

Transport

Revision notes • IB Biology B3.2 transport: capillaries, arteries, veins, pulse, coronary heart disease, xylem, stems and roots, and (HL) tissue fluid, heart, phloem.

For IB Diploma Biology, Standard Level and Higher Level (first assessment 2025). **HL only** is additional higher level content, for HL students only.

Transport Spec B3.2

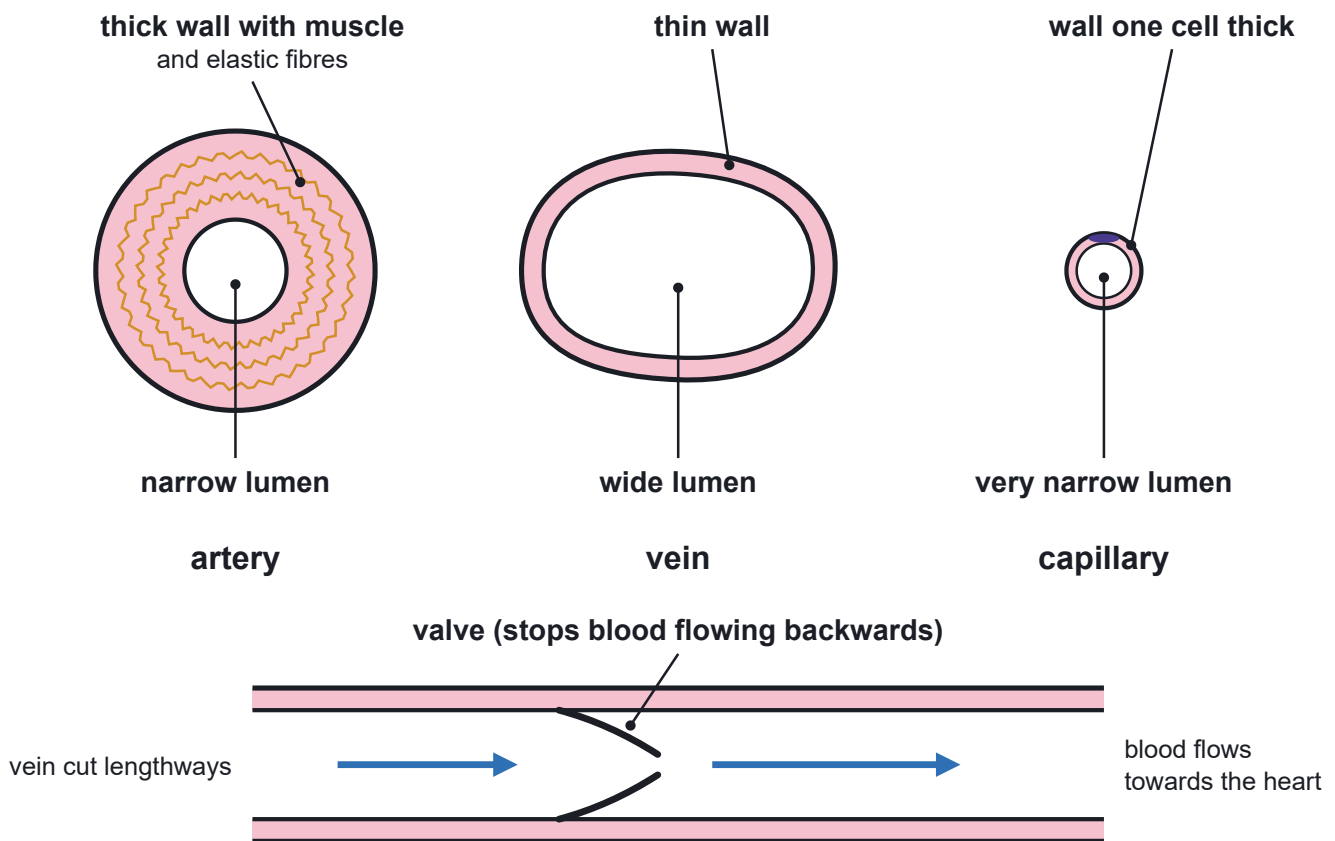
Adaptations of capillaries Spec B3.2.1

Arterioles divide into networks of **capillaries** called capillary beds, which pass close to every active cell. Capillaries rejoin to form venules. All exchange between blood and tissues happens in capillaries.

Adaptations of capillaries	
Adaptation	How it helps exchange
Branching into dense networks	Gives a large total surface area and brings blood close to every cell.
Narrow diameter (about the width of a red blood cell)	Large surface area relative to volume; red blood cells pass close to the wall.
Thin wall: one layer of flattened endothelium cells on a basement membrane	Short diffusion distance.
Fenestrations (pores) in some capillaries	Allow faster exchange of fluid and solutes where exchange needs to be particularly rapid, for example in the glomerulus of the kidney and in the villi of the small intestine.
Slow blood flow	More time for exchange.

Common mistake: Write 'the capillary wall is one cell thick', not 'the capillary has a cell wall'. Animal cells have no cell walls.

Structure and adaptations of arteries and veins Spec B3.2.2, B3.2.3, B3.2.5



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Arteries have thick walls and narrow lumens; veins have thin walls, wide lumens and valves.

