Diploma Programme
Programme du diplôme
Programa del Diploma

Biology
Higher level
Paper 3

Thursday 12 November 2020 (morning)

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 – 9
Option B — Biotechnology and bioinformatics	10 – 14
Option C — Ecology and conservation	15 – 19
Option D — Human physiology	20 – 24

8820 – 6003

41 pages

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

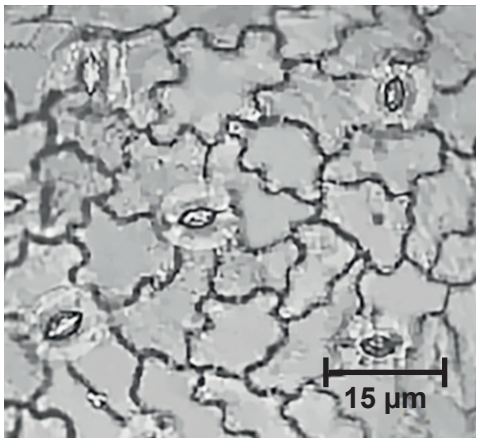
Answers written on this page
will not be marked.

Section A

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

1. The stomatal density is the number of stomata per area of leaf epidermis. A study was done on the stomatal density of the lower epidermis of leaves from *Protium decandrum*, a tree found in the Amazon forest.

The image shows the epidermis stripped from the lower surface of a leaf.



(a) Calculate the magnification of the image, showing your working. [2]

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(b) The mean stomatal density for the lower epidermis of *P. decandrum* was around 600 per mm^2. Predict how the stomatal density for the upper epidermis would compare. [1]

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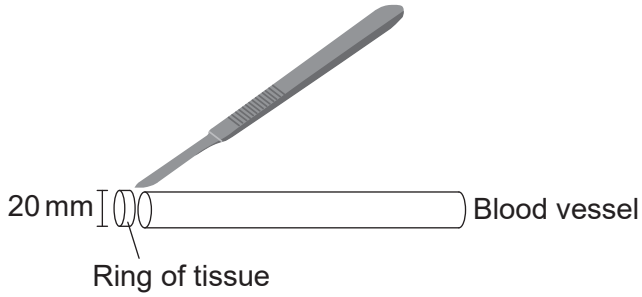
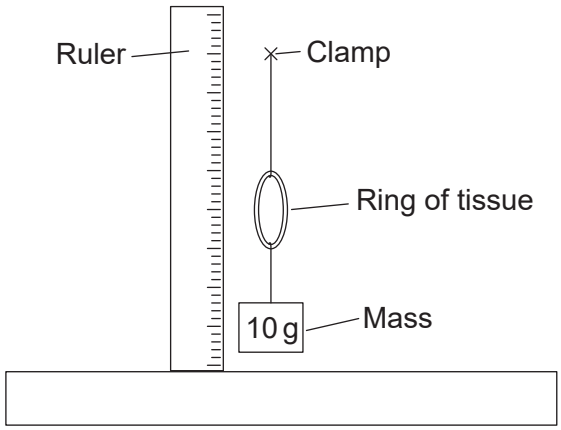
2. In an investigation to compare the elasticity of arteries and veins, rings of the same diameter (20 mm) of artery and vein tissue were cut from blood vessels obtained from a mammal.



Each ring was attached to a clamp. Multiple masses of 10 g were added and removed. The vertical diameter of the artery and the vein was measured, both with the mass and once the mass had been removed.



The results are shown in the table.

	Diameter of vein / mm		Diameter of artery / mm	
Mass / g	**With mass**	**Mass removed**	**With mass**	**Mass removed**
0	20	20	20	20
10	26	26	26	22
20	34	33	30	23
30	38	36	35	23
40	40	37	38	24

(a) State the independent and dependent variables in this experiment. [2]

Independent: . . . . . .

Dependent: . . . . . .

(This question continues on the following page)

(Question 2 continued)

(b) State **one** feature of the rings that has to be kept constant apart from their initial diameter. [1]

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(c) Explain the differences between the results shown for vein and artery. [3]

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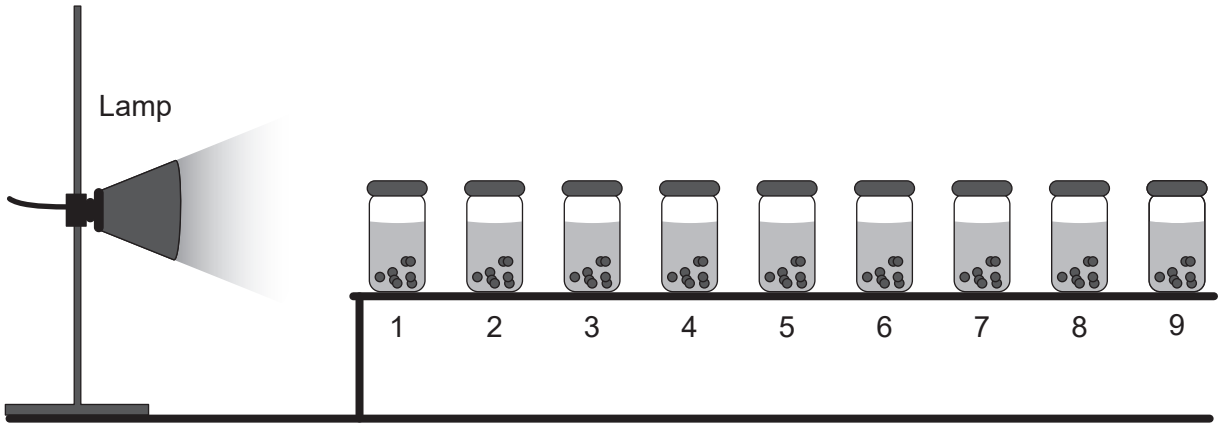
3. Sodium alginate beads were prepared containing a suspension of *Chlorella* algae. These beads were placed in nine small jars containing hydrogencarbonate indicator solution. Hydrogencarbonate indicator is commonly used to detect changes in pH.

Increasing CO_2 in indicator ← **Atmospheric CO_2 level** → **Decreasing CO_2 in indicator**

Yellow		Orange		Red		Magenta		Purple
pH 7.6	pH 7.8	pH 8.0	pH 8.2	pH 8.4	pH 8.6	pH 8.8	pH 9.0	pH 9.2

The jars were placed at different distances from a lamp, which was the only light source. The distances ranged from 40 to 130 centimetres. Jars were placed one at a time to avoid the jars from shading each other. Colour changes were observed.



(a) State the name of the process which occurs in the chloroplasts of *Chlorella*, that uses CO_2. [1]

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(b) The colours of the indicator in the jars ranged from yellow to purple after five hours.

