

## Chapter 6

# Breathing oxygenates the blood to allow food to be respired

### Concepts to be addressed

Students should already be familiar with aerobic respiration to the extent that oxygen is used to oxidise glucose with the release of energy. Therefore, the need to breathe to obtain oxygen is almost universally understood.

The breathing movements will probably be known, but the mechanism of breathing needs to be explained in terms of pressure changes and the concept of fluids moving from areas of high pressure to areas of low pressure. Students should understand that gases are also fluids and that gas comes out of a gas tap because the pressure in the pipes is greater than air pressure. With this established, the breathing movements can be appreciated as ways of changing the pressure gradient between the lungs and the atmosphere, so that air is always moving from a high pressure to a lower pressure.

Partial pressure is not an easy concept for many students, since a proper understanding depends on understanding how pressure in a gas is generated. If the students can understand that air pressure is caused by the gas molecules in the air colliding with objects, then this can be developed to the stage where they appreciate that some of these collisions will be due to oxygen molecules, some due to nitrogen, some due to carbon dioxide and the rest due to the other gases in the air. From here, most will then be happy to quantify this in terms of the proportions of the various gases.

The application of Fick's law to exchange of gases in the alveoli provides a concrete example for students to work with. The various adaptations that produce a large surface area, a short diffusion distance and a concentration gradient are described in appropriate detail in the textbook.

Having met cardiac output in the previous chapter, the concept of pulmonary ventilation should follow quite naturally. It is just another example of 'how much?' multiplied by 'how many?'

### Related practicals

Once again, the scope for quantitative practical work that does not demand sophisticated equipment is limited. However, as in the previous topic, the effects of exercise on breathing rate can be investigated, subject to the necessary risk assessments. As before, this would allow the calculation of means, the calculation of change and/or percentage change and the plotting of bar charts.

Class data would allow the calculation of means and standard deviations, and age-related data would allow the plotting of histograms.

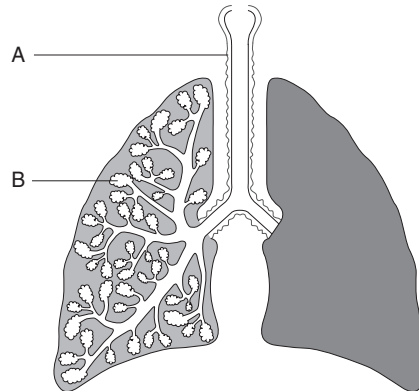
## Questions

### Multiple-choice

- Pulmonary ventilation rate is equal to:
  - breathing rate  $\times$  residual volume
  - breathing rate  $\times$  tidal volume
  - tidal volume  $\div$  breathing rate
  - residual volume  $\div$  breathing rate
- Diffusion of oxygen and carbon dioxide in the alveoli is rapid because there is:
  - a large surface area, a low concentration difference and a short diffusion pathway
  - a small surface area, a high concentration difference and a short diffusion pathway
  - a large surface area, a high concentration difference and a long diffusion pathway
  - a large surface area, a high concentration difference and a short diffusion pathway
- To bring about inhalation:
  - external intercostal muscles contract, internal intercostal muscles relax, diaphragm muscle contracts
  - external intercostal muscles contract, internal intercostal muscles contract, diaphragm muscle relaxes
  - external intercostal muscles relax, internal intercostal muscles relax, diaphragm muscle contracts
  - external intercostal muscles relax, internal intercostal muscles contract, diaphragm muscle relaxes
- During gas exchange in the alveoli, oxygen must diffuse through:
  - the alveolar epithelium
  - the interstitial space
  - the membrane of a red blood cell
  - all of the above
- The tidal volume is:
  - the total volume of air in the lungs
  - the volume inhaled added to the volume exhaled in one breath
  - the volume of air inhaled and then exhaled in one breath
  - the maximum volume of air that can be inhaled in one breath
- The partial pressure of a gas is:
  - the proportion by volume of a gas in a mixture of gases
  - the part of the total pressure that a gas exerts due to its molecules colliding with each other
  - the part of the overall pressure of a mixture of gases that is due to that gas
  - the pressure of a gas when only some of its molecules exert a force
- When air is exhaled, it:
  - diffuses out down a concentration gradient
  - is drawn out because of the higher pressure in the atmosphere
  - is forced out because of the higher pressure in the lungs
  - is drawn in because of the lower pressure in the lungs
- Following exercise, the pulmonary ventilation rate falls only slowly because:
  - the partial pressure of oxygen in the blood is high
  - the levels of lactate are still high
  - the levels of lactate are still low
  - the partial pressure of oxygen in the blood is low
- Ventilating the lungs means:
  - inhaling
  - exhaling
  - inhaling and exhaling
  - exchanging gases
- When compared with inhaled air, exhaled air:
  - has a higher concentration of oxygen, a lower concentration of carbon dioxide and is more moist
  - has a higher concentration of oxygen, a lower concentration of carbon dioxide and is drier
  - has a lower concentration of oxygen, a higher concentration of carbon dioxide and is more moist
  - has a lower concentration of oxygen, a higher concentration of carbon dioxide and is drier