Arteries and veins compared		
Feature	Artery	Vein
Wall thickness relative to lumen	Thick wall, narrow lumen	Thin wall, wide lumen
Tunica media (smooth muscle and elastic fibres)	Thick layer	Thin layer
Shape in a micrograph	Round, with a folded inner lining	Often flattened or irregular
Valves	None along their length	Present
Blood pressure	High, pulsing	Low, steady

Practical skill: To identify a vessel in a micrograph, compare the thickness of the wall with the diameter of the lumen. In an artery the wall is thick relative to a narrow, round lumen; in a vein the wall is much thinner than the width of its wide, often flattened lumen.

Adaptations of arteries

- Elastic fibres** stretch when the ventricles pump blood in, then recoil between beats. The recoil pushes blood on and keeps the pressure up, so flow is less pulsing further from the heart.
- A thick layer of **smooth muscle** can contract to narrow the lumen, helping to maintain blood pressure.

- The thick wall, with a tough outer layer of collagen fibres, withstands high pressure without bursting.
- The narrow lumen helps maintain high pressure.

Adaptations of veins

- Pressure in veins is too low to push blood back to the heart unaided.
- Pocket **valves** close if blood starts to flow backwards, so blood moves only towards the heart.
- The thin, **flexible wall** is compressed when nearby skeletal muscles contract, squeezing blood towards the heart.
- A wide lumen offers little resistance to flow.

Pulse rates and occlusion of the coronary arteries Spec B3.2.4, B3.2.6

Measuring pulse rate

Each heartbeat sends a surge of blood along the arteries, felt as a **pulse**. The pulse rate equals the heart rate.

Practical skill: Press two fingertips (not the thumb, which has its own pulse) on the radial artery on the inside of the wrist or the carotid artery in the neck. Count beats for 30 s and multiply by 2, repeat and find the mean. Compare the result with a digital heart rate monitor or pulse oximeter.

Pulse rate

A student counts 19 beats in 15 seconds. Calculate the pulse rate. (Practice data.)

1. Beats per minute = $19 \times (60 \div 15)$
2. = $19 \times 4 = 76$

Answer: 76 beats per minute

Occlusion of the coronary arteries

The **coronary arteries** branch from the aorta and supply cardiac muscle with oxygen and glucose.

1. Fatty deposits (atheroma or plaque) build up in the wall of a coronary artery, under the endothelium: atherosclerosis.
2. The lumen narrows and the wall hardens, so blood flow is reduced.
3. If a plaque ruptures, a blood clot (thrombus) can form and block the artery completely: **occlusion**.
4. Cardiac muscle beyond the blockage gets too little oxygen for aerobic respiration, causing chest pain (angina) or, if severe, a heart attack (myocardial infarction), when part of the heart muscle dies.

Risk factors include a diet high in saturated fat, high blood cholesterol, smoking, high blood pressure, obesity, lack of exercise, increasing age, male sex and family history.

Exam tip: A correlation coefficient (r) from -1 to +1 measures how strongly two variables are correlated. Even a strong correlation, such as between saturated fat intake and coronary heart disease, does not prove that one causes the other; a low r or no correlation can be evidence against a hypothesis.

Water transport in xylem Spec B3.2.7, B3.2.8

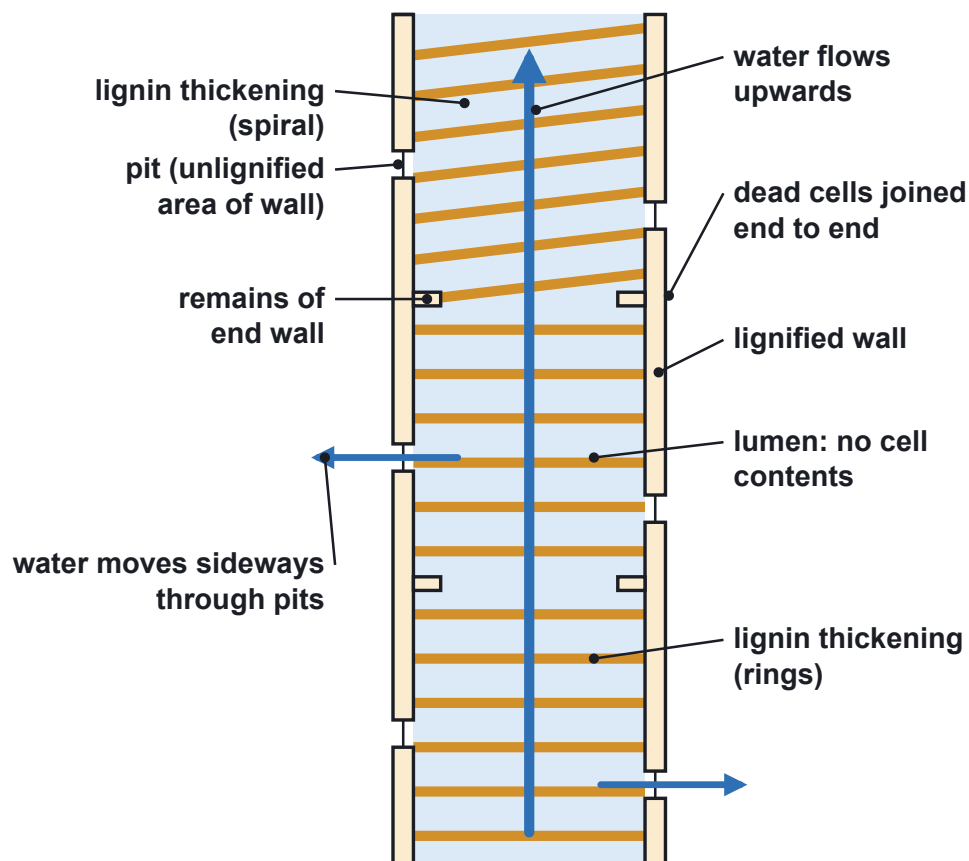
1. Water evaporates from the cell walls of spongy mesophyll cells and diffuses out of the leaf through stomata (transpiration).
2. Water is drawn out of the xylem vessels in the leaf veins and through the cell walls to replace it, by **capillary action** (adhesion of water to cellulose).
3. This generates **tension** (a negative pressure potential) in the xylem.
4. The tension pulls water up the xylem from the roots.

