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BIOLOGY
STANDARD LEVEL
PAPER 3

Candidate session number

Monday 12 May 2014 (morning)

1 hour

Examination code

2	2	1	4	–	6	0	1	8

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- The maximum mark for this examination paper is *[36 marks]*.

Option	Questions
Option A — Human nutrition and health	1 – 3
Option B — Physiology of exercise	4 – 6
Option C — Cells and energy	7 – 9
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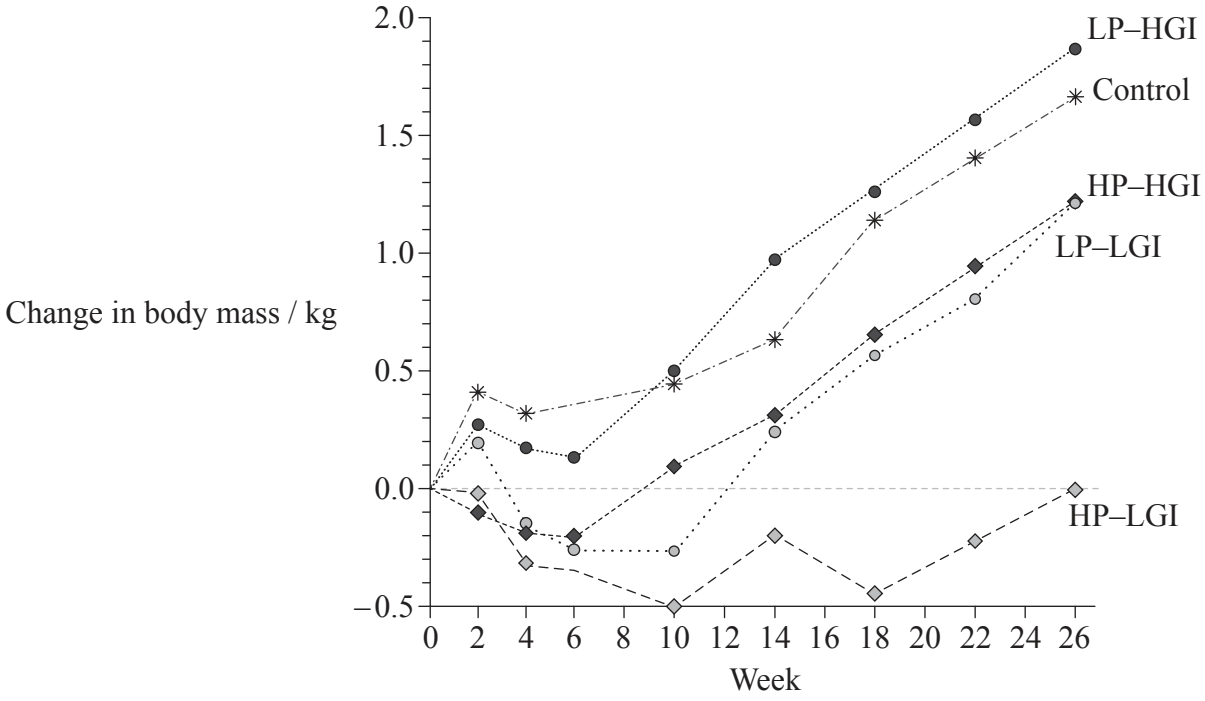
Option A — Human nutrition and health

1. During an investigation, 773 participants who had lost body mass through a low-energy diet were randomly assigned a diet (with no energy restriction) for the next 26 weeks to maintain their mass. These maintenance diets were one of the four combinations of high or low protein with either high or low glycemic index. A control group followed the recommended daily intake. High glycemic index foods enable a quicker release of glucose into the bloodstream than foods with a low glycemic index.



Key:	HP – high protein	HGI – high glycemic index
	LP – low protein	LGI – low glycemic index

[Source: From *The New England Journal of Medicine*, Thomas Meinert Larsen, Stine-Mathilde Dalskov, Marleen van Baak et al., Diets with High or Low Protein Content and Glycemic Index for Weight-Loss Maintenance, vol. 363, pages 2102–2113. Copyright © 2010 Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society.]

(a) State the change in body mass 10 weeks after the start of the maintenance diet for the low protein and high glycemic index group, giving the units. *[1]*

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(Option A continues on the following page)

(Option A, question 1 continued)

(b) State the trend in body mass during the 26 week period for the maintenance diets with high glycemic index. *[1]*

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(c) Evaluate the effectiveness of a high protein with low glycemic index diet in maintaining mass, after a mass-loss diet. *[2]*

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(d) Explain the possible health consequences of diets rich in carbohydrates. *[2]*

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(Option A continues on the following page)

(Option A continued)

2. (a) Define the following terms.

(i) *Nutrient* *[1]*

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(ii) *Non-essential amino acid* *[1]*

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(b) (i) State a **natural** source of vitamin D in the human diet. *[1]*

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(ii) Discuss how the risk of vitamin D deficiency from insufficient exposure to sunlight can be balanced against the risk of contracting malignant melanoma. *[3]*

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(Option A continues on the following page)

(Option A continued)

3. (a) Outline the function of the appetite control centre in the brain. *[3]*

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(b) Discuss reasons for consumers to choose foods to minimize food miles. *[3]*

