

Collins

Cambridge IGCSE™

Biology

STUDENT'S BOOK

Mike Smith, Sue Kearsey,
Jackie Clegg, Gareth Price



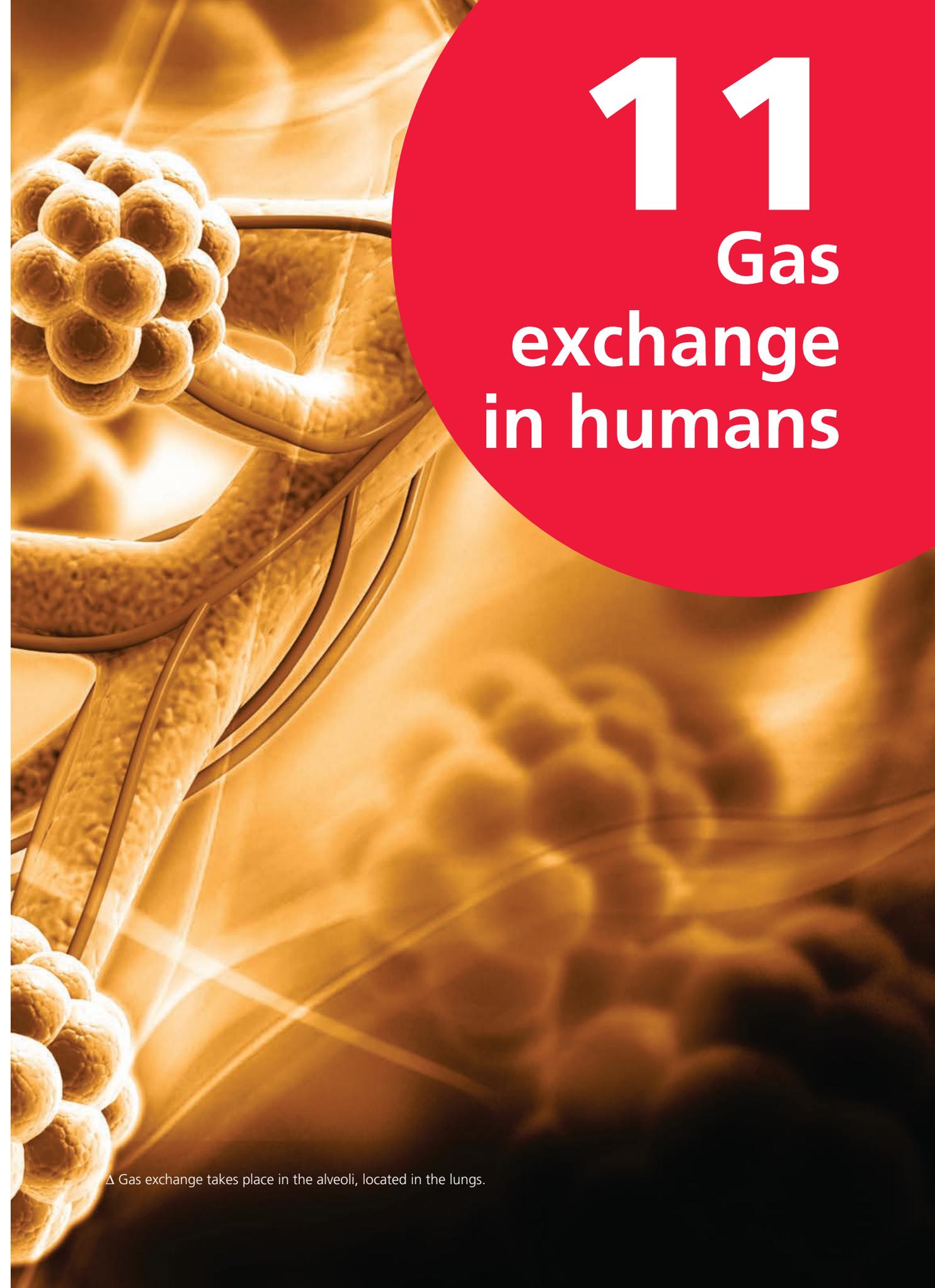
Our lungs are the organs that allow the body to take in oxygen from the air and expel carbon dioxide that is produced in cells. We breathe in and out about 500 ml of air during every breath. Oxygen from this air passes into tiny air sacs in the lungs, which are called alveoli, and diffuses into the capillaries that surround them. From here, the oxygen-rich blood is passed to the heart, where it is pumped around the rest of the body, before being passed back to the lungs to offload the carbon dioxide it has collected and pick up a fresh supply of oxygen.

