



# TAMPINES MERIDIAN JUNIOR COLLEGE

## JC2 PRELIMINARY EXAMINATION

CANDIDATE  
NAME

CIVICS GROUP

## H2 BIOLOGY

**9744/02**

Paper 2 Structured Questions

**17 September 2025**

**2 hours**

Candidates answer on the Question Paper.

No additional materials are required.

### READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

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

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

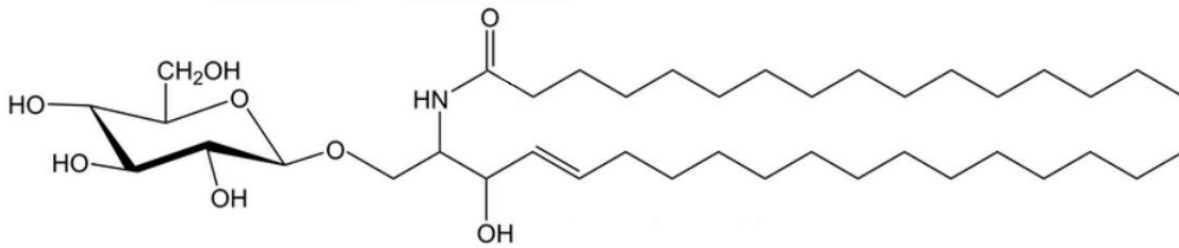
You may lose marks if you do not show your working or if you do not use appropriate units.

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

For examiner's Use	
1	/ 13
2	/ 7
3	/ 9
4	/ 7
5	/ 7
6	/ 13
7	/ 7
8	/ 10
9	/ 9
10	/ 8
11	/ 10
<b>Total</b>	<b>/ 100</b>

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]

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

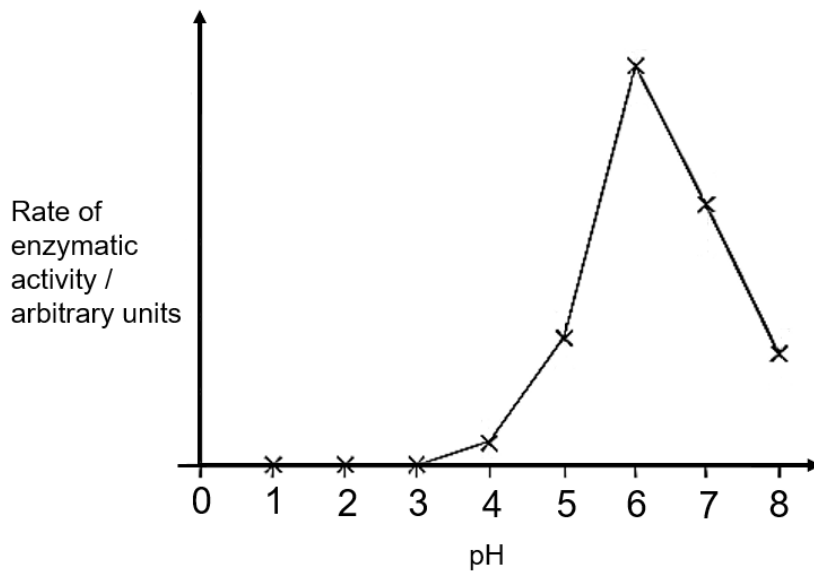
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- (c) Glucocerebrosidase is a glycosidase enzyme that breaks down glycosphingolipids by removing the saccharide portion of the molecule. Another example of a glycosidase enzyme is maltase that breaks down maltose into glucose molecules.

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]

