Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A400U30-1

S23-A400U30-1-R1

WEDNESDAY, 21 JUNE 2023– MORNING

BIOLOGY – A level component 3
Requirements for Life

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**9**	
	2.	**20**	
	3.	**19**	
	4.	**7**	
	5.	**16**	
	6.	**9**	
Section B	**Option**	**20**	
	Total	**100**	

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ADDITIONAL MATERIALS

In addition to this 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 or correction fluid.

You may use a pencil for graphs and diagrams only.

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(s) 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**: 20 marks; Options. Answer **one option only**. You are advised to spend 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 quality of extended response (QER) will take place in question **6**.

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

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SECTION A

Answer **all** questions.

1. (a) The mammalian kidney is an organ which is involved in homeostasis.
Define the following terms.

(i) Organ [1]

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(ii) Homeostasis [1]

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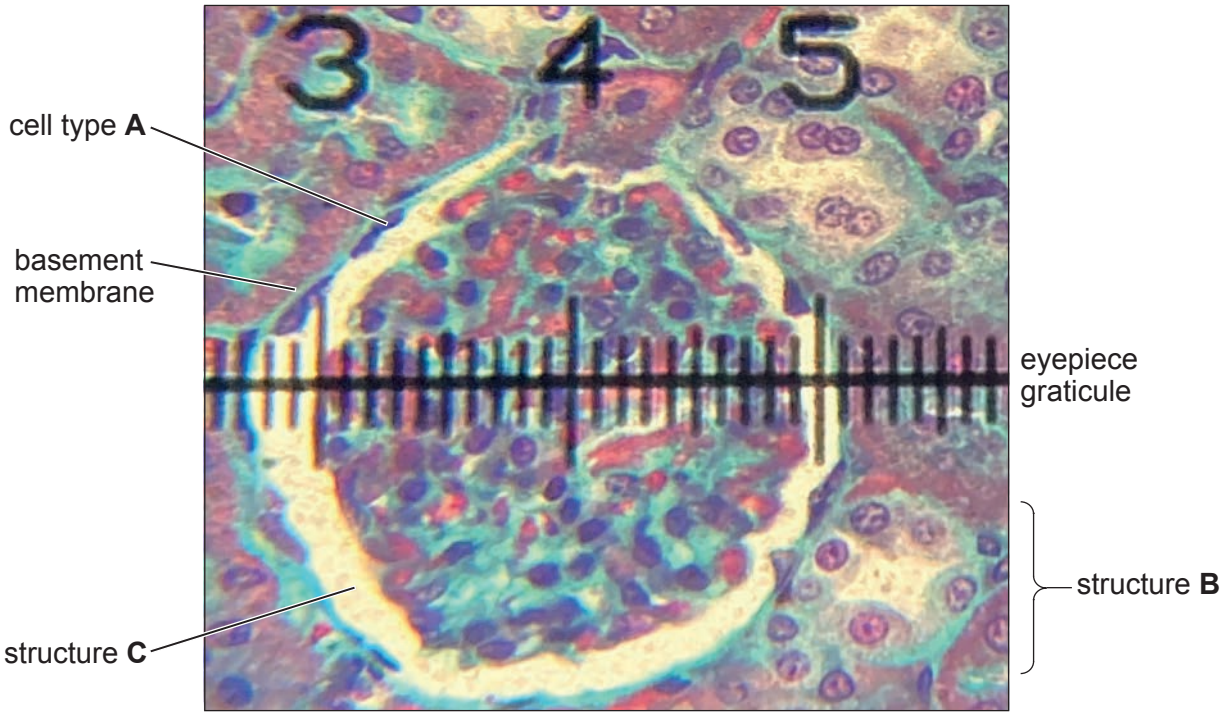
(b) **Image 1.1** shows a section of kidney cortex that has been viewed using a ×40 objective lens. The microscope used was fitted with an eyepiece graticule.

Image 1.1



Identify cell type **A**, structure **B** and structure **C** on **Image 1.1**. [3]

cell type **A** .....

structure **B** .....

structure **C** .....

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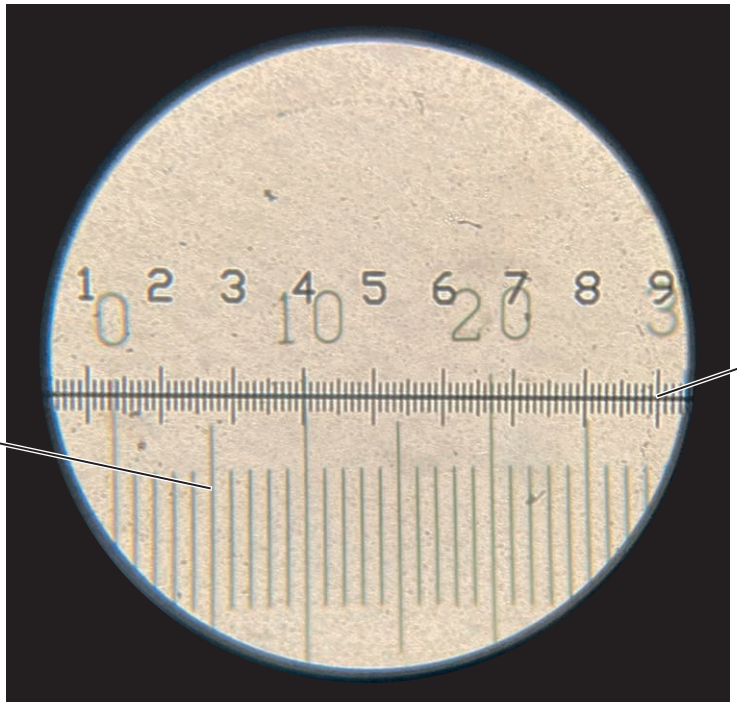
(c) A stage micrometer can be used to calibrate an eyepiece graticule.
Image 1.2 shows part of a stage micrometer viewed using a ×40 objective.

Image 1.2



(i) Calibrate the microscope using **Image 1.2**
(1 stage micrometer division = 0.01 mm).
Show all your working. Give your answer in μm. [2]

One eyepiece unit = ... μm

(ii) I. Use the eyepiece graticule in **Image 1.1** to determine the diameter of the glomerulus in **eyepiece units**. [1]

Diameter = ... eyepiece units

II. Use your calibration of the microscope to calculate the actual diameter of the glomerulus in μm. [1]

Diameter of glomerulus = ... μm

9

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2. A student investigated the numbers of stomata in ivy leaves (*Hedera helix*). Leaves of a similar size were taken from ivy plants growing on two different trees, one grown in full sun and another in shade. Clear nail varnish was used to make a lower epidermal impression from the leaf. **Image 2.1** shows an ivy leaf and an impression of the lower epidermis viewed using a microscope with a ×40 objective lens.

Image 2.1

Nail varnish impressions from ten ivy leaves grown in full sun and ten ivy leaves grown in shade were used to estimate the number of stomata in a field of view for plants grown in each condition. **Table 2.2** shows the number of stomata in a field of view for each leaf.

Table 2.2

Number of stomata in a field of view from ivy leaves grown in full sun	Number of stomata in a field of view from ivy leaves grown in shade
45	23
40	24
42	30
38	32
36	27
38	28
40	32
35	28
45	22
41	24

Examiner only

(a) (i) State the following for this investigation: [1]

the independent variable; .....

the dependent variable. .....

(ii) State **two** variables that were controlled in this investigation. [2]

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(iii) State **two** ways in which the student could improve the reliability of the results. [2]

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Question continued on next page

(b) Student's t-test was used to compare the means of the two samples. The null hypothesis was stated as:

'there was no significant difference between the mean numbers of stomata per field of view found in ivy leaves grown in the shade and in full sun'.

Table 2.3 shows the calculation of the variance for these data.

