

Gas exchange in humans

Revision notes · The structure of the thorax, how ventilation works, how alveoli are adapted, the effects of smoking and the breathing practical.

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. **Biology only** is not in the Double Award and is only examined on Paper 2.

Gas exchange in humans Spec 2.46-2.50

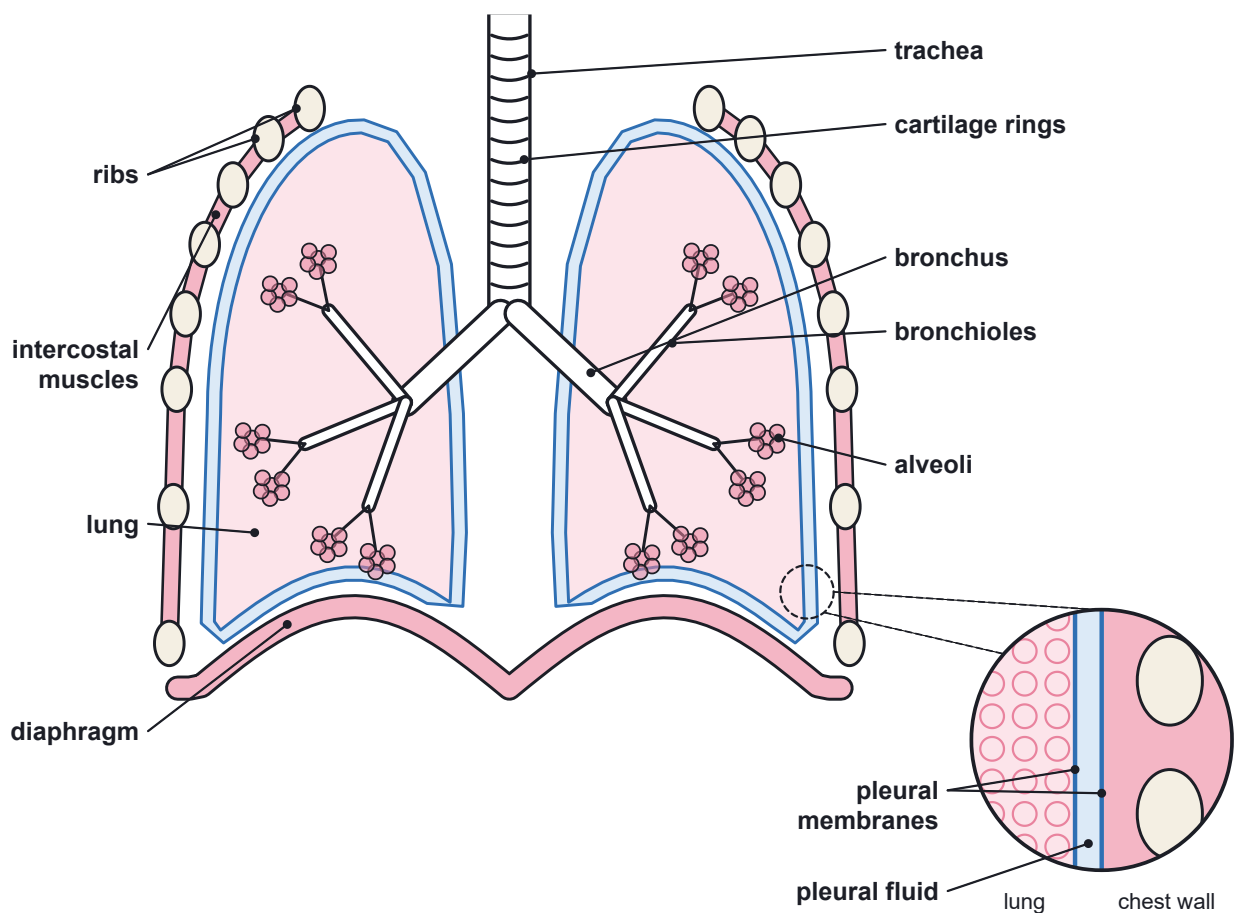
The structure of the thorax Spec 2.46

The **thorax** is the chest. It contains the lungs and the heart, and it is protected by the ribs. Air enters through the nose or mouth and passes along the airways to the alveoli.

