Surname	StemUp Model Solution	Centre Number	Candidate Number
First name(s)			2

GCE A LEVEL

A400U30-1

O20-A400U30-1

TUESDAY, 20 OCTOBER 2020 – AFTERNOON

BIOLOGY – A level component 3
Requirements for Life

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**13**	
	2.	**7**	
	3.	**18**	
	4.	**9**	
	5.	**17**	
	6.	**7**	
	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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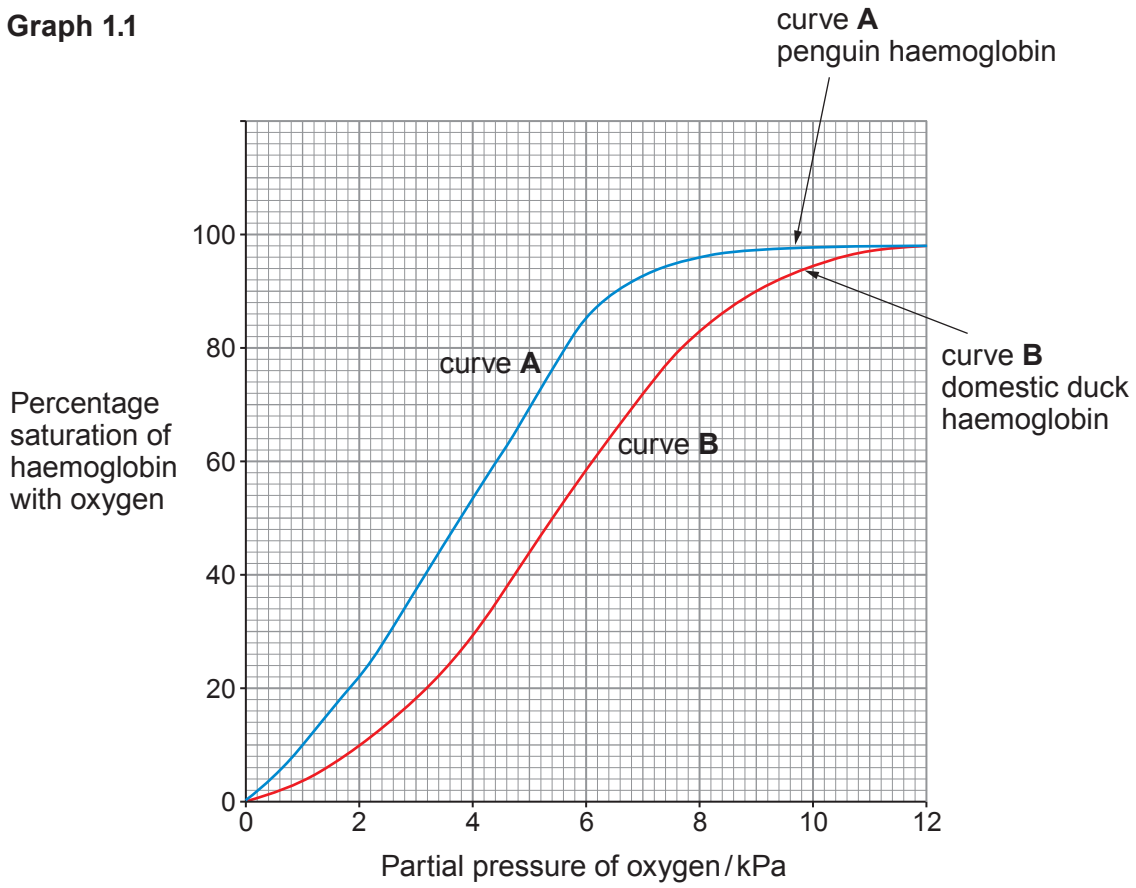
SECTION A

Answer **all** *questions.*

1. Emperor penguins live in the Antarctic. They hunt for fish and can dive for 25 minutes at a time when they are looking for food.

Graph 1.1 shows the oxygen dissociation curve for emperor penguin haemoglobin and domestic duck haemoglobin.

Graph 1.1



(a) Explain the advantage to the penguin of having the haemoglobin dissociation curve as shown on **graph 1.1**. [3]

Penguin haemoglobin has a higher affinity for oxygen: at 6 kPa it is about 80% saturated, the duck's about 55%.

So the haemoglobin acts as an oxygen store during the dive.

Oxygen is only released at a very low partial pressure of oxygen, which delays anaerobic respiration so the penguin can dive for longer.

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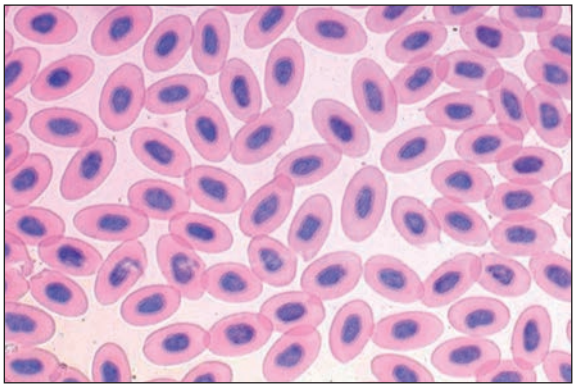
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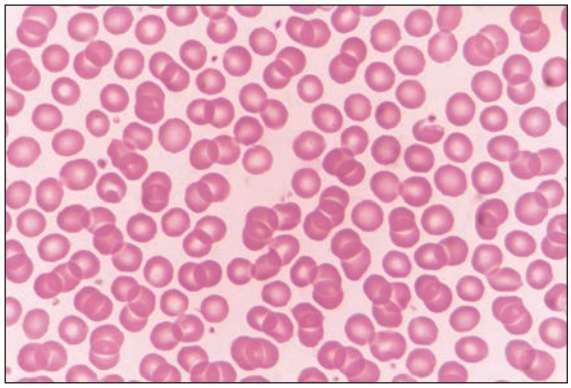
(b) **Image 1.2** shows penguin and human red blood cells.

Image 1.2

Penguin red blood cells



Human red blood cells



(i) Explain why blood is considered to be a tissue. [1]

Blood is a group of similar cells working together to perform a function (transport of oxygen).

(ii) Describe **two** differences between a red blood cell of a human and a red blood cell of a penguin, as seen in **image 1.2**. [2]

Penguin red blood cells are elliptical (oval), whereas human red blood cells are round.

Penguin red blood cells contain a nucleus, whereas human red blood cells have no nucleus; penguin cells are also larger.

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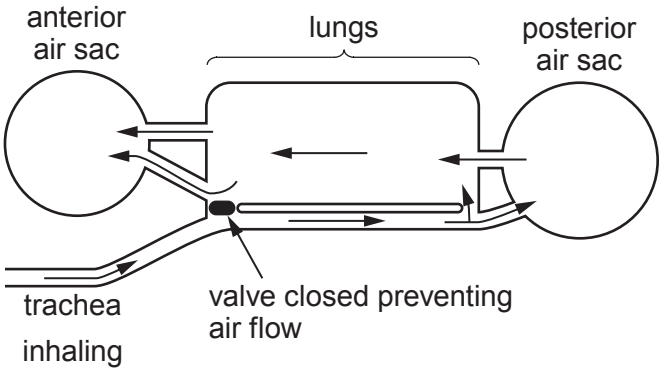
(c) (i) As the penguin breathes in, the air passes over bony plates which have capillaries very close to the surface.

Suggest how this helps to warm the inspired air. [1]

Heat from the blood in the capillaries is transferred to the air, warming it.

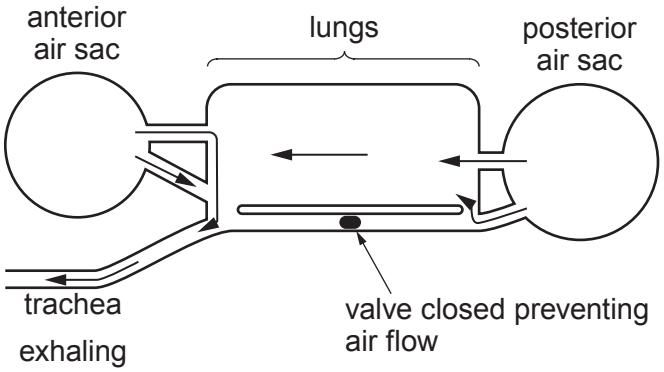
When the penguin inhales, air passes down the trachea and into the posterior air sacs. The anterior air sacs also expand and draw air through the lungs. This is shown in **image 1.3**.

Image 1.3



When the penguin exhales, the posterior air sacs force air through the lungs. The anterior air sacs force air out through the trachea. This is shown in **image 1.4**.

Image 1.4



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(ii) With reference to **images 1.3** and **1.4**, explain **two** features of the gas exchange system of the penguin that make it far more efficient than the gas exchange system of a human. [3]

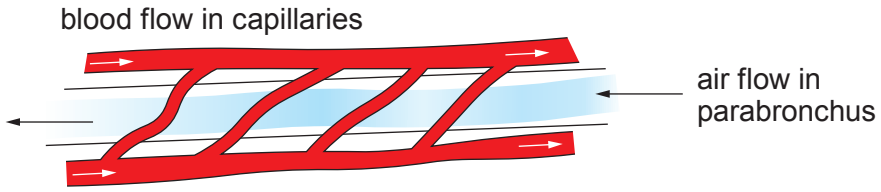
Air flow through the lungs is one way (unidirectional), so fresh and stale air do not mix.

