INQUIRY QUESTION
How does the respiratory system contribute to energy production for movement?
7 Structure and functions of the respiratory system

The respiratory system is the starting point for oxygen delivery to working muscles and the end point for removal of wastes such as carbon dioxide as a result of energy production.

**KEY KNOWLEDGE**
- The structure and function of the respiratory system, including the structure and function of the lungs, mechanics of breathing and gaseous exchange at the alveoli/capillary and the capillary/muscle interface
- The interrelationship of the cardiovascular and respiratory systems to transport oxygen around the body at rest and during exercise

**KEY SKILLS**
- Use and apply correct anatomical terminology to identify the structures and function of the cardiovascular and respiratory systems
- Describe the process of gaseous exchange
- Perform, measure and report on changes to the cardiovascular and respiratory systems at rest compared with exercise

**CHAPTER PREVIEW**
The respiratory system allows the body to breathe, bringing oxygen into the body and removing carbon dioxide. It is able to carry out this essential function during varying activity levels, from unconscious sleep to conscious levels of maximal exertion.

### Functions of the respiratory system

The respiratory system has five important functions. It:

- brings air from the atmosphere into the lungs
- transfers oxygen into the blood
- removes carbon dioxide from the blood
- expels heat and water vapor in the air breathed out
- allows the vocal cords to create speech as air is breathed out.

### Structure of the respiratory system

Figure 7.1 shows the basic structure of the respiratory system. The lungs are the major organs of the respiratory system. Located in the chest cavity behind the ribs, they consist of three main parts:

- the conducting system
- the pleura
- the diaphragm.

**FIGURE 7.1** The respiratory system
The conducting system

The conducting system involves more than just the lungs. Its main elements are:

- **The nasal cavity.** The nose is the initial pathway for air from outside the body. Air is warmed and moistened in the nose to be more readily used by the body's interior. This is especially important in cold climates. The nose has layers of tissue called septa that are covered with cilia, which are small hair-like fibres that filter foreign particles from the air as it enters the respiratory tracts. These cilia cover the respiratory passage down to the pharynx, ensuring your lungs do not become clogged with foreign matter. Smoking destroys cilia, and their absence is the beginning of serious problems for the lungs of smokers.
- **The pharynx.** This section of the throat is where the backs of the mouth and the nose combine. The food is channelled into the oesophagus, while the air moves into the larynx. The air is further warmed here using similar methods as in the nose.
- **The larynx.** This structure is more evident in males with their ‘Adam’s apple’. The larynx contains the vocal cords that create the voice as air passes through them.
- **The trachea.** Often referred to as the windpipe, the trachea is constructed of rings of hyaline cartilage enclosed by other cartilage and tissue. It sits mostly behind the sternum, so it provides a well-protected medium for the passage of air into the lungs.
- **The bronchi.** The trachea divides into two bronchi, with each bronchus having the same characteristics as the trachea. Each bronchus feeds one of the lungs.
- **The bronchioles.** Each bronchus sub-divides into a series of further sub-dividing bronchioles. This system of the lungs’ gradually diminishing series of air passages is similar to an inverted tree, with its main trunk moving to a series of ever-diminishing branches, then to the leaves.
- **The alveoli.** These ‘leaves’ of the lungs are microscopic cup-shaped sacs at the ends of the smallest bronchiole. Each alveolus is only one cell thick and surrounded by a rich network of capillaries that continually exchange oxygen for carbon dioxide and water (see figure 7.2 for the breakdown of the lung anatomy).

**FIGURE 7.2** The structure of the lung
The respiratory system: structure and functions

The pleura
The pleura covers each lung. The gap between the membrane and each lung is filled with a fluid that allows the lung to expand and contract with each breath, with minimal friction between the lung and its surrounding body tissue. The pleura is attached to the inside of the chest cavity and to the top of the diaphragm.

