Surname	Centre Number	Candidate Number
Other Names		2

GCE A LEVEL

A400U30-1

S18-A400U30-1

BIOLOGY – A level component 3
Requirements for Life

MONDAY, 18 JUNE 2018 – MORNING

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**11**	
	2.	**10**	
	3.	**9**	
	4.	**12**	
	5.	**13**	
	6.	**16**	
	7.	**9**	
Section B	**Option**	**20**	
	Total	**100**	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will need a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.

Section A: 80 marks. Answer **all** questions. You are advised to spend about 1 hour 35 minutes on this section.

Section B: Options; 20 marks. Answer **one option only**. You are advised to spend about 25 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **7**.

The quality of written communication will affect the awarding of marks.

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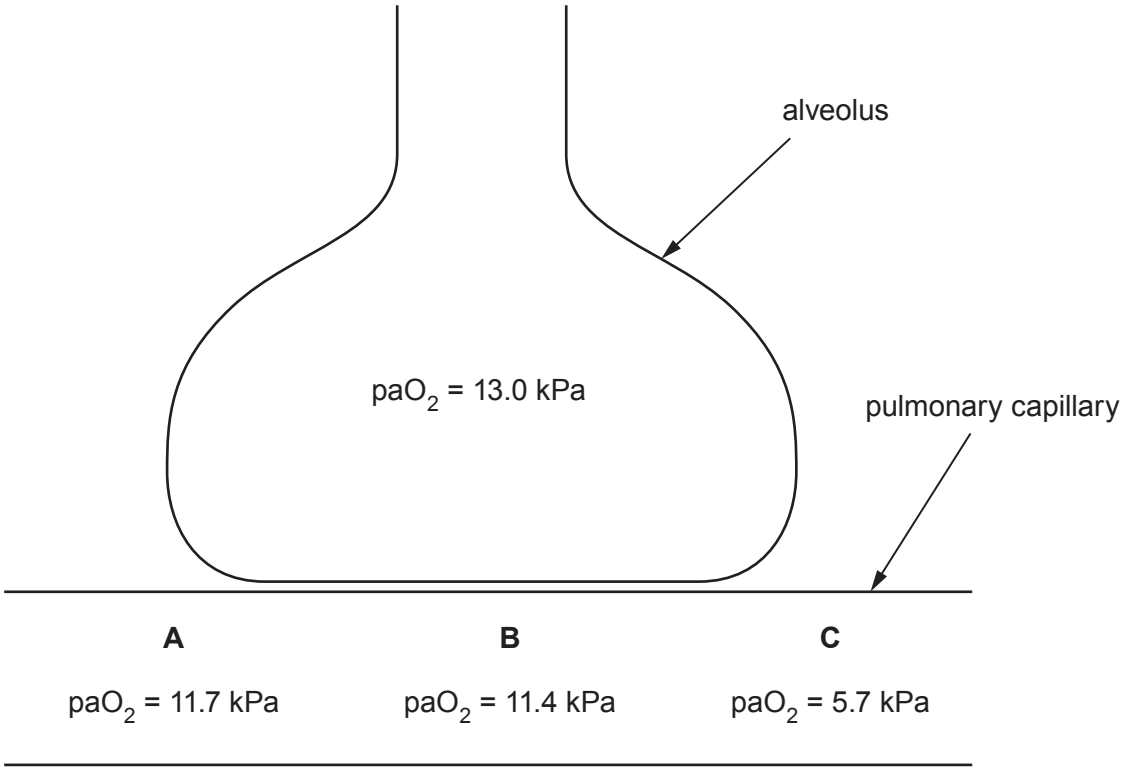
SECTION A

Answer **all** *questions.*

1. Gas exchange in the alveoli relies on maintaining a concentration gradient between the air in the alveoli and the blood. The diagram below shows the oxygen levels (**paO_2**) in the alveoli and at three points along a pulmonary capillary.



(a) (i) Describe **two** ways that an oxygen concentration gradient is maintained between alveolar air and blood. [2]

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(ii) Explain how the information in the diagram shows that **A** is the venous end of the pulmonary capillary. [1]

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(iii) The haemoglobin in blood leaving the lungs is not fully saturated with oxygen but in most healthy people reaches a value of 98 to 99%. Suggest **two** reasons for this. [2]

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(iv) One function of the lungs is the excretion of carbon dioxide. State **two** forms in which carbon dioxide is transported to the lungs for excretion. [2]

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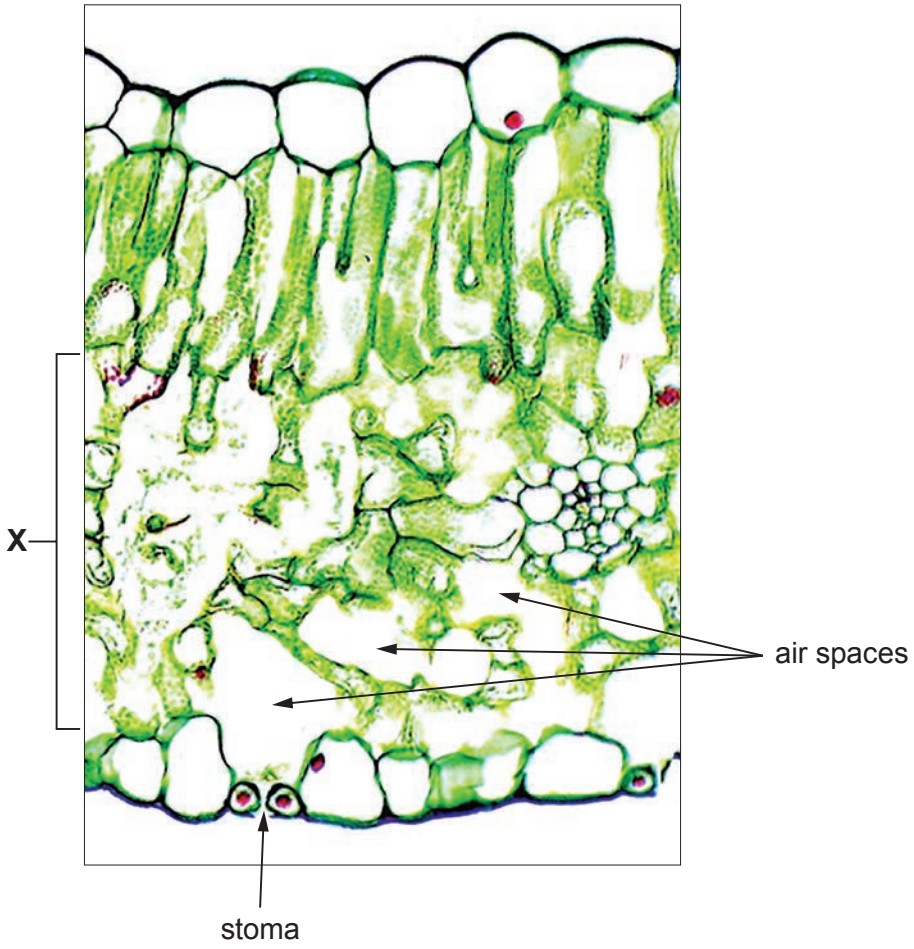
(b) In plants, gas exchange takes place directly between the cells and the air in the air spaces in the tissues. Exchange between the air in the air spaces and the atmosphere is through stomata.
The photomicrograph below shows a section through part of a lily leaf *(Lilium sp.)*.



