Human Gas Exchange

The gas exchange system, alveoli and their adaptations, inspired and expired air, how breathing works, the effect of exercise on breathing, and how the airways protect against pathogens and particles.

11.1 Gas exchange in humans

The gas exchange system

Air passes from the nose or mouth through the **larynx** (voice box), down the **trachea** (windpipe), which divides into two **bronchi** (one for each lung). The bronchi divide into smaller **bronchioles**, which end in tiny air sacs called **alveoli**. The **lungs** are protected inside the **rib cage** and are separated from the abdomen by the **diaphragm**.

Features of a gas exchange surface

> **A gas exchange surface has a large surface area, is thin, and has a good blood supply and a good air supply.**

The alveoli

Feature	How it helps gas exchange
millions of alveoli	a very large surface area
walls one cell thick, and capillary walls one cell thick	a very short diffusion distance, so fast diffusion
a dense network of capillaries	a good blood supply that carries oxygen away and brings carbon dioxide, keeping a steep concentration gradient
moist lining	gases dissolve in it before diffusing across
breathing movements	refresh the air in the alveoli, so the oxygen concentration stays high and the carbon dioxide concentration stays low

Oxygen **diffuses** from the air in the alveoli into the blood (where it combines with haemoglobin in red blood cells). Carbon dioxide diffuses from the blood into the air in the alveoli and is breathed out.

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The composition of air

Gas	Inspired (atmospheric) air	Expired air
nitrogen	about 78%	about 78% (unchanged)
oxygen	about 21%	about 16%
carbon dioxide	about 0.04%	about 4%
water vapour	variable (low)	high (saturated)
temperature	air temperature	warmer (body temperature)

Expired air has **less oxygen** (used in respiration), **more carbon dioxide** (made in respiration) and **more water vapour** (evaporates from the moist lining of the lungs) than inspired air.

Investigation. Breathe through limewater: expired air turns **limewater milky** much faster than inspired air, because it contains more carbon dioxide. A **hydrogencarbonate indicator** also changes colour faster with expired air. Breathing out onto a cold mirror shows the water vapour (it mists).

Breathing

	Breathing in (inhaling)	Breathing out (exhaling)
external intercostal muscles	contract	relax
internal intercostal muscles	relax	contract (in forced breathing)
ribs	move **up and out**	move **down and in**
diaphragm	contracts and **flattens**	relaxes and returns to a **dome** shape
volume of the thorax	**increases**	**decreases**
pressure in the thorax	**decreases** (below atmospheric)	**increases** (above atmospheric)
air movement	air moves **in**	air is forced **out**

Air always moves from a region of **higher pressure** to a region of **lower pressure**.

> **TRY IT**
>
> Explain how air is drawn into the lungs when the diaphragm contracts.

The diaphragm contracts and flattens, and the external intercostal muscles contract and lift the ribs. The **volume of the thorax increases**, so the **pressure falls below atmospheric pressure** and air is forced

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into the lungs.

The effect of exercise

During exercise the muscles respire faster, so they need more oxygen and make more carbon dioxide. The breathing rate and depth (volume of each breath) **increase**, which brings in more oxygen and removes the extra carbon dioxide. The increased carbon dioxide in the blood is detected by the brain, which sends signals to the breathing muscles.

Investigation. Count the number of breaths in one minute at rest, then after exercise (for example, running on the spot for 2 minutes). The rate is higher after exercise and takes time to return to normal. Depth can be measured with a spirometer.

Protection of the gas exchange system

Air contains dust, bacteria and other particles. The airways are lined with:

- **goblet cells**, which make **mucus**;
- **mucus**, which **traps** particles and pathogens;
- **ciliated cells**, with tiny hair-like **cilia** that **beat** and **sweep the mucus** with the trapped particles up to the throat, where it is swallowed.

This stops particles and pathogens from reaching the alveoli. Smoking damages the cilia, so mucus builds up and causes coughing and infection.

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