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

GCE AS

B400U20-1

S23-B400U20-1

THURSDAY, 25 MAY 2023 – MORNING

BIOLOGY – AS component 2
Biodiversity and Physiology of Body Systems

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**18**	
2.	**13**	
3.	**14**	
4.	**9**	
5.	**12**	
6.	**9**	
Total	**75**	

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ADDITIONAL MATERIALS

In addition to this paper you may require 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

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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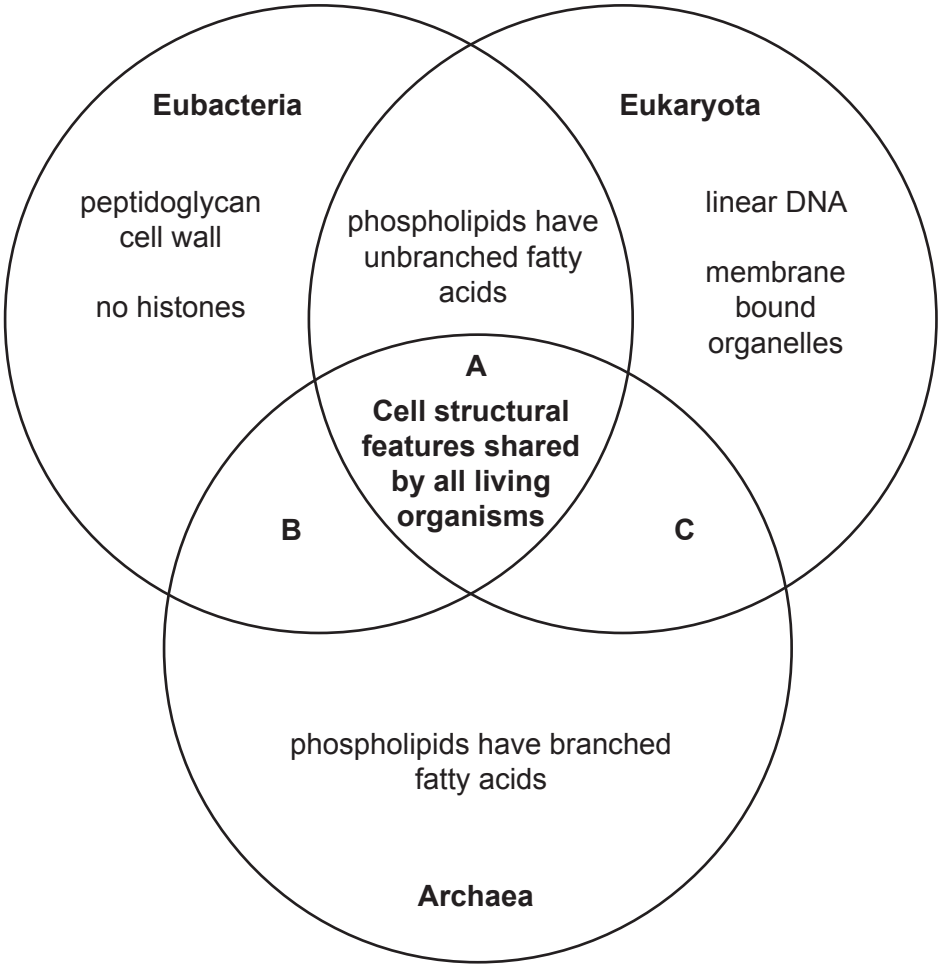
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Answer **all** questions.

1. (a) All living organisms are classified into one of three taxonomic groups called Domains. **Image 1.1** represents the main structural features of cells of the organisms belonging to each of the three Domains.

Image 1.1



(i) State **two** structural features of cells shared by **all** living organisms, as shown by region **A** in **Image 1.1**. [1]

DNA (nucleic acid) and ribosomes; also a plasma membrane and cytoplasm.

(ii) State **one** structural feature shared by cells of Domains that intersect in regions:

I. **B** Circular DNA (plasmids), no nucleus [1]

II. **C** Histones present, no peptidoglycan (murein) [1]

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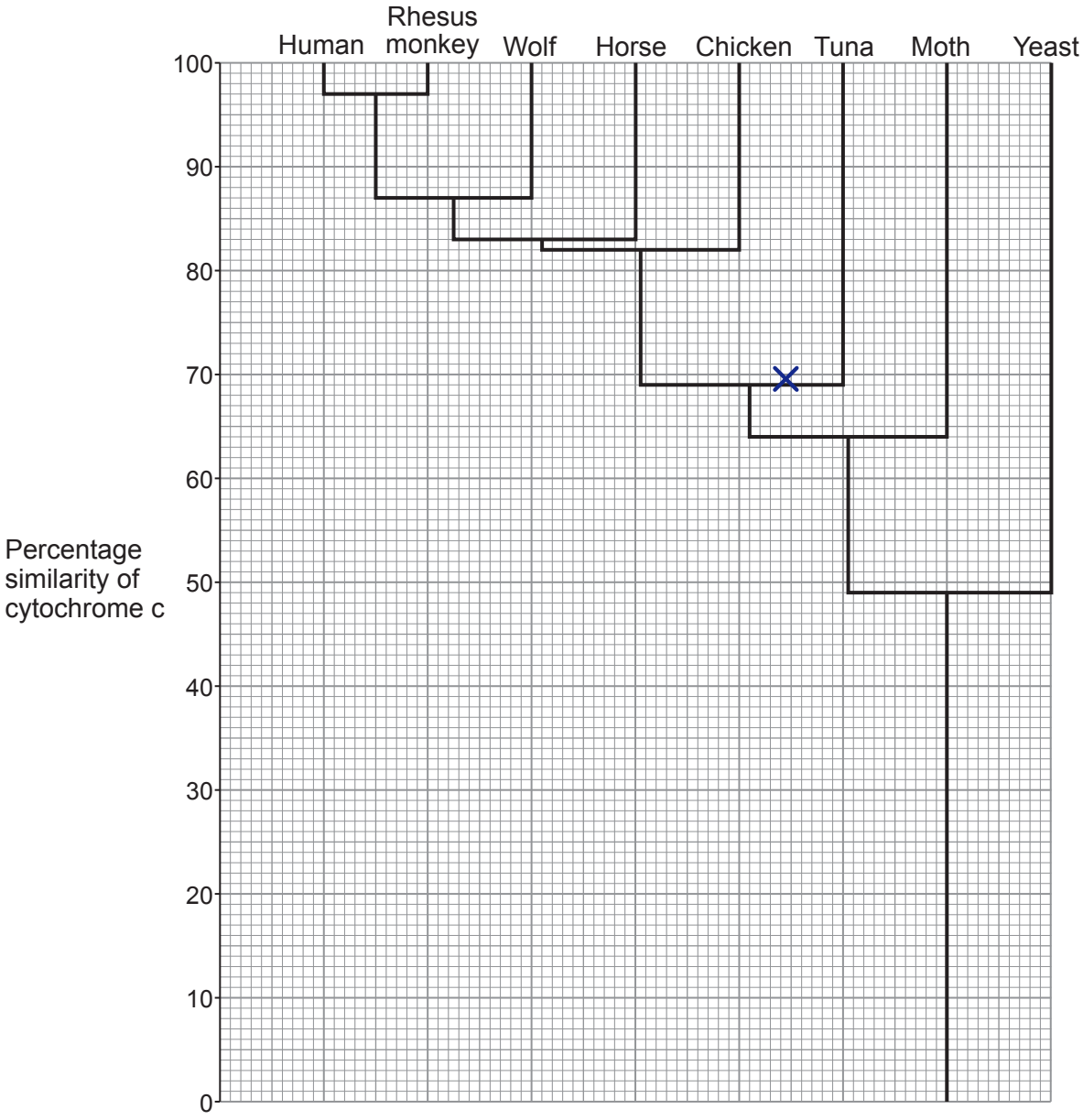
(b) Cytochrome c is a protein involved in aerobic respiration in mitochondria. Comparison of the primary structure of cytochrome c from different species can provide evidence for evolutionary relationships between them.

