Surname	StemUp Model Solution	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]

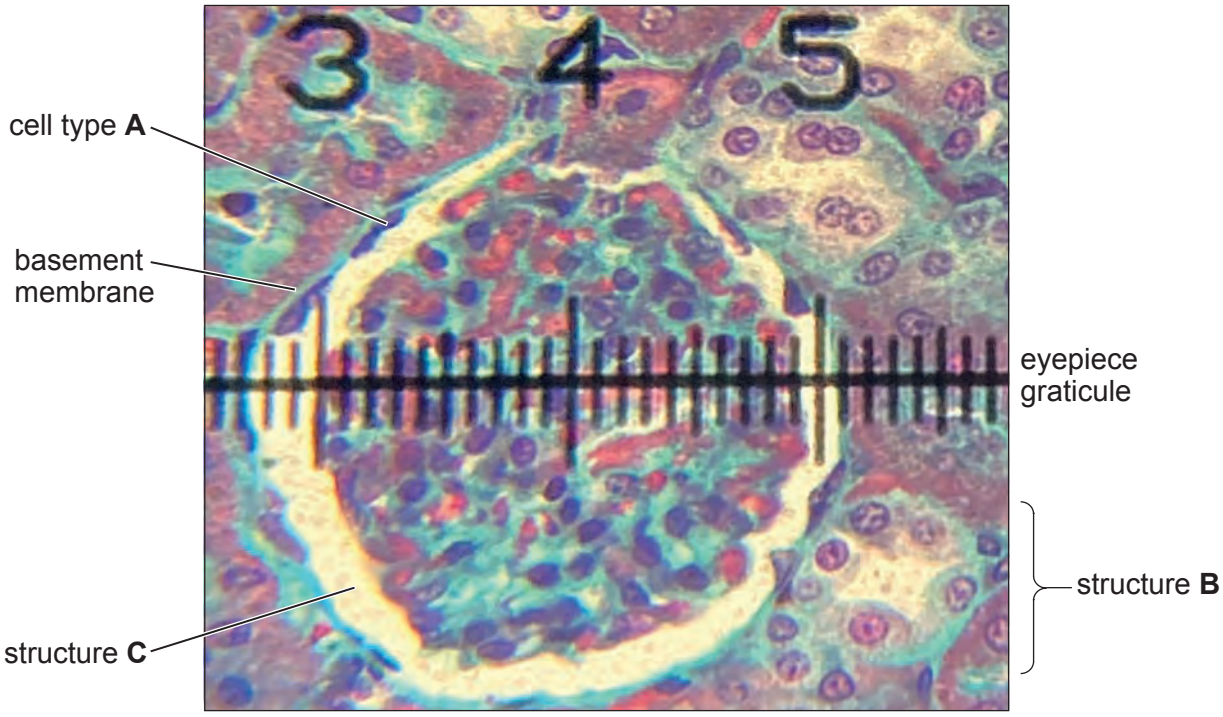
A group of different tissues working together to carry out a specific function.

(ii) Homeostasis [1]

The maintenance of a constant internal environment (internal conditions) in the body.

(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** *(Squamous) epithelium*

structure **B** *Proximal convoluted tubule (PCT)*

structure **C** *Bowman's capsule*

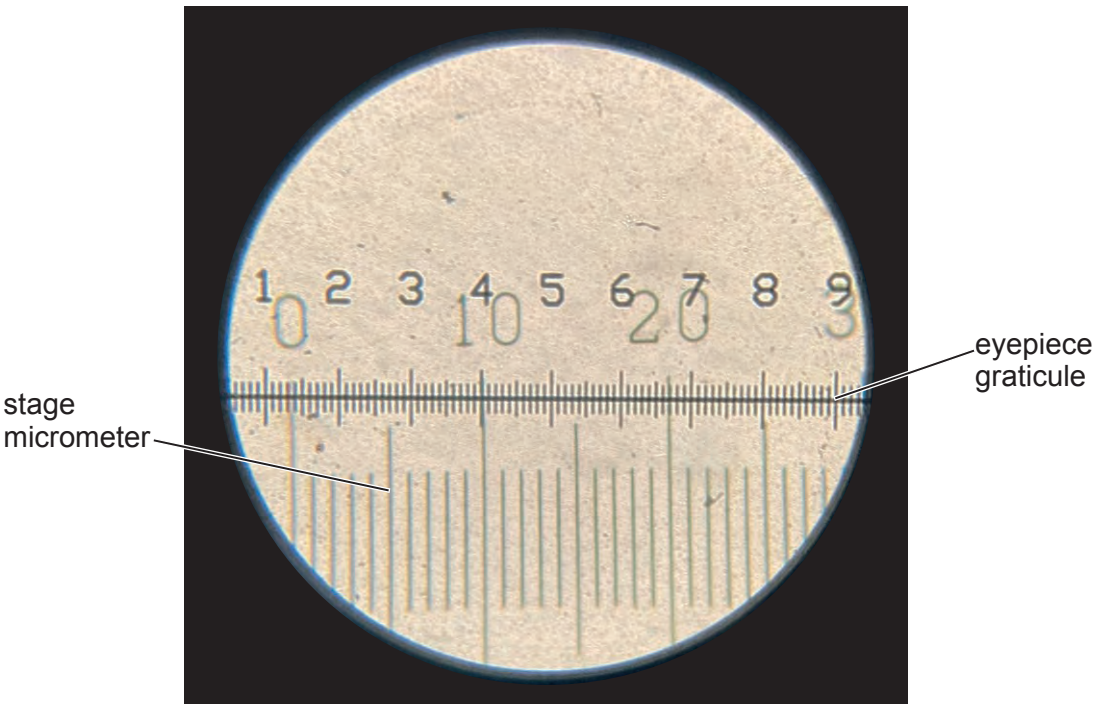
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(c) A stage micrometer can be used to calibrate an eyepiece graticule.
Image 1.2 shows part of a stage micrometer viewed using a ×40 objective.

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]

10 stage divisions = 10 × 0.01 mm = 0.1 mm = 100 µm = 27 eyepiece units
1 eyepiece unit = 100 ÷ 27 = 3.7 µm

One eyepiece unit = 3.7 µm

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

Diameter = 19 eyepiece units

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

19 × 3.7 = 70.3 µm

Diameter of glomerulus = 70.3 µm

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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

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

the independent variable; Grown in full sun or in shade

the dependent variable. Number of stomata in a field of view

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

Similar leaf size; same species (Hedera helix).

Same magnification (×40 objective), same field of view.

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

Increase the number of leaves sampled from each condition (use more than 10 leaves).

Use more plants (more than one plant or tree for each condition) and count more fields of view per leaf, then calculate a mean.