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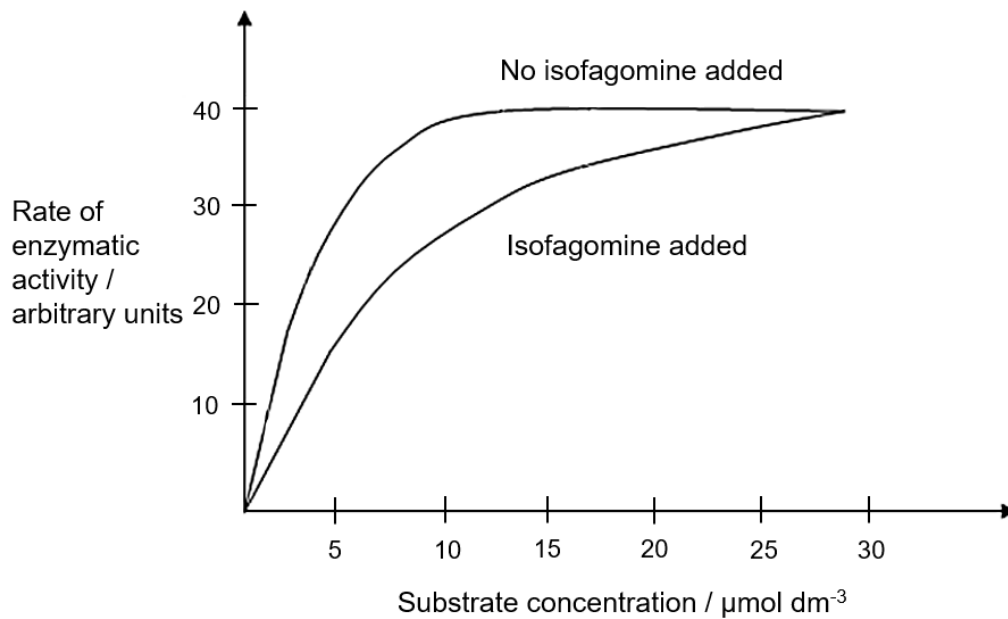
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- (e) Another experiment was conducted to investigate the effect of substrate concentration on the activity of glucocerebrosidase, with and without a chemical called isofagomine.

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]

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

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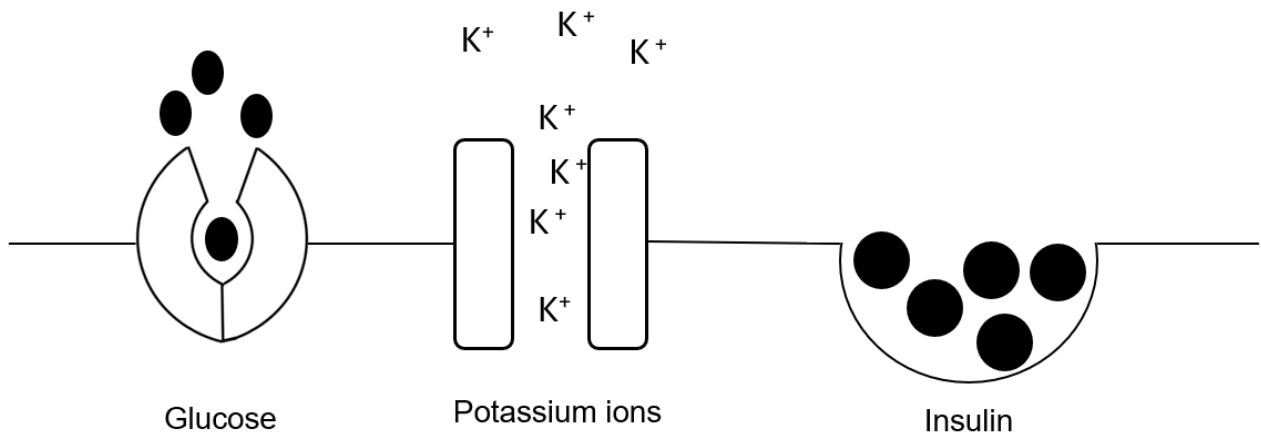
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2. Fig. 2.1 shows the movement of three different substances across a cell surface membrane.



**Fig. 2.1**

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

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

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(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]

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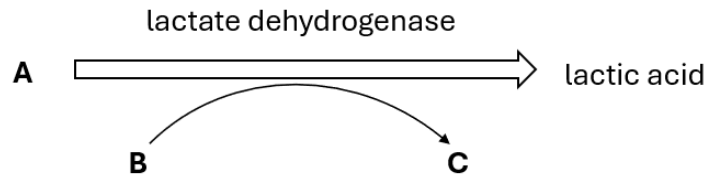
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3. When there is insufficient oxygen in the cell, ATP is synthesised via anaerobic respiration.