Table 2.3

Leaves grown in full sun			Leaves grown in shade		
Number of stomata in a field of view x_1	Deviation from mean $(\overline{x}_1 - x_1)$	Deviation from mean^2 $(\overline{x}_1 - x_1)^2$	Number of stomata in a field of view x_2	Deviation from mean $(\overline{x}_2 - x_2)$	Deviation from mean^2 $(\overline{x}_2 - x_2)^2$
45	–5	25	23	4	16
40	0	0	24	3	9
42	–2	4	30	–3	9
38	2	4	32	–5	25
36	4	16	27	0	0
38	2	4	28	–1	1
40	0	0	32	–5	25
35	5	25	28	–1	1
45	–5	25	22	5	25
41	–1	1	24	3	9
$\overline{x}_1 = 40$		$\sum = 104$	$\overline{x}_2 = 27$		$\sum = 120$
		$s_1^2 = 11.6$			$s_2^2 = 13.3$

Key:

for leaves grown in **full sun**:

x_1 = the number of stomata in a field of view for each ivy leaf
$\overline{x}_1$ = mean number of stomata in a field of view for 10 ivy leaves
$\sum$ = sum
s_1^2 = variance
n_1 = number of ivy leaves grown in full sun

for leaves grown in **shade**:

x_2 = the number of stomata in a field of view for each ivy leaf
$\overline{x}_2$ = mean number of stomata in a field of view for 10 ivy leaves
$\sum$ = sum
s_2^2 = variance
n_2 = number of ivy leaves grown in shade

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(i) Calculate the value of t for these data using the formula: [3]

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

t = ...

(ii) Compare your calculated value for t with the figures in **Table 2.4** at the 5% level of probability, where the degrees of freedom = $(n_1 - 1) + (n_2 - 1)$.
Explain whether you would accept or reject the null hypothesis and give your final conclusion. [4]

Table 2.4

Degrees of freedom	Level of probability				
	1	0.5	0.1	0.05	0.02
15	0.000	0.691	1.753	2.131	2.602
16	0.000	0.690	1.748	2.120	2.583
17	0.000	0.689	1.740	2.110	2.567
18	0.000	0.688	1.734	2.101	2.552
19	0.000	0.688	1.729	2.093	2.539
20	0.000	0.687	1.725	2.086	2.528

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Examiner only

(c) Global atmospheric carbon dioxide concentrations have increased by approximately $60\,\mu mol\,mol^{-1}$ over the past 200 years. Studies on eight species of plants collected over this period have shown that the increase in carbon dioxide concentrations has resulted in a 40% reduction in stomatal density.

(i) Suggest why the increased carbon dioxide concentration resulted in a reduction in stomatal density. [3]

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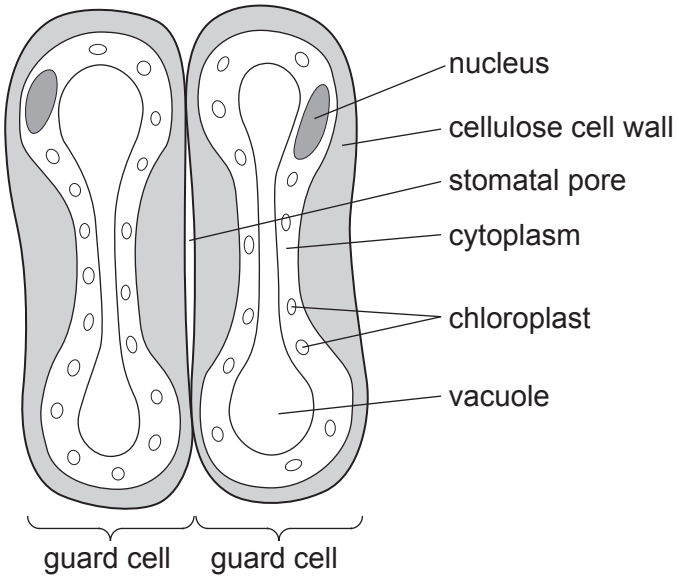
Examiner only

(ii) A diagram of a stomata from a leaf of grass is shown in **Image 2.5**.

Image 2.5



Use your knowledge of stomatal opening mechanisms to explain how the stomata in **Image 2.5** are opened. [5]

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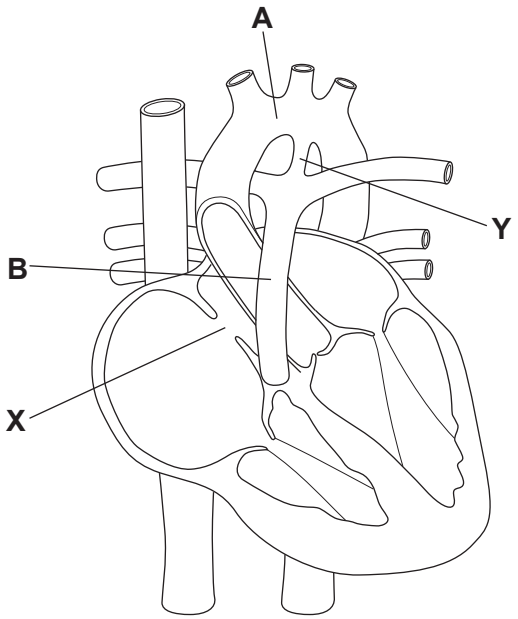
Examiner only

3. (a) Major changes take place in the circulatory system in humans at birth. A diagram of the foetal heart and associated blood vessels is shown in **Image 3.1**.

Image 3.1



(i) During foetal development there is a hole between the right and left sides of the heart as shown by **X** in **Image 3.1**.
Suggest why this hole is open during foetal development. [3]

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(ii) Shortly after birth, this hole closes. If this hole does not close after birth the individual would have symptoms of fatigue.
Suggest why these symptoms occur. [2]

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Examiner only

(b) Vessel **Y** in **Image 3.1** is called the ductus arteriosus. It is open in the foetus but closes at birth.

(i) Give the names of vessels **A** and **B** shown in **Image 3.1** which are connected by the ductus arteriosus. [1]

A .....

B .....

(ii) In some humans the ductus arteriosus is not closed after birth.

Explain why this condition can result in the production of excess fluid in the lung tissue. [2]

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(c) A respiratory surface is defined as the part of the organism where gaseous exchange takes place between the external air or water and the internal tissues.
Complete **Table 3.2** to state the main respiratory surface of each organism. [2]

Table 3.2

Organism	Main respiratory surface
Fish	.....
Mammal	.....
Earthworm	.....
Insect	.....

Examiner only

Many organisms use haemoglobin to transport oxygen from the respiratory surface to the tissues.

(d) There are three different types of haemoglobin molecules that can be found in normal adult humans. Each consists of a combination of polypeptide chains, α, β, γ and δ, as shown in **Table 3.3**.