## Examination-style

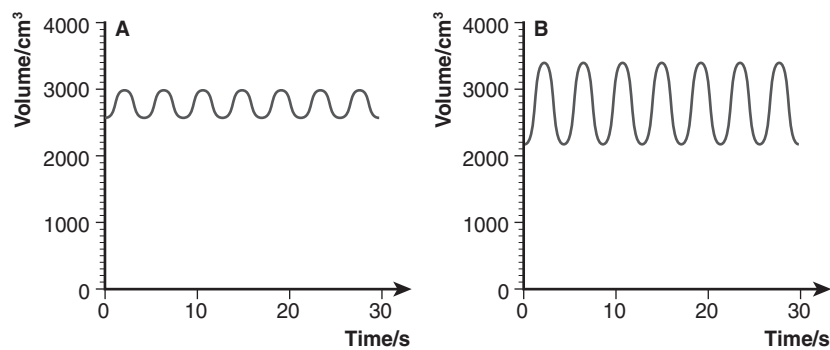
- 1 (a) The diagram below shows the main components of the human breathing system.



- (i) Name the structures labelled A and B. (2 marks)
- (ii) Explain why contraction of the external intercostal muscles and contraction of the diaphragm muscle cause air to be drawn into the lungs. (3 marks)
- (b) Use Fick's law to explain why gas exchange in the alveoli is efficient. (4 marks)

**Total: 9 marks**

- 2 The diagram shows two spirometer traces taken from the same person at different times.



- (a) (i) What is the tidal volume shown in trace A? (1 mark)
- (ii) From trace B, calculate the pulmonary ventilation rate. Show your working. (2 marks)
- (b) Suggest reasons for the difference in breathing shown by the two traces. Explain your answer. (4 marks)

**Total: 7 marks**

- 3 (a) Explain what is meant by the terms:

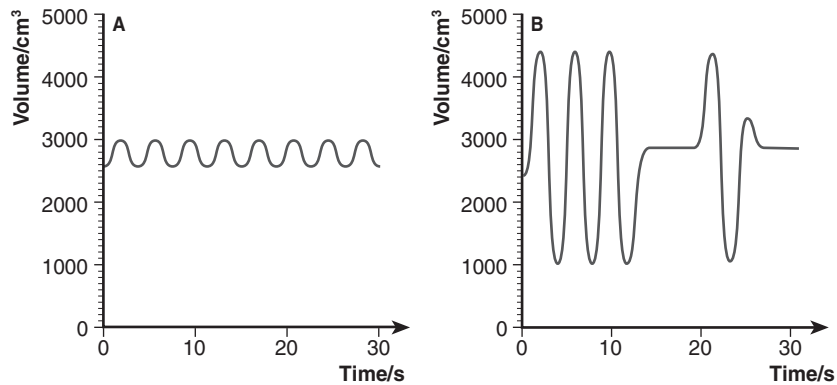
- (i) tidal volume
- (ii) inspiratory reserve volume
- (iii) vital capacity (3 marks)

- (b) When a person suffers a serious chest wound, a condition known as pneumothorax can result. In this condition, air rushes into the space between the two pleural layers surrounding one of the lungs.