(i) Name the tissue labelled **X** on the diagram. [1]

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(ii) Explain why the rate of gas exchange between the air spaces of the leaf and the leaf tissues is lower than between the alveoli and the blood of a mammal. [3]

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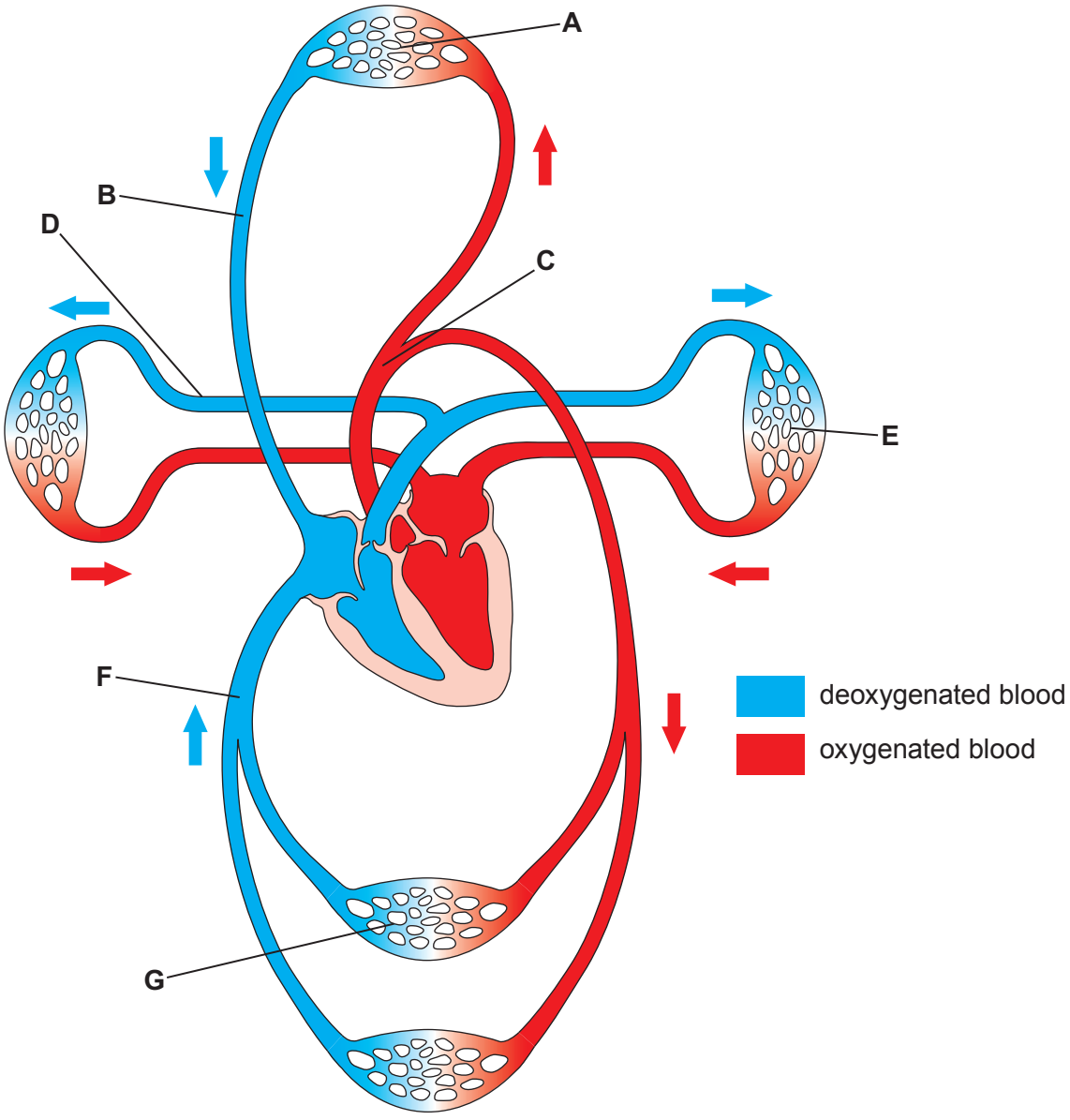
2. Mammals have a double circulatory system as shown in the diagram below. The arrows show the direction of blood flow.



(a) Using **only** the letters **A** to **G** from the diagram, identify the following (letters may be used once, more than once or not at all): [3]

(i) parts of the pulmonary circulation ....

(ii) blood pressure is maintained by elastic recoil ....

(iii) blood flow is maintained by contraction of skeletal muscle and breathing movements ....

Examiner only

(b) Use the information provided in the table below to answer the questions that follow.

	Total number of vessels	Mean length /cm	Mean diameter /cm	Total cross-sectional area /cm^2	Total blood volume /cm^3	Rate of blood flow /$cm^3\ s^{-1}$
aorta	1	40	1.0	0.8	32	28
other large arteries	40	20	0.3	3	60	7.8
arterioles	4×10^7	0.2	0.002	124	25	1.18
capillaries	1.2×10^9	0.1	0.0008	.....	60	0.036

(i) Using the formula below calculate the **total cross-sectional area** of the capillaries. **Express your answer to three significant figures.** [3]

cross-sectional area = πr^2

(π = 3.142)

Total cross-sectional area = ... cm^2

(ii) Explain why a low protein diet would result in fluid retention in the tissues. [4]

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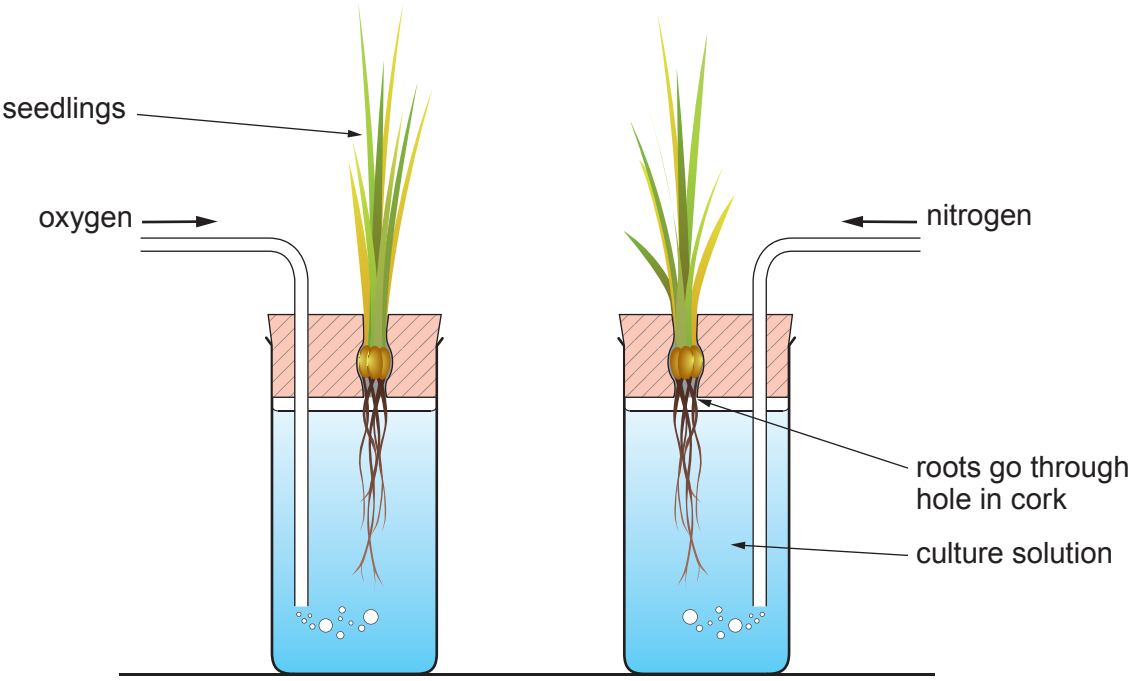
3. Barley seedlings were grown as shown in the diagram below, each in the same volume of culture medium. The culture medium contained known concentrations of all the ions needed for plant growth. Oxygen was bubbled through the culture medium of one experimental set up and nitrogen was bubbled through the other.



The concentration of phosphate ions in each culture solution was measured every four hours for 24 hours. It was assumed that the decrease in the concentration of phosphate ions was due to uptake of phosphate ions by the plant roots.

