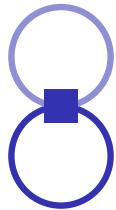
Transport in Mammals

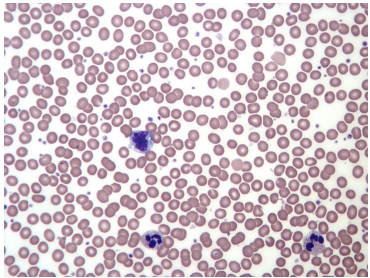
A-Level Biology ▪ Topic 8

A-Level Biology



What we will cover

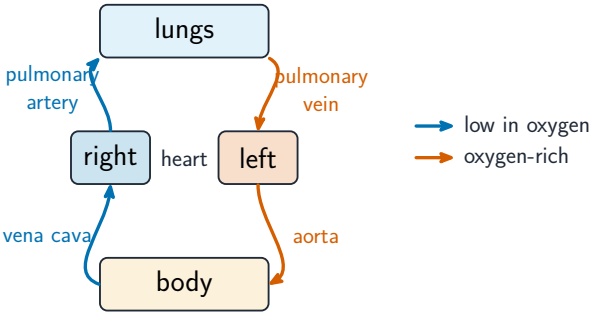
1. Double circulation
2. Blood vessels & tissue fluid
3. Oxygen transport
4. Carbon dioxide transport
5. The heart
6. Controlling the heartbeat



red & white blood cells

1 Circulation

Double circulation



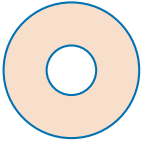
A **closed double circulation** 封闭双循环: blood passes through the heart twice per trip.

- **pulmonary** 肺循环 loop – to the lungs
- **systemic** 体循环 loop – to the body

Order: **arteries** 动脉 → **capillaries** 毛细血管 → **veins** 静脉.

Blood vessels

- **artery** 动脉 – thick muscular & elastic wall; high pressure
- **capillary** 毛细血管 – one cell thick; fast exchange
- **vein** 静脉 – thin wall, **valves** 瓣膜 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** 动脉 → **arterioles** 小动脉 → **capillaries** 毛细血管 → **venules** 小静脉 → **veins** 静脉.
The two great vessels	The **aorta** 主动脉 carries oxygen-rich blood from the heart to the body; the **vena cava** 腔静脉 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.

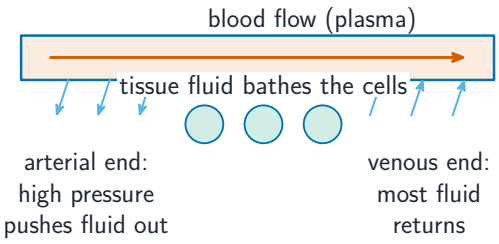
Wall thickness follows pressure: thick and elastic near the heart, thin and valved on the way back.

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** 血浆.

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

The blood cells, and what plasma does

red blood cells 红细胞	carry oxygen – biconcave, no nucleus, packed with haemoglobin
monocytes 单核细胞	large, kidney-shaped nucleus – become macrophages and engulf pathogens
neutrophils 中性粒细胞	a lobed nucleus – the commonest phagocyte
lymphocytes 淋巴细胞	a large round nucleus and little cytoplasm – make **antibodies** 抗体
water as a solvent 溶剂	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.

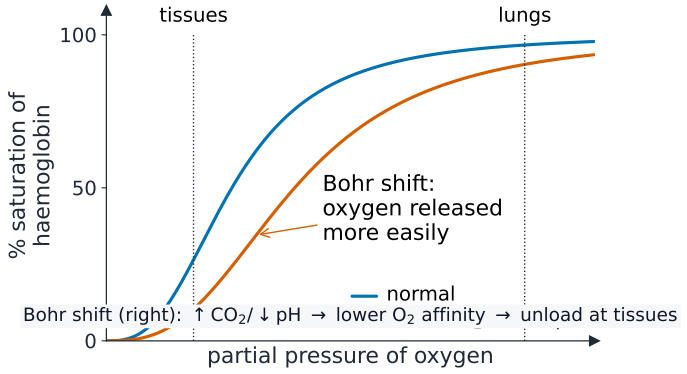
2 Gas transport

Oxygen transport and the Bohr shift

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

> The **Bohr shift** 波尔位移: 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



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

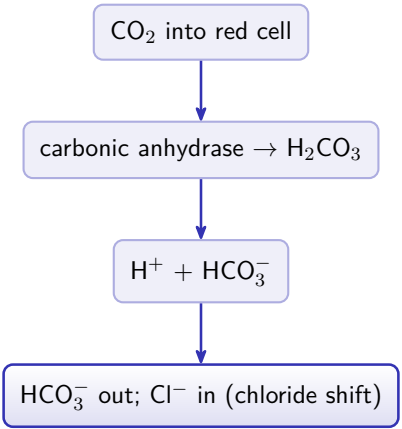
Carbon dioxide transport

Most CO_2 travels as **hydrogencarbonate ions** 碳酸氢根离子:

- **carbonic anhydrase** 碳酸酐酶 speeds CO_2+ water
- the **chloride shift** 氯转移 keeps charge balanced
- haemoglobin mops up the H^+

