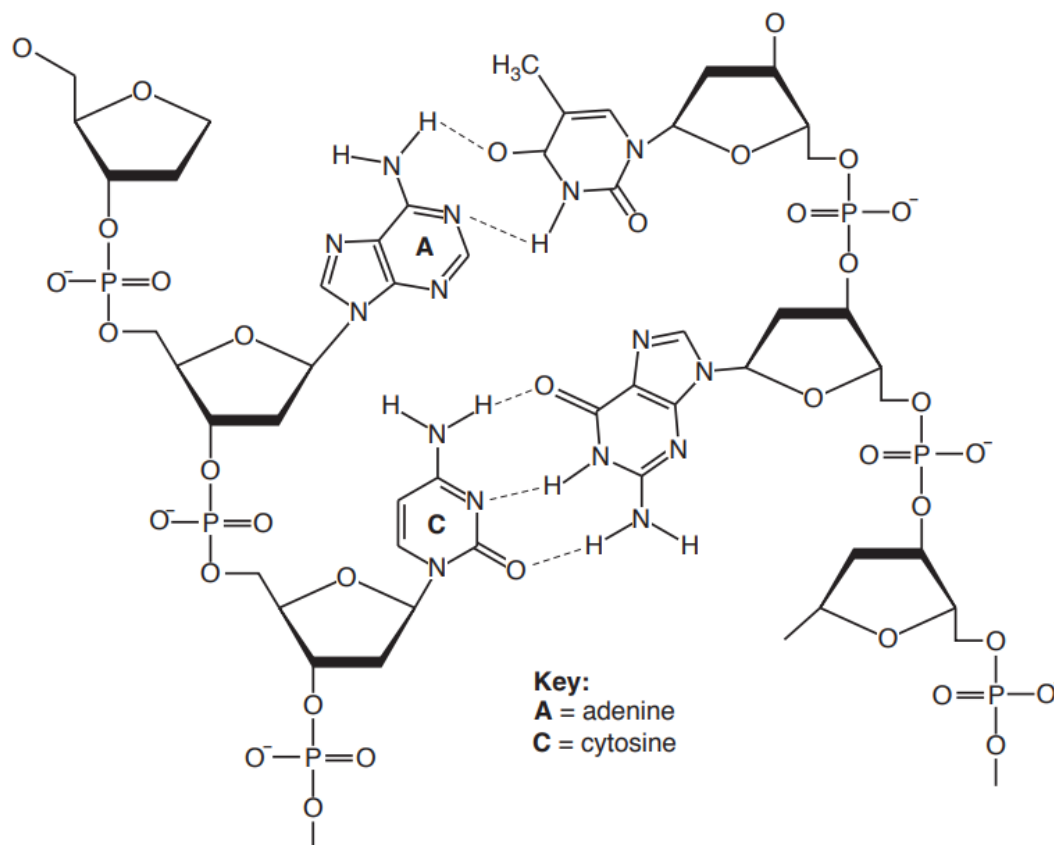
Accept spindle fibres / microtubules as alternative to spindle *Max 2 if named stages are incorrect or not named:*

Any three from:

- In prophase, spindle attach to centromere of each chromosome (via the kinetochore proteins).
- In metaphase, microtubules arrange / align chromosomes at the equator / metaphase plate.
- In anaphase, spindle fibres shorten separate sister chromatids and pulled to opposite poles of the cell.
- In telophase, (non-kinetochore) microtubules elongates and push poles/ nuclei apart / cell elongates.

[Total: 7]

5. Fig. 5.1 shows part of a DNA molecule.



**Fig. 5.1**

(a) Use Fig. 5.1 to explain how the structure of mRNA differs from the structure of DNA. [2]

Features	mRNA	DNA
1. Number of strands;	Single stranded	Double stranded
2. Presence of hydrogen bonding <b>OR</b> complementary base pairing;	No hydrogen bonding or No base pairs	Has hydrogen bonding or Has base pairs;
3. Types of bases present;	<u>Uracil</u> and not thymine	Has <u>thymine</u> instead of uracil
4. Types of pentose sugar <b>OR</b> Detail described;	<u>Ribose</u> as pentose sugar has – OH on carbon -2	<u>Deoxyribose</u> as pentose sugar has –H on carbon -2

In the 1950s, Erwin Chargaff determined the relative quantities of the four bases in DNA in different organisms. His results provided important evidence for the model of DNA proposed by James Watson and Francis Crick in 1953. Some of Chargaff's data is shown in Table 5.1.

