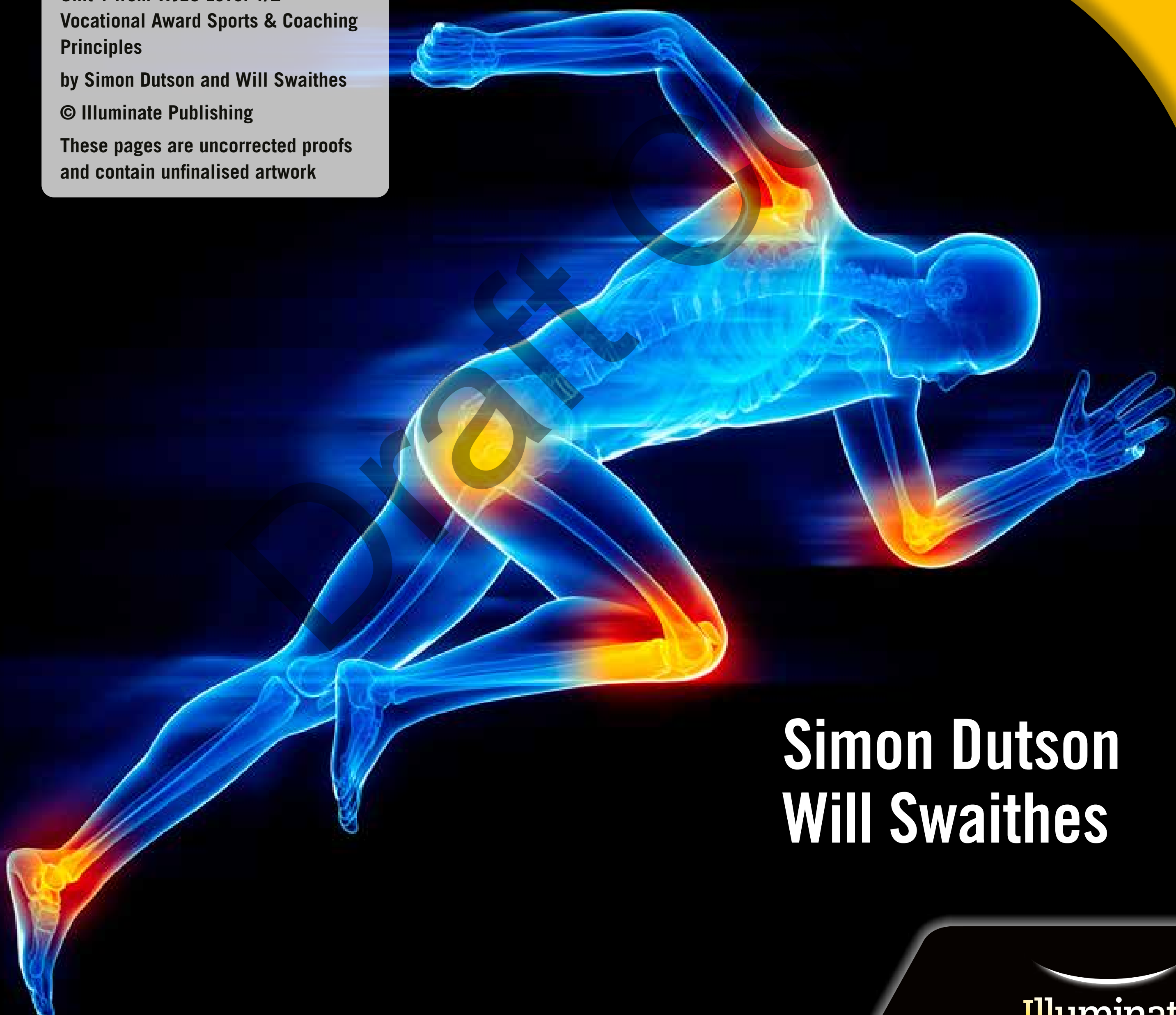
WJEC Level 1/2 Vocational Award

SPORTS AND COACHING PRINCIPLES

Unit 1: 1.1.1–1.1.2



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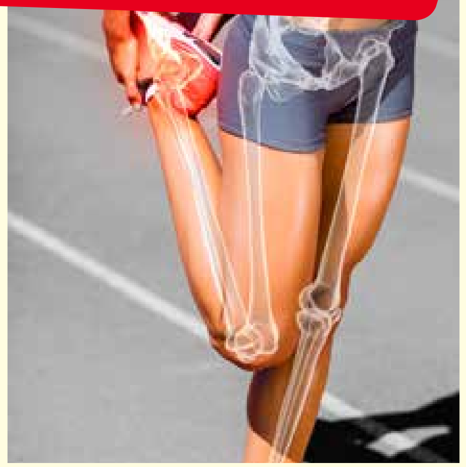
Unit 1 Fitness for Sport

Learning aims

1.1 Structure, functions and adaptations to the body's systems in relation to sport, exercise and physical activity

Before you get started



1.1.1 What do you already know about the structure of the body systems?

A: Where is your heart located?

B: Name three parts of the cardio-respiratory system.

C: Thinking about your muscular-skeletal system, can you name any specific types of joints?

D: Can you name at least five bones in your body?

E: We have different muscle fibre types in our bodies. Can you name any of the fibre types? Some help you run fast, some work more slowly and are good for long-distance athletes.

1.1.2 What do you already know about the functions of body systems?

A: What is the main function of the heart within the cardio-vascular system?

B: What is the main function of the cardio-respiratory system?

C: Identify two functions of the muscular-skeletal system.

D: Which muscle fibre types do you think are used most in each of the exercises listed below?

- 10,000 m run
- Throwing a shot put
- 110 m hurdles race
- 100 kg bench press exercise
- BMX sprint race

E: Our energy systems produce energy for our bodies to use. There are two types of energy systems – aerobic and anaerobic. Outline what aerobic and anaerobic mean.

1.1.3 What do you already know about the short-term effects of exercise?

A: Name two short-term responses to exercise related to the cardio-vascular system.

B: If you were exercising in a high-temperature environment, how would your body cool itself down?

C: What short-term effects would a warm-up have on the muscular-skeletal system?

D: Name two short-term responses to exercise related to the cardio-respiratory system.

1.1.4 What do you already know about the long-term adaptations from exercise?

A: After exercising regularly for a long period of time, what long-term adaptations might you expect to see in the cardio-vascular system?

B: If an athlete trains at their 'lactate threshold' (the point where lactic acid being produced in the muscles increases rapidly), what long-term adaptations do you think might occur?

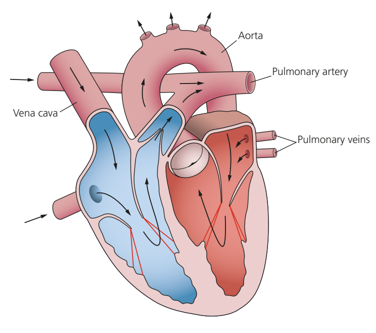
C: What do you think the term 'muscular hypertrophy' means?