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Question continued on next page

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(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 $(\bar{x}_1 - x_1)$	Deviation from mean^2 $(\bar{x}_1 - x_1)^2$	Number of stomata in a field of view x_2	Deviation from mean $(\bar{x}_2 - x_2)$	Deviation from mean^2 $(\bar{x}_2 - x_2)^2$
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
$\bar{x}_1 = 40$		$\sum = 104$	$\bar{x}_2 = 27$		$\sum = 120$
		$s_1^2 = 11.6$			$s_2^2 = 13.3$

Key:

for leaves grown in **full sun**:

x_1 = the number of stomata in a field of view for each ivy leaf
$\bar{x}_1$ = 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
$\bar{x}_2$ = 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]

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

$t = (40 - 27) \div \sqrt{(11.6/10 + 13.3/10)}$

$= 13 \div \sqrt{(1.16 + 1.33)} = 13 \div \sqrt{2.49}$

$= 13 \div 1.578 = 8.238$

$t =$ 8.24

(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

Degrees of freedom = (10 − 1) + (10 − 1) = 18, so the critical value at the 5% level (p = 0.05) is 2.101.

The calculated value of t (8.24) is greater than the critical value of 2.101.

So the null hypothesis is rejected.

Conclusion: there is a significant difference between the mean numbers of stomata per field of view in ivy leaves grown in full sun and in shade; the difference is not due to chance.

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(c) Global atmospheric carbon dioxide concentrations have increased by approximately 60 μmol 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]

Carbon dioxide is used in photosynthesis, so a higher concentration of carbon dioxide can increase the rate of photosynthesis.

A higher carbon dioxide concentration gives a steeper concentration gradient, so carbon dioxide diffuses into the leaf faster through each stoma.

Fewer stomata are therefore needed for the same carbon dioxide intake.

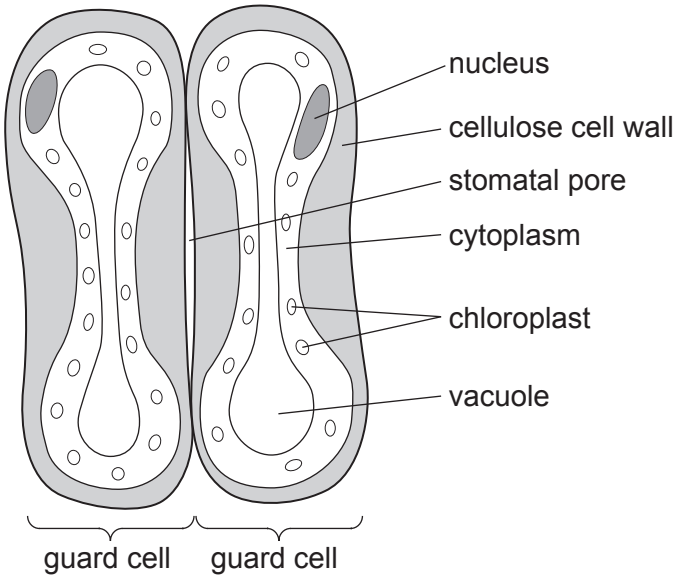
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(ii) A diagram of a stomata from a leaf of grass is shown in **Image 2.5**.

Image 2.5



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

K^+ ions are actively pumped into the guard cells and malate is made, so K^+ and malate accumulate in the vacuoles.

This lowers the water potential of the guard cells.

Water enters by osmosis, so turgor pressure increases and the guard cells become turgid.

The ends of the guard cell walls are thinner and the central walls thicker, so the ends expand and the cells are forced apart, opening the pore.

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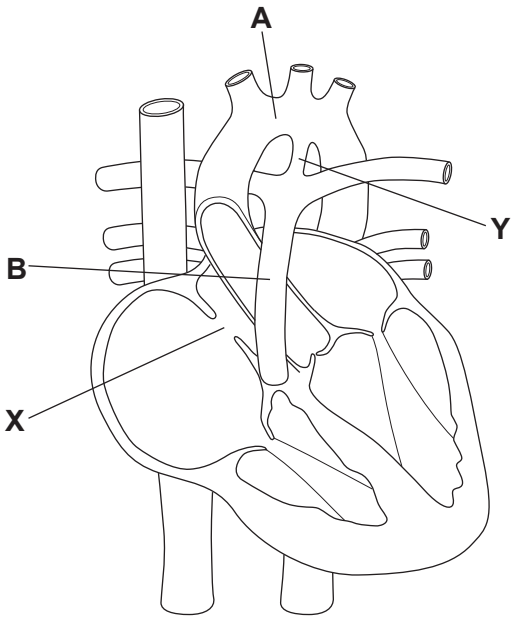
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3. (a) Major changes take place in the circulatory system in humans at birth. A diagram of the foetal heart and associated blood vessels is shown in **Image 3.1**.

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]

In an adult, the right atrium pumps blood into the right ventricle, which sends it to the lungs.

In the foetus the lungs are not functional, so there is no need for pulmonary circulation, as oxygen comes from the mother via the placenta.

The hole allows blood to pass directly from the right atrium to the left atrium (and left ventricle), missing out the lungs.

(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]

Oxygenated and deoxygenated blood would mix, so blood containing less oxygen is pumped around the body.

Less oxygen reaches the tissues and muscles, so there is less aerobic respiration (less ATP).

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(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 Aorta

B Pulmonary artery

(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]

Blood flows from the aorta into the pulmonary artery, increasing hydrostatic pressure in the lung capillaries, which can damage them. More fluid is forced out and less fluid is reabsorbed.

(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	Gills (gill lamellae)
Mammal	Alveoli
Earthworm	Skin (body surface)
Insect	Tracheoles

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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]

