DEMONSTRATING MASS FLOW

Purpose

- To calculate rate of diffusion.
- To appreciate speed of diffusion in air.
- To observe mass flow.

SAFETY
Wear eye protection. Wear disposable gloves when handling the ammonia solution. *The experiment must be undertaken in a fume cupboard.* *See CLEAPSS Student Safety Sheet 30 for further details on safe handling of ammonia and ammonium hydroxide.*

YOU NEED	
• Dilute ammonium hydroxide	• Forceps
• Two glass tubes	• Dropping pipette
• Bungs to fit glass tubes	• Stopclock
• 16 small pieces of litmus paper	• Clamp stand, boss and clamp or piece of adhesive tack
• Glass or wooden rod	• Ruler
• Two small pieces of cotton wool	

Procedure

1 Your teacher/lecturer will set up a glass tube with litmus paper as shown in Figure 1 and measure the distance between the pieces of litmus paper.

2 In a fume cupboard add a few drops (about six) of ammonium hydroxide solution to a small ball of cotton wool and then place it at one end of the glass tube. Seal both ends of the tube with rubber bungs. Immediately start a stopclock. Ammonia is given off by the solution and diffuses along the tube. The litmus paper changes colour from red to blue in the presence of ammonia gas.

3 Record how long it takes each piece of litmus paper to change colour.

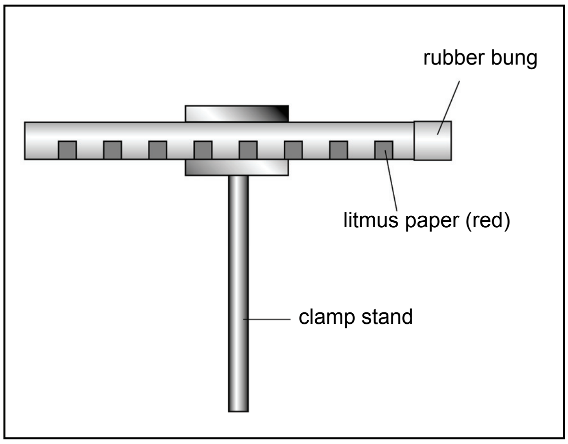

Figure 1 Glass tube with litmus paper.

4 Using a second tube without rubber bungs, place the cotton wool with ammonium hydroxide at one end.

5 Using a large syringe, blow air gently through the tube. Observe how quickly the litmus paper changes colour when the syringe is used.

Questions

Q1 Explain how the ammonia moves along the tube with sealed ends.

Q2 Calculate the speed of diffusion along the tube and comment on your findings.

Q3 Explain how each of these factors would affect the rate of diffusion:
- **a** higher concentration of ammonium hydroxide
- **b** higher temperature
- **c** larger molecules replacing ammonium hydroxide.

Q4 Explain what is happening in the tube without bungs and how the model is similar to mass flow in a transport system, such as the mammalian circulatory system.

DEMONSTRATING MASS FLOW

Purpose

- To calculate rate of diffusion.
- To appreciate speed of diffusion in air.
- To observe mass flow.

SAFETY

Ensure eye protection is worn throughout the activity. Ensure disposable gloves are worn by anyone handling the ammonia solution.

The experiment must be undertaken in a fume cupboard.

See CLEAPSS Hazcard 6 for further details on safe handling of ammonia and ammonium hydroxide.

Notes on the procedure

It is presumed that most students will have observed diffusion in practicals at KS3 or KS4. However, it is worth students completing this practical or having it demonstrated to them to highlight the difference between diffusion and mass flow.

If students take an active part in this practical they need to know, in advance, how to use a fume cupboard.

The sealed tube allows measurements to be taken to determine the speed of diffusion. The open-ended tube demonstrates mass flow of ammonium hydroxide. It is virtually impossible to measure how quickly the litmus paper changes colour.

Stapling pieces of litmus paper to wooden splints and then sliding the splint into the tube overcomes the difficulty of getting the pieces along the tube.

If teaching topics in parallel (or when teaching Topic 2), the ideas here could relate to Fick's law (Topic 2 2.1), which states that:

$$\text{Rate of diffusion} \propto \frac{\text{Surface area to volume ratio} \times \textit{Concentration difference}}{\text{thickness of surface}}$$

Answers

Q1 Molecules are continuously moving due to their kinetic energy. There are more ammonia molecules at the cotton wool end of the tube (high concentration) compared with the other end (a region of low concentration). There is a net movement of molecules due to their random movement from the region of their high concentration to the region of their low concentration.

Q2 The speed of diffusion at the end of the tube away from the cotton wool is slower than near the cotton wool. Rate of diffusion is dependent on the concentration gradient. Near the cotton wool there is a high concentration compared with the rest of the tube: this gives a steep diffusion gradient. Large numbers of ammonia molecules will be diffusing away from the cotton wool so the net movement is rapid. As the molecules diffuse away, their concentration decreases and further along the tube the diffusion gradient is less steep. As a result, the time taken for enough molecules to diffuse between the final two pieces of litmus paper and turn the last one blue will be much longer.

Q3 **a** Higher concentration will speed up diffusion because there is a steeper gradient.

b Higher temperature will speed up diffusion because the molecules will have more kinetic energy.

c Larger molecules would diffuse more slowly because in a vapour or gas, at a given temperature, the larger the molecule, the more slowly it moves.

Q4 The air in the tube moves through the tube and carries the ammonia with it. Blood works in the same way. The fluid is pumped around the body and carries within it substances to be transported.

DEMONSTRATING MASS FLOW

Purpose

- To calculate rate of diffusion.
- To appreciate speed of diffusion in air.
- To observe mass flow.

SAFETY

Wear eye protection and disposable gloves.

The experiment must be undertaken in a fume cupboard.

All ammonia solutions must be dispensed in a fume cupboard as the vapour, ammonia gas, is toxic and extremely irritating to the eyes and lungs. See CLEAPSS Hazcard 6 for further details on safe handling of ammonia and ammonium hydroxide.

Requirements per student or group of students	Notes
Eye protection, disposable gloves and access to a fume cupboard	
Two glass tubes	Approximately 50 cm long and 2 cm in diameter.
Two bungs to fit glass tubes	The bungs should have ventilation holes through them: one to fit the syringe; the other as a vent.
Eight small pieces of red litmus paper	Each piece approximately 1 cm in length. For ease of positioning in the tube the pieces of litmus paper can be stapled at intervals along a wooden splint.
Glass or wooden rod	To position the litmus paper in the glass tube.
Two pieces of cotton wool	Approximately 1.5 × 1.5 cm.
Forceps	
Dilute ammonium hydroxide	Any concentration around 0.5 M should work well.
Large syringe	Any size is fine as long as it provides a good draught of air when the plunger is pushed in.
Dropping pipette	
Stopwatch/clock	
Two bosses, clamps and stands or pieces of adhesive tack	Instead of using a boss and clamp, rest the tubes on the bench with a piece of adhesive tack acting as a wedge to stop them rolling off.
Ruler	

Notes

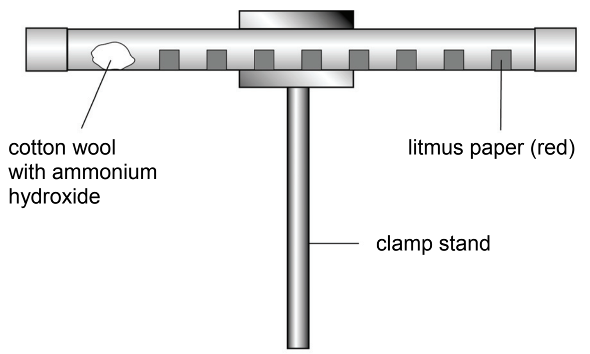

Figure 1 Glass tube with litmus paper (red).

AN IDEAL TRANSPORT MEDIUM

Purpose

- To understand the importance of the dipole nature of water.
- To relate the solvent properties of water to some of the functions of water in living systems.

Properties and polarity

Water is unusual because it is a liquid at room temperature whereas other small molecules are gases. This is because the water molecule is polar; the different ends of the molecule have different charges. Water is a dipole. To help you understand the dipole nature of water and how it affects water's properties, read the Key Biological Principles box on page 8 of the Year 1 Student Book and complete the interactive tutorial that accompanies this activity. Then complete the questions below.

Questions

Q1 Complete and annotate the diagram of water molecules in Figure 1 to explain why water is a liquid at room temperature, unlike other small molecules, such as carbon dioxide.

You should include the following words/ideas in your diagram:

hydrogen bonds
polar charges on oxygen and hydrogen atoms.

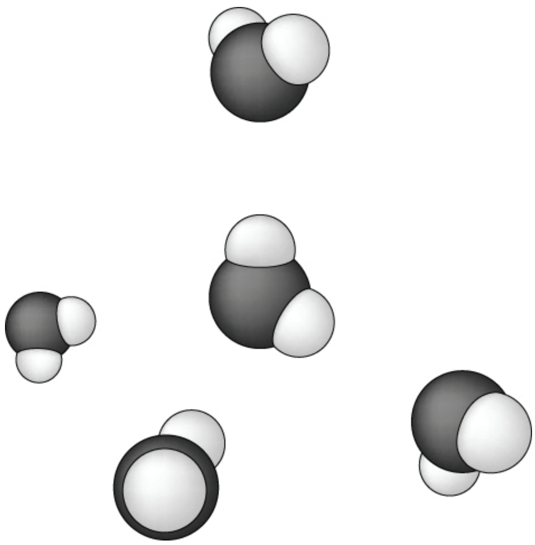

Figure 1 Why water is a liquid at room temperature.

Q2 Oil and water do not mix. They remain as two separate layers, with the less dense oil floating on top of the water. Oil is non-polar; it is hydrophobic (water-repelling).

a Predict what will happen if some drops of water-soluble dye were added to a water-oil mixture.

b Then try doing it, to check if you were correct. Suggest an explanation for what you observe happening.