D: After exercising regularly for a long period of time, what long-term adaptations might you expect to see in the cardio-respiratory system?

Cardio-vascular system

Connectivity

You may have taken other subjects that contain elements of anatomy and physiology, for example PE, health and social care, or science/biology. A lot of the content here, therefore, may seem familiar.



01_03 Fitness for Sport
Barking Dog Art

Figure 1 Position of the heart in the human body

Structure of the cardio-vascular system

The cardio-vascular system in the body is used to pump blood around the body. The heart pumps **oxygenated blood** out of the heart via arteries, and the blood is returned to the heart through veins.

Blood in arteries is therefore *oxygenated* blood and blood in the veins is **deoxygenated blood**. It is important to remember that arteries carry blood *away* from the heart and veins carry blood *towards* the heart.

The heart is located behind your ribs and just to the left side of the body.

The heart is made up of cardiac muscle cells known as cardiac muscle (or the **myocardium**).

The heart has four chambers, as you can see in Figure 2. The **atria** (the plural name for atrium) are the top two chambers of the heart. The right atrium receives blood from the body and the left atrium receives blood from the lungs.

The **ventricles** are the bottom chambers of the heart. These chambers pump blood out of the heart. The right ventricle pumps blood to the lungs and the left ventricle pumps blood to the body. The left ventricle is larger than the right ventricle because the left ventricle has to pump blood to the whole body while the right ventricle only pumps to the lungs.

Key Terms

Oxygenated blood: blood that has returned from the lungs to the heart ready to be pumped to the body. The body's cells will use the oxygen to create energy.

Deoxygenated blood: blood that is returning to the heart from the body ready to be pumped to the lungs. It is deoxygenated as the oxygen has been used by the cells of the body.

Myocardium: The scientific name for the heart muscle.

Atria: The collecting chambers of the heart. There are two chambers and they are positioned above the ventricles.

Ventricles: The pumping chambers of the heart located below the atria. The left ventricle is larger than the right ventricle.

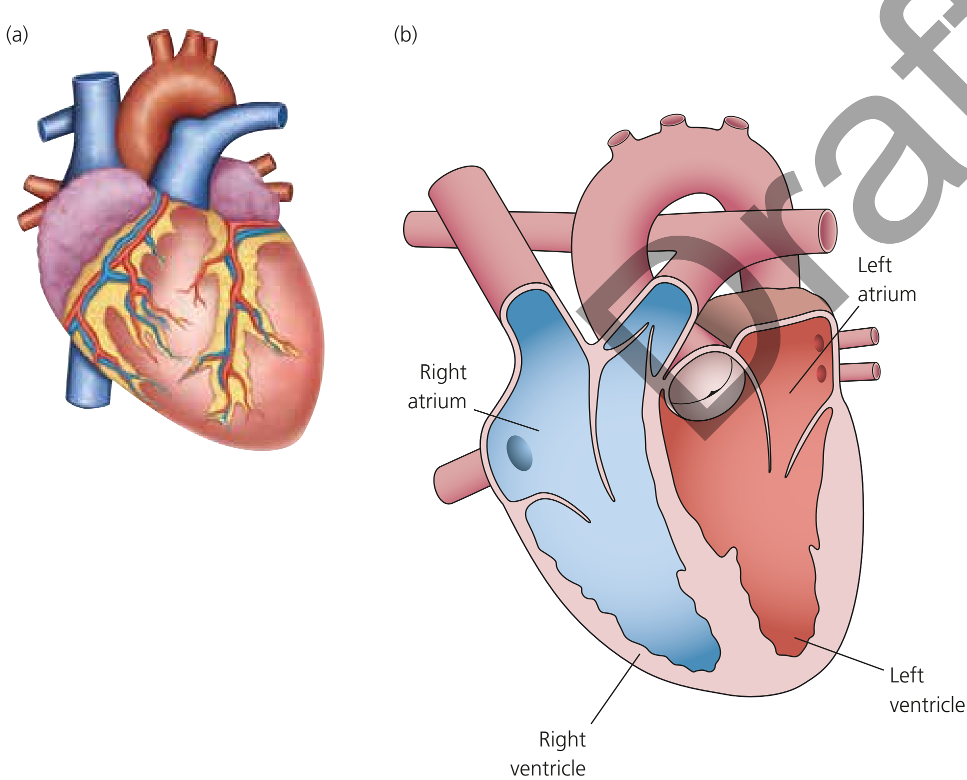


Figure 2 Structure of the heart. (a) External view, (b) section through the heart

style needed

The major blood vessels connecting to the heart are the **aorta**, the **vena cava**, the **pulmonary arteries** and the **pulmonary veins** (you can see these in Figure 3). An explanation of what each of these vessels does is outlined in Table 1.

Table 1 Blood vessels of the heart – what they do

Blood vessel	Information
Aorta	• This is the largest blood vessel in the body. • Oxygenated blood pumped through the aorta is oxygenated and bright red in colour. • The aorta helps pump oxygenated blood through the whole of the body.
Vena cava	• This is the largest vein in the body and it returns deoxygenated blood to the heart into the right atrium.
Pulmonary arteries	• The pulmonary arteries take blood from the heart to the lungs. • The pulmonary arteries are the only arteries in the body that carry deoxygenated blood. • The blood is pumped out to the lungs from the right ventricle, through the pulmonary arteries to become oxygenated.
Pulmonary veins	• The pulmonary veins return blood from the lungs to the heart. • The pulmonary veins carry oxygenated blood (this is the only time oxygenated blood is carried in veins). • The blood has come from the lungs where oxygen is added (diffused) and returned to the left atrium.