Air passes through the lungs on inhaling and exhaling, so gas exchange takes place in both.

The lung fills with fresh air and empties each breath: no residual volume.

In the lungs, gas exchange takes place in structures called parabronchi. **Image 1.5** shows the direction of air flow in a parabronchus and the direction of blood flow in the capillaries that surround them.

Image 1.5



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(iii) Explain how the direction of blood flow in the capillaries further increases the efficiency of gas exchange. [3]

Blood in the capillaries flows in the opposite direction to the air flow in the parabronchus (countercurrent flow).

Blood always meets air with a higher oxygen concentration, so a concentration gradient is maintained and equilibrium is never reached.

Therefore oxygen diffuses into the blood across the whole length of the parabronchus.

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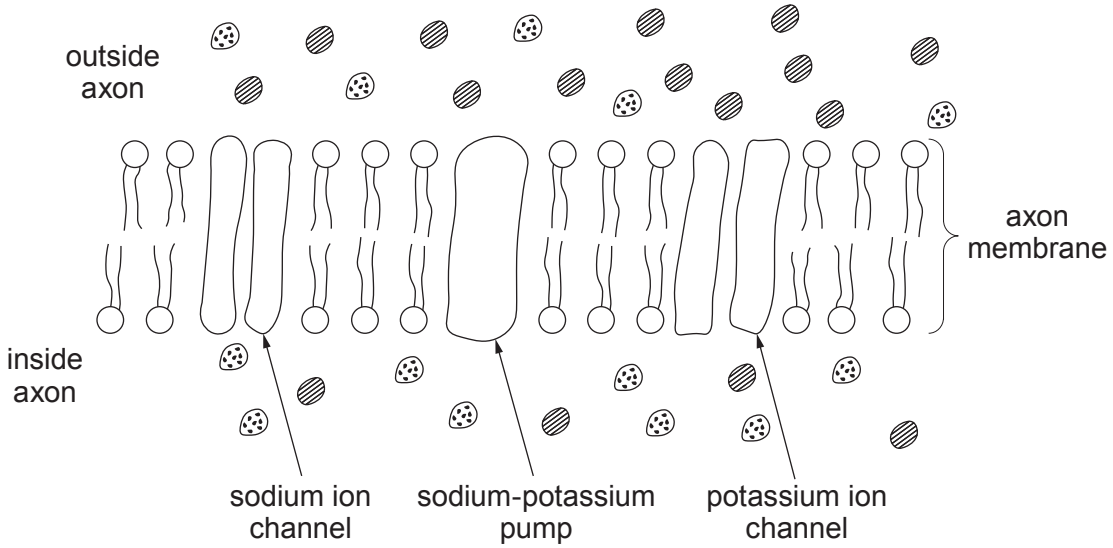
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2. **Image 2.1** shows a diagram of an axon membrane that a student found in a textbook.

Image 2.1

Axon membrane at rest.



(a) (i) Describe and explain the distribution of sodium ions (Na^+) across the membrane at rest. [3]

There are more Na^+ ions outside the axon than inside.

Na^+ ions are actively transported out of the axon by the sodium-potassium pump (3 Na^+ out for every 2 K^+ in), using ATP.

At rest the membrane is relatively impermeable to Na^+ because the sodium ion channels (gates) are shut, so Na^+ cannot diffuse back in.

(ii) Explain why the sodium ions do not diffuse across the **phospholipid bilayer** despite the concentration gradient. [1]

Ions are charged (hydrophilic) and the bilayer has a hydrophobic centre of fatty acid tails, so ions cannot pass through it.

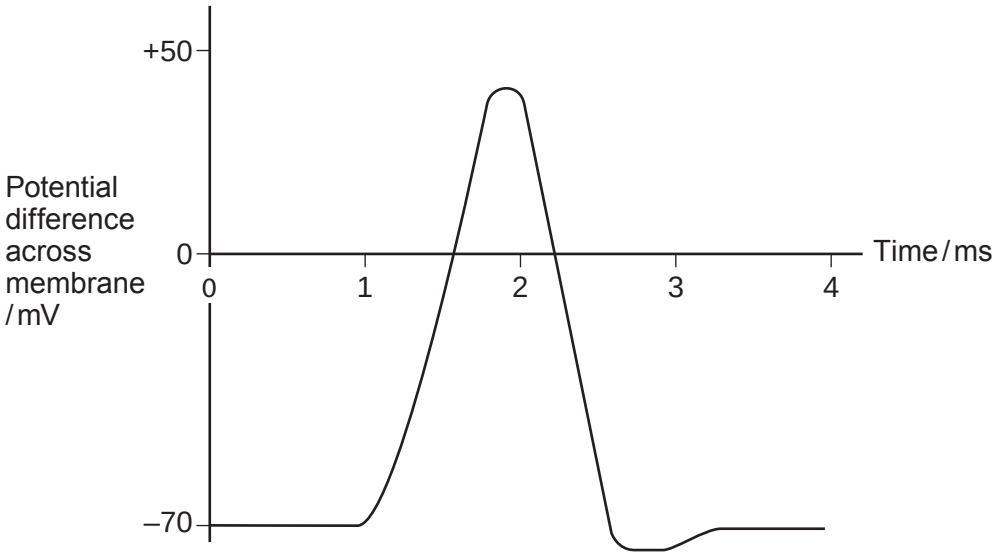
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Image 2.2 shows a typical action potential of an axon.

Image 2.2



The drug tetraethylammonium (TEA) blocks gated potassium channels in the axon membrane.

(b) Describe how the drug TEA would affect the action potential trace. Explain the cause of this effect. [3]

The trace would take longer to return to the resting potential (slower repolarisation) and there would be no hyperpolarisation.

The gated K^+ channels are blocked, so K^+ ions stay inside the axon instead of diffusing out.

So the inside of the axon stays more positive for longer; the resting potential is only restored slowly by the sodium-potassium pump.

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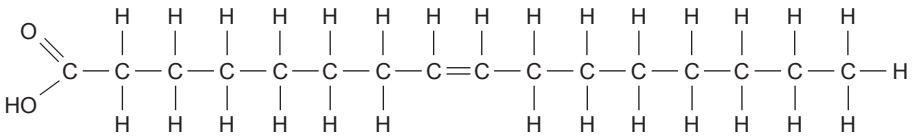
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3. The fat in cow's milk consists of triglycerides with different fatty acid chains.

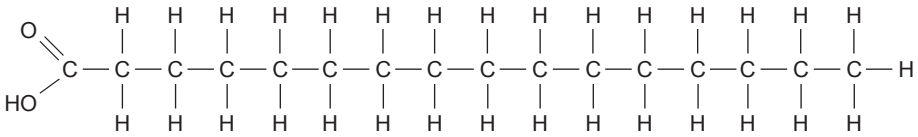
Two fatty acid chains, **A** and **B**, are shown in **image 3.1**.

Image 3.1

Chain **A**



Chain **B**



(a) (i) Identify which of these chains would have a more negative effect on human health. Explain your answer. [1]

Chain B, as it is saturated (no C=C double bonds), which increases the risk of heart disease.

(ii) Explain why triglycerides are not regarded as polymers. [1]

They are not made of repeating monomers; they are made of glycerol and three fatty acids.

Lipase enzymes are released by the pancreas.

(b) (i) State the term given to enzymes which work outside cells. [1]

Extracellular enzymes

(ii) Explain why several different types of lipase enzymes are released by the pancreas. [2]

Different triglycerides have different structures: different lengths of fatty acid chains, and some are saturated while others are unsaturated. Each needs a lipase with a different shaped, specific active site complementary to it.

