BTEC SPORT SUMMER HOMEWORK UNIT 1 INSTRUCTIONS

Please print off pages 1-8 of the Section A skeletal system workbook and use the textbook chapter to complete the tasks.

Gavin Shephard

Learning Aim: A

The Skeletal System Workbook

Name: _____

Table of Contents

Introduction

Before you look at the functions of the skeletal system, it is important to understand which bones make up the skeleton and how they are used to perform the vast range of techniques and actions required in sport. Without bones, you would be a shapeless mass of muscle and tissue, unable to move. The skeletal system is made up of bones, cartilage and joints.

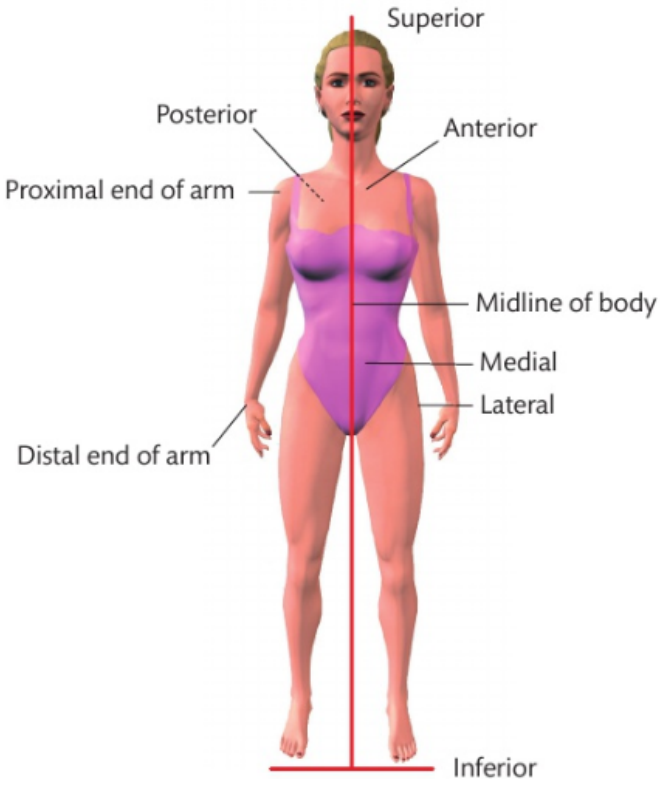
Your skeleton is made up of 206 bones which provide a framework that supports your muscles and skin and protects your internal organs.

Key terms

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

Physiology – study of the way that the body responds to exercise and training.

There are various terms used to describe the location of the bones in the body.

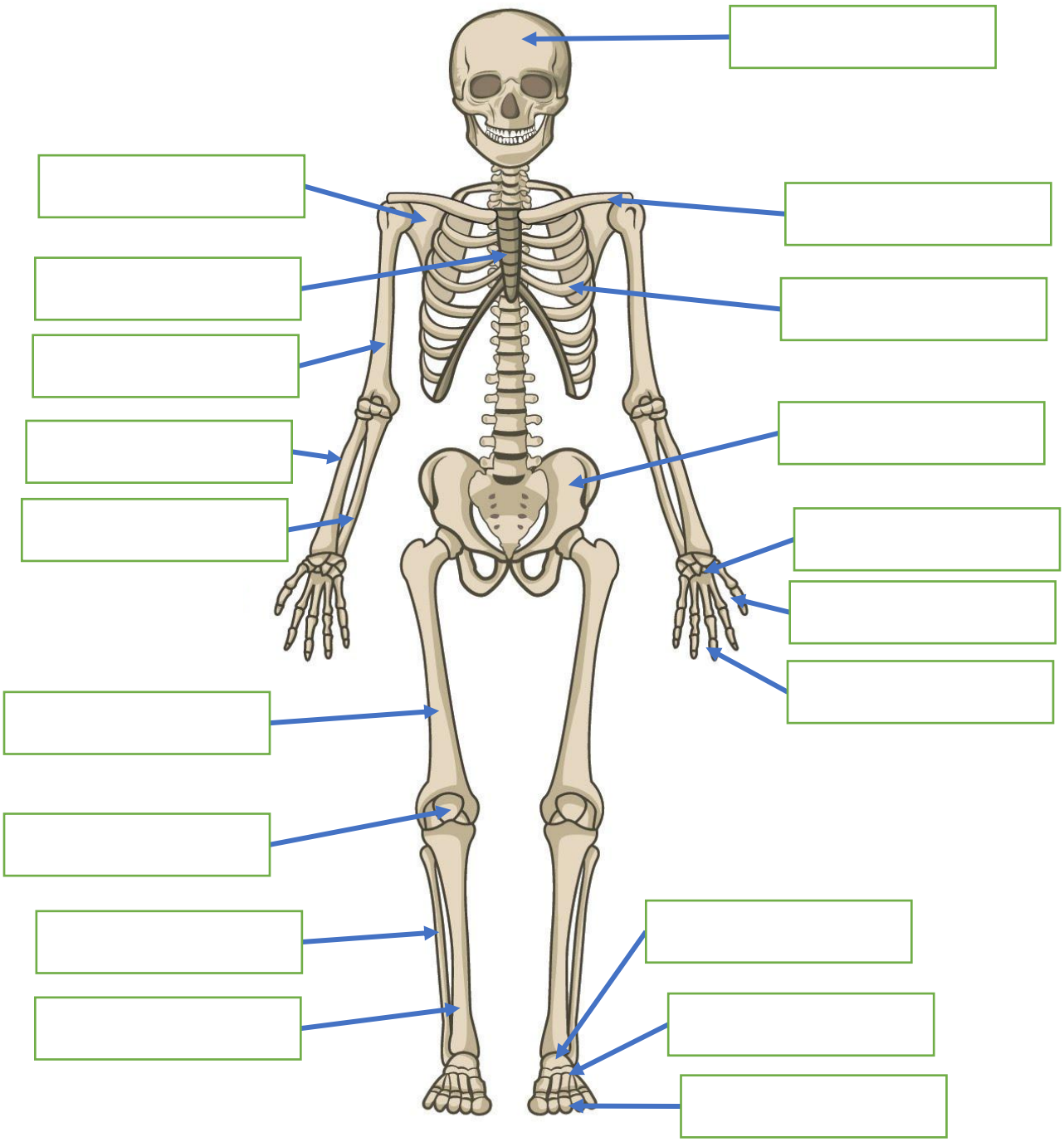


Complete the table below with the definitions

Term	Definition
Anterior	
Posterior	
Medial	
Lateral	
Proximal	
Distal	
Superior	
Inferior	

A1: Structure of the Skeletal System

Complete the diagram below with all the major bones of the body

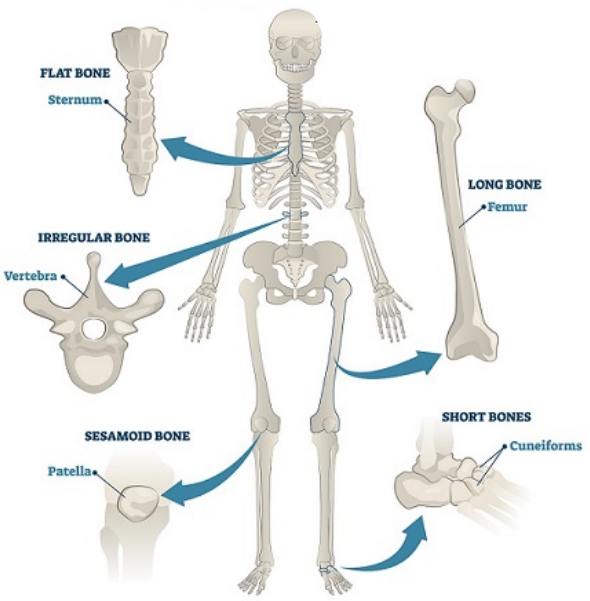


Types of Bones

The skeleton has 5 main types of bone according to their shape and size.

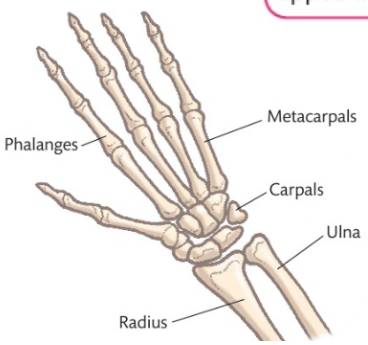
Complete the table below with the definitions

Type of Bone	Description	Example



Key term

Cancellous bone – light and porous bone material that has a honeycomb or spongy appearance.



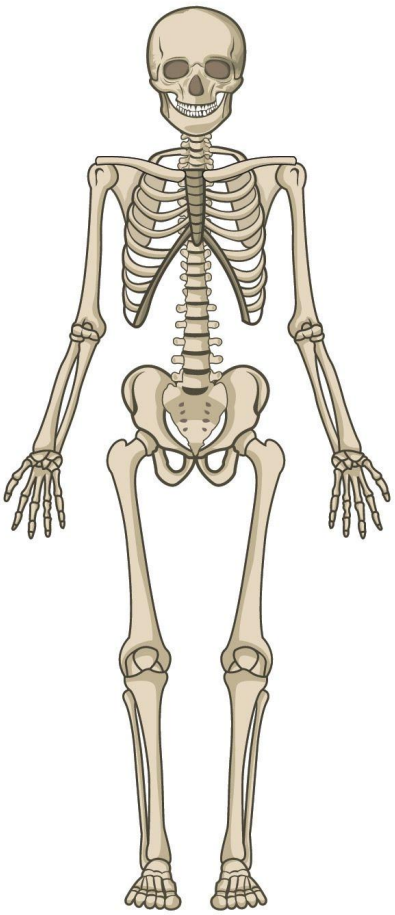
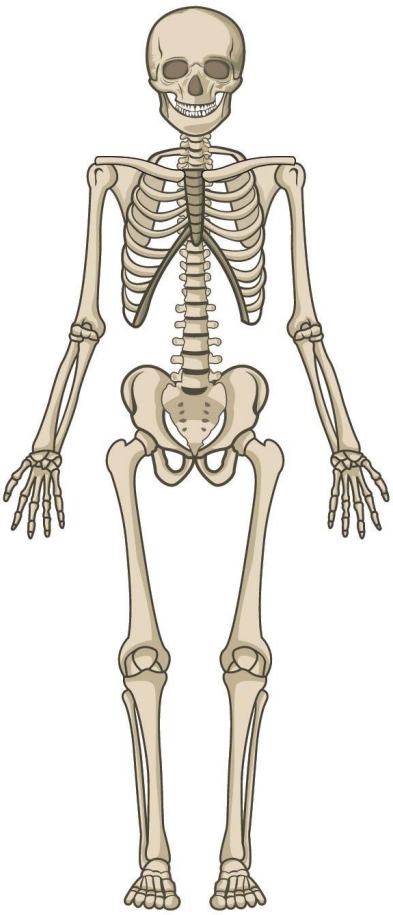
Areas of the Skeleton

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

Highlight the difference between the axial and appendicular skeleton

Axial	Appendicular
	

The Spine or Vertebrae 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.**

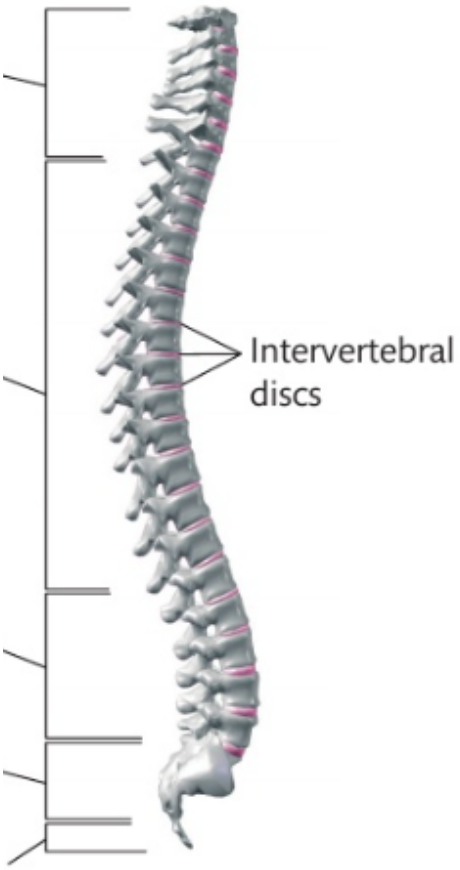
The vertebral column accounts for around 40% of a person's overall height. The vertebrae are held together by powerful **ligaments.** These allow little movement between adjacent vertebrae but a considerable degree of flexibility along the spine.

Label the areas of the spine in the diagram below

Key terms

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

Concave – having an outline or surface that curves inwards.



Key term

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

Complete the table describing each section of the spine

Area of Spine	Number of Vertebrae	Characteristics	Function

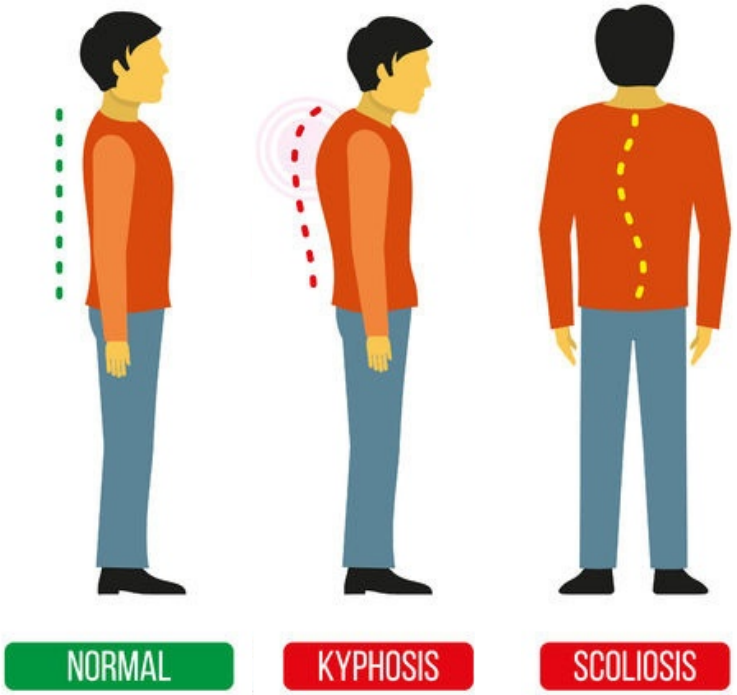
Complete the table describing key functions of the vertebrae column

Functions	

Postural Deviations

The 33 vertebrae of the spine have a distinctive shape when stacked on top of one another. The normal shape consists of a curve when viewed from the side. Occasionally the spine may suffer from disorders which can cause the natural curves to change.

A **neutral spine** refers to a good posture with the correct position of the three natural curves.



Complete the table below describing the two postural deviations

Deviation	Description

Process of Bone Growth

Bone is a living organ that is continuously being reshaped through a process called remodelling.

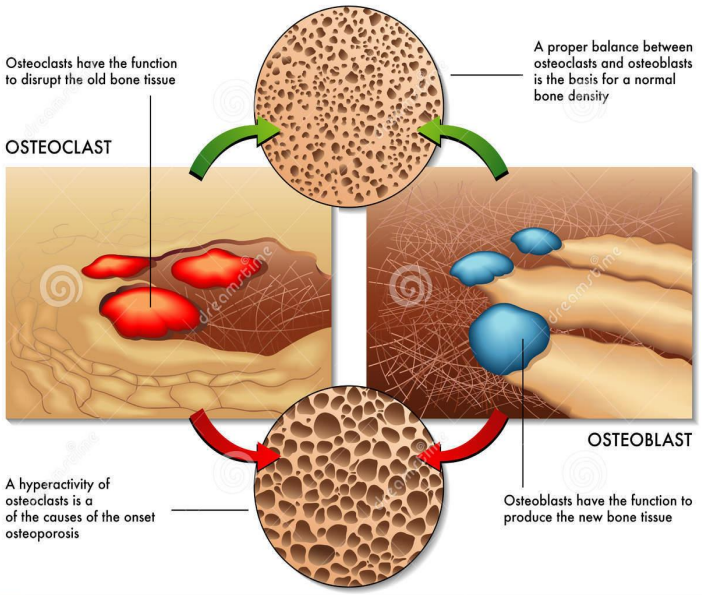
The process in which bones are formed is called _____.

Cells that remove unnecessary calcium are called _____.

Cells that bring the calcium to your bones are called _____.

Ossification is the process in which bones are formed. Throughout this, parts of bone are reabsorbed so that unnecessary calcium is removed (via **osteoclasts**) while new layers of bone are formed.

Cells that bring calcium to your bones are known as **osteoblasts** and create bone matter – this activity increases with exercise so bones will become stronger.

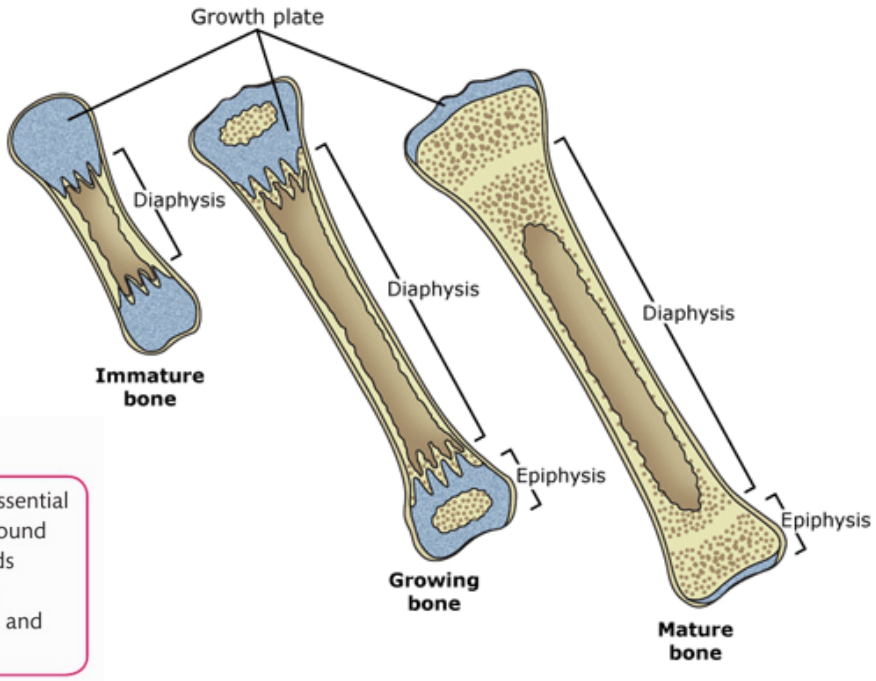


Describe the roles of Osteoblasts and Osteoclasts in the table below

	Role
Osteoblasts	
Osteoclasts	

The ends of each long bone contain a specific area that allows the bone to grow longer, this area is called the _____.

Once a long bone is fully formed, the end of each bone fuses with the main shaft (diaphysis) to create the _____ line.



Key term

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

Use the bullet points to describe how exercise helps bone formation

-
-
-
-

A2: Function of the Skeletal System

Your skeleton has a number of important functions both in sport and in everyday life. When performing sport or exercise there are **8 main functions.**

Complete the table below giving a detailed description of the functions of the skeleton

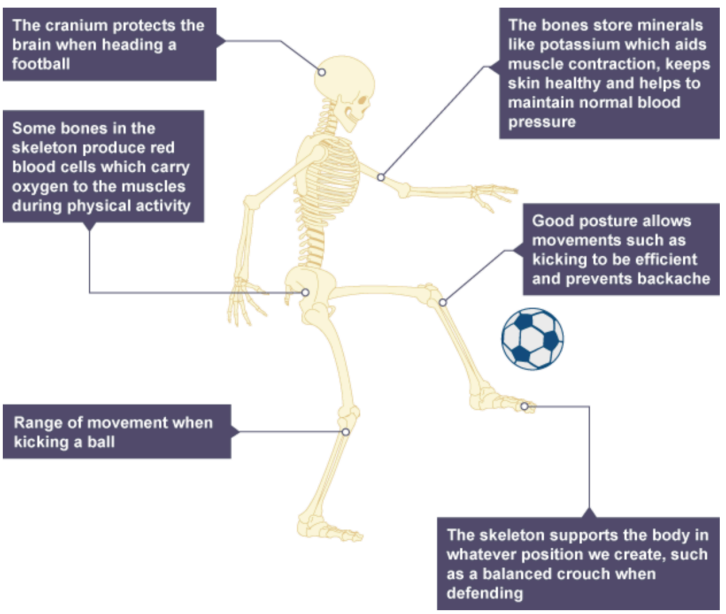
Function	Description	Sporting Example
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

Main Function of Different Bone Types

The bones in our body have many different functions, depending on their shape and location.

Complete the table below describing the functions of the bone types

Type of Bone	Function	Examples
Long		
Short		
Flat		
Irregular		
Sesamoid		



A3: Joints

You have seen that your skeleton is made up of bones that support and protect your body. For movement to occur, the bones must be linked. A joint is formed where two or more bones meet. This is known as **articulation**. The adult human body contains around 350 joints, which can be classified in different ways depending on their structure.

Key term

Articulation – where two or more bones meet.

There are three types of joint, classified according to the degree of movement they allow:

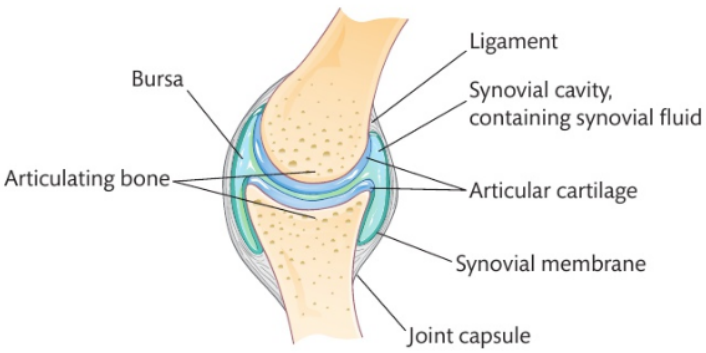
1.

2.

3.

Complete the table below describing the three types of joints

Type of Joint	Description	Example
1.		
2.		
3.		



Synovial Joints

Synovial joints provide the highest level of mobility at a joint and are vital to all sporting movement. The majority of joints in your limbs are synovial.

Complete the table below describing the specific features of a synovial joint

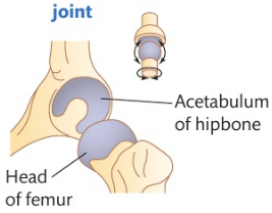
Synovial Joint Feature	Description	Purpose
Joint Capsule		
Bursa		
Articular Cartilage		
Synovial Membrane		
Synovial Fluid		
Ligaments		

Types of Synovial Joints

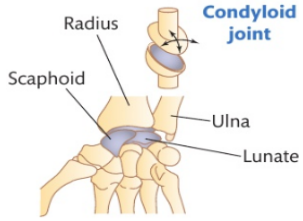
There are 6 types of synovial joints, categorised based on their structure and movements they allow.

Describe each joint with a sporting example in the boxes below

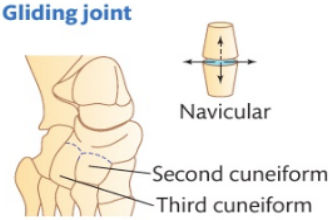
Ball and socket joint



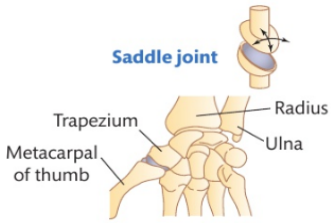
Condyloid joint



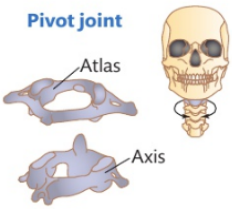
Gliding joint



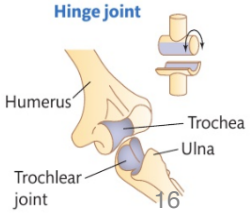
Saddle joint



Pivot joint



Hinge joint



Range of Movement at Synovial Joints

It is important when studying sports performers in action that you are able to break down these techniques and identify the specific movements at each joint. The range of motion is the amount of movement at a joint and is called **flexibility**. Flexibility depends on a number of factors including age, the tension of the supporting connective tissues (tendons) and muscles that surround the joint, and the amount of **soft tissue** surround the joint.

Complete the table below describing each movement

Type of Movement	Diagram	Description	Sporting Example
Flexion			
Extension			
Abduction			
Adduction			
Circumduction			

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.

Type of Movement	Diagram	Description	Sporting Example
Rotation			
Hyper-extension			
Horizontal flexion and horizontal extension			
Plantarflexion			
Dorsiflexion			
Lateral flexion			

A4: Responses of the Skeletal System to a Single Sport or Exercise Session

When you exercise or take part in sport your body's systems will adapt almost instantaneously so that your body is prepared for the additional stresses that will be put on it. This is one of the why you should always complete a warm up before starting any physical activity.

Key terms

Viscous – describes how thick a fluid is. If synovial fluid is too thick then it will be hard to move the joint.

Acute responses – when the body makes an immediate change or response; **chronic responses** are the opposite and take place over a longer period of time.

A short term effect on the skeletal system is to produce more synovial fluid in the synovial joints.

Effect	Description	Why is it beneficial?
Increase in synovial fluid		

Another short term effect is the increased uptake of minerals within the bones

Effect	Description	Why is it beneficial?
Increased uptake of minerals within the bones		

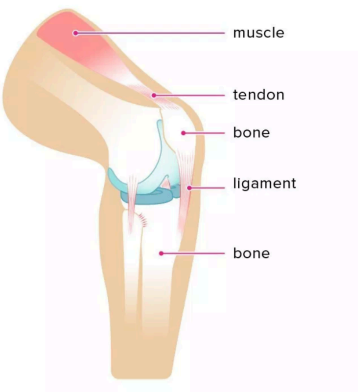
A5: Adaptations of the Skeletal System to Exercise

Your body responds to the stress of exercise or physical activity in a variety of ways. Some of these are immediate and are often referred to as acute responses to exercise. Others are long-term, and are often referred to a **chronic responses** or long term adaptations that contribute to improved fitness and reduces health risks.

The skeletal system has two main long term adaptions.

Fill in the table below on the two main long term adaptations

Effect	Description	Why is it beneficial?
Increase bone strength		
Increased ligament strength		



A6: Additional Factors Affecting the Skeletal System

The benefits of taking part in regular exercise are huge. People who take part in regular exercise are more likely to live longer and are less likely to develop serious disease.

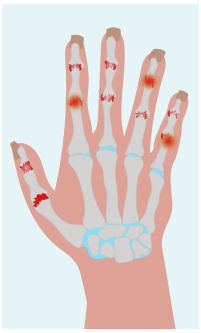
Key term

Vitamin D – is used to regulate the amount of calcium in the body and is produced from sunlight on our skin; it is created under the skin. Small amounts of vitamin D can also be found in oily fish and eggs.

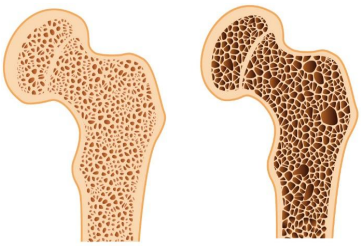
There are 3 factors that you need to know that can affect the skeletal system.

Complete the boxes below by answering the questions

Arthritis *What is it? How can exercise help or prevent it?*



Osteoporosis *What is it? How can exercise help or prevent it?*



Healthy bone Osteoporosis

Age *How can the skeleton be damaged in young people?*

Example Exam Questions

1. Within the body there are different types of bone. One is a sesamoid bone. The function of the sesamoid bone if to reduce friction across a joint.

State the function of the following three types of bone. (3 marks)

Long: _____

_____

Short: _____

_____

Flat: _____

_____

2. Eve is a netballer and plays centre.

a. Identify the movement occurring at Eve's ankle when she is jumping/taking off. (1 mark)

_____

_____

b. The ankle is an example of a synovial joint. State two functions of ligaments within Eve's ankle. (2 marks)

_____

_____

_____

_____

c. Analyse the impact of participation in Netball on Eve's skeletal system. (6 marks)

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

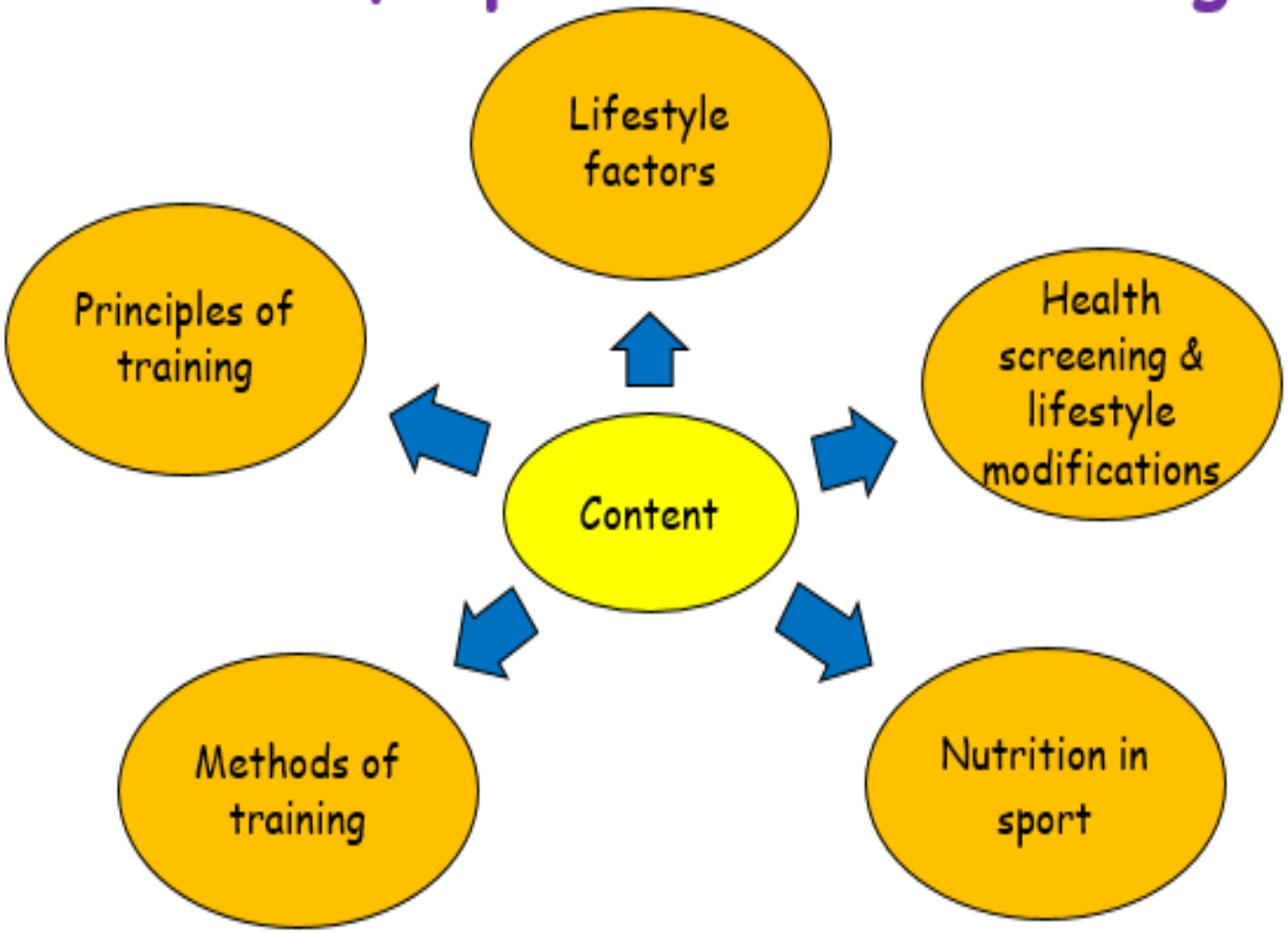
4. Anita has the first stages of osteoporosis. She has been told to take part in exercise to help prevent this condition from getting worse.

a. Identify one type of exercise that Anita could take part in to help prevent the osteoporosis from getting worse. (1 mark)

b. Explain why weight bearing exercise will help to prevent the osteoporosis from getting worse. (3 marks)

6. Analyse how movement at the synovial joints in the lower skeleton allows the gymnast to achieve the position shown in the picture above. (6 marks)

Unit 2: Fitness Training & Programming for Health, Sport and Well-Being



Assessment Method:

Extended writing exam based on pre-release material.

Please complete the following sections 1,2, & 3 for summer homework (Complete just the tables – do not do the extending writing sections) and bring a printed copy of your completed booklet to your first BTEC Sport lesson in September.

The resource you will use to help complete the sections can be found in the BTEC Sport U2 textbook on the college website.

Section 1: Lifestyle Factors & Section 2: Lifestyle Modifications and Barriers – textbook pages 61-84

Section 3: Nutritional Guidance: textbook pages 84-97

Look forward to meeting you in September

Section 1: Lifestyle Factors

Positive Lifestyle Factors

Task: Identify and explain the benefits of the following positive lifestyle factors:

Factor	Benefits
Physical Activity 	
Balanced Diet 	

Outdoor Adventure Activities 	

Negative Lifestyle Factors

Task: Identify and explain the health risks associated with the following negative lifestyle factors:

Factor	Health Risks
Smoking 	
Alcohol 	
Sedentary Lifestyle 	

Stress 	
Lack of Sleep 	

Health Screening Information

Tasks:

1) **Research and briefly describe the procedure, including unit of measurement, for each health screening test below.**
2) **Research benchmark data for each health screening test – i.e. what is a good/poor result compared to other people? This differs for males and females.**

Test	Procedure	Unit of Measurement	Benchmark Data
Blood Pressure		mmHg	Low: Average: High:
Resting Heart Rate		bpm	Excellent: Average: Poor:
Body Mass Index (BMI)		kg/m^2	Underweight: Ideal weight: Overweight: Obese:

Waist-to-Hip Ratio	1)	cm	Excellent: Average: Poor:

Extended Writing Task: Section 1:

Task: Highlight and annotate both source A and source B to identify positive and negative lifestyle factors.

Source A: Written Extract

Lisa is a 38-year-old female who works in an office. She sits at a desk from 9 am until 5 pm for five days a week. She drives 10 miles to work each day and takes her children to school on the way. Lisa has spent many years working full time and also looking after her children. This has had a negative impact on her health and wellbeing. Lisa's family have noticed that she often looks very tired and she knows she has gained extra body weight.

Lisa has made an appointment to see an expert to get some lifestyle advice. Lisa has been told to have a full health screening assessment before she receives any guidance. Lisa would like to improve her health and wellbeing by increasing her energy levels and by losing some of the extra weight she has gained.

Source B: Lifestyle Questionnaire

Section 1: Personal details

Name: Lisa Goddard

Address: 48 The Road
Smalltown
County

Home telephone: 03678 538653
Mobile telephone: 07645 234678
Email: lgoddard@email.com
Age: 38

Please answer the following questions.

Occupation

1. What is your occupation?
   Office worker
2. How many hours do you work each day?
   7.5 hrs
3. How far do you live from your occupation?
   10 miles
4. How do you travel to your occupation?
   Car
5. How active would you say your occupation was?
   Not active

Section 2: Current activity levels

1. How many times a week do you currently take part in physical activity?
   None
2. What type of activity/exercise do you mainly take part in?
   N/A

Section 4: Your lifestyle

Please answer the following questions.

1. How many units of alcohol do you drink in a typical week? **35**
2. Do you smoke? **No** If yes, how many cigarettes a day? **N/A**
3. Do you experience stress on a daily basis? **Yes**

   If yes, what causes you stress (if you know)?

   Work and looking after the children
4. On average, how many hours of sleep do you get per night? **5**

Section 5: Health monitoring tests

Test results

Test	Result
Blood pressure	135/90 mmHg
Resting heart rate	75 bpm
Body mass index	28
Waist-to-hip ratio	0.85

Section 6: Physical activity/sporting goals

What are your physical activity/sporting goals?

To lose some of my extra weight and increase my health and wellbeing.

Day 1	Breakfast	Lunch	Dinner	Snacks
Y/N	Y	Y	Y	Y
Time of day	8.00 am	12.30 pm	6.30 pm	Different times during the day
Food intake	1 piece of white toast with jam	Ham and cheese sandwich with crisps Chocolate bar	Chicken, chips and vegetables Ice cream	Chocolate bar Packet of crisps Sausage roll
Fluid intake	2 x cups of tea, 500 ml of water, 2 x glasses of white wine			

Day 2	Breakfast	Lunch	Dinner	Snacks
Y/N	Y	Y	Y	Y
Time of day	8.00 am	12.30 pm	6.30 pm	Different times during the day
Food intake	Bowl of cereal (coco pops)	Lasagne and chips Ice cream	Fish, potatoes and vegetables	2 x packets of crisps Doughnut Chocolate bar Yoghurt
Fluid intake	2 x cups of tea, 500 ml of water, 3 x glasses of white wine			

2. Do you take any supplements? If yes, which ones?	No

Task: In paragraph form, answer the following question - Interpret the lifestyle factors and screening information for Lisa Goddard. (12)

Tip: Make sure you discuss both positive and negative lifestyle factors and support work with evidence from source A and source B.

