Transport in mammals

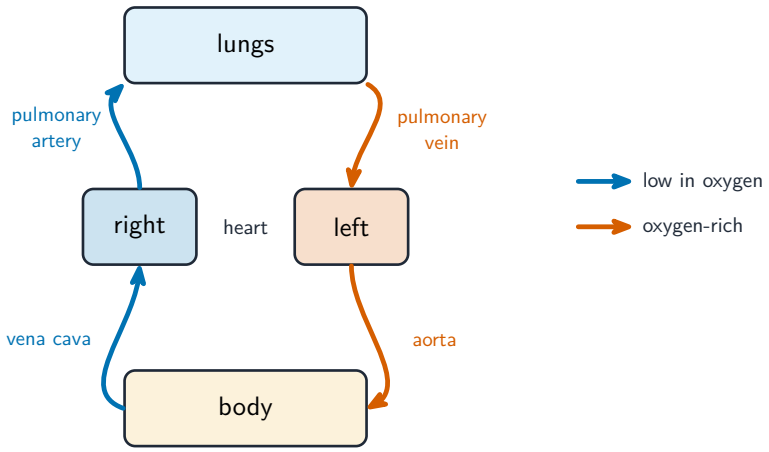
A-Level Biology

The circulatory system

Mammals have a **closed double circulation**. "Closed" means the blood stays inside **blood vessels** 血管 the whole time. "Double" means the blood passes through the **heart** 心脏 twice for each full trip around the body. This gives two linked loops, so we call it a **double circulation** 双循环 and the whole thing a **circulatory system** 循环系统:

- 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.

Blood travels in this order: **arteries** 动脉 → **arterioles** 小动脉 → **capillaries** 毛细血管 → **venules** 小静脉 → **veins** 静脉.



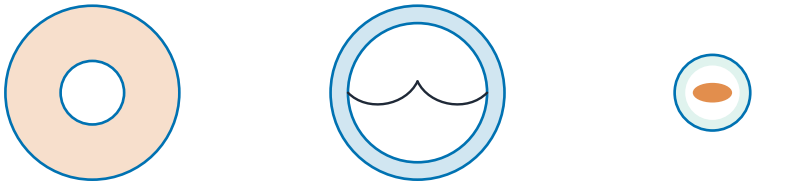
Double circulation 双循环: the pulmonary loop goes to the lungs, the systemic loop to the body; blood passes through the heart twice

The main vessels are:

- 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.
- the **aorta** 主动脉—the big artery that carries oxygen-rich blood from the heart to the body.
- the **vena cava** 腔静脉—the big vein that returns oxygen-poor blood from the body to the heart.

How the vessels suit their jobs

Vessel	Structure	Function
artery	thick wall of **muscle** 肌肉 and **elastic** 弹性 fibres; narrow **lumen** 管腔 (the space inside)	carries blood at high pressure away from the heart; elastic walls stretch and recoil to smooth the flow; muscle controls the flow
capillary	wall just one cell thick; very narrow	short distance for exchange of substances between blood and cells
vein	thin wall; wide lumen; has **valves** 瓣膜	returns blood at low pressure to the heart; valves stop blood flowing backwards



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

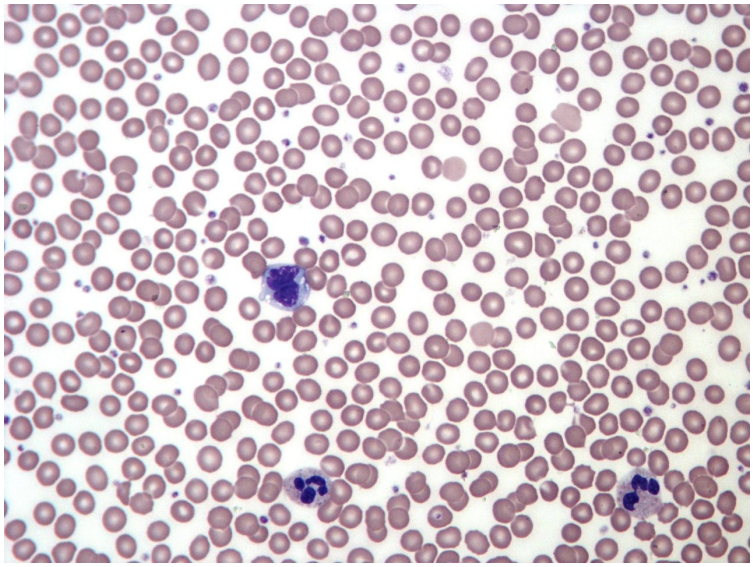
vein
thin wall; wide lumen; valves (low pressure)

capillary
wall one cell thick; very narrow (exchange)

An artery 动脉 has a thick wall and narrow lumen 管腔; a vein 静脉 a thin wall, wide lumen and valves 瓣膜; a capillary 毛细血管 is one cell thick

Blood cells

You should recognise: **red blood cells** 红细胞 (which carry oxygen), and three white blood cells —**monocytes** 单核细胞, **neutrophils** 中性粒细胞 and **lymphocytes** 淋巴细胞.

