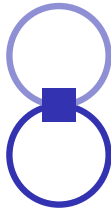


Transport in Mammals

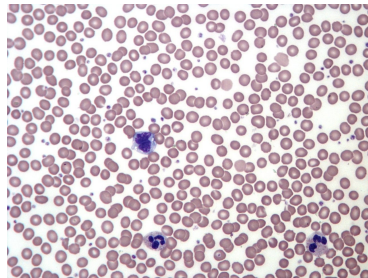
A-Level Biology ■ Topic 8

A-Level Biology



What we will cover

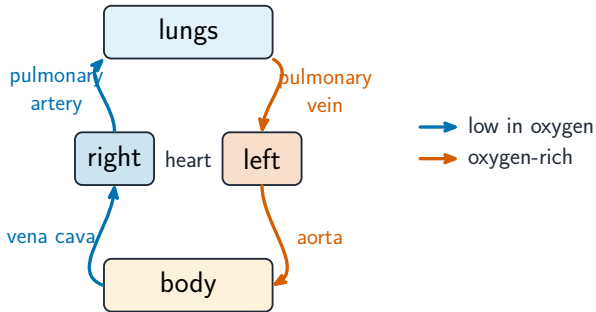
- 1 Double circulation
- 2 Blood vessels & tissue fluid
- 3 Oxygen transport
- 4 Carbon dioxide transport
- 5 The heart
- 6 Controlling the heartbeat



red & white blood cells



Double circulation



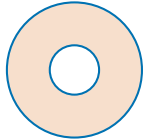
A **closed double circulation** 封闭双循环: blood passes through the heart **twice** per trip.

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

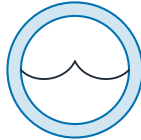
Order: **arteries** 动脉 → **capillaries** 毛细血管 → **veins** 静脉.

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.

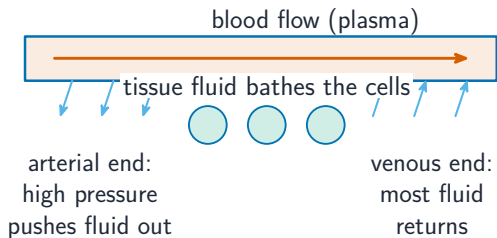
Wall thickness follows pressure: thick and elastic near the heart, thin and valved on the way back.

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.

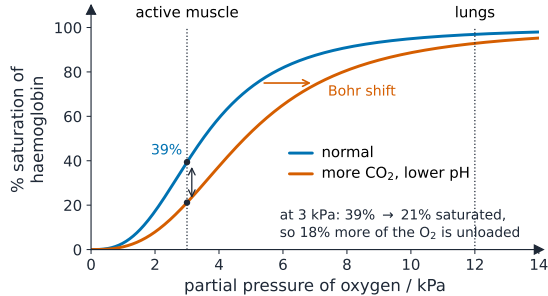
The blood cells, and what plasma does

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.



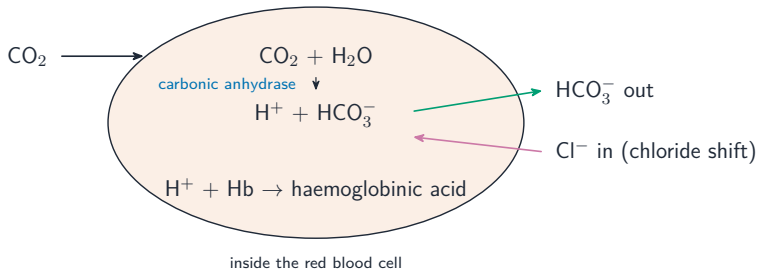
Oxygen transport and the Bohr shift



Bohr shift (right): $\uparrow \text{CO}_2 / \downarrow \text{pH} \rightarrow$ lower O₂ affinity $\rightarrow$ unload at tissues

Haemoglobin 血红蛋白 loads oxygen at high **partial pressure** 分压 (lungs). The **Bohr shift** 波尔位移: more CO₂ (lower pH) moves the curve **right**, so more oxygen is unloaded in respiring tissue.