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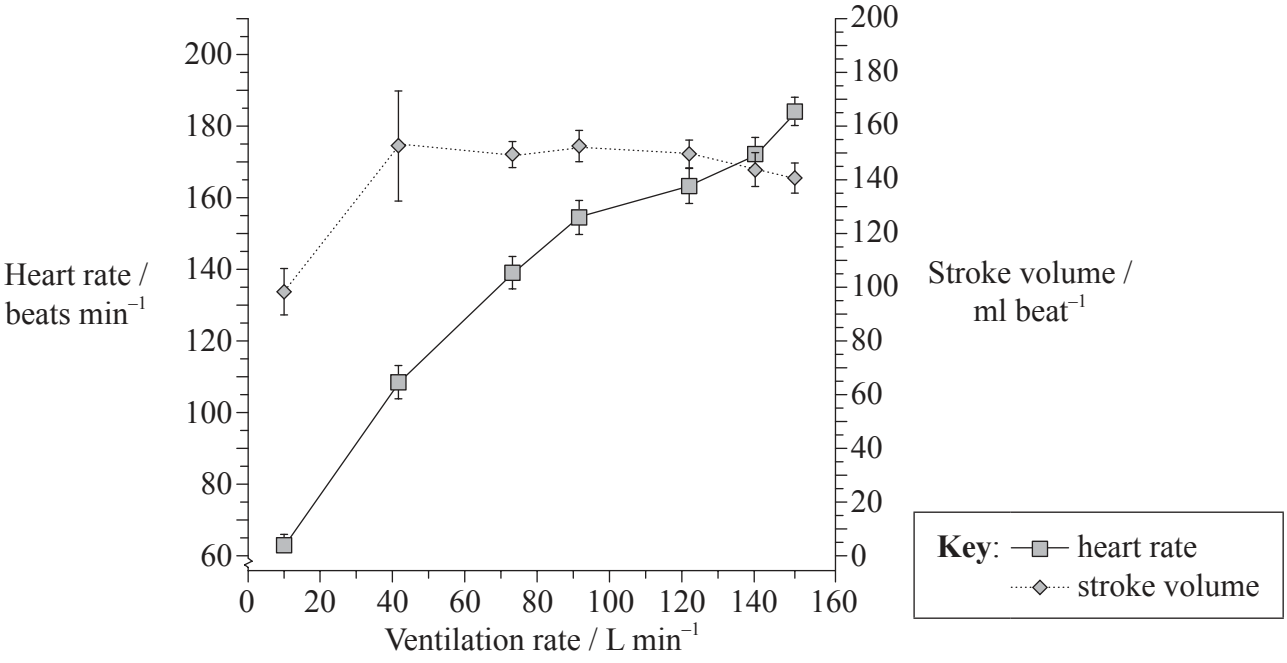
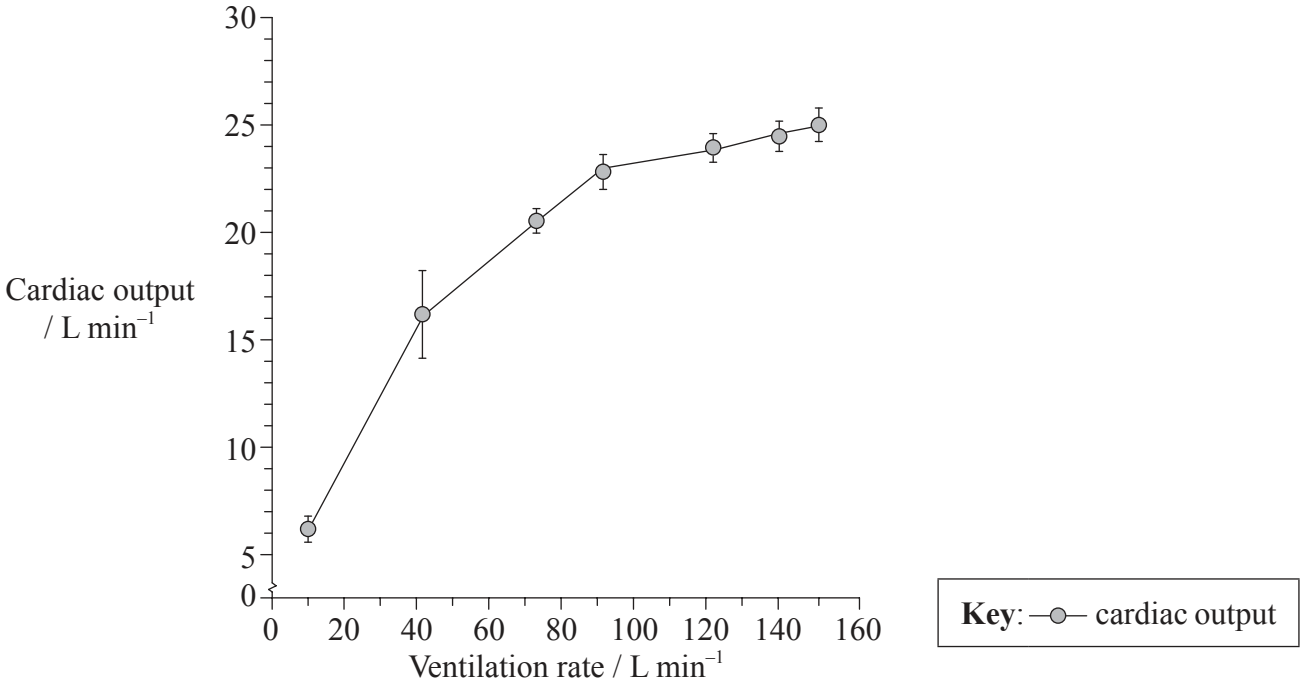
End of Option A

Option B — Physiology of exercise

4. During a study on exercise, researchers obtained the following data on the heart function of athletes as they increased their work rate up to the maximum. The work rate is indicated by the ventilation rate, which is the total volume of gas exchanged by the lungs in one minute.





