

No part of this product may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without written permission from the IB.

Additionally, the license tied with this product prohibits commercial use of any selected files or extracts from this product. Use by third parties, including but not limited to publishers, private teachers, tutoring or study services, preparatory schools, vendors operating curriculum mapping services or teacher resource digital platforms and app developers, is not permitted and is subject to the IB's prior written consent via a license. More information on how to request a license can be obtained from <http://www.ibo.org/contact-the-ib/media-inquiries/for-publishers/guidance-for-third-party-publishers-and-providers/how-to-apply-for-a-license>.

Aucune partie de ce produit ne peut être reproduite sous quelque forme ni par quelque moyen que ce soit, électronique ou mécanique, y compris des systèmes de stockage et de récupération d'informations, sans l'autorisation écrite de l'IB.

De plus, la licence associée à ce produit interdit toute utilisation commerciale de tout fichier ou extrait sélectionné dans ce produit. L'utilisation par des tiers, y compris, sans toutefois s'y limiter, des éditeurs, des professeurs particuliers, des services de tutorat ou d'aide aux études, des établissements de préparation à l'enseignement supérieur, des fournisseurs de services de planification des programmes d'études, des gestionnaires de plateformes pédagogiques en ligne, et des développeurs d'applications, n'est pas autorisée et est soumise au consentement écrit préalable de l'IB par l'intermédiaire d'une licence. Pour plus d'informations sur la procédure à suivre pour demander une licence, rendez-vous à l'adresse <http://www.ibo.org/fr/contact-the-ib/media-inquiries/for-publishers/guidance-for-third-party-publishers-and-providers/how-to-apply-for-a-license>.

No se podrá reproducir ninguna parte de este producto de ninguna forma ni por ningún medio electrónico o mecánico, incluidos los sistemas de almacenamiento y recuperación de información, sin que medie la autorización escrita del IB.

Además, la licencia vinculada a este producto prohíbe el uso con fines comerciales de todo archivo o fragmento seleccionado de este producto. El uso por parte de terceros —lo que incluye, a título enunciativo, editoriales, profesores particulares, servicios de apoyo académico o ayuda para el estudio, colegios preparatorios, desarrolladores de aplicaciones y entidades que presten servicios de planificación curricular u ofrezcan recursos para docentes mediante plataformas digitales— no está permitido y estará sujeto al otorgamiento previo de una licencia escrita por parte del IB. En este enlace encontrará más información sobre cómo solicitar una licencia: <http://www.ibo.org/es/contact-the-ib/media-inquiries/for-publishers/guidance-for-third-party-publishers-and-providers/how-to-apply-for-a-license>.

**Biology**  
**Higher level**  
**Paper 3**

Friday 10 May 2019 (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

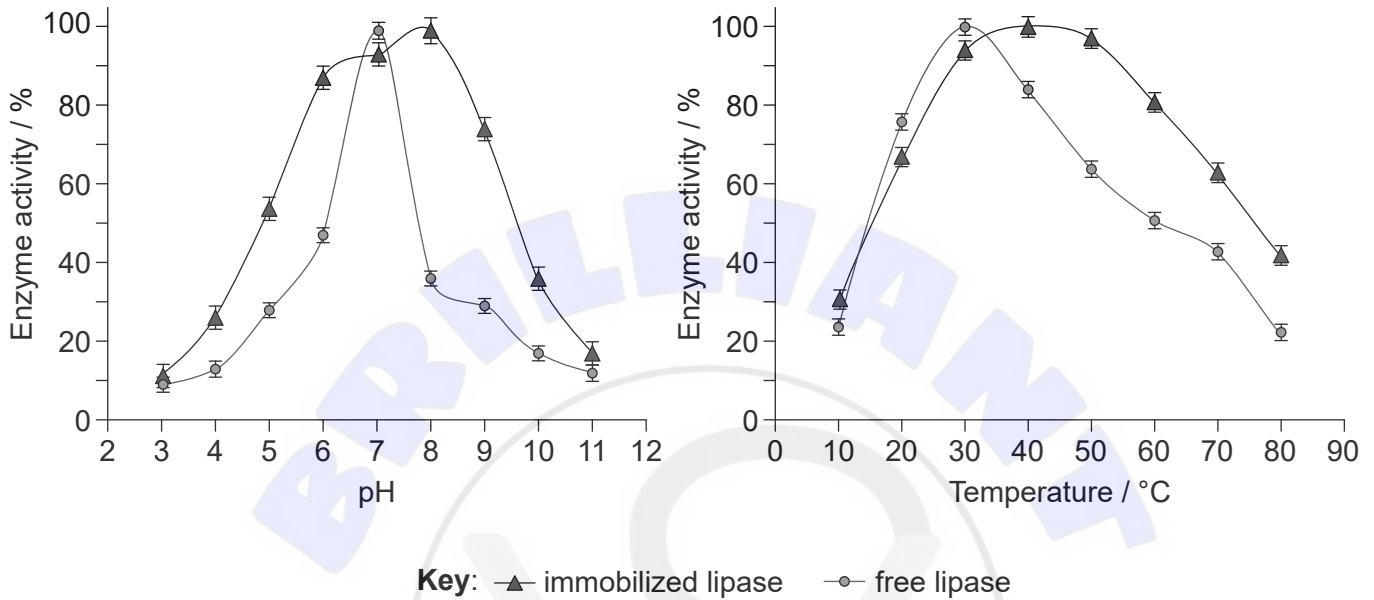
Section B	Questions
Answer all of the questions from one of the options.	
Option A — Neurobiology and behaviour	4 – 8
Option B — Biotechnology and bioinformatics	9 – 13
Option C — Ecology and conservation	14 – 19
Option D — Human physiology	20 – 24



### Section A

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

1. Lipase was extracted from the fungus *Aspergillus niger* and used to hydrolyse one of its substrates. This was repeated for an immobilized form of lipase. The graph shows how the enzyme activity varied at different pH and temperature levels.



[Source: adapted from Zdarta, J.; Klapiszewski, Ł.; Wysokowski, M.; Norman, M.; Kołodziejczak-Radzimska, A.; Moszyński, D.; Ehrlich, H.; Maciejewski, H.; Stelling, A.L.; Jesionowski, T. Chitin-Lignin Material as a Novel Matrix for Enzyme Immobilization. *Mar. Drugs* 2015, **13**, 2424–2446.]

- (a) State the effect immobilization of lipase has on its optimum temperature. [1]

.....

.....

- (b) The graph of the effect of pH on immobilized lipase activity does not allow for the determination of optimum pH precisely. Explain how a more exact value for the optimum pH could be determined. [2]

.....

.....

.....

.....

(This question continues on the following page)



(Question 1 continued)

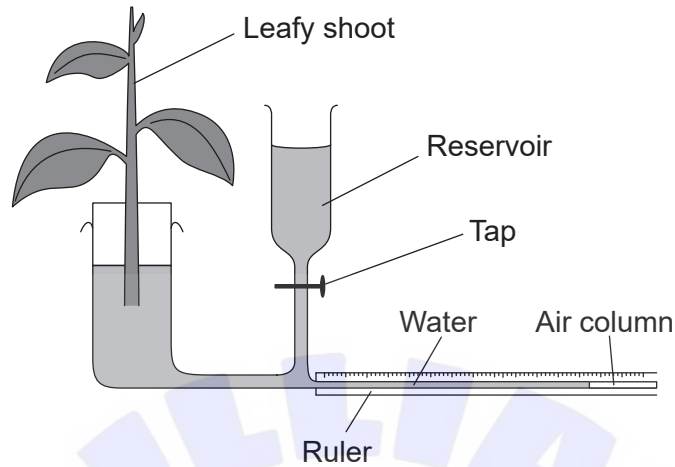
(c) Based on these experimental results, suggest **one** advantage of immobilizing lipase. [1]

.....

.....



2. A leafy shoot was cut from a plant and connected to a potometer to measure the transpiration rate. The length of the air column in the glass tube was measured using the ruler.



[Source: © International Baccalaureate Organization 2019]

- (a) State the function of the tap and reservoir. [1]

.....

- (b) Describe how the apparatus could be used to demonstrate that the transpiration rate is affected by air movement. [3]

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

(This question continues on the following page)



**(Question 2 continued)**

- (c) One criticism of the experiment is that it only measured the rate of transpiration indirectly. Explain how the experiment is an indirect measurement of transpiration. [2]

