Diploma Programme
Programme du diplôme
Programa del Diploma

Biology
Higher level
Paper 3

13 May 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 – 14
Option C — Ecology and conservation	15 – 19
Option D — Human physiology	20 – 24

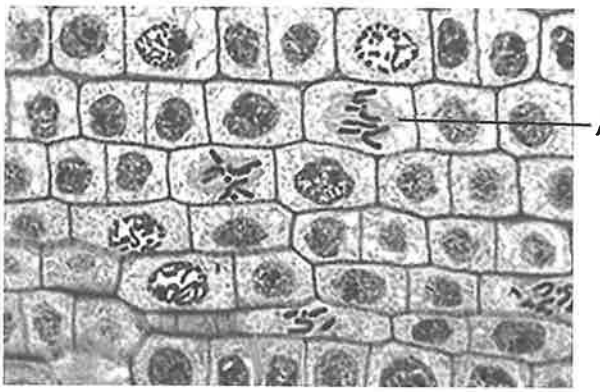
2224–6009

39 pages

Section A

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

1. (a) The photomicrograph shows a section of onion (*Allium cepa*) root tip cells.



× 1000

(i) Describe how a mitotic index could be obtained from this image. [2]

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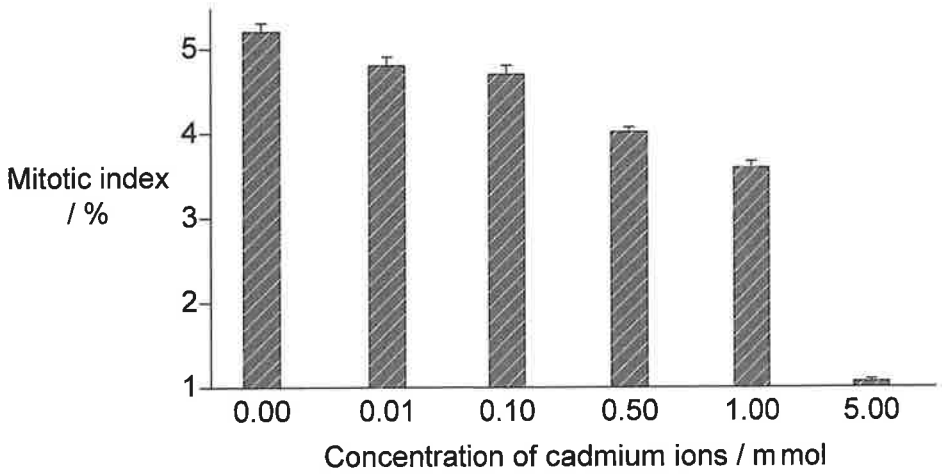
(ii) Calculate the actual length of the cell labelled A, giving the units. [1]

(This question continues on the following page)

(Question 1 continued)

Cadmium is a heavy metal that can cause environmental problems. Cadmium ions are released from various human activities such as the release of sewage sludge, mining and industrial processes. Plants take up cadmium ions and they enter food chains.

A study was carried out to look at the effect of various concentrations of cadmium ions on the mitotic index of the apical meristem of root cells from 4-day-old wheat (*Triticum aestivum*) seedlings.



(b) (i) State the effect of cadmium ion concentration on the mitotic index of root cells from wheat seedlings. [1]

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(ii) Suggest the effect the change in mitotic index would have on the wheat plant. [1]

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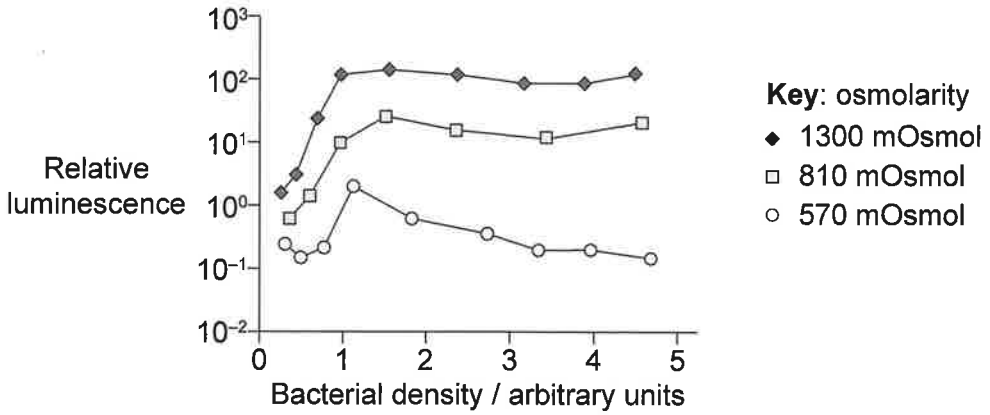
2. *Vibrio fischeri* is a bioluminescent (light-producing) bacterium in the Pacific Ocean. *V. fischeri* grown in the laboratory often has less luminescence. An investigation was carried out to look at the effect of the external osmolarity (in mOsmol) on the bacterium's luminescence, at different densities of bacteria. *V. fischeri* cultures were grown in three different concentrations of artificial seawater. Relative luminescence is the total luminescence divided by the density of bacteria.



(a) Define osmolarity. [1]

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(b) Comment on the effects of osmolarity on the luminescence of the bacterium *V. fischeri*. [2]

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(This question continues on the following page)

(Question 2 continued)

(c) Student osmosis experiments often involve putting plant tissue such as potato cylinders in several salt solutions of different concentrations and measuring the mass before and after immersion. Outline how data collected from such an experiment could be used to estimate the osmolarity of the plant tissues. [2]