5. **Cohesion** between water molecules, due to hydrogen bonding, keeps the column of water continuous so it does not break.

This is the cohesion-tension mechanism. It is passive: the energy comes from evaporation, driven by heat from the sun, not from ATP.

Adaptations of xylem vessels

Xylem vessel adaptations	
Feature	Function
No cell contents (dead cells, no cytoplasm or nucleus)	Unimpeded flow of water.
Incomplete or absent end walls	Cells form a continuous tube, so water flows without obstruction.
Lignified walls (thickened in rings, spirals or networks)	Withstand the tension without collapsing inwards.
Pits (unlignified areas of wall)	Allow water to enter and leave the vessel, and pass between neighbouring vessels.



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A xylem vessel: a continuous tube of dead cells with **lignified walls** that resist tension, and pits for lateral movement of water.

Exam tip: Linking question: how do pressure differences contribute to the movement of materials?
Xylem uses negative pressure (tension); blood and phloem sap use positive pressure.

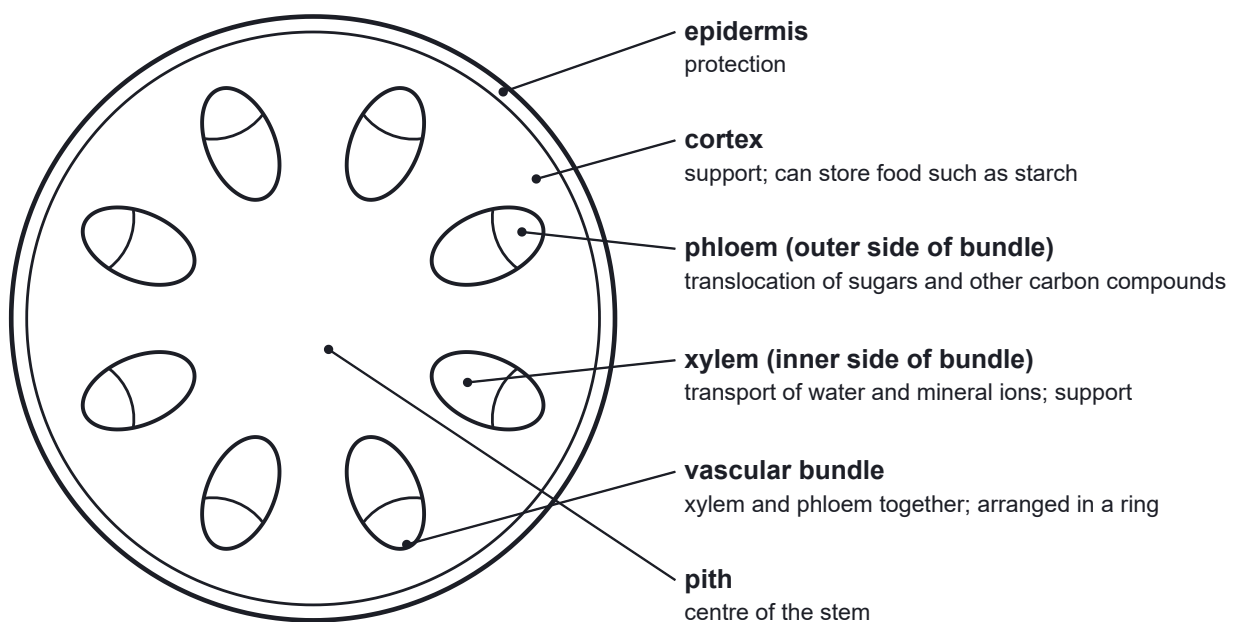
Tissues in dicotyledonous stems and roots Spec B3.2.9, B3.2.10

Functions of tissues in stems and roots

Tissue	Main function
Epidermis	Protective outer layer; in roots it bears root hairs that absorb water and mineral ions.
Cortex	Packing and support tissue between epidermis and vascular tissue; can store food such as starch; in roots water crosses it to reach the xylem.
Xylem	Transports water and mineral ions from roots to leaves; lignified walls give support.
Phloem	Transports sap containing sugars and other carbon compounds by translocation.
Vascular bundle	A strand of xylem and phloem together.

Stem

- Vascular bundles are arranged in a **ring** near the outside of the stem.
- In each bundle, phloem is on the outside and xylem on the inside.
- Cortex lies between the epidermis and the ring of bundles; the centre of the stem is pith.

