Diploma Programme
Programme du diplôme
Programa del Diploma

Biology
Higher level
Paper 3

22 October 2024

Zone A afternoon | **Zone B** afternoon | **Zone C** afternoon

Candidate session number

1 hour 15 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- The maximum mark for this examination paper is **[45 marks]**.

Section A	Questions
Answer all questions.	1 – 3

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Neurobiology and behaviour	4 – 8
Option B — Biotechnology and bioinformatics	9 – 13
Option C — Ecology and conservation	14 – 18
Option D — Human physiology	19 – 23

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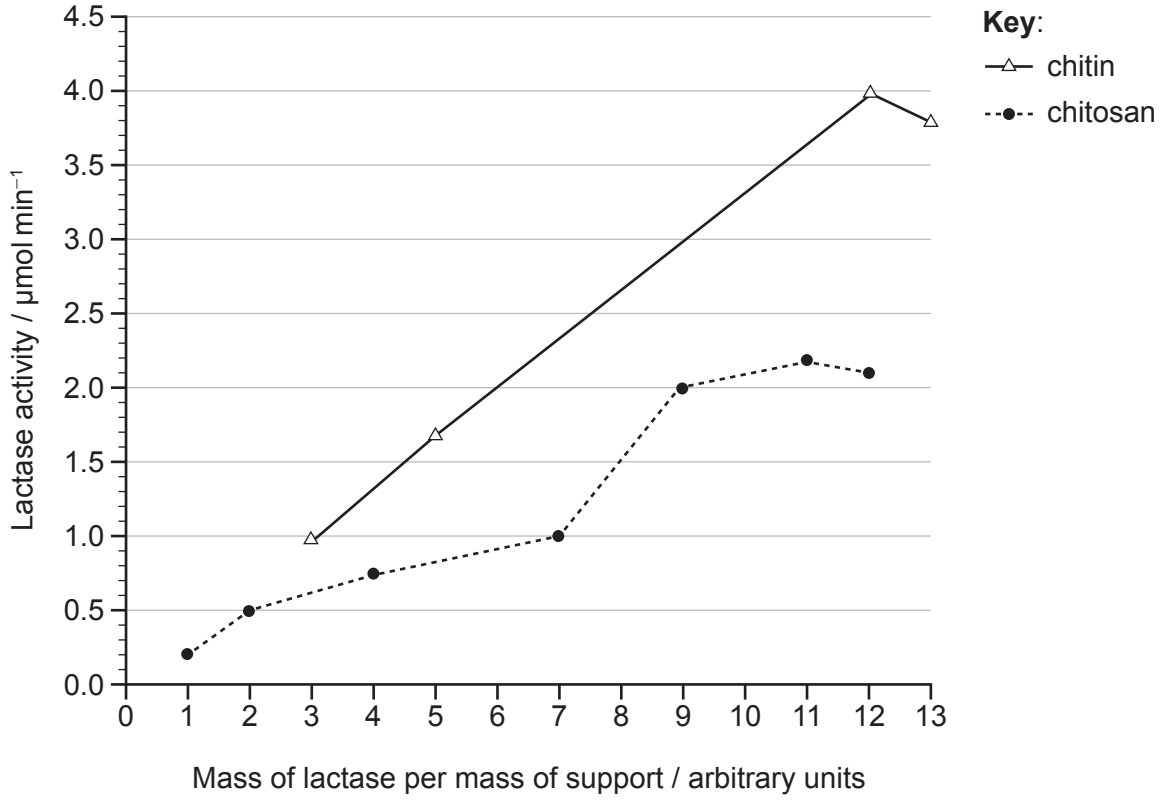
Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Lactase enzyme from the fungus *Aspergillus oryzae* was immobilized on two different support materials, chitin and chitosan. The activity of the immobilized enzyme was measured at 55 °C, pH 4 and 200 g dm^{-3} of lactose at increasing masses of enzyme per kilogram of either chitin or chitosan as a support.

The graph shows enzyme activity of immobilized lactase at increasing masses of enzyme per mass of support.



(a) State the dependent variable. [1]

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(This question continues on the following page)

(Question 1 continued)

(b) Using the data in the graph, deduce with a reason which support should be used for this process. [1]

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(c) Explain reasons for keeping the temperature at 55 °C. [2]

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(d) Suggest a variable that could have been measured to determine lactase enzyme activity in this experiment. [1]

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Please **do not** write on this page.

Answers written on this page
will not be marked.

2. The table shows the percentage of red blood cells that have ruptured (hemolysis) when placed in sodium chloride solutions of different molar concentrations.

NaCl molarity / M	Hemolysis / %
0.000	100
0.075	67
0.150	2
0.460	2

(a) The 0.075 M sodium chloride solution was prepared by dilution from the 0.150 M solution. Describe how to produce this solution. [1]

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(b) Explain the effect of placing red blood cells in distilled water (0.000 M NaCl). [3]

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(c) Deduce with a reason which sodium chloride concentration shown in the table is closest to the osmolarity of the blood cells. [1]

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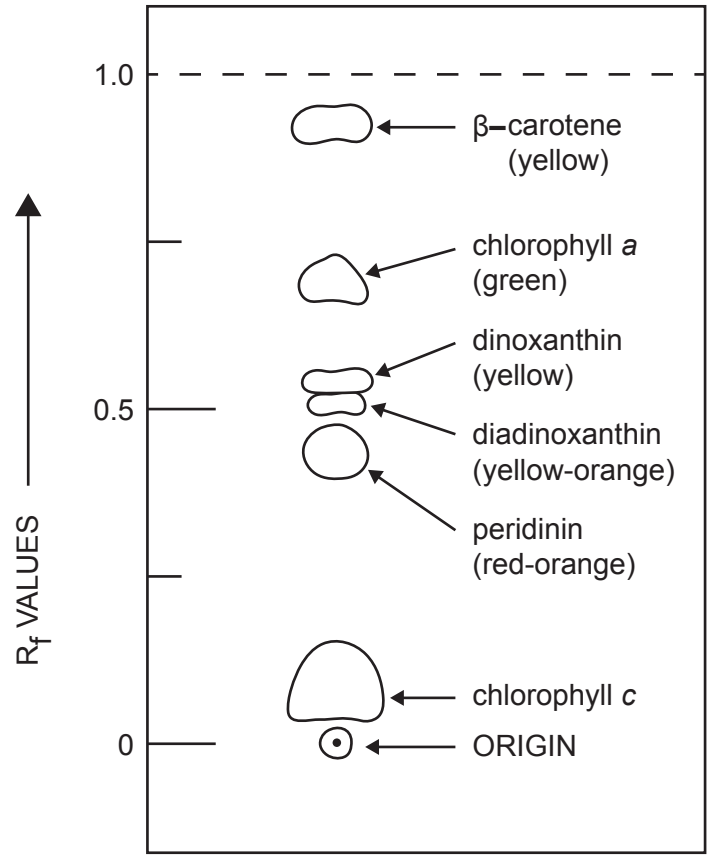
3. The diagram represents the pigment fractions in a thin layer chromatography of the alga *Gambierdiscus toxicus*.