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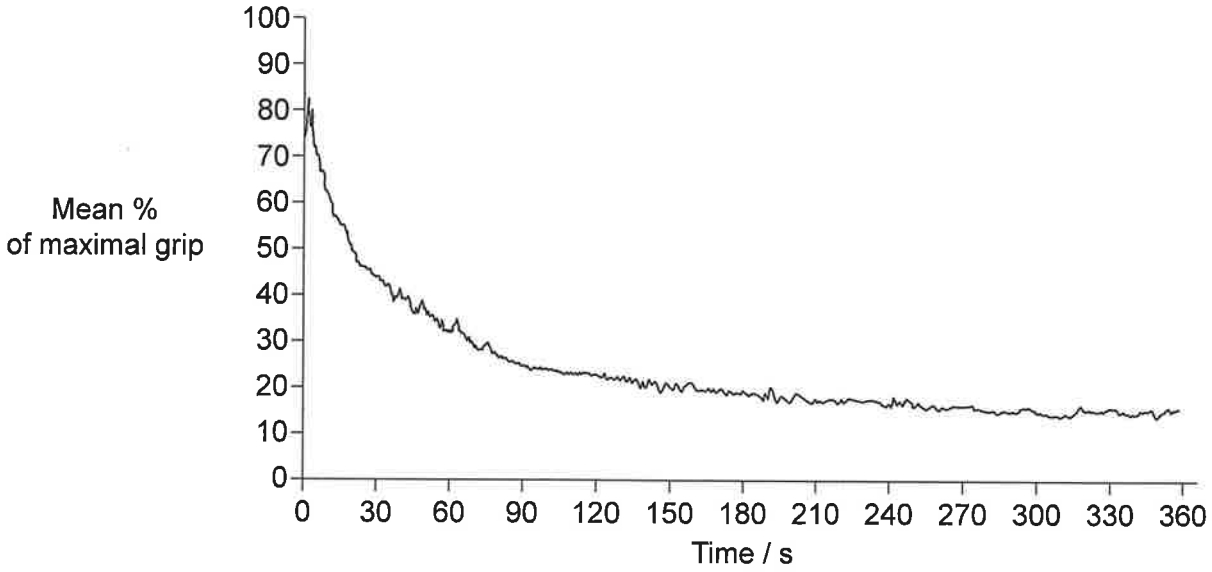
3. (a) A study using 14 people was carried out to examine how much force they could sustain over 6 minutes. The participants were asked to hold a hand grip sensor with as much force as possible throughout this time period. Hand grip strength was measured using the hand grip sensor and related software.



(i) State **one** variable that could influence the results of this study. [1]

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(ii) Suggest a reason for the shape of the graph. [1]

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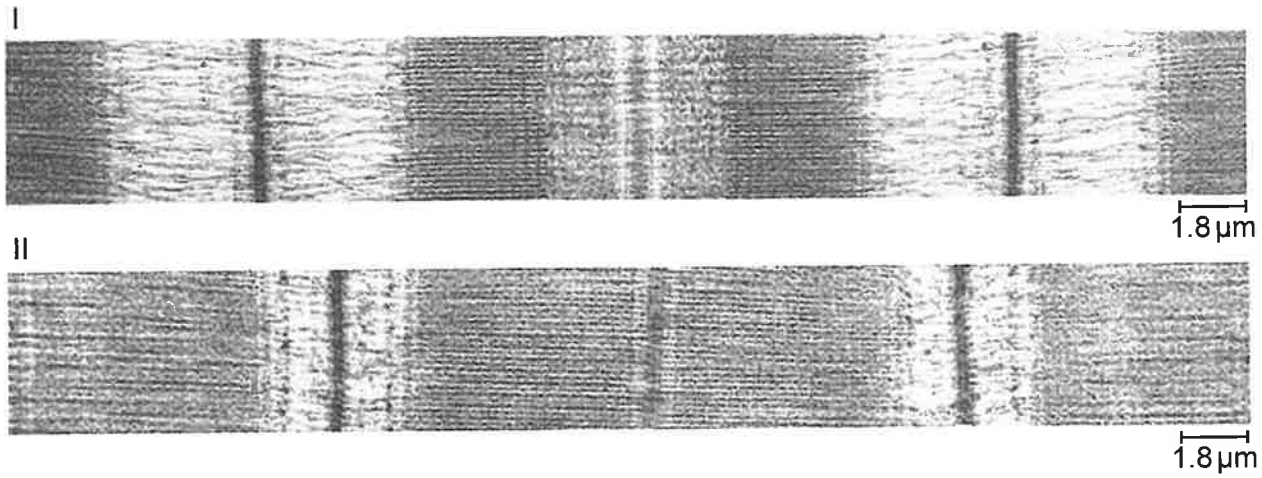
(This question continues on the following page)

(Question 3 continued)

(b) The electron micrographs show sections of muscle fibre in two different states.



(i) Label a sarcomere on electron micrograph I. [1]

(ii) Deduce what events occur in muscle fibres to change them from the state shown in electron micrograph I to the state shown in electron micrograph II. [2]

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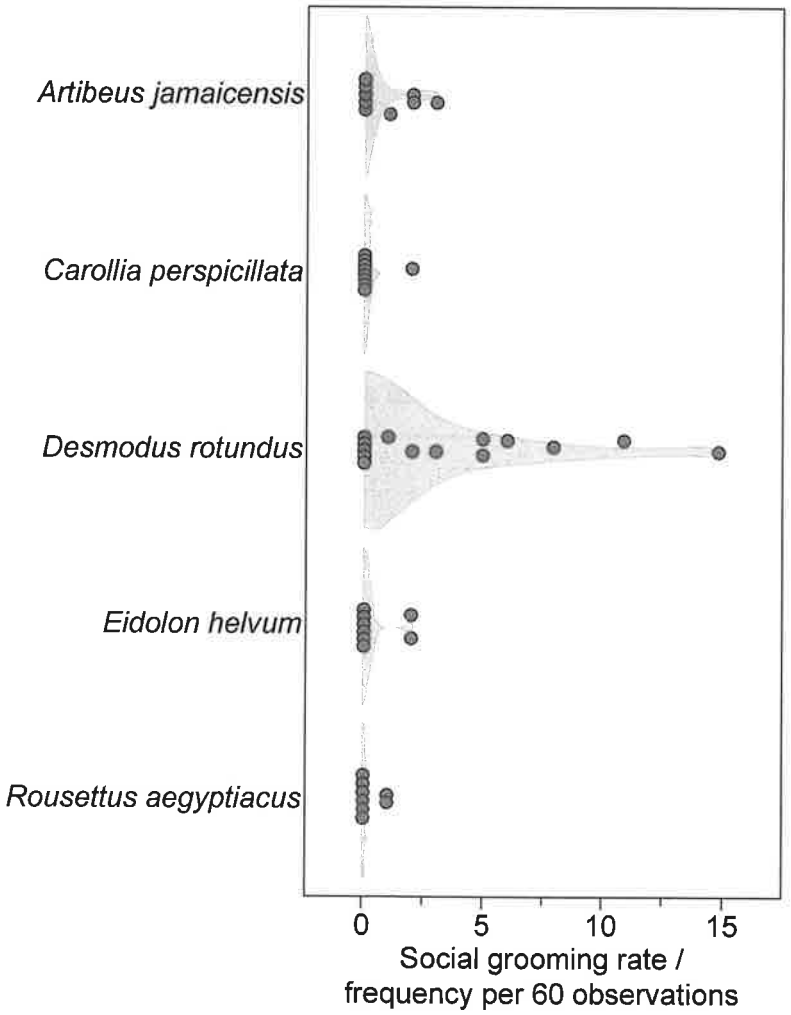
Section B

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. A study was carried out to compare social grooming rates in a species of vampire bat, *Desmodus rotundus*, with four species of non-vampire bats. Social grooming is a behaviour pattern seen in animals that live in groups, where members of the group clean each other's coats. The bats were kept in single-species groups. The groups were kept apart from each other but were housed in the same facility, under the same conditions.



