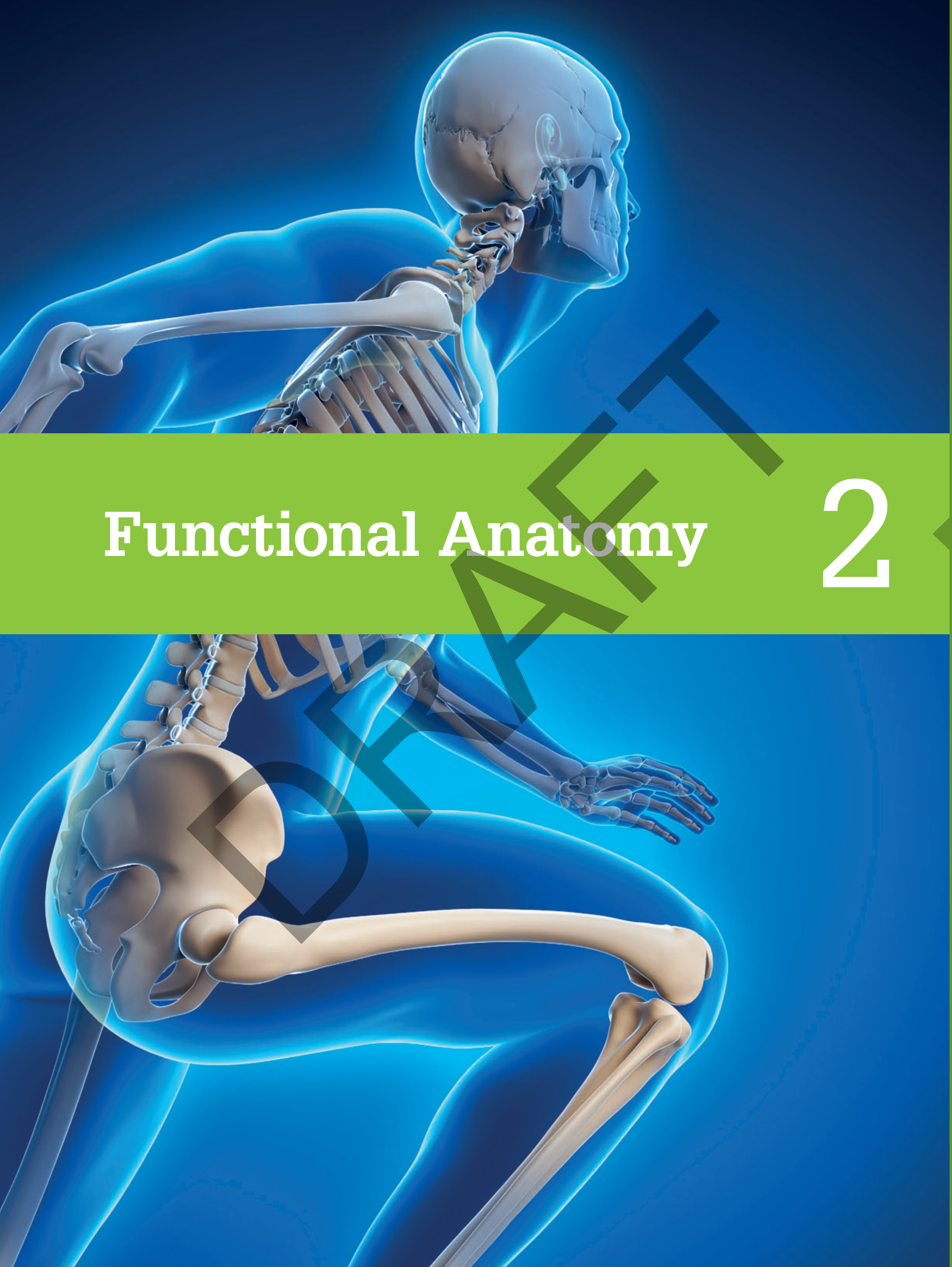
2

Functional Anatomy



Getting to know your unit

Assessment
This unit is assessed by an examination that is set and marked by Pearson.

To understand what happens during sport and exercise, you must know about the different body systems. This unit examines the systems that make up the body, how these systems interact and work with each other, and why they are so important to sports performance. You will be introduced to the structures and functions of the four key systems and the effects that sport and exercise has on them, and how these systems work together effectively to produce movement.

How you will be assessed

This unit will be assessed by an examination set by Pearson. It will last 1 hour and 30 minutes and contain a number of short and long answer style questions. There will be a total of 80 marks available in the examination.

During this examination you will need to show your knowledge and understanding of the anatomy of the cardiovascular, respiratory, skeletal and muscular systems and how they work together to produce movement.

Throughout the unit, you will find assessment practice activities to help you prepare for the exam. Completing each of these will give you an insight into the types of questions and, more importantly, how to answer them.

Unit 2 has four assessment outcomes (AO) which will be included in the external examination. Certain 'command words' are associated with each assessment outcome – see Table 2.1.

- **AO1** Demonstrate knowledge and understanding of the language, structure, characteristics and function of each anatomical system
  - Command words: describe, give, identify, name, state
  - Marks: range from 1 to 5 marks
- **AO2** Apply knowledge and understanding of the structure, characteristics and function of the anatomical systems in context
  - Command words: describe, explain
  - Marks: range from 2 to 5 marks
- **AO3** Analyse the anatomical systems' effectiveness in producing sport and exercise movements and evaluate their impact on performing movements successfully
  - Command words: analyse, assess, evaluate, discuss, to what extent
  - Marks: range from 8 to 20 marks
- **AO4** Make connections between anatomical systems and how they interrelate in order to carry out different exercises and sporting movements in context
  - Command words: analyse, assess, evaluate, discuss, to what extent
  - Marks: range from 8 to 20 marks

Table 2.1: Command words used in this unit

Command word	Definition – what it is asking you to do
Analyse	Identify several relevant facts of a topic, demonstrate how they are linked and then explain the importance of each, often in relation to the other facts.
Assess	Carefully consider varied factors or events that apply to a specific situation and identify those which are the most important or relevant to arrive at a conclusion.
Describe	Give a full account of all the information, including all the relevant details of any features, of a topic.
Discuss	Identify an issue/situation/problem/argument that is being assessed and explore all aspects and investigate fully.
Evaluate	Bring all the relevant information on a topic together and make a judgement on it (for example, on its success, importance, strengths, weaknesses, alternative actions, relevant data or information). This should be clearly supported by the information you have gathered.
Explain	Make an idea, situation or problem clear to your reader by making a point/statement or by linking the point/statement with a justification/expansion.
Give	Provide examples, justifications and/or reasons to a context.
Identify	State the key fact(s) about a topic or subject. The word 'outline' is similar. You should assess factual information that may require a single-word answer, although sometimes a few words or a maximum of a single sentence are required.
State/name	Give a definition or example.
To what extent	Review information then bring it together to form a judgement or conclusion, after giving a balanced and reasoned argument.

Getting started

The human body is made up of a number of different systems that interact together, allowing you to take part in sport and exercise. Write a list of how the body changes immediately before, during and after a sport or exercise session. Consider these changes and think about the system that is affected. Why do you think these changes occur?

A Anatomical positions, terms and references

When examining the human body it is important you are able to refer to the location of different parts of the body. This is particularly important when describing movements and body locations in relation to each other.

The 'anatomical position' is a standard standing position used in most diagrams of the body (see Figure 2.1), with the body facing forward, feet pointed forward and slightly apart, and arms hanging down on each side. This is also known as the **point of reference**.

A number of specialist terms that you need to understand are described in Table 2.2.

Table 2.2: Anatomical terms

Anatomical term	Definition
Anterior	To the front or in front
Posterior	To the rear or behind
Lateral	Away from the midline or axis, an imaginary line down the centre of the body
Medial	Towards the midline or axis
Proximal	Near to the root or origin (e.g. the proximal of the arm is towards the shoulder)
Distal	Away from the root or origin (e.g. the distal of the arm is towards the hand)
Superior	Above
Inferior	Below
Peripheral	Away from the centre of the body
Superficial	Near the surface of the skin
Deep	Away from the surface of the skin
Supine	Lying down with face pointing upwards
Prone	Lying down with face pointing downwards

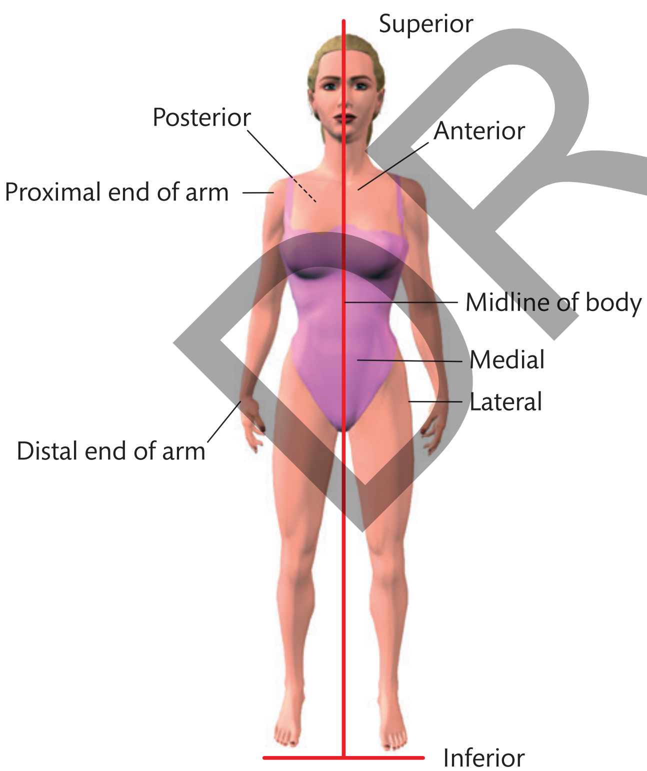


Figure2. 1: Anatomical positions

B Anatomy of the cardiovascular system

The cardiovascular system is also known as the **circulatory system**. It is the major transport system in your body, carrying food, oxygen and all other essential products to cells, and taking away waste products of respiration and other cellular processes, such as carbon dioxide.

Anatomy of the heart

The heart is a unique hollow muscle and is the pump of the cardiovascular system. It is located under the sternum (a long flat bone like a neck tie at the front of the ribcage, which provides protection) and is about the size of a closed fist. The heart drives blood into and through the arteries to the tissues and working muscles.

It is surrounded by a twin-layered sac known as the **pericardium**. The cavity between the layers is filled with pericardial fluid, which prevents friction as the heart beats. The heart wall is made up of three layers: the epicardium (the outer layer), the myocardium (the strong middle layer that forms most of the heart wall) and the endocardium (the inner layer).

The heart is actually two pumps in one: the two chambers on the right (the right atrium and the right ventricle) and the two chambers on the left (the left atrium and the left ventricle). The right side is separated from the left by a solid wall known as the **septum**. This prevents the blood on the right side coming into contact with the blood on the left side.

The specific parts of the heart, also shown in Figure 2.2, are as follows.

Coronary arteries – the blood vessels supplying **oxygenated blood** to the heart muscle. There are two coronary arteries, the left and right.

- **Atria** – the upper chambers of the heart. They receive blood returning to your heart from either the body or the lungs. The right atrium receives **deoxygenated blood** via the superior and inferior vena cava (a large vein). The left atrium receives oxygenated blood from the left and right pulmonary veins.
- **Ventricles** – the pumping chambers of the heart. They have thicker walls than the atria. The right ventricle pumps blood to the pulmonary circulation for the lungs and the left ventricle pumps blood to the systemic circulation for the body including the muscles.
- **Bicuspid (mitral) valve** – one of the four valves in the heart, situated between the left atrium and the left ventricle. It allows the blood to flow in one direction only, from the left atrium to the left ventricle.
- **Tricuspid valve** – located between the right atrium and the right ventricle, it allows blood to flow from the right atrium to the right ventricle and prevents blood from flowing backwards.
- **Semilunar valves** (**aortic valve** and **pulmonary valve**) – between the left ventricle and the aorta, these prevent backflow from the aorta into the left ventricle. They are also situated between the right ventricle and the pulmonary artery.
- **Chordae tendineae** – chord-like tendons connected to the bicuspid and tricuspid valves to prevent valves turning inside out.

Key terms

Anatomy – study of the structure of the body such as the skeletal, muscular or cardiovascular systems.

Oxygenated blood – blood containing oxygen.

Deoxygenated blood – blood without oxygen (containing carbon dioxide).

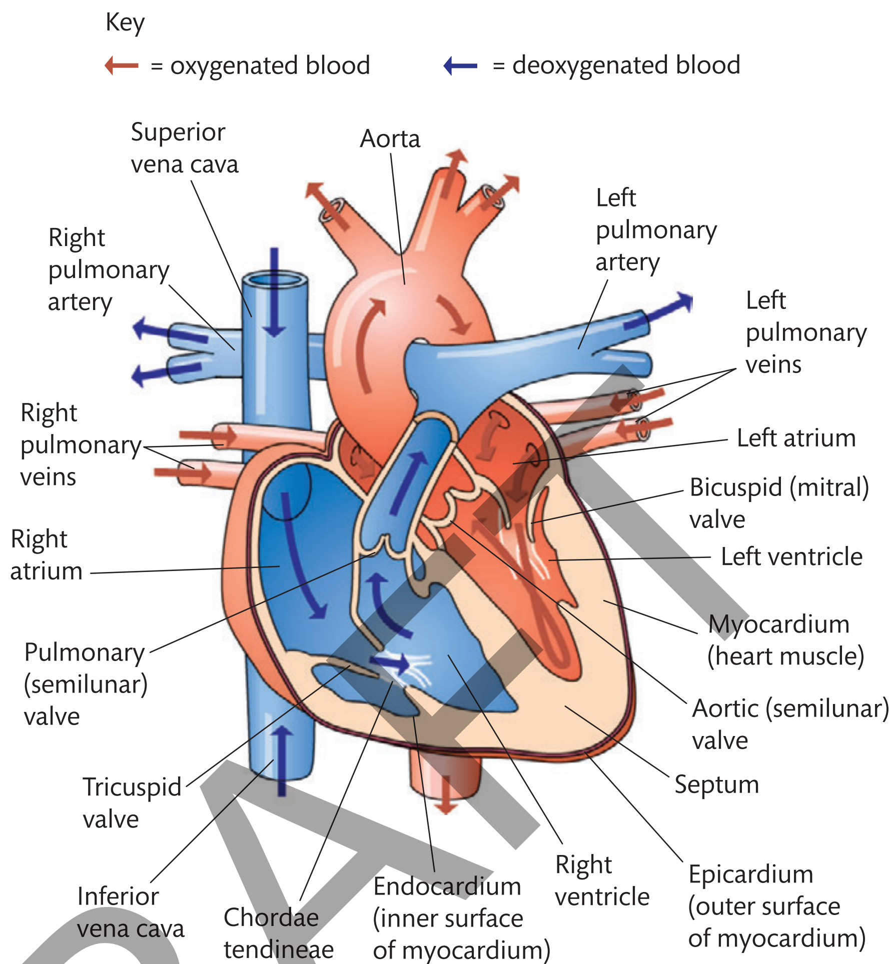


Figure 2.2: Diagram of the heart

Function of the heart

The chambers on the right of the heart supply blood at a low pressure to the lungs via blood vessels, where **gaseous exchange** (see page XX) takes place: oxygen that has been breathed in through the lungs is transferred to the blood, and carbon dioxide, a waste product from the body's activities, is deposited ready to be exhaled from the body. This blood is then returned to the left side of the heart via the blood vessels (see the next section for more information about blood vessels).

