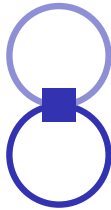


Transport in Mammals

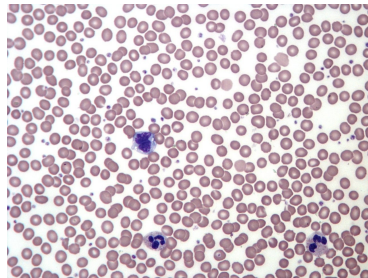
A-Level Biology ■ Topic 8

A-Level Biology



What we will cover

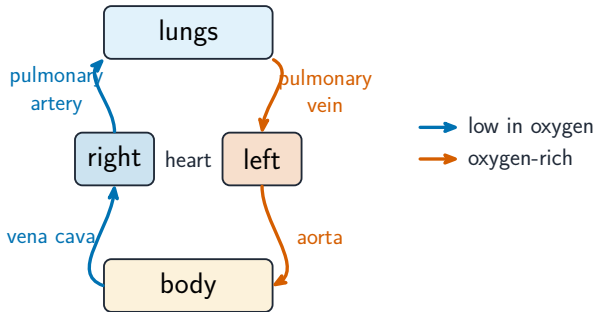
- 1 Double circulation
- 2 Blood vessels & tissue fluid
- 3 Oxygen transport
- 4 Carbon dioxide transport
- 5 The heart
- 6 Controlling the heartbeat



red & white blood cells



Double circulation



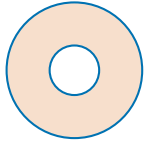
A **closed double circulation** :
blood passes through the heart
twice per trip.

- **pulmonary** loop – to the lungs
- **systemic** loop – to the body

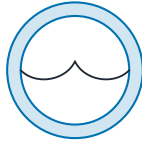
Order: **arteries** → **capillaries**
→ **veins** .

Blood vessels

- **artery** – thick muscular & elastic wall; high pressure
- **capillary** – one cell thick; fast exchange
- **vein** – thin wall, **valves** stop backflow



artery
thick muscular,
elastic wall;
narrow lumen
(high pressure)



vein
thin wall;
wide lumen;
valves
(low pressure)



capillary
wall one cell
thick; very
narrow (exchange)

The circuit, vessel by vessel

The order

Arteries → **arterioles** → **capillaries** → **venules** → **veins** .

The two great vessels

The **aorta** carries oxygen-rich blood from the heart to the body; the **vena cava** returns oxygen-poor blood from the body to the heart.

Where the control is

Arterioles carry the muscle that adjusts flow – which is how blood is redirected to muscle during exercise.

Where the exchange is

Capillaries: one cell thick, huge total surface, and slow flow. Everything the circulation exists for happens here.

Wall thickness follows pressure: thick and elastic near the heart, thin and valved on the way back.

How each vessel suits its job

artery

thick muscular and elastic wall, narrow lumen – withstands and **smooths** high pressure from the heart

arteriole

muscle in the wall can contract – **controls** where blood goes

capillary

one cell thick, and narrow – **short diffusion distance** and slow flow for exchange

venule and vein

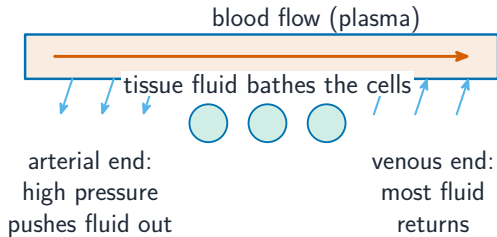
thin wall, **wide lumen**, and **valves** – low pressure, so it needs help returning blood

the return mechanism

skeletal muscle squeezes the veins; the valves stop backflow

Every feature answers a pressure question. Say the pressure first, then the structure that copes with it.

Tissue fluid



At the arterial end, high pressure pushes liquid (not cells/proteins) out of the **plasma** .

This **tissue fluid** bathes the cells with oxygen & glucose; most returns at the lower-pressure venous end.

The blood cells, and what plasma does

red blood cells

carry oxygen – biconcave, no nucleus, packed with haemoglobin

monocytes

large, kidney-shaped nucleus – become macrophages and engulf pathogens

neutrophils

a **lobed** nucleus – the commonest phagocyte

lymphocytes

a large round nucleus and little cytoplasm – make **antibodies**

water as a solvent

the main part of blood; it carries dissolved substances

its high specific heat capacity

means blood absorbs heat with little temperature change, which helps keep the body stable

In a stained **blood smear** the white cells are the larger ones with visible nuclei; the red cells are small, numerous and have none.