(a) (i) Identify the variables in this investigation: [2]

Independent variable

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Dependent variable

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(ii) Identify and justify **two** variables that should have been controlled in this experiment. [2]

Controlled variable I. .....

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Controlled variable II. .....

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(b) The results of the investigation are shown in the table below.

	Concentration of phosphate in culture solution / mmol dm^{-3}	
Time / hours	**with oxygen**	**with nitrogen**
0	100.0	100.0
4	51.5	80.2
8	26.3	55.1
12	12.2	38.4
16	6.3	14.1
20	0.4	6.0
24	0.2	5.2

It was concluded that uptake of phosphate ions can occur by both active transport and diffusion. Explain how the evidence supports this conclusion. [2]

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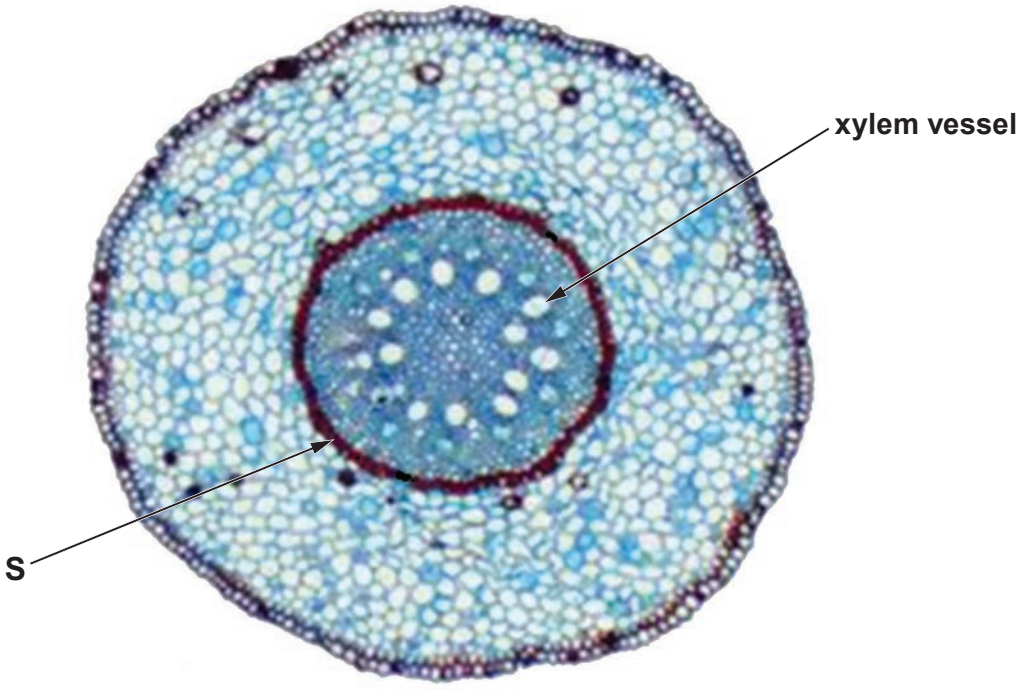
(c) In a different experiment, phosphate ions labelled with a radioactive isotope of phosphorus were found to move through the tissue layer labelled **S** on the image of T.S. root shown below.

It was found that radioactive phosphate ions were only found in the xylem when oxygen was bubbled through the culture solution.



(i) Name tissue **S**. [1]

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(ii) Explain how a feature of the cells found in tissue **S** means that oxygen is needed for the phosphate ions to pass into the xylem. [2]

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4. A study was carried out to investigate the changes to the digestive system of snakes when not fed for extended periods.

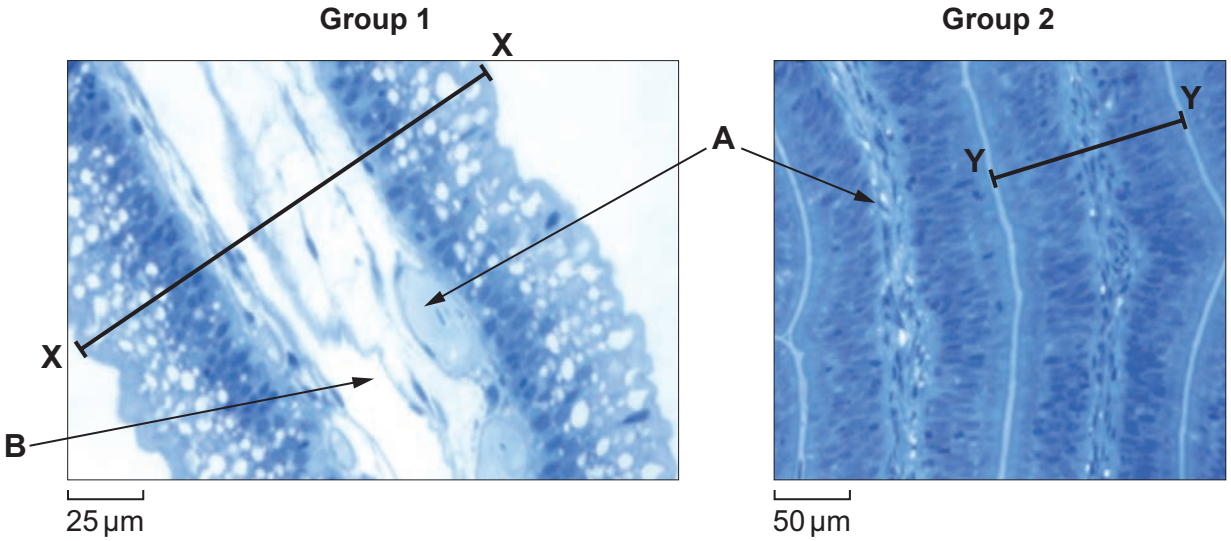
Burmese pythons *(Python molurus bivittatus)* are a species of snake that hide and wait for their prey to come close enough to catch and eat. Their prey is ingested whole and can weigh up to 25% of the snake's body mass. Digestion takes from 10 to 14 days. They can go without food for up to one year.

Two groups of snakes were fed for a four-week period as follows:

Group 1 fed every third day
Group 2 not fed during the period of the study

At the end of the study, snakes from each group were killed and the structure of the ileum examined using light and electron microscopy.

(a) The images below show sections through villi from the ileum of a snake from each group.



(i) The width of the villus shown by **X**-**X** in the Group **1** snake was 140 µm and the width of the villus in the Group **2** snake at **Y**-**Y** was 96 µm. Calculate the percentage decrease in the width of the villus when deprived of food. [2]

Percentage decrease in width = ...

Examiner only

(ii) Structure **A** absorbs glucose and structure **B** absorbs lipids following digestion. Name these structures. [1]

A .....

B .....

(iii) After four weeks, the following observations were made:

- structure **B** was not present in the villi of the snakes from Group **2**
- structure **A** was always present in the villi of snakes from both groups

Explain why structure **B** was not needed in Group **2** snakes whereas structure **A** was essential for all snakes. [2]

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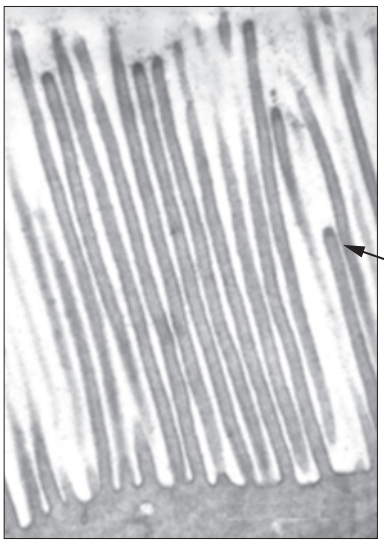
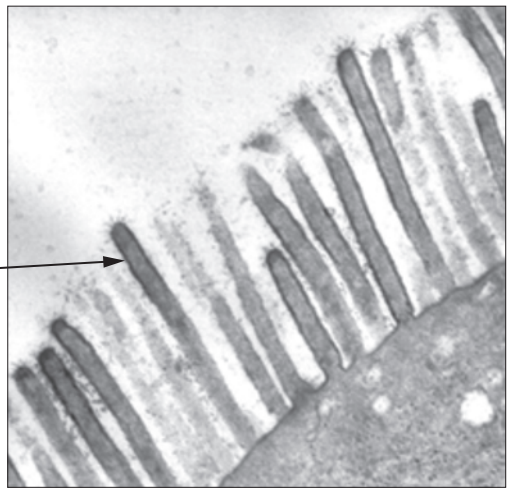
(b) The electron photomicrographs below show high magnification images of the surface of the epithelial cells covering the villi of a snake from each of Groups **1** and **2**.