Section 2: Lifestyle Modifications and Barriers

Lifestyle Modifications

Task: For each negative lifestyle listed below, research and outline strategies that can be used to improve and overcome it. For example, counselling, e-cigarettes and cycling to work.

Factor	Strategies
Smoking 	
Alcohol 	
Sedentary Lifestyle / Lack of Physical Activity 	
Stress 	

Lack of Sleep 	

Barriers

Task: Discuss how the following may be barriers to lifestyle strategies researched and outlined:

Barrier	How/Why?
Time 	
Cost 	
Transport 	
Location 	

Extended Writing Task: Section 2

Task: In paragraph form, answer the following question - Provide and justify lifestyle modification techniques for Lisa Goddard. (12)

Tip: For each negative lifestyle factor listed in section 1 apart from diet, outline two strategies that can be used to combat and improve it, referring back to the health risks it will reduce within justification. You also need to outline barriers that may prevent Lisa from changing her lifestyle.

Section 3: Nutritional Guidance

Task: Using some of the key words, research and outline the features/purpose, sources and quantity needed of each nutrient listed below and explain how this will help performance in a sports training environment, such as a gym.

Component	Key Words	Sources	Quantity	Features/Purpose	How does this help performance when training?
Carbohydrates	Energy; Glucose; Glycogen; Complex; Simple;				
Fats	Energy; Insulation; Saturated; Unsaturated;				
Protein	Growth; Repair; Energy; Recovery; Strength				

Vitamins & Minerals	Immune System; Iron; Calcium;				
Water	Hydration/Dehydration; Body Temperature; Blood Viscosity; Muscle Fatigue	[redacted]			

Extended Writing Task: Section 3

Task: Highlight and annotate both day 1 and day 2 of Lisa's food diary to identify aspects of her diet that require changing.

Day 1	Breakfast	Lunch	Dinner	Snacks
Y/N	Y	Y	Y	Y
Time of day	8.00 am	12.30 pm	6.30 pm	Different times during the day
Food intake	1 piece of white toast with jam	Ham and cheese sandwich with crisps Chocolate bar	Chicken, chips and vegetables Ice cream	Chocolate bar Packet of crisps Sausage roll
Fluid intake	2 x cups of tea, 500 ml of water, 2 x glasses of white wine			

Day 2	Breakfast	Lunch	Dinner	Snacks
Y/N	Y	Y	Y	Y
Time of day	8.00 am	12.30 pm	6.30 pm	Different times during the day
Food intake	Bowl of cereal (coco pops)	Lasagne and chips Ice cream	Fish, potatoes and vegetables	2 x packets of crisps Doughnut Chocolate bar Yoghurt
Fluid intake	2 x cups of tea, 500 ml of water, 3 x glasses of white wine			

2. Do you take any supplements? If yes, which ones?	No

Extended Writing Task: Section 3

Task: In paragraph form, answer the following question - Provide and justify nutritional guidance for Lisa Goddard to meet her specific requirements. (8)

Tip: Identify and justify at least four aspects of Lisa's diet you would change, and explain how these changes would benefit Lisa's weight and help her performance and recovery when training. Support your work with evidence from the food diary.

Anatomy and Physiology 1

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 body systems. This unit explains how the body is made up of a number of different systems, how these systems interact and work together, and why they are important to sports performance. You will:

- be introduced to the structures and functions of the five key systems and the effects that sport and exercise has on them
- investigate the structure and function of the skeletal and muscular systems and their role in causing movement in sport and exercise
- examine the structure and functions of the cardiovascular and respiratory systems
- understand why the heart works as it does and how it works with the lungs to allow sportspeople to cope with the demands of sport
- look at the three different energy systems and the sports in which they are predominantly used.

This is a mandatory unit and introduces knowledge that will link with all other units in the course.

How you will be assessed

This unit will be assessed by an examination set by Pearson. The examination will last 1 hour and 30 minutes and will contain a number of short answer and long answer questions. There will be a total of 90 marks available in the examination. You will be assessed for your understanding of the following topics in relations to sports performance:

- the skeletal system
- the muscular system
- the respiratory system
- the cardiovascular system
- the energy system.

During this examination you will need to show your knowledge and understanding of the interrelationships between these different body systems for sports performance.

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

Unit 1 has five assessment outcomes (AO) which will be included in the external examination. Certain 'command words' are associated with each assessment outcome. Table 1.1 explains what these command words are asking you to do.

The assessment outcomes for the unit are:

- **AO1** Demonstrate knowledge of body systems, structures, functions, characteristics, definitions and other additional factors affecting each body system
  - Command words: identify, describe, give, state, name
  - Marks: ranges from 1 to 5 marks

- **AO2** Demonstrate understanding of each body system, the short- and long-term effects of sport and exercise on each system, and additional factors that can affect body systems in relation to exercise and sporting performance
  - Command words: describe, explain, give, state, name
  - Marks: ranges from 1 to 5 marks
- **AO3** Analyse exercise and sports movements, how the body responds to short-term and long-term exercise, and other additional factors affecting each body system
  - Command words: analyse, assess
  - Marks: 6 marks
- **AO4** Evaluate how body systems are used and how they interrelate in order to carry out exercise and sporting movements
  - Command words: evaluate, assess
  - Marks: 6 marks
- **AO5** Make connections between body systems in response to short-term and long-term exercise and sport participation. Make connections between muscular and all other systems, cardiovascular and respiratory systems, energy and cardiovascular systems
  - Command words: analyse, evaluate, assess, discuss, to what extent
  - Marks: 8 marks

Table 1.1: Command words used in the assessment outcomes

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	Evaluate or estimate the nature, ability, or quality of something.
Describe	Give a full account of all the information about a topic, including all the relevant details of any features.
Discuss	Write about the topic in detail, taking into account different ideas and opinions.
Evaluate	Bring all the relevant information you have on a topic together and make a judgement (for example, on its success or importance). Your judgement should be clearly supported by the information you have gathered.
Explain	Make an idea, situation or problem clear to your reader by describing it in detail, including any relevant data or facts.
Give	Provide examples, justifications and/or reasons.
Identify	State the key fact(s) about a topic or subject. The word *Outline* is similar.
State/name	Give a definition or example.
To what extent	Review information and then bring it together to form a judgement or conclusion, after giving a balanced and reasoned argument.

Getting started

Anatomy and **physiology** are essential ingredients in all sport and exercise performance. List the changes that your body experiences when you take part in sport or exercise. When you have done this, consider each change and try to identify which body system is being affected.

A The effects of exercise and sports performance on the skeletal system

Key terms

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

Physiology – study of the way that the body responds to exercise and training.

Structure of the skeletal system

Before we look at the functions of the skeletal system, it is important to understand which bones make up the skeleton and how they are used to perform the vast range of techniques and actions required in sport. Without bones, you would be a shapeless mass of muscle and tissue, unable to move. The skeletal system is made up of bones, cartilage and joints.

Your skeleton is made up of 206 bones which provide a framework that supports your muscles and skin and protects your internal organs.

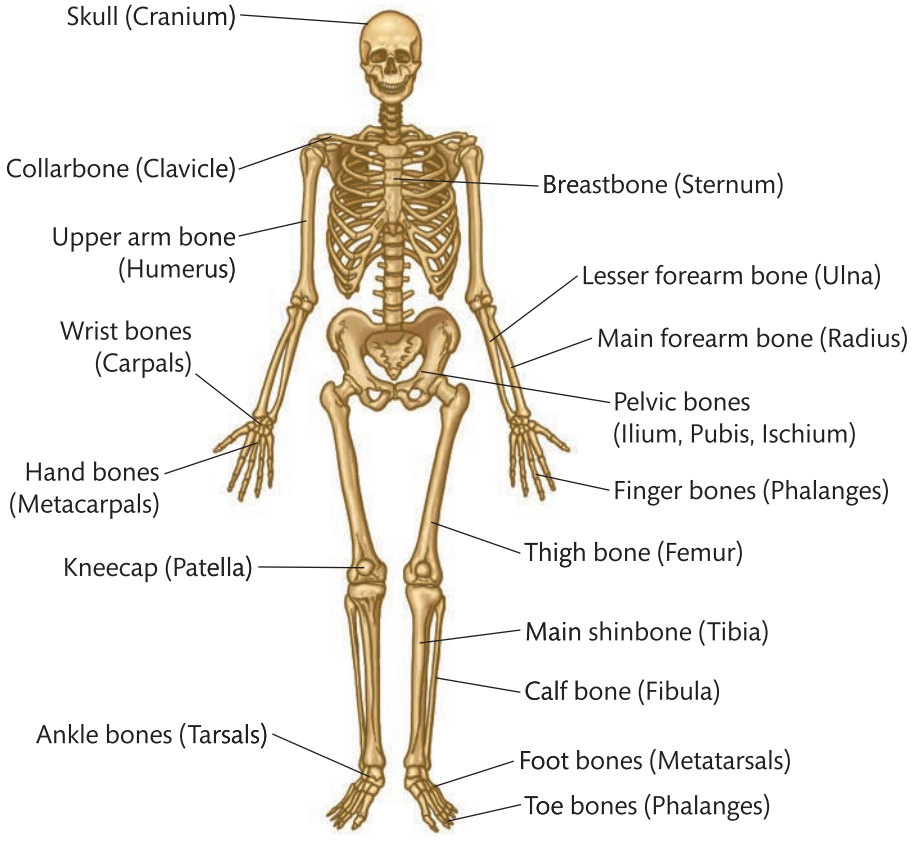


Figure 1.1: Bones of the human skeleton; Latin names are shown in brackets

Many terms are used to describe the location (or anatomical position) of bones. These are described in Table 1.2. You might find it useful to make a note of them.

Table 1.2: Terms used to describe the location of bones

Term	Meaning
Anterior	To the front or in front
Posterior	To the rear or behind
Medial	Towards the midline or axis, an imaginary line down the centre of the body
Lateral	Away from the midline or axis
Proximal	Near to the root or origin (the proximal of the arm is towards the shoulder)
Distal	Away from the root or origin (the distal of the arm is towards the hand)
Superior	Above
Inferior	Below

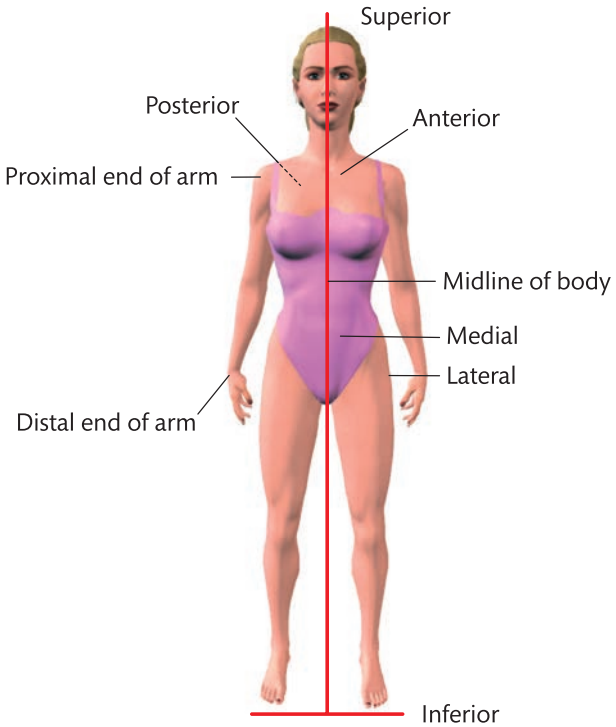


Figure 1.2: Anatomical positions

Types of bone

The skeleton has five main types of bone according to their shape and size. These can be classified as:

- **long bones** – the bones found in the limbs. They have a shaft known as the **diaphysis** and two expanded ends known as the **epiphysis**.
- **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 (introduced later in this section) are examples of short bones.
- **flat bones** – thin, flattened and slightly curved, with a large surface area. Examples include the scapulae, sternum and cranium.
- **irregular bones** – have complex shapes that fit none of the categories above. The bones of the spinal column are a good example.
- **sesamoid bones** – have a specialised function and are usually found within a tendon. These bones provide a smooth surface for the tendon to slide over. The largest sesamoid bone is the patella in the knee joint.

Key term

Cancellous bone – light and porous bone material that has a honeycomb or spongy appearance.

Areas of the skeleton

The skeleton can be divided into two parts: 80 bones form your **axial skeleton** – the long **axis** of your body; 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 is the main core or axis of your skeleton and consists of:

- the skull (including cranium and facial bones)
- the thoracic cage (sternum and ribs)
- the vertebral column.

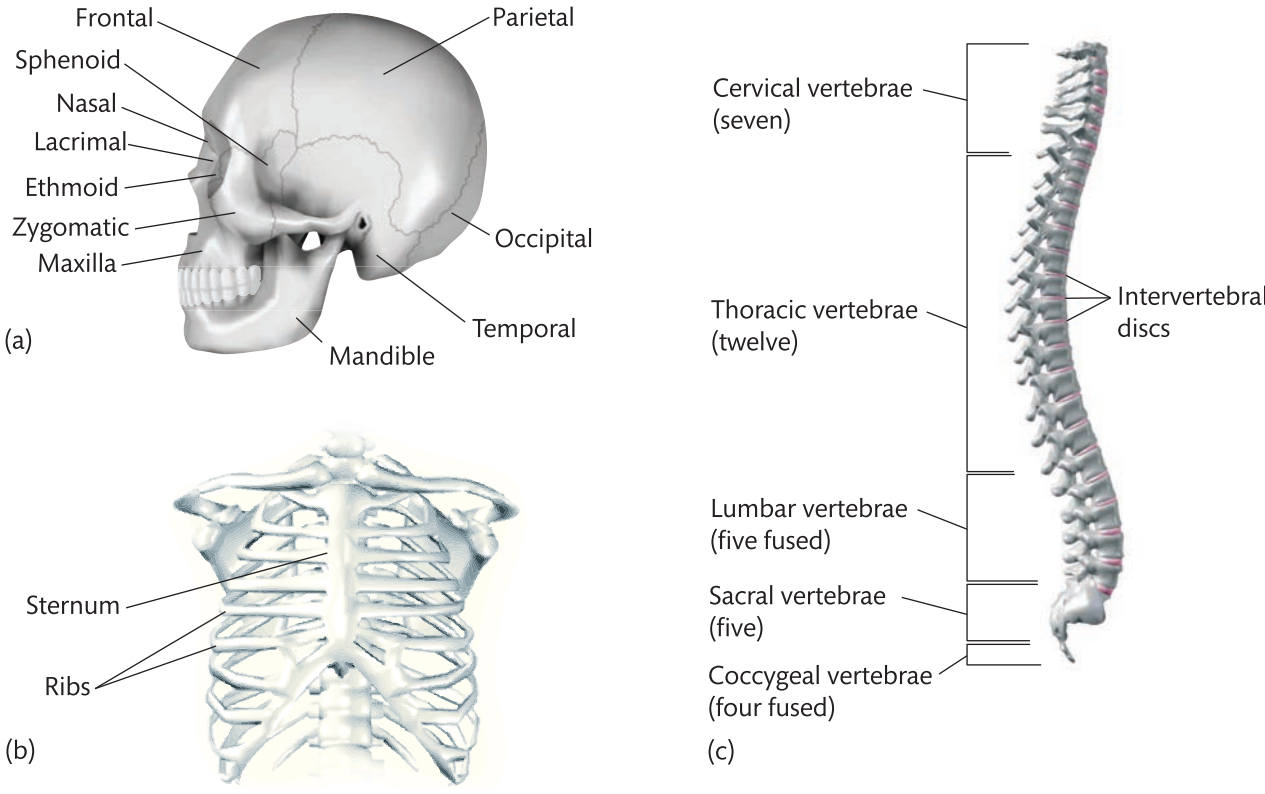


Figure 1.3: The axial skeleton: (a) the skull, (b) the thorax and (c) the vertebral column

Appendicular skeleton

The appendicular skeleton consists of the bones that are attached to the axial skeleton. These bones will be introduced in more detail later in this section, but the appendicular skeleton 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, tibia, fibula, patella, 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 collectively known as the innominate bone. The main function of the pelvic girdle is to provide a solid base through which to transmit 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.

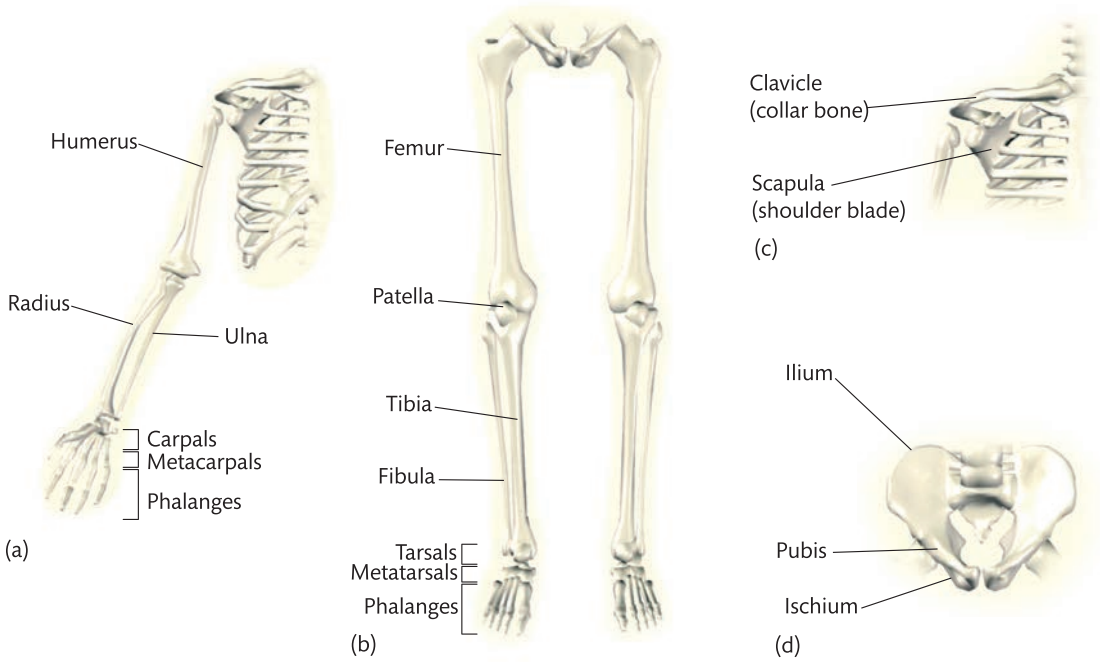


Figure 1.4: The appendicular skeleton: (a) the upper limbs, (b) the lower limbs, (c) the shoulder girdle and (d) the pelvic girdle

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 vertebral column accounts for around 40 per cent of a person's overall height. 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.

The vertebral column can be classified into five sections or regions (see Figure 1.3(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. They are the smallest and most vulnerable vertebrae of the vertebral column.
- **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.
- **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.

Key terms

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

Concave – having an outline or surface that curves inwards.

Key term

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

The vertebral column has many functions. It 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. These, along with the **intervertebral discs**, receive and distribute impact associated with sporting performance, reducing shock.

Postural deviations

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) and lumbar (low back) regions when viewed from the side. A **neutral spine** refers to a good posture with the correct position of the three natural curves. When viewing the spine from the front (anterior), it should be completely vertical. Occasionally the spine may suffer from disorders which can cause the natural curves to change.

- **Kyphosis** – the excessive outward curve of the thoracic region of the spine resulting in a 'hunchback' appearance. This is often caused by poor posture but can be caused by deformities of the vertebrae.
- **Scoliosis** – the abnormal curvature of the spine either to the left or to the right (lateral curvature). Most likely to occur in the thoracic region. Often found in children but can be found in adults. This condition is not thought to be linked to bad posture and the exact reasons for it are unknown, although it seems to be inheritable.

Major bones of the skeletal system

The skeletal system includes the following bones.

- **Cranium** – this box-like cavity (space) consists of interlinking segments of bone that are fused together. The cranium contains and protects the brain.
- **Clavicles** – these are commonly known as the collar bones and are the long, slim bones that form the anterior part of the shoulder girdle. This provides a strong attachment for the arms.
- **Ribs** – there are 12 pairs of ribs and they form part of the **thoracic cage**. The first seven pairs are attached to the sternum (see below) and are known as true ribs; the remaining five pairs are known as false ribs as they do not attach to the sternum. The ribs are long, flat bones.
- **Sternum (breast bone)** – this is the elongated, flat bone that runs down the centre of the chest and forms the front of the thoracic cage. Seven pairs of ribs are attached to the sternum, which provides protection and muscular attachment.
- **Scapula** (plural: scapulae) – commonly known as the **shoulder blades**, these large, triangular, flat bones form the posterior part of the shoulder girdle.
- **Humerus** – this is the long bone of the upper arm and is 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 bones of the forearm. The ulna and radius articulate distally (see Table 1.2) with the wrist.
- **Carpals** – these are the eight small bones that make up the wrist. They are irregular, small bones arranged in two rows of four. They fit closely together and are kept in place by ligaments.

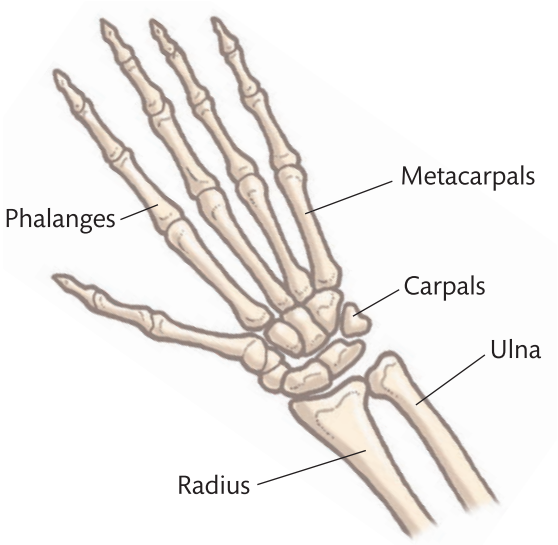


Figure 1.5: The bones of the wrist and hand

- **Metacarpals** – five long bones in the palm of the hand, one corresponding to each digit (finger or thumb). These run from the carpal bones of the wrist to the base of each digit in the hand.
- **Phalanges** – the 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** – the pelvis is made up of two hip bones which in turn consist of three sections (**ilium**, **ischium** and **pubis**) which fuse together during puberty to form one bone. The ilium structure provides the socket for the ball and socket joint (see Figure 1.8) of the femur, allowing the legs to be attached to the main skeleton.
- **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 (kneecap)** – the large, triangular sesamoid bone found in the quadriceps femoris **tendon**. It protects the knee joint.
- **Tibia and fibula** – the long bones that form the lower leg. The tibia is the inner and thicker bone, also 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 collectively as the tarsals form the ankle joint including the heel. The calcaneus, or heel bone, is the largest tarsal bone. It helps to support the weight of the body and provides attachment for the calf muscles via the Achilles tendon. The tarsals are short and irregular bones.
- **Metatarsals** – there are five metatarsals in each foot; they are 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). The metatarsals are responsible for bearing a great deal of weight, and they balance pressure through the balls of the feet. The metatarsals are a common site of fracture in sport.

Key term

Tendon – strong fibrous tissue that attaches muscle to bone.

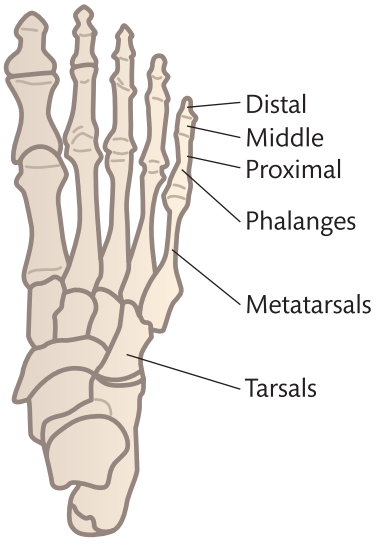


Figure 1.6: The bones of the foot

PAUSE POINT Can you name the main bones of the skeleton and state 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? For each action you identified, explain the functions of the listed bones.

Process of bone growth

Key term

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

Bone is a living organ that is continuously being reshaped through a process called remodelling. **Ossification** is the process in which bones are formed. Throughout this process parts of the bone are reabsorbed so that unnecessary **calcium** is removed (via cells called **osteoclasts**) while new layers of bone tissue are created.

The cells that bring the 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. This means your bone calcium stores increase to cope with the demand for calcium, so exercising also reduces the risk of osteoporosis. Activities that can build stronger bones include tennis, netball, basketball, aerobics, walking and running.

The ends of each long bone contain growing areas – or plates – which allow the bone to grow longer. This continues throughout childhood until they reach full maturity. These areas are called 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**.

Function of the skeletal system

Your skeleton has a number of important functions both in sport and in everyday life. When performing sport or exercise there are eight main functions.

- **Support** – collectively, your bones give your body shape and provide the supporting framework for the soft tissues of your body.
- **Protection** – the bones of your skeleton surround and protect vital tissues and organs in your body. Your skull protects your brain, your heart and lungs are protected by your thorax, your vertebral column protects your delicate spinal cord, and your pelvis protects your abdominal and reproductive 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. Muscles pulling on bones act as levers, and movement occurs at the joints so that you can walk, run, jump, kick, throw etc. Type of joint (see page 12) determines the type of movement possible.
- **Source of blood cell production** – your bones are not completely solid, as this would make your skeleton heavy and difficult to move. Blood vessels feed the centre of your bones, and stored within the bones is **bone marrow**. The marrow of your long bones is continually producing red and white blood cells. This is an essential function as large numbers of blood cells, particularly red cells, die every minute.
- **Store of minerals** – bone is a reservoir for minerals such as calcium and phosphorus, which are essential for bone growth and the maintenance of bone health. These minerals are stored and released into the bloodstream as required, balancing the minerals in your body.

- **Leverage** – the bones provide a lever system against which muscles can pull to create movement.
- **Weight bearing** – your bones are very strong and will support the weight of your tissue including muscles. During sport large forces are applied to your body, and your skeleton provides the structural strength to prevent injury.
- **Reducing friction across joints** – the skeleton has many joints of different types. Synovial joints secrete fluid that prevents bones from rubbing together, reducing friction between the bones.

Main function of different bone types

The bones in your body have many different functions, depending on their shape and location. Consider the bones of the arms and legs and how they are used in sport. In conjunction with your muscles, these long bones can produce large movements such as kicking or throwing as the long bones act like levers. The flat bones of the body are also important in sport as they can provide protection from impact, ensuring your vital organs remain functioning. Look at Table 1.3 for examples of the different bones and their main functions.

Table 1.3: Function of different bones types

Type of bone	Function	Examples
Long	Movement, support, red blood cell production	Femur, humerus, tibia, radius, ulna
Short	Fine or small movements; shock absorption, stability, weight bearing	Carpals, tarsals
Flat	Attachment for muscles; protection	Sternum, scapula, pelvis, cranium
Sesamoid	Protection; reduction of friction across a joint	Patella, pisiform (wrist)
Irregular	Protection (spinal cord); movement	Vertebrae

PAUSE POINT What are the main functions of the skeleton? Why are these important in sport and exercise?

Hint Write down the main functions of the axial skeleton and the appendicular skeleton.

Extend Consider a sporting action. What are the roles of the axial and appendicular skeleton in this action?

Joints

You have seen that your skeleton is made up of bones that support and protect your body. For movement to occur, the bones must be linked. A joint is formed where two or more bones meet. This is known as an **articulation**. The adult human body contains around 350 joints, which can be classified in different ways depending on their structure.

Key term

Articulation – where two or more bones meet.

The bones of the shoulder are shown in Figure 1.4(c) on page 7 and the bones of the hip, knee and ankle are shown in Figure 1.4(b). The structure and movement of the vertebrae are described on pages 7–8 under the heading 'The spine or vertebral column'.

Classification of joints

There are three types of joint, classified according to the degree of movement they allow:

- fixed
- slightly movable
- synovial.

Fixed joints

Fixed joints, or **fibrous** or **immovable joints**, do not move. Fixed joints form when the bones interlock and overlap during early childhood. These joints are held together by bands of tough, fibrous tissue and are strong with no movement between the bones. An example is between the bone plates in your cranium, which are fixed together to provide protection for your brain.

Slightly movable joints

Slightly movable or **cartilaginous joints** allow slight movement. The ends of the bone are covered in a smooth, shiny covering, known as articular or hyaline cartilage, which reduces friction between the bones. The bones are separated by pads of white fibrocartilage (a tough cartilage that is capable of absorbing considerable loads). Slight movement at these joining surfaces is made possible because the pads of cartilage compress, for example between most vertebrae.

Synovial joints

Synovial joints or **freely movable joints** offer the highest level of mobility at a joint and are vital to all sporting movements. Most of the joints in your limbs are synovial.

A synovial joint (see Figure 1.7) consists of two or more bones, the ends of which are covered with articular cartilage, which allows the bones to move over each other with minimum friction. Synovial joints always have a synovial cavity or space between the bones. This cavity is completely surrounded by a fibrous capsule, lined with a synovial membrane, whose purpose is to release or secrete fluid known as synovial fluid into the joint cavity. This lubricates and nourishes the joint. The joint capsule is held together by tough bands of connective tissue known as ligaments. These ligaments provide the strength to avoid dislocation, while being flexible enough to allow a wide range of movement.

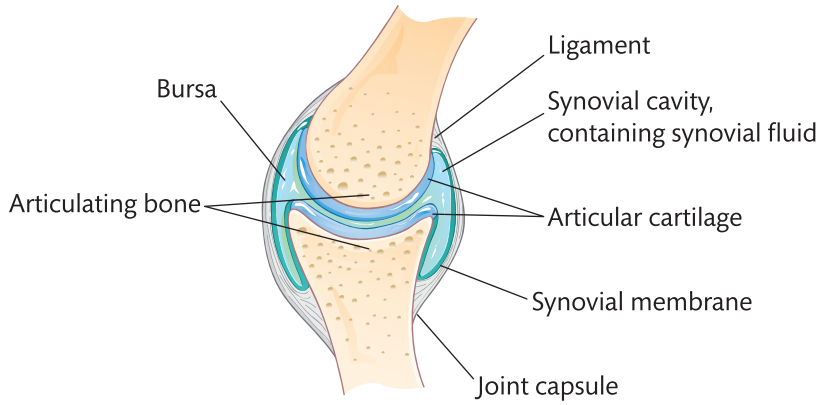


Figure 1.7: A synovial joint

All synovial joints contain the following features.

- A **joint capsule** or fibrous capsule - an outer sleeve to help to hold the bones in place and protect the joint. This capsule will also contain the main structure of the synovial joint.

- A **bursa** – a small fluid-filled sac which provides a cushion between the tendons and the bones, preventing friction. Bursae are filled with synovial fluid.
- **Articular cartilage** on the ends of the bones – provides a smooth and slippery covering to stop the bones rubbing or grinding together.
- A **synovial membrane** – the capsule lining that releases synovial fluid.
- **Synovial fluid** – a viscous (thick) liquid that lubricates the joint and reduces the friction between the bones, preventing them from rubbing together. Synovial fluid also provides nutrients to the articular cartilage.
- **Ligaments** – hold the bones together and keep them in place.

Types of synovial joint

There are six types of synovial joint, categorised according to their structure and the movements they allow. These joints will permit specific movements and, combined, will allow you to perform complex techniques such as a somersault or a tennis serve.

- **Hinge** – These allow movement in one direction only (similar to the hinge of a door). Elbow and knee joints are typical examples and only allow movements forwards and backwards. Exercise examples include running with the knee bending or a bicep curl.
- **Ball and socket** – The 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, used in running and in throwing an object such as a javelin.
- **Condyloid** – Also known as ellipsoidal joints. These are similar to ball and socket joints, 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. An example of a condyloid joint in action is during a basketball game when a player is dribbling or bouncing the ball, with the wrist being used to create this action.
- **Gliding** – These joints allow movement over a flat surface in all directions, but this movement is restricted by ligaments or a bony prominence, for example in the carpals and tarsals of wrists and ankles. This can be seen in a netball jump with the foot pointing downwards.

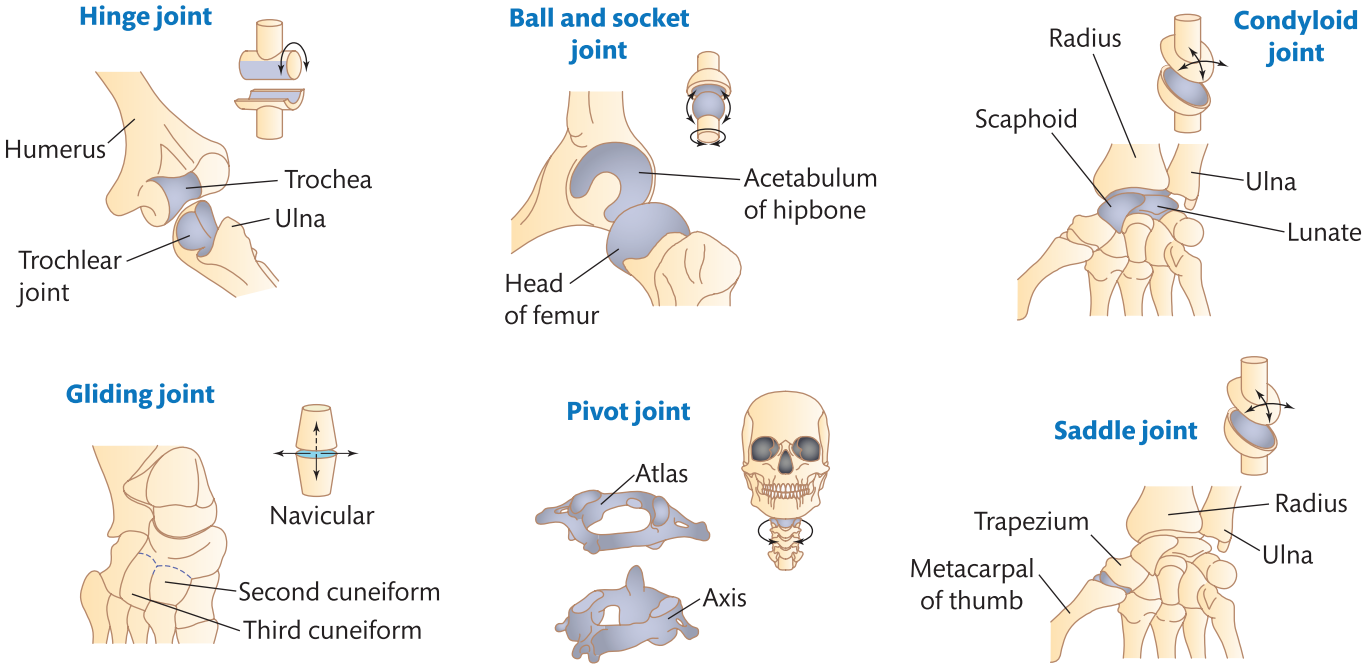


Figure 1.8: Types of synovial joint

Key terms

Concave – where the bone curves or is hollowed inwards.

Convex – where the bone curves outwards.

- **Pivot** – A circular bone fits over a peg of another bone, allowing controlled rotational movement, such as the joint of the atlas and axis in the neck. This joint allows you to turn your head from side to side. When you turn your head in sport you will be using a pivot joint.
- **Saddle** – These are 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 like a rider on a horse. Movement occurs backwards and forwards and from side to side, such as at the base of the thumb. You would use a saddle joint when gripping a racket in tennis or squash.

PAUSE POINT

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

Hint – Describe the location of each of the synovial joints in the body.

Extend – Draw a synovial joint, labelling the main structural features.

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.

The range of movements at synovial joints

The type of movement 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 techniques. For example, a cricketer bowling a ball 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 when studying sports performers in action that you are able to break down these techniques and identify the specific movements at each joint. A coach will often analyse the movements produced by an athlete in order to improve technique, and it is common to see movements filmed and analysed in detail using computer software.

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

The following movements are common across a wide range of sports and are important when performing sport and exercise techniques.

Cricketers use a large number of joints and movements when bowling

- **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 your arm in a bicep curl action or bending the knee when preparing to kick a football.
- **Extension** – straightening a limb to increase the angle at the joint, such as straightening your arm to return to your starting position in a bicep curl action or the kicking action when taking a penalty in football with the knee straightening.
- **Dorsiflexion** – an upward movement, as in moving the foot to pull the toes towards the knee in walking.
- **Plantar flexion** – a movement that points the toes downwards by straightening the ankle. This occurs when jumping to shoot in netball.
- **Lateral flexion** – the movement of bending sideways, for example at the waist.
- **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**.

- **Hyper-extension** – involves movement beyond the normal anatomical position in a direction opposite to flexion. This occurs at the spine when a cricketer arches his or her back when approaching the crease to bowl.
- **Abduction** – movement away from the body's vertical midline, such as at the hip in a side-step in gymnastics.
- **Adduction** – movement towards the body's vertical midline, such as pulling on the oars while rowing.
- **Horizontal abduction and adduction** – this is the movement of bringing your arm across your body (flexion) and then back again (extension).
- **Circumduction** – this is a circular movement that results in a conical action.
- **Rotation** – circular movement of a limb. Rotation occurs at the shoulder joint during a tennis serve.

