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B3. Form and function: Organisms / B3.2 Transport

The big picture

? Guiding question(s)

- What adaptations facilitate transport of fluids in animals and plants?
- What are the differences and similarities between transport in animals and plants?

Keep the guiding questions in mind as you learn the science in this subtopic. You will be ready to answer them at the end of this subtopic. The guiding questions require you to pull together your knowledge and skills from different sections, to see the bigger picture and to build your conceptual understanding.

With speeds of up to 120 km/h, the cheetah (*Acinonyx jubatus*) is the fastest land animal in the world (**Figure 1**). They are known for their specialised acceleration and agility, enabling them to chase, catch and kill their prey and evade predators such as lions, leopards and hyenas.

To maintain these periods of intense energy expenditure, the cheetah's transport system is specialised for delivering nutrients and removing waste products from respiring cells that produce the ATP necessary to maintain the cheetahs activity levels.

Figure 1. A cheetah (*Acinonyx jubatus*) chasing Thomson's gazelle (*Gazella thomsonii*), in Masai Mara.

Credit: James Warwick, Getty Images (https://www.gettyimages.com/detail/photo/cheetah-chasing-thomsons-gazelle-royalty-free-

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Similarly, the *Zea mays* plant, commonly known as maize, also needs to transport substances around its body (**Figure 2**). While the cheetah relies on a circulatory system of blood vessels and a specialised heart, maize has a vascular system that transports nutrients and water throughout the plant.

Figure 2. Maize (*Zea mays*).

Credit: Siegfried Layda, Getty Images (https://www.gettyimages.com/detail/photo/cornfield-in-the-evening-royalty-free-image/88043144)

Transport is a vital system in both animals and plants. But what adaptations facilitate the transport of fluids in plants and animals? And what are the differences and similarities between transport in animals and plants?

Prior learning

Before you study this subtopic make sure that you understand the following:

- The structure of membranes and how molecules are transported across membranes (see subtopic B2.1 (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43205/)).
- Movement of water and water potential (see subtopic D2.3 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43550/)).

Practical skills

Once you have completed this subtopic, you can gain skills on measuring and analysing heart rates by going to Practical 6: Investigating the effect of physical activity on heart rate (/study/app/bio/sid-422-cid-755105/book/investigating-the-effect-of-physical-activity-id-46705/).

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Blood vessels

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B3.2.1: Adaptations of capillaries B3.2.2: Structure of arteries and veins B3.2.3: Adaptations of arteries B3.2.4: Measurement of pulse rates B3.2.5: Adaptations of veins B3.2.6: Occlusion of the coronary arteries

Learning outcomes

By the end of this section you should be able to:

- Describe the structures of the arteries, capillaries and veins and explain how they are adapted for their functions.
- Outline different methods of measuring pulse rate.
- Outline the causes and consequences of occlusion of the coronary arteries.

Structure and adaptation of blood vessels

Arteries, capillaries and veins are three types of blood vessels in our circulatory systems. Each type of blood vessel is adapted to perform a particular function:

- arteries transport blood away from the heart under high pressures
- capillaries facilitate the exchange of substances between the blood and the internal or external environment
- veins return blood to the heart.

How are the structures of these vessels related to their functions?

Capillaries

Capillaries are small, thin-walled blood vessels adapted to exchange materials between the blood and the internal environment or external environment. An example of exchange with the internal environment are capillaries that supply oxygen and nutrients like glucose to respiring cells and remove waste products like carbon dioxide and excess water. An example of exchange between capillaries and the external environment is the exchange of carbon dioxide and oxygen with air in the lungs (see section B3.1.1–4 (/study/app/bio/sid-422-cid-755105/book/gas-exchange-as-a-vital-function-id-44438/) for adaptations of mammalian lungs for gas exchange).

In some cases, the exchange of substances is one-way, such as in the small intestine, where capillaries are specialised to absorb nutrients from the intestinal lumen into the blood, but not for the exchange of materials back into the intestine.

Capillaries are the smallest blood vessel, measuring around 5–10 µm in diameter and they are highly branched. This creates a very large surface area-to-volume ratio across which substances can be exchanged, and slows the flow of blood in the capillaries, allowing more time for exchange of substances. See section B2.3.6 (/study/app/bio/sid-422-cid-755105/book/cell-adaptations-hl-id-44445/) for a reminder of surface area-to-volume ratios.

The wall of the capillary is one cell thick, being composed of thin and flattened endothelial cells. As a result, there is a very short diffusion distance, allowing for rapid diffusion across the capillary wall. Surrounding the endothelial cells is the basement membrane. The basement membrane is a thin layer of extracellular matrix that provides structural support to the endothelium and regulates the exchange of material.

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Most capillaries are continuous, with a complete endothelial lining. Continuous capillaries are found in most tissues including muscle, lung and skin, and they allow for selective exchange of small molecules and ions.

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Other types of capillaries, such as those found in the glomerulus of the kidneys (see section D3.3.8 (/study/app/bio/sid-422-cid-755105/book/osmoregulation-hl-id-44810/)), are fenestrated. Fenestrations are gaps in endothelial cells which allow for more rapid exchange of fluids and solutes between the blood and surrounding tissues (**Figure 1**). Fenestrated capillaries are found in organs with high metabolic demands, such as the kidneys, endocrine glands and small intestine.

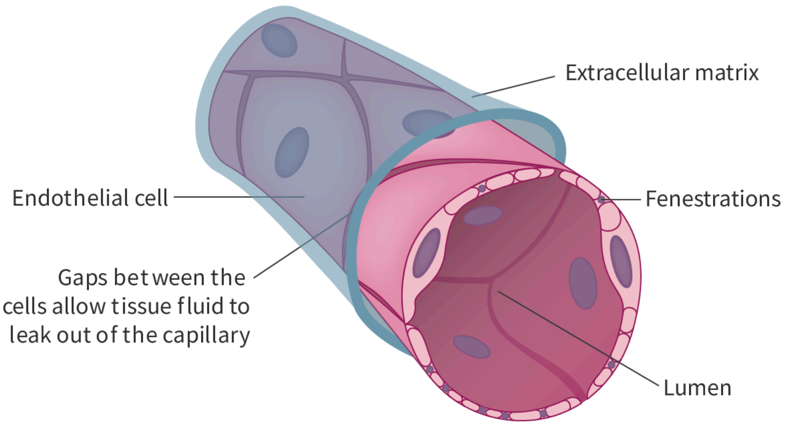

Figure 1. The structure of a fenestrated capillary.

More information for figure 1

The image is a detailed diagram of a fenestrated capillary, a type of blood vessel with tiny pores. The capillary is shown in a cylindrical shape with several labeled components. The outermost label is "Extracellular matrix," indicating the supportive structure surrounding the capillary. "Endothelial cell" is labeled on the pink inner lining of the cylinder, which forms the wall of the capillary. Inside the wall, "Fenestrations," or small pores, are labeled, highlighting the unique characteristic of this type of capillary. The label "Lumen" points to the hollow interior of the capillary where blood flows. A special note reads, "Gaps between the cells allow tissue fluid to leak out of the capillary," pointing to the function of the fenestrations that facilitate the exchange of fluids and solutes between blood and surrounding tissues.

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Arteries

Arteries are adapted to transport blood away from the heart at high pressures. The main artery in our body is called the aorta, which is adapted to receive between 60 and 80 millilitres of blood that is forced out of the left ventricle with every contraction of the heart. The aorta branches into smaller arteries that transport blood to all the body tissues, which in turn branch into smaller arteries called arterioles. Arterioles connect to capillaries, where exchange of substances occurs.

Elastin in the walls of the arteries stretches to accommodate the increased volume of the blood as the heart contracts. The elastic walls then recoil as the heart relaxes, pushing blood forward. The elasticity also reduces fluctuations in blood pressure caused by the pulsating flow of blood as it is pumped from the heart. This reduces the risk of damage to smaller blood vessels caused by high blood pressures.

The wall of the artery also contains a layer of smooth muscle (**Figure 2**) which regulates the diameter of the artery and blood flow by contracting or relaxing in response to various signals, such as changes in blood pressure or hormones such as adrenaline. When the smooth muscle contracts, the diameter of the lumen of the artery decreases (vasoconstriction), causing an increase in blood pressure. When the smooth muscle relaxes, the diameter of the lumen of the artery increases (vasodilation), causing a decrease in blood pressure.

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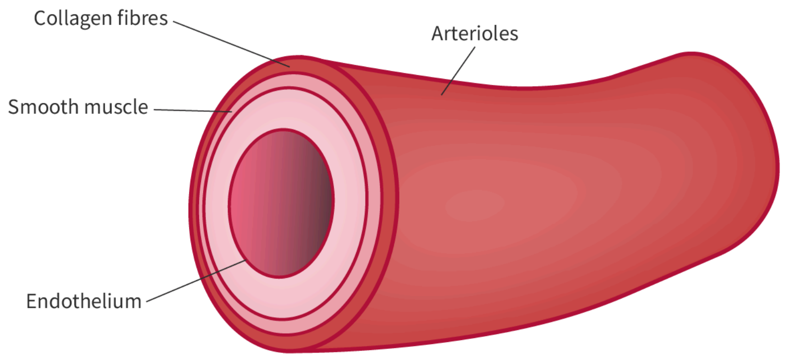

Figure 2. The structure of an artery.

More information for figure 2

The diagram illustrates the structure of an artery, depicting a cross-sectional view. It shows several concentric layers, each labeled. Starting from the inside, the innermost layer is labeled 'Endothelium.' Surrounding this is a thicker layer labeled 'Smooth muscle,' indicating the muscular component responsible for vasoconstriction and vasodilation. The next layer is marked 'Collagen fibres,' which provide strength and elasticity. Additionally, there is a label pointing to 'Arterioles,' which are small branches of arteries that lead to capillaries. This diagram visually represents how these layers are structured and their relative positions in an artery.

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The wall of the artery can be classified in three main layers (**Figure 3**):

- The innermost layer, which is in contact with the blood is called the tunica intima and contains the endothelium layer, which creates a smooth, friction-reducing lining.
- The middle layer is called the tunica media. It is made of smooth muscle cells and elastic fibres. It is usually the thickest of the three layers.
- The outermost layer is called the tunica adventitia, or the tunica externa. It consists mostly of collagen fibres and some elastic fibres that protect the artery and anchor it to surrounding structures.

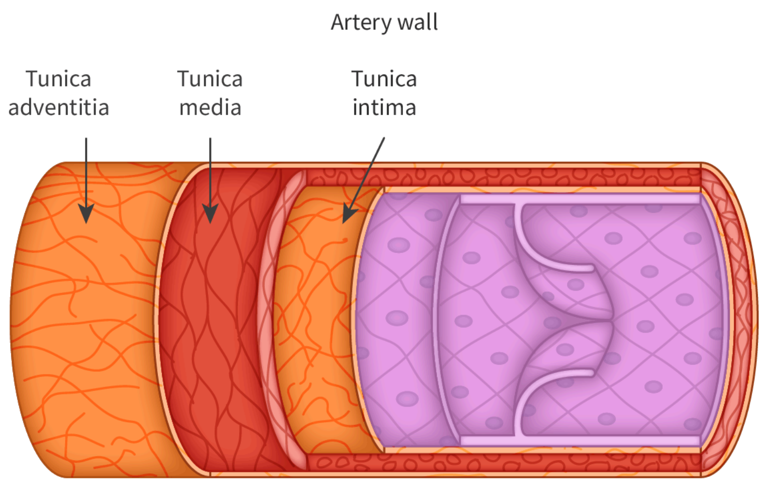

Figure 3. Layers in the artery wall.

More information for figure 3

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This image is a detailed diagram of the layers of an artery wall, showing three main layers labeled as tunica adventitia, tunica media, and tunica intima. The tunica adventitia is the outermost layer, depicted in an orange color with lines pointing inward. The tunica media is the middle layer, shown in red, featuring a thicker structure. The innermost layer, tunica intima, is highlighted in purple, showing a smooth interior with two prominent curved structures, possibly representing internal elastic elements or folds. Arrows point from labels to their respective layers to clearly indicate each section of the artery wall.

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Veins

Veins are adapted to return blood to the heart. Like the wall of an artery, the wall of a vein is made of three layers:

- the innermost layer – the tunica intima
- the middle layer – the tunica media
- the outermost layer – the tunica adventitia.

Unlike the artery, veins have a much thinner wall relative to the diameter of their lumen, with less smooth muscle and elastic tissue in the tunica media (**Figure 4**).

Veins have a much larger lumen than arteries, meaning blood flows through these vessels at a much lower pressure. To prevent the backflow of blood under low pressures, veins contain one-way valves. Valves are formed from flaps of tissue that open in the same direction as blood flow and close if blood tries to flow back in the opposite direction. The valves in veins are especially important in the lower extremities, such as the feet, where the force of gravity makes it harder for blood to flow back to the heart.

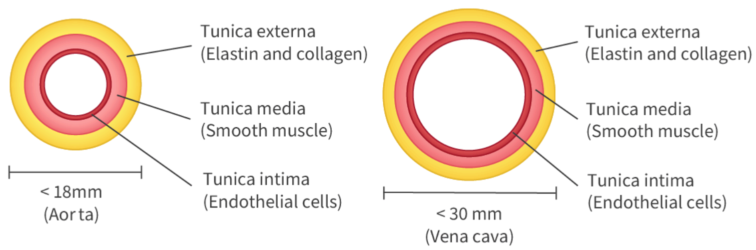

Figure 4. Comparing the layers in the wall of an artery and a vein.

More information for figure 4

This diagram compares the wall layers of an artery and a vein. On the left, it shows a cross-section of an artery with three distinct layers: the tunica intima, made up of endothelial cells; the tunica media, composed of smooth muscle; and the tunica externa, consisting of elastin and collagen. The diameter is labeled as less than 18 mm (Aorta).

On the right, a vein cross-section displays similar layers: the tunica intima (endothelial cells), tunica media (smooth muscle), and tunica externa (elastin and collagen). The vein diameter is labeled as less than 30 mm (Vena cava). The text annotations highlight the differences in wall thickness and diameter between the artery and vein, illustrating that veins usually have thinner walls and larger lumens compared to arteries.

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The wall of the vein is flexible, which allows veins to be compressed by contraction of skeletal muscle, which results in blood being pushed along the vessels. This effect occurs primarily in the limbs, where veins are in close proximity to skeletal muscles, and is more pronounced during vigorous exercise. Because veins contain valves, blood can only be pushed in one direction: towards the heart (**Figure 5**).

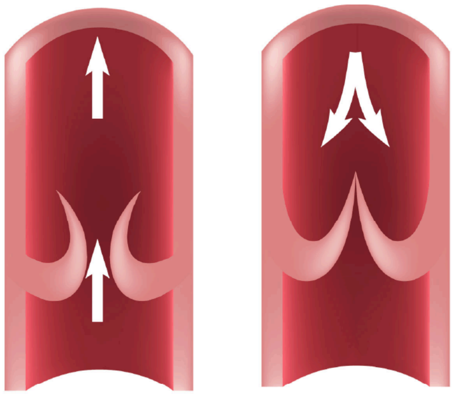

Figure 5. Valves in the veins open in one direction only, preventing the backflow of blood.