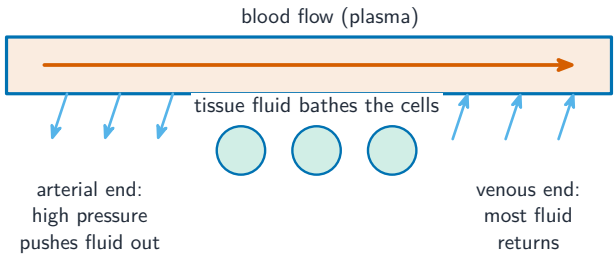


*A stained **blood smear** 血涂片: many small red cells, plus a lymphocyte (centre) and neutrophils (lobed nucleus 分叶核) —the white cells are larger and have a nucleus*

Water, plasma and tissue fluid

Water is the main part of blood. It is a good **solvent** 溶剂, so it carries dissolved substances, and it has a high **specific heat capacity** 比热容, so the blood's temperature stays steady.

At the start of a capillary, the high blood pressure pushes liquid (but not the cells or large proteins) out of the **plasma** 血浆 and through the capillary wall. This liquid around the cells is **tissue fluid** 组织液. It supplies the cells with oxygen and glucose and carries waste away. Most of it returns to the capillary at the far end, where the pressure is lower.



High pressure at the arterial end pushes fluid out to form tissue fluid 组织液; most returns at the venous end

Transport of oxygen and carbon dioxide

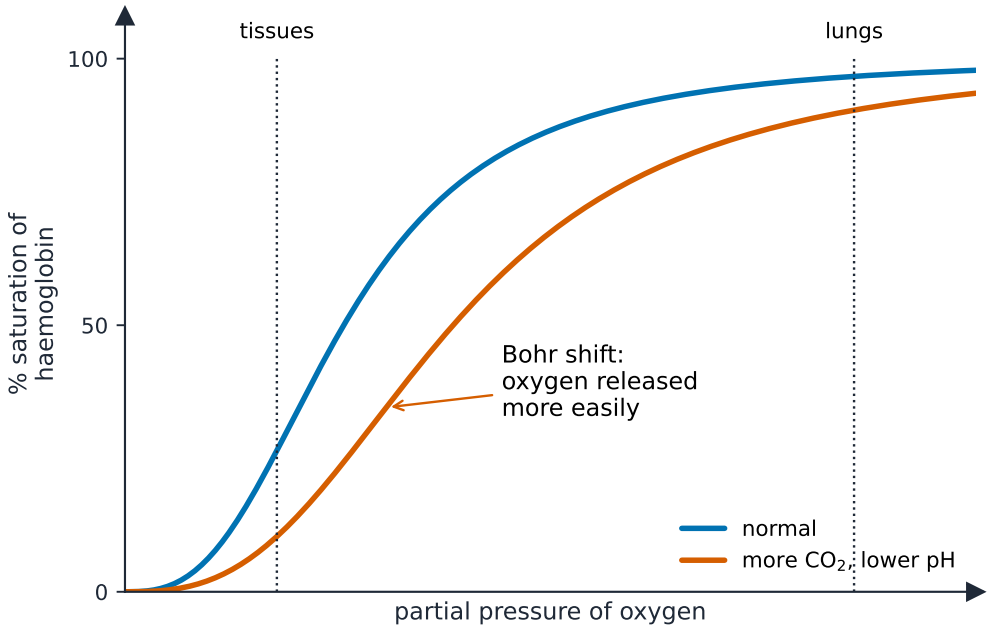
Carrying oxygen

Oxygen is carried by **haemoglobin** 血红蛋白 in the red blood cells. We show how well haemoglobin holds oxygen with the **oxygen dissociation curve** 氧解离曲线. This S-shaped graph plots the **saturation** 饱和度 (how full of oxygen the haemoglobin is) against the **partial pressure** 分压 of oxygen:

- where the partial pressure of oxygen is **high** (in the lungs), haemoglobin loads up and becomes almost fully saturated.
- where it is **low** (in respiring tissues), haemoglobin unloads its oxygen for the cells to use.

