

Transport in mammals

A-Level Biology 9700 · Topic 8 revision notes

Everything from the 4 lessons of this topic on a few pages: the key idea of each lesson, the diagram to remember, the points to learn and the traps examiners set. Read it, cover it, test yourself.

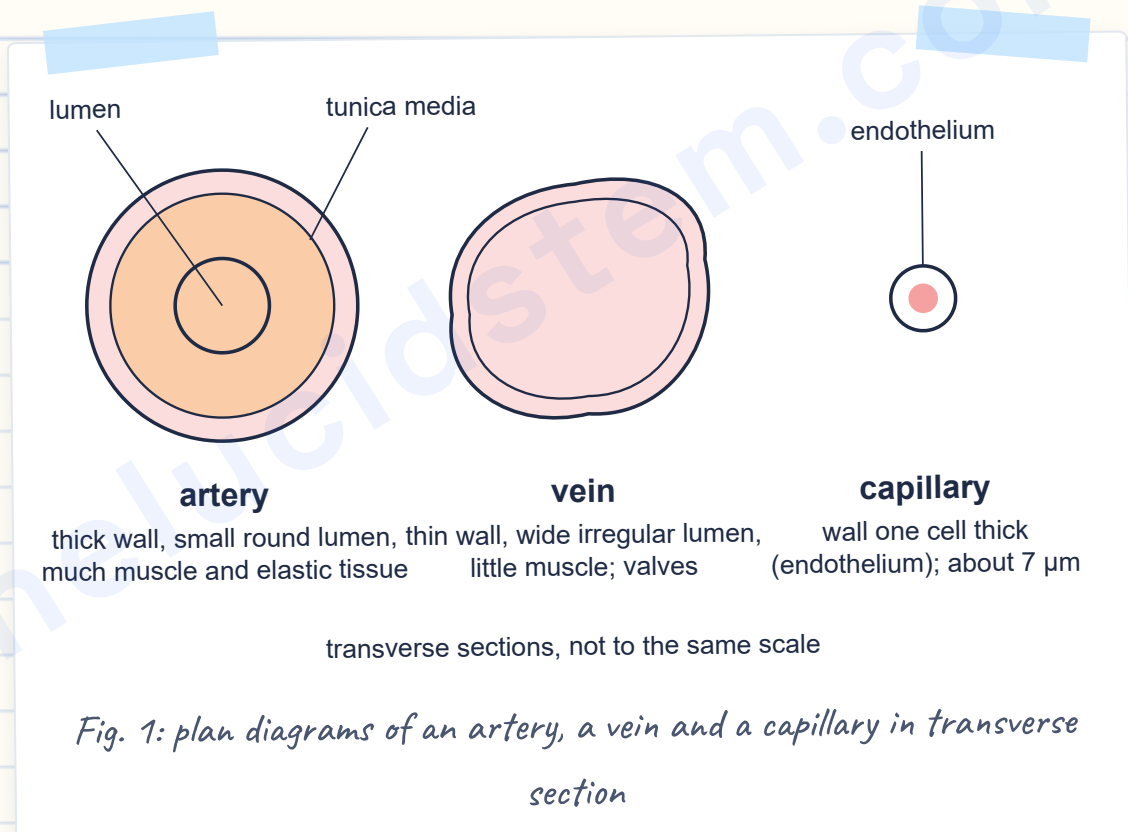
1. A closed double circulation and its blood vessels
2. Blood cells, water and tissue fluid
3. Transport of oxygen and carbon dioxide
4. The heart and the cardiac cycle

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1 A closed double circulation and its blood vessels

Syllabus 8.1

The mammalian circulatory system is a **closed double circulation** made of a **heart**, **blood** and **blood vessels**: arteries, arterioles, capillaries, venules and veins. Closed means the blood stays inside vessels. Double means it passes through the heart twice per complete circuit: the **pulmonary circulation** (right ventricle, **pulmonary artery**, lungs, **pulmonary vein**, left atrium) and the **systemic circulation** (left ventricle, **aorta**, body, **vena cava**, right atrium). **Elastic arteries** near the heart stretch and recoil to smooth the flow; **muscular arteries** have thick smooth muscle to control flow to organs; **veins** carry low-pressure blood in a wide lumen with thin walls and **valves**; **capillaries** have walls one endothelial cell thick for rapid exchange.