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Q3 **a** Vitamin C is water-soluble. Vitamin A is fat-soluble. Give a possible explanation for this difference.

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b A celebrity chef announces on his TV show that it would be better to boil a joint of meat rather than roast it. He says this is because the fat will dissolve out of the meat, making the meal lower in fat and healthier. Is he correct in his explanation of what is happening during the cooking?

Explain your answer.

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Q4 Complete the table below, to show why water is ideal as the transport medium in blood.

Property	Explanation	Role in blood
	The positively charged end of a water molecule is attracted to the negative ends of surrounding molecules. Hydrogen bonds form; these hold the water molecules together.	
Solvent for ionic and polar substances.		
		Blood helps to regulate body temperature because water resists changes in temperature.

Q5 Your young cousins are worried that the fish in their large garden pond will get too hot on very sunny days in summer. What would you say to make them realise that they do not need to worry?

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AN IDEAL TRANSPORT MEDIUM

Purpose

- To understand the importance of the dipole nature of water.
- To relate the solvent properties of water to some of the functions of water in living systems.

Notes on the procedure

Before completing the questions on the Student Sheet, students should read the Key Biological Principles box on page 8 of the Year 1 Student Book and complete the interactive tutorial that accompanies this activity.

The questions on the Student Sheet are to get students thinking about hydrogen bonding between water molecules. Note that in chemistry, students may well use the term intermolecular bonds; we have included this in the interactive tutorial; at this stage students do not need to have detailed knowledge of cohesion. This is included in Topic 4.

The interactive tutorial on water is within the Biochemistry Support section on SNAB Online. It includes material relevant to Topic 4. In Topic 1, students only have to cover those sections that support ideas about the dipole nature of water and its role as a solvent in transport. There is a small amount of information about temperature. This introduces the role of water in temperature regulation and shows that the blood also transfers energy; this is not required for examination purposes.

An additional task could be completed by students. Students are asked how many drops of water will sit on a penny. A penny will take about 27 drops of water from a fine glass pipette, with a large dome of water created before it overflows. There is no requirement to go into surface tension. The large volume able to sit on a penny can be explained by the hydrogen bonds that are holding the water molecule together. This highlights the polarity of water and hydrogen bonds between water molecules. A smear of detergent will reduce the amount of water that can sit on the penny to just a few drops. It is sufficient for students to say that the detergent prevents the formation of hydrogen bonds between the water molecules.

Magnetic water molecule models are very good for demonstrating polarity and solvent properties. They are available from Philip Harris.

Answers

Q1 Students should annotate the diagram to show the polar charges on oxygen and hydrogen atoms, and hydrogen bonds between the molecules.

Q2 The lack of mixing of oil and water in a container could be demonstrated. The water-soluble dye will only dissolve in the water component because of the dipole nature of the water molecule. This can be explained in terms of the formation of hydrogen bonds between the dye molecules and water, but not between the oil and dye.

Q3 **a** Vitamin C is a polar molecule. Vitamin A is not polar. Therefore hydrogen bonds will only form between Vitamin C and water, allowing it to dissolve. Vitamin A is transported in the blood bound to a protein.

b The celebrity chef is not correct to say that the fat dissolves in the water; fat does not dissolve in water. However, at higher temperatures the fat may melt and be released into the water. So, when the meat is removed from the water there is less fat. There may also have been less fat if the meat had been roasted and the fat poured off.

Q4

Property	Explanation	Role in blood
Liquid at room temperature.	The positively charged end of a water molecule is attracted to the negative ends of surrounding molecules. Hydrogen bonds form: these hold the water molecules together.	Blood does not change state, but remains as a liquid solvent, transporting substances around the body.
Solvent for ionic and polar substances.	The positively charged end of a water molecule is attracted to negative ends of surrounding molecules, or negative ions. The negative oxygen atoms in water attract positively charged ions or molecules.	Polar substances dissolve in water, so are transported around the body as solutes in blood.
High specific heat capacity.	A large amount of energy is needed to break the hydrogen bonds between water molecules.	Blood helps to regulate body temperature because water resists changes in temperature.

Q5 Water warms up and cools down slowly, so the fish will not experience rapid changes in water temperature. For older or more able cousins you might add that on a sunny day, a large input of energy causes only a small increase in water temperature. This is because a large amount of energy is required to break hydrogen bonds between the water molecules.

AN IDEAL TRANSPORT MEDIUM

Purpose

- To understand the importance of the dipole nature of water.
- To relate the solvent properties of water to its function in living systems.

The oil and water mixture may be completed as a teacher demonstration.

Requirements per student or group of students	Notes
Glass measuring cylinder	Large, if for teacher demonstration.
Vegetable oil	Sufficient to half-fill the glass measuring cylinder.
Water-soluble dye	Enough to colour the water in the oil-water mix.

Safety checked, but not trialled by CLEAPSS. Users may need to adapt the risk assessment information to local circumstances.

STRUCTURE OF THE HEART (DISSECTION)

Purpose

- To revise your knowledge of the structure of the heart.
- To relate heart structure to function.
- To locate and compare the structure of the main arteries leaving the heart with the main veins entering the heart.
- To observe the coronary arteries.
- To develop practical dissection skills.

SAFETY

Wash your hands carefully after completing the dissection and putting all the equipment ready to be cleaned. Hands should be washed before leaving the lab.

Take care with sharp dissecting instruments.

Wear a plastic apron to protect your clothes. Long sleeved clothing should be rolled up to prevent contamination.

YOU NEED

• Heart • Dissecting board or tray • Dissecting instruments • Rubber tube	• Clamp to seal blood vessel • Access to water supply • Plastic apron to protect your clothes

Procedure

1 Before starting the dissection, use the Student Book to help you label the heart diagram in Figure 2.

2 Locate the four main blood vessels attached to the heart. The two thicker-walled vessels are the arteries; they leave the heart at the more rounded front (ventral) side. The thinner-walled veins enter the heart at the top of the back (dorsal) side. They are often damaged on removal of the heart from the animal.

3 Looking at the front side of the heart, identify the following external features using Figure 1 to help:

a right and left atria

b right and left ventricles

c coronary arteries and veins.

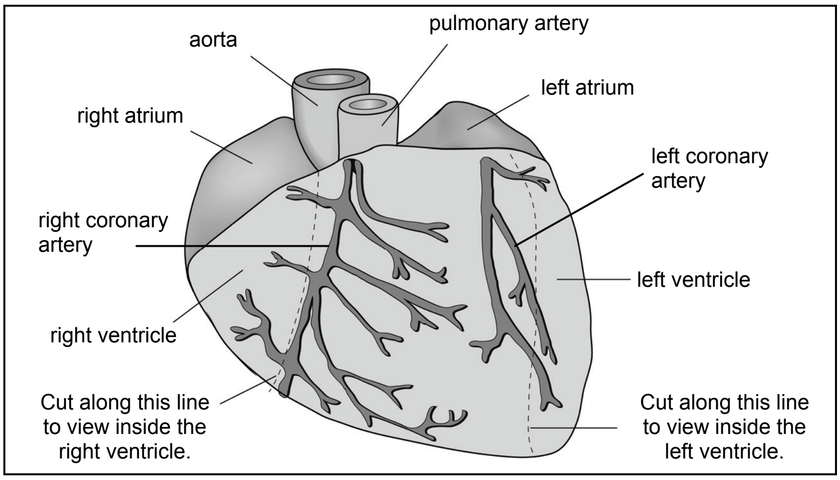


Figure 1 Ventral (front) view of the heart. The pulmonary vein and vena cava enter the atria on the dorsal (back) side of the heart so are not visible on this diagram.

4 Draw a sketch of the heart to show the position of the atria and ventricles.

Q1 Why are the right and left sides apparently on the wrong side?

Q2 **a** Can you distinguish coronary arteries and veins?

b What are their functions?

c Make a sketch showing how they branch across the surface of the heart.

5 If the heart is undamaged you can identify which vessel is the aorta by attaching a rubber tube to a water supply and inserting it into the pulmonary vein. Only use the water supply designated for this activity. Do not attach the rubber tube directly to a tap unless told to do so. Allowing water to flow through the heart (gently!), it will emerge from the aorta. Make sure all the water flowing out of the heart either drains down the sink or is captured in a glass bowl for proper disposal. The same procedure can be used with the superior vena cava after clamping the inferior vena cava shut.

Q3 In this case from which vessel will the water emerge?

Q4 What does this tell us about the internal structure of the heart?

6 To inspect the internal structure of the heart, cut through the ventricle walls, along the lines shown in Figure 1. This is best done with a pair of sharp scissors. Be careful at this stage only to cut through the ventricle walls, leaving the walls of the atria intact.

Q5 Look carefully inside each ventricle and answer these questions:

a Which ventricle has thicker walls?

b Estimate the ratio of the thickness of the two walls.

c Suggest why the ventricle walls are of different thicknesses.

Q6 Locate and carefully observe the atrioventricular valves between the atrium and ventricle on each side of the heart.

a Why is the atrioventricular valve in the right ventricle also called the tricuspid valve?

b Why is the atrioventricular valve in the left ventricle also called the bicuspid valve?

Q7 Locate the semilunar valves at the entrance to the aorta and pulmonary artery. Why are these valves called semilunar?

Q8 Identify the tendons that stretch between the atrioventricular valves and the ventricle walls.

a What is the function of these valves and what is the role of the tendons in their operation?

b Work out how you can test your ideas about valves by inverting the heart and using some water.

Q9 Cut open the atria and examine their internal structure. Explain the relative difference in size between the atria and ventricles.

7 Locate the opening of the coronary vein in the wall of the right atrium.

8 Cut open the aorta and locate the opening to the coronary artery just above the semilunar valve.

Q10 Examine the openings to the vena cava and pulmonary vein. Do these entry points to the heart contain valves? If not, why not?