Group 1



0.5 µm

Group 2



Describe and explain the differences in the length and width of the microvilli seen in Group **1** compared to Group **2**. [3]

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(c) Electron microscopy also showed that the epithelial cells from the snakes in Group **1** had the following differences compared to those from Group **2**.

Group 1	Group 2
large number of mitochondria	few mitochondria
cells arranged in a single layer	cells arranged in several layers

Explain the observations that were made for Group **1**. [2]

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(d) Not feeding animals might be considered unethical and cruel. Explain why not feeding these snakes for four weeks would not be considered an ethical issue, but there may be other ethical issues involved with this study. [2]

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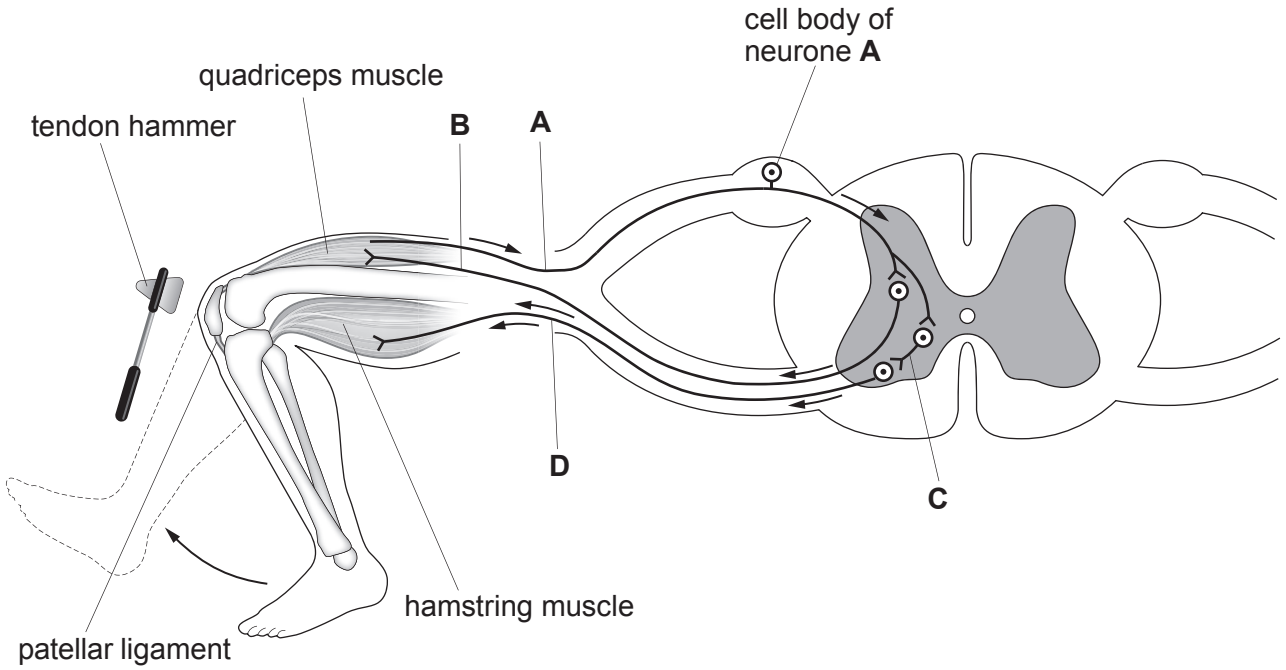
5. The patellar reflex (commonly known as the knee-jerk reflex) can be used to identify problems in neural communication between the quadriceps muscle and the spinal cord. The patellar ligament joins the quadriceps muscle to the lower leg bone. Normally, when the leg is tapped sharply on the patellar ligament (just below the knee cap) the quadriceps muscle contracts involuntarily. Contraction of the hamstring then returns the lower leg to its original position.



(a) Four neurones, **A**, **B**, **C** and **D**, are labelled on the diagram above.

(i) Using the **letters A to D**, identify the neurones involved in the reflex arcs involving: [1]

I. the quadriceps muscle .....

II. the hamstring muscle .....

(ii) With reference to the neurones involved, explain why the contraction of the hamstring muscle occurs after the quadriceps muscle, in response to the same stimulus. [2]

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(b) Impulses are transmitted through the neurones as a wave of action potentials. Explain how the movement of ions results in the **generation** of an action potential. [4]

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Question is continued on the next page

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(c) An experiment was carried out to determine the time taken for a person to kick their leg in response to the following stimuli:

Stimulus **1**. direct stimulus of the patellar ligament by the tendon hammer

Stimulus **2**. hearing the tendon hammer hitting the table

The reaction times to both stimuli were collected for a group of ten people. Mean reaction times were calculated and used to calculate the standard deviations for each stimulus. A t-test value was calculated to assess whether any difference in the results was significant. The results are summarised in the table below.

	STIMULUS 1	**STIMULUS 2**
mean reaction time / s	0.026	0.236
number of measurements	$n_1 = 10$	$n_2 = 10$
standard deviation	0.006	0.108
t-test value	2.41	

(i) Explain why a t-test was used to assess the significance of the differences in the results and not a Chi-squared test. [2]

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Examiner only

(ii) The null hypothesis for this experiment was that *'there was no significant difference between the results for Stimulus **1** and Stimulus **2**'*. The degrees of freedom for this t-test were 18.

Use the t-test value and the information given in the table below to decide whether to accept or reject the null hypothesis at a suitable probability level. Explain your answer. [4]

degrees of freedom	**probability**			
	0.1	**0.05**	**0.01**	**0.005**
1	6.31	12.71	63.66	127.32
5	2.02	2.57	4.03	4.77
8	1.86	2.31	3.36	3.83
10	1.81	2.23	3.17	3.58
18	1.73	2.10	2.88	3.20
20	1.73	2.09	2.85	3.15

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6. *Erwinia* is a genus of Gram-negative bacteria that causes a disease called soft-rot in many different plant species.

The bacteria usually enter the tissues of a plant through wounds in the exterior surface. They obtain respiratory substrates from the host plant by secreting a range of enzymes, including cellulases and phospholipases.

As the infection continues it first induces plasmolysis of the surrounding tissue and then rotting of the tissues. This spreads inwards from the site of infection until it reaches the vascular tissues. The infection then spreads upwards through the plant causing the parts of the plant above the initial site of infection to wilt.

(a) (i) Describe the biochemical breakdown of cellulose to release the respiratory substrates for the bacteria. [2]

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(ii) Explain how the products of cellulose breakdown result in the plasmolysis of cells in the plant tissue surrounding the site of infection. [2]

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(b) (i) Describe how the enzymes produced by the bacteria enable them to reach the vascular tissue. [2]

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Examiner only

(ii) What conclusions can be reached regarding which vascular tissue is responsible for the spread of *Erwinia* infections through a plant? Explain your answer. [2]

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(c) Until recently, the main species of *Erwinia* that caused soft-rot in the UK was *E. carotovora*. This species spreads rapidly in the cool, wet conditions usually found in this country in the spring. Recently, infections caused by another species of the same genus, *E. chrysanthemi* has been identified at over 40 sites in the south of England and Wales but so far has not been found in the colder climate of Scotland. *E. chrysanthemi* is more common in warm countries where it causes far more destruction of fruit and vegetables than *E. carotovora*.