The diaphragm
This involuntary or smooth muscle contracts and relaxes to aid breathing, whether during sleep or consciousness. As the diaphragm moves up and down, the chest cavity decreases and increases in size, causing breathing (inspiration and expiration; see figure 7.3). A blow to the midriff during sport may hit the diaphragm, causing it to spasm. The individual in this case is ‘winded’ and may have difficulty breathing. The individual has to be encouraged to relax and wait for the muscle spasm to subside, which will happen in a short time and allow normal breathing.

**TEST your understanding**
1. Download the ‘Anatomy of the respiratory system’ document from your eBookPLUS. Label the parts of the respiratory system.
2. List the five functions of the respiratory system.
3. Discuss how the diaphragm assists with breathing.
4. Outline the function of alveoli and where they can be found.

**APPLY your understanding**
5. Describe the path that air travels from outside the body to the lungs. Discuss the role of each of the structures it passes.
6. **Practical activity: respiratory rate and exercise**
   (a) Work in pairs. Before you begin the physical activities, sit down quietly and have your partner measure your resting respiratory rate.
   (b) Perform each of the following activities. Get your partner to count your respiratory (breathing) rate for one minute immediately after you complete each activity. Rest until respiratory rate returns to resting levels between each activity.
   - Walking for 2 minutes
   - Jogging for 2 minutes
   - Situps for 30 seconds
   - Steppups on a bench for 2 minutes
   - Seated toe-touches for 30 seconds
   - Running for 3 minutes as fast as possible
   (c) Record and graph your results.
   (d) Identify which activity caused the highest respiratory rate. Suggest reasons for this.
   (e) Discuss the relationship between your respiratory rate and the intensity of the activity. Provide examples.
Ventilation

Ventilation (V) is the amount of air breathed in (inspiration) and out (expiration) during 1 minute. It is calculated by multiplying tidal volume (TV) and respiratory rate (RR). That is, the amount of air per breath multiplied by the amount of breaths per minute, or

\[ V = TV \times RR. \]

For example, at rest ventilation could be

\[ TV \times RR = V \]
\[ 0.5 \times 12 = 6 \text{ L/min} \]

Ventilation will differ depending on whether the individual is at rest or exercising.

Inspiration

The diaphragm initiates inspiration. When the diaphragm contracts, it pulls downwards on the rib cage, thereby expanding the volume of the chest cavity. The intercostal muscles between each pair of ribs contract to help pull the rib cage outwards, also increasing the size of the chest cavity. The widening chest cavity decreases the air pressure inside the lungs, causing air from outside the body to be sucked into the chest cavity (figure 7.3). This occurs because air, like any gas, always travels from high pressure gradients towards low pressure gradients.

A normal intake of a breath for an adult is about 500 millilitres; this is called the tidal volume. During heavy exercise, inspiration may increase about eight times to around 4 litres for each breath. Also during exercise, extra muscles will work to help increase the size of the chest cavity even more, to accommodate the need for a more forceful exchange of a greater volume of air. These muscles include those of the neck and upper chest area.

**Figure 7.3** Inspiration and expiration of the lungs

**KEY CONCEPT** Gas exchange of oxygen and carbon dioxide occurs in the alveoli in the lungs. In order for this to happen, it is important to understand the mechanics of breathing; that is how air, and in particular oxygen, enters the lungs and wastes are removed.
Expiration occurs when the diaphragm and intercostal muscles relax; that is, the diaphragm pushes up and creates a dome shape. This relaxation, along with the natural elasticity of the thorax (or chest area) is enough to squeeze the air within the chest cavity, create a higher pressure inside than out, and force the air to leave the lungs (figure 7.3).

Again, during exercise more muscles will work to help magnify the change in chest cavity volume to promote higher rates and levels of air exchange. Thus the abdominal muscles will contract to aid the speed and force of the chest restriction.

TABLE 7.1 Comparison of inspiration and expiration

<table>
<thead>
<tr>
<th>Structure and/or function</th>
<th>Inspiration</th>
<th>Expiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>Drawn into lungs</td>
<td>Forced out of lungs</td>
</tr>
<tr>
<td>Pressure inside lungs</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Ribcage</td>
<td>Expands up and out</td>
<td>Moves down and in</td>
</tr>
<tr>
<td>Intercostal muscles</td>
<td>Contract</td>
<td>Relax</td>
</tr>
<tr>
<td>Chest cavity and lungs</td>
<td>Expand</td>
<td>Relax</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>Contracts, moves downwards</td>
<td>Relaxes, moves upwards</td>
</tr>
</tbody>
</table>

Lung volumes
The lungs have different levels of capacity (or lung volumes) for holding air from inspiration and for expelling air by expiration. Capacity varies according to the state of health, fitness and activity level of an individual.