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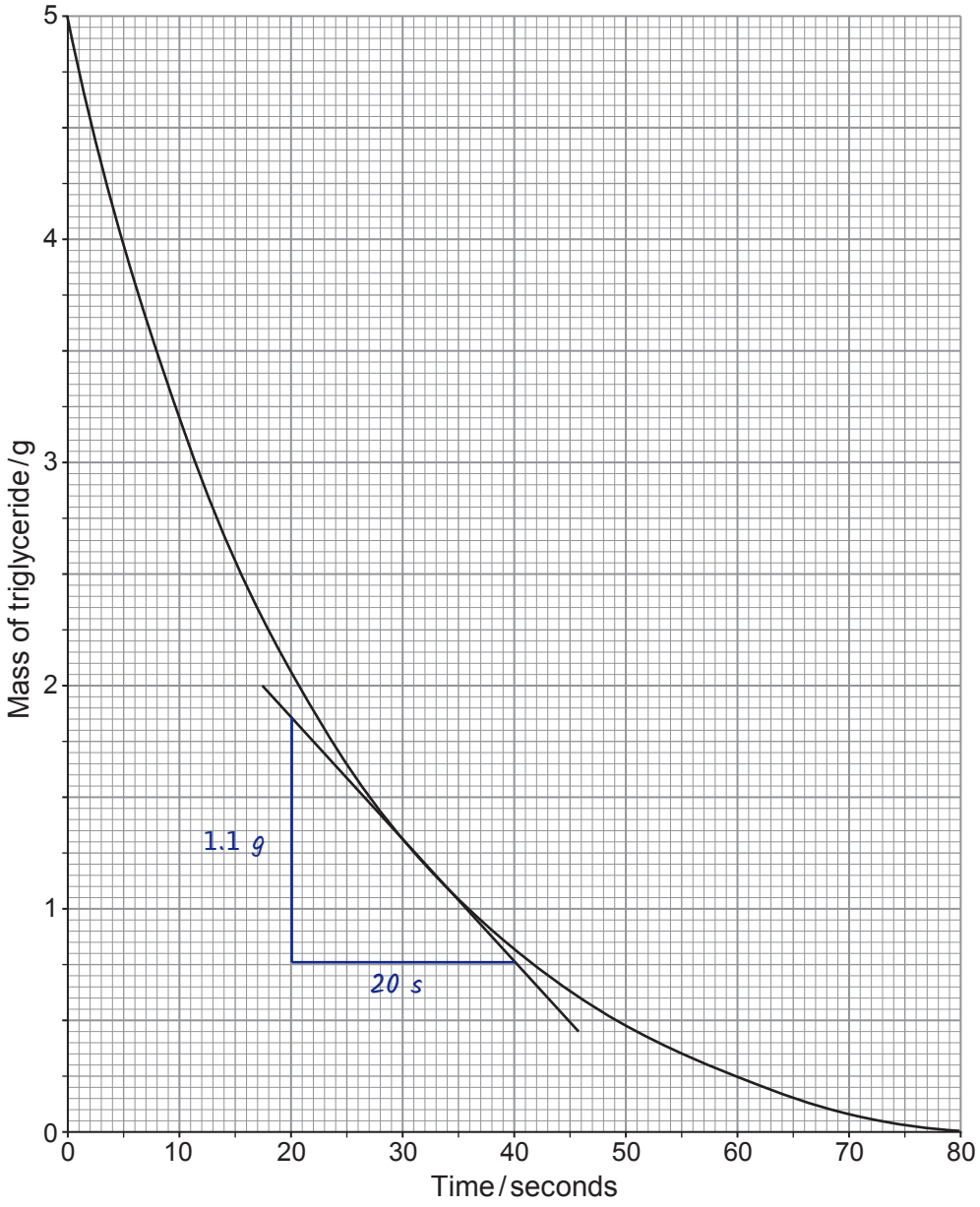
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(c) A scientist determined the mass of fat in a 100 cm^3 sample of cow milk. He added lipase and measured the mass of triglyceride present over a period of time.

Graph 3.2 shows the result of this experiment.

Graph 3.2



(i) A tangent has been drawn at 30 seconds, use this tangent to calculate the rate of digestion per second at that time. **Give your answer in standard form.** [3]

gradient = change in mass ÷ change in time

= (1.86 − 0.76) ÷ (40 − 20) = 1.1 ÷ 20

= 0.055 g s^{-1}

Rate = *5.5×10^{-2}* $g\,s^{-1}$

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(ii) Describe how the shape of the curve on the graph would be different if the scientist had added bile salts to the milk before the start of the experiment. Explain your answer. [3]

The curve would be steeper, so the mass of triglyceride would drop to zero faster (in less time).

Bile salts emulsify the lipids into smaller droplets.

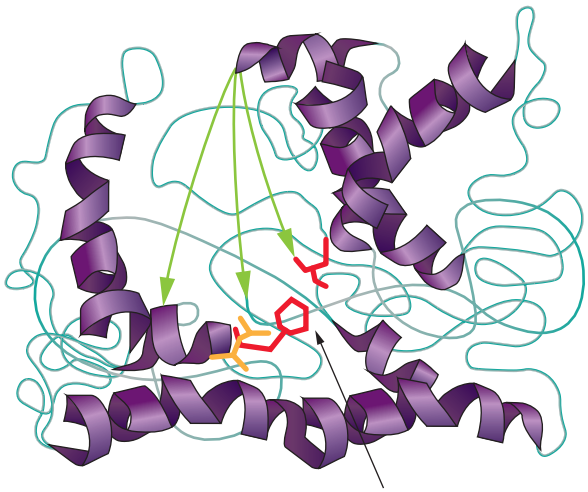
This gives a larger surface area for lipase to work on, so the rate of digestion is faster.

(iii) Suggest why carnivores such as lions and tigers have gall bladders, whereas many herbivores such as deer do not have a gall bladder. [1]

Carnivores have much more fat in their diet; herbivores have little fat in their diet, so do not need to store bile.

(d) **Image 3.3** shows a ribbon diagram of one type of lipase.

Image 3.3



This lipase enzyme is a globular protein with the active site labelled. When the substrate enters the active site, it changes shape to accommodate the lipid. If it did not, the enzyme would not be able to reduce the activation energy needed to hydrolyse the lipid.

State the name of this model of enzyme action. [1]

Induced fit model

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(e) A student decided to time how long it takes lipases to digest lipids. She used the indicator phenolphthalein. Phenolphthalein is pink at pH10. When the pH drops below 8.3 it becomes colourless.

When the triglycerides in milk are hydrolysed they form glycerol and fatty acids. The fatty acids reduce the pH to below 8.3.

The student carried out the following procedure:

- 0.5 cm^3 of phenolphthalein was added to 5 cm^3 of milk in a test tube. 7 cm^3 of sodium carbonate (pH10) was added.
- 1 cm^3 of 5% lipase was added to a separate test tube.
- Both tubes were placed in a thermostatic water bath set at 30 °C for 5 minutes.
- The contents of the tubes were combined and then put back in the water bath.
- The time taken for the indicator to become colourless was recorded.
- The procedure was repeated a further four times using the same type of milk.

The results are shown in **table 3.4**.

Table 3.4

Repeat	Time taken for indicator to become colourless / s
1	65
2	53
3	72
4	58
5	68

(i) Explain why the solutions were left in the thermostatic water bath for 5 minutes before combining. [1]

So that both solutions reach the same temperature (30 °C) before mixing, so the reaction is at 30 °C from the start.

(ii) Suggest **two** sources of inaccuracy in this experimental method that could account for the variation within these results. For each suggestion give **one** way by which the method could be improved. [4]

Inaccuracy 1 *Difficult to judge the end point; colour change is subjective.*

Improvement: use a colorimeter (or compare with a colour standard) to identify the end point.

Inaccuracy 2 *Difficult to mix the two solutions evenly.*

Improvement: agitate (shake) the tube at regular intervals during the reaction.

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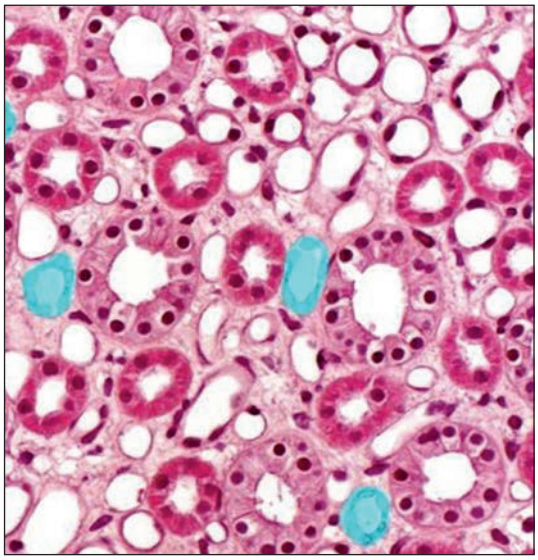
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4. **Image 4.1** shows a cross section through the medulla of the kidney.

Image 4.1



(a) (i) State the evidence shown in **image 4.1** that this is a section through the medulla and not through the cortex. [1]

There are no glomeruli or Bowman's capsules, only loops of Henle and collecting ducts.

Patients with the condition Bartter syndrome have sodium ion and chloride ion channels in the ascending limb of the loop of Henle that are less effective than in people who do not have the condition.

(ii) Explain the effects of Bartter syndrome on the function of the nephron and suggest **one** symptom of this condition. [3]

Na^+ and Cl^- ions are not absorbed into the tissue fluid, so are lost in urine.

This gives a lower water potential gradient, so less water is reabsorbed from the collecting duct into the blood.

Symptom: increased urination, leading to dehydration.

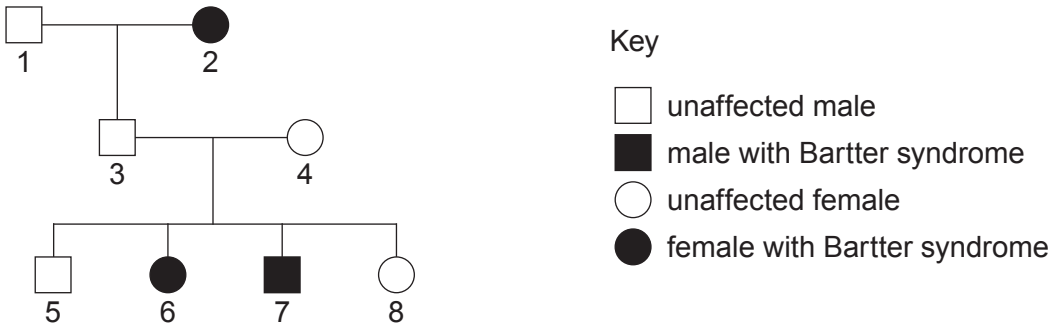
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(b) One type of Bartter syndrome is caused by a recessive allele found on chromosome number 1. The allele for functioning ion channels, **N**, is dominant to that for Bartter syndrome, **n**. **Image 4.2** shows the inheritance of Bartter syndrome in one family.