(Option A continues on the following page)

(Option A, question 4 continued)

(a) Compare and contrast the social grooming behaviour between the five species. [2]

(b) Suggest how social grooming might be related to altruistic behaviour shown by vampire bats. [3]

(Option A continues on the following page)

(Option A continued)

5. (a) Outline how functional magnetic resonance imaging (fMRI) helps to identify the role of different brain parts. [2]

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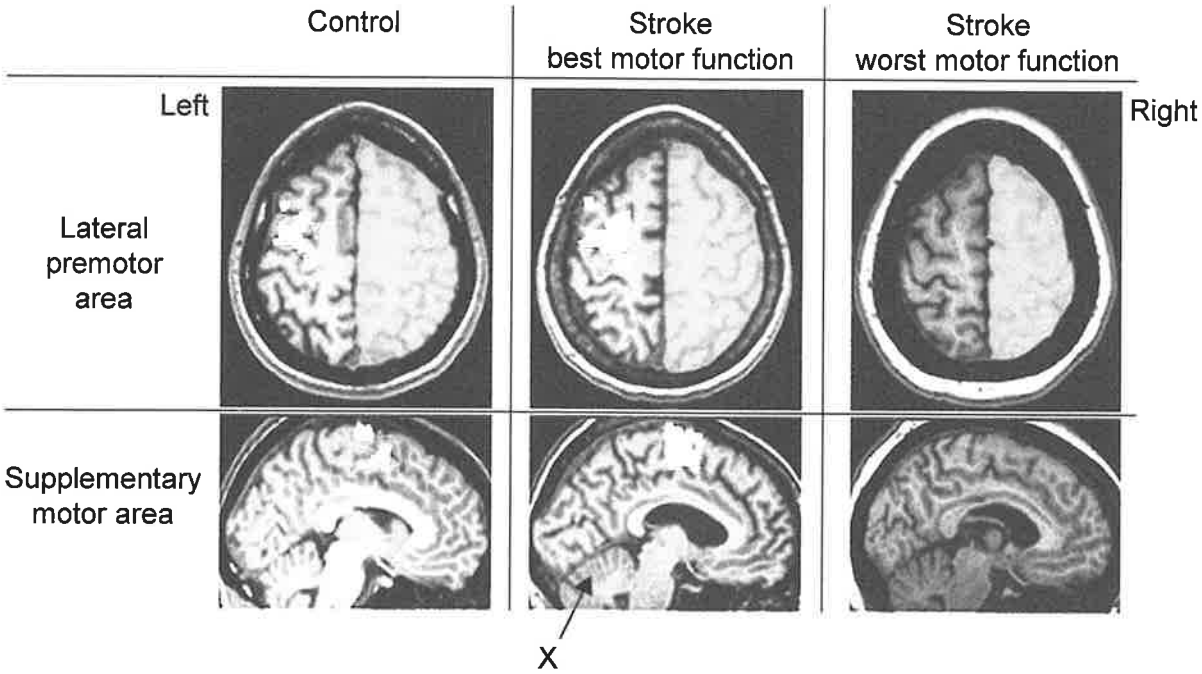
Healthy controls and stroke survivors performed a basic shoulder/elbow reach while being scanned by fMRI.



(Option A continues on the following page)

(Option A, question 5 continued)

(b) Compare and contrast the scan results for the healthy controls with the scans for the stroke survivors. [2]

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(c) Outline a characteristic of the nervous system that would help a stroke survivor recover. [2]

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(d) Identify the name and function of X indicated in the image. [2]

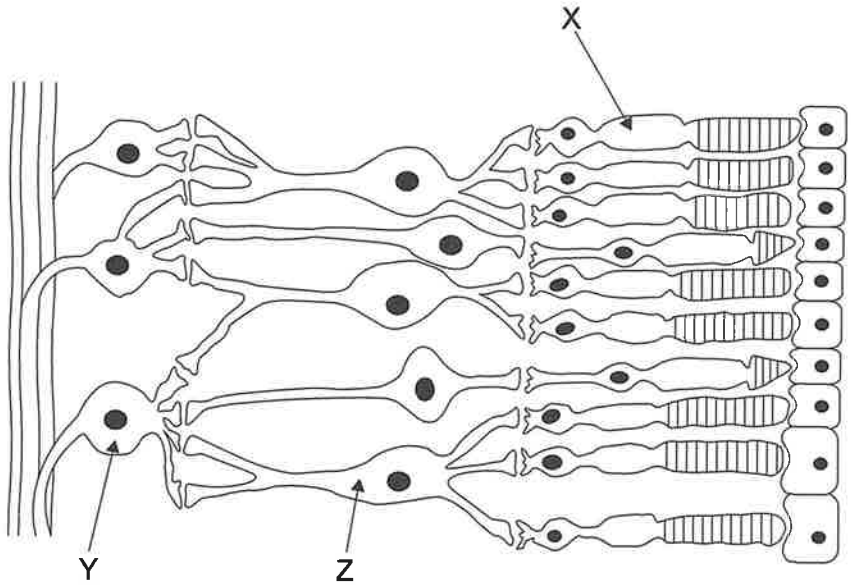
Name: .....

Function: .....

(Option A continues on the following page)

(Option A continued)

6. (a) The diagram shows a section through the retina.



(i) Annotate the diagram to indicate the **functions** of the structures labelled X, Y, Z. [3]

(ii) Draw an arrow to indicate the direction of light. [1]

(b) Outline how red-green colour blindness differs from normal trichromatic vision. [2]

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(Option A continues on the following page)

(Option A continued)

7. (a) Distinguish between innate behaviour and learned behaviour. [2]

(b) Discuss conditioning as a form of learning. [3]

(Option A continues on page 15)

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will not be marked.