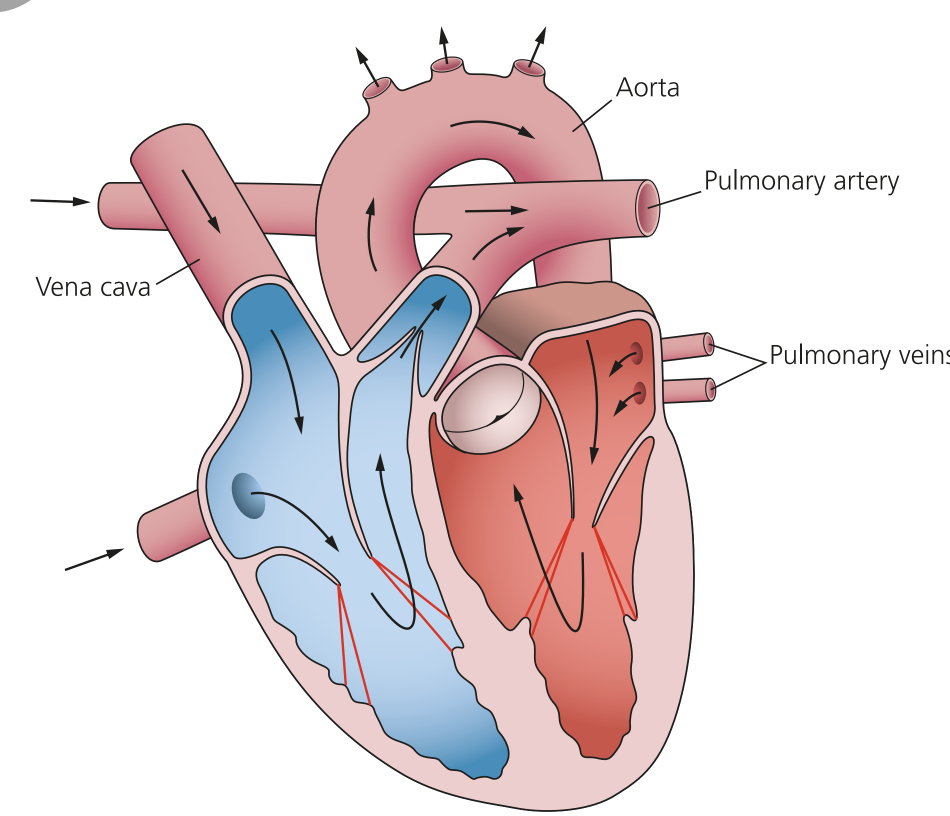


Figure 3 Blood vessels of the heart

Key Terms

Pulmonary: The term 'pulmonary' means related to the lungs. For example, pulmonary veins and pulmonary arteries are blood vessels linked to the lungs.

Top tip

You can remember which direction blood moves in if you remember that 'away' and 'artery' both start with the letter A.

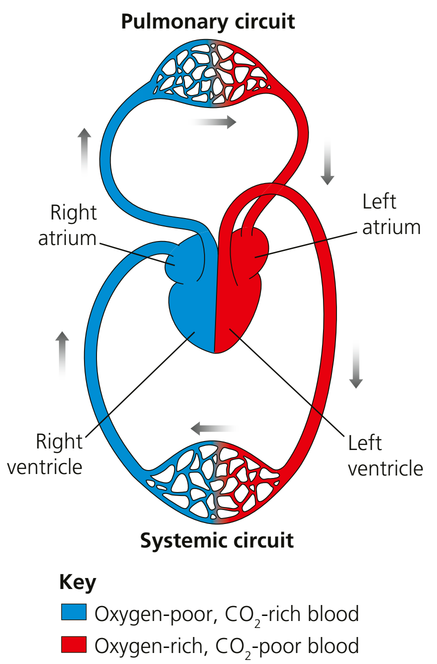


Figure 4 Pathway of blood through the heart and body

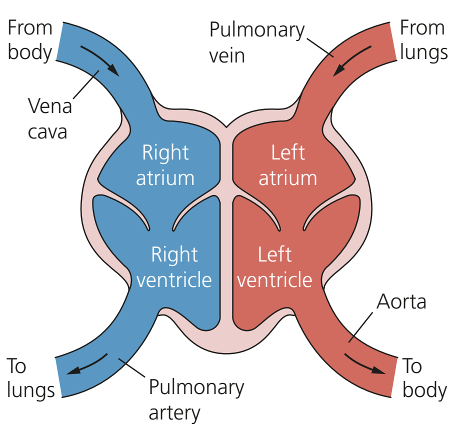


Figure 5 Systemic circulation

Key Terms

Vasodilation: Widening of the blood vessels.

Vasoconstriction: Narrowing of the blood vessels.

Blood pressure: The pressure of blood against the walls of the arteries.

Sphygmomanometer: A machine that measures blood pressure.

Circulation types and functions

There are two types of circulation from the heart:

- systemic circulation
- pulmonary circulation

Systemic circulation

Systemic circulation describes the pathway of blood from the heart to the body, and then back to the heart. This circulation is essential for transporting nutrients such as proteins, sugars, fats, vitamins and minerals, as well as oxygen, to the body tissues and cells. Systemic circulation also helps remove waste products such as carbon dioxide. Carbon dioxide is taken to the lungs via the blood, and we breathe it out.

Systemic circulation helps in managing body temperature. You might see someone get redder as their body warms up. This is caused by the blood vessels widening (**vasodilation**) close to the skin to allow heat to radiate from the body more easily. In the opposite situation, if a person is cold, the blood vessels at the surface of the skin and at the extremities narrow (**vasoconstriction**), reducing blood flow to ensure that the body core stays warm.

The systemic circulation follows the pathway:

Pulmonary veins → Left atrium → Left ventricle → Aorta → **Body cells and tissues** → Vena cava

The systemic circulation circuit is a pressurised system. The heart is a powerful muscle that allows blood to be forced through the arteries. The pressure on the walls of the arteries is known as **blood pressure**. Blood pressure is measured using a **sphygmomanometer** and is measured in mmHg (millimetres of mercury). Blood pressure is normally taken at the top of the left arm, where the brachial artery is located, because of the proximity to the heart. This allows for a more accurate measurement.

Figure 6 Checking blood pressure using a sphygmomanometer

LO1 Understand different factors which influence the risk of injury

The result of a blood pressure test can tell you if your blood pressure is high, normal or low. Table 2 shows the different categories of blood pressure. You will see two numbers in these results: the **diastolic** and the **systolic**. Systolic blood pressure is recorded when the heart beats. It is the measure of the pressure against the artery walls when the heart contracts – this is the higher number of the two. The diastolic pressure is when the heart is in a relaxation phase and is re-filling with blood – this is the lower number.

Key Terms

Systolic pressure: The pressure of blood against the walls of the arteries, measured when the heart beats.

Diastolic pressure: The pressure of blood against the walls of the arteries, measured when the heart contracts.

Table 2 Blood pressure categories (approximate figures)

Category	Systolic (mmHg)	Diastolic (mmHg)
Low	Less than 80	Less than 60
Normal	80–120	60–80
Prehypertension	120–139	80–89
High blood pressure	140–159	90–99
High blood pressure	160 or higher	100 or higher
High blood pressure crisis	Higher than 180	Higher than 110

Pulmonary circulation

This type of circulation describes the circuit of blood from the heart to the lungs. This circuit sends deoxygenated blood to the lungs to become oxygenated, and then back to the heart ready to be pumped to the body. The pulmonary circuit route is:

Right atrium → Right ventricle → Pulmonary artery → **Lungs** → Pulmonary vein

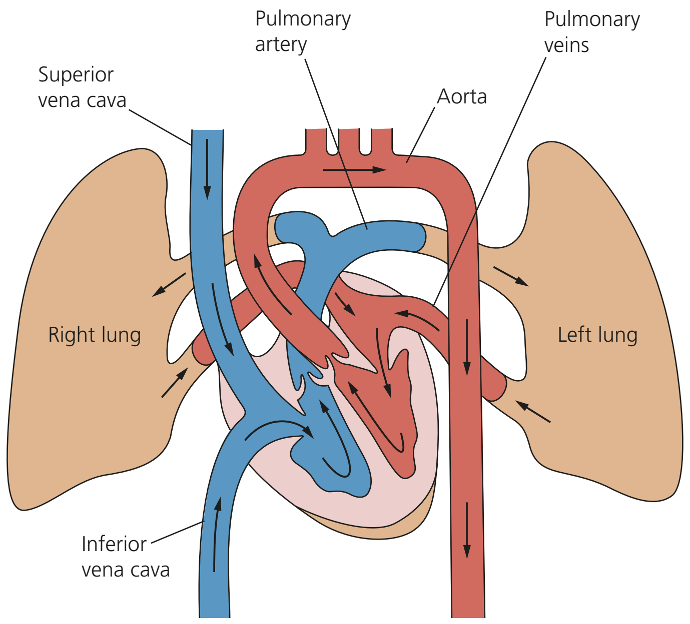


Figure 7 Pulmonary circulation

Top tip

It can be important to check blood pressure regularly because it is an indicator of poor cardio-vascular health. This is why your GP will often start an examination by taking your blood pressure when you have a doctor's appointment. Stress, exercise, medication, high salt intake, poor diet, alcohol consumption and a sedentary lifestyle can all increase blood pressure.