More information for figure 5

The diagram consists of two illustrations side-by-side, each depicting a section of a vein with a valve. The image on the left shows an open valve with arrows pointing upward, indicating that blood is moving through the vein towards the heart. The valve flaps are shown apart, allowing space for blood flow. The image on the right shows a closed valve. Here, arrows point downwards towards the valve, indicating a prevention of backflow. The valve flaps are touching, blocking the passage. Below each illustration, labels read 'Valve open' and 'Valve closed' respectively, correlating to the status of the valves.

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Comparing micrographs of arteries and veins

You should be able to distinguish between arteries and veins in micrographs from the structure of a vessel wall and its thickness relative to the diameter of the lumen (**Figure 6**). In veins, the diameter of the lumen will be much larger relative to the diameter of the vessel wall, which contains less muscle and elastic tissue than arteries. Thicker walls and a smaller lumen results in arteries appearing more rounded in a cross-section.

See section A2.2.1–2 (/study/app/bio/sid-422-cid-755105/book/using-microscopes-id-43573/) for more information on microscopy skills.

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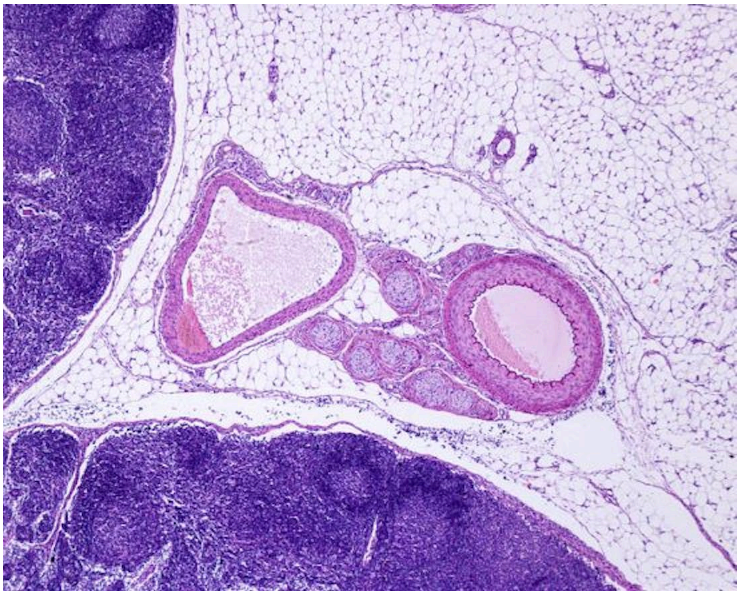

Figure 6. Micrograph of a vein (left) and an artery (right).

Credit: Jose Luis Calvo Martin & Jose Enrique Garcia-Mauriño Muzquiz, Getty Images (https://www.gettyimages.com/detail/photo/artery-and-vein-royalty-free-image/1292384660)

Try the activity below to compare the features of arteries, capillaries and veins.

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual activity

Complete **Table 1** to compare the structures and functions of capillaries, arteries and veins.

Table 1. Features of arteries, capillaries and veins.

	Capillaries	Arteries	Veins
Function of this vessel			
Diagram of a cross-section of this vessel			
Description of the structure of this vessel			
Pressure of blood in this vessel			

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	Capillaries	Arteries	Veins
Examples of this type of blood vessel	Capillary beds in lungs (see section B3.1.1—4 (/study/app/bio/sid-422-cid-755105/book/gas-exchange-as-a-vital-function-id-44438/))		

Measuring pulse rate

Pulse rate, also known as your heart rate, is the number of times your heart beats per minute. Pulse rate fluctuates throughout the day, but resting pulse rate is typically between 60 and 100 beats per minute (bpm). Resting pulse rate can be influenced by age, fitness levels, medication and health conditions such as dehydration or anxiety.

Your pulse rate is usually measured at rest and can be determined manually by feeling the radial artery, which is located on the wrist just below the thumb (**Figure 7**), or the carotid artery, which is on the neck, beside the trachea. You should place your index and middle finger on the artery and count the number of pulses that occur in 15 seconds, and then multiply this value by four to get the number of pulses that occur in one minute. Measuring heart rate using this method is generally considered as an estimate, rather than a precise measurement.

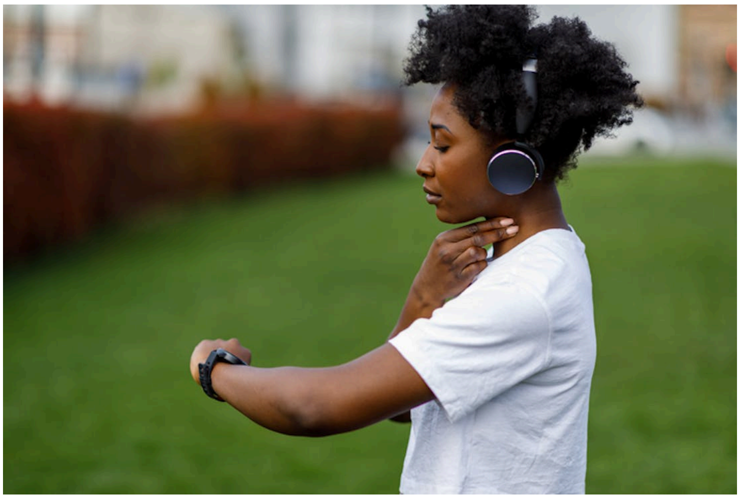

Figure 7. Measuring pulse rate using the carotid artery.

Credit: ProfessionalStudioImages, Getty Images (https://www.gettyimages.com/detail/photo/an-african-woman-is-checking-his-heart-rate-after-a-royalty-free-image/1354835530)

Pulse rate can also be measured using a stethoscope, which is placed on the sternum, slightly to the left side, over bare skin or a thin layer of clothing. The person taking the measurement listens to the stethoscope and counts the number of beats per minute.

Traditional manual measurements of pulse rate, like feeling the radial artery or using a stethoscope, require a degree of knowledge, skill and focus on the part of the person taking the measurements in order to be taken accurately. They can also be impacted by factors that may distract the person taking the measurement, such as a noisy environment.

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Digital methods to measure pulse rates include using a heart rate monitor, which is a device worn around the wrist or chest that measures the electrical signals of the heart, or using a smartphone app, which uses the camera to detect changes in blood colour and flow in the skin. Digital methods of measuring heart rate tend to be more accurate and reliable compared with traditional methods. They can also be used more easily to measure changes in heart rate, for example during exercise.

Occlusion of the coronary arteries

Coronary arteries branch off from the aorta to supply the heart muscle with nutrients and oxygen. Occlusion (blockage) of the coronary arteries leads to coronary heart disease (CHD), a type of cardiovascular disease (CVD), a group of diseases that affect the heart or blood vessels.

CHD is caused by a build-up of plaque, a fatty substance that is mostly made of cholesterol (**Figure 8**). Over time, this hardens into a deposit called atherosclerotic plaque, which narrows the diameter of the coronary artery and reduces blood flow to the heart. Sometimes parts of the atherosclerotic plaque can rupture, exposing and damaging the tissue underneath and resulting in the formation of a blood clot, or thrombus, which can further restrict blood flow. Ischaemia is the medical term used to describe the lack of blood flow to a particular part of the body.

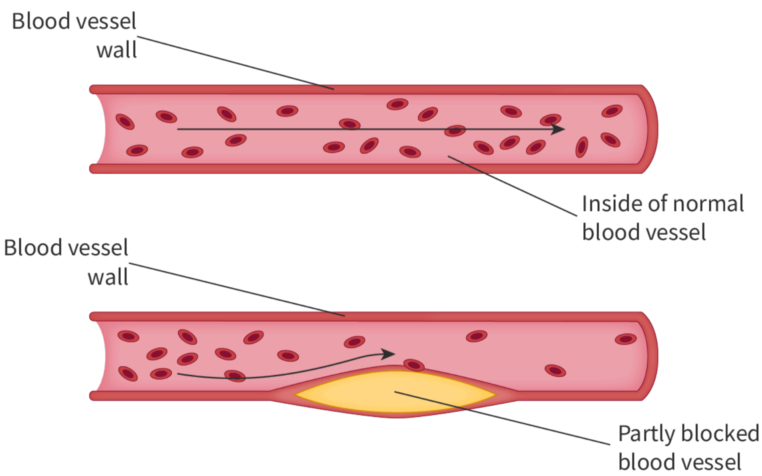

Figure 8. Atherosclerosis narrows the diameter of the blood vessels.

More information for figure 8

The diagram consists of two parts:

1. **Top part:** Shows a normal blood vessel. It is a tubular structure with a label pointing to the "Inside of normal blood vessel". The walls are smooth, and blood cells, represented as small red ovals, are evenly distributed, highlighting unobstructed blood flow marked by an arrow.

2. **Bottom part:** Illustrates a partly blocked blood vessel. The vessel appears similar in shape but contains a yellowish bulge inside the wall, labeled as "Partly blocked blood vessel". This bulge represents an atherosclerotic plaque that narrows the vessel's diameter. The distribution of blood cells is altered, with some accumulating near the plaque. An arrow indicates that blood flow is restricted due to the blockage.

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If blood flow is severely or completely impeded, the part of the heart supplied by that vessel will not receive blood, and therefore the cardiac muscle cells in that part of the heart do not obtain the oxygen and nutrients required for proper function. (See section B2.3.9 (/study/app/bio/sid-422-cid-755105/book/checklist-id-44811/) for more information on

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cardiac muscle cells.)

As a result, that part of the heart can experience tissue damage or death, leading to a myocardial infarction (heart attack) (**Figure 9**). The lack of oxygen and nutrients to the heart tissue also results in a shortness of breath, fatigue and pain called angina.

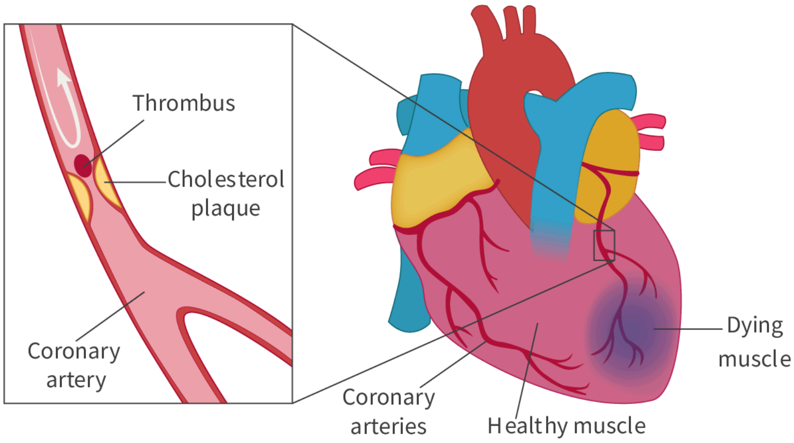

Figure 9. Restricted blood flow to the heart caused by a thrombus can lead to damage or death of the heart muscle.

More information for figure 9

The diagram illustrates a section of a coronary artery and its relationship to the heart. On the left, a cross-section of a coronary artery is shown. The artery is narrow due to a cholesterol plaque deposit along its wall. Above the plaque, a red-colored thrombus (blood clot) can be seen obstructing blood flow, which is indicated by a directional arrow pointing upward along the artery.

The right side of the diagram depicts the heart, highlighting the effects of the thrombus. The heart shows areas labeled as 'Healthy muscle' and 'Dying muscle'. The dying muscle area is shaded darker, indicating damage due to the restricted blood flow caused by the thrombus. The relationship between the blocked artery and the affected part of the heart is marked by lines connecting the artery and the heart illustration.

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Nature of Science

Aspect: Patterns and Trends

A correlation coefficient is a statistical measure that quantifies correlations between variables and allows the strength of the relationship to be assessed. Low correlation coefficients or lack of any correlation could provide evidence against a hypothesis, but even strong correlations do not prove a causal link.

Factors that have a strong correlation coefficient with CHD include diabetes, consuming a diet high in saturated and trans fats, smoking, chronic stress and hypertension (high blood pressure).

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The graph in **Figure 10** shows the incidence of CHD in men and women worldwide. Compare (give similarities) and contrast (give differences) the incidence of CHD between men and women worldwide. But be critical when viewing this data. In what way could the presentation of this data be considered misleading?

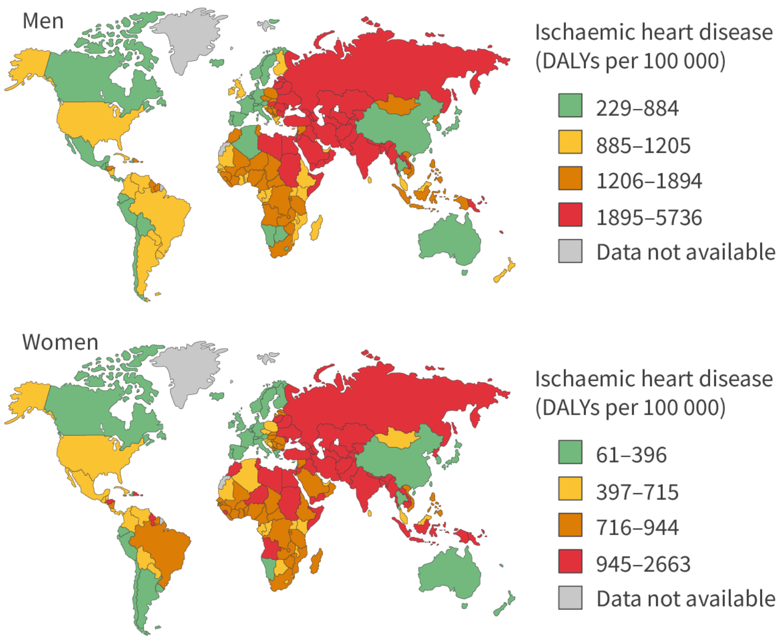

Figure 10. Epidemiological data showing the incidence of CDH in men and women worldwide, measured as the disability adjusted life years (DALYs).

Data source: Nathan D. Wong. Epidemiological studies of CHD and the evolution of preventive cardiology. *Nature Reviews Cardiology* 11, 276—289, 2014

More information for figure 10

The image consists of two world maps illustrating the incidence of ischemic heart disease (CHD), measured in disability-adjusted life years (DALYs) per 100,000 people, for men and women worldwide. Each map is color-coded to indicate different ranges of DALY values, distinguishing regions by severity.

The top map shows data for men: - Light green indicates regions with 229 to 884 DALYs. - Yellow signifies areas with 885 to 1205 DALYs. - Orange represents 1206 to 1894 DALYs. - Red is used for areas with 1895 to 5736 DALYs. - Grey regions indicate data is unavailable.

The bottom map represents data for women: - Light green indicates regions with 61 to 396 DALYs. - Yellow shows 397 to 715 DALYs. - Orange represents 716 to 944 DALYs. - Red signifies areas with 945 to 2663 DALYs. - Grey regions again indicate data is unavailable.

Both maps use the same legend format located in the right corner of each map to explain the color coding, demonstrating the geographical distribution and prevalence differences of CHD in men and women globally.

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Try the activity below to analyse epidemiological data on cardiovascular disease.