Structures of the thorax	
Structure	Description and function
Ribs	Bones that form a cage and protect the lungs and heart. They can move up and out, and down and in.
Intercostal muscles	Muscles between the ribs. They move the rib cage.
Diaphragm	A sheet of muscle under the lungs that separates the thorax from the abdomen.
Trachea	The windpipe. It carries air to the lungs. Rings of cartilage keep it open.
Bronchi (one is a bronchus)	Two tubes that branch from the trachea, one to each lung.
Bronchioles	Small tubes that branch from the bronchi and carry air to the alveoli.
Alveoli	Tiny air sacs at the ends of the bronchioles, where gas exchange happens.
Pleural membranes	Two thin membranes around the lungs and lining the chest wall, with a thin layer of fluid between them. The fluid reduces friction when the lungs move.

The path of air when you breathe in is: nose or mouth, **trachea**, **bronchi**, **bronchioles**, **alveoli**.

Exam tip: Learn the order of the airways. Marks are often lost by writing bronchi and bronchioles the wrong way round: the bronchi are the larger tubes.



Air passes down the **trachea**, **bronchi** and **bronchioles** to the **alveoli**. The ribs, intercostal muscles and diaphragm surround the lungs.

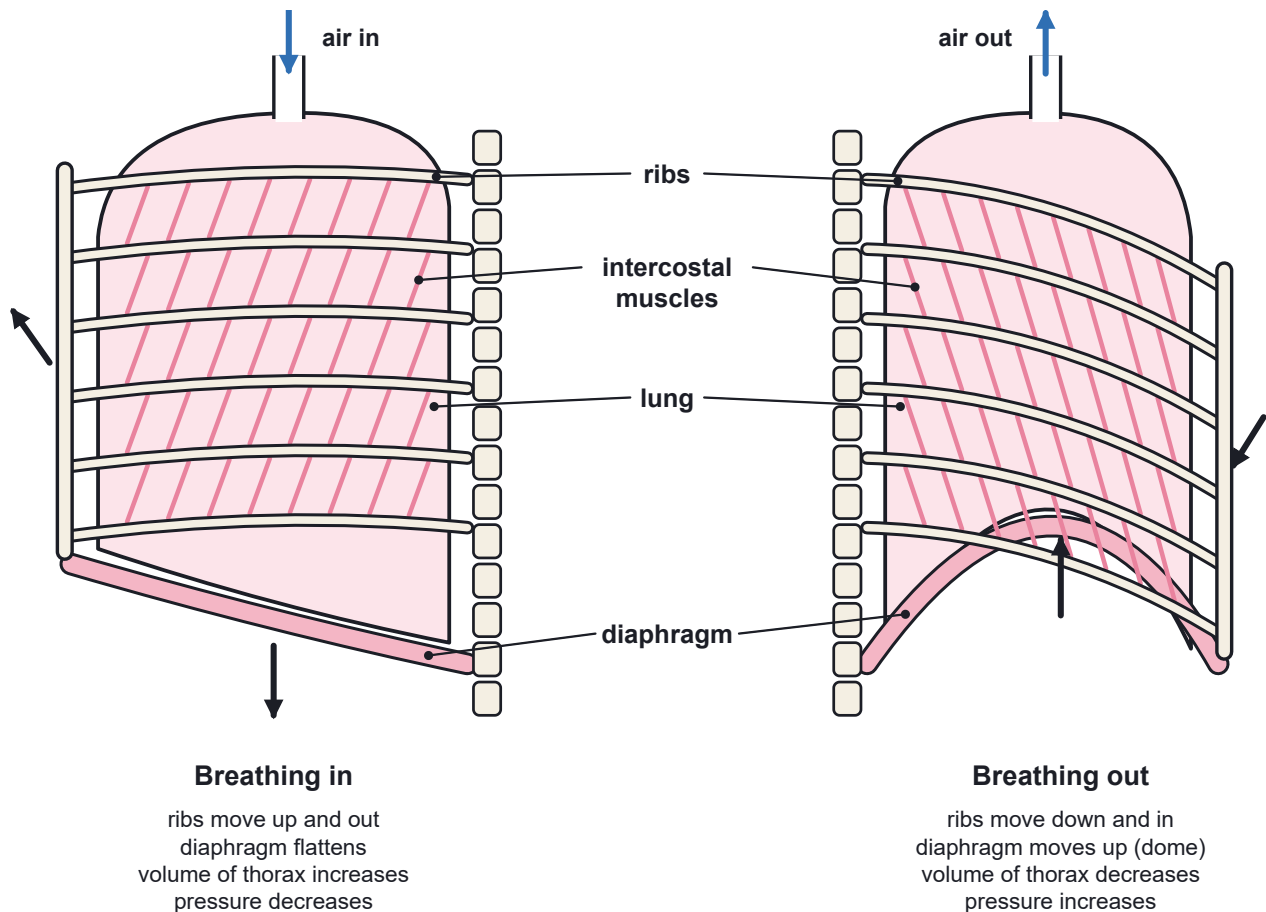
Ventilation: breathing in and out Spec 2.47