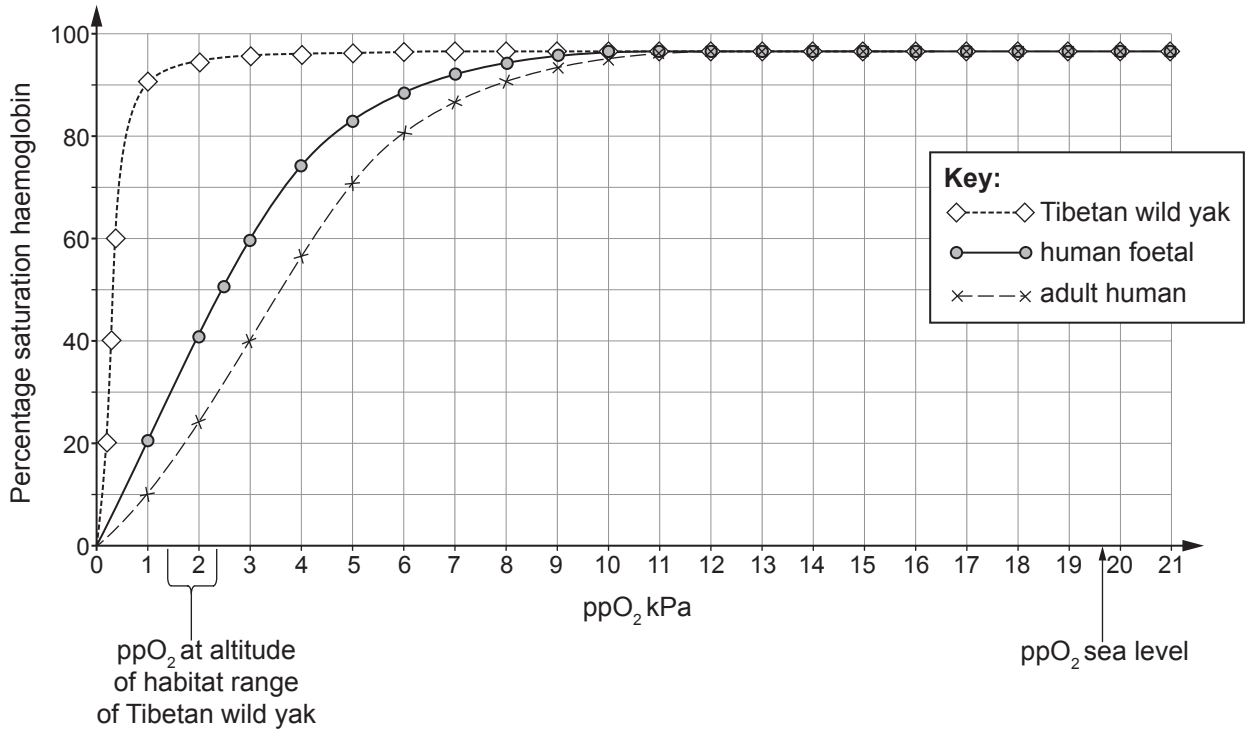
Quaternary structure

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

4

(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



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

HbF is to the left: it has a higher affinity for oxygen, so it is more saturated than HbA at low ppO_2 (below about 11 kPa).

So oxygen passes from the mother's blood to the foetus at the placenta.

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]

Yak haemoglobin is far to the left, so it has a very high affinity for oxygen.

It is highly saturated (about 90%) at the low ppO_2 at altitude (about 1.5 to 2.5 kPa), so enough oxygen is loaded in the lungs.

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

Oxygen dissociates with difficulty: it is only released at very low partial pressures of oxygen.

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(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]

At high altitude the partial pressure of oxygen in the air is lower, so there is less oxygen in each breath.

A higher breathing rate maintains a steep oxygen concentration gradient at the alveoli, so the yak gets sufficient oxygen.

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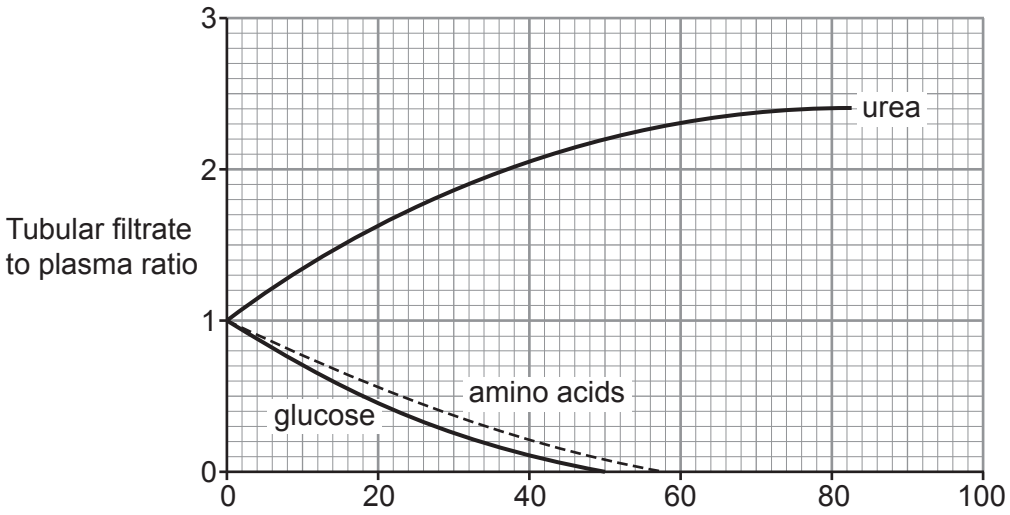
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4. In an adult human, approximately 180 dm^3 of fluid is filtered from the glomeruli into the Bowman's capsules per day. As the filtrate moves along the proximal convoluted tubules (PCT) some substances are selectively reabsorbed. By the time the filtrate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

The ratio falls to zero: glucose and amino acids are all reabsorbed from the filtrate back into the blood in the PCT.

They are reabsorbed by co-transport with sodium ions (secondary active transport).

(ii) urea. [2]

The urea ratio increases because water is reabsorbed, so the volume of filtrate decreases,

but urea is not all reabsorbed and stays in the filtrate, so its concentration rises.

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(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]

Most of the water has been reabsorbed, so DDT is more concentrated in the filtrate, giving a higher concentration gradient.

(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]

Glucose is reabsorbed by co-transport with sodium ions using carrier proteins (secondary active transport).

There is a limited number of carrier proteins, so at high glucose concentrations they are all saturated (and low Na^+ concentration limits co-transport).

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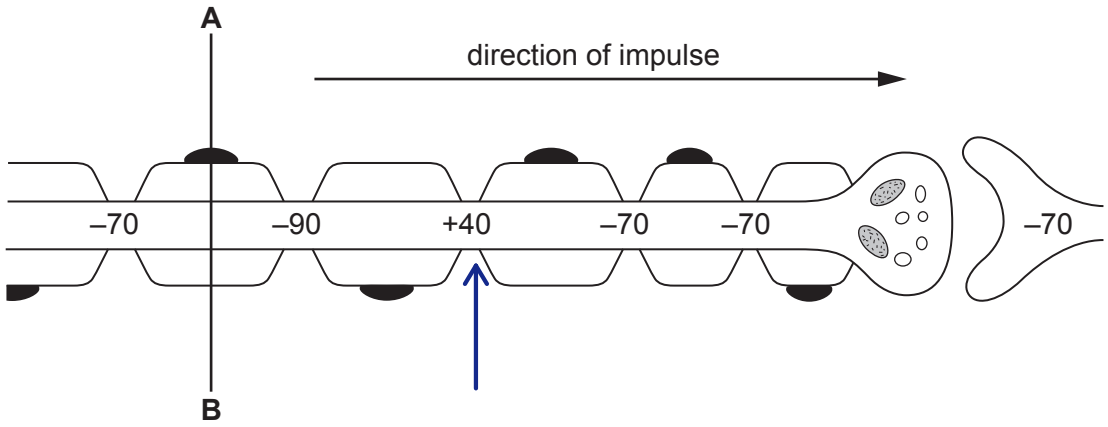
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5. **Image 5.1** shows part of an axon and a synapse. The figures indicate the potential difference across the membrane between the cytoplasm of the axon and the extracellular fluid at intervals along the axon.

