Gas exchange

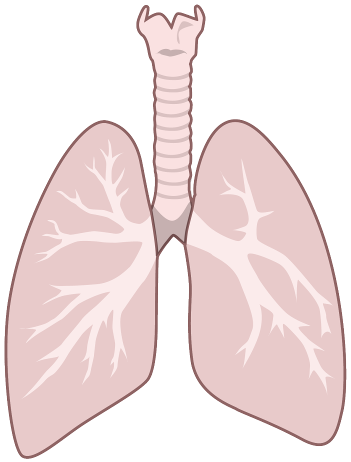
A-Level Biology

The gas exchange system

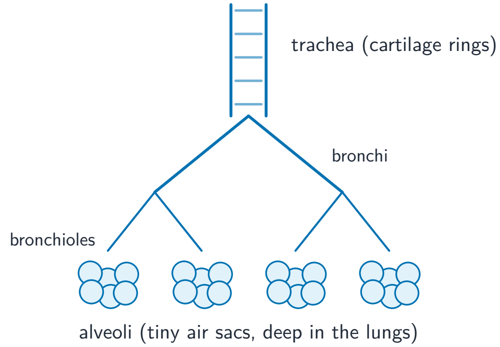
Your body needs to take in oxygen and get rid of carbon dioxide. This swap happens in the **gas exchange** 气体交换 system. Air follows this path into the body:

- down the **trachea** 气管 (the windpipe),
- into two **bronchi** 支气管 (one to each lung),
- into many smaller **bronchioles** 细支气管,
- and finally into tiny air sacs called **alveoli** 肺泡, deep in the **lungs** 肺.

Each alveolus is wrapped in a network of **capillaries** 毛细血管, so air and blood are brought very close together.



The human lungs, where gas exchange takes place across millions of alveoli

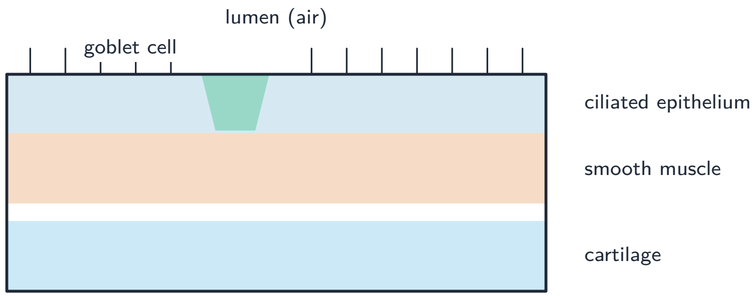


Air passes down the trachea, into the bronchi and bronchioles, to the alveoli

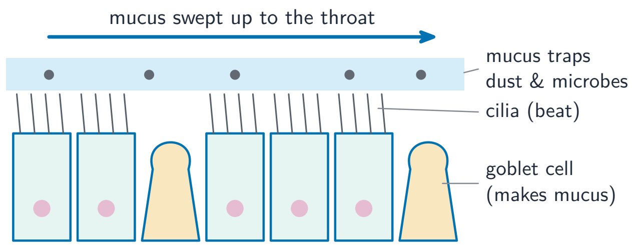
The tissues of the airways and what they do

Tissue	Where it is	Function
cartilage 软骨	C-shaped rings in the trachea and bronchi	holds the airway open so it cannot collapse when you breathe in
ciliated epithelium 纤毛上皮	lining the trachea and bronchi	tiny hairs called **cilia** 纤毛 beat to sweep **mucus** 黏液 up towards the throat, away from the lungs
goblet cells 杯状细胞 and **mucous glands** 黏液腺	in the lining of the airways	make the mucus, which traps dust and **microbes** 微生物 that you breathe in
smooth muscle 平滑肌	in the walls of bronchi and bronchioles	contracts to make the airway narrower
elastic fibres 弹性纤维	in the airway and alveolus walls	stretch when you breathe in, then spring back to help push air out
squamous epithelium 扁平上皮	the very thin, flat lining of the alveoli	gives a very short distance for gases to cross

The cilia, goblet cells and mucous glands work together to keep the lungs clean and healthy: the mucus traps dirt and microbes, and the cilia carry it away to be swallowed.



A section through the airway wall: cilia and goblet cells line the lumen, with smooth muscle and supporting cartilage behind



Goblet cells make mucus that traps dust and microbes; the cilia sweep it up to the throat

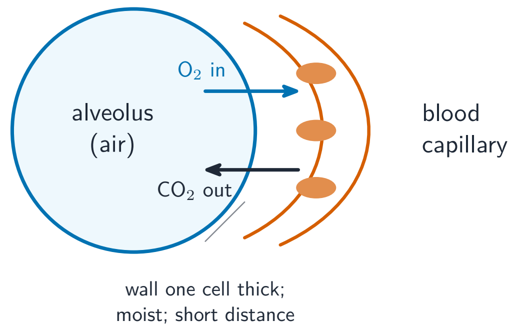
Gas exchange in the alveoli

The alveoli are excellent surfaces for exchanging gases, because they have:

- a very large total surface area (millions of tiny sacs),
- very thin walls — the squamous epithelium of the alveolus and the capillary wall are each only one cell thick, so the distance to cross is tiny,
- a rich blood supply from the capillary network,
- a moist lining, so gases dissolve before crossing.

Gases move by **diffusion** 扩散 down their **concentration gradients** 浓度梯度:

- **oxygen** 氧气 is at a high concentration in the alveolar air and a low concentration in the blood, so it diffuses from the air into the blood.
- **carbon dioxide** 二氧化碳 is at a high concentration in the blood and a low concentration in the alveolar air, so it diffuses from the blood into the air to be breathed out.



Across the thin, moist wall, oxygen diffuses into the blood and carbon dioxide diffuses out

Under the microscope, real lung tissue looks like a fine pink lace. The many open spaces are the alveoli, and the thin pink lines between them are the walls where gas exchange happens:

Real lung tissue stained for the microscope: the open spaces are alveoli and the thin pink walls are where gases cross; a small airway sits in the centre

Breathing keeps fresh air in the alveoli, and the flowing blood keeps carrying gases away. Both of these keep the concentration gradients steep, so gas exchange stays fast.

Worked example. Use Fick's law to explain why the alveoli allow such rapid gas exchange. Fick's law makes the rate of diffusion proportional to

$$\frac{\text{surface area} \times \text{concentration difference}}{\text{diffusion distance}}$$

so a fast rate needs all three terms working for it. **Surface area**: millions of alveoli give a huge total area, roughly 70 m^2. **Diffusion distance**: the alveolar epithelium and the capillary endothelium are each one flattened cell thick, so oxygen crosses in under 1 μm. **Concentration difference**: ventilation constantly refreshes the air while the circulation constantly carries oxygenated blood away, so a **steep gradient is maintained**. Tie each adaptation to the **term of the equation** it serves - listing ”big surface area, thin walls, good blood supply” without linking them to Fick’s law is the weaker answer.

Exam tips

- Link each **alveolar** feature to fast diffusion: large surface area, thin (one-cell) walls, moist surface, good blood supply — a “surface area, short distance, steep gradient” answer.
- Match airway tissue to function: cartilage (holds airways open), ciliated + goblet cells (trap and sweep mucus), smooth muscle and elastic fibres.
- Frame answers with **Fick’s law** ideas: rate $\propto$ surface area $\times$ concentration difference $\div$ distance.