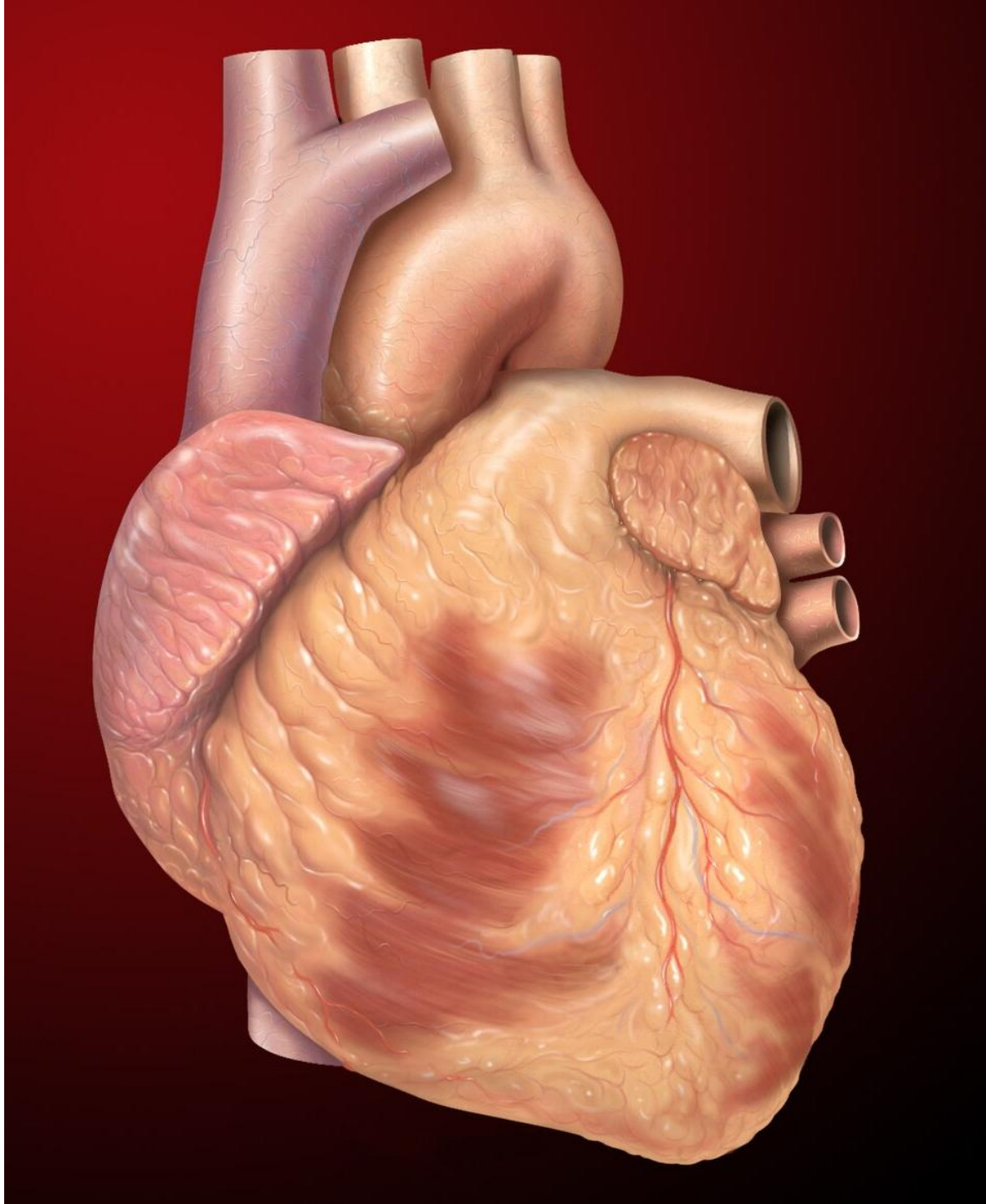
DP Biology – B3.2 (HL extension)

Tissue fluid, the heart and phloem

- Which adaptations help animals and plants move fluids around?
- How does transport in animals compare with transport in plants?

HL statements B3.2.11–18. Textbook pp. 310–325.
Image: the human heart. BruceBlaus, CC BY 3.0.