(i) Predict the distribution of indicator colours in jars 1 to 9. [1]

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(This question continues on the following page)

(Question 3 continued)

(ii) Explain the scientific reasoning for your hypothesis. [3]

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(c) Suggest **one** other factor that has to be kept constant in all the jars during the experiment. [1]

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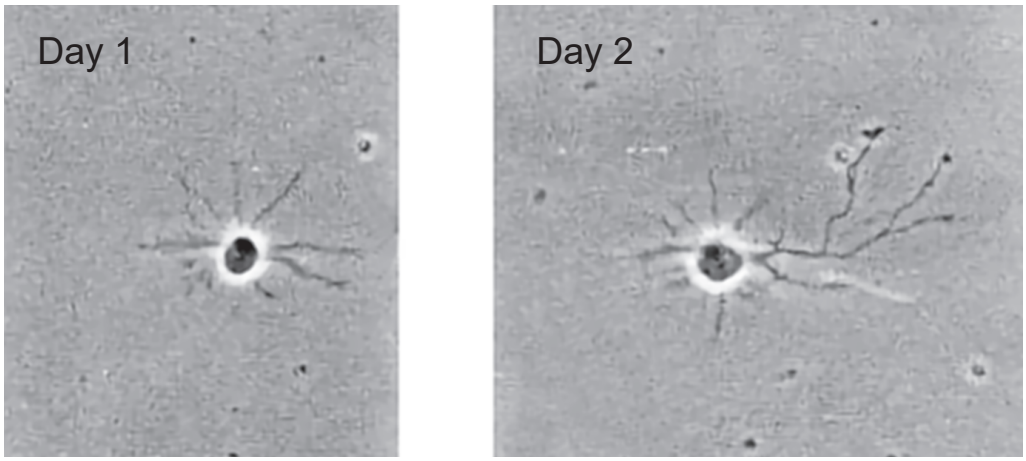
Section B

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. The image on the left shows a developing neuron on the first day of culture (day 1). The image on the right shows the same neuron after one day (day 2).



(a) Describe the changes occurring in this neuron from day 1 to day 2. [2]

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(b) Suggest other processes that may occur during neural development. [2]

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(Option A continues on the following page)

(Option A, question 4 continued)

(c) Suggest what can happen to neurons that are unused in the nervous system. [1]

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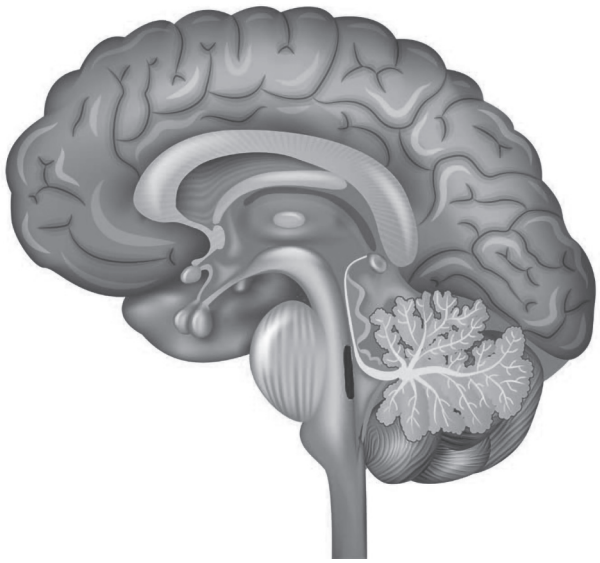
(Option A continues on the following page)

(Option A continued)

5. The drawing shows a vertical section through the brain.



(a) (i) Label the cerebellum on the diagram. [1]

(ii) State a function of the cerebellum. [1]

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(b) On the diagram, label **one named** structure that produces hormones. [1]

(c) Outline **one** method that can be used to investigate the function of different parts of the brain. [2]

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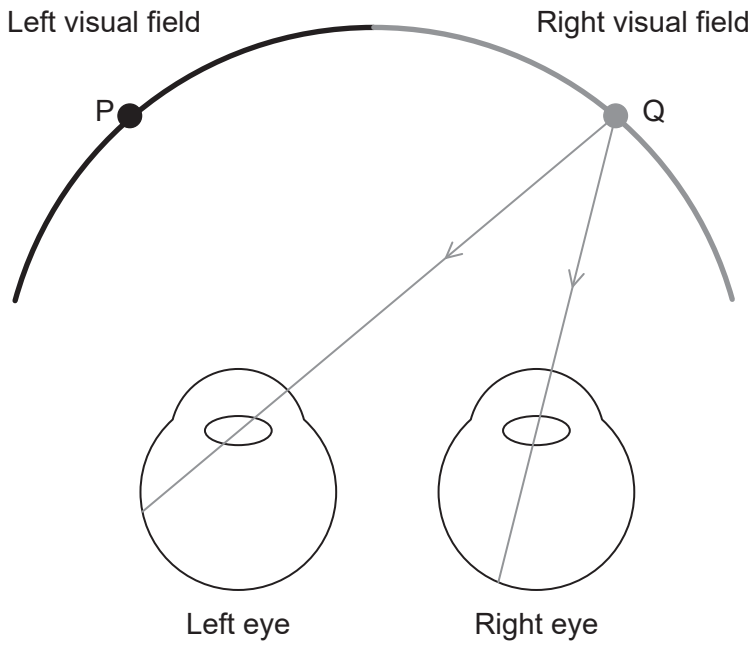
(Option A continues on the following page)

(Option A continued)

6. The diagram shows rays of light entering the eyes from point Q in the right visual field.



(a) Draw a ray of light entering the left eye from point P. [1]

(b) Information about the light from P entering the left eye is processed in the brain.

(i) State what region of the brain would process the information. [1]

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(ii) State the side of the brain that would process the information. [1]

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(c) State the type of cell in the retina which directly transmits impulses through the optic nerve to the brain. [1]

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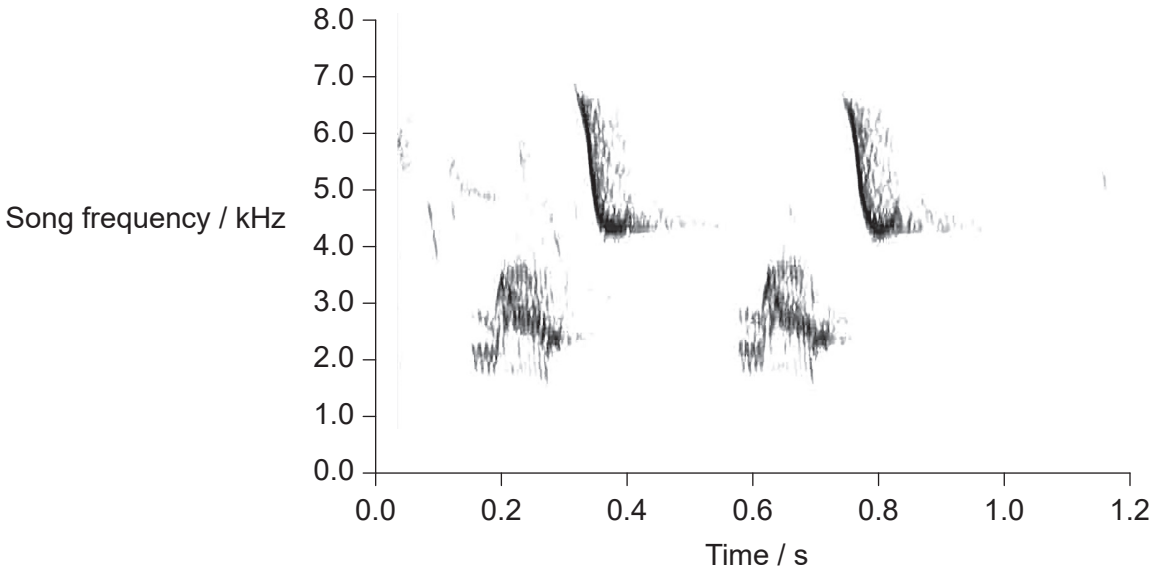
(Option A continues on the following page)