Table 3.3

	Haemoglobin type		
	HbA	HbF	HbA_2
Polypeptide type	2α 2β	2α 2γ	2α 2δ

(i) State the name given to the structure of a protein which is made from different polypeptide chains linked together. [1]

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(ii) Use **Table 3.3** to suggest the minimum number of genes that are involved in the production of haemoglobin. [1]

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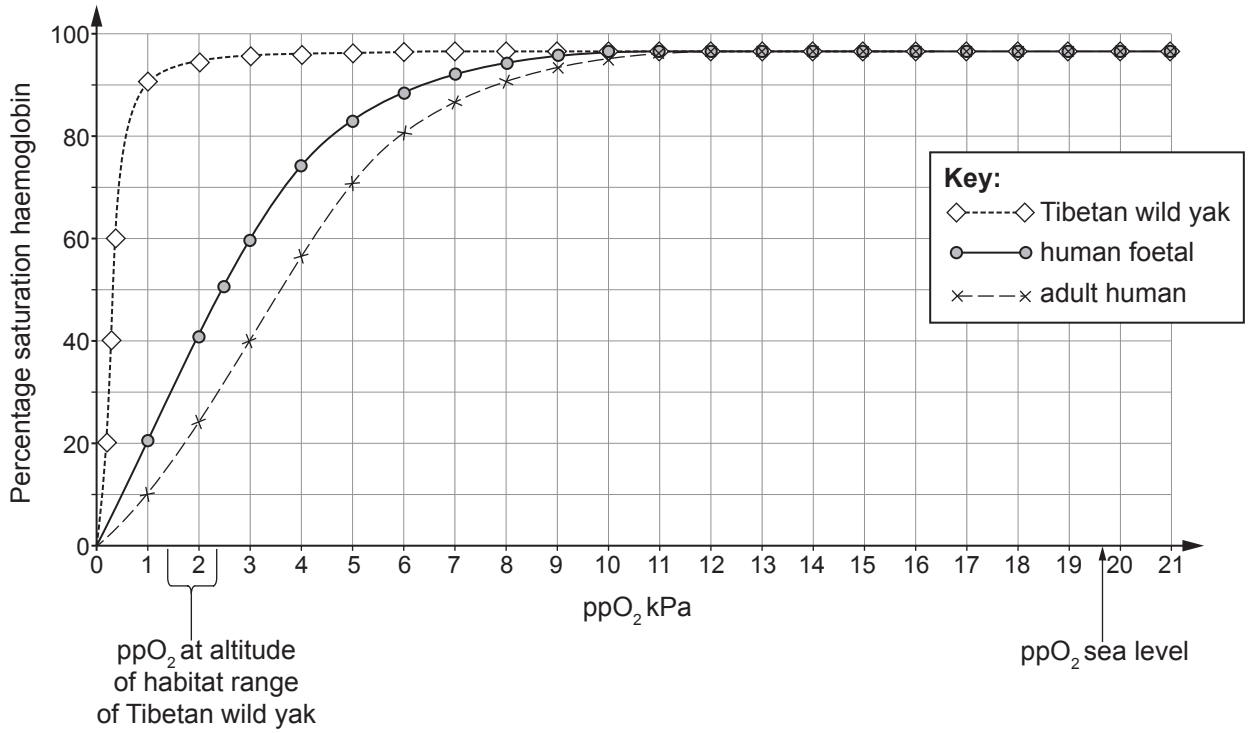
(e) The oxygen dissociation curves for human foetal haemoglobin (HbF), adult haemoglobin (HbA) and the Tibetan wild yak (*Bos mutus*) are shown in **Graph 3.4**.

Graph 3.4



Examiner only

(i) Explain the position of the oxygen dissociation curve of foetal haemoglobin relative to that of adult haemoglobin. [2]

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The Tibetan wild yak shown in **Image 3.5** lives at high altitudes, between 4000 m–6000 m. Very few mammals can live at these altitudes.

Image 3.5

(ii) Use **Graph 3.4** to explain how Tibetan wild yak haemoglobin is an adaptation for living at high altitude. [2]

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(iii) Suggest **one** disadvantage of the position of the Tibetan wild yak dissociation curve. [1]

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Examiner only

(iv) In their natural habitat the breathing rate of Tibetan wild yaks is much higher than that of humans living at sea level.

Explain the difference in the rate of breathing. [2]

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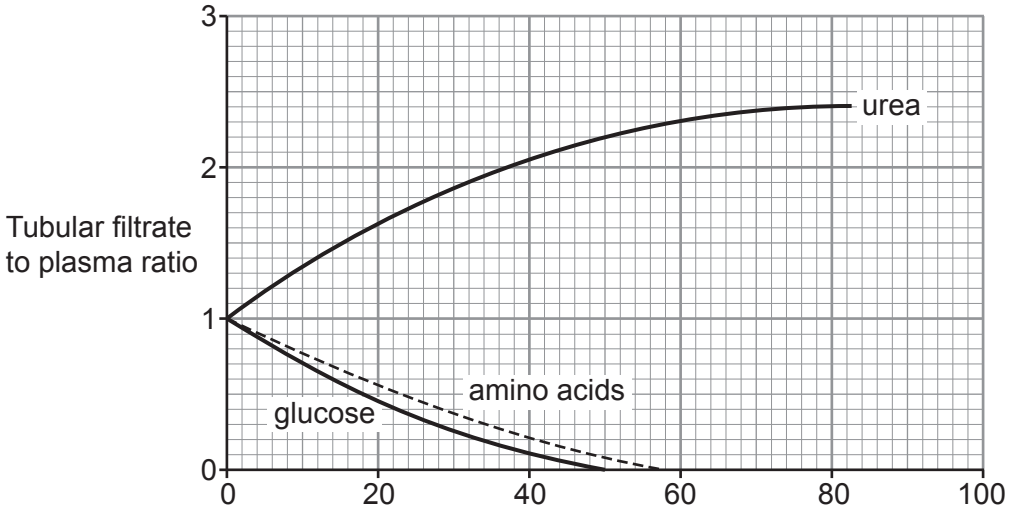
4. In an adult human, approximately 180 dm^3 of fluid is filtered from the glomeruli into the Bowman's capsules per day. As the filtrate moves along the proximal convoluted tubules (PCT) some substances are selectively reabsorbed. By the time the filtrate has reached the end of the proximal convoluted tubules 70% of the water has been reabsorbed.

Graph 4.1 shows the change in the tubular filtrate to plasma ratio due to the reabsorption of water.

Graph 4.1



(a) Explain the change in tubular filtrate to plasma ratios for:

(i) glucose and amino acids; [2]

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(ii) urea. [2]

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Examiner only

(b) Non-polar molecules, such as the insecticide DDT, are fat soluble and diffuse through the cell membranes of the cells in the PCT.
Suggest why more of these molecules diffuse through the cells into the blood at the terminal end of the PCT. [1]

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(c) People with uncontrolled Type 1 diabetes have high concentrations of blood glucose. This results in high concentrations of glucose in the glomerular filtrate. Not all of the glucose can be reabsorbed, resulting in the loss of glucose in the urine.
Use your knowledge of the transport of glucose to explain why not all the glucose can be reabsorbed. [2]

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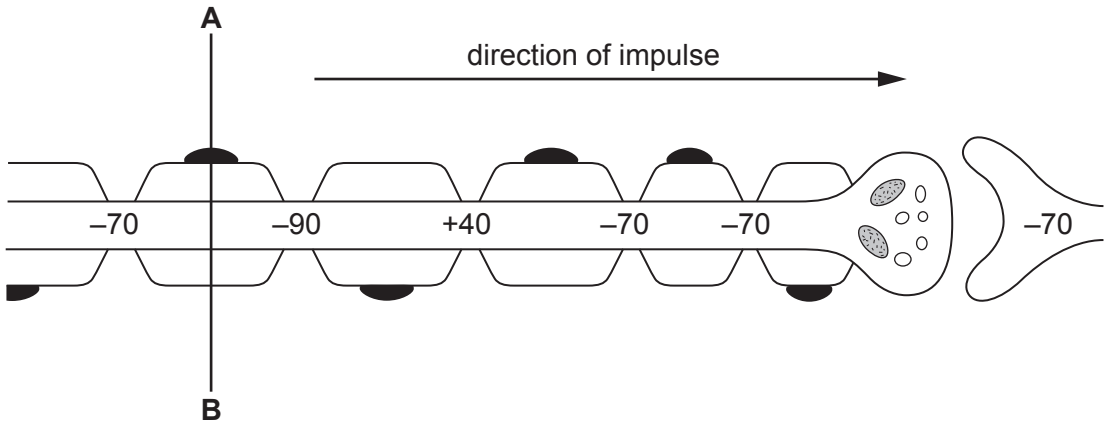
Turn over.