[Source: Adapted from I. Vogiatzis *et al.* (2009) 'Intercostal muscle blood flow limitation in athletes during maximal exercise', *The Journal of Physiology*, 587 (14), pp. 3665–3677. © 2009 The Authors. Journal compilation © 2009 The Physiological Society.]

(Option B continues on the following page)

(Option B, question 4 continued)

(a) State the highest cardiac output, giving the units. *[1]*

. . . . . .

(b) Compare the trends in heart rate and cardiac output as ventilation rate increases. *[2]*

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(c) Giving **one** reason, deduce which ventilation rate value is likely to correspond to VO_2 max, giving the units. *[2]*

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(d) Using all the data, explain how the cardiac output responds to increases in the work rate. *[2]*

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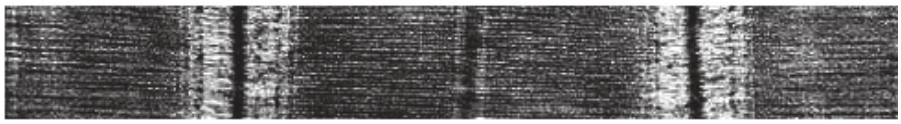
(Option B continues on the following page)

(Option B continued)

5. (a) On the electron micrograph of a muscle section below, label a

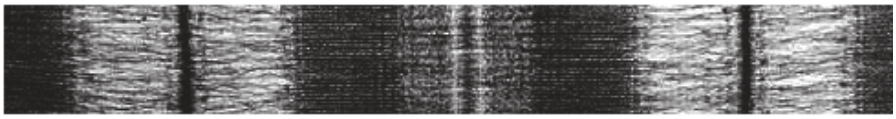
(i) Z line. *[1]*

(ii) dark band. *[1]*



[Source: Used with permission.]

(b) The following electron micrograph of a muscle section has the same magnification as (a).



[Source: Used with permission.]

Identify the state of contraction of this muscle. *[1]*

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(Option B continues on the following page)

(Option B, question 5 continued)

(c) Distinguish between fast muscle fibres and slow muscle fibres. *[2]*

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(d) State which organ receives lactate after an oxygen debt is created. *[1]*

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6. (a) Discuss the need for warm-up routines. *[2]*

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(b) Explain the need for increases in ventilation volume and rate during exercise. *[3]*

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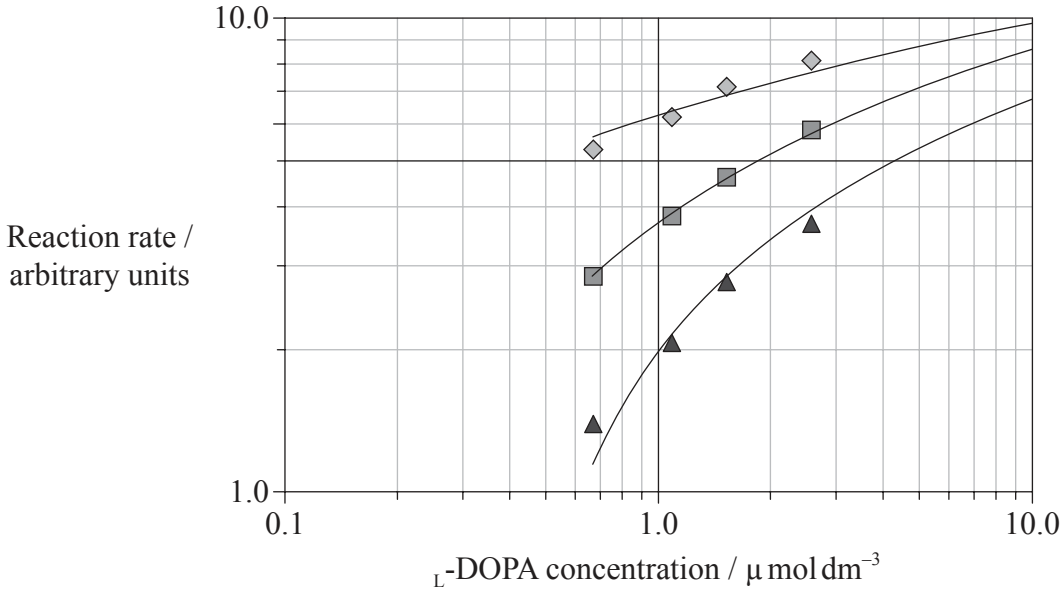
End of Option B

Option C — Cells and energy

7. The black pigment melanin occurs in the skin and hair of animals and is also found in some plants. Plant material can turn brown due to the production of melanin formed by the oxidation of the substrate $_{L}$-DOPA by the enzyme tyrosinase. In an experiment to discover how to prevent food from turning brown, scientists recorded the reaction rate while adding 6-hydroxykaempferol (HK), an inhibitor of tyrosinase. This was repeated with different concentrations of HK and substrate. In each experiment the same concentration of tyrosinase was used. The results are shown in the graph.



[Source: Adapted from H. Gao *et al.* (2007), 'Inhibitory Effects of 5,6,7-Trihydroxyflavones on Tyrosinase', *Molecules*, 12, pp. 86–97, Figure 3.]