Reflect

Think about a common sporting movement such as a javelin throw. Consider the movement at each joint and identify the type of action that is occurring.

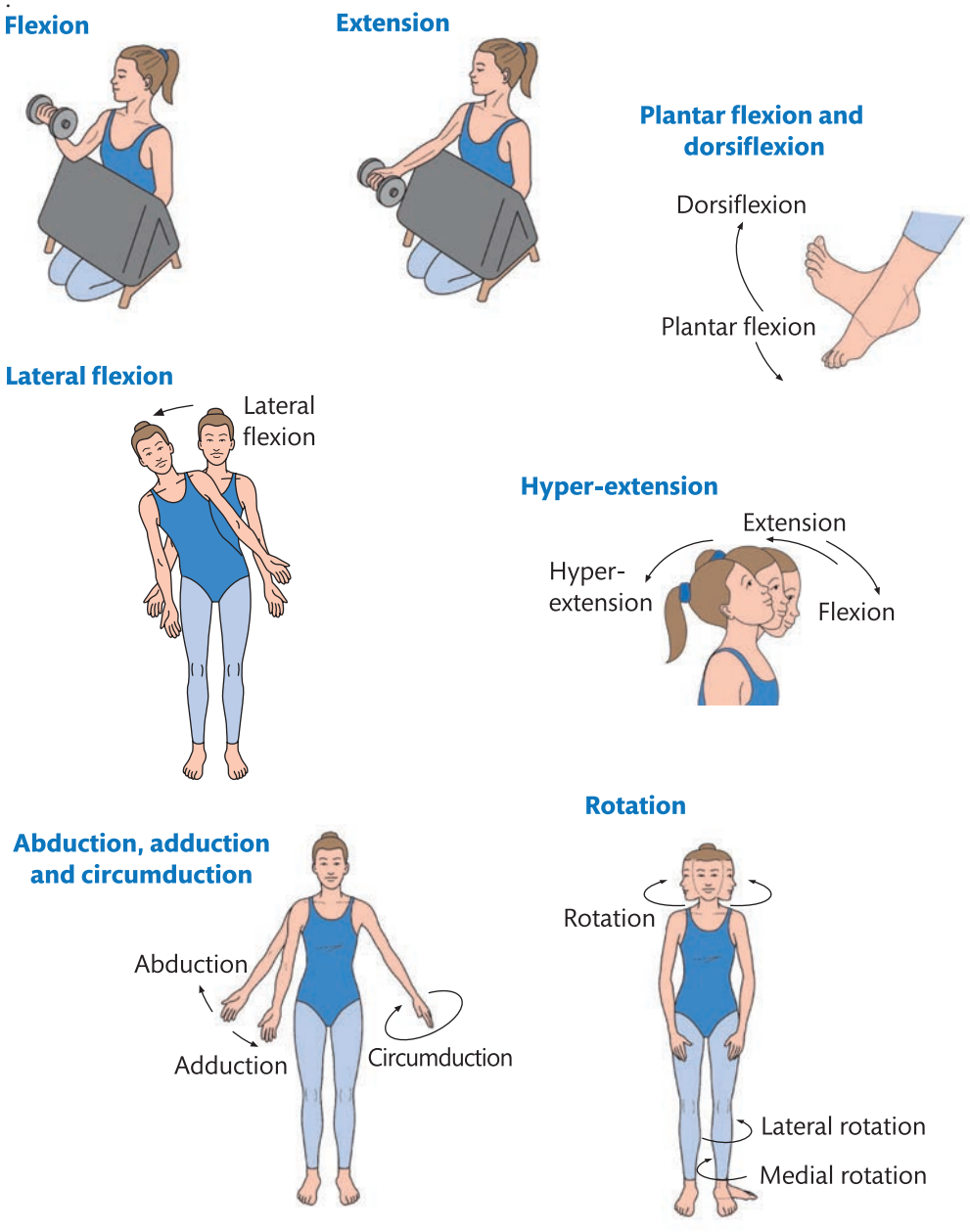


Figure 1.9: Anatomical and biomechanical terms relating to muscle action

Case study

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.

Now consider a tennis serve and the joint actions used. How are these similar to the action of throwing a ball? Many different sporting techniques will use similar joint actions and muscles that are refined to meet the needs of the specific sporting technique.

Check your knowledge

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

Responses of the skeletal system to a single sport or exercise session

You are probably aware that during exercise your heart rate and breathing rate increase, but did you know that your skeletal system will also respond to exercise? This is sometimes overlooked as the changes are small and out of sight. When you exercise or take part in sport your body's systems will adapt almost instantaneously so that your body is prepared for the additional stresses that will be put on it. This is one of the reasons why you should always complete a well-planned and performed warm-up before starting any physical activity.

Key terms

Viscous – describes how thick a fluid is. If synovial fluid is too thick then it will be hard to move the joint.

Acute responses – when the body makes an immediate change or response; **chronic responses** are the opposite and take place over a longer period of time.

Your skeletal system will respond to exercise in the short term by producing more synovial fluid in the synovial joints. This is so that the joints are lubricated and can protect the bones during the increased demands that exercise puts on the skeleton and joints. The fluid will also become less **viscous** and the range of movement at the joint will increase. The release of synovial fluid from the synovial membrane will also provide increased nutrients to the articular cartilage.

Another **acute response** to exercise is the increased uptake of minerals within the bones. Just as muscles become stronger the more you use them, a bone becomes stronger and denser when you regularly place exercise demands upon it. The body will absorb minerals such as calcium which will increase your bone mineral density. This is especially important for weight bearing exercises such as bench pressing. When more stress and force is applied to the bones they must be strong enough to cope with these increased demands.

Adaptations of the skeletal system to exercise

Your body responds to the stress of exercise or physical activity in a variety of ways. Some of these are immediate and are often referred to as acute responses to exercise. Others are long-term, and are often referred to as **chronic responses** or adaptations that contribute to improved fitness for sports participation and reduced health risk.

Like other systems of the body, the skeletal system will adapt to exercise. Exercise will increase your bone mineral density and over time this will result in stronger bones which will be more resistant to the forces found in sport such as kicking, jumping or running.

Long-term physical activity will also increase the strength of the ligaments which attach your bones together at synovial joints. When you exercise as part of a training programme, your ligaments will stretch a little further than normal and as a result will become more pliable over time, resulting in increased flexibility.

PAUSE POINT When you exercise, what are the immediate responses your body makes?

Hint Think about your warm-up before exercise. What happens to your body and why?

Extend Research and draw up a list of the changes that occur in the skeletal system and explain why they happen during exercise.

Additional factors affecting the skeletal system

The benefits of taking part in regular exercise or physical activity are huge. People who take part in regular exercise are more likely to live longer and are less likely to develop serious diseases. Exercise should be part of a healthy lifestyle and it is common to hear about the benefits of physical activity in preventing heart disease and controlling weight. Regular exercise can also help common skeletal diseases such as arthritis and osteoporosis.

Arthritis

Arthritis is a condition where there is an inflammation within a synovial joint, causing pain and stiffness in the joint. The most common type of arthritis is osteoarthritis. This is caused by general wear and tear over a long period of time. This reduces the normal amount of cartilage tissue, which may result in the ends of the bones rubbing together. This natural breakdown of cartilage tissue can be made worse by injury to the joint.

However, regular exercise can prevent arthritis. During physical activity your joints will produce more synovial fluid which will not only improve the joint lubrication, reducing friction between the bones, but will also provide important minerals to the cartilage. Exercises such as stretching will also improve the joint range of motion, lengthen the ligaments holding the bones in place and improve flexibility.

Osteoporosis

Osteoporosis is the weakening of bones caused by a loss in calcium or a lack of **vitamin D**. As you get older your bones slowly lose their mineral density and naturally become brittle, fragile and more likely to break under stress. However, physical activity and exercise can help prevent osteoporosis by promoting increased uptake of minerals within the bones, resulting in an increase in bone mineral density. Resistance training is a good method of preventing osteoporosis, as overloading the skeleton will increase bone density.

Key term

Vitamin D – is used to regulate the amount of calcium in the body and is produced from sunlight on our skin; it is created under the skin. Small amounts of vitamin D can also be found in oily fish and eggs.

Age

The skeletal system is a living tissue that is constantly growing and repairing itself so that it can provide support and protection. Generally, exercise and sports will benefit you. The exception to this is resistance training (weight training) in children, as this can cause more harm than good. The reason for this is that a child's bones are still growing and putting too much force on them can damage the epiphyseal plates which are found at each end of the long bones. Damage to these plates during childhood and puberty can result in stunted bone growth.

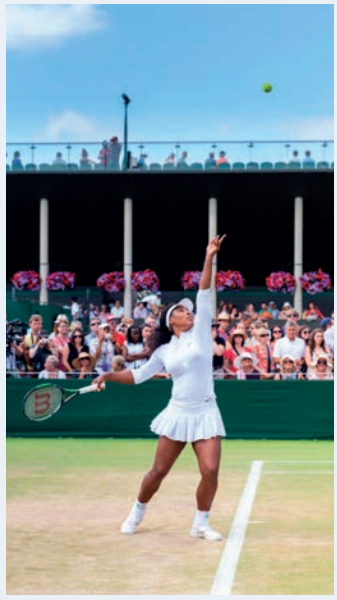
Assessment practice 1.1

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

2 Jack has the first stages of osteoporosis. He has been advised to take part in exercise to help prevent this condition from worsening. Identify one type of exercise that Jack could take part in to prevent the osteoporosis from getting worse. **(1 mark)**

3 Explain why weight bearing exercises will prevent osteoporosis from getting worse. **(3 marks)**

4 Analyse how movement at the synovial joints in the upper skeleton allows a tennis player to serve the ball as shown in the picture. **(6 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

- I will write down the key terms that need to be included in each answer.
- I will ensure that I have given sufficient examples relating to the number of marks available.

Review

- I will check my answer. Is it clear? Do I give suitable examples?

B The effects of exercise and sports performance on the muscular system

There are over 640 named muscles in the human body and these make up approximately 40 per cent of your body mass. The muscles that move your bones during activity are called **skeletal muscles**. In this section you will learn about the principal skeletal muscles, their associated actions, and muscle fibre types. This section also looks at the different types of muscles and their specific functions, as well as the responses and adaptations of the muscular system to sport or exercise.

Characteristics and functions of different types of muscle

There are three main types of muscle tissue in the human body.

- **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, which means it is under conscious control. Skeletal 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 to create movement. They can become fatigued during exercise. Skeletal muscles are explored in more depth from page 19.
- **Cardiac muscle** – this type of muscle tissue is only found in the wall of your heart. It works continuously. It is involuntary, which means it is not under conscious control. It is composed of a specialised type of striated tissue that has its own blood supply. Its contractions help to force blood through your blood vessels to all parts of your body. Each contraction and relaxation of your heart muscle as a whole represents one heartbeat. The cardiac muscle does not fatigue, which means that it does not get tired during exercise.

- **Smooth muscle** – an involuntary muscle that works without conscious thought, functioning under the control of your nervous system. It is located in the walls of your digestive system and blood vessels and helps to regulate digestion and blood pressure.

Discussion

In small groups, compare the different types of muscle tissue and their function. Discuss the importance of each of function in relation to the characteristics of the muscle.

Major skeletal muscles of the muscular system

Skeletal muscles are voluntary muscles which means that they are under your control. For example, 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 not only provide you with movement, strength and power but are also responsible for maintaining posture and generating heat which maintains your normal body temperature.

It can be difficult to remember the names, location and function of all the major skeletal muscles in the body. Figure 1.10 and Table 1.4 will help you to locate the main ones which are important to sport and exercise. You should be able to identify the main muscles used when performing common movements such as a kick in rugby, a tennis serve or a simple exercise such as a press-up.

Table 1.4: Major skeletal muscles and their function

Muscle	Function	Location	Origin	Insertion	Exercise/activity
Triceps	Extends lower arm	Outside upper arm	Humerus and scapula	Olecranon process	Dips, press-ups, overhead pressing
Deltoids	Abducts, flexes and extends upper arm	Forms cap of shoulder	Clavicle, scapula and acromion	Humerus	Forward, lateral and back-arm raises, overhead lifting
Pectorals	Flexes and adducts upper arm	Large chest muscle	Sternum, clavicle and rib cartilage	Humerus	All pressing movements
Biceps	Flexes lower arm at elbow	Front of upper arm	Scapula	Radius	Bicep curl, pull-ups
Wrist flexors	Flexes hand at wrist	Front of forearm	Humerus	Metacarpal	Bouncing a basketball when dribbling
Wrist extensors	Extends or straightens hand at wrist	Back of forearm	Humerus	Metacarpal	Straightening of wrist
Supinators	Supinate forearm	Top and rear of forearm	Humerus	Ulna	Back spin in racket sports, spin bowl in cricket
Pronators	Pronate forearm	Top and front of forearm	Humerus	Ulna	Top spin in racket sports, spin bowl in cricket

Table 1.4: Major skeletal muscles and their function – *continued*

Muscle	Function	Location	Origin	Insertion	Exercise/activity
Abdominals	Flex and rotate lumbar region of vertebral column	'Six-pack' muscle running down abdomen	Pubic crest and symphysis	Xiphoid process	Sit-ups
Hip flexors	Flex 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 lateralis • vastus medialis • vastus intermedius	Extends lower leg and flexes thigh	Front of thigh	Ilium and femur	Tibia and fibula	Squats, knee bends
Hamstrings • semimembranosus • semitendinosus • biceps femoris	Flexes lower leg and extends thigh	Back of thigh	Ischium and femur	Tibia and fibula	Leg curls, straight leg deadlift
Gastrocnemius	Plantar flexion, flexes knee	Large calf muscle	Femur	Calcaneus	Running, jumping and standing on tip-toe
Soleus	Plantar flexion	Back of lower leg	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
Erector spinae	Extension of spine	Long muscle running either side of spine	Cervical, thoracic and lumbar vertebrae	Cervical, thoracic and lumbar vertebrae	Prime mover of back extension
Teres major	Rotates and abducts humerus	Between scapula and humerus	Posterior surface of scapula	Intertubercular sulcus of humerus	All rowing and pulling movements, face pulls, bent over rows
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	Lateral flexion of trunk	Waist	Pubic crest and iliac crest	Fleshy strips to lower eight ribs	Oblique curls
Gluteals	Extends thigh	Large muscle on buttocks	Ilium, sacrum and coccyx	Femur	Knee-bending movements, cycling, squatting

PAUSE POINT What are the different muscle types?

Hint List the characteristics and functions of each muscle type.

Extend Explain the importance of the different types of muscle to sport and exercise.

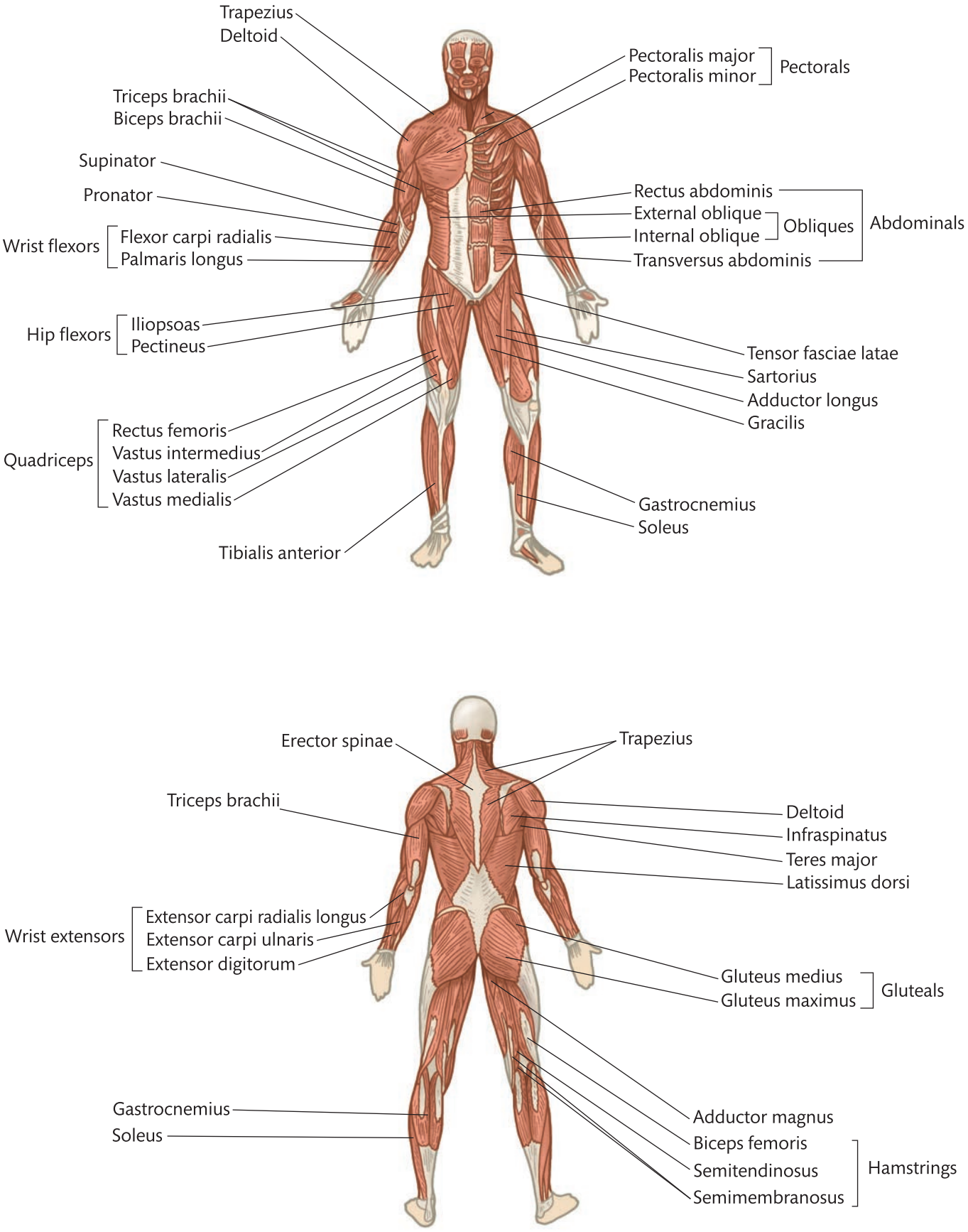


Figure 1.10: Major skeletal muscles and their location

Antagonistic muscle pairs

When a muscle contracts, it exerts a pulling force on the bones to which it is attached, causing them to move together around the joint. Muscles must cross the joints that they move. If a muscle did not cross a joint, no movement could occur.

Under normal circumstances, muscles are in a state of partial contraction, ready to react to a stimulus from your nervous system. When a stimulus from the nerve supply occurs, 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 to which they are attached. When a muscle contracts, one end normally remains stationary while the other end is drawn towards it. The end that remains stationary is known as the **origin**, and the end that moves 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 normally crosses over a joint to allow movement when the muscle shortens.

Muscles do not work in isolation. They are assembled in groups and work together to bring about movement. They act only by contracting and pulling. They do not push, although they are able to contract without shortening, and so hold a joint firm and 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. Many muscles work in antagonistic pairs; for example, Figure 1.11 shows how the bicep and tricep work together to perform a bicep curl.

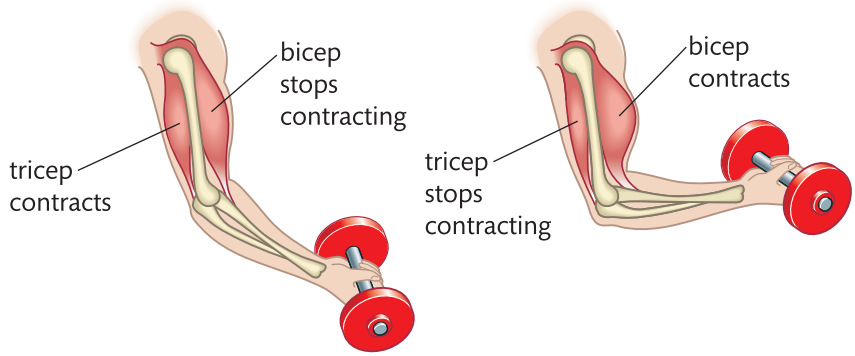


Figure 1.11: Bicep and tricep muscles work together during a bicep curl

Reflect

Consider the main muscle contracting and the opposite muscle 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**. This is the muscle responsible for the opposite movement, and the one that relaxes as the agonist works. If it did not relax, movement could not take place. Antagonists exert a 'braking' control over the movement.

Synergists are muscles that work together to 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 on the agonists to the most advantageous position.

Fixator muscles stop any unwanted movement throughout the whole body 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 in this sport.

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

Theory into practice

When your body is in action during sport and exercise, your muscles shorten, remain the same length or lengthen.

1. Using a dumbbell or other suitable resistance weight, bend your forearm upwards so that your elbow bends in a bicep curl action. Consider your bicep muscle. What is happening?
2. Now return your arm to the starting position by slowly lowering the forearm. What is happening to the bicep muscle now? Consider the action of the tricep muscle on the other side of the elbow joint.
3. Consider how these muscles work as a pair. How do these muscles control the movement?

Types of skeletal muscle contraction

There are three different types of muscle contraction which will be used depending on the sporting technique or exercise action.

Isometric

During an isometric contraction 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. An example is the abdominal plank position. This type of muscle work is easy to undertake but rapidly leads to fatigue. It can cause sharp increases in blood pressure as blood flow is reduced.

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. Concentric contractions are sometimes known as the **positive phase** of muscle contraction.

Eccentric

An eccentric muscular contraction is when a muscle returns to its normal length after shortening against resistance. Again using the bicep curl as an example, this is the controlled lowering of your arm to its starting position. At this point your muscles are working against gravity and act like a braking mechanism. This contraction can be easier to perform, but it does produce muscle soreness.

Eccentric contractions occur in many sporting and daily activities. Walking downstairs and running downhill involve eccentric contraction of your quadriceps muscles which are used to control the movement. 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.

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 Think of a press-up. Which muscles are working as antagonistic pairs in the shoulder?

Extend What types of contraction are taking place for each phase of a press-up at the shoulder joint?

Fibre types

All skeletal muscles are made up from muscle fibres. These fibres fall into two main categories depending on their speed of contraction: Type I ('slow-twitch') and Type II ('fast-twitch'). The mix of fibres varies from individual to individual, and within the individual from muscle group to muscle group. To a large extent this fibre mix is inherited. However, training can influence the efficiency of the different fibre types.

Key terms

Mitochondria – the organelles (parts of cells) in the body where aerobic respiration takes place.

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

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.

Type I

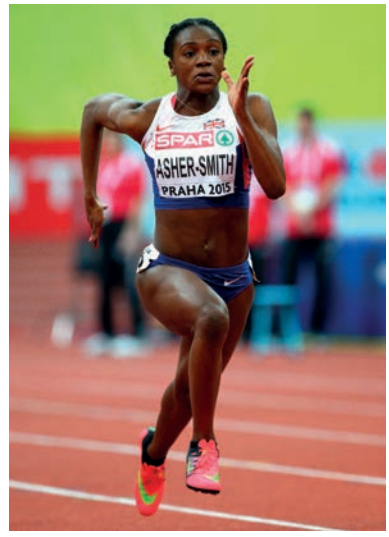
Type I (slow-twitch) fibres contract slowly and with less force. They are slow to fatigue and suited to longer-duration **aerobic** activities. Aerobic activity describes exercise where energy is produced using oxygen. The opposite of this is **anaerobic** activitiy, where movements are produced using energy that has been created without oxygen. Slow-twitch fibres have a rich blood supply and contain many **mitochondria** to sustain aerobic metabolism. Type I fibres have a high capacity for **aerobic respiration**. They are recruited for lower-intensity, longer-duration activities such as long-distance running and swimming.

Type IIa

Type IIa fibres (also called fast-twitch or fast-oxidative fibres) are fast-contracting, able to produce a great force, and are also resistant to fatigue. These fibres are less reliant on oxygen for energy supplied by the blood and therefore fatigue faster than slow-twitch fibres. Type IIa fibres are suited to speed, power and strength activities such as weight training with repeated repetitions (10–12 reps) and fast running events such as the 400 metres.

Type IIx

Type IIx fibres (also called fast-twitch or fast-glycolytic fibres) contract rapidly and have the capacity to produce large amounts of force, but they fatigue more readily, making them better suited to **anaerobic activity**. They depend almost entirely on **anaerobic respiration** and are recruited for higher-intensity, shorter-duration activities. They are important in sports that include many stop–go or change-of-pace activities such as rugby or football.



Sprinters use type IIx fast-twitch fibres

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 muscles 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).

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

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

Extend — Explain why your chosen sports require these types of fibre and how an athlete can improve their performance by understanding this.

Responses of the muscular system to a single sport or exercise session

When you exercise or take part in sport your muscles will respond in a variety of ways. Some of these responses are immediate and are known as acute responses. Responses that take place over a longer period of time are known as chronic responses.

Discussion

In small groups, list the changes in your body immediately after starting a high-intensity exercise. What is happening to your body? Why? Now think about different sports that require different intensities. How do sportspeople train to meet the demands of these physical activities?

Increased blood supply

The short-term effects of exercise on your muscles include an increase in metabolic activity (the rate at which the muscles produce and release energy so that movement can take place). As a result of this increase in metabolic activity, there is a greater demand for oxygen and glucose in the muscles, which is met by an increase in blood supply. Blood vessels expand or get wider to allow more blood to enter your muscles. This is called **vasodilation**. Blood flow increases significantly to ensure that the working muscles are supplied with the oxygen they need as well as to remove waste products such as carbon dioxide.

Increased muscle temperature

When you exercise you get warmer. This is because your muscles need energy from fuels such as fats and carbohydrates, which are broken down using chemical reactions that produce heat as a waste product. The more you exercise or the harder you train, the more energy your muscles need. This results in more heat being produced. The amount of heat your muscles produce is in direct relation to the amount of work they perform – the harder you work out, the more heat your muscles will produce. This principle is used in a warm-up which prepares your muscles for exercise by slowly increasing their temperature.

Increase muscle pliability

The warming of your muscles during activity makes them more pliable and flexible. Pliable muscles are less likely to suffer from injuries such as muscle strains. An increase in pliability will improve joint flexibility, as warm and pliable muscles are able to stretch further.

Lactate (high intensity exercise)

You may have experienced an uncomfortable burning sensation in your muscles during high-intensity exercise. This is most likely caused by the build-up of **lactic acid** which is a waste product produced during anaerobic exercise. This build-up of acid in the muscle tissue will result in rapid fatigue and will impede muscular contractions if it is not removed quickly.

Micro tears (resistance exercise)

During resistance training such as weight training, your muscles are put under stress to the point that tiny tears occur in the muscle fibres. These micro tears cause swelling in the muscle tissue which causes pressure on the nerve endings and pain. Training improvements will only be made if the body has rest and time to repair these micro tears, making the muscle a little bit stronger than it was before. Proteins are used to repair muscle tissue.

Key term

Eccentric muscle contraction – where a muscle lengthens as it contracts. Such contractions occur when controlling a force or movement.

Delayed onset of muscle soreness

Delayed onset of muscle soreness (or DOMS) is the pain felt in muscles 24–48 hours (typically) after taking part in strenuous exercise. The soreness usually occurs at least a day after exercise and can last up to 3 days. DOMS is caused by the microtears that occur when you exercise, particularly if you are unaccustomed to the intensity of exercise. DOMS is often associated with exercises where **eccentric muscle contraction** has occurred.

PAUSE POINT What are the immediate responses your muscles make when exercising?

Hint – Why do these changes happen during exercise?

Extend – What aspects of the warm-up are used to prevent muscle injury? Why is a warm-up before exercise important to your muscles?

Adaptations of the muscular system to exercise

Training or exercising regularly over a long period of time will allow your body's muscular system to change and adapt. For example, you will notice that your muscles change in size if you undertake a strength or resistance training programme. Such changes are known as chronic adaptations to exercise.

Hypertrophy occurs when muscles are regularly overloaded

Hypertrophy

Regular resistance training where the muscles are overloaded will increase muscle size and strength. The increase in muscle size is a result of the muscles fibres becoming larger due to increases in protein in the muscle cells; this is known as hypertrophy. The muscle fibres increase in size over time so that they can contract with greater force.

Increased tendon strength

Tendons are tough bands of fibrous connective tissue designed to withstand tension. Like muscles, tendons adapt to the overloading of regular exercise. Ligaments and tendons, the connective tissue structures around joints, will increase in flexibility and strength with regular exercise. Cartilage also becomes thicker.

Increase in number and size of mitochondria

When muscles are overloaded as part of resistance training, the muscle fibres will become bigger (hypertrophy). Within these muscle fibres are tiny structures called mitochondria which are responsible for energy production. Because of the increase in

fibre size, there is room for more and larger mitochondria, which results in the muscles being able to produce more aerobic energy which will improve aerobic performance.

Increase in myoglobin stores

Myoglobin is a type of haemoglobin (the red protein found in blood used for transporting oxygen) that is found exclusively in muscles. It is responsible for binding and storing oxygen in the blood within skeletal muscles. By following a planned exercise programme, you can increase the amount of myoglobin stored in your muscles. This is important as myoglobin will transport oxygen to the mitochondria which in turn will release energy. The more myoglobin you have, the more energy will be available for the muscle.

Increase in storage of glycogen

Your body needs a constant and steady supply of **glycogen** in order to produce energy. As your body adapts to long-term exercise, your muscles are able to store more glycogen. This means that you will be able to train at higher intensities for longer, as muscle glycogen does not require oxygen to produce energy.

Increase in storage of fat

You are able to use your fat stores to produce energy through a process called **aerobic glycolysis**. Well-trained athletes are able to use these fats more efficiently, breaking them down into fatty acids and into energy using oxygen. This enables them to use fats as an energy source when **carbohydrate** becomes scarce.

Increased tolerance to lactate

Anaerobic training stimulates the muscles to become better able to tolerate lactic acid, and clear it away more efficiently. With endurance training the capillary network (see page 39) extends, allowing greater volumes of blood to supply the muscles with oxygen and nutrients. The muscles are able to use more fat as a fuel source, and become more efficient at using oxygen, increasing the body's ability to work harder for longer without fatiguing. The net result is an increase in the body's maximal oxygen consumption.

Key terms

Glycogen – the stored form of glucose.

Carbohydrate – the sugars and starches found in foods such as potatoes, wheat and rice. Carbohydrates are broken down by the body into sugars which are used for energy production.

PAUSE POINT What long-term adaptations occur in your muscles when you exercise?

Hint: Consider the different muscle fibre types and list the exercises that could be used specifically to train them.

Extend: Explain how strength training changes the structure of the muscles and the benefits of this to sport performance.

Additional factors affecting the muscular system

There are two primary additional factors that will affect your muscular system and in turn affect exercise and sports performance.

Age

As you get older your muscle mass will decrease. The onset of this muscle mass loss begins around the age of 50 and is referred to as **sarcopenia**. Muscles become smaller, resulting in a decrease in muscle strength and power.

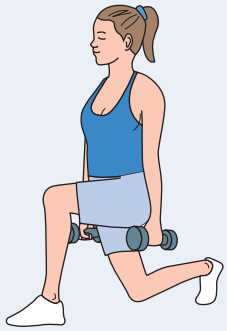
Cramp

Cramp is the sudden involuntary contraction of your muscle. The sensation of muscle spasm where you have no control of the tightening of the muscle fibres can be painful and can be prompted by exercise. The muscles of the lower leg are particularly susceptible to cramp during exercise. Cramp can last from a few seconds up to 10 minutes.

There are a number of factors that can contribute to cramp. The most common one in sport is dehydration which can result in the inadequate supply of blood to the muscles, reducing the supply of oxygen and essential minerals. To prevent cramp you should ensure that you drink plenty of fluid during exercise and sport, especially if the weather is hot. Stretching can also help to prevent cramp as this will lengthen the muscle fibres and improve muscle flexibility.

Assessment practice 1.2

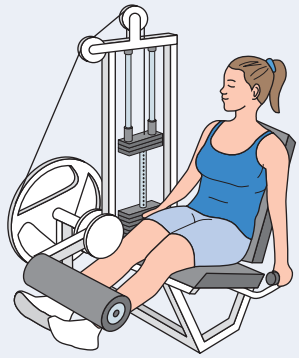
Nancy is a netball player. She uses weighted lunges as part of her training as shown.



1 Explain how the use of weighted lunges will improve Nancy's performance in netball. **(3 marks)**

2 Two days after Nancy's training session she experiences delayed onset of muscle soreness (DOMS). Describe why Nancy's training may cause DOMS. **(1 mark)**

3 Explain how muscle adaptation occurs as a result of Nancy's resistance training. **(2 marks)**



4 The second picture shows Nancy training on a resistance machine. Explain how Nancy's muscles work as antagonistic pairs for each phase of the movement. **(4 marks)**

Plan

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

Do

- I will write down the key words and explain each of them.
- I will make sure I contextualise 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?

C The effects of exercise and sports performance on the respiratory system

The respiratory system provides oxygen to all living tissue in your body, as well as removing waste products such as carbon dioxide, heat and water vapour. Oxygen is required for every cell in your body to function. Central to the respiratory system are your lungs, which enable oxygen to enter the body and carbon dioxide waste to be removed through the mechanism of breathing. Your body's ability to inhale and transport oxygen while removing waste products is critical to sports performance: the better your body is at this process, the better you will be able to train or perform in sport.

Structure and functions of the respiratory system

Air is drawn into your body via the nose and sometimes via the mouth, and passes through a series of airways to reach the lungs. This series of airways is referred to as the **respiratory tract** and can be divided into two main parts. The upper respiratory tract includes the nose, nasal cavity, mouth, pharynx and larynx. The lower respiratory tract consists of the trachea, bronchi and lungs.

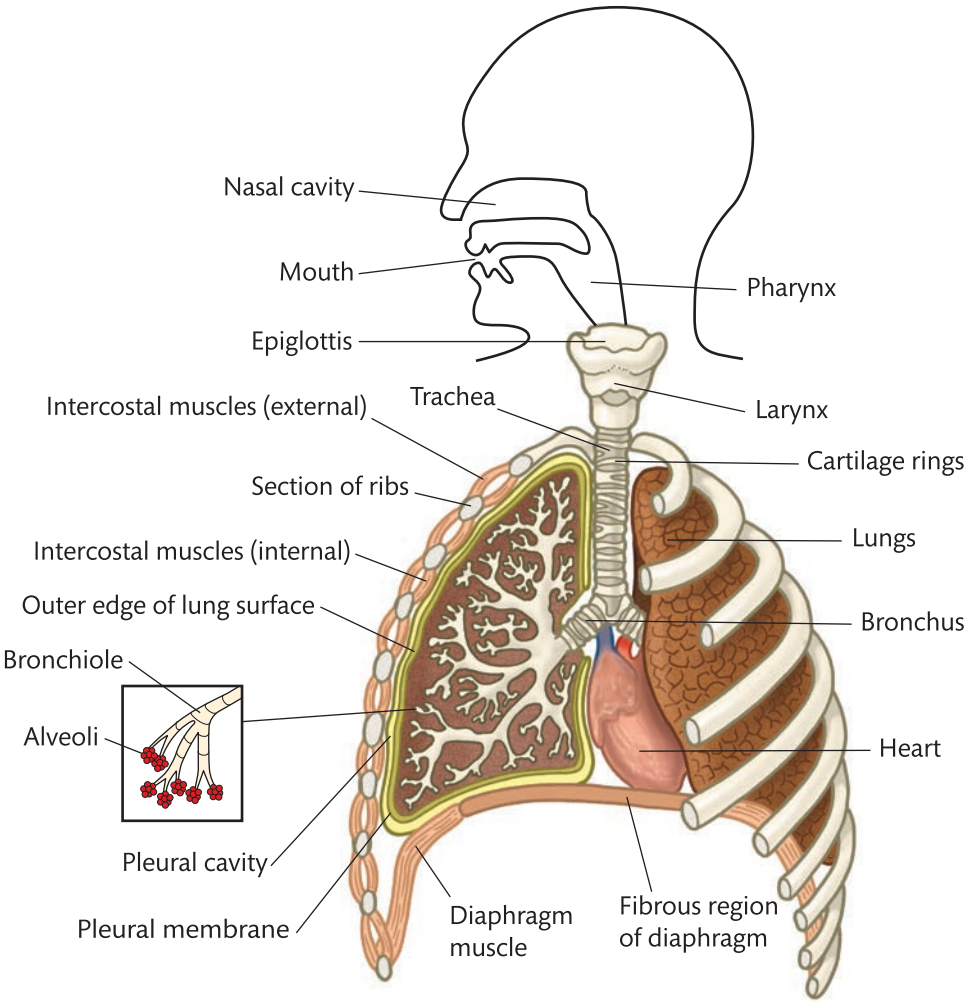


Figure 1.12: Bronchi, bronchial tree and lungs

Nasal cavity

When you breathe in, air enters the nasal cavity by passing through the nostrils. Hairs within the cavity filter out dust, pollen and other foreign particles before the air passes into the two passages of the internal nasal cavity. Here the air is warmed and moistened before it passes into the nasopharynx. A sticky mucous layer traps smaller foreign particles, which tiny hairs called cilia transport to the pharynx to be swallowed.