Examiner only

5. **Image 5.1** shows part of an axon and a synapse. The figures indicate the potential difference across the membrane between the cytoplasm of the axon and the extracellular fluid at intervals along the axon.

Image 5.1



(a) **Draw an arrow** to indicate **one** region of the axon in **Image 5.1** where an action potential is taking place. Explain your choice. [2]

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(b) The nerve impulse is prevented from travelling in the opposite direction to that shown in **Image 5.1**.

Use **Image 5.1** to give **two** pieces of evidence to explain this. [2]

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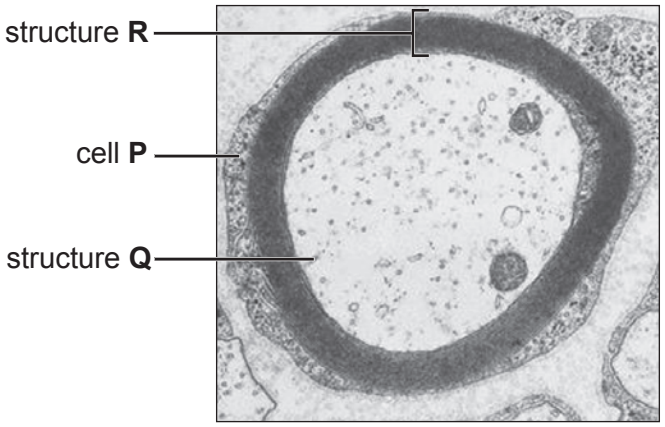
Examiner only

(c) The electron micrograph in **Image 5.2** shows a transverse section along the line marked **A–B** on **Image 5.1**.

Image 5.2



(i) Identify cell **P** and structures **Q** and **R**. [2]

cell **P** .....

structure **Q** .....

structure **R** .....

(ii) Explain what would happen to the rate of transmission of the nerve impulse if structure **R** was not present. [2]

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(iii) **Complete the following table** to state and explain **two** other factors which affect the speed of conduction of the nerve impulse. [2]

Factor	Explanation
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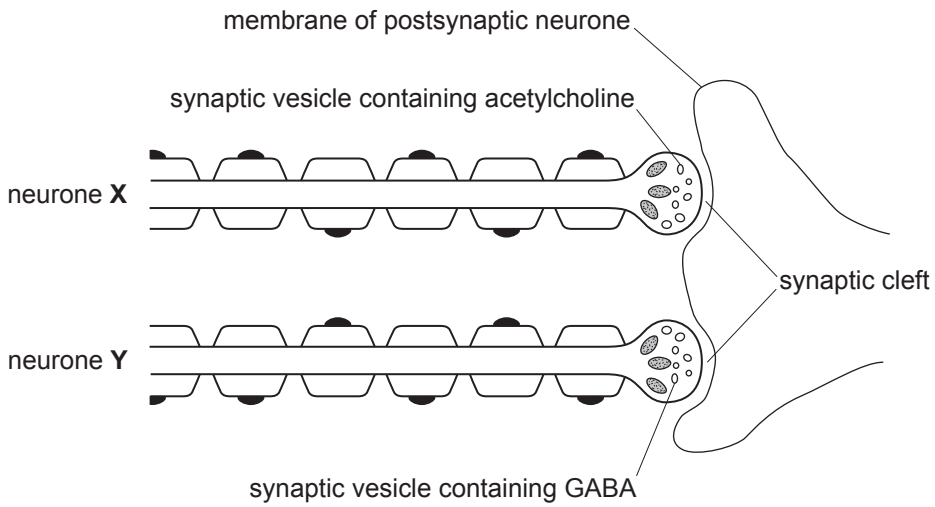
(d) Diagrams of two neurones **X** and **Y**, associated with the same postsynaptic neurone, are shown in **Image 5.3**.

Image 5.3



- An action potential passing along neurone **X** causes the impulse to pass across the synapse and an action potential to be generated in the postsynaptic neurone.
- The neurotransmitter substance in the synaptic vesicles in neurone **Y** is gamma aminobutyric acid (GABA).
- When GABA is released it binds to receptors on the postsynaptic membrane.
- This causes chloride ions (Cl^-) to enter the postsynaptic neurone and potassium ions (K^+) to leave the postsynaptic neurone.
- This is an example of an inhibitory synapse.

If the inhibitory synapse of **Y** is activated first, neurone **X** does not generate an action potential in the postsynaptic neurone.
Use the information in **Image 5.3** to suggest an explanation for this. [4]

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Examiner only

(e) Some organophosphates block the active site of the enzyme acetylcholinesterase that breaks down the neurotransmitter acetylcholine.

Suggest why the presence of organophosphates in a synapse can result in continuous stimulation of the postsynaptic cell. [2]

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16

Turn over.

6. *Amoeba* is a unicellular organism, whilst *Hydra* is an example of a multicellular organism that shows an increased level of adaptation for the digestion and absorption of food material.

Both *Amoeba* and *Hydra* show holozoic nutrition. **Image 6.1** shows the process of holozoic nutrition in *Amoeba*. **Image 6.2A** shows *Hydra* ingesting a worm and **Image 6.2B** is a diagram of its body wall.