(a) State the effect of increasing $_{L}$-DOPA concentration on the reaction rate. *[1]*

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(Option C continues on the following page)

(Option C, question 7 continued)

(b) Outline the effect of increasing the HK concentration on the reaction rate as $_{L}$-DOPA concentration varies. *[2]*

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(c) Using the data, comment on the evidence that HK is a competitive inhibitor of tyrosinase. *[1]*

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(d) Evaluate the use of HK in preventing food from turning brown. *[2]*

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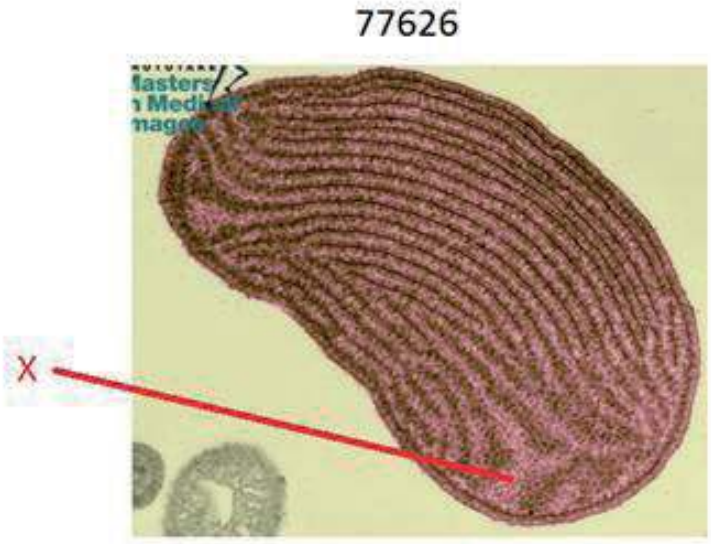
(Option C continues on the following page)

(Option C continued)

8. (a) The following electron micrograph has a magnification of ×44 000.



[Source: ©Phototake Image 77626. Used with permission.]

(i) State the name of the main organelle in the electron micrograph. *[1]*

. . . . . .

(ii) Identify the area labelled X. *[1]*

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(Option C continues on the following page)

(Option C, question 8 continued)

(b) Explain the relationship between the action spectrum and the absorption spectrum in photosynthetic plants. *[2]*

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(c) Annotate the table with **either** the term "gain" **or** "loss". *[2]*

	"gain" or "loss"		"gain" or "loss"	
Oxidation is the	. . . . .	of electrons or the	. . . . .	of oxygen
Reduction is the	. . . . .	of electrons or the	. . . . .	of hydrogen

(d) State **one** function of proteins other than membrane proteins, with a **named** example. *[1]*

Function: . . . . . .

Named example: . . . . . .

(Option C continues on the following page)

(Option C continued)

9. (a) Explain the significance of polar and non-polar amino acids in proteins. *[2]*

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(b) Explain how a molecule of pyruvate is used in aerobic respiration. *[3]*

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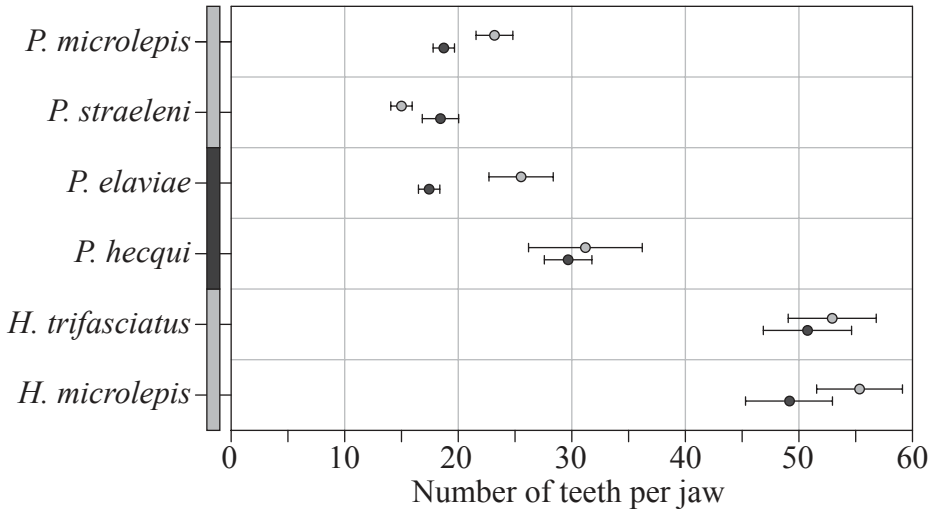
End of Option C

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

Answers written on this page
will not be marked.

Option D — Evolution

10. Scientists examined the teeth of a group of related species of cichlid fishes in Lake Tanganyika, Africa, to determine their evolutionary relationship. The group contains six species from two genera, *Perissodus* and *Haplotaxodon*. The chart shows the number of teeth per jaw of these species and indicates whether each is adapted to feed in shallow water or deep water. Species from the genus *Perissodus* are known for their unique feeding habit of eating the scales of other fish.



Key: ○ upper jaw ● lower jaw ▯ shallow water ▮ deep water

[Source: Adapted from R. Takahashi *et al.* (2007) 'Evolution of feeding specialization in Tanganyikan scale-eating cichlids: a molecular phylogenetic approach', *BMC Evolutionary Biology*, 7 (195), Figure 5.]

(a) State the mean number of teeth on the upper jaw of *P. straeleni*. *[1]*

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(Option D continues on the following page)

(Option D, question 10 continued)

(b) Compare the teeth on the upper and lower jaw of *P. elaviae* and *P. hecqui*. *[2]*

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(c) *P. elaviae* and *H. microlepis* both evolved from a common ancestor. Suggest how they became different species. *[3]*

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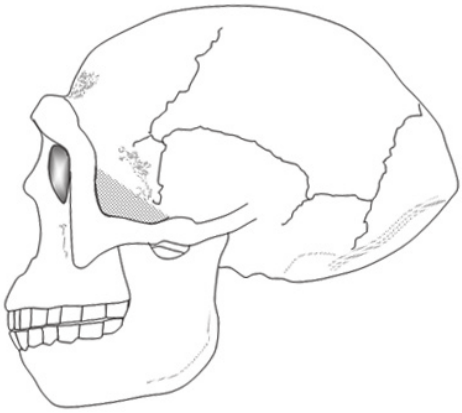
(Option D continues on the following page)

(Option D continued)

11. (a) The following drawing illustrates the fossilized skull of *Homo erectus*.