- (i) What effect will the wound have on the pressure of the air between the two pleural layers? Explain your answer. (2 marks)
- (ii) Explain why the lung affected by pneumothorax can no longer be ventilated. (3 marks)

**Total: 8 marks**

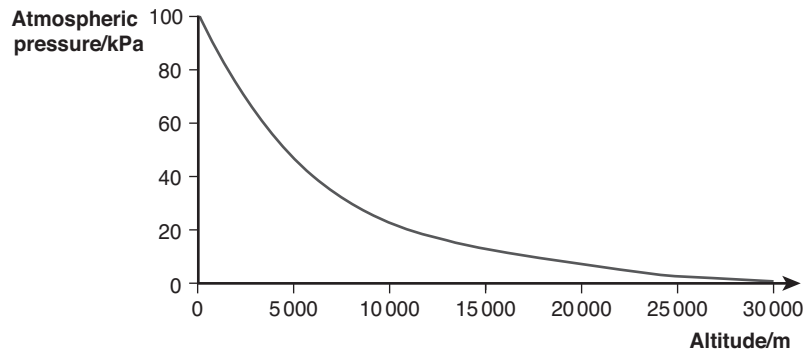
- 4 The diagram shows two spirometer traces. Trace A shows a normal breathing pattern of a person at rest. Trace B shows an abnormal pattern of breathing at rest.



- (a) Calculate the pulmonary ventilation rate shown by trace A. (2 marks)
- (b) Describe two ways in which the pattern of breathing shown by trace B differs from that shown in trace A. (2 marks)
- (c) The pattern of breathing shown in trace B is sometimes found in brain-damaged patients, where the nervous control of breathing fails and then begins again. Suggest how brain damage might produce this abnormal pattern of breathing. (3 marks)

**Total: 7 marks**

- 5 The graph below shows the atmospheric pressure at different altitudes.



- (a) Describe the change in atmospheric pressure between sea level and 10 000 m. (2 marks)
- (b) Assuming that oxygen makes up 21% of the atmosphere at all altitudes, calculate the partial pressure of oxygen at:  
 (i) sea level (1 mark)  
 (ii) an altitude of 5000 m (1 mark)
- (c) Gas exchange takes place in the alveoli. Most of the oxygen absorbed diffuses into red blood cells and combines with haemoglobin to form oxyhaemoglobin.  
 (i) Explain why oxygen combining with haemoglobin does not affect the concentration gradient of oxygen between the alveolar air and the blood. (2 marks)  
 (ii) Suggest why people who live at high altitudes have more red blood cells per cm<sup>3</sup> blood than people who live at sea level. (3 marks)  
 (iii) Use Fick's law to explain the benefit, to a person who has just reached a high altitude, of breathing more quickly. (3 marks)
- (d) Explain to a person not adapted to living at such altitudes, why exercise is more difficult at higher altitudes. (3 marks)

**Total: 15 marks**

## Answers/sample mark schemes

## Multiple-choice

- |     |      |
|-----|------|
| 1 B | 6 C  |
| 2 D | 7 C  |
| 3 A | 8 B  |
| 4 D | 9 C  |
| 5 C | 10 C |

## Examination-style

- 1 (a) (i) A — trachea;  
B — alveolus; (2 marks)
- (ii) Increase volume of thorax/lungs;  
Decrease pressure in thorax/lungs;  
Outside air is at a higher pressure; (3 marks)

(b) Correct statement of Fick's law:

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{difference in concentrations}}{\text{diffusion distance}};$$

Many alveoli give large surface area;

Ventilation/circulation maintain concentration difference;

Alveolar epithelium is very thin;

(4 marks)

**Total: 9 marks**

- 2 (a) (i) 450 cm<sup>3</sup>; (1 mark)

Ⓔ Accept 400 cm<sup>3</sup> but not 500 cm<sup>3</sup>. To earn the mark, the answer must include units.