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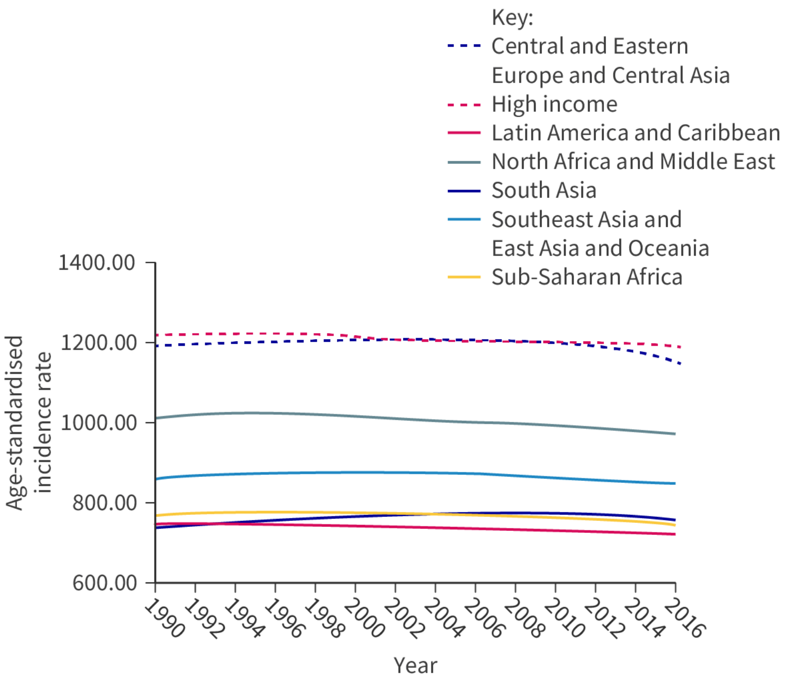
Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Applying key ideas and facts in new contexts
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity

In this activity you will use your knowledge of cardiovascular disease and the provided epidemiological graphs (**Figure 11**) to answer data-based questions.



(a)

More information

The graph displays age-standardized incidence rates from 1990 to 2016 for different regions according to a key. The X-axis represents the year, ranging from 1990 to 2016, while the Y-axis shows the incidence rate, ranging from 600.00 to 1400.00.

Various lines represent different regions: a dashed blue line represents Central and Eastern Europe and Central Asia, a dashed red line represents High income, a solid pink line represents Latin America and the Caribbean, a solid grey line represents North Africa and the Middle East, a solid dark blue line represents South Asia, a solid light blue line represents Southeast Asia and East Asia and Oceania, and a solid yellow line represents Sub-Saharan Africa.

The graph shows that Central and Eastern Europe and Central Asia, as well as High income regions, have consistently high incidence rates, staying above 1100. The Middle Eastern and North African region has a decrease over time, starting around 1990 above 1000 and ending near 900 by 2016. Sub-Saharan Africa rates are lower compared to others, steady around 700.

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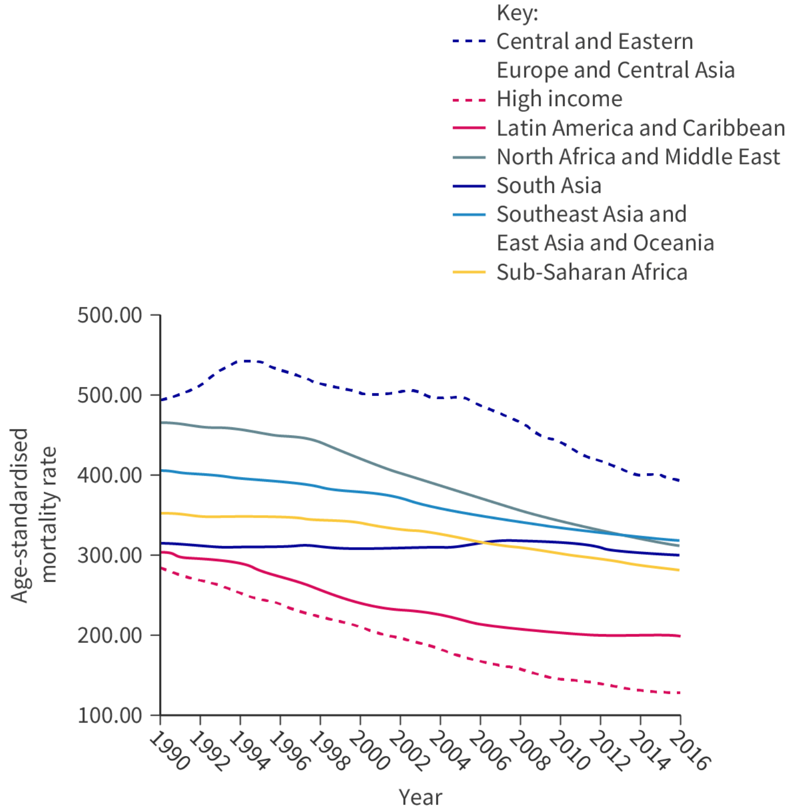

(b)

More information

The line graph represents age-standardized mortality rates from 1990 to 2016 across various regions shown by different colored and styled lines.

Key details: - Central and Eastern Europe and Central Asia are represented with a dotted blue line, starting around 500.00 and gradually decreasing to 400.00. - The High income countries' mortality rate, indicated by a dashed pink line, declines from around 300.00 to just above 150.00. - Latin America and Caribbean, shown with a solid red line, starts slightly above 300.00, decreasing steadily to just under 200.00. - North Africa and Middle East uses a solid grey line, starting around 400.00 and decreasing to around 300.00. - South Asia depicted by a solid dark blue line, starts at about 350.00, dropping consistently towards 250.00. - Southeast Asia and East Asia and Oceania, shown with a solid light blue line, show a decline from approximately 300.00 to just under 200.00. - Sub-Saharan Africa, represented by a solid yellow line, starts just above 300.00, remaining fairly constant with a slight decline towards the end of the period. - The X-axis represents the years from 1990 to 2016, while the Y-axis reflects the age-standardized mortality rate ranging from 100.00 to 500.00.

Overall, there is a notable decline in mortality rates across all regions, with high-income regions showing the most significant decrease.

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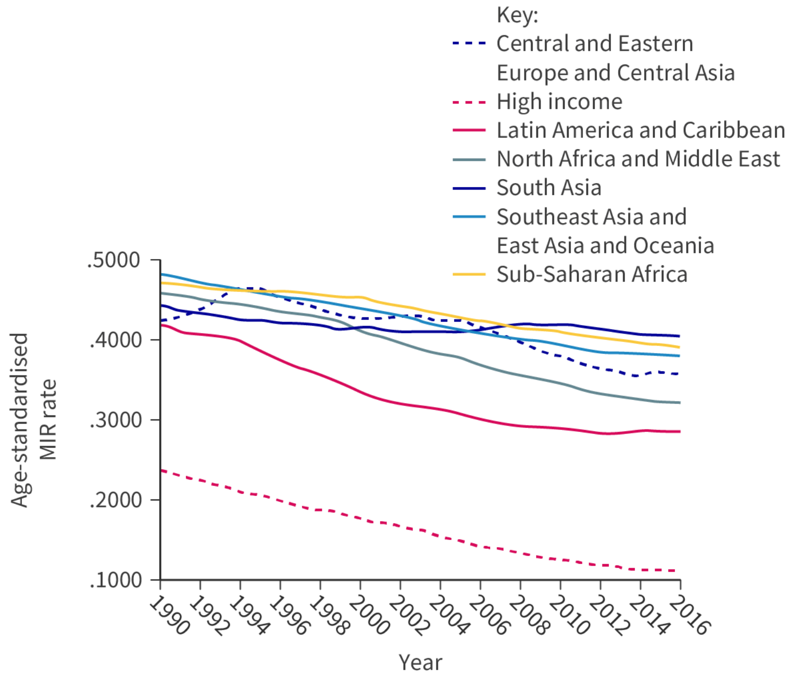

(c)

Figure 11. Epidemiological data for cardiovascular disease in 2017:
(a) age-standardised incidence, (b) mortality and (c) MIR.

More information for figure 11

The line graph displays the age-standardised mortality to incidence ratio (MIR) rates from the years 1990 to 2016. The Y-axis represents the MIR rate, marked from 0.1000 to 0.5000. The X-axis shows the year, ranging from 1990 to 2016.

Multiple lines represent different regions:

- Central and Eastern Europe and Central Asia are depicted by a dashed blue line.
- High income countries are shown with a red dashed line, starting above 0.2000 in 1990 and steadily decreasing below 0.2000 by 2016.
- Latin America and the Caribbean are denoted by a solid pink line, starting just above 0.1000 and remaining fairly constant with a slight decrease towards the end.
- North Africa and the Middle East is represented by a teal line, starting at approximately 0.4000 and gradually declining.
- South Asia is shown by a darker blue line, displaying a steady decline.
- Southeast Asia, East Asia, and Oceania are illustrated by a light blue line.
- Sub-Saharan Africa is shown by a yellow line, slightly undulating but generally decreasing.

The graph indicates a general downward trend in the MIR rates across all regions with some variation in the slopes of the lines.

[Generated by AI]

The graphs above show the age-standardised incidence, mortality and mortality to incidence ratio (MIR) of cardiovascular disease from a global study carried out in 2017.

Age-standardised rates are used in epidemiology to standardise rates of a disease in different populations that differ in age structure by adjusting for differences in age distributions. This allows for meaningful comparisons to be made which are not biased by age.

The incidence rate is the number of new cases of a disease or condition that occur in a defined population over a specified period of time. The mortality rate is the number of deaths in a given population within a specific time period. The MIR is a ratio of the number of deaths from a disease to the number of new cases of the disease over a given time period.

Use your knowledge and the information provided in the graphs in **Figure 11** to answer these questions.

Student
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1. What is cardiovascular disease?
2. Give three factors that can increase a person's risk of developing cardiovascular disease.
3. Describe the trend in the age-standardised incidence of cardiovascular disease in Central Europe, Eastern Europe and Central Asia.
4. Compare and contrast the age-standardised mortality rates of cardiovascular disease in South Asia and Latin America and Caribbean.
5. Using all three graphs, discuss the claim that cardiovascular disease is less of a problem in high-income countries.

5 section questions

B3. Form and function: Organisms / B3.2 Transport

Transport in plants

B3.2.7: Transport of water during transpiration B3.2.8: Adaptations of xylem vessels B3.2.9: Distribution of tissues in a dicotyledonous plant stem
B3.2.10: Distribution of tissues in a dicotyledonous plant root

Learning outcomes

By the end of this section you should be able to:

- Explain how water is transported from the roots to the leaves during transpiration.
- Outline the adaptation of the xylem vessels for the transport of water.
- Draw and annotate plan diagrams from micrographs showing the distribution of tissues in a transverse section of the stem of a dicotyledonous plant, and dicotyledonous root.

The roots, stem and leaves of a vascular plant contain two types of vascular (transport) tissue:

- the xylem, which transports water and dissolved minerals, and
- the phloem, which facilitates the transport of carbon compounds including sugars and amino acids.

Rings on a tree trunk are formed by the growth of xylem tissue, with the thicker, lighter areas representing more rapid growth of the tree during the spring and summer, while the thinner, darker areas represent slower growth during the autumn and winter. As well as being a useful tool to work out the age of a tree, these rings can provide valuable information about the environmental conditions present during each year of the tree's life (**Figure 1**).

Student
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Figure 1. The rings on a tree represent new growth, and are formed by a type of transport tissue called the xylem.

Credit: Ray Wise, Getty Images

Theory of Knowledge

To what extent can the measuring of tree rings be considered a reliable method of measuring past environmental conditions?

Transport of water in the xylem

The xylem transports water unidirectionally, and often against the force of gravity, from the roots to all other parts of the plant. This movement of water is possible due to the process of transpiration – the loss of water from aerial parts of the plant through tiny pores called stomata (see section B3.1.7–10 (/study/app/bio/sid-422-cid-755105/book/gas-exchange-in-leaves-id-44440/) for more information on transpiration and the adaptations of leaves for gas exchange). As water evaporates through the stomata, a negative pressure potential is created, because there is lower water potential outside the stomata compared with inside the leaf (see section D2.3.10 (/study/app/bio/sid-422-cid-755105/book/water-potential-hl-id-44813/)). This results in water being pulled out of the xylem, which in turn pulls water up from the xylem in a process called capillary action, which in turn draws more water into the xylem from the soil (**Figure 2**).

Student view

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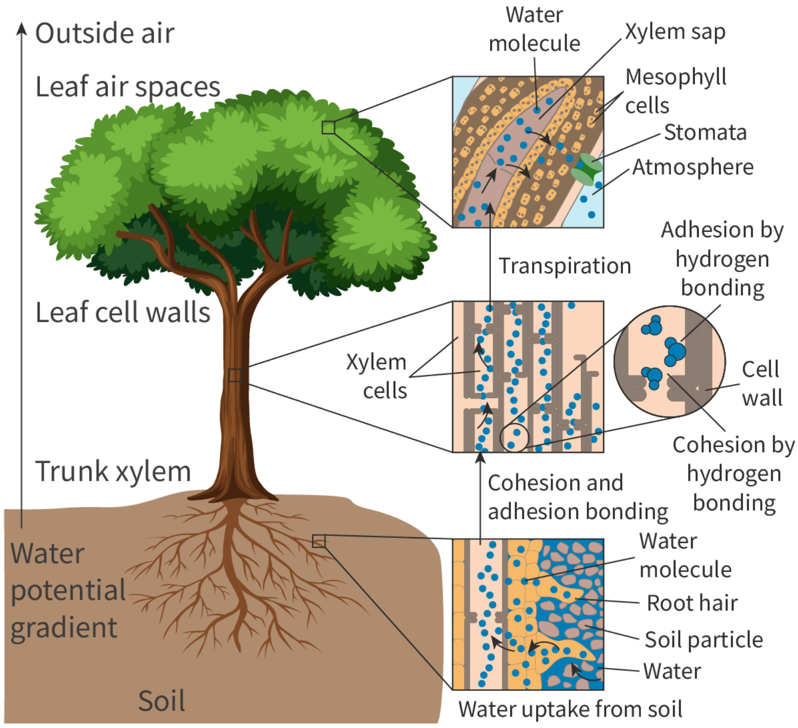

Figure 2. As water is lost through the stomata in the process of transpiration, it creates a negative pressure gradient which pulls water up the xylem, which in turn pulls water into the roots from the soil.

More information for figure 2

The diagram illustrates the process of water movement in a tree, highlighting transpiration and capillary action. It shows a tree with labeled sections illustrating water uptake and movement. The tree's roots in the soil are labeled with 'Water potential gradient', and the root section shows water molecules entering through root hairs.

The trunk section includes a close-up of xylem cells where 'Cohesion and adhesion bonding' occurs, facilitated by hydrogen bonding between water molecules.

Another detailed section shows water movement through the tree's leaf air spaces via 'Transpiration'. The diagram indicates that water molecules move through mesophyll cells to reach stomata, then evaporate into the 'Atmosphere'. Arrows depict the direction of water movement aided by xylem sap and cohesive forces.