(i) Describe how a comparison of the primary structure of cytochrome c from different species may show evolutionary relationships between them. [1]

Fewer differences in the amino acid sequence show species are more closely related; more differences show they are less closely related.

Image 1.2 shows a phylogenetic tree for eight species of organisms based on comparison of their cytochrome c.

Image 1.2



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(ii) **Image 1.2** shows a 3% difference between the primary structures of cytochrome c in humans and Rhesus monkeys. If 0.1% is equivalent to 250 000 years, calculate the number of years since the divergence of these species. [2]

3 ÷ 0.1 = 30

30 × 250 000 = 7 500 000 years (7.5 million)

Time = 7 500 000 years ago

(iii) **Place an X** on **Image 1.2** to show the position of the nearest common ancestor shared by the horse and tuna. [1]

(iv) Yeast is the only organism named in **Image 1.2** that has a cell wall made of chitin. Identify the Kingdom to which yeast belongs. [1]

Fungi

(v) Wings of chickens and moths are known as analogous structures. State what is meant by the term 'analogous structure' and name the type of evolution that gives rise to such structures. [2]

Analogous structures have evolved from different structures to perform the same function (e.g. flight).

They arise by convergent evolution.

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(c) Moths are insects. They are pollinators for many plant species and a source of food for some predatory birds.
Image 1.3 shows a lime hawk moth, *Mimas tiliae*, a species common to Southern England with numbers increasing further north.
Due to natural selection, lime hawk moth life cycles have aligned with the seasonal cycles of lime trees. Climate change can affect the timing of the growth of leaves, which their larvae (caterpillars) feed on.

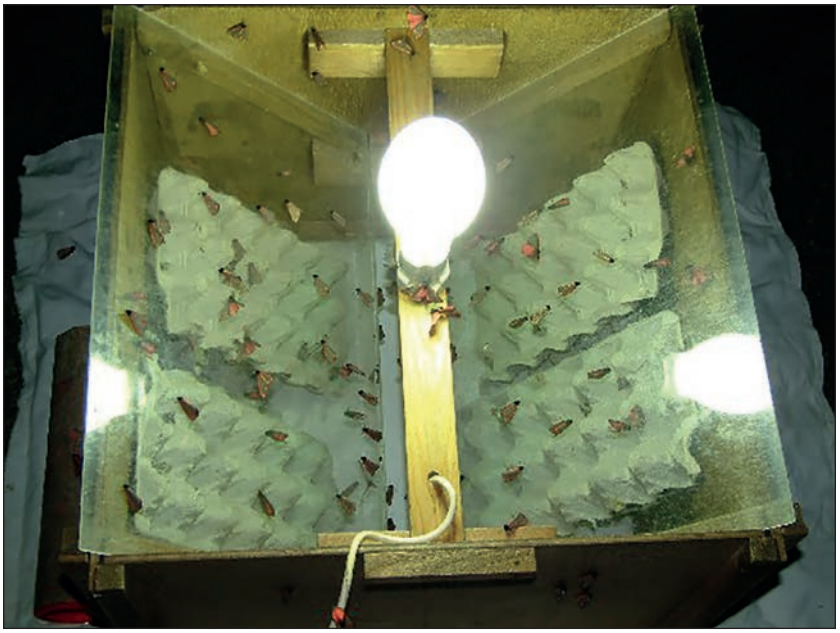
Image 1.3



Scientists monitoring the size of populations of lime hawk moths use light traps to capture moths during warm nights when they are most active.

Image 1.4

A light trap



Moths can fly in through gaps under the glass.

The glass prevents them flying back upwards.

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An investigation was carried out in a southern and northern region of England using the following method.

- Five light traps, 10 metres apart, were left with the light on for four hours at night.
- After this time, captured moths were counted and marked with a small dot placed on the abdomen before releasing them.
- The procedure was repeated the following night without marking the moths after capture.
- All the moths captured on the 2nd night were counted.
- Moths that had a marker dot (those that had been captured previously) were counted.