(a) Identify the pigment that is most soluble in the solvent used in the chromatography. [1]

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(This question continues on the following page)

(Question 3 continued)

(b) Describe the process used to obtain this chromatogram. [3]

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(c) State the equation used to obtain an R_f value. [1]

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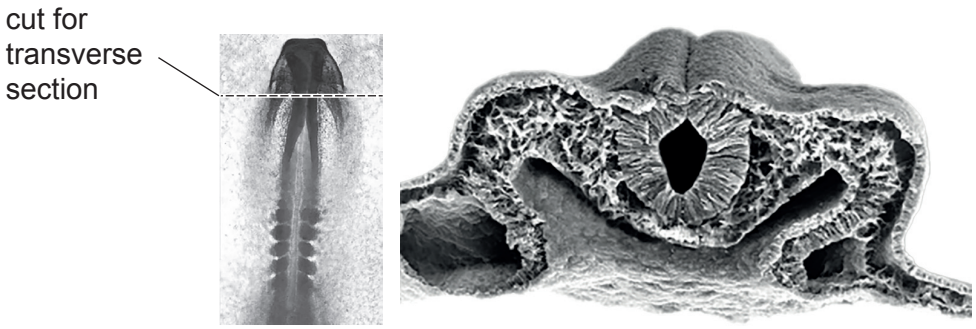
Section B

Answer **all** of the questions from **one** of the options. Answers must be written within the answer boxes provided.

Option A — Neurobiology and behaviour

4. Image A shows a stage of neurulation in a chick embryo, and image B is a scanning electron micrograph (SEM) of a transverse section through the level indicated by the line in image A.



A B

(a) On image B, label

(i) the neural tube; [1]

(ii) the ectoderm. [1]

(b) Describe the formation of neurons. [2]

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(Option A continues on the following page)

(Option A, question 4 continued)

(c) Explain neural plasticity. [2]

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(d) Outline **two** functions of the medulla oblongata. [2]

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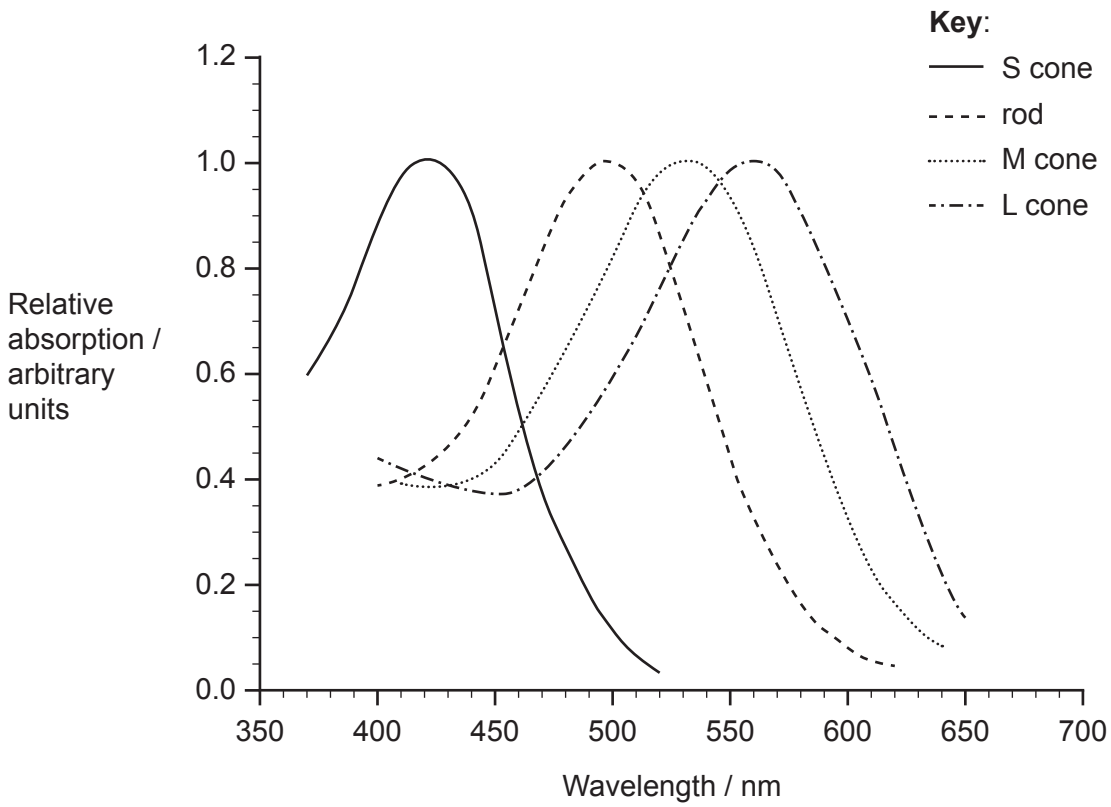
(Option A continues on page 11)

Please **do not** write on this page.

Answers written on this page
will not be marked.

(Option A continued)

5. Human retinas have rods and three types of cones for absorption of light of long (L), medium (M) and short (S) wavelength.



(a) Identify which photoreceptor is more sensitive to red light (600 nm). [1]

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(b) Describe red-green colour-blindness as a variant of normal trichromatic vision. [3]

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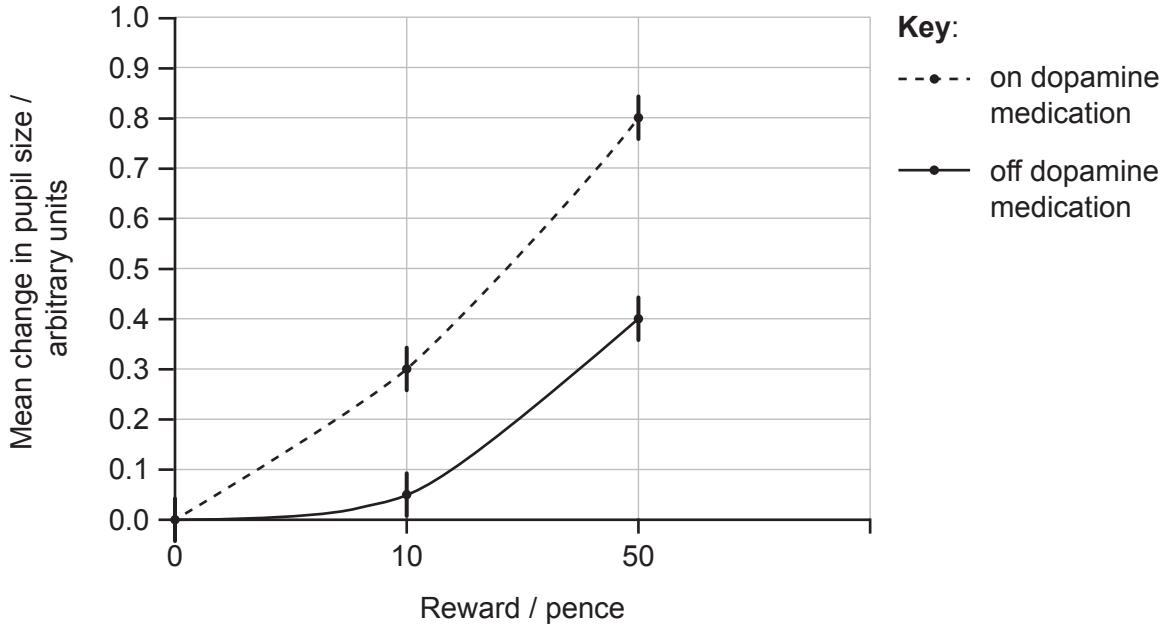
(Option A continues on the following page)

(Option A continued)

6. Monetary reward sensitivity refers to the degree to which an individual's behaviour is motivated by a reward of money.