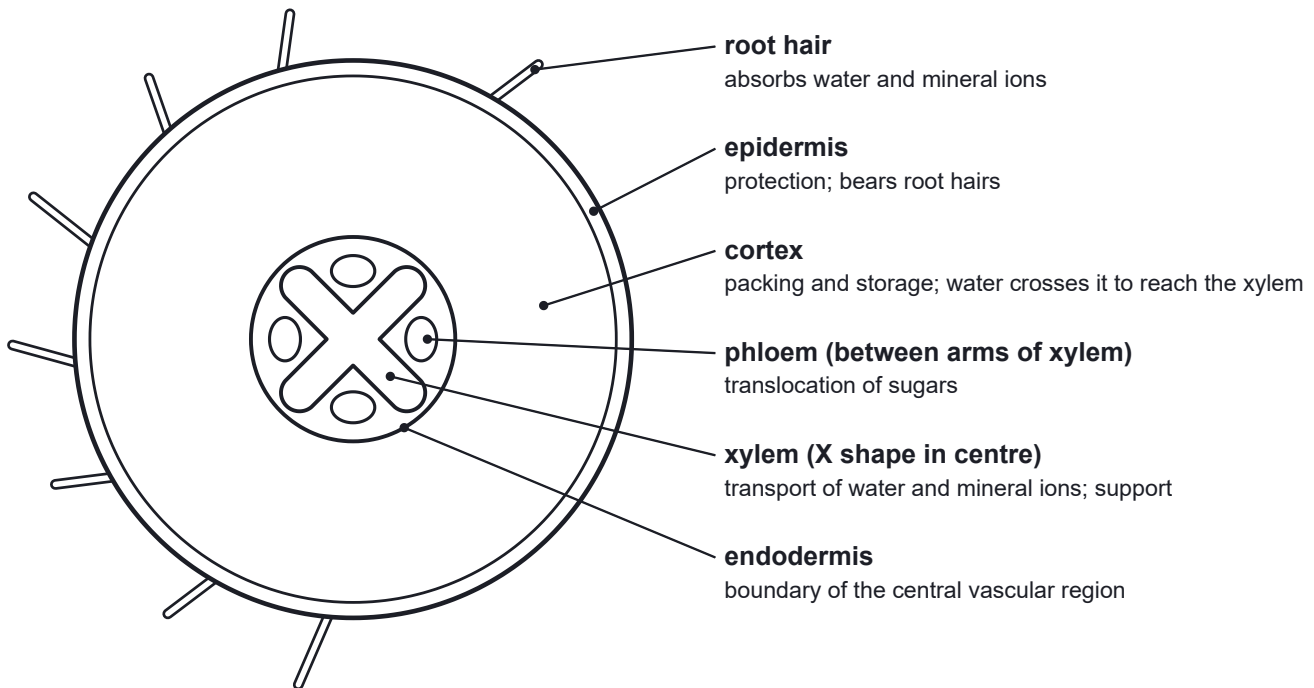


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Plan diagram of a dicotyledonous stem: vascular bundles in a **ring**, phloem outside and xylem inside each bundle.

Root

- Xylem and phloem form a **central vascular region**, not a ring: xylem in a star or X shape with phloem between its arms.
- The guide asks you to identify vascular bundles in the root too. In a root they are **radial**: the groups of xylem and phloem alternate on different radii inside one central vascular cylinder (the stele), instead of xylem and phloem sharing a bundle as in the stem.
- A wide cortex surrounds the vascular region, with the epidermis and root hairs on the outside.
- The central position of vascular tissue resists the pulling forces on a root.



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Plan diagram of a dicotyledonous root: xylem and phloem form a **central vascular region**, with phloem between the arms of the xylem.

Practical skill: Draw plan diagrams from micrographs: outline each tissue with a single clear line, keep proportions accurate, no cells and no shading. Label the tissues the guide lists (epidermis, cortex, vascular bundles, xylem and phloem; pith in the stem) and, for the stem, annotate each label with its main function.

Tissue fluid and lymph Spec B3.2.11, B3.2.12, B3.2.13 HL only

Release and reuptake of tissue fluid

1. At the arteriole end of a capillary bed, blood pressure is high.
2. Plasma is forced out through gaps in the capillary wall: **pressure filtration**. This fluid is **tissue fluid**.
3. Large plasma proteins and blood cells stay in the capillary.
4. Along the capillary, pressure falls. At the venule end the pressure is lower, so tissue fluid drains back into the capillary (the plasma proteins left in the blood help draw water back in by osmosis).