Image 6.1

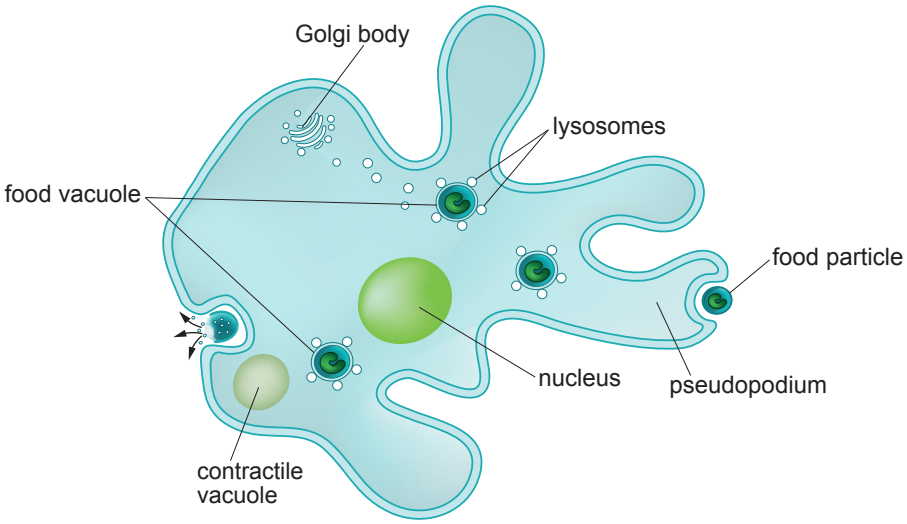


Image 6.2A – *Hydra* ingesting a worm

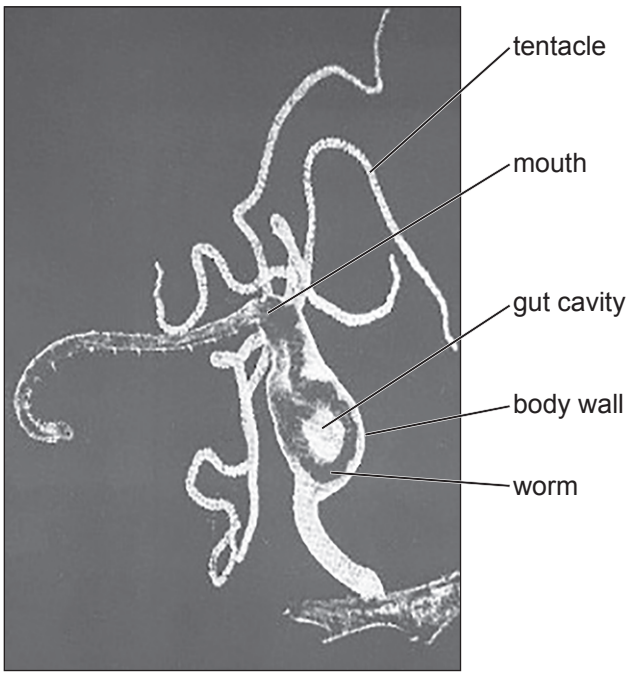
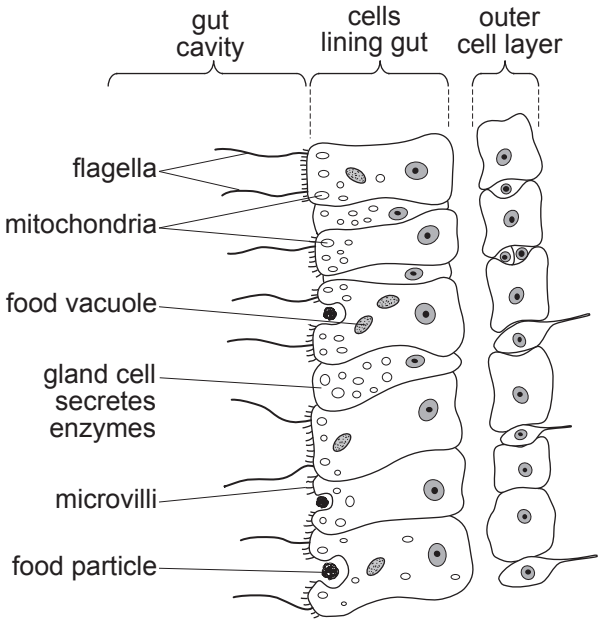


Image 6.2B – Body wall of *Hydra*



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Use **Image 6.1** to describe how *Amoeba* ingests, digests and egests food material.

Use **Image 6.2A and Image 6.2B** to describe and explain how *Hydra* is adapted for digestion and absorption.

Humans also show holozoic nutrition and have a tube gut. Describe how the presence of a tube gut enables humans to have a more efficient digestive system. [9 QER]

Examiner only

Examiner only

9

Examiner only

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.

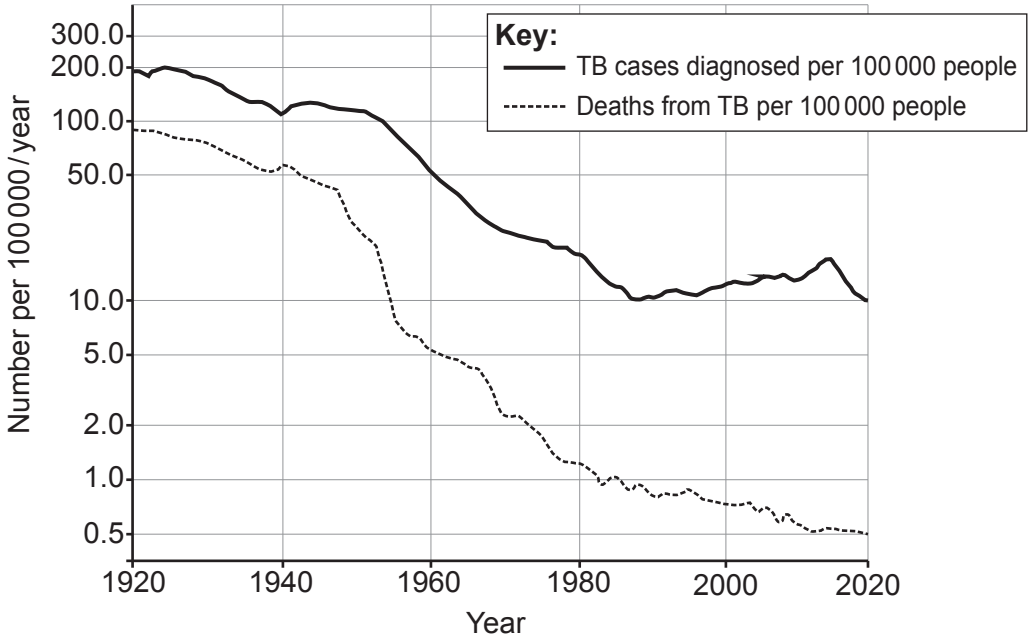
You are advised to spend about 25 minutes on this section.

Examiner only

Option A: Immunology and Disease

7. Tuberculosis (TB) is an endemic disease in the UK. **Graph 7.1** shows the incidence of TB per 100 000 people in the UK between 1920 and 2020.

Graph 7.1



(a) (i) State the meaning of the term endemic. [1]

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(ii) The incidence is expressed as cases per 100 000 population and not as the total number of cases in the population. Explain why. [2]

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(iii) Using **Graph 7.1**, calculate the percentage of the people diagnosed with TB who died from the disease in 2020. [2]

Percentage = ...

Examiner only

(iv) In 1920 approximately 40% of those diagnosed with TB died from the disease. It is thought that the actual percentage of deaths resulting from TB in 1920 may have been lower than 40%.
Suggest why the actual percentage of deaths may have been lower. [1]

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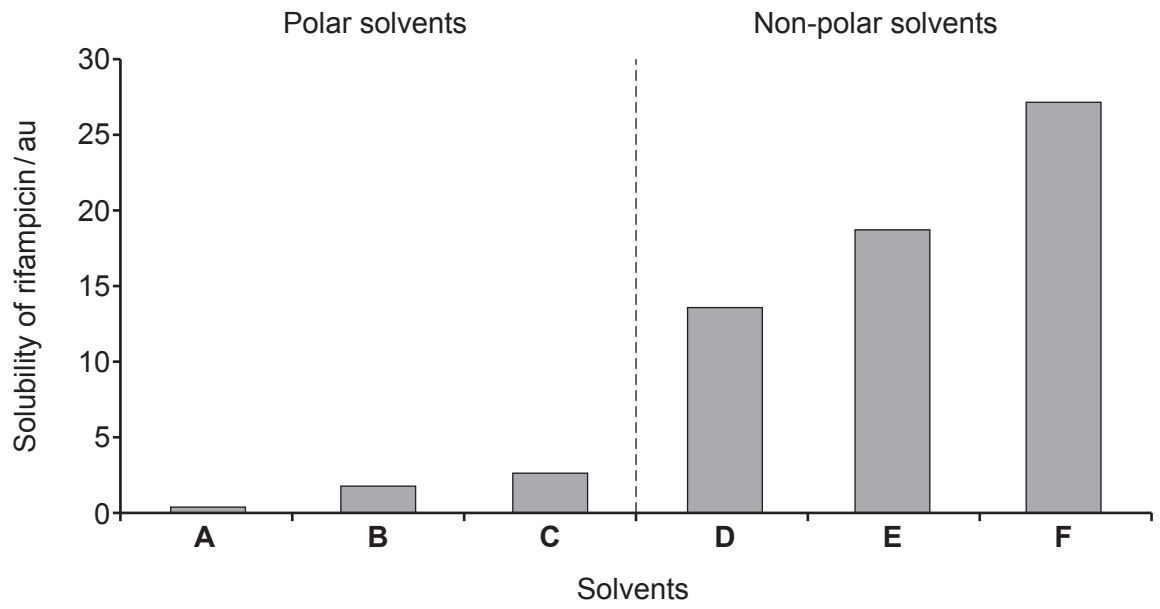
(b) Although TB can be treated with antibiotics, many strains of the bacterium are resistant to antibiotics which are water soluble.

Rifampicin is one antibiotic which is effective against *Mycobacterium tuberculosis*.
An investigation was carried out into the solubility of rifampicin in a range of different solvents. The solvents used in the investigation included three non-polar solvents and three polar solvents.