(Option A continued)

8. Discuss how drugs can affect the release and reception of chemical messengers at synapses. [6]

End of Option A

Option B — Biotechnology and bioinformatics

9. Biogas production has been increasing in most parts of the world.

(a) State **one** benefit of using biogas. [1]

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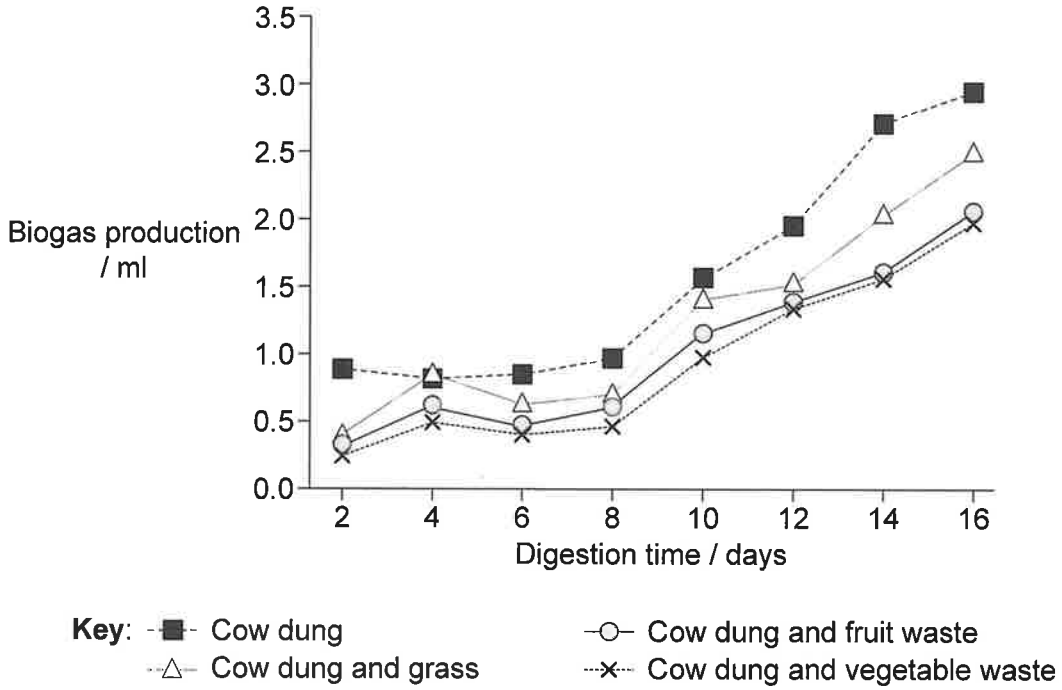
(b) An experiment was conducted to look at the effect on biogas production of mixing cow dung (feces) with other substrates. Two-litre bottles were used as digesters for anaerobic fermentation. Different combinations of waste were used with 50 % waste and 50 % water in each bottle. The pH was maintained between 6.3 and 6.7 and the temperature at 35°C. Biogas production was measured daily for 16 days.



(i) Compare and contrast gas production from the different combinations of waste. [2]

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(Option B continues on the following page)

(Option B, question 9 continued)

(ii) Determine with a reason whether this was an example of batch or continuous fermentation. [1]

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(c) Outline how pathway engineering is used in industrial fermentation. [2]

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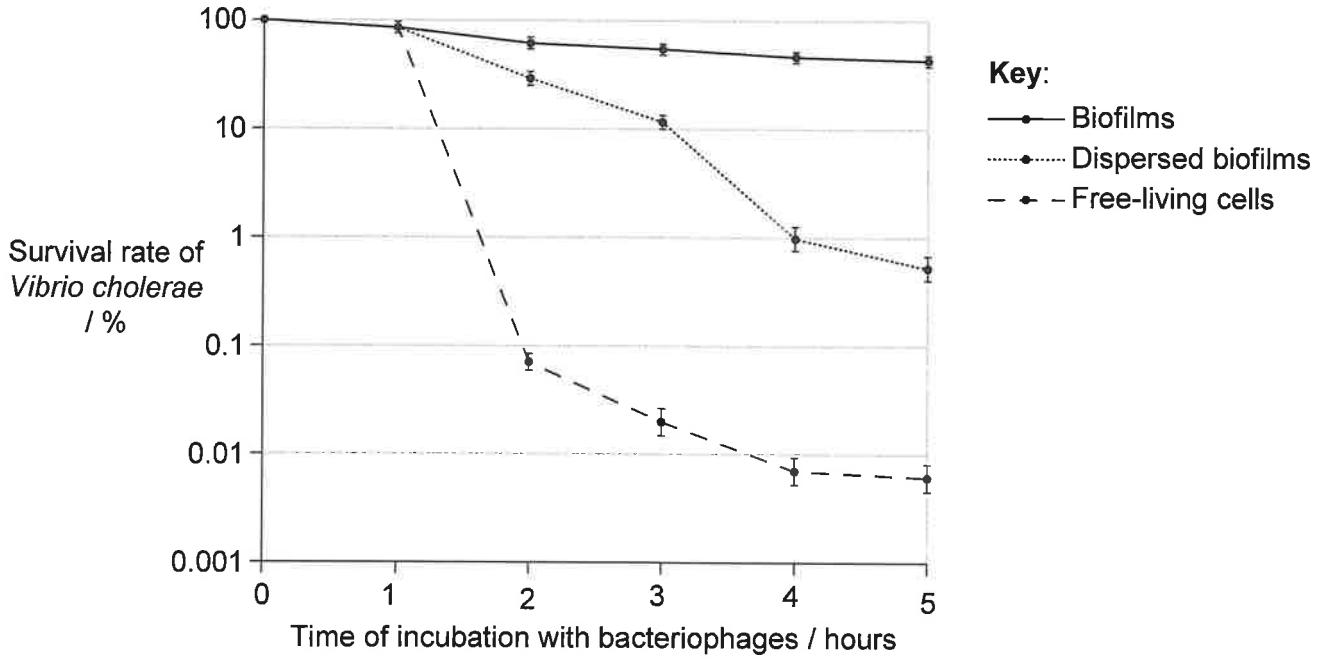
(Option B continues on the following page)

(Option B continued)

10. The bacterium *Vibrio cholerae* is found in aquatic ecosystems mostly in a biofilm-associated state. However, these cells can naturally become the active, free-living form through various mechanisms. They then multiply and can cause epidemics of cholera. An investigation was conducted to study the possible effects of environmental bacteriophages on the survival of *V. cholerae* in three states: in biofilms, in dispersed biofilms (shaken to break them up) and as active free-living forms.