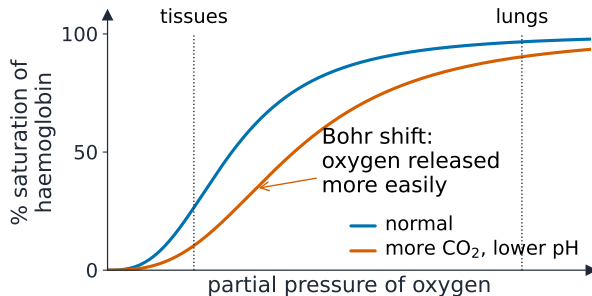


Oxygen transport and the Bohr shift

Haemoglobin loads oxygen in the lungs (high **partial pressure**) and unloads it in the tissues.

The **Bohr shift** : more CO_2 (lower pH) moves the curve **right**, so oxygen is released where it is most needed.

Oxygen transport and the Bohr shift, in detail



Bohr shift (right): $\uparrow \text{CO}_2 / \downarrow \text{pH} \rightarrow$ lower O_2 affinity $\rightarrow$ unload at tissues

Haemoglobin loads oxygen in the lungs and unloads it in the tissues; the Bohr shift moves the curve right so more is released

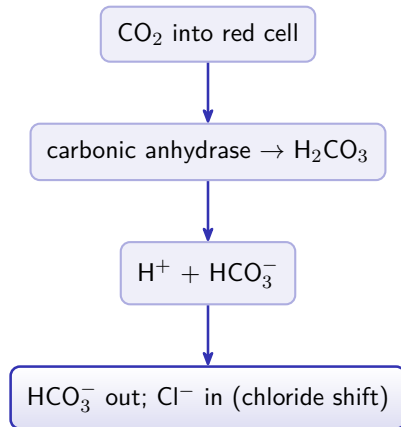
Carbon dioxide transport

Most CO_2 travels as
hydrogencarbonate ions :

- **carbonic anhydrase** speeds $\text{CO}_2 + \text{water}$
- the **chloride shift** keeps charge balanced
- haemoglobin mops up the H^+

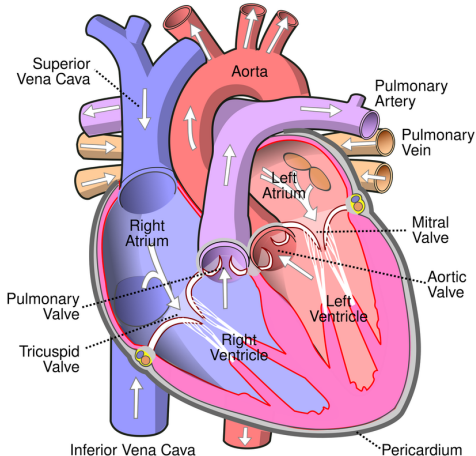
Carbon dioxide transport, continued

Most CO_2 travels as **hydrogencarbonate** ions in the plasma.





The heart



Four chambers: thin-walled **atria** above, thick **ventricles** below.

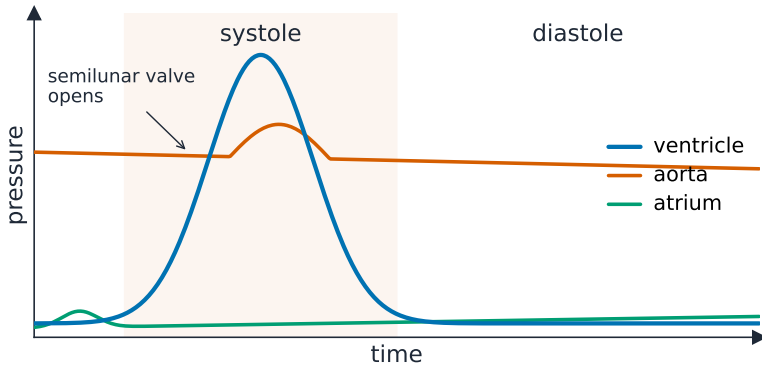
The **left ventricle** wall is thickest – it pumps blood all the way round the body; the right side only reaches the lungs.

The cardiac cycle

One heartbeat: **systole** (contract) then **diastole** (relax & fill).

A pressure change opens or closes a **valve** wherever two pressure curves cross – so blood flows one way only.

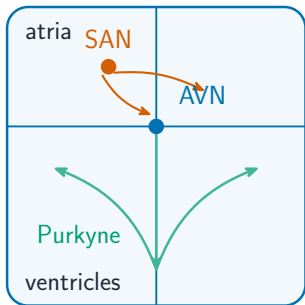
The cardiac cycle, in detail



systole = contraction (high P) · diastole = relaxation/fill · valves open on P gradients

One heartbeat: **systole** (contract) then **diastole** (relax & fill).