The Bohr shift

When tissues are very active, they release more **carbon dioxide** 二氧化碳, which lowers the pH. This makes haemoglobin release oxygen more easily, so the curve moves to the right. This helpful change is the **Bohr shift** 波尔位移: oxygen is given up exactly where it is most needed.



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

Carrying carbon dioxide

A little carbon dioxide dissolves straight into the plasma, but most is carried after a reaction inside the red blood cells:

1. the **enzyme** 酶 **carbonic anhydrase** 碳酸酐酶 speeds up the reaction of carbon dioxide with water to make carbonic acid.
2. the carbonic acid splits into hydrogen ions and **hydrogencarbonate ions** 碳酸氢根离子.
3. the hydrogencarbonate ions move out into the plasma. This is the main way carbon dioxide is carried.
4. to keep the charge balanced, **chloride ions** 氯离子 move into the red blood cells. This movement is the **chloride shift** 氯转移.
5. the hydrogen ions join haemoglobin to form **haemoglobinic acid** 血红蛋白酸; this mops up the hydrogen ions and keeps the pH steady.

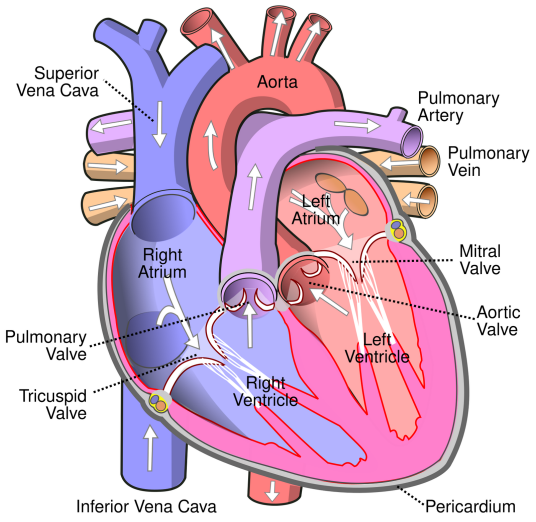
Some carbon dioxide also joins haemoglobin directly to form **carbaminohaemoglobin** 氨甲酰血红蛋白.

The heart

Structure

The heart has four chambers. The two upper chambers are the **atria** 心房 (singular: atrium); they have thin walls because they only push blood down into the chambers below. The two lower chambers are the **ventricles** 心室; they have thick muscular walls because they pump blood out of the heart.

The left ventricle wall is thicker than the right ventricle wall, because the left side must pump blood all the way round the body, while the right side only pumps to the nearby lungs.



The four chambers, the valves 瓣膜 *and the main vessels; the left ventricle* 左心室 *wall is the thickest*

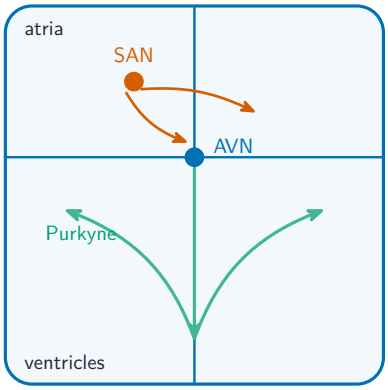
The cardiac cycle

One heartbeat is the **cardiac cycle** 心动周期. It has two parts: **systole** 收缩期 (when heart muscle contracts) and **diastole** 舒张期 (when it relaxes and fills). When a chamber contracts, the pressure inside rises; this pressure change opens and closes the valves so that blood flows one way only.

Controlling the heartbeat

The heart sets its own rhythm:

- the **sinoatrial node** 窦房结 in the right atrium is the pacemaker. It sends out a wave of electrical excitation that spreads across the atria and makes them contract.
- the **atrioventricular node** 房室结 picks up the wave, holds it back for a moment (so the atria empty first), then passes it on.
- the **Purkyne tissue** 浦肯野组织 carries the wave down and through the ventricle walls, so the ventricles contract from the bottom upwards and push blood out.



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

The SAN 窦房结 *sets the rhythm; the wave passes to the AVN* 房室结*, then the Purkyne tissue* 浦肯野组织 *makes the ventricles contract bottom-up*