(a) Identify in which state *V. cholerae* is most susceptible to bacteriophages. [1]

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(b) Suggest how properties of biofilms could account for the survival rate shown in the graph. [3]

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(Option B continues on the following page)

(Option B continued)

11. Outline **one** example of bioremediation in response to a pollution incident. [3]

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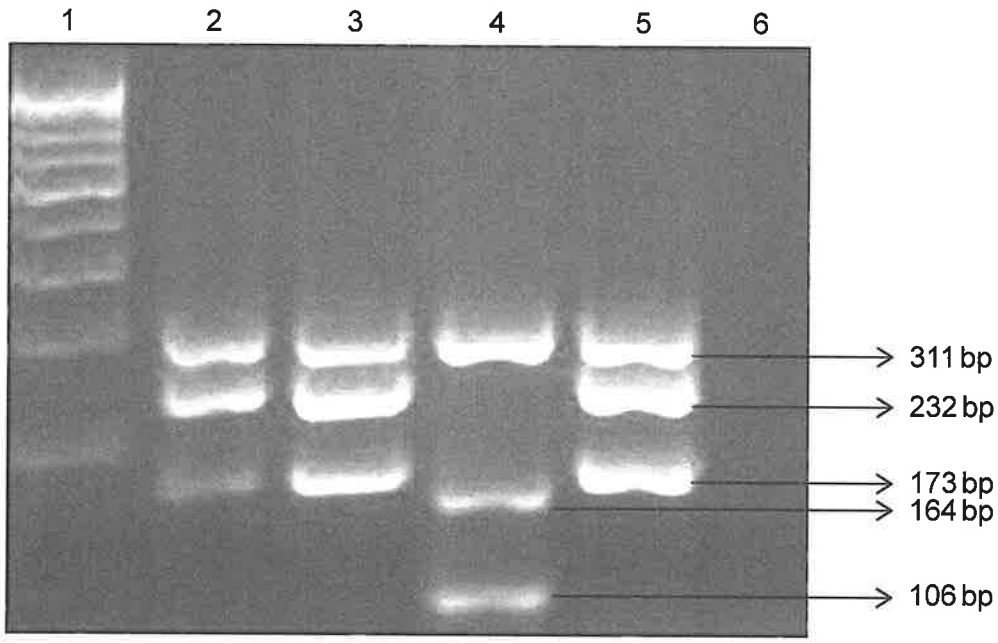
(Option B continues on the following page)

(Option B continued)

12. Rapid, low cost detection and identification of influenza virus types and subtypes would be very useful in controlling infections and preventing transmission. A study was conducted to assess the use of reverse transcriptase PCR assays to detect multiple types of influenza A viruses.

Molecular size marker / number of base pairs	Influenza type / subtype
106	A / N1 subtype
164	A / H1 subtype
173	A / N2 subtype
232	A / H3 subtype
311	A / all subtypes

Gel electrophoresis was carried out on the PCR products of different viral samples (lanes 2–6). Lane 1 contains DNA fragments of known size to act as size markers.



(Option B continues on the following page)

(Option B, question 12 continued)

(a) Suggest the reason that reverse transcriptase PCR was used instead of normal PCR. [2]

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(b) State what is used to visualize the bands on the gel electrophoresis. [1]

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(c) Distinguish between the virus types shown by lanes 3 and 4. [2]

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(Option B continues on the following page)

(Option B continued)

13. (a) Discuss the use of a database such as Ensembl to study chromosome 21. [3]

(b) Describe what an expressed sequence tag (EST) is and how it could be used. [3]

(Option B continues on the following page)

(Option B continued)

14. Discuss the risks and benefits associated with the introduction of genes for resistance to herbicides, such as glyphosate, into crops. [6]

End of Option B

Option C — Ecology and conservation

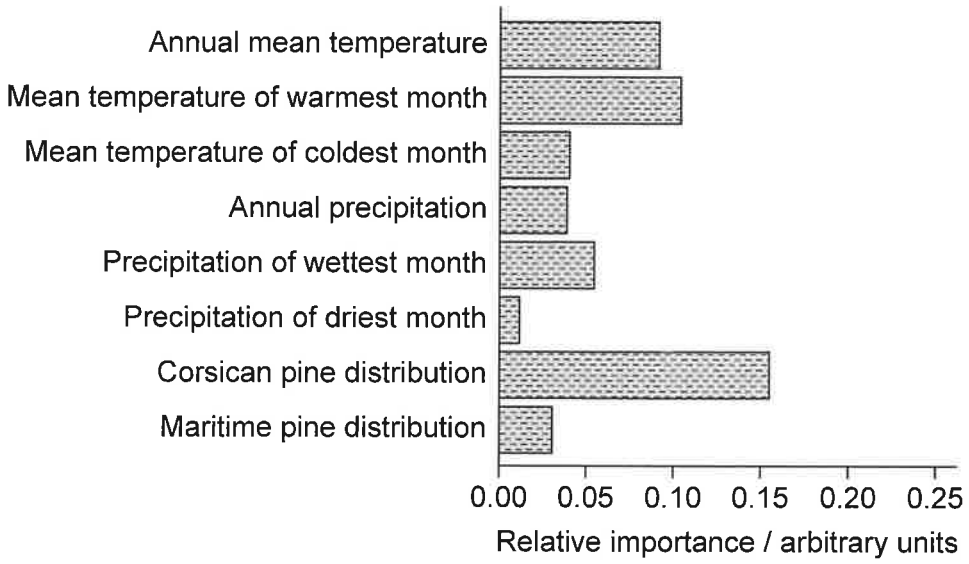
15. The Corsican nuthatch (*Sitta whiteheadi*) lives only on the island of Corsica in Corsican pine (*Pinus nigra laricio*) forests and groves of Maritime pine (*Pinus pinaster*).

Corsican nuthatch (*S. whiteheadi*)

Corsican pine (*P. nigra laricio*)

Maritime pine (*P. pinaster*)

A study looked at the relative importance of a range of factors affecting the distribution of the Corsican nuthatch. The relative importance of each factor was derived from how strongly the factor and the distribution of the nuthatch were correlated.