Pharynx

Commonly called the throat, the pharynx is a small tube that measures approximately 10–13 cm from the base of the skull to the level of the sixth cervical vertebra. The muscular pharynx wall is composed of skeletal muscle throughout its length. The funnel-shaped pharynx connects the nasal cavity and mouth to the larynx (air) and oesophagus (food). It is a passageway for food as well as air, so special adaptations are required to prevent choking when food or liquid is swallowed.

Larynx

The larynx, or 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.

Trachea

The trachea or windpipe denotes the start of the lower respiratory tract. It is about 12 cm long and 2 cm in diameter. It contains rings of cartilage to prevent it from collapsing, and it is flexible. It travels down the neck in front of the oesophagus and branches into the right and left bronchi.

Epiglottis

The epiglottis is 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.

Lungs

Your lungs are the organ that allows 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.

Bronchi

The bronchi branch off the trachea and carry air to the lungs. By the time 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 (sizes) of branching bronchial airways in the lungs. Because of this branching pattern, the bronchial network within the lungs is often called the **bronchial tree**.

Bronchioles

Bronchioles are 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 alveolus is a dense network of **capillaries** to facilitate the process of gaseous exchange. For more on gaseous exchange, see page 32.

PAUSE POINT Explain how air enters the body and how it is used.

Hint: List the journey of air from the mouth to the alveoli.

Extend: Draw a diagram of the journey of air from the nose to the alveoli. Label each part of the respiratory system on your diagram.

Diaphragm

The diaphragm is a flat muscle that is located beneath the lungs within the thoracic cavity and separates the chest from the abdomen. The diaphragm is 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 of the diaphragm decreases the volume of the chest cavity, pushing air out.

Thoracic cavity

This is the chamber of the chest that is protected by the thoracic wall (rib cage). It is separated from the abdominal cavity by the diaphragm.

Internal and external intercostal muscles

The 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.

Mechanisms of breathing

Breathing or **pulmonary ventilation** is the process by which air is transported into and out of the lungs, and it can be considered to have two phases. It requires the thorax to increase in size to allow air to be taken in, followed by a decrease to allow air to be forced out.

Inspiration

Inspiration is the process of breathing air into the lungs. The intercostal muscles between the ribs 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 opposite of inspiration is expiration, and this occurs when the intercostal muscles relax. The diaphragm relaxes, moving upwards, and the ribs move downwards and inwards. Pressure within the lungs is increased and air is expelled or pushed out of the body.

During sport or exercise, greater amounts of oxygen are required, so the intercostal muscles and diaphragm must work harder. This results in an increase in your breathing rate and an increase in the force of your breath.

Control of breathing

Neural control

Breathing is a complex process that is largely under involuntary control by the respiratory centres of your brain. Inspiration is an active process, as the diaphragm muscle is **actively** contracting which causes air to enter the lungs. Expiration is a passive process, as the diaphragm muscle **relaxes** to allow air to exit the lungs. This process is controlled by neurones (cells that conduct nerve impulses) in the brain stem. Neurones in two areas of the **medulla oblongata** are critical in respiration.

Key term

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

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.

Chemical control

Other factors that control breathing are the continually changing levels of oxygen and carbon dioxide in the blood. Sensors responding to such chemical fluctuations are called **chemoreceptors**. These are found in the medulla and in the **aortic arch** and **carotid arteries**. 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 to breathing rates.

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.

Gaseous exchange

Gaseous exchange is the process by 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 and removes carbon dioxide from the bloodstream to the lungs.

The alveolar and capillary walls form a **respiratory membrane** that has gas on one side and blood flowing past on the other. Gaseous exchange occurs readily by simple diffusion across the respiratory membrane. 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.

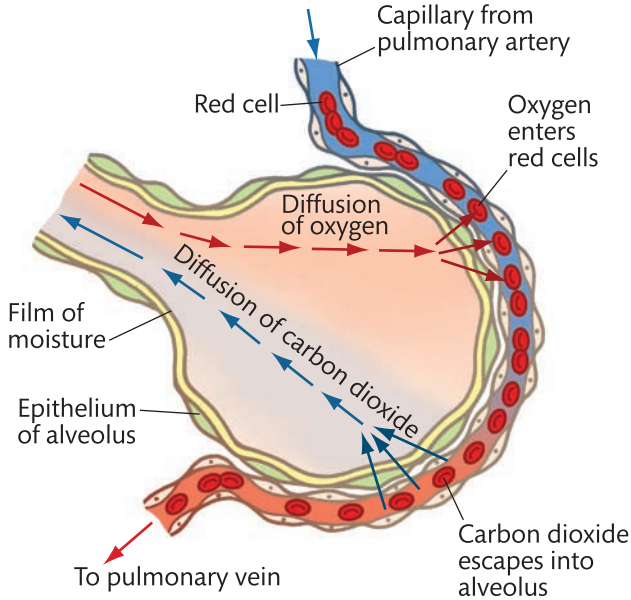


Figure 1.13: Gaseous exchange in action in an alveolus

Lung volumes

What happens to your breathing when you are exercising or training? Your lungs are designed to take in more air during exercise so that more oxygen can reach the alveoli and more carbon dioxide can be removed. Your breathing will become deeper and more frequent to cope with the demands that exercise puts on your body.

Your **respiratory rate** is the amount of air you breathe in one 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. It can increase significantly during exercise, by as much as 30–40 breaths per minute.

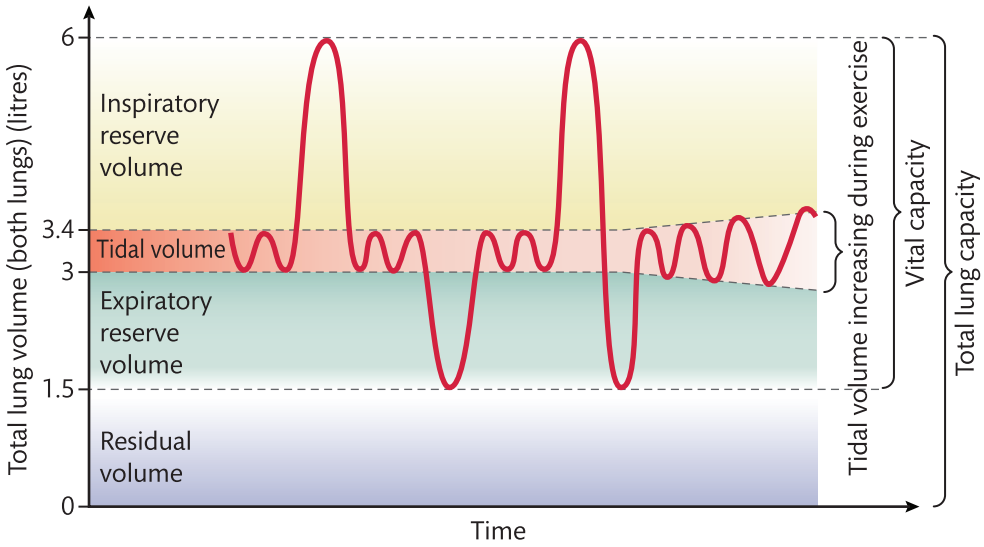


Figure 1.14: Lung volume and capacities of a healthy adult

Tidal volume

Tidal volume is the term used to describe the volume of air breathed in and out with each breath. Under normal conditions this represents about 500 cm^3 of air breathed, both inhaled and exhaled. Of this, approximately two-thirds (350 cm^3) reaches the alveoli in the lungs where gaseous exchange takes place. The remaining 150 cm^3 fills the pharynx, larynx, trachea, bronchi and bronchioles and is known as dead or stationary air.

During exercise, tidal volume increases to allow more air to pass through the lungs. The volume of air passing through the lungs each minute is known as the **minute volume** – it is determined by the breathing rate and the amount of air taken in with each breath.

- The lungs normally contain about 350 cm^3 of fresh air, 150 cm^3 of dead air and 2500 cm^3 of air that has already undergone gaseous exchange with the blood.
- The lungs are never fully emptied of air, otherwise they would collapse. The air that remains in the lungs after maximal expiration, when you breathe out as hard as you can, is referred to as **residual volume**. The volume is around 1200 cm^3 for an average male.
- **Vital capacity** is the amount of air that can be forced out of the lungs after maximal inspiration. The volume is around 4800 cm^3.
- By breathing in deeply, it is possible to take in more air than usual so that more oxygen can reach the alveoli. This is especially important during exercise. You can breathe in up to an additional 3000 cm^3 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 cm^3. 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, after maximal inspiration. It is normally around 6000 cm^3 for an average-sized male.

PAUSE POINT Can you remember the different lung volumes?

Hint Write a list of the different lung volumes and briefly describe each one.

Extend Think about how your breathing changes during exercise. Explain what is happening to each specific lung volume.

Responses of the respiratory system to a single sport or exercise session

Your body is surprisingly insensitive to falling levels of oxygen, yet it is sensitive to increased levels of carbon dioxide. The levels of oxygen in arterial blood vary little, even during exercise, but carbon dioxide levels vary in direct proportion to the level of physical activity. The more intense the exercise, the greater the carbon dioxide concentration in the blood. To combat this, your breathing rate increases to ensure the carbon dioxide can be expelled through expiration.

Increased breathing rate

Exercise results in an increase in the rate and depth of breathing. During exercise your muscles demand more oxygen, and the corresponding increase in carbon dioxide production stimulates faster and deeper breathing. The capillary network surrounding the alveoli expands, increasing blood flow to the lungs and pulmonary diffusion.

A minor rise in breathing rate prior to exercise is known as an anticipatory rise. When exercise begins there is an immediate and significant increase in breathing rate, believed to be a result of receptors working in both the muscles and joints.

After several minutes of aerobic exercise, breathing continues to rise, though at a slower rate, and it levels off if the exercise intensity remains constant. If the exercise is maximal, the breathing rate will continue to rise until exhaustion. After exercise the breathing rate returns to normal, rapidly to begin with and then slowly.

Increased tidal volume

During exercise, tidal volume increases to allow more air to pass through the lungs. Tidal volume is elevated by both aerobic and anaerobic exercise. During exercise, oxygen is depleted from your body, triggering a deeper tidal volume to compensate.

During strenuous exercise, oxygen diffusion may increase by as much as three times above the resting level. Likewise, minute ventilation depends on breathing rate and total volume. During exercise adults can generally achieve minute ventilation approximately 15 times greater than the resting values.

Adaptations of the respiratory system to exercise

Like the cardiovascular system, the respiratory system undergoes specific adaptations in response to an organised and regular training programme. These adaptations help to maximise the efficiency of the respiratory system; oxygen can be delivered to the working muscles to meet the demands of the exercise while waste products can be removed quickly.

Increased vital capacity

Your vital capacity increases in response to long-term physical training to provide an increased and more efficient supply of oxygen to working muscles.

Increased strength of respiratory muscles

The diaphragm and intercostal muscles increase in strength, allowing for greater expansion of the chest cavity. This will mean that it is easier to take deeper breaths as the stronger and more pliable muscles will allow the chest cavity to expand further.

Increase in oxygen and carbon dioxide diffusion rate

Your respiratory system adapts to regular training, allowing oxygen and carbon dioxide to diffuse more rapidly. An increase in diffusion rates in tissues means that you can train longer and harder, as your muscles will be supplied with more oxygen and the increased carbon dioxide will be removed more quickly.

PAUSE POINT Why is the respiratory system so important to sports performance?

Hint Describe how the respiratory system adapts to long-term exercise.

Extend Explain why each adaptation can improve sport and exercise performance.

Additional factors affecting the respiratory system

Although regular training will improve the efficiency of your respiratory system, there are a number of additional considerations that can affect this system.

Asthma

Asthma is a common condition where the airways of the respiratory system can become restricted, making it harder for air to enter the body, resulting in coughing, wheezing or shortness of breath.

During normal breathing, the bands of muscle that surround the airways are relaxed and air moves freely. However, asthma makes the bands of muscle surrounding the airways contract and tighten so that air cannot move freely in or out of the body. Asthma can have a negative effect on sports performance as people with the condition will not be able to get enough oxygen into their lungs to supply their muscles, especially with the increased amounts required during exercise.

However, regular exercise will strengthen your respiratory system and help prevent asthma. Regular aerobic training can help to improve breathing and muscular strength, and endurance training will also improve oxygen uptake.

Safety tip

If you suffer from asthma always carry your inhaler. If you begin to experience the symptoms of asthma then stop the exercise immediately.

Research

For more information about asthma, see NHS Choices – www.nhs.uk/Livewell/asthma.

Case study

Paula Radcliffe

World record marathon runner Paula Radcliffe has had exercise-induced asthma all of her life. However, through determination and the correct medication, she has been able to compete successfully at the highest level and is currently the world record holder for the women's marathon with her time of 2 hours, 15 minutes and 25 seconds.

To ensure that she is able to train and compete, Paula always warms up gently and gradually so that her asthma does not interfere. When training she will use her preventer inhaler first thing in the morning and then her reliever inhaler before she starts exercising.

Paula's message is clear: 'control your asthma, don't let it control you'.

Paula Radcliffe is one of many elite athletes who compete successfully despite suffering from asthma

Check your knowledge

1 How does asthma affect sporting performance?

2 What is the difference between a preventer inhaler and a reliever inhaler?

Effects of altitude/partial pressure on the respiratory system

Many elite athletes like to train at high altitude as the air pressure is lower and the oxygen particles are farther apart. This means that the density of oxygen in the air is lower and it is harder to breathe (inspire) this oxygen into your body due to lower partial pressure. Over time the athletes' respiratory system will adapt to this lower pressure and become more efficient.

In the short term, the effects of altitude on the body are that your lungs have to work harder. Symptoms can include shortness of breath, dizziness, headaches and difficulties in concentrating. The decreased availability of oxygen at higher altitudes can quickly lead to hypoxia, which occurs when the body has insufficient access to oxygen. To cope with the decrease in available oxygen, you must breathe faster and deeper.

Like other systems of the body, the respiratory system will adapt over a long period of time so that it can cope with the decrease in available oxygen at higher altitudes. Your lungs will acclimatise by becoming larger which enables them to take in more oxygen. The body will also produce more red blood cells and capillaries, enabling the lungs to oxygenate the blood more efficiently.

Athletes who train at altitude feel the benefits of a more efficient respiratory system when they return to compete at lower altitudes. Athletes who were born at high altitude benefit even more, having grown up and developed in that environment.

Assessment practice 1.3

Freddie is a football player.

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

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

3 Explain how increasing the strength of the respiratory muscles aids performance in long distance running. **(4 marks)**

Plan

- I will plan longer answers by noting the key words and likely examples.
- I will look at the marks available and allow time to write a full answer.

Do

- I will write a structured answer, especially for questions that offer more marks.
- I will give relevant examples linked to the key theories.

Review

- Have I reread 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 The effects of exercise and sports performance on the cardiovascular system

The cardiovascular system is sometimes referred to as the **circulatory system** and consists of the heart, blood vessels and blood. The cardiovascular system 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. Oxygen is transported from the lungs to the body tissues, while carbon dioxide is carried from the body tissues to the lungs for excretion.

Structure of the cardiovascular system

The heart

The heart is a unique hollow muscle and is the pump of the cardiovascular system. It is located under the sternum (which provides protection) and is about the size of a closed fist. The function of the heart is to drive blood into and through the arteries in order to deliver it to the tissues and working muscles.

The heart is surrounded by a twin-layered sac known as the pericardium. The cavity between the layers is filled with pericardial fluid, whose purpose is to prevent friction as the heart beats. The heart wall itself 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 right side of the heart 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.

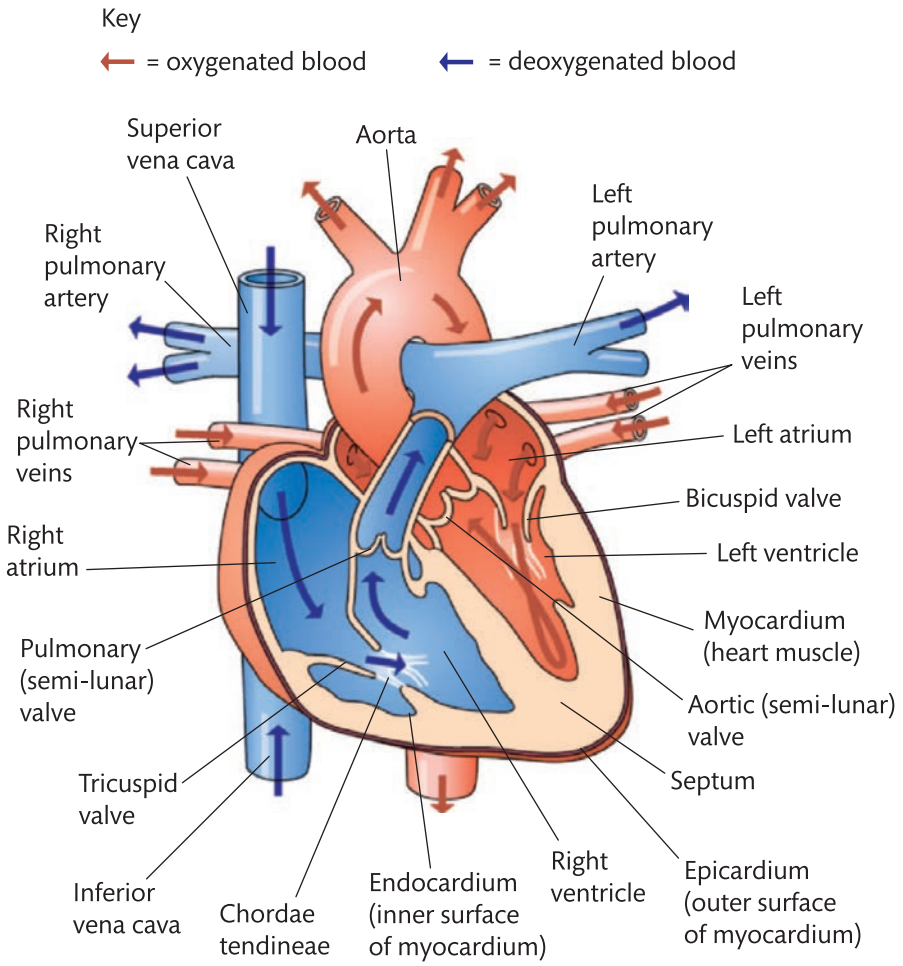


Figure 1.15: Diagram of the heart

The heart can be thought of as two pumps: 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; see Figure 1.15). The chambers on the right supply blood at a low pressure to the lungs via the pulmonary arteries, arterioles and capillaries, where gaseous exchange takes place. This blood is then returned to the left side of the heart via the capillaries, venules and veins.

When the chambers of the left side of the heart are full, it contracts simultaneously with the right side, acting as a high-pressure pump. It supplies oxygenated blood via the arteries, arterioles, and capillaries 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) is taken on board. The blood then returns to the right atrium of the heart via the capillaries, venules and veins.

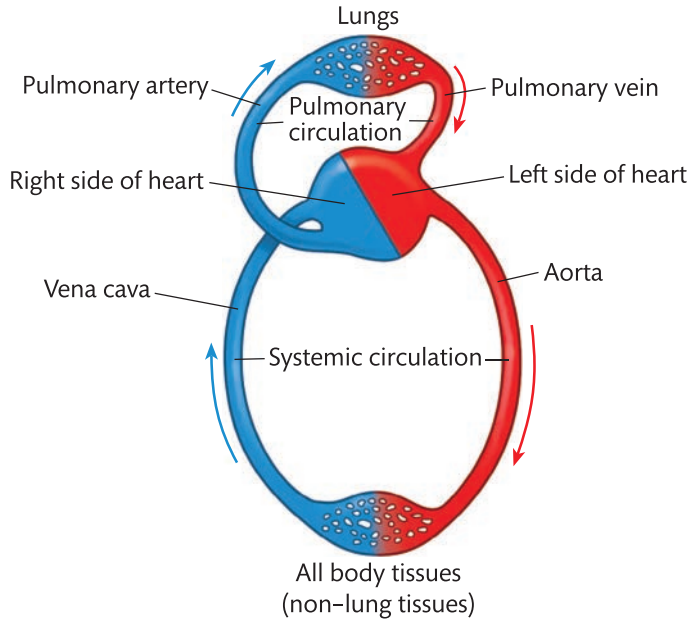


Figure 1.16: Double circulation through the heart

The main parts of the heart are as follows.

Key terms

Oxygenated blood – blood containing oxygen.

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

- **Coronary arteries** – these are the blood vessels that supply oxygenated blood to the heart muscle. There are two coronary arteries, the left and right.
- **Atria** – these are 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** from the superior and inferior vena cava. 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** – situated 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.
- **Semi-lunar valves (aortic valve and pulmonary valve)** – the aortic valve is situated between the left ventricle and the aorta and prevents flow from the aorta back into the left ventricle. The pulmonary valve is situated between the right ventricle and the pulmonary artery.

The major blood vessels connected to the heart are as follows.

- **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.

PAUSE POINT Explain the function of the heart in the cardiovascular system.

Hint Close the book and draw a diagram of the heart. Try to label each part of your diagram.

Extend Label the blood flow through the heart, showing where the blood is flowing to and from.

Structure of blood vessels

As the heart contracts, blood flows around the body in a complex network of vessels. Around 96,000 km of arteries, arterioles, capillaries, venules and veins allow the blood's circulation throughout the body. The structure of these different vessels is determined by their different functions and the pressure of blood within them.

Blood flowing through the arteries appears bright red due to its oxygenation. As it moves through the capillaries it drops off oxygen and picks up carbon dioxide. By the time it reaches the veins it is a darker shade of red than oxygenated blood.

Arteries

Arteries carry blood **away** from the heart, and with the exception of the pulmonary artery they carry oxygenated blood. They have thick muscular walls to carry blood at high speeds under high pressure. When the heart ejects blood into the large arteries, the arteries expand to accommodate this blood. They do not require valves as the pressure within them remains high at all times, except at the point where the pulmonary artery leaves the heart. Arteries have two major properties: **elasticity** and **contractility**.

The smooth muscle surrounding the arteries enables their diameter to be decreased and increased as required. This contractility of the arteries helps to maintain blood pressure in relation to changes in blood flow. The arteries are mostly located deep within the body, except where they can be felt at a pulse point. These vessels branch into smaller arterioles that ultimately deliver blood to the capillaries.

Arterioles

Arterioles have thinner walls than arteries. They control blood distribution by changing their diameter. This mechanism adjusts blood flow to the capillaries in response to differing demands for oxygen. During exercise, muscles require an increased blood flow in order to get extra oxygen, so the diameter of arterioles leading to the muscles dilates, or gets wider. To compensate for this increase in demand for blood by the muscles, other areas, like the gut, have their blood flow temporarily reduced, and the diameter of their arterioles is decreased. Arterioles are essentially responsible for controlling blood flow to the capillaries.

Capillaries

Capillaries connect arteries and veins by uniting arterioles and venules. They are the smallest of all the blood vessels, narrow and thin. The number of capillaries in muscle

may be increased through frequent and appropriate exercise. They form an essential part of the cardiovascular system as they allow the diffusion of oxygen and nutrients required by the body's cells. Capillaries that surround muscles ensure they get the oxygen and nutrients they require to produce energy. The walls of capillaries are only one cell thick, allowing nutrients, oxygen and waste products to pass through. The pressure of blood within the capillaries is higher than that in veins, but lower than in the arteries.

Veins

Veins facilitate **venous return** – the return of deoxygenated blood to the heart. They have thinner walls than arteries and a relatively large diameter. By the time blood reaches the veins, it is flowing slowly and under low pressure. Contracting muscles push the thin walls of the veins inwards to help squeeze the blood back towards the heart. As these muscle contractions are intermittent, there are a number of pocket valves in the veins that help to prevent any backflow when the muscles relax. Veins are mainly close to the surface and can be seen under the skin. They branch into smaller vessels called **venules**, which extend to the capillary network.

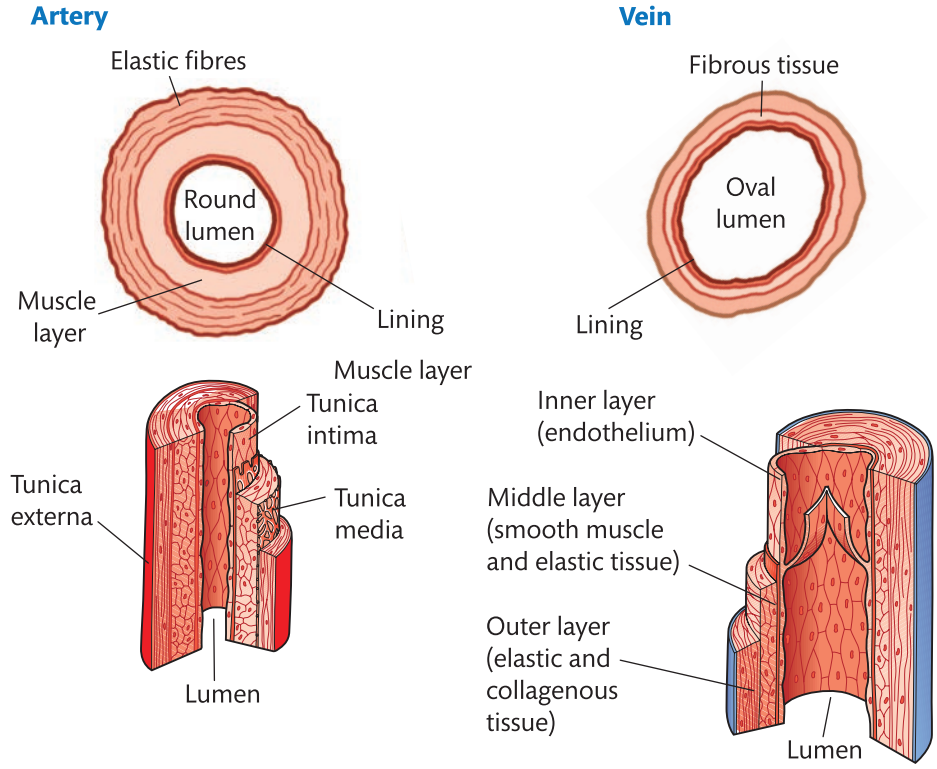


Figure 1.17: Structure of arteries and veins

Table 1.5: Comparison between veins and arteries

Veins	Arteries
Carry blood from the tissues of the body to the heart	Carry blood away from the heart to the tissues of the body
Usually found just beneath the skin	Found deeper within the body
Have less muscular walls than arteries	Are more muscular than veins, with much more elastic fibres
Have valves to prevent the backflow of blood	Do not contain valves
Contain blood under low pressure	Contain blood under high pressure

Venules

Venules are the small vessels that connect the capillaries to the veins. The venules will take the blood from the capillaries and transport this deoxygenated blood under low pressure to the veins which, in turn, will lead back to the heart.

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

Hint Close the book and list the differences between arteries and veins.

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

Composition of blood

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

- **red blood cells** (erythrocytes) – the main function of red blood cells is to carry oxygen to all living tissue. All red blood cells contain a protein called haemoglobin which gives blood its red colour and when combined with oxygen forms oxyhaemoglobin. Red blood cells are round, flattened discs with an indented shape which gives them a large surface area and allows 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 made up of approximately 90 per cent water as well as electrolytes such as sodium, potassium and proteins. The plasma also carries carbon dioxide, dissolved as carbonic acid.
- **white blood cells** (leucocytes) – the components of blood that protect the body from infections. White blood cells identify, destroy and remove pathogens such as bacteria or viruses from the body. White blood cells originate in the bone marrow and are stored in your blood.
- **platelets** (thrombocytes) – disc-shaped cell fragments produced in the bone marrow. The primary function of platelets is clotting to prevent blood loss.

Function of the cardiovascular system

There are a number of important functions that the cardiovascular system plays during exercise and sports performance.

Delivering oxygen and nutrients

The key function of the cardiovascular system is to supply oxygen and nutrients to the tissues of the body via the bloodstream. During exercise your body will need more of these so the cardiovascular system responds to ensure that there is a suitable supply to meet the increased demands. When the cardiovascular system can no longer meet these demands, fatigue will occur in the muscles and performance will deteriorate.

Removing waste products – carbon dioxide and lactate

As well as providing oxygen and nutrients to all the tissues in the body, the circulatory system carries waste products from the tissues to the kidneys and the liver, and returns carbon dioxide from the tissues to the lungs. During exercise your muscles will produce more carbon dioxide and lactate and it is essential that these are removed, otherwise muscle fatigue will occur.

Thermoregulation

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.

Your cardiovascular system uses the following ways of controlling and distributing heat around your body.

- **Vasodilation of blood vessels near the skin** – during exercise, vasodilation of blood vessels occurs in the parts of the active muscles where gaseous exchange takes place. Vasodilation is caused by the relaxation of the involuntary muscle fibres in the walls of the blood vessels and causes an increase in the diameter of blood vessels. This decreases resistance to the flow of blood to the area supplied by the vessels. This will result in a decrease in body temperature as heat within the blood can be carried to the skin surface.
- **Vasoconstriction of blood vessels near the skin** – blood vessels can also temporarily shut down or limit blood flow to tissues. This process is known as vasoconstriction and causes a decrease in the diameter of blood vessels. This will result in an increase in body temperature, as heat loss is reduced as blood is moved away from the surface.

Fighting infection

Leucocytes (white blood cells) are constantly produced inside the bone marrow. They are stored in, and transported around the body by, the blood. They can consume and ingest pathogens (substances that cause illness) and destroy them, produce antibodies that will also destroy pathogens, and produce antitoxins which will neutralise the toxins that may be released by pathogens.

Clotting 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 the 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.

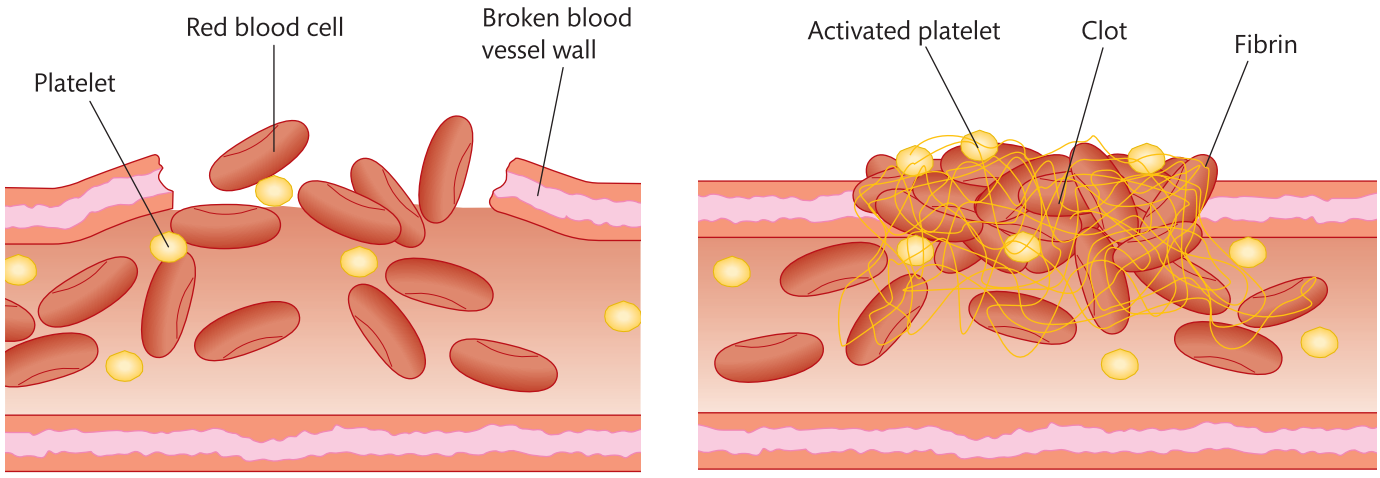


Figure 1.18: Clotting prevents excessive bleeding when a blood vessel is damaged

PAUSE POINT Identify the functions of the cardiovascular system and explain why they are important to sports performance.

Hint – Describe the main functions of the cardiovascular system.

Extend – Explain each of the main functions of the cardiovascular system and why they are so important to sport and exercise performance.

Nervous control of 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.

Your heart's electrical system is made up of three main parts: the sinoatrial node, the atrioventricular node, and the Bundle of His and Purkinje fibres (Figure 1.19).

Sinoatrial node (SAN)

The sinoatrial node (SAN) is commonly referred to as the heart's pacemaker and is located within the wall of the right atrium. The SAN sends an impulse or signal from the right atrium through the walls of the atria, causing the muscular walls to contract. This contraction forces the blood within the atria down into the ventricles.

Atrioventricular node (AVN)

The atrioventricular node (AVN) is 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. Slowing down the signal allows the atria to contract **before** the ventricles, which means that the ventricles are relaxed (or open) and ready to receive the blood from the atria at the top of the heart.

Bundle of His and Purkinje fibres

Bundle of His are specialist heart muscle cells that are responsible for transporting the electrical impulses from the AVN. They are 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 a paced interval. This contraction causes the blood within the ventricle to be pushed up and out of the heart, either to the lungs or to the working muscles.

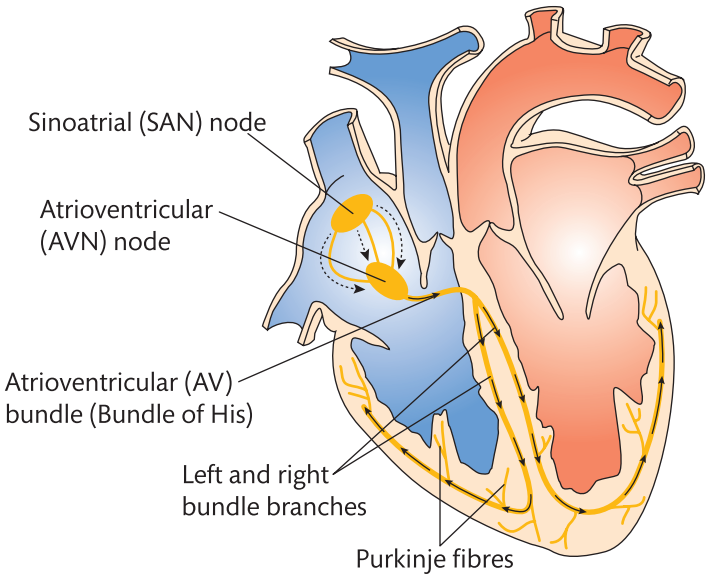


Figure 1.19: The heart's electrical system

Effects of the sympathetic and parasympathetic nervous system

The autonomic nervous system is the part of the nervous system that regulates body functions such as breathing and your heart beating, and it is involuntary.

This system can be further divided into the following nervous systems.

- **Sympathetic nervous system** – prepares the body for intense physical activity and is often referred to as the 'fight or flight' response.
- **Parasympathetic nervous system** – relaxes the body and inhibits or slows many high energy functions. This is often referred to as the 'rest and digest' response.

During exercise and sport the **sympathetic nervous system** will cause the heart to beat faster and your lungs to work harder, allowing you to produce more energy and meet the demands of the exercise.

After exercise your heart rate will need to slow down to its normal resting levels. It is the job of the **parasympathetic nervous system** to do this; if the parasympathetic nervous system did not function then your heart rate would continue to be elevated.

Responses of the cardiovascular system to a single sport or exercise session

During exercise your contracting muscles require a continual supply of nutrients and oxygen to support energy production. These requirements are over and above those required to support normal activities at work or rest. Your heart has to beat harder and faster to meet these increased demands. If these demands are repeated frequently as a result of a systematic training programme, over time your heart will become stronger and your cardiovascular system will become more efficient at supplying oxygen and removing waste products.

Anticipatory increase in heart rate prior to exercise

You may have experienced the feeling that your heart is beating faster than usual immediately before a sports match. This is known as an **anticipatory response**. Your heart rate will increase just before exercise in order to prepare for the increased demands that are about to be put on your body. Nerves that directly supply your heart and chemicals in your blood can rapidly alter your heart rate. The greatest anticipatory heart-rate response is observed in short sprint events.

Increased heart rate

In order for your muscles to receive more oxygenated blood, your heart rate will increase during exercise. Nerve centres in your brain detect cardiovascular activity and this results in adjustments that increase the rate and pumping strength of your heart. At the same time, regional blood flow is altered in proportion to the intensity of the activity undertaken.

Increased cardiac output

Cardiac output is the amount of blood pumped out of the left side of the heart to the body in one minute. It is the product of heart rate (beats per minute) and stroke volume (the amount of blood per heart beat):

- cardiac output = heart rate × stroke volume

During participation in sport and exercise, cardiac output will be greater as a result of increases in heart rate and/or stroke volume. Stroke volume does not increase significantly beyond the light work rates of low-intensity exercise, so the increases in cardiac output required for moderate to high-intensity work rates are mostly achieved by increases in heart rate. Your maximum attainable cardiac output decreases with increasing age, largely as a result of a decrease in maximum heart rate.

Increased blood pressure

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**, e.g. $\frac{120}{80}$ mm Hg

Redirection of blood flow

To ensure that blood reaches the areas of the body that need it the most during exercise (i.e. the working muscles), your body will redirect and redistribute the flow of blood. This ensures that the maximum amount of oxygenated blood can reach the muscles, but other areas of the body that need less oxygen during exercise will receive less blood. The body does this using vasodilation and vasoconstriction – refer back to the section on thermoregulation starting on page 41 for more information.