(Option A continued)

7. The large tree finch (*Camarhynchus psittacula*) communicates through singing. The frequency (pitch) of a finch's song was recorded. The results for a short period of the song are shown.



(a) Outline the trend in large tree finch song frequency. [2]

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(b) Describe the role of inheritance and learning in birdsongs. [2]

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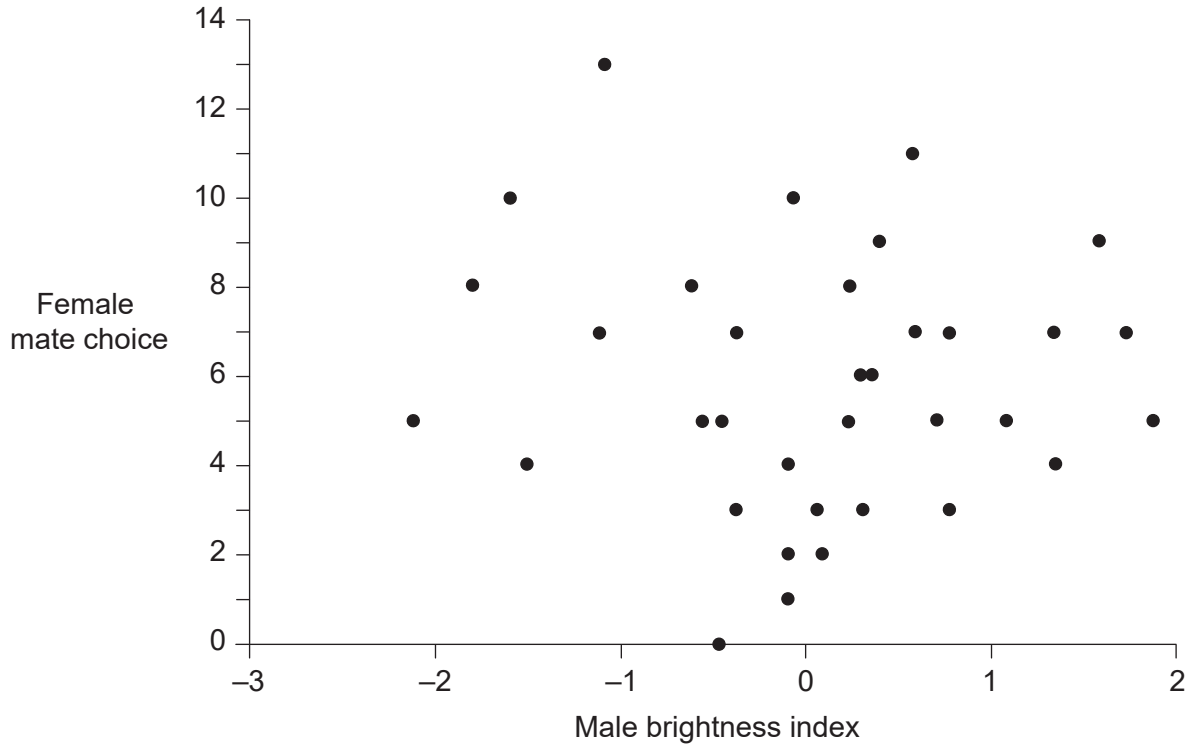
(Option A continues on the following page)

(Option A continued)

8. Male eastern bluebirds (*Sialia sialis*) display brilliant UV-blue feathers on their heads, backs, wings and tails. The brightness index of the male was calculated; the larger the score, the brighter the blue feathers. A brightness value of 0 indicates normal male brightness, so birds with negative scores are less bright than normal.

In an experiment to see the mating behaviour of bluebirds, scientists separated pairs of males and females and then allowed females to choose new partners.

The graph shows the relationship between male brightness index and choice of mate by females in eastern bluebirds.



[Source: Reprinted from *Animal Behaviour*, 78, Liu, M., Siefferman, L., Mays, H., Steffen, J.E. and Hill, G.E., A field test of female mate preference for male plumage coloration in eastern bluebirds. pp.879–885. 2009 with permission from Elsevier and The Association for the Study of Animal Behaviour. https://www.sciencedirect.com/journal/animal-behaviour.]

(a) Evaluate the hypothesis that females prefer to mate with males whose feathers are a brighter blue. [2]

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(Option A continues on the following page)

(Option A, question 8 continued)

(b) Explain how natural selection can cause mate selection behaviour patterns to develop in a species such as eastern bluebirds. [3]

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(c) Another type of behaviour is altruistic behaviour. Outline an example of altruistic behaviour. [1]

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(Option A continues on the following page)

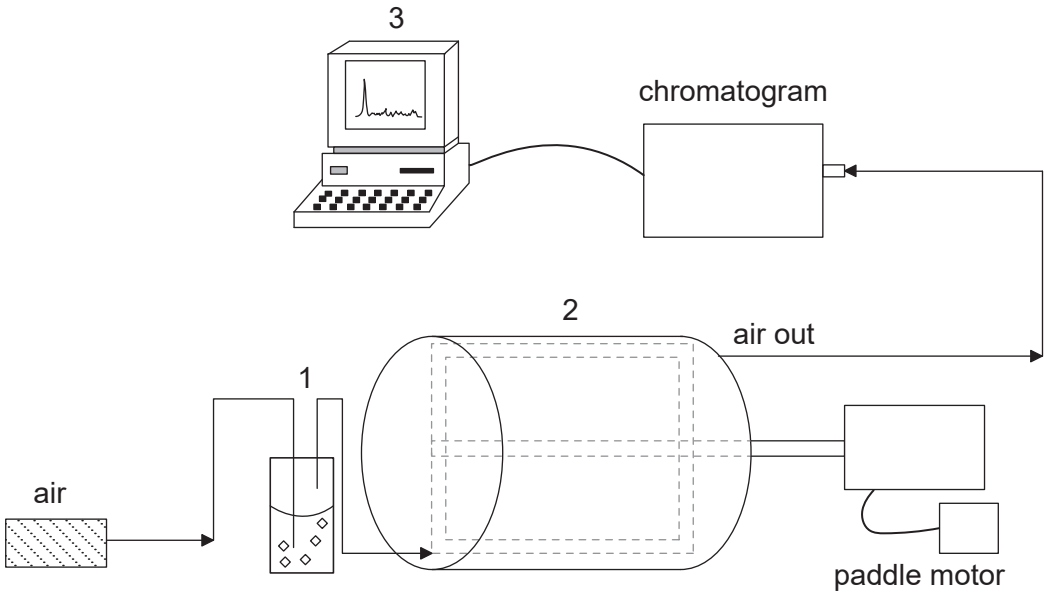
(Option A continued)