**Table 5.1**

organism	percentage of <b>A</b>	percentage of <b>T</b>	percentage of <b>C</b>	percentage of <b>G</b>
<i>Escherichia coli</i> (bacterium)	24.7	23.6	26.0	25.7
yeast	31.3	32.9	18.7	17.1
wheat	27.3	27.1	22.7	22.8
octopus	33.2	31.6	17.6	17.6
sea urchin	32.8	32.1	17.7	17.3
chicken	28.0	28.4	22.0	21.6
human	29.3	30.0	20.7	20.0

(b) With reference to Fig. 5.1, explain how the data in Table 5.1 helps to confirm the structure of DNA. [3]

1. **[compulsory]** The table shows percentage of A = percentage of T and very similar / percentage of C = percentage of G + quote data in support for any organisms;
2. This shows that there is complementary base pairing between A with T and G with C;
3. two (DNA) strands / polynucleotide chains / double helix;
4. ref to purine – pyrimidine / double ring (bases) with single ring (bases)
5. distance between strands always the same / uniform width of 2nm;

Table 5.2 shows Chargaff's data for a virus.

**Table 5.2**

organism	percentage of <b>A</b>	percentage of <b>T</b>	percentage of <b>C</b>	percentage of <b>G</b>
a virus	24.0	31.2	23.3	21.5

(c) With reference to Table 5.1 and Table 5.2, suggest why the results for the virus are different from all the other organisms. [2]

1. idea that percentages of, A and T / C and G, are not the same / similar.
2. the virus has single-stranded DNA.

**[Total: 7]**



6. The  $\beta$ -globin gene codes for the  $\beta$ -globin polypeptide of haemoglobin. It has two alleles, **Hb<sup>A</sup>** (normal) and **Hb<sup>S</sup>** (sickle cell). The sickle cell allele differs from the normal allele due to a base substitution mutation.

There are three possible genotypes and phenotypes.

- **Hb<sup>S</sup> Hb<sup>S</sup>**, sickle cell anaemia, a severe disease
- **Hb<sup>A</sup> Hb<sup>S</sup>**, sickle cell trait with mild or no symptoms of sickle cell anaemia
- **Hb<sup>A</sup> Hb<sup>A</sup>**, normal (healthy)

(a) Describe the effect of a base substitution on the structure of haemoglobin. [3]

1. **Ref to** change in DNA triplet / mRNA codon.
2. Resulting in a change of amino acid from hydrophilic glutamic acid to hydrophobic valine.
3. The hydrophobic R group of valine inserts into the hydrophobic pocket of another  $\beta$ -globin.
4. ...causing the HbS to crystallise to form long fibres at low oxygen concentration.

- (b) A man and woman who both have sickle cell trait may choose to have children by in-vitro fertilization (IVF). This allows the genotype of embryos to be determined by gene testing before the embryos are implanted. Embryos with the normal genotype can then be selected and implanted into the mother.

One technique that can be used in gene testing an embryo for the **Hb<sup>s</sup>** allele is restriction fragment length polymorphism (RFLP) analysis. This involves digesting a DNA sample from an embryo with a restriction endonuclease and then separating the DNA fragments by gel electrophoresis. The position of the DNA fragments on the gel can show if the embryo has the **Hb<sup>s</sup>** allele.

RFLP analysis involves the following steps:

- 1 use specific primers and make many copies of  $\beta$ -globin gene
- 2 add a specific restriction endonuclease
- 3 carry out gel electrophoresis
- 4 stain with a dye to compare banding patterns

The position of the DNA fragments on the gel can show if the embryo has the **Hb<sup>s</sup>** allele.

- (i) Name the technique used to produce many copies of  $\beta$ -globin gene. [1]

- polymerase chain reaction (reject: PCR)

- (ii) state why it is necessary to copy  $\beta$ -globin gene many times in order to test embryos for **Hb<sup>s</sup>** alleles by RFLP analysis. [1]

any one from:

1. Because the starting quantity DNA from embryo is too small.
2. To obtain high concentration of the gene so that DNA fragments are visible on gel.