Parkinson's disease patients were examined on and off their dopamine medication in two counterbalanced sessions, so that the effect of dopamine on monetary reward sensitivity could be assessed using pupil size change.

The graph shows mean changes in pupil size after patients were offered a reward of 10 pence and 50 pence compared to the pupil size when offered no reward (0 pence).



(a) Analyse the effect of dopamine on monetary reward sensitivity in this experiment. [3]

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(Option A continues on the following page)

(Option A, question 6 continued)

(b) Some psychoactive drugs such as MDMA (ecstasy) affect dopamine metabolism in the brain. Explain how addiction is related to dopamine secretion. [3]

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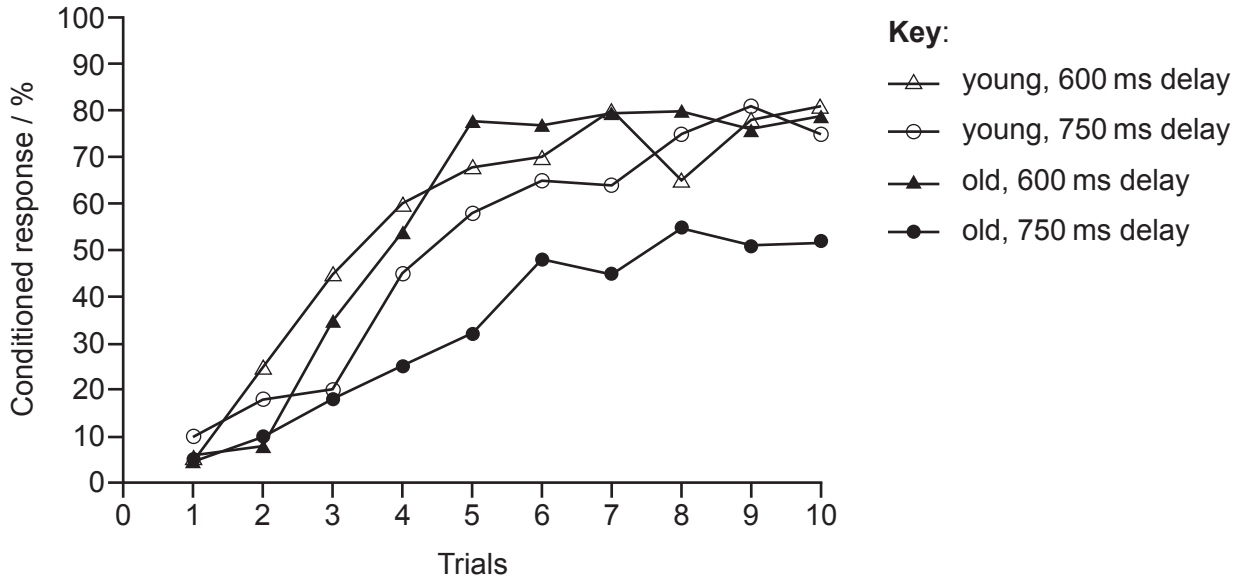
(Option A continues on the following page)

(Option A continued)

7. Young and old rabbits were tested in a classic reflex conditioning experiment. The ringing of a bell (conditioned stimulus) was followed after a delay of either 600 or 750 milliseconds (ms) by an eyeblink stimulus consisting of a mild puff of air to the cornea (unconditioned stimulus). Conditioned learning was measured by the percentage of rabbits that blinked their eyes with the ringing of the bell only. The graph shows the outcome after several trials.



(a) Define learning through reflex conditioning. [1]

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(b) Compare and contrast learning by reflex conditioning in young and old rabbits. [3]

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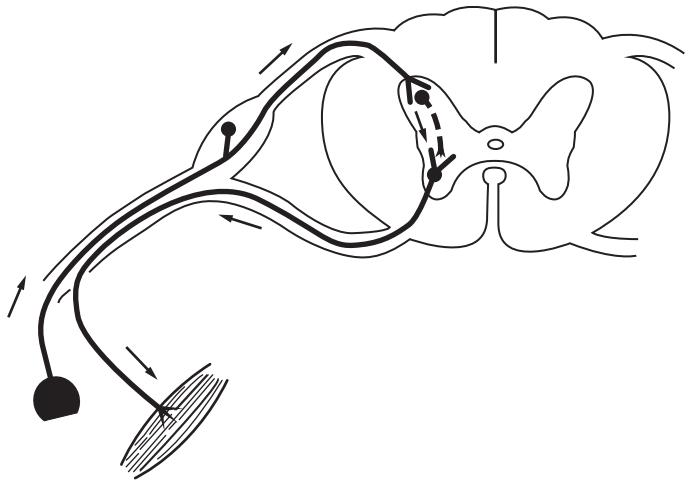
(Option A continues on the following page)

(Option A, question 7 continued)

(c) The diagram shows a reflex arc.



On the diagram, label

(i) a motor neuron; [1]

(ii) a sensory neuron. [1]

(Option A continues on page 17)

Please **do not** write on this page.

Answers written on this page
will not be marked.

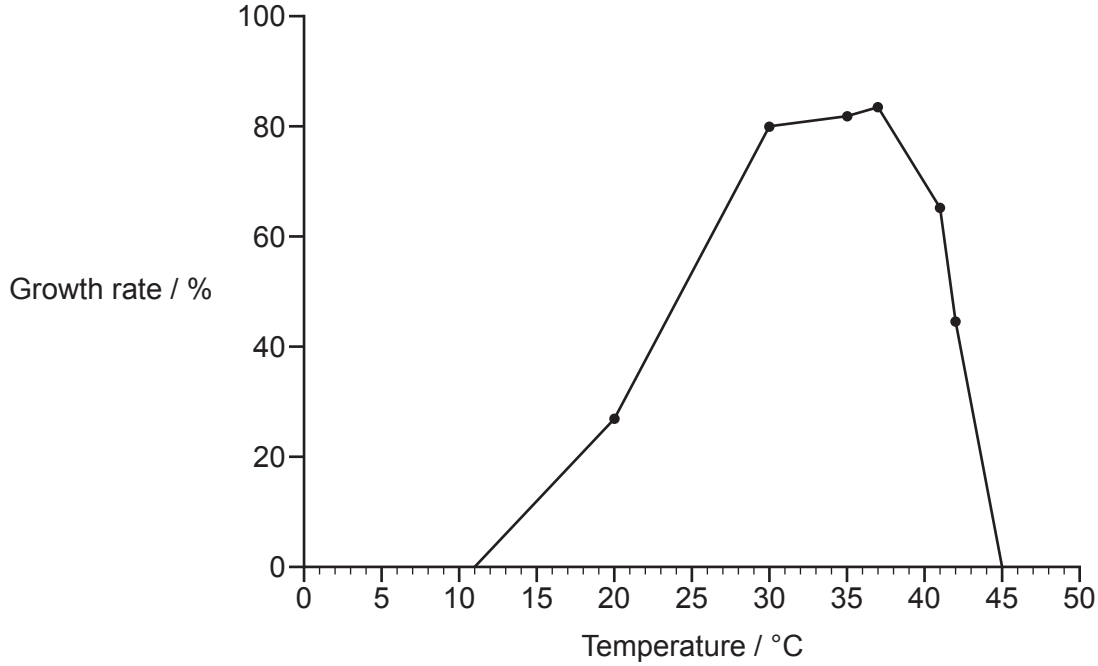
(Option A continued)