All moths were released after counting.
A summary of the data is displayed in **Table 1.5**

Table 1.5

Region of England	Total number of moths		
	1st Sample	2nd Sample	Number marked in 2nd sample
southern	64	75	26
northern	29	25	14

(i) Use the formula below to calculate the population size for hawk moths in the sampled area in the northern region. [2]

$$\text{Population size} = \frac{\text{number in 2nd sample} \times \text{number in 1st sample}}{\text{number marked in 2nd sample}}$$

$(25 \times 29) \div 14 = 725 \div 14 = 51.8$

$= 52$

Number in population = 52

(ii) During the time period between the 1st and 2nd samples, several events might occur that could lead to an inaccurate estimate of population size. Suggest **two** of these possible events. [2]

Some marked moths might be eaten by predators or die between the 1st and 2nd night.

The marker dot may be removed (rub off), or moths might migrate away from the sampling area.

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(iii) The light in the trap was on for four hours each night. State **two** other variables that should have been controlled when setting the moth traps in each region. [2]

The light intensity of the light source and the same size and type of trap.

The same type of habitat (surrounding vegetation), height above ground and the same weather conditions.

(iv) Describe and explain **one** possible effect of an increase in the number of lime hawk moths on biodiversity in the northern region. [2]

The number of some bird species that eat (predate) moths would increase, as there is more food for them.

Some plant species may increase, as moths pollinate them, increasing their reproduction.

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2. **Image 2.1** shows a large, fast swimming fish known as a wahoo, *Acanthocybium solandri*. It lives in warm tropical seas, where it may reach swim speeds of 80 – 90 km per hour.

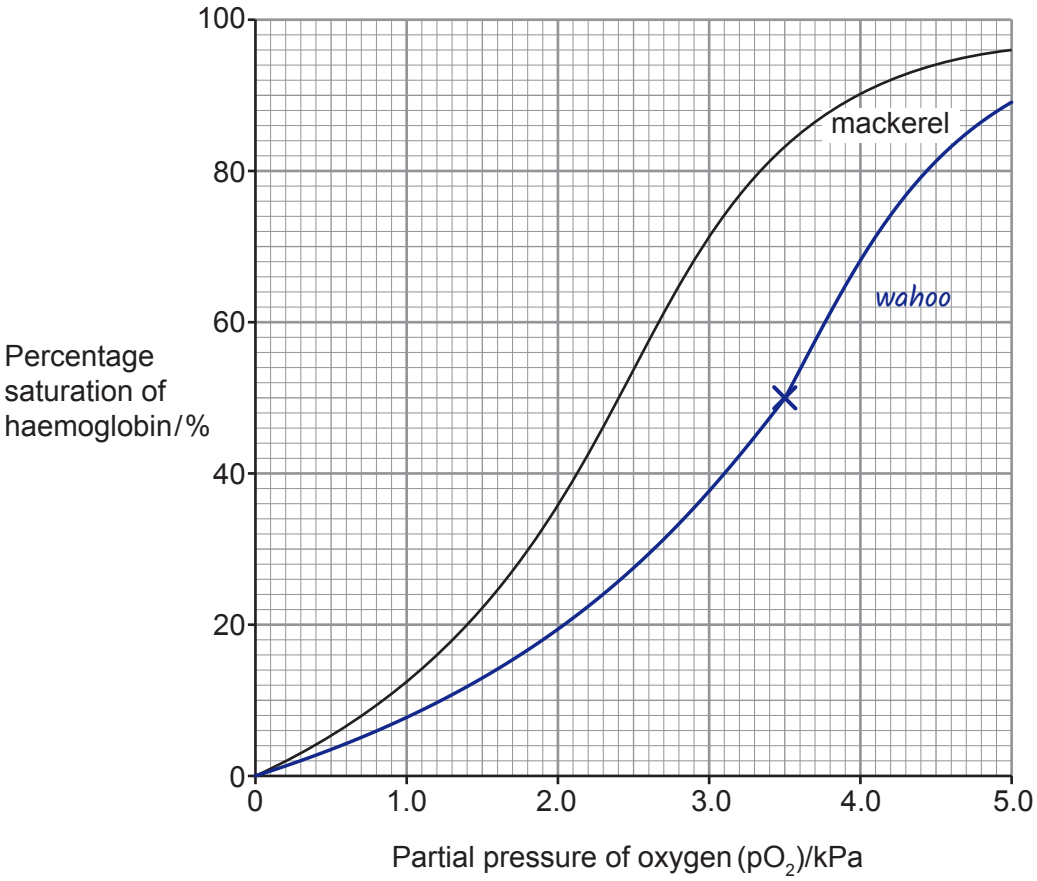
Image 2.1



Mackerel, *Scomber scombrus*, is a similar species of fish that lives in temperate regions where cooler water causes its body temperature to be lower than that of the wahoo.

Graph 2.2 shows an oxyhaemoglobin dissociation curve for mackerel haemoglobin.

Graph 2.2



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(a) The p50 is the partial pressure (pO_2) at which haemoglobin (Hb) is 50% saturated with oxygen.
The p50 for haemoglobin from a wahoo was found to be 3.5 kPa.

(i) On **Graph 2.2**,

I. **plot the position of the p50** for the wahoo [1]

II. **draw a sketch line** to show the expected oxyhaemoglobin dissociation curve for the wahoo. [1]

(ii) Using **Graph 2.2**, determine the difference between the percentage saturation of haemoglobin of a mackerel and a wahoo at a pO_2 of 3.5 kPa. [1]

83 – 50 = 33

Percentage difference = 33 %

(iii) Explain how the fast swimming speed of the wahoo affects the release of oxygen from its haemoglobin. [2]

Faster swimming means a higher rate of respiration in the muscles, producing more CO_2. This lowers the affinity of haemoglobin for oxygen (Bohr effect), so oxygen dissociates more readily.

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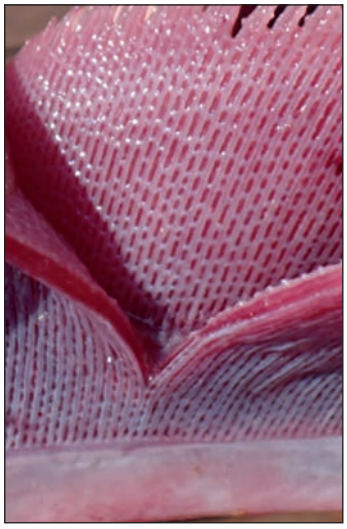
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(b) Icefish, *Channichthyidae spp*, live in extremely cold water around Antarctica which causes them to have a very low metabolic rate. There are no red blood cells or molecules of haemoglobin in the blood of icefish.