Image 4.2

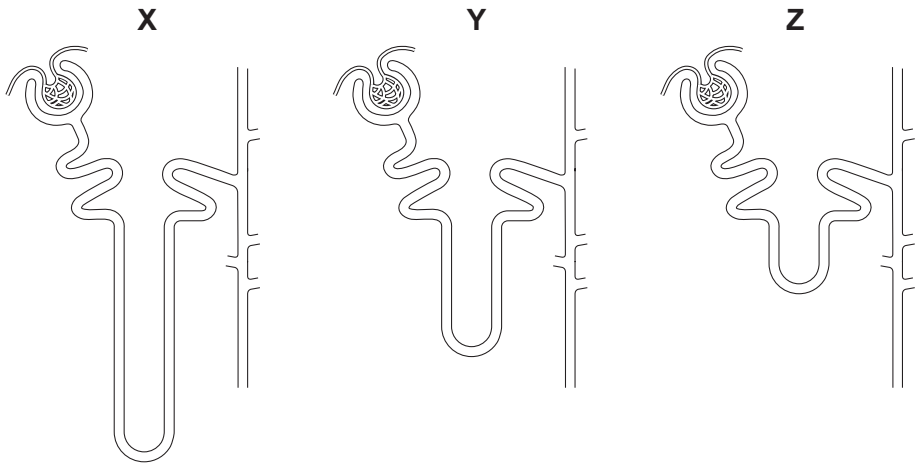


Identify **one** piece of evidence from the diagram that shows the allele for Bartter syndrome is recessive. Explain your answer. [2]

Parents 3 and 4 do not have the condition but children 6 and 7 do, so the alleles (n) must come from both parents.

(c) **Image 4.3** shows the nephrons of three different mammals **X**, **Y** and **Z**.

Image 4.3



Identify which nephron is most likely to belong to a mammal adapted to living in desert conditions. Explain your answer. [3]

X, because it has the longest loop of Henle.

A longer loop increases the concentration difference between filtrate and tissue fluid,

so more water is reabsorbed.

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5. Aphids can be used to investigate translocation in plants. When an aphid inserts its stylet (mouthparts) into a plant, it pierces the phloem. The body of the aphid can be cut off leaving the stylet in place. The fluid moving through the phloem can be collected as it drips from the stylet.

(a) (i) Removing the body of the aphid results in the death of the aphid.
Describe what could be done to ensure that the removal of the body of the aphid does not result in the suffering of the insect. [1]

Sedate (anaesthetise) or stun the aphid before removing its body.

(ii) The fluid collected contains sucrose. Describe a chemical test that the scientist could use to confirm that it was **sucrose** present in the fluid collected from the phloem and **not glucose**. [3]

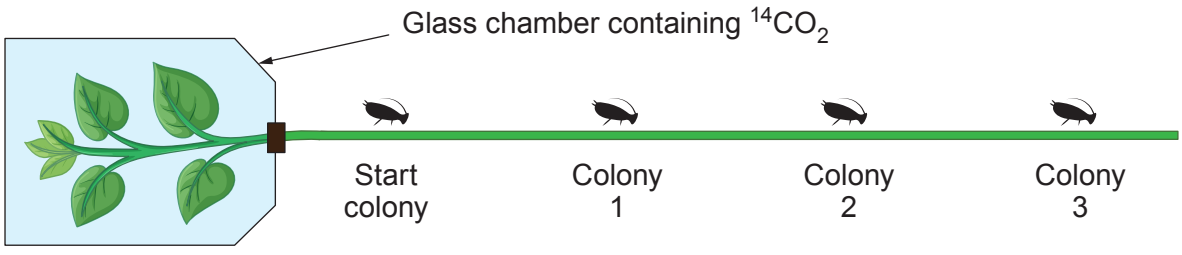
Heat a sample with Benedict's reagent: it stays blue (negative), so no reducing sugar such as glucose is present.

Boil a fresh sample with dilute hydrochloric acid to hydrolyse sucrose, then add alkali (sodium hydrogencarbonate) to neutralise.

Heat with Benedict's reagent: it turns from blue to orange (brick red), confirming sucrose.

(b) The rate of movement of solutes through the phloem can be measured using radioactive carbon dioxide ($^{14}CO_2$) and aphids. Scientists set up the equipment as shown in **image 5.1**. The fluid from the stylets was tested every minute for the presence of radioactive sucrose.

Image 5.1



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Table 5.2 shows the results of one experiment using a tomato plant.

Table 5.2

	Colony 1	Colony 2	Colony 3
Distance from start colony / mm	200	400	600
Time for radiation to be detected at colony / minutes	52	108	164

(i) Calculate the rate of movement of radioactive sucrose from the start colony to colony 2 in **mm s^{-1}**. [2]

time = 108 × 60 = 6480 s

rate = 400 ÷ 6480 = 0.0617 mm s^{-1}

Rate = ..*0.062*.. mm s^{-1}

The scientist who carried out this experiment used a ruler to measure the distances. The ruler was accurate to ± 1 mm.

(ii) Calculate the percentage error of the equipment over the distance from the start colony to colony 2. [2]

error = ±1 mm at each end of the distance = ±2 mm

% error = 2 ÷ 400 × 100 = 0.5%

Percentage error = ..*± 0.5%*..

(c) (i) It was observed that the rate of movement varied throughout the day. The rate was greatest at midday. Explain this observation. [3]

Light intensity and temperature are highest at midday, so the rate of photosynthesis is highest.

Photosynthesis produces sugars, which are loaded into the phloem as sucrose for transport.

This lowers the water potential, so water enters by osmosis and the pressure increases, so the rate of mass flow is greater.

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The destination of translocated sucrose was calculated for a mature tomato plant. The results are shown in **table 5.3**.

Table 5.3

Destination	% of total translocated sucrose
Leaves	8
Stem	22
Roots	28
Fruit	42

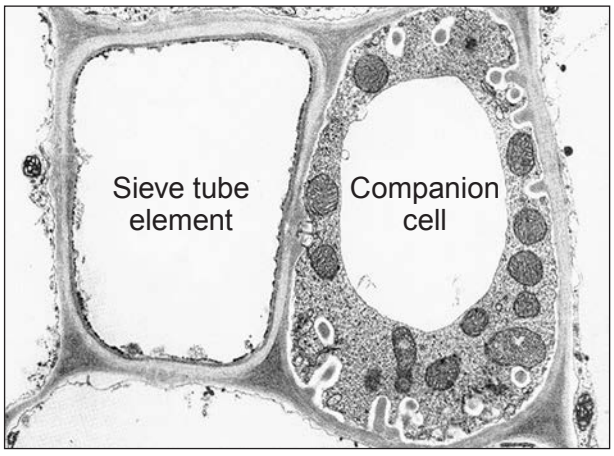
(ii) Using your knowledge of plant reproduction, suggest **two** reasons why more sucrose is transported to the fruit rather than other parts of the plant. [2]

Sucrose provides energy for the growth of the fruit and the seeds inside it.

Sugars make the fruit sweet and attractive to animals, which eat it and disperse the seeds.

(d) **Image 5.4** shows part of the phloem from a tomato plant.

Image 5.4



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Explain how **one** feature of each cell shown in **image 5.4** enables the translocation of sucrose through the plant. [4]

Companion cell

A large number of mitochondria produce ATP,

used to actively transport sucrose into the sieve tubes.

Sieve tube element

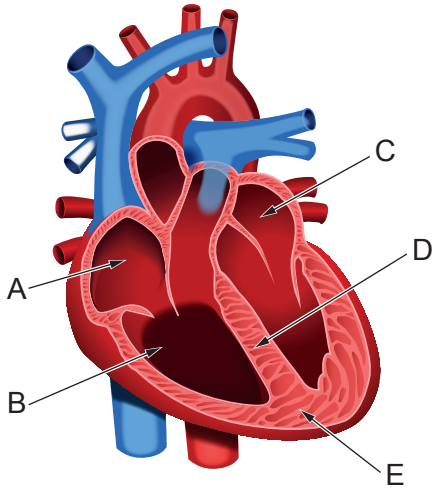
Very few cell contents (no nucleus), giving more space,

for unrestricted mass flow of sucrose solution.

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6. **Image 6.1** shows a vertical section through the heart.

Image 6.1



(a) Give the **letter** which indicates the position of the structure that initiates the electrical impulse through the heart. Name this structure. [1]

Letter A

Name of structure Sinoatrial node (SAN)

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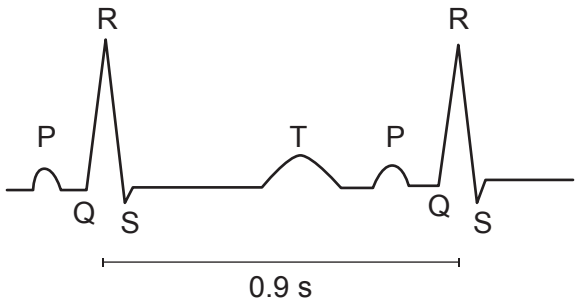
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Sotalol is a drug used to slow heart rate down. **Image 6.2** shows an electrical impulse moving across the heart of a patient who is receiving sotalol.

Image 6.2



The normal heart rate for this patient when not receiving sotalol is 75 beats per minute.

(b) (i) Calculate the difference between the normal heart rate of this patient and the heart rate when he is taking sotalol. [2]

heart rate with sotalol = 60 ÷ 0.9 = 66.7 beats per minute

difference = 75 – 66.7 = 8.3

Difference = ... 8.3 ..... beats per minute.

Torsades de Pointes (TdP) is a condition where there is a prolonged QT interval. It can degenerate into a sustained ventricular fibrillation (uncontrolled contractions) and can be fatal.

TdP can be caused by lifestyle choices or it can be caused by taking certain medications.

A study was carried out into the effects of sotalol on 34 patients who had suffered from TdP previously.