8. Explain how breeding strategies in coho salmon (*Oncorhynchus kisutch*) affect their chances of success. [6]

End of Option A

Option B — Biotechnology and bioinformatics

9. The graph shows the effect of temperature on the growth rate of microorganisms in a biogas batch fermenter.



(a) State the type of microorganism needed to form biogas. [1]

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(b) (i) Suggest a method of measuring the growth rate in this fermenter. [1]

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(ii) Explain the effect of temperature on the growth rate between 10 and 30 °C. [2]

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(Option B continues on the following page)

(Option B, question 9 continued)

(c) (i) The temperature for the process was first set at 35 °C, but was then increased to 37 °C to achieve a higher yield. Evaluate the choice of temperature for biogas production in this fermenter. [2]

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(ii) State **one** factor other than temperature that limits fermentation by microorganisms in batch fermenters. [1]

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(d) Compare and contrast batch and continuous culture fermentation. [2]

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(Option B continues on the following page)

(Option B continued)

10. Tobacco mosaic viruses were genetically modified to produce transgenic tobacco plants for the bulk production of Hepatitis B vaccine antigen (HBsAg). Antibiotic-resistant transformants were analysed to detect mRNA for HBsAg, and the antigen proteins in leaves were quantified.

The RNA blot shows the mRNA coding for HBsAg, and the bar graph shows HBsAg antigen proteins in leaves of transgenic plants.

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(a) Define transgenic organisms. [1]

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(Option B continues on the following page)

(Option B, question 10 continued)

(b) Deduce with a reason the control in this experiment. [1]

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(c) Describe the method used to produce the transgenic tobacco plants. [3]

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(d) State **one** other method that can be used to introduce recombinant DNA into a plant. [1]

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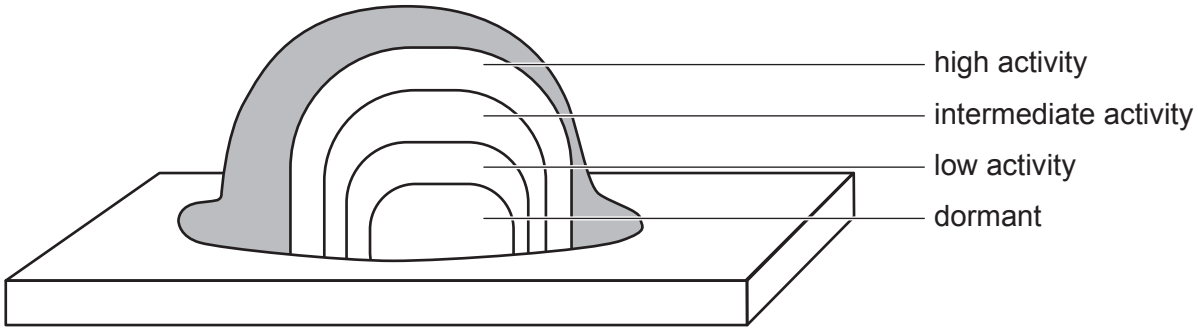
(Option B continues on the following page)

(Option B continued)

11. The diagram shows the results of a study of metabolic activity within biofilm cell clusters, using fluorescent tags for specific metabolic markers.



(a) Define biofilm. [1]

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(b) List **two** examples of problems caused by biofilms. [2]

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(c) Using the diagram, suggest **two** factors affecting the action of antibiotics on this biofilm. [2]

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(Option B continues on the following page)

(Option B continued)

12. The DNA sequences found in human cell lines of various ABO phenotypes are remarkably similar. The blood group gene that codes for intron 6 of glycosyltransferase consists of a 1062 base pair nucleotide sequence.

The table shows the sequence differences in intron 6 of the major ABO alleles for this gene. The nucleotides that are not shown are identical in the three blood group alleles, while the bolded letters show differences with the blood group A allele sequence.

Nucleotide number	42	89	162	178	187	225	234	270	279	445	492	627	717	183	888	898	947	1008	1010
Blood group A	G	T	T	C	G	C	C	A	C	A	T	A	G	A	A	G	A	A	G
Blood group B	**T**	T	**C**	**T**	G	C	C	**G**	**T**	**G**	T	**G**	G	**G**	**G**	**A**	**G**	A	G
Blood group O	G	**A**	**C**	C	**A**	**G**	**G**	A	C	**G**	**C**	A	**A**	**G**	**G**	G	**G**	**G**	**A**

(a) Describe how the alignment was obtained. [2]

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(b) Calculate the percentage difference in bases between the allele for blood group A and the allele for blood group B for intron 6 of this gene, showing your workings. [2]

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(Option B continues on page 25)

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will not be marked.

(Option B continued)

13. Explain the use of viral vectors in the treatment of Severe Combined Immunodeficiency (SCID). [6]

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End of Option B

Option C — Ecology and conservation

14. The table shows the numbers of five different species of algae growing in the River Trent in the United Kingdom from May to October 1939, at different distances from where untreated sewage had entered the river.

Distance from source of pollution / km	**Number of algae per mm^2**				
	Stigeoclonium tenue	*Nitzschia palea*	*Gomphonema parvulum*	*Stigeoclonium farctum*	*Cocconeis placentula*
–1	0	0	0	0	820
3	30	130	20	0	0
5	190	680	130	0	0
8	1620	2380	600	0	0
13	15300	5250	3390	20	0
16	50	620	690	1880	0
21	45	420	660	270	0
27	180	250	3000	300	0
35	30	100	1950	120	0
39	210	620	1950	3240	1930
44	190	1720	9170	70	1330
48	240	8000	4200	110	3500
56	220	150	1280	210	1480

(a) State the species with the greatest growth rate between 13 and 16 kilometres from the source of pollution in the River Trent. [1]

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(Option C continues on the following page)

(Option C, question 14 continued)

(b) Describe the consequence of pollution by untreated sewage in rivers. [3]

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(c) Using the data, deduce with a reason which species of alga could be used as an indicator of pollution in the River Trent. [2]

