Transport

B3.2 · SL and HL

A pump cannot replace local exchange surfaces

Follow the conducting pathway and the exchange step

Common content: capillaries, arteries and veins; pulse and coronary evidence; absorbed nutrients; xylem water transport and dicot tissue plans.

AHL: tissue fluid and lymph; single/double circulation, heart and cardiac cycle; root pressure and phloem.

All numerical examples are invented teaching data.

Branching and narrow lumens solve different problems

Distinguish one vessel from the whole capillary bed

Many branches provide a large collective surface area. A narrow lumen brings red cells close to a one-cell-layer endothelial wall.

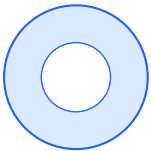
A large combined cross-sectional area lowers average velocity at the same total flow. Thin walls shorten diffusion distance.

Fenestrations in some capillaries aid rapid selected exchange, rather than permitting unrestricted loss of blood cells.

Use combined area when predicting average velocity

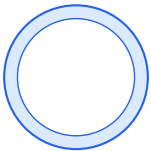
1. **Relation.** Volume flow per time = average velocity × total cross-sectional area.
2. **Controlled change.** At unchanged flow, five times total area gives one-fifth velocity; eight times gives one-eighth.
3. **Limit.** Adequate gradients, permeability and perfusion are still required. One narrow capillary is not the whole parallel network.

Identify structures without assuming oxygen content



Artery

Muscle + elastic wall
Relatively thick



Vein

Flexible thin wall
Many have valves



Capillary

Thin endothelium
Narrow lumen

> Direction defines artery and vein; compare wall and lumen in equivalent vessel sizes.

Connect wall structure to pressure and return

Feature	Functional explanation
Arterial muscle/elastic tissue	Withstands pressure; stretch and recoil sustain pressure between ejections
Venous compliance	Permits compression by surrounding muscles
Valves in many veins	Limit reverse flow under changing pressure; do not actively pump
Identification	Combine wall/lumen ratio, tissue structure and preparation limits

Wall-to-lumen ratio supports an identification

1. **Matched model vessels.** A: wall 0.30 mm, lumen diameter 1.20 mm. B: wall 0.10 mm, lumen 2.00 mm.
2. **Ratios.** A: $0.30/1.20 = 0.25$. B: $0.10/2.00 = 0.05$. A is more consistent with a thicker-walled artery.
3. **Caution.** Section angle, collapse and vessel size matter. Pulmonary arteries are relatively oxygen-poor; pulmonary veins oxygenated.

Convert interval counts and keep repeats distinct

1. **Three 15-second counts.** 18, 19 and 18 beats give 72, 76 and 72 beats/minute; mean about 73.3.
2. **Counting error.** One missed beat changes the estimate by four beats/minute for 15 seconds, but one for a full minute.
3. **Sampling.** Use approved voluntary resting radial measurements or supplied data. Standardize posture, rest and timing. One person measured three times is not three people.

Pulse is a pressure wave, not a packet of blood

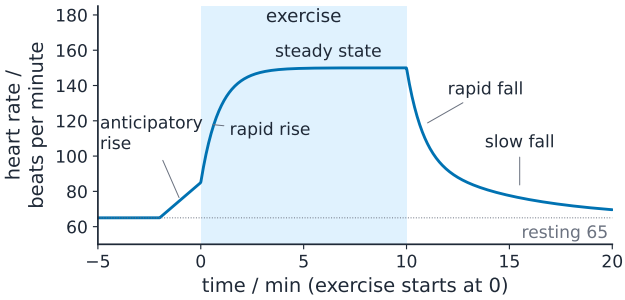
Rate does not provide every circulation quantity

A pulse reflects a travelling pressure wave associated with ventricular ejection.

Pulse count alone does not give stroke volume, cardiac output or blood pressure. Compare sensor and manual methods where appropriate.

Use fingertips lightly at the wrist under an approved protocol and record variation.

Heart rate around a run



A rapid fall, then a slow fall to rest

Coronary blood supplies the contracting muscle

Trace obstruction to impaired ATP supply and contraction

The thick myocardium cannot rely on blood inside chambers supplying it by diffusion alone. Coronary vessels provide its own supply.

Atherosclerotic plaque can narrow arteries; plaque disruption can trigger an obstructing thrombus.