[Source: svt Dijon. Used with permission.]

(i) State **one** feature of *Homo erectus* which distinguishes the skull from *Homo sapiens*. *[1]*

. . . . . .

(ii) State the approximate date when *Homo erectus* first appeared. *[1]*

. . . . . .

(Option D continues on the following page)

(Option D, question 11 continued)

(b) (i) Define the term *gene pool*. *[1]*

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(ii) Describe **two** examples of barriers between gene pools. *[2]*

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2. . . . . .
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(c) State how organic compounds may have been carried to Earth from space. *[1]*

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(d) Identify **two** properties of RNA which may have contributed to the origin of life. *[2]*

1. . . . . .

2. . . . . .

(Option D continues on the following page)

(Option D continued)

12. (a) Discuss the relative importance of genetic and cultural evolution in the recent evolution of humans. *[2]*

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(b) Discuss the definition of the term species. *[2]*

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End of Option D

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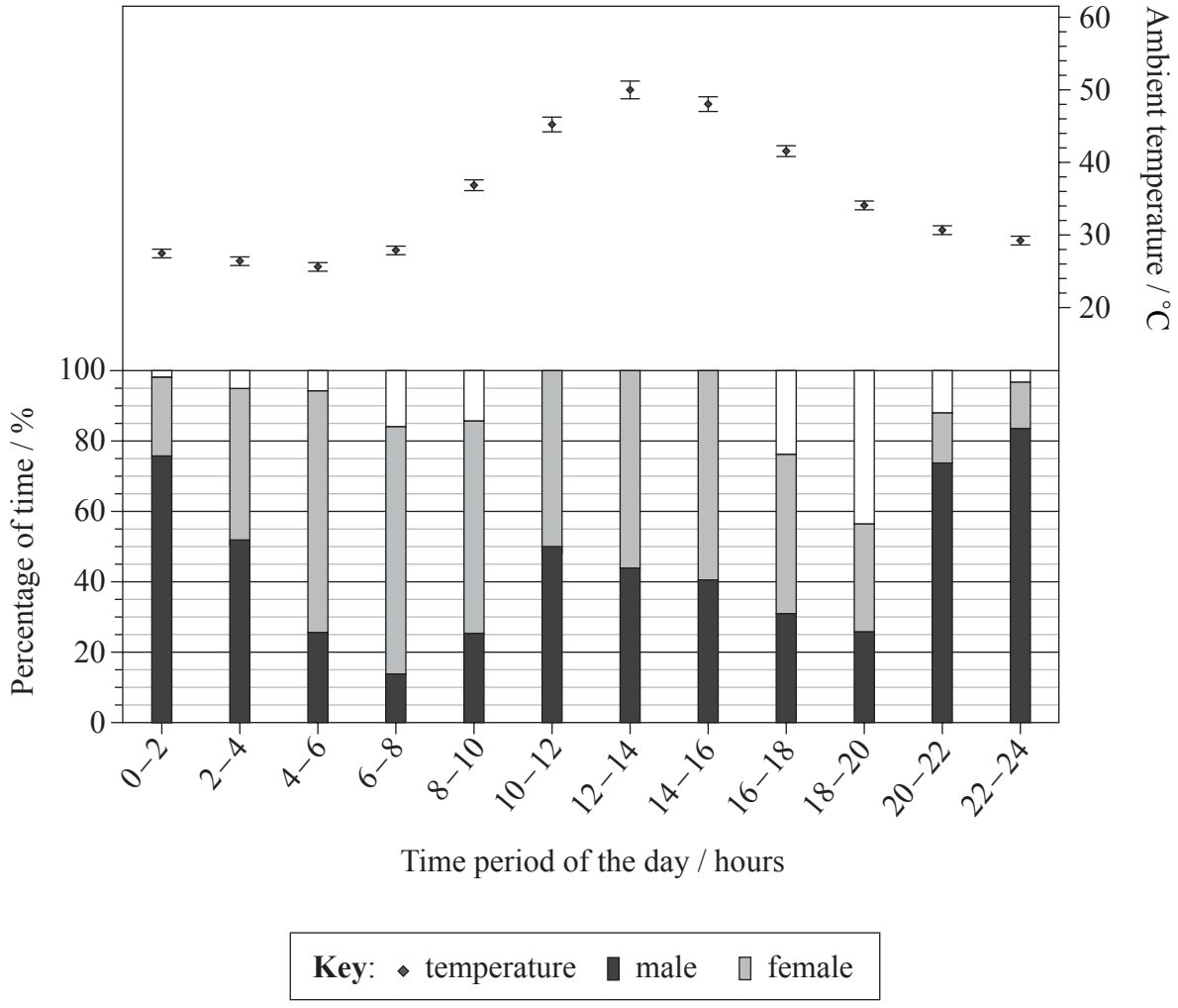
Answers written on this page
will not be marked.

Option E — Neurobiology and behaviour

13. Kentish plovers (*Charadrius alexandrinus*) are birds that make their nests on the ground by the sea in Abu Dhabi, United Arab Emirates. The amount of time spent by male or female birds sitting on their eggs was recorded over a 24 hour period. The air temperature was also recorded over the same 24 hour period. Leaving the eggs unattended for a short time can cause overheating of the eggs and death of embryos.