Image 2.3 shows the difference in appearance of the gills of a wahoo and an icefish.

Image 2.3



Wahoo gill



Icefish gill

(i) Suggest which component of blood transports most oxygen in an icefish. [1]

In the plasma (dissolved in plasma).

(ii) Capillaries have a diameter of 7–10 µm.
Describe and explain **three** effects of the very narrow diameter on gas exchange in a gill capillary. [3]

Increased friction and contact between the blood and the capillary walls, so slower blood flow, giving more time for diffusion.

A greater surface area to volume ratio, so more area for absorption of oxygen.

A shorter diffusion distance from the water to the blood in the capillary.

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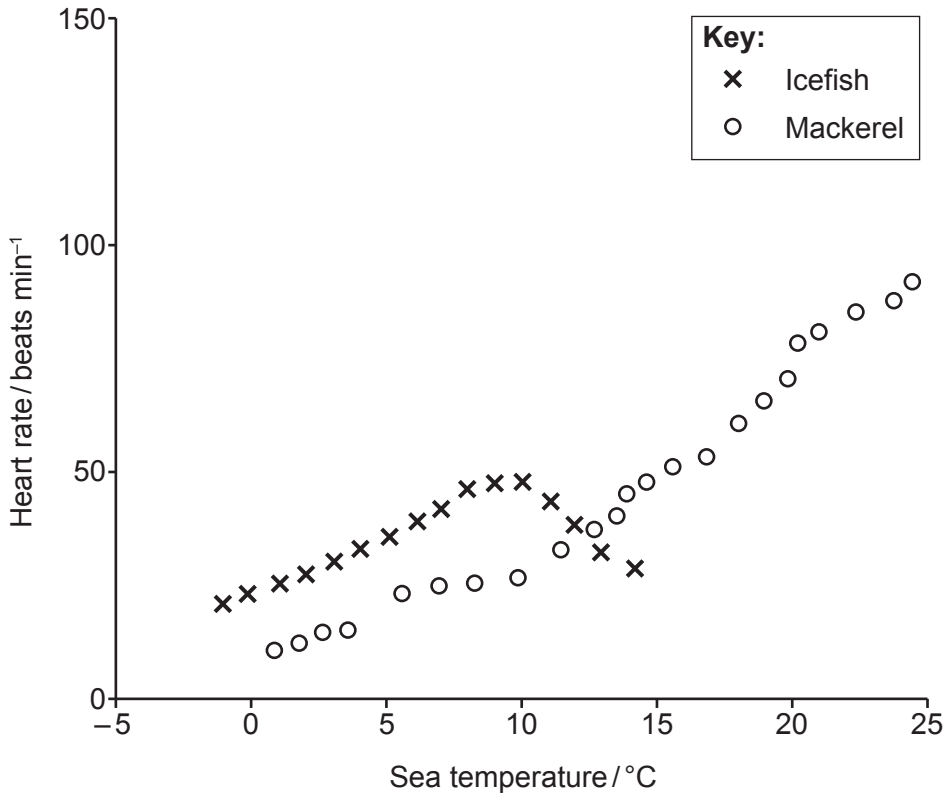
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(c) Scientists are concerned that global warming and increasing sea temperatures threaten the survival of icefish.

It is suggested that several species of fish acclimatise to increasing sea temperatures by increasing their heart rate.

Graph 2.4 shows heart rate in two species, icefish and mackerel, over a range of sea temperatures.

Graph 2.4



(i) It was concluded that icefish can adapt to increasing temperatures by increasing their heart rate. With reference to **Graph 2.4** evaluate this conclusion. [2]

Partly correct: heart rate increases with temperature up to 10 °C (positive correlation, about 20 to 48 beats min^{-1}). But heart rate decreases above 10 °C (to about 29 at 14 °C) and there is no data above 15 °C, so there is a limit.

(ii) Each heartbeat is initiated within the cardiac muscle itself.
Name the property of cardiac muscle that enables this to occur. [1]

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(iii) Higher sea temperatures increase body temperature and therefore metabolic rate and oxygen consumption in fish.
Use the information given to suggest **one** reason why icefish are less likely to survive if the temperature of the water in which they live increases to 15 °C. [1]

Heart rate is too low (falling) to supply the increased oxygen demand,

and with no haemoglobin the plasma alone cannot deliver enough oxygen.

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3. Tomato plants, *Solanum lycopersicum*, are grown commercially for their edible fruit. They produce bright yellow flowers from which the fruit develop.

Sucrose is a disaccharide transported in phloem tissue and used by tomato plants as a source of energy.

Image 3.1A shows a light micrograph of phloem tissue.

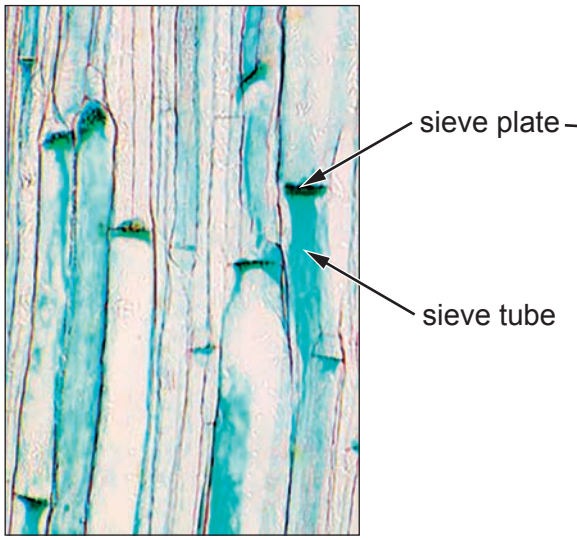
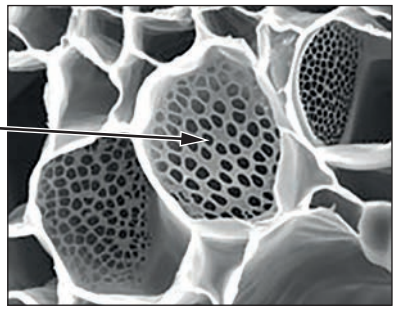


Image 3.1B shows an electron micrograph of a sieve plate.