When the chambers of the left side of the heart are full, it contracts at the same time as the right side. This side of the heart supplies oxygenated blood via the blood vessels to the tissues of the body such as muscle cells. Oxygen passes from the blood to the cells, and carbon dioxide (a waste product of aerobic respiration) passes into the blood from the cells. The blood then returns to the right atrium of the heart via the blood vessels.

Circulation through the heart is shown in Figure 2.3.

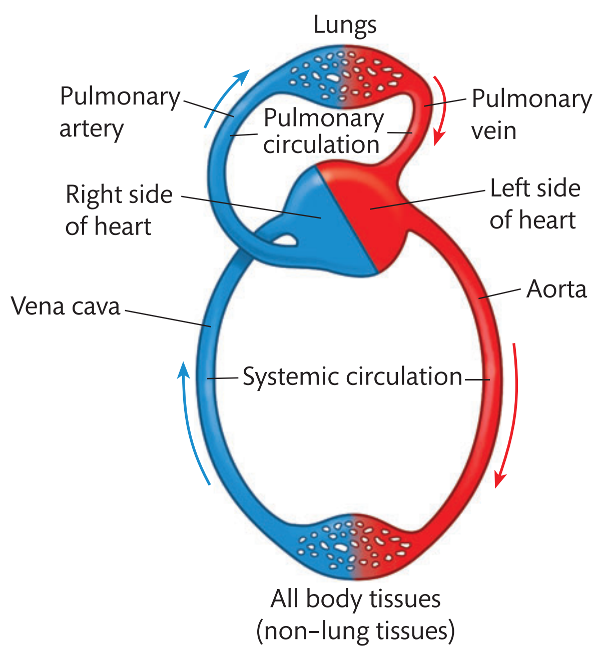


Figure 2.3: Double circulation through the heart

PAUSE POINT Describe the structure and function of the heart.

Hint Draw a basic diagram of the heart and label each part ensuring you check your spelling of anatomical terms.

Extend Label the blood flow and consider the double circulation through the heart.

Blood vessels

As the heart contracts, blood flows around the body in a complex network of vessels. There are five main blood vessels in the human body.

- **Aorta** – this is the body's main artery. It originates in the left ventricle and carries oxygenated blood to all parts of the body except the lungs.
- **Superior vena cava** – a vein that receives deoxygenated blood from the upper body to empty into the right atrium of the heart.
- **Inferior vena cava** – a vein that receives deoxygenated blood from the lower body to empty into the right atrium of the heart.
- **Pulmonary vein** – carries oxygenated blood from the lungs to the left atrium of the heart.
- **Pulmonary artery** – carries deoxygenated blood from the heart back to the lungs. It is the only artery that carries deoxygenated blood.

Structure of blood vessels

The structure of different blood vessels depends on their function and the pressure of blood within them – see Table 2.3

Table 2.3: Types of blood vessel

Blood vessel	Anatomy and location
Arteries	• Carry blood **away** from the heart and (apart from the pulmonary artery) carry oxygenated blood. • Thick muscular walls carry blood at high speeds under high pressure. As they have high pressure, they do not need valves, except where the pulmonary artery leaves the heart. • Have two major properties: **elasticity** and **contractility** – the smooth muscle surrounding them enables their diameter to decrease and increase as needed (e.g. when the heart ejects blood into the large arteries, they expand). This contractility helps maintain blood pressure as blood flow changes. • Largely deep, except where they can be felt at a pulse point. They branch into smaller arterioles that deliver blood to the capillaries.

Table 2.3: – *continued*

Arterioles	• Have thinner walls than arteries and control blood distribution by changing diameter. This adjusts blood flow to the capillaries in response to differing demands for oxygen. • For example, during exercise, muscles require increased blood flow for extra oxygen and the diameter of the arterioles leading to muscles dilates. To compensate for this increase in blood demand, other areas of the body (e.g. the gut) have their blood flow temporarily reduced, and the diameter of their arterioles is decreased.
Veins	• Allow **venous return** (the return of deoxygenated blood to the heart). • Have thinner walls than arteries and a relatively large diameter. • When blood reaches veins it is flowing slowly and under low pressure. Contracting muscles push the thin walls of the veins inwards to squeeze blood towards the heart. As muscle contractions are intermittent, a number of **pocket valves** in veins prevent any backflow when muscles relax. • Mainly close to the surface and can be seen under the skin. • They branch into venules, connected to the capillary network.
Venules	• Small vessels that connect capillaries to veins. • Take blood from the capillaries and transport this deoxygenated blood under low pressure to the veins which, in turn, leads back to the heart.
Capillaries	• Connect arteries and veins by uniting arterioles and venules. • Smallest of all blood vessels, narrow and thin. • Allow the diffusion of oxygen and nutrients required by the body's cells – their walls are one cell thick, allowing nutrients, oxygen and waste products to pass through. • The number in a muscle may increase after frequent and appropriate exercise. This means the surrounding muscles get the oxygen and nutrients to produce energy. • Pressure of blood is higher than veins, but less than arteries.

The walls of blood vessels have three layers – see Figure 2.4a and b . These surround the **lumen**, which is the blood-containing vessel.

- The inner **tunica intima** lines the lumen and creates a slick surface, minimising friction as the blood passes.
- The middle **tunica media** layer is made from smooth muscle cells and elastic tissue. Depending on the needs of the body, either **vasodilation** or **vasoconstriction** occurs.
- The outer **tunica externa** layer is made from **collagen** fibres that protect and reinforce the vessel, and keep it in place in the body's structure.

Key terms

Vasodilation – when blood vessels expand or get wider to allow more blood to enter your muscles during peak demand.

Vasoconstriction – when blood vessels tighten to restrict blood flow to tissues, such as when other parts of the body need blood more urgently.

Collagen – the most abundant protein in the body, providing strength and cushioning for body parts.

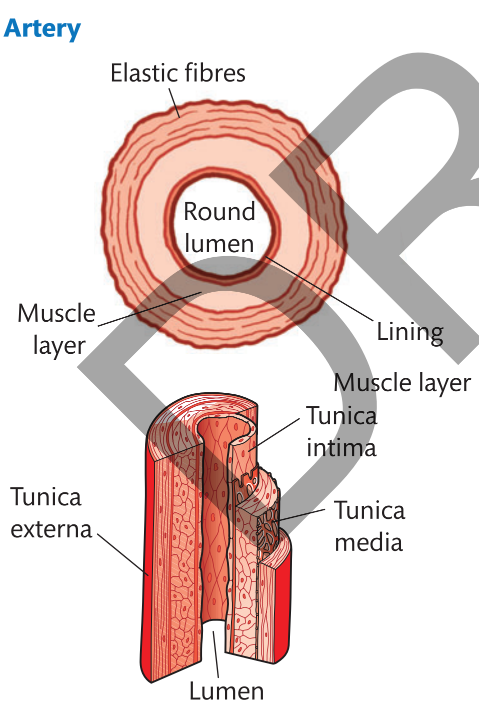


Figure 2.4a: Structure of an artery

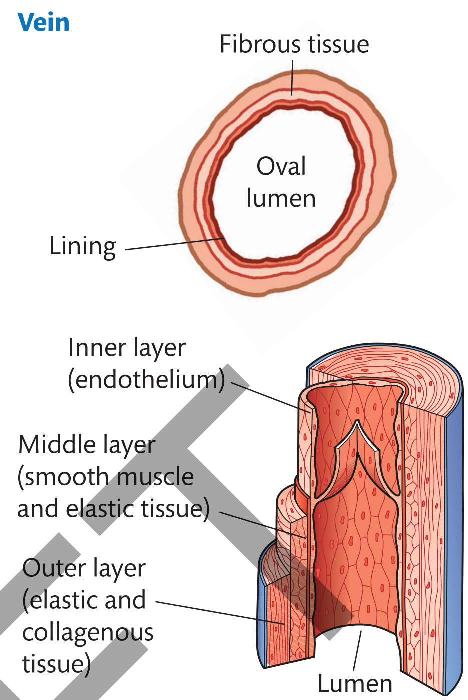


Figure 2.4b: Structure of vein

Composition of blood

The average adult has approximately 4–5 litres of blood. Blood is composed of:

- **red blood cells** (erythrocytes) – carry oxygen to all living tissue. They contain a protein called haemoglobin, giving blood its red colour, which when combined with oxygen forms oxyhaemoglobin. They are round, flattened discs with an indented shape giving them a large surface area and allowing them to flow easily within plasma. A drop of blood contains millions of red blood cells
- **plasma** – the straw-coloured liquid in which all blood cells are suspended. It is approximately 90 per cent water and contains electrolytes such as sodium, potassium and proteins. It also carries carbon dioxide, dissolved as carbonic acid
- **white blood cells** (leucocytes) – the components of blood that protect the body from infections, they account for less than 1 per cent of blood volume. They identify, destroy and remove from the body pathogens such as bacteria or viruses. They originate in bone marrow
- **platelets** (thrombocytes) – disc-shaped cell fragments produced in the bone marrow. Their primary function is clotting to prevent blood loss, sticking to the damaged area to form a temporary plug to seal the break.

PAUSE POINT Explain the functions of veins, venules, arteries, arterioles and capillaries.

Hint What are the main differences between the types of blood vessel?

Extend Explain why there are structural differences between arteries and veins.

Discussion

In groups, discuss the role and importance of the cardiovascular system in sport and exercise. Consider each component of the system. You could also consider the short-term responses of exercise to these components as well as the long-term adaptations.

Lymphatic system

The lymphatic system is a drainage system and also forms part of the immune system. The system is responsible for transporting a clear watery fluid known as **lymph** which contains white blood cells, debris of other cells and bacteria. The system helps the body get rid of excess fluid and waste products through excretion of urine and faeces.

Function of the cardiovascular system

The cardiovascular system fulfils a number of important functions, particularly during sport and exercise.

- The key function is to **supply oxygen and nutrients** to the tissues of the body via the bloodstream. During exercise your body needs more of these so the cardiovascular system responds to meet these increased demands. When it can no longer meet these demands, muscle fatigue occurs and performance deteriorates.
- The circulatory system also **carries waste products** from the tissues to the kidneys and the liver, and returns carbon dioxide from the tissues to the lungs. During exercise, muscles produce more carbon dioxide and lactate and it is essential these are removed, otherwise muscle fatigue will occur.
- The cardiovascular system is responsible for the distribution and redistribution of heat within your body to maintain thermal balance during exercise. This ensures that you do not overheat during exercise.
  - **Vasodilation of blood vessels near the skin** – during exercise the part of the active muscles where gaseous exchange takes place increases through dilation of arterioles, caused by the relaxation of the involuntary muscle fibres in the walls of the blood vessels. This causes an increase in the diameter of blood vessels to decrease resistance to the flow of blood to the area supplied by the vessels. This decreases body temperature as heat within the blood is carried to the body's surface.
  - **Vasoconstriction of blood vessels near the skin** – blood vessels can temporarily shut down blood flow to tissues. This causes a decrease in the blood vessel diameter. This leads to an increase in body temperature as heat loss reduces as blood is moved away from the surface.
- Blood provides the fluid environment for cells and is the medium which carries material to and from these cells. White blood cells (leucocytes) are essential to **fight infection** and defend against viruses and bacteria. Leucocytes are constantly produced inside bone marrow and are stored in your blood. They can consume and ingest **pathogens**, produce antibodies that will also destroy pathogens and produce antitoxins which neutralise the toxins released by pathogens.
- **Blood clotting** is a complex process during which white blood cells form solid clots. A damaged blood vessel wall is covered by a fibrin clot to help repair the damaged vessel. Platelets form a plug at the site of damage. Plasma components known as coagulation factors respond to form fibrin strands which strengthen the platelet plug. This is made possible by the constant supply of blood through the cardiovascular system.

Key term

Pathogen – a bacterium, virus or other microorganism that can cause disease.

The cardiac cycle

Your heart pumps (or beats) when the atria and ventricles work together. Both the atria and the ventricles contract independently, pushing blood out of the heart's chambers. The process of the heart filling with blood followed by a contraction where the blood is pumped out is known as the **cardiac cycle**. The electrical system of your heart is the power source that makes this possible.

Blood flow through the heart

Blood pressure is the pressure of the blood against the walls of your arteries and results from two forces:

- **systolic pressure** – the pressure exerted on your artery walls when your heart contracts and forces blood out of the heart and into the body
- **diastolic pressure** – the pressure on the blood vessel walls when the heart is relaxed between beats and is filling with blood.

During exercise your systolic blood pressure increases as your heart is working harder to supply more oxygenated blood to the working muscles. Your diastolic blood pressure stays the same or decreases slightly.

When blood pressure is measured, it is written with both the systolic and the diastolic pressure noted. The top number is the systolic pressure and the bottom number is the diastolic pressure, for example: $\frac{120}{80}$ mm HG

Neural control of the cardiac cycle

Your heart's electrical system (see Figure 2.5) is made up of three main parts.

- **Sinoatrial node (SAN)** – located within the walls of the right atrium. The SAN sends an impulse or signal from the right atrium through the walls of the atria which causes the muscular walls to contract. This contraction forces the blood within the atria down into the ventricles.
- **Atrioventricular node (AVN)** – located in the centre of the heart between the atria and the ventricles, and acts as a buffer or gate that slows down the signal from the SAN. By slowing down the signal, the atria are able to contract **before** the ventricles which means the ventricles are relaxed (or open) ready to receive the blood from the atria at the top of the heart.
- **Bundle of His** and **Purkinje fibres** – specialist heart muscle cells responsible for transporting the electrical impulses from AVN, and found in the walls of the ventricles and septum. At the end of the Bundle of His are thin filaments known as Purkinje fibres which allow the ventricle to contract at regular intervals (i.e. your regular heartbeat). This causes the blood to be pushed out of the heart, either to the lungs or to the working muscles.

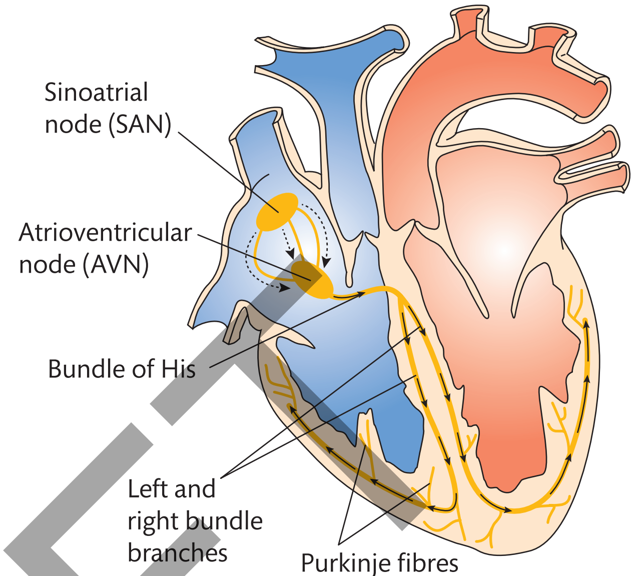


Figure 2.5: The heart's electrical system

Theory into practice

In pairs, choose a single-person sport you both enjoy. Take 8–10 minutes to perform a thorough warm-up and then take part in your chosen activity for at least 20 minutes at moderate intensity levels. At the end of the session spend approximately 5 minutes to cool down. During each part of the activity, pay close attention to the changes that are taking place in your body. Get your partner to record these for you, then swap roles.