Suggest how human impact on the climate change planetary boundary could be a reason for the distribution of *E. chrysanthemi* in the UK. [3]

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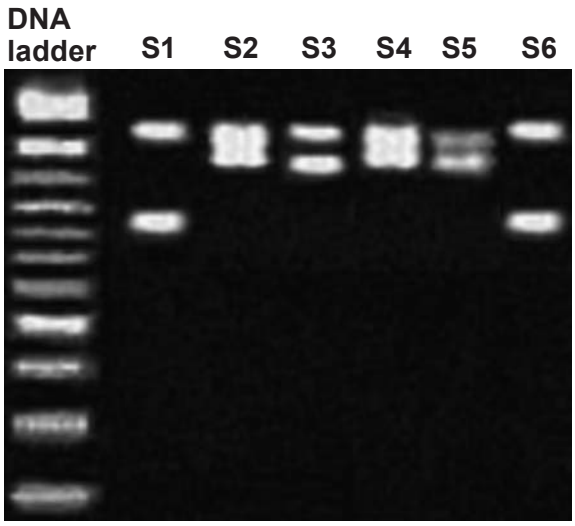
Examiner only

(d) Identification of different species of *Erwinia* is difficult as the symptoms caused are very similar and there are few differences in the range of organisms infected. DNA analysis is now used to identify different species.

Gel electrophoresis was carried out on samples of DNA, **S1** to **S6**, isolated from six different bacteria all believed to be the same species of *Erwinia*.
The image below shows the result of this analysis. A DNA ladder was included for reference.



(i) Explain the purpose of the DNA ladder on the image. [2]

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(ii) With reference to the quality and validity of the results, identify how many species of bacteria could be represented by the six samples and explain how you arrived at your conclusion. [3]

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7. **MDMA** (Ecstasy) is an illegal recreational drug which has side-effects including:

- increased body temperature and sweat production
- increased ADH secretion
- increased thirst
- decreased urine output

Furosemide is a prescription drug used to reduce hypertension (high blood pressure) by lowering blood volume. It acts as an inhibitor of sodium ion transport proteins in the ascending limb of the loop of Henle and increases urine output.

Hyponatraemia (low plasma concentration of Na^+) is a condition where the concentration of sodium ions in the plasma falls below normal levels. This can disrupt the transmission of action potentials and lead to muscle weakness, seizures and even coma.

Using your knowledge of urine production, explain how ecstasy reduces urine output and furosemide increases urine output and how misuse of both drugs can result in hyponatraemia.

[9 QER]

Examiner only

Examiner only

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SECTION B: OPTIONAL TOPICS

Option A: **Immunology and Disease** ☐

Option B: **Human Musculoskeletal Anatomy** ☐

Option C: **Neurobiology and Behaviour** ☐

Answer the question on **one topic only**.

Place a tick (✓) in **one** of the boxes above, to show which topic you are answering.

You are advised to spend about 25 minutes on this section.

Examiner only

Option A: Immunology and Disease

8. Zika is an RNA virus, which can be spread by the *Aedes* mosquito. Most people infected with the Zika virus experience no or very mild symptoms. A recent outbreak in South America was accompanied by an increase in the number of babies being born with microcephaly (a significantly smaller head and abnormal brain development). The incubation period for the Zika virus is estimated to range between 3 and 12 days. The symptoms, if experienced, are similar to other mosquito-borne diseases such as malaria and include: fever, rash, muscular pain, joint pain and headaches.

In 2016, concern was expressed by athletes travelling to the Olympics in Brazil regarding possible infection with Zika. The World Health Organisation concluded that the risk of transmission was relatively low. The advice given to anyone travelling to the Olympics was:

- use insect repellent and wear loose clothing that covers the body
- keep windows closed at night and sleep under a mosquito net
- avoid areas with poor sanitation and stagnant water.

(a) (i) State the term given to the *Aedes* mosquito in the lifecycle of the Zika virus. [1]

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(ii) Explain how the preventative methods described above would help reduce the chance of infection with Zika. [2]

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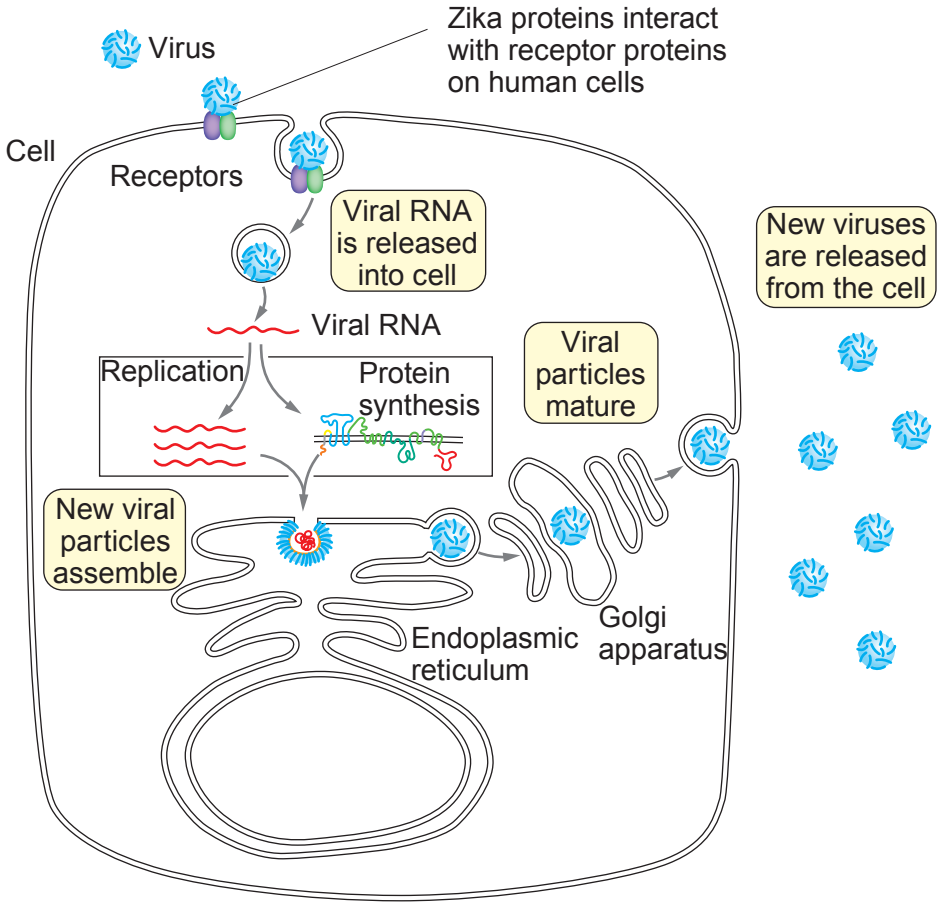
Examiner only

(b) The diagram below describes how the Zika virus replicates inside a human cell.



(i) With reference to the diagram, suggest why viruses are difficult to treat with drugs and state the challenges faced when attempting to develop a vaccine against Zika. [3]

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(ii) State **two** features of a successful vaccine. [1]

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Examiner only

(c) Urgent research is being carried out to provide protection against Zika to pregnant women, as quickly as possible as well as providing a long-term prevention strategy.

Two research projects currently in progress are:

1. The use of an injection containing anti-Zika antibodies for use in pregnant women. This has had some success in animal trials with mice.
2. The development of a vaccine to confer immunity against the virus.