Ventilation is the movement of air into and out of the lungs. The lungs have no muscle of their own. Air moves because the **intercostal muscles** and the **diaphragm** change the volume of the thorax, and this changes the air pressure inside it.

Breathing in and breathing out		
	Breathing in (inhaling)	Breathing out (exhaling)
Intercostal muscles	Contract	Relax
Ribs	Move up and out	Move down and in
Diaphragm	Contracts and flattens	Relaxes and moves up (dome shape)
Volume of the thorax	Increases	Decreases
Pressure in the thorax	Decreases, below atmospheric pressure	Increases, above atmospheric pressure
Movement of air	Air moves into the lungs	Air moves out of the lungs

Air always moves from a region of higher pressure to a region of lower pressure. When you breathe in, the pressure inside the thorax falls below the pressure of the air outside, so air moves in. When you breathe out, the pressure inside rises above the outside pressure, so air moves out.

Common mistake: Do not say that the lungs 'pull in' air or that the ribs 'push' air in. The muscles change the volume and pressure of the thorax, and the difference in pressure moves the air.



Breathing in: volume up, pressure down, so air moves in. Breathing out: volume down, pressure up, so air moves out.

Alveoli and gas exchange Spec 2.48

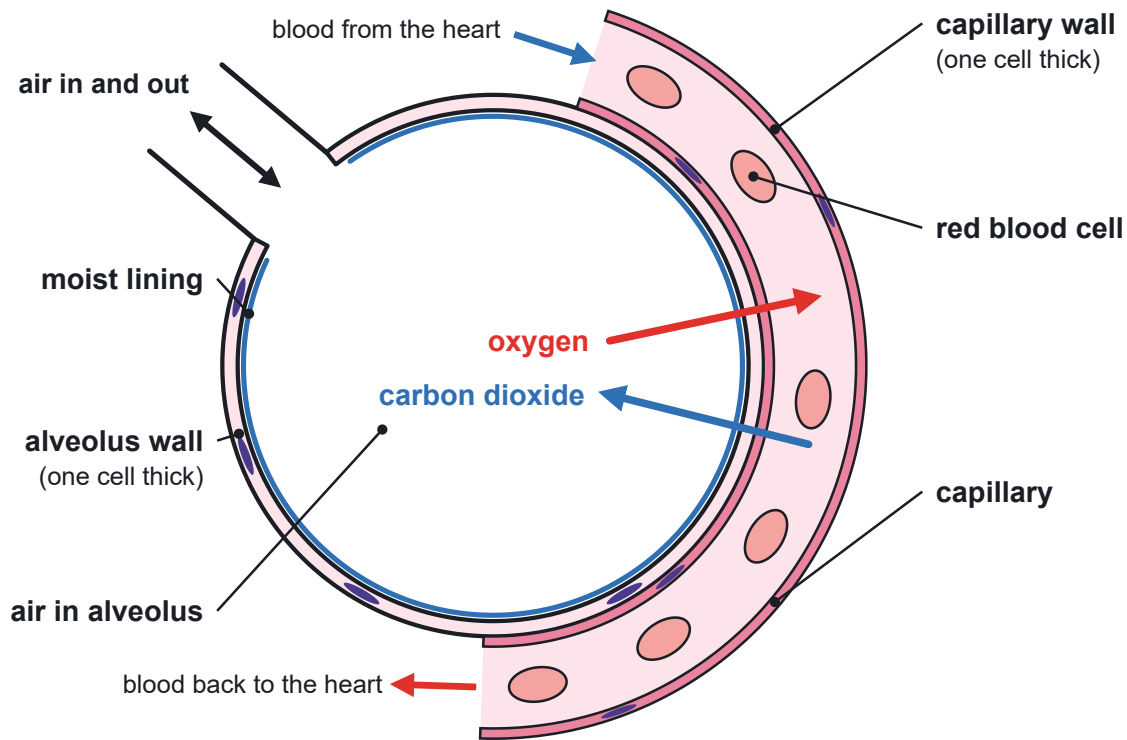
The lungs are the exchange surface for oxygen and carbon dioxide. Each lung contains millions of tiny air sacs called **alveoli**. Gases move between the air in the alveoli and the blood in the capillaries around them by **diffusion**.