9. Explain how psychoactive drugs affect the nervous system. [6]

End of Option A

Option B — Biotechnology and bioinformatics

10. Citric acid was produced in a fermenter using the pulp of cassava (*Manihot esculenta*) and the fungus *Aspergillus niger*. This process was carried out at room temperature for 6 days and citric acid was then collected. The apparatus was cleaned and set up for a new fermentation. The process is shown in the diagram.



(a) (i) State in which numbered part of the process you would find the probes to detect changes in pH. [1]

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(ii) Explain the possible causes of these changes in pH. [2]

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(Option B continues on the following page)

(Option B, question 10 continued)

(b) Suggest, with a reason, whether this is a batch or a continuous fermentation. [1]

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(c) State **one** use of the citric acid produced. [1]

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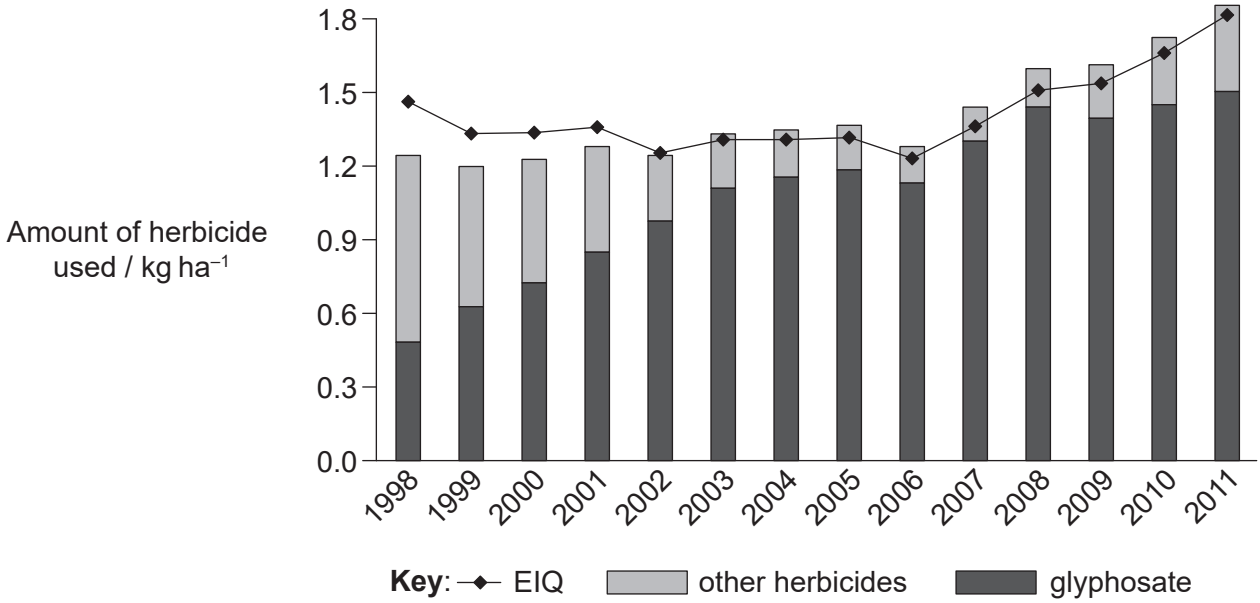
(Option B continues on the following page)

(Option B continued)

11. The chart shows the use of glyphosate and other herbicides on soybeans (*Glycine max*) grown in the US from 1998 to 2011. Also shown is the trend for the environmental impact quotient (EIQ) which is calculated from the toxicity of herbicides to wildlife and to humans, their persistence in the environment and their other ecological effects.



(a) State the year with the lowest EIQ for herbicides used in soybean growth in the US from 1998 to 2011. [1]

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(b) Using the data from 1998 to 2004, evaluate whether the use of glyphosate has a greater impact on the environment than other herbicides. [2]

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(Option B continues on the following page)

(Option B, question 11 continued)

(c) Explain the role of *Agrobacterium tumefaciens* in introducing glyphosate resistance into soybean crops. [3]

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(Option B continues on the following page)

(Option B continued)

12. (a) Bacteria sometimes form biofilms inside metal pipes in water systems. Distinguish between free bacteria and bacteria in biofilms. [3]

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Disinfectants can be used to break up the biofilms. One of the most commonly used disinfectants is chlorine. Hypochlorous acid forms when chlorine mixes with water. Two different disinfectants were tested experimentally: monochloramine and hypochlorous acid. The concentration of disinfectant needed to kill 99 % of the bacteria was determined, both for free bacteria and for bacteria in biofilms. The table shows the results.

Disinfectant	**Concentration needed to kill 99 % of bacteria in 1 minute / mg dm^{-3}**	
	Free	**Biofilm**
Monochloramine	94	188 to 9400
Hypochlorous acid	0.08	12 to 240

(b) The use of monochloramine is replacing the use of chlorine, as it is more stable, but it can produce by-products that pose possible health risks. Evaluate the data to see whether monochloramine is a good choice as a disinfectant for water systems. [2]

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(c) State how viruses could be used to treat water systems, in order to avoid the use of a disinfectant. [1]

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(Option B continues on the following page)

(Option B continued)

13. Plant-derived proteins are likely to be safer for human use than those derived from mammalian cell cultures, as plant pathogens are not harmful to humans. The hepatitis B vaccine has been produced in tobacco plants.