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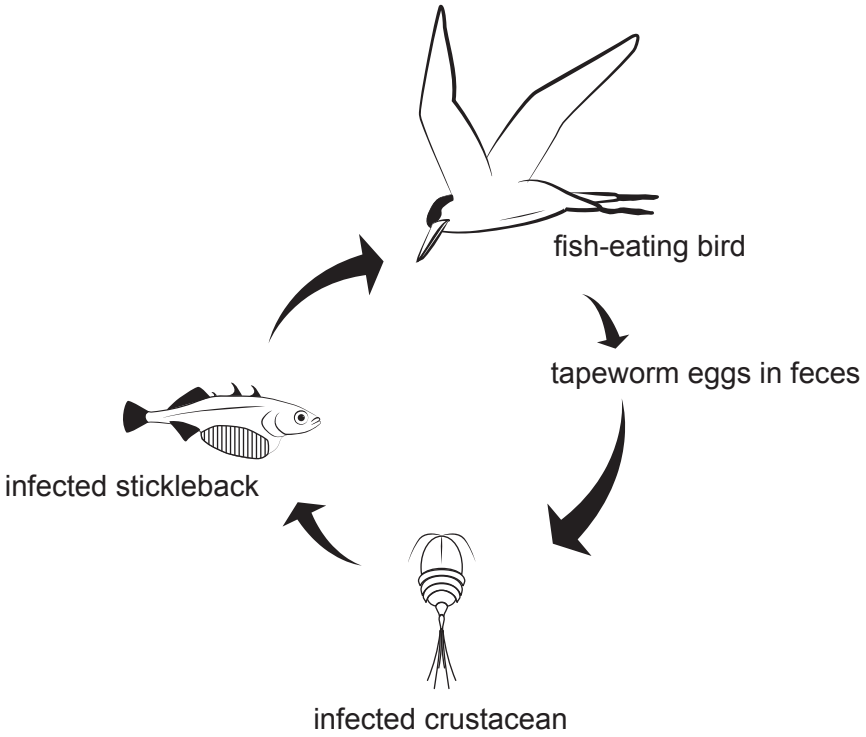
(Option C continues on the following page)

(Option C continued)

15. The tapeworm *Schistocephalus solidus* is a parasite that must grow in two intermediate hosts before it can reproduce in the gut of the final host, a fish-eating bird (*Larus michahellis*). For transmission, an infected crustacean (*Macrocydops albidus*) must be preyed upon by a stickleback fish (*Gasterosteus aculeatus*).



(a) Discuss the trophic level of the tapeworm. [2]

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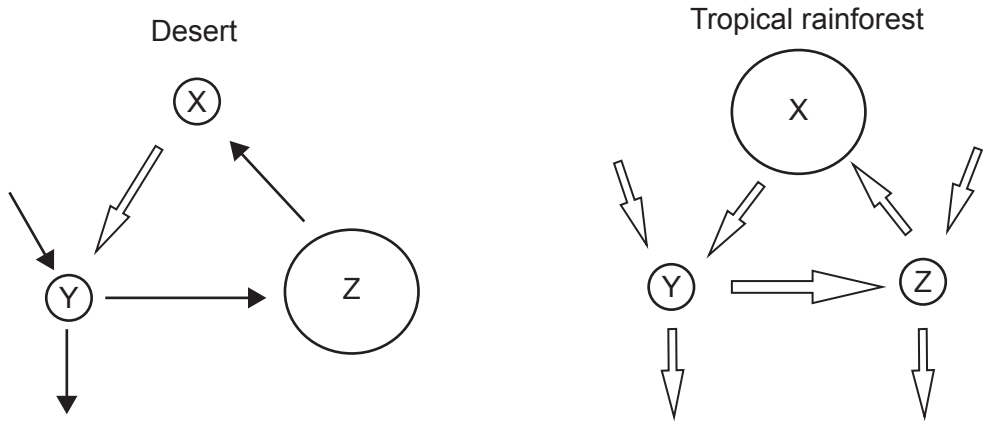
(Option C continues on the following page)

(Option C, question 15 continued)

(b) The Gersmehl diagrams show the interrelationships between nutrient stores and flows in desert and tropical rainforest.



Deduce with a reason the nutrient store labelled X. [1]

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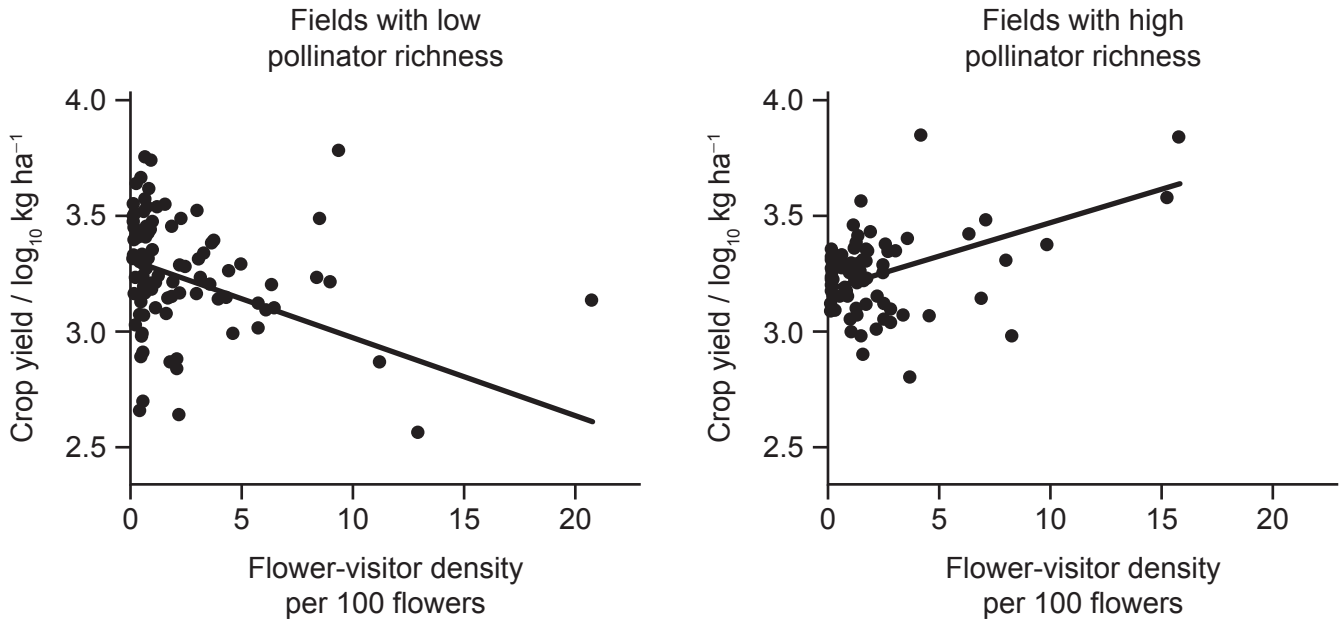
(Option C continues on the following page)

(Option C continued)

16. A worldwide study measured different crop yields according to number of visits by pollinators. Fields of crops were categorized according to pollinator richness as either low (less than three species) or high (three or more species).