Overall, the diagram effectively demonstrates the unidirectional flow of water from roots through the trunk and into leaves, facilitated by transpirational pull and the cohesive, adhesive characteristics of water.

[Generated by AI]

Capillary action occurs in the xylem due to cohesive and adhesive forces, which result from hydrogen bonding and the dipolar nature of water (see section A1.1.1–3 (/study/app/bio/sid-422-cid-755105/book/structure-of-water-id-43194/)).

Student view

Water molecules in the xylem are attracted to each other through cohesive forces, which allows them to form a continuous column. In addition, water molecules adhere to the walls of the xylem through adhesive forces, which helps to prevent the column of water from breaking apart as it moves through the xylem. See sections A1.1.1–3 (/study/app/bio/sid-422-cid-755105/book/structure-of-water-id-43194/) and A1.1.4–5 (/study/app/bio/sid-422-cid-755105/book/interactions-with-water-id-43195/) for more information on cohesion and adhesion.

Capillary action also occurs when you dip the end of a paper towel in water **(Figure 3**).

Figure 3. Place the corner of a paper towel in water and the water will be drawn up in between the fibres that make up the paper towel, against the force of gravity. This process is called capillary action, and it occurs due to the cohesive and adhesive properties of water.

Credit: Monika Nesslauer, Getty Images

While the majority of water movement in the xylem occurs due to transpiration, some will occur due to root pressure. Root pressure is covered later in this section.

Adaptations of xylem vessels for transport of water

Xylem are thin, continuous columns that run from the roots through the stems of plants (**Figure 4**). Xylem are formed from specialised cells, which lose their cell contents and cell membrane as they mature, becoming dead, hollow tubes that are specialised for the transport of water.

Student view

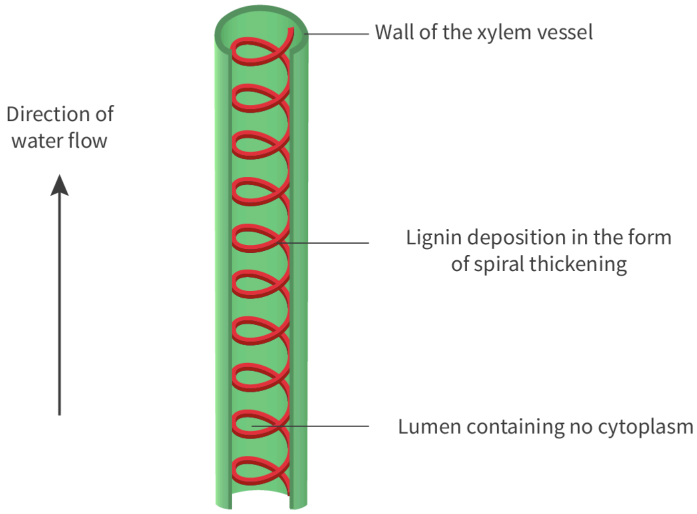

Figure 4. A xylem vessel.

More information for figure 4

This diagram illustrates a xylem vessel, highlighting key features involved in water transport in plants. The xylem vessel is represented as a vertical, cylindrical structure. An arrow is shown on the left, indicating the upward direction of water flow through the vessel.

The structure is labeled with three main components:

1. **Wall of the xylem vessel:** The outer boundary of the vessel, providing structural integrity.
2. **Lignin deposition in the form of spiral thickening:** Inside the vessel wall, a red spiral pattern represents lignin depositions. Lignin is a complex polymer providing rigidity and waterproofing to the vessel.
3. **Lumen containing no cytoplasm:** The empty, hollow central space of the vessel, called the lumen, where water and nutrients are transported.

The combination of these features enables the specialized function of xylem vessels in transporting water from the roots to other parts of the plant.

[Generated by AI]

The walls of xylem vessels are strengthened with lignin. Lignin is a complex polymer that binds to cellulose, creating strength and rigidity, which can allow plants to withstand tension and mechanical stress. Lignin also waterproofs the xylem, making xylem walls impermeable to water. Lignin can be deposited throughout cell walls as rings or spirals inside the xylem vessels, as shown in **Figure 5**.

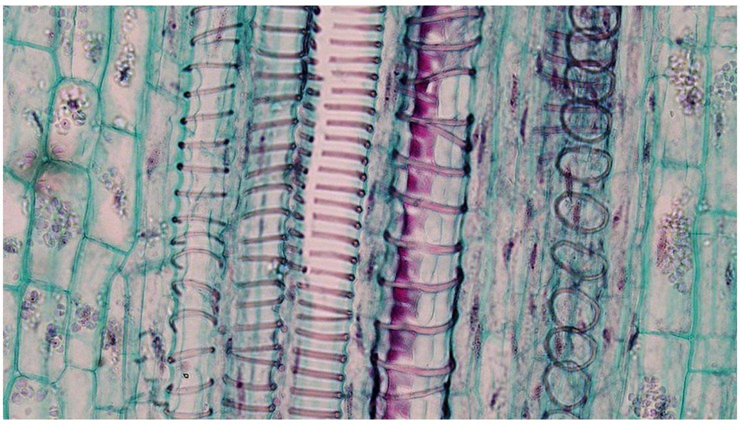

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Figure 5. Xylem lignin (stained purple).

More information for figure 5

The image shows a close-up microscopic view of xylem vessels within a plant stem. The xylem vessels are prominently displayed with their walls attracting attention due to a stained purple coloration. This purple stain highlights spiral patterns within the walls, attributed to the presence of lignin. The lignin is a complex polymer that strengthens and waterproofs these xylem walls. Surrounding the vessels, other plant cells are visible with a greenish tint, providing a contrasting backdrop. This detailed cellular structure illustrates the spiraled reinforcement typical of xylem cells, crucial for conducting water and nutrients while maintaining mechanical stability.

[Generated by AI]

The specialised cells that make up xylem walls contain areas called pits, which are regions where the cell wall is thinner and contains no lignin (**Figure 6**). These pits allow water and other molecules to move between adjacent cells, allowing the lateral movement of water into and out of xylem.

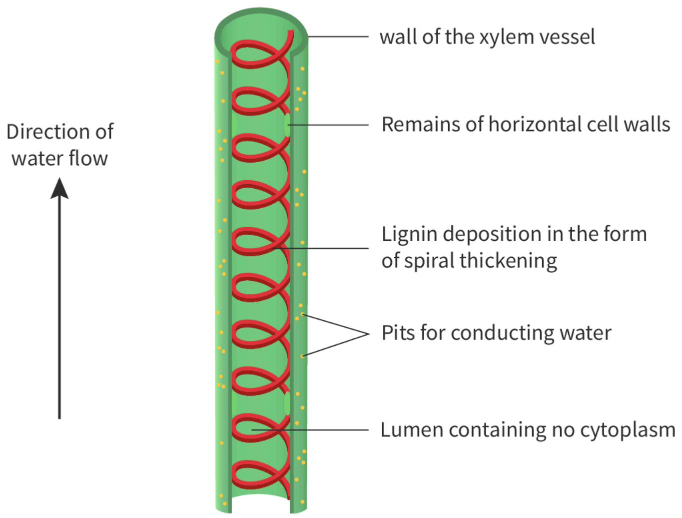

Figure 6. Pits in the xylem.

More information for figure 6

The image is a diagram of a section of a xylem vessel. It shows the components of the vessel, which include the wall of the xylem vessel, remains of horizontal cell walls, lignin deposition in the form of spiral thickening, and pits for conducting water. The image indicates the direction of water flow with an arrow pointing upwards. The central part of the vessel, called the lumen, is highlighted and noted as containing no cytoplasm. Labels clearly explain each part of the vessel.

[Generated by AI]

Student view

Overview (/study/app/bio/sid-422-cid-755105/o

Distribution of tissues in the stems and roots of dicotyledonous plants

Dicotyledonous plants are a type of flowering plant that is characterised by having two embryonic leaves (cotyledons) in its seeds.

The epidermis is an outermost layer of tissue that protects the stem and roots. It is thin and transparent, usually composed of one layer of cells. In the stem, the walls of the epidermal cells often contain a cuticle, a waxy layer that prevents water loss from the stem, except for areas where stomata are present. In the roots, the epidermis absorbs water and minerals from the soil, and contains many finger-like projections, called root hairs, which increase the surface area of the root for efficient absorption.

The xylem and phloem make up the vascular bundles. In the stem of dicotyledonous plants, vascular bundles are distributed to form a ring, with the xylem being closer to the inside of the stem and the phloem being closer to the epidermis. In the roots, the vascular bundles are arranged in a central cylinder called the stele, with the xylem being located on the inside, surrounded by the phloem (**Figure 7**). Between the xylem and the phloem is the cambium, a thin layer of actively dividing cells that can differentiate into xylem and phloem cells (see section D2.1.12 (/study/app/bio/sid-422-cid-755105/book/control-of-the-cell-cycle-hl-id-44812/) for more information on cell proliferation for growth, cell replacement and tissue repair).

Between the vascular bundles and the epidermis is a layer of tissue called the cortex. The cortex provides structural support to the stem and roots and helps these structures to maintain their shape. The cells that make up the cortex may be involved in storage of nutrients and some may contain chloroplasts, allowing them to carry out photosynthesis.

The distribution of tissues in a leaf is covered in section B3.1.7–10 (/study/app/bio/sid-422-cid-755105/book/gas-exchange-in-leaves-id-44440/).

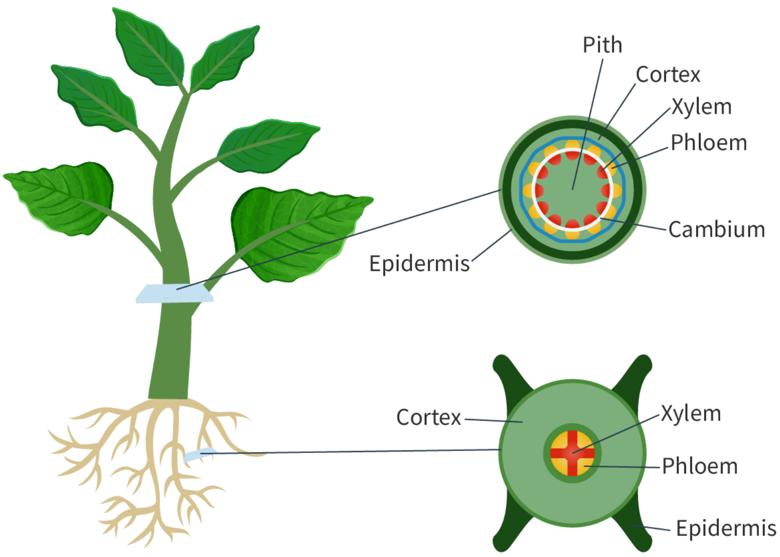

Figure 7. The distribution of tissues in the stem and root of dicotyledonous plants.

More information for figure 7

The image is a diagram illustrating the tissue distribution in the stem and root of dicotyledonous plants.

In the upper portion, the cross-section of a stem is shown. The diagram labels the following components of the stem: - **Epidermis:** The outermost layer. - **Cortex:** Located beneath the epidermis. - **Cambium:** Situated between the xylem and phloem. - **Xylem:** The tissue responsible for water transportation, positioned centrally. - **Phloem:** The tissue involved in nutrient transport, surrounding the xylem. - **Pith:** The central part of the stem.

Student view

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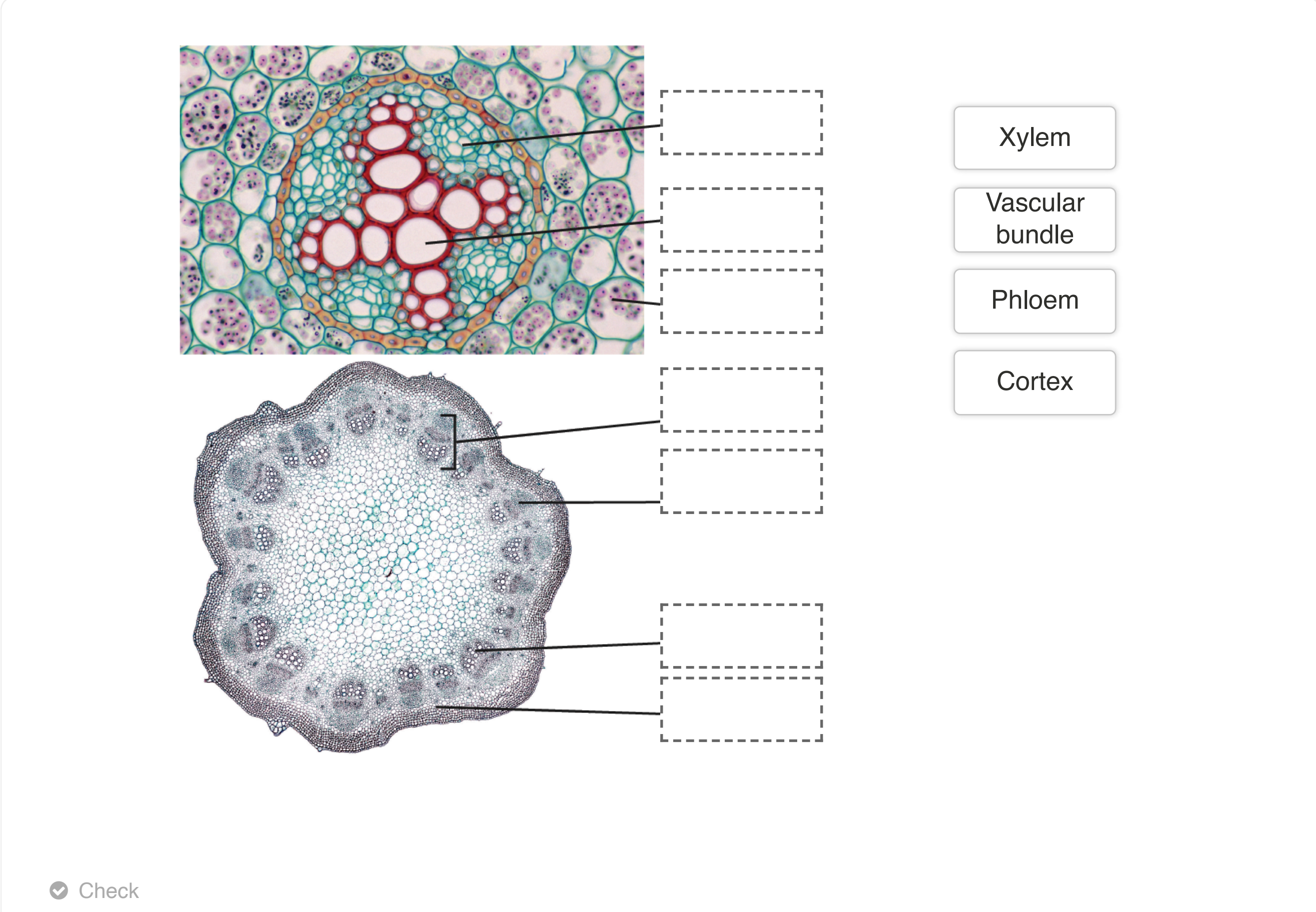
In the lower portion, the cross-section of a root is displayed. This section is also labeled similarly: - **Epidermis**: Surrounds the outermost layer. - **Cortex**: Encloses the inner tissues. - **Xylem**: Forms the core, organized in a star-like shape. - **Phloem**: Located between the points of the xylem.