(a) The mechanism of transport in phloem is described as the mass flow hypothesis. Increasing hydrostatic pressure in the sieve tubes at the source in the leaves drives the transport of sucrose to sinks elsewhere in the plant.

(i) Name **two** regions of a tomato plant that are considered 'sinks' for sucrose. [1]

Roots

Fruit (flowers, developing seeds)

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(ii) The rate of flow of solutes in the phloem sieve tubes of tomato plants may be up to ten times faster than the flow of solutes through other cells.

Using Images 3.1A and 3.1B and your knowledge of sieve tube structure, describe and explain **one** structural feature that allows a relatively fast flow rate to be achieved in the sieve tubes. [2]

Sieve plates have many pores (sieve tubes have very little cytoplasm and few organelles).

So there is less resistance to the flow of phloem solution.

(iii) Sucrose is loaded into the phloem in the leaves where it is formed. Explain why loading sucrose at the source results in increased hydrostatic pressure in the sieve tubes at that point. [2]

Increased sucrose concentration lowers the water potential (Ψ) in the sieve tubes.

Water enters by osmosis from the xylem, so the volume of water in the phloem increases, raising the pressure.

(iv) The rate of uptake and translocation of sucrose in phloem was found to be inhibited by:

- low temperature
- phosphate deficiency
- cyanide.

Explain why **each** of these observations appear to contradict the mass flow hypothesis, which describes a passive process. [3]

Each suggests that energy (ATP) is required, so the process is active, not passive.

Low temperature slows respiration and decreases kinetic energy, so less ATP is made.

Phosphate is needed for the production of ATP.

Cyanide inhibits respiration (the electron transport chain), so no ATP is produced.

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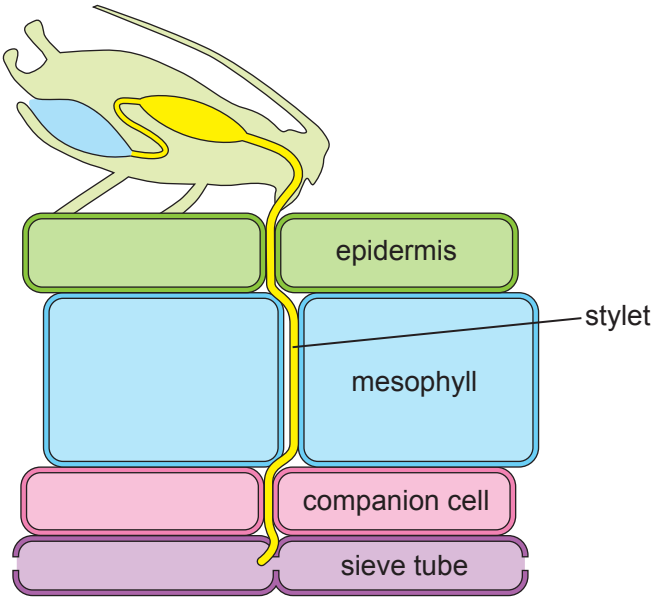
(b) An experiment to investigate the rate of transport of organic molecules in the phloem of tomato plants used aphids to sample phloem contents.

Aphids are insects that insert a tubular mouthpart called a stylet into the phloem, through which it feeds on phloem solution.

Plants may respond to phloem damage by blocking some pores in the sieve plates and restricting flow. Aphids can suppress this response.

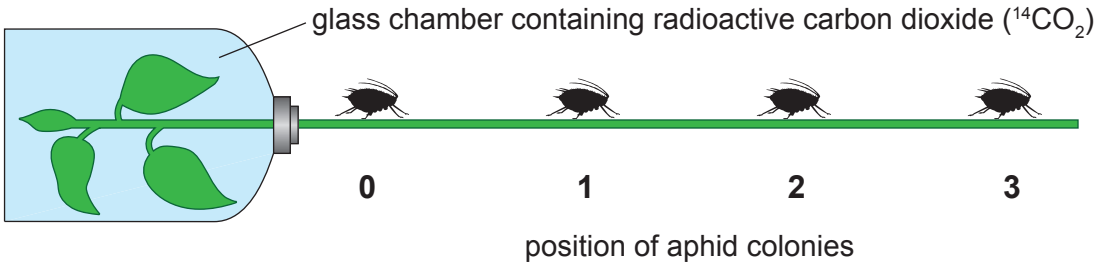
Image 3.2 shows a diagram of an aphid feeding on phloem.

Image 3.2



The experiment was set up as shown in **Image 3.3**

Image 3.3



- Aphid colonies were placed at 25 cm intervals from a start point (0) near the leaves on a branch and allowed to feed.
- The aphids were detached from their stylets which were left in place penetrating the phloem.
- Leaves were covered by a sealed glass chamber and provided with $^{14}CO_2$ containing the radioisotope ^{14}C. Organic compounds became radioactive as ^{14}C was incorporated during and after photosynthesis.
- Phloem solution, collected from the stylet at regular intervals, was tested for radioactivity. The time taken for radioactivity to reach each colony position was recorded.

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Table 3.4 shows the time taken for the radioactivity to travel between positions on the branch.

Table 3.4

Direction of movement of radioactivity between positions. (25 cm intervals)	Time taken for radioactivity to travel between positions / hours
0 to 1	1.2
1 to 2	1.4
2 to 3	1.5

(i) Calculate the mean rate of flow of the solution in the phloem between position 0 and position 3. **Give your answer to 3 significant figures**. [3]

total distance = 3 × 25 = 75 cm

total time = 1.2 + 1.4 + 1.5 = 4.1 hours

rate = 75 ÷ 4.1 = 18.29 cm hr^{-1}

Rate = ..18.3.. cm hr^{-1}

(ii) Suggest **one** advantage and **one** disadvantage of using several aphids at each position. [2]

Advantage: a greater volume of solution for analysis, and if some stylets become blocked, others still exude sap.