In the scattergraphs, each point represents the crop yield of one field according to the flower-visitor density expressed in number of visits per 100 flowers in 30 minutes.



(a) Define richness as a component of biodiversity. [1]

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(Option C continues on the following page)

(Option C, question 16 continued)

(b) Evaluate whether crop yield may be improved through enhancement of pollinator richness. [3]

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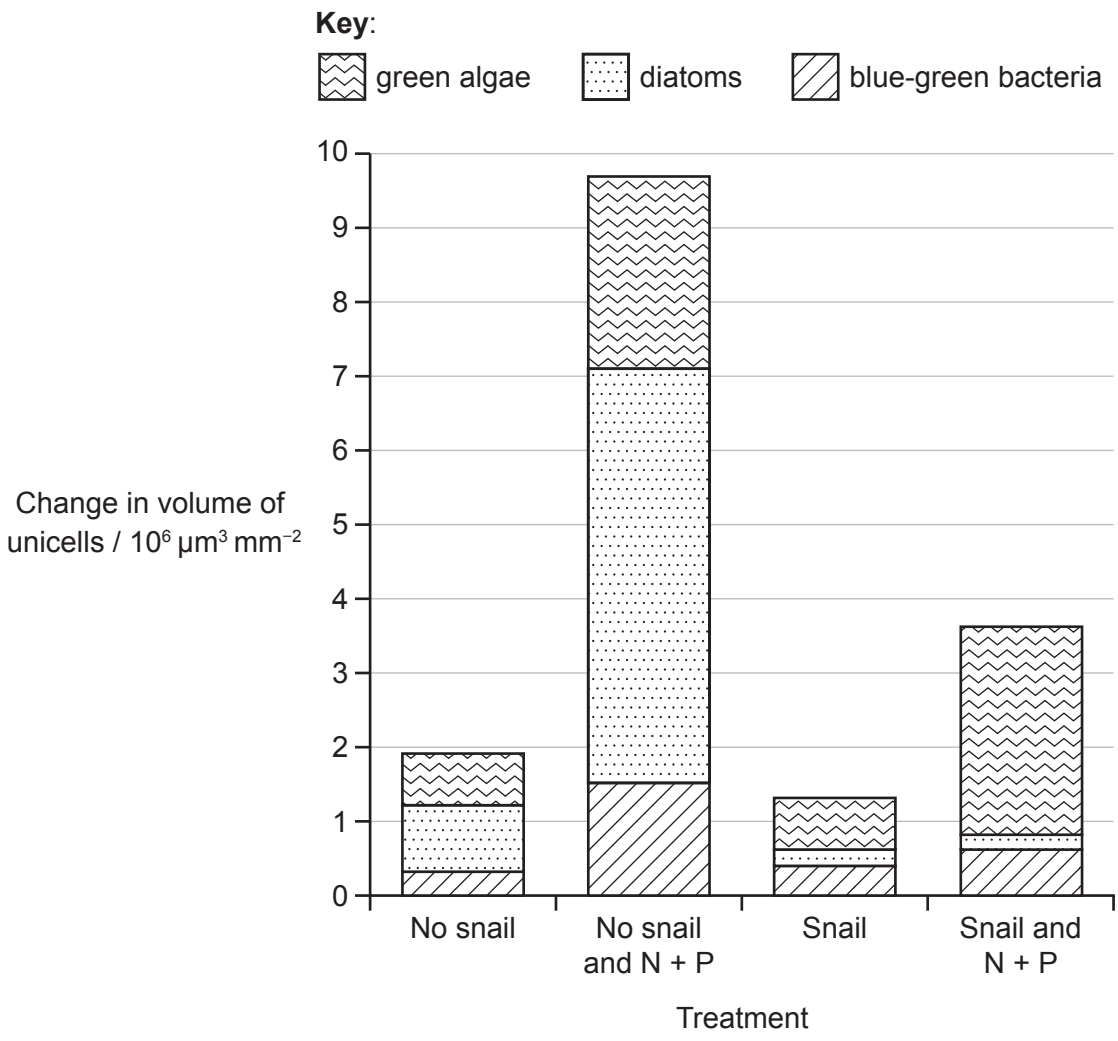
(Option C continues on the following page)

(Option C continued)

17. An investigation was carried out on the effects of herbivory by snails and the addition of nutrients such as nitrates and phosphates (N + P) on a community of photosynthetic unicells in a stream in Tennessee, USA. It was previously shown that other organisms did not affect the interaction between snails and these unicells.

Flow-through channels (102 cm long x 8 cm wide Plexiglas tubes) were constructed and positioned in the stream. Treatments involved the addition or not of nitrates and phosphates and the addition or not of snails in each channel. After 7 weeks, samples were taken, and the volumes of all unicells were calculated using the number of individual cells seen in a microscope.

The graph shows the change in taxonomic composition and volume of unicells after 7 weeks of each treatment.



(Option C continues on the following page)

(Option C, question 17 continued)

(a) (i) Identify the type of unicell that changed the most when nutrients only were added. [1]

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(ii) Distinguish between the results obtained when snails were present or absent from treatments with added nutrients. [2]

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(iii) Discuss whether top-down or bottom-up control exerts more influence over the unicell community in this stream. [3]

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(Option C continues on the following page)

(Option C, question 17 continued)

(b) State **two** sources of phosphate in the phosphorus cycle. [2]

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(c) (i) Outline nitrogen fixation in the nitrogen cycle. [2]

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(ii) Define denitrifying. [1]

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(Option C continues on the following page)

(Option C continued)