Q11 Describe the safety precautions you took during the practical.

Vertical section of the heart

Label the diagram. Add arrows to show the route of blood flow through the heart.

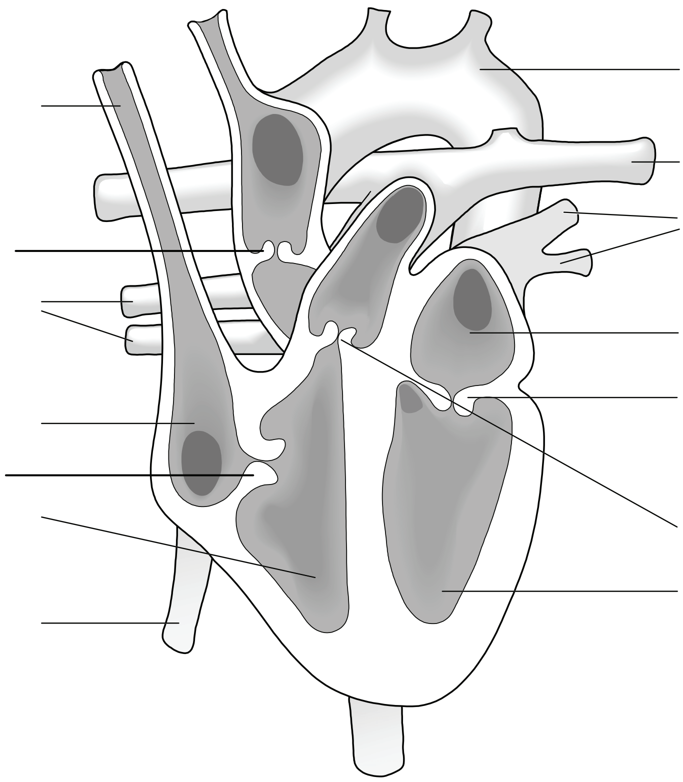


Figure 2 Vertical section of the heart.

STRUCTURE OF THE HEART (DISSECTION)

Purpose

- To revise knowledge of the structure of the heart.
- To relate heart structure to function.
- To locate and compare the structure of the main arteries leaving the heart with the main veins entering the heart.
- To observe the coronary arteries.
- To develop practical dissection skills.

In preparation for the dissection or as an alternative, there is a simulated dissection in Activity 1.5 and a stepwise photo dissection accessible through the weblinks for both activities.

SAFETY

Hands should be washed carefully after completing the dissection and putting all the equipment ready to be cleaned. Hands should be washed before leaving the lab.

Take care with sharp dissecting instruments.

Plastic aprons should be available to protect students' clothes whilst doing a dissection. Long sleeved clothing should be rolled up to prevent contamination.

See CLEAPSS Guidance leaflets G267 and G268 for further details.

Notes on the procedure and answers

1 The diagram in the Student Book (page 9) and Figure 1 on page 2 of this sheet show the labels and blood-flow arrows needed to complete the heart diagram sheet.

2 The two arteries leave the heart at the front (ventral) side. The thinner-walled veins enter the heart at the top of the back (dorsal) side.

3 Deciding which side is the front of the heart is difficult for the student particularly if the heart is damaged. The ventral (front) side of the heart is more convex.

4 Sketch will be similar to one on the Student Sheet.

Q1 The right and left sides appear to be on the wrong side because the drawing is done as if the student is looking down on the heart inside the chest. The sides refer to the sides of the person's/animal's body.

Q2 **a** Coronary arteries and veins are very hard to distinguish as they lie alongside each other.

b They supply blood to the heart muscle.

5 Running water through the heart will only be successful if it is not damaged.

Q3 If water is run into the superior vena cava it will emerge through the pulmonary artery.

Q4 The water flowing into and out of the heart through the separate vessels shows that the heart is separated into two distinct halves internally.

Q5 The left ventricle has thicker walls. They need to generate a greater force to push blood around the body.

Q6 **a** The valve in the right ventricle is called the *tri*cuspid valve because it is composed of *three* triangular flaps.

b The valve in the left ventricle is called the *bi*cuspid valve because it is made up of *two* flaps.

Q7 The valves at the entrance to the aorta and the pulmonary artery are called semilunar because of their half-moon shape.

Q8 **a** The function of the atrioventricular valves is to prevent blood returning into the atria when the ventricles contract. The tendons stop the valves from inverting when blood pressure builds up in the ventricle.

b A small quantity of water poured into the heart through the artery should not run out through the veins due to the closing of the semilunar valves.

Q9 The relative difference in size between the atria and ventricles should be explained with respect to thickness of ventricle walls and their need to generate a greater force.

Q10 Valves in veins prevent any backflow that might occur. However, there are no valves at the openings to the vena cava and pulmonary vein. When the atria contract, blood is forced downwards into the ventricles; blood is not pushed back out along the veins so there is no need for valves.

Q11 Safety precautions: washing hands; care with sharp instruments; careful and safe disposal of the heart; thorough cleaning of apparatus; disinfection of bench; washing hands at end of practical.

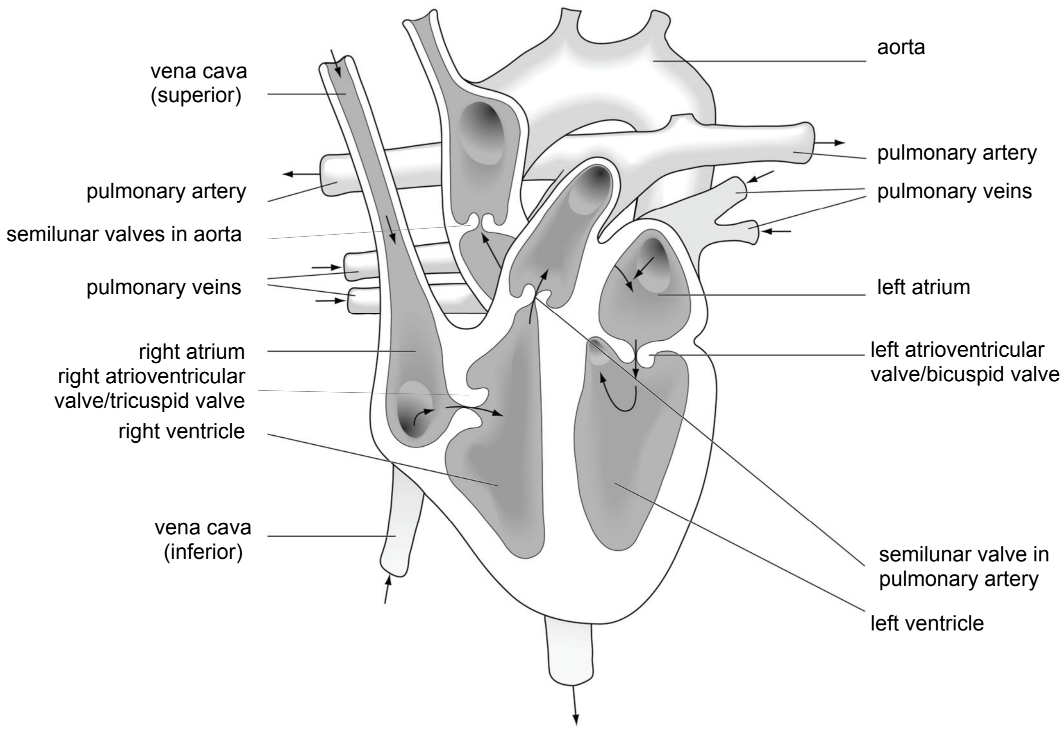


Figure 1 Vertical section of the heart showing direction of blood flow.

STRUCTURE OF THE HEART (DISSECTION)

Purpose

- To revise knowledge of the structure of the heart.
- To relate heart structure to function.
- To locate and compare the structure of the main arteries leaving the heart with the main veins entering the heart.
- To observe the coronary arteries.
- To develop practical dissection skills.

SAFETY

You should wash your hands after handling the hearts. Hands should be washed before leaving the lab.

Work surfaces should be disinfected after the practical with 1% Virkon™ and dissecting instruments should be washed and autoclaved to make sure all organic matter is removed.

See CLEAPSS Guidance leaflets G267 and G268 for further details.

See CLEAPSS Guidance Notes G14 for details on laboratory water supplies.

Requirements per student or group of students	Notes
Heart	A cow's or pig's heart is the best size for viewing detail, but use of lambs' hearts presents the fewest religious or cultural issues. Ask the butcher to leave the heart intact otherwise he/she may cut through the wall when removing it. Ask for the hearts to be removed with as much of the blood vessels attached as possible. A 'pluck' (heart and lungs removed together) is best for obtaining blood vessels. Make it clear that you do not want the liver, as this should reduce the price dramatically. After using the heart in this dissection, the vessels should be kept for use in the arteries and veins activity (1.6). They can be frozen. The rest of the hearts should be wrapped in an opaque plastic bag and disposed of as normal waste.
Dissecting board or tray	Enamel trays are fine; they can be lined with paper towels to make them less 'slippy and drippy'.
Dissecting instruments	Scissors (often the best for cutting open the heart), seekers and forceps.
Clamp to seal blood vessel	This can be any suitable clip to hold the vein closed.
Disinfectant	For cleaning benches. 1% Virkon™ can be used for general disinfection. Allow 10 minutes disinfection time. (NB: Virkon™ is not recommended for soaking metal instruments – they should be autoclaved.)
Cloth	For cleaning benches.
Soap and paper towels	For washing hands.
Access to a sink	Ensure the laboratory water supply has backflow preventing valves (see CLEAPSS G14 for details). If not, use a large beaker of water poured through a funnel and rubber tube.
Rubber tube	This needs to be attached to the water supply so that water can be run gently through the heart. A washing-up bowl may be useful if sinks are small.