Short-term effects of exercise on the cardio-vascular system

Connectivity

This unit is closely linked with Unit 2, which will cover psychological and physiological factors affecting performance in sport. The knowledge you learn in Unit 1 will therefore be a good basis for understanding the next topic.

When you participate in exercise, for example a 400 m race or a game of football, short-term effects on your body will occur. Short-term effects can also be observed in less strenuous activity such as walking up a few flights of stairs.

Short-term effects of exercise are those effects that occur during exercise but cease when you stop exercising. You will notice some short-term effects of exercise and can observe them happening. Other effects happen in your body and you will not necessarily notice these.

When you are about to start exercising, and as you begin, adrenaline is released from the adrenal glands in your body. Adrenaline is a hormone. It causes short-term responses in your body such as:

- increased heart rate (bpm – beats per minute)
- increased stroke volume (ml/beat)
- increased cardiac output (litre/minute)
- increased concentration of carbon dioxide in blood returning from muscles
- increased release of oxygen from red blood cells at the working muscles
- increased body temperature results in sweating to maintain homeostasis

Increase in heart rate

Your heart rate will increase as you exercise and will continue to increase until the demand for oxygen is met. When your muscles are working, they will need an increased supply of oxygen and glucose to produce energy.

Your heart rate also increases to help your body remove waste products from the working muscles, such as carbon dioxide and lactic acid.

Calculating maximum heart rate

It can be dangerous to go beyond your maximum heart rate. To calculate your maximum heart rate, you can use the following equation:

$$220 - \text{your age} = \text{maximum heart rate}$$

For example, a 23-year-old would complete the equation as:

$$220 - 23 = 197$$

Their maximum heart rate would therefore be 197.

Measuring your heart rate

Radial pulse (wrist): place your index and middle fingers together on your opposite wrist. Place them about 1.5 cm down from the inside of the joint, in line with your index finger. Once you find a pulse, count the number of beats you feel in 1 minute.

Top tip

The longer you measure your pulse for, the more accurate your result. If you have a heart rate monitor, this will be the most accurate way to measure your heart rate.

Carotid pulse (neck): to measure your heart rate at the neck, place your first two fingers on either side of the neck until you can feel the beats. Be careful not to press too hard. Again, count the number of beats for 1 minute.

Alternatively, you can estimate a per minute rate by counting for 10 seconds and multiplying this figure by six. Similarly, you could count over 15 seconds and multiply by four.

Figure 8 Checking your carotid pulse rate

Increase in stroke volume

Stroke volume is defined as the volume of blood pumped out of the heart per beat. It is measured in millilitres per beat. As exercise intensity increases, stroke volume also increases to help you pump more blood to the working muscles. To allow this to happen, the muscular wall of the left ventricle expands further to fill the left ventricle with more blood. This creates a more powerful contraction that enables the heart to force more blood out to the body.

Increase in cardiac output

Cardiac output is the amount of blood pumped out from the heart per minute. It is measured in litres per minute. Cardiac output is linked to an increase in heart rate and stroke volume. Since the heart is pumping more blood out in one beat (stroke volume), and the heart is also beating more often (heart rate), the amount of blood pumped out of the heart in 1 minute will increase. Cardiac output is normally about 5 litres per minute, but can increase to 40 litres per minute during strenuous exercise.

Key Terms

Stroke volume: the amount of blood pumped out of the heart in one beat.

Cardiac output: the amount of blood pumped out of the heart in 1 minute.

Thermoreceptors: Sensors in the body that detect changes in body temperature and send messages to the brain to warm up the body or cool it down.

Increase in body temperature

The production of energy for your working muscles to repeatedly contract requires many chemical reactions to occur. These chemical reactions use fat, carbohydrates and proteins (only when necessary) to produce energy. These reactions also produce by-products including water, carbon dioxide and heat. It is the heat from these chemical reactions that causes our bodies to warm up.

In response to this increase in temperature, **thermoreceptors** trigger the body to start sweating.

Sweat evaporates off the skin, cooling us down. Vasodilation (see page xx) also occurs, which increases blood flow to the skin. The heat, carried in the blood, is then lost through a process known as radiation. Radiation will be noticeable as your face will generally turn red when you exercise.

Figure 9 Sweating helps to control body temperature

Key Terms

Aerobic: Producing energy in the presence of oxygen. (Compare **anaerobic** – energy production without the presence of oxygen.

Progressive overload: This is a principle of training in exercise where you overload your body over a period of time. If overload does not happen, then long-term adaptations will not occur.

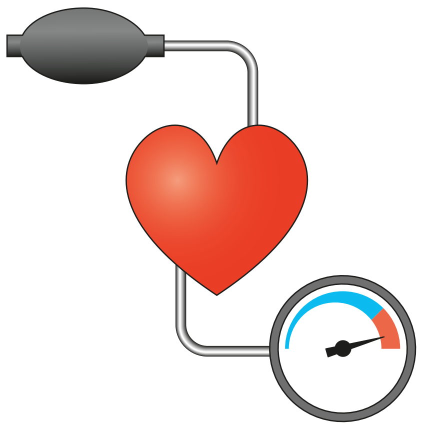


Figure 10 Exercise increases blood pressure

Connectivity

In Unit 3 you will learn about creating coaching sessions and how to undertake development planning in the long term. Understanding how the body will improve and develop from exercise over time is useful for factoring into this sort of coaching planning.

Key Terms

Left ventricular hypertrophy: The increase in size and strength of the left ventricle of the heart due to the stresses placed on it.

Increase in blood pressure

As more blood is being pumped out of the heart during exercise, there will be an increase in blood pressure. This is normally seen in the systolic blood pressure number (see page xx).

Different exercises can create different blood pressure responses. **Aerobic** exercises such as swimming, running and cycling will cause an increase in blood pressure that should be fairly gradual. Other exercises such as holding a plank position can cause a rapid and large increase in blood pressure, which can be dangerous for some people, for example those who have a history of cardiac problems.

Long-term adaptations from exercise on the cardio-vascular system

Long-term adaptations occur as the body responds to the stresses placed on it by increased physical activity and exercise over a long period of time. Long-term adaptations occur following regular training and the **progressive overload** placed on the body systems. These adaptations normally start to become noticeable within 4 weeks, depending on the frequency and intensity of the exercise. Adaptations are designed to make your body systems more efficient.