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]

The arrow points to the node at +40 mV.

This region is depolarised: the inside of the axon is positive compared with the outside.

(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]

The region behind the action potential is at –90 mV, so it is hyperpolarised (refractory) and cannot be depolarised again.

Synaptic vesicles are only found on the presynaptic side (in the synaptic knob), so transmission is one way.

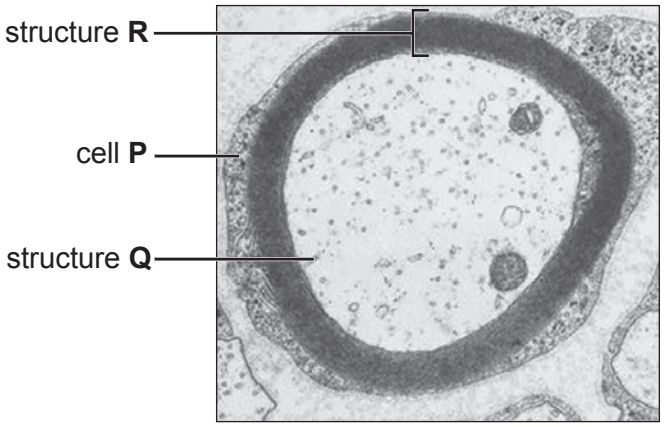
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(c) The electron micrograph in **Image 5.2** shows a transverse section along the line marked **A–B** on **Image 5.1**.

Image 5.2



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

cell **P** *Schwann cell*

structure **Q** *Axon (axoplasm)*

structure **R** *Myelin sheath*

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

The rate of transmission would slow down. Without myelin there is no saltatory conduction: depolarisation must occur along the whole membrane by many local circuits instead of jumping from node to node.

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

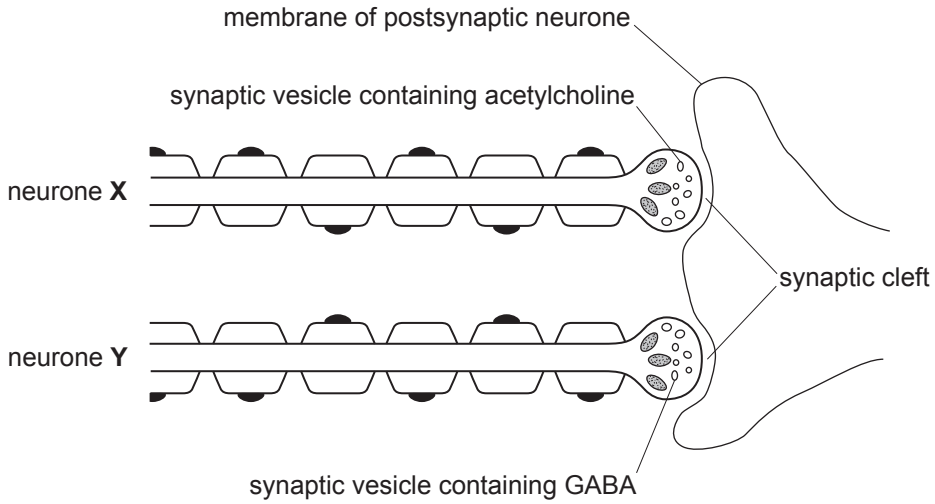
Factor	Explanation
Temperature	*Higher temperature increases kinetic energy, so ions diffuse faster (up to about 40 °C).*
Axon diameter	*A wider axon has less resistance to the flow of ions, so the impulse is conducted faster.*

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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]

GABA from neurone Y binds to receptors and causes Cl^- to enter and K^+ to leave the postsynaptic neurone. This makes the inside of the postsynaptic neurone more negative, so its membrane is hyperpolarised. When neurone X then releases acetylcholine, it binds to receptors and Na^+ enters, causing some depolarisation. However, starting from a more negative potential, the depolarisation does not reach the threshold, so no action potential is generated.

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(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]

Acetylcholinesterase cannot break down acetylcholine, so acetylcholine remains in the synaptic cleft.

Acetylcholine continually binds to the receptors on the postsynaptic membrane, so Na^+ keeps entering and the cell is continually stimulated.

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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