(ii) Breathing rate = 14 breaths per minute

Tidal volume = 1250 cm<sup>3</sup> (accept 1200 cm<sup>3</sup>);

Pulmonary ventilation = 14 × 1250 = 17 500 cm<sup>3</sup> min<sup>-1</sup>; (2 marks)

Ⓔ 14 × 1200 = 16 800 cm<sup>3</sup> min<sup>-1</sup> is also acceptable. Either answer, however derived, with units earns 2 marks. To score either individual point, units must be present. Pulmonary ventilation, with units, calculated correctly from wrong reading of the trace earns 1 mark. A correct answer without units earns 1 mark.

(b) In B:

Person could be exercising;

(Increased breathing) obtains more oxygen for increased respiration in muscles/increased energy release/ATP production in muscles;

Person could be recovering from exercise;

(Increased breathing) obtains more oxygen to oxidise/remove lactate (that built up during exercise);

(4 marks)

**Total: 7 marks**

- 3 (a) (i) Tidal volume is the amount of air breathed in/out per breath; (1 mark)

(ii) Inspiratory reserve volume is the amount of air that could be taken in by inhaling deeply; (1 mark)

(iii) Vital capacity is the maximum amount of air that can be brought in and out of the lungs in a single breath; (1 mark)

(b) (i) Pressure between the two pleural layers will increase;

Air entering the space means more particles, so more pressure; (2 marks)

(ii) Ventilation of lung depends on pressure differences;

Between air inside lung and air around lung;

Pressure inside lung is now the same as pressure around lung; (3 marks)

**Total: 8 marks**

- 4 (a) 8 breaths in 30 seconds = 16 breaths per minute  
 Tidal volume =  $400 \text{ cm}^3/450 \text{ cm}^3$ ;  
 Pulmonary ventilation =  $400 \times 16 = 6400 \text{ cm}^3 \text{ min}^{-1}/450 \times 16 = 7200 \text{ cm}^3 \text{ min}^{-1}$ ; (2 marks)

**e** The correct answer, however derived and with units, earns 2 marks. A correct answer without units earns 1 mark.  
 A correct calculation (with units) from wrong readings earns 1 mark.

- (b) In B:  
 Ventilations are deeper/tidal volume is greater;  
 There are periods when no ventilation takes place; (2 marks)

**e** The reverse argument for A is acceptable.

- (c) Nervous impulses make intercostal muscles/muscles in diaphragm contract and relax;  
 To bring about breathing movements;  
 No nerve impulses will stop breathing movements;  
 When impulses are generated again, breathing restarts; (max. 3 marks)

**e** This is an occasion where the ideas are much more important than precise terminology. At this stage, students have not yet studied nervous control and so will not be aware of 'action potentials'.

**Total: 7 marks**

- 5 (a) Decreases;  
 By 75%/from 100 kPa to 25 kPa; (2 marks)

**e** Please note that the question should state *10 000 m*.

- (b) (i) 21 kPa; (1 mark)  
 (ii) 9.66 kPa–10.08 kPa; (1 mark)

**e** Answers based on pressures of 46–48 kPa should be allowed.

- (c) (i) Concentrations depend on numbers of free oxygen molecules;  
 Oxygen bound to haemoglobin is not free; (2 marks)

- (ii) Less oxygen in air;  
 Reduced concentration gradient between air and red blood cells;  
 Reduced oxygen uptake by each red blood cell;  
 More red blood cells to compensate; (max. 3 marks)

- (iii) Correct statement of Fick's law:

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{difference in concentrations}}{\text{diffusion distance}};$$

Breathing more quickly maintains concentration gradient;  
 Allows increased diffusion of oxygen; (3 marks)

- (d) Strenuous exercise requires more energy release;  
 So requires much greater intake of oxygen;  
 For aerobic respiration;  
 Reduced concentration means that the extra oxygen is not available;  
 Lactate accumulates quickly; (max. 3 marks)

**Total: 15 marks**