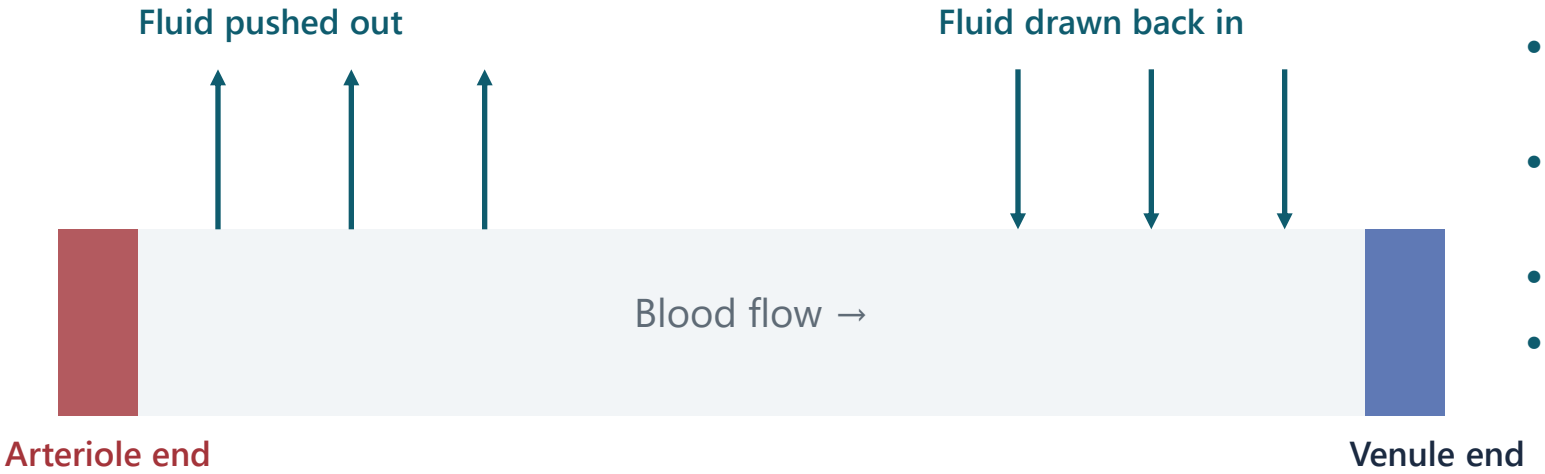


Objectives for each class

Class	Statements	By the end of the class, you can...
1	B3.2.11–13	Explain how tissue fluid forms, exchanges with cells and drains into lymph
2	B3.2.14	Compare how blood circulates in bony fish (once through the heart) and in mammals (twice)
3	B3.2.15	Explain how the structures of the heart deliver blood under pressure
4	B3.2.16	Describe the cardiac cycle and interpret blood pressure data
5	B3.2.17–18	Explain root pressure, and the adaptations of phloem for translocation

How tissue fluid forms

B3.2.11



Simplified capillary. Arrows show the net movement of fluid.

- Blood arrives from arterioles at **high pressure**
- Plasma is forced out through gaps in the capillary wall: **pressure filtration**
- Large proteins and cells stay in the blood
- Pressure is lower at the venule end, so most fluid drains back in

Key idea

Tissue fluid bathes every cell. It is constantly made at the arteriole end and reabsorbed at the venule end, so it is renewed all the time.

Two forces at work

B3.2.11

	Arteriole end	Venule end
Blood pressure (pushes fluid out)	High: about 4.5 kPa	Low: about 2 kPa
Solute pull of plasma proteins (draws fluid in)	About 3.5 kPa	About 3.5 kPa
Net movement	Out of the capillary	Into the capillary

Why the pull stays the same

Plasma proteins are too large to leave the capillary, so their concentration, and the water they attract by osmosis, stays about the same along its length.

Try it

Predict what happens to tissue fluid if blood pressure rises, or if the blood loses protein through starvation.

Plasma and tissue fluid compared

B3.2.12

Component	Plasma	Tissue fluid
Water, ions, glucose, amino acids	Present	Present, similar concentrations
Large proteins	High concentration	Very little
Red blood cells	Present	Absent
Some white blood cells	Present	Present (they squeeze out)
Oxygen	Higher	Lower: used by cells
Carbon dioxide, urea	Lower	Higher: made by cells

Key idea

Tissue fluid is plasma without its large proteins and red blood cells.