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]

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

**B** ..... **C** .....

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

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

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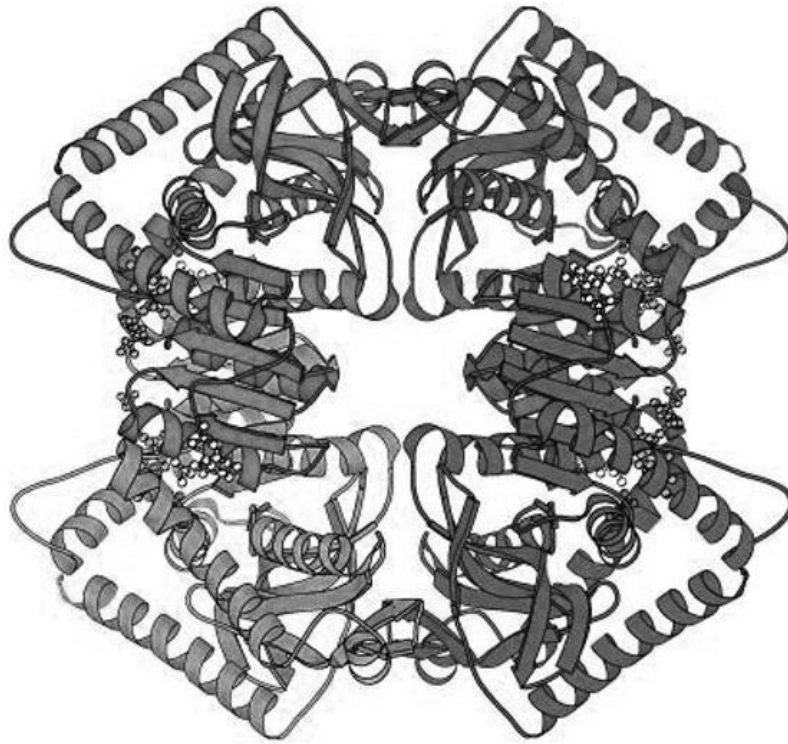
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- (d) Fig. 3.2 shows the structure of lactate dehydrogenase 3 (LDH-3), which is found in the lungs.



**Fig. 3.2**

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

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- (e) Lactate dehydrogenase is an allosteric enzyme.

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

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**[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*.