1. During the warm-up what changes occurred to your heart rate and breathing?
2. During the main exercise what changes occurred? Think about how you felt: did you get hot? How did your body adapt to control your temperature? What do think would have happened if you had exercised at higher intensities?

PAUSE POINT

Check your knowledge of the cardiovascular system by identifying and listing the key components of this system.

Hint Describe the function of each component of the cardiovascular system.

Extend Explain why each described component is important to sport and exercise.

Assessment practice 2.1

1. Identify the function of the sinoatrial node. (1 mark)
2. Describe the function of red blood cells. (2 marks)
3. Identify the functions of the cardiovascular system. (5 marks)
4. Describe how the cardiovascular system helps the body to thermoregulate in hot environments. (4 marks)

Plan
- Have I planned my answers based on the point I want to make?
- Have I written some notes on a blank page, including key words that should be included in my answers?

Do
- Have I answered the simpler questions first, making sure I have enough time for the more complex questions?
- Have I allowed enough time to answer all the questions and to check my answers?

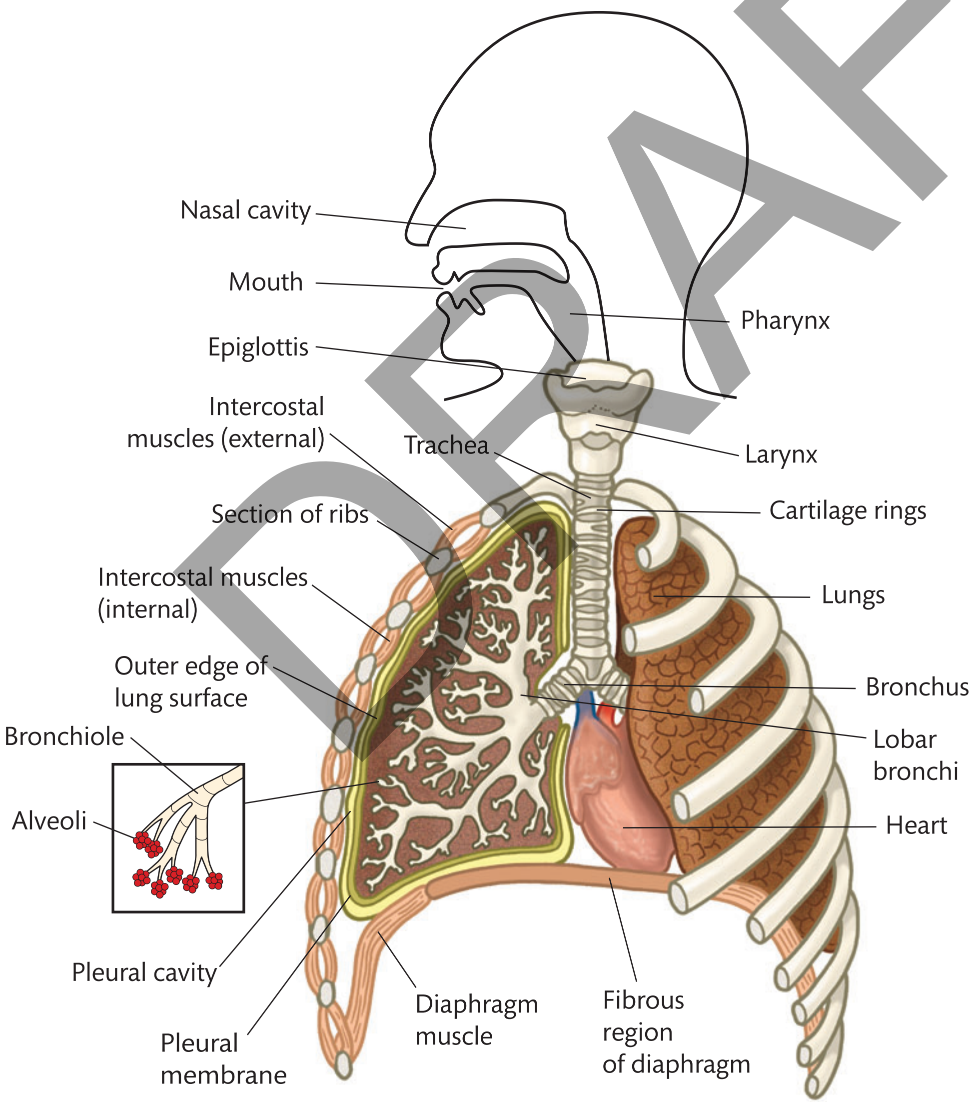
Review
- Have I re-read my answers and made any necessary changes?

C Anatomy of the respiratory system

The respiratory system provides oxygen to all living tissue in your body, and removes waste products such as carbon dioxide, heat and water vapour. Your body's ability to inhale and transport oxygen while removing waste products is critical to exercise: the better your body is at this, the better you will perform in sport.

Location, anatomy and function of respiratory system components

Air is drawn into your body via the nose and mouth, and passes through a series of airways to reach the lungs. This is referred to as the **respiratory tract**. The upper respiratory tract includes the nose, nasal cavity, mouth, pharynx and larynx; the lower respiratory tract includes the trachea, bronchi and lungs. The different parts of the respiratory system are shown in Figure 2.6 and examined in more detail in Table 2.4.



▸ **Figure 2.6:** The anatomy of the respiratory system

Table 2.4: Parts of the respiratory system

Component	Description
Nasal cavity	Air enters the nasal cavity through the nostrils. Hairs filter out dust, pollen and other foreign particles before air passes into the two passages of the internal nasal cavity. Air is warmed and moistened before passing into the pharynx. A sticky mucous layer traps smaller foreign particles, which tiny hairs (cilia) transport to the pharynx to be swallowed.
Pharynx (throat)	A small tube approximately 10–13 cm from the base of the skull to the level of the sixth cervical vertebra. The funnel-shaped pharynx connects the nasal cavity and mouth to the larynx (air) and oesophagus (food) and is a passageway for food and air, so special adaptations are required to prevent choking when food or liquid is swallowed.
Epiglottis	The small flap of cartilage at the back of the tongue which closes the top of the trachea when you swallow to ensure food and drink pass into your stomach and not your lungs.
Larynx (voice box)	Has rigid walls of muscle and cartilage, contains the vocal cords and connects the pharynx to the trachea. It extends for about 5 cm from the level of the third to sixth vertebra.
Lungs (lobes)	The organs that allow oxygen to be drawn into the body. The paired right and left lungs occupy most of the thoracic cavity and extend down to the diaphragm. They hang suspended in the right and left pleural cavities straddling the heart. The left lung is smaller than the right.
Trachea (windpipe)	The start of the lower respiratory tract. It is about 12 cm long by 2 cm in diameter. It contains rings of cartilage to prevent it collapsing and is flexible. It travels down the neck in front of the oesophagus and branches into the right and left bronchi.
Bronchus	Carry air to the lungs, divided into the right and left bronchi formed by the division of the trachea. When inhaled air reaches the bronchi, it is warm, clear of most impurities and saturated with water vapour. Once inside the lungs, each bronchus subdivides into lobar bronchi: three on the right and two on the left. The lobar bronchi branch into segmental bronchi, which divide again into smaller and smaller bronchi. Overall, there are approximately 23 orders of branching bronchial airways in the lungs. Because of this branching pattern, the bronchial network within the lungs is often called the **bronchial tree**. (See Figure 2.6.)
Bronchioles	Small airways that extend from the bronchi and connect the bronchi to small clusters of thin-walled air sacs, known as alveoli. Bronchioles are about 1 mm in diameter and are the first airway branches of the respiratory system that do not contain cartilage.
Alveoli	At the end of each bronchiole is a mass of air sacs called alveoli. In each lung there are approximately 300 million gas-filled alveoli. These are responsible for the transfer of oxygen into the blood and the removal of waste such as carbon dioxide out of the blood. This process of transfer is known as **gaseous exchange**. Combined, the alveoli have a huge surface area for maximal gaseous exchange to take place – roughly the size of a tennis court. Surrounding each alveoli is a dense network of **capillaries** (refer back to Table 2.3) to facilitate the process of gaseous exchange.
Diaphragm	A flat muscle beneath the lungs within the thoracic cavity separating your chest from your abdomen. One of several components involved in breathing which is the mechanism of drawing air – including oxygen – into the body (inhalation) and removing gases including carbon dioxide (exhalation). Contraction of the diaphragm increases the volume of the chest cavity, drawing air into the lungs, while relaxation involves recoil of the diaphragm and decreases the volume of the chest cavity, pushing air out.
Thoracic cavity	The chamber of the chest that is protected by the thoracic wall (ribcage). It is separated from the abdominal cavity by the diaphragm.
Pleura (visceral and parietal)	Each lung is surrounded by a fluid-filled membrane known as the pulmonary pleura. The outer membrane is known as the parietal membrane and lines the chest cavity while the inner membrane (visceral) lines each lung. The pleura contains pleural fluid which lubricates and reduces friction between the lungs and the thoracic cavity when breathing.
Internal and external intercostal muscles	Intercostal muscles lie between the ribs. To help with inhalation and exhalation, they extend and contract. • The **internal intercostal** muscles lie inside the ribcage. They draw the ribs downwards and inwards, decreasing the volume of the chest cavity and forcing air out of the lungs when breathing out. • The **external intercostal** muscles lie outside the ribcage. They pull the ribs upwards and outwards, increasing the volume of the chest cavity and drawing air into the lungs when breathing in.

PAUSE POINT List the key components of the respiratory system. It may be useful to draw a diagram.

Hint Describe the function of each of these components.

Extend Explain the role of the diaphragm in breathing.

Function of the respiratory system

Breathing or **pulmonary ventilation** is the process by which air is transported into and out of the lungs. The thorax increases in size to take in air, followed by a decrease to allow air to be forced out. Breathing has two clear phases.

- **Inspiration** – the process of breathing air into the lungs. The intercostal muscles contract to lift the ribs upwards and outwards, while the diaphragm is forced downwards. This expansion of the thorax in all directions causes a drop in pressure within the lungs to below atmospheric pressure (the pressure of the air outside the body), which encourages air to be drawn into the lungs.
- **Expiration** – the process of breathing air out of the lungs. It occurs when the intercostal muscles relax. The diaphragm relaxes too, moving upwards, and the ribs retract. Pressure within the lungs is increased and air is pushed out of the body.

Greater amounts of oxygen are required by the body during exercise, requiring the intercostal muscles and diaphragm to work harder. This increases your breathing rate and the force of your breath.

Gaseous exchange

Gaseous exchange is the process in which one type of gas is exchanged for another. In the lungs, gaseous exchange occurs by **diffusion** between air in the alveoli and blood in the capillaries surrounding their walls. It delivers oxygen from the lungs to the bloodstream while removing carbon dioxide. Table 2.5 shows the percentage amount of carbon dioxide and oxygen inspired and expired during respiration.

Key term

Diffusion – the process by which a substance such as oxygen passes through a cell membrane either to get into the cell or to get out of the cell. Substances move by diffusion from an area where they are more concentrated to an area where they are less concentrated.

You can see how much more carbon dioxide is exhaled than is inhaled as well as the amount of oxygen that the body extracts from the air (approximately 5%).

Table 2.5: Percentage amount of carbon dioxide and oxygen inspired and expired during respiration

Gas	% in inhaled air	% in exhaled air
Oxygen	21	16
Carbon dioxide	0.04	4

The alveolar and capillary walls form a **respiratory membrane** with gas on one side and blood flowing past on the other. Blood entering the capillaries from the pulmonary arteries has a lower oxygen concentration and a higher carbon dioxide concentration than the air in the alveoli. Oxygen diffuses into the blood via the surface of the alveoli, through the thin walls of the capillaries, through the red blood cell membrane and finally latches on to haemoglobin. Carbon dioxide diffuses in the opposite direction, from the blood plasma into the alveoli.

Lung volumes

Your **respiratory rate** is the amount of air you breathe in 1 minute. For a typical 18-year-old, this represents about 12 breaths per minute at rest, during which time about 6 litres of air passes through the lungs. During exercise this can increase by as much as 30–40 breaths per minute. The lung volume and capacities of a healthy adult are shown in Figure 2.7.

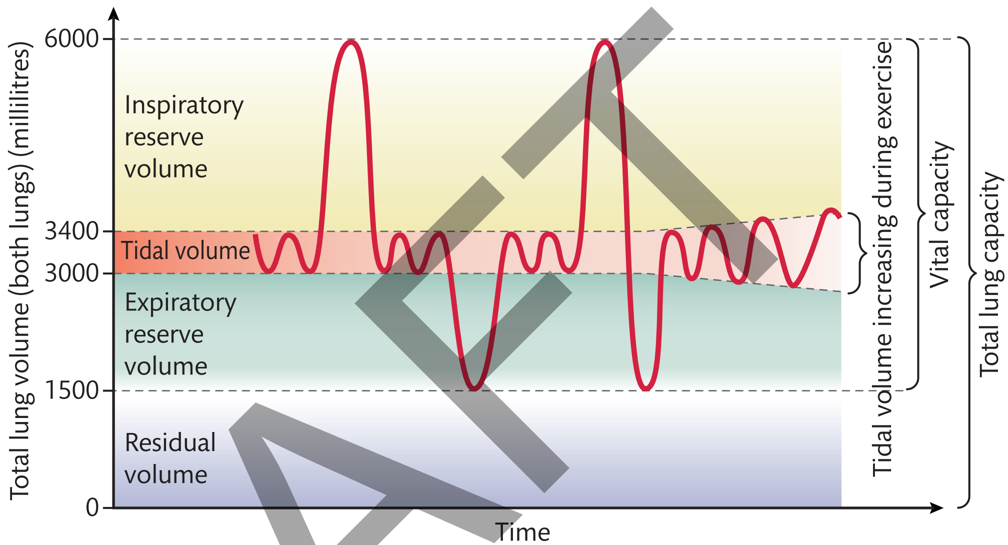


Figure 2.7: Lung volume and capacities of a healthy adult

- **Tidal volume** is the volume of air breathed in and out with each breath. Normally this represents about 500 ml of air breathed, both inhaled and exhaled. Approximately two-thirds (350 ml) reaches the alveoli where gaseous exchange takes place. The remaining 150 ml fills the pharynx, larynx, trachea, bronchi and bronchioles and is known as dead or stationary air. During exercise, tidal volume increases during exercise to allow more air to pass through the lungs. The volume of air passing through the lungs each minute is known as **minute volume**, determined by the breathing rate and the amount of air taken in with each breath.
- The lungs usually contain about 350 ml fresh air, 150 ml dead air and 2500 ml air that has already undergone gaseous exchange with the blood.
- The lungs are never fully emptied of air, otherwise they would collapse. The air remaining in the lungs after maximal expiration (when you breathe out as hard as you can) is the **residual volume**. This volume is around 1200 ml for an average male.
- **Vital capacity** is the amount of air that can be forced out of the lungs after maximal inspiration. This volume is around 4800 ml.
- By breathing in deeply, you can take in more air than usual, so more oxygen can reach the alveoli. You can breathe in up to 3000 ml of fresh air in addition to the normal tidal volume – this is known as the **inspiratory reserve volume**.
- The **expiratory reserve volume** is the amount of additional air that can be breathed out after normal expiration. This can be up to 1500 ml. At the end of a normal breath, the lungs contain the residual volume plus the expiratory reserve volume. If you then exhale as much as possible, only the residual volume remains.
- **Total lung volume** is your total lung capacity after you have inhaled as deeply and as much as you can. It is around 6000 ml for an average male.

