Your teacher may watch to see if you can:

- follow instructions carefully
- work safely, avoiding spills.

Aim

To find out how **surface area : volume ratio (SA : V ratio)** affects how quickly substances can diffuse to the centre of a cube.

Method

- beaker of water
- potato cubes
- paper towel
- cutting board
- beaker of iodine solution
- ruler
- forceps
- gloves
- stop clock
- knife
- eye protection

⚠ Safety

- Iodine solution stains skin and clothes. Wear eye protection and gloves.
- Be careful with knives.
- Do not eat anything in the lab.

A Measure the length, in millimetres, of one side of each potato cube. Record the lengths.

B Carefully use the forceps to pick up each cube and lower it gently into the beaker of iodine solution.

C Time 15 minutes.

D Use the forceps to remove the cubes from the iodine solution in the same order that you put them into the iodine. Lower each one gently into the water.

E Once all your cubes are in the water, take them out again.

F Blot the cubes with the paper towel to dry them.

G Cut each cube in half and measure the distance that the colour has spread from the middle of one surface towards the centre of the cube.

Recording your results

1 Draw a table to record your results, using these headings.

Length of cube side (mm)	Surface area of the whole cube (mm^2)	Volume of cube (mm^3)	Surface area : volume (SA : V) ratio of cube	Shortest distance to centre of cube (mm)	Distance travelled by iodine into cube (mm)

Considering your results/conclusions

2 **a** The iodine travels a certain distance from the outside into the cube. How is this distance travelled affected by the size of the cube?

b What does this tell you about the speed of **diffusion** of iodine in potato?

3 **a** The iodine may not reach the centre of the cube. Look at the distances from the centres of the cubes to where the iodine reached. Is this distance affected by the size of the cube?

b What is the correlation between the SA : V ratio and this distance?

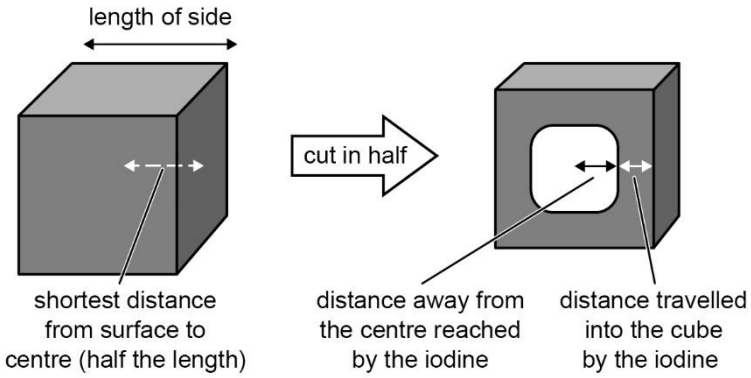
c What is the correlation between the SA : V ratio and the time needed for substances to reach the centre of the cube?

4 Explain how this experiment can be used to explain why there is a limit to cell size.

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The drawings show some of the measurements you will have taken in this experiment.



For a cube, the length of one side is the same as its width and height. The length of the cube side can be used to work out: ● the shortest distance to the centre of the cube (is half the length) ● the surface area of one side of the cube (is length × width ● the surface area of the whole cube (is 6 × (length × width)) ● the volume of the cube (is length × width × height) ● the SA : V ratio (is the surface area divided by the volume)	**Examples** For a cube of side length 5 mm: = 5/2 = 2.5 mm = 5 × 5 = 25 mm^2 = 6 × (5 × 5) = 150 mm^2 = 5 × 5 × 5 = 125 mm^3 = 150/125 = 1.2

Recording your results

1 **a** Complete the last column of the table with the distances for the potato cubes that you tried.

b Complete the remaining columns.

Length of cube side (mm)	Surface area of the whole cube (mm^2)	Volume of cube (mm^3)	Surface area : volume (SA : V) ratio of cube	Shortest distance to centre of cube (mm)	Distance travelled by iodine into cube (mm)
5				2.5	
10					
15					
20					

Considering your results/conclusions

2 Cross out the incorrect words in the brackets in the following.

The distance the iodine travels into each cube (*does* / *does not*) change. So, the speed of **diffusion** is always (*different* / *the same*) in potatoes. However, the larger the cube, the (*further* / *less far*) the iodine reaches towards its centre. The larger the cube, the (*larger* / *smaller*) its SA : V ratio. So, the (*larger* / *smaller*) a cube's SA : V ratio, the less far the iodine reaches towards its centre.

This helps us to understand why cells only reach a certain size. If a cell has too (*big* / *small*) an SA : V ratio, the substances it needs will not be able to reach all parts of the cell quickly enough.

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1 Look at the words in the box.

carbon dioxide	glucose	mineral ions
oxygen	**urea**	water

a Circle two common waste substances that the human body needs to remove.

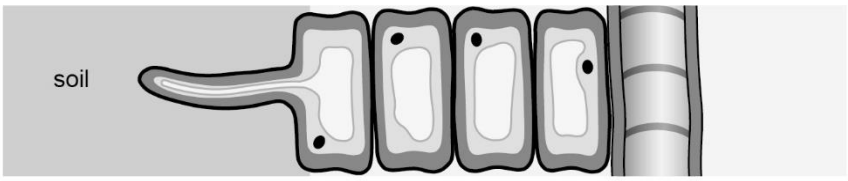
b Use a different colour to circle two substances taken in by plant roots.

c Use another colour to circle two substances needed for **aerobic respiration** in plants and animals.

The **surface area : volume (SA : V) ratio** is the surface area of something divided by its volume. The higher the SA : V ratio, the more quickly a cell can supply all of its parts with useful substances (and remove wastes).

Some cells have shapes that increase their SA : V ratios. For example, neurones (nerve cells) are long and thin, and this gives them a high SA : V ratio.

2 The diagram on the right shows some cells in a root. Label the diagram to:

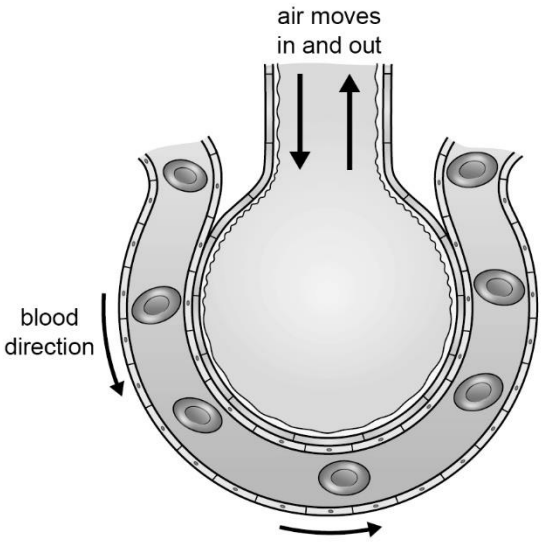


a indicate the cell that has the highest SA : V ratio, and explain how you can tell

b explain what this cell does

c explain how its shape helps it do its job.

3 The diagram on the right shows an **alveolus**.



a Label the diagram to show the overall movements of the two gases that are exchanged.

b State how alveoli increase the SA : V ratio of the lungs.

_____

_____

_____

c Explain why an increase in the SA : V ratio is necessary.

_____

_____

d Explain one other adaptation of alveoli that helps to speed up **gas exchange**.

_____

_____

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Name _____ **Class** _____ **Date** _____

EASIER

1 Human cells use **aerobic respiration** to release energy.

a Circle the two gases in the box below.

carbon dioxide	glucose	oxygen

b Complete the word equation for aerobic respiration using words from the box.

_____ + _____ → _____ + water

c Unjumble the phrase to give the name of the process that allows these gases to get into and out of cells.

IF IS FOUND The process is called _____

S1 List two gases that enter or leave muscle cells. For each, describe how it enters or leaves cells and why it needs to enter or leave.

2 The **surface area : volume (SA : V) ratio** is something's surface area divided by its volume. Smaller cubes have higher SA : V ratios than larger cubes. Use the steps below to calculate the SA : V ratio of a cube of side 15 µm.

a Calculate the surface area of one side of the cube (length × width). _____ μm^2

b All six surfaces of a cube have the same area. Calculate the surface area of the cube. _____ μm^2

c Calculate the volume of the cube (length × width × height). Include the unit in your answer. _____

d Calculate the SA : V ratio of the cube. _____

S2 Compare the SA : V ratios of two cube-shaped cells, one with sides of 15 µm and the other with sides of 25 µm.

3 Tick (✓) the boxes to show whether each substance is usually excreted by humans or taken in.

Substance	Excreted	Taken in
carbon dioxide		
oxygen		
urea		

HARDER

4 **a** Which organ removes carbon dioxide from the body? _____

b How is the SA : V ratio of this organ increased? _____

_____

c Why is the SA : V ratio of this organ increased? _____

_____

5 **a** What waste substance is formed during the breakdown of amino acids? _____

b Which organ removes this waste substance from the blood? _____

c This organ has about the same volume as a tennis ball. Suggest a reason why the SA : V ratio of this organ needs to be much greater than that of a tennis ball.

_____

_____

_____

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Name _____ **Class** _____ **Date** _____

1 **a** What gas is needed for **aerobic respiration**? _____

b What sugar is needed for aerobic respiration? _____

c What waste gas do humans excrete? _____

d What waste product is made by breakdown of amino acids? _____

e State the reason the body needs to excrete wastes. _____

2 Plants need nitrates to help them make proteins. What are nitrates an example of? _____

3 Lungs have a large **surface area : volume (SA : V) ratio** because they are filled with small pocket-shaped structures (shown in the diagram on the right).

a Name of this structure.

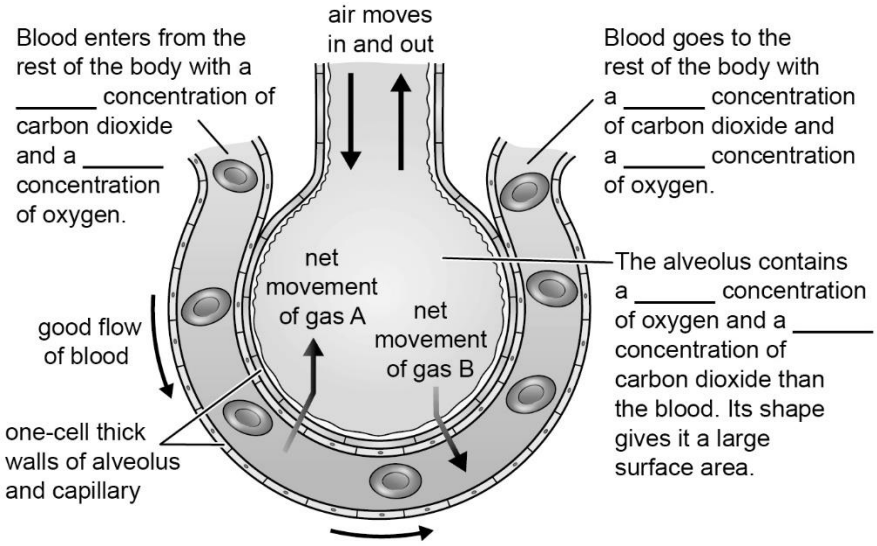
_____

b Fill in the missing words in the labels.

c Identify gases A and B.

gas A _____

gas B _____



d Underline two phrases that show adaptations that help to increase the rate of **gas exchange**.

e For each phrase you have underlined, explain how the adaptation increases the rate of gas exchange.

_____

_____

_____

4 **a** Cell S has a volume of 1000 μm^3 and its surface area is 600 μm^2. Calculate its SA : V ratio.

_____

b Cell T is shaped like a cube with sides 20 µm. Calculate its SA : V ratio.

_____

c Explain which cell (S or T) exchanges substance with the outside more efficiently.

_____

_____

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1 For each of the following, state why it needs to be taken into the body or removed from it.

a oxygen

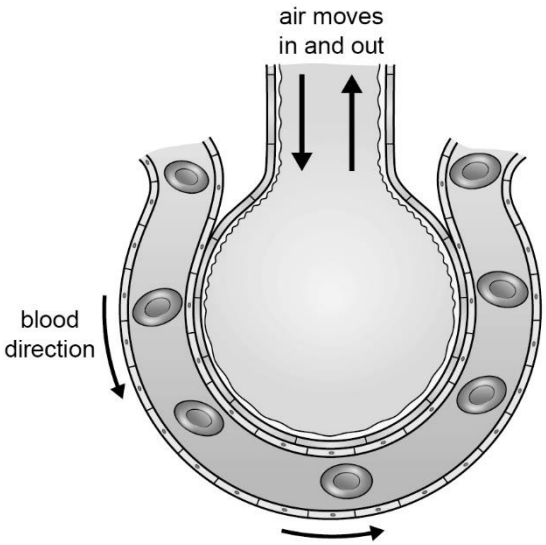
b **urea**

c glucose

2 A grape has a volume of 2 cm^3 and a surface area of 7 cm^2. An orange has a volume of 700 cm^3 and a surface area of 350 cm^2.

a Compare the **surface area : volume (SA : V) ratios** of the orange and the grape.

b The diagram on the right shows an **alveolus**. You can imagine the alveoli in the lungs as being arranged as bunches of grapes, rather than the lung being one big orange. Use this idea to explain why the lung is full of tiny alveoli.