Exchange between tissue fluid and cells

B3.2.12

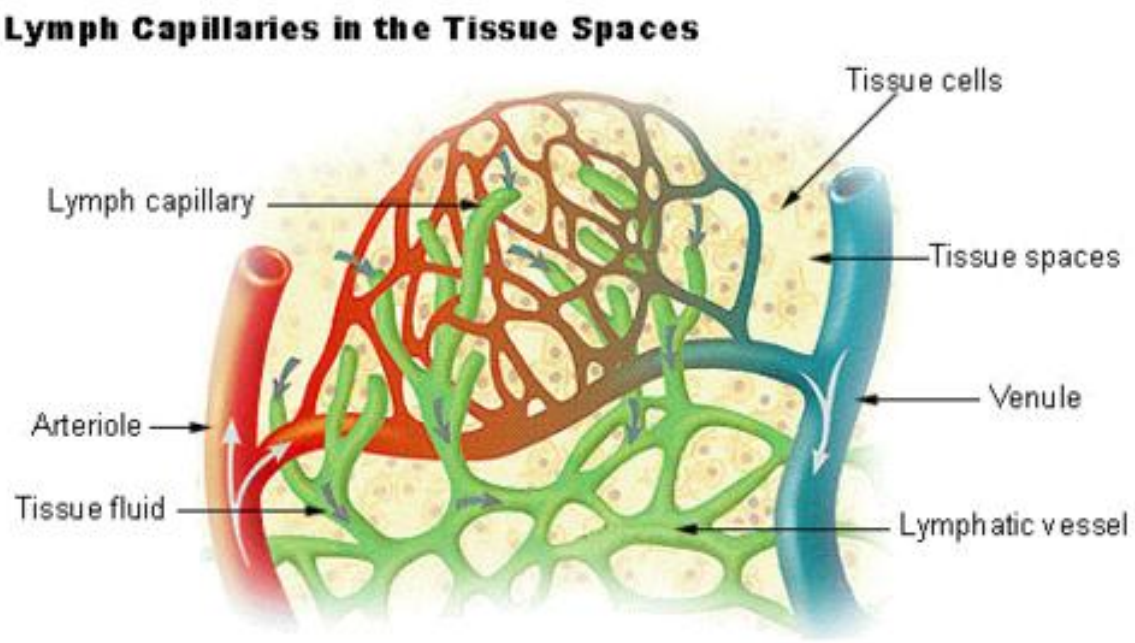
- Cells take in **oxygen**, **glucose**, amino acids and ions from tissue fluid
- Cells release **carbon dioxide**, urea and other wastes into it
- Movement is by diffusion, facilitated diffusion and active transport across the plasma membrane
- The short distance from capillary to cell makes diffusion fast
- Hormones reach target cells through tissue fluid
- Products of cells, such as some hormones and proteins, enter it
- Fluid that returns to the capillary carries the wastes away

Link

Every exchange in the body happens across tissue fluid: it is the internal environment that homeostasis keeps constant.

Draining tissue fluid into lymph

B3.2.13



Lymph capillaries among tissue cells. SEER, NCI, public domain.

- Not all tissue fluid returns to the blood: the excess enters **lymph capillaries**
- Their thin walls have **gaps** that let fluid in easily
- Fluid in them is now called **lymph**
- **Valves** keep lymph moving one way
- Lymph returns to the blood in veins near the heart

If drainage fails

Tissue fluid builds up and tissues swell (oedema).

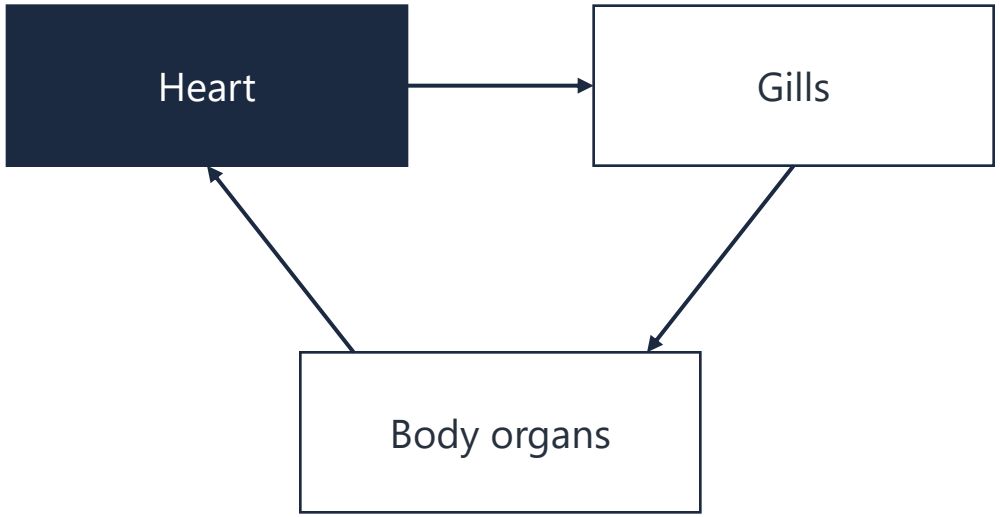
Lymph nodes

Lymph passes through nodes that filter it and hold white blood cells.