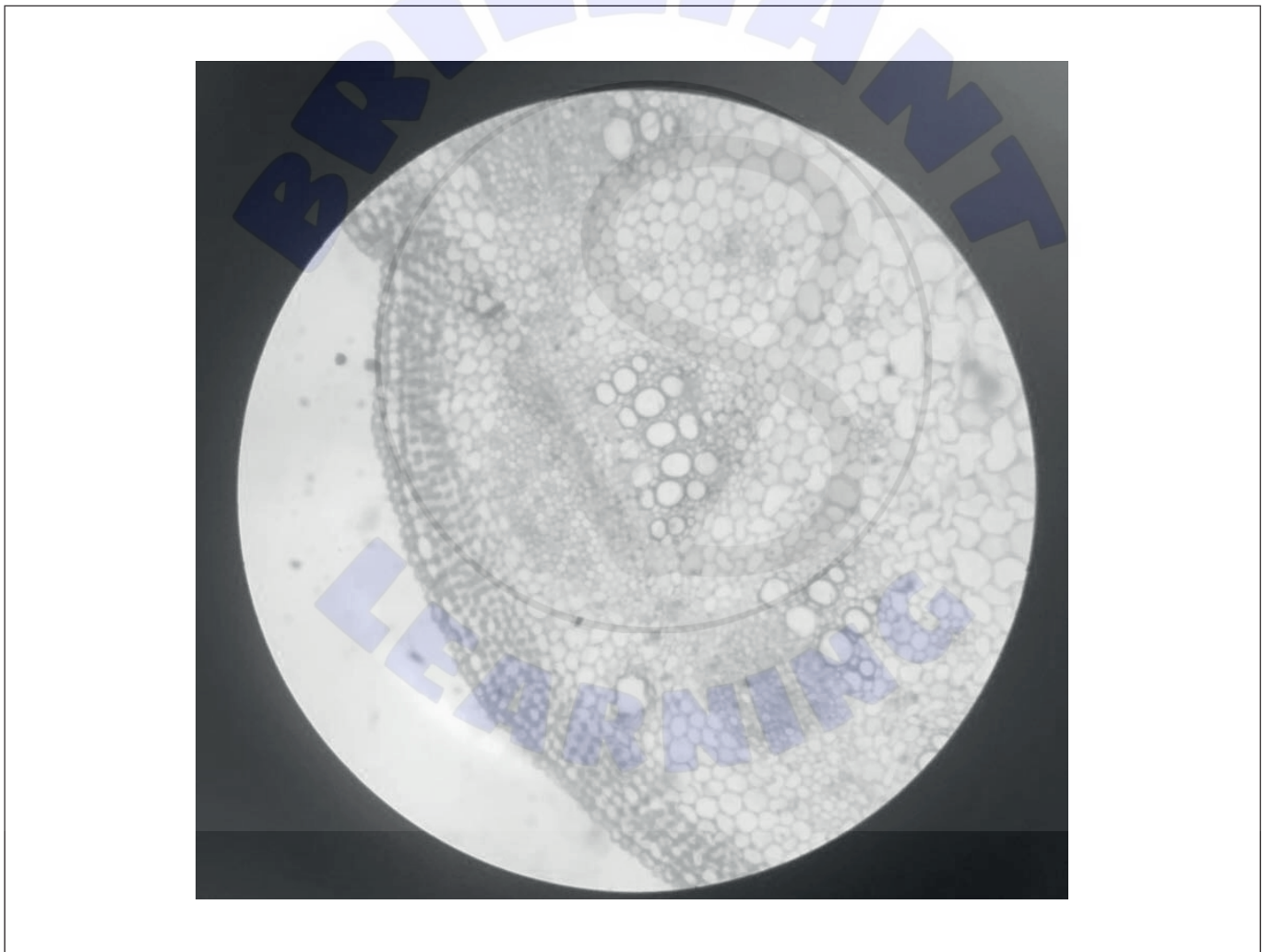
.....

.....

.....

.....

- (d) Red dye was added to the water in the potometer. A cross section of the stem was observed under the light microscope.



[Source: Nbnidhi, [https://commons.wikimedia.org/wiki/File:Transverse\\_section\\_of\\_dicot\\_stem.jpg](https://commons.wikimedia.org/wiki/File:Transverse_section_of_dicot_stem.jpg)]

- (i) Label with an R the tissue where the red dye would appear. [1]
- (ii) Label with a C the tissue where organic compounds are transported. [1]



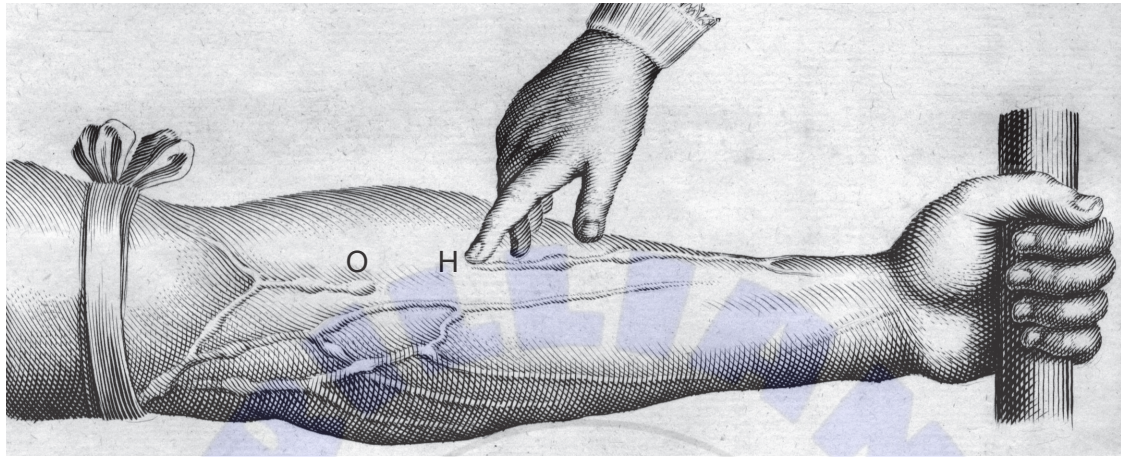


Please **do not** write on this page.

Answers written on this page  
will not be marked.



3. In 1628, the physician William Harvey described details of the circulation of blood for the first time. In one experiment, he tied a tight bandage around the upper arm of a volunteer to display the blood vessels in the lower arm more clearly. He pressed his finger on the blood vessel at H. At the same time, he pushed the blood in the vessel from H to O with a second finger, removing the blood as shown in the diagram. When the finger at H was released, the blood vessel refilled with blood.



[Source: adapted from William Harvey original plate]

- (a) Identify the type of blood vessels shown in the diagram. [1]

.....

- (b) Deduce what the experiment demonstrated about the circulation of blood. [2]

.....  
.....  
.....  
.....



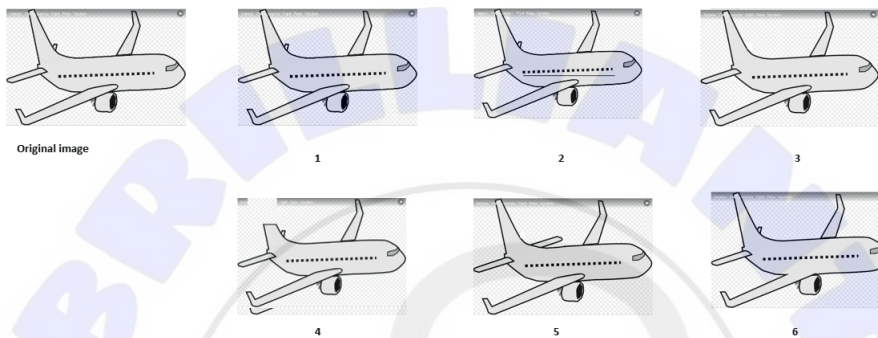


### Section B

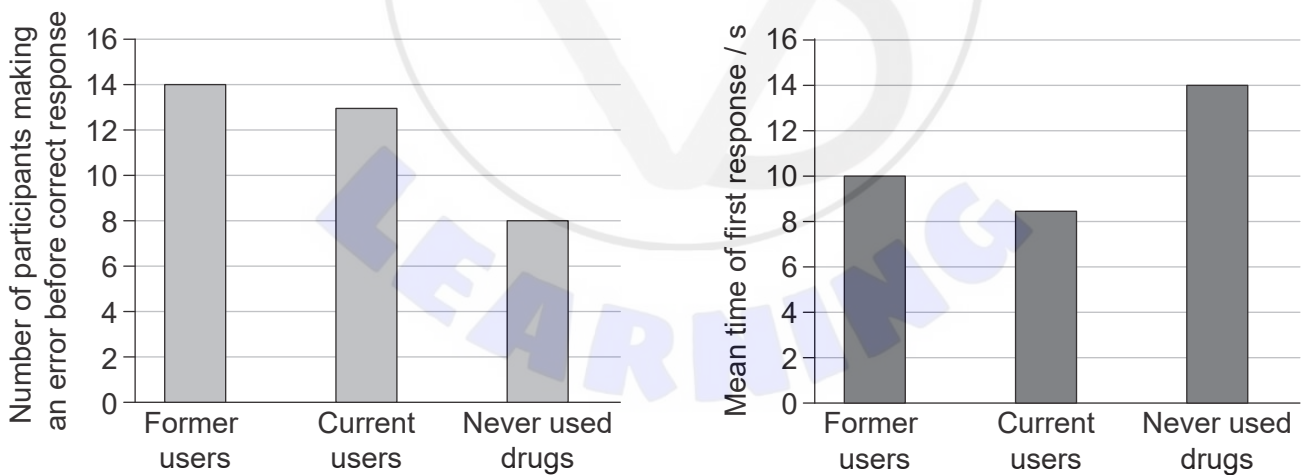
Answer **all** of the questions from **one** of the options. Answers must be written within the answer boxes provided.

#### Option A — Neurobiology and behaviour

4. To investigate the effects of the drug MDMA (ecstasy) on impulsive behaviour, investigators carried out a test on former users, current users and those who had never taken the drug. Impulsive behaviours were defined by the researchers as those done quickly, without fully considering the consequences. The participants in the study were asked which of the images (1 to 6) was identical to the original image on the left.



The time and accuracy of their responses were recorded. The results are based on 15 participants per group.



[Source: National Institute on Drug Abuse; National Institutes of Health; U.S. Department of Health and Human Services]

(Option A continues on the following page)



**(Option A, question 4 continued)**

- (a) Calculate the difference in the number of former users of MDMA and those who have never used the drug making an error before a correct response. [1]

.....

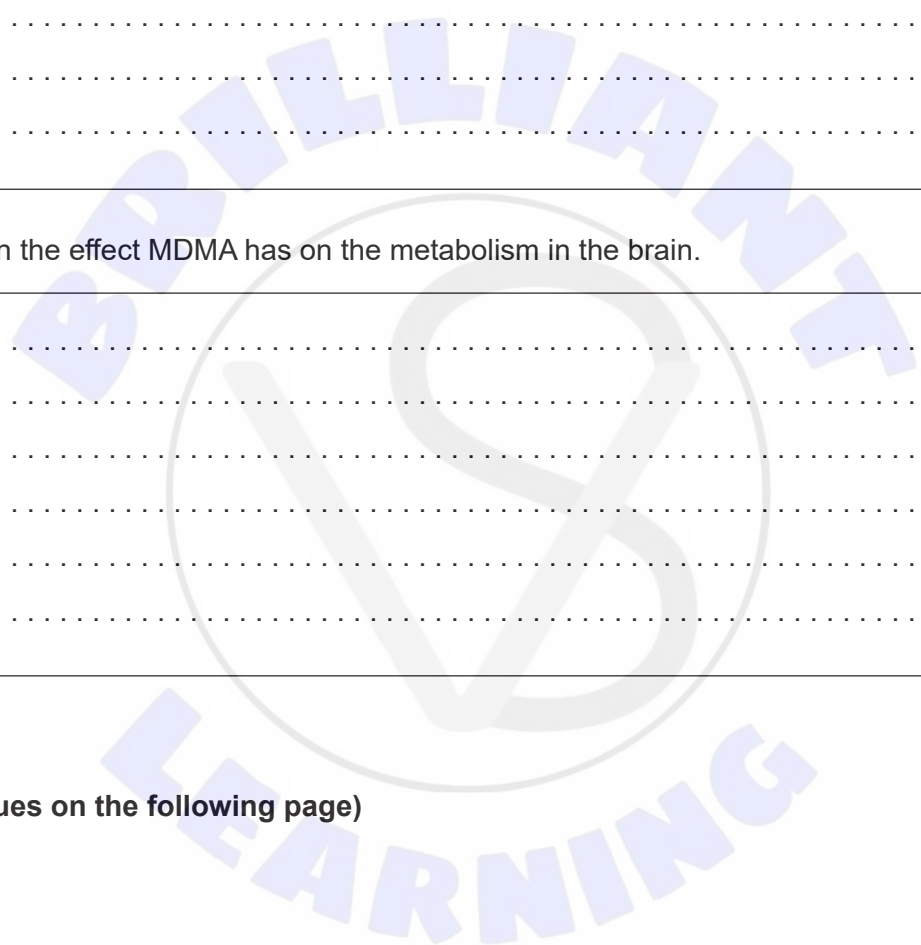
- (b) Outline the evidence that MDMA leads to impulsive behaviour. [2]

.....  
.....  
.....  
.....