(Option C continues on the following page)

(Option C, question 15 continued)

(a) (i) Identify which variable is of greatest importance to the Corsican nuthatch. [1]

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(ii) Suggest **one** reason for the importance of the variable identified in (a)(i) for the Corsican nuthatch. [1]

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(b) The Corsican pine (*P. nigra laricio*) has suffered large distribution losses due to human activity, intensively managed forests and wildfires. Thus, its realized niche is likely to be different from its fundamental niche. Distinguish between realized and fundamental niches. [2]

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(c) The Corsican nuthatch is red-listed as vulnerable to extinction by the IUCN (International Union for Conservation of Nature). Using the information in this question, suggest a reason for its population decline. [1]

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(Option C continues on the following page)

(Option C, question 15 continued)

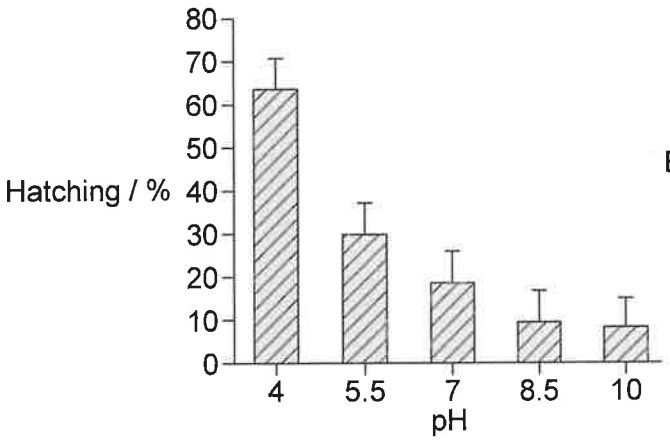
(d) The forests on the island have become fragmented and isolated. Discuss the impact of island size and edge effects on biodiversity. [3]

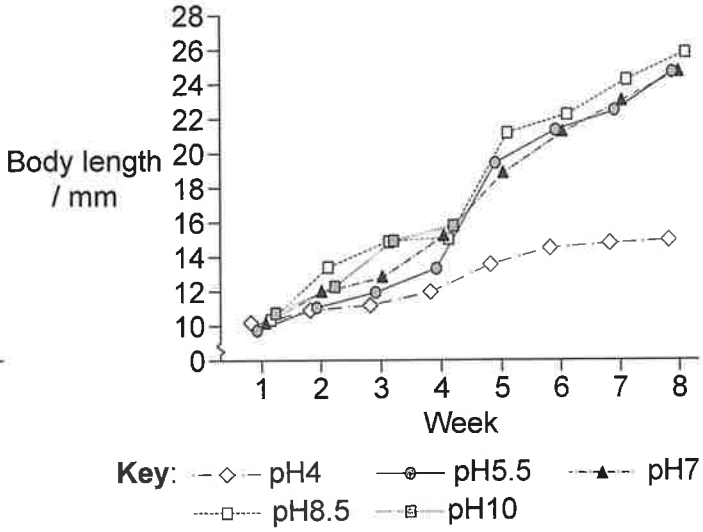
16. (a) Outline the introduction of the cane toad (*Rhinella marina*) into Australia. [2]

(Option C continues on the following page)

(Option C, question 16 continued)

Cane toads in their native range in Venezuela breed in clear water with a pH only slightly higher than neutral (pH 7.1–7.6). Fieldwork in northeastern New South Wales, Australia, showed that natural water bodies varied in pH from pH4 to pH10. Laboratory investigations were conducted to look at the effect of this range of pH on the hatching and body length of cane toads.





(b) Using the information provided, discuss whether pH of water bodies is likely to limit the distribution of cane toads in Australia. [3]

(Option C continues on page 29)

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will not be marked.

(Option C continued)

17. (a) Define indicator species. [1]

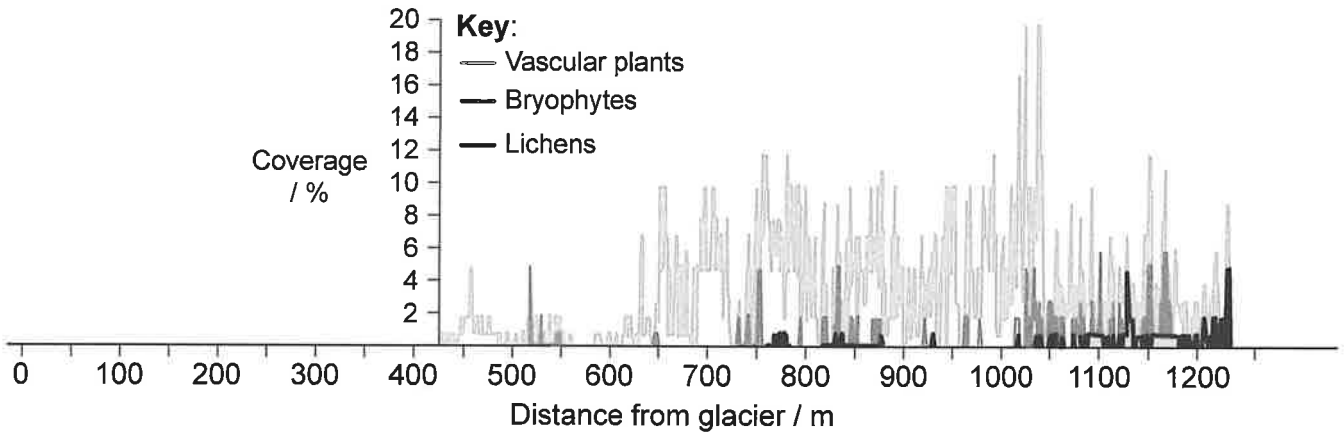
(b) Explain the use of a biotic index. [3]

(c) Outline the effect of DDT on the environment. [2]

(Option C continues on the following page)

(Option C continued)

18. An investigation was undertaken in Gåsbreen, Norway, in a freshly de-glaciated area to look at the organisms present at different times since the retreating glacier had exposed the land. A linear transect and 1 m^2 quadrat were used starting at the edge of the retreating glacier. The first producers were recorded at a distance of 426 m from the glacier.