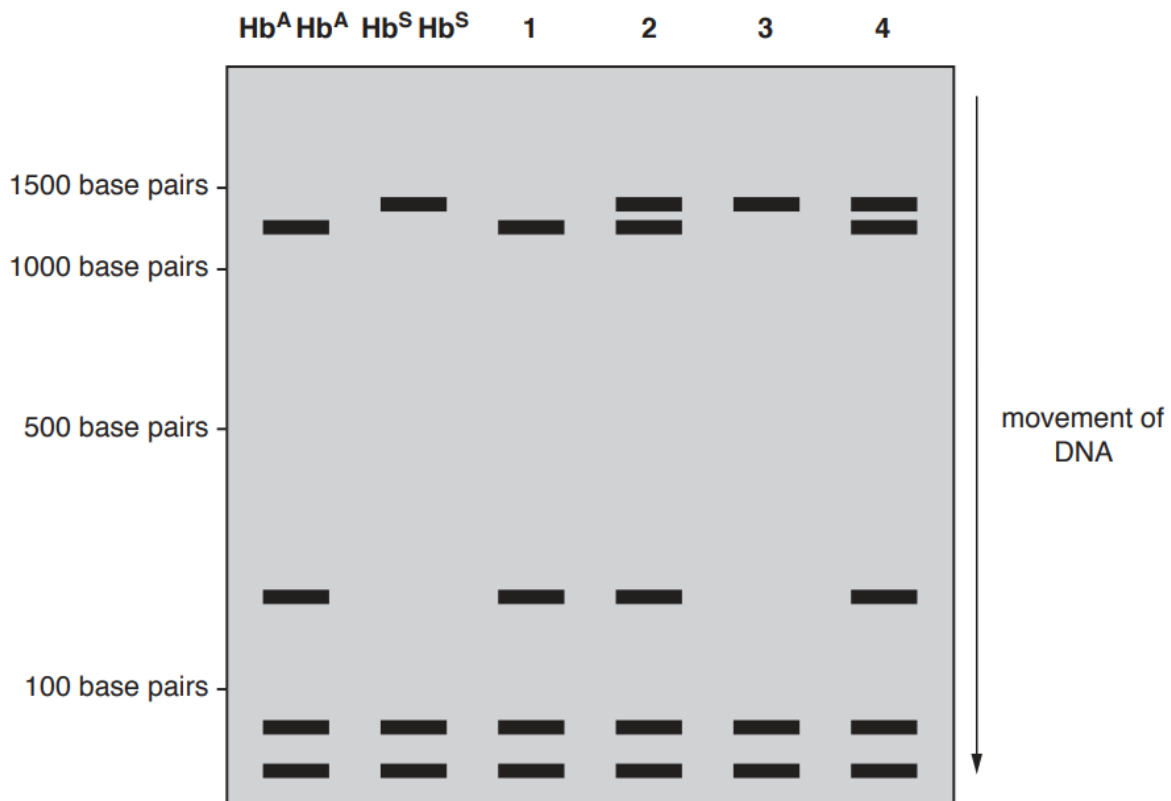
- (iii) Explain how gel electrophoresis separates DNA fragments produced from digestion by restriction endonucleases. [3]

any three from:

1. Cutting DNA with restriction endonucleases produces **DNA** fragments of **different** sizes / length ;
2. As (phosphate groups of) DNA is **negatively-charged**, DNA migrate to anode / positive electrode ;
3. Gel matrix acts as **molecular sieve** to separate DNA fragments based on molecular size/ weight
4. **Shorter / smaller fragments** move **faster / further** away from well / cathode or larger / longer DNA fragments move slower / nearer to the well / cathode ;

(c) Four embryos, **1**, **2**, **3** and **4**, were tested for the **Hb<sup>S</sup>** allele using RFLP analysis.

Fig. 6.1 shows the DNA fragments separated by gel electrophoresis for the four embryos. The DNA fragments for two individuals of known genotype, homozygous for **Hb<sup>A</sup>** and homozygous for **Hb<sup>S</sup>**, are also shown.



**Fig. 6.1**

(i) Explain the purpose of using DNA from individuals homozygous for **Hb<sup>A</sup>** and for **Hb<sup>S</sup>**. [1]

1. used as a comparison / reference / standard to show correct position of **Hb<sup>A</sup>** and **Hb<sup>S</sup>** allele on gel / band patterns with individuals with unknown genotype [reject: control] ;

(ii) With reference to Fig. 6.1, complete Table 6.1 to show the genotypes of embryos **2**, **3** and **4**. [1]

**Table 6.1**

embryo	genotype
1	<b>Hb<sup>A</sup> Hb<sup>A</sup></b>
2	<b>Hb<sup>A</sup> Hb<sup>S</sup></b>
3	<b>Hb<sup>S</sup> Hb<sup>S</sup></b>
4	<b>Hb<sup>A</sup> Hb<sup>S</sup></b>

- one mark for correctly identifying all genotypes;

- (iii) Discuss the ethical and social considerations of gene testing embryos for genetic diseases. [3]

Any three from:

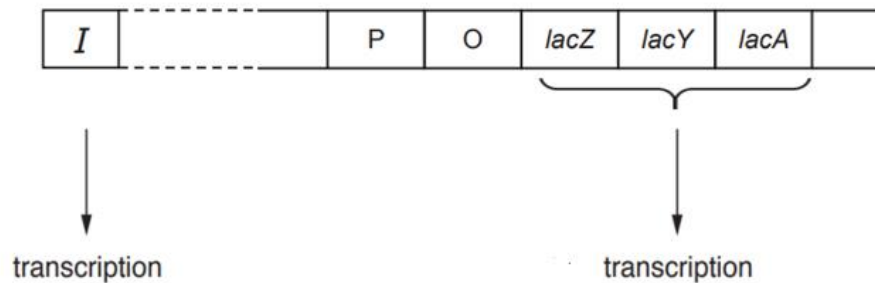
1. can avoid having offspring with serious / genetic disease to prevent suffering of child / parents.
2. can avoid late abortions (if genetic disease discovered later in foetal development).
3. allows couples to have children who would otherwise choose not to (due to risk of genetic disease).
4. allows couples to undergo counselling to make informed decisions.
5. viable embryo(s) discarded. **reject**: abortion
6. idea of use of healthcare resources by couple that can conceive naturally.
7. may conflict with religious beliefs.
8. could lead to selection based on gender or specific traits (designer babies).
9. **idea of** stigmatization / discrimination / confidentiality.
10. Affordability of the gene testing.
11. **AVP** e.g. genetic disease may not develop

[Total: 13]



7. The *lac* operon is a section of DNA present in the genome of the bacterium *Escherichia coli*. The structural genes of the operon are only fully expressed when *E. coli* is exposed to high lactose concentrations.

Fig. 7.1 is a diagram showing the *lac* operon and a nearby region of the *E. coli* genome.



**Fig. 7.1**

- (a) With reference to Fig. 7.1, state **one** way the organisation of genes differs between prokaryotes and eukaryotes. [1]

1. Multiple (structural) genes (like lac Z, Y, A) are controlled by a single promoter vs Each gene has its own promoter.
2. Genes with related functions are organized in operons vs genes with related functions are usually scattered throughout the genome.

- (b) When the genes of the *lac* operon are expressed, the enzymes  $\beta$ -galactosidase and lactose permease are produced in large quantities.

Outline the functions of  $\beta$ -galactosidase and lactose permease. [2]

$\beta$ -galactosidase

- Hydrolyses / break down of lactose into glucose and galactose.
- converts / isomerises lactose into allolactose

lactose permease

- allows for lactose to be transported into the cell.

- (c) The *lac I* gene is located a short distance away from the *lac* operon. The product of *lac I* gene, a repressor protein, is a constitutive protein.

Suggest what is meant by the term constitutive protein. [1]

- protein is always produced / present at all time / the *lac I* gene continuously expressed into an (active) repressor protein.

OR

- protein concentration do not vary (in responses to molecular signals);

- (d) A strain of *E. coli* has been produced with a mutation in *lac I* gene. Expression of this gene results in a non-functional repressor protein.

Explain the negative effect that this mutation will have on this strain of *E. coli*. [3]

1. Non-functional repressor is no longer complementary in shape to operator and do not bind to operator;
2. Allows RNA polymerase to bind to promoter and transcribes the structural genes ;
3. Lac operon always switched on even in the absence of lactose / Enzymes are produced all the time even when not needed;
4. Waste of amino acids / energy / ATP / nucleotides ~~reject: cellular resources~~ resulting in decrease growth of *E.coli*;

[Total: 7]

8. In the sweet pea plant, *Lathyrus odoratus*, one gene codes for flower colour and one gene codes for pollen grain shape.

Flower colour is either purple or red. Pollen grain shape is either long or round.

The inheritance of these genes is an example of autosomal linkage.

- The allele F for purple flowers is dominant over the allele f for red flowers.
- The allele G for long pollen grains is dominant over allele g for round pollen grains.

(a) Explain the meaning of the term autosomal linkage. [2]

1. (autosomal) genes located on the same non-sex chromosome ;
2. (linkage) genes are on the same chromosome / always inherited together ;

**Reject: alleles**

- (b) A dihybrid cross was carried out between a pure breeding sweet pea plant with purple flowers and round pollen grains and a pure-breeding pea plant with red flowers and long pollen grains to produce the F1 generation. The offspring from the F1 generation were crossed to produce the F2 generation.

The results of the dihybrid cross are shown in Table 8.1.

**Table 8.1**

phenotypes of F2 offspring	number of individuals
purple flowers, round pollen grains	284
purple flowers, long pollen grains	21
red flowers, round pollen grains	21
red flowers, long pollen grains	55

Describe how the results support the fact that this is an example of autosomal linkage. [2]

1. do not show expected 9:3:3:1 ratio / no fixed ratio.
2. larger numbers of parental phenotypes / lower numbers of non-parental (recombinant) phenotypes.

- (c) A test cross was carried out with the F1 sweet pea plants known to be heterozygous for both flower colour and pollen grain shape.

The results of the test cross are shown in Table 8.2.