Reduced oxygen delivery limits aerobic ATP production and contraction. Prolonged severe ischaemia can kill muscle.

Interpret risks before claiming a cause

1. **Invented cohort.** 30 outcomes/600 exposed versus 12/600 comparison participants over ten years.
2. **Compare.** Risks 5% and 2%; difference three percentage points; risk ratio 2.5.
3. **Evaluate.** Age, smoking, activity, measurement and follow-up can confound comparison. Even a strong correlation does not by itself prove causation.

Keep chemical breakdown, crossing and bulk movement separate

Process	Example and limit
Digestion	Enzymes produce absorbable products; bile assists emulsification but is not an enzyme
Absorption	Sugars/amino acids enter blood; much packaged dietary lipid initially enters intestinal lymph
Transport	Blood or lymph distributes absorbed material
Food tests	Controlled component detection is not evidence that a food causes a health outcome

Trace the origin and transmission of the pull

1. **Evaporation.** Water leaves moist mesophyll walls; curved interfaces in wall pores generate tension.
2. **Transmission.** Water is drawn from xylem toward walls. Cohesion helps maintain a continuous column; adhesion supports wall contact.
3. **Pathway.** Water-potential differences drive flow through soil, plant and atmosphere. Xylem sap may be under negative pressure; it is not an ATP-powered water pump.

Explain the vessel adaptation rather than listing it

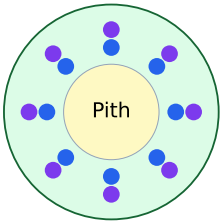
Xylem feature	**Functional consequence**
Dead, hollow elements	Lack of contents leaves a low-resistance lumen
Open/perforated ends	Permit longitudinal flow
Lignified walls	Resist collapse under tension
Pits	Permit lateral exchange through appropriate wall regions

Negative pressure is still a pressure comparison

1. **Same height and solute conditions.** Root xylem -0.2 MPa; leaf xylem -0.8 MPa.
2. **Compare.** The leaf pressure is lower by 0.6 MPa, favouring movement toward it.
3. **Limits.** Whole-plant movement also depends on height, solute contributions, resistance and pathway continuity. Cavitation can disrupt conducting columns.

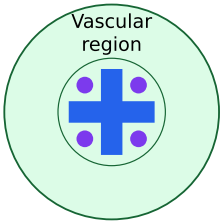
Locate transport tissues before drawing individual cells

Young dicot stem



Epidermis outside; cortex within

Young dicot root



Epidermis outside; cortex within

Blue: xylem Purple: phloem

Stem bundles form a peripheral ring; root vascular tissues occupy a central region in this representative model.

Annotate a plan with the main tissue functions

Region	Location and function
Stem bundle	Xylem toward centre, phloem outward; water support and organic-solute transport
Root vascular cylinder	Often star-shaped xylem, phloem between arms
Cortex/epidermis	Surrounding tissues; storage/support and outer interface
Plan drawing	Tissue regions and relative positions, not every nucleus or sieve pore

Calibrate a measurement in the same units

1. **Invented image.** Stem image 12 mm across; specimen 0.60 mm.
2. **Magnification.** $12/0.60 = 20$. A 3.0 mm cortex region in the image is $3.0/20 = 0.15$ mm in the specimen.
3. **Drawing.** Use clear tissue boundaries, labels and relative positions. Match the actual section because species, age and secondary growth alter patterns.

Tissue fluid is a selective filtrate, not pure water

Connect plasma, interstitial exchange and lymphatic return

Hydrostatic pressure favours filtration; retained proteins oppose fluid loss osmotically. Tissue fluid has many plasma small solutes but usually much less protein and normally no red cells.

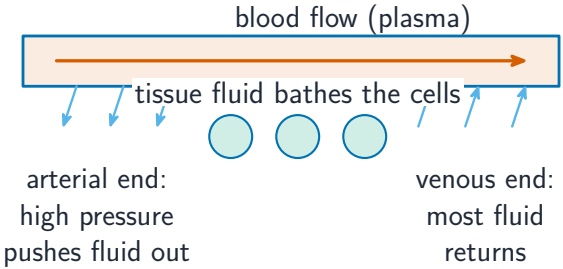
Oxygen/nutrients cross tissue fluid and cell membranes; carbon dioxide and wastes move out of cells through appropriate pathways.

