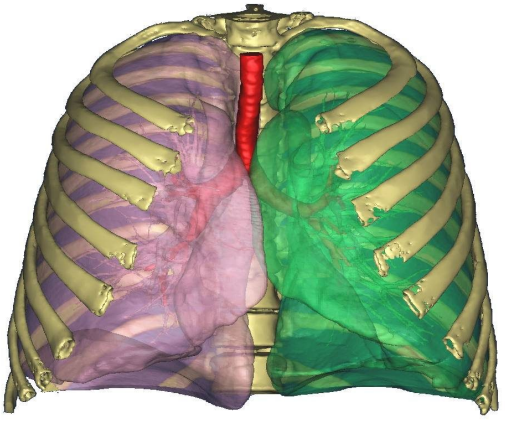
Gas exchange in humans

IGCSE Biology

Gas exchange surfaces

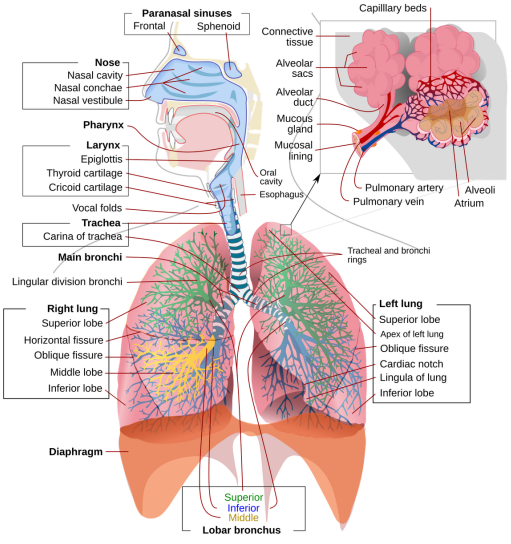


Gas exchange happens across the huge surface of the lungs.

Gas exchange 气体交换 is how **oxygen** 氧气 gets into the blood and **carbon dioxide** 二氧化碳 gets out, by **diffusion** 扩散. A good gas exchange surface has four features:

- a large **surface area** 表面积 — so more gas can cross at once.
- a **thin** surface — so gases have only a short distance to diffuse.
- a good **blood supply** — to keep a steep difference in concentration.
- good **ventilation** 通气 with air — fresh air keeps the difference steep.

The breathing system

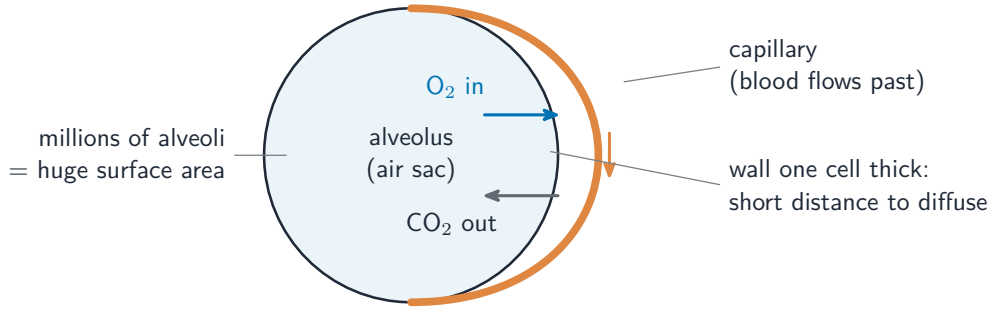


The lungs are the gas-exchange organs of the human body.

Air travels in and out through these parts:

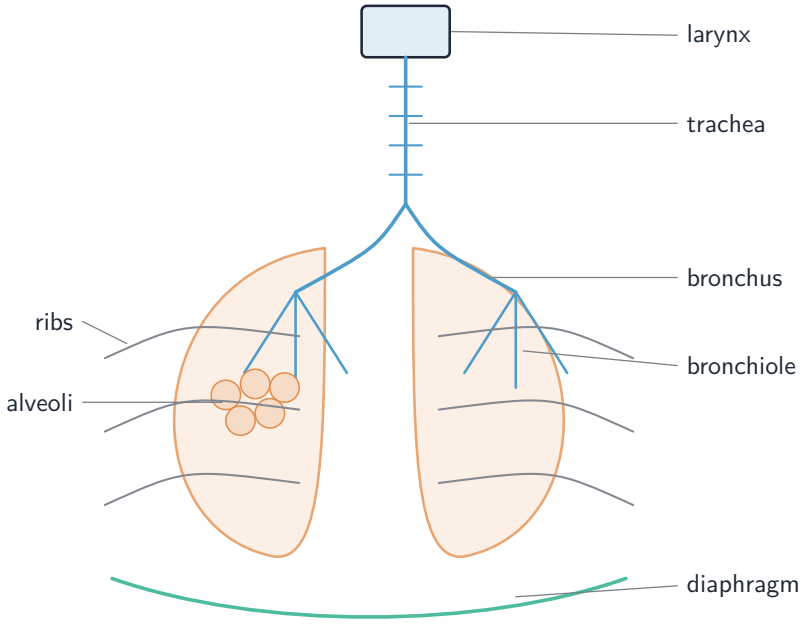
Part	Job
larynx 喉	the voice box, at the top of the windpipe
trachea 气管	the windpipe; carries air towards the lungs
bronchi 支气管	two tubes, one going to each lung
bronchioles 细支气管	smaller branching tubes inside the lungs
alveoli 肺泡	tiny air sacs where gas exchange happens; each is wrapped in **capillaries** 毛细血管

The alveoli make excellent gas exchange surfaces: there are millions of them (a huge surface area), each has a wall only one cell thick (a short distance), and each is surrounded by capillaries (a good blood supply).



At an alveolus, oxygen diffuses into the blood and carbon dioxide diffuses out

The lungs sit in the chest, protected by the **ribs** 肋骨. Below them is a sheet of muscle, the **diaphragm** 膈肌. Between the ribs are the **intercostal muscles** 肋间肌. **(Supplement)** The trachea is held open by rings of **cartilage** 软骨, so it cannot collapse when you breathe in.



Air travels from the trachea through the bronchi and bronchioles to the alveoli

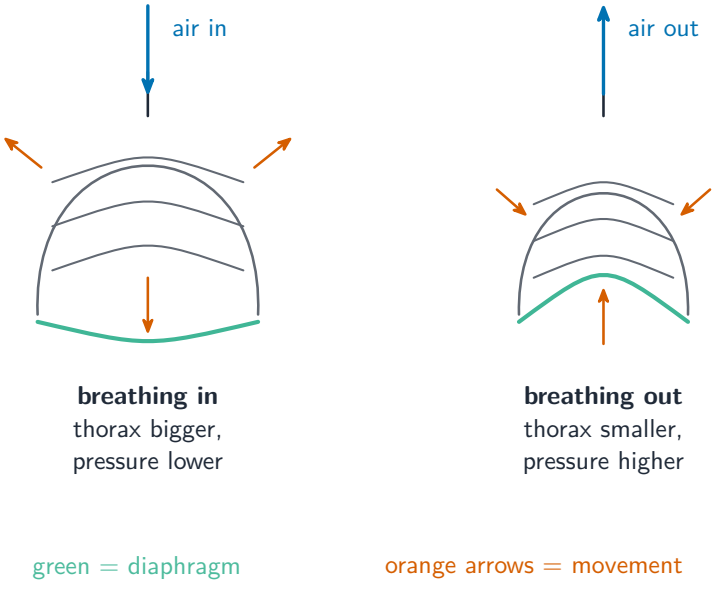
How you breathe (Supplement)

Breathing changes the volume and **pressure** 压力 inside the chest (the **thorax** 胸腔).

Breathing in (**inhaling** 吸气):

- the external intercostal muscles contract, pulling the ribs up and out.
- the diaphragm contracts and flattens (moves down).
- the thorax becomes bigger, so the pressure inside drops below the outside air pressure.
- air is pushed in.