Theory into practice

In pairs, choose a sport that 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 take approximately five 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.

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 you think would have happened if you had exercised at higher intensities?

Adaptations of the cardiovascular system due to exercise

If you undertake a purposeful and well-planned exercise programme, your cardiovascular system will adapt over time and you will become fitter and more able to cope with the demands of exercise. The extent of these changes will depend on the type, intensity and frequency of exercise undertaken, and the overload achieved.

Cardiac hypertrophy

Cardiac hypertrophy is the enlargement of your heart over a long period of time. Training will cause the walls of your heart to get thicker. In particular the wall of the left ventricle will thicken, increasing the strength potential of its contractions.

Increase in resting and exercising stroke volume

Stroke volume is the amount of blood that can be ejected from the heart in one beat. In simple terms, the more blood that can be pushed out of the heart, the more oxygen can get to the muscles. Stroke volume at rest has been shown to be significantly higher after a prolonged endurance-training programme. The heart can therefore pump more blood per minute, increasing cardiac output during maximal levels of exercise. Blood flow increases as a consequence of an increase in the size and number of blood vessels. This allows for more efficient delivery of oxygen and nutrients.

Decrease in resting heart rate

The result of cardiac hypertrophy and an increase in stroke volume through long-term exercise is that your resting heart rate falls, reducing the workload on your heart.

Reduction in resting blood pressure

Exercise causes your blood pressure to rise for a short time. However, when you stop, your blood pressure should return to normal. The quicker it does this, the fitter you are likely to be. Research indicates that regular exercise can contribute to lowering blood pressure. For people suffering from high blood pressure (hypertension), steady aerobic exercise is often recommended to reduce this.

Decreased heart rate recovery time

Heart rate recovery is a measure of how much your heart rate falls during the first minute after exercise. The fitter your heart, the quicker it returns to normal after exercise. Fitter individuals generally recover more rapidly because their cardiovascular system can adapt more quickly to the imposed demands of exercise.

Capillarisation of skeletal muscle and alveoli

Long-term exercise, particularly aerobic exercise, can lead to an increase in the number of capillaries in the cardiac and skeletal muscle. Blood flow increases as a consequence of this increase in the size and number of blood vessels. This allows for more efficient delivery of oxygen and nutrients.

Increase in blood volume

Your blood volume represents the amount of blood circulating in your body. It varies from person to person, and increases as a result of training. Blood volume increases as a result of capillarisation. An increase in blood volume means your body can deliver more oxygen to your working muscles and your body will also be able to regulate your body temperature more effectively during exercise.

PAUSE POINT What is meant by 'cardiac output'?

Hint — Describe what happens to your cardiac output during exercise.

Extend — Consider the two components of cardiac output. What are the long-term adaptations affecting your cardiac output due to an exercise programme?

Additional factors affecting the cardiovascular system

Regular training has many long-term benefits for the cardiovascular system. However, when considering any training programme there are a number of additional factors that can affect the cardiovascular system which will impact on exercise and sport performance. Therefore when starting any new training programme, and especially if you have not exercised for a long period of time, you should see a doctor to get checked over.

Sudden arrhythmic death syndrome (SADS)

Sudden arrhythmic death syndrome (SADS) is a genetic heart condition that can cause sudden death in young, apparently healthy people even though the person has no disease affecting the structure of the heart. If the heart's normal, natural rhythm becomes disrupted then the heart can stop beating, which can cause death. There have been a number of high-profile cases where elite sportspeople have suffered from SADS, such as Bolton Wanderers footballer Fabrice Muamba.

Case study

Fabrice Muamba

Fabrice Muamba was a professional footballer playing for Bolton Wanderers in the English Premier League. During an FA Cup match between Tottenham Hotspur and Bolton on 17 March 2012 he suffered a cardiac arrest (heart attack) and collapsed on the pitch.

Muamba received lengthy treatment on the pitch to revive him and he was transferred to a specialist heart hospital, where it was later revealed that his heart had stopped beating for 78 minutes. Muamba made a full recovery, although due to the seriousness of the incident he has retired from football.

This incident highlights that even elite athletes who are seemingly fit and healthy can suffer from serious illness, and many clubs now have regular specialist heart testing for all of their athletes.

In pairs, find out more about Sudden Arrhythmic Death Syndrome (SADS). Visit the Cardiac Risk in the Young (CRY) website, www.c-r-y.org.uk.

Check your knowledge

1. Find examples of SADS in sport.
2. What is being done to help protect sportspeople from SADS?
3. Report back your findings to the rest of the group.

In 2012 footballer Fabrice Muamba, aged 23, collapsed on the pitch during Bolton Wanderers' game against Tottenham Hotspur

High and low blood pressure

The long-term benefits of exercising are enormous. However, exercise can affect your blood pressure, especially during exercise. When you start to exercise, your blood pressure will increase as your heart works harder and pushes more blood out of the heart with greater force. If you already suffer from high blood pressure (**hypertension**), this sudden increase in demand on the heart can be dangerous as too much force may be exerted on the heart and arteries. Anybody suffering from hypertension should seek medical advice before starting an exercise programme.

Low blood pressure (**hypotension**) means that your blood is moving slowly around your body, which can restrict the amount of blood reaching vital organs and muscles. Symptoms of low blood pressure include dizziness, fainting and tiredness. If you suffer from low blood pressure then it will be harder for your cardiovascular system to respond during exercise; if your muscles are not receiving enough oxygenated blood, this will affect performance. If insufficient blood is supplied to the brain then fainting may occur. As with hypertension, anybody suffering from hypotension should seek medical advice before starting an exercise programme.

Hyperthermia/hypothermia

All athletes should be aware of hyperthermia and hypothermia, and their causes and symptoms.

- **Hyperthermia** is the prolonged increase in body temperature that occurs when the body produces or absorbs too much heat. When you exercise your body produces heat as a waste product. Your cardiovascular system will regulate your body temperature by dilating the blood vessels closer to the body's surface and making you sweat so that the heat can dissipate. However, if you are exercising in a hot environment it is difficult for the heat to be removed. Likewise, if you are wearing incorrect clothing that traps the heat then you may suffer from hyperthermia.

Exercising in hot conditions can contribute to hyperthermia

- **Hypothermia** is where your body becomes too cold, with your core temperature dropping below 35°C. (The ideal internal body temperature for humans is 37°C.) Symptoms will include shivering, confusion and, in severe cases, an increased risk of your heart stopping. Hypothermia may occur if you are training in a cold environment without adequate clothing.

Assessment practice 1.4

1 Describe the pathway of blood flow from the heart through the major blood vessels to the body and lungs. **(4 marks)**

2 State the function of the bicuspid valve. **(1 mark)**

3 Describe the nervous control of the cardiac cycle. **(4 marks)**

4 Grace is a basketball player. The table shows Grace's heart rate at rest and then one minute before taking part in basketball. Grace has been taking part in regular basketball for over 8 months. In this time Grace's resting heart rate has decreased from 77 to 70 bpm (beats per minute). Explain why Grace's resting heart rate has decreased. **(3 marks)**

Resting heart rate (bpm)	Heart rate one minute before taking part in basketball (bpm)
70	80

5 Explain the change in Grace's heart rate shown in the two columns of the table. **(4 marks)**

Plan

- I will plan my answer and have a clear idea of the point I am making. I will make sure this point comes across in everything I write.
- When reading through a question, I will write down notes on a blank page.

Do

- I will try to answer all the simpler questions first and then come back to the harder questions.
- I will allow time to answer all the questions and to check my answers.

Review

- I will reread my answers and make any corrections.

E The effects of exercise and sports performance on the energy systems

All movement requires energy. The method by which your body generates energy is determined by the intensity and duration of the activity being undertaken. Activities that require short bursts of effort, such as sprinting or jumping, require the body to produce large amounts of energy over a short period. In contrast, marathon running or cycling require continued energy production over a longer period and at a slower rate.

The body's energy systems facilitate these processes. The energy systems of the body can function aerobically (with oxygen) or anaerobically (without oxygen). Movements that require sudden bursts of effort are powered by energy systems that do not require oxygen – anaerobic systems – whereas prolonged activities are aerobic and require oxygen.

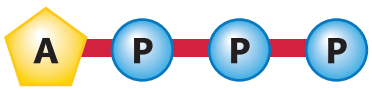
All energy systems work together, but the type of activity and its intensity will determine which system is predominant.

The role of ATP in exercise

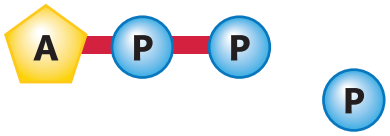
Energy is required in order to make the muscle fibres contract. This energy is obtained from the breakdown of foods in the diet, particularly carbohydrate and fat. The body maintains a continuous supply of energy through the use of **adenosine triphosphate (ATP)**, which is often referred to as the energy currency of the body.

ATP is a molecule that stores and releases chemical energy for use in body cells. When ATP is broken down, it gives energy for immediate muscle contractions. It is the only molecule that can supply the energy used in the contraction of muscle fibres (see Figure 1.20).

ATP consists of a base (adenine) and three phosphate groups. It is formed by a reaction between an **adenosine diphosphate (ADP)** molecule and a phosphate. Energy is stored in the chemical bonds in the molecules; when a bond is broken, energy is released.



(a) ATP is formed when adenosine diphosphate (ADP) binds with a phosphate



(b) When a cell needs energy, it breaks the bond between the phosphate groups to form ADP and a free phosphate molecule

Figure 1.20: ATP and energy released from the breakdown of ATP

ATP works like a rechargeable battery. Energy is released by converting ATP to ADP, which is the 'uncharged' form. By binding a phosphate back with the ADP to resynthesise ATP, the 'battery' is charged again and ready to be used for immediate and powerful muscular contractions.

However, your muscles have only very small amounts of ATP stored in them, so to replenish ATP quickly, the body has to use a number of other systems as well.

The ATP–PC (alactic) system in exercise and sports performance

The ATP–PC (alactic) system is **anaerobic**, which means that it does not require oxygen to produce energy. This is important in sports where sudden and powerful movements are required, such as shot put or sprinting, as the muscles can use ATP to produce energy and movement without having to 'wait' for oxygen to be delivered.

A muscle cell has a small amount of ATP in it that it can use immediately, but there is only enough to last for about three seconds. To replenish the ATP levels quickly, muscle cells also contain a high-energy phosphate compound called creatine phosphate (or phosphocreatine, or PCr). When the high-energy bond in PCr is broken, the energy it releases is transferred to ADP to resynthesise ATP.

The ATP–PC system only supports high-intensity exercise for short periods of time (approximately 10 seconds) as the PC store runs down quickly. If exercise continues at a high intensity these stores will only partially replenish, as there will not be enough energy available for creatine and phosphate to reform phosphocreatine. A ratio called the 'work-to-rest ratio' can be used to determine how quickly a system will replenish. For the ATP–PC system this ratio is 1 : 10–12. This means that for every second of work you need to allow 10–12 seconds for recovery.

The lactate system in exercise and sports performance

The lactate system is a short-term energy system and is used to meet energy requirements of higher intensity over a longer period, such as during a 400-metre race. It is an **anaerobic** process that does not require oxygen and therefore is not sustainable over a long duration.

The body breaks down most carbohydrates from the foods we eat and converts them to a type of sugar known as glucose. When the body does not need to use the glucose for energy, it stores some of it in the liver and muscles where it is easily accessible for energy production and is known as **glycogen.**

In the lactate energy system, ATP is made by the partial breakdown of glucose and glycogen through the process of **anaerobic glycolysis**. Around 60–90 seconds of maximal work are possible using this system.

Anaerobic glycolysis

When the ATP–PC system begins to fade at around 10 seconds, the process of anaerobic glycolysis begins. This system breaks down liver and muscle glycogen stores without needing the presence of oxygen. The breakdown of glucose and glycogen releases energy which can be used to resynthesise ATP; the breakdown of glucose produces two molecules of ATP, whereas the breakdown of glycogen can produce three molecules of ATP.

Lactic acid production

Unfortunately, anaerobic glycolysis produces lactic acid as a by-product. Lactic acid is the limiting factor of the anaerobic system. It accumulates and diffuses into the tissue fluid and blood. If this substance is not removed quickly enough by the circulatory system, it builds up to impede muscle contraction and cause fatigue. You may have experienced this as an uncomfortable burning sensation and soreness in your muscles during intense exercise.

A recovery time of approximately eight minutes will aid the removal of lactic acid from the muscles as well as the storage of glycogen in your muscles.

The aerobic system in exercise and sports performance

The **aerobic** energy system is the long-term energy system. If plenty of oxygen is available, as it is during everyday movements and light exercise, glycogen and fatty acids break down to yield the largest amounts of ATP. This produces carbon dioxide and water, which do not affect the ability of muscles to contract, unlike the lactic acid produced by the lactate system.

Aerobic energy production occurs in the mitochondria of the muscle cells. The aerobic system relies on the breakdown of carbohydrates and stored fats to produce energy, and improved aerobic fitness makes it easier for the body to convert these food sources.

The production of energy within the aerobic system is slow to engage because it takes a few minutes for the heart to deliver oxygenated blood to working muscles. Long, continuous and moderate exercise, such as long-distance running, produces energy using this system.

The aerobic energy system can be broken down into three processes.

1 **Aerobic glycolysis** – this is the first stage of **aerobic metabolism** (the breakdown of foods into energy). It converts carbohydrates (in the form of either glucose or glycogen) into pyruvic acid using oxygen. This breakdown requires 10 chemical reactions: another reason why the aerobic system is slower to deliver energy and is suited to steady sports performance. The process of aerobic glycolysis produces two molecules of ATP.

2 **Krebs cycle** – sometimes known as the **citric acid cycle**, this is the second phase in the process of anaerobic metabolism. It takes place in the mitochondria. The pyruvic acid that was produced during aerobic glycolysis enters the mitochondria and is converted to citric acid. This results in two molecules of ATP being produced, with carbon dioxide and hydrogen being produced as waste products. The carbon dioxide will be exhaled by the lungs and the hydrogen will be used in the next phase of energy production, the electron transport chain.

3 **Electron transport chain** – the hydrogen that was released as part of the Krebs cycle is vital in the production of energy. The electron transport chain is the most important step in energy production and is where the majority of ATP is created. This process will create 34 molecules of ATP from glucose. The hydrogen created as part of the Krebs cycle is accepted by the hydrogen acceptor found in the mitochondria where, in the presence of oxygen, ATP can be produced.

In total the aerobic energy system will produce 38 molecules of ATP from one molecule of glucose. Depending on the duration and intensity of the exercise, as well as your level of fitness, recovery of the aerobic energy systems can range from a few hours to 2–3 days.

The energy systems in combination

During exercise the body does not switch from one system to another – energy at any time is derived from all three systems. However, the emphasis changes depending on the intensity of the activity relative to the efficiency of your aerobic fitness, i.e. your ability to deliver and utilise oxygen. Table 1.6 shows different types of sport and the relative contributions made by the different energy systems. Figure 1.21 illustrates the contribution of different energy systems during exercise.

When you start running, the following process takes place.

- The muscle cells burn off the ATP they already contain in about three seconds.
- The creatine phosphate system kicks in and supplies energy for 8–10 seconds. This would be the major energy system used by the muscles of a 100-metre sprinter or a weightlifter, where rapid acceleration, short-duration exercise occurs.
- If exercise continues, the lactic acid energy system kicks in. This occurs in short-distance exercises such as a 200- or 400-metre run or a 100-metre swim.
- If exercise continues, the aerobic energy system takes over. This occurs in endurance events such as an 800-metre run, a marathon run, rowing, cross-country skiing and distance skating.

Table 1.6: The different lengths of time for each energy system, with sport examples

Duration	Classification	Energy supplied by	Sport example
1–3 seconds	Anaerobic	ATP (in muscles)	A punch in boxing
3–10 seconds	Anaerobic	ATP + PC	100-metre sprint
10–45 seconds	Anaerobic	ATP + PC + muscle glycogen	200-metre run
45 seconds–2 minutes	Anaerobic, Lactic	Muscle glycogen	400-metre run
2 minutes–4 minutes	Aerobic + Anaerobic	Muscle glycogen + lactic acid	1500-metre run
Over 4 minutes	Aerobic	Muscle glycogen + fatty acids	Marathon running

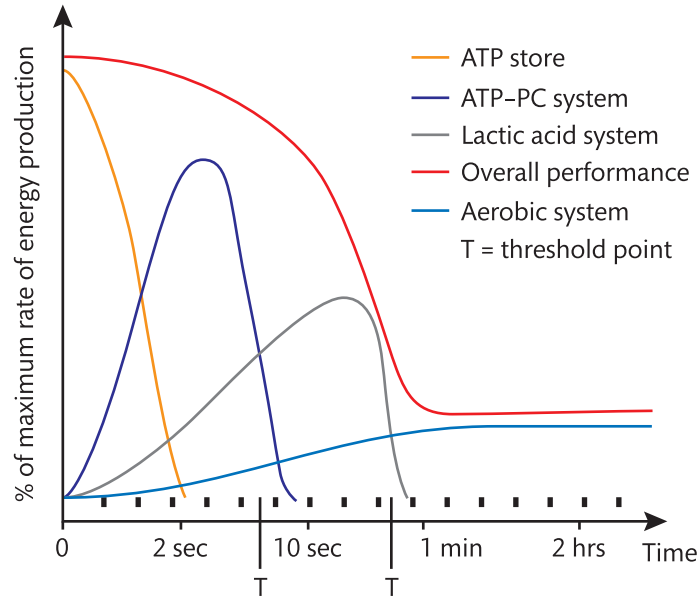


Figure 1.21: The contribution of different energy systems during exercise

PAUSE POINT

Why do different sports use different energy systems?

Hint

Choose a sport. What is the main energy system that is used?

Extend

Now consider a team sport and a specific position. Are different energy systems used during a performance? If so, why?

Case study

Mo Farah versus Usain Bolt

As part of his charity, the Mo Farah Foundation, Mo Farah has challenged the world 100-metre champion, Usain Bolt, to race over a distance that would not suit either runner. Mo Farah is the current Olympic champion over 5000 metres and 10,000 metres, while Usain Bolt is the Olympic champion over 100 metres and 200 metres. Farah has suggested that they race between 600–800 metres.

1 Suggest an optimum distance that would be fair for both athletes.

2 Why do you think that one athlete is better suited to one distance than another distance?

Adaptations of the energy systems to exercise

Long-term exercise will allow the body's energy systems to adapt to the physical demands of exercise. This means that by following an exercise programme it is possible to train each energy system so that you can perform for longer and at increasingly harder intensities.

Increased creatine stores

Short–duration, interval training sessions using high-intensity exercises will improve your ability to produce anaerobic energy. Your body will adapt and be able to store more creatine in the muscles which will improve the ATP–PC system. This will result in you being able to exercise anaerobically for longer using fast and powerful movements.

Increased tolerance to lactic acid

Anaerobic training stimulates the muscles to become better able to tolerate lactic acid and to clear it away more efficiently. With endurance training the capillary network extends, allowing greater volumes of blood to supply the muscles with oxygen and nutrients. The muscles are able to use more fat as a fuel source and become more efficient at using oxygen, increasing the body's ability to work harder for longer without fatiguing. The net result is an increase in the body's maximal oxygen consumption.

Aerobic energy system

Long-term exercise will improve the ability of the aerobic energy system to produce energy, as improvements in the cardiovascular system will allow for increased oxygen to be delivered which is needed to produce ATP aerobically. Likewise, adaptations of the cardiovascular system will aid the removal of lactic acid through oxidisation.

Increased use of fats as an energy source

Fat is the primary energy source during low-intensity exercise. Fat combustion powers almost all exercise at approximately 25 per cent of **aerobic capacity** (which is approximately 60–70 per cent of your maximum heart rate). Fat oxidation increases if exercise extends to long periods, as glycogen levels deplete. When considering the effects of long-term exercise, the trained athlete has a greater opportunity to burn fat as a fuel than the non-trained athlete because they have a more efficient system of delivering oxygen to the working muscle, as well as a greater number of mitochondria.

Key term

Aerobic capacity – the maximum amount of oxygen that can be consumed during maximal exercise.

Increased storage of glycogen and increased numbers of mitochondria

Muscles increase their oxidative capacity with regular training. This is achieved by an increase in the number of mitochondria within the muscle cells, an increase in the supply of ATP and an increase in the quantity of enzymes involved in respiration. The ability of the muscles to store more glycogen is also increased, meaning that anaerobic glycolysis can last for longer.

Link

You can find more information on this topic in *Unit 5: Application of Fitness Testing*.

Additional factors affecting the energy systems

There are two main additional factors that must be considered when examining the energy systems and their impact on sport and exercise performance.

Diabetes and hypoglycaemic attack

Diabetes is a condition where the amount of glucose in your blood is too high. This is known as type I diabetes. It develops when glucose cannot enter the body's cells to be used as fuel. **Insulin** is the hormone produced by the pancreas that allows glucose to enter the body's cells, where it is used as fuel for energy. If you have diabetes, your body cannot make proper use of this glucose so it builds up in the blood and cannot be used.

Hypoglycaemia is an abnormally low level of glucose in your blood. When your glucose (sugar) level is too low, your body does not have enough energy to carry out its activities. Hypoglycaemia mainly occurs if someone with diabetes takes too much insulin, misses a meal or exercises too hard. Typical early warning signs are feeling hungry, trembling or shakiness, and sweating. Additional symptoms include confusion, and you may have difficulty concentrating. In severe cases, a person experiencing hypoglycaemia can lose consciousness.

Children's lack of lactate system

Although we all possess the same body systems, a child's body systems are still growing and developing, with significant changes occuring during puberty. One such area is the lactate energy system, which is not fully developed in children. During high-intensity exercise, lactic acid will build up in the muscles and, due to their developing cardiovascular system, it is more difficult for children to remove this waste product. Therefore it is generally recommended that children exercise aerobically.

Assessment practice 1.5

1 Explain why it is an advantage for marathon runners to have high numbers of mitochondria. **(2 marks)**

2 Describe the process of ATP production from carbohydrates through the aerobic energy system. **(5 marks)**

3 The graph (Figure 1.22) shows the ATP–PC stores in a performer's muscles while competing in a rugby match. Explain why playing in a rugby match will have this effect on muscle ATP–PC stores. **(3 marks)**

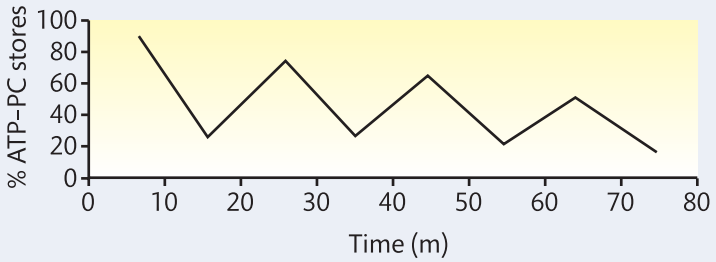


Figure 1.22: ATP is the only immediately usable source of energy in the human body

4 Compare and contrast the importance of the aerobic and anaerobic energy systems for an elite 100-metre sprinter in competition and in training. **(8 marks)**

5 Denise is training for a marathon. Analyse how adaptations to Denise's cardiorespiratory system could improve her marathon-running performance. **(8 marks)**

6 Identify four key long-term adaptations that are linked to aerobic training and explain the benefit of each adaptation. **(8 marks)**

Plan

- I will listen to, and read carefully, any instructions that I am given.
- I will look for the command words in the question and plan a response to them.

Do

- I will make sure I write a detailed response for the questions with more marks.
- I will include key words and information and use them to structure my answer.

Review

- I will check that I have answered all the questions.
- I will check that I have given examples and that they are clear.

Further reading and resources

Books

Bartlett, R. (2014) *Introduction to Sports Biomechanics*, London: Routledge.

Marieb, E. (2015) *Human Anatomy and Physiology*, Oxford: Pearson.

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

Sharkey, B.J. and Gaskill, S.E. (2006) *Fitness and Health*, Champaign, IL: Human Kinetics.

Tortora, G.J. and Derrickson, B.H (2008) *Principles of Anatomy and Physiology*, London: John Wiley and Sons.

Websites

www.humankinetics.com – Human Kinetics: educational resources relating to all areas of sport and physical activity.

www.sportsci.org – Sport Science: research into sport, including articles considering the functions of different bodily systems in sport.

www.topendsports.com – Top End Sports: information on many aspects of anatomy and physiology.

THINK FUTURE

Helen Reardon

Sports Therapist

I have been working as a sports therapist for seven years, and over this time I have worked with a wide range of people in a variety of places. In any given day I will work with different people, each of whom will have specific fitness goals. For example, I may provide one-to-one support for somebody training to run a marathon or work with an athlete who is returning from a long-term injury.

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. In particular I have to understand anatomy and physiology so that I can manage and prevent sporting injuries. It is essential that I understand the adaptations the body makes so that I can set each of my clients personal and challenging goals and develop specific training programmes. Often I will be working with clients who are returning from injury, so it is essential that the programmes I set are at the correct level so that the injury does not reoccur. I have to ensure that each of my clients can train safely and use the correct techniques so that they do not injure themselves.

As part of my job I am responsible for providing sports massage and giving advice on preventive and rehabilitative exercises to help prevent and manage injuries. My work also involves testing joints for ease and range of movement, strapping and taping, and advising on stretching and warm-up and cool-down exercises.

One of the most important skills for a successful sports therapist is the ability to motivate people. Being able to get a client 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 personal trainer. Consider the following questions.

- 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 different types of exercise will you recommend and how will these affect each of the body's systems?
- What types of training goals will you need to help people with? Will you work with elite athletes or people who are trying to lose weight?
- 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 is 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 worth up to 8 marks.

Remember that 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 to your response; plan your answer and write in detail.

Preparing for the test

To improve your chances on the test you will need to make sure you have revised all the key **assessment outcomes** that are likely to appear. The assessment outcomes were introduced to you at the start of this unit.

Do not start revising too late! Cramming information is stressful and does not work.

Useful tips

- **Plan a revision timetable** – identify all the topics you need to revise and try to spend several short revision sessions on each of them. Coming back to each topic several times will help you to reinforce the key facts in your memory.
- **Take regular breaks** – short bursts of 30–40 minutes are more effective than long hours of revision. Remember, most people's concentration lapses after an hour and they need a break.
- **Allow yourself rest** – do not fill all your time with revision. You could schedule one evening off a week, or book in a 'revision holiday' of a few days.
- **Take care of yourself** – stay healthy and rested, and eat properly – this will help you to perform at your best. The less stressed you are, the easier you will find it to learn.

Revise all the key areas likely to be covered – draw up a checklist to make sure you do not forget anything!

Read each question carefully before you answer it to make sure you understand what you have to do.

Sitting the test

- Listen to, and read carefully, any instructions you are given. Lots of marks are lost because people do not read questions properly and then fail to complete their answers correctly.
- Most questions contain command words (see Table 1.1). Understanding what these words mean will help you understand what the question is asking you to do.
- The number of marks can relate to the number of answers you are expected to give – if a question asks for two examples, do not only give one! Similarly, do not offer more information than the question needs: if there are two marks for two examples, do not give four examples.
- Plan your time carefully. Work out what you need to answer and then organise your time. You should spend more time on longer questions. Set yourself a timetable for working through the test and then stick to it – do not spend ages on a short 1–2 mark question and then find you only have a few minutes for a longer 7–8 mark question.
- It is useful when reading through a question to write down notes on a blank page. This way you can write down all the key words and information required and use this to structure your answer.
- If you are writing an answer to a longer question, try to plan your answer before you start writing. Have a clear idea of the point you want to make, and then make sure this point comes across in everything you write.
- If you finish early, use the time to re-read your answers and make any corrections – this could really help to make your answers even better and could make a big difference to your final mark.

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 our tips on how to answer them well.

Answering short answer questions

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

Worked example

Explain the effects of taking part in exercise on tidal volume. [3]

Answer: 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.

This answer gives a brief description of 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:

Craig is a 17-year-old swimmer who has asthma. Discuss the effects of participating in swimming on the respiratory system for an individual suffering with asthma. [6]

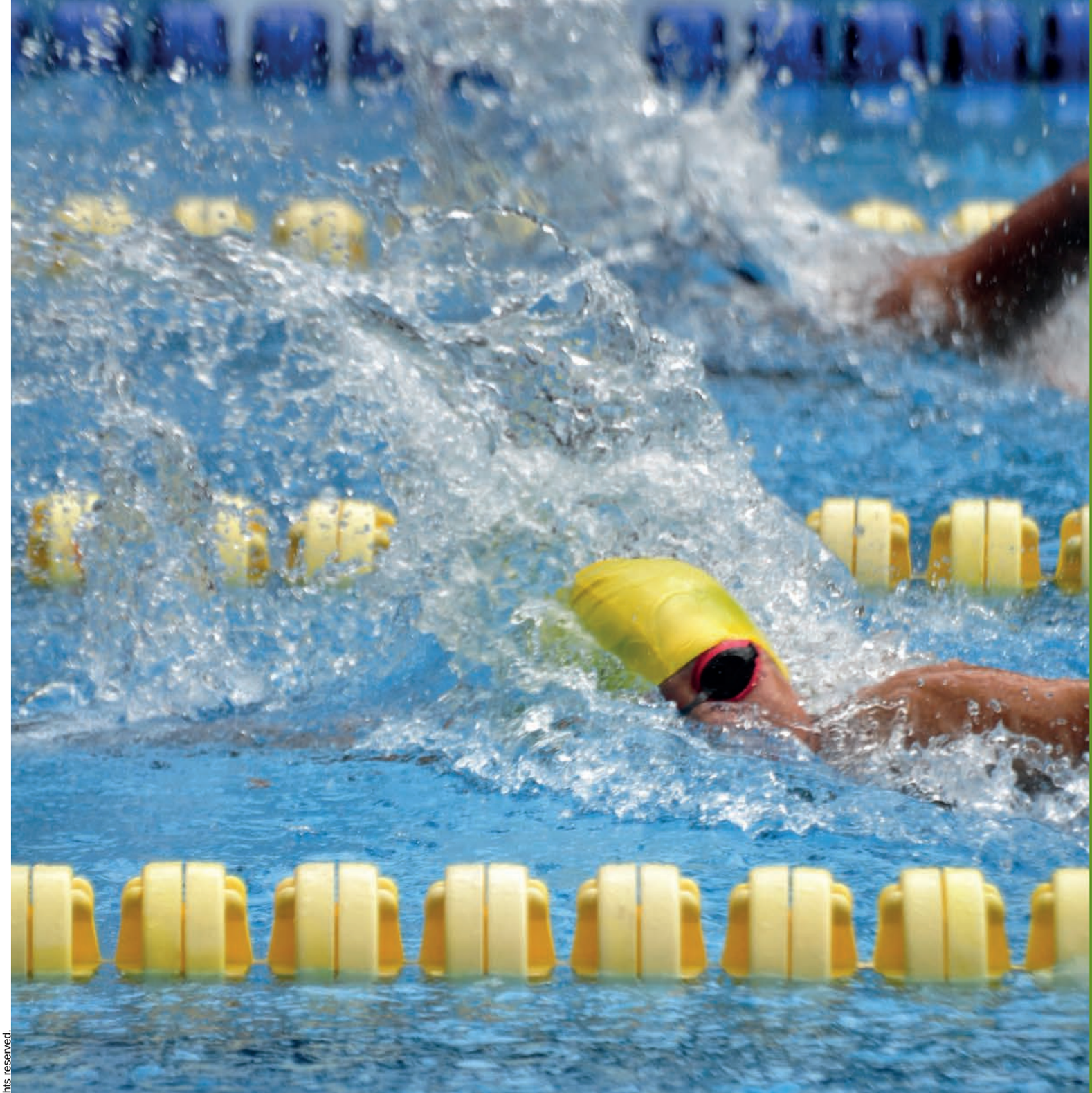
Answer: Craig may experience both positive and negative effects of swimming. The positive aspects of swimming for an asthma sufferer are that the air breathed in will be moist and warm, which reduces the chances of an exercise-induced asthma attack. Exercise will also increase Craig's vital capacity and strengthen the respiratory muscles. This will allow more air to be breathed, which will help reduce the effects of asthma.

The negative or disadvantage of exercise for Craig is that he may suffer from an exercise-induced asthma attack. This may result in wheezing while breathing or coughing. Craig may experience tightness in his chest. If asthma occurs then the bronchi may become inflamed or the airways might narrow, which will reduce the amount of air getting into the lungs.

For a question using the word 'discuss', you must do more than just explain. You might need to talk about the issues or the advantages (positive) and disadvantages (negative) of an approach or theme.

This answer describes the causes and symptoms of asthma in general as well as in relation to exercise. Further discussion includes the advantages and disadvantages of exercise with specific reference made to swimming.

When answering an extended answer question, you may write several paragraphs. Remember to make notes before you start to answer the question and ensure that you plan all aspects of your longer answer to gain all the available marks.



Fitness Training and Programming for Health, Sport and Well-being

2

Getting to know your unit

Assessment
You will be assessed using an externally set written task worth 60 marks.

In this unit, you will explore the ways of screening clients and assessing their lifestyle and nutritional habits. The ability to screen clients and design fitness training programmes is essential for anyone working in the health and fitness industry, and for sports coaches looking to improve individuals' or teams' performance.

This unit has been selected as an externally assessed unit, as it introduces many of the skills and processes required in the industry.

This unit links with *Unit 5: Application of Fitness Testing* and *Unit 7: Practical Sports Performance*.

How you will be assessed

This unit will be assessed externally using an examination set by Pearson. The examination will contain two parts.

- **Part A** is supplied two weeks before your examination so that you can carry out independent research about a scenario based on an individual who requires guidance on training, lifestyle and nutrition.
- **Part B** is a written examination lasting two hours under controlled conditions in which you can use your research notes to complete a task that builds on Part A.

You will be assessed for your understanding of the following topics:

- lifestyle factors and their effect on health and well-being
- recommendations to promote health and well-being
- screening processes for training programming
- programme-related nutritional needs
- training methods for different components of fitness
- appropriate training activities to meet the needs of a specific client
- principles of fitness training programming.

Throughout this unit you will find activities that will help you to work towards your assessment. Completing these activities will not mean that you have achieved a particular grade, but you will have carried out useful research or preparation that will help you later when you do your external assessment.

Unit 2 has five assessment outcomes (AO) which will be included in the external examination. Certain 'command words' are associated with each assessment outcome. Table 2.1 explains what these command words are asking you to do.

The assessment outcomes for the unit are:

- **AO1** Demonstrate knowledge and understanding of the effects of lifestyle choices on an individual's health and well-being
- **AO2** Apply knowledge and understanding of fitness principles and theory, lifestyle modification techniques, nutritional requirements and training methods to an individual's needs and goals
- **AO3** Analyse and interpret screening information relating to an individual's lifestyle questionnaire and health monitoring tests
- **AO4** Evaluate qualitative and quantitative evidence to make informed judgements about how an individual's health and well-being could be improved
- **AO5** Be able to develop a fitness training programme with appropriate justification

Table 2.1: Command words used in this unit

Command word	Definition
Justification	Give reasons or evidence to: • support an opinion or decision • prove something right or reasonable
Qualitative evidence	Descriptive information from interviews or questionnaires
Quantitative evidence	Numerical or statistical information
Interpretation	Drawing the meaning, purpose or qualities of something from source material
Relevance	Importance to the matter at hand

Getting started

Consider how athletes train to meet the physical demands of their sport at an elite level. Now consider the rising levels of obesity and heart disease in the world. How can knowledge of fitness training and programming help in both these different scenarios?

A Examine lifestyle factors and their effect on health and well-being

Positive lifestyle factors and their effect on health and well-being

Evidence suggests that leading a healthy lifestyle by following a sensible diet, participating in regular physical activity, maintaining a healthy body weight and avoiding smoking, excessive alcohol consumption and stress, is important to health and well-being.

Reflect

Think about your own lifestyle and what pressures may affect your ability to train or compete. Consider five factors that may limit the amount of time you have for sporting activities. How could you begin to overcome these pressures?

Exercise and physical activity

There is overwhelming scientific evidence to prove that people leading active lives are less likely to die early or suffer from chronic disease such as **cancer**, **coronary heart disease (CHD)** or **type 2 diabetes**. They are also better able to cope with stress and anxiety. Figure 2.1 shows just some of the benefits of physical exercise.

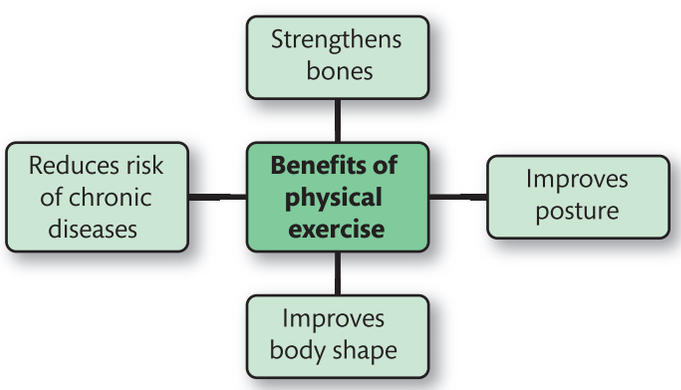


Figure 2.1: Benefits of exercise and physical activity on health and well-being

The Department of Health recommends people do at least 30 minutes of moderate exercise at least five days a week. 'Moderate' means you must get a little warmer and slightly out of breath – the more vigorous the activity, the greater the gain in cardiovascular health. The exercise can be anything that raises energy expenditure above resting level, which is enough to expend approximately 200 calories. This may include brisk walking, swimming, cycling, jogging or even gardening.

