

Gas exchange in humans

Revision notes • The breathing system, how the lungs are adapted for gas exchange, how ventilation works and how breathing changes with exercise.

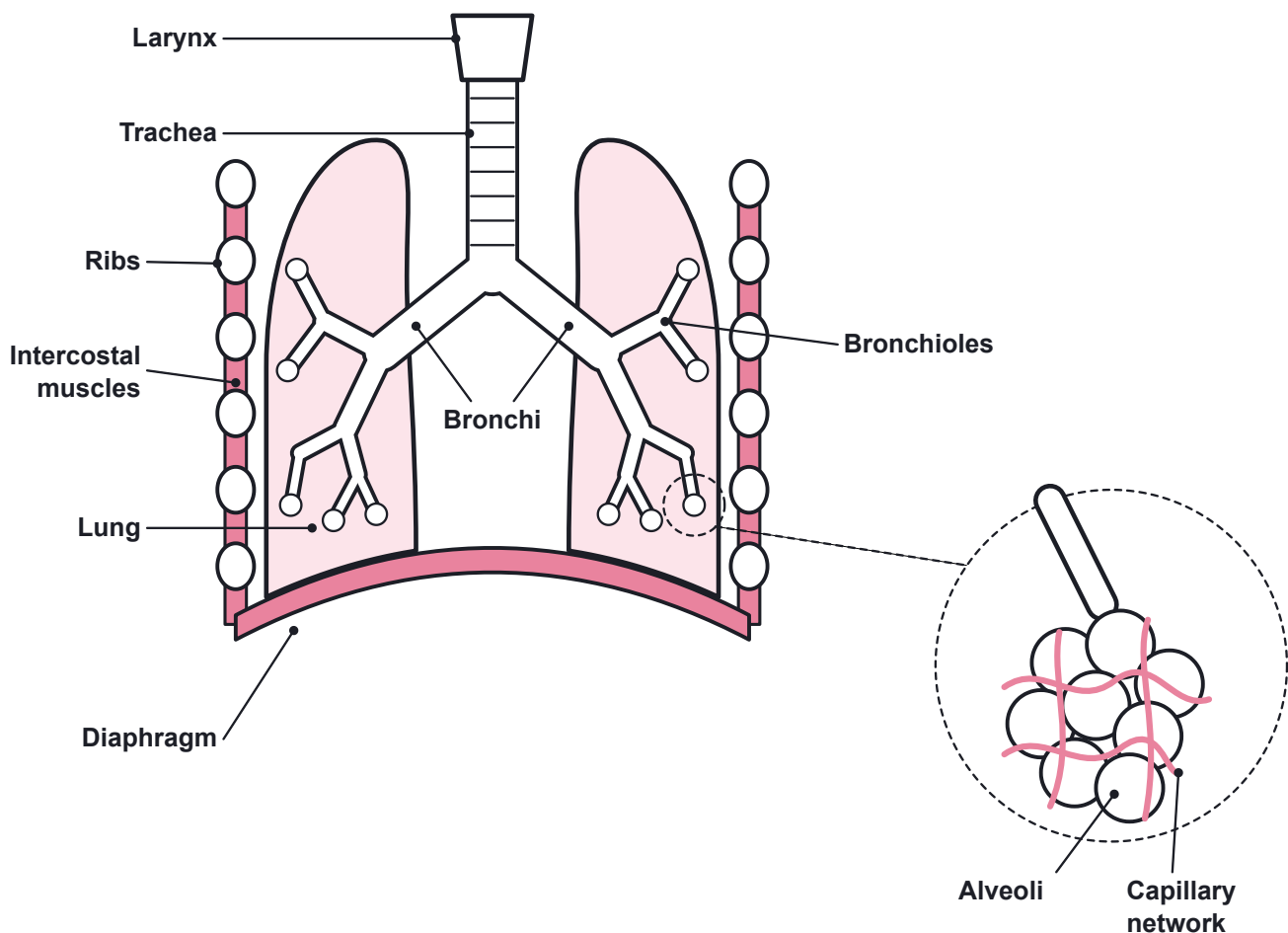
For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). **Supplement** is Extended content, only examined on Papers 2 and 4.

Gas exchange in humans Spec 11.1

The breathing system Spec 11.1.2, 11.1.6, 11.1.7

Air enters the body through the nose or mouth and travels to the lungs along a series of tubes. The lungs sit inside the thorax (chest), protected by the ribs. The **diaphragm** forms the floor of the thorax.