Research

In pairs investigate **inspiratory reserve volume** and **expiratory reserve volume**. How do these relate to the normal volume of air in the lungs? How can they be affected by breathing? What benefits can they give to sports performance? Report your findings to the rest of the group.

PAUSE POINT Identify each of the different lung volumes that make up total lung volume.

Hint Describe each of these volumes and consider how exercise affects each of them.

Extend Explain why your breathing changes during exercise and the impact this has on your lung volumes.

Control of breathing

Breathing is a complex process largely under involuntary or automatic control by the respiratory centres of your brain. Remember that inspiration is an active process as the diaphragm **actively** contracts causing air to enter the lungs; expiration is a passive process as the diaphragm **relaxes** to allow air to exit the lungs. This process is controlled by neurones, cells that conduct nerve impulses, and which are part of the brain stem.

Neurones in two areas of the **medulla oblongata** are critical in respiration. These are the dorsal respiratory group (DRG) and the ventral respiratory group (VRG). The VRG is thought to be responsible for the rhythm generation that allows rhythmic and continuous breathing.

Other factors controlling breathing are the continually changing levels of oxygen and carbon dioxide. Sensors responding to such chemical fluctuations are called **chemoreceptors**. These are found in the medulla and in the **aortic arch** and **carotid arteries**. During exercise, these chemoreceptors detect changes in blood carbon dioxide levels as well as changes in blood acidity, and send signals to the medulla that will make changes in breathing rates.

Key term

Medulla oblongata – located in the middle of your brain, it is responsible for involuntary functions such as breathing, heart rate and sneezing.

Assessment practice 2.2

Felix is football player.

1 Explain the short-term effect of taking part in football on Felix's tidal volume. (3 marks)

2 Explain the role of carbon dioxide in the chemical control of breathing during exercise. (3 marks)

3 Explain the function of visceral pleura when breathing. (2 marks)

4 Describe the process of gaseous exchange in the lungs. (5 marks)

Plan

- Have I planned my longer answers by noting the key words and identifying suitable examples?
- Have I looked at the marks available and allowed time to write a full answer?

Do

- Have I structured my answers carefully to ensure I cover all the necessary points?
- Have I given relevant examples linked to the structure and function of the body system?

Review

- Have I re-read my answers? Have I included a response to the key terms?
- Have I fully answered the question making the relevant number of points linked to the marks available?

D Anatomy of the skeletal system

Anatomy of bone

Bones contain living tissue that grows, repairs and contains vital minerals. **Long bones** are the bones found in the limbs. Their primary function is to support body mass and to create large movements. Long bones such as the femur are also crucial in producing bone marrow, essential for blood cell production. The structure of a long bone is shown in Figure 2.8 and explained in more detail in Table 2.6.

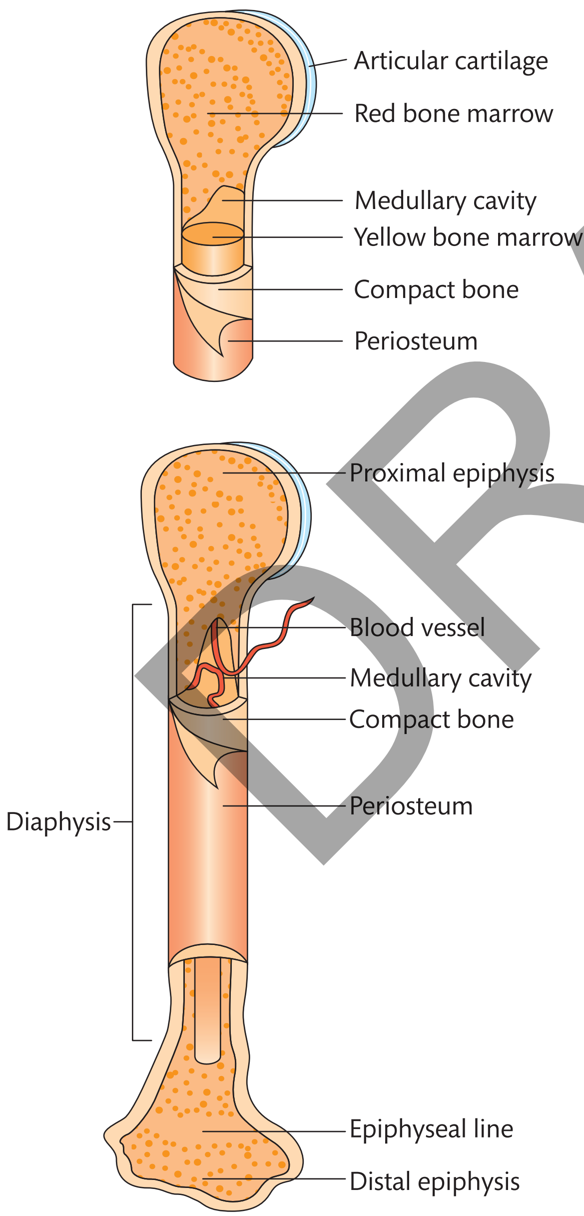


Figure 2.8: Structure of a long bone

Table 2.6: Parts of a long bone

Part of a long bone	Description
Periosteum	The tough outermost layer of the bone.
Bone minerals	Bone minerals such as calcium and phosphorus are stored within the bone. They are essential in bone creation and reabsorption of bone tissue.
Bone marrow	Soft and spongy tissue found within bones. There are two types of bone marrow: • red bone marrow which produces red blood cells, white blood cells and platelets • yellow bone marrow which produces fat and cartilage.
Epiphysis	The rounded end of the bone, it commonly forms an articulation or joint with another bone.
Diaphysis	The central shaft or long part of the bone.
Growth plates (or epiphyseal plate)	A disc of cartilage found at the end of each long bone of children and adolescents and responsible for the bone growth. It separates the diaphysis from the epiphysis and is the only place where an increase in bone length can take place. Once growing stops it is replaced by an epiphyseal line.
Cancellous bone	The spongy bone found within the ends (epiphysis) of long bones. The cancellous bone has a honeycomb appearance and provides space for the red bone marrow inside the bone structure.
Compact bone	The hard tissue surrounding the bone and often referred to as 'cortical bone'.
Articular cartilage	The ends of long bones are covered with articular cartilage, allowing bones to move over each other with minimum friction.
Medullary cavity	The space in a bone where marrow is stored.
Blood vessel	Provides blood to the bone.

Long bones of the body contain many distinct regions due to the way they develop. These include:

- **notches** – the V shaped depression at the edge of a flat area
- **fossas** – a shallow depression on the surface of the bones which commonly receive another articulating bone were a joint is formed
- **condyles** – a rounded bump or large rounded prominence which usually fits into a fossa on another bone to form a joint

- **borders** – the main portion of the bone
- **processes** – a raised area or projection that can be used to attach connective tissue
- **tuberosity** – a large rounded projection that looks like a raised bump. Tuberosities are often sites for muscle attachment.

Process of bone growth and remodelling

Bone is a living organ that is continuously being **remodelled** through a process called **ossification**. Throughout this process parts of the bone are reabsorbed, so unnecessary **calcium** is removed (via cells called **osteoclasts**) while new layers of bone tissue are created.

The cells that bring calcium to your bones are known as **osteoblasts**, and are responsible for creating bone matter. Osteoblast activity increases when you exercise, so your bones will become stronger the more exercise you do. Bone calcium stores increase to cope with the demand for calcium, so exercising also reduces the risk of osteoporosis. Weight-bearing activities build stronger bones, including tennis, netball, basketball, aerobics, walking and running.

Osteocytes form from osteoblasts and make up the majority of mature bone matter.

Key terms

Bone remodelling – the ongoing replacement of old bone tissue with new bone tissue as well as the redistribution of bone tissue to areas where stress forces are greatest.

Calcium – a mineral essential for bone growth and found in a wide range of foods including milk, cheese, yoghurt, nuts, broccoli and beans.

Osteoporosis – a medical condition where the bones become brittle and fragile from loss of tissue.

The end of each long bone contains growing areas – or plates – which allow the bone to grow longer. This continues throughout childhood until the child reaches full maturity. These areas are call the **epiphyseal plates** and allow the long bones to extend. Once a long bone is fully formed the head – or end of each bone – fuses with the main shaft (diaphysis) to create the **epiphyseal line**.

Use of minerals (calcium, vitamin D)

Calcium and vitamin D are essential in the formation, growth and remodelling of bone tissue. If the body removes more calcium than it replaces, bones will become weak and brittle. It is important your diet includes food containing calcium. This is particularly important in young children, adolescents and older people.

Vitamin D is needed to absorb calcium. Without vitamin D bones will become weaker as existing stores will be used to maintain bone structure and cannot be replaced by new calcium found in the diet.

PAUSE POINT What is bone remodelling?

Hint Draw a simple diagram of a long bone and label the key structures.

Extend Further explain the function of each of these structures.

Structure of the skeletal system

The human skeleton is made of 206 bones held together by connective tissue known as ligaments, while joints at the junction between bones provide mobility. The skeletal system (see Figure 2.9) is made up of bones, **cartilage** and joints.

Key term

Cartilage – a strong and flexible tissue that is commonly found in joints of the body. It is smooth in texture and acts to reduce friction at joints and stop bones from grinding together.

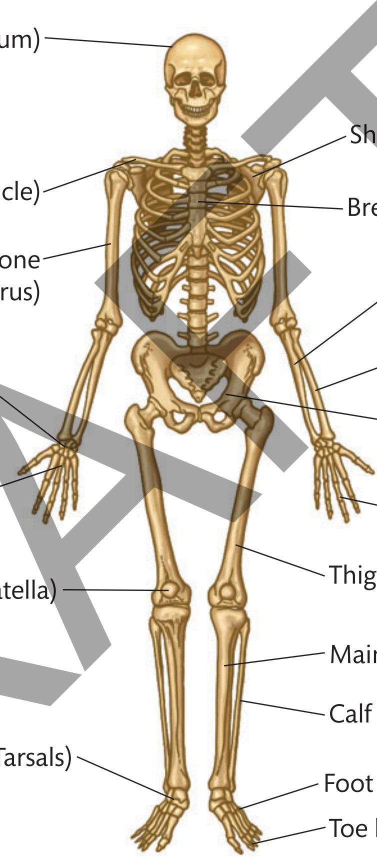


Figure 2.9: Bones of the human skeleton; Latin names are shown in brackets

Types of bone

The skeleton has five main types of bone according to their shape and size. As well as **long bones** these are:

- **short bones** – small, light, strong, cube-shaped bones consisting of cancellous bone surrounded by a thin layer of compact bone. The carpals and tarsals of the wrists and ankles (see Table 2.7) are examples of short bones
- **flat bones** – thin, flattened and slightly curved, they have a large surface area. Examples include the scapulae, sternum and cranium (see Table 2.7)
- **sesamoid bones** – these have a specialised function and are usually found within a tendon. They provide a smooth surface for the tendon to slide over. The largest sesamoid bone is the patella in the knee joint
- **irregular bones** – have complex shapes that fit none of the categories above. The bones of the spinal column are a good example.

Major bones of the skeletal system

The major bones of the skeletal system are identified in Table 2.7.

Table 2.7: Major bones of the skeletal system

Bone	Description
Cranium	Box-like cavity of interlinking segments of bone fused together. It contains and protects the brain.
Clavicles	Commonly known as the collar bones. Long, slim bones form the anterior part of the shoulder girdle. Provide a strong attachment for the arms.
Ribs	There are 12 pairs of ribs and they are part of the **thoracic cage**. The first seven pairs are 'true ribs' attached to the sternum; the remaining five are 'false ribs', i.e. not attached to the sternum. Ribs are long, flat bones.
Sternum (breastbone)	The elongated, flat bone running down the centre of the chest and forming the front of the thoracic cage. Seven pairs of ribs are attached to the sternum, providing protection and muscular attachment.
Scapula	Or shoulder bone. Large, triangular, flat bone forms the posterior part of the shoulder girdle.
Humerus	The long bone of the upper arm and the largest bone of the upper limbs. The head of the humerus articulates (joins) with the scapula to form the shoulder joint. The distal end articulates with the radius and ulna to form the elbow joint.
Radius and ulna	The ulna is the longer of the two forearm bones. The ulna and radius articulate distally with the carpals.
Carpals	Eight small bones that make up the wrist. Irregular, small bones arranged in two rows of four. They fit closely together and are kept in place by ligaments.
Metacarpals	Five long bones in the palm of the hand, one corresponding to each digit (finger). These run from the carpal bones of the wrist to the base of each digit in the hand.
Phalanges	Bones that make up the thumbs, fingers and toes. Most fingers and toes have three phalanges, but the thumbs and big toes have two.
Pelvis	Made up of two hip bones of three sections: **ilium**, **ischium** and **pubis** which fuse together during puberty. The ilium structure provides the socket for the ball and socket joint of the femur, allowing the legs to be attached to the main skeleton. The **iliac crest** is the curved superior border of the ilium.
Femur	The longest and strongest bone in the body, sometimes referred to as the **thigh bone**. The head fits into the socket of the pelvis to form the hip joint; the lower end joins the tibia to form the knee joint.
Patella	The large, triangular sesamoid bone found in the quadriceps femoris **tendon**. It protects the knee joint.
Tibia and fibula	The long bones forming the lower leg. The tibia is the inner and thicker bone, known as the **shin bone**. The upper end of the tibia joins the femur to form the knee joint, while the lower end forms part of the ankle joint. The fibula is the outer, thinner bone of the lower leg; it does not reach the knee, but its lower end does form part of the ankle joint.
Tarsals	Along with the tibia and fibula, seven bones known as tarsals form the ankle joint. The calcaneus, or heel bone, is the largest tarsal bone. It helps support the weight of the body and provides attachment for the calf muscles via the Achilles tendon. The tarsals are short and irregular bones.
Calcaneus (heel bone)	A large bone that forms the foundation of the rear part of the foot.
Metatarsals	There are five metatarsals in each foot, located between the tarsals and the phalanges (toes). Each metatarsal has a similar structure, with a distal and proximal head joined by a thin shaft (body). Responsible for bearing a great deal of weight and balancing pressure through the balls of the feet. A common site of fracture in sport.

Key term

Tendon – strong fibrous tissue that attaches muscle to a bone.