The group was divided into 17 patients who had a history of lifestyle choice induced TdP and 17 patients who had medication induced TdP.

All the patients gave informed consent for the test. They were given sotalol intravenously at a constant rate over a 20 minute period and their ECGs were recorded during this time. The patients were closely monitored in the intensive care unit of a hospital. Their ECGs were studied to show signs of a prolonged QT interval.

Some information regarding the patients is shown in **table 6.3**.

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Table 6.3

Medication-induced TdP	
Age	Gender
39	f
47	f
58	m
72	f
54	f
55	m
77	f
61	f
64	f
70	m
64	m
63	m
39	m
72	f
52	m
75	f
40	m

Lifestyle-induced TdP	
Age	Gender
47	f
60	f
67	f
70	f
61	f
65	f
70	f
64	f
62	f
82	f
63	m
56	m
36	m
70	f
54	m
73	f
37	m

(ii) Comment on the validity of this study. [4]

The sample size is too small (17 per group), so the results may not be representative.

There is a gender imbalance between groups: 12 f and 5 m with lifestyle TdP, 9 f and 8 m with medication TdP; the age range (37 to 82) also varies.

No information on which medications were taken or when, on other health problems, or on genetic predisposition to TdP.

Symptoms may occur later than the 20 minute exposure.

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7. **Table 7.1** shows information for several species of fish found in the Amazon River in Brazil.

Table 7.1

Genus	Mean Mass / kg	Mean surface area of gills / mm^2kg^{-1}	Behaviour	Habitat
Colossoma	48	1000	fast swimmer	fast moving water
Hydrolycus	30	950	fast swimmer	fast moving water
Electrophorus	20	143	hides on river bed ambushes prey	often buried in mud
Cichla	12	350	swims slowly but will make sudden movements to catch prey	slow moving water

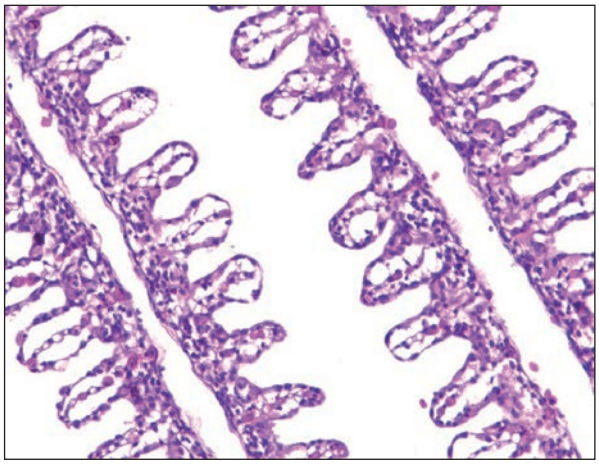
Image 7.2 shows the lamellae from the gills of the *Cichla* from a non-polluted and a polluted area of the Amazon river drawn to the same scale.

Image 7.2

Healthy gill lamellae



Lamellae from fish in a polluted area



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With reference to **table 7.1** and **image 7.2** and your own knowledge, describe and explain the general relationship between mass of fish and the surface area of their gills. Describe and explain the relationship between the surface area of gills and their behaviour and habitat. Describe and explain the effect of pollution on the fish gills and how this would affect the fish. [9 QER]

In general, the larger the mass of the fish, the larger the surface area of its gills per kg: Colossoma (48 kg) has 1000 mm^2 kg^{-1} and Hydrolycus (30 kg) has 950 mm^2 kg^{-1}, whereas Electrophorus (20 kg) has only 143 mm^2 kg^{-1}. A larger fish has more cells and tissues to supply with oxygen, so it needs a large gill surface area to absorb more oxygen, giving a greater rate of oxygen absorption. As mass increases the surface area to volume ratio of the body falls, so the gills increase the surface area to volume ratio for gas exchange. More oxygen enters the blood, so more aerobic respiration can take place. Cichla does not fit this trend: it has the smallest mass (12 kg) but a larger gill surface area (350 mm^2 kg^{-1}) than Electrophorus. The fast swimmers, Colossoma and Hydrolycus, have the largest gill surface areas (1000 and 950 mm^2 kg^{-1}). Fast swimming fish have a higher metabolic rate and need a higher rate of respiration, so a larger surface area is needed to gain enough oxygen for their needs. Electrophorus hides on the river bed, often buried in mud, and ambushes prey, so it has a low level of activity. Only a low level of respiration is needed, so it has the smallest gill surface area. Cichla swims slowly but makes sudden movements to catch prey, so it needs a larger surface area (350 mm^2 kg^{-1}) to supply oxygen for this. It also lives in slow moving water, which does not maintain the concentration gradient across the gills, so a larger surface area compensates for this. In the polluted area the gill lamellae are thickened, shortened and fused together compared with the healthy lamellae. This gives a smaller surface area for gas exchange and a larger diffusion

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distance, so oxygen diffuses into the blood more slowly.

This means the fish will not gain as much oxygen in its blood, so less aerobic respiration can take place. The fish will move more slowly, be less able to catch prey and will need a higher ventilation rate to compensate.

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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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Option A: Immunology and Disease

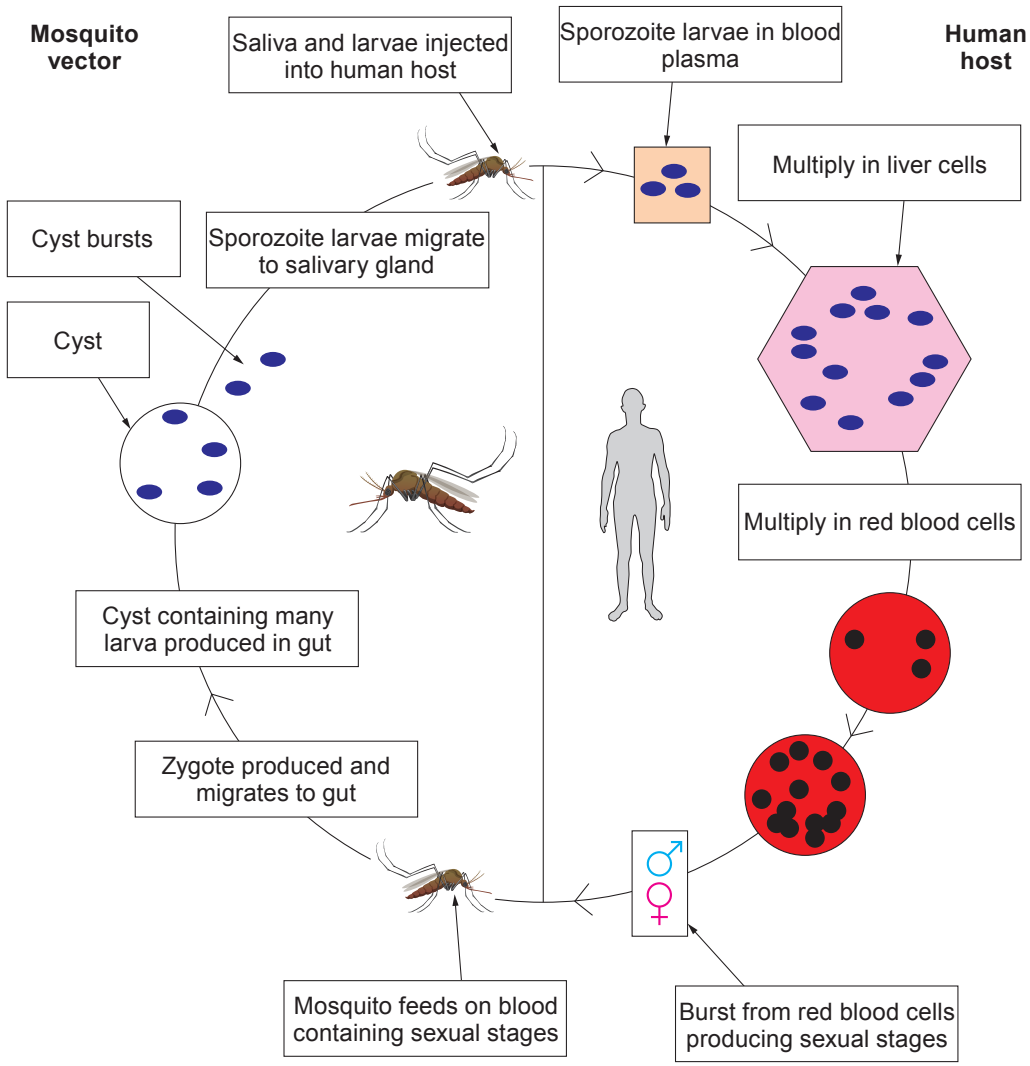
8. Malaria is a disease caused by the parasitic protoctist, *Plasmodium* and carried by a vector, the *Anopheles* mosquito.

Malaria is endemic in many tropical countries. A large proportion of the 1 million people who die from malaria each year are children under five years of age and 90% of cases occur in sub-Saharan Africa.

There are many stages in the life cycle. A larval form of the parasite is passed into human blood plasma when a mosquito feeds on blood. The parasite reproduces rapidly in the liver and erythrocytes (red blood cells) of a human host.

A summary of the life cycle of *Plasmodium falciparum* is shown in **image 8.1**.

Image 8.1



(a) State the meaning of the word 'endemic'. [1]

A disease that is always present (at low levels) in an area or population, occurring at a predictable rate.

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In 2015, 'Mosquirix' (trade name) was the first vaccine licensed for use against malaria.