Safety checked, but not trialled by CLEAPSS. Users may need to adapt the risk assessment information to local circumstances.

STRUCTURE OF THE HEART (SIMULATED DISSECTION)

Purpose

- To revise knowledge of the structure of the heart.
- To relate heart structure to function.
- To locate and compare the structure of the main arteries leaving the heart with the main veins entering the heart.
- To observe the coronary arteries.

Procedure

Complete the activity by referring to diagrams and photographs in textbooks, and the animation that accompanies this activity. There are also some useful websites in the weblinks for this activity.

1 Draw a sketch of the external features of the heart viewed from the front (ventral) side. The two thicker-walled vessels are the arteries; they leave the heart at the front (ventral) side. The thinner-walled veins enter the heart at the top of the back (dorsal) side. You should draw and label the following features: atria, ventricles, aorta, pulmonary artery and coronary arteries.

2 Label the vertical section diagram of the heart in Figure 1. Add arrows to show the route of blood flow through the heart.

Questions

Q1 Why are the right and left sides apparently on the wrong side?

Q2 What are the functions of the coronary arteries and veins?

Q3 If water were poured into the vena cava, through which vessel would it emerge from the heart?

Q4 What does this tell us about the internal structure of the heart?

Q5 Which ventricle has thicker walls?

Q6 Suggest why the walls of the left and right ventricles are of different thicknesses.

Q7 Why is the atrioventricular valve in the right ventricle called the tricuspid valve and the atrioventricular valve in the left ventricle called the bicuspid valve?

Q8 What is the function of the atrioventricular valves?

Q9 Why are the valves at the entrance to the aorta and pulmonary artery called semilunar?

Q10 What is the function of the tendons that connect the atrioventricular valves and the ventricle walls?

Safety checked, but not trialled by CLEAPSS. Users may need to adapt the risk assessment information to local circumstances.

Vertical section of the heart

Label the diagram. Add arrows to show the route of blood flow through the heart.

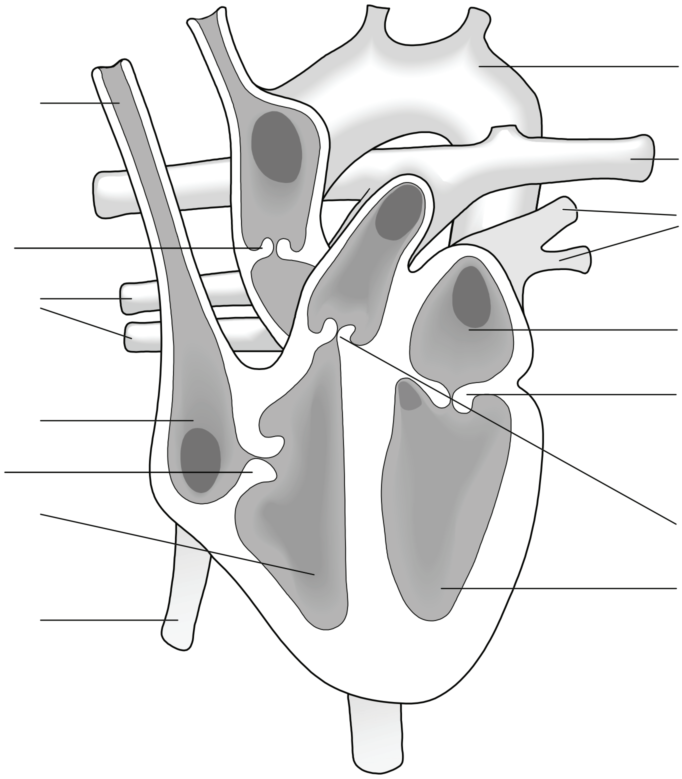


Figure 1 Vertical section of the heart.

STRUCTURE OF THE HEART (SIMULATED DISSECTION)

Purpose

- To revise knowledge of the structure of the heart.
- To relate heart structure to function.
- To locate and compare the structure of the main arteries leaving the heart with the main veins entering the heart.
- To observe the coronary arteries.

The simulation can be used in preparing for the real dissection or as an alternative to the dissection.

Notes on the procedure

1 The sketch should be similar to the one that appears on the Student Sheet of Activity 1.4.

2 The diagram in the Student Book (page 9) and Figure 1 in the Teacher Sheet of Activity 1.4 show the labels and blood-flow arrows needed to complete the heart diagram.

Answers

Q1 The right and left side of the heart appear to be on the wrong side because the diagram is drawn from the perspective of the person whose heart it is, not from the point of view of a spectator looking at the front of the person whose heart it is.

Q2 The coronary arteries and veins supply blood to the heart muscle.

Q3 If water is poured into the vena cava it will emerge from the pulmonary artery.

Q4 The heart is separated internally into distinct halves.

Q5 The left ventricle has thicker walls.

Q6 The left ventricle walls are thicker because they need to generate a greater force to push blood around the body. The right ventricle walls only pump blood to the lungs, so the walls need to generate a relatively smaller force.

Q7 The *tri*cuspid valve is composed of *three* triangular flaps. The *bi*cuspid valve has only *two* flaps.

Q8 The atrioventricular valves prevent blood returning into the atria when the ventricles contract.

Q9 The semilunar valves are formed of (three) half-moon-shaped flaps.

Q10 These tendons stop the atrioventricular valves from inverting when blood pressure builds up in the ventricles during ventricular contraction.

Safety checked, but not trialled by CLEAPSS. Users may need to adapt the risk assessment information to local circumstances.

INVESTIGATING ARTERIES AND VEINS

Purpose

- To investigate how the structures of blood vessels relate to their functions.
- To develop practical skills.

SAFETY
Wear eye protection and plastic aprons. Long sleeves should be rolled up to prevent contamination.
Benches should be thoroughly cleaned with 1% Virkon™ or other suitable disinfectant.
Wash your hands after handling tissue once cleaning is finished. Hands should be washed before leaving the lab.
Place a tray under any suspended masses in case the blood vessel snaps.
Be aware of the danger of using microscopes where direct sunlight may strike the mirror.

YOU NEED	
• Ring of artery and vein • Mass carrier • 5 × 10 g masses • Hook • Clamp stand, boss and clamp • Metre rule • Graph paper	• Prepared slide of artery and vein transverse section (T.S.) • Prepared slide of lung or thyroid gland T.S. to show capillaries • Microscope • Histology book for microscope images and notes • Drawing paper

Procedure

Before you start the practical work:

- read the practical instructions carefully
- identify the dependent and independent variables, and any others that might need to be controlled or taken into account
- draw up a table in which to record your results.

A good table of results should have:

- an informative title
- the first column containing the independent variable (the factor that is varied by the experimenter; in this experiment it is the mass)
- the second and subsequent columns containing the dependent variables. (The value of the dependent variable *depends* on the value of the independent variable. In this case, the length of the ring depends on how much mass is added, so ring length is the dependent variable.)
- informative column headings; each column should have a descriptive heading
- units in the heading, not next to the numerical data in the table.
- results recorded with appropriate precision, for example, if the ruler you are using to measure lengths in this experiment has mm divisions you can probably measure to 0.5 mm, but no less, so when recording a length of eleven millimetres you would enter 11.0 in the table; the measurement uncertainty is ±0.5 mm.

Additional columns can be added to include calculations based on raw data such as percentage change in length, etc. Now follow the instructions, carrying out the practical in a safe and well-organised manner.

Part A: Elastic recoil in arteries and veins

1 Suspend a ring of artery from a hook on a clamp stand. Use a metre rule to record the length of the ring once the mass carrier has been attached to the free end of the ring.

2 Attach a 10 g mass (see Figure 1) and record the length of the ring after the mass is added.

3 Remove the mass and record the length of the ring.

4 Repeat steps 2 and 3 using 20, 30, 40 and 50 g masses. Record the length with and without the masses each time.

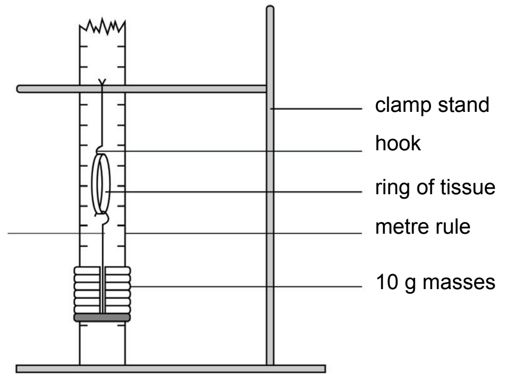


Figure 1 Measuring the length of the ring.

Part B: Histology of blood vessels

5 Examine slides of artery and vein. Identify the three main regions of the vessel wall, and the tissues in these regions:

a external, middle and inner layers of tissue

b elastic and collagen fibres

c smooth muscle.

6 Use an eyepiece graticule to measure the thickness of the walls of the artery and the vein. For more detail on how to use a microscope and how to measure using an eyepiece graticule read Practical Skills Support Sheet 8 – using a microscope and Sheet 9 – size and scale.

7 Sketch a plan of a cross-section across both vessels to show the amount and distribution of each type of tissue. See Practical Skills Support Sheet 8 for guidance on biological drawing.

8 Annotate the sketch with notes on the three regions and other features of the vessel, for example, thickness of wall, tissues in the three regions.

9 Using H.P. (high power) examine a capillary in a section of an organ, for example, lung or thyroid. Measure the average diameter of a capillary.

Analysis and interpretation of data

1 Calculate percentage change in length:

$$\% \text{ change in length} = \frac{(\text{new length - original length})}{\text{original length}}$$

2 Enter all your results into an appropriate table.

3 Plot two appropriate graphs, one for artery and one for vein. Remember that the most appropriate type of graph should be chosen to represent data, for example, bar chart, pie chart, histogram or line graph.