STARTING POINTS

1. What is gas exchange and where does it happen in humans?
2. What happens when we breathe?
3. How is breathing affected by physical activity, and why?

SYLLABUS SECTIONS COVERED

- 11.1** Gas exchange in humans



11

Gas exchange in humans

△ Gas exchange takes place in the alveoli, located in the lungs.



Gas exchange in humans

INTRODUCTION

Respiration uses oxygen from the air and produces carbon dioxide that is returned to the environment. These gases must get into and out of the body fast enough to support the rate at which respiration needs to work. For single-celled organisms this isn't a problem. They have a large surface area to volume ratio, and diffusion across the cell membrane can supply and remove the gases at a fast enough rate. Larger organisms

Δ Fig. 11.1 The lungs are the site of gas exchange in humans.

cannot do this. Not only do they have a much smaller external surface area to volume ratio, which slows the rate of diffusion, but many of them also live on land, where the delicate surface required for gas exchange would dry out if it was directly exposed to the external environment. Different groups of organisms have different solutions to these problems but all involve structures with a large surface area. Plants exchange gases inside the leaf; insects have internal tubes (a tracheal system) inside the body where they exchange gases; fish have gills; and many vertebrates, including humans, have lungs.

KNOWLEDGE CHECK

- ✓ Animals use oxygen from the air inspired and give out the carbon dioxide they produce in the air they expire.
- ✓ Humans use lungs for breathing.

LEARNING OBJECTIVES

- ✓ Describe the features of gas exchange surfaces in humans, limited to: large surface area, thin surface, good blood supply and good ventilation with air.
- ✓ Identify in diagrams and images the following parts of the breathing system: lungs, diaphragm, ribs, intercostal muscles, larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries.
- ✓ **SUPPLEMENT** Identify in diagrams and images the internal and external intercostal muscles.
- ✓ **SUPPLEMENT** State the function of cartilage in the trachea.
- ✓ **SUPPLEMENT** Explain the role of the ribs, the internal and external intercostal muscles and the diaphragm in producing volume and pressure changes in the thorax leading to the ventilation of the lungs.
- ✓ Investigate the differences in composition between inspired and expired air using limewater as a test for carbon dioxide.
- ✓ Describe the differences in composition between inspired and expired air, limited to: oxygen, carbon dioxide and water vapour.

- ✓ **SUPPLEMENT** Explain the differences in composition between inspired and expired air.
- ✓ Investigate and describe the effects of physical activity on the rate and depth of breathing.
- ✓ **SUPPLEMENT** Explain the link between physical activity and the rate and depth of breathing in terms of: an increased carbon dioxide concentration in the blood, which is detected by the brain, leading to an increased rate and greater depth of breathing.
- ✓ **SUPPLEMENT** Explain the role of goblet cells, mucus and ciliated cells in protecting the breathing system from pathogens and particles.

Gas exchange

Animals need to exchange gases with the environment, to supply oxygen for respiration in cells and to remove the waste product of respiration – carbon dioxide. These gases are exchanged at surfaces by diffusion. So **gas exchange surfaces**, such as in the human lungs, need adaptations to maximise the rate at which diffusion occurs.

An effective gas exchange surface has:

- a large surface area
- a short distance over which substances have to diffuse, so cells across which diffusion occurs are usually thin
- a good blood supply and good ventilation to deliver oxygen and remove carbon dioxide from the body rapidly – this maintains high concentration gradients for both gases.