The bones that make up the wrist, hand and foot are shown in detail in Figures 2.10 and 2.11.

Figure 2.10: The bones of the wrist and hand

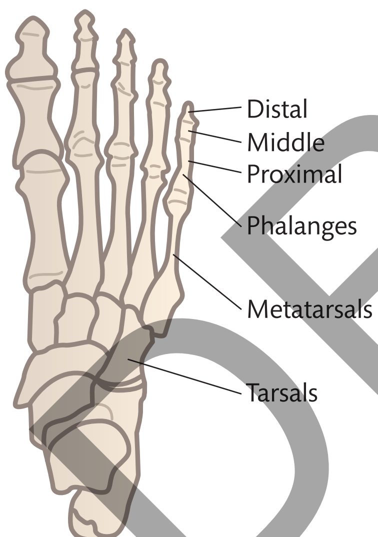


Figure 2.11: The bones of the foot

Areas of the skeleton

The skeleton can be divided into two groups: 80 bones form your **axial skeleton** (the long **axis** of your body) and the other 126 bones form your **appendicular skeleton** (the bones that are attached to this axis).

Key term

Axis – a centre line through any body or object. The body or object to either side of the line should be symmetrical (a mirror image).

Axial skeleton

The axial skeleton (see Figure 2.12) is the main core or axis of your skeleton and consists of the skull, the thoracic cage and the vertebral column.

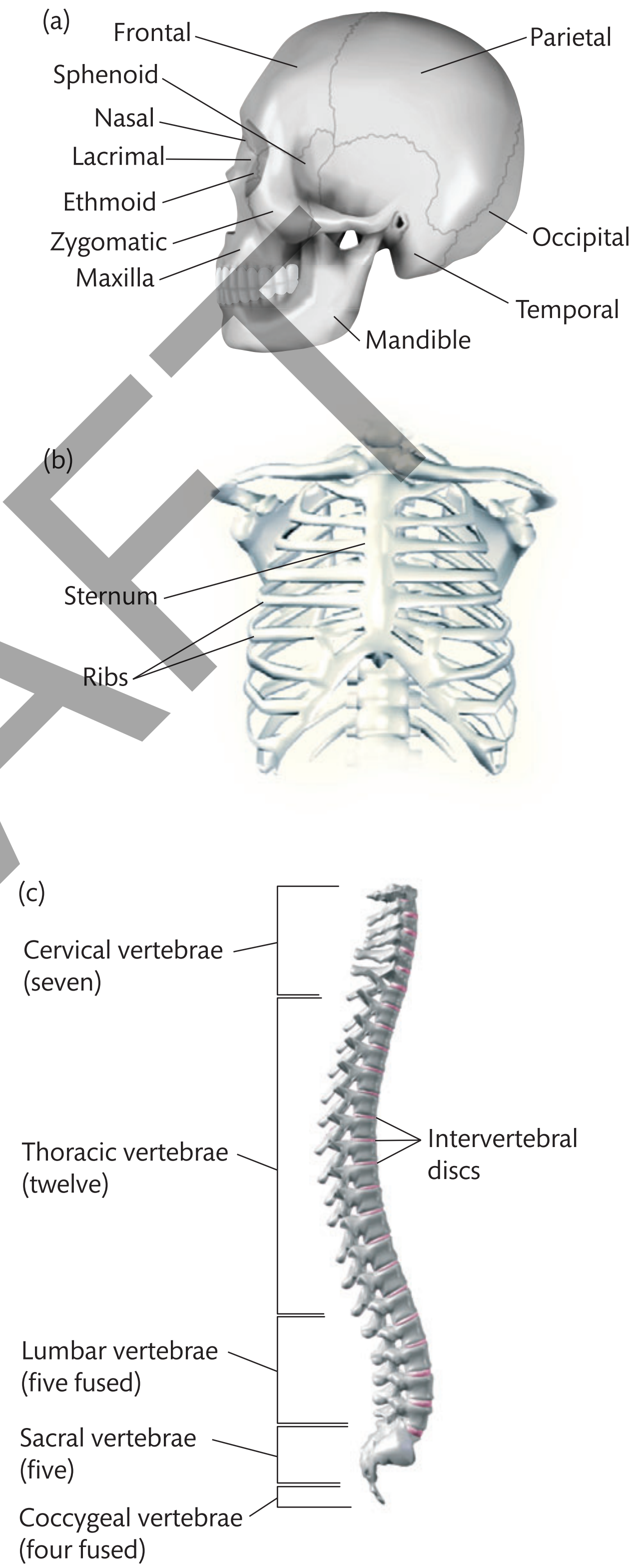


Figure 2.12: The axial skeleton: (a) the skull, (b) the thorax and (c) the vertebral column

Appendicular skeleton

The appendicular skeleton (see Figure 2.13) consists of the bones that are attached to the axial skeleton. It consists of the following parts.

- **The upper limbs** consist of 60 bones (30 in each arm) including the humerus, radius, ulna, carpals, metacarpals and phalanges.
- **The lower limbs** consist of 60 bones (30 in each leg) including the femur, patella, tibia, fibula, tarsals, metatarsals and phalanges.
- **The shoulder girdle** consists of four bones – two clavicles and two scapulae – which connect the limbs of the upper body to the thorax.
- **The pelvic girdle** is made of three bones: the ilium, pubis and ischium. These fuse together with age and are known as the innominate bone. Its main function is to provide a solid base for transmitting the weight of the upper body. It also provides attachment for the powerful muscles of the lower back and legs, and protects the digestive and reproductive organs.

The spine or vertebral column

The vertebral column is commonly known as the spine or backbone and extends from the base of the cranium to the pelvis, providing a central axis for the body. It is made up of 33 irregular bones called **vertebrae**. The vertebrae are held together by powerful **ligaments**. These allow little movement between adjacent vertebrae but a considerable degree of flexibility along the spine as a whole.

Key terms

Ligaments – short bands of tough and fibrous flexible tissue that hold bones together.

Concave – having an outline or surface that curves inwards.

The vertebral column can be classified into five sections or regions (see Figure 2.12(c)):

- **cervical vertebrae** – the seven vertebrae of the neck. The first two are known as the atlas (C1) and the axis (C2). They form a pivot joint that allows the head and neck to move freely
- **thoracic vertebrae** – the 12 vertebrae of the mid-spine, which articulate with the ribs. They lie in the thorax, a dome-shaped structure that protects the heart and lungs
- **lumbar vertebrae** – the five largest of the movable vertebrae, situated in the lower back. They support more weight than other vertebrae and provide attachment for many of the muscles of the back. The discs between these vertebrae produce a **concave** curve in the back

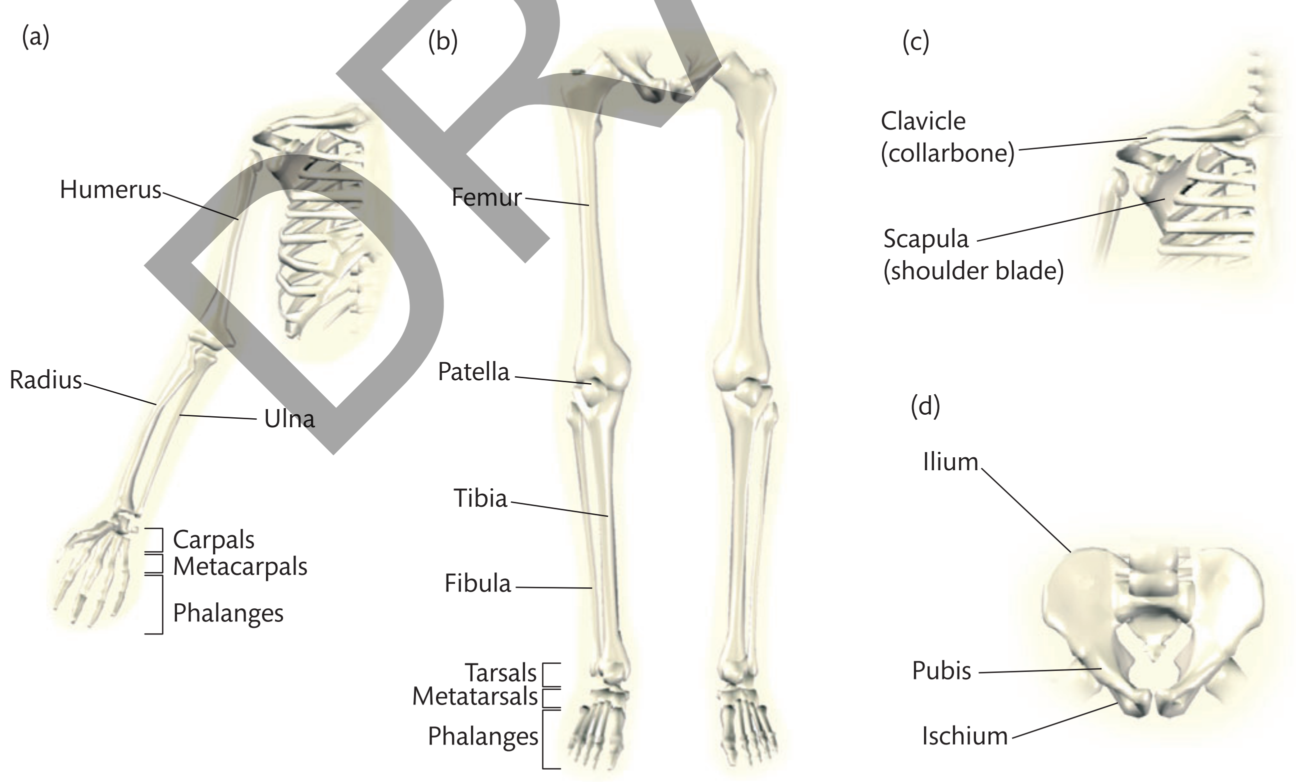


Figure 2.13: The appendicular skeleton: (a) the upper limbs, (b) the lower limbs, (c) the shoulder girdle and (d) the pelvic girdle

- **sacral vertebrae** – the five sacral vertebrae are fused together to form the **sacrum**, a triangular bone located below the lumbar vertebrae. It forms the back wall of the pelvic girdle, sitting between the two hip bones. The upper part connects with the last lumbar vertebra and the bottom part with the coccyx
- **coccygeal vertebrae** – at the bottom of the vertebral column there are four coccygeal vertebrae, which are fused together to form the **coccyx** or tail bone.

The vertebral column protects the spinal cord and supports the ribcage. The larger vertebrae of the lumbar region support a large amount of body weight. The flatter thoracic vertebrae offer attachment for the large muscles of the back and the four curves of the spine. These, along with the **intervertebral discs**, receive and distribute impact associated with sporting performance, reducing shock.

Key terms

Intervertebral discs – fibrocartilaginous cushions that act as the spine's shock-absorbing system which prevent injury to the vertebrae and brain.

Hyper-extension – a movement of a joint beyond its normal limits, normally beyond 180°.

Hyper-flexion – the flexion of a joint beyond its normal limits or range.

Articulation – where two or more bones meet.

Curves of the spine

The 33 vertebrae of the spine have a distinctive shape when stacked on top of one another. The normal shape consists of a curve in the cervical (neck), thoracic (mid back), lumbar (lower back) and sacral (bottom of spine) regions when viewing laterally. A **neutral spine** refers to a good posture with the correct position of the four natural curves. When viewing the spine from the front (anterior), it should be completely vertical.

Function of the skeletal system

The main functions of the skeletal system when performing sport or exercise are:

- **support and weight bearing** – your bones give the body shape and provide a supporting framework for the body. Bones also support the weight of your tissue
- **protection** – bones surround and protect vital tissues and organs
- **attachment for skeletal muscle** – parts of your skeleton provide a surface for your skeletal muscles to attach to, allowing you to move. Tendons attach muscles to bone, providing leverage
- **source of blood cell production** – blood vessels feed the centre of your bones and store blood marrow which continually produces red and white blood cells
- **store of minerals** – bone is a reservoir for minerals such as calcium and phosphorus, essential for bone growth and the maintenance of bone health
- **leverage** – the bones provide a lever system against which muscles can pull and movement can occur.

Ligaments

Ligaments are short bands of tough and fibrous flexible tissue holding bones together. Their primary function is to maintain joint structure and stability by holding the bones of a joint in place. However, they are also slightly elastic so the bones of the joint can move correctly. Generally the more ligaments a joint has, the stronger and more stable it is.

Ligaments also restrict excessive movements such as **hyper-extension** or **hyper-flexion**. Some ligaments also prevent movement in certain directions. For example, the ligaments of the knee control the forward and backward movement of the hinge joint as well as prevent twisting of the knee joint.

Joints

For movement to occur, bones must be linked. A joint is where two or more bones meet, known as an **articulation**. The adult body contains around 350 joints. There are three types of joint, classified according to the degree of movement they allow.

PAUSE POINT Can you name the main bone types of the skeleton and give an example of where they are located?

Hint Consider a sport of your choice and identify the bones that are used in the main actions involved in that sport.

Extend How could understanding how these bones work affect your performance in sport?

- **Fixed** (**fibrous** or **immoveable**) **joints** do not move. They form when bones interlock and overlap during early childhood. Held together by bands of tough, fibrous tissue, they are strong with no movement between the bones. An example is the bone plates in your cranium, fixed together to protect your brain.
- **Cartilaginous joints** allow slight movement and are therefore also known as **slightly moveable joints**. The ends of the bone are covered in a smooth, shiny covering known as articular or hyaline cartilage, reducing friction between the bones. The bones are separated by pads of white fibrocartilage (a tough cartilage which absorbs considerable loads). Slight movement is made possible because the pads of cartilage compress.
- **Synovial joints**, or **freely moveable joints**, offer the highest level of mobility at a joint and are vital to all sporting movements (see Figure 2.14). They make up most of the joints of your limbs. They include the following features:
    - a **joint capsule** to help to hold the bones in place and protect the joint
    - a **bursa,** a small fluid-filled sac providing a cushion between the tendons of the muscles and the bones preventing friction. Bursae are filled with synovial fluid
    - **articular cartilage** on the ends of the bones, to provide a smooth and slippery covering to stop the bones rubbing or grinding together
    - a **synovial membrane** is the capsule lining that releases synovial fluid
    - **synovial fluid** which lubricates the joint and reduces the friction. It also provides nutrients to the articular cartilage
    - **ligaments** to support the joint.

Key terms

Concaven – where the bone curves or is hollowed inwards.

Convex – curving outwards.

Research

1. What are the main ligaments of the knee and what are their functions?
2. Why are knee injuries in football relatively common?
3. Why does a ligament injury take so long to heal?

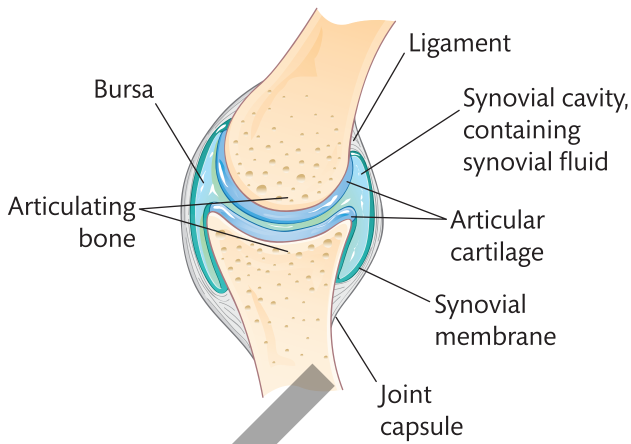


Figure 2.14: A synovial joint

Types of synovial joints

There are six types of synovial joint (see Table 2.8 and Figure 2.15) and each is categorised according to its structure and the movements it allows. These joints will permit specific movements and combined will allow you to perform complex techniques such as a somersault or a tennis serve.