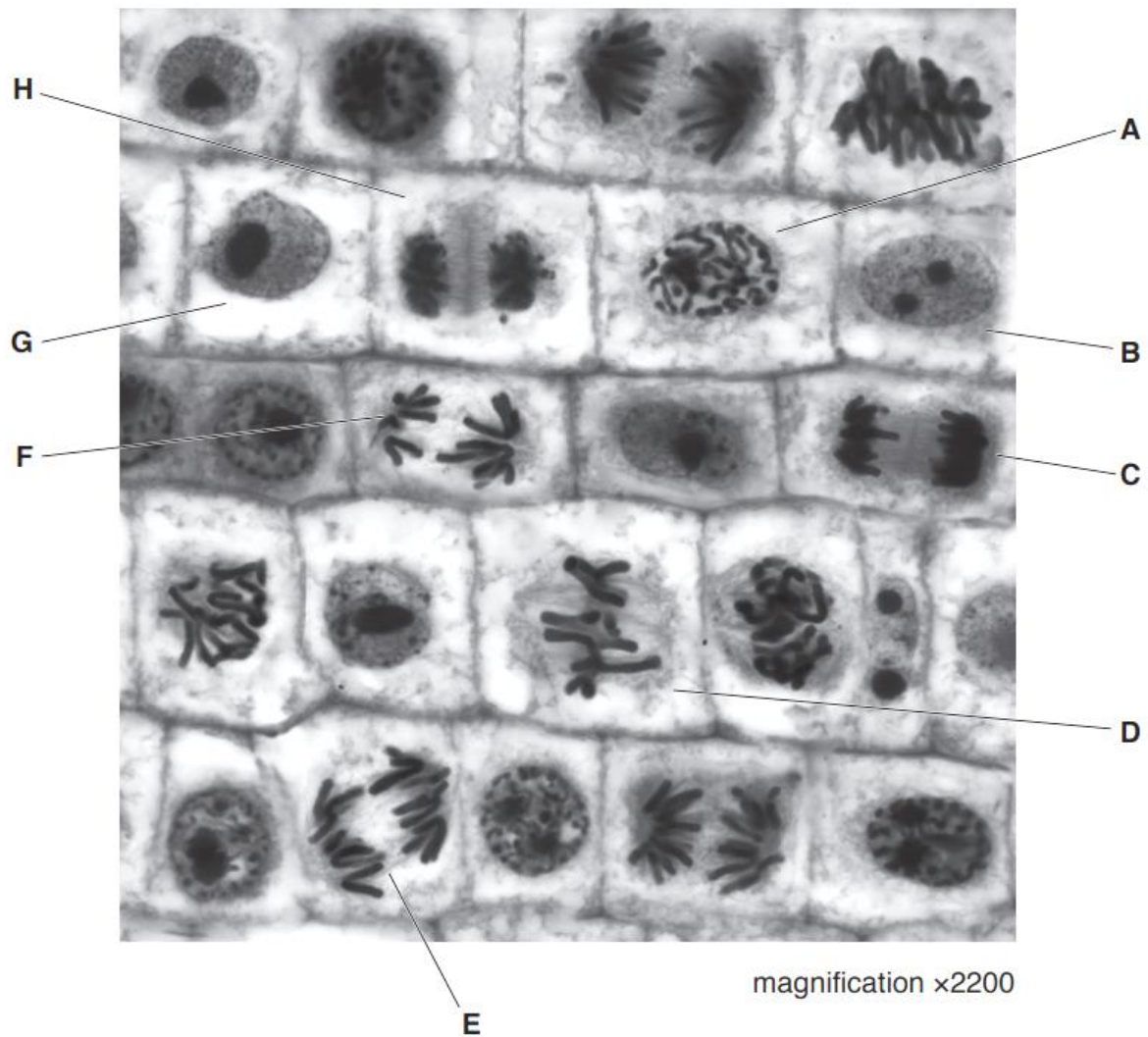


Fig. 4.1

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		148	159	155	154
metaphase		38	47	40	42
anaphase		25	33	28	29
telophase		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]

(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]

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]

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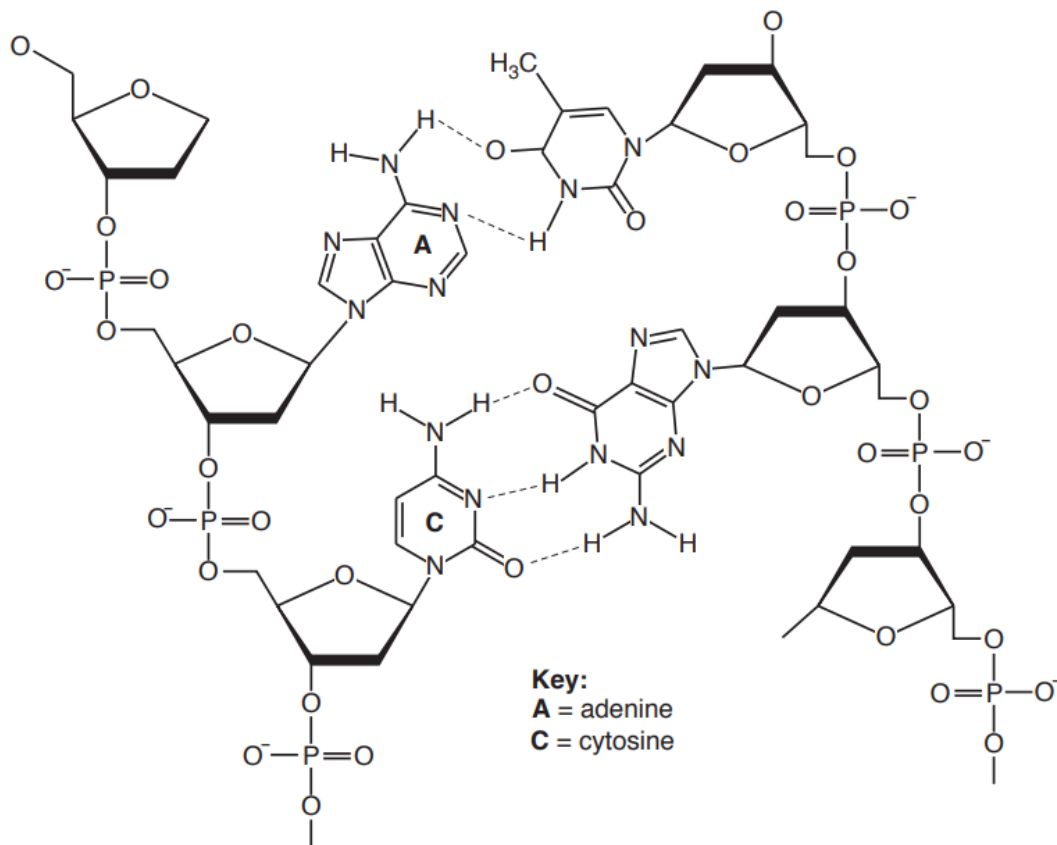
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5. Fig. 5.1 shows part of a DNA molecule.