Disadvantage: the exact position of each aphid (distance between sampling positions) is less precise.

(iii) For ethical reasons, the use of micro-injection needles inserted into the phloem was suggested as an alternative to using aphids for sampling the phloem. Suggest **one** reason why the use of micro-injection needles may provide less precise results. [1]

Needles are rigid and may damage or block the phloem, and it is hard to be certain the phloem is being sampled.

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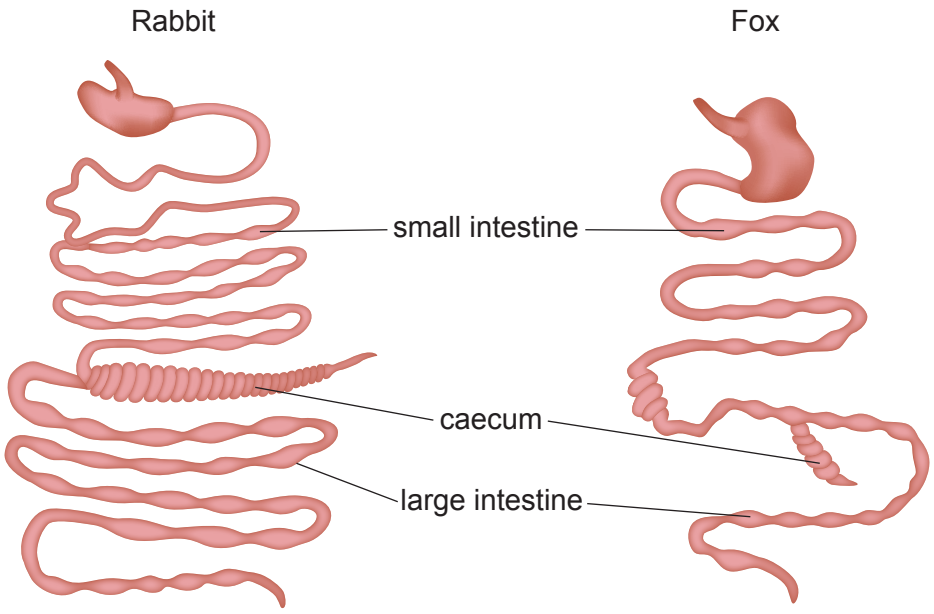
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4. (a) Rabbits and foxes are mammals that consume different proportions of macronutrients. **Image 4.1** shows the digestive systems of a rabbit (a herbivore) and a fox (a carnivore).

Image 4.1



(i) Most products of digestion are absorbed in the ileum which is the longest section of the small intestine. With reference to its diet, explain why a fox has a proportionally shorter ileum than a rabbit. [2]

A fox eats protein, so more products of digestion (amino acids) enter the ileum, as protein is already digested in the stomach. So the ileum is shorter as less time (surface area) is needed for absorption.

(ii) The caecum and large intestine are proportionally larger in a rabbit than in a fox and contain micro-organisms similar to those found in the rumen of cattle. State **one** function carried out by these micro-organisms. [1]

They digest cellulose (produce cellulase enzymes).

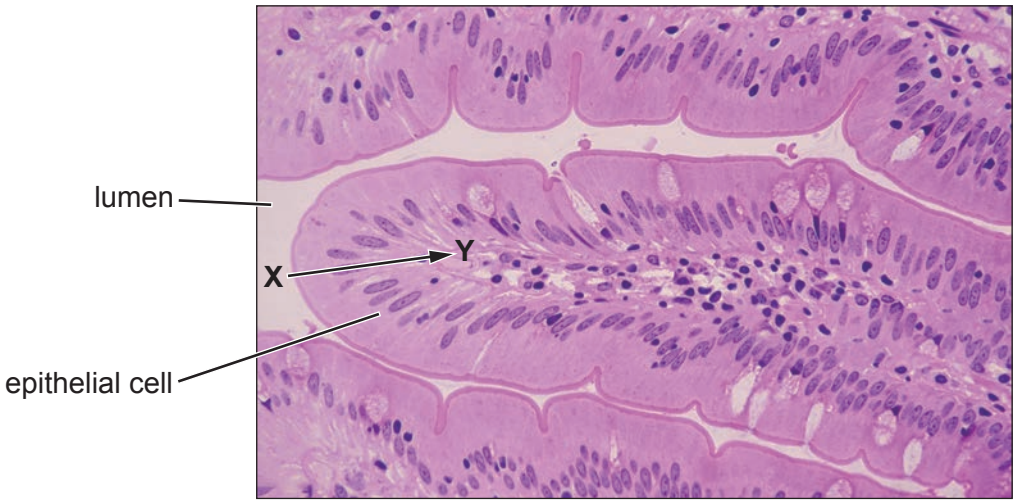
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(b) **Image 4.2** is a photomicrograph of part of the ileum. An epithelial cell is labelled.

Image 4.2



(i) The specimen in **Image 4.2** has been viewed using a light microscope. Suggest the magnification of the **objective lens** that was used to provide the visual detail seen in this photograph. [1]

Magnification = × 40

(ii) Describe the process of glucose transport from the lumen of the small intestine into and then out of epithelial cells as it is absorbed along the pathway from **X** to **Y**, indicated by the arrow in **Image 4.2**. [3]

Glucose enters the epithelial cell by co-transport with sodium ions (Na^+).

Na^+ ions are actively transported out of the cell into the blood, creating a concentration (diffusion) gradient for Na^+.

Glucose leaves the epithelial cell by facilitated diffusion into the blood.

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(iii) The lumen of the small intestine contains water from food and digestive secretions. Describe how the transport of glucose into the epithelial cells affects the absorption of water from the lumen. [2]

Glucose lowers the water potential of the epithelial cells.

So water moves out of the lumen into the epithelial cells by osmosis.

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5. Terrestrial organisms obtain oxygen from air. They have internal gas exchange surfaces that provide a large surface area for sufficient diffusion of oxygen and carbon dioxide.