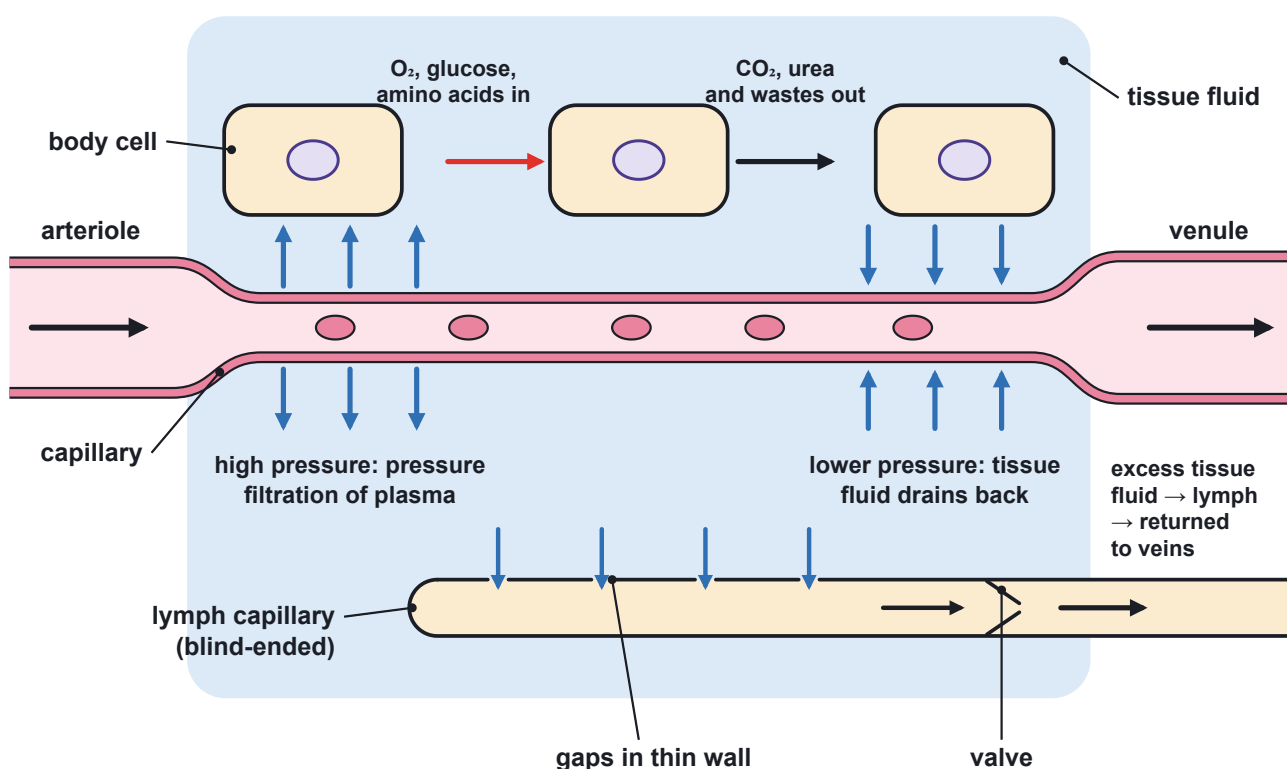
Exchange between tissue fluid and cells

Tissue fluid bathes every cell. Oxygen, glucose, amino acids and ions diffuse or are transported from the fluid into cells; carbon dioxide, urea and other wastes pass from cells into the fluid and then into the blood.

Composition of plasma and tissue fluid		
Component	Plasma	Tissue fluid
Water, ions, glucose, amino acids	Present	Present, at similar concentrations
Large proteins	High concentration	Very little
Oxygen	Higher	Lower (used by cells)
Carbon dioxide and wastes	Lower	Higher (released by cells)
Red blood cells	Carried in the blood but not part of plasma	Absent

Drainage into lymph ducts

- Not all tissue fluid returns to the capillaries. The excess drains into blind-ended lymph capillaries, which have **thin walls with gaps** that let fluid in. The fluid is now lymph.
- Lymph ducts have valves, so lymph flows in one direction only, squeezed along by surrounding muscles.
- Lymph is returned to the blood circulation in veins near the heart (the subclavian veins).



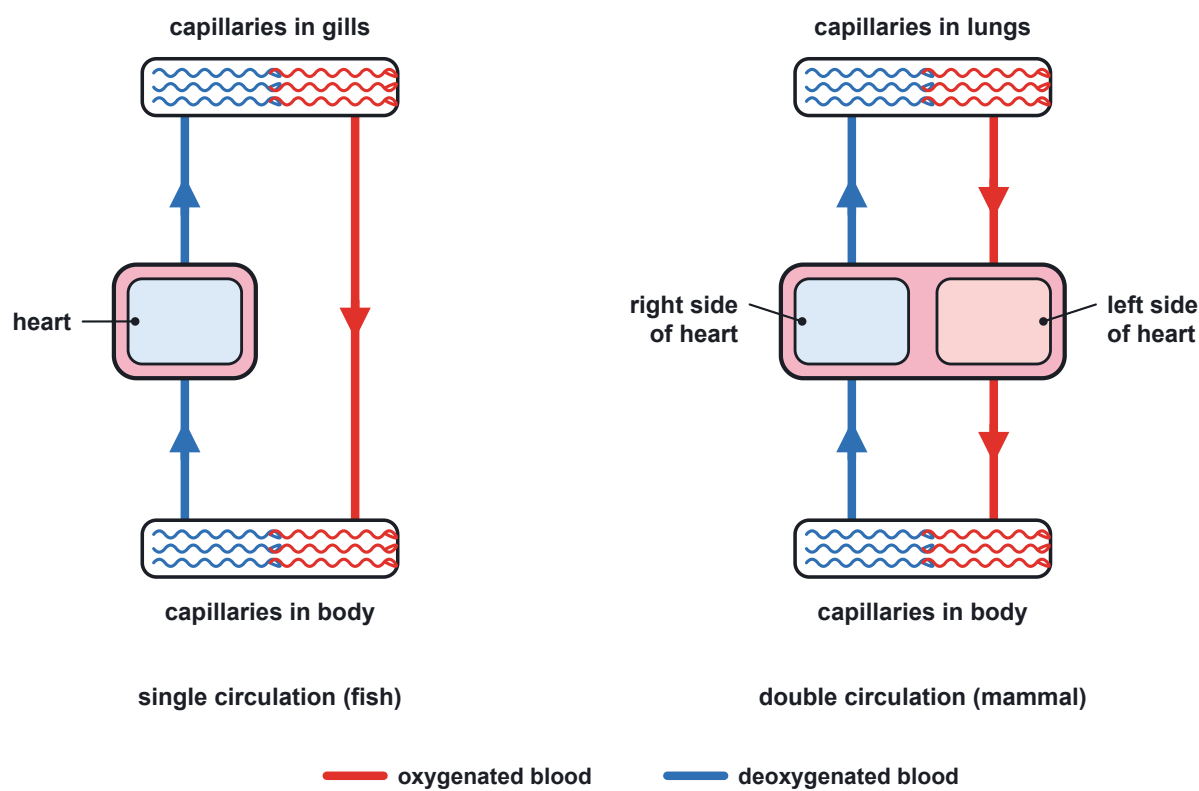
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Pressure filtration forms tissue fluid at the arteriole end; most drains back at the venule end and the excess becomes lymph.