**Table 8.2**

phenotypes of offspring of test cross	number of individuals
purple flowers, round pollen grains	215
purple flowers, long pollen grains	30
red flowers, round pollen grains	32
red flowers, long pollen grains	210

- (i) Draw a genetic diagram to show the results of the test cross in Table 8.2. [3]

**Phenotype of parents:** purple flowers, long pollen grains x red flowers, round pollen grains

**Genotype of parents: [1m]**

$$\begin{array}{c} F \quad g \\ | \quad | \\ \hline f \quad G \end{array} \quad \times \quad \begin{array}{c} f \quad g \\ | \quad | \\ \hline f \quad g \end{array}$$

**Gametes produced (n): [1m]**

$$\begin{array}{cc} \begin{array}{c} F \quad g \\ | \quad | \\ \hline \end{array} & \begin{array}{c} f \quad G \\ | \quad | \\ \hline \end{array} \\ \begin{array}{c} F \quad G \\ | \quad | \\ \hline \end{array} & \begin{array}{c} f \quad g \\ | \quad | \\ \hline \end{array} \end{array} \quad \times \quad \begin{array}{c} f \quad g \\ | \quad | \\ \hline \end{array}$$

Recombinant gametes  
(Small number)

**Genotype and phenotype of offspring: [1m]**

♀ \ ♂	$\begin{array}{c} F \quad g \\   \quad   \\ \hline \end{array}$	$\begin{array}{c} f \quad G \\   \quad   \\ \hline \end{array}$	$\begin{array}{c} F \quad G \\   \quad   \\ \hline \end{array}$	$\begin{array}{c} f \quad g \\   \quad   \\ \hline \end{array}$
$\begin{array}{c} f \quad g \\   \quad   \\ \hline \end{array}$	$\begin{array}{c} F \quad g \\   \quad   \\ \hline f \quad g \end{array}$ purple, round	$\begin{array}{c} f \quad G \\   \quad   \\ \hline f \quad g \end{array}$ red, long	$\begin{array}{c} F \quad G \\   \quad   \\ \hline f \quad g \end{array}$ purple, long	$\begin{array}{c} f \quad g \\   \quad   \\ \hline f \quad g \end{array}$ red, round

Parental type (large number)
Recombinant type (small number)

Note: Mark once in mp2 and mp3 for stating recombinant (small numbers) in either gametes or phenotypes

- (ii) The result of a test cross can be used to determine a crossover value (COV). A crossover value is the percentage of the total number of offspring showing recombination. The COV can be calculated using the formula shown in Fig. 8.1.

$$COV = \frac{\text{number of recombinants}}{\text{total number of individuals}} \times 100$$

**Fig. 8.1**

Calculate the COV from the results in Table 8.2 and give your answer to three significant figures. [1]

$$(30+32) / (215+30+32+210) = 12.7 \%$$

- (iii) Suggest how such breeding experiments could be used to map the position of many different genes on the chromosomes of pea plants. [2]

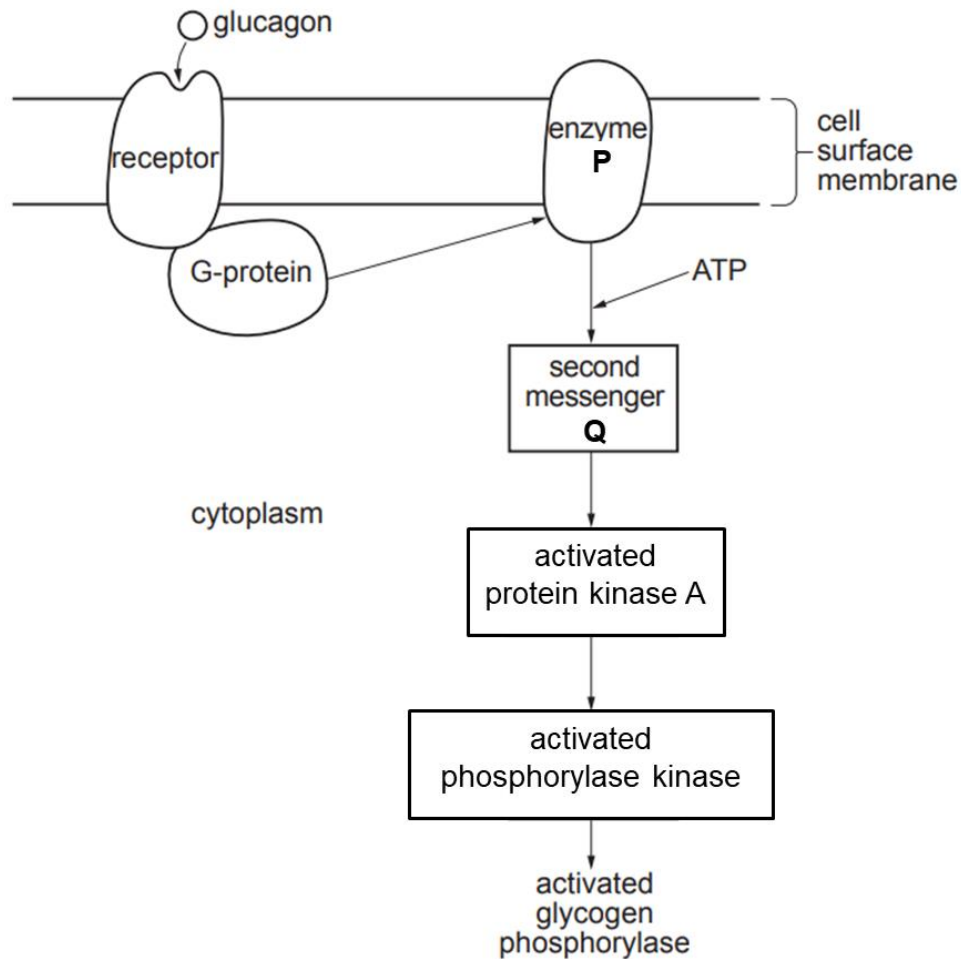
1. Conduct cross between pea plants for different pairs of gene of interest (e.g. A-B, A-C, B-C);
2. The greater the COV, the further apart the linked genes are on the chromosomes,