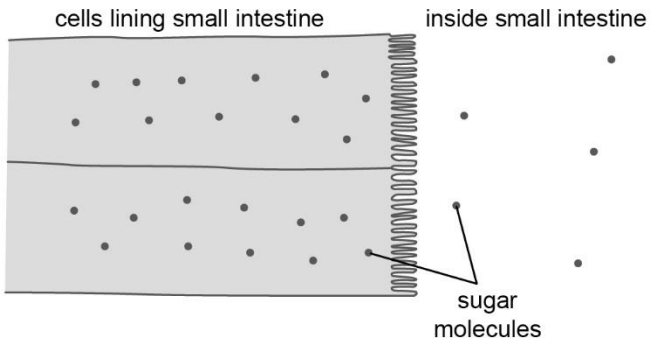


c There is a net movement of two gases during **gas exchange** in the alveoli. Explain how this occurs.

d Give one way in which both the **capillaries** and alveoli are adapted to help this movement.

e Explain why a faster flow of blood in the capillaries increases the rate at which oxygen gets into the blood.

3 The drawing below shows two cells in the wall of the small intestine. Use ideas about SA : V ratios to explain the shape of the cells.



Extra challenge

4 **a** Draw diagrams to show the typical structure of animal and plant cells.

b Explain why plant cells can become much bigger than animal cells.

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Progression questions

Answer these questions.

1 What substances need to be transported into and out of the body?

_____

_____

2 Why is the surface area : volume ratio important for exchange of substances?

_____

_____

3 How are lungs adapted for gas exchange?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

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Your teacher may watch to see if you can:

- follow instructions carefully
- work safely.

Introduction

You will be using some agar blocks that contain an indicator called phenolphthalein. The indicator makes the blocks pink but it turns colourless in acidic conditions. When the blocks are submerged in hydrochloric acid, the acid diffuses through the edge of the block, and eventually the entire block will turn from pink to colourless.

Aim

To find out how **concentration** affects the rate of diffusion.

Prediction

1 **a** What do you think will happen to the rate of diffusion of the acid into the blocks as you increase its concentration?

b Explain why you think this.

Method

- agar blocks
- white tile
- eye protection
- stop clock
- forceps
- Petri dish
- capped bottles containing different concentrations of hydrochloric acid

⚠ Safety

- Wear eye protection.
- These concentrations of hydrochloric acid are irritants. Let your teacher know at once if you spill any acid or get it on your skin.
- Phenolphthalein is harmful if swallowed.
- Wash your hands after doing the experiment.

A Place the Petri dish base on the white tile. Take the bottle containing the lowest concentration of acid and stand it in the centre of the Petri dish. Remove the cap.

B Working with a partner, one of you should pick up an agar block with the forceps and slowly lower it into the bottle. Let it drop *gently* into the acid when the forceps are just inside the bottle. This will prevent splashing of the acid. As soon as the block is in the acid, start the stop clock and put the cap back on the bottle.

C Stop timing when the block has lost all its colour.

D Dispose of the bottle as instructed by your teacher.

E Repeat steps **A**–**D** with the other concentrations of acid.

Recording your results

2 Draw a table to record how long it took for each block to lose its colour.

Considering your results/conclusions

3 Draw an appropriate chart or graph to display your data.

4 What is the correlation between the time taken for the block to become colourless and the concentration?

5 **a** What do your results tell you about the effect of concentration on the rate of diffusion?

b Do your results support your prediction? If not, explain what you think now.

Evaluation

6 How could you improve the quality of the data that you collected?

7 Describe how you would change the experiment to investigate the effect of surface area : volume ratio.

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Fick's law shows how various factors affect the rate of diffusion across a cell membrane.

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{concentration difference}}{\text{thickness of membrane}}$$

1 Use Fick's law to describe the relationship between the rate of diffusion and:

a surface area only

b **concentration** difference only

c thickness of membrane only.

2 Place X has a carbon dioxide concentration of 5000 molecules/μm^3. Place Y has a concentration of 10 000 molecules/μm^3. The concentration at place Z is 4000 molecules/μm^3.

a Calculate the concentration difference between each pair of places (X&Y, X&Z, Y&Z).

b Between which two places will the rate of diffusion be the fastest? Explain your answer.

3 The concentration of sodium ions at place P is 50 000 ions/mm^3. The sodium ion concentration at place Q is 150 000 ions/mm^3. The sodium ion concentration at place R is 80 000 ions/mm^3.

a Calculate the concentration difference between each pair of places (P&Q, P&R, Q&R).

b Between which two places will the rate of diffusion be the fastest? Explain your answer.

4 The concentration of ethanol at place S is 0.205 g cm^{-3}. The ethanol concentration at place T is 0.020 g cm^{-3}. The ethanol concentration at place U is 0.025 g cm^{-3}.

a Calculate the concentration difference between each pair of places (S&T, S&U, T&U).

b Between which two places will the rate of diffusion be the fastest? Explain your answer.

5 Oxygen is diffusing into a cell. What will happen to the rate of diffusion of oxygen into the cell if its concentration outside the cell is:

a doubled

b tripled

c halved?

6 Oxygen is diffusing into a cell at a rate of 2000 molecules per second. The thickness of the cell membrane is 10 nm. Use Fick's law to calculate the rate of diffusion of oxygen at the following membrane thicknesses. Assume that no other variables change.

a 20 nm

b 5 nm

c 0.016 µm

7 Carbon dioxide diffuses into an alveolus at 0.02 µg/s. Calculate the rate of diffusion if the:

a surface area is reduced by 25 per cent (but all other variables remain the same)

b concentration difference is increased by 30 per cent (but all other variables remain the same)

c alveolus wall thickness is halved (but all other variables remain the same).

8 A cell is roughly a cuboid with sides 20 µm × 25 µm × 30 µm. Carbon dioxide molecules diffuse out of the cell at a rate of 150 molecules per second.

a Calculate an estimate for the surface area of the cell.

b The height of the cell changes from 30 µm to 40 µm. What will the new rate of diffusion be?

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EASIER

1 Complete each of the following sentences by putting a tick (✓) next to the correct ending.

a A concentration is:

- ☐ the amount of a substance in a certain volume of a mixture.
- ☐ the volume that a certain substance takes up.
- ☐ the maximum amount of a substance that will dissolve in a solvent.
- ☐ another term for density.

b Common units for concentration include:

- ☐ cm/g^3
- ☐ cm^3/g
- ☐ g/cm^3
- ☐ g^3/cm

c 1 cubic decimetre is the same volume as:

- ☐ 1 cm^3
- ☐ 10 cm^3
- ☐ 100 cm^3
- ☐ 1000 cm^3

2 **Fick's law** shows how various factors affect the rate of diffusion.

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{concentration difference}}{\text{thickness of membrane}}$$

If one variable is proportional ($\propto$) to another, then when one variable increases by a given scale factor so does the other. For example if one variable is multiplied by 4, so is the other variable.

Fick's law says that the rate of diffusion $\propto$ surface area.

So, if we double the surface area, we double the rate of diffusion. What happens to the rate of diffusion if:

a the surface area is tripled _____

b the surface area is halved _____

c the concentration difference is halved _____

d the concentration difference is doubled? _____

HARDER

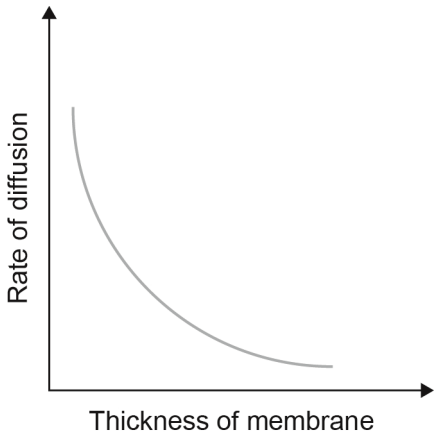
3 The graph shows the relationship between the rate of diffusion and the thickness of the cell membrane.

a Does the rate of diffusion increase, decrease or stay the same as the thickness of the membrane increases?

_____

b Circle the two words from the list below that, when used together, describe this relationship.

directly	proportional
inversely	unproportional



4 In the sentences below, <u>underline</u> the correct word in each *pair*.

a When surface area increases, the rate of diffusion *increases* | *decreases.*

b When the thickness of the membrane increases, the rate of diffusion *increases* | *decreases.*

c When the concentration difference decreases, the rate of diffusion *increases* | *decreases.*

S1 Draw a table to show how different variables affect diffusion.

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1 Complete the sentences using words from the box. You may use each word once, more than once or not at all.

concentration	down	**gradient**	greater	higher	lower	$m/\mu g^3$
$m^3/\mu g$	mass	smaller	volume	$\mu g/m^3$	$\mu g^3/m$	up

The _____ of a substance is the amount of that substance in a unit volume of a mixture. If there is 200 µg of nitrogen dioxide in each cubic metre of air, its _____ is 200 _____.

Diffusion is the overall movement of particles from where they are in _____ concentration to where they are in _____ concentration. The difference between the two concentrations is called the concentration _____. There is an overall flow of particles _____ a concentration gradient. The _____ the concentration gradient, the _____ the rate of diffusion.

2 The table shows the concentrations of some molecules between different pairs of places.

a For each pair, calculate the concentration gradient.

b Put numbers in the last column to show the order of the rates of diffusion, where 1 is the fastest rate and 4 is the slowest rate.

Concentration at place X (molecules/µm^3)	Concentration at place Y (molecules/µm^3)	Concentration gradient	Order of rate of diffusion
5000	4500		
4555	4445		
3000	1950		
3500	2005		

3 **Fick's law** shows how various factors affect the rate of diffusion across a cell membrane.

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{concentration difference}}{\text{thickness of membrane}}$$

State the relationship between the rate of diffusion and:

a surface area _____

b the thickness of the membrane. _____

4 The rate of diffusion of oxygen molecules across a 10 cm^2 piece of artificial membrane is 0.8 µg/s. Calculate the rate of diffusion if:

a the surface area is doubled _____

b the concentration difference is tripled _____

c the thickness of the membrane is halved _____

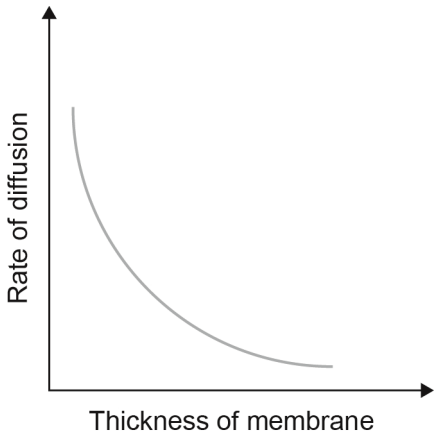
d the concentration difference is increased by 40% _____

e the thickness of the membrane is increased by 70% _____

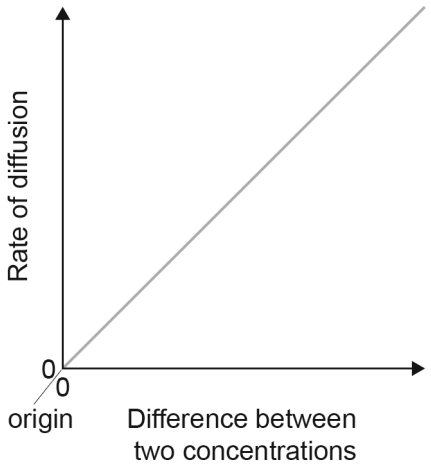
f the surface area is changed to 17 cm^2. _____

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1 Look at the two graphs below.



Graph P



Graph Q

a Describe the type of relationship shown by the line on each graph.

b State three factors that affect the rate of diffusion of a substance into a cell deep inside the human body.

c For each of your three factors state which graph it should be plotted on (P or Q).

2 For each of the following give the final **concentration** of the solution formed in g/cm^3.

a 25 g of sucrose dissolved in 100 cm^3 of water

b 2 g of salt dissolved in 200 cm^3 of water

c 75 ml of water containing 24 g of dissolved calcium chloride

d 0.04 kg of ammonium chloride dissolved in 160 cm^3 of water

3 For each of the following give the final concentration of the solution formed in g dm^{-3}.

a 2 g of fructose dissolved in 160 cm^3 of water

b 2.5 litres of water containing 0.05 kg of sodium chloride

c 80 cm^3 of water containing 2 mg of dissolved urea

d 2×10^{-2} g of sodium hydroxide dissolved in 2.2×10^{-4} m^3 of water

4 **Fick's law** is shown below.

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{concentration difference}}{\text{thickness of membrane}}$$

The rate of diffusion of oxygen from a section of a lung alveolus into the blood is 0.004 μg/s.

a Use Fick's law to calculate the rate of diffusion if each of the following changes occur. For each one, assume that no other variables change.

i The surface area is tripled.

ii The thickness of the membranes is cut by 50%.

iii The concentration difference is doubled and the surface area is cut by 30%.

iv The surface area is increased by 60%, the concentration difference is reduced to a half and the thickness of the membrane is doubled.

b Explain what will happen to the rate of diffusion in this section of alveolus when the person starts to exercise.

Extra challenge

5 Compare and contrast the terms 'density' and 'concentration'.

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Progression questions

Answer these questions.

1 How do surface area and concentration affect the rate of diffusion?

_____

_____

2 What is the relationship between the rate of diffusion and diffusion distance?

_____

_____

3 What is Fick's law?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

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SB8c.1 Examining human blood

Your teacher may watch to see if you can:

- remember how to use a microscope
- work carefully.