Single and double circulation and the mammalian heart

Spec B3.2.14, B3.2.15

HL only



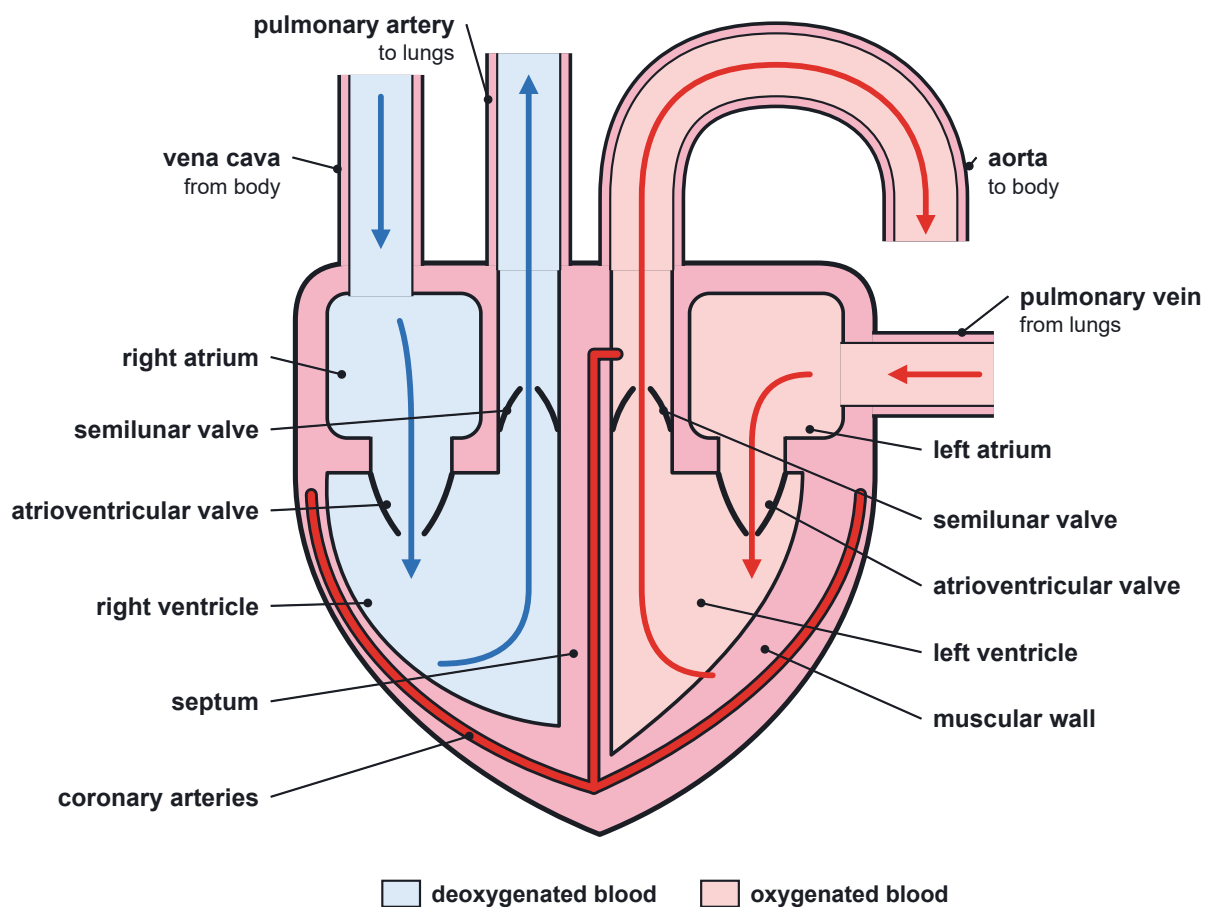
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In a fish blood passes through the heart once per circuit; in a mammal it passes through twice.

Single and double circulation		
Feature	Bony fish (single)	Mammal (double)
Sequence of organs	Heart → gills → body → heart	Heart (right side) → lungs → heart (left side) → body → heart
Passes through heart per circuit	Once	Twice
Pressure of blood reaching the body	Low, because pressure is lost in the gill capillaries	High, because blood is pumped again after the lungs
Separation of blood	Only deoxygenated blood in the heart	Septum keeps oxygenated and deoxygenated blood apart

Adaptations of the mammalian heart

Form and function in the heart	
Structure	Adaptation
Cardiac muscle	Contracts without nerve stimulation (myogenic); branched, connected cells pass impulses rapidly so the walls contract together; does not fatigue.
Pacemaker (sinoatrial node)	A group of specialised cells in the wall of the right atrium that initiates each heartbeat.
Atria	Thin-walled chambers that collect blood from veins and pump it a short distance into the ventricles.
Ventricles	Thick muscular walls generate high pressure; the left ventricle wall is thicker because it pumps blood around the whole body.
Atrioventricular valves	Close when ventricles contract, preventing backflow into the atria.
Semilunar valves	In the aorta and pulmonary artery; close when ventricles relax, preventing backflow into the ventricles.
Septum	Wall separating left and right sides, keeping oxygenated and deoxygenated blood apart.
Coronary vessels	Supply cardiac muscle with oxygen and glucose and remove CO ₂ .