[Generated by AI]

Try the drag and drop activity in **Interactive 1** to test your understanding of the arrangement of vascular tissues in a root and stem.



Interactive 1. Arrangement of Vascular Tissues in a Root and Stem.

More information for interactive 1

This interactive has illustrations of two microscopic cross sections of root and stem. This is a drag and drop interactive activity.

Top Cross-section

This shows a roughly circular arrangement of root tissues. At the very center, there is a solid core of tissue, appearing as a multi-lobed or star-shaped region. Surrounding the xylem are smaller clustered cells, located in the regions between the arms of the star shaped region. Encircling the central vascular bundle is a thick layer of cells, which appears as a wide ring of relatively uniform cells.

Bottom Cross-section

This shows a more scattered arrangement of vascular bundles within the stem's ground tissue. Several distinct oval or somewhat circular structures are visible. Within each of these circular structures, towards the inner side or center of the stem, there's another set of cells appearing as larger, often more open-looking cells. The cells towards the outer side of the circular structures, consisting of smaller, more densely packed cells. The ground tissue surrounding these circular structures and filling the center of the stem is another set of cells, which appear as areas of relatively large, loosely packed cells.

The drag-and-drop options are given in the right side of the interactive. They are Xylem, Vascular bundle, Phleom and Cortex.

Student view

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Read below for the solution:

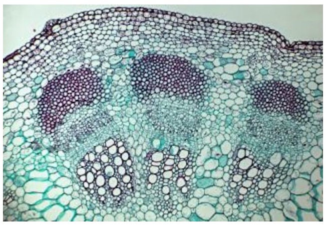
For the top cross section, the small clustered cells located between the star-shaped region is Phloem. The star-shaped cells are Xylem. The layer of cells outside the Xylem and Phloem are Cortex.

For the bottom cross section, the grouping of phloem and Xylem cells is Vascular bundle. The cells located toward the outer side of the Vascular bundle are Phloem. The cells closer to the center of the Vascular Bundle are Xylem. The outer layer surrounding the Vascular bundles is the Cortex.

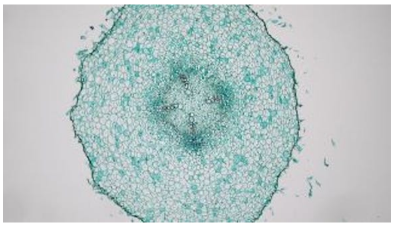
Try the activity below to draw plan diagrams of the distribution of vascular tissue in roots and stems.

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity



Credit: Ed Reschke, Getty Images



Source: "Young Herbaceous Dicot (https://commons.wikimedia.org/wiki/File:Young_Herbaceous_Dicot_Root_Ranunculus_(34745654101).jpg)" by Berkshire Community College Bioscience Image Library is licensed under CC0 1.0 (https://creativecommons.org/publicdomain/zero/1.0/)

Figure 8. Micrographs of cross-sections of dicotyledonous plants.

Using the micrographs provided:

1. Identify which shows a transverse (cross-) section of a stem, and which shows a transverse section of a root.
2. Draw plan diagrams from each image and identify the relative positions of vascular bundles, xylem, phloem, cortex and epidermis in the stems and roots of dicotyledonous plants.
3. Annotate your diagram with the main functions of the visible structures.

Student view

Overview (/study/app/bio/sid-422-cid-755105/o

You can review section A2.2.1—2 (/study/app/bio/sid-422-cid-755105/book/using-microscopes-id-43573/) for a reminder of microscopy skills and conventions for recording your observations from microscope images.

5 section questions

B3. Form and function: Organisms / B3.2 Transport

Transport of fluid in mammalian tissues (HL)

B3.2.11: Release and reuptake of tissue fluid in capillaries (HL) B3.2.12: Exchange of substances between tissue fluid and cells (HL)
B3.2.13: Drainage of excess tissue fluid into lymph ducts (HL)

Higher level (HL)

Learning outcomes

By the end of this section you should be able to:

- Describe how tissue fluid is released and taken back up by the capillaries.
- Compare and explain the composition of plasma and tissue fluid.
- Outline how excess tissue fluid is drained into lymph ducts.

Capillaries are specialised to facilitate the exchange of substances between the blood and the external or internal environment. How is this exchange facilitated? And how does the concentration of various substances in the blood compare with the fluids outside the blood vessels?

Release and reuptake of tissue fluid in capillaries

Tissue fluid, also called interstitial fluid, is formed from the blood plasma that is pushed through the capillary walls and into the surrounding tissues. Along with water, this tissue fluid contains small solutes such as ions, hormones and nutrients (see section A1.1.4–5 (/study/app/bio/sid-422-cid-755105/book/interactions-with-water-id-43195/)). Tissue fluid bathes cells and facilitates the exchange of substances between the blood and the cells.

Due to their size, plasma proteins, platelets and red blood cells will remain in the capillary, although oxygen will diffuse out of red blood cells into the plasma, and then into the tissue fluid. When infection or injury occurs, chemical signals are released by the damaged tissues or by pathogens causing the infection. These are detected by white blood cells which then squeeze out through the capillary walls and move towards the site of infection, as shown in **Video 1**.

Student view

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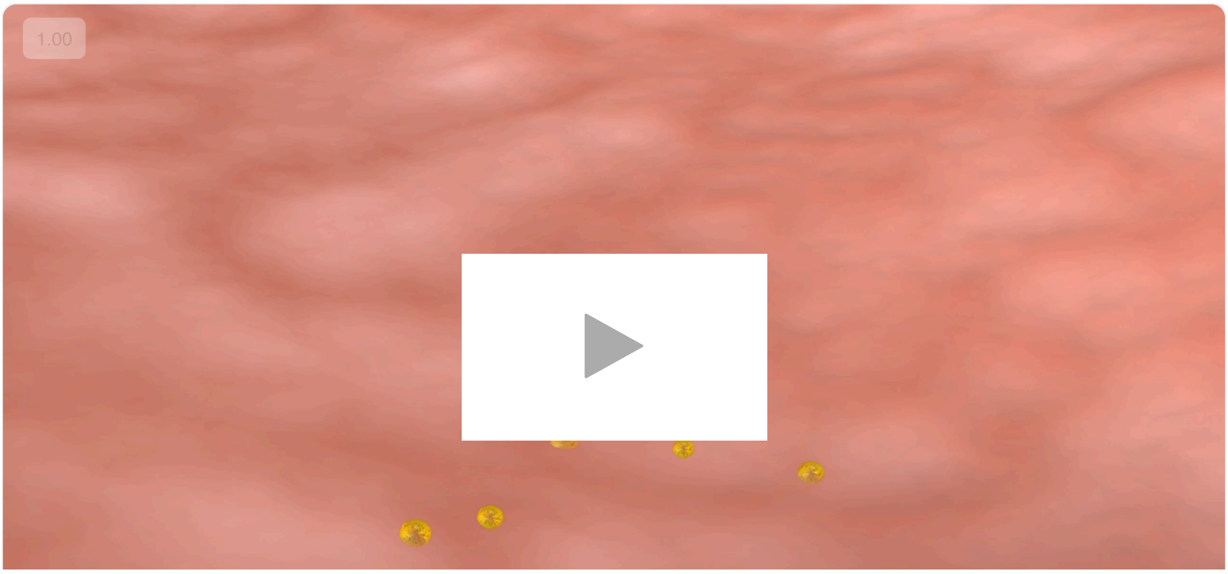

Video 1. White Blood Cells Leaving Capillaries and Travelling to the Site of Infection.

More information for video 1

In the interactive video, the process of white blood cells moving out of capillaries to fight infection is demonstrated. The scene begins by showing an area inside the body, likely a tissue containing infectious particles. These infectious particles are represented by small yellow circles.

The video then proceeds to show the bloodstream inside the capillaries, flowing steadily. The bloodstream carries red blood cells and three large yellow-colored circles with spikes, which represent white blood cells. These white blood cells are initially seen traveling along the interior of a capillary, closely following the movement of the red blood cells.

As the videoprogresses, the white blood cells begin to slow down and roll along the inner lining of the capillary wall. This rolling behavior indicates the start of a process known as margination, where white blood cells move closer to the endothelial lining in response to signals from nearby infected tissues. Soon after, the cells come to a stop—this is adhesion, where they bind to the blood vessel wall using specific receptor interactions.

The next critical step is diapedesis, where the white blood cells squeeze between the tightly packed endothelial cells and move out of the capillary wall. The video shows the yellow-colored cells exiting the bloodstream and entering the surrounding tissue space. Once outside the capillary, these cells begin to move through the tissue, indicating that they are responding to chemical signals released from an infection site—this guided movement is known as chemotaxis.

Upon reaching the infection site, it is shown that the white blood cells engulf the infectious particles. This process is known as phagocytosis. Later in the video, the white blood cells are seen re-entering the bloodstream, signifying the end of their immune surveillance in the tissue or a possible return after neutralizing the infection. They once again flow along with the red blood cells, completing their journey.

By watching this video, learners understand how white blood cells exit blood vessels to reach sites of infection and then potentially return to circulation. The animation highlights critical steps in immune response, including margination, adhesion, diapedesis, chemotaxis, and phagocytosis. This helps learners appreciate how the body rapidly responds to infections and the dynamic role white blood cells play in maintaining immune defense. The interactive also explains the release and reuptake of tissue fluids in the capillaries.

The amount of fluid and solutes that are pushed out of the capillary wall is influenced by the hydrostatic pressure exerted by the blood on the capillary wall.

At the arteriole end of the capillary, where the blood enters the capillary, hydrostatic pressure is high, resulting in fluid being pushed out of the capillary wall into the surrounding tissue (also called the interstitial space), by a process called ultrafiltration. Ultrafiltration also occurs across the glomerulus wall in the kidneys (see section D3.3.8 (/study/app/bio/sid-422-cid-755105/book/osmoregulation-hl-id-44810/)).

At the venule end of the capillary, much fluid has already been lost from inside the capillary, decreasing the hydrostatic pressure, resulting in the majority of tissue fluid being drawn back into the capillaries. A small amount of fluid will not return to the capillaries and will drain into the lymph ducts, forming lymph.

Student
view

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Exchange of substances between tissue fluid and cells in tissues

The exchange of substances between tissue fluid and tissue cells can occur through diffusion or active transport. Nutrients, hormones and oxygen will move from the tissue fluid into cells. This means that the concentrations of these substances are lower in the tissue fluid than in the blood plasma at the arterial end of the capillaries. This causes these materials to move from the blood plasma into the tissue fluid and then into the cells.

Excess water and waste products, including carbon dioxide, will move from the cells into the tissue fluid. This means the concentration of these substances will be higher in the tissue fluid than the blood plasma at the arterial end of the capillaries. This causes materials to move from the cells into the tissue fluid and then into the blood plasma.

Drainage of excess tissue fluid into lymph nodes

Around 90% of tissue fluid will drain back into capillaries and the remaining 10% will move into lymphatic capillaries, which are found in the interstitial space. The walls of lymphatic capillaries are thin and permeable, being made of a single layer of endothelial cells which contain small gaps between cells.

Once inside the lymphatic system, the fluid is called lymph. Lymph is a colourless fluid containing excess tissue fluid, white blood cells, proteins and other substances. Lymph functions to help transport immune cells and remove foreign particles and toxins from the body.

Lymphatic capillaries drain into lymphatic vessels, which transport lymph to lymph nodes. Pressure is low in the lymphatic vessels, which rely on the contraction of surrounding skeletal muscle to squeeze the vessels to move lymph along. Like veins, lymphatic vessels contain valves to ensure that lymph flows in one direction.

Lymph nodes act as a filter, trapping or destroying anything harmful that the body does not need or could cause harm, such as foreign particles and toxins. Dendritic cells, a type of lymphocyte, sample the lymph for pathogens or parts of pathogens, in which case they would trigger an immune response. Lymph can then be returned to the circulatory system via larger lymph vessels. Once in the blood, the waste products and destroyed bacteria can be removed from the blood by the liver or kidneys.

Creativity, activity, service

Strand: Service
Learning outcome: Demonstrate engagement with issues of global significance

Blood donation is a voluntary service whereby a person donates a pint (around 470 ml) of blood. The donation process usually takes around 30 minutes and is carried out by trained professionals.

Once collected, blood donations are used to help patients who have suffered blood loss due to surgery trauma or illnesses, as well as certain conditions such as anaemia and cancer. Blood donations are always needed, and the demand increases during emergencies and disasters.

Please check the eligibility age and other criteria before considering donating blood (https://www.who.int/campaigns/world-blood-donor-day/2018/who-can-give-blood#:~:text=Below%20are%20some%20basic%20eligibility,that%20appropriate%20consent%20is%20obtainec
Your country may also have additional criteria.

Read more about blood donation in this World Health Organization Q+A (https://www.who.int/news-room/questions-and-answers/item/blood-products-why-should-i-donate-blood).

Student view

Try the activity below to understand the compositions of blood and tissue fluid.

Overview (/study/app/bio/sid-422-cid-755105/o

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 10 minutes
- **Activity type:** Individual activity

Compare the compositions of blood plasma and tissue fluid by dragging and dropping the statements to the correct place on the table.

	Blood plasma in arteriole end of capillary	Tissue fluid
Description		
Role		
Blood cells present		
Platelets present?		
Plasma proteins present?		
Relative amount of O_2		
Relative amount of CO_2		
Relative amount of glucose		
Relative amount of amino acids		

Red and White | Fluid found in cell spaces | Liquid component of the blood
White only | Substance exchange | Higher | Lower
Red only | Transport, coagulation | Yes | No

Check

Interactive 1. Drag and drop statements comparing blood plasma and tissue fluid.

5 section questions

B3. Form and function: Organisms / B3.2 Transport

Adaptations of the heart (HL)

B3.2.14: Differences between single and double circulation (HL) B3.2.15: Adaptations of the mammalian heart (HL) B3.2.16: Stages in the cardiac cycle (HL)

Higher level (HL)

Student view

Learning outcomes

By the end of this section you should be able to:

Overview (/study/ap 422-cid-755105/o

- Compare the single circulation of bony fish to the double circulation of mammals.
- Explain the adaptations of the mammalian heart for delivering pressurised blood to the arteries.
- Outline the stages of the cardiac cycle.

In one day, the average human heart will pump 115 000 times. In that time, approximately 7500 litres of blood will flow through the heart and then around the body, supplying your cells with oxygen and nutrients, and removing waste products. How does your heart carry out this amazing feat of endurance?

Single and double circulatory systems

Bony fish have a single circulatory system. This means that to complete one circulation around the body, blood has to pass through the heart once.

In contrast, mammals have a double circulatory system. This means that to complete one circulation around the body, blood has to pass through the heart twice (**Figure 1**). This double circulation is composed of:

- the pulmonary circulation, where blood is pumped from the heart to the lungs, and then returned to the heart, and
- the systemic circulation, where blood is pumped from the heart to the rest of the organism and back to the heart.