Aim

To examine some different types of cells found in human **blood**.

Method

- microscope
- transparent ruler
- slide of human blood

⚠ Safety

- Take care with glass microscope slides.

A Set up your microscope on its lowest magnification and place a transparent ruler under the clips so that the millimetre scale is over the hole in the stage.

B Focus your microscope so that you can see the millimetre scale. Position the scale so that it is across the full diameter of the field of view. Count the number of millimetre markings you can see across the field of view. This gives you the width of the field of view in millimetres.

C Still using the lowest power lens, examine the blood and see what you can identify. You should see many **red blood cells** (**erythrocytes**) and a few **white blood cells**. Estimate how many red blood cells you can see.

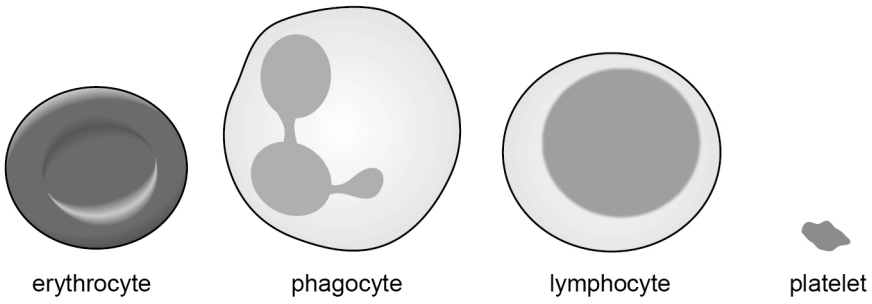
D Use your measurement of the width of the field of view to estimate the size of one red blood cell.

E Using the next power lens, look in more detail at some red blood cells. Draw what you see.

F Return to the lower power lens and try to identify white blood cells. Estimate how many white blood cells you can see.

G Now using the higher power lens again, focus on one white blood cell. Draw what you see.

H Try to identify the white blood cell that you have drawn. There are many different types. **Phagocytes** often have a nucleus with different lobes on it. They have a lot of cytoplasm, in which you may be able to see many small specks. **Lymphocytes** have very large, rounded nuclei and little cytoplasm.



Components of blood

Recording your results

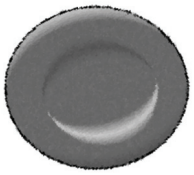
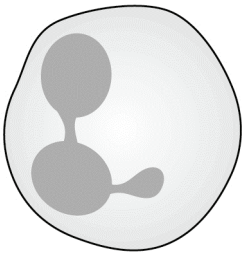
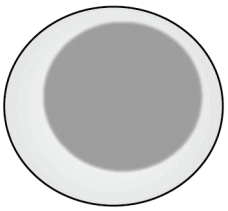
1 Make labelled drawings of the cells that you observe.

2 Compare the number of red blood cells with the number of white blood cells. Present your answer as a ratio of red to white.

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1 Cut out the cards and match each diagram with its name and two facts. Stick the cards down in order to create a table. *Remember:* **Phagocytes** often have a nucleus with different lobes on it. **Lymphocytes** have very large, rounded nuclei and little cytoplasm.

2 Find out one other fact about four of the components. Write these facts on the blank cards. Give them to a partner to add to their table.

			
	makes antibodies	contains **haemoglobin**	cell fragment
a straw-coloured liquid	surrounds and destroys foreign cells	type of **white blood cell** that destroys foreign cells	type of white blood cell that destroys foreign cells
erythrocyte	**platelet**	**plasma**	helps **blood** to clot
transports oxygen	transports dissolved substances (e.g. glucose)	lymphocyte	phagocyte

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Name _____ **Class** _____ **Date** _____

EASIER

1 Tick (✓) the appropriate boxes to show whether each statement applies to **veins**, **arteries** or both.

Statement	Veins	Arteries
a form part of the human circulatory system		
b have a thin, flexible wall		
c carry **blood** away from the **heart**		
d usually carry blood that contains more oxygen		
e have **valves** in them		
f have a narrow central tube		

S1 Draw a table to contrast arteries and veins. Include their structures and the substances in the blood inside them.

2 Tick (✓) the correct response to complete each statement.

a **Red blood cells** are also called:

☐ platelecytes ☐ erythrocytes ☐ leucocytes ☐ haemocytes

b The cells that produce **antibodies** are called:

☐ lymphocytes ☐ erythrocytes ☐ antigens ☐ phagocytes

c **Platelets** are used to help:

☐ make antigens ☐ make antibodies ☐ make plasma ☐ blood to clot

d There are about 5 000 000 000 red blood cells in each cubic centimetre of blood, or:

☐ 50×10^{10} cells/cm^3 ☐ 5×10^{9} cells/cm^3 ☐ 5×10^{-9} cells/cm^3 ☐ 0.5×10^{9} cells/cm^3

e Glucose is carried by the blood in:

☐ white blood cells ☐ mitochondria ☐ plasma ☐ enzymes

HARDER

3 How are red blood cells adapted so that they can carry more **haemoglobin**? _____

_____

4 **a** What type of blood vessel links arteries to veins? _____

b How are these blood vessels adapted to allow fast diffusion of substances into and out of them?

_____

5 The heart pumps blood through arteries. However, blood often has to be helped to flow through veins. Describe how this help is provided.

_____

_____

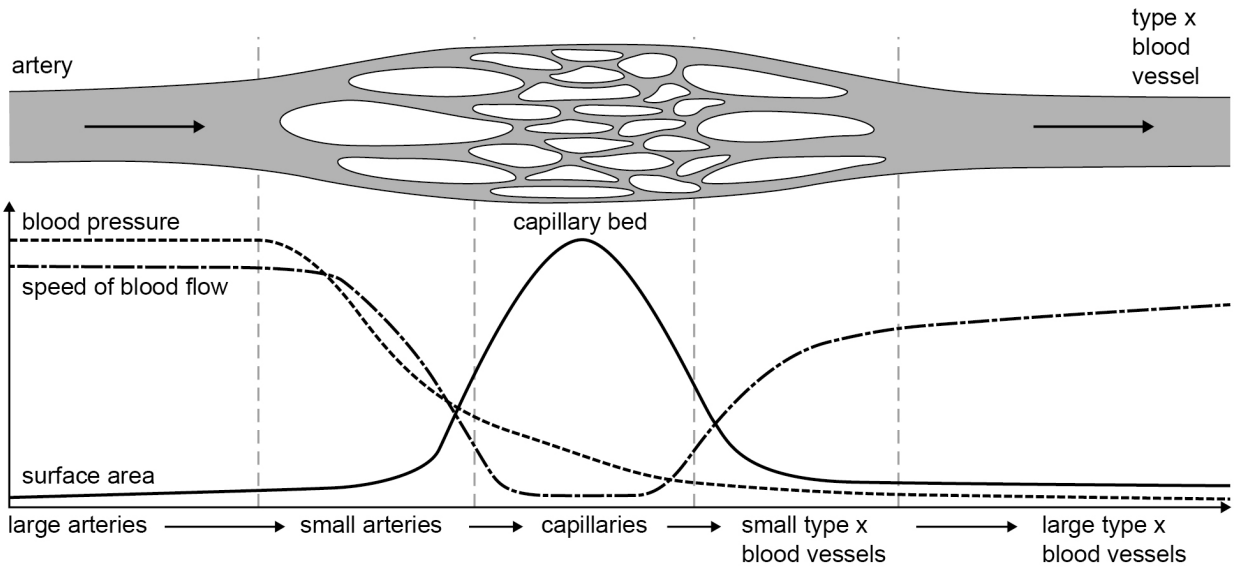
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Name _____ **Class** _____ **Date** _____

1 Draw lines to link each component of **blood** with a description and function.

Component	Description	Function
lymphocyte	straw-coloured liquid	to digest foreign cells
platelet	**white blood cell**	to transport dissolved substances
phagocyte	cell fragment	to produce antibodies
plasma	white blood cell	to help blood clotting

2 The graph shows how some factors change as blood flows into and out of a **capillary** bed.



a Give the correct name of a 'type x blood vessel'. _____

b In which blood vessels is the speed of blood flow highest? _____

c Which blood vessels give the greatest surface area for the blood? _____

d Explain the need for this large surface area. _____

_____

e Complete the sentences using words from the box to explain how **arteries** are adapted to their function.

contract	**heart**	high	low	muscle	smoothly	stretch	thick	thin

Artery walls are _____ to withstand the _____ pressure of the blood squirted into them from the _____. As the heart pushes out blood, the walls of the arteries _____. The elastic fibres and _____ fibres make the artery walls _____ back to their original size between each _____ beat, and this helps to make the blood flow _____.

f Explain the speed of blood flow in type x blood vessels, even though the blood pressure is low.

_____

_____

3 Give one reason for each of the following adaptations of **red blood cells**.

a They have no nucleus. _____

b They have a hollow on each side. _____

_____

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1 Two different types of **white blood cell** are **phagocytes** and **lymphocytes**. Describe how each type of cell helps to destroy foreign cells in the body.

2 Give one reason for each of the following adaptations of **erythrocytes**.

a They are shaped like biconcave discs, with a hollow on each side.

b Unlike most cells, they do not have a nucleus.

c They are very small and flexible.

3 In a sample of 1 mm^3 of **blood**, there were about 4 900 000 erythrocytes, 5000 white blood cells and 250 000 **platelets**.

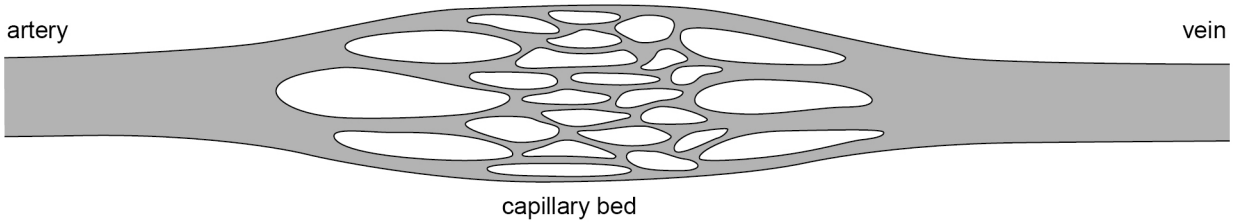
a Write the number of erythrocytes per mm^3 of blood in standard form.

b Write the number of white blood cells per mm^3 of blood in standard form.

c Two quantities differ by one order of magnitude if one is 10 times bigger than the other. By approximately how many orders of magnitude do the numbers of **red blood cells** and white blood cells differ?

d 70% of white blood cells are phagocytes. How many cells is this per mm^3 of blood?

4 In body tissues, blood flows through a network of fine **capillaries** (a capillary bed).



a In which direction is blood flowing in the diagram above?

b What happens to the surface area : volume (SA : V) ratio of the blood as it moves into a capillary bed?

c State why this change in SA : V ratio is useful.

d What other adaptation do capillaries have to ensure efficient exchange of substances?

5 An experiment was done to find out which of two types of blood vessel is the more elastic (stretchy). In the experiment, ring-shaped sections were cut from an **artery** and from a **vein**. The rings were suspended on a clamp stand and had 10 g masses hung from them to make them straight. The length of each was measured and recorded as 'original length'. An additional 100 g was then hung on each section of blood vessel and the lengths were recorded as 'new length'. The results are shown in the table.

Blood vessel	Original length (mm)	New length (mm)
A	35	38
B	38	45

a Calculate the percentage change in length for blood vessels A and B.

b Explain which blood vessel is an artery.

c Explain why arteries have this adaptation.

Extra challenge

6 People can faint when their brains do not get enough oxygen. Soldiers who have to stand still for long periods of time often faint. Explain this observation.

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Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 What are the components of the circulatory system?

_____

_____

2 How are blood vessels adapted to their functions?

_____

_____

3 How is blood adapted to its function?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

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SB8d.1 Fitness and cardiac output

Name _____ **Class** _____ **Date** _____

Your teacher may watch to see if you can:
- work together.

Aims



To investigate the short-term effects of exercise on heart and breathing rates, and to calculate **cardiac outputs**.

Method

- stop clock
- exercise block (optional)
- pulse sensor and finger probe (optional)
- breathing sensor and chest strap (optional)
- 1 kg mass (optional)
- datalogger (optional)

⚠ Safety

- Listen carefully to any safety instructions given to you about the exercise you will be doing.

A Sit still and measure your resting pulse rate (in beats per minute) and resting breathing rate (in breaths per minute). One breath is when you breathe in and out again. You could measure the rates by counting or by using a datalogger. Write down these rates.

B Choose an exercise to do for two minutes. Your teacher may give you some ideas, such as running on the spot, lifting and lowering a 1 kg mass continuously for two minutes, or stepping up and down from an exercise block while holding 1 kg of mass.

C As soon as you have finished your exercise, measure your breathing rate for 15 seconds while your partner measures your pulse rate. Multiply each reading by 4 to get your results in beats or breaths per minute.

D Continue measuring your pulse and breathing rates every minute until they are the same as they were before you did the exercise. Remember to record all your results.