(a) Describe how the tobacco mosaic virus is used in the production of hepatitis B vaccine. [3]

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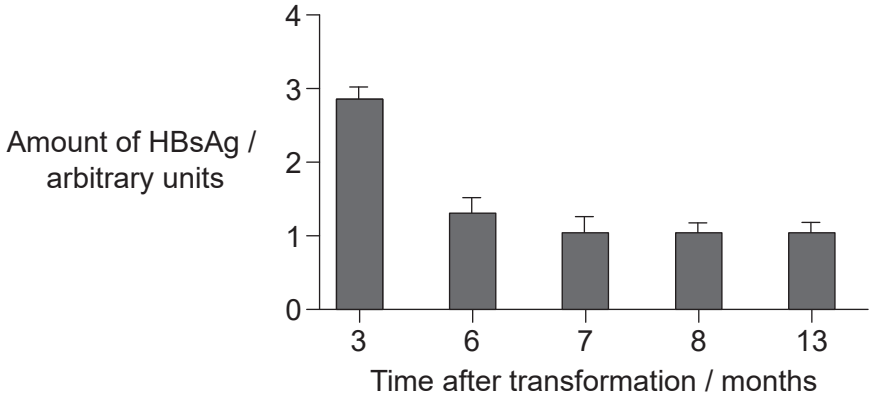
In an experiment, soybean (*Glycine max*) cells were transformed using *Agrobacterium tumefaciens* to produce hepatitis B surface antigen (HBsAg). The amount of HBsAg made by the transformed soybean cells was measured at different times after transformation. The results are shown in the bar chart.



[Source: Reprinted by permission from Springer Nature from *Plant Cell Reports*.
Analysis of the limitations of hepatitis B surface antigen expression in soybean cell suspension cultures.
Ganapathi, T.R., Sunil Kumar, G.B., Srinivas, L., Revathi, C.J. and Bapat, V.A., © 2007.]

(b) Using the data, identify **one** limitation of using soybean cell cultures. [1]

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(Option B continues on the following page)

(Option B, question 13 continued)

(c) The open reading frame (ORF) of HBsAg used in tobacco plants was the same one used in soybean plants. Define ORF. [1]

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(d) Describe **one** bioinformatic method that could have been used to find the gene sequence for HBsAg. [2]

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(Option B continues on the following page)

(Option B continued)

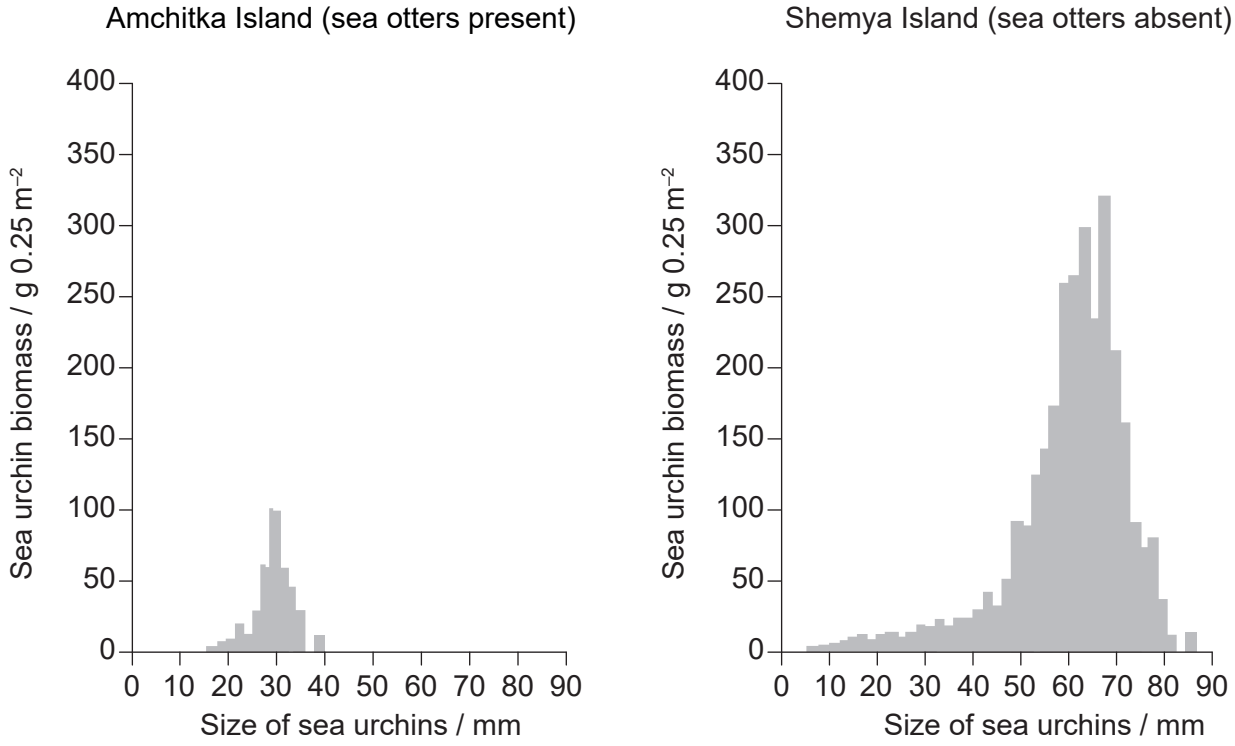
14. Explain how infection by a pathogen can be detected by the presence of its genetic material and of its proteins. [6]

End of Option B

Option C — Ecology and conservation

15. Sea urchins (*Strongylocentrotus*) are echinoderms that consume large quantities of algae. Sea otters (*Enhydra lutris*) feed on sea urchins.

The graphs show the biomass of sea urchins in an area of 0.25 m^2 plotted against their size. Data were collected in two Aleutian Islands, Amchitka and Shemya. In Amchitka the sea otter population is high while at Shemya there are no sea otters.



(a) Outline a method that could have been used in this study to measure the numbers of sea urchins per 0.25 m^2. [2]

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(Option C continues on the following page)

(Option C, question 15 continued)

(b) Sea otters are considered keystone species in this environment. Suggest how the presence of sea otters could affect the algae population. [3]

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(c) Sea urchins are destroying the giant kelp alga (*Macrocystis pyrifera*) marine forests of South East Australia. Suggest a reason that sea urchins might be an invasive species in this environment. [1]

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(Option C continues on the following page)

(Option C continued)

16. Plastic has accumulated in marine environments and is now causing problems for wildlife. Some marine birds have become entangled in plastic debris and some have been harmed by ingesting it. The table shows the extent of the problem worldwide in different groups of birds.

Group	Species	Number of species	Species with problems due to entanglement / %	Species with problems due to ingestion / %
A	penguins	16	38	6
B	grebes	20	10	0
C	albatrosses, petrels and shearwaters	99	10	63
D	pelicans, boobies, gannets, cormorants, frigatebirds and tropicbirds	51	22	16
E	skuas, gulls, terns and auks	122	18	33

(a) (i) Calculate the number of species of grebe with problems due to entanglement. [1]

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(ii) Suggest how entanglement in plastics can lead to the death of marine birds. [1]

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(Option C continues on the following page)

(Option C, question 16 continued)

(b) (i) Identify the group with the greatest number of species with problems due to ingestion of plastics. [1]

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(ii) Describe how ingested plastics can cause problems to marine birds. [2]

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(Option C continues on the following page)

(Option C continued)

17.