- **Total lung capacity** is the volume of air that can be held in the lungs after maximum inspiration. It is approximately 6 litres for males and 4.2 litres for females.

- **Vital capacity** is the maximum amount of air that can be expired (breathed out) after a maximum inspiration. It consists of the inspiratory reserve capacity, the tidal volume and the expiratory reserve capacity. Table 7.2 shows the vital capacity for students in Australian schools. Generally, the larger the person, the higher their vital capacity. Large rib cages and chest cavities lead to larger lungs. Males generally have higher vital capacity readings than females because males usually have larger frames.

TABLE 7.2 Vital capacity readings for adolescent male and female students

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Boys (litres)</th>
<th>Girls (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 years</td>
<td>15 years</td>
</tr>
<tr>
<td>Top 10 per cent</td>
<td>3.65</td>
<td>5.5</td>
</tr>
<tr>
<td>Mid-range</td>
<td>3.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Lowest</td>
<td>2.15</td>
<td>3.15</td>
</tr>
</tbody>
</table>

- **Tidal volume** is the amount of air inspired and expired with each breath. It is approximately 500 millilitres at rest, but can increase dramatically during exercise (figure 7.4).

- **Residual volume** is the amount of air left in the lungs at the end of a conscious, maximal expiration. This is the same amount whether the individual is at rest or during maximal exertion (figure 7.4). Sometimes when there has been a blow or trauma to the chest...
area, this residual volume may be expelled to some extent and may add to the sensation of being ‘winded’ when the diaphragm goes into spasm (see page xx).

- Inspiratory reserve capacity is the maximal amount of air that can be inspired after a normal inspiration (figure 7.4).
- Expiratory reserve capacity is the maximal amount of air that can be expired after a normal expiration (see figure 7.4).

**Maximum oxygen uptake**

- Maximum oxygen uptake (VO₂ max) is the maximum amount of oxygen per minute that can be taken in, transported to, and used by the working muscles to produce ATP. This reading reflects aerobic power (or the body’s ability to use oxygen). It is the usual measure for comparing different sports’ or individuals’ aerobic power levels. VO₂ max is different for males and females due to lung capacity differences; that is, males generally have a greater VO₂ max than females due to larger heart and lung capacity. VO₂ max tests are the best way to measure the efficiency of the cardiovascular, respiratory and muscular systems under exercise conditions.

**Gaseous exchange**

The respiratory and the cardiovascular system work together to transfer and transport gas molecules, in particular oxygen and carbon dioxide, around the body. In order to do this, gases are exchanged through the process of diffusion. Diffusion involves the movement of a molecule from a higher concentration to a lower concentration across a thin membrane. The sites of exchange important for the delivery of oxygen for energy production and the removal of waste occur at the alveoli/capillary interface in the lungs and the capillary/muscle interface at the cell site.

**Exchange of gases in the lungs**

Pulmonary diffusion is the process to describe the exchange of gases in the lungs. Inspiration involves air entering the lungs and travelling into the alveoli. Capillaries surround the alveoli. Both structures have very thin walls, only one cell thick, that allow the oxygen just breathed in to move from the higher concentration in the alveoli to the lower concentration of the surrounding capillaries. Once in the capillaries, the
oxygen attaches to the haemoglobin in the red blood cells to be transported to the muscles and other cells in the body.

During expiration, the carbon dioxide in the capillaries is under higher concentration than the air in the alveoli. The carbon dioxide diffuses into the alveoli and is expelled on outward breaths.