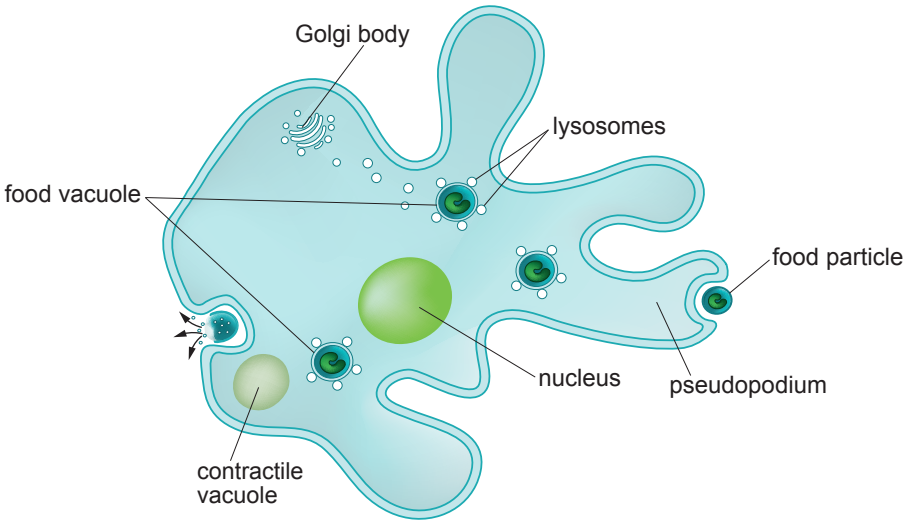


Image 6.2A – *Hydra* ingesting a worm

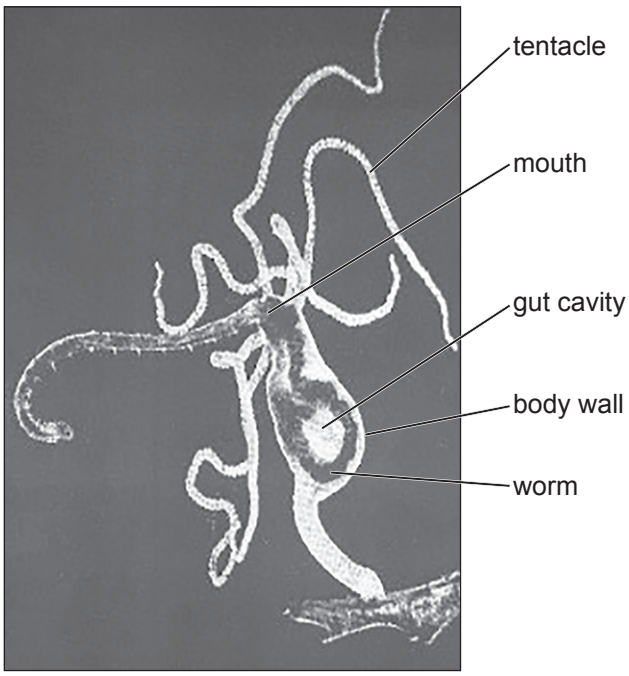
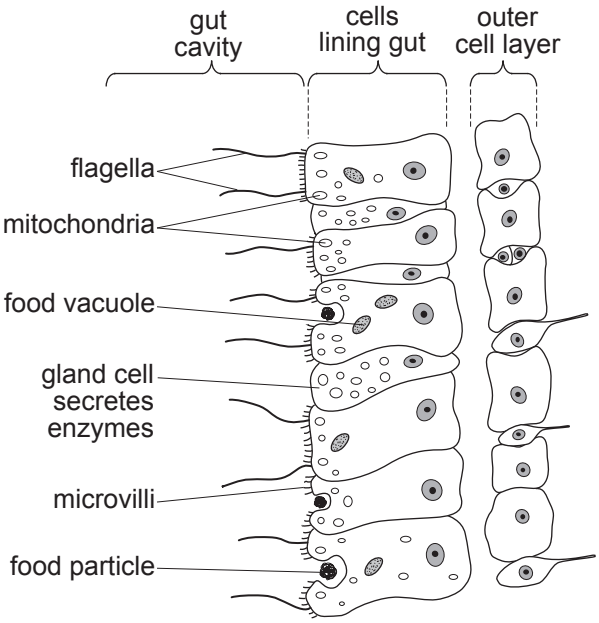


Image 6.2B – Body wall of *Hydra*



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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]

Amoeba: Amoeba ingests food by phagocytosis (endocytosis). Pseudopodia extend around the food particle and surround it, and the membrane fuses to enclose the food in a food vacuole. The Golgi body produces lysosomes containing hydrolytic (digestive) enzymes. The lysosomes fuse with the food vacuole and release their enzymes into it, so digestion is intracellular, inside the food vacuole. The soluble products of digestion are absorbed across the vacuole membrane into the cytoplasm and used by the cell. The vacuole containing undigested waste moves to the cell surface membrane, fuses with it and releases the waste by exocytosis (egestion).

Hydra: Hydra is multicellular and uses its tentacles to catch and push large prey, such as a worm, through its mouth into the gut cavity, so it can ingest whole organisms much larger than any single cell. Gland cells in the cells lining the gut secrete enzymes into the gut cavity, so digestion begins outside the cells (extracellular digestion), breaking the prey into small food particles. Flagella beat to mix the enzymes with the food and move food and waste around the gut cavity. Small food particles are taken into the gut cells by phagocytosis, forming food vacuoles, where digestion is completed intracellularly. Microvilli on the gut lining cells increase the surface area for absorption of the products of digestion. The cells contain large numbers of mitochondria, which release energy as ATP for active transport during absorption and for phagocytosis. However, Hydra has only one opening, so undigested waste must leave through the mouth.

Humans: humans have a tube gut with a mouth at one end for ingestion and

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an anus at the other for egestion, so food moves in one direction and feeding and digestion can happen continuously. Mechanical digestion by the teeth (chewing) and churning in the stomach breaks food into smaller pieces, increasing the surface area for enzymes. Food is moved along the gut by peristalsis, waves of contraction of the circular and longitudinal muscle. The gut is long, so there is plenty of time for digestion and absorption to be completed. Different regions are specialised for different functions: for example, the stomach digests proteins with pepsin in acidic conditions, the duodenum receives pancreatic enzymes (amylase, lipase, proteases) and bile, the ileum completes digestion and absorbs the products, and the colon absorbs water. The ileum is adapted for absorption, with folds, villi and microvilli giving a very large surface area, a thin epithelium and a good blood supply, so the products of digestion are absorbed efficiently. As a result the human digestive system is far more efficient than that of Amoeba or Hydra.

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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.

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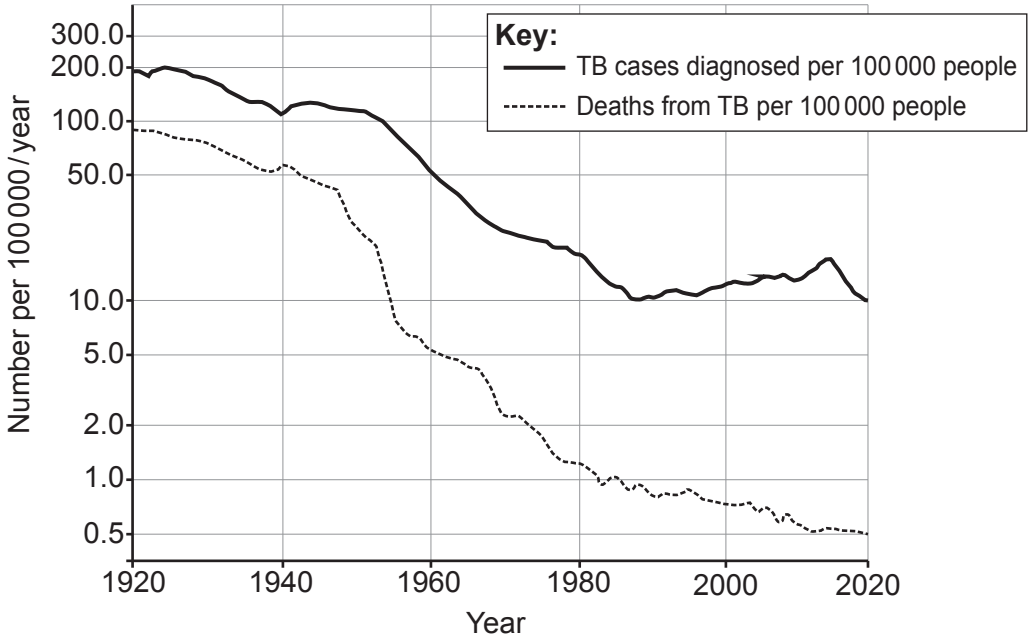
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Option A: Immunology and Disease

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]

A disease that is always present in a population (in a specific area) at a low, predictable rate.

(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]

The population size varies from year to year, so the number of cases is made proportional to population size, which allows a valid comparison between years (to show the trend).