Circuit, then vessel, then wall.

- ✓ **Closed:** blood stays in vessels. **Double:** through the heart twice per circuit.
- ✓ **Arteries** carry blood away from the heart; **veins** carry it back.
- ✓ **Elastic artery:** stretch and recoil.
Muscular artery: control flow.
- ✓ **Vein:** thin wall, wide lumen, valves.
Capillary: one cell thick.

Watch out!

Arteries carry blood **away from** the heart and veins carry blood **towards** it. Do not define them by oxygen: the pulmonary artery carries deoxygenated blood and the pulmonary vein carries oxygenated blood.

An artery has a **small** lumen relative to its thick wall; a vein has a **wide** lumen and often looks squashed or irregular on a slide because its thin wall does not hold its shape.

2 Blood cells, water and tissue fluid

Syllabus 8.1

Blood contains **red blood cells** (biconcave, no nucleus, full of haemoglobin) and white cells: **neutrophils** (lobed nucleus, granular cytoplasm, phagocytes), **monocytes** (the largest, with a kidney-shaped nucleus, becoming macrophages) and **lymphocytes** (small, with a large round nucleus filling most of the cell). **Water** is the main component of blood plasma and of tissue fluid. Its **solvent action** lets it carry glucose, ions, amino acids, urea and hormones in solution, and its **high specific heat capacity** lets blood carry heat without large temperature changes. **Tissue fluid** bathes the cells, supplying them with oxygen, glucose and ions and removing wastes such as carbon dioxide. It forms at the **arterial end** of a capillary, where **hydrostatic pressure** forces fluid and small solutes out; plasma proteins stay in, so at the **venous end**, where hydrostatic pressure has fallen, water returns by **osmosis**. Excess fluid drains into lymph vessels.

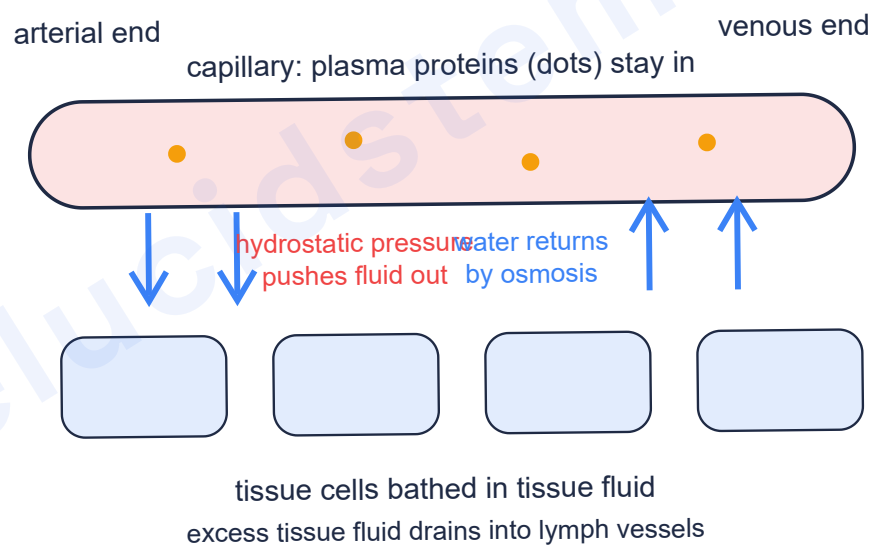


Fig. 1: formation of tissue fluid in a capillary network

Nucleus first, then pressure.

- ✓ **Neutrophil:** lobed nucleus. **Monocyte:** largest, kidney-shaped nucleus.
- ✓ **Lymphocyte:** small, round nucleus filling the cell. **Red cell:** no nucleus.
- ✓ **Water:** solvent action and high specific heat capacity.
- ✓ **Arterial end** hydrostatic pressure out; **venous end** osmosis back in.