**[Total: 10]**

9. In mammals, the blood glucose concentration must be maintained within narrow limits so that the body cells can function efficiently.

Glucagon is released by the alpha ( $\alpha$ ) cells of the pancreas when the blood glucose concentration decreases below the set point.

Fig. 9.1 outlines the response of liver cells to glucagon.



**Fig. 9.1**

(a) Name enzyme **P** and second messenger **Q**. [2]

enzyme **P** adenyl cyclase / adenylate cyclase / adenylyl cyclase

second messenger **Q** cAMP / cyclic AMP

(b) Describe how enzyme **P** is activated. [2]

1. The binding of glucagon to receptor causes the G protein to replace GDP with GTP, and is activated.
2. The active G protein then dissociates from the G protein-linked receptor and translocate along the cell surface membrane to enzyme P.
3. Active G-protein binds to and cause a conformation change to enzyme P, activating it.

(c) Suggest why second messenger **Q** is necessary. [3]

1. Ref glucagon cannot pass through hydrophobic phospholipid bilayer of cell surface membrane because it is a large / hydrophilic peptide hormone
2. cAMP is small and water-soluble / can diffuse within cytoplasm to reach target proteins.
3. cAMP binds to and activate protein kinase A, activating downstream process.
4. (signal amplification) Many cAMP molecules can be produced from one enzyme P, allowing for signal amplification / Q activate a protein kinase A which in turn phosphorylate multiple phosphorylase kinase.

(d) Explain how the activation of glycogen phosphorylase is an example of post-translational control of gene expression. [2]

1. Glycogen phosphorylase has already been synthesized via translation but in an inactive form.
2. Activation of glycogen phosphorylase is by the addition of phosphate groups by phosphorylase kinase

[Total: 9]

10. The collared flycatcher, *Ficedula albicollis*, and the pied flycatcher, *F. hypoleuca* are two closely related species of bird. DNA analysis has shown that speciation from a common ancestor occurred approximately 1 million years ago.

A study was carried out on the island of Öland, Sweden. In Öland, the breeding areas of the two bird species overlap and small numbers of hybrid flycatchers are produced.

- Birds were captured and their DNA was analysed to identify whether each bird was *F. albicollis*, *F. hypoleuca* or a hybrid.
- Sperm samples were taken from the male birds.

Table 10.1 shows the percentage of males of each bird type with normal sperm.

**Table 10.1**

bird type	percentage of males with normal sperm
<i>F. albicollis</i>	68
<i>F. hypoleuca</i>	78
male hybrid	0

- The researchers observed that female birds mostly choose mates of their own species based on plumage (feathers) and song.
- Hybrid flycatchers are produced when female *F. albicollis* mate with male *F. hypoleuca* that have a song that is similar to *F. albicollis*.
- Analysis showed that all female hybrids were sterile.

The group of eggs a female bird lays at a single time in its nest is called a clutch. The offspring in the nest are looked after by a male-female pair. Sometimes the male in the male-female pair does not provide the sperm that fertilise the eggs of the female.

Table 10.2 shows:

- the percentage of clutches with eggs that hatched
- the percentage of extra-pair nestlings (offspring in the nest fathered by a male that was different from the male of the male-female pair)

**Table 10.2**

male-female pair of nest		percentage of clutches with eggs that hatched	percentage of extra-pair nestlings
male	female		
<i>F. albicollis</i>	<i>F. albicollis</i>	94.5	17.2
<i>F. hypoleuca</i>	<i>F. hypoleuca</i>	89.3	22.4
hybrid	<i>F. albicollis</i> or <i>F. hypoleuca</i>	38.0	100.0



(a) Using the data in Table 10.2, compare the percentage of clutches with eggs that hatched between the different pairs of parents. [2]

1. [describe] Both pure species pair *F. albicollis* pairs and *F. hypoleuca* pairs have higher percentage of clutches with eggs that hatched compared to female pairs with hybrid males.
2. [quote data] 94.5% and 89.3% vs 38.0%.