A **bar chart** is used when the independent variable is non-numerical or discontinuous, for example, the different stages of mitosis.

A **pie chart** can be used to display data that are proportions or percentages.

A **histogram** is used when the independent variable is numerical and the data are continuous, but classified into groups, for example, mass in kg, which is divided into classes, such as 41–50 kg, 51–60 kg, etc. There are no gaps between the bars of a histogram and the area of the bar represents the frequency.

A **line graph** can be used to show relationships in data that are not immediately obvious from tables. Both the dependent and independent variables are continuous. The independent variable normally goes on the *x*-axis.

Remember to include:

- an informative title
- sensible scales on each axis, if appropriate
- labels on both axes
- units on both axes, if appropriate
- a key.

(For more detail on presenting data see Cadogan A. (ed.) (2000) *Biological Nomenclature: Standard terms and expressions used in the teaching of biology*, 3rd edition. London: Institute of Biology.)

In this experiment plot percentage change in length against mass.

Values for adding and removing masses should be plotted on the same graph. (You could colour-code the points to show which are adding and which removing masses.)

4 Identify any trends or patterns in your data. Think about answering the following question: how do the results for artery and vein compare when looking at percentage change in length on loading, and return to the original length on unloading?

Conclusion

Bearing in mind the purpose of this practical work – to investigate how the structures of blood vessels relate to their function – state a conclusion to your work: this should summarise what you have found out. You should explain any trends or patterns in the data, supporting your ideas with evidence from the data and your biological knowledge of the structure of arteries and veins.

Evaluation

1 If you made changes to the method provided, describe them and explain the reasons for the alterations.

2 Comment on any safety issues that you had to consider when performing this experiment.

3 Describe any systematic or random errors you noticed when completing the practical work.

4 Comment on the validity of the experimental design and of your conclusion. An experimental design is valid if the procedure used is suitable for the investigation being undertaken, measures what is supposed to be measured and allows one to answer any question being asked.
A conclusion is valid if it is supported by data obtained from a valid experimental design, and it is based on sound scientific reasoning.

INVESTIGATING ARTERIES AND VEINS

Purpose

- To investigate how the structures of blood vessels relate to their functions.
- To develop practical skills.

SAFETY

Ensure eye protection is worn while vessels are being stretched.

All organic material should be collected for disposal. All equipment should be cleaned thoroughly with detergent.

Benches where fresh biological material has been handled should be thoroughly cleaned with 1% Virkon™ or other suitable disinfectant.

Hands should be washed before leaving the lab.

Be aware of the danger of using microscopes where direct sunlight may strike the mirror.

Demonstrate how to insert the slide correctly onto the stage. Ramming the slide may produce glass shards.

Notes on the procedure

This activity has two parts. In Part A students stretch blood vessels to compare their elasticity. In Part B they look at the histology of blood vessels. Part B could be completed in advance of the practical work on elastic recoil so students can draw on this understanding when analysing the results of the experiment.

Part A: Elastic recoil in arteries and veins

In the procedure on the Student Sheet there is no instruction as to the cutting of the rings. It is assumed that the rings will have been cut in advance. If this is not the case students may need to be reminded that the rings of arteries and veins should be cut to the same width (about 2 mm).

If veins are not available, students could complete the investigation using an artery and then compare their results with the sample ones shown below. These results are for rings of a vein approximately 2 mm in width, so rings of artery the same length should be used to allow valid comparisons.

Mass/g	Length of vein/mm	
	Vein 1 with mass	Vein 1 without mass
0 (original length)		21
10	36	36
20	38	37
30	40	39
40	41	39
50	41	41

Part B: Histology of blood vessels

Instead of making the sketches, students could use images of blood vessels downloaded from the website, or captured themselves using video-cam. They could paste these into a word document, then label and annotate using lines and textboxes.

For help on this see the Digital Capture Tutorial in ICT Support.

Guidance on the use of the eyepiece graticule for measuring can be found in Practical Skills Support Sheet 9 – size and scale.

Notes

Analysis and interpretation of data

Students should calculate the percentage change in length and present all the results in a suitable table.

The most suitable graph for this practical work is a line graph plotting percentage change in length against mass.

Students should describe any trends or patterns, with supporting data. The artery is expected to show a greater percentage increase in length than the vein. The artery should return closer to the original length than the vein.

Conclusion

Students need to explain any trends or patterns using biological knowledge, for example, 'The artery has a greater proportion of elastic tissue in its walls, so would be expected to be more extensible and more elastic than the vein, which has a greater proportion of collagen'.

This should link structure and properties of arteries and veins with their function. Arteries are stretched during systole. During diastole, the walls recoil, helping to smooth the flow of blood through the vessel. There is no pulse in the venous system, therefore veins do not extend and recoil as blood enters them. Contraction of skeletal muscles assists in movement of blood through veins.

Evaluation

Any changes or additions to the method provided need to be explained with an appropriate reason, for example, use of finer scale ruler to increase precision, or eye level when recording to avoid a systematic error.

Relevant safety comments would include: hand-washing after handling tissue, disinfection of equipment and bench, care with suspended masses.

There is not really a clear question to address or hypothesis to test so assessing the validity of the experimental design should highlight this flaw. At this stage of the course one might decide to structure the write-up as a series of questions to guide students more directly to the areas of interest.

Questions might be

Q1 How do the results for artery and vein compare when looking at:

- **a** percentage change in length on loading?
- **b** return to the original length on unloading?

Q2 What are the main properties of:

- **a** elastic fibres?
- **b** collagen?

Q3 Explain any trends or patterns in the data, supporting your ideas with evidence from the data and your biological knowledge of the histology of arteries and veins.

Q4 Explain how the properties of arteries and veins that you have investigated link to the functions of arteries and veins in the body.

Q5 Comment on any safety issues that should be considered when performing this experiment.

Q6 Suggest modifications to the experimental procedure that would ensure that more valid results are produced. Remember that valid results are produced with apparatus and experimental procedures that are suitable for the task.

Answers would be:

Q1 **a** The artery is expected to show a greater percentage increase in length than the vein.

b The artery should return closer to the original length than the vein.

Q2 **a** Elastic and extensible.

b Inelastic and inextensible.

Q3 Describe any trend or pattern, support with data and explain using biological knowledge, for example, 'The artery has a greater proportion of elastic tissue in its walls, so would be expected to be more extensible and more elastic than the vein, which has a greater proportion of collagen'.

Q4 Arteries are stretched during systole. During diastole, the walls recoil, helping to smooth the flow of blood through the vessel. There is no pulse in the venous system. Veins do not extend as blood enters them.

Q5 Relevant comments would include: hand-washing after handling tissue, disinfection of equipment and bench, care with suspended masses.

Q6 Any comments about repeating measurements and appropriate modifications to improve precision and validity, for example, use of finer scale rulers, use of calipers, eye level when recording.

INVESTIGATING ARTERIES AND VEINS

Purpose

- To investigate how the structures of blood vessels relate to their functions.
- To develop practical skills.

This activity has two parts. In part A students stretch blood vessels (a piece of artery and a piece of vein) and measure how elastic they are. In part B they look at the histology of the blood vessels using a microscope.

SAFETY
Eye protection should be used in case of 'flyback' from bits of animal tissue when the tissue breaks. Place a tray under the suspended masses. *You should wash your hands after handling the sections of blood vessels. Hands should be washed before leaving the lab.* *Work surfaces should be disinfected after the practical with 1% Virkon™.* *All apparatus should be thoroughly cleaned with detergent ensuring all organic material is completely removed.* *Do not soak metal instruments in Virkon™.* *Wrap all organic matter together and dispose of as normal food waste. Store in freezer/refrigerator until the day of disposal.* *Ensure students are aware of the danger of using microscopes where direct sunlight may strike the mirror.*

Part A: Elastic recoil in arteries and veins

Requirements per student or group of students	Notes
Rings cut from aorta and vein (1 of each)	Rings cut during the heart dissection practical can be frozen for this investigation. Rings from arteries and veins should be cut to be the same width (e.g. 2 mm). A 'pluck' (heart and lungs removed together) is best for obtaining blood vessels.
Hook suspended on cotton thread	Hooks can be made from paperclips or piano wire. Check that the cotton is not stretchy too.
Mass carrier and five 10 g and five 50 g masses	The mass needed varies. Some centres report that a total mass of up to 300 g has to be used.
Clamp stand, boss and clamp	
Metre rule	
Disinfectant and cloths for wiping down benches	Use 1% Virkon™ or suitable alternative.
Soap and (paper) towels for washing hands	
Graph paper	
Calculator	A few spares per class (students should bring their own).
Eye protection	

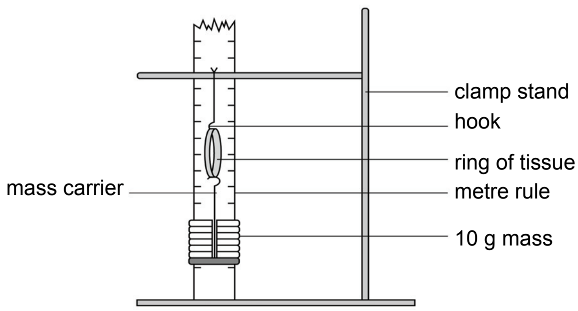


Figure 1 Measuring the length of the ring.

Part B: Histology of blood vessels

Requirements per student or group of students	Notes
Prepared slides of artery and vein T.S.	
Prepared slides of lung or thyroid gland T.S. to show capillaries	
Microscope	Microscopes with high power lenses are needed.
Lamp if not built into microscope	
Eyepiece graticule	
Stage micrometer	
Histology book	
Drawing paper	
Pencils	

Notes

HARVEY'S CIRCULATION EXPERIMENTS

Purpose

- To demonstrate the function of valves in veins.