Single and double circulation

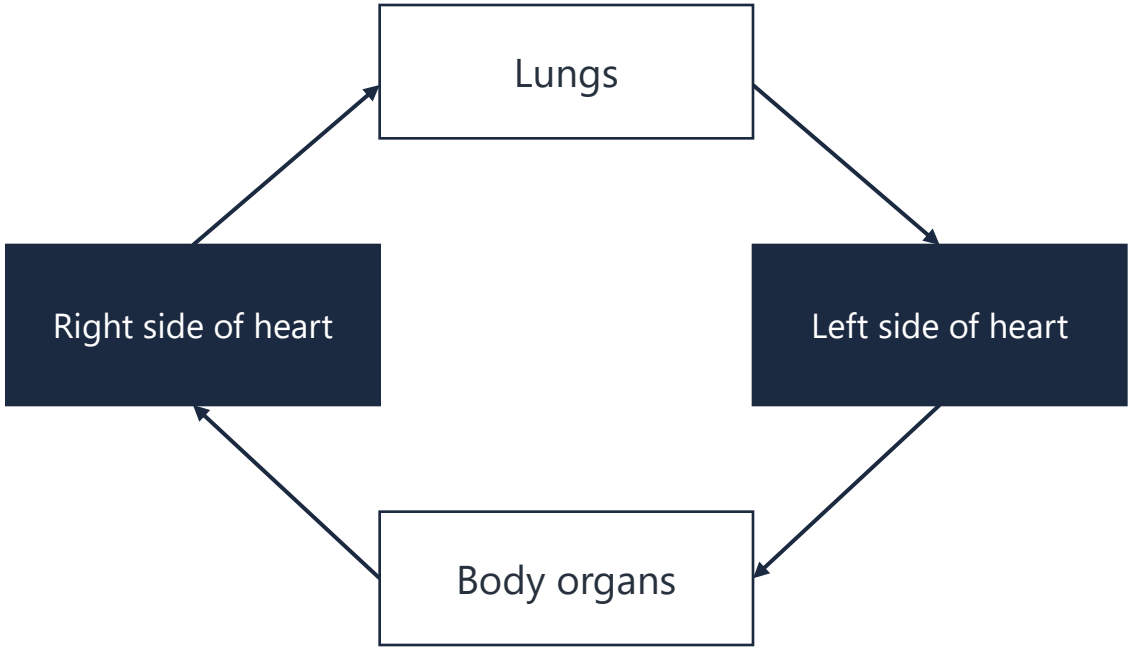
B3.2.14

Bony fish: single circulation



Blood passes through the heart once per circuit.

Mammals: double circulation



Blood passes through the heart twice per circuit.

Draw it

Simple circuit diagrams like these are all you need: show the order of organs and the direction of flow.

Why two circuits?