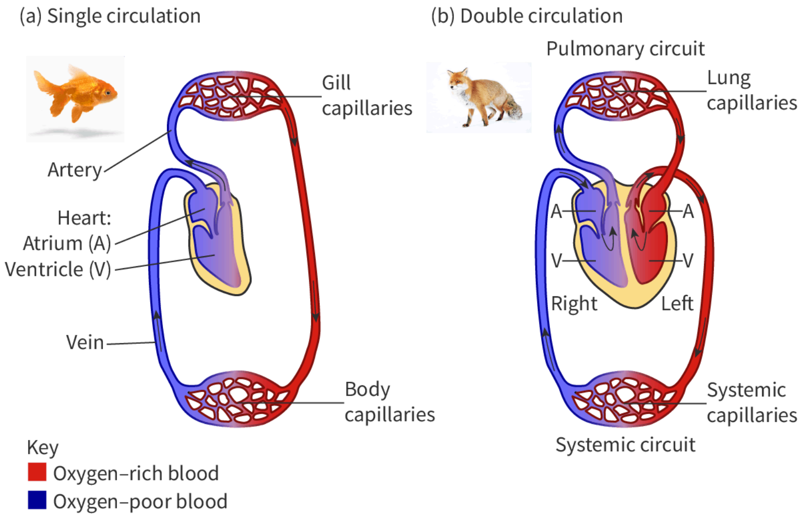

Figure 1. Bony fish have a single circulatory system whereas mammals have a double circulatory system.

Credit: Chris Clor, Getty Images

Credit: Sorin Rechitan / EyeEm, Getty Images

More information for figure 1

The image is a diagram comparing single and double circulatory systems. On the left, it illustrates the single circulation of bony fish, showing a heart with one atrium (A) and one ventricle (V). Blood moves from the heart to the gill capillaries where gas exchange occurs, then through the body capillaries and back to the heart via veins. Thick red and blue arrows indicate oxygen-rich and oxygen-poor blood, respectively.

On the right, it presents the double circulation of mammals. This system features a heart with two atria (A) and two ventricles (V), dividing into right and left sides. Blood flows through a pulmonary circuit (from the heart to the lung capillaries for oxygenation, then back to the heart) and a systemic circuit (from the heart to the systemic capillaries to deliver oxygen to the body, then returning to the heart). A key at the bottom shows red for oxygen-rich blood and blue for oxygen-poor blood.

[Generated by AI]

Advantages of a double circulatory system

The mammalian heart is divided into a right side and a left side by the septum. Deoxygenated blood returns to the right-hand side of the heart and is then pumped to the lungs. In the lungs this blood is oxygenated, and returns to the left-hand side of the heart where it is pumped to the rest of the body. The physical separation of

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oxygenated and deoxygenated blood helps to maintain high concentration gradients, allowing more efficient removal of carbon dioxide and a higher rate of oxygen delivery per unit of blood flow. In this way, the double circulatory system can meet the high metabolic demands of mammals.

See section B3.1.1–4 (/study/app/bio/sid-422-cid-755105/book/gas-exchange-as-a-vital-function-id-44438/) for more information about concentration gradients.

The structure of the mammalian heart

The heart is an organ of the circulatory system, functioning to pump blood around the body. It is made of cardiac muscle, a tissue that is found only in the heart, which is in turn composed of cardiac muscle cells, or cardiomyocytes. Cardiomyocytes are myogenic, which means they can generate their own electrical contractions without external stimulation. The adaptations of cardiac muscle cells are covered in section B2.3.9 (/study/app/bio/sid-422-cid-755105/book/checklist-id-44811/).

The heart is always labelled as it would appear in the chest. When referring to the sides of the heart, you are referring to the left and right sides of the heart as they are positioned in someone's body. This means that the left side of the diagram is the right side of the heart, and the right side of the diagram is the left side of the heart.

The left ventricle wall is thicker than the right ventricle wall, because the left side of the heart needs to generate enough force to pump blood around the whole body (systemic circulation). The right side of the heart needs to generate a comparatively smaller force to pump blood to the lungs (pulmonary circulation).

The mammalian heart contains (**Figure 2**):

- Four chambers. The two upper chambers are called atria (singular, atrium), and the two lower chambers are called ventricles.
- Valves, to prevent the backflow of blood, ensuring that blood only flows through the heart in one direction. Valves located between the atria and the ventricles are called atrioventricular valves. The right atrioventricular valve is called the tricuspid valve and the left atrioventricular valve is called the bicuspid valve. Valves located between the ventricles and the arteries are called the semilunar valves. The right semilunar valve is called the pulmonary valve, and the left semilunar valve is called the aortic valve.
- Associated blood vessels, which transport blood into and out of the chambers of the heart. Veins return blood to the heart and arteries transport blood away from the heart. The vena cavae (singular: vena cava) are veins that return deoxygenated blood to the right side of the heart, delivering it to the right atrium. The vena cavae consist of the inferior vena cava, which carries blood from the lower part of the organism, and the superior vena cava, which transports blood from the upper part of the organism. The pulmonary artery transports deoxygenated blood away from the heart, to the lungs. In the lungs, the blood is oxygenated and returned to the left atrium via the left pulmonary vein. The oxygenated blood is then pumped out of the heart via the largest artery in the body, the aorta.
- Coronary blood vessels, which supply the cardiac muscle tissue with blood. Narrowing or blockage of these vessels can result in coronary heart disease (see section B3.2.1—6 (/study/app/bio/sid-422-cid-755105/book/blood-vessels-id-44450/)).
- The septum, which forms a physical barrier between the left and right sides of the heart, preventing the mixing of deoxygenated and oxygenated blood.

Study skills

There are a lot of words and structures in this section that may be new to you. It may be helpful to use memory tricks and triggers to help you. For example:

- **A**rteries transport blood **a**way from the heart, and the **a**orta is a type of artery. (artery, away and aorta all begin with the letter 'a')
- The t**r**icuspid valve is on the **r**ight side of the heart, and the bicuspid is on the left (tricuspid and right both contain the letter 'r')

Student view

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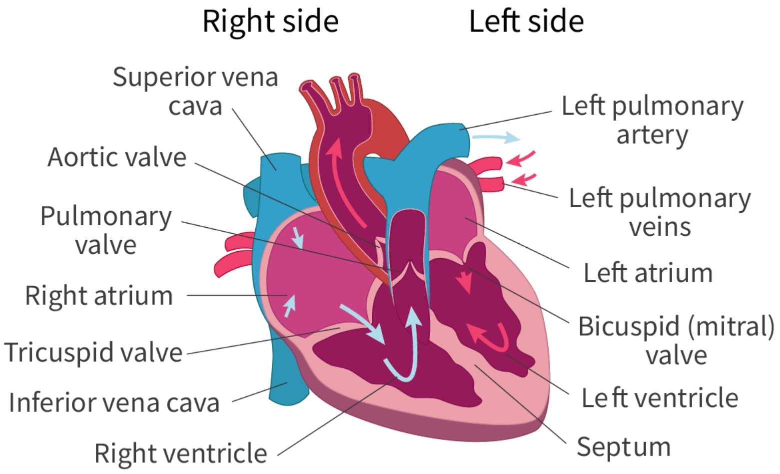

Figure 2. The structure of the mammalian heart.

More information for figure 2

The diagram depicts the structure of the mammalian heart, labeling various components and their locations. It is divided into the right side and left side.

On the right side of the heart, the following parts are labeled: - Superior vena cava: Positioned at the top right, this vessel returns deoxygenated blood from the body to the heart. - Aortic valve: Situated near the top center. - Pulmonary valve: Located to the right of the Aortic valve. - Right atrium: Positioned centrally towards the top. - Tricuspid valve: Found between the right atrium and right ventricle. - Inferior vena cava: Shown at the bottom right, it brings deoxygenated blood from the lower body. - Right ventricle: Located at the bottom right, it pumps deoxygenated blood to the lungs.

On the left side of the heart, the labeled parts include: - Left pulmonary artery: Positioned top left, carrying blood from the heart to the lungs. - Left pulmonary veins: Situated below the pulmonary artery, returning oxygenated blood from the lungs to the heart. - Left atrium: Located centrally. - Bicuspid (mitral) valve: Located centrally, below left atrium. - Left ventricle: Positioned at the bottom left. - Septum: The dividing wall between the right and left sides of the heart, shown centrally.

Arrows indicate blood flow direction through the heart chambers and valves, facilitating the circulation of blood to the lungs and rest of the body.

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International Mindedness

Different cultures and religions may have different attitudes, beliefs and rules that influence and guide how heart dissections are approached and perceived. For example, in some indigenous cultures in North and South America the heart is thought to be the seat of the soul and should be treated with great respect. In these cultures, heart dissections are approached with caution, reverence and the incorporation of traditional healing practices into the dissection.

Flow of blood through the heart

The right side of the heart pumps deoxygenated blood to the lungs. Deoxygenated blood returns to the right atrium via the vena cavae. As mentioned, the superior vena cava returns blood from the upper part of the body to the heart, and the inferior vena cava returns blood from the lower part of the body.

Student
view

When the atria contract, the deoxygenated blood in the right atrium passes through the tricuspid valve into the right ventricle. The tricuspid valve prevents the backflow of blood from the right ventricle into the right atria. When the right ventricle contracts blood passes through the pulmonary valve into the pulmonary artery. The pulmonary valve prevents the backflow of blood from the pulmonary artery into the right ventricle.

Although most arteries transport oxygenated blood, the pulmonary artery transports deoxygenated blood. The pulmonary artery branches into the left pulmonary artery, which transports blood to the left lung, and the right pulmonary artery which transports blood to the right lung.

In the lungs, exchange of carbon dioxide and oxygen occurs between the blood and the alveoli – carbon dioxide diffuses out of the blood and oxygen diffuses into the blood.

Although most veins transport deoxygenated blood, the pulmonary veins transport oxygenated blood. The right pulmonary vein transports blood from the right lung, and the left pulmonary vein transports blood from the left lung.

Blood returns to the left atrium. When the atria contract, oxygenated blood in the left atrium passes through the bicuspid valve into the left ventricle. The bicuspid valve prevents the backflow of blood from the left ventricle into the left atria. When the left ventricle contracts, blood passes through the aortic valve into the aorta. The aortic valve prevents the backflow of blood from the aorta into the left ventricle.

Try **Interactive 1** to match the structures of the heart to their correct descriptions.

Match the structure to the description

A specialised tissue found only in the heart, is able to initiate its own electrical impulses
Receive blood from veins and pump it into the ventricles
Receive blood from atria and pump it into the arteries
Prevent blood from flowing from the ventricles back into the atria
Prevent blood from flowing from the arteries back into the ventricles
Separates the left and right sides of the heart
Supply the cardiac tissue with blood

Atrioventricular valves | Cardiac muscle | Semilunar valves | Coronary vessels | Ventricles | Septum | Atria

Check

Interactive 1. Match the Structure to the Description.

The cardiac cycle

The cardiac cycle is the series of events that allow the heart to complete one beat. The cardiac cycle consists of three stages: atrial systole, ventricular systole and diastole.

The cardiac cycle is initiated by a group of specialised cardiomyocytes in the upper wall of the right atrium called the sinoatrial (SA) node, commonly called the pacemaker. The SA node initiates each contraction of the heart and it sets the heart rate, sending out electrical signals to neighbouring cells at regular intervals. This results in a resting heart rate of around 60–100 beats per minute for a healthy adult heart.

The electrical signal sent out from the SA node causes the left and right atria to contract simultaneously in a process called atrial systole. This pushes blood from the atria into the ventricles through the atrioventricular valves.

In order for the electrical signals to pass to the ventricles, they must be transmitted through the atrioventricular (AV) node, which is situated in the lower right atrium. Once the AV node is excited, signals pass down the interventricular septum via the bundle of His, and then along Purkinje fibres in the ventricle walls (**Figure 3**). This causes the left and right ventricles to contract simultaneously in a process called ventricular systole. Contraction of the ventricles pushes blood through semilunar valves into the arteries.

After each contraction of the heart there is a short period where the cardiac cells cannot be excited, called diastole. During this period, the heart muscle relaxes, pressure in the heart decreases and the heart refills with blood before another cardiac cycle begins. The atrioventricular valves will be open during diastole to allow blood to flow from the atria into the ventricles.

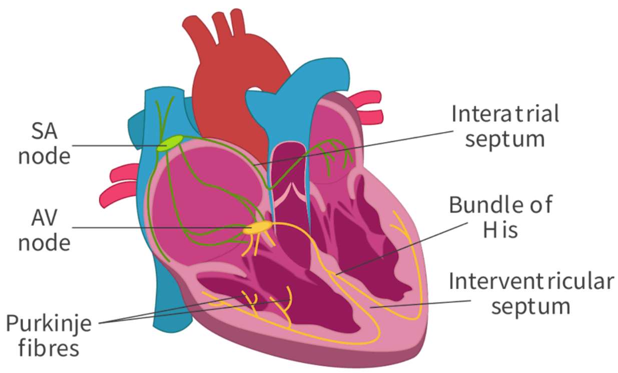

Figure 3. Structures involved in atrial and ventricular systole.

More information for figure 3

The diagram illustrates the anatomy of the heart, specifically structures involved in atrial and ventricular systole. Key components are labeled, including the SA node (sinoatrial node) located at the top of the right atrium, which acts as the heart's natural pacemaker. The AV node (atrioventricular node) is situated at the junction between the atria and ventricles and delays the electrical signal before passing it to the ventricles. The Purkinje fibers spread throughout the ventricles to distribute the electrical impulse evenly and coordinate contraction. Labeled septal structures include the interatrial septum, which separates the left and right atria, and the interventricular septum, separating the left and right ventricles. The Bundle of His, part of the heart's electrical conduction system, is shown leading from the AV node down the interventricular septum. These components play crucial roles in the heart's rhythm and contraction cycle.

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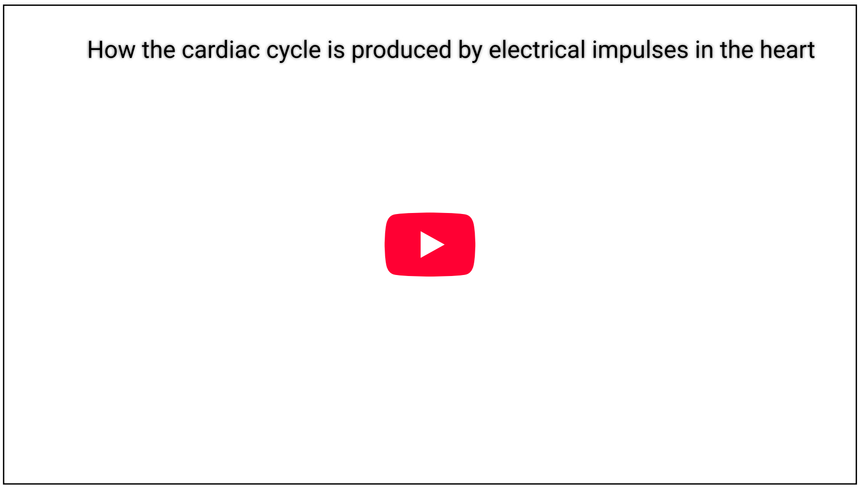
The cardiac cycle is shown in **Video 1**.