Perform Harvey's experiment

In 1603, Hieronymous Fabricus (1537–1619), an Italian professor of anatomy and surgery, was the first to publish a description of the valves in veins, although he was uncertain as to their function. The English anatomist, William Harvey, one of Fabricus's medical students, completed some simple experiments to solve the puzzle and demonstrate circulation. Harvey's book, '*De Motu Cordis*' (Concerning the Motion of the Heart and Blood), published in 1628, described the experiments, which you can perform for yourself or get a friend to help.

The experiments

- Allow your hand to hang downwards below waist level until the veins on the back of the hand stand out.
- Press hard on a vein close to your knuckle.
- Keep pressing and at the same time with another finger, push along the vein towards your wrist. You will see the vein seems to disappear.
- Lift the second finger and observe what happens. Sometimes you have to repeat several times pushing further up towards the wrist to see the effect that Harvey will have observed.
- Now lift your first finger and see what happens.

Explain how the results of this experiment provided evidence supporting Harvey's idea that veins contain one-way valves. You could use the questions below to help you structure your answer.

Q1 What will pressing the vein close to your knuckle do to blood in the vein?

Q2 What does pushing along the length of the vein do to blood in the vein?

Q3 What did you observe happen when you removed your second finger from the vein?

Q4 What can you conclude from this observation?

Q5 What happened when you lifted your first finger?

More evidence

⚠ **DO NOT do this experiment yourself**

Figure 1 is similar to the one in Harvey's book. He pressed the vein at point H to block the flow from the wrist. He pushed the blood out of the vein to point O, then he tried to force the blood back along the vein; a swelling occurred at point K in the vein.

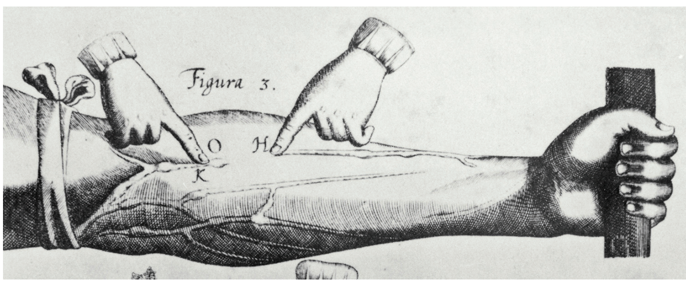


Figure 1 Illustration of Harvey's experiment from his book on the motion of the heart and blood.

Q6 What did he conclude from this observation?

HARVEY'S CIRCULATION EXPERIMENTS

Purpose

- To demonstrate the function of valves in veins.

Perform Harvey's experiment

The simple experiment described is based on the one completed by William Harvey, which demonstrated that veins contain one-way valves. It can be completed by students individually although working in pairs will make it easier. Boys have less subcutaneous fat so the effect is often more obvious in them.

The original Harvey diagram included a ligature around the upper arm: this use of a ligature on the arm must **not** be attempted by students.

An additional question could be set as outlined below. It is omitted from the Student Sheet due to space constraints and its somewhat gruesome nature.

Additional question

In another experiment operating on a live snake Harvey bound the vena cava and observed that the heart failed to fill with blood. He then bound the aorta and showed that the heart became engorged with blood as it was unable to escape.

Q7 What could Harvey conclude from these observations?

Answers

The explanation of evidence supporting Harvey's idea that veins contain one-way valves should include the answers to the questions.

Q1 Pressing the vein close to your knuckle stops the blood flowing along the vein back towards the wrist and arm.

Q2 Pushing along the length of the vein moves blood out of that section of the vein towards the wrist.

Q3 When you removed your second finger from the vein it does not refill.

Q4 Valves in the veins allow the movement of blood in one direction; they prevent back flow of blood along the vein.

Q5 On lifting your first finger, the vein refills with blood.

More evidence

⚠ **DO NOT do this experiment**

Q6 The blood is stopped by a valve and it cannot go any further so the swelling occurs as the blood collects in front of the valve.

Additional question

⚠ **DO NOT do this experiment**

Q7 Harvey could have made conclusions about the circulation of the blood, into the heart from the vena cava and out of the heart through the aorta.

Safety checked, but not trialled by CLEAPSS. Users may need to adapt the risk assessment information to local circumstances.

THE CARDIAC CYCLE

Purpose

- To describe the sequence of events in a single heartbeat, the cardiac cycle.

Use the section on the cardiac cycle in your Student Book or the interactive tutorial that accompanies this activity to help you complete this worksheet.

Procedure

1 Cut out the pictures from page 2 and stick these into the correct boxes on the right to match the order of descriptions below.

2 Complete the descriptions and make deletions as appropriate, i.e. when you are provided with two alternatives separated by a /.

3 Add arrows to each diagram to show blood flow.

Cardiac diastole

During diastole blood flows into the atria from the ______________ ______________ and ______________ ______________. Elastic recoil of the atrial walls generates low pressure in the atria, helping to draw blood into the heart.

Initially the atrioventricular valves are open/closed.

As the ventricles begin to relax, blood tends to fall back from the aorta and pulmonary artery causing the ______________________ valves to close. This causes the second heart sound 'dub'.

Atrial systole

As the atria fill with blood, the pressure in the atria increases/decreases, the atrioventricular valves are pushed open and blood flows into the relaxing ventricles. The two atria contract simultaneously, forcing the remaining blood into the ventricles.

Ventricular systole

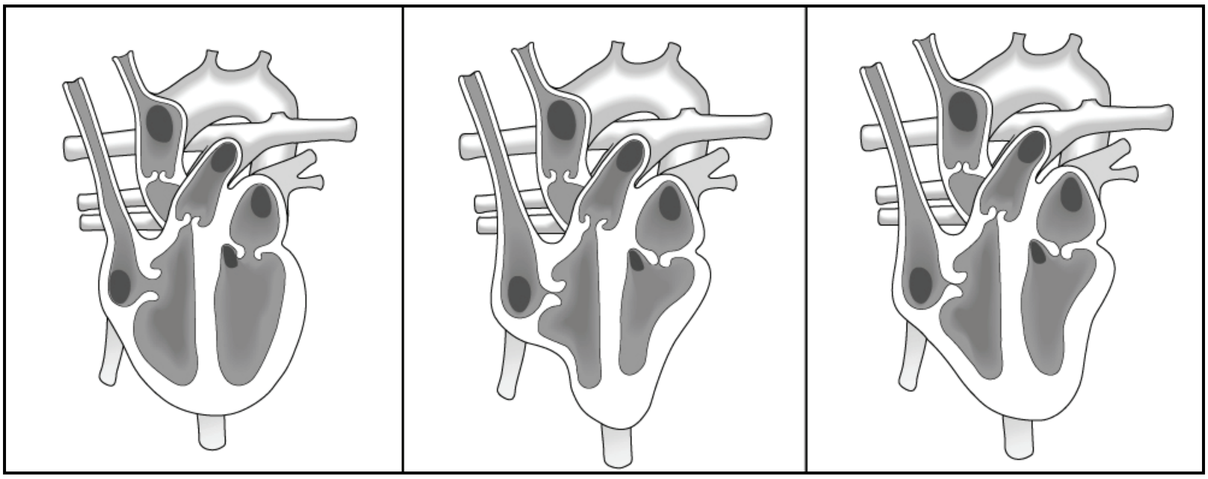
After a slight delay, the ventricles contract. This increases/decreases the pressure in the ventricles so the atrioventricular valves open/close. This causes the first heart sound 'lub'.

Blood is forced into the ________________ and ________________.

The semilunar valves are open/closed.

Blood begins to flow into the relaxing ________________.

Safety checked, but not trialled by CLEAPSS. Users may need to adapt the risk assessment information to local circumstances.



THE CARDIAC CYCLE

Purpose

- To describe the sequence of events in a single heartbeat, the cardiac cycle.

Notes on the procedure

Each student needs one strip of heart pictures to cut up. The Student Sheet has a single strip of pictures on page 2, and the Technician Sheet has a master with multiple strips for photocopying.

Cardiac diastole

During diastole blood flows into the atria from the *pulmonary veins* and *vena cava*. Elastic recoil of the atrial walls generates low pressure in the atria, helping to draw blood into the heart.

Initially the atrioventricular valves are *closed*.

As the ventricles begin to relax, blood tends to fall back from the aorta and pulmonary artery causing the *semilunar* valves to close. This causes the second heart sound 'dub'.

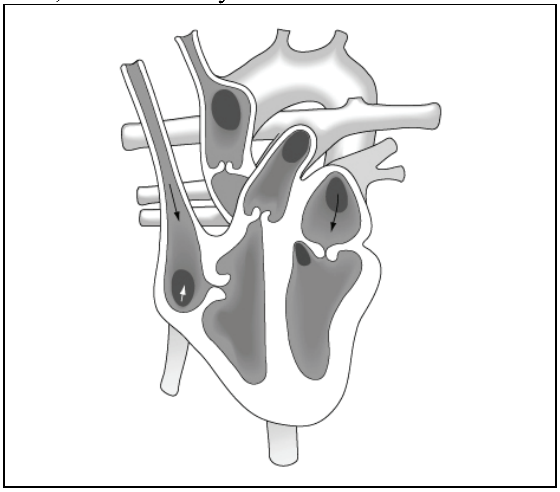


Figure 1 Cardiac diastole.

Atrial systole

As the atria fill with blood, the pressure in the atria *increases*, the atrioventricular valves are pushed open and blood flows into the relaxing ventricles. The two atria contract simultaneously, forcing the remaining blood into the ventricles.