- (c) Explain the effect MDMA has on the metabolism in the brain. [3]

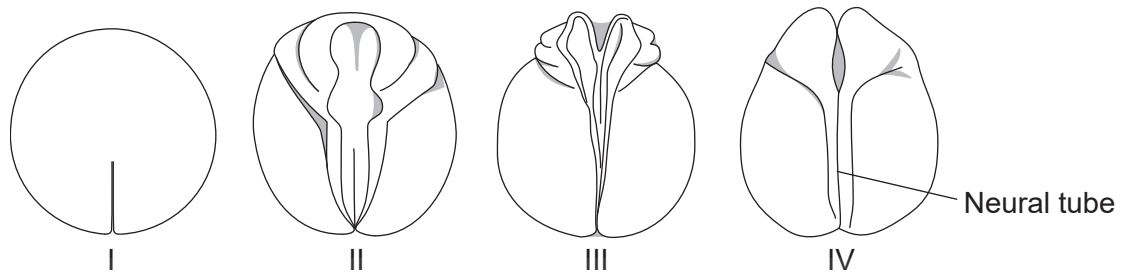
.....  
.....  
.....  
.....  
.....  
.....

**(Option A continues on the following page)**



**(Option A continued)**

5. The diagram shows part of the embryonic development in a clawed toad of the genus *Xenopus*.



[Source: © International Baccalaureate Organization 2019]

(a) Describe the process occurring in the diagram. [3]

.....

.....

.....

.....

.....

.....

(b) State what would occur in the embryo immediately after stage IV. [1]

.....

(c) Outline the consequences of incomplete closure of the neural tube in humans. [2]

.....

.....

.....

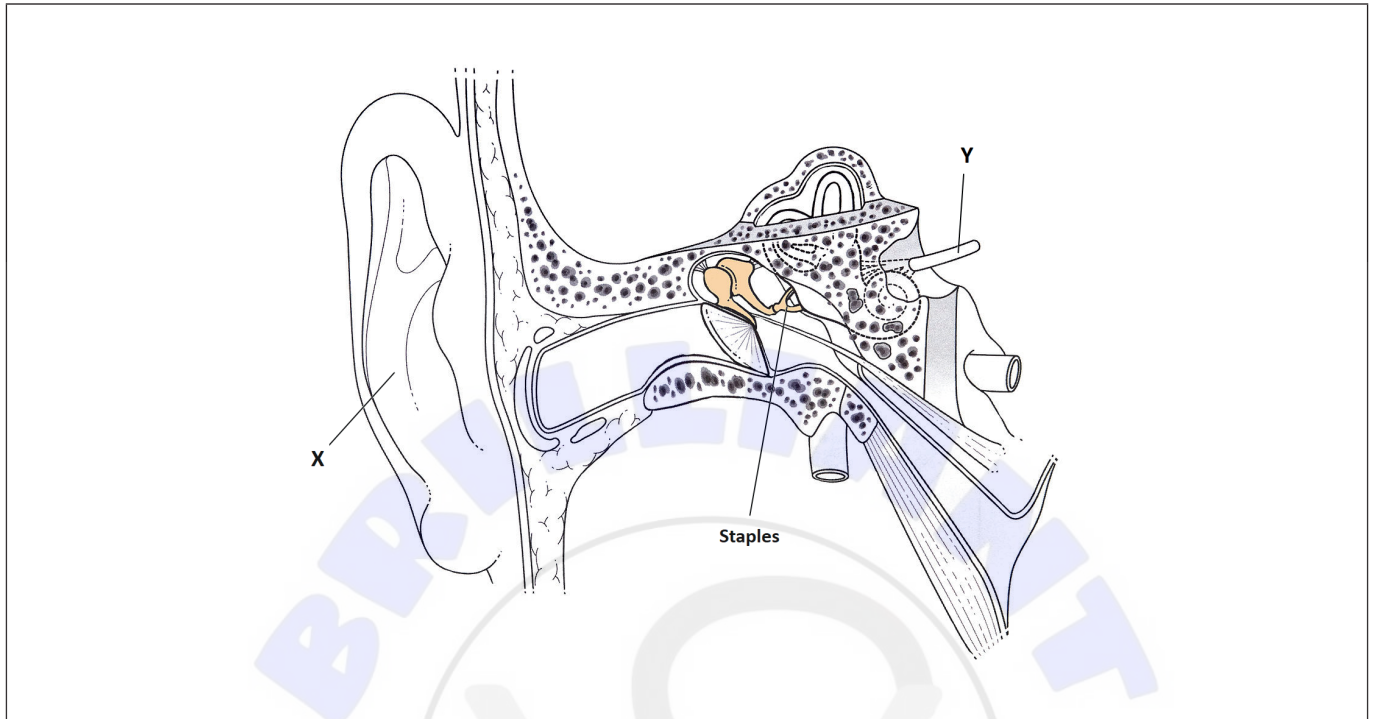
.....

**(Option A continues on the following page)**



**(Option A continued)**

6. The diagram shows the human ear.



[Source: Didier Descouens, [https://commons.wikimedia.org/wiki/Category:Human\\_middle\\_ear#/media/File:Place-des-osselets-Schema.jpg](https://commons.wikimedia.org/wiki/Category:Human_middle_ear#/media/File:Place-des-osselets-Schema.jpg), licensed under CC BY-SA 3.0]

(a) Identify the structures labelled X and Y in the diagram. [2]

X: .....

Y: .....

(b) Identify the structure in the inner ear that is in contact with the stapes. [1]

.....

**(Option A continues on the following page)**



**(Option A, question 6 continued)**

(c) Explain the function of the semicircular canals.

[3]

.....

.....

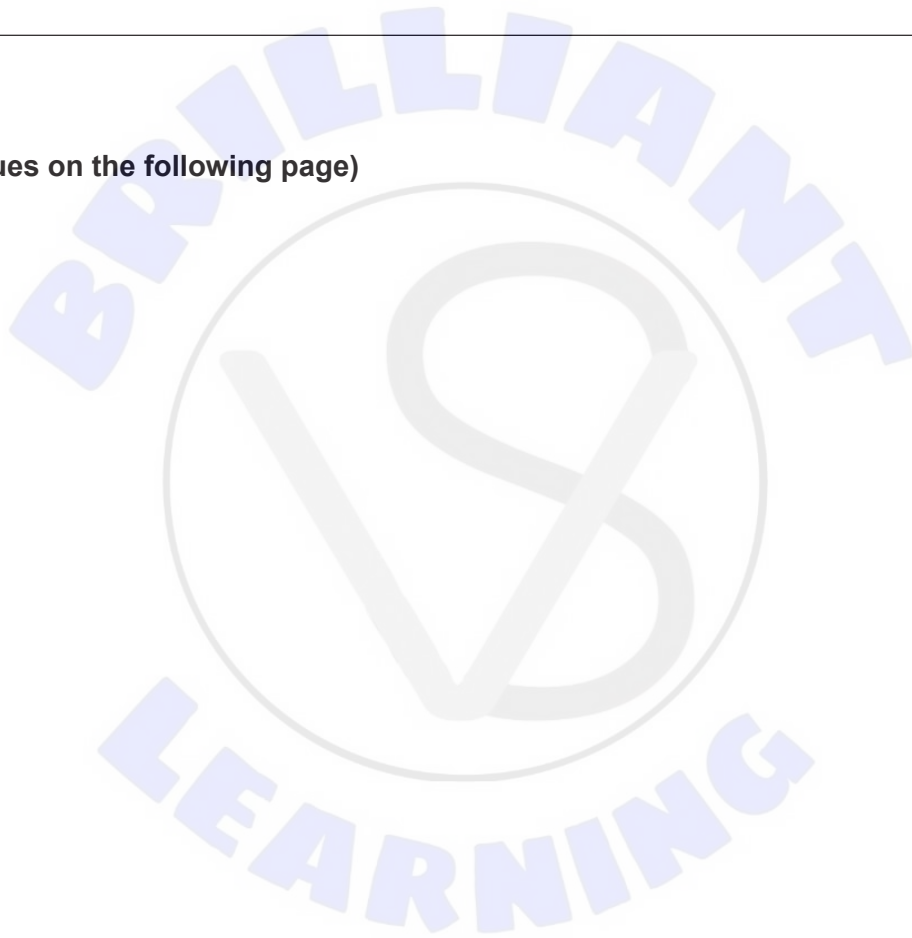
.....

.....

.....

.....

**(Option A continues on the following page)**



**(Option A continued)**

7. The diagram shows a section through the human brain.



[Source: <https://pixabay.com/vectors/brain-anatomy-human-medicine-150935/>]

- (a) (i) Label the diagram to show part of the visual cortex of the brain. [1]
- (ii) Outline how the diagram can be identified as a human brain and not the brain of a monkey. [2]

.....

.....

.....

.....