1. Air passes through the larynx (voice box) into the trachea (windpipe).
2. The trachea divides into two bronchi (singular: bronchus), one to each lung.
3. Each bronchus branches into many smaller tubes called bronchioles.
4. The bronchioles end in tiny air sacs called alveoli (singular: alveolus).
5. Each alveolus is surrounded by a network of capillaries, where gas exchange happens.



Air passes through the larynx, trachea, bronchi and bronchioles to the **alveoli**, which are surrounded by a network of capillaries.

Parts of the breathing system

Part	Description or function
Lungs	Organs in the thorax where gas exchange takes place
Ribs	Bones that protect the lungs and move to change the volume of the thorax
Intercostal muscles	Muscles between the ribs that move the ribs
Diaphragm	Sheet of muscle below the lungs that separates the thorax from the abdomen
Larynx	Voice box at the top of the trachea
Trachea	Windpipe: carries air to the bronchi
Bronchi	Two tubes that carry air into the lungs
Bronchioles	Small tubes that carry air to the alveoli
Alveoli	Air sacs where oxygen and carbon dioxide are exchanged with the blood in the capillaries

Supplement

Intercostal muscles

Supplement

There are two sets of intercostal muscles between each pair of ribs. The **external intercostal muscles** are on the outside. The **internal intercostal muscles** are on the inside, underneath them. The two sets work against each other to move the ribs.

Supplement

Cartilage in the trachea

Supplement

The wall of the trachea contains C-shaped rings of **cartilage**. The function of the cartilage is to **support the trachea and keep it open**, so air can always flow through it, even when the pressure inside falls as you breathe in.

Exam tip: Spell bronchi (plural, two tubes) and bronchioles (the small tubes) carefully. They are often mixed up, and the mark is lost if the wrong one is written.

Features of gas exchange surfaces Spec 11.1.1

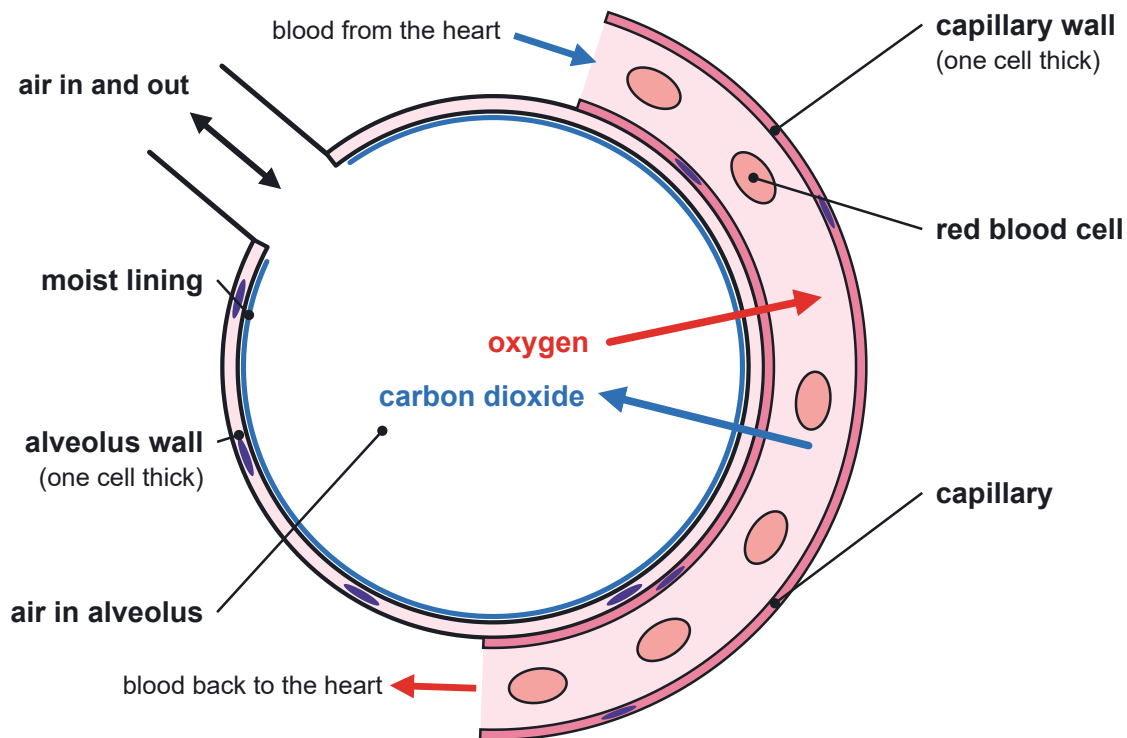
Gas exchange happens at the surface of the alveoli. Oxygen moves from the air in the alveoli into the blood, and carbon dioxide moves from the blood into the air in the alveoli. Both gases move by diffusion.