Evaluate the relative advantages and disadvantages of these strategies in the prevention of Zika cases. State which one would be more effective in the long term and explain your reasoning. [5]

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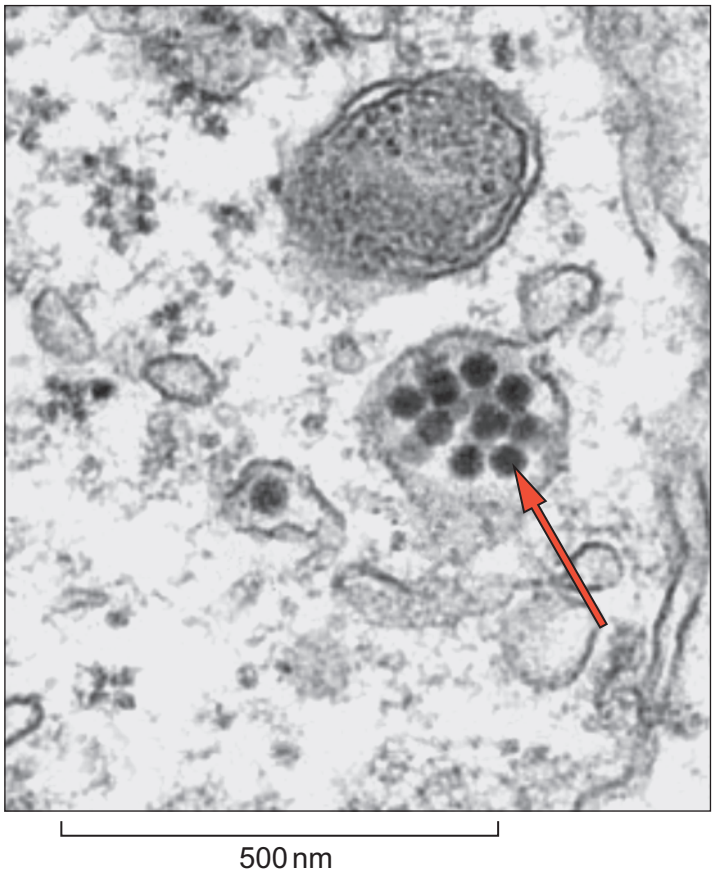
(d) The image below is an electron micrograph showing part of a human cell infected with Zika. Virus particles are in membranous vesicles, the **arrow on the micrograph** below indicates **one virus particle**.



Use the scale bar to calculate the diameter of the labelled Zika virus particle. [2]

Diameter = ... nm

Examiner only

(e) Methicillin works in a similar way to penicillin and is said to be bactericidal. It is no longer produced for medical use because of the rapid increase in bacterial resistance to it. Methicillin resistant *Staphylococcus aureus* (MRSA) is endemic in the general human population. Infections caused by MRSA are common in hospital patients.

(i) State what is meant by the term *endemic* and suggest why MRSA is not a major cause for concern amongst the general population. [2]

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(ii) Erythromycin can be bactericidal or bacteriostatic depending on the dose. It binds to the large ribosomal subunit in bacterial cells. Suggest how erythromycin may work to treat bacterial infection and why it does not affect the patient's cell metabolism. [2]

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(f) Antibiotic resistance is a global crisis and measures are needed to control the use of antibiotics as well as developing new antibiotics. Clinical trials need to be done on any new antibiotic. A trial was carried out to test the safety of a new antibiotic using 20 healthy male volunteers from the same ethnic background. Evaluate the validity of this trial in terms of its use in the whole population. [2]

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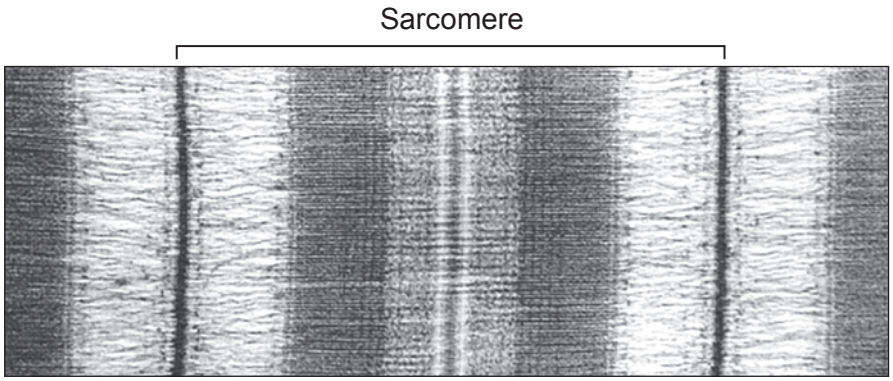
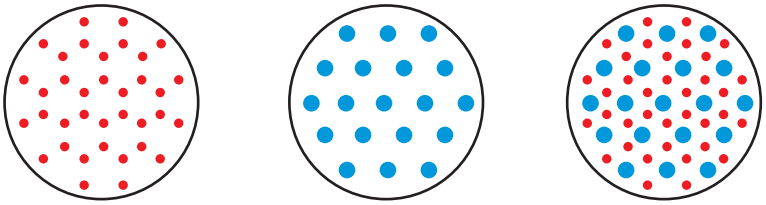
Option B: Human Musculoskeletal Anatomy

9. Skeletal muscle is made up of bundles of fibres, which have a striated appearance. Each fibre contains numerous myofibrils. The image below shows a micrograph of a sarcomere.



The drawings below represent the same structure from different regions but in a different plane from the image above.



(a) (i) State whether circles **A**-**C** represent transverse or longitudinal sections. [1]

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(ii) With reference to the micrograph, for each of the circles state which region of the sarcomere they are taken from and explain your reasoning. [3]

A .....

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B .....

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C .....

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Examiner only

(iii) Describe how the different protein fibres interact to bring about contraction of the sarcomere. [4]

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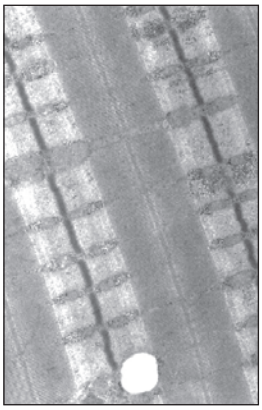
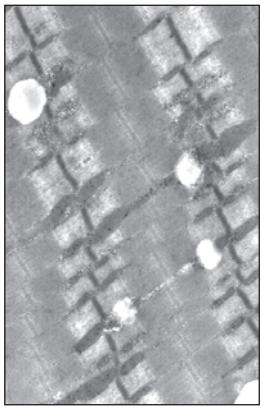
Examiner only

(b) In 2016 Tim Peake was the first British astronaut to spend time on the International Space Station. Research has taken place on astronauts into the effect of prolonged space flight on muscle atrophy. During space flight, astronauts have to exercise, often spending several hours per day on a treadmill.
The images below show electron micrographs of muscle fibres obtained from the muscles of an astronaut before (**A**) and after (**B**) a 17-day space flight. The before flight fibres have wider myofibrils whereas myofibrils after flight are narrower, indicating atrophy.

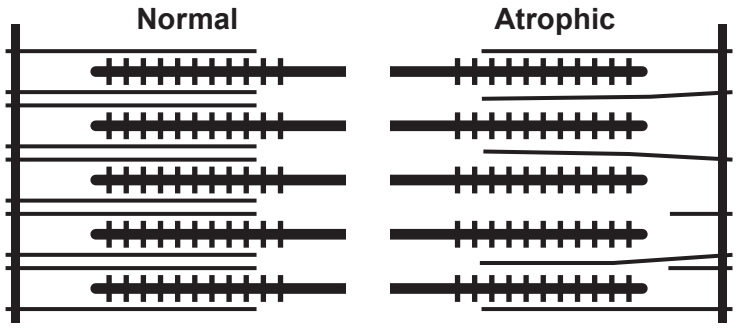
A before flight



B after flight



The diagram below represents the atrophy demonstrated in the protein fibres after flight when compared to normal protein fibres.