The human breathing system

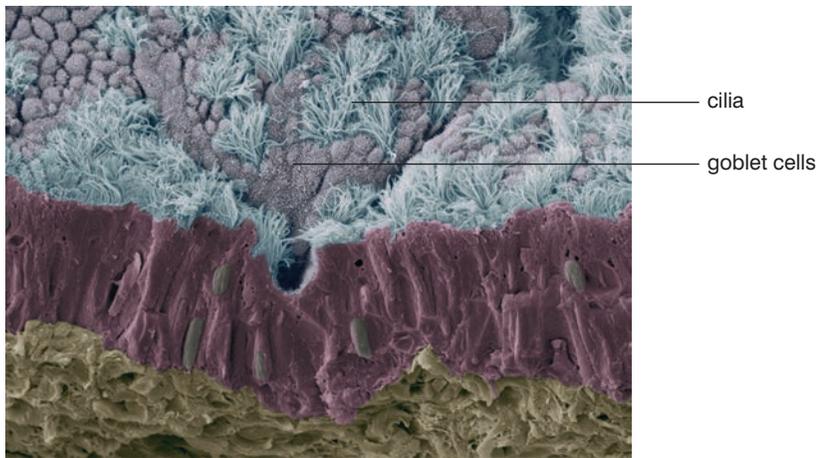
Breathing is the way that oxygen is taken into our bodies and carbon dioxide is removed. When we breathe, air is moved into and out of our lungs. This involves different parts of the breathing system within the chest.

When we breathe in, air enters through the nose and mouth. In the nose the air is moistened and warmed. The air passes over the **larynx**, where it may be used to make sounds, for example when we talk. The air travels down the **trachea** to the **lungs**. The air enters the lungs through the **bronchi** (singular: bronchus), which branch and divide to form a network of **bronchioles**.

SUPPLEMENT

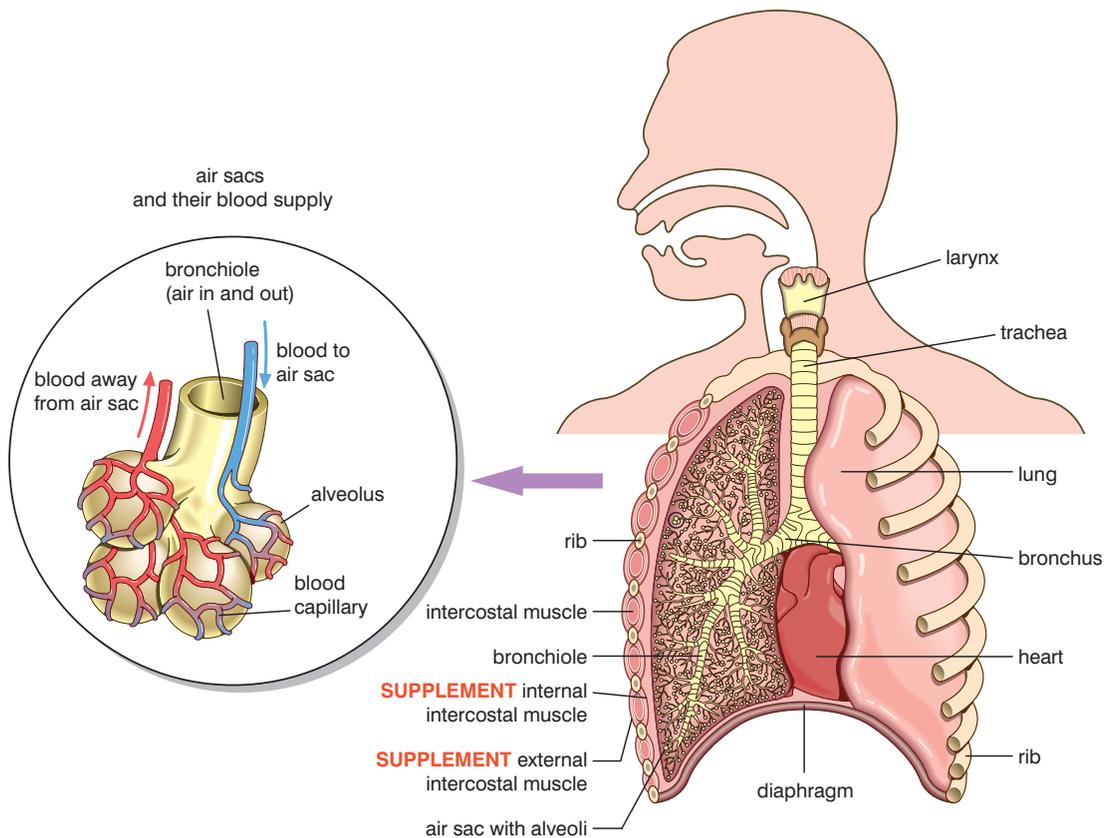
Bands of **cartilage** surround the trachea and bronchi. These support the tubes and keep them open during breathing, as otherwise they might collapse when air pressure inside them is reduced.