(a) (i) State **one** reason, other than protection, why it is an advantage for gas exchange surfaces to be internal in all terrestrial organisms. [1]

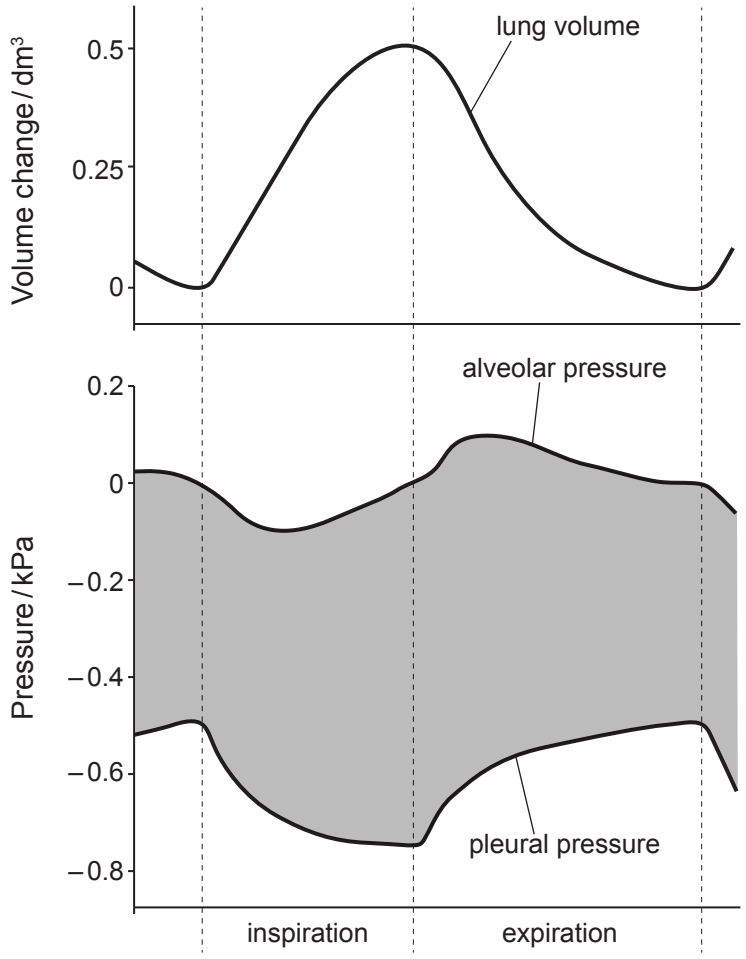
To reduce water loss (by evaporation) from the gas exchange surface.

(ii) Explain the purpose of ventilation in the lungs of mammals. [1]

To maintain a steep diffusion gradient for oxygen and carbon dioxide at the gas exchange surface.

(b) **Graph 5.1** shows changes in volume and pressure in an adult human lung while breathing.

Graph 5.1



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(i) Describe how muscles of the thorax, together with the pleural membranes, cause the change in alveolar pressure seen in **Graph 5.1** during inspiration. [4]

External intercostal muscles contract, so the rib cage moves upwards and outwards; diaphragm muscles contract and the diaphragm flattens.

The outer pleural membrane pulls the inner pleural membrane outwards (pleural pressure falls from −0.5 to −0.75 kPa).

This increases lung volume (by 0.5 dm^3), so alveolar pressure falls below atmospheric, to about −0.1 kPa.

Question continued overleaf

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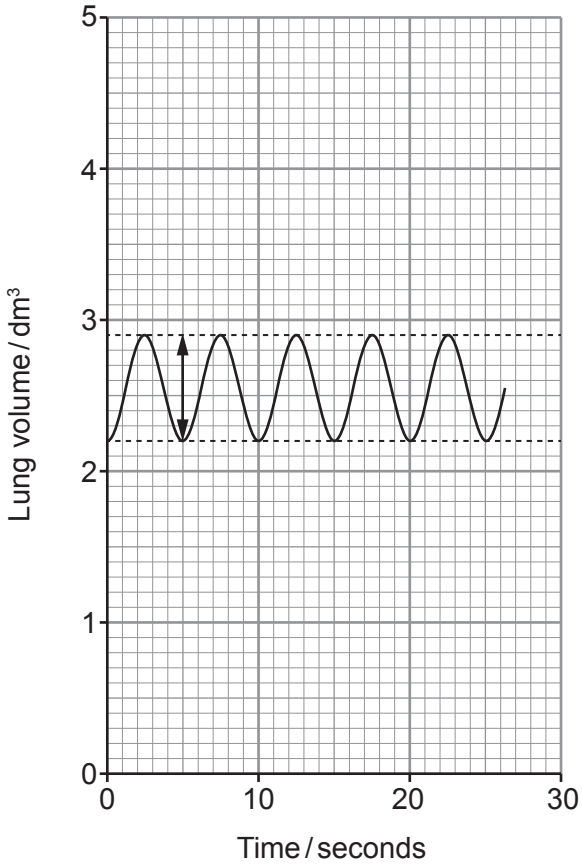
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Graph 5.2 illustrates the changes in lung volume for an adult human while breathing at rest.

The arrow on **Graph 5.2** represents the volume change as this individual breathes in or out.

Graph 5.2



(ii) Using the data in **Graph 5.2** calculate the total volume of air inspired in one minute when this individual is breathing normally at rest. [2]

volume of 1 breath = 2.9 – 2.2 = 0.7 dm^3

4 breaths in 20 s, so 4 × 3 = 12 breaths per minute

12 × 0.7 = 8.4 dm^3

Total volume inspired in one minute = ... 8.4 ..... dm^3

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The volume of air inspired and expired is equal, however, the composition of gases varies.

Table 5.3 shows the percentage of three gases in air from three points of the breathing cycle.

Table 5.3

Gas	Percentage of gas mixture / %		
	Inhaled (atmospheric) air	Exhaled air	Alveolar air
Oxygen	20.96	16.2	14.0
Carbon dioxide	0.04	4.2	6.4
Nitrogen	79.0	79.6	79.6

(iii) The percentage of carbon dioxide in exhaled air is lower than in alveolar air. Explain why. [1]

Some CO_2 remains in the trachea, bronchi and bronchioles (dead space air mixes with alveolar air).