[Source: Adapted from M. AlRashidi *et al.* (2010), 'The influence of a hot environment on parental cooperation of a ground-nesting shorebird, the Kentish plover Charadrius alexandrines', *Frontiers in Zoology*, 7(1), Figure 1.]

(a) Calculate the amount of time female Kentish plovers sit on their eggs in the time period 10 to 12. *[1]*

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(Option E continues on the following page)

(Option E, question 13 continued)

(b) (i) Identify the time period of the day during which the percentage of time spent sitting on the eggs by males and females was lowest. *[1]*

. . . . . hours

(ii) Suggest reasons for the percentage of time spent sitting on the eggs being higher at other times. *[2]*

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(c) Both males and female birds need to forage for food. Predict with a reason, the time periods of the day when males are most likely to forage for food. *[2]*

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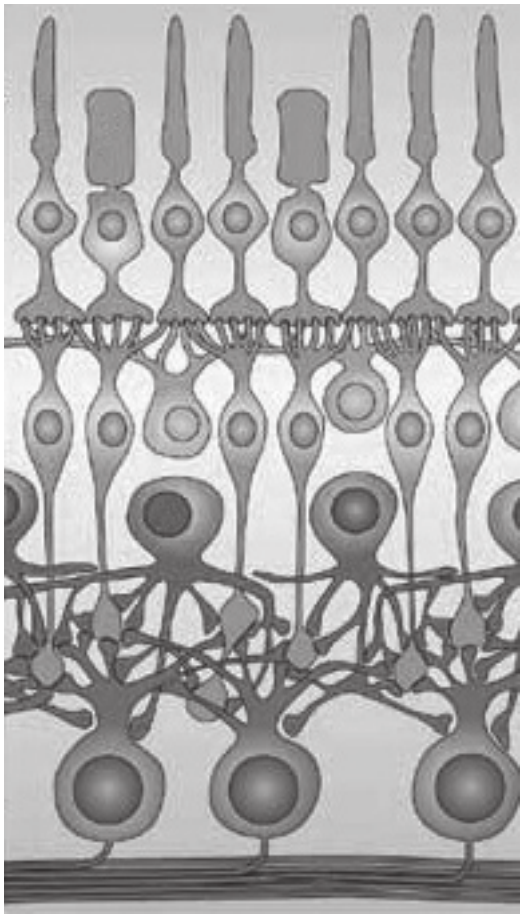
(Option E continues on the following page)

(Option E continued)

14. (a) The following diagram represents the organization of the retina.



[Source: Reprinted by permission from Macmillan Publishers Ltd. Adapted from Heinz Wässle (2004), 'Parallel processing in the mammalian retina', *Nature Reviews Neuroscience*, 5, pp. 747–757. doi: 10.1038/nrn1497.]

(i) Label a bipolar neuron on the diagram. *[1]*

(ii) Using an arrow, annotate the diagram to show the direction in which light moves. *[1]*

(Option E continues on the following page)

(Option E, question 14 continued)

(b) Distinguish between rod cells and cone cells. *[2]*

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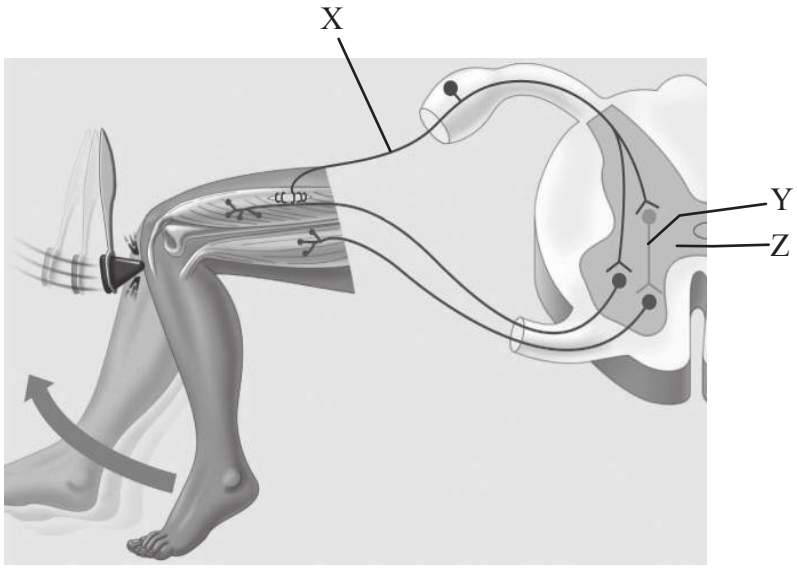
(Option E continues on the following page)

(Option E, question 14 continued)

(c) The following diagram shows a reflex arc.



[Source: CAMPBELL, NEIL A., REECE, JANE B., BIOLOGY, 7th edition © 2005. Reprinted by permission of Pearson Inc, Upper Saddle River, NJ.]

(i) Using an arrow, annotate the diagram to show the direction of the impulse in X. *[1]*

(ii) Label cells X and Y. *[1]*

X: . . . . . .

Y: . . . . . .