**Exchange of gases at the muscle (cell) site**

At the muscle (cell) site, the concentration of the gases inside and outside the capillaries is the reverse of those within the lungs (figure 7.6). Oxygen-rich blood is transported to the muscles in response to the increased demand for energy production. The low levels of oxygen within the muscles attract the higher concentration oxygen from within the capillaries through the thin capillary wall. The opposite situation affects the movement of the high levels of carbon dioxide produced as a by-product from energy production from the muscle into the capillary to be transported to the alveoli and expired.
Table 7.3 depicts the approximate composition of inhaled and exhaled air in the lungs.

**TABLE 7.3** Approximate percentage composition of inhaled and exhaled air of the lungs

<table>
<thead>
<tr>
<th></th>
<th>Inhaled air</th>
<th>Exhaled air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>0.03</td>
<td>4</td>
</tr>
</tbody>
</table>

**TEST your understanding**

1. Define ventilation.
2. Outline the major differences in the gas content of inspired air compared to that of expired air.
3. Download the diagram of lung volumes in your eBookPLUS. Label and define each of the types of lung volumes.
4. Define maximum oxygen uptake ($VO_2$ max).

**APPLY your understanding**

5. Describe the process of inspiration and expiration. Include the role of the diaphragm, intercostal muscles, air movements and air pressure both within and outside the lungs. Use a diagram to assist.
6. Explain how gas exchange occurs at the lungs.
7. Calculate the ventilation ($V$) of an individual who has a respiratory rate of 15 breaths per minute and a tidal volume of 0.5 litres per breath.
8. **Practical activity: measurement of lung capacity**
   - You will need a spirometer to complete this activity.
   - Pinch your nose with your fingertips to prevent air escaping.
   - Take a deep breath until you cannot take in any more air.
   - Place your mouth around the spirometer and exhale until you cannot exhale any more.
   - (a) Record your vital capacity.
   - (b) Compare it to the values for adolescent male and female students in table 7.2.
**7.3 Responses of the respiratory system to physical activity**

**KEY CONCEPT** Under exercise conditions, certain changes occur to the respiratory system to allow the body to meet the new demands placed on it. These responses last only for the duration of the activity and for a short period afterwards (recovery).

**The respiratory system and physical activity**

As an individual begins to exercise, a number of changes occur within the respiratory system to meet the requirements of the body. As with the cardiovascular system, these changes revolve around the greater demand for oxygen to be delivered to the working muscles to create energy, and the associated removal of waste products. Figure 7.7 summarises these changes.

![Figure 7.7: The change in lung volumes and function from rest to working levels](image)

**Increased respiratory (breathing) rate (RR)**
- At rest, adult respiration rate is 12–15 breaths per minute.
- Under high intensity exercise, RR can reach 35–45 breaths per minute due to the increased demand for oxygen and the need for removal of carbon dioxide.

**Increased tidal volume (TV)**
- Depth of breathing (tidal volume) at rest is approximately 0.5 litres per breath.
- This can increase to 4–5 litres per breath at maximal workloads in order to supply more oxygen to the blood to deliver to working muscles.

**Increased ventilation (V)**
- Due to the increases in respiratory rate (RR) and tidal volume (TV), ventilation (V) will also increase.
- At rest, ventilation is approximately 6.0 L/min.
- During maximal exercise, this value can increase dramatically. For example,

\[
RR \times TV = V \\
45 \times 4 = 180 \text{ L/min}
\]
TABLE 7.4 Comparison of respiratory rate, tidal volume and ventilation at rest and during exercise

<table>
<thead>
<tr>
<th></th>
<th>Respiratory rate (breaths/minute)</th>
<th>Tidal volume (L/breath)</th>
<th>Ventilation (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>12</td>
<td>0.5</td>
<td>6</td>
</tr>
<tr>
<td>Submaximal exercise</td>
<td>30</td>
<td>2.5</td>
<td>75</td>
</tr>
<tr>
<td>Maximal exercise</td>
<td>45</td>
<td>4.0</td>
<td>180</td>
</tr>
</tbody>
</table>

Increased diffusion

During physical activity, the diffusion capacity at the alveoli/capillary and muscle/capillary interface is increased to allow greater amounts of oxygen and carbon dioxide to be exchanged at these sites.