Table 2.8: Types of synovial joint

Synovial joints	Description
Hinge	Allow movement in one direction only (like a door hinge), for example, elbow and knee joints which only allow movements forwards or backwards.
Ball and socket	Round end of one bone fits into a cup-shaped socket in the other bone, allowing movement in all directions. Examples include hip and shoulder joints.
Condyloid	Also known as **ellipsoidal joints**. Similar to a ball and socket joint, in which a bump (condyle) on one bone sits in the hollow formed by another. Movement is backwards and forwards and from side to side. Ligaments often prevent rotation.
Gliding	Allow movement over a flat surface in all directions, restricted by ligaments or a bony prominence, for example, in the carpals and tarsals of wrists and ankles.
Pivot	A circular bone fits over a peg of another, allowing controlled rotational movement, such as the joint of the atlas and axis in the neck, which allows you to move your head from side to side.
Saddle	Similar to condyloid joints but the surfaces are **concave** and **convex**. The joint is shaped like a saddle with the other bone resting on it. Movement occurs backwards and forwards and from side to side, like that at the base of the thumb.

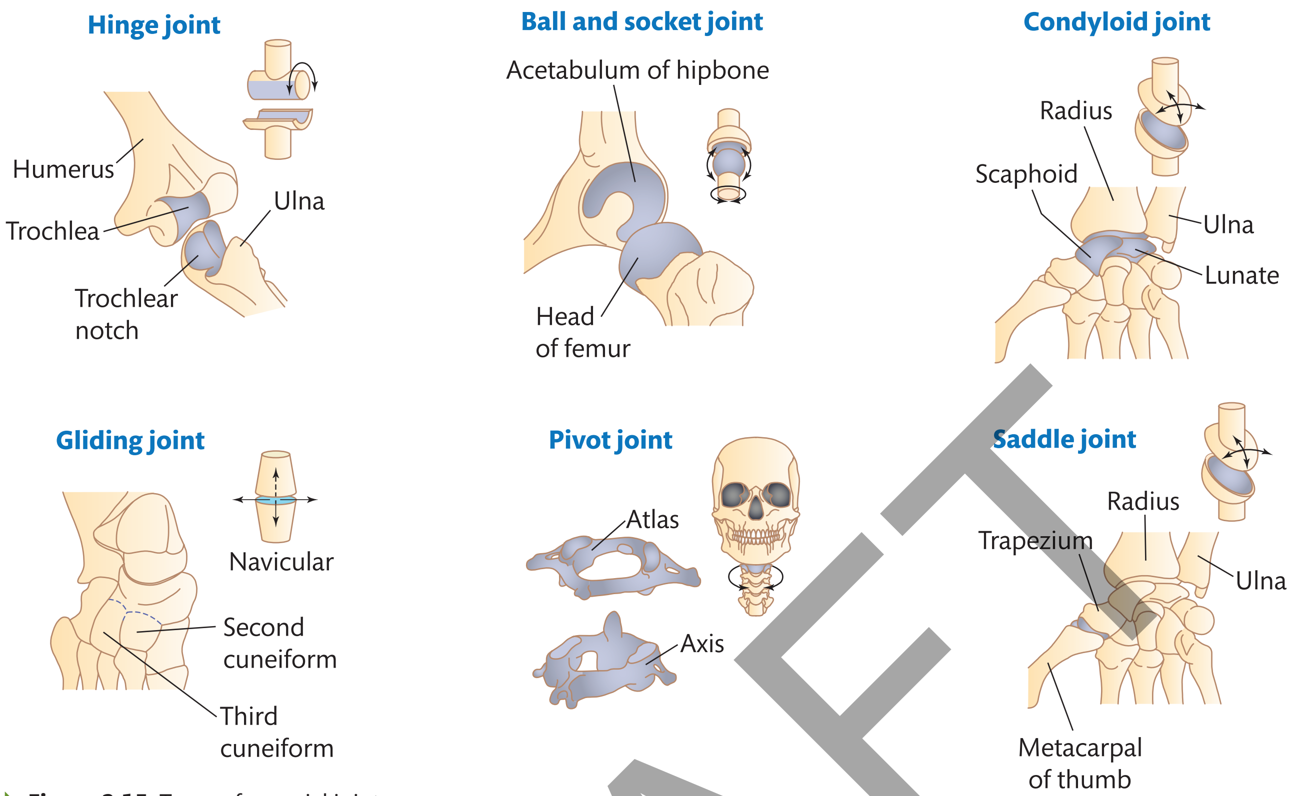


Figure 2.15: Types of synovial joint

Research

In groups, analyse a sporting movement such as a throw in cricket, a serve in tennis or a free throw in basketball. Identify the main bones being used as well as the function of those bones. You should also identify and analyse the main synovial joints that are used and how they combine to produce the overall action.

Movements at synovial joints

The types of movements that each synovial joint allows is determined by its structure and shape. Sporting techniques usually use a combination of different joints to allow a wide range of movement or technique. For example, when bowling, a cricketer will use joints in the fingers (phalanges), wrist, elbow and shoulder. They will also use the joints of the foot, ankle, knee and hip when running.

It is important that you are able to break down these techniques and identify the specific movements at each joint.

The range of motion at a joint is often referred to as joint **flexibility**. Flexibility will also depend on a number of factors including age, the tension of the supporting connective tissue (tendons) and muscles that surround the joint, and the amount of **soft tissue** surrounding the joint.

Key terms

Flexibility – the range of movement around a joint or group of joints.

Soft tissue – the tissue that connects, supports and surrounds structures such as joints or organs. It includes tendons, ligaments, skin, fat and muscles.

PAUSE POINT What are the different types of joint? Can you identify the location of each of these types of joint?

Hint Draw a synovial joint, labelling the main structural features.

Extend Explain the functions of the main structural features of your labelled synovial joint.

Assessment practice 2.3

1 Explain how the bones of the skeleton are used in movement for sport. (2 marks)

2 Describe the process of bone remodelling. (3 marks)

3 Identify the six types of synovial joint and give an example of where each one is located. (6 marks)

4 Explain the function of the axial and appendicular skeleton. (4 marks)

Plan

- What is the question asking me to do? Do I need to give sporting examples?
- What are the key words that I will need to include relating to the skeletal system?

Do

- Have I identified the key terms that need to be included in each answer?
- Have I given sufficient examples relating to the number of marks available?

Review

- Have I checked my answer? Is it clear? Did I give suitable examples?

E Anatomy of the muscular system

Muscle types

There are over 640 named muscles in the human body making up approximately 40 per cent of your body mass. There are three main types of muscle.

- **Skeletal muscle** – also known as striated or striped muscle because of its striped appearance when viewed under a microscope, this type of muscle is voluntary (under your conscious control). These muscles are critical to sport and exercise as they are connected to the skeletal system via tendons and are primarily responsible for movement. Skeletal muscles contract and as a result pull on your bones resulting in an action. They can get fatigued during exercise.
- **Cardiac muscle** – this type of muscle tissue is only found in the wall of your heart. It works continuously. It is involuntary (not under conscious control). It is composed of a specialised type of striated tissue with its own blood supply. Its contractions help force blood through your blood vessels to all parts of your body. The cardiac muscle does not fatigue which means that it does not get tired during exercise.
- **Smooth muscle** – an involuntary muscle, under the control of your nervous system, it is located in the walls of your digestive system and blood vessels and helps regulate digestion and blood pressure.

Key terms

Mitochondria – the organelles within cells in the body where aerobic respiration takes place.

Aerobic respiration – the process of producing energy using oxygen where energy is released from glucose.

Fibre types

All skeletal muscles are made up from muscle fibres. The mix of fibres varies from individual to individual, but training can influence the efficiency of these different fibre types. There are three main types.

- **Type I (slow-twitch) fibres** – contract slowly and with less force. They are slow to fatigue and suited to longer duration aerobic activities. They have a rich blood supply and contain many **mitochondria** to sustain aerobic metabolism. They have a high capacity for **aerobic respiration**.
- **Type IIa fibres (fast-twitch or fast-oxidative fibres)** – fast-contracting, able to produce a great force and resistant to fatigue. They are less reliant on oxygen for energy supplied by the blood and fatigue faster than slow-twitch fibres.

- **Type IIx fibres (fast-twitch or fast-glycolytic fibres)** – contract rapidly and have the capacity to produce large amounts of force, but fatigue faster so are better suited to **anaerobic activity**. They depend almost entirely on **anaerobic respiration** and are recruited for higher-intensity, shorter-duration activities.

Key terms

Anaerobic activity – activity where your body uses energy **without** oxygen; that is, activity that results in muscle cells using anaerobic respiration.

Anaerobic respiration – the process of breaking down glucose without oxygen to produce energy.

Discussion

Sometimes you can override a reflex or learn to ignore it. People wearing contact lenses have to overcome the blinking reflex. Can you think of any other examples of overriding a reflex?

Link

You can read more about the body's energy systems in *Unit 1: Sport and Exercise Physiology.*

Anatomy of the skeletal muscle

Skeletal muscles contain thousands of individual muscle fibres or strands (see Figure 2.16). These are combined into bundles known as fasciculi (or **fascicle** if referring to just one bundle). Each fascicle is held together by a connective tissue known as **perimysium**. Each fascicle contains between 10 and 100 muscle fibres, depending on the muscle. For example, a large muscle required to produce big powerful movements would have a large number of fibres in each fascicle. All muscle fibres (e.g. all fasciculi) are held in place by a muscle sheath known as **epimysium** which also protects the muscle from friction against other muscles and bones.

When examining an individual muscle fibre you will see these are covered in a fibrous connective tissue which acts as an insulator. This is known as the **endomysium**.

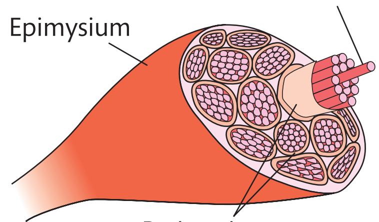


Figure 2.16: The structure of a skeletal muscle

Neuromuscular process of muscle contraction

The term 'neuromuscular' refers to both the nervous system and the muscular system. There are two kinds of nerves:

- **sensory neurons** (or nerves) which carry information **from** our extremities (the skin) to the central nervous system (the brain and spinal cord)
- **motor neurons** (or nerves) which carry information from our central nervous system **to** our muscles.

Muscles only contract when a nerve ending is stimulated by electrical impulses from the **central nervous system** (CNS).

Key term

Central nervous system – the brain and spinal cord responsible for transferring electrical impulses.

A muscular contraction occurs when the CNS sends a signal or **nerve impulse** to the muscle. This is received by a motor neurone contained within the muscle fibres and converts the impulse into a muscular contraction. The site where this occurs is known as the **neuromuscular junction** or **synapses**. When the impulse is received the motor neuron releases a chemical (**acetylcholine**) which transmits the signal into a muscle fibre resulting in a contraction. The release of acetylcholine occurs at the **neurotransmitter**.

When a motor neuron is not conducting an impulse it has a resting potential. This changes when a stimulus reaches a resting neuron. The motor neuron transmits the signal known as the action potential.

PAUSE POINT Can you explain how different muscle fibre types affect sport?

Hint List three sports and the types of muscle fibres required for each.

Extend Explain why your chosen sports require these fibres and how an athlete can use them to improve performance.

Sliding filament theory

Sliding filament theory explains how muscles contract (see Figure 2.17). Muscles are comprised of thin muscle fibres know as **myofibrils** each containing **myosin** and **actin** filaments in series (one after the other). During contraction, myosin filaments attach to actin filaments forming chemical bonds called **crossbridges**. This basic unit of a muscle cell is known as a **sarcomere**. Sarcomeres give skeletal muscle tissue its striped or striated appearance. Each sarcomere is divided into different areas as follows:

- **H zone** – the centre of the A band of each sarcomere. Here there are only thick filaments, no thin filaments
- **Z line** – the area at each end of separate sarcomeres where the actin filaments are attached
- **A band** – the active area where contraction takes place between the actin filaments and the myosin filaments. It is the relatively dark area of the sarcomere and contains the thick filaments
- **I band** – the region between adjacent A bands, in which there are only thin filaments and no thick filaments. Each I band extends across two adjacent sarcomeres.

Myosin molecules act like a ratchet, while actin molecules form passive filaments transmitting the force generated by the myosin to the ends of the muscle tissue. The myosin progresses along an actin filament, constantly binding, ratcheting and then letting go. This process allows muscles to contract. When the muscle does not need to contract, thin strands of a further protein (**tropomyosin**) are wrapped around the actin filaments to stop the myosin from binding. As a muscle undergoes contraction:

- molecules called **troponin** attach to tropomyosin
- **calcium ions** are introduced into the muscle cell and bind with troponin
- calcium binding changes the shape of troponin, causing tropomyosin to move, exposing actin
- myosin is now free to bind with actin and the muscle contracts.

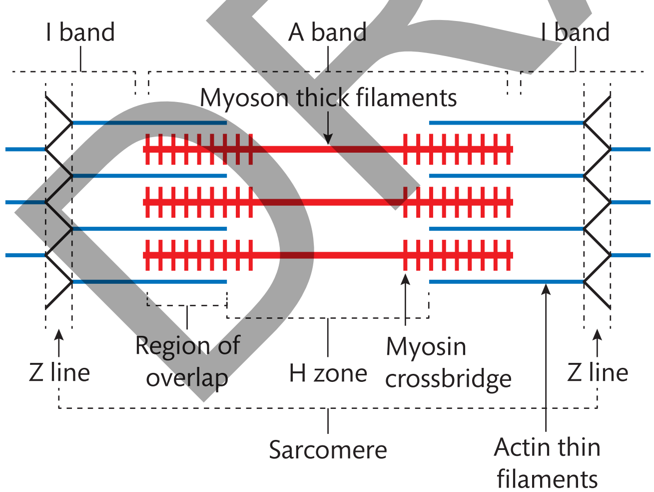


Figure 2.17: Sliding filament theory

Troponin and tropomyosin are proteins that form part of the thin or actin filament. Tropomyosin is a rod-shaped protein that spirals about the actin core to stiffen it. Troponin binds to the tropomyosin and helps it bind to the actin. The skeleton is the major mineral storage site for calcium and releases calcium ions into the bloodstream under controlled conditions. Circulating calcium is either ionised or bound to blood proteins such as troponin. The ions are stored in the **sarcoplasmic reticulum** of muscle cells.

Key term

Sarcoplasmic reticulum – regulates the calcium ion concentration in the muscle cells.

> **Link**
>
> You can read more about ATP, ADP, phosphate and reversible reaction in *Unit 1: Sport and Exercise Physiology*.