- Oxygen diffuses from the air in the alveoli (high concentration) into the blood (low concentration).
- Carbon dioxide diffuses from the blood (high concentration) into the air in the alveoli (low concentration), and is breathed out.

How alveoli are adapted for gas exchange

Adaptation	Why it helps
Millions of alveoli	Gives a very large surface area for diffusion
Walls only one cell thick	Short diffusion distance, so gases diffuse quickly
Capillary walls only one cell thick	Short diffusion distance between the air and the blood
Rich network of capillaries (good blood supply)	Blood carries oxygen away and brings carbon dioxide, keeping a steep concentration gradient
Moist lining	Gases dissolve, which helps them to diffuse
Ventilation (breathing in and out)	Keeps a high oxygen concentration in the alveoli and a low carbon dioxide concentration, which maintains the concentration gradient

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



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

Smoking, the lungs and the circulatory system Spec 2.49

Tobacco smoke contains many harmful substances. The three you need to know about are tar, carbon monoxide and nicotine.

Harmful substances in tobacco smoke	
Substance	Effect
Tar	Contains carcinogens (chemicals that cause cancer), so increases the risk of lung cancer. Also damages the airway lining.
Carbon monoxide	Combines with haemoglobin in red blood cells, so they carry less oxygen. The heart has to work harder to supply the body with oxygen.
Nicotine	An addictive drug. It increases heart rate and blood pressure.

Effects on the lungs

- The airways are lined with ciliated cells, which have tiny hairs (cilia), and goblet cells, which make mucus. Mucus traps dust and bacteria, and the cilia sweep it up to the throat.
- Tar damages and destroys the cilia, so mucus and the microorganisms in it stay in the airways. This causes infections and a smoker's cough.
- **Chronic bronchitis**: smoke irritates the airways, so goblet cells make more mucus. The airways become inflamed and blocked with mucus, which makes breathing difficult.
- **Emphysema**: the walls of the alveoli break down, so the surface area for gas exchange is much smaller. The person is short of breath.
- **Lung cancer**: carcinogens in tar can make lung cells divide out of control and form a tumour.