Recording your results

1 Record your results below.

Resting pulse rate = _____ beats per minute

Resting breathing rate = _____ breaths per minute

Time after finishing exercise (min)	Pulse rate (beats per minute)	Breathing rate (breaths per minute)
1		
2		
3		
4		
5		

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Considering your results/conclusions

2 **a** What happens to your **heart rate** and breathing rate when you exercise? _____

b Explain why this happens. _____

_____

_____

3 One indicator of fitness is how quickly the heart rate falls back to its resting value. In the first minute after exercise, it should drop by about 20 beats per minute for someone of average fitness.

a Plot a line graph for your pulse rate and for your breathing rate.

b How many minutes did it take for your heart rate to return to its resting value? _____

c How many minutes did it take for your breathing rate to return to its resting value? _____

d What do your results suggest about your fitness? _____

_____

4 The volume of blood that your heart pumps out in one minute is known as your cardiac output. This is an important measure in medicine because the cardiac output goes up when some problems occur (e.g. infection) and down when other problems occur (e.g. heart disease). Doctors estimate someone's cardiac output using the surface area of a person's body.

To estimate your surface area you can use the following equation. You will need to know your mass and height. Be careful with the units.

$$\text{body surface area } (\text{m}^2) = \sqrt{\left(\frac{\text{your height (cm)} \times \text{your mass (kg)}}{3600}\right)}$$

a What is your estimated body surface area? _____

The cardiac index is how much blood a heart pumps for every square metre of surface area. It varies with age. For teenagers the cardiac index is about 3 l/m^2/min (when resting).

Multiply your body surface area by the cardiac index (3 l/m^2/min) to find out how many litres of blood your heart pumps in one minute. This is your cardiac output.

cardiac output (l/min) = cardiac index (l/m^2/min) × body surface area (m^2)

b What is your estimated cardiac output? _____

Your cardiac output is related to your heart rate and **stroke volume** by the equation below. Your stroke volume is the volume of blood your heart pumps out into the **aorta** with each beat.

cardiac output (l/min) = stroke volume (litres) × heart rate (beats/min)

c What is your estimated stroke volume in litres? _____

d What is your estimated stroke volume in cm^3? _____

5 **a** From which part of the heart does the blood that is pumped into the aorta come from? _____

b Suggest an explanation for why stroke volume increases during exercise. _____

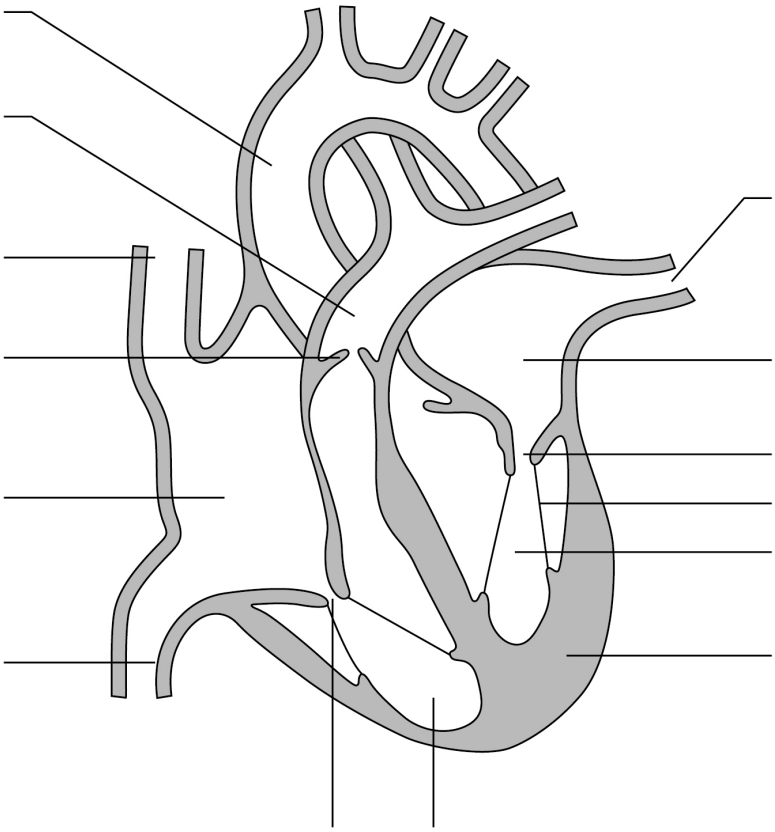
c Use the equation to explain how cardiac output will be affected by exercise.

_____

_____

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Name _____ **Class** _____ **Date** _____



1 Use a brown colour to lightly shade in the blood vessels and **chambers** of the heart that transport **deoxygenated blood**.

2 Use a bright red colour to lightly shade in the blood vessels and chambers of the heart that transport **oxygenated blood**.

3 Draw arrows in the chambers of the heart and blood vessels to show the direction of blood flow.

4 Write in labels to identify the main structures of the heart.

5 **a** The walls of the heart are mainly made out of muscle tissue. How does muscle tissue allow the heart to do its job?

_____

b Cardiac arteries supply the heart muscle with blood. What happens when blood stops flowing in one or more of these arteries? _____

c Explain why the thickness of the muscle tissue is not the same in all parts of the heart.

_____

_____

6 **a** State what **heart valves** do. _____

b Describe how heart valves work. _____

_____

c What structures hold the flaps of the heart valves in position? _____

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Name _____ **Class** _____ **Date** _____

EASIER

1 The statements describe ideas that different scientists have had about the heart in the last 2000 years. Tick (✓) *two* statements that we still think are true today.

- ☐ It produces heat for the body.
- ☐ It pumps blood.
- ☐ It has two **chambers**.
- ☐ Valves make sure that blood only flows in one direction.
- ☐ Air enters the heart from the lungs.
- ☐ It allows a person to feel things.
- ☐ It controls the other organs of the body.
- ☐ The **septum** between the right and left sides has holes in it.

2 **a** The heart is mainly made of a certain type of tissue that lets it do its job. Name this tissue.

_____

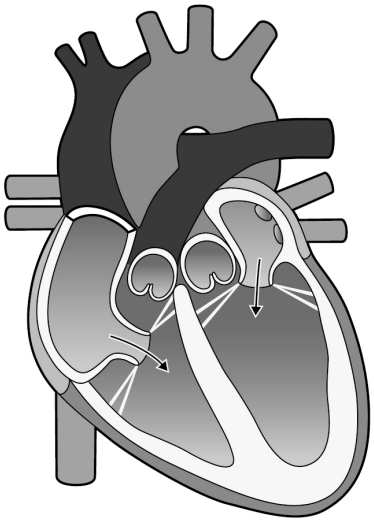
b The left side of the heart has thicker walls of this tissue because it has to work harder. Why does it have to work harder?

_____

_____

S1 Explain two ways in which the heart is adapted to its function.

3 The diagram on the right shows blood flowing from the **atria** of the heart into the **ventricles**.



a Add two arrows to the diagram to show how blood leaves the ventricles.

b What has to happen to the tissue in the walls of the ventricles for the blood to leave the ventricles?

_____

c Blood from the right side of your heart enters the lungs through the **pulmonary artery**. Label the pulmonary artery on the diagram.

d Label the septum on the diagram.

HARDER

4 Martha feels the pulse in her wrist and counts 20 beats in 15 seconds.

a A pulse is caused by a wave that flows through the wall of which type of blood vessel? _____

b What is Martha's pulse rate in beats per minute? _____

c The volume of blood that flows into the **aorta** with each heart beat is the **stroke volume**. Martha's stroke volume is 50 cm^3. The **cardiac output** is the amount of blood that flows into the aorta each minute. Calculate Martha's cardiac output in cm^3/min. Show your working.

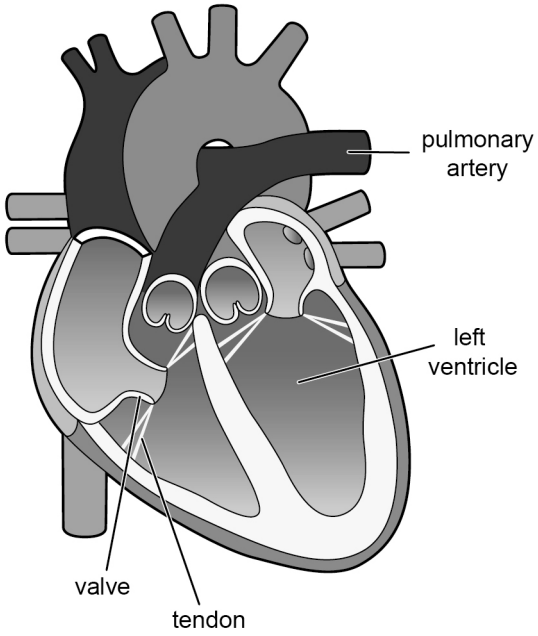
Martha's cardiac output is _____ cm^3/min.

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Name _____ **Class** _____ **Date** _____

1 Blood flows from the **vena cava** through the right side of the heart and then through the **pulmonary artery** to the lungs. It then flows back to the heart before being pumped around the body. Number the vessels and heart **chambers** in the order that blood flows through them.

___ **aorta**
___ left **atrium**
___ left **ventricle**
___ lungs
___ pulmonary artery
___ **pulmonary vein**
___ right atrium
___ right ventricle
___ vena cava



2 **a** The muscle tissue in the heart does not get tired. Why is this an important adaptation?

_____

_____

b The muscle tissue needs oxygen. Name one other substance this tissue needs. _____

c Describe how oxygen is transported from the lungs and heart to a muscle cell. _____

_____

_____

d Explain why the muscle tissue in the wall of the left ventricle is thicker than in the right ventricle.

_____

_____

3 **a** State the function of the **heart valves**. _____

b Explain why someone might feel short of breath if one of the heart **tendons** breaks. _____

_____

_____

4 Look at the following equation.

cardiac output (litres/min) = **stroke volume** × **heart rate** (beats/min)

a What does stroke volume measure? _____

_____

b Suggest suitable units for stroke volume in the equation above. _____

c Complete the missing values in the table below.

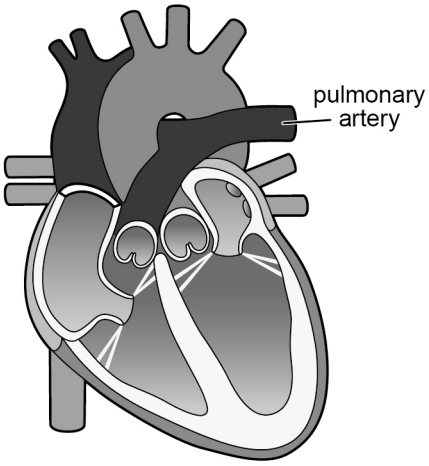
Heartbeats in 15 seconds	Heart rate (beats/minute)	Stroke volume	Cardiac output (litres/min)
15	60	0.06	
	80	0.05	
25			4.0

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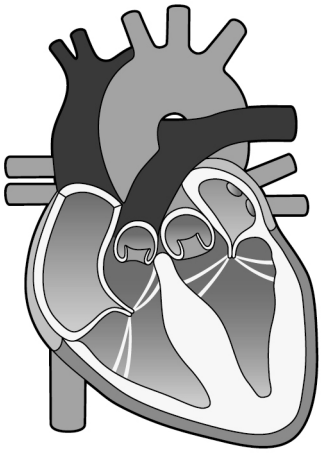
You do not need to remember the details of blood pressure for your exam but you may be asked to apply knowledge of the heart and circulatory system to new contexts.

Blood pressure is the pressure of your blood pushing against the walls of your larger arteries. It is still measured in old units for pressure called millimetres of mercury (or mmHg for short). A blood pressure reading contains two numbers, usually written as, for example, 120/70 and said as '120 over 70'.

The higher measurement is the pressure in the arteries when the **ventricles contract** (a process called systole – pronounced '***sis***-*tol*-*ee*') and push blood out of the heart. The lower measurement is the pressure in the arteries when the ventricles relax (diastole – pronounced '*dy*-***ass***-*tol*-*ee*') and the heart refills with blood again.



Diastole – blood flows into the upper heart chambers, which then contract, pushing blood into the lower chambers.



Systole – the lower chambers contract, pushing blood out of the heart.

1 Describe the route that blood takes inside the heart and in the blood vessels connected to it during:

a diastole **b** systole.

Include the proper names of the parts in your answers.

2 **a** The two measurements in a blood pressure reading are called systolic pressure and diastolic pressure. Which of these is the higher measurement?

b Why is the reading in your answer to part **a** higher than the other of the two measurements?

3 **a** The **heart valves** consist of flaps of tissue. Explain the importance of heart valves during systole.

b Describe how the position of the valve flaps is maintained.

4 The thickness of the walls of the two ventricles is not the same. Explain this observation.

5 The heart is affected by a person going into space. The table shows data collected from an astronaut before and immediately after a nine-day mission in space.

	Heart rate (beats/min)	Stroke volume (litres)
Before the mission	45	0.083
After the mission	60	0.065

a What is the **stroke volume** a measure of?

b Explain what the data suggest about changes to the size of the heart during space travel.

c Use the following equation to calculate the astronaut's **cardiac output** before and after the mission.

cardiac output = stroke volume × heart rate

d Some days after the mission, the astronaut's heart rate is still 60, but his cardiac output is now the same as it was before the mission. Calculate his stroke volume.

Extra challenge

6 In some people, fatty deposits build up inside the arteries, making them narrower. Explain why this will cause an increase in blood pressure.

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Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 What is the structure of the heart like?

_____

_____

2 How does the heart pump blood?

_____

_____

3 How do you calculate cardiac output?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	1	2	3
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	1	2	3
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

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Your teacher may watch to see if you can…

- work carefully with living organisms
- make accurate measurements.