Cells called **goblet cells** in the lining of the trachea, bronchi and bronchioles secrete **mucus**, which is a slimy liquid. This traps microorganisms and dust particles that are breathed in. The lining of the trachea and bronchi are covered in tiny hairs called **cilia**, which are found on the surface of **ciliated cells**. The cilia sweep in a combined motion to move the mucus up from the lungs, up the trachea to the back of the mouth, where it can be swallowed and pass to the stomach. The combined action of mucus and cilia helps to prevent dirt and pathogens entering the lungs and causing damage and infection.



Δ Fig. 11.2 Section through the trachea lining, showing goblet cells, which secrete mucus, and cilia, which sweep the mucus along the surface.

At the end of the bronchioles are air sacs. The bulges on an air sac are called **alveoli** (singular: alveolus). The alveoli are covered in tiny blood capillaries. This is where oxygen and carbon dioxide are exchanged between the blood and the air in the lungs. This is called **gas exchange**. The movement of air across the alveolar surface is called **ventilation**.

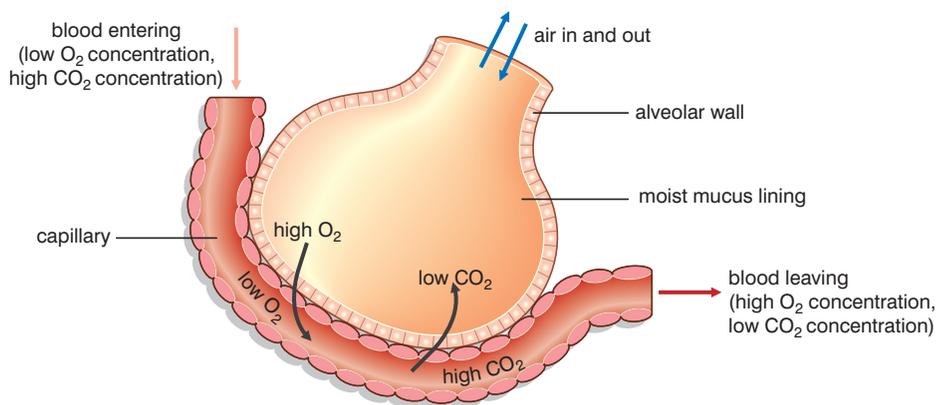


Δ Fig. 11.3 The human breathing system.

The alveoli are where oxygen and carbon dioxide diffuse into and out of the blood. For this reason the alveoli are described as the *gas exchange surface*.

The alveoli are adapted for efficiency in exchanging gases by diffusion. They have:

- thin permeable walls, which keep the distance over which diffusion of gases takes place between the air and blood to a minimum
- a moist lining, in which the gases dissolve before they diffuse across the cell membranes
- a large surface area – there are hundreds of millions of alveoli in a human lung, giving a surface area of around 70 m² for diffusion
- high concentration gradients for the gases, because the blood is continually flowing past the air sacs, delivering excess carbon dioxide and taking on additional oxygen, and because of ventilation of the lungs, which refreshes the air in the air sacs.



Δ Fig. 11.4 Gas exchange in an air-filled alveolus.

REMEMBER

Be careful how you describe the process of gas exchange between the air in the lungs and the blood. Remember that diffusion is a passive process that only occurs while there is a concentration gradient. Also, do not make the mistake of stating that all the oxygen in the air we breathe in is replaced by carbon dioxide in the air we breathe out.