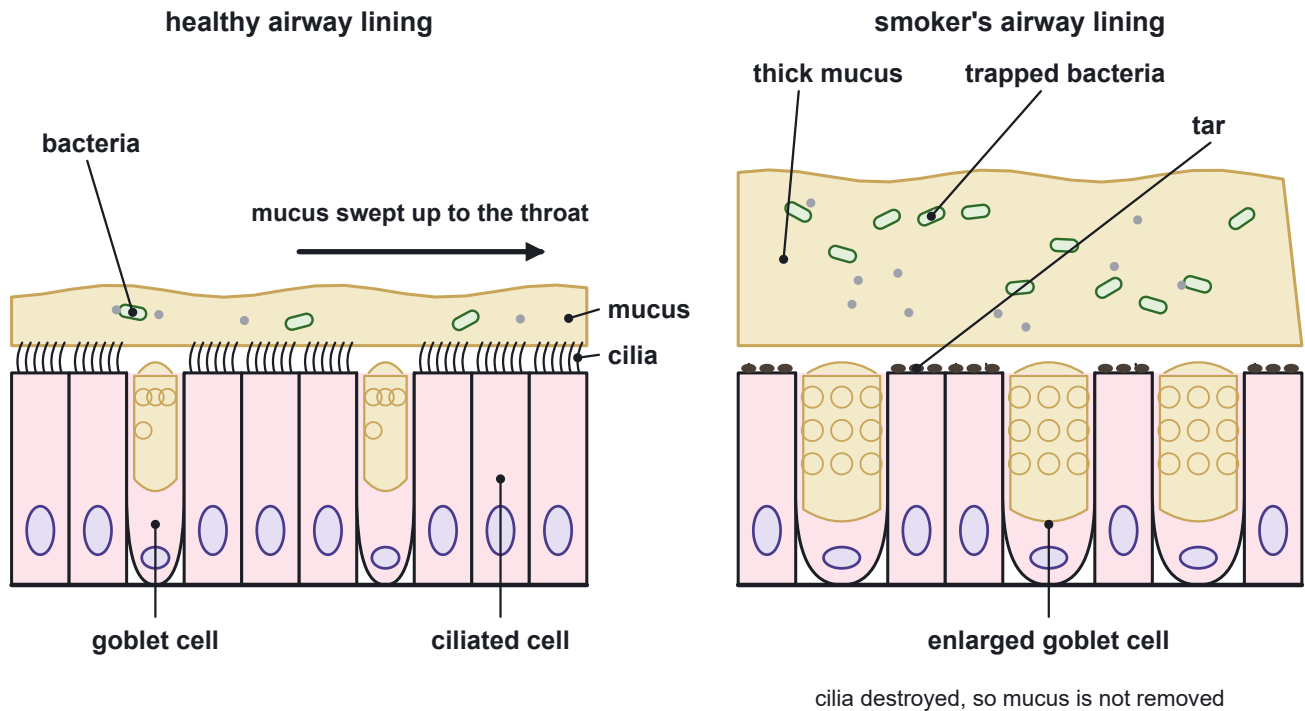
Effects on the circulatory system

Smoking raises the risk of **coronary heart disease**. In this disease the coronary arteries, which supply the heart muscle with oxygenated blood, become narrowed by fatty deposits. Less blood reaches the

heart muscle, so it gets less oxygen. If a coronary artery is completely blocked, part of the heart muscle is starved of oxygen and a heart attack results.

Smoking makes this more likely. Chemicals in smoke and raised blood pressure damage the lining of the arteries, so fatty deposits build up more easily and blood clots are more likely to form. Nicotine raises heart rate and blood pressure, and carbon monoxide reduces the oxygen carried by the blood, so the heart has to work harder.

Exam tip: Name the substance, then state its effect. 'Smoking damages the lungs' gains nothing: say that tar destroys the cilia, so mucus is not removed.



Tar destroys the **cilia**, so mucus and the bacteria trapped in it are **not removed** from the airways.

Practical: breathing, carbon dioxide and exercise Spec 2.50

You can investigate breathing in two ways: by finding the carbon dioxide in the air you breathe out, and by measuring how exercise changes your breathing rate.

Carbon dioxide in exhaled air

1. Set up two boiling tubes, each containing the same volume of limewater (or hydrogen-carbonate indicator). Join them with tubing and glass tubes so that air breathed in comes through one tube and air breathed out goes through the other.
2. Breathe gently in and out through a clean mouthpiece, so that you breathe in through the first tube and out through the second.
3. Observe the limewater in each tube.

Limewater turns **cloudy** (milky) when carbon dioxide is present, and hydrogen-carbonate indicator turns from red/orange to yellow. The limewater in the tube for exhaled air turns cloudy much faster than in the tube for inhaled air, because exhaled air contains more carbon dioxide. This carbon dioxide comes from respiration in body cells.

The effect of exercise

1. Sit still and count the number of breaths in one minute. Repeat and calculate a mean breathing rate at rest.

- Exercise for a set time, for example two minutes of stepping or running on the spot.
- Count the number of breaths in one minute straight away after exercise.
- Continue to record the breathing rate each minute until it returns to the resting rate.