A good gas exchange surface in humans has four features: a **large surface area**, a **thin surface**, a **good blood supply** and **good ventilation with air**.

How the alveoli are adapted for gas exchange

Feature	Why it helps
Large surface area (millions of alveoli)	More space for oxygen and carbon dioxide to diffuse across, so more gas can be exchanged at once
Thin surface (walls of the alveoli and capillaries are one cell thick)	Short distance for the gases to diffuse, so diffusion is fast
Good blood supply (network of capillaries around each alveolus)	Blood carries oxygen away and brings carbon dioxide, which keeps a steep concentration gradient
Good ventilation with air (breathing in and out)	Fresh air keeps the oxygen concentration high and the carbon dioxide concentration low in the alveoli, which keeps a steep concentration gradient

Exam tip: Do not stop at the feature. Link it to its effect: for example, thin walls give a short diffusion distance, so diffusion is faster.



Oxygen diffuses into the blood and carbon dioxide diffuses out, across two walls that are each one cell thick.

Breathing in and out (ventilation) Spec 11.1.8 Supplement

Ventilation moves air into and out of the lungs. The lungs cannot inflate themselves. Air moves because the ribs, the intercostal muscles and the diaphragm change the volume and pressure in the thorax.

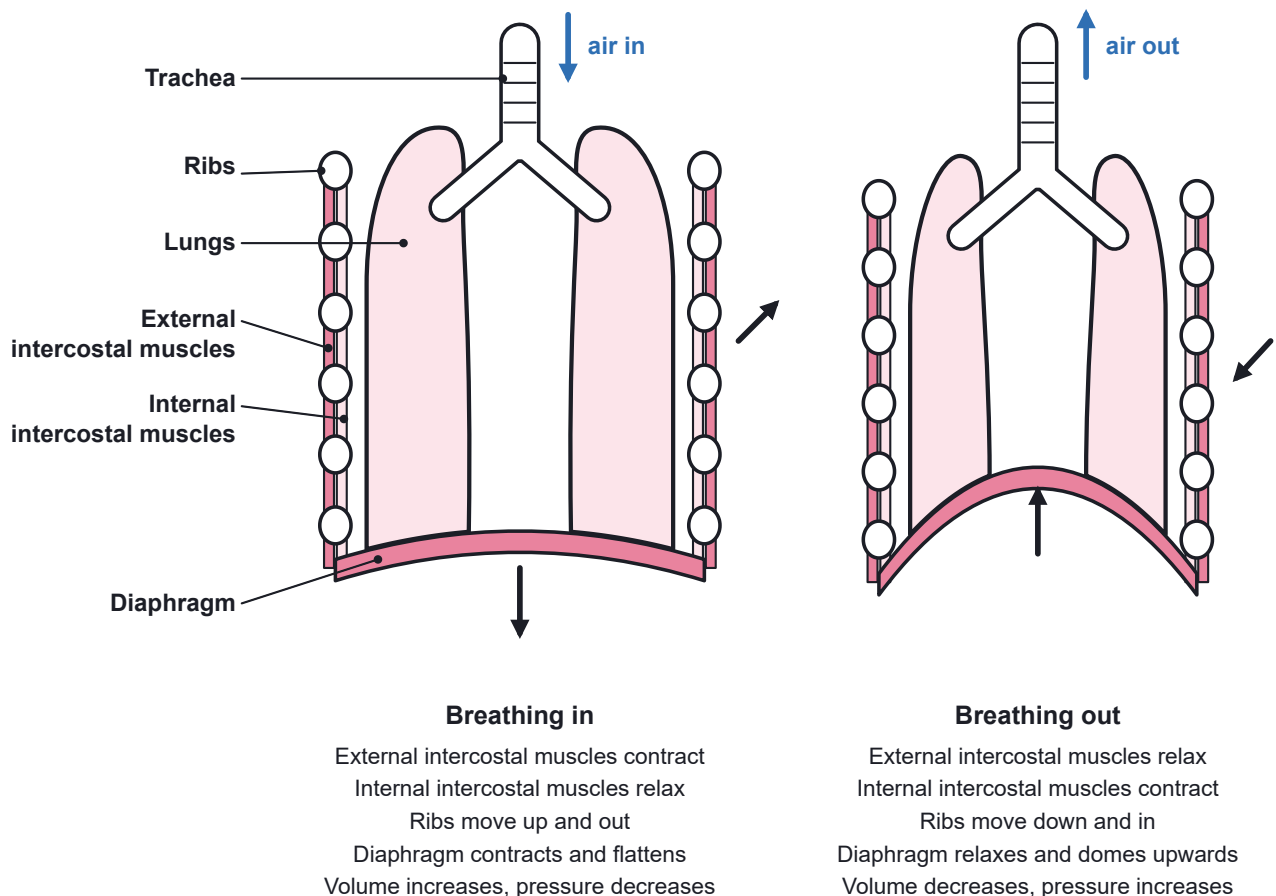
Breathing in (inhalation)