(b) Using the data from Table 10.1 and Table 10.2, explain why hybrid males do not pass on their genes to their nestlings. [2]

1. As 0% of hybrid males produce normal sperm, hybrid males are not able to fertilize any eggs, despite forming pairs with *F. albicollis* or *F. hypoleuca* females;
2. In pairs with hybrid males, all offspring (100%) are fathered by other males / idea that all nests with hybrid male, in male-female pair, were parented by another male (of same species as female)

(c) Suggest how the two species *F. albicollis* and *F. hypoleuca* could have evolved from one original ancestral population. [4]

1. Genetic variation in plumage colours / mating calls exists within the ancestral population due to random mutations.
2. a. Ref to behavioural isolation due to specific plumage colours / mating calls **or**  
Ref to habitat isolation due to different habitats / ecological niches.  
b. Hence reduce gene flow between the separated populations.
3. Different selection pressures in each area where each population resides.
4. Birds with alleles that confer selective advantage (able to find a mate and reproduce) and pass on these alleles for specific plumage colours / mating calls to offspring.
5. Results in changes in allele frequency.
6. Accumulation of sufficient genetic differences, hence unable to interbreed to produce viable and fertile offspring ...
7. ...leading to sympatric speciation.

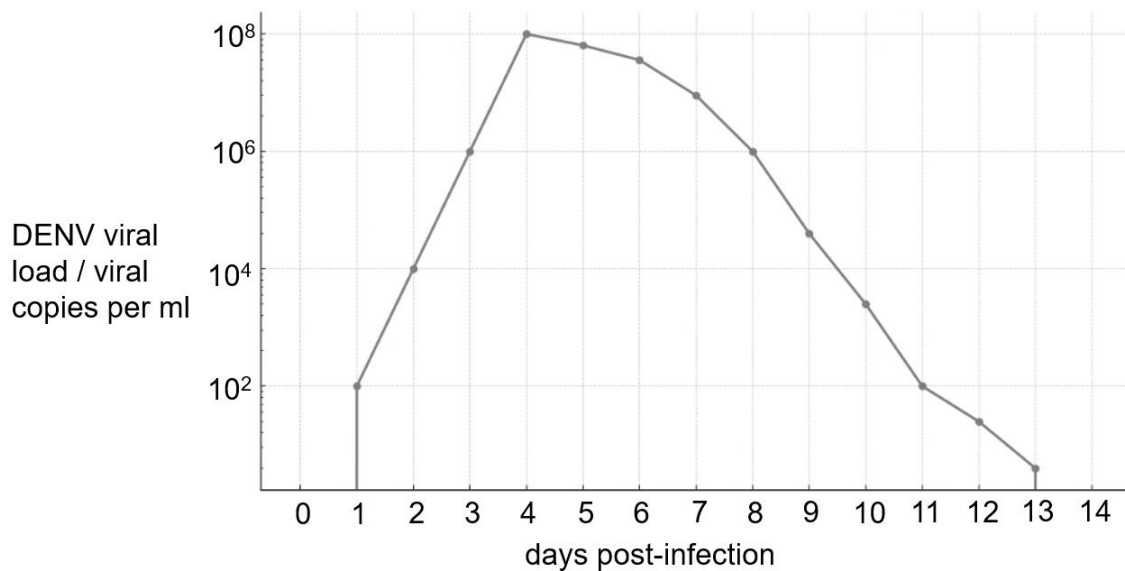
[Total: 8]



11. Dengue fever is caused by the dengue virus (DENV), which is spread by mosquitoes.

Mosquitoes can transmit DENV if they feed on an infected person with a viral load of at least  $10^6$  viral copies per ml.

Fig. 11.1 shows the levels of DENV in the body of a patient two weeks after initial infection with DENV from a mosquito bite.



**Fig. 11.1**

- (a) State the period post-infection that the patient must be bitten by a mosquito for DENV to be passed on to another person. [1]

Days 3-8

- (b) Upon injection of DENV into a host, the host macrophages are infected by DENV. DENV-infected macrophages secrete a group of cytokines called interferons.

Describe the role of interferons in the host immune response against DENV. [2]

1. Nearby uninfected cells detect the interferons and begin to express anti-viral genes to produce anti-viral proteins.
2. Anti-viral proteins inhibit reproduction of DENV in the cell, preventing DENV from multiplying and spreading to other cells.