Watch out!

A lymphocyte's nucleus nearly fills the cell, leaving a thin rim of cytoplasm; a monocyte is much bigger with a bean-shaped nucleus. Do not call any cell with a large nucleus a monocyte.

Tissue fluid is not the same as plasma. It has almost no plasma proteins and no red blood cells, because these are too large to leave the capillary.

3 Transport of oxygen and carbon dioxide

Syllabus 8.2

Each **haemoglobin** molecule has four polypeptide chains, each with a **haem group** that binds one O_2 , so it carries up to four oxygen molecules. Binding is **cooperative**: once one O_2 binds, the molecule changes shape and the next bind more easily, giving the S-shaped (sigmoid) **oxygen dissociation curve**. In the **lungs** (high partial pressure of oxygen) haemoglobin is almost fully saturated; in **respiring tissues** (low pO_2), on the steep part of the curve, a small fall in pO_2 releases a lot of oxygen. Carbon dioxide diffuses into red blood cells, where **carbonic anhydrase** catalyses $CO_2 + H_2O \rightarrow H_2CO_3$, which dissociates to H^+ and HCO_3^- . H^+ combines with haemoglobin to form **haemoglobinic acid**, releasing oxygen and buffering the blood. HCO_3^- diffuses into the **plasma**, balanced by Cl^- moving in: the **chloride shift**. Some CO_2 binds haemoglobin as **carbaminohaemoglobin** and a little dissolves in plasma. High CO_2 lowers haemoglobin's affinity for oxygen and moves the curve to the right: the **Bohr shift**.

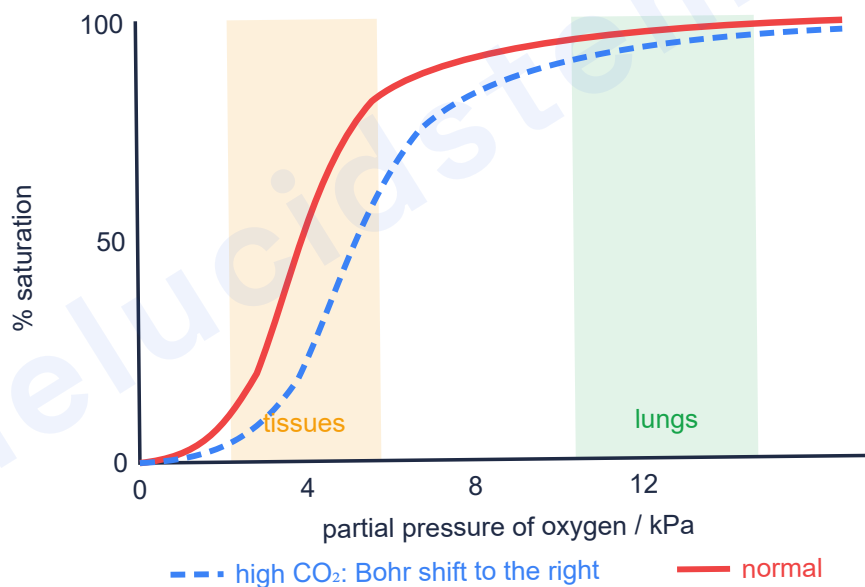


Fig. 1: oxygen dissociation curve of adult haemoglobin and the Bohr shift

Curve, shift, then ions.

- ✓ **Sigmoid curve:** cooperative binding of four O_2 per haemoglobin.
- ✓ **Lungs:** high pO_2 , near full saturation.
Tissues: steep part, big unloading.
- ✓ **Bohr shift:** more CO_2 , curve to the right, lower affinity, more O_2 released.
- ✓ **CO_2 :** carbonic anhydrase, H^+ to HHb, HCO_3^- out, Cl^- in.

Watch out!

A curve shifted to the **right** means **lower** affinity: haemoglobin is less saturated at any given pO_2 and gives up oxygen more readily. Do not say the Bohr shift helps haemoglobin pick up oxygen.