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(a)

(b)

(Option C continues on the following page)

(Option C, question 17 continued)

(c)

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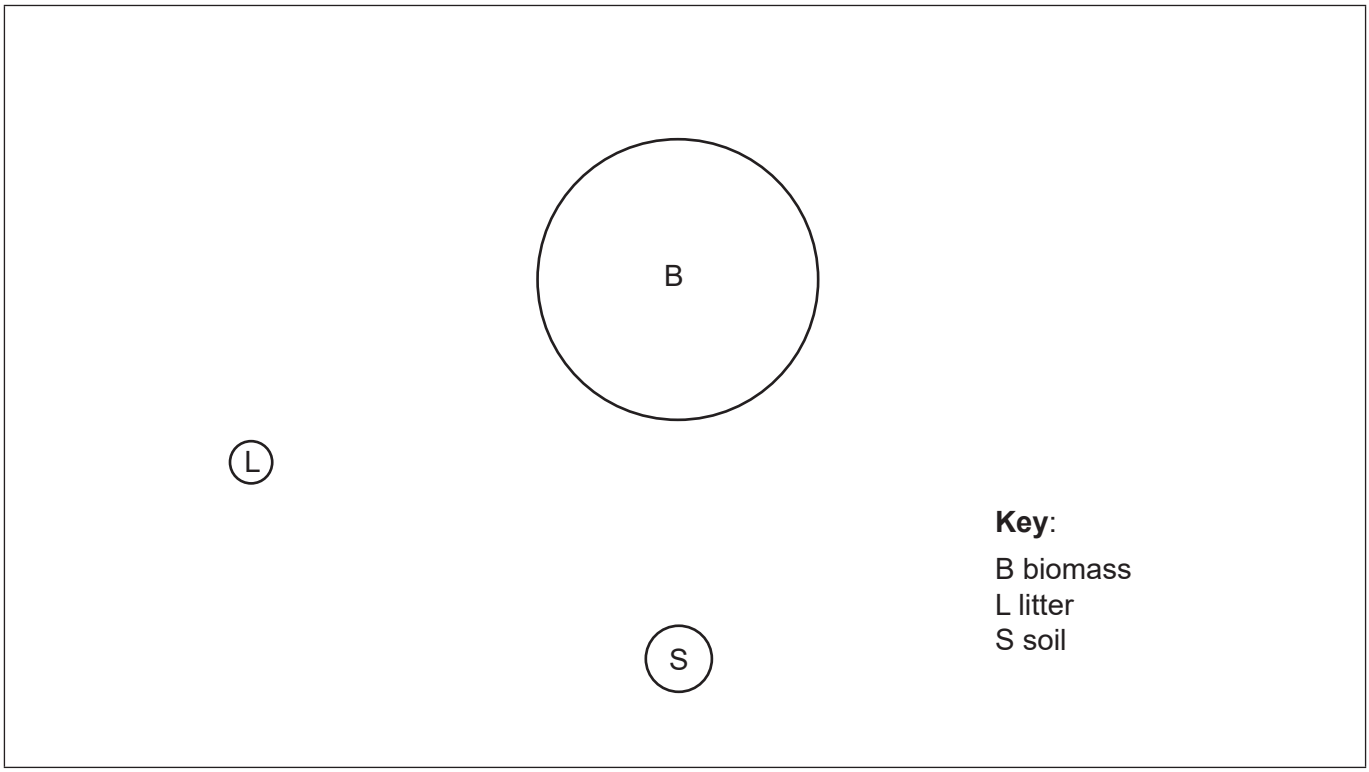
(d) Another type of ecosystem in Brazil is tropical rainforest. Construct a Gersmehl diagram on the outline provided, to show flows of nutrients between stores in tropical rainforests. [3]

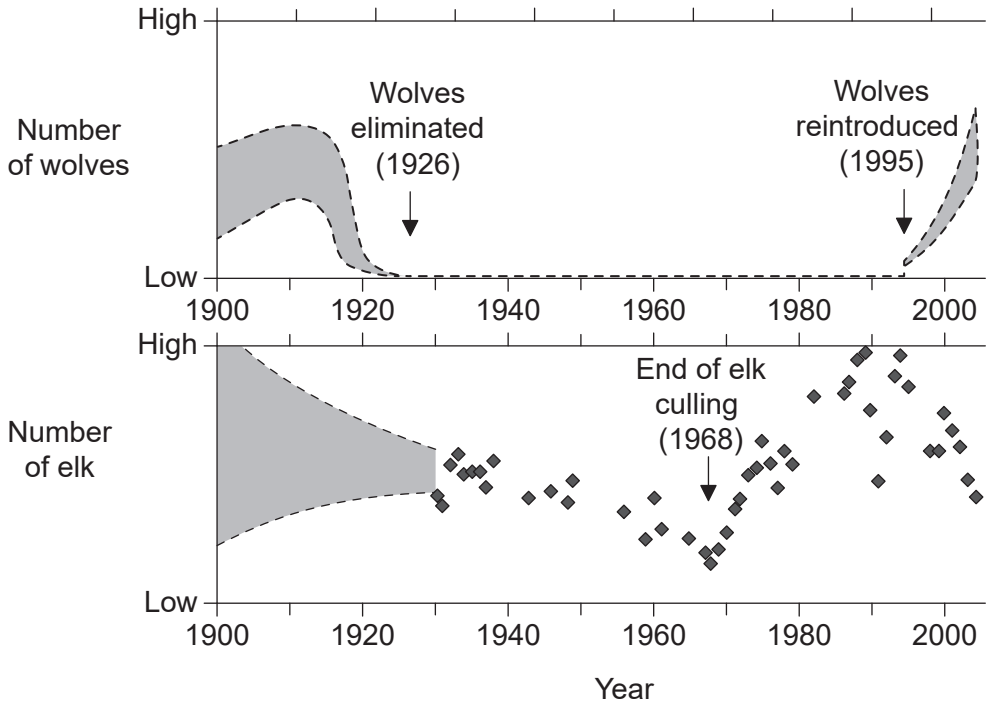


(Option C continues on the following page)

(Option C continued)

18. The elimination of wolves (*Canis lupus*) from Yellowstone National Park in 1926 and their reintroduction in 1995 provided the opportunity to examine ecological interactions with elk (*Cervus elaphus*). The National Park Service made efforts between the 1920s and 1968 to reduce the size of elk herds by culling (selective killing) because of concerns about overgrazing.

The graphs provide the trends for the numbers of wolves and elk in Yellowstone National Park from 1900 to 2004.



[Source: Ripple, W.J. and Beschta, R.L., 2004. Wolves and the Ecology of Fear: Can Predation Risk Structure Ecosystems? *BioScience*, 54(8), pp.755–766 by permission of Oxford University Press on behalf of the American Institute of Biological Sciences. Translated and reprinted by permission of Oxford University Press on behalf of the American Institute of Biological Sciences. Please visit: https://academic.oup.com/bioscience/article/54/8/755/238242.]

(a) Outline the changes in elk population between the years 1930 and 2004. [3]

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(Option C continues on the following page)

(Option C, question 18 continued)

(b) List **two** biotic factors, other than wolf predation or culling, that could affect the elk population. [2]

1:. . . . . .