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

In 2020: cases = 10 per 100 000, deaths = 0.5 per 100 000

Percentage = 0.5 ÷ 10 × 100 = 5%

Percentage = *5%*

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(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]

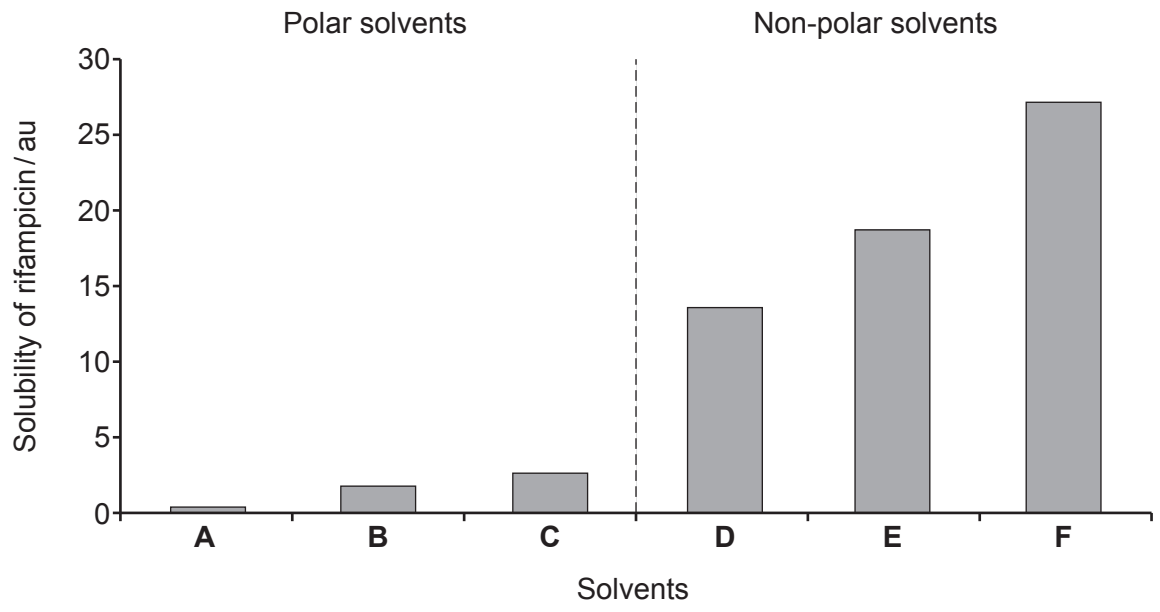
Not all deaths were caused by TB: some people who died may have been misdiagnosed with TB, as diagnosis was less reliable in 1920.

(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



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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]

Rifampicin has low solubility in polar solvents (water) but is highly soluble in non-polar solvents D, E and F.

So rifampicin can pass through the thick, hydrophobic outer envelope to enter the bacterial cell.

Rifampicin is a broad-spectrum, bactericidal antibiotic.

(ii) State what is meant by the terms:

I. broad-spectrum; [1]

It is effective against many different types of bacteria (Gram positive and Gram negative).

II. bactericidal. [1]

It kills bacteria.

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

Without RNA polymerase, no mRNA is formed, so transcription cannot take place.

With no mRNA, translation cannot take place, so the cell cannot synthesise proteins, including enzymes.

Essential processes such as metabolism and cell division cannot occur without enzymes, so the bacterium dies.

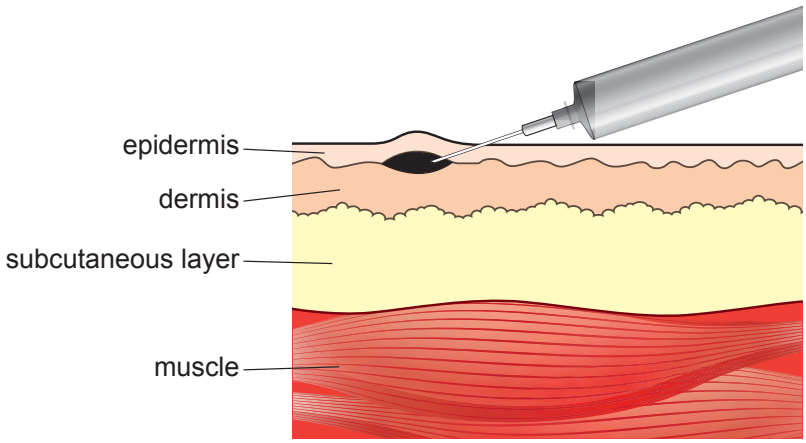
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(c) The most widely used vaccine against TB is the BCG vaccine. The vaccine is prepared with a live, attenuated form of *Mycobacterium bovis*. *M. bovis* is closely related to *M. tuberculosis*. The vaccine is administered by an injection below the 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]

The epidermis acts as a physical barrier to infection, so the vaccine must penetrate it to reach the blood and the antigen presenting cells (macrophages), to initiate a primary immune response.

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

Macrophages engulf the bacteria by phagocytosis and present their antigens.

T helper cells are activated and release cytokines, which activate B cells with complementary antibodies (clonal selection).

These B cells divide by mitosis (clonal expansion) and some differentiate into plasma cells, which secrete antibodies.

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(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]

The live attenuated bacteria could revert to a pathogenic form and cause disease, especially in people with weak immune systems.

Alternative: a vaccine made from a dead (inactivated) pathogen, or from isolated antigens or RNA.

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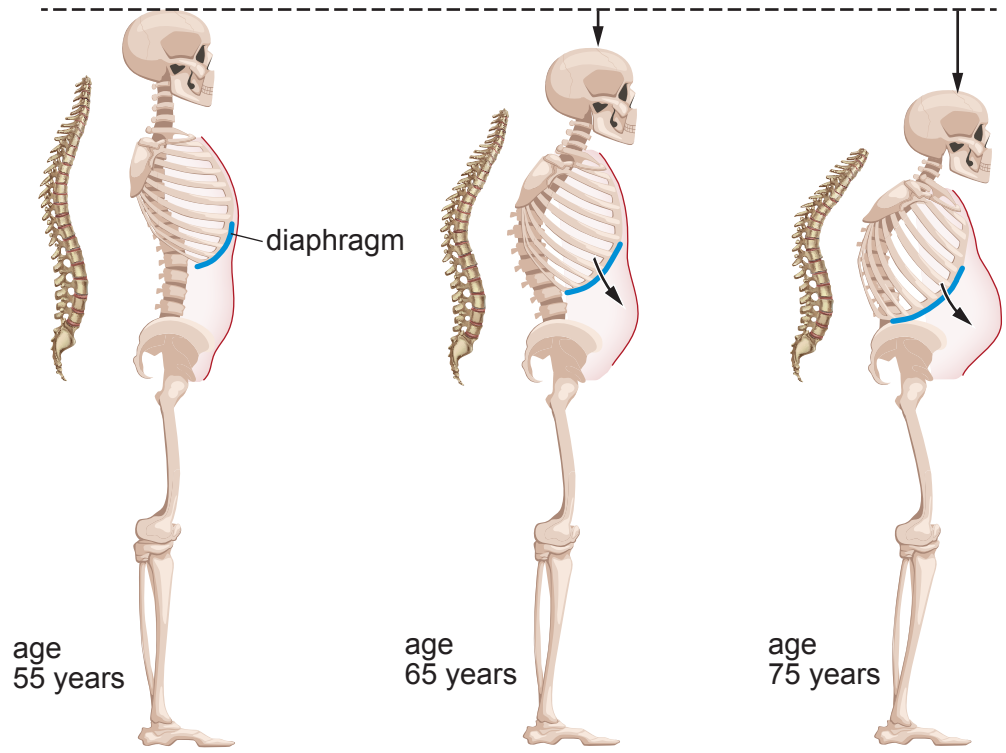
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Option B: Human Musculoskeletal Anatomy