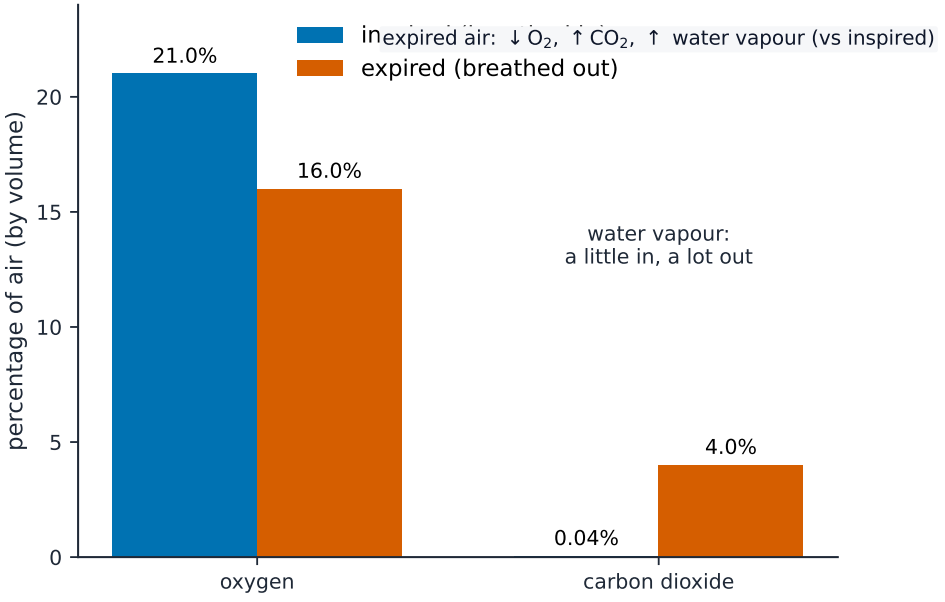
Breathing out (**exhaling** 呼气) is the opposite: the muscles relax (and the internal intercostal muscles may contract), the thorax becomes smaller, the pressure rises, and air is pushed out.



Breathing in makes the thorax bigger (lower pressure); breathing out makes it smaller

Inspired and expired air

Gas	Inspired air (breathed in)	Expired air (breathed out)
oxygen	about 21%	about 16% (less)
carbon dioxide	about 0.04%	about 4% (more)
water vapour 水蒸气	a little	a lot (more)



Expired air has less oxygen and much more carbon dioxide than inspired air

You can test for carbon dioxide with **limewater** 石灰水, which turns cloudy. Expired air turns limewater cloudy much faster than inspired air, showing it contains more carbon dioxide.

Breathing and exercise

During exercise your muscles respire faster and make more carbon dioxide. This raises the **concentration** 浓度 of carbon dioxide in the blood. **(Supplement)** Your **brain** 大脑 detects the rise and makes you breathe at a faster **rate** 速率 and a greater depth. This brings in more oxygen and removes the extra carbon dioxide quickly.

Worked example. At rest a person takes 12 breaths per minute, moving 500 cm^3 of air per breath. During exercise this becomes 20 breaths per minute at 900 cm^3 per breath. How much air passes through the lungs each minute in each case? Multiply the rate by the depth. At rest: $12 \times 500 =$ **6000 cm^3 per minute**. During exercise: $20 \times 900 =$ **18 000 cm^3 per minute**, three times as much. Exercise raises **both** the

rate and the depth of breathing - an answer that changes only the rate throws away half the marks.

Keeping the airways clean (Supplement)

The airways are lined with two kinds of cell that trap and remove dirt:

- **goblet cells** 杯状细胞 make **mucus** 黏液, which traps **pathogens** 病原体 and dust **particles** 粒子.
- **ciliated cells** 纤毛细胞 have tiny hairs that sweep the mucus, with the trapped dirt, up to the throat, where it is swallowed.

Exam tips

- A gas exchange surface is large, thin, with a good blood supply and good ventilation.
- Air path: larynx → trachea → bronchi → bronchioles → alveoli.
- Breathing in: external intercostal muscles and diaphragm contract → thorax bigger → pressure lower → air in. Breathing out is the opposite.
- Expired air has **less** oxygen, **more** carbon dioxide and **more** water vapour. Limewater tests for carbon dioxide.
- Exercise → more carbon dioxide in the blood → brain → faster, deeper breathing.