Aim

To investigate the effect of temperature on the rate of **aerobic respiration** in invertebrates.

Method

Apparatus

- boiling tube containing soda lime (and a cotton wool plug)
- capillary tube and bung
- weighing boat
- stop clock
- water baths at different temperatures
- millimetre scale
- small organisms
- coloured liquid

⚠ Safety

Treat living things with care.

Wash your hands after the practical.

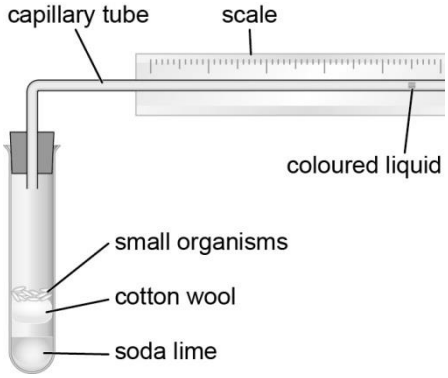
Soda lime is corrosive.

A Collect a boiling tube with some soda lime in it, held in place with cotton wool. The soda lime absorbs carbon dioxide. Soda lime is corrosive, so do not handle it. The cotton wool is to protect you and the organisms.

B Carefully collect some of the small organisms in a weighing boat.

C Gently shake the organisms out of the container and into the boiling tube.

D Insert the bung and capillary tube, as shown in the diagram.



E Set up a control tube (without the organisms).

F Place both tubes into a rack in a water bath at a preset temperature. It is best to tilt the rack slightly so that the capillary tubes hang over the side of the water bath at an angle.

G Wait for five minutes to let the organisms adjust to the temperature of the water bath (maximum 40 °C).

H Hold a beaker of coloured liquid to the ends of the capillary tubes, so that liquid enters.

I Mark the position of the coloured liquid in the tubes and time for five minutes.

J Mark the position of the coloured liquid again, and measure the distance travelled.

K Repeat the experiment at different temperatures. Use the same number of organisms each time.

Recording your results

1 Record your results in a neat table.

Considering your results/conclusions

2 Plot your results on a suitable chart or graph.

3 Use your chart or graph to draw a conclusion. Explain your conclusion.

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Name _____ **Class** _____ **Date** _____

Recording your results

1 Record your results in the table below.

Temperature (°C)	Distance moved by the coloured liquid in the tube containing organisms (mm)	Distance moved by the coloured liquid in the control tube (mm)

Considering your results/conclusions

2 Plot your results on a scatter diagram.

3 **a** What was the independent variable in this investigation? _____

b What was the dependent variable? _____

c State one control variable described in the method. _____

d Explain why the variable you gave in **c** needs to be controlled.

_____

_____

e Describe the relationship between the temperature and rate of aerobic respiration.

_____

_____

f Suggest an explanation for this relationship. (*Hint:* think about the effect of temperature on chemical reactions.)

_____

_____

_____

Evaluation

4 The organisms in the tube are respiring aerobically.

a What gas are they using up? _____

b What gas are they producing? _____

c Explain why the gas you named in **b** does not collect in the tube. _____

_____

_____

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Your teacher may watch to see if you can:

- work carefully.

Aims

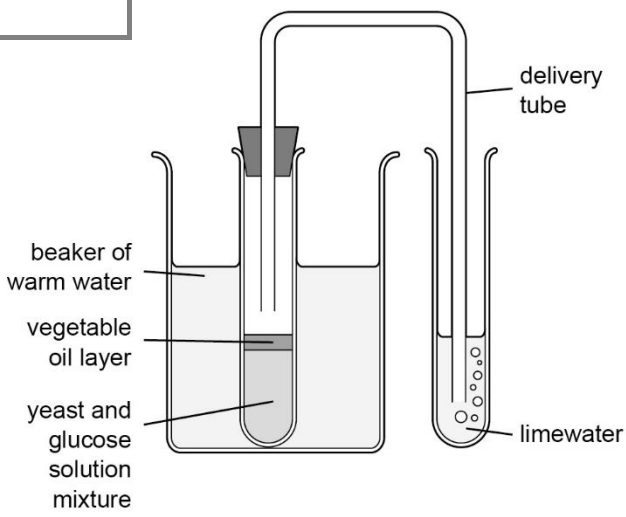
To investigate the effect of **glucose** concentration on the rate of **anaerobic respiration** in yeast.

Method

- boiling tubes
- labels
- syringes
- large beaker
- clamp and stand
- delivery tube and bung
- stop clock
- different glucose solutions
- limewater
- yeast culture
- vegetable oil
- warm water

⚠ Safety

- Wear eye protection.
- Wash your hands after completing the practical.



A Choose glucose concentrations to test, and label one boiling tube with each concentration.

B Use a syringe to add 10 cm^3 of each glucose concentration to the correct *labelled* tubes.

C Use another syringe to add 20 cm^3 of limewater to an equal number of *unlabelled* tubes.

D Use another syringe to add 10 cm^3 of yeast culture to each *labelled* tube. Gently swirl the mixture.

E Pour a thin layer of oil onto the mixture.

F Place the tube containing the yeast into a large beaker and clamp it in place.

G Add warm water to the large beaker, so that the yeast mixture in the tube is surrounded by water.

H Insert the bung into the tube and then put the end of the delivery tube into a boiling tube of limewater, as shown in the diagram.

I Immediately start timing. Note down the time at which the limewater goes cloudy.

Recording your results

1 a Record your results in a neat table. You may include the results of other groups.

b Calculate mean times for any repeat measurements and add these to your table.

Considering your results/conclusions

2 a What gas is produced by the yeast?

b How can you tell from the experiment that this is the gas released?

c Write out the word equation for anaerobic respiration in yeast.

d Explain the function of the layer of vegetable oil.

3 a Describe the correlation between the glucose concentration and the rate of anaerobic respiration.

b Suggest an explanation for this correlation.

Evaluation

4 This investigation has no control. Suggest a suitable control and explain its purpose.

5 a Identify the source of the greatest random error in making measurements in this investigation.

b Suggest a way of reducing this error.

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Name _____ **Class** _____ **Date** _____

EASIER

1 In the box below:

a Underline the reactant(s) in **aerobic respiration** in humans.

b Circle the product(s) of aerobic respiration in humans.

c Draw a rectangle around the product(s) of **anaerobic respiration** in humans.

carbon	carbon dioxide	carbon monoxide	ethanol
glucose	**lactic acid**	oxygen	water

2 The products of anaerobic respiration contain more energy than the products of aerobic respiration. What does this tell you about the two types of respiration? Tick (✓) one.

☐ Anaerobic respiration releases more energy than aerobic respiration.

☐ Aerobic respiration releases more energy than anaerobic respiration.

☐ Anaerobic and aerobic respiration use different reactants.

☐ It is better for the body to use anaerobic respiration rather than aerobic respiration.

3 Unmuddle the anagrams to answer the following questions.

a In which structures does aerobic respiration occur in a human cell? HOMINID ACTOR

_____

b Where does anaerobic respiration occur in a human cell? CALM TYPOS

_____

c What word describes processes that transfer energy to the surroundings? CHROME EXIT

_____

S1 Design a table to compare and contrast aerobic and anaerobic respiration.

HARDER

4 **a** Tick (✓) the *two* sentences that are correct from the following list.

☐ Aerobic respiration stops when anaerobic respiration is occurring.

☐ The rate of anaerobic respiration increases greatly during hard exercise.

☐ Anaerobic respiration only occurs when someone is resting.

☐ The rate of aerobic respiration decreases greatly during hard exercise.

☐ Anaerobic respiration and aerobic respiration occur all the time.

b Combine the two sentences to write out one longer sentence.

_____

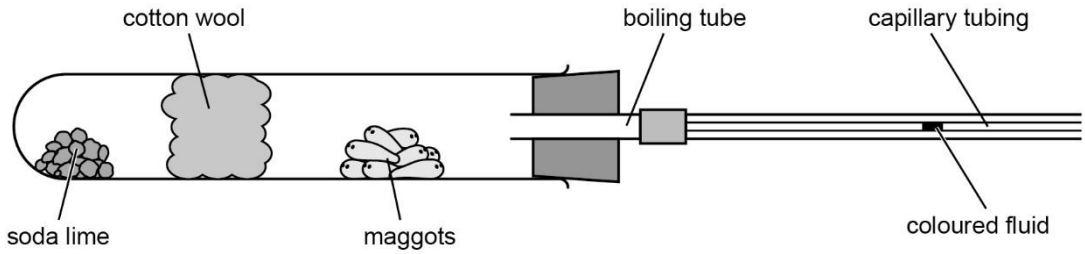
_____

_____

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Name _____ **Class** _____ **Date** _____

1 A respirometer is used to measure the rate of respiration. A simple respirometer is shown below.



In a respirometer, changes in the volume of gases in the boiling tube cause the coloured fluid to move in the capillary tubing. The soda lime absorbs carbon dioxide.

A student sets up the respirometer using 5 g of maggots. After a few minutes, she records the start position of the coloured fluid. The student then measures the position of the coloured fluid five minutes later.

a Complete the word equation for **aerobic respiration**.

_____ + oxygen → carbon dioxide + _____

b Why do the maggots need to respire? _____

_____

c In which parts of maggot cells does aerobic respiration occur? _____

d Explain the function of the soda lime. _____

_____

e The coloured fluid moves 30 mm towards the boiling tube during the five minutes. What change causes this to happen? _____

_____

f Suggest why it is important that respirometers stay at a constant temperature during repeat experiments.

_____

_____

2 **a** Write the word equation for **anaerobic respiration**.

b Compare the amount of energy released by aerobic and anaerobic respiration.

_____

c Explain why anaerobic respiration is important for animals. _____

_____

_____

3 Complete the following sentences about respiration, using words from the box. You may use each word once, more than once or not at all.

decrease	endothermic	**exothermic**	increase	pressure	reactants	temperature	transferred

In all types of respiration, energy is _____ from the _____ to the surroundings. All types of respiration are _____. The energy transfer causes an _____ in the _____ of the surroundings.

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1 **a** Why do organisms respire?

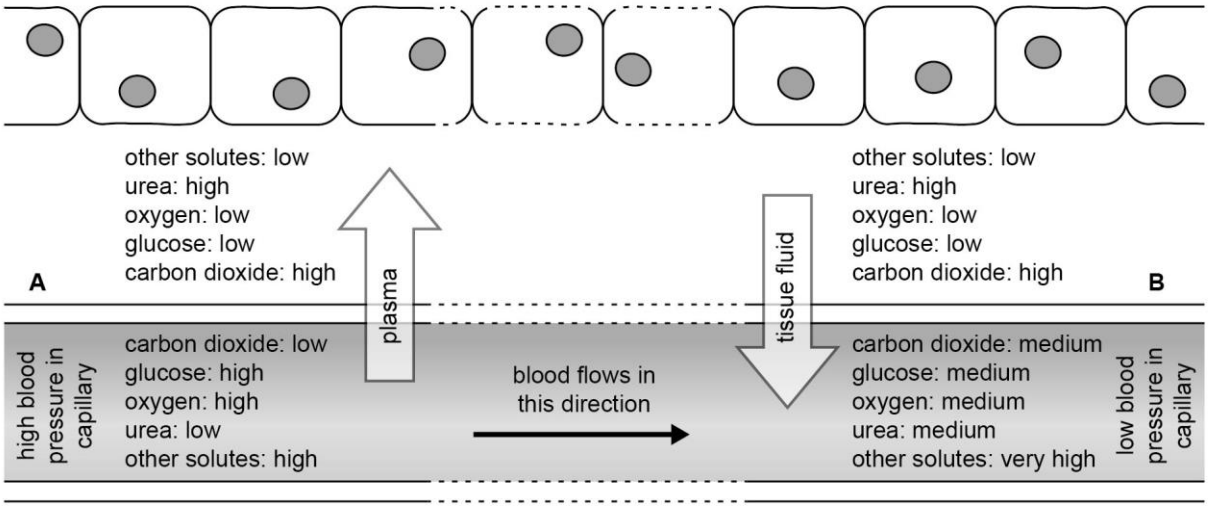
b Write the word equation for **aerobic respiration**.

c State the differences in products and reactants between aerobic respiration and **anaerobic respiration** in humans.

d Compare the amount of energy released by aerobic and anaerobic respiration.

e Explain why anaerobic respiration is important for animals.

2 The diagram shows a capillary in a capillary bed inside the liver. Blood enters from the left. Plasma that leaks out of the capillaries is called tissue fluid.



a Why is the concentration of carbon dioxide higher near the cells than inside the capillary?

b Why is the concentration of **glucose** lower near the cells than inside the capillary?

c At point A, in which direction would you expect the net movement of oxygen molecules to be: into or out of the capillary? Explain your answer.

d Why does the amount of urea in the capillary increase from one end to the other?

e At point A, in which direction would you expect the net movement of water molecules to be: into or out of the capillary? Explain your answer.

f Why does plasma move out of the capillary at point A?

g How does this help to supply the cells with oxygen and glucose?

h During exercise, the body reduces the flow of blood through the capillaries in the liver and increases it through the capillaries in the muscles. Suggest an explanation for why the body makes these changes.