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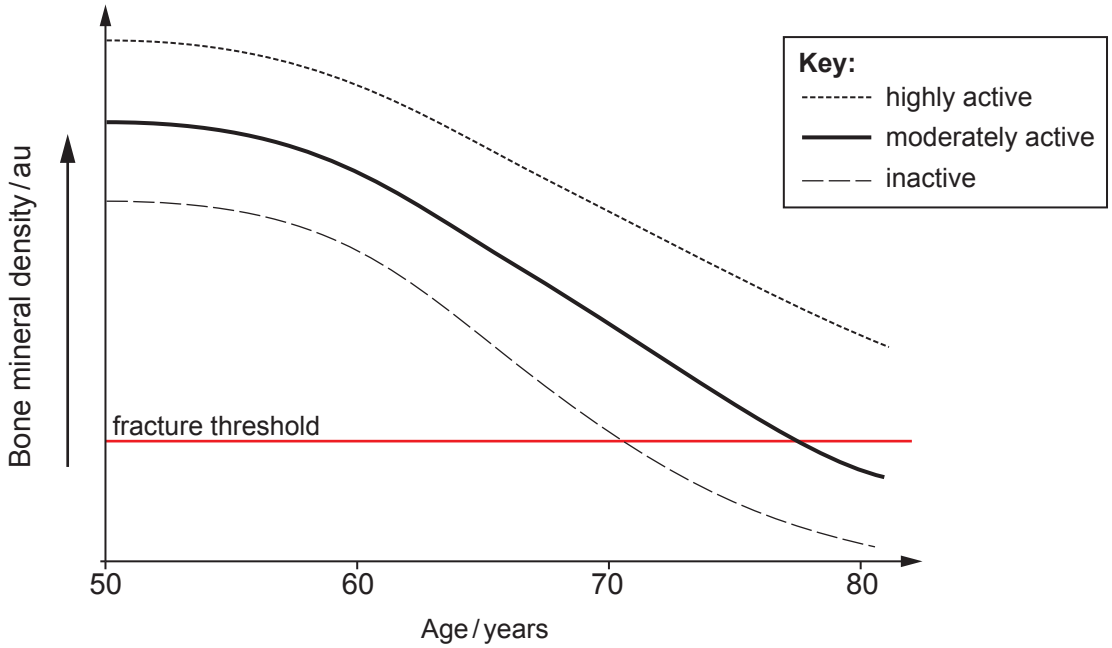
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Regular exercise is recommended as a precaution against the development of osteoporosis.

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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(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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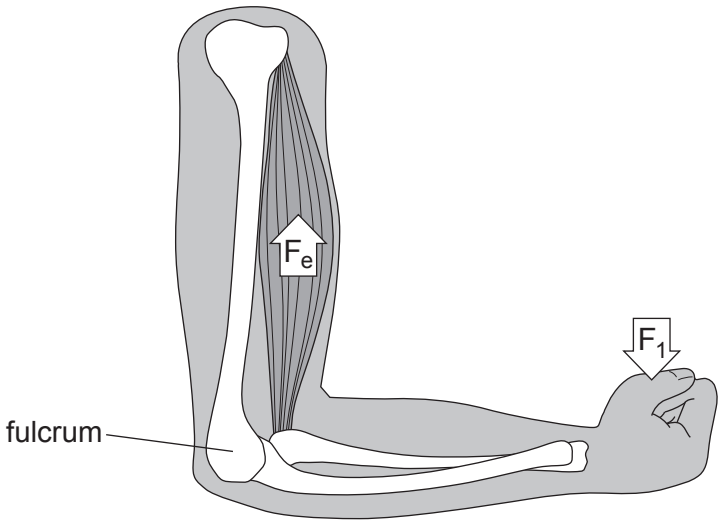
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(c) Studies have shown that load bearing exercises give the greatest benefit in preventing osteoporosis. Repetitively lifting an object by flexing the elbow as shown in **Image 8.4**, is an effective load bearing exercise that can easily be performed 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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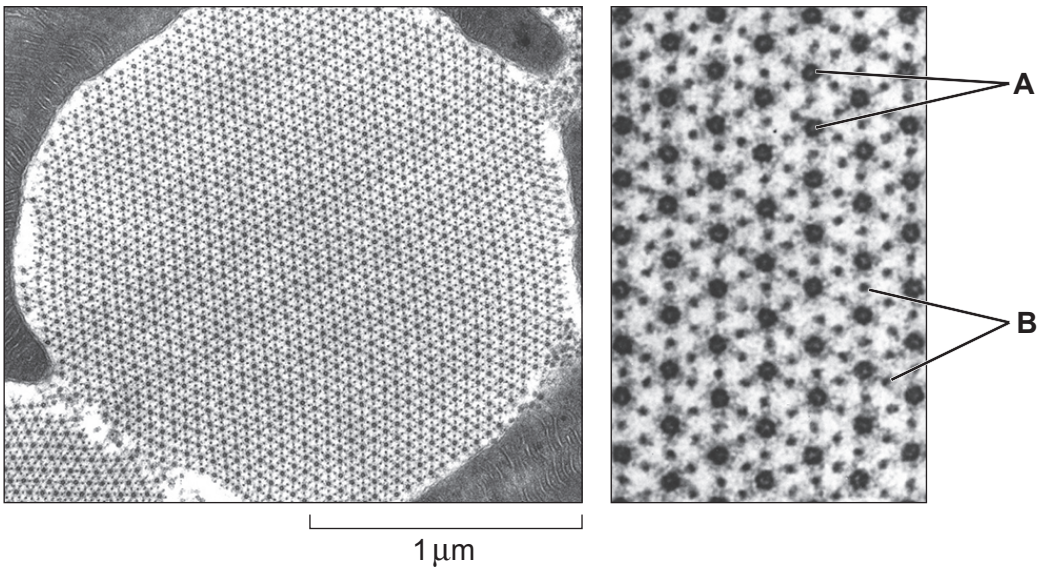
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(d) **Image 8.5** shows an electron micrograph of a transverse section through a single cell from a biceps muscle.

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: .....