Cardiac hypertrophy

The heart is made up of cardiac muscle and, as with any muscle in the body, it will get bigger and stronger if it is exercised. This increase in size is known as 'cardiac hypertrophy'. More specifically, the size of the walls of the left ventricle increase. This is because the left ventricle does more work pumping blood to the whole body, while the right ventricle pumps to the lungs and therefore does not need to work as hard.

Aerobic exercise activities such as swimming, running, cycling and being active for extended periods of time will cause cardiac hypertrophy. Generally, cardiac hypertrophy is noticeable after 6 weeks of regular exercise.

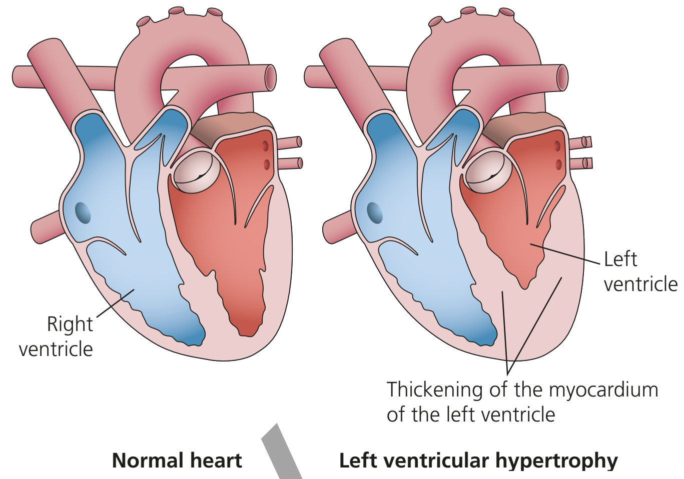


Figure 11 Left ventricular hypertrophy

Figure 12 Aerobic exercise

Increase in stroke volume and reduction in resting heart rate

As a result of cardiac hypertrophy, there will be an increase in stroke volume both at rest and during exercise. As your heart is now bigger and stronger, more blood can be pumped out in one beat. This means your heart does not have to beat as many times per minute and that is why you will have a reduced **resting heart rate**. The reduction in resting heart rate is known as **bradycardia**. Bradycardia means the heart is more efficient at pumping blood around the body and puts much less strain on the muscle.

The average person has a resting heart rate of 60–100 beats per minute (bpm). However, elite athletes can have a heart rate as low as 30 beats per minute. For example, Usain Bolt's resting heart rate was reported as 33 bpm, as was Sir Mo Farrah's. The average resting heart rate for an elite female athlete is between 54 and 59 beats per minute.

Sir Bradley Wiggins' resting heart rate was measured at 35 bpm. Resting heart rate is considered a good measure of a person's fitness level because it indicates how efficiently the heart pumps blood throughout the body.

Key Terms

Resting heart rate: Heart rate at rest.

Bradycardia: The reduction in resting heart rate as a result of having a stronger heart.

Figure 13 Mo Farah wins the 10,000m at the IAAF World Championships, 2013

Table 3 shows average resting heart rates for men and women at different stages of physical fitness.

Table 3 Average resting heart rates

Male	Age			
	18–25	26–35	36–45	46–55
Athlete	49–55	49–54	50–56	50–57
Excellent	56–61	55–61	57–62	58–63
Good	62–65	62–65	63–66	64–67
Above average	66–69	66–70	67–70	68–71
Average	70–73	71–74	71–75	72–76
Below average	74–81	75–81	76–82	77–83
Female				
Athlete	54–60	54–59	54–59	54–60
Excellent	61–65	60–64	60–64	61–65
Good	66–69	65–68	65–69	66–69
Above average	70–73	69–72	70–73	70–73
Average	74–78	73–76	74–78	74–77
Below average	79–84	77–82	79–84	78–83

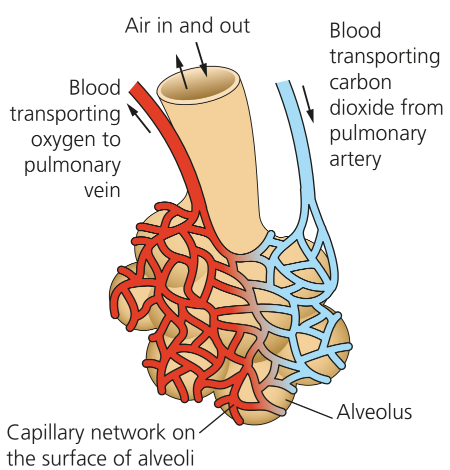


Figure 14 Capillarisation

Capillarisation

Capillarisation is a process where more **capillaries** are formed around the alveoli in the lungs and the skeletal muscles. Capillarisation significantly increases the surface area for blood diffusion in these locations. Capillaries are tiny blood vessels. They are just one cell thick, which allows for diffusion to occur across the capillary walls. Molecules of oxygen, carbon dioxide, glucose and other waste products are able to diffuse through capillaries. Diffusion cannot happen between the other blood vessels such as arteries and veins as they are too thick.

The more an individual exercises, the more capillarisation occurs, which makes the body much more efficient at delivering oxygen to working muscles, as well improving the removal of waste products such as carbon dioxide.

Decreases in blood pressure

As outlined previously, exercise makes the heart bigger and stronger. It also leads to a decrease in blood pressure. This is because a stronger heart can pump blood around the body with less effort, meaning that the force on the artery walls decreases (which affects blood pressure).

Long-term exercise also reduces the risk of obesity and improves blood circulation, which reduces the risk of developing arterial blockages. These factors further help to reduce blood pressure.

Key Terms

Capillaries: Tiny blood vessels that are one cell thick, they allow molecules through their cell wall into the blood. Capillarisation is when more capillaries are produced following long-term exercise.

Apply your learning

Activity 1

Using a blank diagram of the heart, label the following parts of the heart:

- Left atrium
- Right atrium
- Left ventricle
- Right ventricle
- Aorta
- Pulmonary arteries
- Pulmonary veins
- Vena cava

Activity 2

On a sheet of paper, draw a flow chart showing the route of blood through the systemic circulation system and the pulmonary circuit.

Activity 3

Work out your maximum heart rate using the equation: 220 – your age

Activity 4

Using a blood pressure monitor and the correct protocol, work with a partner to measure and record each other's blood pressure.

Take it one step further...

Examine the impact of exercise on heart rate.

1. First, take your resting heart rate and record it. To measure your resting heart rate, lie down or sit still for 2 minutes and then take your pulse for 1 minute.
2. Undertake 5 minutes of vigorous activity – this could be stair climbing, running, cycling or rowing.
3. If you have a smart watch or a heart rate monitor, you can monitor your heart rate every minute and record it.
4. If you cannot measure your heart rate electronically, exercise for 45 seconds and then take your pulse for 15 seconds. Repeat this for 5 minutes in total. For each heart rate, multiply the result by four to work out your total heart rate per minute.
5. Use your results to draw a graph showing your heart rate over 5 minutes while undertaking exercise.