(i) Why is it important that muscle sample, before and after flight, is taken from the same muscle in the same astronaut? [1]

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(ii) Using the image and your knowledge of muscle contraction, conclude how spaceflight would affect the maximum force that the muscle could generate. [2]

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Examiner only

(c) The bones of the skeleton can fracture for a variety of reasons. The X-rays below show two such injuries:

C Lower right leg

D Left hip

X-ray **C** is taken from a healthy 19-year-old male with a displaced fracture of the fibula. X-ray **D** is from a 75-year-old woman, suffering from osteoporosis with a non-displaced fracture of the femur.

(i) Explain why the fracture shown in X-ray **C** is more likely to heal with the best chance of full recovery than the fracture shown in X-ray **D**. [2]

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(ii) Both fractures required surgery and the use of screws and/or metal plates. Suggest why this treatment would lead to a faster recovery than bed rest or immobilisation. [1]

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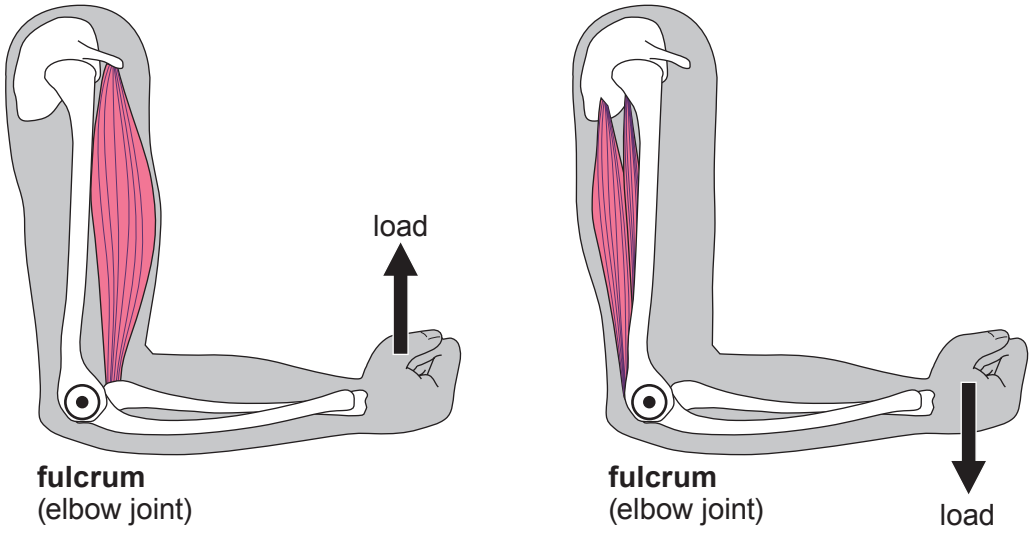
Examiner only

(d) The drawings below show the muscles that control movement of the lower arm. These muscles work with the elbow joint as levers.



(i) State the orders of lever represented in the elbow joint when the: [1]

Biceps are contracting .....

Triceps are contracting .....

(ii) Explain why there is a difference in the type of lever represented when the arm is being bent and straightened. [2]

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(iii) In experiments to determine the force generated by the biceps and triceps muscles in individuals, comparisons can be made regarding the relative strength of the two muscles. Suggest **one** feature of the human subjects that should be controlled to make any conclusions valid. [1]

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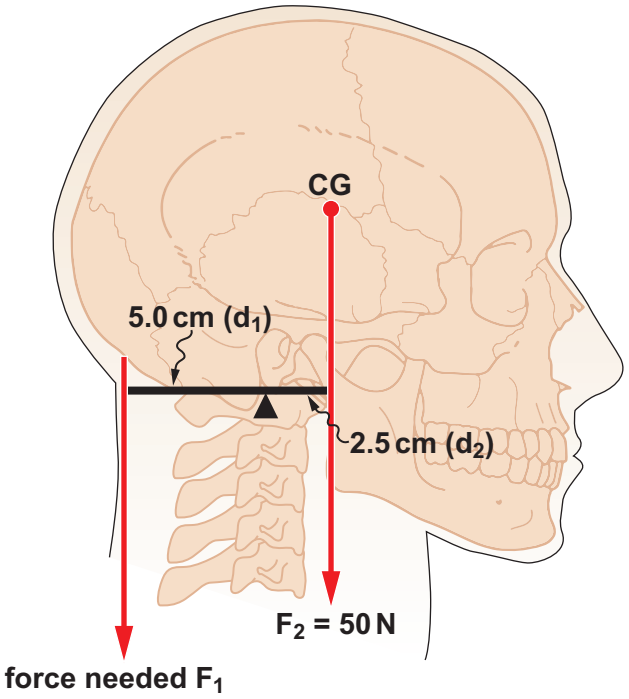
Examiner only

Even when the head is held erect, its centre of gravity is not directly over the principal point of support (the atlanto-occipital joint). The muscles at the back of the neck exert a force to keep the head erect. That is why your head falls forward when you fall asleep.



(iv) Using the formula below, calculate the force needed to hold the head erect in the position shown [2]

$F_1 \times d_1 = F_2 \times d_2$

Force = ... N

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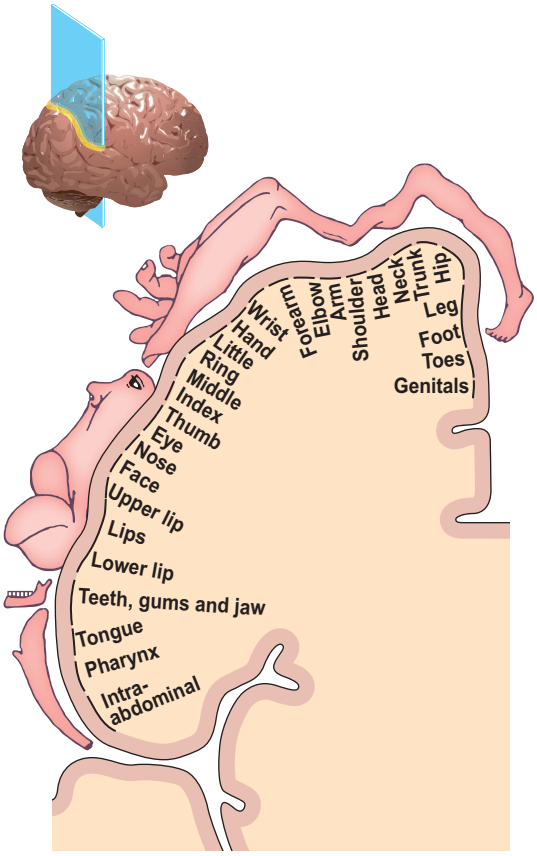
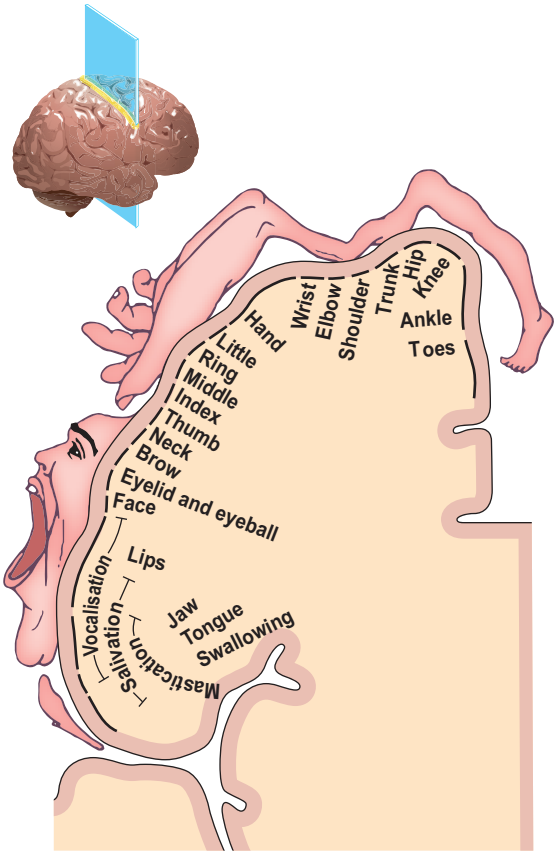
Option C: Neurobiology and Behaviour

10. *(a)* The cortical homunculus is a drawing showing the area of cortex devoted to specific regions of the body. It correlates the anatomy of the body with a neurological map. There are two types of cortical homunculus: the sensory homunculus and the motor homunculus.