Graph 7.2 shows the results of the investigation.

Graph 7.2



Examiner only

All strains of *M. tuberculosis* have a thick, hydrophobic envelope surrounding the cell which prevents water soluble compounds from entering the cell.

(i) Use **Graph 7.2** to explain why rifampicin is effective against *M. tuberculosis*. [2]

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Rifampicin is a broad-spectrum, bactericidal antibiotic.

(ii) State what is meant by the terms:

I. broad-spectrum; [1]

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II. bactericidal. [1]

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(iii) Rifampicin works by inhibiting bacterial RNA polymerase enzyme, preventing transcription from taking place.
Explain how rifampicin would affect *M. tuberculosis*. [3]

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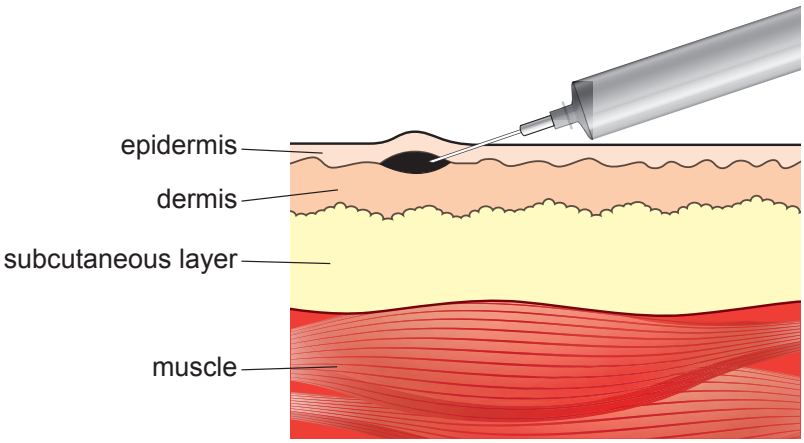
Examiner only

(c) The most widely used vaccine against TB is the BCG vaccine. The vaccine is prepared with a live, attenuated form of *Mycobacterium bovis*. *M. bovis* is closely related to *M. tuberculosis*. The vaccine is administered by an injection below the epidermis of the skin (intradermal injection) as shown in **Image 7.3**.

Image 7.3



(i) To be effective the injection must penetrate the epidermis layer of the skin. Explain why. [2]

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(ii) Describe how injecting the vaccine would result in antibody production. [3]

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Examiner only

(iii) There may be concerns regarding the use of a live vaccine. Suggest what these concerns may be and give a suitable alternative to a live vaccine. [2]

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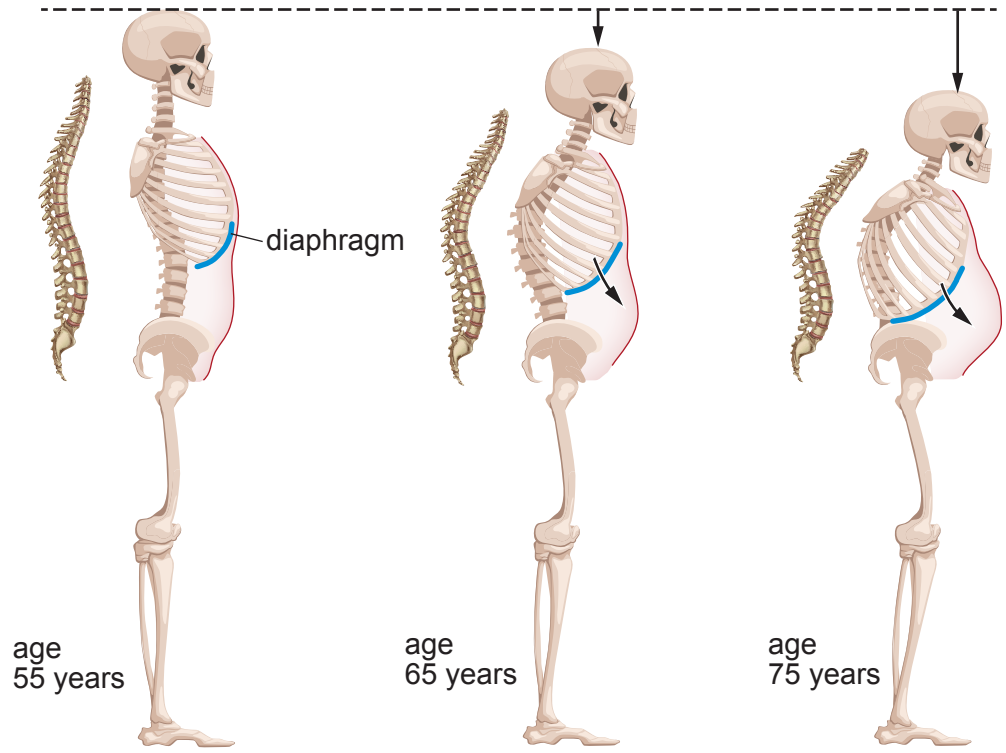
Examiner only

Option B: Human Musculoskeletal Anatomy

8. Osteoporosis is a progressive condition where the bone mineral density reduces over time. If it is not treated, osteoporosis can lead to postural changes as shown in **Image 8.1**.

Image 8.1



(a) (i) The postural changes that can occur in later life with osteoporosis sometimes cause breathing difficulties in sufferers. Use **Image 8.1** to suggest why people with these postural changes may have difficulty breathing. [2]

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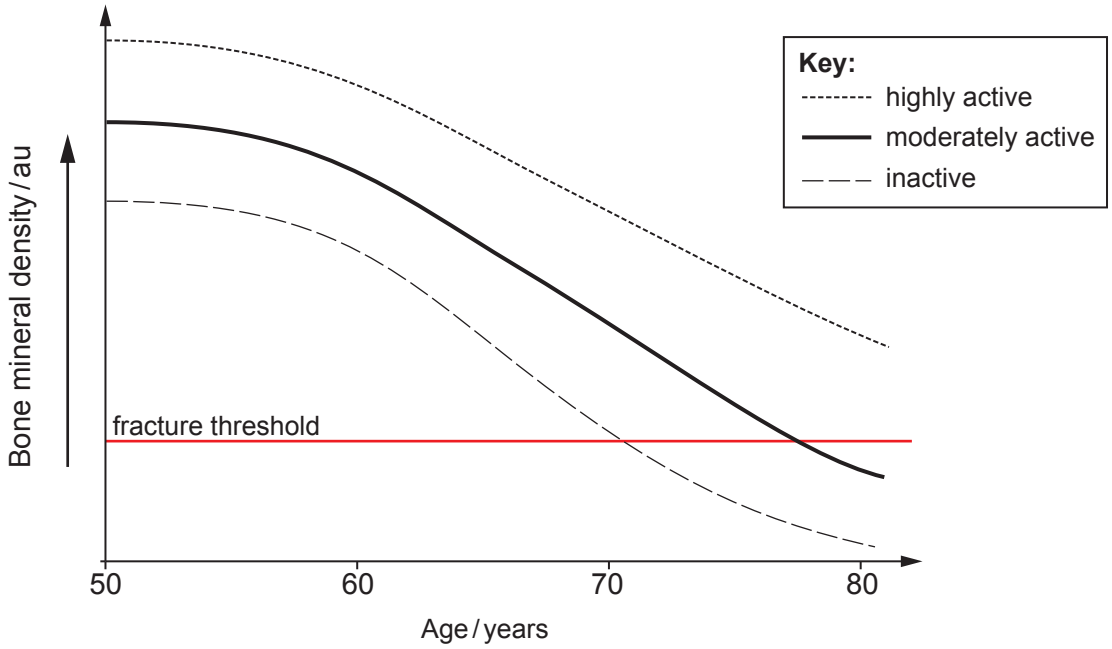
Regular exercise is recommended as a precaution against the development of osteoporosis.