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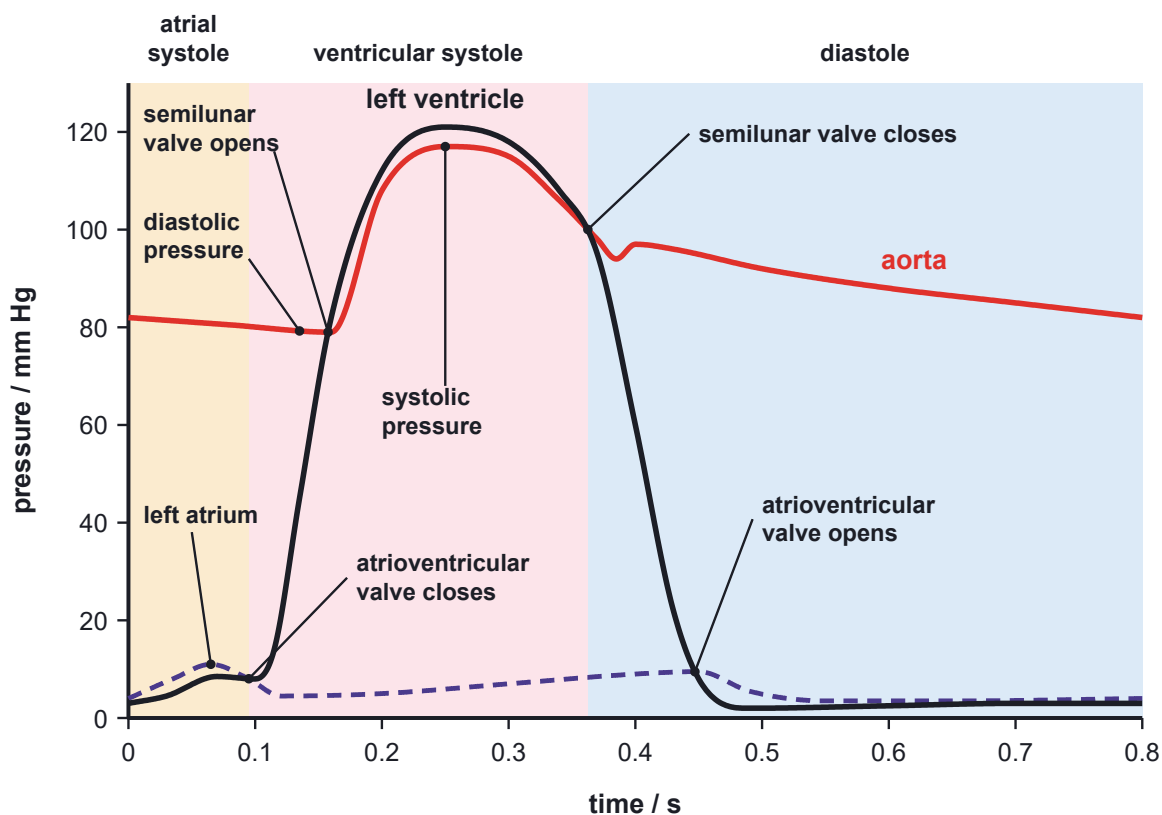
The heart in the frontal plane is drawn as if facing the person, so its left side is on the right of the page. The coronary arteries are drawn schematically (in life they branch from the base of the aorta and run over the outer surface), and the sinoatrial node, in the wall of the right atrium near the vena cava, is not drawn.

1. Vena cava → right atrium → atrioventricular valve → right ventricle → semilunar valve → pulmonary artery → lungs.
2. Pulmonary veins → left atrium → atrioventricular valve → left ventricle → semilunar valve → aorta → body.

Stages in the cardiac cycle Spec B3.2.16 HL only

The **sinoatrial node** (the pacemaker) sends out an electrical signal that spreads across the walls of both atria. After a short delay at the atrioventricular node, it spreads through the ventricle walls from the apex (the bottom) upwards. Events in the left side of the heart:

1. **Atrial systole:** the left atrium contracts, raising its pressure slightly above ventricular pressure. The atrioventricular valve is open, so blood is pushed into the left ventricle, topping it up.
2. **Ventricular systole begins:** the ventricle contracts. When ventricular pressure rises above atrial pressure, the **atrioventricular valve closes**.
3. With both valves closed, ventricular pressure rises steeply.
4. When ventricular pressure exceeds aortic pressure, the **semilunar valve opens** and blood is ejected into the aorta.
5. **Diastole:** the ventricle relaxes. When its pressure falls below aortic pressure, the semilunar valve closes, preventing backflow.
6. When ventricular pressure falls below atrial pressure, the atrioventricular valve opens and blood flows passively from the left atrium into the ventricle, which fills before the next atrial systole.



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Pressure changes in the left side of the heart. Each valve opens or closes where **two pressure lines cross**. Values are illustrative.

Systolic and diastolic blood pressure

- **Systolic pressure** is the highest arterial pressure, during ventricular systole.
- **Diastolic pressure** is the lowest arterial pressure, during diastole; it stays well above zero because the elastic artery walls recoil.
- A typical healthy adult reading is about 120/80 mm Hg (systolic/diastolic). Readings persistently above about 140/90 mm Hg indicate hypertension.