1. The external intercostal muscles contract and the internal intercostal muscles relax.
2. The ribs move upwards and outwards.
3. The diaphragm muscles contract, so the diaphragm moves down and flattens.
4. The volume of the thorax increases.
5. The pressure in the thorax decreases, so it is lower than the air pressure outside.
6. Air moves into the lungs from the higher pressure outside.

Breathing out (exhalation)

1. The external intercostal muscles relax and the internal intercostal muscles contract (they contract most strongly when you breathe out forcefully).
2. The ribs move downwards and inwards.
3. The diaphragm muscles relax, so the diaphragm moves up into a dome shape.
4. The volume of the thorax decreases.
5. The pressure in the thorax increases, so it is higher than the air pressure outside.
6. Air is pushed out of the lungs to the lower pressure outside.

Summary of ventilation		
	Breathing in	Breathing out
External intercostal muscles	Contract	Relax
Internal intercostal muscles	Relax	Contract
Ribs	Move up and out	Move down and in
Diaphragm	Contracts and flattens	Relaxes and domes upwards
Volume of thorax	Increases	Decreases
Pressure in thorax	Decreases	Increases



Muscles change the **volume** of the thorax, which changes the **pressure**, so air moves in or out.

Common mistake: Do not say that air is sucked in because the lungs expand. The thorax volume increases first, the pressure falls, and then air moves in because the pressure outside is higher.

Exam tip: Give the answer in order: muscle action, rib or diaphragm movement, volume change, pressure change, air movement. Marks are usually awarded for each link.

Inspired and expired air Spec 11.1.3, 11.1.4, 11.1.9

Inspired air is the air you breathe in. Expired air is the air you breathe out. Their composition is different because of what happens in the body between breathing in and breathing out.

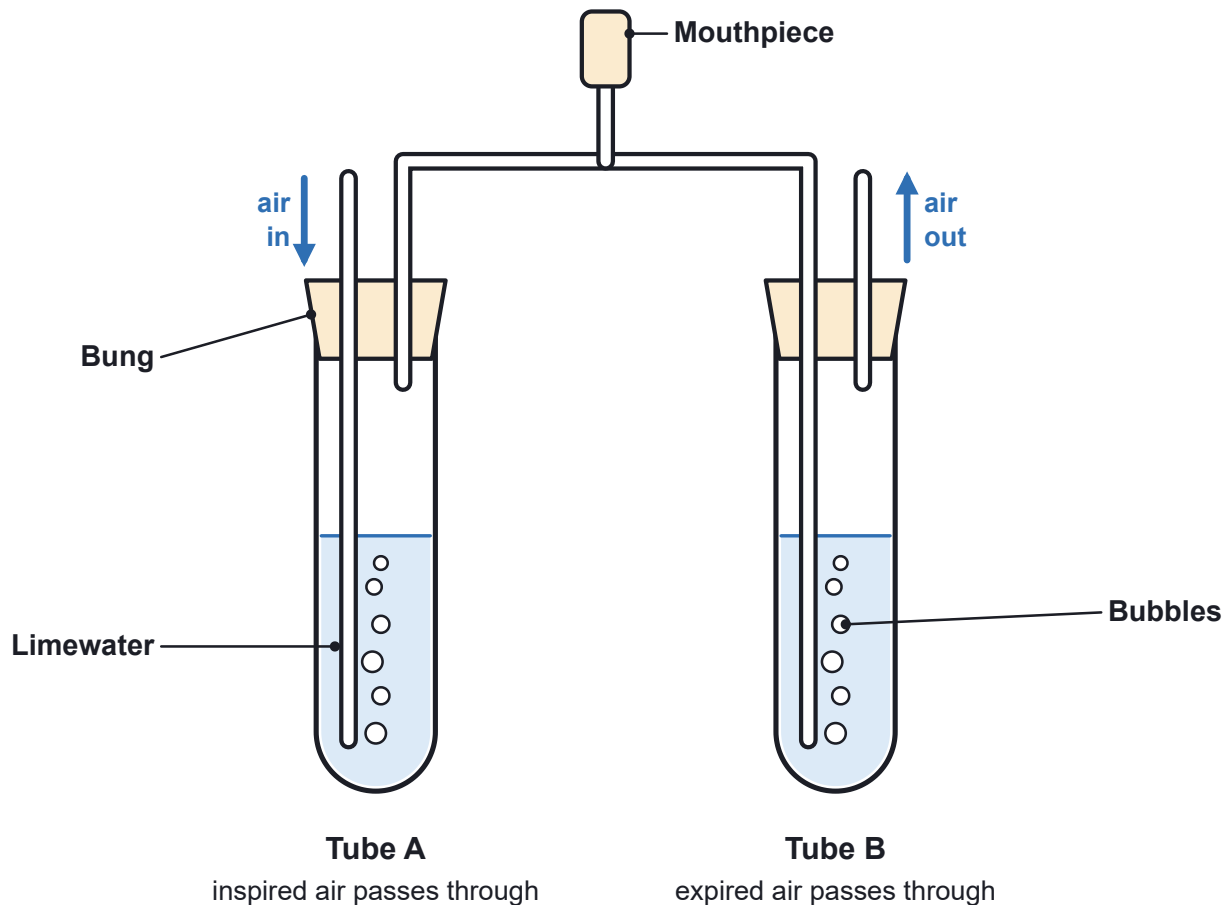
Approximate composition of inspired and expired air		
Gas	Inspired air	Expired air
Oxygen	About 21%	About 16% (less)
Carbon dioxide	About 0.04% (very little)	About 4% (more)
Water vapour	Variable, usually low	Higher (saturated)