**(Option A continues on the following page)**



**(Option A, question 7 continued)**

- (b) Explain how studies of lesions have helped to identify the functions of different parts of the brain.

[3]

.....

.....

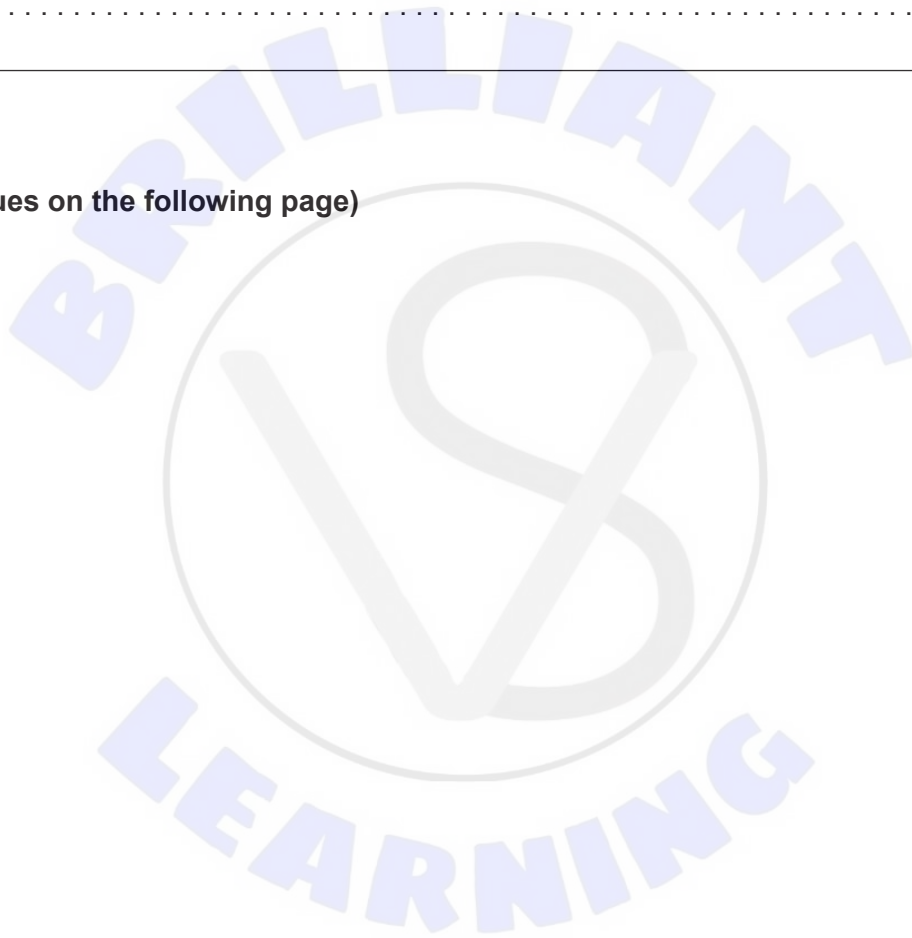
.....

.....

.....

.....

**(Option A continues on the following page)**



**(Option A continued)**

- 8. A dog owner wants to teach a dog to stop jumping up on people.



[Source: © Nevit Dilmen]

Explain how operant conditioning could be used to train the dog.

[6]

A large rectangular area containing horizontal dotted lines for writing the answer. A large, faint watermark reading 'BRILLIANT LEARNING' is visible across the center of this area.

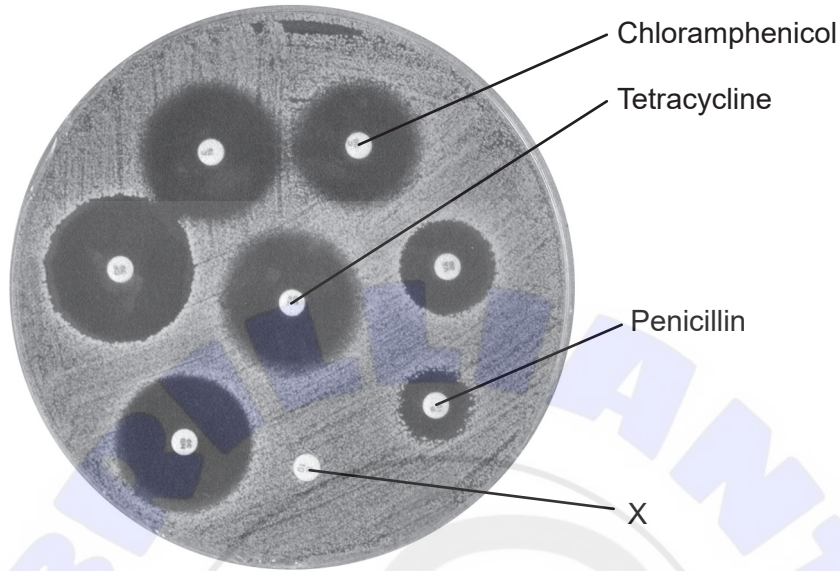
**End of Option A**





**Option B — Biotechnology and bioinformatics**

9. Discs were soaked in different antibiotics and were placed on a culture of *Bacillus subtilis* spread on sterile agar in a Petri dish. The Petri dish was left in an incubator, after which zones of inhibition were observed surrounding some of the discs. The photograph is to scale.



[Source: Tasha L. Sturm. 2009. Kirby-Bauer disk diffusion susceptibility test. Visual Resources. American Society for Microbiology, Washington, DC. www.microbelibrary.org Accessed 29 September 2014]

- (a) (i) Estimate the diameter of the zone of inhibition of chloramphenicol. [1]

.....

- (ii) Distinguish between the action of tetracycline and penicillin on *B. subtilis*. [1]

.....  
.....

- (iii) Suggest a reason for the result with disc X. [1]

.....  
.....

**(Option B continues on the following page)**



**(Option B, question 9 continued)**

(b) Explain how it could be determined that *B. subtilis* is a Gram-positive bacterium. [2]

.....  
.....  
.....  
.....

(c) *B. subtilis* colonies form biofilms through quorum sensing.

(i) Define quorum sensing. [1]

.....  
.....

(ii) State **three** possible advantages to *B. subtilis* of forming a biofilm. [3]

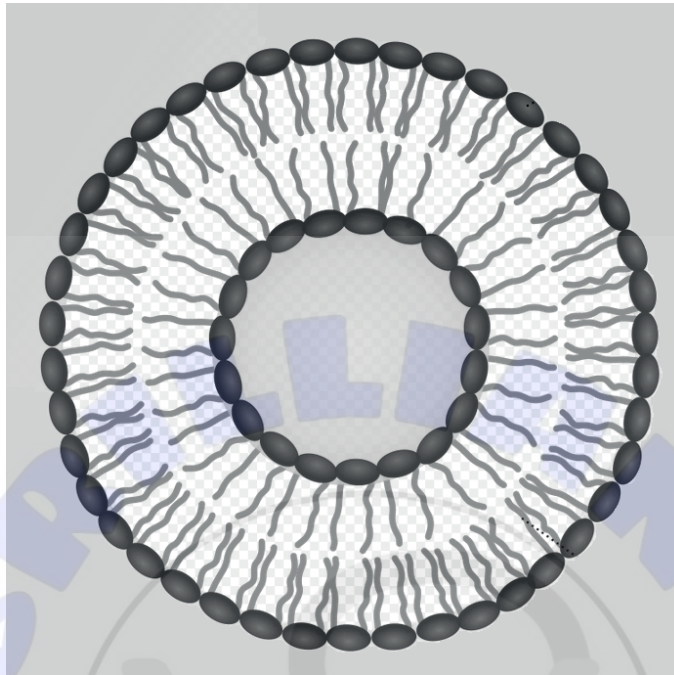
1. ....  
2. ....  
3. .....

**(Option B continues on the following page)**



**(Option B continued)**

- 10. The diagram shows a spherical array of phospholipid molecules enclosing a water droplet. Such structures can be used to introduce genes into plant protoplasts.



[Source: SuperManu, [https://en.wikipedia.org/wiki/Liposome#/media/File:Liposome\\_scheme-en.svg](https://en.wikipedia.org/wiki/Liposome#/media/File:Liposome_scheme-en.svg)]

Explain briefly how plant protoplasts are prepared and how vesicles can be used to introduce genes into them.

[3]

.....

.....

.....

.....

.....

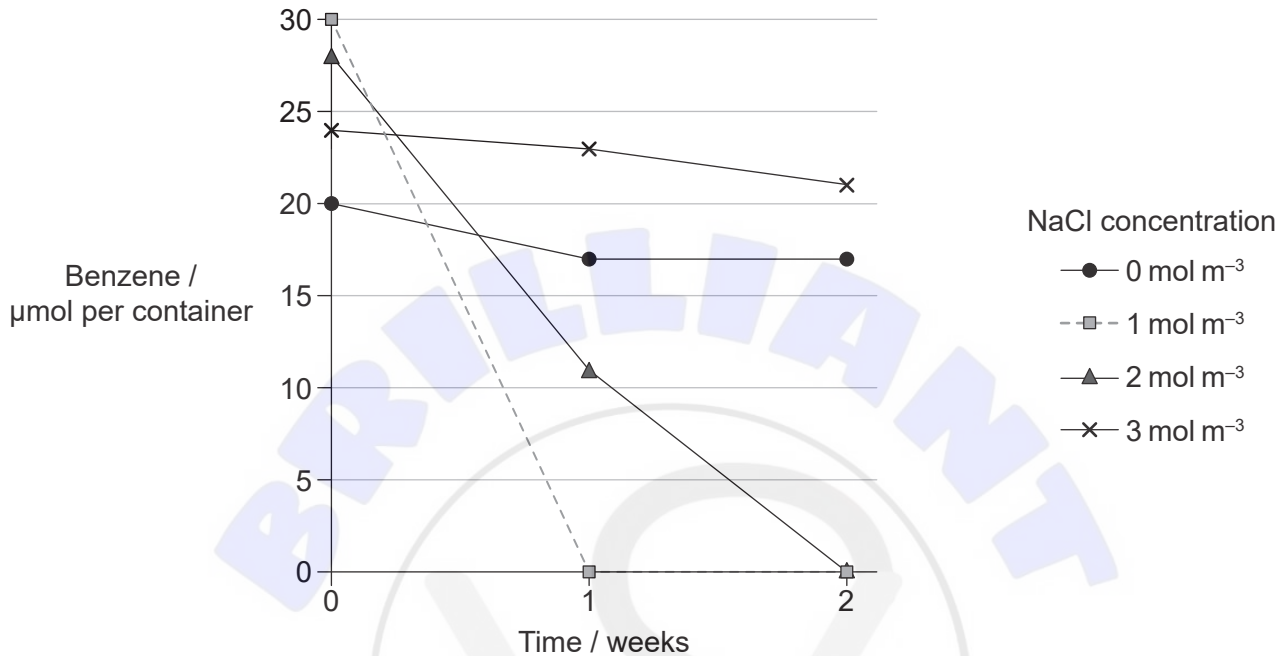
.....