Carbon dioxide transport

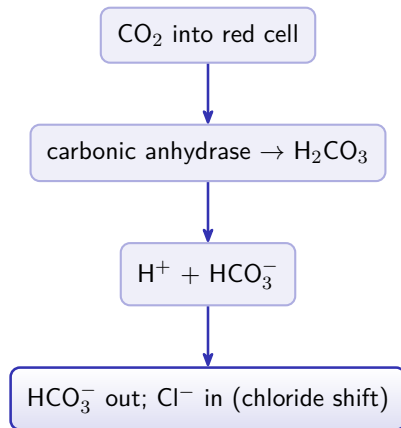


Most CO_2 travels as **hydrogencarbonate ions** 碳酸氢根离子:

- **carbonic anhydrase** 碳酸酐酶 speeds $\text{CO}_2 + \text{water} \rightarrow \text{carbonic acid}$
- the **chloride shift** 氯转移 (Cl^- in as HCO_3^- leaves) keeps charge balanced
- haemoglobin mops up the H^+ , forming haemoglobinic acid

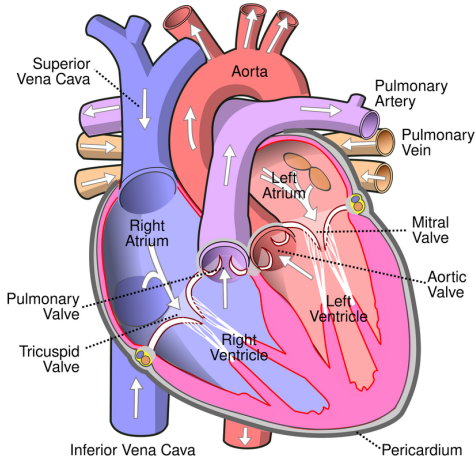
Carbon dioxide transport, continued

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





The heart



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

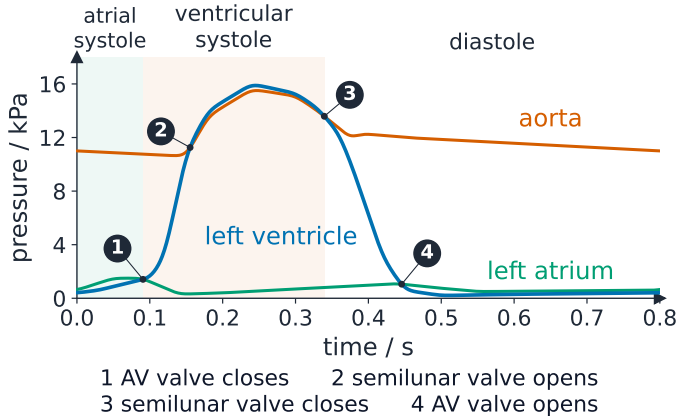
The **left ventricle** wall is thickest – it pumps blood all the way round the body; the right side only reaches the lungs.

The cardiac cycle

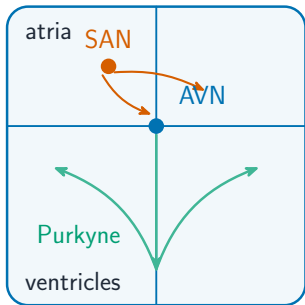
One heartbeat:

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.



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.

Carbon dioxide, in five steps

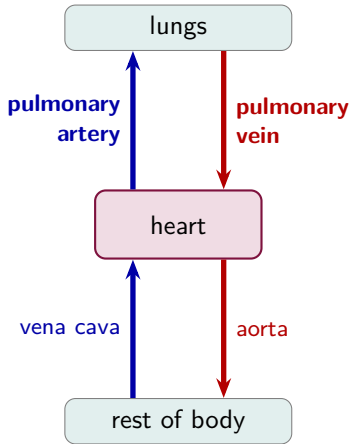
- | | |
|----------------------|---|
| 1. The enzyme | The enzyme 酶 carbonic anhydrase 碳酸酐酶 speeds the reaction of CO_2 with water to make carbonic acid. |
| 2. It dissociates | Carbonic acid splits into hydrogen ions and hydrogencarbonate ions 碳酸氢根离子. |
| 3. Out to the plasma | The hydrogencarbonate 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: a **closed double circulation**
– blood passes through the heart **twice** per circuit.

Pulmonary 肺循环
heart → lungs → heart

Systemic 体循环
heart → body → heart

■ low in oxygen ■ oxygen-rich



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 O₂

3

Carbon dioxide

carried as hydrogencarbonate; chloride shift

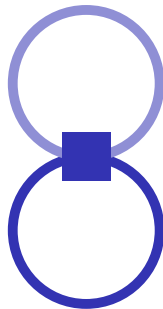
4

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)