(iii) Label structure Z. *[1]*

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(Option E continues on the following page)

(Option E continued)

15. (a) Explain contralateral processing. *[2]*

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(b) Explain the effect of the interaction between the activities of excitatory and inhibitory presynaptic neurons at synapses on the central nervous system. *[3]*

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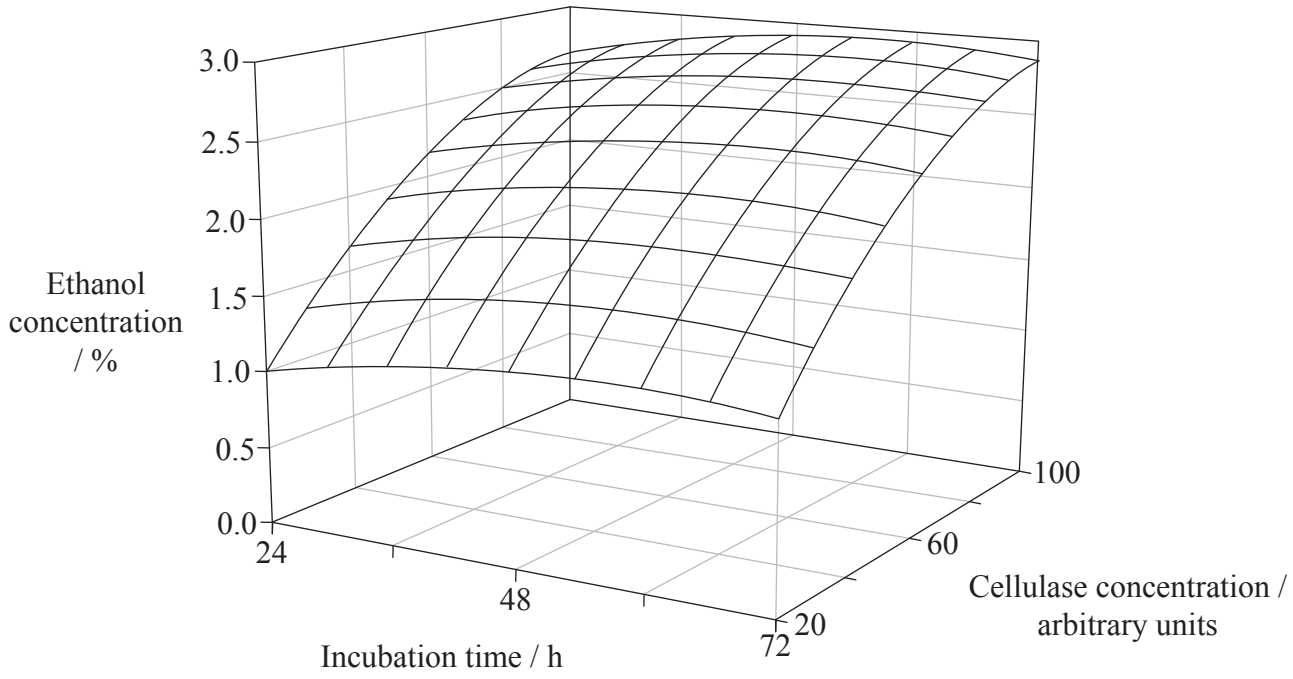
End of Option E

Option F — Microbes and biotechnology

16. Saccharification and fermentation (SSF) of cellulose is a process used to produce ethanol for fuel. Researchers used the leaves of the Mexican coral vine (*Antigonum leptopus*) as a source of cellulose. The leaves were mixed with *Saccharomyces cerevisiae* and cellulase obtained from the fungus *Trichoderma reesei* at the optimum temperature of 38.5 °C. The amount of ethanol produced was measured. The experiment was repeated while varying the concentration of cellulase and the incubation time.



[Source: Adapted with permission from S. Hari Krishna and G. V. Chowdary (2000) 'Optimization of Simultaneous Saccharification and Fermentation for the Production of Ethanol from Lignocellulosic Biomass', *The Journal of Agricultural and Food Chemistry*, 48, pages 1971–1976. © 2000 American Chemical Society.]

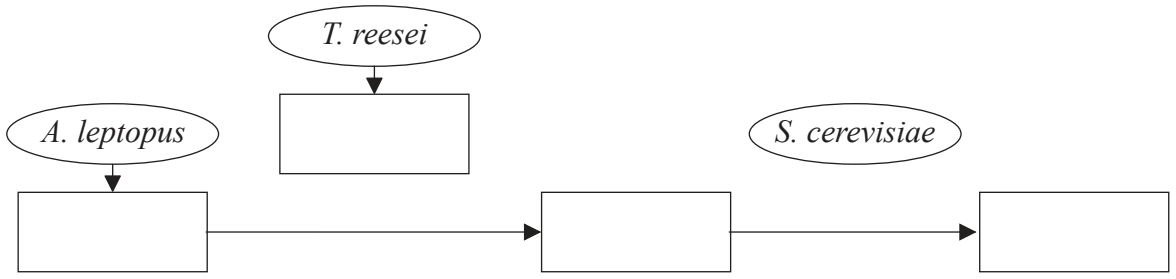
(a) State the ethanol concentration after 24 hours of incubation with 20 units of cellulase. *[1]*

. . . . . %

(Option F continues on the following page)

(Option F, question 16 continued)

(b) Construct a flow diagram showing the substances (boxes) and the role of each organism (ovals) involved in this process, by completing the four empty boxes below. *[2]*



(c) Compare the effect of cellulase concentration with incubation time on ethanol concentration. *[2]*

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(d) The highest ethanol concentration occurs at 100 units of cellulase after 54 hours of incubation. Suggest why industrial ethanol producers might choose different conditions. *[2]*

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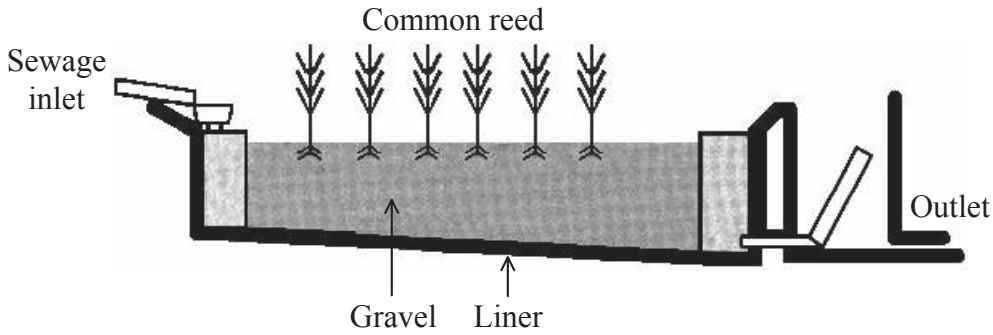
(Option F continues on the following page)