2:. . . . . .

(Option C continues on the following page)

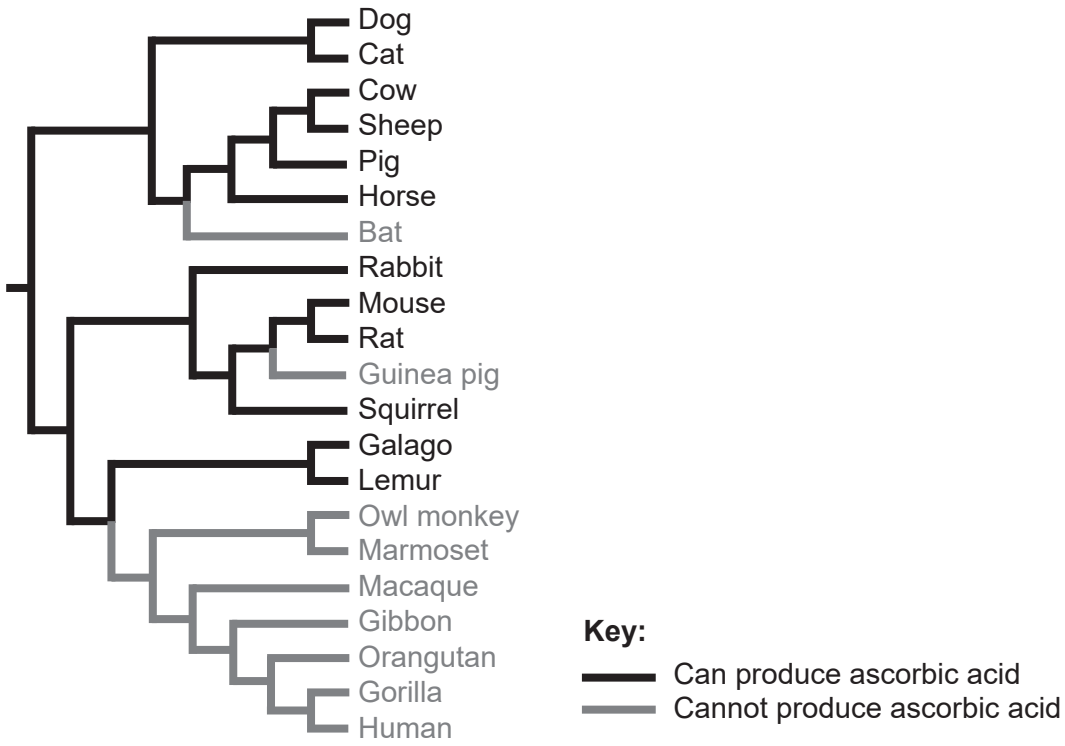
(Option C continued)

19. Suggest how nitrogen and phosphate cycles can be disrupted by humans or extreme weather events. [6]

End of Option C

Option D — Human physiology

20. The cladogram shows where mutations probably occurred in ancestral lines resulting in some animal species being unable to produce ascorbic acid (vitamin C).



(a) On the cladogram, label with an M, the point at which a mutation occurred, preventing the gibbon from synthesizing ascorbic acid. [1]

(b) Outline the reason for ascorbic acid being described as an essential nutrient in the diet of humans. [1]

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(Option D continues on the following page)

(Option D, question 20 continued)

(c) A small box of orange juice contains these details on the side of the package:

Nutrition facts

Per 1 package (200 mL)

Nutrient	% Daily value
Fat	0 %
Sodium	1 %
Potassium	11 %
Protein	-
Vitamin C	80 %
Folate	25 %

Calculate the volume of juice needed to obtain the recommended daily requirement of vitamin C. [1]

. . . . . mL

(Option D continues on the following page)

(Option D continued)

21. (a) Outline the function of the stomach in food digestion. [2]

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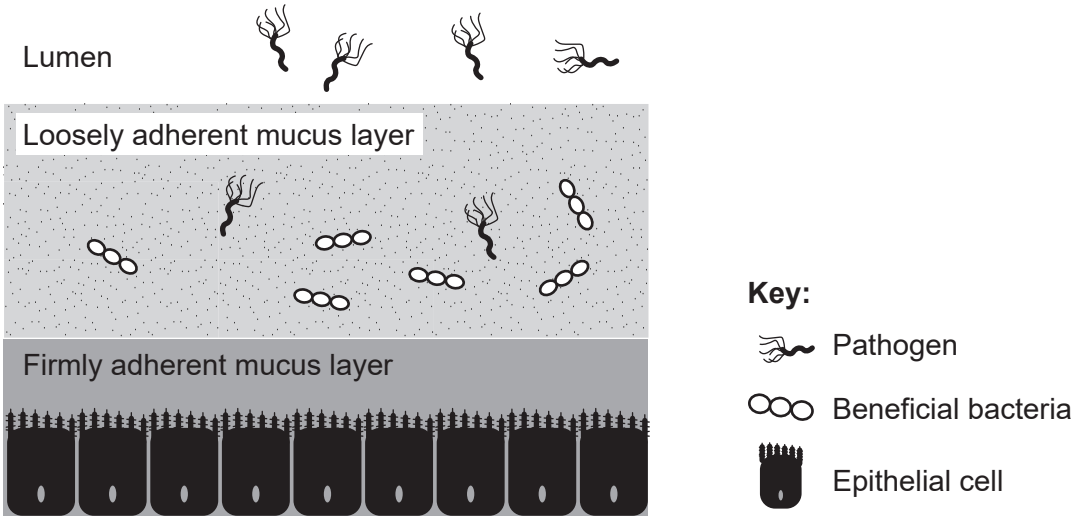
The human stomach kills pathogenic bacteria while allowing some beneficial bacteria to survive. The diagram shows how mucus lining the stomach helps in this process.



[Source: Kavanaugh, D., O'Callaghan, J., Kilcoyne, M., Kane, M., Joshi, L. and Hickey, R.M., 2015. The intestinal glycome and its modulation by diet and nutrition. *Nutrition Reviews*, 73(6), pp.359–375 by permission of Oxford University Press on behalf of the International Life Sciences Institute. Translated and reprinted by permission of Oxford University Press on behalf of the International Life Sciences Institute. Please visit: https://academic.oup.com/nutritionreviews/article/73/6/359/1845190.]

(b) State a mechanism by which the stomach destroys pathogens. [1]

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(Option D continues on the following page)

(Option D, question 21 continued)

(c) There are times when pathogenic bacteria infect the stomach, causing ulcers.