Increased oxygen uptake (VO$_2$)

- Oxygen uptake increases due to the greater demand for oxygen by the muscles. This increase is linear, but will not increase further once maximum levels of oxygen uptake are achieved (i.e. VO$_2$ max, see figure 7.8).
- At rest, the average amount of oxygen that an individual can take into the body is about 0.35 L/min.
- During submaximal exercise, this can increase to around 2.0–3.5 L/min.
- Under maximal exercise, depending on the individual's aerobic fitness levels, this can reach 4–6 L/min.

![Figure 7.8](image.png)

**FIGURE 7.8** Oxygen consumption relative to exercise intensity.

Source: Adapted from sportfitnessadvisor.com and sciencebasedrunning.com.

Increased efforts from ribcage muscles and diaphragm

- During physical activity, the external and internal intercostal muscles as well as the diaphragm will all work harder to enable increased expansion and contraction of the thoracic cavity.
- This increased movement of the cavity will accommodate the increased air volumes that are being demanded by the working muscles in order to gain their extra oxygen.
Responses of the respiratory system to physical activity

**TEST your understanding**

1. Copy and complete the table below by indicating whether the physiological parameter has increased, decreased or remained unchanged as a result of participating in exercise. Include the measurement values for rest and exercise.

<table>
<thead>
<tr>
<th>Physiological parameter</th>
<th>Acute response</th>
<th>Measurement at rest</th>
<th>Measurement at submaximal exercise</th>
<th>Measurement during maximal exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tidal volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen uptake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**APPLY your understanding**

2. Explain the relationship between respiratory rate (RR) and tidal volume (TV) during exercise.

3. Refer to figure 7.7 and describe what happens to the following measures of lung volume from points B to C:
   (a) tidal volume
   (b) inspiratory reserve volume
   (c) expiratory reserve volume
   (d) vital capacity
   (e) total lung capacity.

4. **Practical activity: circuit**
   (a) Before you begin the physical activities, sit down quietly and record your resting respiratory rate.
   (b) Complete the following circuit. Spend 2 minutes at each station and record your respiratory rate for 10 seconds at the end of each station. Rest for 1 minute between each station.
   - Skipping
   - Situps
   - Shuttle run
   - Pushups
   - Agility run
   - Bicep curls
   - Star jumps
   - Lunges
   (c) Describe your respiratory rate responses to the circuit.
   (d) Identify the station that had the highest RR.
   (e) Identify the station that had the lowest RR.
   (f) Suggest reasons for this difference.
KEY CONCEPT The cardiovascular and respiratory systems work together to deliver oxygen to the working muscles during physical activity. For the oxygen to reach the muscles, it must be inhaled efficiently through the respiratory system and then carried efficiently through the cardiovascular system to the muscle sites.

Figure 7.9 below and the description that follows summarise the interaction of the cardiovascular and respiratory systems.
7.4 Summary of interactions of the cardiovascular and respiratory systems during physical activity

The cardiovascular system and the respiratory system work together to deliver oxygen to working muscles in the following way:

- The respiratory system transfers oxygen to and from the lungs via the mechanisms of inspiration and expiration. This ventilation of air into and out of the lungs occurs at an average rate of 4 L/min during rest, increasing to 15–35 L/min during exercise and increasing intensities.
- Gaseous exchange (or diffusion) occurs at the alveoli and capillary interface where oxygen breathed in is in a higher concentration in the alveoli and diffuses across the thin membrane wall into the capillaries. This is the point of entry into the cardiovascular system where the oxygen will be transported via the blood, blood vessels and heart around the body.
- Oxygen combines with haemoglobin on the red blood cells to be transported via the arteries and heart to the muscles. At rest, cardiac output of the heart is 5 L/min, increasing to 20–30 L/min during exercise at increasing intensities.
- Oxygen enters the muscles at the capillary/muscle interface via diffusion where the concentration of oxygen is higher in the capillaries. Oxygen is used for energy production and carbon dioxide is produced as a result of this process. At this point, the carbon dioxide is in a higher concentration in the muscle than the capillary and also diffuses across the thin membrane into the capillaries to be transported away. Greater amounts of oxygen and carbon dioxide are used and produced during exercise in comparison to rest.
- Carbon dioxide travels via the veins and the heart back to the lungs where it is diffused into the alveoli and expired via the respiratory system.