**(Option B continues on the following page)**



(Option B continued)

11. Some halophilic bacteria biodegrade benzene, which makes them useful in treating oil spills as benzene is contained in crude oil. Investigators added cultures of the bacteria to benzene solutions at different salinities in containers. The amount of benzene remaining in the container was recorded once a week for two weeks.



[Source: *Applied and Environmental Microbiology*, 2004, **70**, 1222-1225, DOI: 10.1128/AEM.70.2.1222-1225. 2004, reproduced with permission from American Society for Microbiology]

(a) Outline what is meant by halophilic when describing the bacteria. [1]

.....

.....

(b) Identify the salt concentration with the greatest rate of benzene biodegradation. [1]

..... mol m<sup>-3</sup>

(c) State **one** genus of halophilic bacteria known to biodegrade benzene. [1]

.....

(Option B continues on the following page)



(Option B, question 11 continued)

(d) Suggest **one** advantage to the bacteria of breaking down benzene.

[1]

<p>.....</p> <p>.....</p>
---------------------------

12. In bioinformatics, multiple sequence alignment can compare the order of nucleotides in similar lengths of DNA. The output can be used in phylogenetics. The table shows a sample of 20 nucleotides in strands of DNA from four different species.

Species	Nucleotides in DNA strand																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	A	G	G	C	C	A	A	G	C	C	A	T	A	G	C	T	G	T	C	C
2	A	G	G	C	A	A	A	G	A	C	A	T	A	C	C	T	G	A	C	C
3	A	G	G	C	C	A	A	G	A	C	A	T	A	G	C	T	G	T	C	C
4	A	G	G	C	A	A	A	G	A	C	A	T	A	C	C	T	G	T	C	C

[Source: © International Baccalaureate Organization 2019]

The chart is a distance matrix. It shows the number of base sequence differences between pairs of strands, expressed as a proportion.

Removed for copyright reasons

(a) (i) Calculate the value of X in the distance matrix.

[1]

<p>.....</p> <p>.....</p>
---------------------------

(Option B continues on the following page)



**(Option B, question 12 continued)**

- (ii) Explain how differences in base sequence between species can indicate likely phylogeny. [3]

.....

.....

.....

.....

.....

.....

- (iii) Suggest **one** reason for data in a distance matrix sometimes not corresponding with the actual phylogeny of a group of species. [1]

.....

.....

- (b) State **one** type of molecule, other than DNA nucleotides, that can be used in multiple sequence alignments. [1]

.....

- (c) State a **named** example of sequence alignment software that can be used in phylogenetic analysis and **one** advantage of the use of such software. [2]

Example: .....

Advantage: .....

**(Option B continues page 23)**





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

Answers written on this page  
will not be marked.

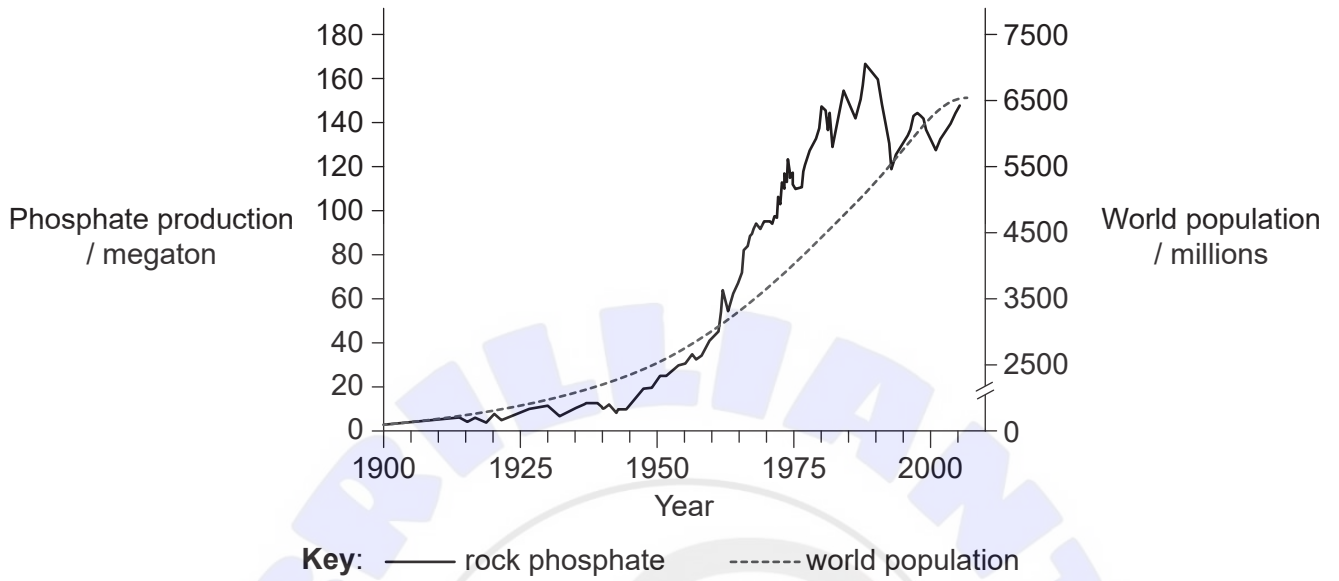






**Option C — Ecology and conservation**

14. The graph shows how the world rock phosphate production and world population changed between 1900 and 2005.



[Source: Patrick D'ery and Bart Anderson]

(a) Describe the relationship between rock phosphate production and world population. [2]

.....

.....

.....

.....

(b) Phosphate can be lost from agricultural land in several different ways. State **one** of these. [1]

.....

(Option C continues on the following page)



**(Option C, question 14 continued)**

- (c) Describe how the changes in world rock phosphate production after 1985 may have affected world food supplies.

[2]

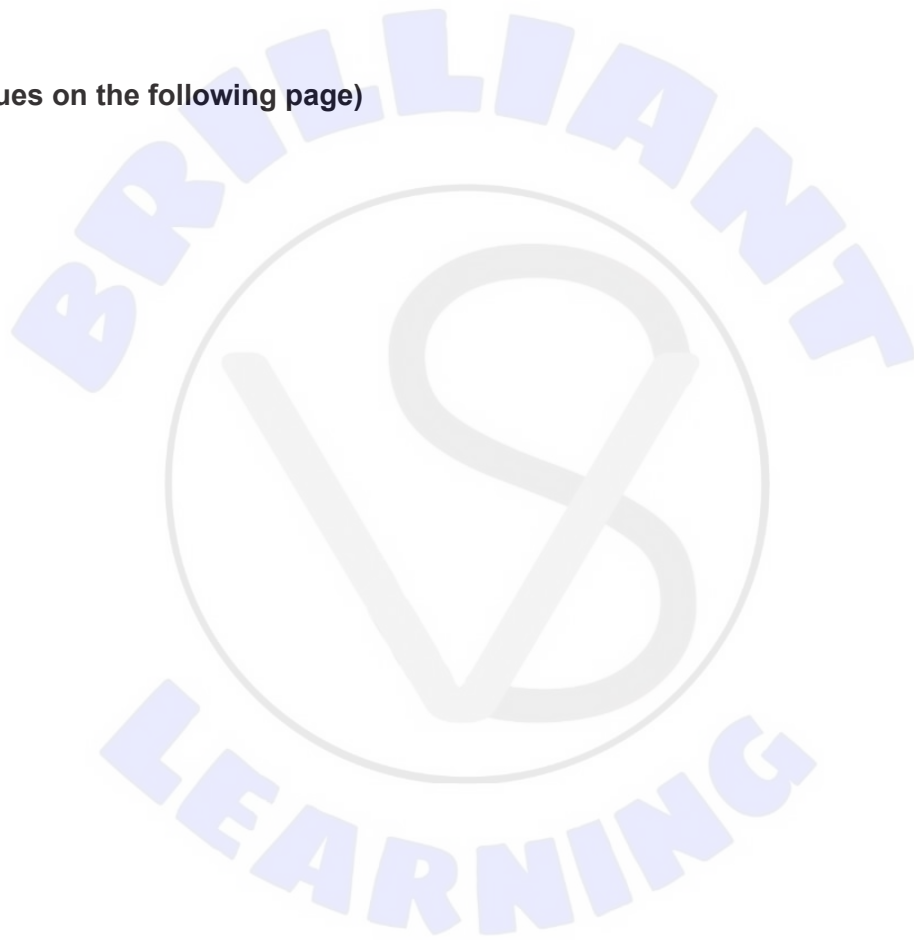
.....

.....

.....

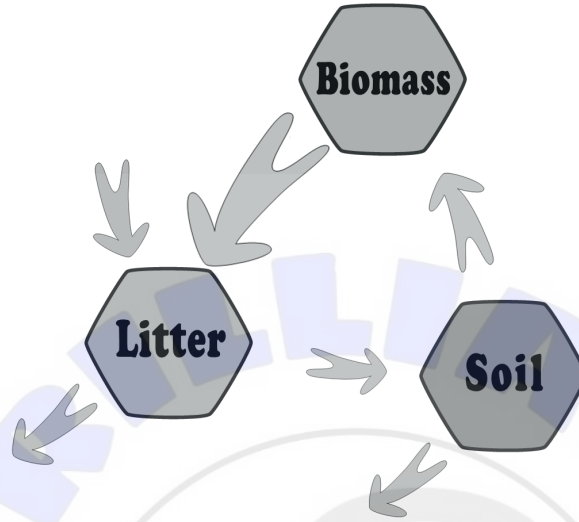
.....