Practice questions

1. Describe how the cardio-vascular and respiratory systems work together to deliver oxygenated blood to the working muscles. (4 marks)
2. Outline three examples of **short-term adaptations** of the cardio-respiratory system and describe their impact on the body. (6 marks)
3. Outline three examples of **long-term adaptations** of the cardio-respiratory system and describe their impact on the body. (6 marks)
4. Describe aerobic and anaerobic energy systems and identify which sports or activities they likely will commonly occur in. (6 marks)
5. Describe three functions of the skeletal system. (6 marks)

Cardio-respiratory system

The role of the cardio-respiratory system is to enable us to breathe. It is the body system that deals with the movement of air into and out of the lungs. All our cells must obtain oxygen so that they can produce energy and remove carbon dioxide. The exchange of oxygen and carbon dioxide occurs in the lungs between the air and the blood.

Structure of the cardio-respiratory system

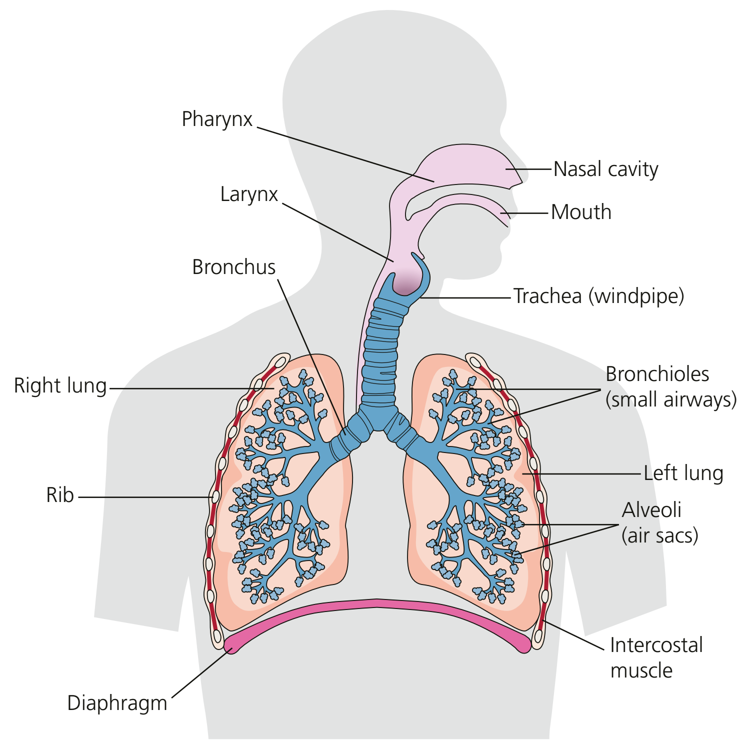


Figure 15 Structure of the cardio-respiratory system

- Air is breathed in through the nose or mouth. The air is warmedin the nose and throat, and filtered by the nasal hairs.
- The pharynx is the throat area The tonsils can be found in the pharynx.
- The air continues through the larynx, where the voice box is located.
- The trachea (windpipe) is a long, toughened tube where the air we breathe in is cleaned and filtered.
- Small hairs called cilia filter and clean the air to help reduce the risk of any particles in the air reaching our lungs. Mucus is also present in the trachea, and also traps pathogens and particles.
- Air travels from the trachea to the bronchus and bronchioles, which are tree-like formations.
- At the end of the bronchioles are the **alveoli**. This is where diffusion and gaseous exchange occurs, and oxygen is absorbed into the blood and carbon dioxide is removed to be breathed out. The alveoli appear like bunches of grapes, and they are surrounded by a vast capillary bed.

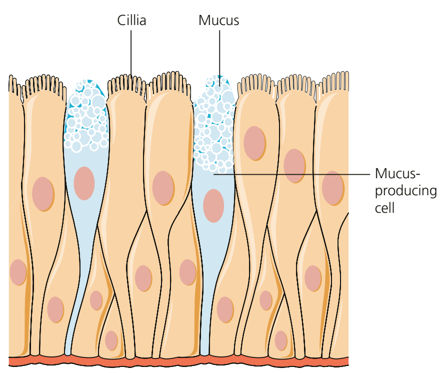


Figure 16 Cilia

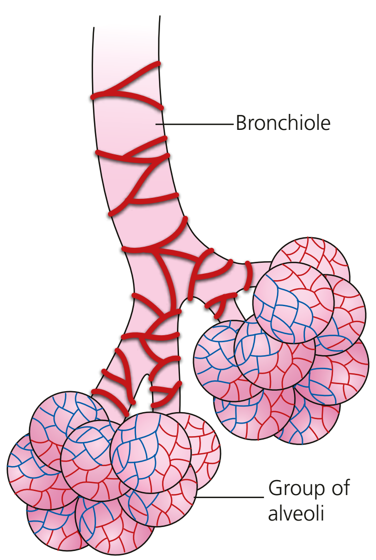


Figure 17 Alveoli

- The **diaphragm** is a dome-shaped muscle that helps expand the **thoracic cavity**. When it contracts it flattens and when it relaxes it returns to a dome shape (see p. xx).
- The intercostal muscles are found between the ribs. They are used to increase and decrease the size of the thoracic cavity (see p. xx).

Functions of the cardio-respiratory system

Breathing is the main function of the cardio-respiratory system. Breathing in is also known as inspiration. We breathe in air containing oxygen, nitrogen, some carbon dioxide and other gases. These gases undergo an exchange through the process of **diffusion** in our bodies (see p. xx). It is the oxygen specifically that we need for our cells to produce energy.

Breathing out is also known as expiration. We breathe out carbon dioxide and water as well as other gases.

Table 4 shows the percentages of gases we breathe in and out.

Table 4 Gases inhaled and exhaled

Inhaled air	Exhaled air
Nitrogen 78%	Nitrogen 78%
Oxygen 21%	Oxygen 16%
Carbon dioxide 0.04%	Carbon dioxide 4%
Other gases <1%	Other gases <1%

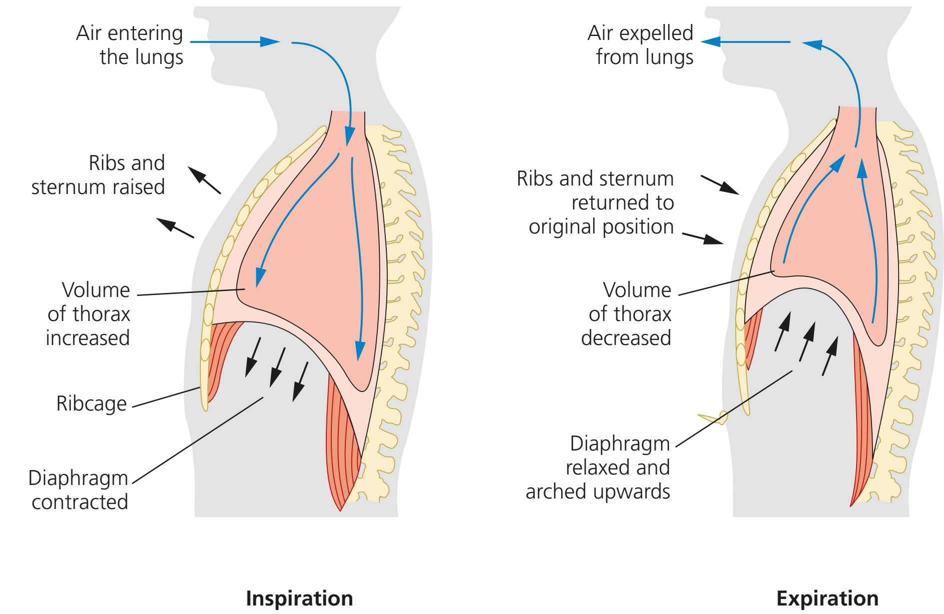


Figure 18 Mechanism of breathing

We take about twelve breaths per minute at rest when awake and about six breaths per minute while we are sleeping.