**Fig. 5.1**

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

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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]

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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]

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**[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]

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- (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]

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- (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]

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

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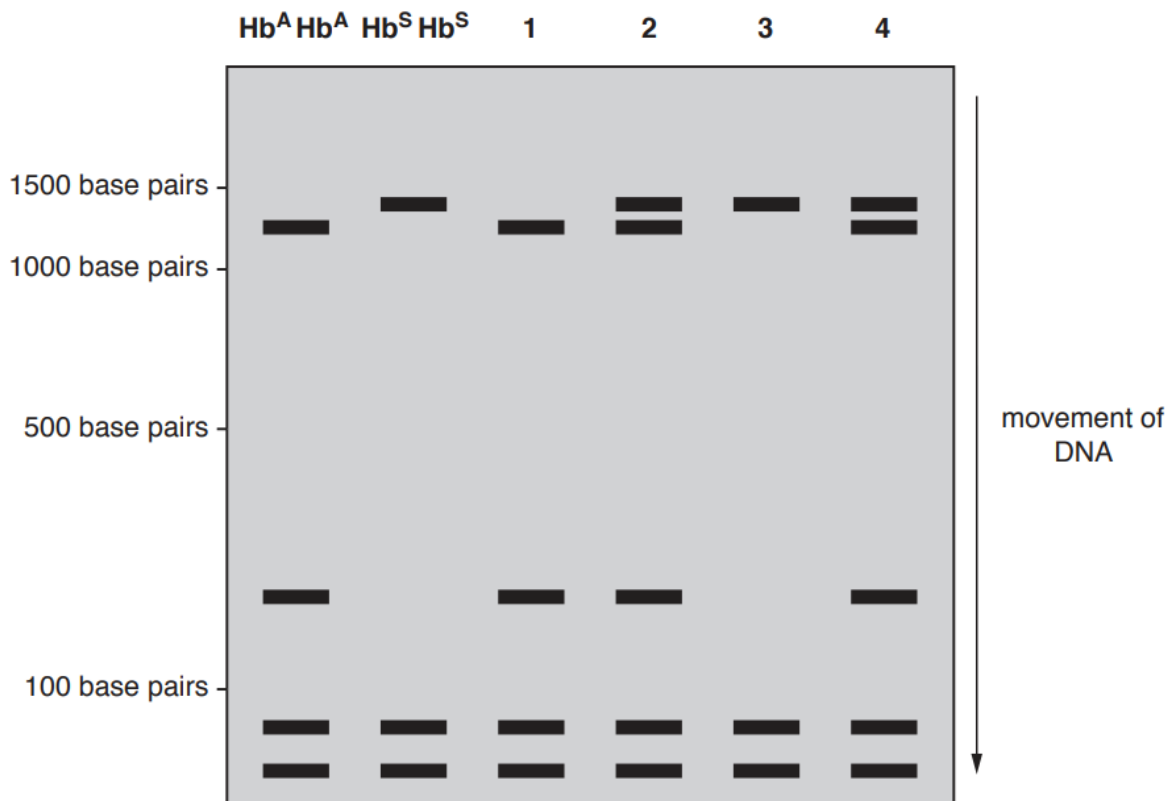
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(c) Four embryos, **1**, **2**, **3** and **4**, were tested for the **Hb<sup>S</sup>** allele using RFLP analysis.

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 who are homozygous for **Hb<sup>A</sup>** and for **Hb<sup>S</sup>**. [1]

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- (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	
3	
4	

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

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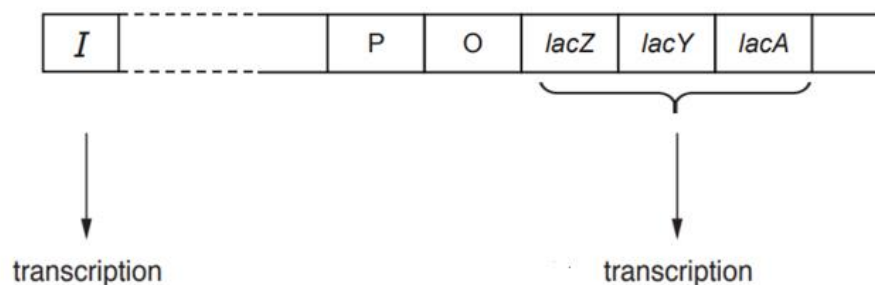


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7. The *lac* operon is a section of DNA present in the genome of the bacterium *Escherichia coli*. The structural genes of the operon are only fully expressed when *E. coli* is exposed to high lactose concentrations.