Exam tip: Describe differences using comparison words: expired air has less oxygen, more carbon dioxide and more water vapour than inspired air. Only quote percentages if the question gives them or asks for them.

Investigating the difference using limewater

Limewater is a test for carbon dioxide. It turns from colourless to **cloudy (milky)** when carbon dioxide is bubbled through it. The more carbon dioxide there is, the faster it goes cloudy.

1. Set up two boiling tubes, each containing the same volume of limewater, joined by tubing and glass tubes so that one is used for breathing in through and the other for breathing out through.
2. Breathe in and out through the mouthpiece several times. Air you breathe in passes through the first tube of limewater. Air you breathe out passes through the second tube.
3. Compare how quickly the limewater in each tube turns cloudy.



The limewater in tube B turns cloudy faster: expired air contains more carbon dioxide.

The limewater in the expired-air tube turns **cloudy** faster, so expired air contains more **carbon dioxide**.

Practical skill: Keep the volume of limewater, the size of the tubes and the number of breaths the same in both tubes so that it is a fair test. Wear eye protection and take care not to suck limewater into the mouth.

Result: the limewater in the tube for expired air turns cloudy much faster than the limewater in the tube for inspired air. This shows that expired air contains more carbon dioxide.

Supplement

Explaining the differences

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- **Less oxygen:** oxygen is absorbed into the blood at the alveoli, and the cells of the body use it in aerobic respiration. Only some of the oxygen is removed, so expired air still contains a lot.
- **More carbon dioxide:** carbon dioxide is produced by the cells in respiration, carried to the lungs in the blood and diffuses into the alveoli.
- **More water vapour:** water evaporates from the moist lining of the alveoli into the air in the alveoli.

Physical activity and breathing Spec 11.1.5, 11.1.10

During physical activity, your **rate of breathing** (the number of breaths per minute) increases. Your **depth of breathing** (the volume of air in each breath) also increases. Together, these bring more oxygen into

the body and remove more carbon dioxide.

Investigating the effect of exercise on breathing

1. Sit still and count the number of breaths taken in one minute (or count for 30 seconds and double it). This is the resting breathing rate. Repeat and calculate a mean.
2. Do a set amount of exercise, such as running on the spot for 2 minutes.
3. Immediately count the breaths in one minute.
4. Record the rate every minute until it returns to the resting value. To measure depth, use a spirometer to find the volume of each breath, or measure chest expansion with a tape measure around the chest.
5. Repeat with different intensities of exercise, allowing full recovery between each.