TEST your understanding

1. Discuss the importance of the relationship between the cardiovascular and respiratory systems during physical activity.
2. Explain how gaseous exchange occurs between the cardiovascular and respiratory systems.

APPLY your understanding

3. Outline the pathway a molecule of oxygen takes through the body — from entering the nose until it reaches the muscle fibre.
4. Outline the pathway a molecule of carbon dioxide takes through the body — from the muscle fibre until it is expelled into the atmosphere via the nose.
5. Practical activity: conduct and report on an exhaustive aerobic test
   Undertake the following tests in a laboratory working as a class:
   (a) Measure individual students’ vital capacity (VC) using dry spirometers.
   (b) Select two to three of the more aerobically fit students in the class. The number depends on your class size and how many exercise bikes you have. As a class, decide how to organise work increments for a 15–20 minute exercise bike aerobic test. Observe the subjects exercising at gradually increasing work increments over the exercise period.
   (c) Organise groups and individuals within the groups to be responsible for the following measurements. Everyone will be expected to make some form of oral report to the class on their area of responsibility:
      - respiration rates at rest and after each 5-minute increment
      - heart rates at rest and after each 5-minute increment
      - blood pressure readings at rest and after each 5-minute increment
      - any observable amounts and patterns of perspiration at rest and after each 5-minute increment
      - any observable signs of fatigue or discomfort at rest and after each 5-minute increment
      - production of data gathering sheets.
   (d) After taking time to prepare the results, all class members are to make oral reports to the class on each of the parameters observed.
KEY SKILLS
- Use and apply correct anatomical terminology to identify the structures and function of the cardiovascular and respiratory systems
- Describe the process of gaseous exchange
- Perform, measure and report on changes to the cardiovascular and respiratory systems at rest compared with exercise

UNDERSTANDING THE KEY SKILLS
To address these skills, it is important to remember the following:
- Correct anatomical names for the structures and functions of the cardiorespiratory system
- Understand how gaseous exchange occurs and the structures where gaseous exchange can occur.

PRACTICE QUESTION (ACHPER Trial exam 2015, question 6)
1. List the two structures between which gaseous exchange of oxygen and carbon dioxide takes place in the lungs. 2 marks
2. Using the above example, explain gaseous exchange in terms of the concentration levels of each gas and the resultant movement. 3 marks

Sample response
a. Alveoli and capillaries
b. Gaseous exchange is the movement of gas from an area of high concentration to an area of low concentration (1). In the lungs after inspiration, the alveoli are high in oxygen and low in carbon dioxide compared to the blood in the surrounding capillaries which is high in carbon dioxide and low in oxygen (1). As a result, the oxygen diffuses into the blood and the carbon dioxide diffuses into the lungs (1).

PRACTISE THE KEY SKILLS
1. Identify all the structures of the respiratory system that an oxygen molecule will pass during inspiration prior to entering the cardiovascular system.
2. Describe what is meant by gaseous exchange and identify two areas in the body where this may occur.

KEY SKILLS EXAM PRACTICE (adapted from ACHPER Trial Exam 2012, question 1b)
1. Gaseous exchange occurs at the lungs, as outlined in the diagram above, to allow increased oxygen into the blood. Gaseous exchange also occurs at the muscles. Explain this process at the muscle. 3 marks

HOW THE MARKS ARE AWARDED
- 1 mark for each correct structure listed.
- 1 mark for explaining what gaseous exchange is.
- 1 mark for identifying the concentration levels of the gases (oxygen and carbon dioxide) within the structures.
- 1 mark for discussing the movement of the gases between the structures.
CHAPTER 7