Video 1. The cardiac cycle.

Systolic and diastolic blood pressure

Blood pressure measurements are given as two numbers. One number will be higher, and is called the systolic blood pressure. This is the pressure exerted on the aorta wall when the left ventricle contracts during ventricular systole. The lower number represents the pressure exerted on the arterial walls when the heart relaxes during diastole. This value is called diastolic blood pressure.

Blood pressure is measured in millimetres of mercury (mmHg). Normal blood pressure is around 120/80 mmHg, which means that there is a pressure of 120 mmHg during systole, and a pressure of 80 mmHg during diastole (**Figure 4**).

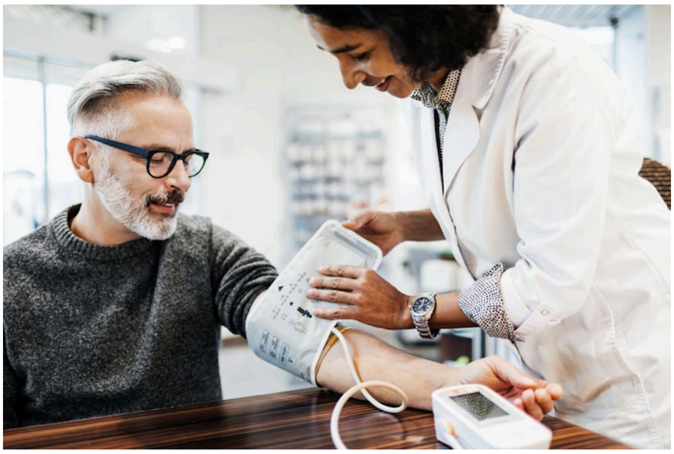


Figure 4. Blood pressure is measured using a sphygmomanometer, which consists of an inflatable cuff and a measuring device.

Credit: Tom Warner, Getty Images

A person with a resting blood pressure of 140/90 mmHg or higher has hypertension, where the pressure in their blood vessels is considered to be too high (**Figure 5**). Hypertension is common, but if left untreated can contribute to serious conditions such as coronary heart disease, stroke and kidney failure. When resting blood pressure falls below 90/60 mmHg, a person has hypotension, a condition where the blood pressure is dangerously low. Hypotension can lead to a variety of problems including dizziness, fainting, fatigue and confusion.

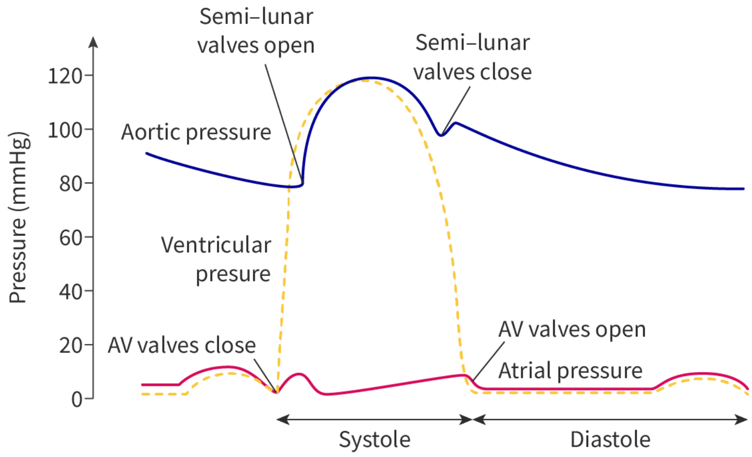


Figure 5. Graph showing how blood pressure changes during a heart beat.

More information for figure 5

The graph illustrates how blood pressure changes during a heartbeat. The X-axis represents time, with phases labeled as "Systole" on the left and "Diastole" on the right. The Y-axis displays pressure in millimeters of mercury (mmHg), ranging from 0 to 140.

Within the graph, there are three curves:

1. **Aortic pressure:** This curve starts at a lower value, rises sharply to a peak of about 120 mmHg during systole, then gradually declines entering diastole.
2. **Ventricular pressure:** Begins near 0, increases during systole to just above 120 mmHg, closely following the aortic pressure line, and drops back to near baseline with diastole.
3. **Atrial pressure:** Displays a smaller fluctuation, starting around 0, with a slight hump during systole, mirroring a minor rise, and remains relatively stable.

Markers on the graph indicate when semi-lunar valves open and close, and AV valves open and close, correlating with the pressure changes. The graph gives a visual representation of the cyclical nature of pressures in different heart chambers during a heartbeat.

[Generated by AI]

Try the activity below to learn more about the heart, its blood vessels and the cardiac cycle.

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual activity

In this activity you will start by labelling the heart and its blood vessels then view and analyse an interactive of the cardiac cycle.

1. Use this link (https://www.sciencelearn.org.nz/labelling_interactives/1-label-the-heart) to label the four chambers of the heart and the associated blood vessels.
2. Use this link (https://library.med.utah.edu/kw/pharm/hyperheart/) to learn more about the flow of blood through the heart and pressure changes during the cardiac cycle. Write a paragraph to explain what is happening during the following stages. In your answer, refer to pressure and

electrical activity in the heart.

a. Atrial systole
b. Ventricular systole
c. Diastole

5 section questions

B3. Form and function: Organisms / B3.2 Transport

Phloem and xylem (HL)

B3.2.17: Generation of root pressure in xylem vessels (HL) B3.2.18: Adaptations of phloem sieve tubes and companion cells (HL)

Higher level (HL)

Learning outcomes

By the end of this section you should be able to:

- Explain how root pressure is generated in xylem vessels.
- Outline the adaptations of phloem sieve tubes and companion cells for the translocation of sap.

Aphids are small insects that feed on the nutrient-rich phloem sap of plants (**Figure 1**). Aphids cut into the plant tissue and then penetrate the phloem wall without damaging it using specialised mouthpieces called stylets. When the stylet penetrates the phloem, the high pressure of sap in the vessel causes it to flow into the stylet, rather than the aphid sucking it up. Scientists can use this phenomenon to study the rate of flow of the phloem by removing the aphid from the plant and measuring the rate at which sap continues flowing out of the phloem vessel. Scientists can also use aphids to analyse the substances excreted by the aphid after they have fed. How might they do this?

Figure 1. Aphids are used to study the structure of phloem tissue and the composition of sap transported in the phloem.
Credit: Oxford Scientific, Getty Images (https://www.gettyimages.com/detail/photo/nettle-aphid-microlophium-evansii-royalty-free-image/90051334)

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Generation of root pressure in the xylem

The majority of water transport is driven by the process of transpiration, the loss of water from the aerial parts of the plant. This creates a negative pressure that pulls water through the xylem in the process of capillary action. Transpiration is covered in more detail in section B3.1.7–10 (/study/app/bio/sid-422-cid-755105/book/gas-exchange-in-leaves-id-44440/).

When transport in the xylem due to transpiration is insufficient to meet the needs of the plant, root pressure is generated to enhance water movement through the xylem (**Figure 2**).

Root pressure is a positive pressure potential, meaning that it is created against and is greater than an opposing force, in this case, the force of gravity. Root pressure is generated by the active transport of mineral ions, including potassium, magnesium and nitrogen ions from the soil into root hair cells. This increased solute concentration reduces the water potential inside the root hair. As a result, water moves down its water potential gradient from the soil into the root by the process of osmosis. See subtopic D2.3 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43550/) for more information on water potential.

The movement of water into the xylem in the root creates a hydrostatic pressure that pushes the contents of the xylem upwards. The process of root pressure tends to be more pronounced at night, when lower temperatures and light intensity reduce the rate of transpiration, or during spring, before the leaves on deciduous plants have opened.

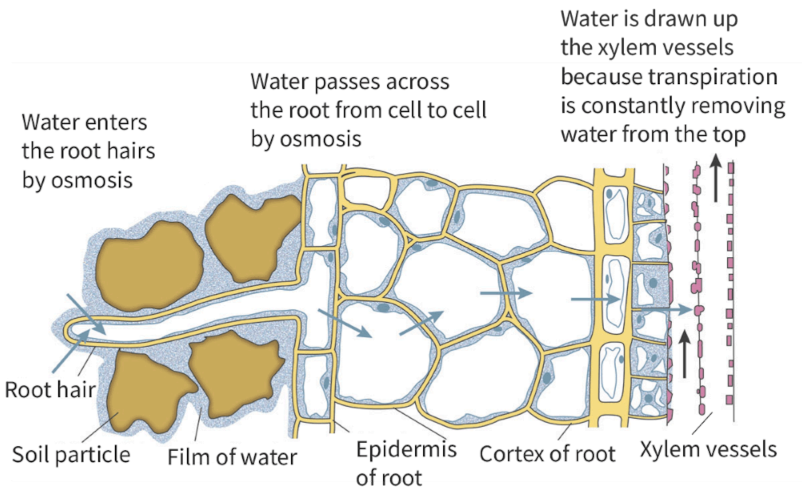

Figure 2. Root pressure.

More information for figure 2

The diagram illustrates the process of water movement in plant roots. Starting from the left, water enters root hairs by osmosis, moving across soil particles with a film of water surrounding them. The entry point is labeled as "Root hair" adjacent to a "Soil particle" encapsulated by a "Film of water." Arrows indicate the direction of water movement.

Water then moves from cell to cell across the root's epidermis and cortex, again by osmosis, as depicted by several interconnected cells. This area is labeled "Epidermis of root" and "Cortex of root," and the arrows show the lateral movement of water between cells.

On the right, the diagram depicts the xylem vessels, where water is drawn upward. Text indicates that "Water is drawn up the xylem vessels because transpiration is constantly removing water from the top." The xylem is visually represented by a series of elongated cells, with arrows showing the upward movement of water due to transpiration.

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The phloem

All plant cells require carbon compounds such as sugars and amino acids, but only a small number of plant cells are capable of producing them. Photosynthetic cells, mostly palisade mesophyll cells, produce quantities large enough to supply the needs of the whole plant and these nutrients are then transported by a vascular tissue called the phloem.

Sources are locations that are producing or releasing carbon (organic) compounds. For example:

- the leaves, which produce carbon compounds through photosynthesis, or
- the roots or tubers which store carbon compounds that can later be transported to the rest of the plant.

Sinks are any part of the plant that is storing or consuming carbon compounds, often actively growing or metabolically active tissues.

Carbon compounds are transported in phloem from a source to a sink in the process of translocation. This involves the active transport of sugars and other carbon compounds into the phloem at the source, increasing the solute concentration in the phloem, hence decreasing the water potential. As a result, water is drawn into the phloem from the xylem by osmosis, increasing hydrostatic pressure at the source. This hydrostatic pressure exerted on the sap creates a pushing effect, moving sap along the phloem towards the sink. This is a type of movement called mass flow, because water and solutes are moving together. See section A1.1.4–5 (/study/app/bio/sid-422-cid-755105/book/interactions-with-water-id-43195/) for more information about the solvent properties of water. At the sink, solutes are unloaded, either passively or through active transport. This decreases the solute concentration in the phloem, causing water to return to the xylem by osmosis and lowering the hydrostatic pressure.

Because any one organ may be a source at some times and a sink at others (for example, leaves may be a sink when budding, and then a source once developed), transport in the phloem is bidirectional, unlike the xylem where transport is unidirectional. Unlike the movement of water in the xylem, translocation requires active transport. Because of this, phloem cells are living, whereas xylem cells are dead at maturity.

Structure of phloem

Phloem is composed of cells called sieve tube elements, which are arranged end to end to form a long tube called the sieve tube. The walls connecting sieve tube elements are perforated structures called sieve plates through which phloem sap can flow (**Figure 3**).

Sieve tube elements contain limited cytoplasm with a few mitochondria and other organelles, but the nucleus, vacuole, cytoskeleton and ribosomes are broken down to provide more space for the transport of nutrients. Because sieve tube elements are eukaryotic cells that lack a nucleus, they are an example of atypical cell structure (see section A2.2.8–11 (/study/app/bio/sid-422-cid-755105/book/animal-plant-and-fungal-cells-id-44719/)).

As sieve tube elements lack many essential structures, they require support from companion cells that run alongside them. Companion cells contain many mitochondria, which produce the ATP necessary to actively load and transport nutrients into the phloem at the source and support the metabolic activity of sieve tube elements. Companion cells also play a role in unloading nutrients from the phloem at the sink, and they may do this through active transport or by passive means.

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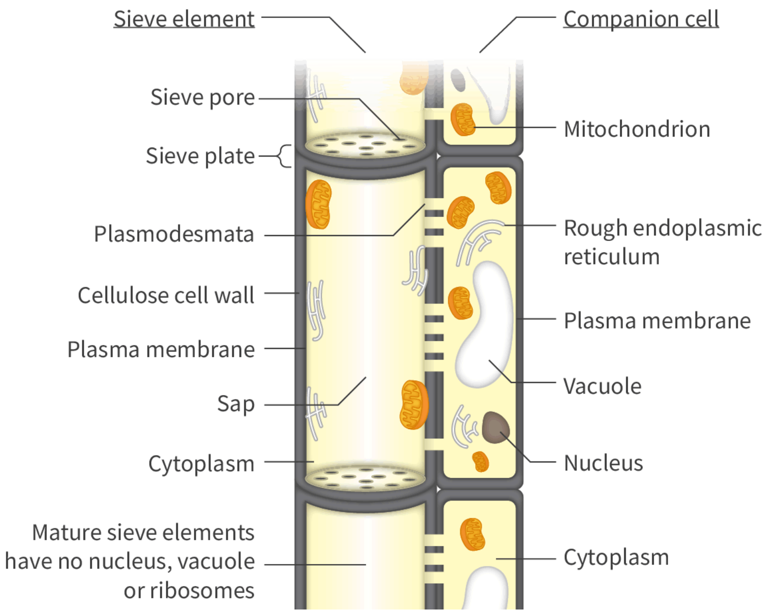

Figure 3. Longitudinal section of phloem.

More information for figure 3

The image is a diagram depicting a longitudinal section of a plant phloem. On the left, it features a sieve element with labels for various parts such as: sieve pore, sieve plate, plasmodesmata, cellulose cell wall, plasma membrane, sap, and cytoplasm. In contrast, on the right, it shows a companion cell, illustrated with mitochondrion, rough endoplasmic reticulum, plasma membrane, vacuole, nucleus, and cytoplasm. A note indicates that mature sieve elements lack a nucleus, vacuole, or ribosomes. The diagram highlights the structural differences between sieve elements and companion cells and their mutual connection through plasmodesmata for nutrient transport.

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Sieve tube elements and companion cells are connected by pores called plasmodesmata (singular: plasmodesma), as seen in **Figure 4**. Plasmodesmata are important for transporting nutrients and facilitating communication between cells.