Example results (for practice)

Activity	Breathing rate / breaths per minute
At rest	16
After walking	22
After running	34

Practical skill: The independent variable is the type or amount of exercise. The dependent variable is the breathing rate. Control the time for each exercise and the time of counting, use the same person, and repeat to find a mean.

Percentage change in breathing rate

A student breathes 16 times per minute at rest and 34 times per minute after running. Calculate the percentage increase.

1. Increase = $34 - 16 = 18$ breaths per minute
2. Percentage increase = $18 \div 16 \times 100$

Answer: 112.5% (about 113%)

Supplement

Why breathing changes during exercise

Supplement

1. Muscles respire faster during exercise, so more carbon dioxide is produced.
2. The concentration of carbon dioxide in the blood increases.
3. This increase is detected by the brain.
4. The brain sends signals to the muscles used in breathing, so the rate of breathing increases and the breaths are deeper.
5. More carbon dioxide is removed and more oxygen is taken in.

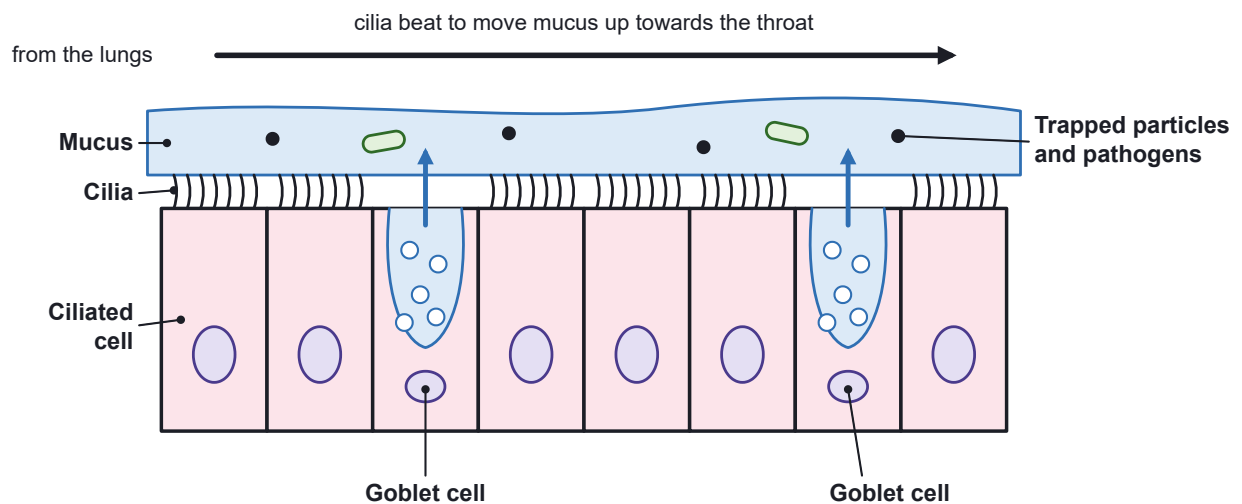
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Common mistake: Do not say that the brain detects a lack of oxygen. For this syllabus, the stimulus is the increased concentration of carbon dioxide in the blood.

Protecting the breathing system Spec 11.1.11 Supplement

The air you breathe in contains dust and particles, and microorganisms that cause disease (pathogens). The lining of the trachea and bronchi has two types of cell, **goblet cells** and **ciliated cells**, that protect the lungs from these.

Cells that protect the breathing system	
Cell or substance	Role
Goblet cells	Make and release mucus
Mucus	Sticky liquid that traps pathogens and particles from the air
Ciliated cells	Have tiny hair-like projections called cilia that beat to move the mucus, with the trapped pathogens and particles, up and away from the lungs towards the throat, where it is swallowed



Goblet cells make mucus that traps particles and pathogens, and **cilia** beat to move it up towards the throat.

Exam tip: A full answer links the three parts: goblet cells make mucus, mucus traps the pathogens and particles, and cilia move the mucus away from the lungs.

Quick check

1. Name the tubes that carry air into each lung.
2. State the four features of a gas exchange surface in humans.
3. Which gas turns limewater cloudy?
4. **Supplement** What happens to the pressure in the thorax when the diaphragm contracts?
5. **Supplement** State the function of cartilage in the trachea.

Quick check answers

Gas exchange in humans

1. Bronchi.
2. Large surface area, thin surface, good blood supply and good ventilation with air.
3. Carbon dioxide.
4. It decreases, because the volume of the thorax increases.
5. It supports the trachea and keeps it open.