CHAPTER REVIEW

CHAPTER SUMMARY

Respiratory system
- The respiratory system brings oxygen into the body and removes carbon dioxide.
- The conducting system of the respiratory system includes the nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles and alveoli.
- The diaphragm contracts and relaxes to aid breathing.
- Inspiration is when the lungs take in air, while expiration is when air is forced out of the lungs.
- Gas exchange occurs at the alveoli and capillaries, and at the capillaries and muscles, and involves the movement of oxygen and carbon dioxide from areas of high concentration to areas of low concentration.
- Everyone has different lung volumes and this affects their capacity for holding and expelling air.
- Vital capacity measures the maximum amount of air that you can breathe out after a maximum inhalation.
- Maximum oxygen uptake (VO₂ max) is the maximal amount of oxygen that can be utilised by the body in 1 minute.
- The respiratory system adapts to the onset of exercise via increases in respiratory rate, tidal volume, ventilation, diffusion and oxygen uptake by the muscles.

Interaction of the cardiovascular and respiratory systems
- Figure 7.9 (page 163) summarises the interaction of both the cardiovascular and respiratory systems to efficiently deliver oxygen to working muscles.

MULTIPLE CHOICE QUESTIONS

1. Which is not a function of the respiratory system?
   (A) Bring air from the atmosphere to the lungs
   (B) Transfer oxygen into the blood
   (C) Transport oxygen to the muscles
   (D) Remove carbon dioxide from the blood

2. The diaphragm contracts and moves downwards during
   (A) inspiration
   (B) expiration
   (C) ventilation
   (D) diffusion

3. The site of gaseous exchange in the respiratory system is the
   (A) trachea
   (B) bronchus
   (C) alveoli
   (D) diaphragm

4. Ventilation is calculated by multiplying
   (A) heart rate and respiratory rate
   (B) respiratory rate and vital capacity
   (C) tidal volume and vital capacity
   (D) respiratory rate and tidal volume

5. Diffusion is when gas molecules move from
   (A) an area of high concentration to low concentration
   (B) an area of low concentration to high concentration
   (C) an area of equal concentration
   (D) one capillary to another

6. The amount of air that can be inspired and expired with each breath is called
   (A) total lung capacity
   (B) vital capacity
   (C) tidal capacity
   (D) tidal volume

7. During exercise, which muscles work harder to enable increased expansion and contraction of the chest cavity?
   (A) Sternum and ribcage
   (B) Heart and lungs
   (C) Intercostals and diaphragm
   (D) Abdominals and deltoids
The gas that diffuses across the capillary/muscle interface to be expelled from the body after energy production is

(A) oxygen.
(B) carbon dioxide.
(C) lactic acid.
(D) myoglobin.

Respiratory rate increases during exercise due to the increased demand for

(A) food fuels.
(B) haemoglobin.
(C) oxygen.
(D) All of the above.

The main function of the nasal cavity is to

(A) warm and moisten the air.
(B) cool and moisten the air.
(C) protect the air.
(D) exchange air and carbon dioxide.

EXAM QUESTIONS

Question 1 (adapted from ACHPER Trial Exam 2013, question 4)

To allow the above to occur, the cardiovascular system will make a number of changes.

a. Describe how the respiratory system would change in response to the exercise shown in the graph above. 2 marks

b. Outline how these changes are made possible by referring to the following respiratory system structures: diaphragm and intercostals. 2 marks

c. Explain why the above changes occur using your understanding of the relationship between the cardiovascular and respiratory systems.

Question 2 (adapted from ACHPER Trial Exam 2012, question 1)

a. Complete the following table outlining the acute respiratory responses to increasing exercise intensities.

<table>
<thead>
<tr>
<th>Exercise condition</th>
<th>Respiratory rate (breaths/min)</th>
<th>Tidal volume (L/breath)</th>
<th>Ventilation (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td></td>
<td>0.5</td>
<td>6</td>
</tr>
<tr>
<td>60% Max HR</td>
<td>20</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>100% Max HR</td>
<td>40</td>
<td></td>
<td>160</td>
</tr>
</tbody>
</table>

b. Explain why the above responses occur. 2 marks

c. Explain how the cardiovascular system and respiratory system work together to allow the body to work aerobically. 3 marks