- (c) In 2016, the Dengvaxia vaccine was approved for clinical use in Singapore. This vaccine is offered to those who have been previously infected with dengue but is not part of the national immunisation programme.

Discuss the likelihood of success of the Dengvaxia vaccination programme against dengue fever. [3]

*[Will be successful] – at least one*

1. Those who are vaccinated are unlikely to be infected again, so they will not spread the virus to others.

Reject: herd immunity since proportion of population who get dengue is less than 1%

2. The vaccine is safe for use / no side effects, hence more people are likely to take the vaccine.

*[Will not be successful] – at least one*

3. This vaccine is not part of national programme, hence people who were infected before (the target group) may not be willing to take the vaccine.

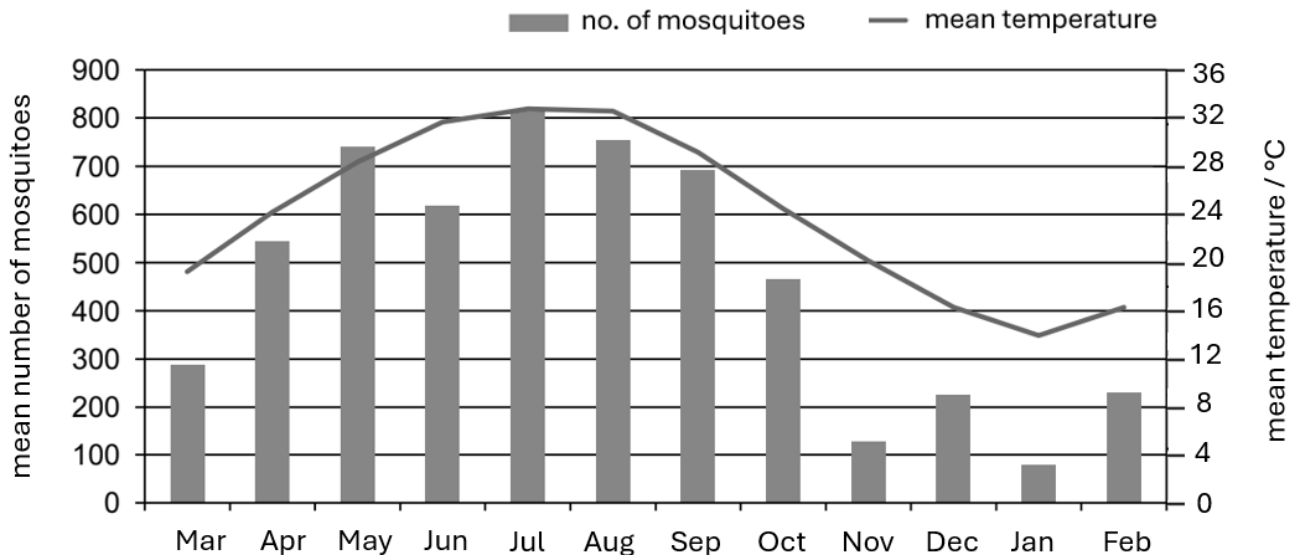
Reject: herd immunity since proportion of population who get dengue is less than 1%

4. As only those who have been previously infected by DENV can be vaccinated, those who have never been infected cannot be given the vaccine and protected from DENV infection, unable to achieve herd immunity.

5. Resistance of people in taking vaccine due to misconceptions/low effectivity/ high cost/AVP

- (d) Global warming can influence the physiology of mosquitoes, causing changes in the spread of dengue.

Fig. 11.2 shows the changes in number of mosquitoes due to seasonal changes in temperature from March 2005 to February 2006.



**Fig. 11.2**

Discuss whether Fig. 11.2 provides sufficient evidence to support a direct relationship between temperature and number of mosquitoes. [4]

*[sufficient] – at least one*

1. *[must cite trend data]* As temperature increases from 19-33°C ( $\pm 1$ ), no. of mosquitoes increases from 290 to 810 / other relevant data
2. Mosquitoes are ectotherms / have limited ability to regulate their own body temperatures, hence are strongly affected by environmental temperatures.
3. At higher temperatures, mosquitoes have increased metabolic rates, leading to shortened maturation time / life cycle hence increased number of mosquitoes.

*[not sufficient] – at least one*

4. Other causative factors not shown in the graph: precipitation / humidity / food availability / human control of mosquito population / **AVP**
5. The graph only shows a correlation between temperature and mean number of mosquitoes. Correlation does not equate to causation.
6. Anomalies in the trend. From May to June, as temperature increases (28.5 to 32°C), the number of mosquitoes decreased (720 to 610) / other relevant anomalies.
7. Changes only tracked for 1 year, insufficient data to make conclusions.

**[Total: 10]**

**END OF PAPER 2**



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