The simple arteriolar-filtration/venular-return comparison is a model. Modern glycocalyx evidence shows slight steady filtration in many tissues, making lymphatic return essential; venous reabsorption is not a universal fixed percentage.

Use conservation to predict accumulation

1. **Invented flows.** Filtration 4.0 mL/hour; direct reabsorption 0.8 mL/hour.
2. **Stable volume.** Lymphatic removal must average $4.0 - 0.8 = 3.2$ mL/hour.
3. **Limited removal.** At 2.5 mL/hour, accumulation is 0.7 mL/hour. Thin lymphatic entry routes, valves and pressure/muscle movements support one-way return to venous blood.

How tissue fluid forms

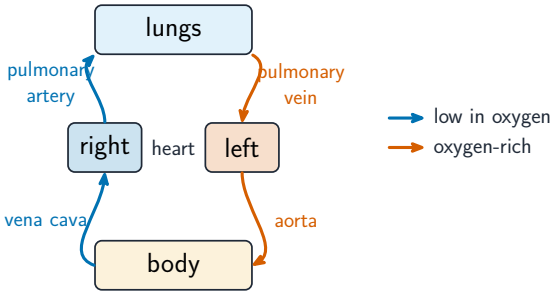


The rest drains into the lymph

A complete circuit returns to its starting point

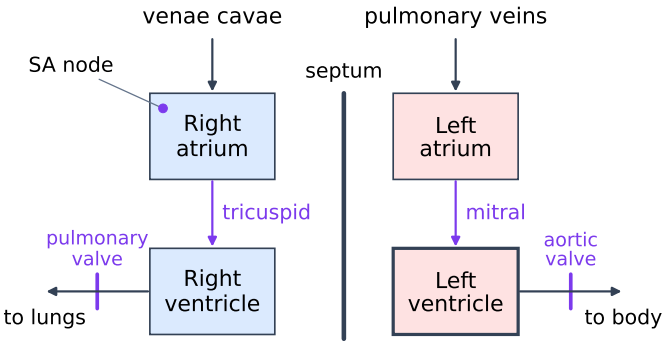
Circuit	Sequence and consequence
Bony fish	Heart → gills → body → heart; one heart passage per complete circuit
Mammal	Right heart → lungs → left heart → body → right heart; two heart passages
Double circuit advantage	Repressurization after lungs supports higher systemic than pulmonary pressure
Stable flow	Both sides pump equal average volumes over time; thicker left wall does not imply greater continuous volume output

Double circulation



Blood passes the heart twice per circuit

Follow a frontal chamber arrangement



Right and left are the person's sides; trace the valves in order.

Trace the named route through both pumps

1. **Right side.** Venae cavae → right atrium → tricuspid valve → right ventricle → pulmonary valve → pulmonary arteries.
2. **Left side.** Pulmonary veins → left atrium → mitral valve → left ventricle → aortic valve → aorta.
3. **Adaptations.** Septum separates the pumps; thicker left ventricular muscle supports higher systemic pressure; coronary vessels supply the wall itself.

The pacemaker coordinates; valve leaflets respond to pressure

Do not turn tendinous cords into valve-opening muscles

The sinoatrial node initiates the normal heartbeat; atrial excitation and an atrioventricular delay help coordinate atrial before ventricular contraction.

Pressure differences open or close valves. Tendinous cords/papillary muscles restrain atrioventricular valve inversion during contraction.

Atria receive and help complete filling; ventricles eject into arteries. Semilunar valves prevent return from arteries as ventricular pressure falls.

Follow the left side through filling, contraction and ejection

1. **Filling.** Mitral valve open; atrial contraction completes filling late in ventricular diastole.
2. **Contraction.** Ventricle exceeds atrial pressure: mitral closes. Both valves initially closed; pressure rises. Above aortic pressure, aortic valve opens and ejection starts.
3. **Relaxation.** Below aortic pressure, aortic closes. Both briefly closed; below atrial pressure, mitral opens and filling resumes.