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]

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- (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 .....

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lactose permease .....

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- (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]

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- (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]

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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]

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- (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]

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- (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]

- (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]

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

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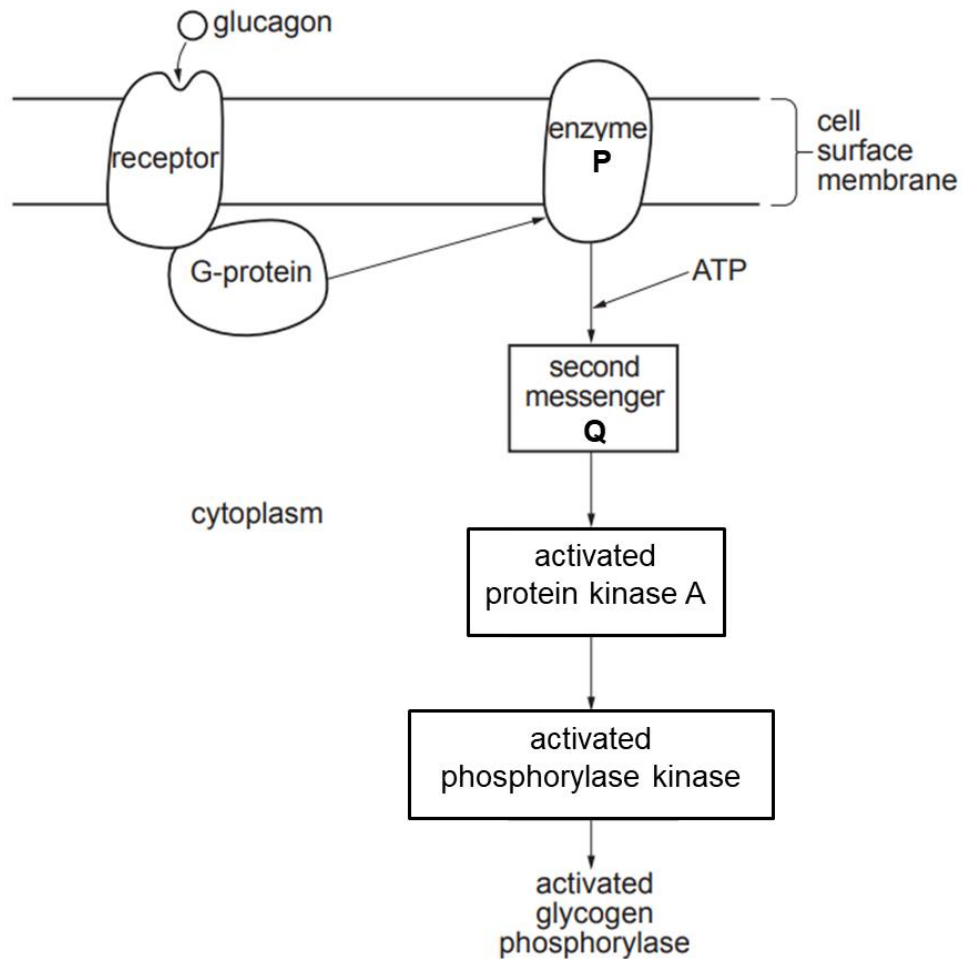
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9. In mammals, the blood glucose concentration must be maintained within narrow limits so that the body cells can function efficiently.

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** .....

second messenger **Q** .....