(a) Outline how a transect and quadrats can be used in ecological fieldwork. [2]

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(b) Identify which group of organisms had the highest percentage coverage of the area studied. [1]

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(Option C continues on the following page)

(Option C, question 18 continued)

(c) Outline the type of succession shown here. [2]

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(Option C continues on the following page)

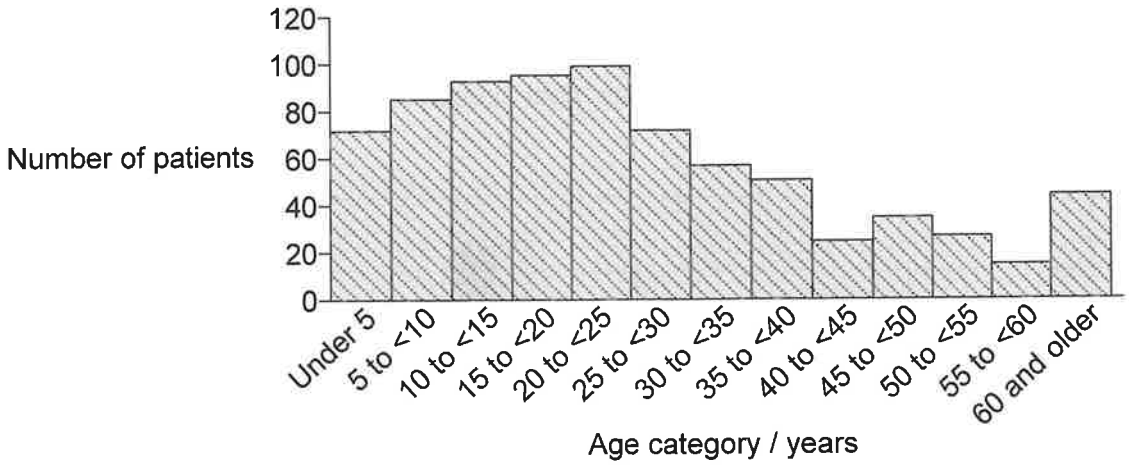
(Option C continued)

19. Discuss the risks and benefits associated with the use of phosphate fertilizers in agriculture. [6]

End of Option C

Option D — Human physiology

20. In 2012, Sierra Leone suffered a nationwide cholera epidemic. The graph shows the number of people admitted to cholera wards during a two-month period.



(a) State the main symptom of cholera that would have resulted in admission to hospital. [1]

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(b) Suggest **one** reason for the age distribution of patients admitted to cholera wards. [1]

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(c) Outline the processes that occur in the large intestine of a healthy person. [2]

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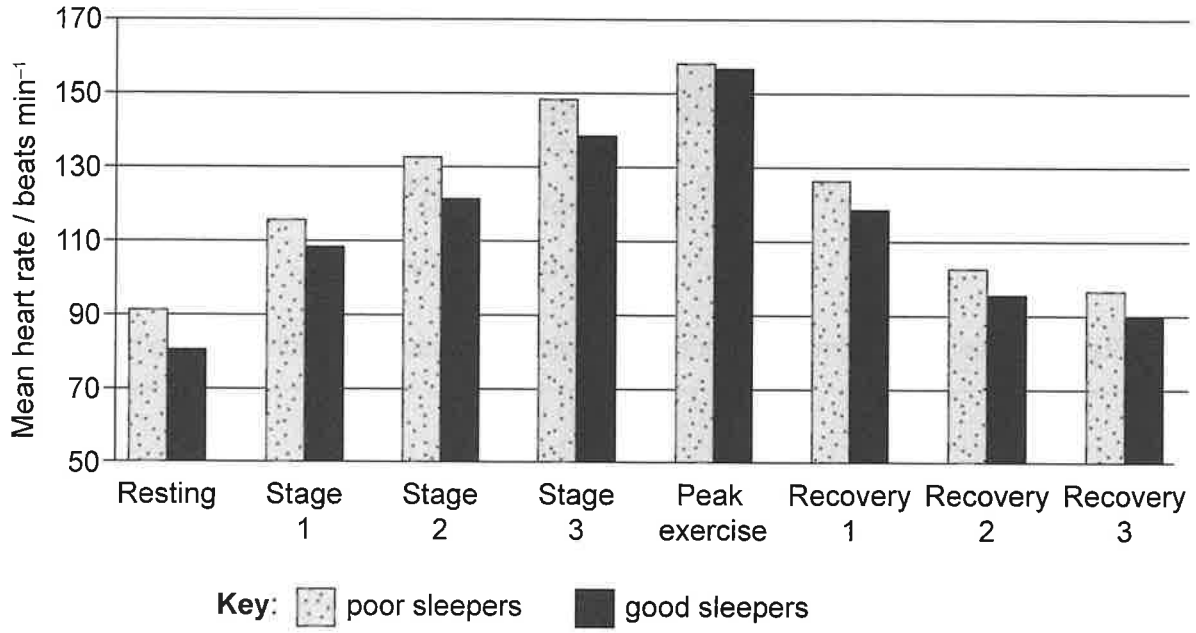
(Option D continues on the following page)

(Option D continued)

21. A study was conducted using 113 healthy individuals to look at the effect of sleep quality on heart rate during exercise. All participants performed a treadmill stress test. Speed and incline of the treadmill increased during the first three stages until peak exercise was reached. This was followed by a recovery period as speed and incline decreased. Sleep quality of participants was assessed using the Pittsburgh Sleep Quality Index (PSQI) questionnaire; 48 subjects were categorized as "poor sleepers" and the rest were grouped as "good sleepers".



(a) Compare and contrast the effect of sleep on heart rate during the various stages of the treadmill stress test. [2]

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(Option D continues on the following page)

(Option D, question 21 continued)

(b) Outline the reasons for the heart sounds heard during a heartbeat. [2]

(c) A total of 106 potential participants in this study were excluded due to hypertension. Outline the consequences of hypertension. [2]

(Option D continues on the following page)

(Option D continued)

22. (a) Outline the cause of phenylketonuria (PKU). [2]