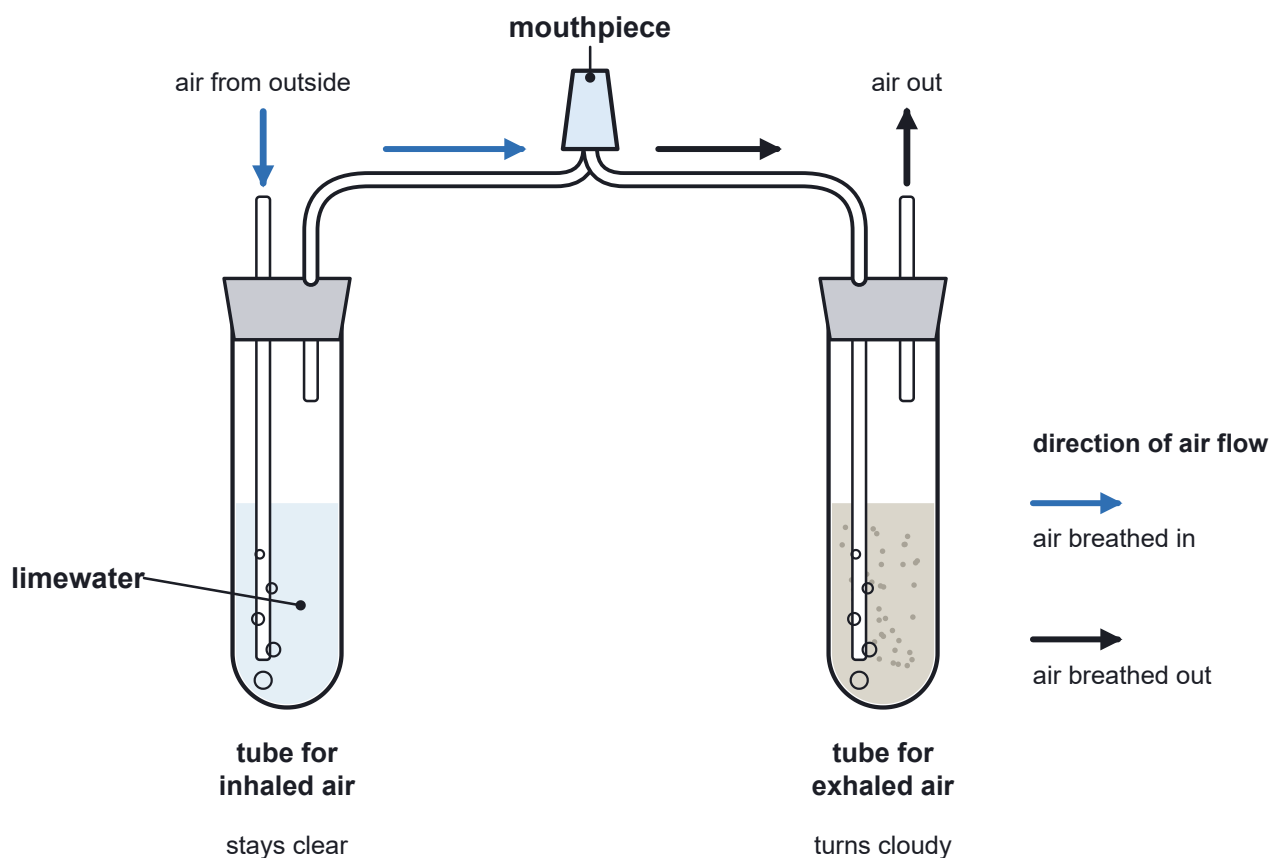
$$\text{breathing rate (breaths per minute)} = \text{number of breaths} \div \text{time in minutes}$$

Expected result: the **breathing rate** is higher after exercise and takes a few minutes to return to normal. Breathing is also deeper. Exercising muscles respire faster, so they make more carbon dioxide. Faster, deeper breathing removes the extra carbon dioxide and takes in more oxygen for respiration. If you breathe out through limewater or indicator after exercise, it changes faster than at rest.

Variables in the investigation

Type of variable	Example
Independent variable	Rest or exercise (or the length or type of exercise)
Dependent variable	Breathing rate, or time for the indicator to change colour
Control variables	Volume of limewater or indicator, same person, same type of exercise, same time of counting

Practical: Never suck liquid back into your mouth: use a clean (disinfected) mouthpiece and tubes arranged so you cannot. Limewater is an irritant, so wear eye protection. Anyone with asthma or a medical condition should not do the exercise, and everyone should stop if they feel dizzy.



Limewater turns **cloudy** in the tube for exhaled air, because exhaled air contains more carbon dioxide.

Quick check

- 1 . Name the muscles that contract when you breathe in.
- 2 . What happens to the pressure in the thorax when you breathe in?
- 3 . Why are alveolus walls only one cell thick?
- 4 . Which substance in tobacco smoke combines with haemoglobin?
- 5 . What happens to limewater when carbon dioxide is bubbled through it?

Quick check answers

Gas exchange in humans

1. The intercostal muscles and the diaphragm.
2. It decreases, because the volume of the thorax increases.
3. To give a short diffusion distance so gases diffuse quickly.
4. Carbon monoxide.
5. It turns cloudy (milky).