A student uses bean seeds to investigate the process of respiration in plants. He soaks the seeds for 12 hours, then boils 10 g of the seeds to kill them, allows them to cool and washes them in dilute bleach. He then places them in an insulated flask, labelled A. A second batch of 10 g (unboiled) seeds is washed in dilute bleach then placed in an identical flask, labelled B. He places thermometers in both flasks and records the temperature over the next five hours. The table shows his results.

Time (hours)	0	1	2	3	4	5
Temp. in A (°C)	20	19	20	20	21	20
Temp. in B (°C)	20	21	23	24	24	25

3 There is an increase in temperature in B but not in A. Explain this observation fully, using the term **exothermic** in your answer.

Extra challenge

4 Suggest how and why the results might be different if the seeds were not washed in dilute bleach.

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Name _____ **Class** _____ **Date** _____

Progression questions

Answer these questions.

1 Why do organisms need to respire?

_____

_____

2 Why is respiration an exothermic process?

_____

_____

3 What are the differences between aerobic and anaerobic respiration?

_____

_____

Now circle the faces in the 'Start' row in the table showing how confident you are of your answers.

Question	**1**	**2**	**3**
Start			

Assessment

Using a different colour, correct or add to your answers above. You may need to use the back of this sheet or another piece of paper. Then circle the faces in the 'Check' row in the table.

Question	**1**	**2**	**3**
Check			

Feedback

What will you do next? Tick one box.

☐ strengthen my learning ☐ strengthen then extend ☐ extend

Note down any specific areas you need to improve.

_____

Action

You may now be given another activity. After this, note down any remaining areas you need to improve and how you will try to improve in these areas.

_____

_____

_____

_____

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SB8a Efficient transport and exchange

Word	Pronunciation	Meaning
aerobic respiration	*air-**O**-bick res-pir-**ay**-shun*	A type of respiration in which oxygen is used to release energy from substances such as glucose.
alveolus	*al-vee-**O**-lus*	A small pocket in the lungs in which gases are exchanged between the air and the blood. (Plural is alveoli.)
capillary		A tiny blood vessel with thin walls to allow for the transfer of substances between the blood and tissues.
circulatory system		The system that moves blood through the body. It consists of the heart, arteries, veins and capillaries.
diffusion	*diff-**yoo**-zshun*	The random movement and spreading of particles. There is a net (overall) diffusion of particles from a region of higher concentration to a region of lower concentration.
excretion	*ex-**kree**-shun*	The removal of waste materials that have been produced inside an organism.
gas exchange		A process in which one gas diffuses across a membrane and another gas diffuses in the opposite direction.
metabolism		All the chemical reactions that occur in an organism.
multicellular organism		An organism that is made up of many cells.
surface area : volume (SA : V) ratio		The total amount of surface area of an object divided by its volume. The bigger the ratio, the more surface area something has per unit volume.
urea	*yoo-**ree**-a*	A waste product made in the liver from excess amino acids.

SB8b Factors affecting diffusion

Word	Pronunciation	Meaning
concentration	*con-sen-**tray**-shun*	The amount of solute dissolved in a certain amount of solution.
concentration gradient	*con-sen-**tray**-shun **gray**-dee-ent*	The difference between two concentrations. There will be an overall movement of particles *down* a concentration gradient, from higher concentration to lower concentration.
directly proportional		A relationship between two variables in which if one variable doubles, the other also doubles.
Fick's law		The relationship between the different variables that affect diffusion: rate of diffusion $\propto$ $\frac{\text{surface area} \times \text{concentration difference}}{\text{thickness of membrane}}$
inversely proportional		A relationship between two variables in which if one variable doubles, the other halves.
linear relationship		A relationship between two variables shown by a straight line on a graph.

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SB8c The circulatory system

Word	Pronunciation	Meaning
antibody		A protein produced by lymphocytes. It attaches to a specific antigen on a microorganism and helps to destroy or neutralise it.
artery		A blood vessel that carries blood away from the heart.
blood		The fluid that carries oxygen and other substances from the heart to the body.
capillary		A tiny blood vessel with thin walls to allow for the transfer of substances between the blood and tissues.
erythrocyte	*er-**ree**-throw-site*	Another term for red blood cell.
haemoglobin	*hee-mO-**glO**-bin*	The red, iron-containing pigment found in red blood cells.
heart		A muscular organ in the circulatory system that pumps blood around the body.
lymphocyte	***lim**-fO-site*	A type of white blood cell that produces antibodies.
phagocyte	***fag**-O-site*	A white blood cell that is capable of engulfing microorganisms such as bacteria.
plasma		The straw-coloured liquid component of blood.
platelet		Cell fragments that are important in the clotting mechanism of the blood.
pulse		A shock wave caused by the contraction of the heart muscles, which travels through the walls of arteries leading from the heart.
red blood cell		A biconcave disc containing haemoglobin that gives blood its red colour and carries oxygen around the body to the tissues. Also known as an erythrocyte.
valve		A structure made of flaps of tissue that stops blood flowing in the wrong direction.
vein		A blood vessel that transports blood towards the heart.
white blood cell		A type of blood cell that forms part of the body's defence system against disease. There are many different types of white blood cell, including lymphocytes and phagocytes.

SB8d The heart

Word	Pronunciation	Meaning
aorta		The major artery leading away from the heart.
atrium		An upper chamber in the heart that receives blood from the veins. (Plural is atria.)
cardiac output		The volume of blood the heart can pump out in one minute. It is calculated using the equation: cardiac output = stroke volume × heart rate
chamber		An enclosed space. A human heart has four chambers.

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Word	Pronunciation	Meaning
contract		To become smaller. When muscles contract, they shorten and become fatter.
deoxygenated blood		Blood in which the red blood cells are only carrying small amounts of oxygen. Deoxygenated blood is a dark red colour.
heart attack		When the heart stops pumping properly due to a lack of oxygen reaching part of it.
heart rate		The number of heart beats in a unit of time, usually per minute (beats/min).
heart valve		A structure made of flaps of tissue between an atrium and a ventricle of the heart. The heart valve stops blood flowing in the wrong direction when the heart muscle contracts.
impulse		An electrical signal transmitted along a neurone.
oxygenated blood		Blood in which the red blood cells are carrying large amounts of oxygen. Oxygenated blood is a bright red colour.
pulmonary artery		An artery that carries deoxygenated blood from the right atrium to the lungs.
pulmonary vein		A vein that carries oxygenated blood from the lungs to the left atrium.
septum		A wall of tissue. The septum in the heart completely separates the chambers on the right from those on the left.
stroke volume		The volume of blood the heart can pump out with each beat.
tendon		A strand of tissue used to connect other tissues. The tendons in the heart connect the valves with the heart walls.
vena cava	***vee**-na **kay**-va*	A major vein leading to the heart.
ventricle		A lower chamber in the heart that pumps blood out into the arteries.

SB8e Cellular respiration

Word	Pronunciation	Meaning
aerobic respiration	*air-**O**-bick res-pir-**ay**-shun*	A type of respiration in which oxygen is used to release energy from substances such as glucose.
anaerobic respiration	***an**-air-O-bick res-pir-**ay**-shun*	A type of respiration that does not need oxygen.
cellular respiration		Chemical process by which living cells produce energy in the cell.
exothermic		A type of reaction in which energy is transferred to the surroundings from the reactants. This energy transfer usually causes the temperature of the surroundings to rise.

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Word	Pronunciation	Meaning
glucose		A sugar produced by the digestion of carbohydrates and needed for respiration.
lactic acid		The waste product of anaerobic respiration in animal cells.
mitochondrion	*my-toe-**kon**-dree-on*	A sub-cellular structure (organelle) in the cytoplasm of eukaryotic cells, where aerobic respiration occurs. (Plural is mitochondia.)

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Name _____ **Class** _____ **Date** _____

1 The pumping action of the heart makes shock waves travel through the walls of certain blood vessels. These shock waves can be felt as a pulse in the wrist.

a A student feels their pulse. The student measures 20 beats in 15 seconds.

Calculate the pulse rate of the student in beats per minute.

_____ beats per minute

(1)

b Name the type of blood vessels that carry the pulse in their walls.

_____

(1)

c Another type of blood vessel in the body contains valves.

State the function of valves in blood vessels.

_____

_____

(1)

d Blood leaves the heart under high pressure.

Explain how the structure of the blood vessels that carry the blood away from the heart helps them withstand the high pressures.

_____

_____

_____

_____

(2)

(Total for Question 1 = 5 marks)

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2 **Figure 1** shows the numbers of different types of blood cell in four different people.

Cell type	Cell count (cells/cm^3)			
	Person A	**Person B**	**Person C**	**Person D**
red blood cells	2 500 000 000	4 500 000 000	5 000 000 000	5 250 000 000
white blood cells	11 000 000	9 500 000	10 500 000	1 000 000
Platelets	2 000 000	370 000 000	300 000 000	325 000 000

Figure 1

a State which type of cell is found in the greatest numbers in blood.

_____

(1)

b What is the name of the liquid part of blood in which blood cells are found?

Tick **one** box.

☐ **A** plasma

☐ **B** tissue fluid

☐ **C** lymph

☐ **D** synovial fluid

(1)

c There are various types of white blood cell.

What are the names of two types of white blood cell?

Tick **one** box.

☐ **A** grey cells and white cells

☐ **B** lymphocytes and phagocytes

☐ **C** erythrocytes and leucocytes

☐ **D** haemocytes and blancocytes

(1)

d A blood test measures the amount of haemoglobin in 1 cm^3 of blood.

Explain which **one** of the people (**A**, **B**, **C** or **D**) in **Figure 1** you would expect to have the least mass of haemoglobin per cm^3.

Person: _____

Reason: _____

_____

(2)

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e **One** of these people (**A**, **B**, **C** or **D**) has a condition in which their blood does not clot properly.

Use the information in **Figure 1** to decide which person it is. Explain your answer.

Person: _____

Reason: _____

_____

(2)

(Total for Question 2 = 7 marks)

3 Human lungs contain millions of tiny 'pockets' that are grouped together at the ends of tiny tubes.

Figure 2 shows one of these 'pockets'.

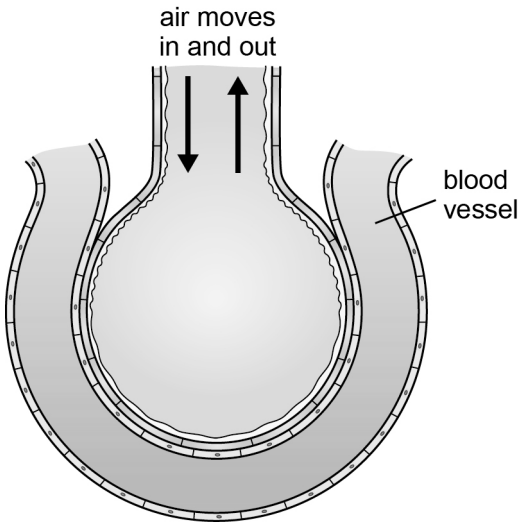


Figure 2

a What name is given to the 'pocket-shaped' structure shown in **Figure 2.**

Tick **one** box.

- ☐ **A** alveolus
- ☐ **B** maleus
- ☐ **C** air exchanger
- ☐ **D** mitochondrion

(1)

b What is the function of the 'pocket-shaped' structure?

Tick **one** box.

- ☐ **A** decreases the surface area to decrease gas exchange
- ☐ **B** increases the surface area to decrease gas exchange
- ☐ **C** decreases the surface area to increase gas exchange
- ☐ **D** increases the surface area to increase gas exchange

(1)

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c Name the process by which gases move between the blood and the air inside the lung.

_____

(1)

d Explain how the blood vessel in **Figure 2** is adapted to speed up the exchange of gases.

_____

_____

_____

(2)

(Total for Question 3 = 5 marks)

4 Body cells need to respire in order to release energy.

a State **two** reasons why the human body requires a constant supply of energy.

1 _____

2 _____

(2)

The amount of anaerobic respiration in muscle cells increases as muscles work harder.

b Give the word equation for anaerobic respiration in humans.

_____

(1)

c State **two** differences between anaerobic respiration and aerobic respiration in humans.

_____

_____

_____

_____

(2)

(Total for Question 4 = 5 marks)

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5 A student investigated rates of respiration in different types of larvae.

Figure 3 shows the apparatus the student used.

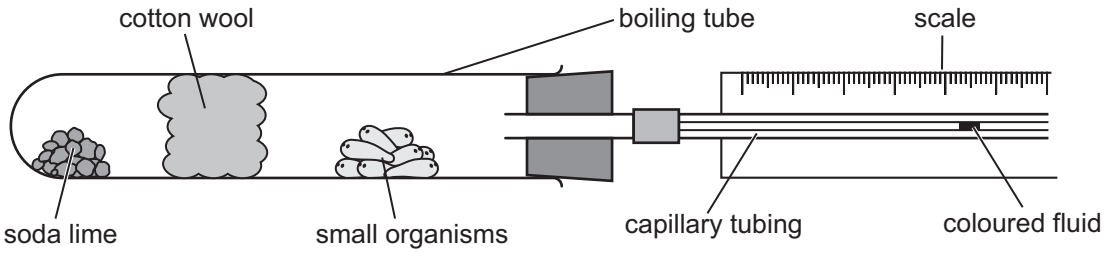


Figure 3

The coloured fluid starts at 0 mm on the scale in each experiment. The movement of the coloured fluid is then measured every 5 minutes for 15 minutes. The experiment is repeated with different types of larvae.