**(Option C continues on the following page)**



(Option C continued)

15. The illustration shows a Gersmehl diagram of the taiga biome.



[Source: adapted from P J Gersmehl]

(a) Outline what is represented by the arrows in the Gersmehl diagram. [1]

.....

.....

(b) Explain how the amount of litter in a tropical rainforest would differ from the taiga's and how this would be represented in a Gersmehl diagram. [3]

.....

.....

.....

.....

.....

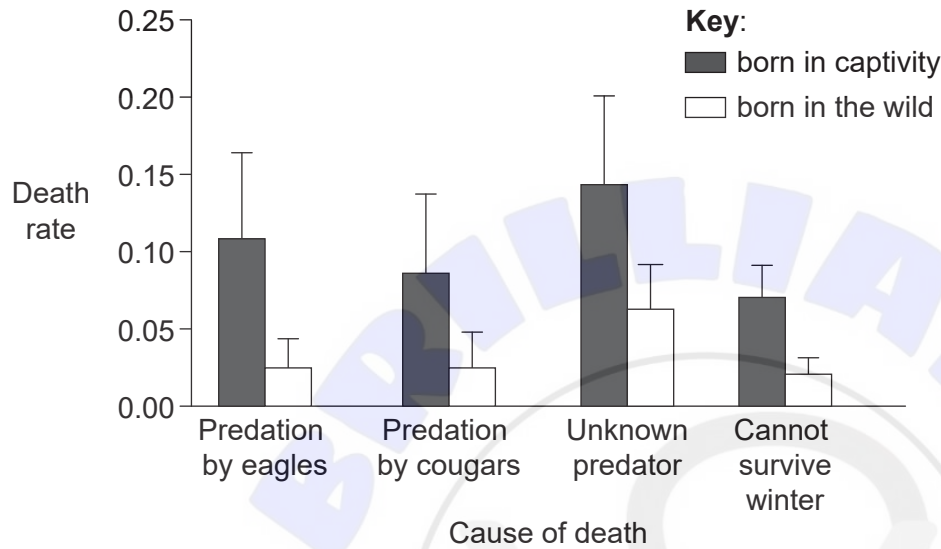
.....

(Option C continues on the following page)



(Option C continued)

16. The Vancouver Island marmot (*Marmota vancouverensis*) is a small rodent that is only found on Vancouver Island and is listed as critically endangered. Captive breeding and release programs for this species began in 1997 to attempt to restore population numbers on the island. The graph shows the causes of death of the marmots born in the wild and of those marmots released after being born and reared in captivity.



[Source: Reprinted from *Biological Conservation*, 142, K Aaltonen *et al*, Reintroducing endangered Vancouver Island marmots: Survival and cause-specific mortality rates of captive-born versus wild-born individuals, 2181–2190, Copyright 2009, with permission from Elsevier]

[Source: Photo: Oli Gardner]

(a) (i) Distinguish between levels of predation in marmots born in the wild and those born in captivity. [1]

.....

.....

(ii) Suggest reasons for the differences in predation. [2]

.....

.....

.....

.....

(Option C continues on the following page)



(Option C, question 16 continued)

(b) Distinguish between *ex situ* and *in situ* conservation of endangered species. [1]

.....

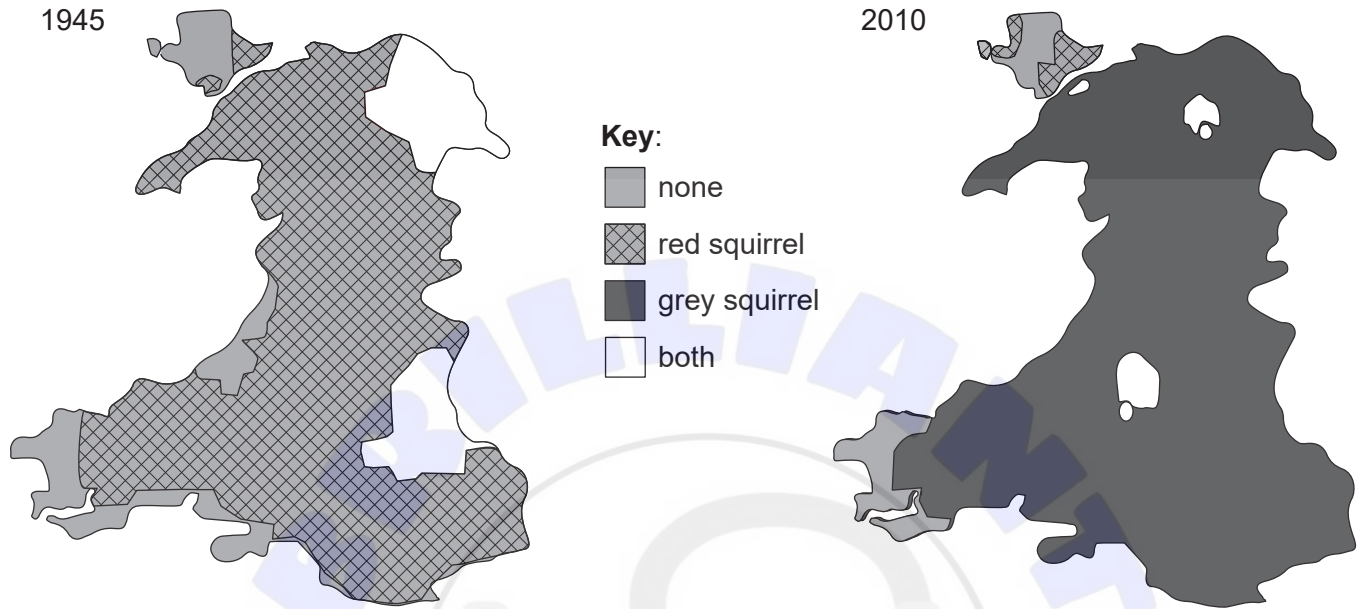
.....

(Option C continues on the following page)



(Option C continued)

17. In Wales, UK, the grey squirrel (*Sciurus carolinensis*) is an alien species and the red squirrel (*Sciurus vulgaris*) is endemic. The maps show the distribution of red and grey squirrels in 1945 and 2010.



[Source: © The Red Squirrel Survival Trust]

(a) (i) Outline the changes of distribution of the grey squirrel from 1945 to 2010. [2]

.....

.....

.....

.....

(ii) Suggest **two** possible reasons for the change in distribution. [2]

1. ....

2. ....

(Option C continues on the following page)



**(Option C, question 17 continued)**

- (b) The niches of the red and grey squirrels overlap. Explain the concept of competitive exclusion with respect to the changes in squirrel distribution shown in the maps. [3]

.....

.....

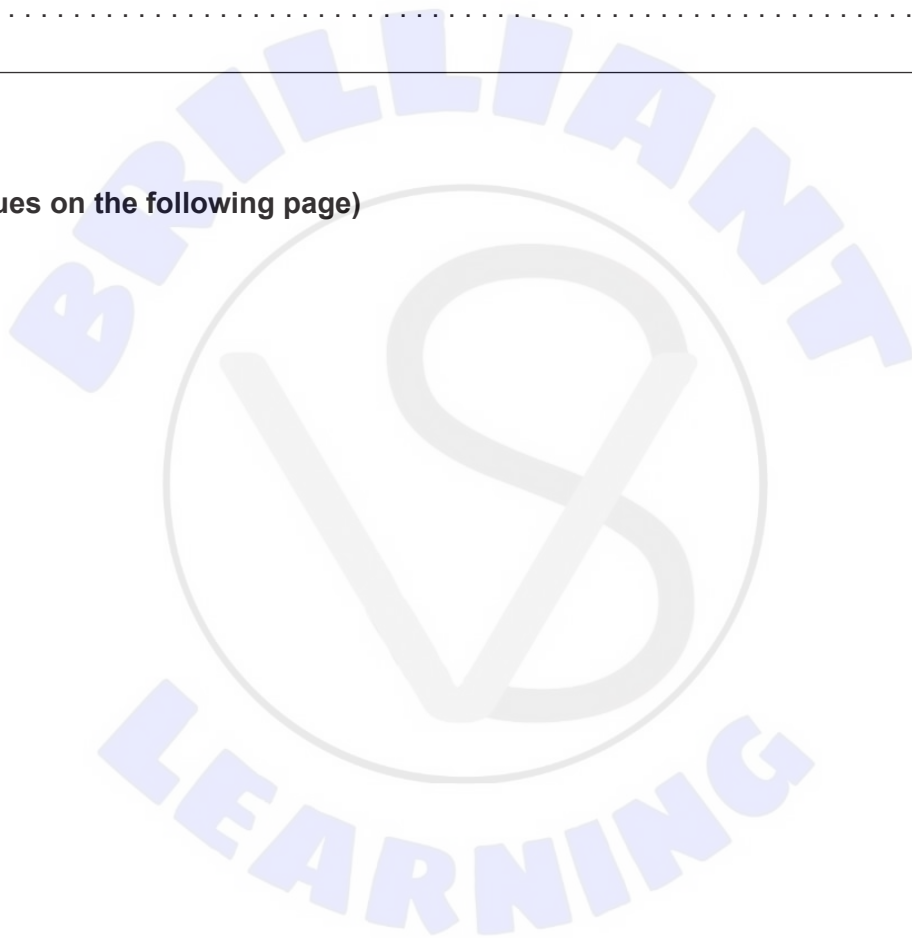
.....

.....

.....

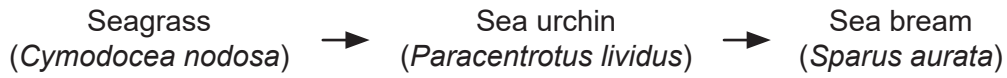
.....

**(Option C continues on the following page)**



**(Option C continued)**

18. Torre Guaceto is a marine protected area which covers over 22 km<sup>2</sup> of the Adriatic Sea in south-eastern Italy. The diagram shows a food chain within this area.



The data refers to the numbers of these three species inside the marine protected area, where fishing is limited, and outside the marine protected area, where fishing is allowed.

	Within the fully protected area	Outside the fully protected area
Sea bream individuals per 100m <sup>2</sup>	30	3
Sea urchin individuals per 100m <sup>2</sup>	70	690
% algae cover	47	15

[Source: data provided by The Science of Marine Reserves Project (PISCO), based on Guidetti 2006 Ecological Applications]

(a) State the trophic level of the sea urchin. [1]

.....