Key terms

Cancer – a group of diseases characterised by uncontrolled growth of abnormal cells that can spread throughout the body.

Coronary heart disease (CHD) – when your coronary arteries (which supply your heart muscle with oxygen-rich blood) become narrowed by a gradual build-up of fatty material within their walls.

Type 2 diabetes – a disorder characterised by an increase in blood glucose levels that usually develops in adulthood.

Physical exercise can also have social, economic and psychological benefits. Some of these are shown in Table 2.2.

Table 2.2: Wider benefits of physical activity and exercise

Social	Economic	Psychological
• Encourages social interaction	• Reduces NHS costs	• Relieves stress
• Improves social skills	• Creates employment	• Reduces depression
• Reduces isolation	• Supports local businesses	• Improves mood
• Enhances self-esteem and confidence	• Reduces absenteeism from work	• Improves concentration

Balanced diet

'Diet' refers to your typical food consumption, while a 'balanced diet' is one that provides the correct amount of nutrients required by your body.

Eatwell Guide

The Eatwell Guide is a way in which the UK government promotes a balanced diet. It is made up of the following food groups:

- bread, rice, potatoes, pasta and other starchy carbohydrate foods
- fruit and vegetables
- dairy and alternatives
- meat, fish, eggs, beans, pulses and other protein
- oil and spreads.

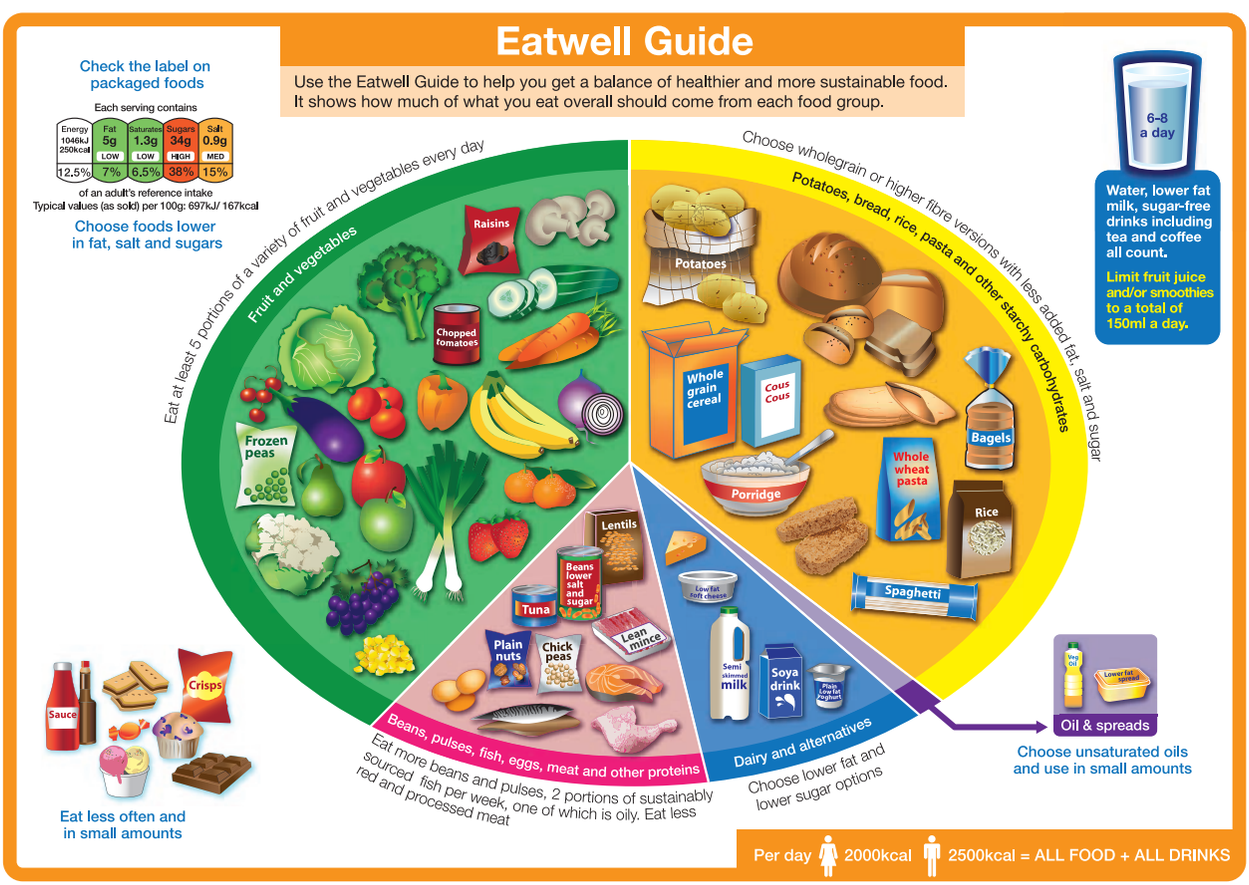


Figure 2.2: The Eatwell Guide

The model identifies the types and proportions of food from each group required to achieve a healthy, balanced diet. It is illustrated by a plate with divisions of varying sizes representing each of the five main food groups (see Figure 2.2). The larger the slice of the plate, the more that food group should feature in your diet, while those with smaller slices should be consumed in smaller portions or only occasionally.

Benefits of a healthy diet

Improved immune function

A poor diet can force the immune system – the body's natural defence that fights off disease – to work without enough nutritional support, reducing its ability to protect the body. A weakened immune system leads to a higher risk of illness, which can cause a loss of appetite. This then weakens the immune system further, creating a cycle that has to be broken to allow recovery. In contrast, a healthy diet helps boost the immune system and prevents this cycle of poor nutrition leading to ill-health.

Maintaining a healthy body weight

A healthy diet and regular exercise can help you avoid excess weight gain and maintain a healthy weight. Eating a low-fat and low-sugar diet can also help to control weight. Starting the day with a healthy breakfast may help to reduce snacking later in the day. The government recommends incorporating 'five a day' – five portions of fruits and vegetables which are low in calories and high in nutrients – into your diet to help with weight control.

Research

Data available from the Health Survey for England (HSE) suggests that in 2012 around 28 per cent of children aged 2–15 years of age were classed as either overweight or obese. Similar figures available in 2007 suggest the figure was around 24 per cent.

Research the possible causes of this increase in childhood obesity. Consider the types of food and drink available, and the opportunities children have to exercise, both at home and in school.

Reduced risk of chronic disease

A healthy diet can reduce the risk of chronic diseases such as coronary heart disease, stroke, and **hypertension** by increasing the levels in our body of high-density lipoprotein (HDL) or 'good' cholesterol and decreasing the levels of low-density lipoprotein (LDL) or 'bad' cholesterol. This keeps your blood flowing smoothly, reducing the risk of heart disease and hypertension. A healthy diet can also help prevent or manage a range of other chronic health problems, including diabetes, depression, cancer, and osteoporosis.

Fluid intake requirements

The water of the body fluids makes up 55–60 per cent of an adult's body. All of the body's chemical reactions occur there, and water is the main transport mechanism in your body, carrying nutrients, waste products and internal secretions. Water also plays a vital role in regulating your temperature, particularly during exercise, and aids the passage of food through your digestive system. Therefore, it is vital to remain hydrated at all times.

Around 10 per cent of your daily fluid requirements come from the **metabolic processes** that release water within your body. The other 90 per cent come from your diet. Approximately 60 per cent of this comes from fluids and the rest from food, particularly food with a high water content.

Key terms

Hypertension – also known as high blood pressure, it is a chronic medical condition in which the blood pressure in the arteries is continually raised. It is considered a potential threat to health and well-being.

Metabolic processes – chemical reactions that take place in the body to sustain life.

Key terms

Caffeine – a mildly addictive central nervous system stimulant found in coffee, tea and some energy drinks.

Metabolic rate – the energy expended by an individual over a period of time, usually expressed in units of energy per unit of body mass, per unit of time.

Stimulant – a substance that raises levels of physiological or nervous activity in the body.

Moderation of caffeine intake

Caffeine provides no nutritional value. However, because it is an addictive, mild **stimulant**, it can affect your mood and cause physical side effects. Caffeine is found in coffee, tea, energy drinks and some fizzy drinks (particularly colas). Moderate caffeine consumption, of around 400 mg caffeine or the equivalent of up to 4–5 cups of coffee per day (depending on the blend strength), can be considered part of a healthy balanced diet.

Research shows that caffeine can improve physical performances requiring speed and strength. However, a larger caffeine consumption can lead to negative physiological side effects such as hypertension and digestive problems.

Discussion

In 2004, caffeine was taken off the World Anti-Doping Agency (WADA) list of banned substances. However, research has shown that caffeine can raise heart rate and enhance sports performance. Why did the WADA take caffeine off the list of banned substances? Do you think it was the right choice? Discuss this as a small group.

Strategies for improving dietary intake

Sportspeople should eat foods that can enhance their preparation for, and recovery from, training and competition. Most sportspeople will obtain all the energy and nutrients they need by eating when they are hungry and choosing a balanced and varied diet. To improve their dietary intake, sportspeople should consider the following factors:

- **Timing of meals** – What you eat has an impact on your health and well-being. However, when and how you eat can also have an impact. You should aim to eat every 3–4 hours. Timing your meals in this way will improve fat burning, help to control your appetite and balance your stress hormones. You should also try to eat your meals at the same time every day.

  It is important to start your day with a good breakfast. Research has shown that people who regularly skip breakfast are more susceptible to weight gain (perhaps because they are more likely to snack during the day) and type 2 diabetes.

  Eating too close to bedtime raises your body temperature and increases blood sugar levels. These factors interfere with the quality of your sleep and the natural fat-burning benefits of a good night's rest.

Eating a healthy breakfast kick-starts your metabolism for the day

- **Eating less/more of certain food groups** – as we have seen, the Eatwell Guide illustrates that, in order to have a healthy and balanced diet, you should try to eat a good balance of different foods, with approximately two thirds of your diet consisting of:
  - fruit and vegetables
  - starchy foods, such as bread, rice, potatoes and pasta.

  Some sportspeople change the balance of their diet depending on their requirements at the time, such as eating more protein (to aid muscle recovery) or carbohydrates (to provide slow-release energy before an event).

Case study

Menu for an Olympic rower

A heavyweight rower in training for the Olympics will undergo a rigorous and often punishing training regime involving three training sessions per day for 6 days a week. To maintain the intensity of this regime, the rower will need to consume around 6000 calories a day. The daily meal plan shown in Table 2.3 gives an indication of what type of diet an elite-level athlete needs in order to train and compete.

Table 2.3: Example daily meal plan for an Olympic rower

Time	Meal
7 a.m.: breakfast	• large bowl of cereal or porridge and 500 ml skimmed milk • 2 slices of wholemeal bread with honey • glass of fruit juice • 1 litre fruit squash
8 a.m.: training	• 1 litre isotonic sports drink during training
9:30 a.m.: post-training	• 4 scrambled eggs • 2 rashers grilled bacon • portion grilled tomatoes • 2 slices of wholemeal bread with honey • 1 litre of fruit squash
11 a.m.: training	• 1 litre isotonic sports drink during training • 500 ml protein shake immediately after training
12:30 p.m.: lunch	• pasta with grilled chicken breast • green side salad • piece of fruit • 1 litre fruit squash
4 p.m.: training	• 1 litre isotonic sports drink during training
5:30 p.m.: post-training	• large bowl of cereal or porridge and 500 ml skimmed milk • piece of fruit • 500 ml of water
7:30 p.m.: dinner	• grilled lean meat or fish • 6–8 new potatoes or 1 cup of boiled rice • large portion of steamed vegetables • 1 low-fat yoghurt • piece of fruit • 750 ml of fruit squash
9:30 p.m.: bedtime snack	• 1 cereal bar
10:30 p.m.: bed	

Key term

Fibre – an indigestible dietary component with no calorie content that helps to decrease the time food takes to pass through the digestive system.

In the UK, many people eat and drink too many calories, too much fat, sugar and salt, and not enough fruit, vegetables, oily fish and **fibre**. It is important to have some fat in your diet, but as part of a healthy diet try to avoid foods that are high in fat and/or sugar.

- **Five a day** – 'Five a day' highlights the health benefits of including five 80 g portions of fruit and vegetables as part of a healthy diet. It is based on advice from the World Health Organization (WHO), which recommends eating a minimum of 400 g of fruit and vegetables to lower the risk of chronic health problems.

  Including fruit and vegetables in your diet is an excellent way of improving your dietary intake because fruit and vegetables:
  - are good sources of vitamins and minerals
  - are an excellent source of dietary fibre, which helps to maintain a healthy digestive system
  - can help to reduce the risk of heart disease, stroke and cancer
  - are generally low in fat and calories, so they can help maintain a healthy weight.

Case study

Sports Scientist: Jack Donnelly and the nutrition dilemma

Jack is a qualified sports scientist at a professional football club. He works with the club's academy, where boys and girls from 9 to 16 years old are developed into football players. Jack is responsible for a range of duties, including monitoring all the players' height and weight throughout the training season, and working with coaches to set training programmes, improve fitness and give nutritional advice.

A balanced diet is vital for the players' health, well-being and sports performance, so Jack must make sure the advice he gives is up-to-date and correct so the players, regardless of their age or ability, get the best out of their sessions with him. He gets to work with all ages as part of his job and having the opportunity to improve their dietary habits is rewarding.

Recently, Jack was approached by the parents of an under-9 player who were worried that their son would not eat much in the way of fruit or vegetables. They were concerned it might be affecting his performance as he was tired after training and matches.

Check your knowledge

1. Discuss as a group what advice you would give the parents if you were in Jack's position.
2. Come up with a five-point plan that deals with the gaps in the player's diet and explains to the parents what they need to consider when addressing their son's eating habits.
3. Present this plan as a verbal discussion, in an email to the parents or by producing a leaflet that could be used as guidelines for similar occasions.

- **Reducing salt intake** – Too much salt can raise your blood pressure, putting you at increased risk of heart disease and strokes. A diet high in salt can raise your blood pressure (hypertension) – this condition currently affects more than one third of adults in the UK. Adding salt to your diet is often unnecessary: 75 per cent of the salt we eat is already in our diet in the form of bread and breakfast cereals. Reducing added salt is only a small part of the solution. You need to become aware of the salt that is already in the foods you buy, and choose lower-salt options. Adults should eat no more than 6 g of salt per day.

- **Healthy alternatives** – Opting for a healthier diet may simply involve small changes to what you eat. Try to eat fewer foods high in fat, salt or sugars and substitute them with fruit or vegetables. For example, choose skimmed or semi-skimmed milk instead of full-fat milk, or wholegrain instead of white bread. A simple way to monitor your diet and what you eat is to look at the front-of-pack red, amber and green nutrition labels. These have been in effect since 2013 and show you if the food has high, medium or low amounts of fat, saturated fat, sugars and salt.

  Healthy eating can also involve adding new foods to your diet. Soya foods can simulate meat and dairy products such as milk, cheese and yogurt. Soya offers health benefits as it is high in protein, vitamins, minerals and fibre. Vegetarians tend to enjoy diets high in carbohydrates, fibre and vitamins. Research shows vegetarians are less likely to suffer from obesity, type 2 diabetes and hypertension.

PAUSE POINT Do you understand the elements of a balanced diet and their contribution to general health and well-being?

Hint A balanced diet consists of the correct amounts of nutrients required by the body.

Extend What additional sources of information are available to you that support and promote a positive lifestyle in terms of a balanced diet?

Positive risk-taking activities

Not all risk-taking is bad. In fact, some risks are good and promote healthy development. Risk-taking is linked to developmental changes in the brain that help you to become a healthy adult. An element of positive risk-taking is necessary for children and young adults so they can test their boundaries and develop as individuals.

Discussion

Research shows that many children in the UK prefer to watch television, play computer games or go online rather than play outdoors, and parents – for a variety of reasons – simply agree to their children's less active preferences. Do you think a childhood that lacks outdoor play will have a detrimental effect on later adult life? Discuss this complex issue as a class debate.

Outdoor and adventurous activities

Outdoor and adventurous activities are increasingly popular with adults as team-building exercises or as part of their continued professional development (CPD). What makes these activities risky is that they involve the potential for failure. Learning how to win and lose, succeed and fail, take risks to help others and meet challenges in unfamiliar surroundings are important factors for people's development.

Safety tip

Although risks should always be minimised to prevent harm or injury, these risks can be managed to be within acceptable boundaries to promote healthy development. To achieve this, you should consider what might cause harm and decide if you are taking reasonable steps to prevent this from happening.

Key terms

Endorphins – hormones that reduce the sensation of pain and affect emotions, generally in a positive way, during and after exercise.

Neurotransmitter – a chemical released across a synapse of a neurone (the space between two neurones where signals are passed) which affects the activity of muscle fibres or organs.

Endorphin release

Have you heard of thrill-seekers feeling ecstatic after a bungee jump or a tandem parachute jump? This 'high' is because **endorphins** are released into the brain when you exercise. Endorphins are **neurotransmitters**, chemicals that can be linked with an energetic and positive outlook on life. They possess other potential benefits too, by:

- reducing stress
- helping to fight anxiety and depression
- boosting self-esteem
- promoting restful sleep.

Improved confidence

Exercise can impact your health and well-being by improving your confidence in a number of ways.

- You feel better physically and mentally, helping to develop a positive attitude.
- Exercise can help build your self-esteem by improving the physical condition of your body and how you think about it.
- When you witness what your body is physically capable of, your self-confidence may increase.
- You feel a sense of accomplishment from achieving your exercise goals.

Government recommendation/guidelines

UK government recommendations

To promote a healthy population, the UK government issues guidelines. The hope is that people will follow these suggestions and enjoy a healthy lifestyle, reducing the amount of money the NHS has to spend to combat obesity and smoking-related disease.

In terms of **physical activity**, the government advises adults aged 19–64 years old to do two types of exercise each week: aerobic and strength exercises. The reccomendations for children are slightly different (see Table 2.4).

Table 2.4: Government advice on physical activity

Age of participants	Types of exercise
Children aged 5–18 years old	At least 60 minutes of physical activity every day such as cycling and playground activities, and vigorous activity, such as running or tennis. On three days a week, these activities should involve exercises for strong muscles, such as push-ups, and exercises for strong bones, such as running and jumping.
Adults 19–64 years old	Should be active daily and should do at least 150 minutes of moderate aerobic activity such as cycling or fast walking every week, and strength exercises on two or more days a week that work all the major muscle groups.

Alcohol is a drug that affects every organ in your body. It is a central nervous system depressant that is quickly absorbed by your stomach and small intestine into the bloodstream. 'Binge drinking' (excessive alcohol consumption in a single day or night) is a major public health concern. Current government guidelines for **alcohol consumption** are 14 units per week for men and women (equivalent to about half a pint of lager, beer or cider or one 175 ml glass of wine per day). Any alcohol intake should be spread across a week to avoid binges and should include two or three alcohol-free days each week. One unit is equivalent to 8 grams of alcohol, typically a small glass of wine, half a pint of beer, lager or cider, or a single pub measure of spirits.

The government takes **healthy eating** seriously and has introduced a number of initiatives designed to encourage improved dietary practices – see Table 2.5 for more details.

Table 2.5: Government healthy eating initiatives

Initiative	Details
Love your labels	The best way of checking what you are eating is to look at food labels, as they can tell you what is inside the food. Once you know how to use them, you will soon be able to make healthier choices when shopping.
Eatwell Guide	The Eatwell Guide helps you eat a balanced diet by showing you how much of each type of food to eat at each meal.
Eat a little slower	It takes time for the brain to register you are full, so try to pace yourself and eat more slowly.
Aim to feel satisfied, not stuffed	Try eating just one plate of food and do not go back for seconds.

Negative lifestyle factors and their effects on health and well-being

Smoking

Tobacco smoke contains **nicotine** and tar which are both damaging to health. When you smoke, more than 7000 chemicals spread throughout your body and all of your organs. Nicotine is one of these chemicals, a powerful drug that causes addiction. It stimulates the central nervous system and increases heart rate and blood pressure. Tar is a complex mixture of chemicals, many of which cause cancer. Tar largely collects in the respiratory tract and is then gradually absorbed.

Key term

Nicotine – an addictive chemical found in tobacco that stimulates the central nervous system. Research suggests nicotine has a negative impact on physical performance because of its effects on the cardiorespiratory system.

Health risks associated with smoking

The risk of disease increases not only with the volume of smoking and number of years smoked, but also how deeply the smoke is inhaled.

- **Coronary heart disease (CHD)** – a generic term to describe conditions caused by an interrupted or reduced flow of blood through the coronary arteries to the heart. Smokers have a higher risk of developing **atherosclerosis** (a build-up of fatty deposits in the arteries) which is a primary contributor to CHD. Smoking alone leads to an increased risk, but when it is combined with other risk factors – such as high blood pressure, high cholesterol and physical inactivity – it increases the likelihood of the blood clotting, leading to a heart attack.
- **Cancer** – lung cancer is the most common form of cancer worldwide and the type most commonly associated with smoking. The earlier in life you begin to smoke, the higher your risk of developing lung cancer. A study of ex-smokers showed those who started smoking before the age of 15 had twice as many cell mutations (a key factor in the development of cancer) as those who started after the age of 20. Smoking not only leads to an increased risk of cancer in the lungs – studies have shown it is also linked to cancers of the mouth, oesophagus, bladder, breast, cervix, colon, liver and kidneys.
- **Lung disease** – smokers are likely to suffer more respiratory tract infections than non-smokers. They are more likely to suffer from colds and flu, and take longer to recover. Pneumonia is a serious lung infection and is more likely to be fatal among smokers due to the effects of smoking on their lungs. Smoking is by far the biggest cause of **emphysema**, a chronic disease of the lungs that causes breathing

difficulties. Emphysema leads to damage to the tissues supporting the shape and function of the lungs. Sufferers' lungs are gradually unable to hold their shape properly when they exhale, making the lungs inefficient when transferring oxygen into, and removing carbon dioxide from, the blood. This leads to about 25,000 deaths in the UK each year.

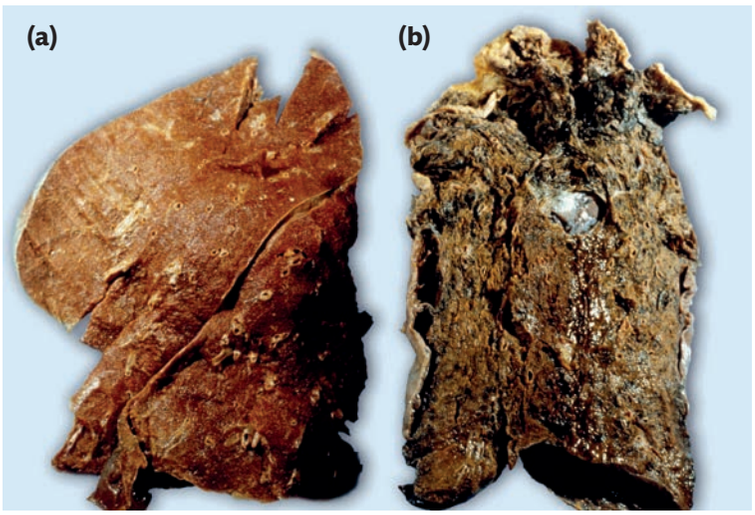
- **Bronchitis** – a condition that inflames the lining of the bronchial tubes; it can be an **acute** or **chronic** condition. The most common symptom of bronchitis is coughing. Acute bronchitis is often caused by a viral or bacterial infection, while chronic bronchitis is most often seen in smokers. Smoking causes damage to the **cilia** lining the airways; over time they become less efficient at clearing debris and irritants, making the lungs more susceptible to infection.
- **Infertility** – smokers are likely to have more fertility problems than non-smokers. Female smokers have an increased chance of developing ovulation problems. Male smokers can suffer a lower sperm count and erectile dysfunction. Second-hand or passive smoking is also linked to fertility problems, as well as a range of other health-related issues.

Key terms

Acute – a condition which develops rapidly and occurs for a short duration.

Chronic – a condition which develops slowly and occurs over a long duration.

Cilia – tiny hairs that protect the respiratory tract by filtering particles and mucus away from the lungs.



The internal effects of smoking: (a) a healthy lung and (b) a smokers lung

Alcohol

Moderate alcohol consumption is thought to help reduce the risks of heart disease. However, too much alcohol can cause health problems such as malnutrition, cirrhosis of the liver, certain types of cancer and psychological health problems.

Health risks associated with excessive alcohol consumption

- **Stroke** – this occurs when brain tissue dies as a result of sudden and severe disruption of blood flow to the brain. Heavy alcohol use is associated with increased risk of stroke.
- **Cirrhosis** – chronic abuse of alcohol over a prolonged period can lead to cirrhosis, the progressive replacement of healthy liver tissue with **scar tissue**, which may result in liver failure and death.
- **Hypertension** – the relationship between alcohol use and blood pressure is important as hypertension is a key factor in the risk of coronary heart disease and stroke. Hypertension is defined as a **systolic blood pressure** above 140 mm Hg and a **diastolic blood pressure** above 90 mm Hg.
- **Depression** – excessive alcohol consumption can cause depression. Alcohol dependence and depression can occur together, and depression is commonly reported in people being treated for alcohol dependence.

Key terms

Scar tissue – connective tissue replacing damaged tissue that failed to heal itself.

Systolic blood pressure – pressure exerted in the arteries when the heart contracts.

Diastolic blood pressure – pressure exerted in the arteries when the heart relaxes and fills with blood.

PAUSE POINT Do you understand the likely risks of excessive alcohol consumption to health and well-being?

Hint: Think about the four main health conditions associated with excessive alcohol consumption.

Extend: Find out, from government statistics, how many people were affected by each of these four health conditions in the last calendar year.

Stress

Stress is a physiological and mental response to your environment. Factors that lead to stress are known as 'stressors' and they take on different forms. Potential stressors include major life events, such as divorce and moving house; injury or trauma; and environmental situations such as a demanding work environment or even sporting competition. Whatever the stressor, the responses usually include feelings of **anxiety** and tension.

Health risks associated with excessive stress

Many health problems are caused by, or exacerbated by, stress.

- **Hypertension** – the body produces a surge of hormones (**adrenaline** and **cortisol**) when faced with a stressful situation. These hormones – adrenaline in particular – cause a temporary sharp increase in blood pressure. These short-term spikes in blood pressure added together over time may put you at risk of developing long-term hypertension.
- **Angina** – associated with chest pain and usually a symptom of coronary heart disease (CHD) when the narrowing and hardening of the coronary arteries limits blood flow to the heart. Stress increases heart rate and blood pressure, and if the coronary arteries are narrowed, the blood will be unable to reach the heart efficiently, often causing chest pain.
- **Stroke** – stress causes a temporary rise in blood pressure. The main cause of stroke is high blood pressure which, in turn, can weaken the arteries in the brain and make them split or rupture, causing a bleed on or around the brain.
- **Heart attack** – although it is difficult to link stress directly with heart attacks, symptoms of stress (such as hypertension and the exposure to persistently high levels of stress hormones) may contribute to heart attacks.
- **Stomach ulcers** – it was believed that lifestyle factors such as stress and alcohol caused stomach ulcers. However, recent research suggests there is little evidence to confirm this, though such lifestyle factors may make the symptoms of a stomach ulcer worse.
- **Depression** – short-term stress can be good for you – it keeps you alert and ready for action. However, chronic stress can lead to depression. If stress responses fail to shut off once a difficult situation passes, elevated levels of cortisol and reduced levels of serotonin, a 'feel good' hormone, can lead to depression.

Key terms

Anxiety – a feeling of apprehension and heightened physiological tension.

Adrenaline – a hormone responsible for preparing the body for the 'fight or flight' mechanism by increasing heart rate, breathing rate and metabolic rate. It can also improve the force of muscle action and delay the onset of fatigue.

Cortisol – a hormone associated with stress that increases blood sugar levels, suppresses the immune system and aids the metabolism of macronutrients.

Lack of sleep

Health risks associated with lack of sleep

Sleep allows your body to rest and restore itself and plays a vital role in healthy living. Getting the right amount of sleep can help protect your mental and physical health, and improve your quality of life. A lack of sleep is linked with an increased risk of heart disease.

Research by the National Sleep Foundation suggests that a healthy adult requires between seven and nine hours of sleep per night. Athletes often require more sleep due to the added recovery and repair requirements as a consequence of training.

- **Depression** – one of the symptoms of depression is insomnia or an inability to sleep properly. This in turn can have a negative effect on general health and well-being, leading to a cycle of chronic mental and physical symptoms if not treated.
- **Overeating** – how much we sleep plays an important role in regulating how much we eat, the number of calories we burn and when we eat. Eating when we should be sleeping may increase weight gain.

Sedentary lifestyle

Key term

Sedentary – applied to an individual who is relatively inactive and has a lifestyle characterised by sitting.

Physical inactivity in general terms counts as doing less than 30 minutes physical activity per week. **Sedentary** behaviour refers to activities that use little energy (for example, watching television or sitting down). Physical inactivity and sedentary behaviour have both been shown to be significant risk factors in the increase in chronic diseases such as CHD, stroke, type 2 diabetes, certain types of cancer and hypertension. Physical inactivity can also add to feelings of depression.

Lifestyle modification techniques

Common barriers to change

Poor health is a drain on national resources and increases the amount spent on healthcare by the government. However, many people encounter difficulties in living a healthy lifestyle. Age, ethnicity and social and economic status may all present challenges to achieving wellness.

- **Time** – modern lifestyles are busy and time seems to be at a premium. Working hours constantly change and working from 9 a.m. to 5 p.m. is not the norm for everyone. Finding the time to exercise or simply undertake some form of physical activity may prove difficult. To overcome this, some people put more physical activity into how they get to work (such as cycling), what they do at work, or what they do during their leisure time. It is important to make an effort to exercise during the day and try to enjoy it.
- **Cost** – if people have the time and money, they can join a gym. If not, some forms of physical activity are basically free. Walking to work or increasing the physical activity you do at home (for example, housework or gardening) does not cost anything. Buying a pair of running shoes and a tracksuit and going walking or jogging is another cheaper alternative to a gym.
- **Transport** – many gyms, health clubs and even open spaces are only a short car journey away. Not everyone has access to a car though, so many people rely on public transport to get there. This may add an additional expense. How reliant on a car are you for journeys of less than 5 miles? Could you walk or cycle any of these journeys? It would save you money and help to increase your fitness levels.
- **Location** – where you live often influences your lifestyle choices. The availability of leisure activities, their cost and the ease in getting there often decide the type and level of physical activity we do. However, we often forget what we can do in our immediate surroundings. If, for example, you live in a flat, you could walk up and down the stairs instead of taking the lift. Always consider how your location and environment can be used for maximum exercise benefit.

Strategies to increase physical activity levels

Despite the strong case for keeping active, many people find it difficult to take up exercise. For some people exercise conjures up unpleasant thoughts, such as boring exercise classes, or rough competitive sports with a risk of injury.

People who have never exercised before, or who are in poor shape, should not expect immediate results. Achieving physical fitness requires time and consistency, but there are strategies that can be used in their everyday lives to help produce improvements.

At home

Increasing physical activity at home is probably easier than you think. Its main advantage is that you can manage your own time, and it will help to encourage others (such as children) to be active. Activities can be added to daily routines and household chores can be enhanced to increase general fitness, for example:

- going for a short walk – from 10–30 minutes – before breakfast
- doing housework instead of hiring someone to do it or, if you already do your own housework, doing it more vigorously
- standing up while talking on the telephone
- gardening – just 30 minutes per day will help improve fitness levels
- taking a dog for a walk.

At work

Evidence suggests that moderate-intensity lifestyle activities, such as taking the stairs instead of the lift, can be more successfully promoted than vigorous exercise programmes. Stair climbing can occur throughout the day and, with an energy cost of approximately 8–10 kcals per minute, can help with weight control, as well as leg power, bone strength and cardiovascular fitness. People can also be encouraged to go for a run or gentle jog during their lunch hour for 20 minutes – leaving time for a shower and something to eat.

During leisure time

There are lots of opportunities for physical activity during leisure time. If time permits, people can play a new sport, join a club that promotes physical activity (walks, tours, dancing, etc.) or plan family outings that include physical activity (such as hiking, walking, swimming, etc.). People can also listen to music – which can increase motivation – while exercising. Whatever they choose, as it is their leisure time, they should enjoy it.

Method of transport

Scientific evidence supports the benefits of regular walking for health and well-being. It is an easy and economical way to become and stay active. All ages can participate and it can be a social activity.

To achieve health benefits, you will aim for 10,000 steps a day (about 5 miles). The average sedentary individual achieves around 2000–3000 steps a day. If they can walk to a destination rather than taking the car or bus, they may be surprised how many additional steps – and calories – they will use. A **pedometer** can be used as a motivational tool to measure progress towards achieving a target. A sensible approach to reaching the 10,000 a day target is to increase daily steps by 500 each week until the 10,000 target is reached. If a person commutes to work, they could increase their steps by getting off a stop earlier and walking the remaining distance.

Key term

Pedometer – an instrument for estimating the distance travelled on foot by recording the number of steps taken. Many smartphones now include a pedometer app.

With around 70 per cent of all car trips being less than 5 miles, cycling can be an excellent form of transport, not least because you can cover much greater distances than when walking. Cycling is also an effective and enjoyable form of exercise. Daily cycling has been shown to lead to significant health benefits. People of most fitness levels can participate in cycling, although anyone with heart disease or other pre-existing conditions should consult their doctor beforehand.

PAUSE POINT Can you recognise and explain the barriers to changing a sedentary lifestyle?

Hint Using paper, a whiteboard or a tablet, list the barriers to change.

Extend How best do you think these barriers can be overcome? How would you go about changing or advising people with a sedentary lifestyle?

Quitting smoking strategies

Smoking increases the risk of lung cancer and heart disease. As with most behaviour-changing goals, to give up smoking the smoker must want to stop. After this there are several methods that can help.

- **Acupuncture** – a traditional Chinese therapy which may help someone to stop smoking by increasing the body's production of mood-enhancing endorphins that reduce or alleviate withdrawal symptoms.
- **NHS smoking helpline** – this was launched in 2000 as part of an initiative to encourage 1.5 million people in the UK to stop smoking by 2010. The helpline offers information, advice and support.
- **NHS smoking services** – the range of services promoted include group and one-to-one counselling and information on nicotine replacement therapy. Studies show you are more likely to quit smoking if you do it through the NHS.
- **Nicotine replacement therapy** – this refers to a range of products (gums, patches, lozenges and sprays) available to help smokers give up. They are available on prescription and are suitable for most smokers, although pregnant women or anyone taking regular medication should consult their doctor first. Unlike cigarettes, they do not contain the harmful cancer-causing toxic chemicals.
- **Quit Kit support packs** – funded by the NHS, these kits offer free support. Smokers can obtain a Quit Kit, download an app, and receive an email programme or text messages that will help keep them focused on giving up smoking.

Strategies to reduce alcohol consumption

Key term

Alcoholism – a chronic disorder characterised by a dependence on alcohol.

When alcohol consumption becomes both excessive and frequent, it has a severe and negative impact on health. This is called **alcoholism**. Alcoholics have an intense craving for alcohol and become physically dependent on it. Alcoholism is serious, but recovery is possible if the alcoholic is strongly motivated to stop. Some possible treatments are covered below.

- **Self-help groups** – successful treatment depends on sufferers recognising they have a problem. Self-help groups such as Alcoholics Anonymous (AA) help many sufferers through a step-by-step recovery programme.
- **Counselling** – individual or group counselling is provided by specially trained therapists; this might involve other family members as well. Counselling and therapy often focus on exploring and developing awareness of the triggers for alcohol consumption and on changing behaviour. Relapse, or slipping back into previous habits, is often high for alcoholics, so preventing this is a key feature of the process.

Treatment for alcohol abuse often begins with detoxification and withdrawal from alcohol. This is necessary when alcohol consumption has continued for long periods of time. It can be an uncomfortable process with unpleasant withdrawal symptoms. In extreme cases it can be fatal (which is why detoxification is usually undertaken under supervision within an alcohol treatment facility).

- **Alternative treatments** – some alcohol users may seek alternative treatments and therapies such as acupuncture and hypnosis which are thought to lessen the symptoms of withdrawal. However, there are mixed views about their value within the medical profession.

PAUSE POINT Do you understand the effects of alcohol on the body?

Hint: Consider three of the negative implications (physical and/or mental) of excessive alcohol consumption on health and well-being.

Extend: Research the impact of excessive alcohol consumption on the lives of former footballers George Best, Tony Adams or Paul Merson. Has the modern footballer's approach to alcohol consumption changed and, if so, how?

Stress management techniques

There are two general approaches to controlling stress.

- Try to reduce the amount of overall stress.
- Develop coping or stress management techniques.