(Option F continued)

17. (a) (i) Using an arrow, annotate the diagram to show the path of nitrates from their entry from the sewage inlet into the reed bed system. *[1]*



[Source: Adapted from Alan Feest, Ian Merrill and Philippa Aukett (2011) 'Does Botanical Diversity in Sewage Treatment Reed-Bed Sites Enhance Invertebrate Biodiversity?', *International Journal of Ecology*, Volume 2012 (2012), Article ID 324295, 9 pages http://dx.doi.org/10.1155/2012/324295.]

(ii) Outline the role of saprotrophic bacteria in this reed bed system. *[1]*

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(iii) State the role of *Rhizobium* in the nitrogen cycle. *[1]*

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(b) State the role of reverse transcriptase in molecular biology. *[1]*

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(Option F continues on the following page)

(Option F, question 17 continued)

(c) State **one** example of bacteria forming aggregates that show characteristics not seen in individual bacteria. *[1]*

Name of bacterium: . . . . . .

Characteristic in aggregates: . . . . . .

18. (a) Outline the symptoms, method of transmission and treatment of a **named** food poisoning. *[3]*

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(b) Discuss the risks of gene therapy. *[3]*

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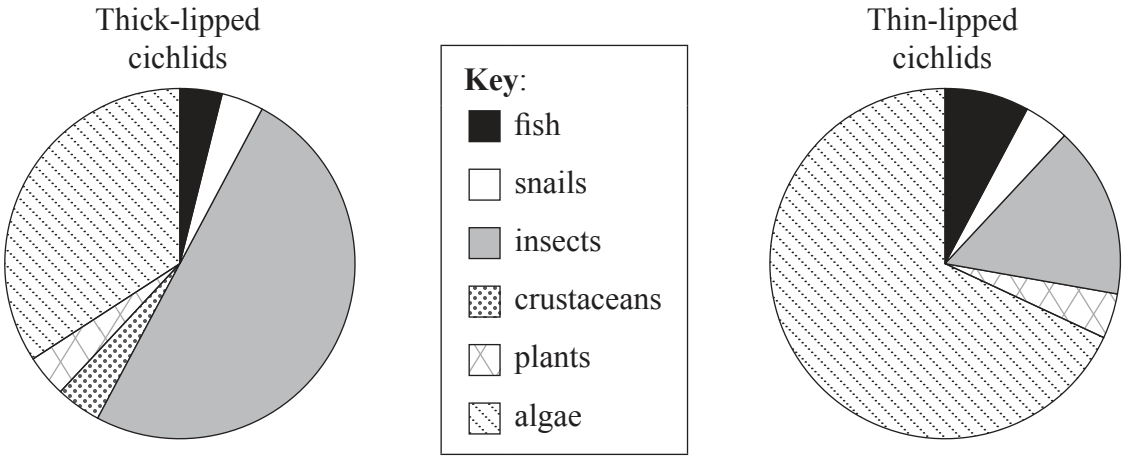
End of Option F

Option G — Ecology and conservation

19. Cichlid fishes of the genus *Amphilophus* live in crater lakes in Nicaragua. Scientists studying the niches of two groups analysed the composition of the stomach contents. The pie charts show the food eaten by the thick-lipped cichlids and thin-lipped cichlids.



[Source: Adapted from Kathryn R. Elmer, Topi K. Lehtonen, Andreas F. Kautt, Chris Harrod and Axel Meyer (2010) 'Rapid sympatric ecological differentiation of crater lake cichlid fishes within historic times', *BMC Biology*, 10 (70), Figure 4a.]

(a) State the percentage of insects in the diet of thick-lipped cichlids. *[1]*

. . . . . .

(b) Compare the food of the thick-lipped and thin-lipped cichlids. *[2]*

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(Option G continues on the following page)

(Option G, question 19 continued)

(c) Suggest a reason for thin-lipped cichlids not eating crustaceans. *[1]*

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(d) Discuss, using the principle of competitive exclusion, whether the thick-lipped and thin-lipped cichlids are distinct species. *[2]*

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(Option G continues on the following page)

(Option G continued)

20. (a) The following table shows the approximate production of organisms living in a salt marsh in the USA.

Organism	Trophic level	Production / kJ m^{-2} y^{-1}
Spartina (cordgrass)	Producer	15 500
Algae	Producer	8500
Insects	Primary consumer	1200
Spiders	Secondary consumer	170
Mud crabs	Secondary consumer	130
Other invertebrates	Primary consumer	1800

Construct a pyramid of energy showing the trophic levels for this salt marsh. *[3]*

(Option G continues on the following page)

(Option G, question 20 continued)

(b) Define the following terms.

(i) *Biomagnification* *[1]*

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(ii) *Biomass* *[1]*

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(c) A school football field has plantain plants (*Plantago media*) growing on it as well as grass. Each plantain plant has a short stem with a circle of wide leaves. Outline how the size of the plantain population could be estimated using a quadrat method. *[2]*

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(Option G continued)

21. (a) Explain the effects of plants on the abiotic environment during primary succession. *[2]*

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(b) Outline the effect of chlorofluorocarbons (CFCs) on the ozone layer. *[3]*

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End of Option G