(iv) Exhaled air has a slightly higher percentage of nitrogen than inhaled air despite this gas being inert in mammals. Use the information in **Table 5.3** to suggest a reason for the difference. [1]

The proportions of oxygen and carbon dioxide (and water vapour) have changed, so nitrogen is a different proportion of the mixture.

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(c) Exposure to cigarette smoke has been shown to have a damaging effect on the lungs and reduce respiratory efficiency.

Images 5.4 A and **B** show two electron micrographs of lung tissue at the same magnification.

Image 5.4 A tissue from a lung that has had long-term exposure to cigarette smoke.
Image 5.4 B lung tissue that has not been exposed to cigarette smoke.

Image 5.4 A
Exposed to smoke

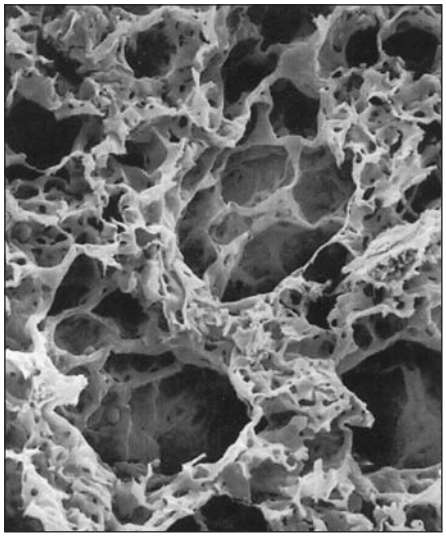
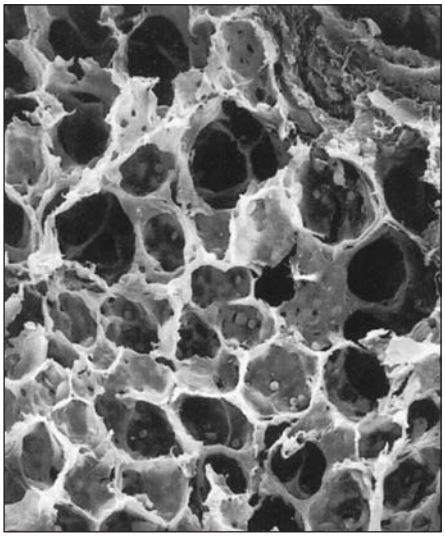


Image 5.4 B
Not exposed to smoke



With reference to **Images 5.4 A** and **B**, describe **one** difference in the appearance of the two lung samples and explain how this would decrease gas exchange efficiency. [2]

In A the alveoli (air spaces) have become larger, as the walls between the alveoli have broken down.

This reduces the surface area for gas exchange, so less diffusion of oxygen.

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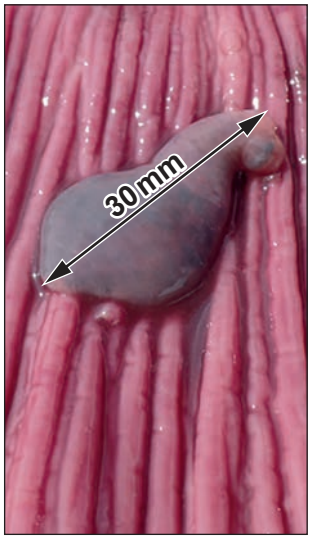
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6. **Image 6** is a photograph of an adult endoparasitic worm, *Hirudinella ventricosa*, attached to the folds inside the stomach of its primary host, which is a large fish.

Image 6



Hirudinella's thick body wall has a cuticle covered in mucus. The anterior end has two suckers. It feeds on the host's blood through mouthparts that penetrate the stomach lining.
The parasite is hermaphrodite (has male and female reproductive organs). One adult can release many eggs into the host's digestive tract from which they are egested in faeces.
Eggs hatch into larvae which swim in sea water then penetrate the secondary host, a marine snail. Several larval stages reproduce asexually inside the snail.

Using the above information together with your knowledge of parasitic nutrition, state what is meant by the term 'endoparasite' and distinguish between the terms 'primary host' and 'secondary host'.

Suggest how the features of this parasitic life cycle increase the chance of *Hirudinella* infecting its primary host.

Describe the problems encountered by an adult *Hirudinella* in the stomach of its host and explain how it is adapted to survive in such conditions. [9 QER]

An endoparasite is an organism that lives, feeds and reproduces inside its host, gaining nutrition from it and causing it harm. Hirudinella lives inside the stomach of the fish and feeds on the host's blood, so it is an endoparasite. The primary host is the host in which the parasite reaches its adult form and undergoes sexual reproduction: here the large fish, where the hermaphrodite adult produces eggs. The secondary host is the host in which the parasite undergoes asexual reproduction and only larval forms exist: here the marine

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snail.

Life cycle: one adult releases very large numbers of eggs into the host's gut, which are egested in faeces. This increases the number of larvae, so more secondary hosts (snails) are infected, even though many eggs and larvae die in the sea.

Being hermaphrodite means a single adult can produce fertilised eggs by sexual reproduction even if no other Hirudinella is present in the same fish, so it does not need to find a mate.

Several larval stages reproduce asexually inside the snail, producing large numbers of larvae from each infection. This increases the probability that some will infect and survive in the primary host. The fish becomes infected when it ingests (eats) the infected snail, so the parasite is passed along the food chain.

Problems in the stomach: peristalsis and the muscular contractions of the stomach wall could detach the parasite and move it out of the stomach.

Hirudinella has two suckers at its anterior end for attachment to the stomach folds, which prevent detachment.

The stomach has a low pH (hydrochloric acid) and protease enzymes such as pepsin, and the host's immune response could also damage the parasite's cells and tissues and kill it. The thick body wall with a cuticle covered in mucus protects the parasite's tissues from the low pH, the digestive enzymes and the host's immune response.

To feed, it has sharp mouthparts that penetrate the stomach lining, enabling it to feed on the host's blood through the stomach wall. These adaptations allow Hirudinella to survive, feed and reproduce in the hostile conditions of the host's stomach.

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