(b) With respect to this food chain, outline what is meant by a keystone species. [3]

.....

.....

.....

.....

.....

.....

**(Option C continues on the following page)**





(Option C continued)

19. The garden snail, *Helix aspersa*, is a herbivore.



[Source: Sinan Önder /<https://www.pexels.com/photo/animal-close-up-crawling-garden-243128/>]

Explain how the population of snails in an ecosystem could be estimated by capture-mark-release-recapture, identifying the limitations in the method.

[6]

Area for student response with horizontal dotted lines for writing. A large, faint watermark reading "BRILLIANT LEARNING" is overlaid on the page.

**End of Option C**



**Option D — Human physiology**

20. The use of human growth hormone (HGH) to enhance athletic performance is now banned from most major sporting events including the Olympics. To investigate the effect of HGH on athletic performance, doctors in the US looked at changes in body composition and strength in a group of athletes taking the drug. This was compared with a control group of similar athletes who had never taken the drug.

	Mean change in mass compared with control group / kg
Body fat	- 0.3
Muscle	+ 2.1
Maximum mass that can be lifted using arm muscles	- 0.2
Maximum mass that can be lifted using leg muscles	- 0.1

[Source: From *Annals of Internal Medicine*, H Liu and D M Bravata, Systematic Review: The Effects of Growth Hormone on Athletic Performance, **148.**, 10, 747–758. Copyright © 2008 American College of Physicians. All Rights Reserved. Reprinted with the permission of American College of Physicians, Inc.]

(a) Deduce from the results of the study whether HGH improves strength. [1]

.....

.....

(b) Suggest **one** reason that it is difficult to detect illegal use of HGH to enhance athletic performance. [1]

.....

.....

(c) HGH is a peptide hormone. Describe the mode of action of peptide hormones on target cells. [3]

.....

.....

.....

.....

.....

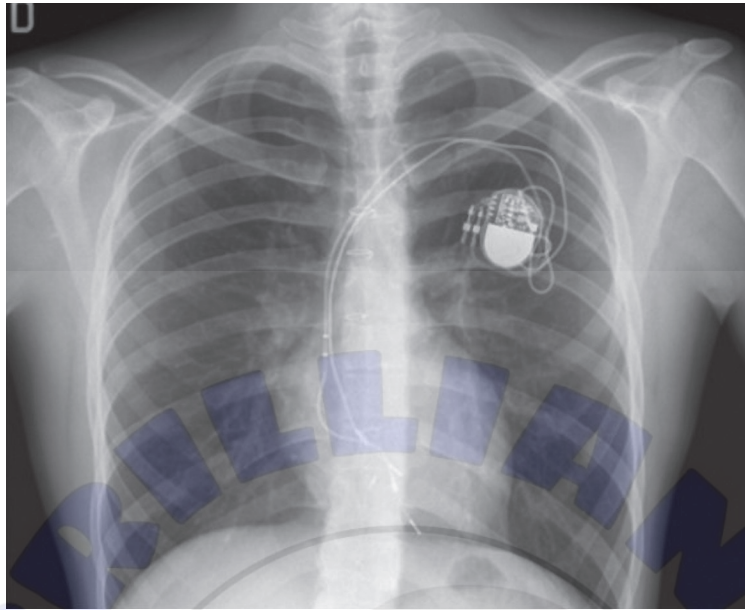
.....

(Option D continues on the following page)



**(Option D continued)**

**21.** The X-ray shows the thorax of a patient who has had an artificial pacemaker fitted.



[Source: M S Silveti and F Drago, Twenty years of paediatric cardiac pacing: 515 pacemakers and 480 leads implanted in 292 patients, *Europace*, 2006, 8, 7, 530–536, by permission of Oxford University Press]

(a) (i) State **one** condition which would require the use of an artificial pacemaker. [1]

.....

(ii) Describe briefly how an artificial pacemaker works. [2]

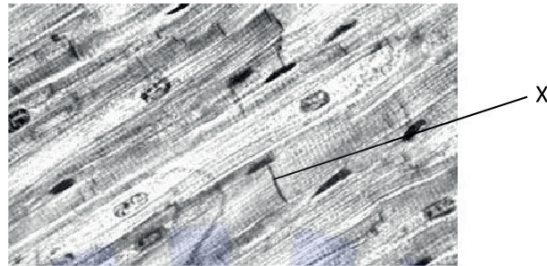
.....  
.....  
.....  
.....

**(Option D continues on the following page)**



**(Option D, question 21 continued)**

(b) The micrograph shows cardiac muscle.



[Source: <https://commons.wikimedia.org/wiki/File:Musculocardiaco.jpg> by Goyitrina, licensed Creative Commons Attribution-Share Alike 3.0]

(i) The structure labelled X in the micrograph is a junction between two cardiac muscle cells. Identify the structure labelled X. [1]

.....

(ii) Explain how the structure of cardiac muscle cells allows propagation of stimuli through the heart wall. [2]

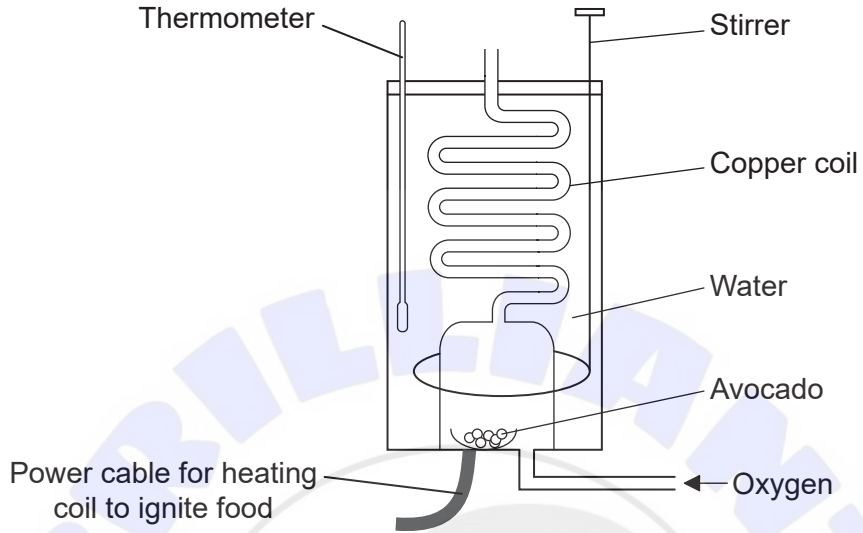
.....  
.....  
.....  
.....  
.....  
.....

**(Option D continues on the following page)**



(Option D continued)

22. Water in a calorimeter is heated by burning food in oxygen. The temperature change of the water is used to calculate the energy value of the food. An experiment was set up to calculate the energy value of avocado.



[Source: © International Baccalaureate Organization 2019]

- (a) Apart from the water temperature, state **two** other values to be measured at the start of the experiment. [2]

1. ....
2. ....

- (b) The energy value calculated for avocado was  $750 \text{ kJ } 100 \text{ g}^{-1}$ . The actual energy value of avocado is  $840 \text{ kJ } 100 \text{ g}^{-1}$ . Suggest a source of error in the experiment. [1]

.....
.....

(Option D continues on the following page)



**(Option D, question 22 continued)**

(c) Avocados are known to be a good source of dietary fibre and contain all the essential amino acids.

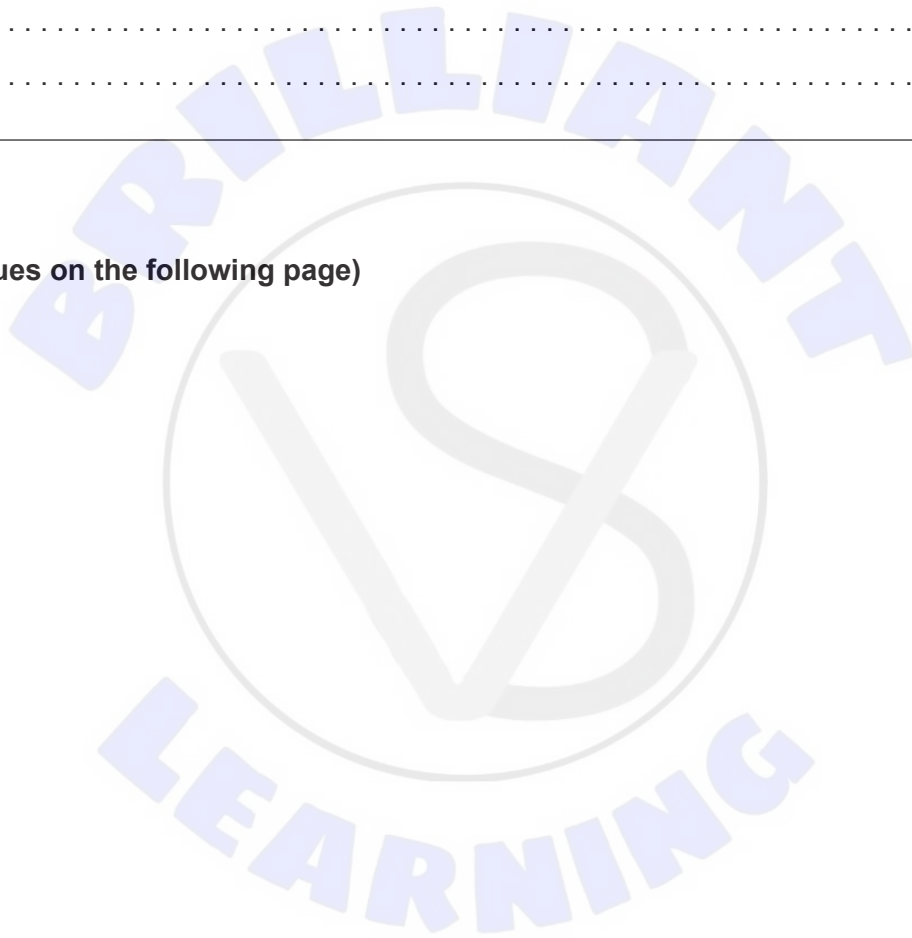
(i) State **one** health benefit of a diet high in fibre. [1]

.....