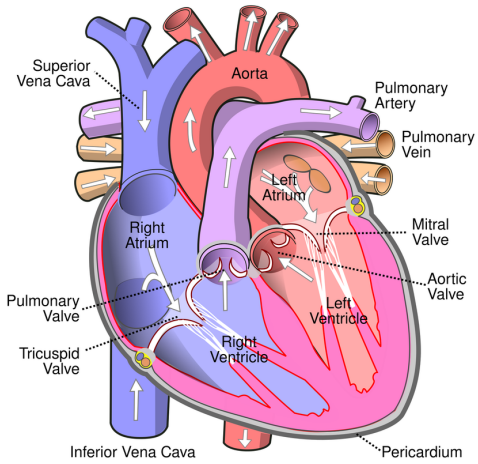
Carbon dioxide transport, continued

Most CO_2 travels as **hydrogencarbonate** 碳酸氢根 ions in the plasma.



3 The heart

The heart



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

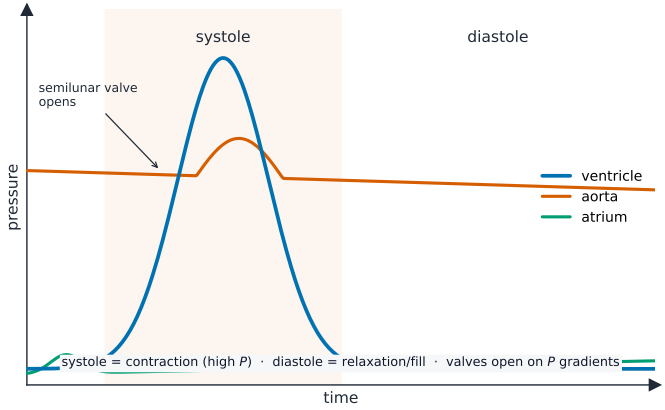
> The left ventricle wall is thickest – it pumps blood all the way round the body; the right side only reaches the lungs.

The cardiac cycle

One heartbeat: **systole** 收缩期 (contract) then **diastole** 舒张期 (relax & fill).

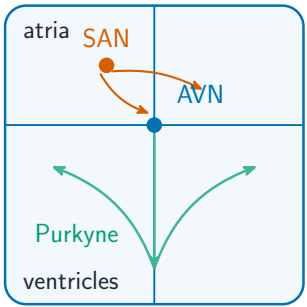
> A pressure change opens or closes a **valve** 瓣膜 wherever two pressure curves cross – so blood flows one way only.

The cardiac cycle, in detail



One heartbeat: **systole** 收缩期 (contract) then **diastole** 舒张期 (relax & fill).

Controlling the heartbeat



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

The heart sets its own rhythm:

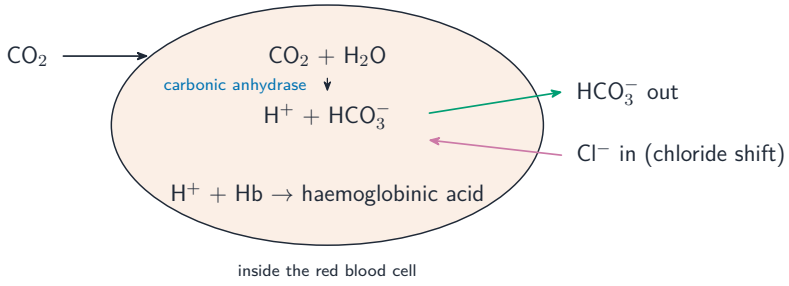
- the **SAN** 窦房结 (pacemaker) fires; the atria contract
- the **AVN** 房室结 delays, then passes it on
- **Purkyne tissue** 浦肯野组织 makes ventricles contract bottom-up

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 房室结	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 carbamino-haemoglobin 氨甲酰血红蛋白	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 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** 酶 **carbonic anhydrase** 碳酸酐酶 speeds the reaction of CO_2 with water to make carbonic acid.
2. It dissociates	Carbonic acid splits into hydrogen ions and **hydrogencarbonate ions** 碳酸氢根离子.
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** 氯离子 move into the red blood cells.
5. Buffering	The hydrogen ions join haemoglobin as **haemoglobinic acid** 血红蛋白酸, 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 CO_2 shifts it right, unloading more O_2 to active tissue).
- Most CO_2 is carried as **hydrogencarbonate** (via the chloride shift).

The circulatory system

Mammals have a **closed double circulation**.

- the **pulmonary circulation** 肺循环 carries blood from the heart to the lungs and back.
- the **systemic circulation** 体循环 carries blood from the heart to the rest of the body and back.
- the **pulmonary artery** 肺动脉 – carries blood low in **oxygen** 氧气 from the heart to the lungs.
- the **pulmonary vein** 肺静脉 – carries oxygen-rich blood from the lungs back to the heart.

4 Recap

Worked example – the Bohr shift

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

- An exercising muscle respires 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 pO_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

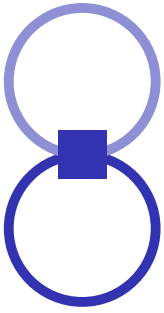
carried as hydrogencarbonate; chloride shift

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.** hydrogencarbonate ions **4.** the sinoatrial node (SAN)