18. Discuss the use of DDT (dichlorodiphenyltrichloroethane) in the control of the malarial parasite. [6]

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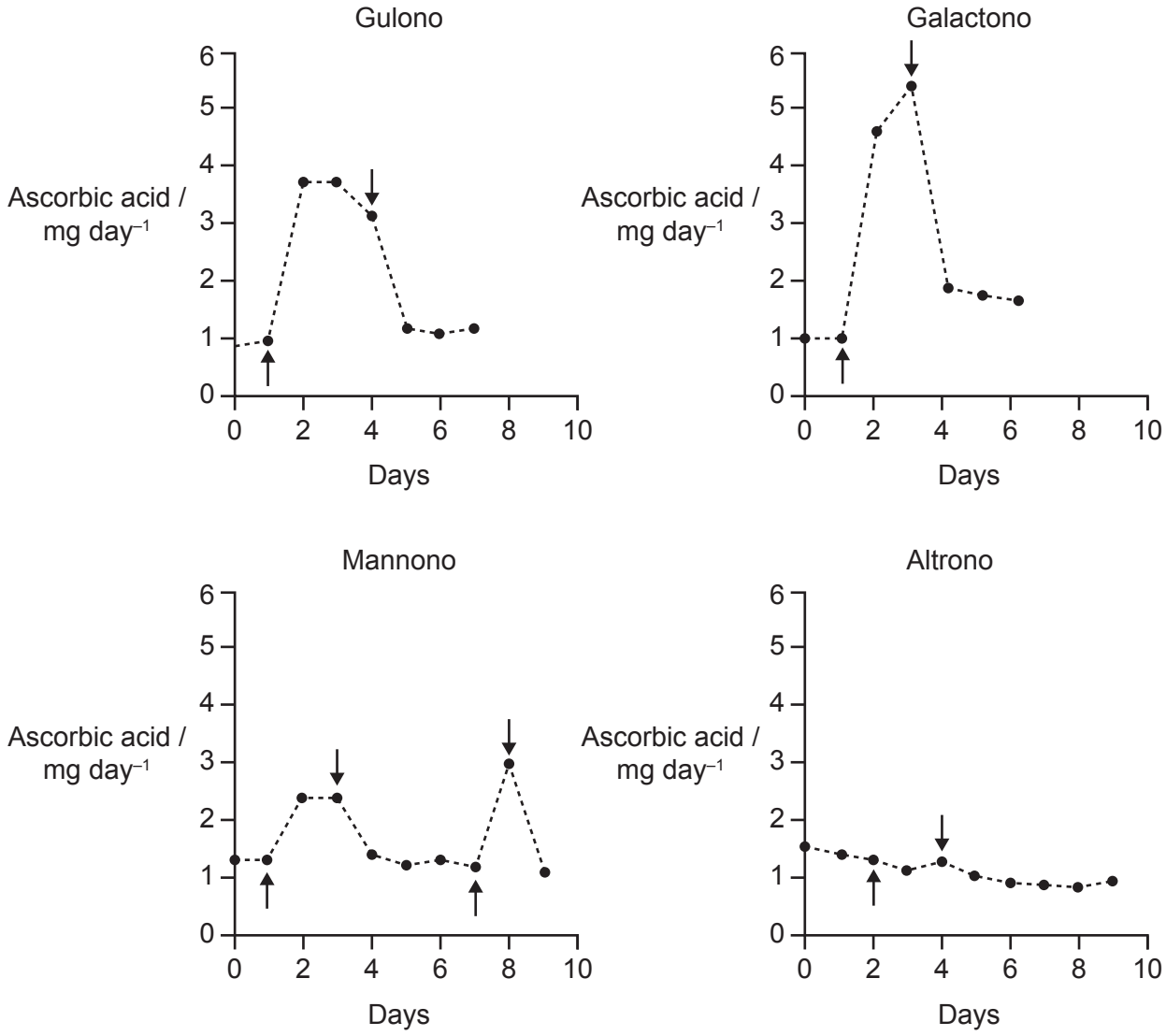
End of Option C

Option D — Human physiology

19. Many animals have a gene that codes for L-gulonolactone oxidase (GULO), a key enzyme in the biosynthesis of ascorbic acid (vitamin C). The graphs show the presence of ascorbic acid in rats' urine after the injection of the lactones gulono, galactono, mannono and altrono.

Key:

↑ lactone injected ↓ lactone no longer injected



(Option D continues on the following page)

(Option D, question 19 continued)

(a) Determine with a reason which lactone **cannot** be used in the synthesis of ascorbic acid in rats. [2]

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(b) Explain the need in humans to include ascorbic acid in the diet. [2]

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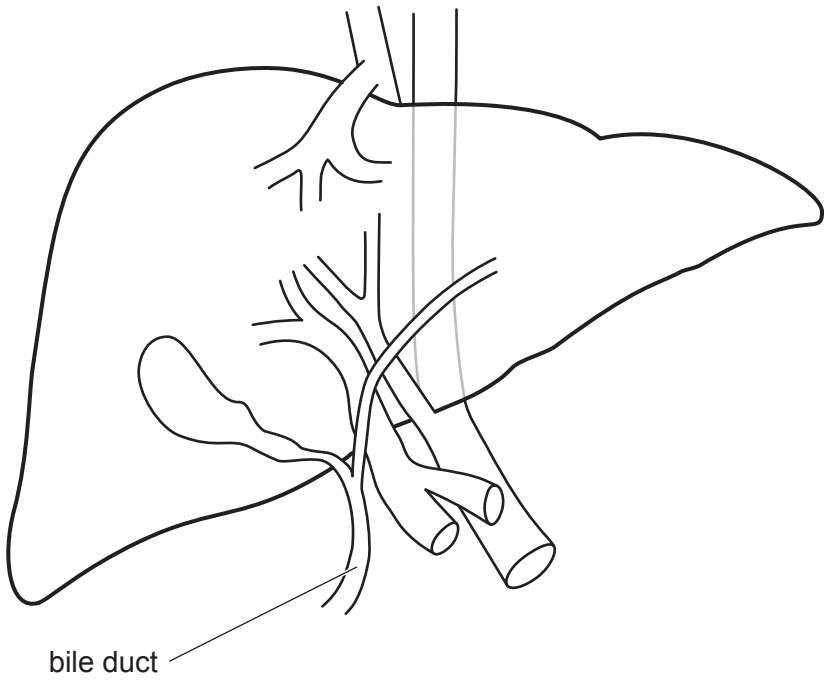
(Option D continues on the following page)

(Option D continued)

20. The diagram shows the liver.



(a) In the blood supply to the liver, state

(i) the vessel that carries blood from the gut; [1]

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(ii) the vessel carrying oxygenated blood. [1]

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(Option D continues on the following page)

(Option D, question 20 continued)

(b) State **one** possible cause of jaundice. [1]

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(c) Iron is stored in the liver and carried to the bone marrow to produce hemoglobin in new red blood cells. Outline the role of hemoglobin in the transport of gases. [2]

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(Option D continues on the following page)

(Option D continued)

21. Researchers measured blood pH in several individuals and plotted the results in a scattergraph. The solid line shows the line of best fit through the points and the dotted line shows the equal pH values in venous and arterial blood.

Removed for copyright reasons

(a) (i) State how the pH of blood in the arteries differs from the pH of blood in the veins. [1]

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(ii) Outline reasons for the differences in the pH of the venous and arterial blood. [2]

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(Option D continues on the following page)

(Option D, question 21 continued)

(b) State the type of receptors that monitor blood pH. [1]

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(c) State the relationship between blood pH and exercise. [1]

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(d) Explain how the Bohr shift increases the supply of oxygen to tissues during exercise. [3]