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

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

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

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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]

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- (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]

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

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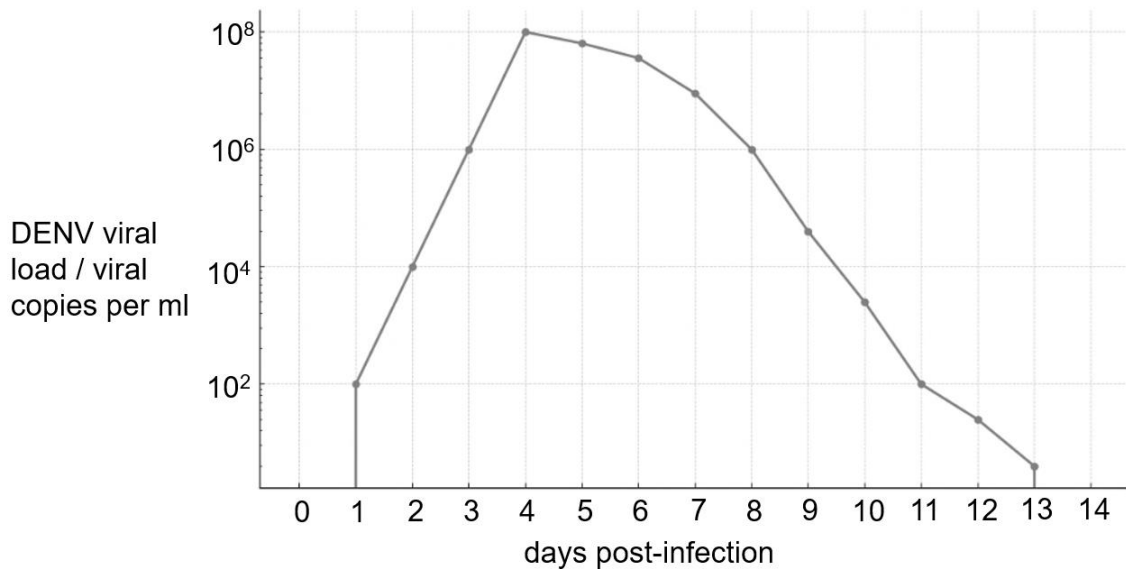
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11. Dengue fever is caused by the dengue virus (DENV), which is spread by mosquitoes.

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]

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- (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]

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- (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]

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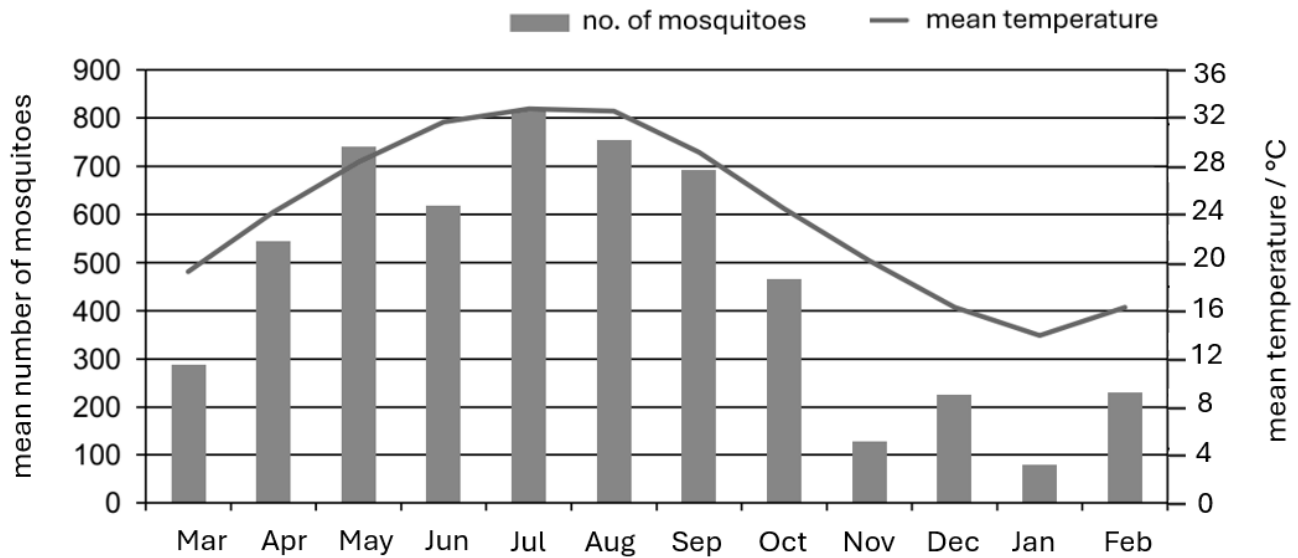
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- (d) Global warming can influence the physiology of mosquitoes, causing changes in the spread of dengue.

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]

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