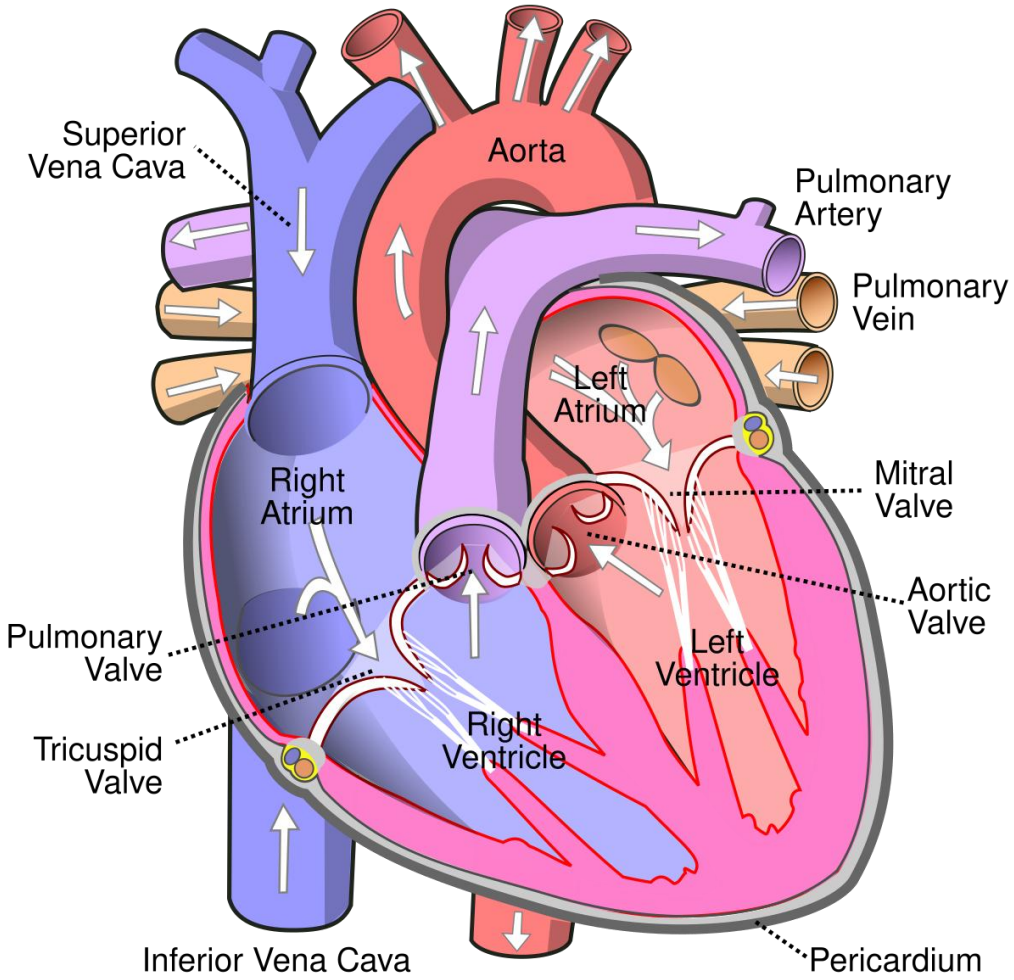
B3.2.14

	Bony fish (single)	Mammal (double)
Heart chambers	One atrium, one ventricle	Two atria, two ventricles
Passes through heart	Once per circuit	Twice per circuit
After the gas-exchange organ	Blood goes straight on to the body at low pressure	Blood returns to the heart and is pumped again
Pressure to the body	Low	High

Why it matters

Gills or lungs have narrow capillaries that cut blood pressure. Re-pumping lets mammals send blood to the body fast and at high pressure, supporting a high metabolic rate and a constant body temperature.

The heart in frontal section



The heart in frontal section. Wapcaplet, CC BY-SA 3.0.

- Vena cava → **right atrium** → tricuspid valve → **right ventricle**
- → pulmonary valve → pulmonary artery → lungs
- Pulmonary vein → **left atrium** → bicuspid (mitral) valve → **left ventricle**
- → aortic valve → aorta → body
- The left and right sides pump at the same time

Try it

Trace one red blood cell from a toe back to a toe.