A clinical trial of the vaccine involved 1000 healthy infants under 3 months old and 1000 healthy children aged 3 months to 5 years across Africa. The trial included a control group.
Infants and children in the trial were injected with an antigen, a protein called CSP, found on the plasma membrane of the sporozoite stage of the life cycle.

Scientists measured the immune response to the antigen by recording the concentration of anti-CSP antibody in the blood of individuals in each age group.

(b) (i) Using the information in **image 8.1** together with your own knowledge, suggest **two** reasons for developing a vaccine that targets the sporozoite stage of the life cycle. [2]

At the sporozoite stage the parasite is in the blood plasma, outside human cells, so antibodies and T cells can detect its antigens.

It targets the early stage while parasite numbers are low, destroying it before it enters the liver cells and reproduces.

(ii) State **one** reason why a vaccine for malaria has proved difficult to produce. [1]

Mutations in the Plasmodium DNA change the shape of its antigens (high antigenic variation).

(iii) Suggest a suitable control that could have been used in this trial. [1]

A group injected with a placebo (an inert substance) instead of the CSP antigen.

A summary of the results of the trial is shown in **table 8.2**.

Table 8.2

Age Group	Mean anti-CSP antibody concentration / a.u.
< 3 months (infants)	333
3 months – 5 years (children)	465

The concentration of anti-CSP antibody was lower in infants than in children. Despite this, the infant group did **not** show a higher frequency of cases of malaria.

Most infants in the trial were breast fed. Infants produced even lower concentrations of the anti-CSP antibody if their mother lived in an area which had a higher incidence of malaria cases.

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(iv) Use your knowledge of immunity to suggest an explanation for:

I. the infants' lower antibody production; [1]

The infants' immune system is not fully developed (less developed than children), so less antibody is produced.

II. the infants' lower susceptibility to malaria. [2]

Passive immunity: infants receive anti-malaria antibodies from their mother across the placenta and in breast milk.

Mothers exposed to a higher incidence of malaria produce more antibodies to Plasmodium antigens and pass them to the infants.

(c) The puff adder is a venomous snake that lives in parts of Africa.

Victims of puff adder bites may be given an injection of anti-venom containing antibodies specific to a toxin found in the puff adder's venom.

Anti-venom is produced by injecting very small volumes of the toxin (the antigen) into a mammal such as a sheep. The sheep produces specific antibodies that are purified from blood taken from the sheep.

(i) The sheep's immune system produces specific B lymphocytes in response to the antigen. The B lymphocytes then increase their numbers rapidly. Explain how the formation of B lymphocytes leads to the production of antibodies, which can be used as anti-venom. [2]

The B lymphocytes differentiate into plasma cells.

Plasma cells produce large amounts of antibodies specific (complementary) to the puff adder toxin, which are purified from the blood.

(ii) Suggest why anti-venom is administered to a person bitten by a puff adder even though they would produce their own antibodies to the toxin in the venom. [1]

Their own immune response would be too slow (long latent period) to prevent tissue damage or death.

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Anti-venom containing the purified antibodies is frozen or refrigerated to protect antibody proteins from heat damage while in storage until it is needed.

Scientists in Dubai have carried out research into the use of camels to produce anti-venom.

Camels are very large mammals that are able to tolerate body temperatures up to 41°C, several degrees higher than that of a sheep.

(iii) Giving a reason for your answer, suggest **one** advantage of using camels rather than sheep to produce puff adder anti-venom. [2]

Camel antibodies are more thermostable, as camels tolerate body temperatures up to 41 °C.

So the anti-venom needs less refrigeration or freezing in hot countries.

(d) Diphtheria is a potentially fatal bacterial disease caused by the Gram positive bacteria, *Corynebacteria diphtheria*.

Parts of South Africa have seen a rise in the number of cases of diphtheria due to a decrease in the number of children vaccinated.

Patients suffering from diphtheria are treated with antibiotics such as penicillin.

Penicillin inhibits an enzyme that is involved in the formation of the bacterial cell wall.

(i) Explain how inhibition of the enzyme described above causes bacterial cells to die. [2]

Fewer cross links form between peptidoglycan molecules, so the cell wall is weaker.

Water enters the cell by osmosis and the weak wall cannot withstand the pressure, so the cell bursts.

(ii) Explain why penicillin is more effective against *Corynebacteria diphtheria* than it is against Gram negative bacteria. [2]

Gram negative bacteria have an extra outer layer of lipopolysaccharide around the cell wall.

This layer protects the peptidoglycan wall from penicillin.

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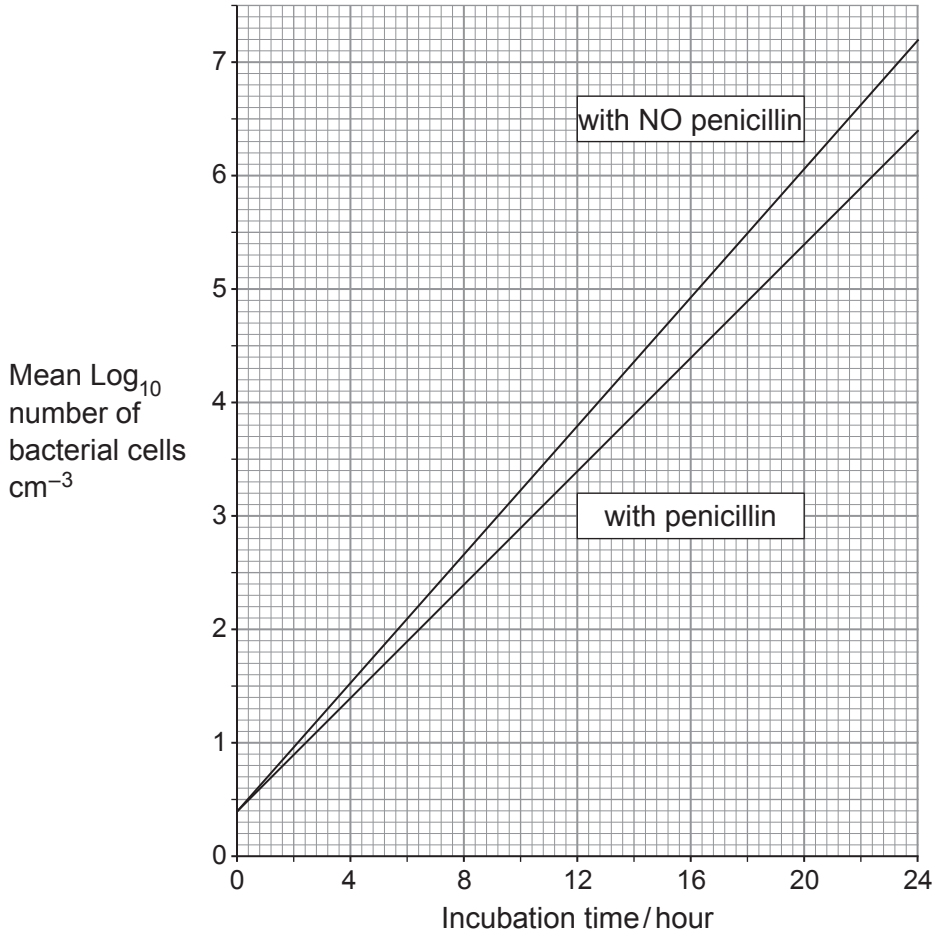
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(e) Scientists investigated the effect of penicillin on the number of *C.diphtheria* cells growing in a nutrient broth in a laboratory.

A culture of *C. diphtheria* was incubated at 37°C in nutrient broth containing penicillin. A second culture was incubated at the same temperature in the same volume of nutrient broth containing no penicillin. Samples were taken from each culture at hourly intervals and the number of bacteria counted.

The mean $\log_{10}$ numbers of bacterial cells were plotted on a graph as shown in **graph 8.4**.

Graph 8.4



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After 24 hours incubation with **no** penicillin, a $\log_{10}$ value of 7.2 on the graph indicated that the actual number of bacteria was 15 848 932 cm^{-3}

(i) Calculate the **actual** number of bacteria after 24 hours incubation with penicillin. [2]

$\log_{10}$ value from graph at 24 hours = 6.4

actual number = $10^{6.4}$ = 2 511 886

Actual number of bacteria = 2 511 886 cm^{-3}

(ii) The nutrient broth used to grow each *C.diphtheria* population contained compounds called peptones which provide a source of organic nitrogen. Explain why a source of nitrogen is included in the nutrient broth. [1]

So the bacteria can make proteins (enzymes) and nucleic acids, which contain nitrogen.

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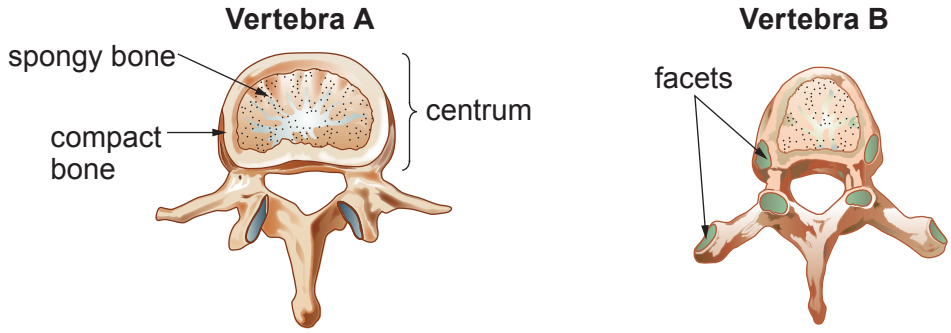
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Option B: Human Musculoskeletal Anatomy

9. *(a)* **Image 9.1** shows two different vertebrae.