Infer valves from adjacent pressure differences

1. **Model 1: atrium/ventricle/aorta = 10/6/80.** Mitral favoured open; aortic closed.
2. **Model 2: 8/100/90.** Mitral closed; aortic open.
3. **Arterial trace.** Maximum 122 and minimum 78 mmHg gives 122/78. These are the higher/lower pressures in the artery during the cycle, not pressures from two different heart chambers.

Do not double-count output from the two linked pumps

1. **Given.** 70 beats/minute and 75 mL ejected per beat.
2. **Output.** $70 \times 75 = 5{,}250$ mL/minute $= 5.25$ L/minute per side in a stable circuit.
3. **Interpretation.** Adding left and right outputs would double-count the systemic circulating volume. Pulse count alone did not supply the stroke volume used here.

Separate energy-dependent ion handling from osmotic water entry

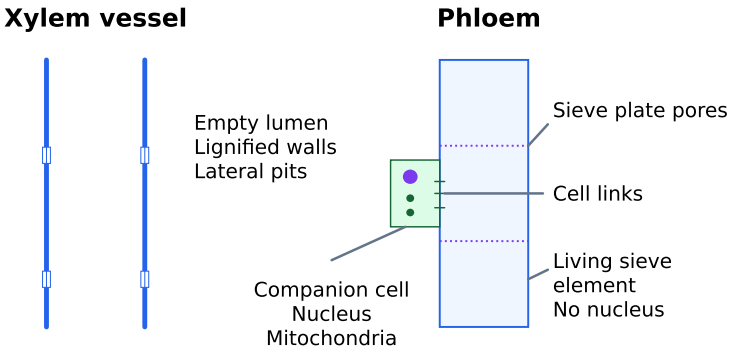
Positive root pressure is different from transpiration tension

Living root cells accumulate mineral ions in the vascular region using energy-dependent transport, lowering solute potential and drawing water in osmotically.

Positive xylem pressure can assist movement when transpiration is low, such as humid conditions or some spring situations. It does not universally replace cohesion–tension in tall plants.

Guttation can release liquid at leaf margins; dew is atmospheric condensation. Water follows a potential gradient rather than direct ATP pumping.

Compare conducting cells and their support



Xylem vessels are dead; sieve elements are living; companion cells retain nuclei.

Source–sink pressure flow does not mean always downward

1. **Source.** Solute loading can lower sieve-tube water potential, draw in water and raise hydrostatic pressure.
2. **Sink.** Unloading helps maintain lower pressure; sap moves in bulk down the pressure gradient. Loading pathways differ among species.
3. **Roles.** A storage root may receive reserves as a sink, then mobilize them as a source. Different sieve tubes can serve different directions; pumps do not carry every sucrose molecule along the whole tube.

Attempt the complete handout questions before checking

Start with units, direction and the comparison model

Wall/lumen pairs 0.24/0.96 and 0.08/1.60 mm: calculate ratios and justify identification.

Counts 23, 24, 25 in 20-second intervals: calculate rates and mean; explain sampling limits.

Coronary cohort: 24/400 versus 8/400. Calculate risks, difference and ratio; evaluate causation.

Check the main quantitative comparisons

1. **Vessels and pulse.** Ratios 0.25 and 0.05; thicker relative wall supports arterial identification. Rates 69, 72, 75; mean 72 beats/minute.
2. **Cohort.** 6% versus 2%; difference four percentage points; risk ratio three. Check confounding and measurement/follow-up.
3. **Plant image.** $18/0.90 = 20\times$; image region $4/20 = 0.20$ mm. Pressure -0.9 versus -0.3 MPa differs by 0.6 MPa.

AHL practice: conservation, valves and output

1. **Tissue fluid.** $5.0 - 0.6 - 3.7 = 0.7$ mL/hour accumulation.
2. **Valves.** At 9/5/82: mitral open, aortic closed. At 7/110/95: mitral closed, aortic open.
3. **Output and pressure.** $72 \times 80 = 5{,}760$ mL/minute $= 5.76$ L/minute per side. 124/76 gives higher/lower arterial pressures during the cycle.

Check yourself

Name direction, pathway, pressure and evidence

Distinguish individual vessels from collective capillary area; sample repeats from independent participants; components from causal health outcomes.

In plants trace the force-generating process and the conducting tissue. Use the actual tissue section.

AHL: explain valve pressure differences, tissue-fluid model limits, and solute loading versus bulk flow.