To reduce overall stress, the factors promoting stress should be identified and, if possible, eliminated or reduced. Careful time management and prioritisation of workloads and commitments may help an individual to manage their stress better.

It is not possible to eliminate all the stresses in daily life. Therefore, having techniques or participating in activities to reduce stress levels will have a positive impact on health and well-being. Exercise can be viewed as a positive stress for the body. Other ways to manage stress are described below.

- **Assertiveness training** – the ability to express your feelings and rights while respecting those of others. Assertiveness may come naturally to some, but it is a skill that can be learned. It can help people deal with conflict situations that may be a cause of stress in their daily life.
- **Goal setting** – properly set goals can be motivating and rewarding. Achieving these goals can build self-confidence and reduce stress.
- **Time management** – this is a critical element of effective stress management. Time management is about achieving your tasks in good time by using techniques such as goal setting, task planning and minimising time spent on unproductive activities.
- **Physical activity** – this can have a positive effect on anxiety, depression, self-esteem and mood. It can be a stress reliever by producing an outlet for frustration, releasing endorphins (the 'feel good' hormones that lift mood) and providing a distraction from stressors.
- **Positive self-talk** – this is the inner dialogue you have with yourself. It influences most of your emotional life and reflects how you respond to your thoughts, feelings and actions. Self-talk can be negative or positive. Positive self-talk involves taking an optimistic view of life and your situation. In daily life you will face many challenges, difficulties and deadlines – taking a positive view of these and having constructive ways of dealing with them helps to reduce and manage stress.
- **Relaxation** – relaxation is not lying on a sofa or going to sleep but a mentally active process that ensures the body is relaxed and calm. When you relax, a series

of responses are activated that decrease your heart rate, lower your breathing rate, decrease your blood pressure and help your muscles to relax. There is no single relaxation technique that works for everyone, but techniques such as meditation or breathing techniques generally work for most people.

- **Breathing techniques** – exercises that focus on breathing are a simple way of trying to control or reduce stress. They involve controlled inhalation and exhalation, and are best undertaken when the participant is quiet and comfortable.
- **Meditation** – meditation produces a deep state of relaxation and a calm mind. During meditation, an individual will focus their attention on eliminating any thoughts causing stress. This can promote a sense of calm and balance that benefits both physical and mental well-being.

- **Alternative therapies** – these can work best when used alongside traditional treatment such as counselling or medication. Alternative therapies can include herbal remedies. Research continues to investigate the effects of herbal remedies to treat stress and anxiety, so it is a good idea to speak with your doctor before beginning any alternative treatment since some herbal remedies can cause complications if combined with certain prescription medicines.
- **Changes to work–life balance** – the pressure of an increasingly demanding work culture is a significant factor on stress levels. People can think more about their approach to work and consider:
  - taking proper breaks at work
  - ensuring a line is drawn between work and leisure by trying not to take work home
  - informing employers if you feel stressed
  - using relaxation techniques after work
  - engaging in leisure activities and spending time with family and friends.

Assessment practice 2.1

You have secured a position as an assistant community coach at a local tennis club as part of your course's work experience requirement. In addition to assisting the full-time coach with fitness coaching and fitness programming for boys and girls aged from 9 to 16, you have been asked to design a presentation on general health and well-being as part of an induction evening at the tennis club.

The club is expecting about 30–40 sets of parents and their children, the players. You are on first and you have a 30-minute slot (20 minutes for the presentation and 10 minutes for questions and answers). The general manager of the club has asked you to prepare a presentation in a format of your choice (PowerPoint, posters, slideshow, etc.) but it must address the following key points:

- positive lifestyle factors
- negative lifestyle factors
- lifestyle modification techniques.

You will need to carry out some research on these three points and demonstrate you understand what each of the three points mean and how they may be applicable to your audience (players and parents). Make sure your presentation is relevant and informative. You will need to outline the importance of the positive lifestyle factors and how they might benefit performance, how the negative factors can contribute to an unhealthy lifestyle and a likely decrease in performance, and how lifestyle modification techniques may help reduce unhealthy practices.

Plan

- What is the task? What is my presentation being asked to address?
- How confident do I feel in my own abilities to complete this task? Are there any areas I think I may struggle with?

Do

- I know how to examine lifestyle factors and their effect on health and well-being.
- I can identify when my presentation may have gone wrong and adjust my thinking/approach to get myself back on course.

Review

- I can explain what the task was and how I approached the construction of my presentation.
- I can explain how I would approach the more difficult elements differently next time (i.e. what I would do differently).

B Understand the screening processes for training programming

Screening processes

Poor training programmes or the wrong type of training lead to a lack of motivation and few training gains. Collecting appropriate information about your client through an efficient screening process that may include goals, lifestyle information, medical history and physical activity history, means you will produce a more effective programme for your client.

Screening questionnaires

Lifestyle questionnaires

When designing a training programme, you need to know about the client's lifestyle factors such as alcohol intake, diet, time availability, occupation, family and financial situation – all of these will influence how you design their training programme. The training programme should be built into a routine rather than becoming an extra stress, as this will help your client to stick with the programme and will produce the best results. You can gather this information using a lifestyle questionnaire similar to the one shown in Figure 2.3.

Physical Activity Readiness Questionnaires (PAR-Q)

For most people, physical activity is safe and will pose no problems or hazards. However, some people will need to check with their doctor before they start regular physical exercise. Completion of a PAR-Q is a recommended first step if a client is planning to start or increase the amount of regular exercise they undertake. The PAR-Q is designed to identify those people for whom physical activity might be inappropriate, or who should consider medical advice regarding which type of activity will be most suitable for them.

If your client is aged between 15 and 69 years old, the PAR-Q will tell you if they should check with their doctor before they start. If your client is over 69 years old, and not used to being physically active, it is vital they check with their doctor before starting a physical exercise programme. Before you design an exercise programme for a client, ensure your client answers a PAR-Q of a similar format to the example in Figure 2.4.

If a client answers 'Yes' to one or more questions on the PAR-Q, they need to talk to their doctor before taking any fitness tests or starting a training programme. If a female client is, or may be, pregnant they should also consult a doctor before starting.

Legal considerations

Collecting information about your client is important, not only to make your programme effective, but also for health and safety reasons. If you are a self-employed fitness instructor or personal trainer, it is also important for your own insurance. Remember that the information you possess about clients is privileged and is subject to the **Data Protection Act**. This means you have to keep their personal information secure and inaccessible to other people. Client confidentiality should be maintained at all times.

Before you being any training programme, or administer any health or fitness test, you must make sure your client has completed an informed consent form. This shows that you have given your client all the information they need about what the programme or test will involve and any possible consequences. You can find out more about informed consent forms in *Unit 5: Application of Fitness Testing*.

Key term

Data Protection Act – a law that controls how personal information is used by organisations, businesses or the government.

Lifestyle questionnaire

Work
1. What is your occupation?
2. How physically demanding is your job? ☐ Not at all ☐ Moderately ☐ Extremely
3. On an average day, how much time do you spend sitting down? ☐ 0–2 hours ☐ 2–5 hours ☐ 5–10 hours ☐ 10+ hours
Sleep
4. How many hours of sleep do you usually get each night?
5. When you wake up, do you feel refreshed? ☐ Always ☐ Usually ☐ Occasionally ☐ Never
6. Do you have trouble falling asleep or often wake up at night? ☐ Always ☐ Usually ☐ Occasionally ☐ Never
Lifestyle
7. Do you smoke? ☐ Yes ☐ No
8. If yes, roughly how many cigarettes do you smoke each day?
9. If you have smoked in the past, how long ago did you stop?
10. Do you drink alcohol? ☐ Yes ☐ No
11. If yes, roughly how many units of alcohol do you drink per week?
Exercise
12. On a scale of 1–10 (1 = not active, 10 = very active), how active are you on a daily basis? 1 2 3 4 5 6 7 8 9 10
13. What exercise do you do in an average week? (*e.g. Do you participate in a regular sporting activity, or go to the gym on a regular basis?*)

Figure 2.3: An example lifestyle questionnaire

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

1.	Has your doctor ever told you that you have a heart condition and should only do physical activity recommended by a doctor?	☐ Yes ☐ No
2.	Have you ever felt pain in your chest when you do physical exercise?	☐ Yes ☐ No
3.	Have you ever felt pain in your chest when NOT exercising?	☐ Yes ☐ No
4.	Have you ever suffered from unusual shortness of breath while resting or during mild exercise?	☐ Yes ☐ No
5.	Do you often feel faint, have dizzy spells, or lose consciousness?	☐ Yes ☐ No
6.	Has your doctor ever told you that you have a bone or joint problem that could be made worse by exercise?	☐ Yes ☐ No
7.	Do you have high blood pressure?	☐ Yes ☐ No
8.	Do you have low blood pressure?	☐ Yes ☐ No
9.	Do you have insulin-dependent diabetes or any other metabolic disease?	☐ Yes ☐ No
10.	Has your doctor ever told you that you have high cholesterol levels?	☐ Yes ☐ No
11.	Are you currently taking any prescribed medication?	☐ Yes ☐ No
12.	Is there any history of coronary heart disease in your family?	☐ Yes ☐ No
13.	Are you, or is there any possibility you might be, pregnant?	☐ Yes ☐ No

If you answered Yes to any of these questions, please provide details below.

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Figure 2.4: An example PAR-Q

PAUSE POINT

At which point during a screening process would you refer a client to see a GP?

Hint

Think about the questions on the PAR-Q and answers that might raise concerns.

Extend

How would you tell a client that they might be unable to continue with their health tests, training programme and exercise? What skills should you ideally possess to explain your decision?

Health monitoring tests and their results

Before planning a training programme for a client, you should also do some health monitoring tests. These include calculating their blood pressure, heart rate, body mass index (BMI) and waist-to-hip ratio. These tests can be done again during and after the fitness programme to help measure progress.

It is important to follow the correct protocol when undertaking health monitoring tests. If you do a test one way and then re-do it in a slightly different way, the results will be invalid and you will not be able to compare against normative data (see below). Always bear in mind that the client may be nervous during a test – health-related tests can have far-reaching outcomes, so always treat your client with courtesy and respect and try to help them relax.

Interpreting results against normative data

You can use published data interpretation tables to compare your clients' results against data for sports performers and elite athletes. Your choice when selecting data tables for interpretation of fitness test results will depend on your selected individual, their needs and their personal goals. However, most individuals will be interested to know how they compare against normative data.

PAUSE POINT

How might negative lifestyle factors discussed in this unit influence the results of a resting heart rate test?

Hint

Consider how each of the negative lifestyle factors might affect resting heart rate. Use websites such as **www.nhs.uk/Livewell** to find more information.

Extend

What are the signs that a client may be under the influence of negative lifestyle factors? Make a list of what to look out for.

Population norms

Making judgements about the results of health monitoring tests can be subjective. You should bear in mind that you are dealing with an individual, and individuals are all different. When judging tests against population norms, remember that these norms are benchmarks that exist to guide your next action with your client. They are not a method of diagnosing a client with an illness or disorder.

Norms for sports performance

It is difficult to interpret norms for sports performance. The best advice that can be given is that they should be between the population average and elite athletes.

Norms for elite athletes

It is reasonable to expect the results of health monitoring tests for elite athletes to be at the top end of what can be expected. There are no definitive data sets for elite athletes, but it is fair to say that it is unlikely someone would be able to compete at an elite level if their test results were average compared to population norms.

Blood pressure test

Blood pressure can be measured using a digital blood pressure monitor, which provides a reading of blood pressure as: systolic blood pressure/diastolic blood pressure (expressed in units of mm Hg).

Accepted health ranges

Table 2.6 shows the accepted health ranges of blood pressure results for men and women.

Table 2.6: Accepted blood pressure ranges for men and women

Rating	Blood pressure reading (mm Hg)
Average (desirable)	120/80 mm Hg
Above average (borderline hypertension)	140/90 mm Hg
High blood pressure (hypertension)	160/100 mm Hg*
* An individual should seek advice from their GP if blood pressure is >160/100 mm Hg on at least two separate occasions.	

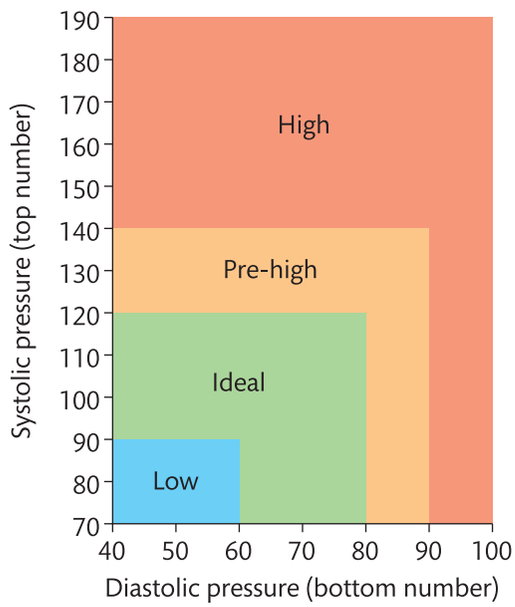

Figure 2.5: Blood pressure chart

PAUSE POINT

What might you need to keep in mind when conducting a blood pressure test? What anomalies might occur during the test and why?

Hint: Think about how you might feel if you were having your blood pressure tested.

Extend: How might you prepare a client for fitness tests? What strategies might you use to ensure your tests are accurate and your client is relaxed?

Resting heart rate test

This can be measured manually via the radial artery in the wrist or using a digital blood pressure monitor. Resting heart rate is measured in beats per minute (bpm). The average resting heart rate for a male is 68 bpm and for a female is 72 bpm. This difference is because males generally have larger hearts than females, which can pump a greater volume of oxygenated blood around the body per beat. A high resting heart rate (**tachycardia**) is above 100 bpm.

Key term

Tachycardia – a fast heart rate characterised by a resting heart rate of over 100 bpm or 20–30 beats above normal heart rate.

Accepted health ranges

Tables 2.7 and 2.8 show the accepted health ranges for men and women.

Table 2.7: Resting heart rate data for men (bpm)

Age	18–25	26–35	36–45	46–55	56–65	65+
Athlete	49–55	49–54	50–56	50–57	51–56	50–55
Excellent	56–61	55–61	57–62	58–63	57–61	56–61
Good	62–65	62–65	63–66	64–67	62–67	62–65
Above average	66–69	66–70	67–70	68–71	68–71	66–69
Average	70–73	71–74	71–75	72–76	72–75	70–73
Below average	74–81	75–81	76–82	77–83	76–81	74–79
Poor	82+	82+	83+	84+	82+	80+

Table 2.8: Resting heart rate data for women (bpm)

Age	18–25	26–35	36–45	46–55	56–65	65+
Athlete	54–60	54–59	54–59	54–60	54–59	54–59
Excellent	61–65	60–64	60–64	61–65	60–64	60–64
Good	66–69	65–68	65–69	66–69	65–68	65–68
Above average	70–73	69–72	70–73	70–73	69–73	69–72
Average	74–78	73–76	74–78	74–77	74–77	73–76
Below average	79–84	77–82	79–84	78–83	78–83	77–84
Poor	85+	83+	85+	84+	84+	84+

Body mass index (BMI) test

Key term

Body composition – the relative amounts of fat-free (or lean) mass and fat mass in the body.

BMI is a measure of **body composition** (expressed in kg/m^2) and is used to determine whether a person is a healthy weight. It is only an estimate, as the test does not take into account the individual's frame size or muscle mass.

To calculate someone's BMI:

1 Measure the individual's body weight in kilograms and height in metres.
2 Divide their weight by their height.
3 Divide the answer by their height again to find a value for their BMI (expressed in kg/m^2).

Research shows a significant relationship between high BMI and incidence of cardiovascular disease, and high BMI and diabetes. The risk of cardiovascular disease increases sharply at a BMI of 27.8 kg/m^2 for men and 27.3 kg/m^2 for women.

Worked example

A man is 1.8m tall and weighs 78 kg. Calculate his BMI.

1 78 ÷ 1.8 = 43.33

2 43.33 ÷ 1.8 = 24.07

The man's BMI is 24.07 kg/m^2.

Accepted health ranges

Table 2.9 shows the accepted health ranges for the BMI of both men and women.

Table 2.9: BMI data for men and women

BMI	Comments
<18.5	You are underweight; consult your GP to discuss a plan to achieve a more healthy weight
18.5–24.9	Healthy range
25–30	Above the healthy range – you may be overweight and likely to be heavier than is healthy for someone of your height
>30	Classed as obese; being obese puts you at an increased risk of health problems (e.g. CHD, stroke and type 2 diabetes)

PAUSE POINT Is BMI an accurate measure of whether or not an individual is potentially overweight?

Hint: Consider athletes such as rugby players, weightlifters and boxers. They may have BMIs over 25 but are considered elite athletes.

Extend: What might explain these high BMIs? Think in terms of the specific types of body composition that are important in these sports.

Waist-to-hip ratio test

The waist-to-hip ratio can determine levels of obesity and help identify those at risk of heart disease. Use a tape measure placed firmly against the individual's skin to measure their waist circumference in centimetres at the narrowest level of the torso. Next, measure the individual's hips by placing the tape measure at the maximum circumference of the buttocks. Make sure the tape measure is level when taking measurements. Divide the waist measurement (cm) by the hip measurement (cm) to obtain the waist-to-hip ratio.

Accepted health ranges

A ratio of 1.0 or more in men or 0.85 or more in women indicates an individual is carrying too much weight.

Theory into practice

The results of health monitoring tests can be the first step in identifying an underlying chronic health problem or disorder that has gone unnoticed for years. Although a GP will treat any problem or disorder, they are busy professionals and may not have the time to conduct such tests on a regular basis.

What do you think are the wider social or economic benefits of trained sport scientists or sports health practitioners conducting health monitoring tests on patients for GPs as part of a referral scheme?

Assessment practice 2.2

Your role at a local tennis club is going well and you are in the final week of your work experience requirement. Following your presentation on health and well-being, the tennis club is now offering general health checks for all members. The general manager has asked you to design a new health monitoring booklet to be used by the full-time fitness coach and given to club members. The booklet will have three sections:

1. A description of each test and why it is carried out.
2. A blank template for each test into which the results can be inserted.
3. An exemplar test with mock results filled in and analysed.

The design of the booklet is up to you, but it must be in these three parts and should include the following key features:

- PAR-Q
- written confirmation of a commitment to client confidentiality
- blood pressure test and interpretation of results
- resting heart rate test and interpretation of results
- body mass index (BMI) test and interpretation of results
- waist-to-hip ratio test and interpretation of results.

You will need to carry out research to complete this task. You should be able to show you understand each of the three sections and how the key features fit into the format of the booklet. Make sure your booklet is relevant and informative. You will need to highlight healthy results and flag up potential areas for concern (maybe using a traffic light system).

Plan

- What is the task? What is my booklet being asked to address?
- Are there any areas of the test analysis that I think I may struggle with?

Do

- I know how to design my own booklet, put a PAR-Q into practice, carry out the health monitoring tests and interpret the results of these tests correctly.
- I can identify where my booklet may have gone wrong and adjust my thinking to get back on course.

Review

- I can explain what the task was and how I approached the construction of my booklet.
- I can explain how I would approach the more difficult parts differently next time.

C Understand programme-related nutritional needs

Common terminology

The health and fitness industry uses some fairly standard terms when talking about nutrition. It is important you understand what these terms mean so that you can properly engage with other professionals working in the industry and explain the terms to your clients.

Dietary Reference Values (DRVs)

Dietary standards have been used in the UK since the 1940s. The first set of standards focused on a Recommended Daily Allowance (RDA) for each nutrient, which aimed to prevent nutritional deficiency. In the late 1980s, the government set up a panel of experts to review the RDAs and new **Dietary Reference Values** (DRVs) were established. The panel imagined a group of people and worked out the nutritional requirements of the people in that group to see what 'usual' requirements were. DRVs are now the responsibility of the European Food Safety Authority and, following a European regulation of 2011, RDAs are no longer used. The term 'dietary reference value' covers all of the following measures of nutrient intake:

- **Reference Nutrient Intake (RNI)** – the best estimate of the amount of nutrient considered to be sufficient for 97 per cent of people in the group.

- **Estimated Average Requirements (EAR)** – the nutrient intake needed to meet the average (median) requirements of the group. About half these people will usually need more than the EAR and half will usually need less.
- **Lower Reference Nutrient Intake (LRNI)** – the amount of a nutrient that is sufficient for only a few members of the group who have exceptionally low requirements. Intakes below the LRNI by most individuals within the group will almost certainly be inadequate.
- **Safe Intake (SI)** – the range of intakes of a nutrient for which there is not enough information to establish RNI, EAR or LRNI. It is an amount sufficient for the majority of the group but not so large that it causes negative side-effects.

PAUSE POINT What is Reference Nutritional Intake (RNI)? What does it tell us about our dietary habits?

Hint Think about the RNI (sometimes called RI) for different **macronutrients** and **micronutrients**. Use websites such as **www.nhs.uk/Livewell** if you need more information.

Extend What did you have to eat yesterday? Compare your dietary intake with the RNI values. Is your diet healthy or not?

Energy

Energy comes from the foods we eat. It is used to support your **basal metabolic rate** and all additional activity carried out at work and leisure. Energy is measured in **calories** or **joules**. As both these units are small, they are multiplied by 1000 and referred to as **kilocalories** (the UK system) or **kilojoules** (the metric or international system).

Key terms

Macronutrients – nutrients required in large amounts (carbohydrates, fats and proteins) to maintain health and well-being.

Micronutrients – nutrients required in small amounts (vitamins and minerals) to maintain health and well-being

Basal metabolic rate (BMR) – minimum rate of metabolism in an individual who is not digesting or absorbing food. BMR represents the lowest rate of energy usage that can sustain life.

Calories – one calorie is the energy needed to raise the temperature of 1 gram of water by 1°C.

Joules – 1 joule of energy moves a mass of 1 gram at a velocity of 1 metre per second. Approximately 4.2 joules = 1 calorie.

Kilocalories (kcal) – one kilocalorie is the energy required to raise the temperature of 1 litre of water by 1°C. It is equal to 1000 calories and used to state the energy value of food. Kilocalories are often simply referred to as calories.

Kilojoules (kJ) – a unit of energy, equivalent to 1000 joules.

Energy balance

You are in 'energy balance' when the amount of energy you take in as food and drink (your energy input) is the same as the amount of energy you expend (your energy output). You will be neither losing nor gaining weight.

There are four major components of energy output: resting metabolic rate, dietary thermogenesis, physical activity and adaptive thermogenesis.

- **Resting metabolic rate** (RMR) – this is the metabolic rate of a person at rest and accounts for 60–75 per cent of total energy output. It represents the largest component of the total daily energy expenditure. RMR is closely related to lean body mass and is influenced by the composition of your body: muscle tissue is much more metabolically active than fat tissue (muscle burns energy more quickly than the same weight of fat). Gains in muscle mass will result in increases in RMR. RMR is also influenced by your age, gender, and genetic background.
- **Dietary thermogenesis** (DT) – refers to any energy expended over RMR for digestion, absorption, transport and storage of food. It is influenced by the calorie content and composition of your diet and your own nutritional needs. High energy intakes and a regular eating pattern help to maintain higher rates of dietary thermogenesis. In a healthy individual this means that DT accounts for about 10 per cent of the total energy expenditure per day, while skipping meals and other restrictive dietary practices reduces this number.
- **Physical activity** (PA) – represents the most variable component of your total energy expenditure. This is the additional energy expended above RMR and DT, and in active individuals it can be the highest total daily energy use. Exactly how much it is depends on how active your general lifestyle is – how often, how energetically and for how long you participate in sport and exercise, and what type of activity you do.
- **Adaptive thermogenesis** (AT) – this is energy expenditure that comes from environmental or physiological stresses that may require you to respond by shivering, or stress that causes anxiety or fidgeting.

Basal metabolism

To estimate energy requirements, you first need to calculate basal metabolic rate (BMR) in kilocalories per day. The way of doing this for men and women of different ages is shown in Table 2.10.

Table 2.10: Calculating BMR

	Age (years)	Basal metabolic rates in kcal per day (W = weight in kg)
Males	10–17	BMR = 17.7W + 657
	18–29	BMR = 15.1W + 692
	30–59	BMR = 11.5W + 873
	60–74	BMR = 11.9W + 700
Females	10–17	BMR = 13.4W + 691
	18–29	BMR = 14.8W + 487
	30–59	BMR = 8.3W + 846
	60–74	BMR = 9.2W + 687

BMR is affected by a number of different factors.

- **Age** – basal metabolism decreases with age. After the age of 30, it falls by approximately 2 per cent per decade.

- **Gender** – males generally have greater muscle mass than females, so generally have a higher basal metabolic rate.
- **Climate** – exposure to hot or cold climates causes an increase in basal metabolism to maintain the body's internal temperature.
- **Physical activity** – to estimate total energy requirements you also need to consider your level of physical activity and training. This involves taking account of the calories used in different physical activities and the intensity and length of time over which you did the activity. Your intensity levels can be estimated by wearing a heart rate monitor and calculating your resting heart rate to work out your health range (see Tables 2.7 and 2.8).

Components of a balanced diet

All activity affects your body's need for fuel and fluid. Knowing the nutrients your body requires, along with their different functions, is the basis for understanding nutrition.

Macronutrients

Nutrients in food are categorised according to the relative amounts required by your body. Carbohydrate, protein and fat are termed **macronutrients**, as they are required in relatively large amounts on a daily basis. These nutrients are also the energy-providing nutrients of your diet.

Carbohydrate

Carbohydrates are your body's most readily available source of energy and can be accessed rapidly. One gram of carbohydrate provides approximately 4 kcal of energy. Carbohydrate foods are divided into two basic types: simple and complex.

Key term

Saccharide – a compound containing sugar or sugars.

Simple carbohydrates are sugars. They are easily digested and absorbed to provide a quick energy source. The simplest carbohydrate unit is monosaccharide (**saccharide** means 'sugar', **mono** means 'one'). Simple carbohydrates are found in most sweet-tasting foods such as fruit, fruit juices and honey.

Longer chains of simple sugars are called polysaccharides or **complex carbohydrates**. Complex carbohydrates are found in bread, rice, pasta, potatoes, beans and lentils.

Complex carbohydrates are an important source of energy since they are broken down slowly in your body to release energy over longer periods. They should form the largest percentage of your total carbohydrate intake. Unrefined sources such as wholemeal bread, wholegrain rice and wholemeal pasta are best as they also contain a higher nutritional value from macronutrients and provide a source of fibre.

After you eat foods containing carbohydrates your body sugar level rises. This causes the pancreas to release the hormone insulin. Insulin normalises blood sugar levels and helps the transport of **glucose** from the blood to the cells. Glucose is then used directly by the cells for energy or stored as **glycogen** in your liver and muscles. Glycogen is a crucial source of glucose for fuelling activity.

Key terms

Glucose – a monosaccharide that is converted to glycogen in the body.

Glycogen – type of blood sugar and major fuel source that the body converts from dietary carbohydrates.

Around 80 per cent of glycogen is stored in your muscles while the rest is stored in your liver, with a small amount of glucose circulating in your bloodstream as blood glucose. Excess carbohydrate not required for glycogen stores is converted to fat and stored in your body's adipose tissue.

Carbohydrate can only be stored as glycogen in limited amounts – approximately 375–475 grams – in an average adult, equivalent to approximately 1500–2000 kcal. Day-to-day stores of glycogen are influenced by dietary carbohydrate intake and levels of physical activity or training. Regular exercise can encourage muscles to adapt to store more glycogen. This is an important training adaptation for elite athletes, particularly in endurance-type sports.

A general recommendation is that carbohydrates should comprise 45–70 per cent of your total calories consumed. If your activity level is high, for example in endurance sports, you will need nearer 70 per cent to replace your depleted glycogen stores. A lower activity level, for example distance walking, will need nearer 45 per cent.

Table 2.11: Sources of carbohydrate

Simple carbohydrates 'Quick release' energy	**Complex carbohydrates** 'Slow release' energy
Sugar, syrup, jam, honey, marmalade, sugary fizzy drinks, boiled sweets, fudge, fruit juice, sports drinks, energy gels.	Bread, bagels, crispbread, crackers, rice, pasta, noodles, couscous, potatoes, breakfast cereals, pulses, root vegetables.

Fats

Key term

Triglycerides – the main component of plant and animal fats. They are the most concentrated source of energy in the body and stored in subcutaneous (under the skin) fat deposits where they also contribute to insulation.

Fat is an essential basic nutrient and the body's most concentrated source of energy. Each gram of fat gives approximately 9 kcal of energy. Fats also provide the body with heat insulation, mechanical cushioning and buoyancy.

Triglycerides are the basic component of fats. Each triglyceride is made from a glycerol molecule with three fatty acids attached. When triglycerides are digested and absorbed by your body they break down into these two substances. Fats come from animal and vegetable sources and there are two main types:

- **Saturated fats** – fatty acids, mainly from animal sources; along with cholesterol, they are linked to the build-up of fatty substances on artery walls. Saturated fats are usually solid at room temperature.
- **Unsaturated fat** – fatty acids usually liquid at room temperature and considered less likely to build up fatty acids on artery walls.

Most dietary experts recommend cutting back on fat intake. Many people in the UK eat too much saturated fat. The government recommends an average man should have no more than 30 g a day, and an average woman no more than 20 g.

Cutting back on fat intake is particularly good advice for athletes as it allows them to gain a greater proportion of their energy intake from carbohydrates (maintaining glycogen stores), to support training and competition. The primary function of fats is to provide a concentrated source of energy, forming your body's largest potential energy source. Even the leanest people have large amounts of energy stored as fat. Fat is more than twice as energy-dense as other macronutrients, yielding 9 calories per gram.

Fats protect and cushion your vital organs, provide structural material for cells and act as an insulator. Animal fats are a source of the fat-soluble vitamins A, D, E and K. Fats add flavour and texture to foods, which can be the reason for over-consumption.

All fats in your diet are a mixture of three fatty acid types (see Table 2.12). Fats that contain mostly saturated fatty acids (such as butter and ordinary margarine) are generally solid at room temperature and are usually found in meat, eggs and dairy foods. The two exceptions are palm and coconut oil, which are plant sources. Fats composed mainly of unsaturated fatty acids are usually liquid at room temperature, for instance, olive or sunflower oils.

Table 2.12: Sources of fat

Saturated	Monounsaturated	Polyunsaturated
Full-fat dairy products, butter, hard margarine, lard, dripping, suet, fatty meat, meat pies, pâté, cream, cakes, biscuits, chocolate, coconut, coconut oil	Olive oil, olive oil spreads, rapeseed oil, corn oil, peanuts, peanut butter, peanut oil	Soft margarine, low-fat spreads labelled as high in polyunsaturated fats, sunflower oil, safflower oil, soya oil, oily fish, nuts

Protein

Proteins are essential for maintaining health and physical performance. They play a vital role in the structure and function of cells, enzymes, hormones and antibodies.

The smallest units of protein are **amino acids**. You do not need to know the names and functions of the 20 individual amino acids, but the body needs all of them to be present simultaneously in order to grow and function properly. Different proteins contain different numbers and combinations of amino acids. The eight your body is unable to make are called **essential amino acids** (EAAs) – they are a necessary part of your diet. The remaining amino acids are called non-essential – your body is able to synthesise them if all the essential ones are present.

Key term

Amino acids – the chemicals which form the building blocks of protein.

The chief role of protein in your body is to build and repair tissue. Proteins may also be used as a secondary source of energy when carbohydrate and fats are limited, such as towards the end of prolonged endurance events or during severe energy restriction that may accompany dieting.

Proteins, like carbohydrates, have an energy value of approximately 4 calories per gram. Unlike carbohydrate and fat, excess protein cannot be stored in your body. All proteins carry out functional roles, so daily protein ingestion is required. If your protein intake exceeds your requirements for growth and repair, excess intake is used to provide energy immediately or converted to fat or carbohydrate and stored.

Protein foods are classified into two groups (see Table 2.13). The value of foods for meeting your body's protein needs is determined by their amino acids. Foods that contain all of the EAAs are known as first-class or **complete proteins**. These are mainly from animals (for instance, eggs, meat, fish, milk and other dairy products) and soya. Foods lacking in one or more of the EAAs are called second-class or **incomplete proteins**. These come from plant sources such as cereals, bread, rice, pasta, pulses, nuts and seeds.

Vegetarians and vegans must make sure they eat a variety of incomplete proteins in careful combinations to ensure an adequate intake of all EAAs. For example, beans and wheat complement each other well.

Table 2.13: Sources of protein

Complete proteins	Incomplete proteins
Meat, poultry, offal, fish, eggs, milk, cheese, yoghurt, soya	Cereals, bread, rice, pasta, noodles, pulses, peas, beans, lentils, nuts, seeds

On average, men should eat 55 g and women should eat 45 g of protein per day. This is roughly two palm-sized portions of protein.

Theory into practice

Both Venus and Serena Williams have, during their careers, switched to vegan or vegetarian diets. Both claim these diets have improved both their athletic ability, and their health and well-being. Venus says raw, organic foods are key to maintaining her body at its optimum health, although she admits the calorific needs of training and competition require her to eat pasta, bread and rice before matches due to the low calorific value of raw vegan foods.

Think about which vegan or vegetarian diet foodstuffs might contain the protein required by a top-level athlete. Do you think it is possible for an elite athlete to be vegan or vegetarian throughout their career?

Micronutrients

Vitamins and minerals are referred to as micronutrients as they are required in much smaller amounts than macronutrients. Despite the relatively small requirements for these nutrients, many play a critical role in regulating the chemical reactions in your body.

Vitamins A, B, C and D

Vitamins are vital, non-calorific nutrients required in very small amounts. They perform specific metabolic functions and prevent particular deficiencies and diseases. For example:

- **Vitamin A** – helps with the normal functioning of the eyes and respiratory tract. Vitamin A is found in green vegetables and carrots.
- **Vitamin B** – this group of vitamins plays an essential role in releasing energy from foods. The B vitamins are found in lean meats, eggs, cereals, wholegrains and milk.
- **Vitamin C** – essential for the formation and healthy functioning of collagen (major component of skin, bone and connective tissue) and a stimulant for the body's defence mechanisms. Vitamin C is found in vegetables and citrus fruits.
- **Vitamin D** – helps with the absorption of calcium and phosphorus to aid bone health. Vitamin D is found in oily fish, eggs and margarine, or it is produced in the skin by the action of ultraviolet light.

Most vitamins required to maintain health cannot be produced by your body and must be supplied by your diet. The exceptions are vitamin D, which your body is able to synthesise by the action of sunlight on the skin, and vitamin K, which can be produced by the bacteria in the large intestine. Vitamins play an essential role in regulating the many metabolic processes in your body, particularly those that release energy. They also support growth and the immune and nervous system, and some are involved in producing hormones.

Specific vitamins have specific functions and are required in differing amounts, suggested by the Dietary Reference Values (DRVs) – refer back to page 84 for more information. A balanced and varied diet with adequate energy content should supply sufficient intake of all vitamins.

It is important to note that large amounts of some vitamins can harm your health. This is particularly true for fat-soluble vitamins, as they can be stored in your body. The only situation in which large doses of any vitamin may be good for you is when the body has a severe lack of a particular vitamin or is unable to absorb or metabolise vitamins efficiently.

Vitamins are obtained from a variety of plant and animal sources and are broadly grouped depending on whether they are fat- or water-soluble. Vitamins A and D are in the fat-soluble group, with B and C being water-soluble.

- All fat-soluble vitamins such as A and D have common features. They are found in fatty or oily parts of foods. Once digested they are absorbed and transported in the lymphatic system to the blood. Because they are insoluble in water, they are not removed from the body in urine and can build up in the liver and **adipose tissue**.
- Vitamins B and C are water-soluble. Many B vitamins serve similar functions, helping the use of energy within your body. Excess vitamins of this type are excreted in urine, so your body has only limited stores, meaning you need to have a regular intake of them. Many of these vitamins are destroyed by food processing and preparation.

Key terms

Adipose tissue – tissue containing a high proportion of fat-storing cells that generally forms under the skin where it can act as an insulator or shock absorber.

Trace elements – minerals required by the body in relatively small amounts (less than 100 mg per day).

Minerals

Minerals are non-calorific nutrients that are essential to life. Like vitamins they are required in small or trace amounts. Minerals are classified in two categories depending on the relative amounts required by your body:

- **Macrominerals** such as calcium are required in relatively large amounts, sometimes as much as several hundred milligrams per day.
- **Trace elements** such as copper (found in seafood, nuts, seeds and wholegrains) and selenium (found in seafood, fish, lean meat and wholegrains) are required in much smaller quantities (micrograms per day).

Calcium

This mineral is essential for the development of healthy bones and teeth, and general health and well-being. Calcium is the most abundant mineral found in the body – over 1 kg is found in the average adult – and is required for blood clotting, muscle and nerve activity, and cell permeability.

Sources of calcium include meat, poultry, fish, vegetables, dairy products and nuts. In the UK, the calcium Reference Nutrient Intake (RNI) for adult males and females is 700 mg.

Iron

This mineral is a component of haemoglobin, and is essential for general health and well-being. A lack of iron leads to a condition known as anaemia which decreases oxygen transport in the blood, leading to apathy and fatigue.