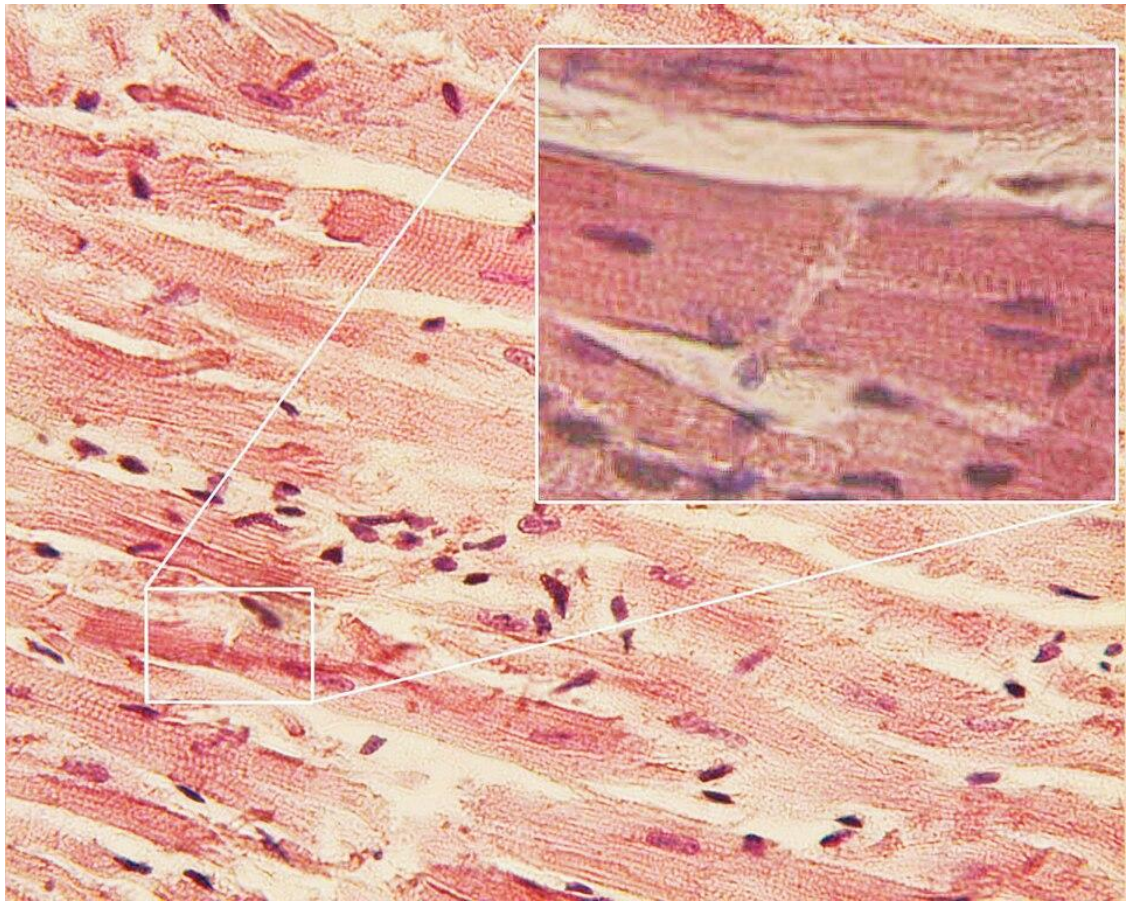
Structure and function of the heart

B3.2.15

Structure	How it helps deliver blood under pressure
Cardiac muscle	Contracts strongly and rhythmically without tiring; branched cells spread each contraction
Pacemaker (SA node)	Starts each beat, so the heart contracts at a steady rate
Atria	Thin walls; collect blood and push it a short distance into the ventricles
Ventricles	Thick walls pump blood out; the left is thickest, as it pumps to the whole body
AV valves	Close when the ventricles contract, so blood cannot go back to the atria
Semilunar valves	Close when the ventricles relax, so blood cannot return from the arteries
Septum	Keeps oxygenated and deoxygenated blood apart
Coronary vessels	Supply the heart muscle with oxygen and glucose

Cardiac muscle

B3.2.15



Cardiac muscle, light micrograph; the inset shows an intercalated disc. Girod and Becker, CC BY 2.5.

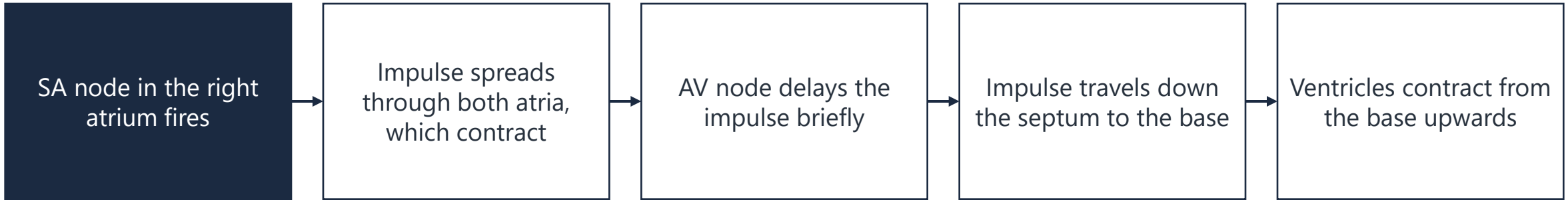
- Cells are **branched** and joined end to end by **intercalated discs**
- Electrical impulses pass quickly from cell to cell, so they contract together
- Many mitochondria supply ATP for constant work
- **Myogenic**: contraction starts in the muscle itself, not from a nerve

Link

Striated muscle and sliding filaments (B3.3).

Starting each heartbeat

B3.2.16



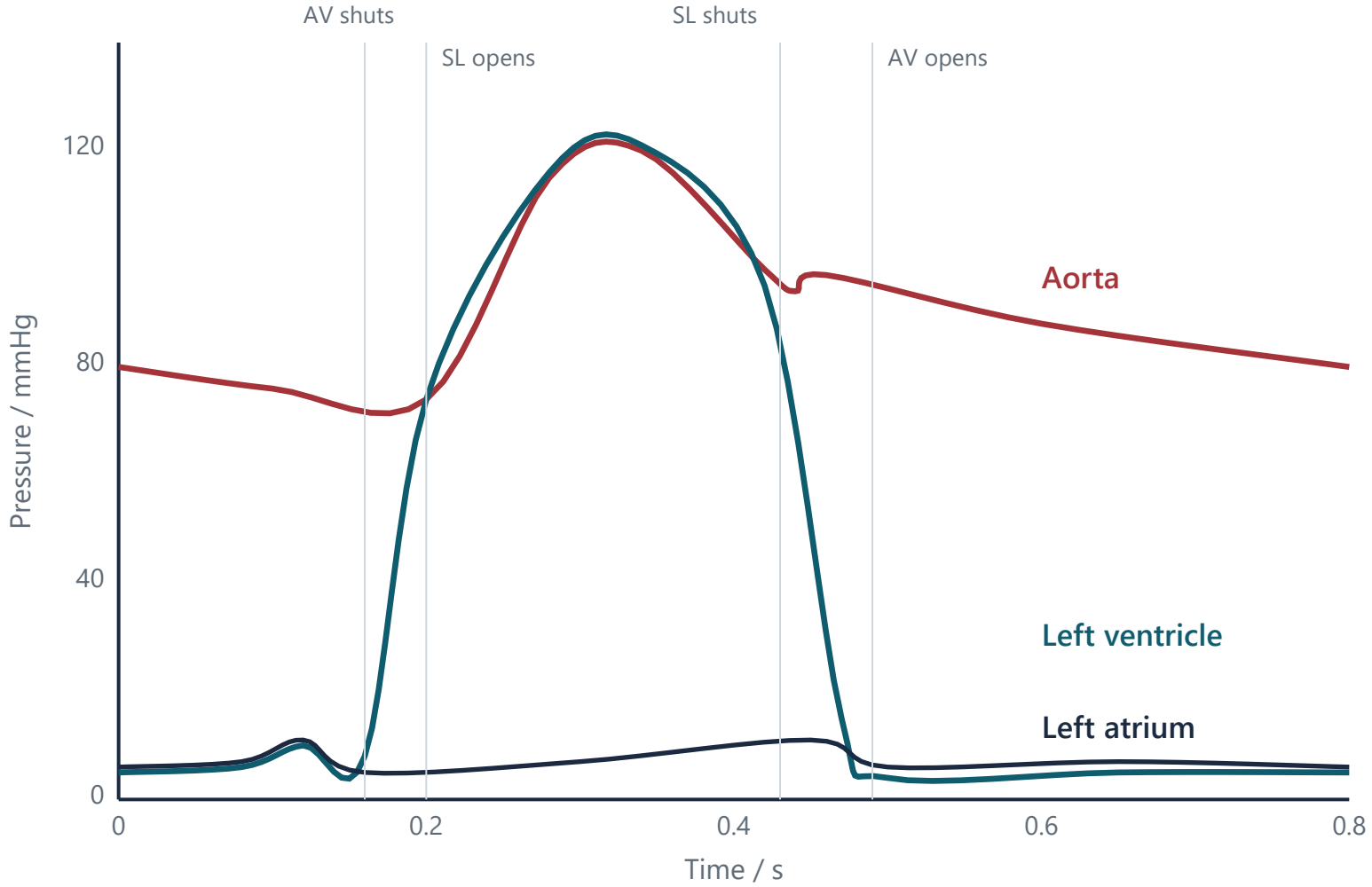
Why the delay?