QUESTIONS

1. Explain as fully as you can how the lungs are adapted for a rapid rate of diffusion for gas exchange.
2. Give the structures of the human breathing system and, for each structure, explain its role in breathing.
3. Sketch a diagram of an alveolus and annotate it to show how it is adapted for efficient gas exchange. (Hint: remember to refer to diffusion.)
4. **SUPPLEMENT** Explain the roles of the cilia and mucus in the human breathing system.

Breathing in and out

Breathing in is known as *inhalation* or **inspiration**, and breathing out as *exhalation* or **expiration**. Both happen because of changes in the volume of the chest cavity. These changes are caused by movements of:

- the **ribs** which are joined together by **intercostal muscles**
- the **diaphragm** which is a domed sheet of muscle below the lungs.

SUPPLEMENT

The change in volume of the chest cavity or **thorax** causes pressure changes, which in turn cause air to enter or leave the lungs. There are two sets of intercostals: the internal intercostal muscles and the external intercostal muscles. The ribs, intercostal muscles and diaphragm work together to bring about breathing or ventilation of the lungs.

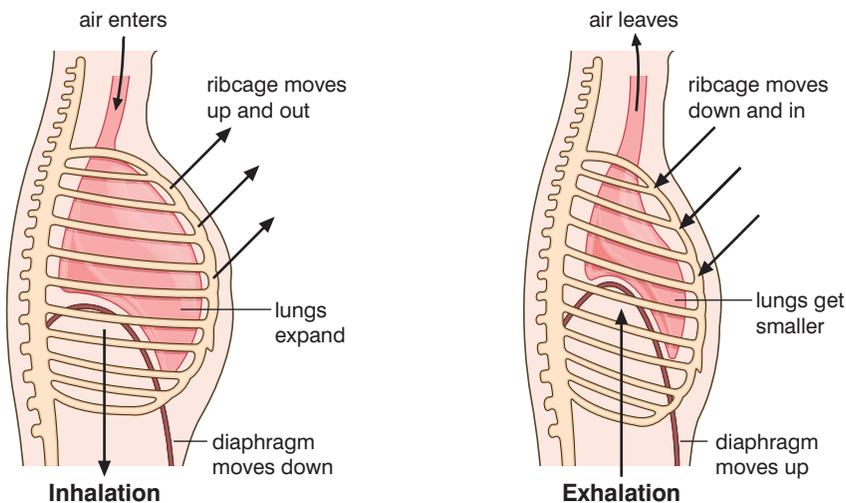
In gentle breathing, only the diaphragm may be involved. In deeper breathing, such as during exercise, or if we think about it, the ribs and intercostal muscles become involved.

Breathing in

Air is breathed into the lungs in a large breath as follows.

1. The diaphragm muscle *contracts* so it *flattens* in shape.
2. The external intercostal muscles *contract*, making the ribs move upwards and outwards.
3. These changes cause the *volume* of the thorax to *increase*.
4. This causes the *air pressure* in the thorax to *decrease*.
5. This decrease in pressure causes air from outside to enter the lungs.

Rings of cartilage in the trachea and bronchi keep the air passages open and prevent them from collapsing when the air pressure decreases and from bursting when air pressure increases.



△ Fig. 11.5 Left: breathing in. Right: breathing out.

Breathing out

Air is breathed out from the lungs as follows.

1. The diaphragm muscle *relaxes* and returns to its domed shape, pushed up by the liver and stomach. This means it pushes up on the lungs.
2. The external intercostal muscles *relax*, allowing the ribs to drop back down. This also presses on the lungs. If you are breathing hard the internal intercostal muscles also contract, helping the ribs to move down.
3. These changes cause the *volume* of the thorax to *decrease*.
4. This causes the *air pressure* in the thorax to *increase*.
5. This causes air to *leave* the lungs.

REMEMBER

Explain breathing in terms of comparing the pressure inside the lungs and external air pressure. Air moves from an area of higher pressure to an area of lower pressure.

- During inhalation, air enters because the air pressure inside the lungs is lower than the air pressure outside the body.
- During exhalation, air leaves the lungs because the air pressure inside is higher than the air pressure outside the body.