Key Terms

Alveoli: Tiny air sacs that fill with air and enable diffusion and gaseous exchange to occur.

Diaphragm: A dome-shaped muscle, the main muscle for breathing.

Thoracic cavity: The area of the chest where the ribs and lungs are located. This can expand and contract using respiratory muscles.

Diffusion: The movement of molecules from an area of high concentration to a region of lower concentration, e.g. high concentration of oxygen in the alveoli to the lower concentration of oxygen in the blood.

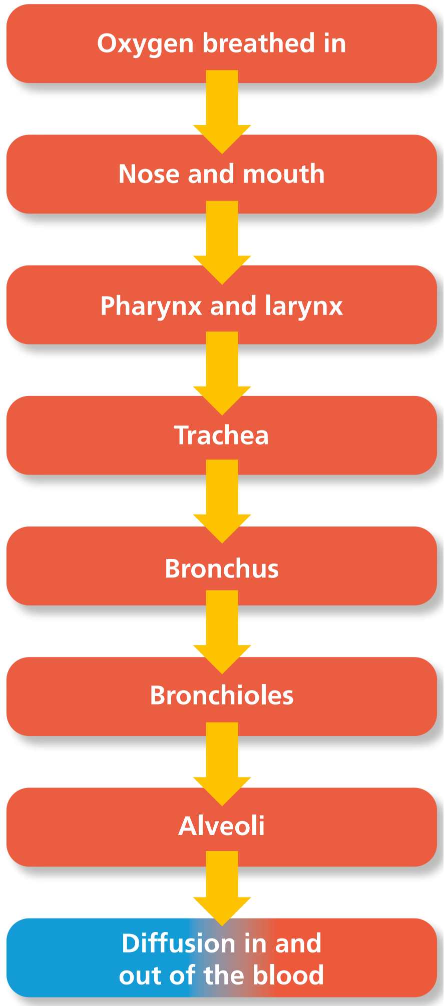


Figure 19 Route of air through the respiratory system

Diffusion and the alveoli

Diffusion is the process of a molecule moving from an area of high pressure to an area of lower pressure. In the example of the alveoli, it is molecules of oxygen and carbon dioxide that move across this gradient. When we breathe in, there is a high pressure and concentration of oxygen in our lungs. This pressure forces the oxygen in through the cell walls of the capillaries and into the blood where it is attached to red blood cells for transportation round the body.

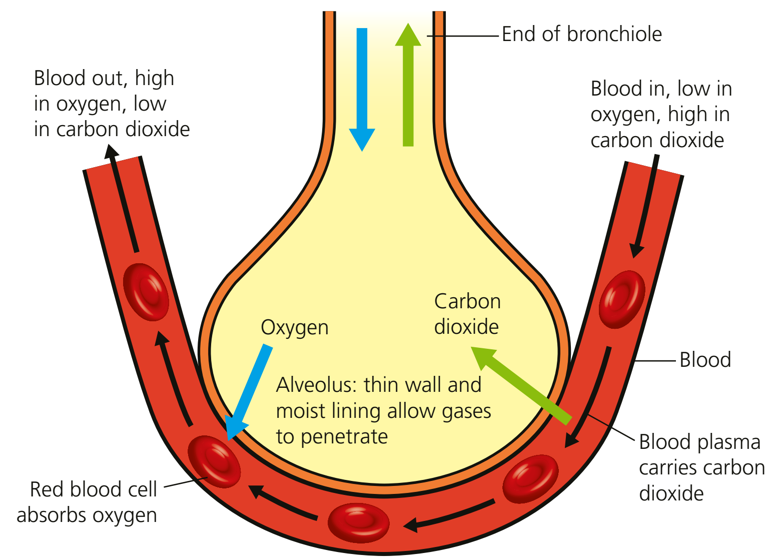


Figure 20 Pulmonary alveoli and gaseous exchange taking place inside them

Key Terms

Gaseous exchange: The exchange of oxygen and carbon dioxide at the alveoli.

When we breathe out, there is a high concentration and pressure of carbon dioxide in the blood ready to be removed. This carbon dioxide is forced into the alveoli from the capillaries and we breathe it out.

The exchange of gases at the lungs through this diffusion process is known as **gaseous exchange**.

Use of the breathing/respiratory muscles

The diaphragm is a major muscle of the respiratory system. When the diaphragm muscle contracts, it increases the size of the thoracic cavity and causes air to be drawn into the lungs. When the diaphragm relaxes, it reduces the size of the thoracic cavity causing air to be pushed out of the lungs and we breathe out.

The intercostal muscles also help in the breathing process. The external intercostal muscles pull the ribs up and out, increasing the size of the thoracic cavity. You can see this happening when you breathe in. The internal intercostal muscles pull your ribs down and in, reducing the size of the thoracic cavity. You can see this happening when you breathe out.

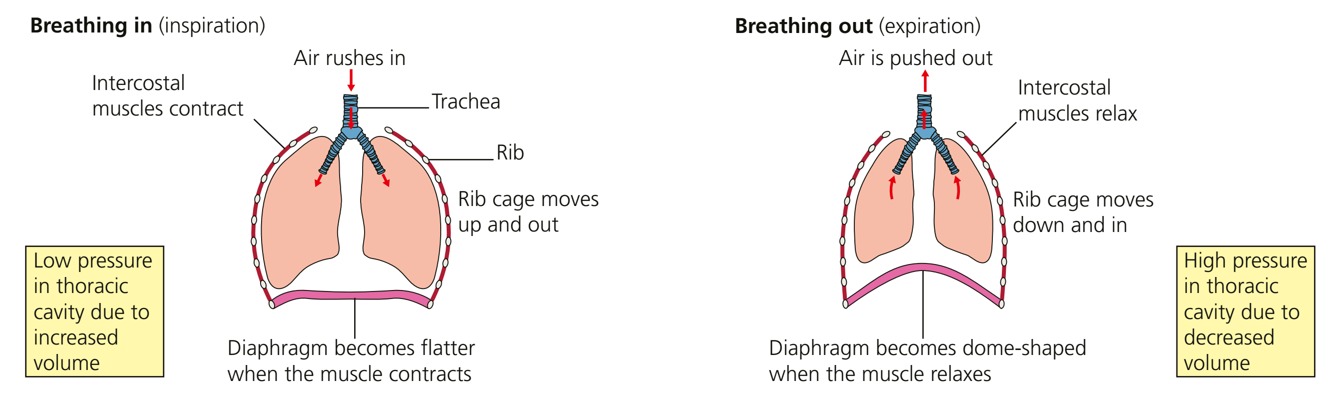


Figure 21 Function of the diaphragm during breathing

Short-term effects of exercise on the cardio-respiratory system

Increase in breathing rate

When we begin to exercise, our muscles work harder and at a greater intensity. As a result, there is an increased demand for oxygen and carbon dioxide. Oxygen is required to create energy for the muscle cells, while carbon dioxide is a by-product of the energy production process. When adrenaline is released prior to exercise, it triggers an increase in **breathing rate** to help draw in more oxygen to the working muscle. Breathing rate can increase from an average of twelve breaths at rest to thirty breaths per minute during exercise.