For blowfly larvae, the readings were 4 mm, 8 mm, 12 mm.

For darkling beetle larvae, the readings were 6 mm, 13 mm, 21 mm.

For wax moth larvae, the readings were 3 mm, 7 mm, 10 mm.

a Complete **Figure 4** below to show these results. The table has been started for you.

	Distance in mm moved by the coloured fluid after:		
	5 minutes		

Figure 4

(2)

b Calculate the mean rate at which the coloured fluid moved for the blowfly larvae in the first 10 minutes.

_____ mm/minute

(2)

c State the gas that is absorbed by the soda lime.

_____

(1)

d Give **two** reasons why the temperature should be kept the same in this investigation.

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1 _____

_____

2 _____

_____

(2)

e One way of improving this experiment is to use a **control**.

i State the purpose of a control.

_____

_____

(1)

ii Give a suitable control for this experiment.

_____

_____

(1)

(Total for Question 5 = 9 marks)

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6 **Figure 5** shows the internal structure of the heart.

a Draw arrows on the diagram to show the direction of the blood as it moves into, through and out of the heart.

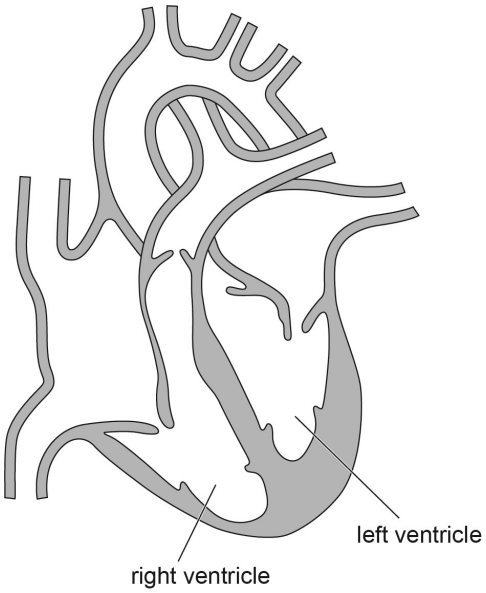


Figure 5

(2)

b Give **one** reason why the left ventricle of the heart has a thicker wall than the right ventricle.

_____

_____

(1)

(Total for Question 6 = 3 marks)

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7 During strenuous exercise there are changes in the circulatory and breathing systems in humans.

Explain the changes in the circulatory and breathing systems of the body during strenuous exercise.

(6)

(Total for Question 7 = 6 marks)

TOTAL FOR PAPER = 40 MARKS

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Name _____ **Class** _____ **Date** _____

1 **Figure 1** shows the numbers of different types of blood cell in four different people.

Cell type	Cell count (cells/cm^3)			
	Person A	**Person B**	**Person C**	**Person D**
red blood cells	2500000000	4500000000	5000000000	5250000000
white blood cells	11000000	9500000	10500000	1000000
platelets	2000000	370000000	300000000	325000000

Figure 1

a Phagocytes are one type of white blood cell. Which sentence describes how phagocytes destroy foreign cells?

Tick **one** box.

☐ **A** they produce antibodies against foreign cells

☐ **B** they produce antigens against foreign cells

☐ **C** they surround and digest foreign cells

☐ **D** they produce plasma against foreign cells

(1)

b **One** of these people (**A**, **B**, **C** or **D**) has a condition in which their blood does not clot properly.

Use the information in **Figure 1** to decide which person it is.

Explain your answer.

Person: _____

Reason: _____

_____

_____

(2)

(Total for Question 1 = 3 marks)

2 Blood from the heart enters arteries under high pressure.

Explain how the structure of arteries helps them to withstand this pressure.

_____

_____

_____

_____

(2)

(Total for Question 2 = 2 marks)

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3 Human lungs contain millions of alveoli. Alveoli are arranged in clusters at the ends of tiny air tubes.

Capillaries are found closely associated with each alveolus, as shown in **Figure 2**.

Figure 2 shows one alveolus.

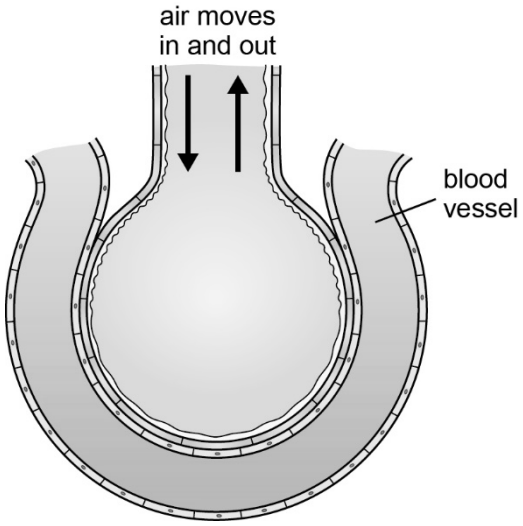


Figure 2

a Explain how the blood vessel in **Figure 2** is adapted to speed up the exchange of gases.

_____

_____

_____

_____

(2)

b Some people suffer from a lung disease called **emphysema**.

In people with emphysema the walls of the alveoli break down and the alveoli join together to form larger 'pockets'.

Explain why people with emphysema often need to breathe air with a higher concentration of oxygen than normal air.

_____

_____

_____

_____

_____

_____

(3)

(Total for Question 3 = 5 marks)

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4 **Figure 3** gives some information for four sizes of cell.

Cell	Surface area (μm^2)	Volume (μm^3)	SA : V ratio
A	24	8	3
B	64	64	1
C	384	512	
D	432	240	1.8

Figure 3

a Calculate the surface area to volume (SA : V) ratio for cell C.

Show your working.

_____

(2)

b Explain why there is a limit to how large a cell can be.

_____

_____

_____

_____

(2)

(Total for Question 4 = 4 marks)

5 A student investigated rates of respiration in different types of larvae.

Figure 4 shows the apparatus the student used.

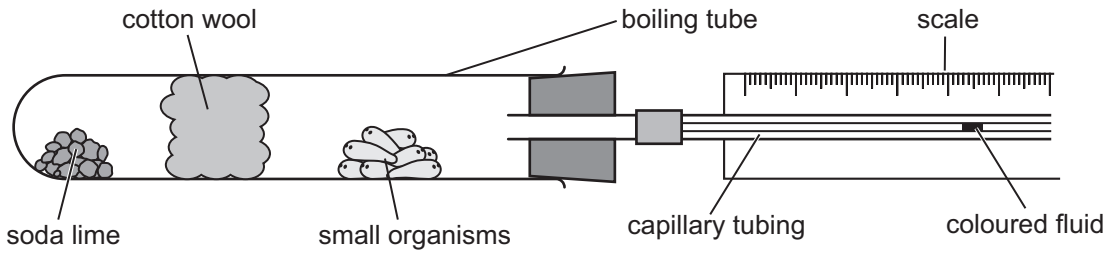


Figure 4

The coloured fluid starts at 0 mm on the scale in each experiment.

The movement of the coloured fluid is then measured every 5 minutes for 15 minutes.

The experiment is repeated with different types of larvae.

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The results are shown in **Figure 5**.

Type of larvae	Distance in mm moved by the coloured fluid after:		
	5 minutes	10 minutes	15 minutes
blowfly	4	8	12
darkling beetle	6	13	21
wax moth	3	7	10

Figure 5

a Calculate the mean rate at which the coloured fluid moved for the blowfly larvae in the first 10 minutes.

_____ mm/minute

(2)

b Give **two** reasons why the temperature should be kept the same in this investigation.

1 _____

_____

2 _____

_____

(2)

c State and explain the role of the soda lime in this experiment.

_____

_____

_____

(2)

d One way of improving this experiment is to use a 'control'. Which of the following gives the purpose of a control?

Tick **one** box.

☐ **A** a control shows that it is the control variable that is affecting the dependent variable

☐ **B** a control shows that it is the control variable that is affecting the independent variable

☐ **C** a control shows that it is the independent variable that is affecting the dependent variable

☐ **D** a control shows that it is the dependent variable that is affecting the independent variable

(1)

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e Describe a suitable control for this experiment.

_____

_____

(1)

(Total for Question 5 = 8 marks)

6 Cellular respiration is a series of chemical reactions that involve the breakdown of glucose.

a Which of the following statements about energy changes in respiration is correct?

Tick **one** box.

☐ **A** respiration is exothermic because energy is released

☐ **B** respiration is endothermic because energy is released

☐ **C** respiration is exothermic because energy is taken in

☐ **D** respiration is endothermic because energy is taken in

(1)

b State the word equation for anaerobic respiration in human cells.

_____

(1)

Figure 6 shows how increasing exercise intensity affects the concentration of oxygen dissolved in the blood.

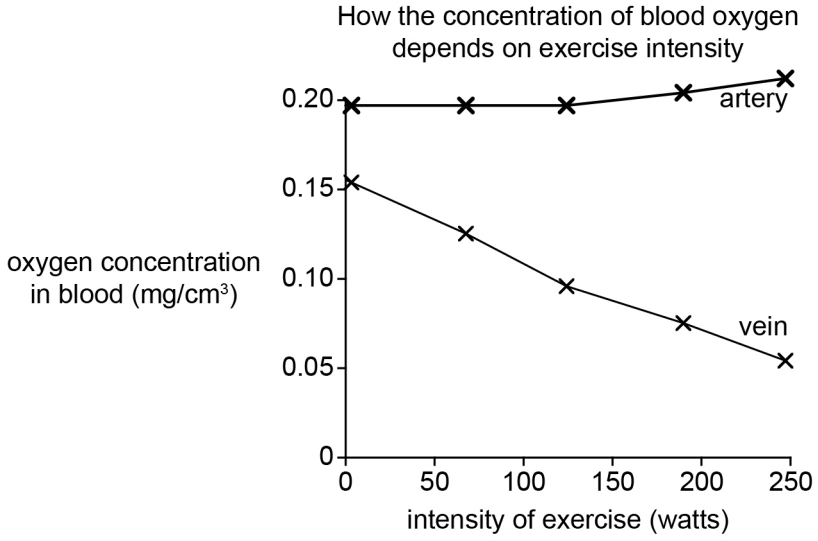


Figure 6

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c Explain the pattern shown by each of the lines on the graph.

Artery: _____

_____

_____

_____

Vein: _____

_____

_____

_____

(4)

(Total for Question 6 = 6 marks)

7 A U-shaped piece of tubing is put in a beaker of urea solution. The open ends of the tube are outside the beaker. The tubing is made of partially permeable membrane and contains distilled water.

The rate of diffusion across the membrane is measured and a graph is drawn, as shown in **Figure 7**.

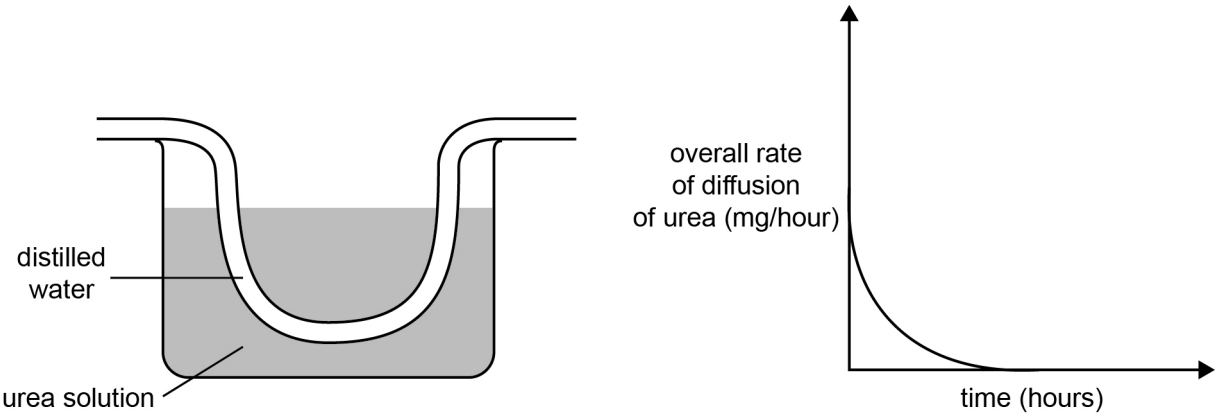


Figure 7

a What is meant by the word 'concentration'?

Tick **one** box.

☐ **A** the amount of substance in a certain volume

☐ **B** the amount of substance that can cross a membrane

☐ **C** the amount of substance in a certain container

☐ **D** the amount of space that a substance occupies

(1)

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b The beaker contains 400 cm^3 of urea solution, containing a total of 300 g of urea.

Calculate the concentration of urea in $g\,cm^{-3}$.

_____ $g\,cm^{-3}$

(2)

c The relationship of the different factors that affect diffusion is shown by Fick's law:

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{concentration difference}}{\text{thickness of membrane}}$$

Explain the shape of the graph above. Use Fick's law to help you.

_____

_____

_____

_____

(2)

d In another investigation, the concentration of the urea is doubled.

Draw another line on the graph in **Figure 7** to show the effect of this.

(1)

(Total for Question 7 = 6 marks)

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8 Compare and contrast the different types of respiration occurring in the muscle cells of a sprinter during the course of a 400 m race.