Image 9.1



(i) Vertebra **A** is found in the lumbar region of the vertebral column.
Identify the region of the vertebral column where vertebra **B** is found and state the specific function of the facets labelled on the image. [2]

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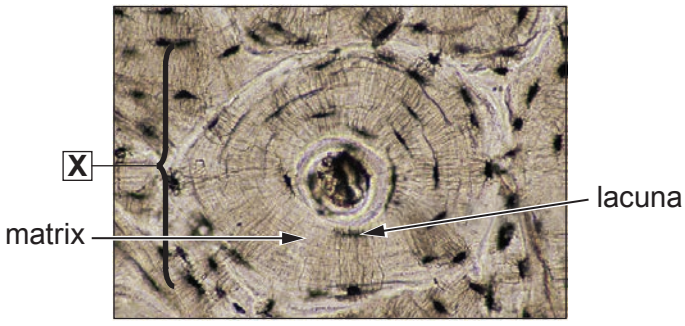
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The centrum is formed from spongy (cancellous) bone and compact bone.

Image 9.2 shows a transverse section through an area of compact bone.

Image 9.2



(ii) Identify structure **X**. [1]

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In the matrix, organic and inorganic compounds contribute to bone density and hardness.

(iii) Name **one** organic and **one** inorganic compound found in the matrix. [2]

Organic ..... Inorganic .....

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(b) The centrum plays a role in supporting body weight when upright. Bone should have a high enough density to carry out this function.

A bone density loss of 25% results in a condition called osteoporosis which carries a greater risk of fractures.

Bone density loss is a problem for astronauts on long duration space flights.

In 1989, American and Russian scientists investigated bone density changes in astronauts before and after space flights lasting 4–14 months.

Eighteen crew members underwent spine, pelvis and wrist bone density scans.

A baseline reading was taken from a scan 30 days before flight.

All astronauts carried out regular exercise, such as running on a treadmill, during flights. The space station was at 0.6 of the Earth's gravity.

A summary of the results is shown in **table 9.3**.

Table 9.3

Region of skeleton	Mean loss of bone density / % month^{-1}	Standard deviation (sd)
Spine (L1–L4) Lumbar		0.63
Spine Cervical	–1.15	0.84
Pelvis	–1.56	0.54
Wrist	–0.04	0.88

(i) The mean baseline total mass of four lumbar vertebrae (L1–L4) was 59.74 g.
At the end of a flight this had decreased to 52.14 g.
Calculate the percentage loss of bone density in these vertebrae during the entire flight. [2]

Percentage loss of bone density = ...

(ii) State the region of the skeleton that provides the greatest confidence in the data. Give a reason for your answer. [1]

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(iii) Suggest a reason why the scientists chose to measure the bone density of lumbar vertebrae and the wrist as part of their study. [2]

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(iv) Describe why running on a treadmill might be expected to increase bone density or reduce bone density loss in parts of bones such as the centrum of the vertebrae. Explain how osteocytes (bone cells) in the lacunae of compact bone reduce bone density loss as a result of an activity such as running. [3]

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(c) Arthritis is a disease that causes inflammation and pain at joints.
Image 9.4 is an X-ray photograph showing osteoarthritis in part of the spine.

Image 9.4



(i) The position of inflammation is highlighted by the red areas. From the image, identify the tissue most likely to be affected in those areas. Explain how pain and further damage to the joint is likely to be the result. [2]

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(ii) Rheumatoid arthritis is an autoimmune disease that results in joint inflammation. Explain the cause of inflammation in this form of arthritis. [1]

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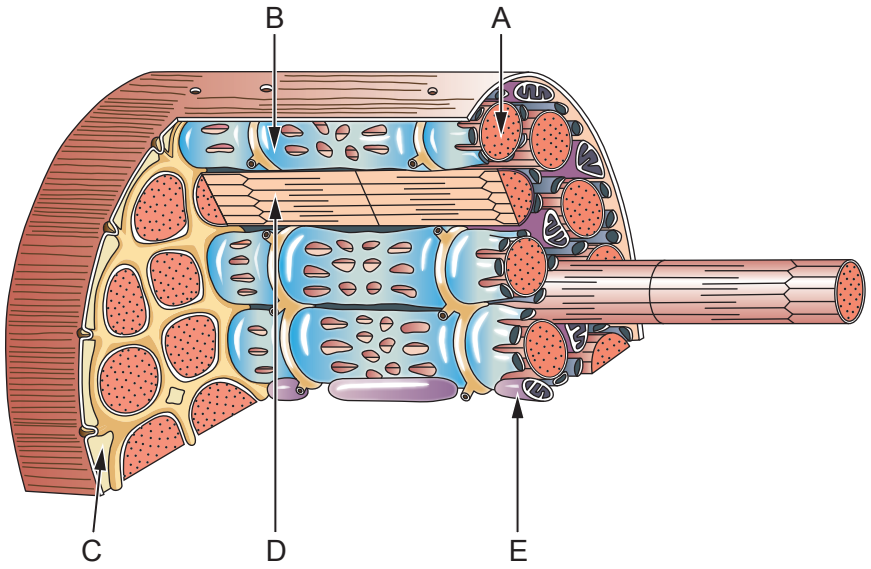
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The spine provides a means of attachment for the spinal extensor muscles which contract to hold the body upright.

Strengthening bones and muscles can reduce the risk of back pain in non-arthritic joints.

Calcium in the diet can increase bone density in the vertebrae and is needed for normal muscle contraction. **Image 9.5** shows part of a striated muscle fibre.

Image 9.5



(iii) State the letter and name the component of the muscle fibre where calcium ions are stored. [1]

Letter .....

Name .....

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Image 9.6 shows a representation of the arrangement of proteins of an actin filament in a myofibril.

Image 9.6

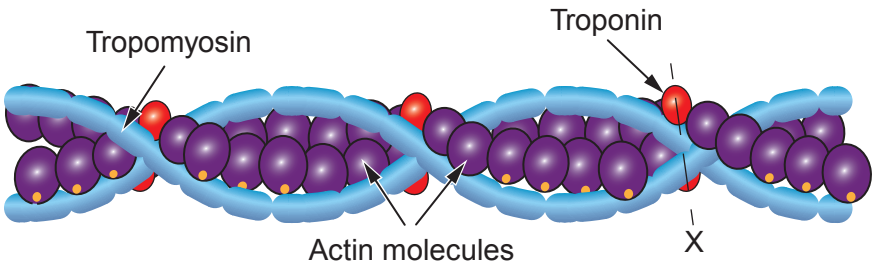


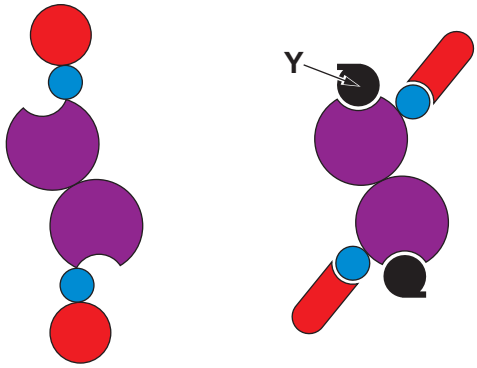
Image 9.7 shows a cross section through the structures of **Image 9.6** at the point marked **X**.

I. Represents their position when calcium ions are absent and

II. Represents their position when calcium ions are present.

Image 9.7

I. Calcium ions absent II. Calcium Ions present



(iv) With reference to structures represented in **image 9.7** and using your knowledge of proteins in the myofibril, explain the relationship between the presence of calcium ions and the position of structure **Y** in the process of muscle contraction. [3]

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Option C: Neurobiology and Behaviour

10. Many animals exhibit simple forms of innate behaviour.

(a) (i) Explain what is meant by innate behaviour. [1]

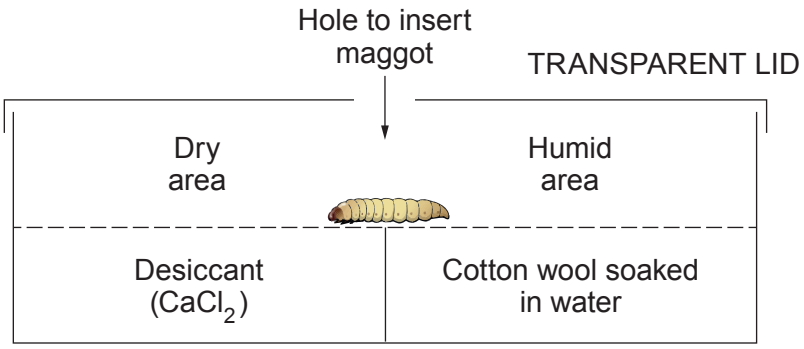
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Blowflies *(Calliphora spp)* are insects that lay eggs on recently dead animals. Eggs hatch into larvae called maggots that feed inside the dead animal.

A student investigated the effect of humidity on the movement of maggots. The apparatus is shown in **image 10.1**.

Image 10.1



The student set up a choice chamber as shown in **image 10.1**.

- The base was separated into two compartments.
- Cotton wool soaked with water was placed in one compartment and calcium chloride granules were placed in the other ($CaCl_2$ is a desiccant or drying agent).
- A grid was placed above the compartments and the lid replaced.
- The air above each compartment became humid or dry depending on the content of the compartment.
- One maggot selected randomly from a large sample group, was placed carefully in the centre of the grid through a hole in the lid.
- At 10 second intervals, the position of the head of the maggot was marked by a numbered dot on the transparent lid.