ATPase is an enzyme that catalyses (speeds up) the following reversible reaction enabling a quick supply of energy for muscle contraction:

$$ATP + H_2O \Leftrightarrow ADP + phosphate$$

Types of skeletal muscle contraction

There are three different types of muscle contraction.

- **Concentric** – when you make any movement such as a bicep curl, your muscle will shorten as the muscle fibres contract. In the bicep curl, the brachialis and bicep shorten, bringing your forearm towards your upper arm. They are sometimes known as the **positive phase** of muscle contraction.
- **Eccentric** – when a muscle returns to its normal length after shortening against resistance. In a bicep curl this is the controlled lowering of your arm to its starting position. At this point your muscles work against gravity and act like a brake. This can be easier to perform but does produce muscle soreness. Eccentric contraction can be a significant factor in the stimulus that promotes gains in muscle strength and size. Eccentric contractions are sometimes known as the **negative phase** of muscle contraction.
- **Isometric** – the length of a muscle does not change and the joint angle does not alter. However, the muscle is actively engaged in holding a static position, for example, during the abdominal plank. This work is easy to undertake but rapidly causes fatigue. It can cause sharp increases in blood pressure as blood flow is reduced.

> **Key term**
>
> **Motor unit** – made up of a motor neuron and all the associated fibres it affects. Motor units work together to coordinate contractions of a single skeletal muscle.

All or none law

For a muscle to contract it must receive a nerve impulse and this stimulus must be sufficient to activate at least one **motor unit** which contains the motor neuron (nerve cell) and the attached muscle fibres. Once activated, **all** the muscle fibres within the motor unit will contract and produce a muscle twitch. This is known as the 'all or none' law as muscle fibres either respond completely (all) or not at all (none). For more intense exercises, more motor units will be recruited or used and therefore more fibres will contract.

> **Discussion**
>
> Muscles can only pull on a bone, they can never push. In small groups, discuss a rugby scrum where a pushing force is required. Explain how a pushing force is created when muscles can only pull. What muscles are being used to create this movement?

PAUSE POINT Can you explain the importance of different muscle contractions in sport?

Hint For a press-up, what types of contraction are taking place for each phase at the shoulder joint?

Extend Explain why these contractions are important in sport and exercise.

Major skeletal muscles of the muscular system

Skeletal muscles are voluntary muscles, meaning you must send a conscious signal from your brain to your muscles to perform any sporting action. Skeletal muscles are attached to your skeleton by tendons which pull on specific bones when a muscle contracts. Skeletal muscles provide you with movement, strength and power and are also responsible for maintaining posture and body temperature. Figure 2.18 and Table 2.9 will help you locate the main ones which are important to sport and exercise.

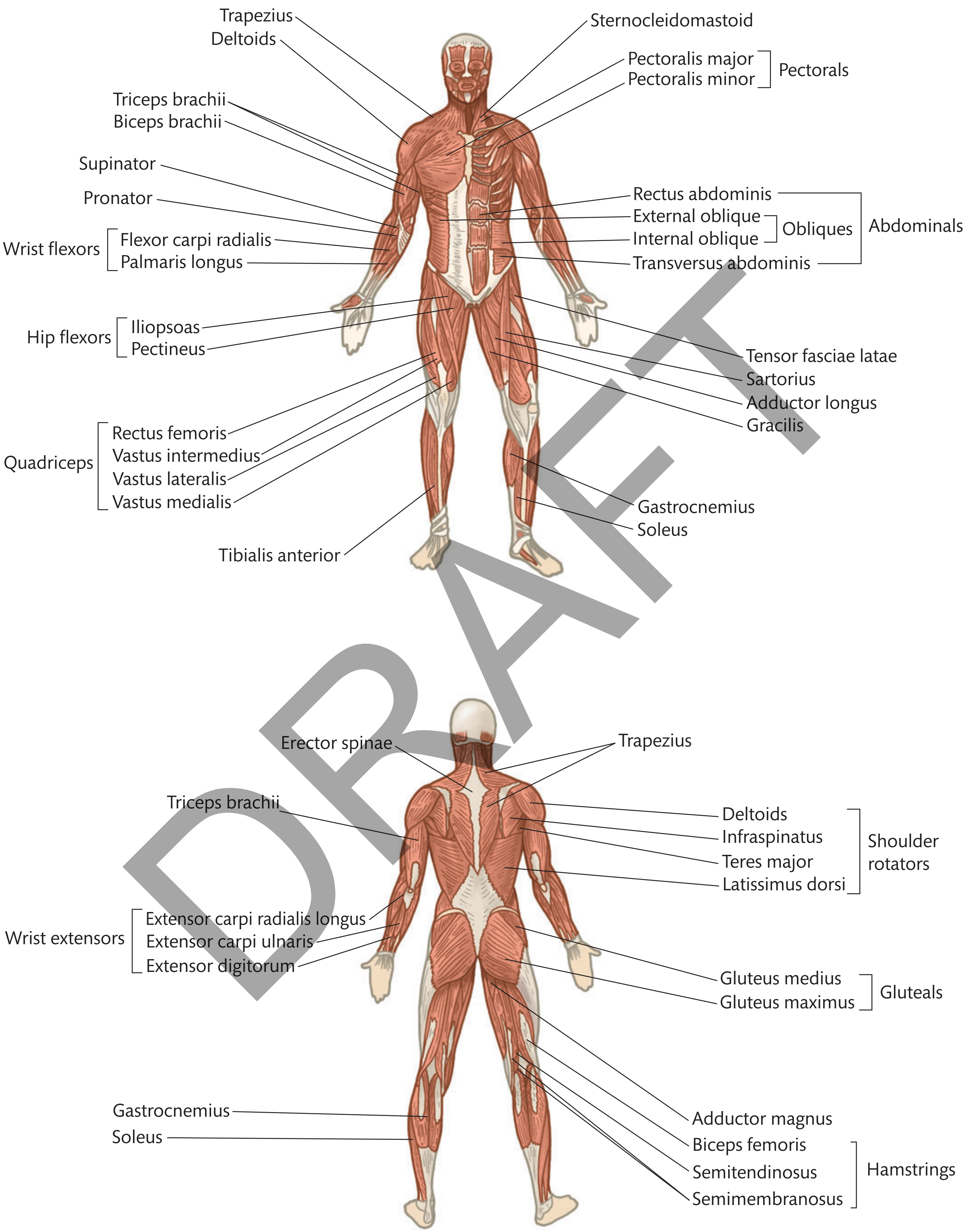


Figure 2.18: Major skeletal muscles and their location

Table 2.9: Major skeletal muscles and their function

Muscle	Function	Location	Origin	Insertion	Exercise/activity
Triceps brachii	Extends lower arm	Outside upper arm	Humerus and scapula	Olecranon process	Dips, press-ups, overhead pressing
Deltoids • posterior • anterior • medial	Abducts, flexes and extends upper arm	Forms cap of shoulder	Clavicle, scapula and acromion	Humerus	Forward, lateral and back-arm raises, overhead lifting
Shoulder rotators • medial • lateral	Provide stability of shoulder joint Rotation of humerus	Shoulder joint	Scapula	Humerus	Forward, lateral and back-arm raises, overhead lifting
Pectoralis major	Flexes and adducts upper arm	Large chest muscle	Sternum, clavicle and rib cartilage	Humerus	All pressing movements
Sternocleidomastoid	Rotates the head	On both sides of neck (cervical vertebrae)	Clavicle	Temporal bone (side of skull)	Rotation of head such as looking in different directions
Biceps brachii	Flexes lower arm at the elbow	Front of upper arm	Scapula	Radius	Bicep curl, pull-ups
Wrist flexors	Flexes hand at the wrist	Front of forearm	Humerus	Metacarpal	Bouncing a basketball when dribbling
Wrist extensors	Extends or straightens hand at the wrist	Back of forearm	Humerus	Metacarpal	Straightening of wrist
Forearm supinator	Supinates the forearm	Top and rear of forearm	Humerus	Ulna	Back spin in racquet sports
Forearm pronator	Pronates the forearm	Top and front of forearm	Humerus	Ulna	Top spin in racquet sports
Rectus abdominis	Flexes and rotates lumbar region of vertebral column	'Six-pack' muscle running down abdomen	Pubic crest and symphysis	Xiphoid process	Sit-ups
Transverse abdominis (TVA)	Provides stability of the spine and pelvis Maintains posture	Front and side of abdomen	Anterior iliac crest	Pubic crest and symphysis	Contracts during most weightlifting as it provides stability to the back (core strength)
Iliopsoas	Flexes hip joint (lifting thigh at hip)	Lumbar region of spine to top of thigh (femur)	Lumbar vertebrae	Femur	Knee raises, lunges, squat activation
Quadriceps • rectus femoris • vastus intermedius • vastus lateralis • vastus medialis	Extends lower leg and flexes thigh	Front of thigh	Ilium and femur	Tibia and fibula	Squats, knee bends
Hamstrings • biceps femoris • semitendinosus • semimembranosus	Flexes lower leg and extends thigh	Back of thigh	Ischium and femur	Tibia and fibula	Leg curls, straight leg deadlift
Gastrocnemius	Plantarflexion, flexes knee	Large calf muscle	Femur	Calcaneus	Running, jumping and standing on tiptoe
Soleus	Plantarflexion	Deep to gastrocnemius	Fibula and tibia	Calcaneus	Running and jumping
Tibialis anterior	Dorsiflexion of foot	Front of tibia on lower leg	Lateral condyle	By tendon to surface of medial cuneiform	All running and jumping exercises

Table 2.9: Major skeletal muscles and their function – *continued*

Erector spinae	Extends spine	Long muscle running either side of spine	Cervical, thoracic and lumbar vertebrae	Cervical, thoracic and lumbar vertebrae	Prime mover of back extension
Rhomboids (not shown in Figure 2.18)	Retract the scapula toward the vertebral column; hold the scapula against thoracic cage	Upper back between the scapula and the vertebral column	Thoracic vertebra	Scapula	Shoulder raise
Trapezius	Elevates and depresses scapula	Large triangular muscle at top of back	Continuous insertion along acromion	Occipital bone and all thoracic vertebrae	Shrugging and overhead lifting
Latissimus dorsi	Extends and adducts lower arm	Large muscle covering back of lower ribs	Vertebrae and iliac crest	Humerus	Pull-ups, rowing movements
Obliques	Flexes trunk laterally	Waist	Pubic crest and iliac crest	Fleshy strips to lower eight ribs	Oblique curls
Gluteals • Gluteus maximus • Gluteus medius • Gluteus minimus (not shown in Figure 2.18)	Extends thigh	Large muscle on buttocks	Ilium, sacrum and coccyx	Femur	Knee-bending movements, cycling, squatting

Antagonistic muscle pairs

When a muscle contracts, it exerts a pulling force on the bones it is attached to, causing movement at joint. Muscles must cross the joints that they move – without this no movement can occur.

Muscle fibres work on an 'all or nothing' basis – either contracting completely or not at all. At the point of contraction your muscles shorten and pull on the bones they are attached to. When a muscle contracts, one end normally remains stationary while the other is drawn towards it. The end that remains stationary is known as the **origin**, and the moving end is called the **insertion**.

Key terms

Origin – the fixed end of the muscle that remains stationary.

Insertion – the end of the muscle that moves. The insertion usually crosses over a joint to allow movement when the muscle shortens.

Muscles are assembled in groups and work together to bring about movement. They act only by contracting and pulling. They do not push, but can contract without shortening and hold a joint fixed in a certain position. When the contraction ends, the muscles become soft but do not lengthen until stretched by the contraction of the opposing muscles. This is known as **antagonistic pairs** of muscles. Figure 2.19 shows how the bicep and tricep work together to perform a bicep curl.

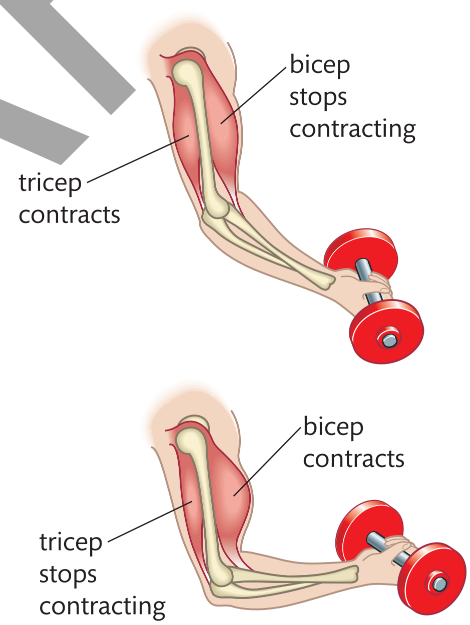


Figure 2.19: Bicep and tricep muscles work together during a bicep curl

Reflect

Consider the main muscle contracting and the opposite relaxing during a movement. What happens when the opposite movement occurs?

- The muscle that shortens to move a joint is called the **agonist** or prime mover. This is the muscle principally responsible for the movement taking place – the contracting muscle.

- The muscle that relaxes in opposition to the agonist is called the **antagonist**. If it did not relax, movement could not take place. Antagonists exert a 'braking' control over the movement.
- **Synergists** are muscles that enable the agonists to operate more effectively. They work with the agonists to control and direct movement by modifying or altering the direction of pull to the best position.
- **Fixator** muscles stop any unwanted movement by fixing or stabilising the joint or joints involved. Fixator muscles stabilise the origin so that the agonist can achieve maximum and effective contraction.

PAUSE POINT Can you name the main skeletal muscles and where they are located?

Hint Consider a sport and describe the role of the specific muscles used in this sport.

Extend Think of a sporting movement and list the pairs of muscles being used for each phase of the movement.

Types of movement

Muscles can combine to achieve the movements shown in Table 2.10, all of which are common across a wide range of sports.

Table 2.10: Types of movement

Type of movement	Description
Flexion	Reducing the angle between the bones of a limb at a joint: muscles contract, moving the joint into a bent position. Examples include bending the knee when preparing to kick a football
Hip flexion	Moving the femur forwards reducing the angle between the thigh and the anterior torso
Shoulder flexion	Raising the arm at the shoulder joint
Hip extension	Moving the femur backwards increasing the angle between the thigh and the anterior torso
Shoulder extension	Lowering the arm at the shoulder joint
Dorsiflexion	An upward movement, e.g. moving the foot to pull the toes towards the knee in walking
Plantarflexion	A movement that points the toes downwards by straightening the ankle, e.g. jumping to defend in netball
Lateral flexion	The movement of bending sideways, for example, at the waist
Extension	Straightening a limb to increase the angle at the joint, e.g. straightening your arm to return to your starting position in a bicep curl
Hyper-extension	Movement beyond the normal anatomical position in a direction opposite to flexion, e.g. at the spine when a cricketer arches their back when bowling
Horizontal flexion and horizontal extension	Bending the elbow (flexion) while the arm is in front of your body; straightening the arm at the elbow is extension
Abduction	Movement away from the body's vertical midline, e.g. at the hip in a side-step in gymnastics
Adduction	Movement towards the body's vertical midline, e.g. pulling on the oars while rowing
Horizontal abduction and adduction	Movement of bringing your arm across your body (flexion) and then back again (extension)
Rotation	Circular movement of a limb. Rotation occurs at the shoulder joint during a tennis serve. Rotation can also occur at the hip and a movement where the thigh moves outwards is known as lateral rotation whereas the movement where the thigh moves inwards is known as medial rotation
Circumduction	A circular movement that results in a conical action
Pronation	A rotational movement where the hand and upper arm are turned inwards. Also where the foot is turned outwards at the ankle
Supination	Where the forearm or palm are rotated outwards. Also where the foot is turned inwards at the ankle
Elevation	An upwards movement (superior), e.g. shrugging where the scapular is raised

Table 2.10: Types of movement – *continued*

Type of movement	Description
Depression	The opposite of elevation and involves a downwards or inferior action
Protraction	A forward movement away from the frontal plane of motion, e.g. the shoulder joint moving forward during the reaching phase of a rowing action
Retraction	A backwards movement towards the frontal plane of motion, e.g. the shoulder joint moving backwards during the pulling phase of a rowing action

Planes of movement

Sporting movements are based on planes and axes of movement. There are three planes.