(i) State a pathogenic bacterium that can cause stomach ulcers. [1]

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(ii) Explain how proton pump inhibitors (PPIs) reduce conditions that favour ulcer formation. [3]

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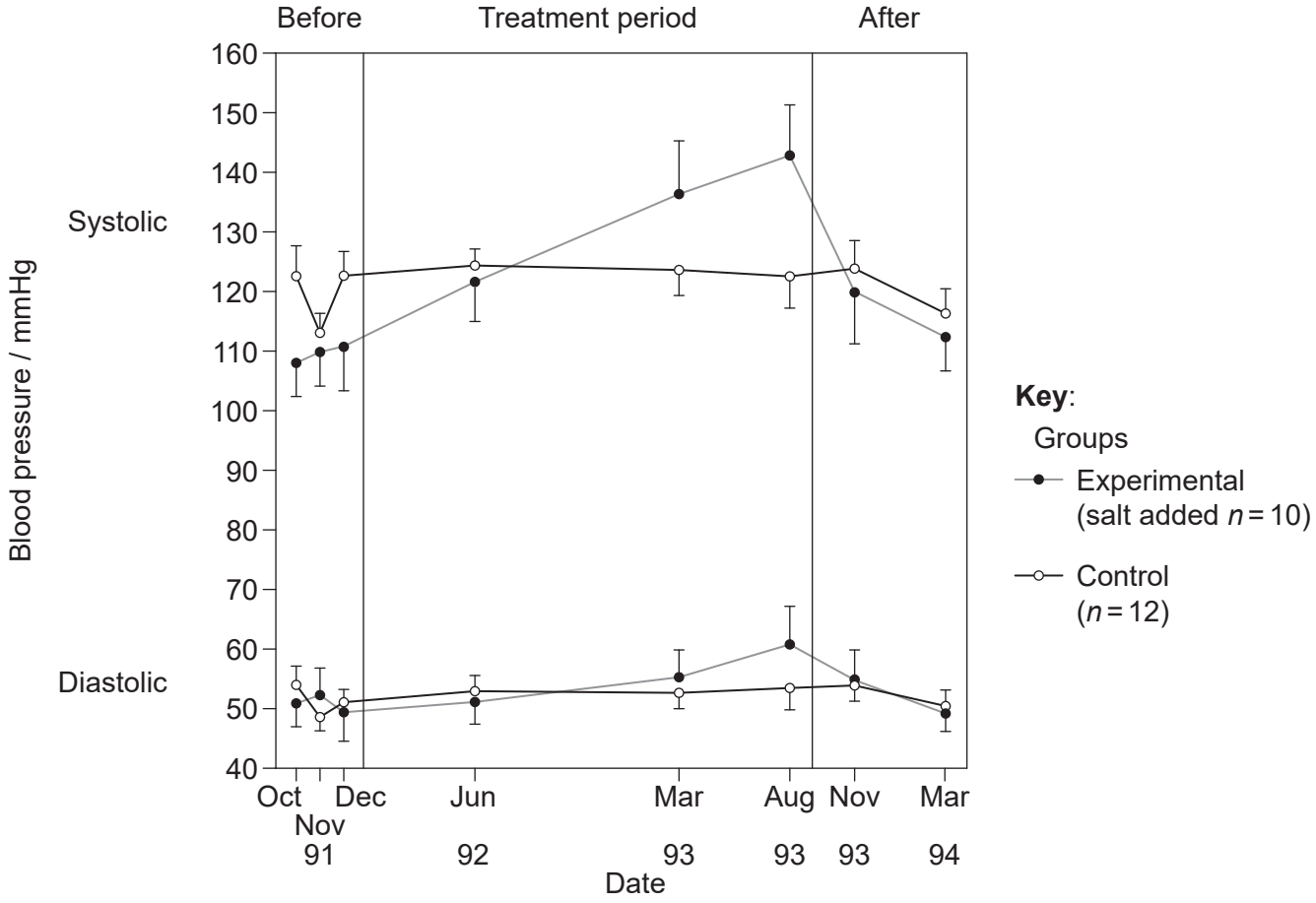
(Option D continues on the following page)

(Option D continued)

22. Blood pressure changes in chimpanzees (*Pan troglodytes*) fed a salt-supplemented diet during a two-and-a-half-year treatment period were compared to the blood pressure of those fed a normal diet. The graph shows the mean systolic and diastolic blood pressure (± standard deviation) before, during and after the treatment period.



(a) Evaluate the effect of salt on blood pressure using the data in the graph. [2]

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(Option D continues on the following page)

(Option D, question 22 continued)

(b) State the instrument used by doctors to measure blood pressure. [1]

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(c) Describe the mechanism by which the heartbeat is initiated. [2]

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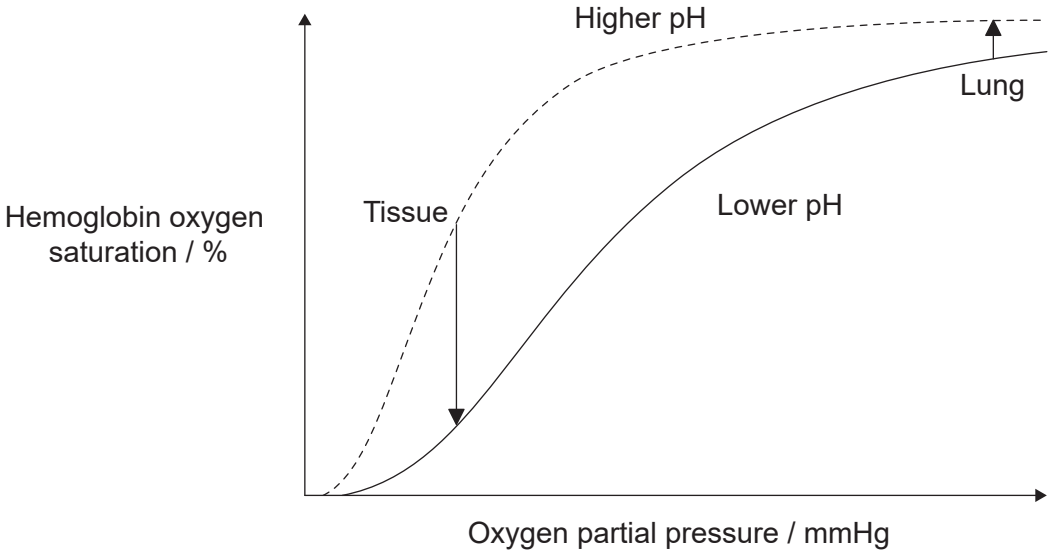
(Option D continues on the following page)

(Option D continued)

23. The graph shows the Bohr shift.



(a) Using the graph, explain the Bohr shift. [3]

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(b) State **two** modes of transport of carbon dioxide in blood. [2]

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2:. . . . . .

(Option D continues on the following page)

(Option D, question 23 continued)

(c) State the effect of carbon dioxide in blood on the rate of ventilation. [1]

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(d) Describe what happens to the hemoglobin from old or damaged red blood cells that are broken down. [3]

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(Option D continues on the following page)

(Option D continued)

24. Explain how steroid and peptide hormones exert their effect. [6]

End of Option D

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