Controlling the heartbeat



SAN fires → atria contract → AVN delays → Purkyne → ventricles contract from the bottom up

The heart sets its own rhythm:

- the **SAN** (pacemaker) fires; the atria contract
- the **AVN** delays, then passes it on
- **Purkyne tissue** makes ventricles contract bottom-up

The conducting system of the heart

the sinoatrial node

the pacemaker, in the right atrium – it sets the rate and starts each wave

the atria contract

the wave spreads across both atria, emptying them into the ventricles

the atrioventricular node

picks up the wave and **holds it back for a moment**, so the atria finish emptying first

the bundle of His

carries it down the septum to the apex

the Purkyne fibres

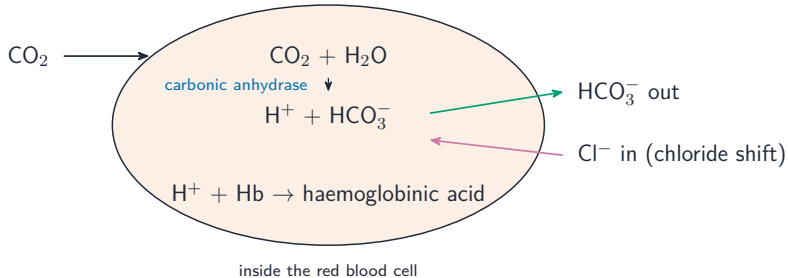
spread it up through the ventricle walls, so they contract **from the bottom up**

and carbaminohaemoglobin

some carbon dioxide is carried by joining haemoglobin directly, rather than as hydrogencarbonate

The AVN delay is the point of the whole system: without it the ventricles would contract while the atria were still filling them.

Carrying carbon dioxide



Most CO_2 travels as hydrogencarbonate ions; the chloride shift keeps the charge balanced and haemoglobin mops up the H^+

Carbon dioxide, in five steps

1. The enzyme

The **enzyme carbonic anhydrase** speeds the reaction of CO_2 with water to make carbonic acid.

2. It dissociates

Carbonic acid splits into hydrogen ions and **hydrogencarbonate ions**.

3. Out to the plasma

The hydrogencarbonate ions diffuse out of the red blood cell into the plasma, where most CO_2 is carried.

4. Chloride shift

To keep the charge balanced, **chloride ions** move into the red blood cells.

5. Buffering

The hydrogen ions join haemoglobin as **haemoglobinic acid**, which mops them up and keeps the pH steady.

That last step *is* the Bohr effect: hydrogen ions binding haemoglobin make it release oxygen exactly where respiration is fastest.

Exam tips

- Trace the **double circulation** and name the chambers, valves and vessels; the left ventricle wall is thicker (pumps further at higher pressure).
- Read the **cardiac-cycle** pressure graph: a valve opens/closes when the pressures across it cross over.
- Explain the **oxygen dissociation curve** (S-shaped) and the **Bohr shift** (more CO₂ shifts it right, unloading more O₂ to active tissue).
- Most CO₂ is carried as **hydrogencarbonate** (via the chloride shift).

The circulatory system

Mammals have a **closed double circulation**.

- the **pulmonary circulation** carries blood from the heart to the lungs and back.
- the **systemic circulation** carries blood from the heart to the rest of the body and back.
- the **pulmonary artery** – carries blood low in **oxygen** from the heart to the lungs.
- the **pulmonary vein** – carries oxygen-rich blood from the lungs back to the heart.



Worked example – the Bohr shift

Explain why the oxygen dissociation curve shifts right in an exercising muscle.

- An exercising muscle respire hard, so it releases more CO_2 .
- CO_2 forms carbonic acid in the blood $\Rightarrow$ pH falls.
- Lower pH slightly changes haemoglobin's shape, lowering its affinity for oxygen.
- At the same $p\text{O}_2$ it is now less saturated $\Rightarrow$ more oxygen unloaded exactly where it is needed.

Right shift = unloads more readily. The S-shape itself comes from cooperative binding: the first O_2 makes the next one easier to bind.

Topic 8 – key takeaways

1

Circulation

closed, double; arteries to capillaries to veins

2

Oxygen

dissociation curve; Bohr shift releases O_2

3

Carbon dioxide

carried as hydrogencarbonate; chloride shift

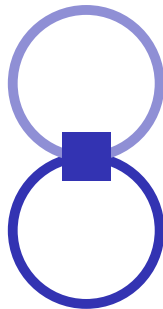
4

Heart

SAN sets rhythm; left ventricle wall thickest

Check yourself

- 1 Which vessel has valves to stop back-flow?
- 2 Which way does the Bohr shift move the curve?
- 3 In which form is most CO_2 carried?
- 4 Which node is the heart's pacemaker?



Answers 1. veins 2. to the right 3. hydrogen carbonate ions 4. the sinoatrial node (SAN)