Sensory cortex in right cerebral hemisphere



Motor cortex in right cerebral hemisphere

With reference to the homunculi shown above, identify what they show and describe and explain the major differences between the two images. [4]

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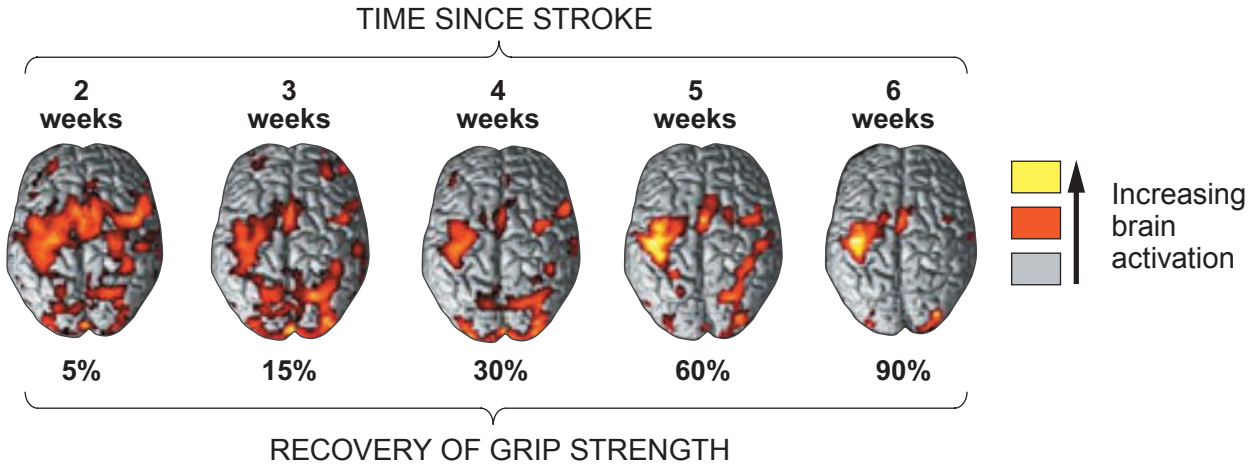
Examiner only

(b) A stroke is the interruption of blood flow to the brain. It may result in the death of brain cells. Individual patients can recover from strokes over a period of time. The image below shows functional magnetic resonance imaging (fMRI) scans showing the brain during repetitive gripping with the hand. Each brain image represents the activation pattern at different time points over the first six weeks after a stroke for one patient. After 6 weeks, the image is very similar to what is seen during learning of a new complex motor task in the undamaged human brain.



(i) With reference to the image, describe the advantage of fMRI over computerised tomography (CT) and magnetic resonance imaging (MRI) scans. Explain what has happened in the brain in order to recover from the stroke. [3]

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(ii) Some studies suggest that in a healthy person 375 neurones per hour die due to the aging process. In an untreated stroke patient, it is estimated that 1.9 million neurones per minute die. Calculate how many times greater the neurone loss is in a patient who has a stroke that is untreated for 1 hour compared to a healthy person. [2]

Times greater = × .....

Examiner only

(iii) Use the scans opposite to suggest which part of the brain was damaged. Give reasons for your answer. [2]

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(iv) A stroke affecting Wernicke's area has a different affect to a stroke affecting Broca's area. Using your knowledge of these areas of the cerebral cortex describe the effect of each type of stroke. [2]

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(c) Meerkats, *Suricata suricatta*, live in social groups called mobs, of 5-30 individuals. They inhabit open dry land such as the Kalahari desert. Meerkats share parental care responsibilities. Each mob has a dominant alpha male and dominant alpha female. These are usually the only individuals who produce offspring. This social structure is referred to as a dominance hierarchy.

(i) What are the advantages, to the meerkat colony, of this dominance hierarchy? [2]

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(ii) There is little difference between the size of males and females in meerkats. In other mammals, however, such as African lions, *Panthera leo*, the male is much larger than the female. Explain the reason for the large size of the male lions. [1]

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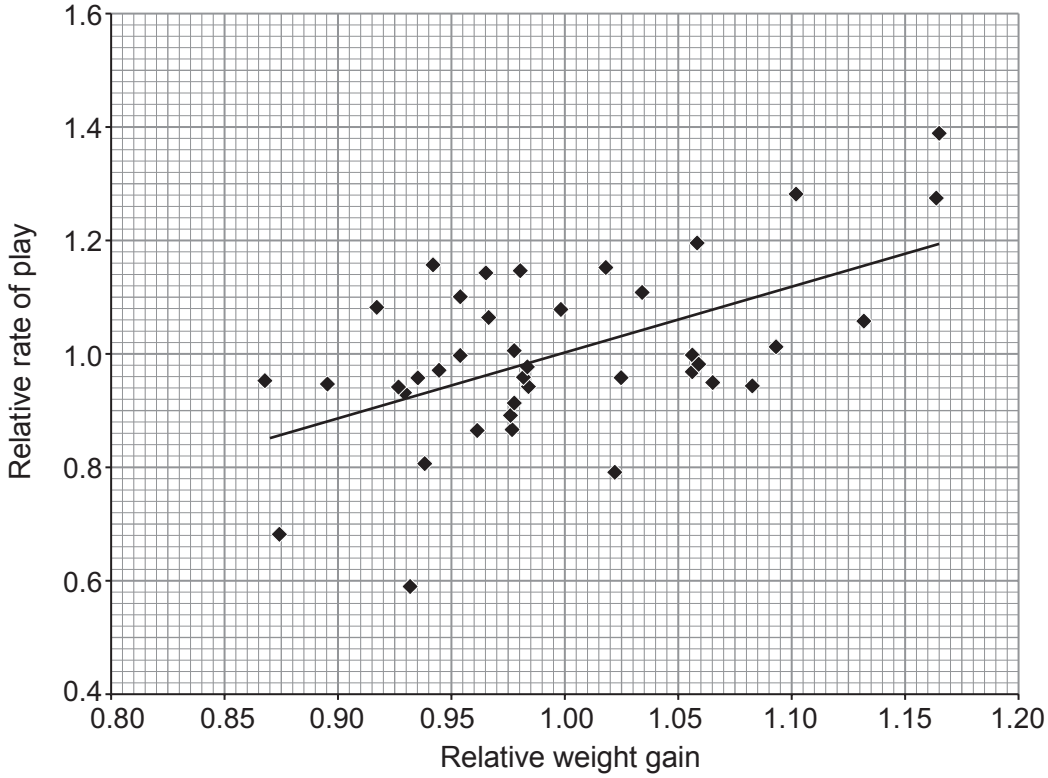
Examiner only

(d) A study of 39 wild meerkats in South Africa investigated whether engaging in play behaviour was more likely in individuals in a better nutritional state. The meerkats were habituated to close observation and handling, they were individually marked and regularly weighed. The researchers observed play in the early morning. They calculated the mean play rates for the young meerkats and compared the individual play rates to the mean. The results are shown in the scatter graph below.



(i) What is the advantage to the study of using meerkats 'habituated' to close observation and handling? [1]

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(ii) What type of correlation is shown between relative weight gain and relative rate of play? [1]

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(iii) How could this investigation be improved to give more valid data? [2]

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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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