Graph 8.2 shows how bone mineral density changes with age and level of activity.

Graph 8.2



Credit: International Osteoporosis Foundation – 2005 Invest in Your Bones Report 'Move it or Lose it.'

A person is considered to have osteoporosis when bone mineral density falls below the fracture threshold. This means that the person is likely to suffer a fracture.

(ii) Use **Graph 8.2** to conclude the effect of increased levels of activity on the development of osteoporosis by the age of 80 years. [2]

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(iii) Suggest **two** factors that should be kept constant when selecting candidates for the study. [2]

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Examiner only

(b) A common fracture in osteoporosis sufferers is a fracture of the wrist as shown in **Image 8.3**.

Image 8.3

Identify the type of fracture **and** the bones involved in the wrist fracture shown in **Image 8.3**. Describe **one** possible course of treatment required. [3]

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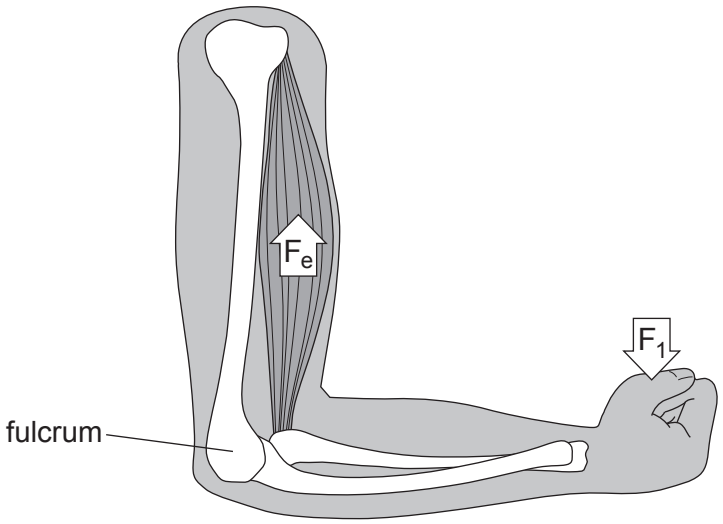
Examiner only

(c) Studies have shown that load bearing exercises give the greatest benefit in preventing osteoporosis. Repetitively lifting an object by flexing the elbow as shown in **Image 8.4**, is an effective load bearing exercise that can easily be performed at home.

Image 8.4



(i) Name the order of lever shown in **Image 8.4**. [1]

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(ii) In **Image 8.4** the elbow to hand distance is 36 cm and elbow to biceps is 4 cm. Use this information and the formula below to calculate the force required to lift a weight with a mass of 1.2 kg. **Give your answer in Newtons.** [2]

$$F_e = F_1 \times \frac{D1}{D2}$$

Where:

F_e = force exerted by the effort

F_1 = mass (kg) × 9.8 N

D1 = distance from load to fulcrum

D2 = distance from effort to fulcrum

Force = ... Newtons

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(iii) The flexion and extension of the elbow involves antagonistic pairs of muscles which alternately contract and relax to flex and extend the elbow.

Explain why the muscles of the upper arm are arranged in this way and how they work to produce movement at the elbow. [4]

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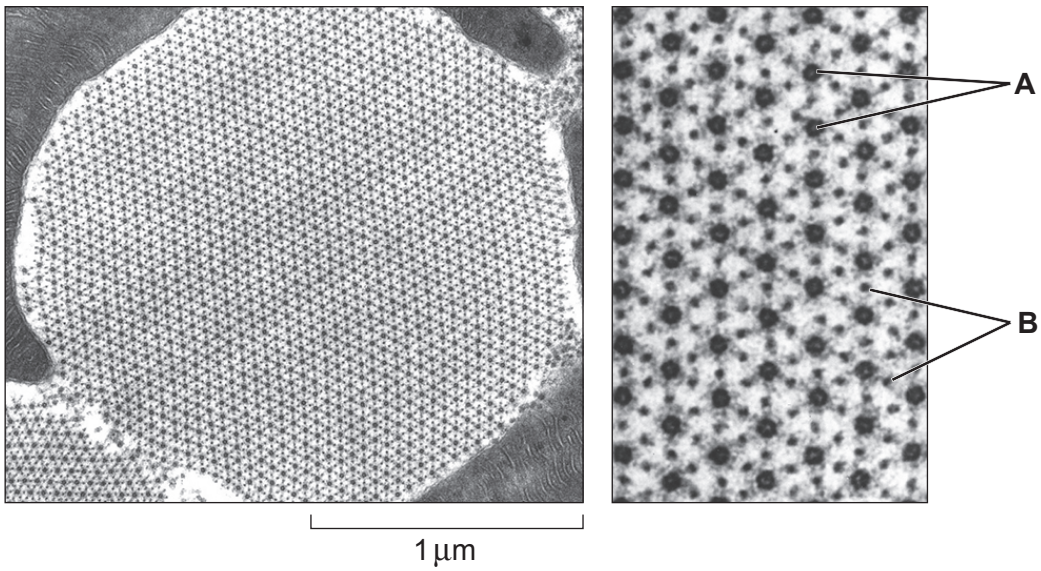
(d) **Image 8.5** shows an electron micrograph of a transverse section through a single cell from a biceps muscle.

Image 8.5



(i) Name the type of muscle cell shown in **Image 8.5**. [1]

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(ii) Identify the molecules labelled **A** and **B** in **Image 8.5**. [2]

A: .....

B: .....

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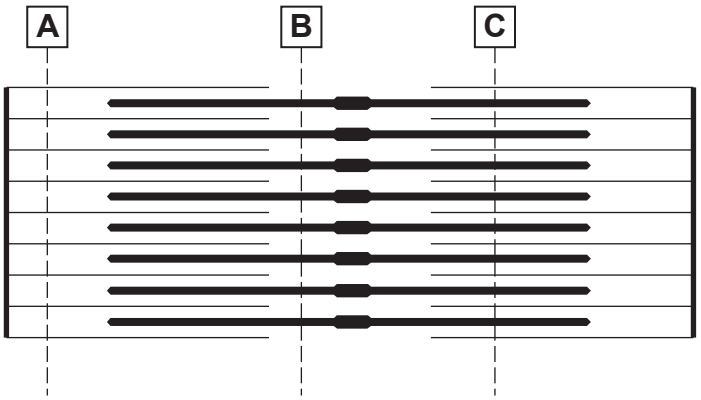
Image 8.6 shows a longitudinal view of a single sarcomere.

Image 8.6



(iii) Identify which of the three lines **A**, **B** or **C** drawn on **Image 8.6** best represents the region from where the cross section in **Image 8.5** was taken. [1]

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Option C: Neurobiology and Behaviour

9. **Image 9.1** is a photograph of a section through the brain showing the right hemisphere.

Image 9.1

(a) (i) Identify the structures labelled **A**, **B** and **C** on **Image 9.1**. [2]

Label	Name of structure
A	.....
B	.....
C	.....

(ii) The symptoms of a patient who had suffered a brain injury included partial paralysis of the right arm and hand and the right side of the face. Conclude which hemisphere of the brain is likely to have been damaged and explain your reasoning. [2]

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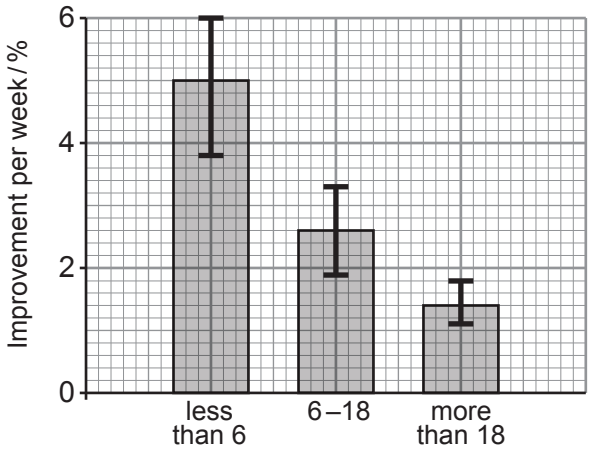
Examiner only

(b) Studies have demonstrated that patients who receive therapy following brain injuries can recover some of the original function of their limbs over time.