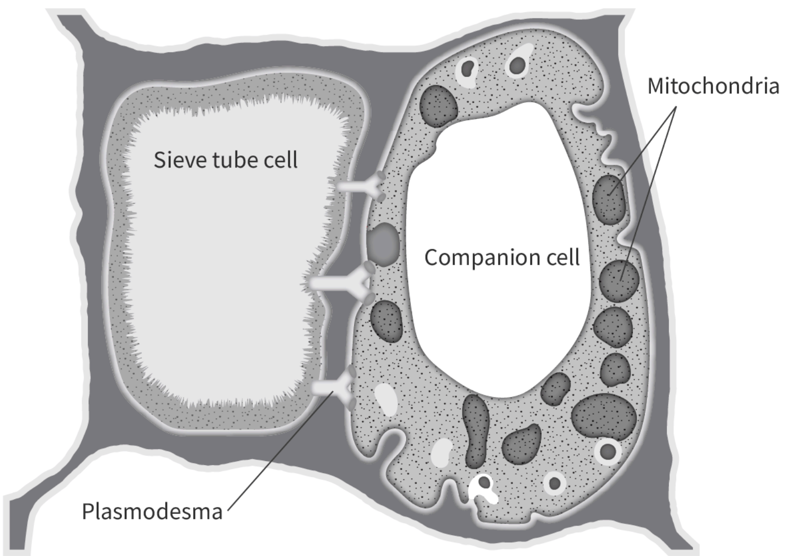

Figure 4. Sieve tube cell and companion cell connected by plasmodesmata.

More information for figure 4

Student view

The diagram illustrates a sectional view of a sieve tube cell adjacent to a companion cell. The sieve tube cell is on the left and is depicted with a large, central vacuole-like area, labeled "Sieve tube cell." To the right is the companion cell, shown with a dotted texture and labeled "Companion cell." The companion cell contains several dark, circular spots labeled as "Mitochondria." Connecting the two cells are structures labeled "Plasmodesma," indicating the pores that allow communication and nutrient transport between the sieve tube and companion cells. The background showcases a textured boundary, emphasizing the distinct separation and connection between these two plant cells.

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The adaptations of phloem tissue structures are outlined in **Table 1**.

Table 1. Structures found in phloem tissue and their functions.

Structure	Function
Sieve plates	Perforated structures that separate sieve tube elements. Sap can flow freely through the perforations
Sieve tube elements have reduced cytoplasm and organelles and do not contain a nucleus	More space within the sieve tube element for sap
Companion cells contain many mitochondria	Provide the ATP necessary to actively transport nutrients into and out of the phloem
Plasmodesmata between sieve tube elements and companion cells	Allow communication and transport of nutrients between sieve tube elements and companion cells

Try this comparison activity to check your understanding about xylem and phloem.

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 10 minutes
- **Activity type:** Individual activity

Your task

Using the information you have learned in this section, complete **Table 1** to distinguish between xylem and phloem. Discuss your answers with your class.

Table 1. Xylem vs. phloem.

	Xylem	Phloem
Substances transported in this vessel		
Direction of transport in this vessel		
Name of process(es) by which substances are transported in this vessel		
Description of transport processes in this vessel		

Overview (/study/app/bio/sid-422-cid-755105/o

	Xylem	Phloem
Names of the cells that make up this vessel		
Are cells that make up this vessel dead or alive?		
Description of the structure of this vessel		

5 section questions

B3. Form and function: Organisms / B3.2 Transport

Summary and key terms

- There are three types of blood vessels in our bodies: arteries, capillaries and veins. Arteries transport blood away from the heart at high pressures. They have a thick wall of muscle and elastic tissue which functions to withstand the high pressures exerted by the heart. Capillaries facilitate the exchange of substances between the blood and internal and external surfaces. They have a large surface area and thin walls that are permeable to fluids and solutes. Veins transport blood back to the heart. They have thinner walls and larger lumens than arteries, and valves to prevent the backflow of blood.
- Pulse rate, also known as heart rate, is the number of times your heart beats per minute and is usually 60–100 bpm. It can be measured manually or digitally.
- Coronary arteries supply the heart tissue with blood. Occlusion (blockage) of the coronary arteries by atherosclerotic plaque can restrict blood flow to the heart, a condition called coronary heart disease.
- In plants, water is transported in a vascular tissue called xylem, a hollow continuous tube that is strengthened with lignin. The transpiration of water from the aerial parts of a plant creates a pull which draws water up this vessel in a process called capillary action.

Higher level (HL)

- Tissue fluid bathes cells and facilitates the exchange of substances between the blood and the cells. It is formed when blood plasma is pushed out through the walls of capillaries. Following exchange, most tissue fluid will be taken back up into the capillary, but a small amount will form lymph.
- Mammals have a double circulatory system, which means that blood travels to the heart twice in order to travel around the body once — deoxygenated blood returns to the right side of the heart and is then pumped to the lungs for oxygenation before returning to the left side of the heart to be pumped to the rest of the body. Separation of deoxygenated and oxygenated blood helps to ensure steep concentration gradients and efficient gas exchange between the blood and cells.
- The heart contains four chambers: two atria and two ventricles, as well as valves to prevent the backflow of blood. Deoxygenated blood flows into the right atrium, and then passes through the tricuspid valve into the right ventricle. Blood is pumped from the right ventricle through the pulmonary valve and into the pulmonary artery, which transports blood to the lungs. In the lungs, blood is oxygenated, following which it returns to the left atria of the heart. Blood passes from the left atria through the bicuspid valve into the left ventricle, and is then pumped out of the heart through the aortic valve, into the aorta.
- The cardiac cycle is the sequence of events that occur in every heart beat. It is initiated by the sinoatrial node, the heart's pacemaker, and involves atrial systole, ventricular systole and diastole.

Student view

Overview (/study/app/bio/sid-422-cid-755105/o

- Root pressure is generated by the active transport of mineral ions into the root, which causes water to be drawn in by osmosis. This increases hydrostatic pressure in the root, pushing water up the xylem. Root pressure is especially important when transpiration is insufficient to meet the needs of the plant, for example during periods of high humidity.
- Carbon compounds, including sugars and amino acids are transported in the phloem. The carbon compounds are actively loaded onto the phloem at the source, which in turn draws water into the phloem, increasing the hydrostatic pressure in the phloem and pushes the sap (the phloem contents) along to the source where it is unloaded.
- The phloem is made of specialised cells called sieve tube elements and companion cells. Companion cells provide the ATP necessary to actively load substances into the sieve tube, which is made of sieve tube elements.

Key terms

Review these key terms. Do you know them all? Fill in as many gaps as you can using the terms in this list.

1. There are three blood vessels in our bodies: ______, which transport pressurised blood away from the heart, ______, which facilitate exchange of substances with tissue cells, and ______, which return blood back to the heart. Veins have thinner walls and larger ______ than arteries, and they also have ______ to prevent the backflow of blood.
2. Occlusion of the ______ arteries, which supply the heart muscle with blood, can be caused by the build-up of fatty ______ in the walls of these vessels and can lead to coronary heart disease.
3. In plants, water is transported by a vascular tissue called ______, hollow continuous tubes which are reinforced with ______. As water is lost from the aerial parts of a plant in the process of transpiration, water is drawn up the xylem by the process of ______ action.
4. [HL] Tissue fluid is formed by the ultrafiltration of blood ______ out through the capillary wall. Tissue fluid bathes cells and facilitates the ______ of substances between the blood and the cells.
5. [HL] The cardiac cycle is the series of stages that occur in one heart beat and includes atrial systole, ventricular systole and ______.
6. [HL] Root pressure is generated when mineral ions are ______ transported into plant roots, which causes water to follow by ______, increasing the hydrostatic pressure in the roots and pushing water up the xylem.
7. [HL] In the process of translocation, carbon compounds such as sugars and amino acids are loaded into the phloem of a plant at the ______, and they then move to the ______ where they are unloaded by active or passive means.

coronary | capillaries | exchange | actively | valves | capillary | veins | osmosis | diastole | lignin | lumens | sink | source | plaque | xylem | plasma | arteries

Check

Student view

Interactive 1. Types of Blood Vessels in Our Bodies.

Checklist

What you should know

After studying this subtopic you should be able to:

- Describe the structures of the arteries, capillaries and veins and explain how they are adapted for their functions.
- Outline different methods of measuring pulse rate.
- Outline the causes and consequences of occlusion of the coronary arteries.
- Explain how water is transported from the roots to the leaves during transpiration.
- Outline the adaptation of the xylem vessels for the transport of water.
- Draw and annotate plan diagrams from micrographs showing the distribution of tissues in a transverse section of the stem of a dicotyledonous plant, and dicotyledonous root.

Higher level (HL)

- Describe how tissue fluid is released and taken back up by the capillaries.
- Compare and explain the composition of plasma and tissue fluid.
- Outline how excess tissue fluid is drained into lymph ducts.
- Compare the single circulation of bony fish to the double circulation of mammals.
- Explain the adaptations of the mammalian heart for delivering pressurised blood to the arteries.
- Outline the stages of the cardiac cycle.
- Explain how root pressure is generated in xylem vessels.
- Outline the adaptations of phloem sieve tubes and companion cells for the translocation of sap.

Practical skills

Once you have completed this subtopic, go to Practical 6: Investigating the effect of physical activity on heart rate (/study/app/bio/sid-422-cid-755105/book/investigating-the-effect-of-physical-activity-id-46705/) in which you will measure the heart (pulse) rate of humans at rest and after performing vigorous exercise.

Investigation

Overview (/study/app/bio/sid-422-cid-755105/o

- **IB learner profile attribute:** Thinkers
- **Approaches to learning:** Thinking skills – Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 40–60 minutes
- **Activity type:** Individual activity

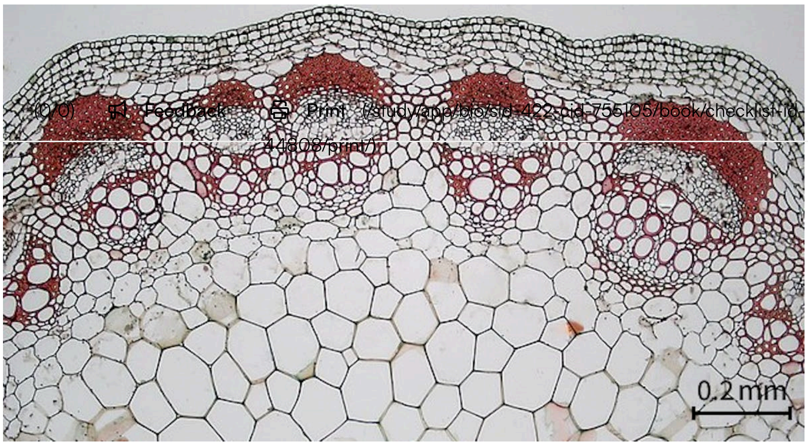
Your task

In this activity you will be given a number of photomicrographs of transport vessels. For each photomicrograph:

1. Identify the vessel (or vessels).
2. Draw a labelled scientific diagram of what you can see of the vessel (or vessels).
3. Calculate the magnification of the photomicrograph using the scale bar.
4. Label the visible structures.
5. Write a paragraph explaining how that vessel is adapted for its function.

See section A2.2.1 (/study/app/bio/sid-422-cid-755105/book/using-microscopes-id-43573/) for a reminder of conventions when drawing images from microscopes and for a reminder of how to calculate magnification.

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/checklist-id-44808/print/) Assign



Source: "Herbaceous Dicot Stem Vascular Bundles Young Helianthus (https://commons.wikimedia.org/wiki/File:Herbaceous_Dicot_Stem_Vascular_Bundles_Young_Helianthus_(36834307513).jpg)" by Berkshire Community College Bioscience Image Library is licensed under CC0 1.0 (https://creativecommons.org/publicdomain/zero/1.0/)

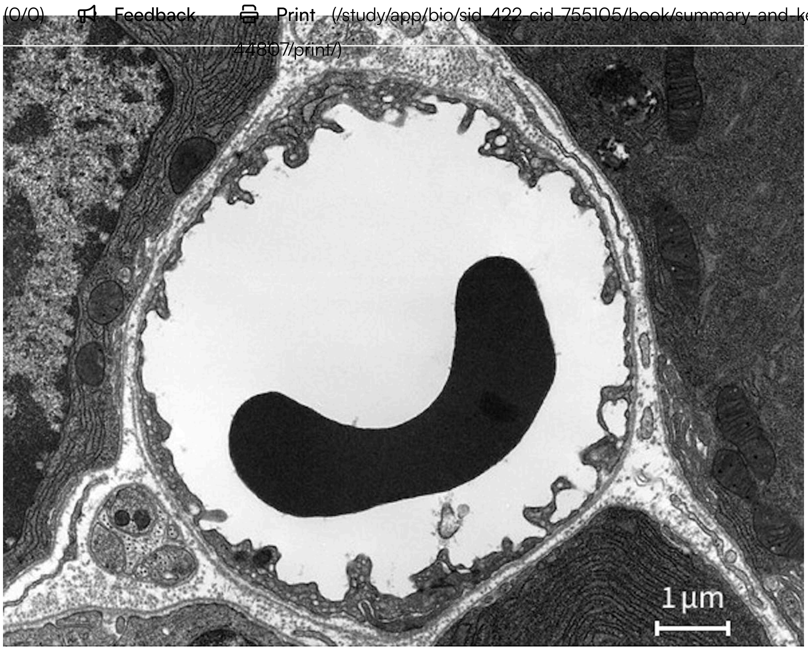
Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/adaptations-of-the-heart-hl-id-44448/print/) Assign

Student view

Overview (/study/app/bio/sid-422-cid-755105/o

Credit: Ed Reschke, Getty Images (https://www.gettyimages.co.uk/detail/photo/artery-and-vein-showing-three-distinct-layers-or-royalty-free-image/139812233)

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/summary-and-key-terms-id-44807/print/) Assign



Source: "A red blood cell in a capillary, pancreatic tissue (https://commons.wikimedia.org/wiki/File:A_red_blood_cell_in_a_capillary,_pancreatic_tissue_-_TEM.jpg)" by Louisa Howard is licenced under CC0 1.0 (https://creativecommons.org/publicdomain/zero/1.0/)

B3. Form and function: Organisms / B3.2 Transport

Reflection

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/reflection-id-46877/print/) Assign

Teacher instructions

The goal of this section is to encourage students to reflect on their learning and conceptual understanding of the subject at the end of this subtopic. It asks them to go back to the guiding questions posed at the start of the subtopic and assess how confident they now are in answering them. What have they learned, and what outstanding questions do they have? Are they able to see the bigger picture and the connections between the different topics?

Students can submit their reflections to you by clicking on 'Submit'. You will then see their answers in the 'Insights' part of the Kognity platform.

Reflection

Now that you've completed this subtopic, let's come back to the guiding question introduced in The big picture (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43215/).

- What adaptations facilitate transport of fluids in animals and plants?
- What are the differences and similarities between transport in animals and plants?

With these questions in mind, take a moment to reflect on your learning so far and type your reflections into the space provided.

Student view

Overview
(/study/ap
422-
cid-
755105/o

You can use the following questions to guide you:

- What main points have you learned from this subtopic?
- Is anything unclear? What questions do you still have?
- How confident do you feel in answering the guiding questions?
- What connections do you see between this subtopic and other parts of the course?

Once you submit your response, you won't be able to edit it.

0/2000

Submit

Rate subtopic B3.2 Transport

Help us improve the content and user experience.

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/phloem-and-xylem-hl-id-44454/print/) Assign

Student view