The pause at the AV node gives the atria time to finish emptying before the ventricles contract.

Rate

The SA node alone sets about 60 to 100 beats per minute. Nerves and adrenaline change the rate to match activity.

Pressures in the left side of the heart



Schematic, one beat at 75 beats per minute. AV: atrioventricular valve. SL: semilunar valve.

- Valves open and close because of **pressure differences**
- A valve opens when pressure behind it is higher than in front
- **Systole**: contraction. **Diastole**: relaxation

Try it

Find the time when both valves are shut and the ventricle is contracting.

Stages of the cardiac cycle

B3.2.16

Stage	What happens	Valves
Atrial systole	Atria contract and top up the ventricles	AV open, SL shut
Early ventricular systole	Ventricles contract; pressure rises fast, closing AV valves (first heart sound)	Both shut
Ventricular systole	Ventricle pressure passes artery pressure; blood is ejected	AV shut, SL open
Early diastole	Ventricles relax; blood falls back against SL valves, closing them (second sound)	Both shut
Diastole	Atria and ventricles fill passively from the veins	AV open, SL shut

Remember

Blood always flows from higher to lower pressure.

Systolic and diastolic blood pressure



A cuff and gauge for measuring blood pressure. Public domain.

- **Systolic**: the highest pressure in the arteries, as the ventricles eject blood
- **Diastolic**: the lowest pressure, while the heart relaxes
- Written as systolic/diastolic, for example **120/80 mmHg**
- A resting reading above about 140/90 mmHg is high blood pressure (hypertension)

Using data

From a pressure graph, read systolic as the peak in the aorta and diastolic as its lowest point. Pulse pressure = systolic – diastolic. Why does pressure in the aorta never fall to zero?