Heart rate from a pressure graph

On a pressure graph, the peaks of ventricular pressure are 0.75 s apart. Calculate the heart rate. (Practice data.)

1. One cycle lasts 0.75 s
2. Heart rate = $60 \div 0.75 = 80$

Answer: 80 beats per minute

Exam tip: Valves open and close because of pressure differences on either side of them. Always say which pressure is higher when explaining a valve movement.

Root pressure and phloem transport Spec B3.2.17, B3.2.18 HL only

Root pressure

1. Root cells use ATP to **actively transport mineral ions** into the xylem vessels.
2. The solute concentration in the xylem rises, so water enters the xylem from surrounding cells by osmosis.
3. This generates a **positive pressure potential** (root pressure) that pushes water up the xylem.

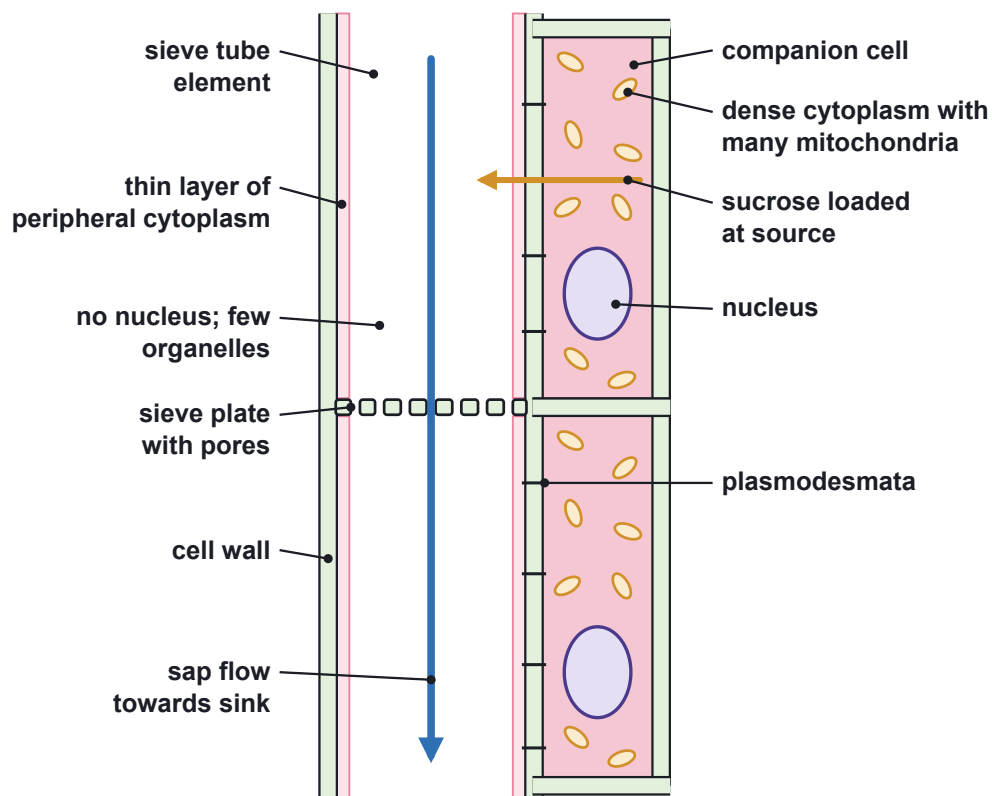
Root pressure matters when transport by transpiration is insufficient: for example when high humidity prevents transpiration, or in spring before the leaves of deciduous plants have opened.

Phloem: sieve tubes and companion cells

Phloem carries sap containing sucrose and other carbon compounds from **sources** (for example photosynthesising leaves) to **sinks** (for example roots, fruits and growing tissues). This is **translocation**.

Adaptations of phloem	
Feature	How it helps translocation
Sieve tube elements joined end to end	Form a continuous sieve tube for sap flow.
Sieve plates (perforated end walls)	Let sap flow from one element to the next.
Reduced cytoplasm and organelles, no nucleus in sieve tube elements	Less resistance, so sap flows more easily.
Companion cells with many mitochondria	Produce ATP for active transport to load sugars into sieve tubes at sources.
Plasmodesmata between companion cells and sieve tube elements	Connect their cytoplasm, so the companion cell can keep the sieve tube element alive and pass loaded sugars into it.

Loading carbon compounds at the source raises the solute concentration, so water enters by osmosis and pressure rises. Unloading at the sink lowers it. Sap flows from high to low pressure.



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Sieve tube elements carry the sap; **companion cells** supply the ATP for loading sucrose at the source.

Quick check

1. What are fenestrations in capillaries?
2. How do elastic fibres in artery walls help maintain blood pressure?
3. What causes tension in the xylem?
4. Where is xylem found in a dicotyledonous root?
5. **HL only** Which node initiates each heartbeat?

Quick check answers

Transport

- 1 . Pores in the capillary wall that allow particularly rapid exchange, for example in the kidney glomerulus.
- 2 . They stretch when blood is pumped in and recoil between beats, pushing blood on and keeping the pressure up.
- 3 . Loss of water by transpiration from leaf cell walls draws water out of the xylem by capillary action.
- 4 . In the centre, in a star or X shape, with phloem between its arms.
- 5 . The sinoatrial node (the pacemaker) in the wall of the right atrium.