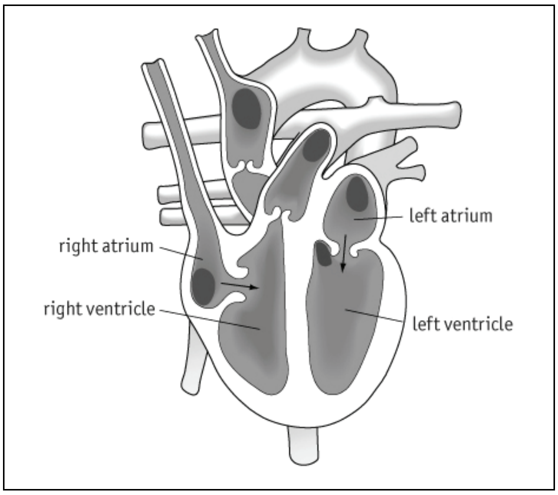


Figure 2 Atrial systole.

Ventricular systole

After a slight delay, the ventricles contract. This *increases* the pressure in the ventricles so the atrioventricular valves close. This causes the first heart sound 'lub'.

Blood is forced into the *aorta* and *pulmonary artery*. The semilunar valves are *open*.

Blood begins to flow into the relaxing *atria*.

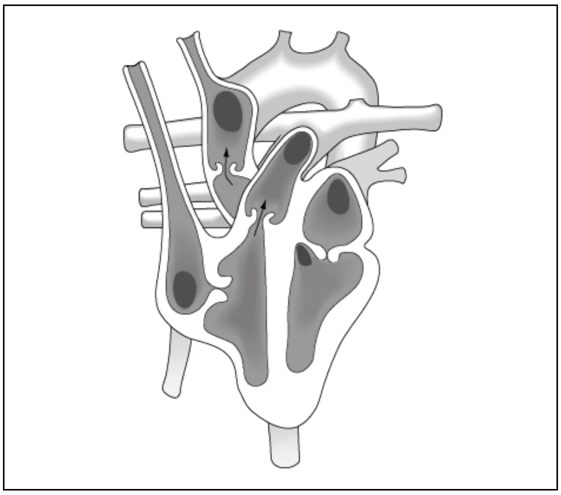


Figure 3 Ventricular systole.

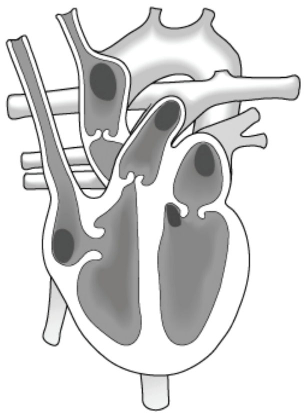
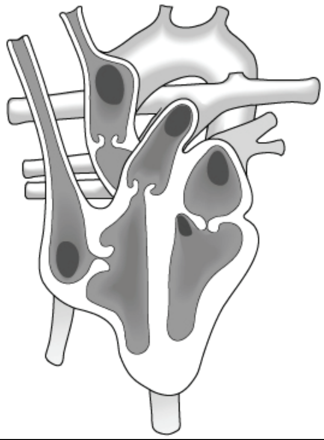
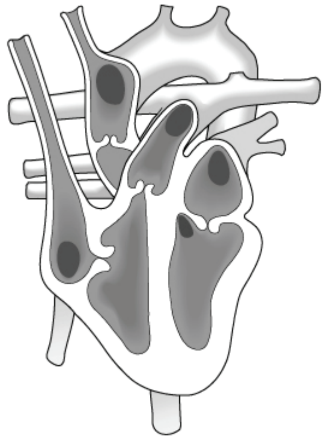
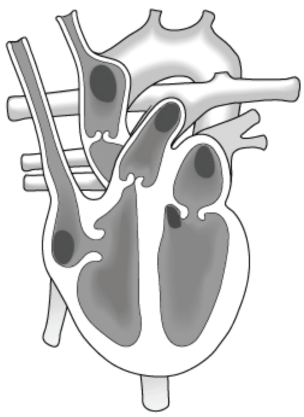
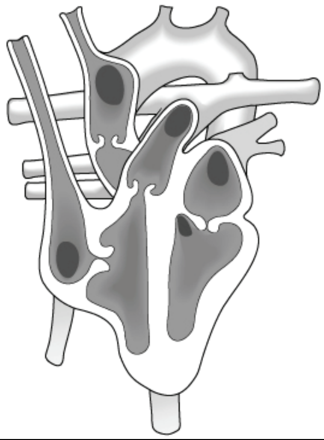
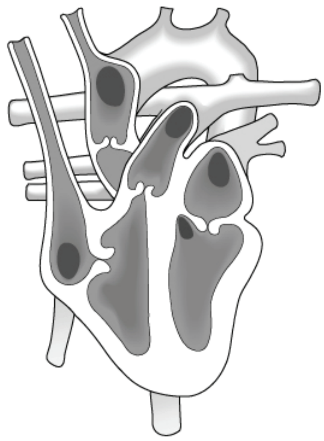
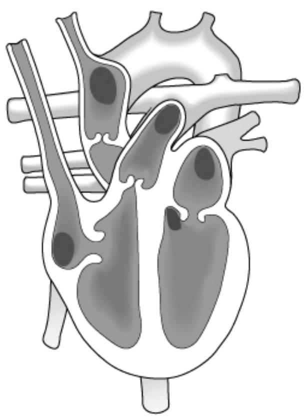
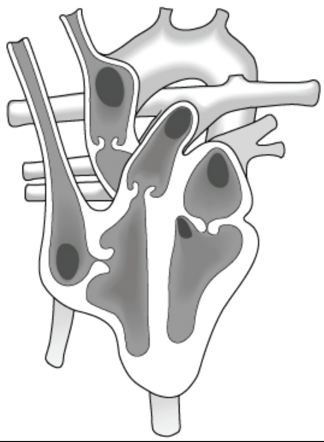
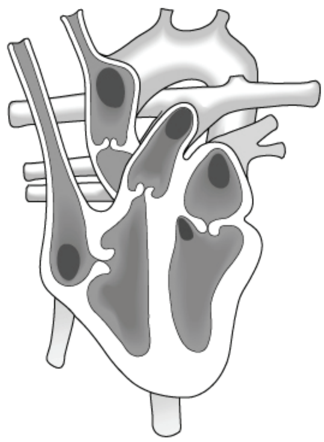
THE CARDIAC CYCLE

Purpose

- To describe the sequence of events in a single heart beat, the cardiac cycle.

This is a cut-and-stick exercise.

Requirements per student or group of students	Notes
Copy of the Student Sheet	
Strip of heart pictures	This is on a separate photocopiable sheet.
Pair of scissors	
Glue	

ATHEROSCLEROSIS

Purpose

- To explain the course of events that lead to atherosclerosis.
- To describe the blood-clotting process.

Effects of atherosclerosis

Atherosclerosis is the name given to the process that occurs within arteries, causing them to narrow. This can lead to coronary heart disease (CHD). A patient may only be aware that they have CHD when their blood flow is restricted, causing angina – pain associated with a lack of oxygen in the heart muscle. Ultimately, atherosclerosis can result in thrombosis – the blockage of an artery by a blood clot. If the blood supply to the heart muscle cells is stopped they are said to be ischaemic, i.e. without blood. The cells will die if they are starved of oxygen and nutrients for an extended period.

Procedure

Cut up the table below to make a set of cards with key words and phrases written on them. Sort the cards into a sequence that follows the events in the development of atherosclerosis and thrombosis. Using the key words and phrases, create a complete description, a flow chart or an annotated diagram of the processes of atherosclerosis and blood clotting.

1	Fibrin	13	Platelets in contact with damaged artery wall
2	Hard plaque forms	14	Artery narrows
3	Tangled mesh	15	Platelet plug forms
4	Large white cells enter wall	16	Rising blood pressure
5	Platelets become sticky	17	Artery wall damaged
6	Inflammatory response	18	Wall elasticity reduced
7	Thrombin	19	Atheroma forms
8	Cholesterol accumulates	20	Blood cells trapped
9	Prothrombin	21	Fibrinogen
10	Calcium salts and fibrous tissue accumulate	22	Atherosclerosis
11	Cascade of chemical changes	23	Thromboplastin released from platelets/damaged tissue
12	A blood clot forms		

ATHEROSCLEROSIS

Purpose

- To explain the course of events that lead to atherosclerosis.
- To describe the blood-clotting process.

Notes on the procedure

The key words and phrases are provided in a table with the Student Sheet. This can be used as a table or cut up to provide a set of cards. These are then sorted into the order of events that occur in the process of atherosclerosis and blood clotting. The Student Book could be used to help with this process or students could be encouraged to work out what is happening, using the cards, before checking in the textbook to see if they are correct. Once the sorting is completed, students can write a full description based on the cards, produce some sort of flow chart, or use the phrases as annotations on a diagram to represent the processes of atherosclerosis and blood clotting.

The correct order for the cards is shown below.

17	Artery wall damaged	5	Platelets become sticky
6	Inflammatory response	15	Platelet plug forms
4	Large white cells enter wall	23	Thromboplastin released from platelets/damaged tissue
8	Cholesterol accumulates	11	Cascade of chemical changes
19	Atheroma forms	9	Prothrombin
10	Calcium salts and fibrous tissue accumulate	7	Thrombin
2	Hard plaque forms	21	Fibrinogen
18	Wall elasticity reduced	1	Fibrin
14	Artery narrows	3	Tangled mesh
16	Raising blood pressure	20	Blood cells trapped
22	Atherosclerosis	12	A blood clot forms
13	Platelets in contact with damaged artery wall		

Safety checked, but not trialled by CLEAPSS. Users may need to adapt the risk assessment information to local circumstances.

ATHEROSCLEROSIS

Purpose

- To explain the course of events that lead to atherosclerosis.
- To describe the blood-clotting process.