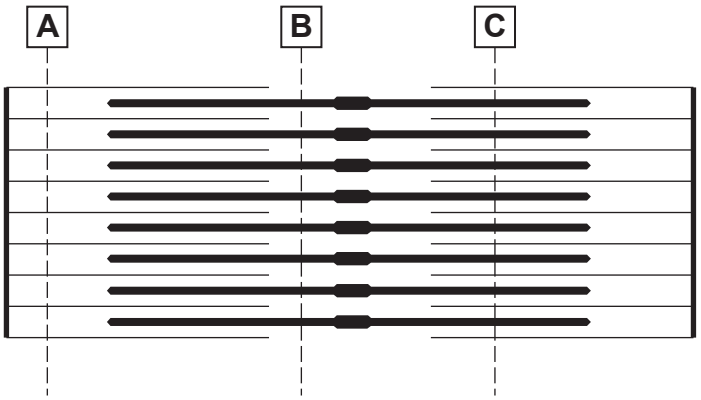
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Image 8.6 shows a longitudinal view of a single sarcomere.

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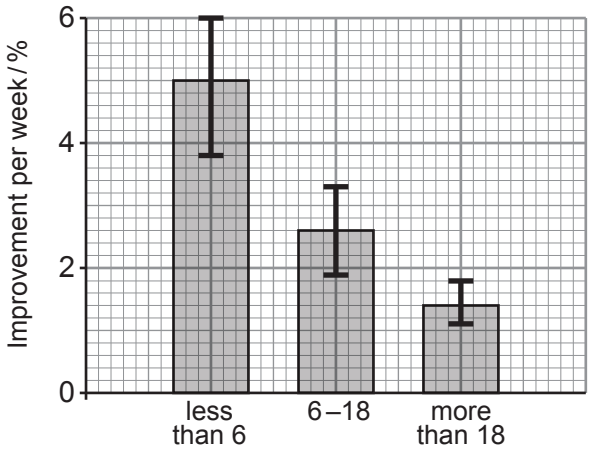
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(b) Studies have demonstrated that patients who receive therapy following brain injuries can recover some of the original function of their limbs over time.

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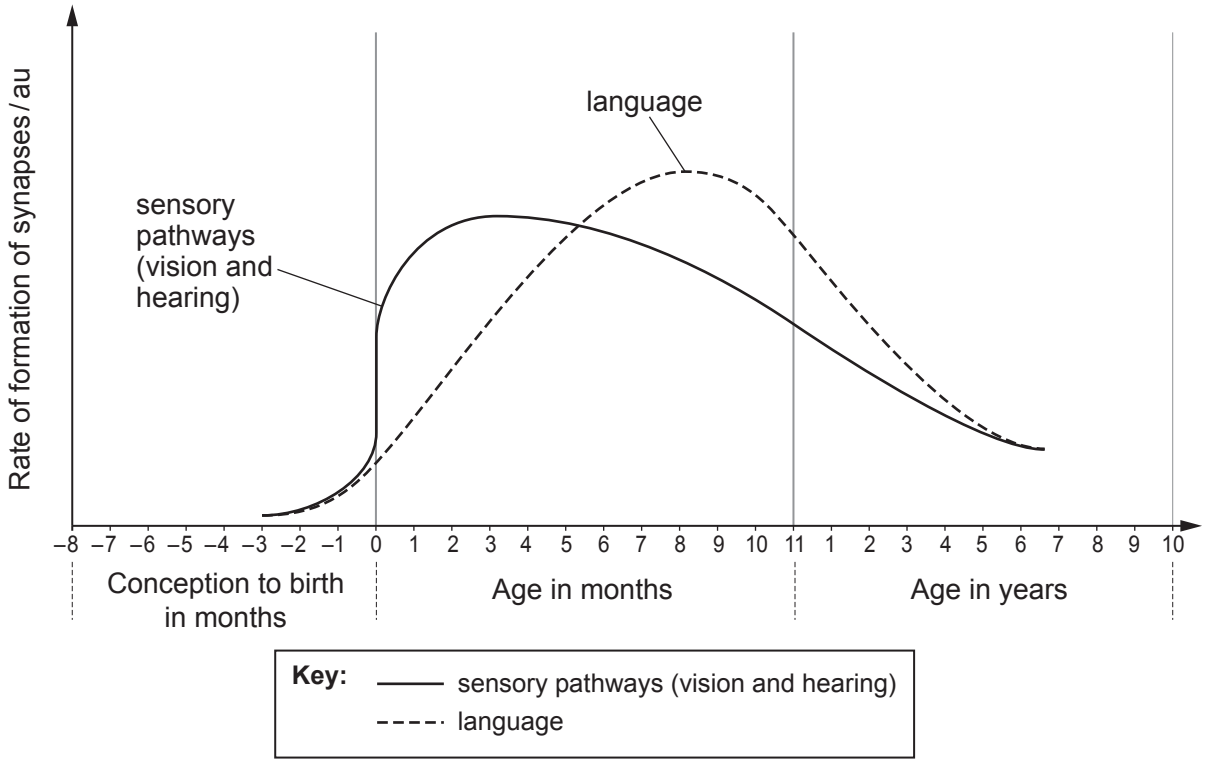
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During early childhood, the rate of formation of new synapses between neurones in the central nervous system in the healthy developing brain reaches its maximum.

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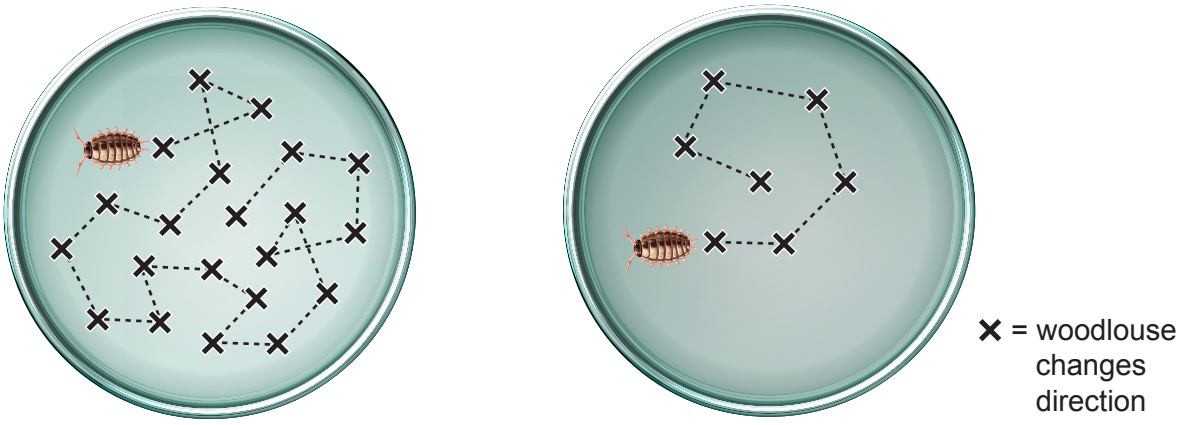
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(c) Woodlice are common invertebrates which are often found under rotting wood in damp locations in gardens and woodland.

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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