Another process that increases breathing rate occurs through the **chemoreceptors** in the brain, as well as in some blood vessels. These detect changes in blood pH. Increases in carbon dioxide are linked to increased pH of the blood, so the brain triggers the breathing rate to increase to eliminate carbon dioxide.

Key Terms

Breathing rate: The number of breaths we take in 1 minute.

Chemoreceptors: Receptors in the brain and some blood vessels that detect changes in pH in the body.

Increase in tidal volume

Tidal volume is the amount of air that we breathe in with each normal breath. When we exercise, tidal volume increases as the depth of breathing increases. This occurs so that we can breathe in more oxygen and breathe out more carbon dioxide. We take much deeper breaths when we exercise – the respiratory muscles (diaphragm and intercostal muscles) expand the thoracic cavity to allow us to take large breaths in. The average tidal volume at rest measures approximately 500 ml but during exercise it can increase to over 3000 ml (3 litres).

Key Terms

Tidal volume: The amount of air breathed in with one breath.

Increase in minute ventilation

Minute ventilation is the total volume of air entering the lungs in 1 minute. The average minute ventilation is between 5 and 8 litres per minute. Minute ventilation increases when we exercise, and the amount it increases depends on the intensity of the exercise. As breathing rate increases with exercise, the amount of air entering the lungs in 1 minute will also increase.

Long-term adaptations from exercise on the cardio-respiratory system

If you have been exercising regularly with progressive overload, in approximately 6 weeks you should start noticing the long-term adaptations on the cardio-respiratory system.

Hypertrophy of respiratory muscles

Hypertrophy of respiratory muscles occurs due to the overload placed on them from intense breathing actions. Just like any muscles of your body, if you train them, they will become stronger and more efficient. By undertaking intense exercise activities, you are training your respiratory muscles. As the muscles become stronger and more efficient, they can expand and contract the thoracic cavity more powerfully with a reduced chance of fatigue.

Capillarisation

Capillarisation also occurs following long-term exercise (see page xx). An increase in the number of capillaries surrounding the alveoli will increase the surface area of the capillary bed and create a more efficient gaseous exchange process.

Increase in alveoli number

Another long-term adaptation will be an increase in the number of alveoli. This significantly increases the area where gaseous exchange can occur, making the gaseous exchange process more efficient. It is estimated that there are 150 million alveoli in each lung. The surface area of both lungs is roughly the same size as a tennis court.

Increase in tidal volume

The tidal volume of the lungs increases in the long term and your lungs become more efficient. This means that for every breath you take, you can inhale and exhale more air at rest and during exercise. This is linked to having more alveoli, stronger respiratory muscles and a larger thoracic cavity. Since you are breathing more air in and out in one breath, *and* the system cardio-respiratory system is more efficient, you may notice a slight reduction in your breaths per minute at rest.

Increase in minute ventilation

Owing to the increase in tidal volume, there will also be a long-term increase in per minute ventilation. This is because more air is inhaled per breath, so there will be an increase per minute.

LO1 Understand different factors which influence the risk of injury

Apply your learning

Activity 1

Measure your own breathing rate by lying down and staying relaxed and still for 2 minutes. Count the number of breaths you take in 1 minute. Record that and compare with your classmates or someone you know.

Activity 2

Measure your resting breathing rate, then complete a 5-minute circuit of exercises without rest. Measure your breathing rate immediately after the circuit. Write down your results, describe what you have found and explain why it has happened.

Activity 3

Independently, create a poster on which you:

- label the parts of the respiratory system
- draw a flow chart of the route of air through the respiratory system

Activity 4

Using a blood pressure monitor and the correct protocol, work with a partner to measure and record each other's blood pressure.

Take it one step further...

Try the Dutson One Breath Experiment:

1. Using a questionnaire, find out how much physical activity or exercise your classmates do.
2. Using a packet of identical balloons, ask each person who is part of the experiment to take the biggest breath in they can and then blow the air out into the balloon.
3. Keep the air in the balloon and measure the circumference of the balloon to see who took the largest breath.
4. Is there a link between those who are more physically active?
5. Discuss what other factors could impact the results.

Practice questions

1. Describe the main functions of the respiratory system. (4 marks)
2. Outline the process of gaseous exchange. (4 marks)
3. Describe two short-term adaptations that occur in the respiratory system and the impact they will have on exercise. (4 marks)
4. Describe two long-term adaptations that occur in the respiratory system and the impact they will have on the body. (4 marks)

Fitness for Sport Unit Checklist (1.1.1–1.1.2)

Learning topics	Covered it	Learnt it	Smashed it!
1.1.1 The structure of body systems			
Cardio-vascular system			
Location of atria			
Location of ventricles			
Location of vena cava			
Location of aorta			
Location of pulmonary artery			
Location of pulmonary vein			
Cardio-respiratory system			
Location of larynx			
Location of trachea			
Location of bronchus			
Location of bronchioles			
Location of alveoli			
Location of lungs			
Location of diaphragm			
Location of intercostal muscles			
1.1.2 The functions of body systems			
Cardio-vascular system (systemic circulatory system)			
Transport of nutrients and oxygen			
Removal of waste products			
Regulation of body temperature (vasodilation and vasoconstriction)			
Blood pressure			
Cardio-respiratory system (pulmonary circulatory system)			
Inspiration of oxygen and expiration of carbon dioxide and water through breathing			
Gaseous exchange			
Diffusion			

1.1.3 The short-term effects of exercise on body systems			
Cardio-vascular system			
Changes in cardiac output			
Changes in heart rate			
Changes in stroke volumes			
Changes in temperature			
Cardio-respiratory system			
Changes in breathing frequency/rate			
Changes in tidal volume			
Changes in minute ventilation			
1.1.4 The long-term adaptations from exercise on the body systems			
Cardio-vascular system			
System changes to cardiac values			
System changes to capillarisation			
System changes to blood pressure			
Cardiac hypertrophy			
Cardio-respiratory system			
System changes to respiratory values			
System changes to capillarisation			
Hypertrophy of muscles			