(6)

(Total for Question 8 = 6 marks)

TOTAL FOR PAPER = 40 MARKS

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Question number	Part	Step	Answer	Additional guidance	Marks
1	a	3	20 × 4 = 80 (beats per minute)	Working need not be shown	**1 mark**
	b	3	arteries		**1 mark**
	c	3	to prevent blood flowing the wrong way/to stop backflow		**1 mark**
	d	4–5	Artery (wall) is thick/strong/muscular (1) so can withstand high pressures without being damaged/bursting. (1) OR Artery (wall) is elastic/contains elastic tissue/fibres (1) so can stretch as blood enters under high pressure. (1)		**2 marks**
2	a	3	red blood cells/erythrocytes		**1 mark**
	b	3	**A** plasma		**1 mark**
	c	3	**B** lymphocytes and phagocytes		**1 mark**
	d	5	Person A (1) because they have the fewest red blood cells (which contain haemoglobin). (1)		**2 marks**
	e	5	Person A (1) because they have the fewest platelets (which help the blood to clot). (1)		**2 marks**
3	a	3	**A** alveolus		**1 mark**
	b	4	**D** increases the surface area to increase gas exchange		**1 mark**
	c	5	diffusion		**1 mark**
	d	8	Thin wall/wall is only one cell thick (1) means that substances have a shorter distance to diffuse over. (1)		**2 marks**

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<table>
<tr><th>Question number</th><th>Part</th><th>Step</th><th>Answer</th><th>Additional guidance</th><th>Marks</th></tr>
<tr><td rowspan="3">4</td><td>a</td><td>6</td><td>Any two sensible reasons, such as:
● for movement (1)
● to keep warm (1)
● producing/breaking down substances (1)
● maintaining brain/nervous system function (1)</td><td>Allow other correct examples of energy-use in the body</td><td>2 marks</td></tr>
<tr><td>b</td><td>7</td><td>glucose → lactic acid</td><td>Accept a correct symbol equation</td><td>1 mark</td></tr>
<tr><td>c</td><td>7</td><td>Any two from:
• Aerobic respiration requires oxygen but anaerobic respiration does not. (1)
• Aerobic respiration occurs in mitochondria but anaerobic respiration does not. (1)
• Anaerobic respiration releases less energy from glucose than aerobic respiration. (1)
• Anaerobic respiration causes muscles to tire more quickly. (1)
• Anaerobic respiration produces lactic acid, whereas aerobic respiration produces carbon dioxide and water. (1)</td><td>Do not allow air for oxygen

Or reverse argument</td><td>2 marks</td></tr>
<tr><td rowspan="3">5</td><td>a</td><td>4–6</td><td><table><tr><th rowspan="2">Type of larvae</th><th colspan="3">Distance in mm moved by the coloured fluid after:</th></tr><tr><th>5 minutes</th><th>10 minutes</th><th>15 minutes</th></tr><tr><td>blowfly</td><td>4</td><td>8</td><td>12</td></tr><tr><td>darkling beetle</td><td>6</td><td>13</td><td>21</td></tr><tr><td>wax moth</td><td>3</td><td>7</td><td>10</td></tr></table></td><td>1 mark for correct headings
1 mark for correctly completed table</td><td>2 marks</td></tr>
<tr><td>b</td><td>6</td><td>8/10 (1)
= 0.8 (mm/minute) (1)</td><td>2 marks for correct answer with no working</td><td>2 marks</td></tr>
<tr><td>c</td><td>5</td><td>carbon dioxide</td><td>Allow CO_2</td><td>1 mark</td></tr>
</table>

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Question number	Part	Step	Answer	Additional guidance	Marks
	d	7	Any **two** from: ● Temperature affects the rate of respiration/higher temperatures cause the enzymes to work at a faster rate. (1) ● At warmer temperatures gases expand and this might change the readings in the capillary tube. (1) ● If the temperature is changed, the independent variable (type of organism) will not be the only variable affecting the readings/the results will not be valid if a variable other than the independent variable affects the readings (1) ● so temperature must be controlled to make results comparable. (1)		**2 marks**
	ei	6	Any **one** of: ● to use as a baseline to compare the results to (1) ● to ensure that the independent variable/the variable that you change is having an effect (1) ● to rule out other variables that have not been controlled having an effect (1)		**1 mark**
	eii	7	a respirometer/same apparatus but without any organisms or with dead organisms		**1 mark**
6	a	6	Arrows showing the following: blood entering the right atrium from one or both venae cavae, flowing into the right ventricle, leaving the right ventricle (through the pulmonary artery) (1) Arrows showing the following: blood entering the left atrium from the pulmonary vein, flowing into the left ventricle, leaving the left ventricle (through the aorta) (1)	All arrows must be as described for each mark	**2 marks**
	b	7	Any **one** of: ● Left ventricle has to pump with more force/is more powerful/muscular than the right ventricle. (1) ● Left ventricle has to pump blood around the whole body, but the right ventricle only pumps to the lungs/left ventricle pumps to more of the body than the right ventricle. (1) ● Blood leaving the left ventricle needs to be at higher pressure than that leaving the right ventricle. (1)	Do not accept 'the right ventricle pumps more blood' or 'the right ventricle pumps blood faster'	**1 mark**

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Question number	Part	Step	Answer	Additional guidance	Marks
7		8	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are therefore not required to include all the material that is indicated as relevant. Additional content included in the response must be scientific and relevant. **Indicative content** **AO2 (3 marks) and AO3 (3 marks)** ● Muscles require additional energy during exercise. ● Energy is released by respiration, mainly aerobic respiration. ● Aerobic respiration requires oxygen. ● Aerobic respiration requires glucose. ● Aerobic respiration produces carbon dioxide. ● Oxygen is carried in the blood. ● Oxygen is carried in red blood cells. ● Oxygen is carried attached to haemoglobin molecules. ● Glucose is carried in the blood. ● Glucose is dissolved in the plasma. ● Waste carbon dioxide is carried in the blood. ● Waste carbon dioxide is dissolved in the plasma/carried in red blood cells attached to haemoglobin. ● Heart rate increases with exercise ● to pump more blood containing oxygen and glucose so that more of these substances are available to muscle tissue. ● Breathing rate increases with exercise ● to get oxygen into the blood at a faster rate ● (and) to remove carbon dioxide from the blood at a fasters rate. ● Faster breathing rate helps to increase the concentration gradients of oxygen/carbon dioxide so that diffusion occurs at a faster rate.		**6 marks**

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Step	Marks	Descriptor
U	0	No awardable content.
3–4	1–2	**Level 1** ● The explanation attempts to link and apply knowledge and understanding of scientific ideas, flawed or simplistic connections made between elements in the context of the question. (AO2) ● Interpretation and evaluation of the information attempted but will be limited with a focus on mainly just one variable. Demonstrates limited synthesis of understanding. (AO3)
5–6	3–4	**Level 2** ● The explanation is mostly supported through linkage and application of knowledge and understanding of scientific ideas, some logical connections made between elements in the context of the question. (AO2) ● Interpretation and evaluation of the information on both variables, synthesising mostly relevant understanding. (AO3)
7–8	5–6	**Level 3** ● The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2) ● Interpretation and evaluation of the information, demonstrating throughout the skills of synthesising relevant understanding. (AO3)

Step boundaries

Step	Marks
U	0–2
1	3–6
2	7–10
3	11–13
4	14–15
5	16–17
6	18–19
7	20–24
8	25+

Indicative grade boundaries

Indicative Grade	Marks
U	0–6
1	7–10
2	11–15
3	16–19
4	20–24
5	25+

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Question number	Part	Step	Answer	Additional guidance	Marks
1	a	6	**C** they surround and digest foreign cells		**1 mark**
	b	8	Person A (1) because they have the fewest platelets (which help the blood to clot). (1)		**2 marks**
2		7	Artery (wall) is thick/strong/muscular (1) so can withstand high pressures without being damaged/bursting. (1) OR Artery (wall) is elastic/contains elastic tissue/fibres (1) so can stretch as blood enters under high pressure. (1)		**2 marks**
3	a	8	thin wall/wall is only one cell thick (1) means that substances have a shorter distance to diffuse over (1)		**2 marks**
	b	9	Fewer alveoli means a smaller surface area (for gas exchange) (1) so rate of gas exchange/diffusion is slower/less oxygen enters the blood. (1) greater concentration of oxygen needed in the air to give faster diffusion/allow enough oxygen to enter the blood (1)		**3 marks**
4	a	9	384/512 (1) = 0.75 or 0.75:1 (1)	2 marks for correct answer with no working Accept 0.8	**2 marks**
	b	9	As cells get bigger, their SA : Vol ratio gets smaller. (1) It then takes too long for materials to enter and diffuse through the whole cell. (1)	Accept the cell does not have enough surface area for its volume	**2 marks**

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Question number	Part	Step	Answer	Additional guidance	Marks
5	a	8	8/10 (1) = 0.8 (mm/minute) (1)	2 marks for correct answer with no working	**2 marks**
	b	7	Any **two** from: • Temperature affects the rate of respiration/higher temperatures cause the enzymes to work at a faster rate. (1) • At warmer temperatures gases expand and this might change the readings in the capillary tube. (1) • If the temperature is changed, the independent variable (type of organism) will not be the only variable affecting the readings/the results will not be valid if a variable other than the independent variable affects the readings (1) • so temperature must be controlled to make results comparable. (1)		**2 marks**
	c	9	It absorbs carbon dioxide (1) so that the decrease in volume can be followed as oxygen is used up/without it, the carbon dioxide produced would take up some of the volume lost by the removal of oxygen. (1)	Accept to make sure that the change in volume in the apparatus is only due to the changes in oxygen volume	**2 marks**
	d	10	**C** a control shows that it is the independent variable that is affecting the dependent variable		**1 mark**
	e	7	a respirometer/same apparatus but without any organisms or with dead organisms		**1 mark**
6	a	9	**A** respiration is exothermic because energy is released		**1 mark**
	b	7	glucose → lactic acid	Accept a correct and balanced symbol equation	**1 mark**
	c	11	**Artery:** ● Oxygen concentration increases (slightly) as exercise intensity increases (1) ● because the breathing becomes faster and deeper/more oxygen enters the blood in the lungs. (1) **Vein:** ● Oxygen concentration decreases as exercise intensity increases (1) ● because as muscles work harder they remove more oxygen for respiration. (1)	Arteries – accept oxygen concentration remains fairly constant Arteries – accept answer in terms of maintaining a high concentration gradient/expanding the lungs to increase surface area	**4 marks**

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Question number	Part	Step	Answer	Additional guidance	Marks
7	a	10	**A** the amount of substance in a certain volume		**1 mark**
	b	11	300/400 (1) = 0.75 (1)	2 marks for correct answer with no working	**2 marks**
	c	12	Urea diffuses through the membrane into the tubing during the experiment OR the concentration gradient/concentration difference decreases as time increases. (1) Lower concentration gradient/concentration difference results in a slower rate of diffusion. (1)		**2 marks**
	d	12	Line starting at twice the height of existing line of *y*-axis/line ends after end point on the *x*-axis of the original line Line follows same shape as existing curve	The curve must be the right shape AND have at least one of the other features mentioned for the mark	**1 mark**
8		9–12	Answers will be credited according to the candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **Indicative content AO1 (6 marks)** **Similarities** ● Both aerobic and anaerobic respiration release energy/are exothermic. ● Both require a source of glucose. ● Both provide energy for all the processes that occur in the athlete. ● During the race, the amount of both types of respiration may reach a peak (although possibly for different reasons).		**6 marks**

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Question number	Part	Step	Answer	Additional guidance	Marks
			Differences ● Word equations: glucose + oxygen → carbon dioxide + water glucose → lactic acid ● comments made contrasting the reactants needed and/or products made ● Anaerobic respiration is used more and more as the amount of oxygen available becomes less/because aerobic respiration is happening at a higher and higher rate. ● Lactic acid causes muscles to tire. ● Anaerobic respiration can supply a sudden burst of energy without the need for additional oxygen, which is important at the start of the race. ● During the race there will be a sudden increase in anaerobic respiration at the start, whereas the rate of aerobic respiration will increase more gradually as more oxygen is taken into the body. ● During the race, the amount of aerobic respiration may reach a peak due to the inability of the body to get any more oxygen into the blood, whereas the rate of anaerobic respiration may reach a peak due to a limited supply of glucose or saturation of the enzymes with substrate. ● Anaerobic respiration produces an 'oxygen debt' so more oxygen than usual is needed, even after the exercise ends, to remove the lactic acid. ● Anaerobic respiration occurs in the cytoplasm; aerobic respiration requires mitochondria.		

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Step	Marks	Descriptor
U	0	No awardable content.
9	1–2	**Level 1** ● Demonstrates elements of biological understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) ● Presents an explanation with some structure and coherence. (AO1)
10–11	3–4	**Level 2** ● Demonstrates biological understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) ● Presents an explanation that has a structure which is mostly clear, coherent and logical. (AO1)
11–12	5–6	**Level 3** ● Demonstrates accurate and relevant biological understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) ● Presents an explanation that has a well-developed structure which is clear, coherent and logical. (AO1)

Step boundaries

Step	Marks
U	0–6
5	7–8
6	9–10
7	11–14
8	15–18
9	19–21
10	22–25
11	26–30
12	31+

Indicative grade boundaries

Indicative Grade	Marks
U	0–6
3	7–10
4	11–14
5	15–18
6	19–21
7	22–25
8	26–30
9	31+

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