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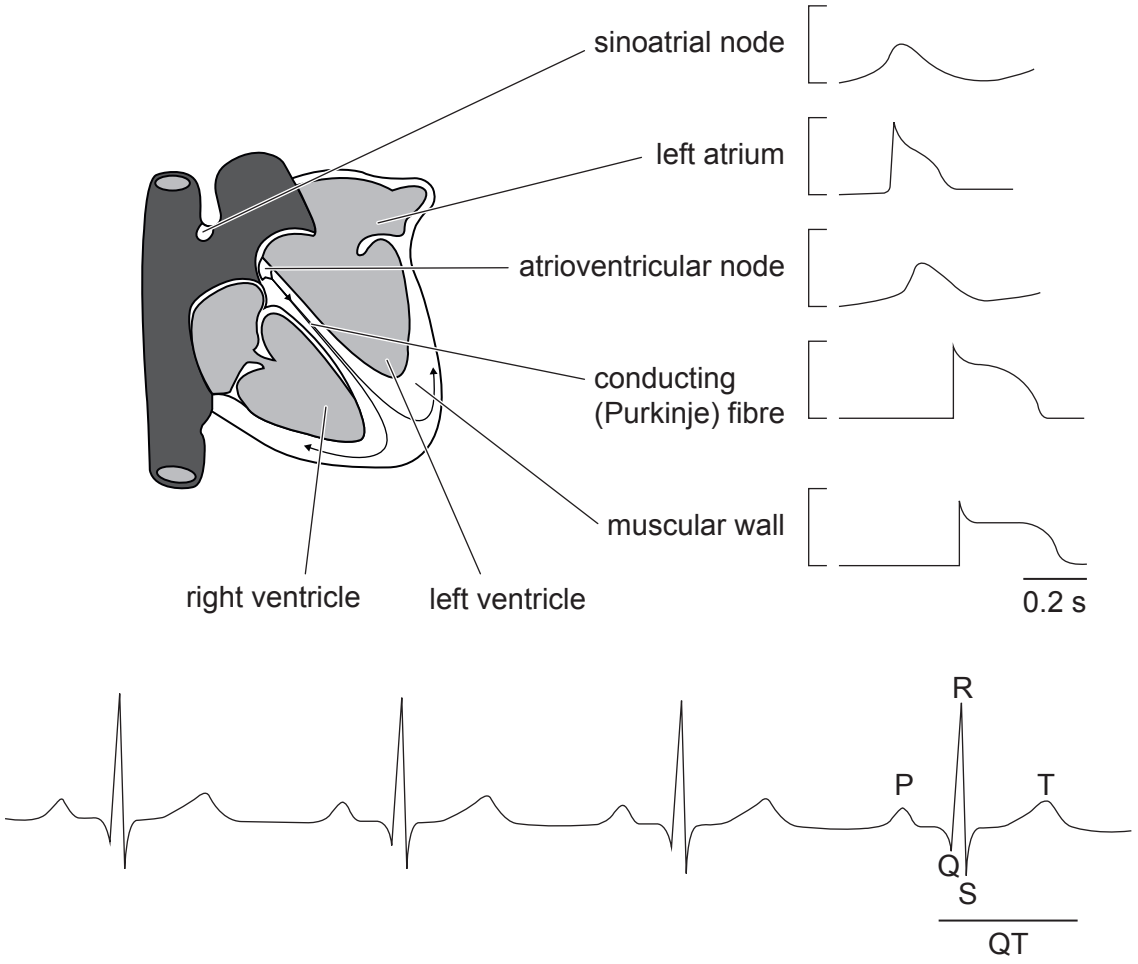
(Option D continues on the following page)

(Option D continued)

22. The diagram of the human heart shows typical action potential waveforms recorded in different regions of the heart during one beat. At the bottom, there is a typical electrocardiogram (ECG) trace where four beats are displayed.



(Option D continues on the following page)

(Option D, question 22 continued)

(a) Outline the need of a time delay of about 0.1 seconds in the atrioventricular node before the electrical signal is conveyed to the ventricles. [1]

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(b) Outline the events occurring between Q and T shown on the ECG trace. [2]

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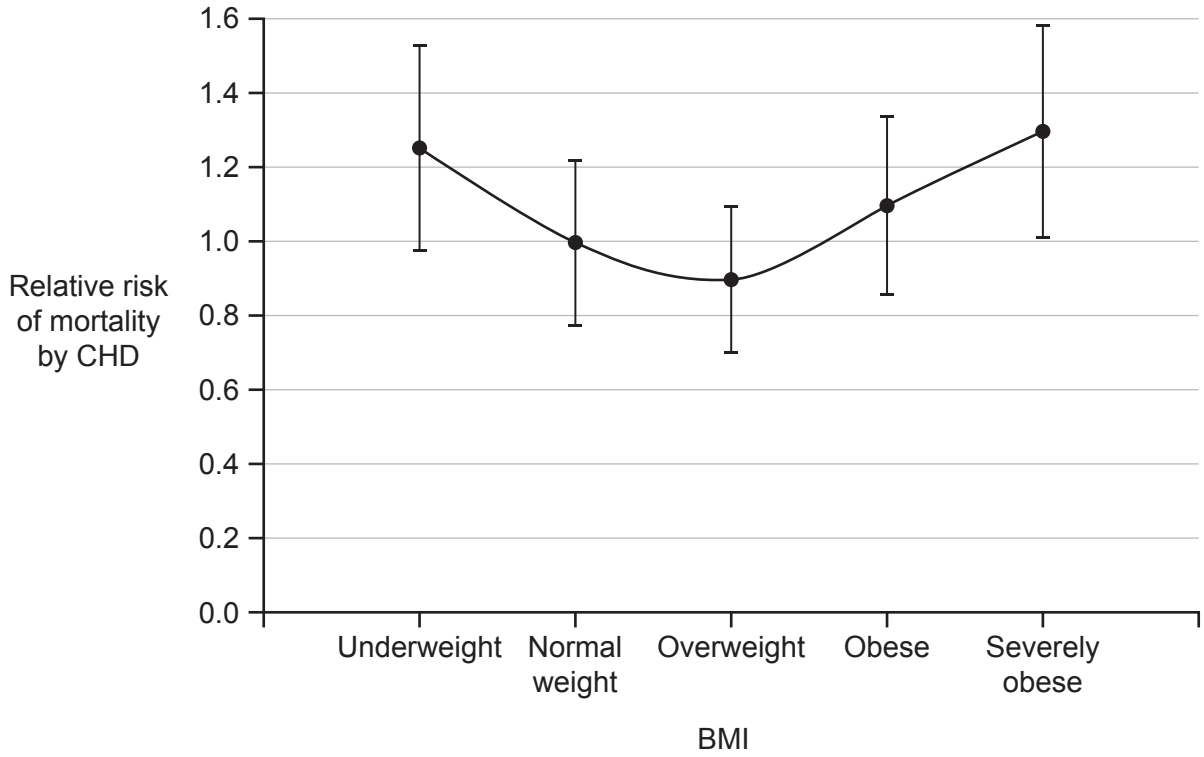
(Option D continues on the following page)

(Option D, question 22 continued)

Coronary heart disease (CHD) occurs when the blood supply to the heart is blocked or interrupted by a build-up of fatty substances in the coronary arteries. The relative risk of mortality by CHD is the ratio between risk of death by CHD for a certain population group and the risk of death by CHD for all other population groups.

The line graph shows the relative risk of mortality by CHD due to body mass index (BMI) of 37 674 men.



(c) Identify the **two** BMIs that have the highest risk of mortality by CHD in men. [1]

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(Option D continues on the following page)

(Option D, question 22 continued)

(d) Scientists concluded that in some cases a larger BMI is due to increased muscle mass and not to increased body fat. Discuss this conclusion using the data provided. [2]

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(e) State **one** disease other than CHD for which being overweight or obese is a risk factor in men. [1]

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(Option D continues on the following page)

(Option D continued)

23. Explain the control of milk secretion by hormones from the hypothalamus and pituitary gland. [6]

End of Option D

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