Graph 9.2 shows the percentage rate of recovery of original limb function in patients with brain injury depending on how soon after the injury they received therapy.

Graph 9.2



(i) Use the data in **Graph 9.2** to conclude how the number of months after injury before therapy started affected the improvement. Explain how the range bars increase confidence in the conclusions made. [2]

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(ii) Explain how the brain can recover following a brain injury that destroys neural pathways. [2]

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(iii) The data shown in **Graph 9.2** were obtained by studying the recovery of many patients over an extended period.

Suggest **two** factors that would have to be controlled when carrying out such a study. [2]

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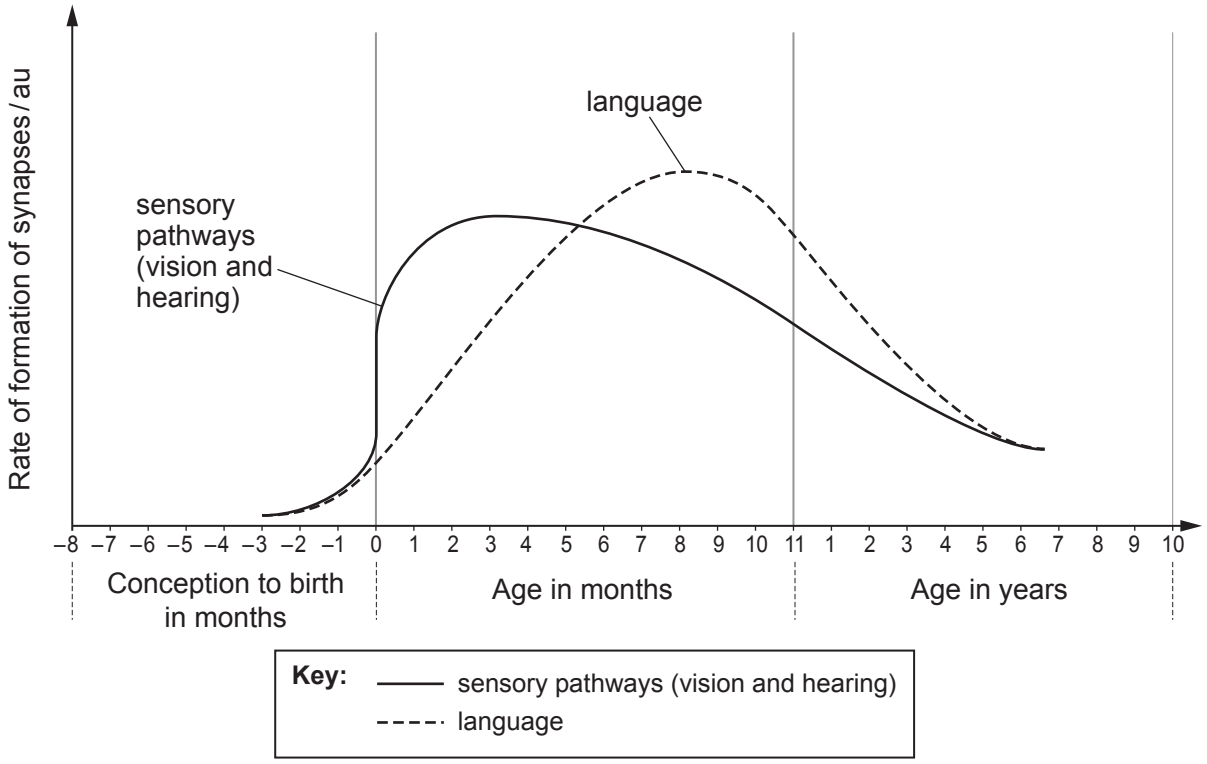
Examiner only

During early childhood, the rate of formation of new synapses between neurones in the central nervous system in the healthy developing brain reaches its maximum.

Graph 9.3 shows the rate of formation of synapses involved in sensory pathways and language development in early childhood.

Graph 9.3



(iv) Use **Graph 9.3** to suggest why children who are not exposed to language between birth and four years of age are less likely to develop language skills. [4]

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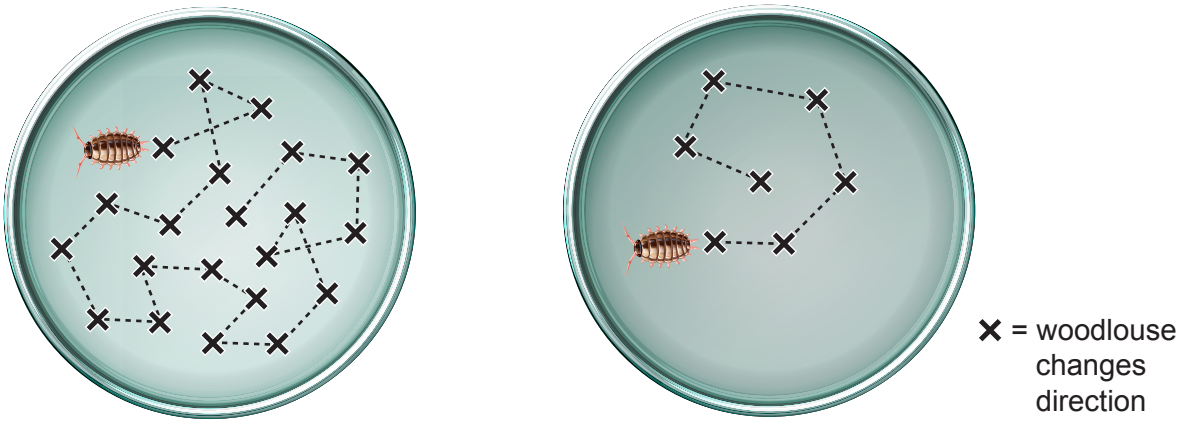
Examiner only

(c) Woodlice are common invertebrates which are often found under rotting wood in damp locations in gardens and woodland.

Image 9.4 shows an investigation into innate behaviour in woodlice.
Five woodlice were placed in separate Petri dishes on pieces of filter paper. Each Petri dish was exposed to varying levels of light intensity. The distance travelled by each woodlouse in 20 seconds was recorded. This distance was used to calculate the speed of movement.

Image 9.4



(i) State the type of innate behaviour shown by the woodlice in this investigation. [1]

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The results of this investigation are shown in **Table 9.5**.

Table 9.5

Light intensity / au	Speed of woodlice / mm s^{-1}					Mean speed / mm s^{-1}
	Woodlouse 1	Woodlouse 2	Woodlouse 3	Woodlouse 4	Woodlouse 5	
2	1.0	1.0	1.2	0.9	1.3	1.1
4	4.4	5.1	4.1	4.3	4.2	.....
6	5.6	5.4	5.2	5.6	5.2	5.4
8	6.7	6.4	6.3	6.9	6.7	6.6
10	6.8	6.0	7.2	6.8	7.0	6.8

(ii) Calculate the mean speed of the woodlice at 4 au light intensity **and record your answer in Table 9.5**. [1]

(iii) State the relationship between light intensity and mean speed of the woodlice in the investigation. [1]

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(iv) Explain how this type of behaviour would benefit woodlice in their natural habitat. [1]

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(v) Suggest how this method could be adapted to investigate the effect of humidity on the behaviour of the woodlice. [2]

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END OF PAPER

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

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