Root pressure

B3.2.17



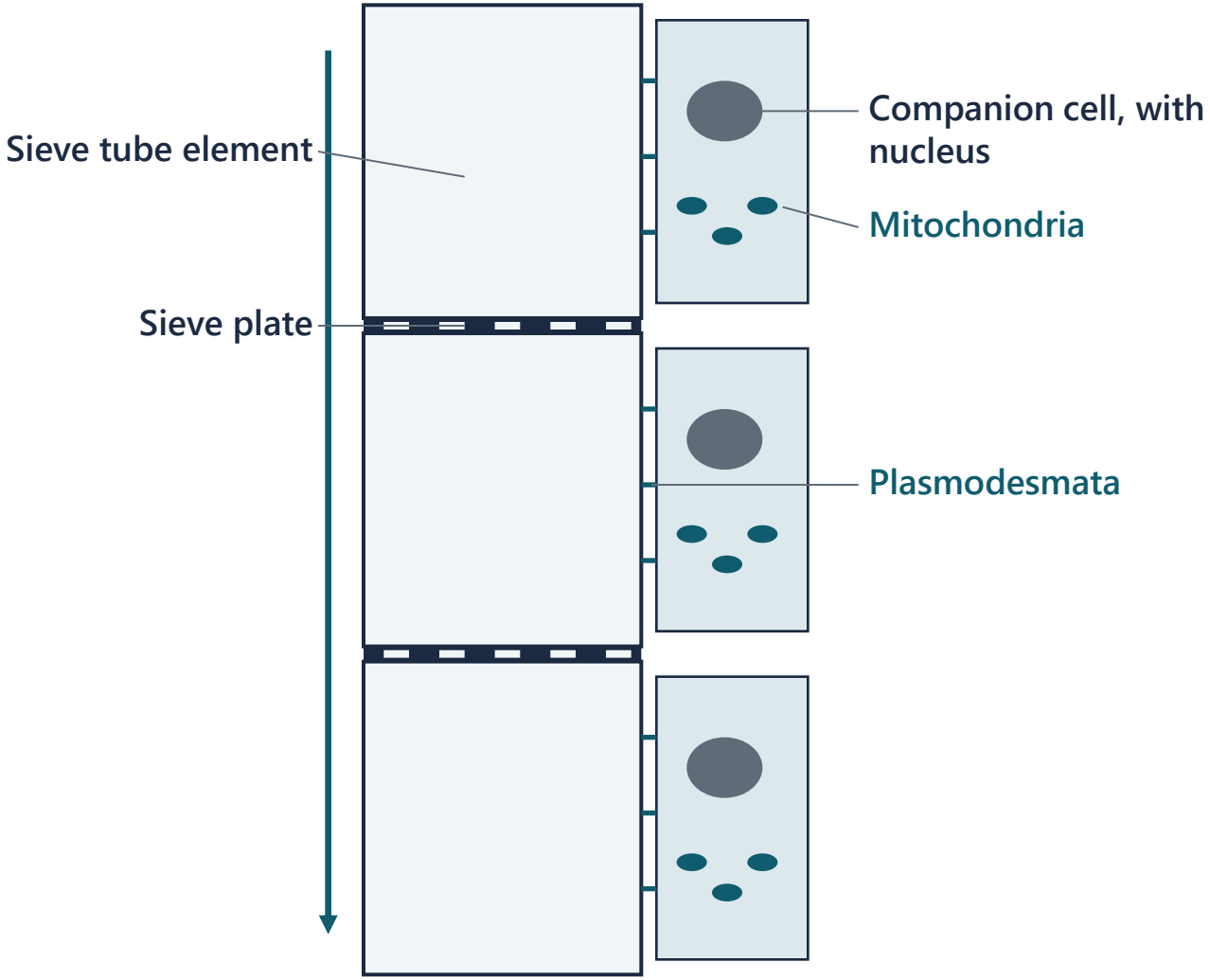
Guttation: drops pushed out of a leaf by root pressure. Public domain.

- Usually water is **pulled** up by transpiration (tension)
- When transpiration is low, roots can **push** sap up instead
- This happens in very humid air, at night, or in spring before deciduous leaves open
- It can refill xylem vessels that have filled with air

Root cells pump mineral ions into the xylem (active transport, ATP) → Xylem sap becomes more concentrated → Water follows by osmosis → Positive pressure pushes sap up the xylem

Sieve tubes and companion cells

B3.2.18



Simplified longitudinal section. The arrow shows sap flow, which can go either way.

- **Translocation**: moving sap with sugars and amino acids from **sources** to **sinks**
- Source: where sugars are made or released, such as mature leaves
- Sink: where they are used or stored, such as roots, fruits and growing buds
- Sap flows under pressure in living sieve tubes

Adaptations for translocation

B3.2.18

Feature	How it helps
Sieve plates with large pores	Sap flows from one element to the next
Little cytoplasm, few organelles	Less resistance to the flow of sap
No nucleus in sieve tube elements	More space for flow; the companion cell keeps the element alive
Many mitochondria in companion cells	ATP for active loading of sucrose at sources
Plasmodesmata between the two cells	Sucrose and other molecules pass into the sieve tube
Thick, rigid cell walls	Withstand the high pressure of the sap

Key idea

Loading at sources raises pressure; unloading at sinks lowers it, so sap flows from source to sink.

Check that you can explain

1. How tissue fluid forms and returns to capillaries
2. How plasma and tissue fluid differ, and what passes to and from cells
3. How lymph capillaries drain excess fluid
4. Single and double circulation, with circuit diagrams
5. How the parts of the heart deliver blood under pressure
6. The stages of the cardiac cycle, and systolic and diastolic pressure
7. How root pressure is generated
8. How sieve tubes and companion cells are adapted

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. Explain why fluid leaves a capillary at the arteriole end and returns at the venule end.
2. State two differences between the circulation of a bony fish and of a mammal.
3. Explain why the semilunar valves close at the start of diastole.

Image credits

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