(ii) Distinguish between essential and non-essential amino acids. [1]

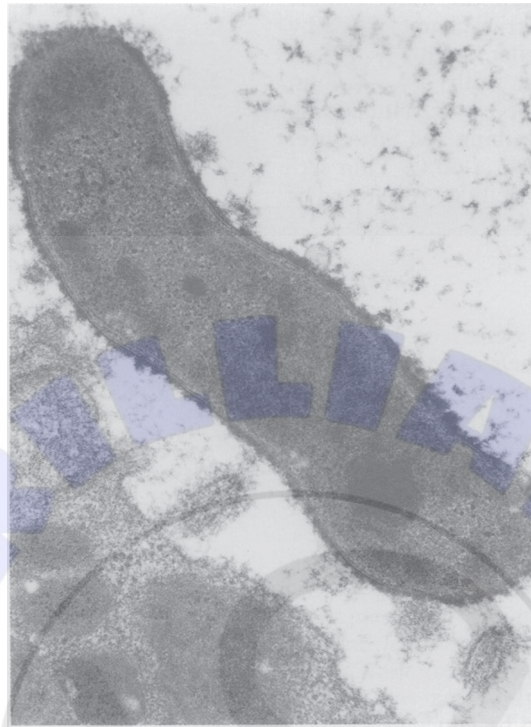
.....  
.....

**(Option D continues on the following page)**



**(Option D continued)**

23. The diagram shows the bacterium *Helicobacter pylori* attacking the gastric mucosa of the stomach.



[Source: Reproduced from Gut, B A Hills, 34, 588–593, 1993 with permission from BMJ Publishing Group Ltd.]

- (a) Outline the possible consequences of a *Helicobacter pylori* infection of the stomach wall. [2]

.....

.....

.....

.....

- (b) The bacterium secretes an enzyme that breaks down urea, resulting in an increase in pH. Outline how this would help the bacterium survive in the stomach. [1]

.....

.....

**(Option D continues on the following page)**



(Option D, question 23 continued)

(c) Explain hormonal control of gastric secretion.

[3]

.....

.....

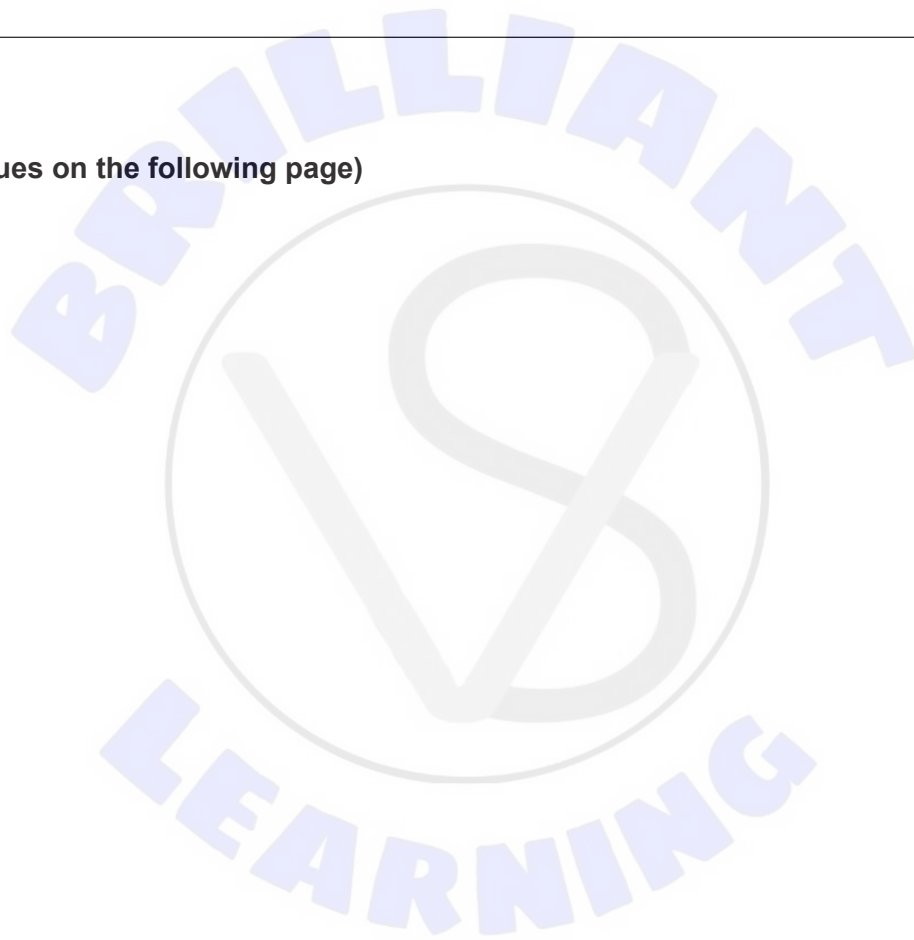
.....

.....

.....

.....

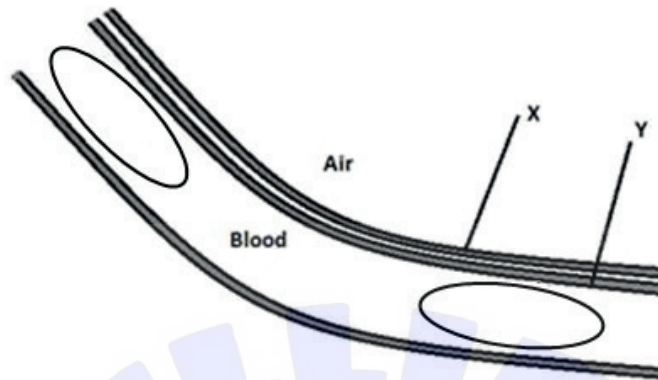
(Option D continues on the following page)





(Option D continued)

24. The electron micrograph shows a section through an alveolus showing blood in a capillary.



[Source: © International Baccalaureate Organization 2019]

(a) Identify the cells found at X and Y.

[2]

X: .....

Y: .....

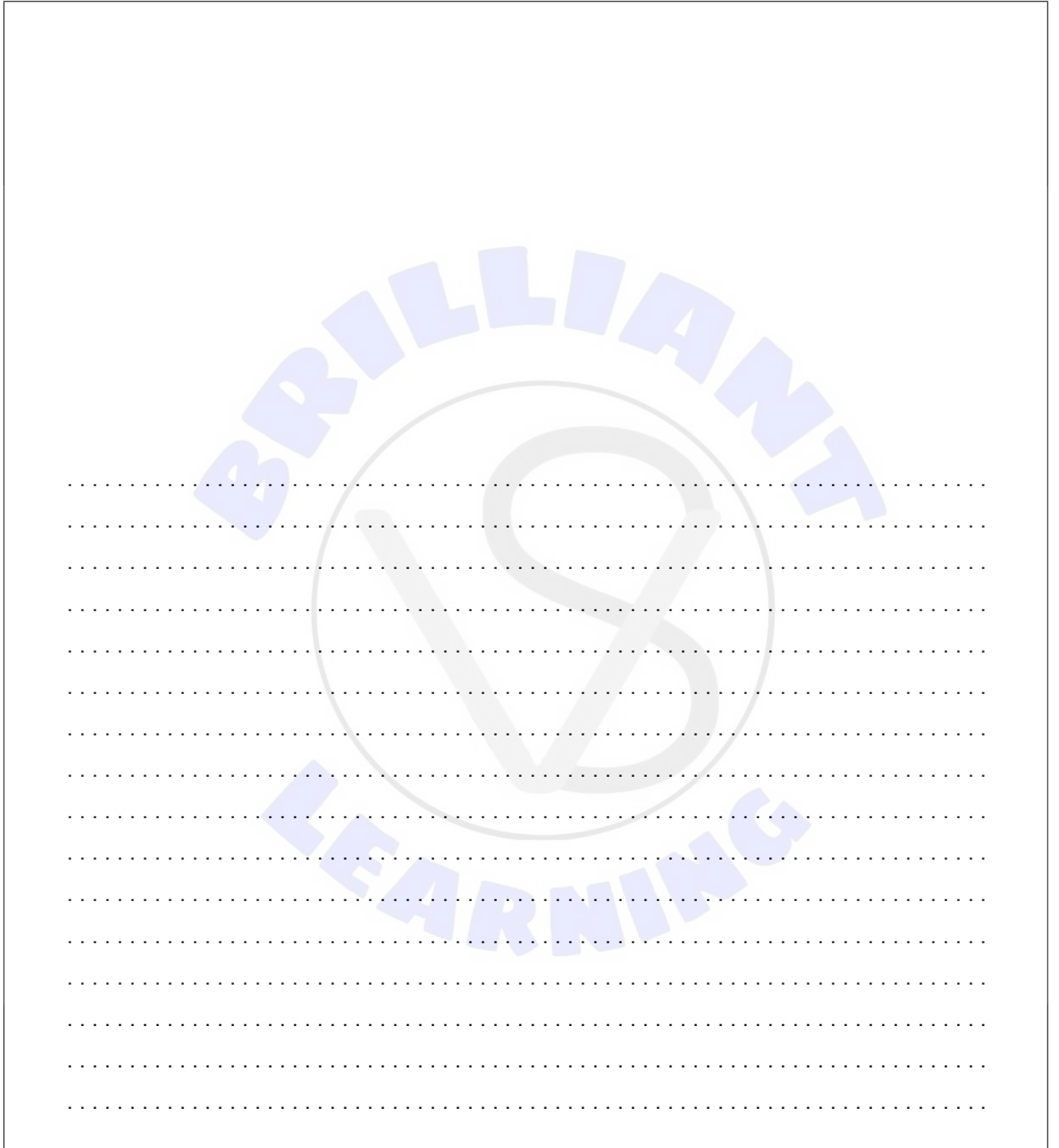
(Option D continues on the following page)



**(Option D, question 24 continued)**

- (b) Explain, with the aid of an annotated diagram, how physical exercise affects the affinity of hemoglobin for oxygen.

[6]



**End of Option D**





Please **do not** write on this page.  
Answers written on this page  
will not be marked.





Please **do not** write on this page.  
Answers written on this page  
will not be marked.





Please **do not** write on this page.  
Answers written on this page  
will not be marked.