Requirements per student or group of students	Notes
Set of key word cards	The master sheet can be photocopied onto card.
Scissors if cards not cut up in advance	

1	Fibrin	13	Platelets in contact with damaged artery wall
2	Hard plaque forms	14	Artery narrows
3	Tangled mesh	15	Platelet plug forms
4	Large white cells enter wall	16	Rising blood pressure
5	Platelets become sticky	17	Artery wall damaged
6	Inflammatory response	18	Wall elasticity reduced
7	Thrombin	19	Atheroma forms
8	Cholesterol accumulates	20	Blood cells trapped
9	Prothrombin	21	Fibrinogen
10	Calcium salts and fibrous tissue accumulate	22	Atherosclerosis
11	Cascade of chemical changes	23	Thromboplastin released from platelets/damaged tissue
12	A blood clot forms		

BLOOD FLOW

Purpose

- To describe what factors affect blood flow in arteries.
- To describe what has the greatest effect on blood flow.

What has the greatest effect on blood flow in arteries?

Blood flows through arteries due to a difference in pressure between one end of the vessel and the other end. High pressure is generated at one end of the artery by the action of the heart pumping blood. Blood entering the aorta is under pressure.

Flow in blood vessels or any tubes can be modelled using the equation:

$$F = \frac{P\pi r^4}{8l\eta}$$

P is pressure

r is radius

l is length

η is viscosity (η is the Greek letter Eta)

We are not going to do calculations of flow so don't panic: by just looking at the equation you can tell what factors determine flow rate, F.

What effect will these factors have on flow?

1 For each of the factors decide what impact an increase and a decrease will have on flow rate. Draw a table to summarise your suggestions, the first row of the table is shown below. Give a reason for each suggestion.

Thinking about the equation will help here, an increase in a factor that is on the top of the equation will result in an increase in flow, whereas an increase in a factor that is on the bottom of the equation will decrease the calculated value for flow.

Factor	Change in factor	Effect on flow increase/decrease	Reason for effect on flow
Pressure	Increase		
	Decrease		

2 Look at the equation and decide which factor you think will have the largest effect and give a reason for your choice.

If you double viscosity or length you half the flow, the number being used to divide in the equation has doubled. The effect of a change in radius is very different.

Blood flows through a vessel in layers, with the blood closest to the walls affected by friction. The width of the blood vessel will affect how much blood is slowed by this resistance.

Think about a vessel with a radius of 1 mm and a flow rate of 1 arbitrary unit.

If it dilates to a give a radius of 2 mm, flow would be affected by r^4, that is 2^4 or 16. Thus, doubling the radius of a blood vessel increases the flow by 16 times.

3 Use the ideas above to work out how much the flow will increase if the vessel dilates further to 3 mm.

4 What implications does the relationship between radius and flow have for the effects of atherosclerosis?

BLOOD FLOW

Purpose

- To describe what factors affect blood flow in arteries.
- To describe what has the greatest effect on blood flow.

What has the greatest effect on blood flow in arteries?

The aim of this activity is to get students thinking about blood flow in arteries and how the change in radius has a major impact when considering atherosclerosis. Blood flow is proportional to the fourth power of the radius, $F \propto r^4$. There are no calculations to be completed using the equation on the sheet; however, thinking about the equation allows students to estimate the impact of changing quantities in the mathematical equation. The Student Sheet guides this thinking.

What effect will these factors have on flow?

1 For each of the factors students decide what impact an increase and a decrease will have on flow rate and give a reason for each suggestion.

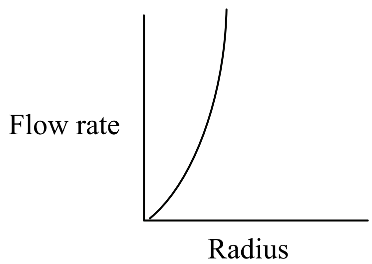
Factor	Change in factor	Effect on flow increase/decrease	Reason for effect on flow
pressure	increase	increase	Blood flow is due to a difference in pressure: if the difference is greater the flow rate will be faster and vice versa.
	decrease	decrease	
radius	increase	increase	Less blood is in contact with the wall so less friction to slow the blood and vice versa
	decrease	decrease	
length	increase	decrease	The longer a blood vessel the greater the resistance to flow and vice versa. However, the length of vessels does not change much *in vivo* so will have little impact.
	decrease	increase	
viscosity	increase	decrease	The less fluid (more viscous) the blood the higher the friction within the moving liquid and hence the slower the flow and vice versa.
	decrease	increase	

2 As explained on the Student Sheet it is change in radius that has the largest effect on flow.

3 If the blood vessel dilates to 3 mm the flow will increase by 3^4, that is 81 times faster.

4 The narrowing of a blood vessel due to atherosclerosis will have a very significant effect, reducing flow rate and hence supply of oxygen and nutrients to cells. A two-fold decrease in radius will decrease flow by 16-fold.

A graph of flow rate against radius would look something like this:



- a small change in radius will have a very significant impact on flow rate.

ESTIMATING RISK

Purpose

- To estimate risks and investigate people's perceptions of risk.
- To analyse and interpret quantitative data on illness and mortality rates.
- To distinguish between correlation and causation.

Estimating risks and analysing data

Q1 In the year 2012, there was a total of 499 331 deaths in England and Wales. Of these, 1754 were due to road accidents. For each of the causes of death in Table 1, estimate the number of deaths occurring in 2012. (Note that there are causes of death other than those listed here.)

Cause of death in England and Wales	Estimated number of deaths in 2012	Actual number of deaths in 2012
Accidental falls		
Appendicitis		
Asthma		
Cancer		
Diabetes		
Epilepsy		
Heart disease		
Huntington's disease		
Influenza		
Lightning strike		
Meningitis		
Murder		
Pregnancy		
Railway accidents		
Road accidents		

Table 1 Causes of death in England and Wales, 2012.

Disease	Incidence of disease in 2012 (new cases)	Number of deaths in 2012
All cancers	299 147	142 107
Lung cancer	38 273	30 273
Breast cancer	44 851	10 373
Prostate cancer	39 555	9 698
Chlamydia	99 086	–

Table 2 Incidence of disease and number of deaths in England and Wales, 2012.
(Source: Office for National Statistics, Health Protection Agency, and Public Health Wales.)

Q2 Your teacher/lecturer will provide you with the actual number of deaths that occurred in 2012 due to each of the causes in Table 1. The figures come from the Office of National Statistics. Compare your estimates with these figures. If there are discrepancies between your estimates and the official statistics, try to explain why you may have overestimated the risks.

Q3 It is not unusual for people to overestimate the risk of death from train accidents. Suggest reasons for this overestimation.

Q4 It is not unusual for people to underestimate the risk to their health of smoking. Suggest reasons for this underestimation.

Study the year 2012 incidence (number of new cases) and number of deaths data for England and Wales in Table 2 and then answer the questions below. The 2012 population of England and Wales was 56 567 800. The total number of deaths in England and Wales during the year 2012 was 499 331.

Q5 Calculate the percentage of total deaths in England and Wales in 2012 that resulted from each of the five categories of disease in Table 2. (Hint: The number of deaths due to a particular disease is divided by the total number of deaths for the year 2012 and multiplied by 100 to give a percentage. So the percentage of total deaths in the year 2012 due to all cancers is 142 107 ÷ 499 331 × 100.)

Q6 **a** Use the 2012 data to estimate the probability of an average person in England and Wales developing each of the diseases. Express your answers as 1 in ? values or as decimals. The population of England and Wales in 2012 was 56 567 800. (See section 1.2 in your Student Book, or Maths and Stats Support Sheet 8 – probability, if you need help in getting started with the calculations.)

When completing these calculations, think about the number of significant figures you use when presenting your answers. For information on significant figures see Maths and Stats Support Sheet 4 – significant figures.

b Use the 2012 data to estimate the probability of an average person dying from each of the diseases in any year.

c The probabilities you have calculated are for the population as a whole. Why is it that the probability for each individual will typically be very different?

Risk calculator

Risk calculator models provide scientists and other medical professionals with a useful tool to analyse information based on research data. The models can predict the interaction of biological factors and the impact of these factors on a range of disorders. Models can be used to support decisions involving interventions, for example, drug prescriptions, changes to lifestyle and dietary changes. There are many examples of risk calculators to be found on the Internet.

You can create your own coronary heart disease (CHD) risk calculator or use the one in the weblinks for this activity to compare risk factors for a certain patient with ‘normal range’ of risk. It will also show how CHD is influenced by the complex interaction of different factors. Full details of how to create your own risk predictor using a Microsoft Excel® spreadsheet are provided in the ICT Support section of the resources.

The data used to develop the risk calculator model were taken from the Framingham Heart Study, started in 1948 in the USA. For more details about this study see the Student Book page 22.

Using the risk calculator model

Use the information below and the risk calculator model to answer the questions.

PATIENT A
A 46 year old male
Height: 6 feet 0 inches
Cholesterol levels: LDL = 4.95 mmol l^{-1} (191 mg/dl), HDL = 1.2 mmol l^{-1} (46.33 mg/dl)
Blood pressure reading: systolic = 145, diastolic = 90
Diabetic
Smoker
No symptoms of CHD experienced.

Q7 What is the risk of patient A developing CHD over the next 10 years?

Q8 Use Table 3 to describe patient A's risk compared with that of a low risk and average risk man of the same age.

Q9 Suggest lifestyle changes that might help patient A to reduce his risk of developing CHD.

Q10 What are the two most significant risk factors for patient A?

Comparative risk		
Age (years)	**Average 10 year CHD risk (%)**	**Low* 10 year CHD risk (%)**
30–34	3	2
35–39	5	3
40–44	7	4
45–49	11	4
50–54	14	6
55–59	16	7
60–64	21	9
65–69	25	11
70–74	30	14

*Low risk was calculated for a man the same age, normal blood pressure, LDL cholesterol 100–129 mg/dl, HDL cholesterol 45 mg/dl, non-smoker, no diabetes.

Table 3 Risk values for an average man and a low risk man of the same age.