(ii) Before use in the experiment, the maggots were kept at room temperature for 10 minutes to allow them to equilibrate. Explain why this was necessary. [1]

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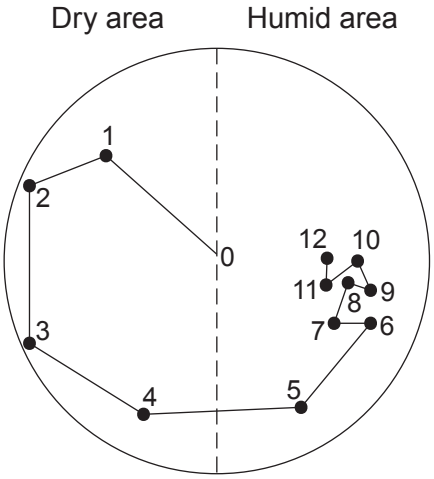
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After 2 minutes, the student removed the maggot then joined the dots on the lid. The pathway of the maggot over 2 minutes showing its position at 10 second intervals is shown in **image 10.2**.

Image 10.2.



The procedure was repeated several times using a different maggot each time.

(iii) Identify the type of innate behaviour shown by the maggot in this experiment and describe **one** feature of the pattern of movement that supports your conclusion. [2]

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(iv) Suggest how this behaviour would be an advantage to the maggot in its natural environment. [2]

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(v) The rate of movement during the first minute was calculated by measuring the total length of the lines drawn on the lid from 0 to 6 and dividing by 60 seconds. Suggest why calculating the rate of movement from this data is likely to be inaccurate. [1]

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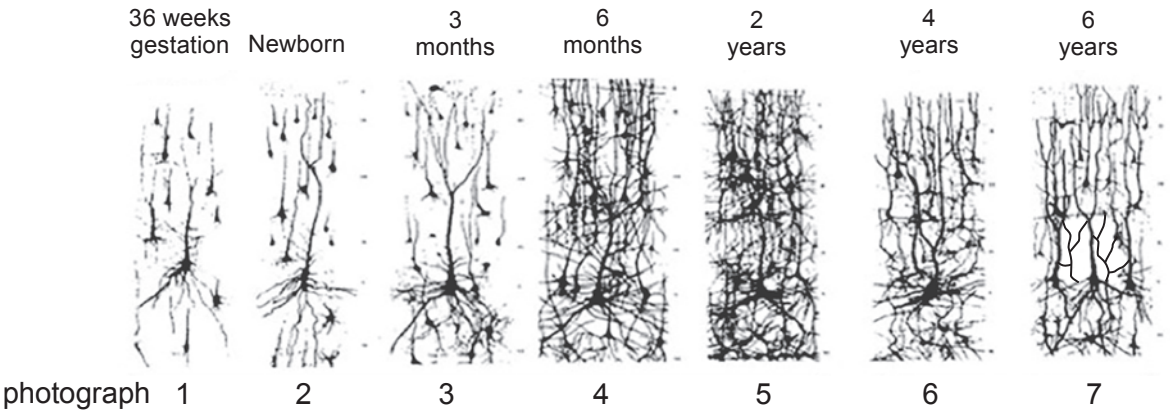
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(b) Mammals exhibit innate and learned behaviour.

Young mammals need sensory input during a critical receptive stage of early development. This enables them to develop learned behaviour that also uses motor areas of the brain.

Image 10.3 shows the developmental changes in the neurones of a human cerebral cortex before, during and after this critical time period.

Image 10.3



(i) State the name that describes the changes in the development of neurones illustrated in **image 10.3**. [1]

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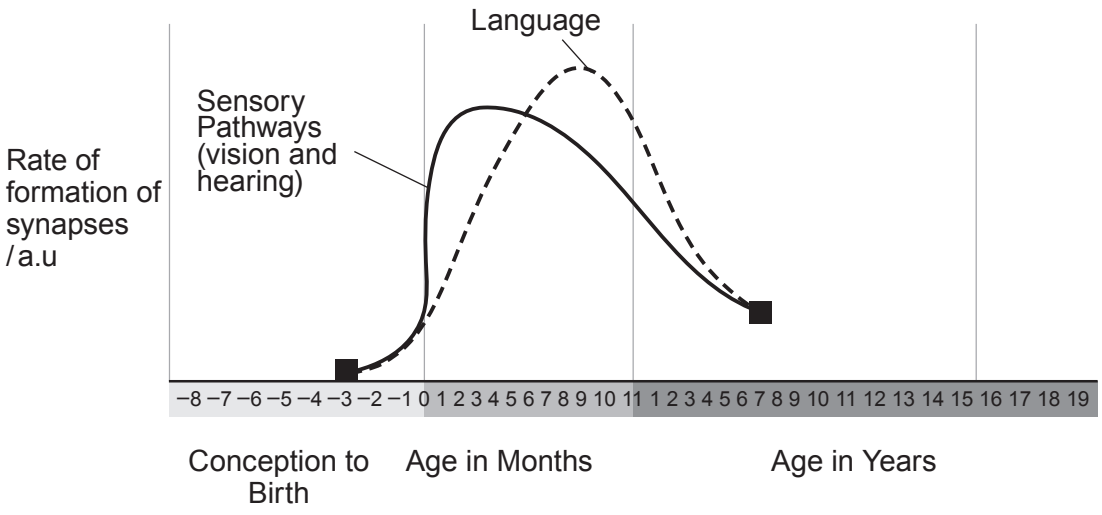
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Graph 10.4 shows the rate of formation of synapses involved in sensory pathways and language development in early childhood.

Graph 10.4



(ii) Using information from **graph 10.4**, together with your own knowledge, explain why hearing deficiency during the critical period for the formation of sensory pathways can result in poor speech and language development. [3]

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(iii) With reference to the neurones of a 4 year old and 6 year old (photographs **6** and **7**), suggest why speech and language does not improve significantly if hearing is restored after the critical period. [1]

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(iv) State the names of the **two** areas of the cerebral cortex associated with the development of speech and language. [1]

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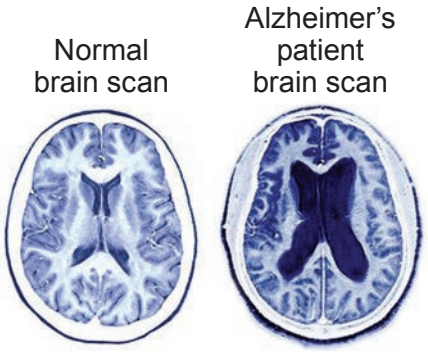
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(c) Alzheimer's disease is a condition that causes gradual deterioration of tissue in the brain over several years. The onset of Alzheimer's disease is associated with increasing age.

Patients suffering from Alzheimer's disease show varying degrees of atrophy (brain shrinkage) as shown in the CT scan in **image 10.5**.

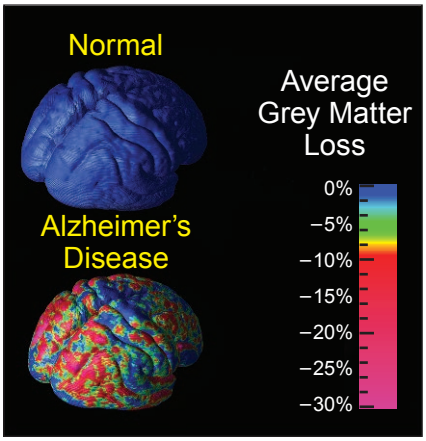
Image 10.5



The degree of atrophy can also be measured using an MRI scan such as the one shown in **image 10.6**.

Image 10.6

MRI comparison of a normal brain and the brain of a patient with Alzheimer's disease.



(i) Compare the way that a CT and MRI scan image is produced and suggest **two** advantages of using an MRI scan for monitoring the progression of Alzheimer's disease. [3]

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(ii) State **one** factor that should be considered in order to make a valid comparison between the brain of an Alzheimer's patient and a normal brain. [1]

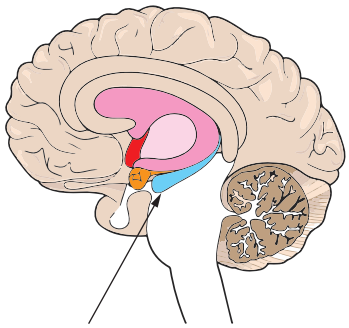
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Memory loss can be a symptom of Alzheimer's disease.

The hippocampus is one area of the brain where memory is processed. The position and relative size of the hippocampus is shown in **image 10.7**.

Image 10.7



hippocampus

Scientists suspected that loss of volume of the hippocampus may account for some memory loss. MRI scans were used to measure the volume of the hippocampus and the total brain volume in several Alzheimer's patients with degrees of memory loss over a 12 month period.

A summary of the results is shown in **table 10.8**.

Table 10.8

Component / portion of the brain	Mean volume / mm^3	
	At Start	After 12 months
Hippocampus	4065	3537
Total Brain	1.534×10^6	1.453×10^6

(iii) The ratio of the total brain volume to hippocampus volume at the start of the 12 month period was 377 : 1.

I. Calculate the ratio of the total brain volume to hippocampus volume after 12 months. [2]

Ratio = ... : .....

II. Explain what the difference between these two ratios indicates about the size of the brain and the hippocampus. [1]

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