The chloride shift moves chloride ions **into** the red blood cell as hydrogencarbonate ions move **out**. It is about balancing charge, not about carrying carbon dioxide.

4 The heart and the cardiac cycle

Syllabus 8.3

The heart has four chambers: thin-walled **atria** receive blood from the vena cava (right) and pulmonary vein (left) and pump it a short distance into the **ventricles**. The **left ventricle** has a thicker muscular wall than the right because it pumps blood at high pressure all round the body, while the right ventricle pumps only to the nearby lungs at lower pressure. The **septum** keeps oxygenated and deoxygenated blood apart.

Atrioventricular valves stop backflow into the atria; **semilunar valves** stop backflow from the aorta and pulmonary artery. Valves open and close only because of **pressure differences**. In the **cardiac cycle**, atrial systole tops up the ventricles, ventricular systole closes the AV valves and opens the semilunar valves, and in diastole the semilunar valves close and the AV valves open as the heart refills. The **sinoatrial node** starts each wave of excitation, the **atrioventricular node** delays it, and the **Purkyne tissue** carries it to the apex so the ventricles contract from the bottom up.

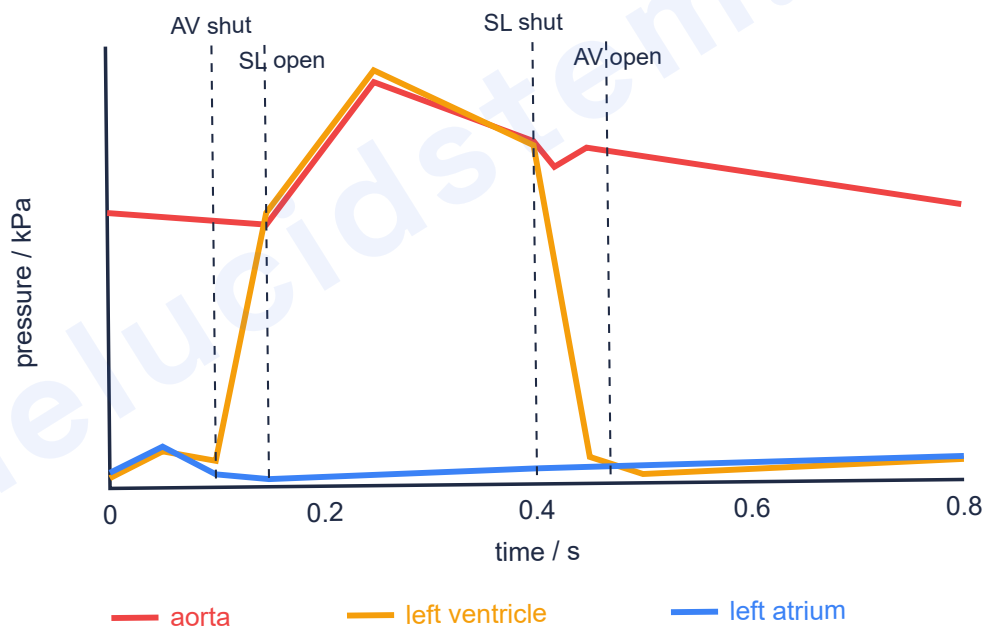


Fig. 1: pressure changes in the left side of the heart and aorta during one cardiac cycle (0.8 s), with valve events

Pressure first, then valve.

- ✓ **Walls:** atria thin; left ventricle thicker than right (body versus lungs).
- ✓ **Valve rule:** higher pressure behind opens it; higher pressure in front shuts it.
- ✓ **Systole:** AV shut, then SL open.
Diastole: SL shut, then AV open.
- ✓ **SAN** starts; **AVN** delays about 0.1 s; **Purkyne** to the apex.

Watch out!

The ventricles have thicker walls than the atria because of the **distance** and resistance they pump against, not because they hold more blood. Both ventricles pump the same volume per beat.

The AVN does not start the heartbeat; the SAN does. The AVN's job is the **delay**.

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