- **Sagittal plane** – splits the body into imaginary left and right halves. Movements in the sagittal plane are related to flexion and extension (side to side). Running and cycling will take place in the sagittal plane.
- **Frontal plane** – separates the body into imaginary front to back halves. Movements in the frontal plane are related to abduction and adduction (front to back). Raising your arms to the side will take place in the frontal plane.
- **Transverse plane** – splits the body into imaginary top to bottom halves. Movements in the transverse plan are related to rotation (up and down). Twisting movements such as turning your head will take place in the transverse plane.

Link

Axes of movement are covered in Unit 7, on page XXX.

Assessment practice 2.4

1. Explain the different muscle fibre types, giving an example of a sport that would predominantly use each one. (3 marks)
2. Describe the three types of muscular contraction and give an example of an exercise for each that would use each one. (3 marks)
3. Explain sliding filament theory in relation to muscular contraction. (6 marks)
4. Giving a sporting example, describe each of the following actions: extension, rotation, supination, circumduction, protraction. (5 marks)

Plan

- What are the key terms and words being used in the question?
- Do I need to include specific examples, such as different types of movement?

Do

- Have I written down the key words and explained them?
- Have I contextualised my answers by giving relevant examples?

Review

- Have I given sufficient examples linked to the marks available?
- Have I broken down any movements into key phases and explained all the key terms used?

F Analysis of the skeletal and muscular systems and how they produce movements in sport and exercise

Phases of sport and exercise movement

All sport and exercise movements require interaction and coordination of the skeletal and muscular systems. The muscular system allows the athlete to maintain posture, holding joints in place and providing muscular contractions that pull on the bones of the skeletal system, resulting in movement. There are three phases in these movements.

- **Preparation** – where the athlete is preparing to undertake an action or exercise, they will be both physically and psychologically preparing themselves. During this phase the athlete may consider what they wish to achieve, for example, where they wish to place the football when taking a penalty.
- **Execution** – immediately following the preparation phase, the athlete will perform the planned action. This will involve the interaction of the muscular and skeletal systems to produce the chosen movement or technique.
- **Follow through** – this is the action the body undertakes following the execution of a movement or **technique**. This may involve slowing down a body part using the muscular system or a change in direction.

Key term

Technique – a series of basic movements that combine to result in a recognised sporting or exercise movement.

Case study

Sporting movements

Many sporting movements look complex but in reality they can be viewed and analysed as separate, smaller movements. It is commonplace for modern coaches to use video equipment to film specific techniques so that the series of movements can be analysed and discussed with the athlete.

Consider the action of throwing a ball. You will use a number of different joints including the ball and socket joint of the shoulder, the hinge joint of the elbow and the gliding joints of the wrist (carpals). In combination with the skeletal muscles, you will be able to use the long bones as levers to produce a large powerful movement in order to throw the ball.

Check your knowledge

1. Can you think of any other sporting techniques that are similar to throwing a ball?
2. What sports share the same movements?
3. How would a coach benefit from being able to identify different and identical sporting movements?

Interrelationship of muscular and skeletal systems in movement analysis

When examining the three phases of a sporting movement, it is useful to examine the different body sections separately so a detailed analysis can be conducted. The three broad body sections that can be analysed are:

- the upper trunk including the shoulders and arms
- the trunk (main torso)
- the lower body.

Being able to break movement down into smaller body parts will make it easier for you to analyse the chosen sporting or exercise movement during the three phases.

For each of the phases and body areas you should consider:

- the bones being used (including their type)
- the muscles being used, the role or function they are playing in the movement and the types of contraction taking place
- the type of joint being moved
- the type of action occurring, such as flexion
- the planes of movement that are involved.

Remember it is easier to break down complex actions such as a rugby place kick into smaller stages so a clear analysis can be made – and many sports and exercise techniques share the same basic movements, such as running, jumping and throwing. Having an understanding of each of these will allow you to transfer your knowledge to a wider range of sporting movements.

Worked example: the rugby place kick

- The action of kicking takes place in a sagittal plane about a frontal axis and involves the hip, knee and ankle joints.
- The hip bones involved are the femur and pelvic girdle which form a ball and socket joint.
- The knee bones involved are the femur and tibia which form a hinge joint.
- The ankle bones involved are the tibia and calcaneus.
- Kicking comprises three phases: the preparatory phase, execution phase and the follow through phase.

The three phases can be summarised as shown in Tables 2.11, 2.12 and 2.13.

Table 2.11: The preparation phase of a rugby place kick

Joint	Joint type	Joint movement	Agonist	Type of contraction of agonist	Antagonist
Left shoulder	Ball and socket	Abduction	Middle deltoid	Concentric	Latissimus dorsi
Right hip	Ball and socket	Extension	Gluteus maximus	Concentric	Iliopsoas
Right knee	Hip	Flexion	Biceps femoris, semitendinosus, semimembranosus	Concentric	Rectus femoris, vastus lateralis, vastus medialis, vastus intermedius

The preparation phase of a rugby place kick

Table 2.12: The execution phase of a rugby place kick

Joint	Joint type	Joint movement	Agonist	Type of contraction of agonist	Antagonist
Left shoulder	Ball and socket	Horizontal flexion	Pectoralis major	Concentric	Trapezius
Spine	Cartilaginous Pivot Gliding	Rotation	External obliques	Concentric	Internal obliques
Right hip	Ball and socket	Flexion	Iliopsoas	Concentric	Gluteus maximus
Right knee	Hinge	Extension	Rectus femoris, vastus lateralis, vastus medialis, vastus intermedius	Concentric	Biceps femoris, semitendinosus, semimembranosus
Right ankle	Hinge	Dorsiflexion	Tibialis anterior	Concentric	Gastrocnemius

The execution phase of a rugby place kick

Table 2.13: The follow through phase of a rugby place kick

Joint	Joint type	Joint movement	Agonist	Type of contraction of agonist	Antagonist
Left shoulder	Ball and socket	Horizontal extension	Trapezius	Concentric	Pectoralis major
Spine	Cartilaginous Pivot Gliding	Rotation	Internal obliques	Concentric	External obliques
Right hip	Ball and socket	Extension	Gluteus maximus	Concentric	Iliopsoas
Right knee	Hinge	Flexion	Biceps femoris, semitendinosus, semimembranosus	Concentric	Rectus femoris, vastus lateralis, vastus medialis, vastus intermedius
Right ankle	Hinge	Dorsiflexion	Gastrocnemius	Concentric	Tibialis anterior

The follow through phase of a rugby place kick

Movement efficiency

Link

This section links with *Unit 7: Biomechanics in Sport and Exercise Science*.

Sport and exercise can be very strenuous on the body, with large internal and external forces applied to the skeletal and muscular systems. It is essential when undertaking a sporting technique that you only use the body parts required for the movement. This will prevent wasted energy and limit unwanted movement that may have a negative effect on your technique and performance.

- **Static and dynamic balance** are basic skills needed in practically every sport activity. Ensuring your joints are stable will provide you with a platform to perform complicated sporting movements. Your muscular system will help by using fixator muscles to ensure specific joint actions only occur when required.
- A **kinetic chain** is a series of joint movements contributing to an overall complex movement. For example, a basketball free throw can be broken down into movement at the ankles, knee, hip, shoulder, elbow and wrist. Each of these joint movements will affect the overall action or technique.
- Most actions occur **across different body segments**, for example, a bowler in cricket uses the lower body to run and create speed and this supports the action of the upper body in generating the power and technique to deliver the ball. Each separate action will have an effect on the other parts of the body within the overall action.
- To ensure your body can cope with the demands placed on it while maintaining performance, your skeletal and muscular system will **transfer the forces** so that one specific area is not overloaded. This transfer of loads also helps maintain movement efficiency as one particular area will not become overworked.
- When one muscle is stronger than its opposing muscle, you do not have **muscle balance**. For instance, if you do push-ups or bench presses daily, but never do rows, pull-ups, or other upper body pulling movements, there is a chance your chest will become stronger than your back, and you have a strength imbalance where one particular muscle group may dominate. It is important when you train to consider all parts of the muscular system so that muscles remain balanced.
- The more efficiently you move, with the least amount of effort expended, the longer you will be able to perform. This is known as **mechanical efficiency**. This is particularly important in sports that put high demands on the body such as rowing, marathon running or swimming.

Assessment practice 2.5

Otis is practising his basketball free throw. There are three phases to the movement:
- preparation
- execution
- follow through

Joint	Type of joint	Bones	Joint movement	Plane of movement	Muscles	Muscle contraction
Elbow					Agonist –	
					Antagonist –	
Shoulder					Agonist –	
					Antagonist –	
Wrist					Agonist –	
					Antagonist –	

Copy and complete the table three times, once for each phase of the movement. (20 marks)

Plan
- What are the key phases of movement being used?
- What main joints of the upper body are being used and what movements occur for each phase?

Do
- Have I written down the joints, muscles and movements and explained them all?
- Have I identified the plane of movement in which each action is taking place?

Review
- Have I given sufficient examples linked to the marks available?
- Have I broken down the movements into each key phase and explained all the key terms used?

Further reading

Books

Marieb, E. N. and Hoehn, K. (2015) *Human Anatomy*, Oxford: Pearson.

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Palastanga, N. and Soames, R. (2012) *Anatomy and Human Movement: Structure and Function*, London: Churchill Livingstone.

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Websites

www.humankinetics.com – Human Kinetics: a range of books, journals and articles focused on fitness, anatomy and physiology.

www.sportscoachuk.org – sports coach UK: extensive information on sports coaching and sports education.

www.topendsports.com – Top End Sports: a wide range of information about sport, sports science, fitness and nutrition.

www.brianmac.co.uk – Brian Mac Sports Coach: a wide range of information related to fitness and training.

THINK FUTURE

GraceV osper

Sportsc oach

I have been working as a sports coach for six years and over this time I have worked with a wide range of people in a variety of places. On any given day I will work with people of different ages and different abilities. For example, I may work with children helping them develop the basic core skills such as throwing and catching for a variety of sports or I may work with an experienced athlete who is trying to improve their personal performance in readiness for a competition.

Having a detailed knowledge of anatomy and physiology is essential to my job as I have to understand how each body system works and how the body will be affected by exercise. I also have to understand how each system interacts with others and how this can affect performance.

Often I will be working with athletes who are looking to improve a specific aspect of their performance. This requires to me to analyse their fitness and technique and make recommendations based on my findings. Often I will make suggestions based on fitness, and a knowledge of functional anatomy allows me to set targets and goals that will help that individual.

When setting goals or giving advice it is essential that these are set at the correct level so that injury does not occur. I have to ensure that each of my clients can train safely and use the correct techniques so that they do not harm themselves.

One of the most important skills that you need to be a successful sports coach is the ability to motivate people. Being able to get an athlete to reach their goal when they are tired or returning from injury is challenging but also one of the most rewarding parts of my job. Seeing individuals and teams achieve their long-term goals and knowing that you were key to their success is hugely satisfying.

Focusing your skills

Think about the role of a sports coach. Consider the following:

- What types of people will you work with and how will you support them?
- What role will you play in helping them achieve their goals?
- What types of training goals will you need to help people with? Will you work with elite athletes or children that are new to sport?
- What different types of exercise activities will you recommend and how will these affect each of the body's systems?
- What skills do you currently have? What skills do you think may need further development?

Getting ready for assessment

This section has been written to help you to do your best when you take the assessment test. Read through it carefully and ask your tutor if there is anything you are still not sure about.

About the test

The assessment test will last 1 hour and 30 minutes and there are a maximum of 90 marks available. The test is in one section and will ask a range of short answer questions as well as some longer answer questions.

- Short answer questions will be worth 1–2 marks.
- A longer answer question will be worth up to 8 marks.

Remember all the questions are compulsory and you should attempt to answer each one. Consider the question fully and remember to use the key words to describe, explain and analyse. For longer questions you will be required to include a number of explanations in your response.

Remember to plan your answer and write in detail.

Sample answers

For some questions you will be given some background information on which the questions are based. Look at the sample questions which follow and the tips on how to answer these.

Answering short answer questions

- Read the question carefully.
- Highlight or underline key words.
- Note the number of marks available.
- Make additional notes that you can include in your answer.
- Make sure you make the same number of statements as there are marks available. For example, a two mark question needs two statements.

Worked example

Look carefully at how the question is set out to see how many points need to be included in your answer.

The table below shows Jack's tidal volume as he takes part in a game of rugby.

Tidal volume before taking part in rugby	Tidal volume after 40 minutes of playing rugby
500ml	650ml

Explain why Jack's tidal volume has changed after 40 minutes of exercise. **[4]**

Answer: Tidal volume is the amount of air in one breath. Tidal volume increases during exercise because during exercise a person has to take in (inhale) more air. More air is required as it contains oxygen which is needed to provide energy for the working muscles so that they can contract. The body also needs to remove waste products such as carbon dioxide during exercise.

This answer gives a brief description of what tidal volume is (1 mark) and what happens to tidal volume during exercise (1 mark) plus an explanation of how (1 mark) and why this increases (1 mark).

Answering extended answer questions

Example:

Nancy is a marathon runner and Grace is a 100-metre sprinter. They recruit different skeletal muscle fibre types to compete in their sport.

Explain why different muscle fibre types would be recruited when taking part in the marathon and 100-metre events. [6]

For a question using the word 'explain', you must do more than just describe. You might need to talk about the structure and function of the different fibre types and then highlight why these are suited to different sports.

Answer: Grace would need powerful movements for the 100-metre sprint and would therefore use fast-twitch fibres [1] as these contract at speed and with a high amount of force [1] without using oxygen [1]. Nancy would need her muscles to produce steady movement over a longer period of time without fatiguing [1]. These would be slow-twitch fibres [1] which produce less powerful movements, do not fatigue easily and use the aerobic energy system [1].

This answer describes the different fibre types in relation to the two different athletics events and explains the types of contraction that these produce. The answer further explains why these types of fibres are suited to the selected sports.

It is possible that you will write a considerably longer section when answering an extended answer question, perhaps even multiple paragraphs. Before you start to answer the question, remember to make notes, writing down all the key words that could be included in your answer. Ensure that you plan all aspects of your longer answer to cover the number of marks available.