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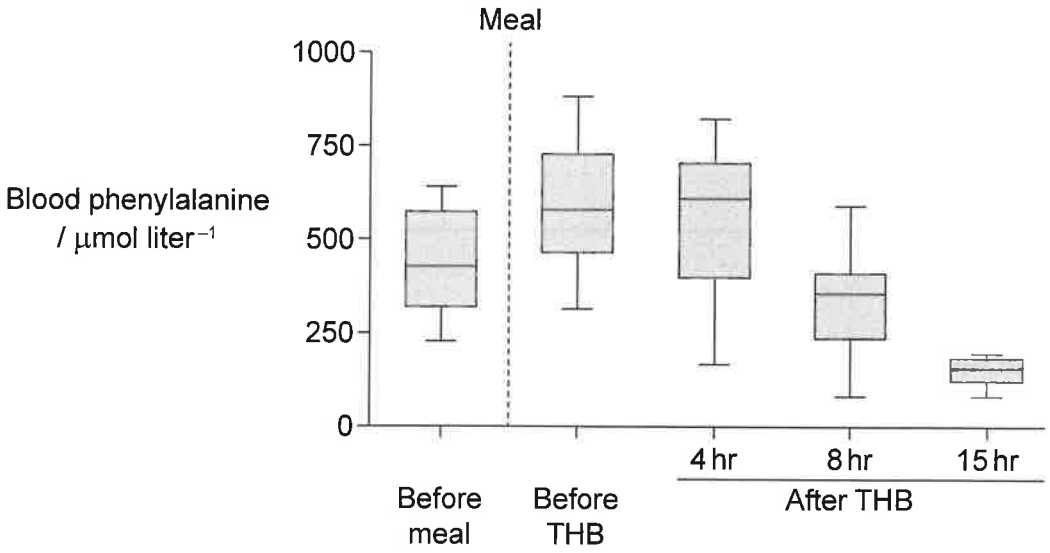
Because of disadvantages with current treatments for PKU, researchers have attempted to develop new treatments. One investigation looked into the effect of tetrahydrobiopterin (THB) given to children with mild phenylketonuria one hour after a meal rich in protein. Blood phenylalanine levels were measured before the meal, after the meal but before THB was given, and at certain intervals after THB was given.



(Option D continues on the following page)

(Option D, question 22 continued)

(b) Using the data in the graph, evaluate the hypothesis that THB is an effective treatment for PKU. [2]

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(c) Suggest potential advantages of treatment with THB over traditional treatments. [2]

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(Option D continues on the following page)

(Option D continued)

23. (a) Distinguish between steroid and peptide hormones. [2]

(b) Explain the role of hormonal mechanisms in the control of gastric juice secretion. [3]

(c) Outline the role of hormones in the control of milk secretion. [3]

(Option D continues on the following page)

(Option D continued)

24. Explain the role of red blood cells in the transport of respiratory gases. [6]

End of Option D

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References:

1. (a) [*Mitosis*], n.d. [micrograph online] Available at: <https://www.pinterest.com.au/pin/547468898431696572/> [Accessed: 4 April 2019].

1. (b)(i) Bezrukova, M.V., et al., 2016. [*Concentrations of cadmium ions*]. [graph] (*Russian Journal of Plant Physiology*, 63(3), pp.358–364).

2. Stabb, E.V., *et al.*, 2004. *Fig. 2B. Effects of medium osmolarity on V. fischeri growth and luminescence.* [graph] (*Journal of Bacteriology*, 186(9), p.2907).

3. (a) Masakatsu, N. and Shinichi, D., 2013. *Figure 1. Cross-correlation coefficients and the changes of force values during two maximal sustained hand grip and toe grip exertions.* [graph] (*American Journal of Sports Science and Medicine*, 1(2), pp. 28–32).

3. (b) [*Sections of muscle fibre*], 2014. [micrograph online] Available at: <http://163.178.103.176/tema1g/aportal/fisiogencg/gymob6/miosinaactina/mi0act.html> [Accessed: 9 April 2019].

4. Carter, G. and Leffer, L., 2015. *Fig. 1. Social grooming rates in five captive bat species.* [graph] (*PLoS One*, 10(10), e0138430).

5. (a) Daly, J.J., *et al.*, 2014. Brain control of functional reach in healthy adults and stroke survivors. *Restorative Neurology and Neuroscience*, 32 (5), pp. 559–573.

9. (b) Dhanapal, T., *et al.*, 2016. *Figure 5. The TS value is obtained for various experimental set-ups vs. digestion time.* [graph] (*Thermal Science*, 20(4), p.S1116).

10. Bin Naser, I., *et al.*, 2017. *Fig. 3. Resistance of biofilm-associated Vibrio cholerae to lytic phages JSF3 and JSF4.* [graph] (*PLoS One*, 12(7), e0180838).

12. Dhakad, S., *et al.*, 2015. Comparison of multiplex RT-PCR with virus isolation for detection, typing and sub-typing of influenza virus from influenza-like illness cases. *Indian Journal of Medical Microbiology*, 33(1), pp.73–77.

15. Nicolle, S., n.d. *Corsican Nuthatch Sitta whiteheadi.* [image online] Available at: <http://ec.europa.eu/environment/nature/conservation/wildbirds/threatened/s/sitta_whiteheadi_en.htm> [Accessed: 8 April 2019].

johnny_automatic, 2007. *Corsican Pine*. [image online] Available at: <https://openclipart.org/detail/6207/corsican-pine> [Accessed: 8 April 2019].

Van Bel, *et al.*, n.d. *PLAZA Gymnosperms : Pinus pinaster.* [image online] Available at: <https://bioinformatics.psb.ugent.be/plaza/versions/gymno-plaza/organism/view/Pinus+pinaster> [Accessed: 8 April 2019].

Barbet-Massin, M. and Jiguet, F., 2011. *Figure 5. Relative importance of the variables used to model the Corsican Nuthatch distribution.* (*PLoS ONE*, 6(3)).

16. (b) for both graphs:

Wijethunga. U., *et al.*, 2015. The Acid Test: pH Tolerance of the Eggs and Larvae of the Invasive Cane Toad (*Rhinella marina*) in Southeastern Australia. *Physiological and Biochemical Zoology*, 88(4), pp. 433–443.

18. Wietrzyk, P., *et al.*, 2016. *Fig. 2. Stages of succession on the Gåsbreen foreland.* [graph] (*Polish Polar Research*, 37(4), p.499).

20. Blacklock, A., *et al.*, 2014. *Fig. 2 Age distribution of total patient population admitted to the cholera wards.* [graph] (*Global Health Action*, 8(1)).

21. Yuksel, M., 2014. *FIGURE 2. Heart rate course during treadmill stress test.* [graph] (*Clin Invest Med*, 37(6), p.E352).

22. (a) Muntau, A.C., *et al.*, 2002. *Figure 1. Blood Phenylalanine Concentrations.* [graph] (*The New England Journal of Medicine*, 347, pp.2122–2132).