Sources of iron include red meat, liver, dried fruit, vegetables and nuts. In the UK, the iron Reference Nutrient Intake (RNI) for adults aged 19–50 is 8.7 mg for men and 14.8 mg for women.

Discussion

How closely should governments be involved in what we eat? Do you think multivitamins or 'five a day' should be available to all, without charge, on the NHS? Would this help lower the risk of chronic diseases or reduce the impact of poor diet? Or is diet a personal choice and any health issues something the NHS should deal with, rather than preventing the causes?

In small groups discuss this dilemma and consider whether or not the government should focus on prevention or cure.

PAUSE POINT Do you understand why micronutrients are an important part of dietary intake?

Hint Micronutrients (vitamins and minerals) have different specific roles in the body.

Extend Find out the Reference Nutrient Intake (RNI) values for all vitamins and essential minerals for a healthy adult male and female.

Hydration

Water is the main transport mechanism in your body, carrying nutrients, waste products and internal secretions. It also plays a vital role in temperature regulation, particularly during exercise, and helps the passage of food through your digestive system.

Water makes up around 50–60 per cent of your total body weight – actual amounts vary depending on age, gender and body composition. Muscle has higher water content than fat tissue, so leaner individuals have higher water content than fatter individuals of the same body mass.

Water can be lost from your body in a number of ways, including urine, faeces, evaporation from the skin and breathing out. If water loss is high, your body becomes dehydrated. Normally your body maintains a balance between fluid input and output. Table 2.14 shows the balance between water intake and water loss.

Table 2.14: Daily water balance for a sedentary 70 kg adult male (Source: Bush *et al.* (2012) *Foundations in Sports Science*, London: Pearson Education Ltd)

Daily water input		**Daily water output**	
Source	**Millilitres**	**Source**	**Millilitres**
Fluids	1200	Urine	1250
Food	1000	Skin	850
Metabolism	350	Lungs	350
		Faeces	100
Total	**2550**	**Total**	**2550**

Different types of fluid intake

Around 10 per cent of your daily fluid requirements come from metabolic processes that release water within your body. The other 90 per cent is taken from your diet. Approximately 60 per cent come directly from fluids and the rest comes from food. Factors that affect the amount of fluid you need are listed below:

- **Climate** – where you live or train, and its climate, will affect the level of fluid intake you need. A hot climate requires an increase in fluid intake and a **humid** climate even more so, due to the body's reduced ability to keep cool due to the high water content in the surrounding atmosphere. Athletes who train or compete in hot or humid conditions need to monitor **electrolyte** levels due to the amount of minerals and salts lost due to sweating.
- **Levels of exercise** – athletes should begin training fully hydrated and drink plenty of water both during and after activity. Training is an opportunity to practise fluid-replacement strategies for competitive situations. Many factors influence the effectiveness of fluid-replacement strategies during exercise. Make sure your hydration strategy is correct, especially for long-duration aerobic events. Fluid replacement can be accelerated by drinking reasonable volumes of still, cool water drinks. They should not be too concentrated, and must be ready to drink.

Key terms

Humid – air containing a high amount of water or water vapour.

Electrolytes – substances such as potassium, magnesium, calcium and sodium which are dissolved in bodily fluids and lost through sweat. Without electrolytes, your cells and organs will not be able to function correctly.

The more intense the activity, the more the absorption of fluid is slowed. Unpleasant symptoms experienced when drinking during exercise usually means you started drinking too late and your body is already dehydrated. Try to drink regularly during exercise, especially if you are exercising for more than an hour.

- **Time of year** – athletes should be encouraged to take more care when hydrating in the summer months due to higher outdoor temperatures. Although outdoor temperatures are often lower during winter months, it is still essential to make sure correct hydration takes place.

Dehydration and hyperhydration

Dehydration can reduce strength, power and aerobic capacity. Severe dehydration can cause heatstroke and may be fatal. A water loss as small as 2 per cent of body mass can be enough to affect your ability to perform muscular work. For a 75 kg male this would mean a fluid loss of only 1.5 litres. Remember, thirst is a poor indicator of your body's hydration status. Warning signs include:

- lack of energy and early fatigue during exercise
- feeling hot and/or clammy or flushed skin
- not needing to go to the toilet
- nausea, headache or disorientation
- shortness of breath.

Hyperhydration is when you have more water than the normal body water content. Starting exercise in a hyperhydrated state can improve thermoregulation, improving heat dissipation and exercise performance. However, a hyperhydrated state can also be dangerous, causing symptoms similar to dehydration.

Hyperhydration can also cause **hyponatremia**, a potentially fatal condition resulting from a low level of sodium in the body fluids, made worse by excessive water consumption. Endurance athletes, who often lose large volumes of water and sodium through sweating, are particularly at risk from hyponatremia if they replace water volumes but not sodium (further diluting their already reduced sodium levels). The drinking of electrolyte replacement sports drinks is recommended to prevent this.

Key terms

Dehydration – a reduction in the normal water content of your body, when you lose more fluid than you take in. Dehydration can lead to decreased blood pressure, increased heart rate and increased core body temperature.

Hyperhydration – an increase in the normal water content of your body, when you take in more fluid than you lose.

Hyponatremia – a state of low sodium levels in the body fluids.

PAUSE POINT Complete a daily nutrition audit on yourself or a friend.

Hint: List what you or a friend ate yesterday and break down this daily intake into macronutrients, micronutrients and hydration categories.

Extend: Can you identify gaps in the daily nutritional intake? Make recommendations about what foods could be eaten to cover these gaps.

Nutritional strategies for individuals taking part in training programmes

Adapting diet to gain or lose weight

Weight can be gained by increasing the amount of fat or the amount of lean body mass. Both will register as increases in weight on a set of scales, but your body composition results will be very different. Gains in fat weight are relatively easy to achieve. However, gains in lean body mass can only be achieved from the body's responses to a progressive strength training programme, supported by an adequate diet, high in protein (to aid muscle growth) and low in fat. These diets generally involve adding additional lean meat, fish or poultry to your diet, or low-fat protein drinks.

Key terms

Optimal body weight – an ideal weight for a body composition that enables an athlete to perform successfully in a specific sport or activity.

Ergogenic aids – any aid that enhances physical performance.

Most athletes are concerned with achieving and/or maintaining an **optimal body weight**. Sports that group participants by weight category include body-building, boxing, horse racing, martial arts and rowing. Participants in these sports must compete within a certain weight range.

For some sports, low body weight may be crucial. In some cases this may be below a person's natural weight. These sports can be called weight-controlled sports, and include distance running, gymnastics, figure skating and diving. Inappropriate weight-loss practices affecting athletes include fasting or skipping meals, laxative abuse, bingeing and purging, and deliberate dehydration via sweatsuits or saunas.

When most athletes talk about achieving weight loss, they usually mean fat loss. Losses in muscle mass may result in unfavourable changes in their power-to-weight ratio.

Theory into practice

Chris Hoy and Nairo Quintana are both professional cyclists, but their sizes are very different. Hoy is a track cyclist who specialised in sprint events; he is 1.85 m tall and weighs 92 kg. Nairo Quintana is a road cyclist who specialises in long-distance events such as the Tour de France; he is 1.66 m tall and weighs 58 kg.

Hoy's event requires muscular power to achieve high speeds over short distances on the indoor track. This power is provided by large muscles that add to Hoy's overall bodyweight. Quintana's event requires considerable endurance, allowing him to cycle up to 200 km per day, sometimes up steep mountains. This requires excellent muscular endurance, cardiorespiratory fitness and much lighter overall bodyweight.

Quintana's smaller bodyweight is ideal for long-distance cycling. Any additional weight will affect his performance over long distances, as more energy will be required to move just one additional kilogram of bodyweight over 200 km. Hoy does not have to worry too much about this; his event is over in minutes.

Do you think Chris Hoy would be able to compete effectively on a 200 km mountain stage of the Tour de France?

Using ergogenic aids in training programmes

Athletes and coaches are always looking for ways to gain a competitive advantage and improve athletic performance. In response to this, a range of **ergogenic aids** are marketed and sold to athletes at all levels. Some are commercially available and legal, others available on prescription only, while some are illegal and their use and possession may result in criminal investigation or sporting penalties.

Energy gels and bars

Energy gels are designed to replenish depleted carbohydrate stores after exercising. Remember, the body relies on carbohydrate – glycogen – as its primary fuel source when exercising. Generally, the greater the exercise intensity, the greater the percentage of fuel that comes from carbohydrates. However, we can only store a limited amount of carbohydrate in our skeletal muscles and liver.

Energy gels do not provide a simple one-to-one replacement because the glycogen you ingest from gels does not always get to the working muscles. For glycogen to get to the muscles, it must be digested, and then absorbed by the muscles. This takes time and is inefficient, especially during exercise when blood is diverted from the digestive system. Energy gels consumed at least 30 minutes before exercise can give maximum benefit.

Protein drinks

Protein is used for the production of muscle, to manufacture hormones, enzymes and immune system components. If you do not consume enough protein, your body cannot put together the structures that make up cells, tissues and organs, nor will muscles heal as quickly, which could lead to injury.

Solid food takes longer to digest, and breaking down protein to send it to the muscles can take hours. A protein drink taken after a workout will only take about 30 minutes to reach the muscle area after ingestion.

Carbohydrate loading

Carbohydrate loading (also known as 'glycogen loading') is used by endurance athletes before an event to maximise storage of glycogen in skeletal muscles. Carbohydrate loading involves increasing your intake of carbohydrate and decreasing your training for approximately three days before competition. Carbohydrate loading is based on a regular, controlled diet and is legal.

Your body can store enough glycogen to sustain approximately 90 minutes of exercise. After this, without extra fuelling, you are in danger of running out of energy. Carbohydrate stores can be maximised two to three days before an event by increasing your carbohydrate intake at mealtimes, with an approximate guide being 10 g of carbohydrate per kilogram of bodyweight. Increase the carbohydrate content of your diet by adding larger portions of wholemeal bread, pasta, rice, potatoes and plenty of fruit juice at mealtimes. Two hours before the event, try to eat a high carbohydrate snack such as citrus fruits or muffins.

Case study

Sports Scientist: Jack Donnelly and the new menu

Jack is progressing well as the football club's new sports scientist. Now the academy manager has asked him to help the club's chef ensure the academy players get the correct nutrition during their daily meals with the club. He has been asked to make sure all components of a balanced diet are present in the correct amounts. Failure to do so may result in impaired performance and the players leading a less-than-healthy lifestyle.

Jack is due to sit down with the chef and compose a dietary plan for a five-day week, including breakfast, lunch, dinner and all hydration.

Check your knowledge

Draw up a five-day (Monday to Friday) dietary plan for the players.

- Research the recommend amounts for an athlete of each macronutrient (carbohydrates, fats, proteins).
- Ensure all macronutrients are included and in the correct amounts.
- Use ergogenic aids (energy gels and bars, protein or carbohydrate drinks) if you deem them appropriate.
- Make sure you include hydration times and amounts.
- Think about the most appropriate times for each meal.

Theory into practice

Nutritionists at the English Institute of Sport (EIS) (www.eis2win.co.uk/) use the term 'unleash the power of food'. Their belief is that through the science of nutrition, athletes have been able to reduce injuries, increase capacity to train, and improve competitive performance. They have done this by being involved in all aspects of nutrition from getting the food right at hotels to ergogenic aids.

Consider how these principles might be adapted to a more local coaching role, say at a school, college or local sports club. Do you think you could get a local team or athlete to embrace the same methods?

Using sports drinks

Most sports drinks provide three nutrients: carbohydrates to replace energy, water to replace fluid and electrolytes to replace minerals lost in sweat. The carbohydrate is usually glucose, fructose, sucrose or maltodextrins, which are all saccharides that are quickly absorbed. Sports drinks often contain a range of minerals and vitamins, but most often include the electrolytes sodium and potassium – both these macrominerals are lost in sweat. Sodium promotes the absorption of glucose and water. Magnesium is another mineral lost in sweat, and is present in water and most sports drinks.

Isotonic

Isotonic drinks contain the same concentration of glucose to water as blood (4–8 per cent or up to 8 g per 100 ml of water). Because of this, although they are hydrating, they have no effect on the volume of tissues or cells. They usually also contain sodium, making them quicker to absorb into the bloodstream. They are useful for prolonged exercise or during warmer weather. They can also be used before exercise.

Hypertonic

Hypertonic drinks are high-energy, concentrated sports drinks containing over 8 per cent of carbohydrate; they are absorbed more slowly than isotonic drinks. Although they provide carbohydrates, they are not ideal for optimal rehydration and may need to be consumed with other fluids. They have a higher total salt concentration than body fluids and are best used in the recovery phase after exercise.

Hypotonic

Hypotonic drinks have a lower concentration of carbohydrates and are more diluted than isotonic or hypertonic drinks. They contain less than 4 per cent carbohydrates (4 g per 100 ml of water) and are generally easily absorbed and well tolerated. Although water is adequate for non-endurance athletes or when sweat losses are small, these drinks encourage fluid replacement. Their salt concentration is lower than body fluids.

Discussion

Energy drinks are big business: they promote the benefits of hydration and electrolyte balance and may improve your sports performance, but they can be expensive. Are they any more beneficial than tap water or less-expensive orange squash? In small groups, discuss this and consider whether or not energy drinks are worth the expense. Feed back your findings to the group in the form of a sales pitch for both alternatives.

Assessment practice 2.3

Your health monitoring booklet has proved a success and is currently being used by the full-time fitness coach on a daily basis. Because of your efforts and commitment over your work experience placement, the general manager of the tennis club has asked you to stay on in a part-time capacity to perform fitness training and programming, and to assist the fitness coach in giving clients the correct health advice.

The first job the fitness coach has asked you to do is prepare an information leaflet for all members explaining their nutritional needs while they are training for and competing in tennis tournaments. Your leaflet should contain the following information:

- an explanation of common nutritional terminology (e.g. RNI and energy balance)
- components of a balanced diet (e.g. macronutrients, micronutrients and hydration)
- different strategies used by tennis players taking part in training programmes.

The design of the leaflet is up to you, but the coach has asked you to state the key nutritional requirements and explain why they are important to the members if they are undertaking his training programmes. Once the coach is happy with the leaflet, he will give copies to all members, telling them to contact you if they have any further questions.

Plan

- What is the task? What is my leaflet being asked to address?
- How confident do I feel in my own abilities to complete this task? Are there any areas of the nutritional requirements and their impact that I think I may struggle with?

Do

- I know how to design my own leaflet, include all the necessary nutritional information and explain why this information is important.
- I can identify where my leaflet may have gone wrong and adjust my thinking/approach to get myself back on course.

Review

- I can explain what the task was and how I approached making my leaflet.
- I can explain how I would approach the more difficult parts differently next time.

D Examine training methods for different components of fitness

Components of fitness to be trained

Fitness is the ability to meet the demands of your environment. It includes social, spiritual, psychological, emotional and physical well-being. Though it is often defined as one of the following, it is not only concerned with muscle size, body tone or the ability to run far or fast.

- **Physical fitness** – focusing on the health-related aspects of fitness – good scores in components in this area mean you have only a small chance of developing health problems.
- **Skill-related fitness** – fitness that allows the individual to perform an activity, task or sport (also known as motor fitness).

Physical fitness

Physical fitness involves six main components:

- **Aerobic endurance** – also known as stamina or cardiorespiratory endurance, it is the ability of the cardiovascular and respiratory systems to work efficiently and supply the muscles with nutrients and oxygen to maintain exercise over time. It is important not only for daily tasks such as walking to work, but also for a range of sport, leisure and recreational activities. A number of events rely on aerobic endurance, and poor aerobic endurance can lead to poor performance in some sports.

- **Strength** – the ability of a specific muscle or muscle group to exert a force in a single maximal contraction. When you think about strength, you might think about weightlifters or boxers, but strength is required in most sports. For instance, a Formula 1 driver needs strong neck muscles to withstand the pressure put on their head when going round corners fast.
- **Muscular endurance** – this is needed where a specific muscle or muscle group makes repeated contractions over a significant period of time (possibly over a number of minutes) against a light to moderate fixed resistance load. Sporting examples include:
  - a boxer making a repeated jab
  - continuous press-ups or sit-ups
  - the 400 metres in athletics.

Boxers need muscular endurance to make repeated jab punches

- **Flexibility** – this is important for all sports and for health. It relates to having an adequate range of motion in all joints of the body and the ability to move a joint fluidly through its complete range of movement.
- **Speed** – a component of physical fitness, speed is required to maximise performance in order to move the whole body quickly or limbs rapidly. It is the ability to move over a distance in the quickest possible time. Athletic sports such as the 100-metre sprint and long jump require high levels of speed.
- **Body composition** – the amount of body fat and fat-free lean body tissue an athlete has. It is important from a health and sports performance perspective. Lean body mass includes the combined weight of the vital organs, bones, muscles and connective tissues.

Skill-related fitness

Skill-related fitness involves five main components.

- **Agility** – the ability of an athlete to quickly and precisely move or change direction while maintaining control of the movement.
- **Balance** – being able to maintain stability or equilibrium while performing. There are two forms of balance: **static balance**, where the athlete is stationary, for example in a handstand in gymnastics, and **dynamic balance**, where the athlete is moving, for example a footballer sprinting with the ball.
- **Coordination** – the ability to control movement of two or more body parts, smoothly and efficiently, to perform a task. Most sporting movements require different joints and muscles to be used in a specific order.

- **Reaction time** – the time taken for a sports performer to respond to a stimulus and initiate their response. An obvious example is a starting pistol (the stimulus) and the sprint start (the movement) in sprint events.
- **Power** – the ability to produce a maximal force in the shortest possible period of time, or to generate and use muscular strength quickly. Stronger athletes tend to produce a greater amount of power during an action. Power is generally needed more by athletes in specific sports and is developed using advanced training methods. For example, sprinters need power when pushing away from the blocks, golfers need it to strike a long-range drive and boxers for delivering a punch.

Training methods for physical fitness-related components

To develop different components of fitness to meet the needs of different sports, athletes, coaches and personal trainers often need to use a variety of training methods. These methods might be in indoor or outdoor environments or using a range of equipment.

Aerobic endurance training methods

The three most common methods used to improve aerobic endurance (also known as **VO_2 max**) are:

- continuous training
- fartlek training
- interval training.

Circuit training is also used. There is insufficient evidence to suggest which aerobic training method is best, but all will lead to improvements in aerobic endurance.

Aerobic endurance training is often used by people who want to lose or manage their weight by reducing their body fat content; as such, aerobic training is often used during pre-season by football and rugby teams. Body fat is reduced because training results in increased levels of the hormones **epinephrine** and **norepinephrine** which then help break down fat to be used as an energy source.

As well as the health benefits of aerobic endurance training methods, they have different benefits for sport-specific performance: they can help to improve blood volume, improve mitochondrial size and density, develop neuromuscular patterns and improve muscle tone.

Training thresholds

Different intensities of aerobic exercise can be classed as different training thresholds or zones of training. In order to use training thresholds in your training, you need to understand the principles behind **maximum heart rate**. When the body is in action, **cardiac output** can increase by five to seven times in order to accelerate the delivery of blood to exercising muscles, and meet their aerobic demands. This is a result of increases in either heart rate, **stroke volume** or both. Since stroke volume does not increase significantly beyond the light work rates of low intensity exercise, the increases in cardiac output required for moderate- to high-intensity work rates can only be achieved by increases in heart rate.

Key terms

VO_2 max – the maximum amount of oxygen that can be taken in by and used by the body. Also a measure of the endurance capacity of the cardiovascular and respiratory systems and exercising skeletal muscles.

Epinephrine – a chemical in the body used for communication between cells in the nervous system and other cells in the body. It works with norepinephrine to prepare the body for the 'fight or flight' response.

Norepinephrine – a chemical in the body used for communication between cells in the nervous system and other cells in the body. It works with epinephrine to prepare the body for the 'fight or flight' response.

Cardiac output – the volume of blood pumped out (in litres) by the left ventricle in one minute.

Stroke volume – the volume of blood pumped out (in millilitres) by the left ventricle during one heartbeat.

Maximum heart rate can be estimated using the following formula:

Maximum heart rate = 220 – age (in years)

The formula includes the person's age because heart rates vary with age: children have relatively higher rates than adults, and maximal cardiac output decreases with age (as a result of a decrease in maximum heart rate).

Once you know someone's maximum heart rate (MHR), you can get them to target specific heart rate zones during their training which will have different effects on how their body develops (see Table 2.15).

Table 2.15: Training zones

Training zone	% MHR	Purpose
Warm-up or cool-down zone	50%	Mainly for the sedentary or unfit person who wants to start training.
Active recovery zone	60%	Useful for aiding recovery and removing waste products, and provides a good next step for those new to aerobic training.
Fat burning (or weight management) zone	60–70%	A progression for people once they have increased their fitness levels, but also used by athletes training for long-distance events such as a marathon. You may use continuous training when training in this zone.
'Target heart rate' zone	60–75%	Some coaches have been known to expand this zone as high as 85 per cent. This zone has the greatest benefits for cardiovascular health and for improving the body's ability to use fats as an energy source.
Aerobic fitness zone	70–80%	The zone where you develop your aerobic endurance. This zone is suitable for more active or trained athletes.
Peak performance zone	80–90%	The highest zone of aerobic training is geared towards competitive sport and helps develop the anaerobic threshold. You will often use up-tempo methods such as fartlek and interval training when training through the aerobic fitness and peak performance zones.
Anaerobic threshold	80–100%	Exercising with legs that are starting to get hot, tight and achy, with much more laboured breathing is a sign you are close to your anaerobic threshold. This is the point where you can no longer meet the energy requirements of exercise using your aerobic energy system, so your body compensates by producing energy using your anaerobic systems. This is the point that your **blood lactate** levels increase significantly. (Refer to Unit 1 for more information.) Training at high percentages of your maximum heart rate helps to increase this threshold, allowing you to train at higher intensities and longer durations while still using your aerobic energy system. Training close to your anaerobic threshold significantly stresses your cardiovascular system, so it is not suitable for inexperienced trainers. Training at 100% of maximum heart rate is only recommended for highly experienced and elite athletes.

Key term

Blood lactate – lactate dissolved in blood as a result of a build-up in blood carbon dioxide levels. Lactate is not the same thing as lactic acid.

PAUSE POINT

How would you differentiate the aerobic training zone of an 18-year-old athlete and a 40-year-old trying to get fit and healthy?

Hint – What is your maximum heart rate and what heart rate would you see in your aerobic training zone?

Extend – What training methods might you use to progress an experienced athlete into the peak performance zone?

Types of aerobic endurance training methods

Continuous training

Also known as steady-state or long, slow distance training: the athlete trains at a steady pace over a long distance. The intensity of continuous training should be moderate (approximately equal to or less than 70 per cent of VO_2 max) over a long distance and time.

This method is suited to long-distance runners and swimmers. Due to the lower level of intensity, an athlete can train for longer. It can also be useful for:

- beginners who are starting structured exercise
- athletes recovering from injury
- 'specific population' individuals such as children or elderly people.

Its disadvantages include a higher risk of injury when running long distances on harder surfaces. It can also be boring and it is not always **sport specific**: the sport specific benefits are small.

Continuous training can be performed in a gym using a range of cardiovascular equipment (for example, treadmill, cross-trainer or exercise cycle) or outdoors at a suitable park or track area.

Fartlek training

Fartlek training is designed to improve an athlete's aerobic endurance. It is based on running outdoors, and varies the intensity of work according to the athlete's requirements. The intensity of training is changed by varying terrain, such as sand, hills, soft grassland or woodland, or by running at a more sustained pace to a landmark such as a lamp post or tree.

Some of the benefits of this training method include improving aerobic endurance, improving muscular endurance and improving balance and **proprioception** in the ankle, knee and hip, all of which have a variety of benefits ranging from improved sport performance during a game to helping with injury rehabilitation.

Fartlek training can be more useful than continuous training because it can be individual- and sport-specific. This method also uses both aerobic and anaerobic energy systems to improve aerobic endurance and can involve changes in direction, so it is useful for team sports players as it can mimic the sport.

In fartlek training there is no rest period, but the athlete has more control and is able to decrease intensity at any time to rest. The benefits of fartlek training are that:

- it is less technical than other methods (such as interval training), making it easier to use
- athletes control their own pacing
- the boredom of conventional training is reduced.

Fartlek training can be done in a gym using a range of cardiovascular equipment (for example, treadmill, cross-trainer or exercise cycle) so long as the speed, resistance or gradient can be changed regularly. Fartlek training can be undertaken outdoors at a suitable park area where the intensity can be changed by varying terrain.

Research

Fartlek training can use both aerobic and anaerobic energy systems, involving changes in gradient, pace, resistance and direction, closely mimicking the requirements of a specific sport. Some common examples of fartlek sessions include Astrand, Gerschler, Saltin and Watson methods. Research these examples and examine their different approaches.

Key terms

Sport specific – a training activity that reproduces an element of the sport that is being trained for. For instance, although footballers do lots of running during their sport, they do not do it for long, continuous periods of time but in short bursts.

Proprioception – the awareness of the body's position in space.

Interval training

Interval training improves both anaerobic endurance components and aerobic endurance by varying the intensity and length of the work periods. In interval training, athletes perform a work period, followed by a rest period, before completing another work period. They can repeat this pattern many times, depending on their fitness levels. When designing an interval training programme, you should consider:

- the number of intervals (rest and work periods)
- the intensity of the work and rest intervals
- the duration of the work and rest intervals.

'Sets' and 'reps' are common terms that provide structure and organisation when referring to the number of exercises in the training programme.

- **Reps** is short for repetitions and describes how many times you perform an exercise.
- A **set** tells you how many times you repeat that exercise for the set number of reps.

Key term

Overload – an increased stress or load must be placed on the body for a training adaptation to take place.

An example of an interval training programme for aerobic endurance could be one set of three repetitions of five-minute runs interspersed with two minutes of rest. This would be written in a training diary as *1×3×5:00 Work: Rest 2:00*. This method of training allows clear progression and **overload** to be built into the programme by increasing the intensity of work periods, increasing the number of intervals, decreasing the duration of the rest period or increasing the intensity of the rest period (for example, using a slow jog rather than a walk).

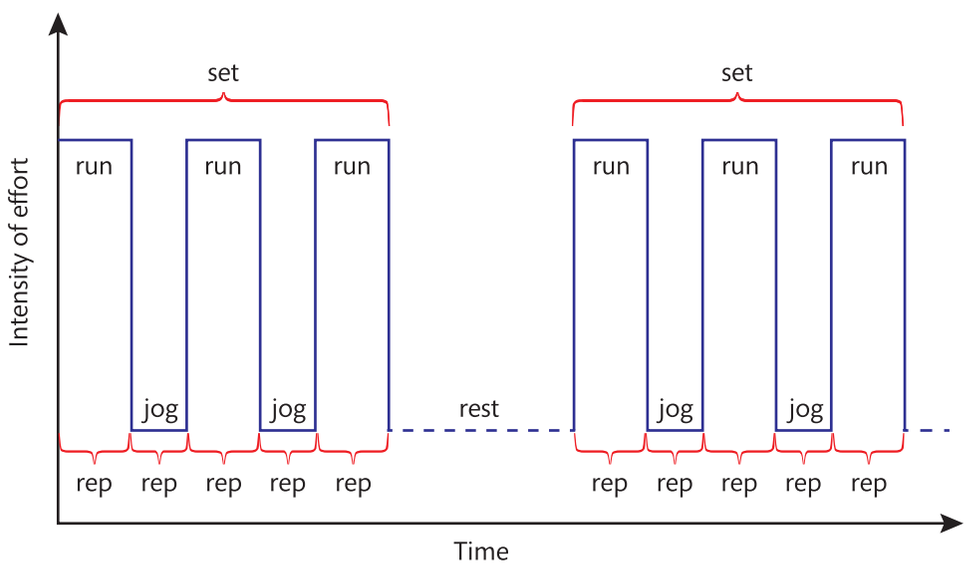

Figure 2.6: Combining reps into a set

- Interval training can be performed in a gym using a range of cardiovascular equipment (for example, treadmill, cross-trainer or exercise cycle) so long as the speed, resistance or gradient can be changed at the required intervals, or outdoors at a suitable park or track area where running or cycling can be undertaken safely.

Circuit training

In a circuit training session, a number of different exercises (or 'stations') are organised around a room. Each station contains a different activity. Individuals are set a time limit to do these exercises, e.g. one minute per station. Between the stations there should be a rest period dependent on the individual or groups completing the circuit.

A circuit can be designed to improve aerobic endurance, muscular endurance or strength, or a combination of all three. To avoid fatigue, the stations should allow consecutive exercises to use different muscle groups: for example, repeated sprints (legs) may be followed by press-ups (upper body). To increase progression and overload, the individual may wish to:

- decrease the rest periods
- increase the number of stations
- increase the number of circuits
- increase the time spent at each station
- increase the number of circuit sessions per week.

Circuit training can be performed in a gym using a range of equipment, though space for all the stations can be an issue. Circuit training can use cardiovascular equipment, free weights, resistance machines or simple body weight exercises at the stations. Circuit training can also be performed outdoors at a suitable park or track area so long as you have equipment mobile enough to take with you for use at any of the stations.

Muscular strength training methods

If you visit a gym or fitness suite, you will often see people lifting different weights at different speeds. This is because a number of the training methods used to improve muscular strength can also be used to improve muscular endurance simply by doing the training differently, for example by altering the weight, the number of repetitions and the number of sets. Common training methods used to improve muscular strength and muscular endurance include:

- resistance machines
- free weights (such as dumbbells)
- medicine ball training
- circuit training
- core stability training.

If you think about how a person's appearance changes after using muscular strength training in a gym, you may say they look 'built' or 'pumped'. These changes are due to increased muscle tone and muscle **hypertrophy**. Muscle tone is where muscles have a more defined appearance, whereas muscle hypertrophy is the growth of the muscle and happens when the **muscle fibres** increase in size.

Key terms

Hypertrophy – an increase in the size of muscle tissue (or organs) due to growth of individual cells without an increase in the overall number of cells.

Muscle fibres – the contractile element of muscle tissue which appears banded or striped under a microscope. A single muscle contains between 10,000 and 450,000 fibres.

Principles when training for strength

Strength is the ability of a specific muscle or muscle group to exert a force in a single maximal contraction. Strength training can provide benefits and improvement to health and well-being by increasing muscle, bone and connective tissue strength, improving cardiovascular function and increasing bone density and metabolic rate. Sports where strength training is important include weightlifting, track and field, rugby, wrestling, rowing, boxing and, increasingly, football and basketball.

The basic principles for strength training are to use a high weight, low repetitions and a high set count. This is because strength training targets predominantly the Type IIa and Type IIx fast-twitch muscle fibres (as described in Unit 1). Type IIx fibres use anaerobic metabolism to transfer energy and are the classic 'fast' twitch muscle fibres that produce quick, powerful bursts of speed. This muscle fibre has the highest rate of contraction of all fibre types but also has a much faster rate of fatigue. Type IIa fibres (also known as intermediate fast-twitch fibres) can use both aerobic and anaerobic metabolism to transfer energy, and can exhibit similar properties to Type IIx fibres.

Link

This content links to *Unit 1: Anatomy and Physiology.*

It is important to establish a one-repetition maximum (or 1RM) before undertaking strength training. This is the most force the participant can apply in a single attempt at an exercise movement. For example, their 1RM for the bench press may be 80 kg.

- **Repetitions and sets** – the potential for fatigue when using a heavy load is high. Therefore, the numbers of repetitions tend to be lower (6–10 repetitions) so the participant is doing **low reps and high loads**. Strength training generally relies on a high number of sets to work the fast-twitch muscle fibres for longer. The number of sets depends on your level of fitness, training experience and the muscle area being worked. Large muscle groups (for example, chest or legs) can tolerate a higher number of sets (5–8 sets), whereas smaller muscle groups (for example, arms) can tolerate fewer sets (4–6 sets). An experienced gym user training their chest muscles for strength might perform the workout shown in Table 2.16.

Table 2.16: A workout for an experienced gym-user training their chest muscles

Exercise	Reps	Sets	Weight (% of 1RM)
Bench press	8	6	75% = 60 kg

- **Rest periods between sets** – fast-twitch muscle fibres take longer to recover from exercise than slow-twitch muscle fibres. Because fast-twitch muscle fibres are fundamental for achieving increased strength, a rest period of 2–4 minutes between sets is ideal. The higher your training intensity and the more demanding it is on your body, the longer you should rest between sets. If your training intensity is lower and less demanding on your body, your rest period should be towards the shorter end of the range. The chest muscle workout shown in Table 2.16 can be adapted to specify a rest period (see Table 2.17).

Table 2.17: Updated workout targeting chest muscles

Exercise	Reps	Sets	Weight (% of 1RM)	Rest period
Bench press	8	6	75% = 60 kg	3 minutes

- **Order of exercise to prevent or maximise muscle fatigue** – a general order of exercise to prevent muscle fatigue is to work the largest muscle groups first, then proceed to the smaller groups. Include all major muscle groups to avoid strength imbalances in the body. It is recommended you train your abdominal muscles at the end of a workout to make sure they are fresh to help stabilise your body while exercising other muscle groups in your next workout. An example of a workout designed to prevent muscle fatigue is shown in Table 2.18.

Table 2.18: Order of exercise (muscle groups) to prevent muscle fatigue

Order	Muscle groups – muscles
1	chest – pectorals
2	back – latissimus dorsi, trapezius
3	legs – quadriceps, hamstrings, glutes, calves
4	shoulders – deltoids
5	arms – biceps, triceps
6	core – abdominals, erectus spinae

Key term

Repetitions until failure – an exercise (usually with free weights or bodyweight) during which the set is performed until the muscles worked can no longer achieve a further full contraction due to fatigue.

Maximisation of muscle fatigue is used in a specific exercise method. To truly fatigue a muscle, it should be exercised with **repetitions until failure**, an advanced training method that requires a 'spotter' – someone to support the participant. The order in which you should approach this type of training is similar to Table 2.18, allowing all muscle groups to be trained to their fullest extent.

Methods

Pyramid sets are a highly effective training technique that use an upward, then downward sequence in weight, reps and sets to maximise muscular strength and endurance goals. Pyramid sets have a number of benefits. Starting with a light weight allows joints and muscle tissue to warm up so your body is better prepared for later, heavier lifts. It also creates an intense routine as muscles become overloaded. The chest muscle workout shown in Tables 2.16 and 2.17 could be adapted to become a pyramid set (shown in Table 2.19).

Table 2.19: A pyramid set

Set number	Reps	Weight	Rest
1	12–15	50% 1RM = 40 kg	2 minutes
2	10–12	70% 1RM = 56 kg	2 minutes
3	8–10	80% 1RM = 64 kg	2 minutes
4	4–6	90% 1RM = 72 kg	2 minutes
5	8–10	80% 1RM = 64 kg	2 minutes
6	10–12	70% 1RM = 56 kg	2 minutes
7	12–15	50% 1RM = 40 kg	2 minutes

When you go back down in weight (sets 5–7 in Table 2.19), your muscles will be increasingly fatigued, your strength will decrease and you may not be able to complete as many reps as you did at the start (sets 1–4).

Pyramid sets can be used at an advanced training level. This usually involves adaptations such as a small weight increase for sets 5–7, and/or repetitions until failure at set 7.

Equipment

- **Free weights** – barbells or dumb-bells, allowing an individual to have a constant resistance during dynamic action. Free weights increase strength in the short term, increase the range of movements and allow focus on certain movements or muscle groups, and some movements aid the training of balance and coordination. However, the use of free weights can increase the risk of injury. For safety reasons when using larger weights, helpers (or 'spotters') are required to oversee (or 'spot') for an individual.
- **Fixed-resistance machines** – your local fitness centre will have a number of fixed-resistance machines, allowing individuals to change the load based on their training programme. Variable resistance ranges from 0–100 kg on most machines, allowing the programme to include overload and progression, pyramid training, etc. These machines are expensive, making them impractical for home use. Due to their design they are limited to specialist exercises such as chest or leg press. On the positive side, they have an increased safety element compared to free weights, and can be used by novice trainers still learning different movement patterns. The range of movement can be changed at a specific joint by adjusting the machine's setting. Fixed-resistance machines are ideal for novice trainers undertaking strength training for the first time, regardless of whether they train with a helper or not – the risk of injury from repetition failure or over-extending joints is far less with resistance machines than with free weights.

People using larger free weights should have a 'spotter' to maintain safety

Research

Pyramid sets are an established and highly effective training technique that helps to maximise muscular strength and achieve endurance goals. However, there are a number of other advanced muscular strength and endurance training methods that can be incorporated into the programme of any intermediate or advanced gym user.

Research three of these additional methods: establish how each method is carried out, what exercises are used, what loads are used, what rest periods are used and how the number of reps and sets differ. You should be prepared to present your findings as a small group to the rest of your class.

PAUSE POINT

If you start a free weight strength routine with chest exercises, is there any danger of exhausting other muscle groups first?

Hint – What muscle groups facilitate the chest press action and help to move the barbell?

Extend – Research other chest exercises that isolate the chest muscle and place less stress on smaller assisting muscle groups.

Muscular endurance training methods

Principles when training for endurance

Muscular endurance is the ability of a specific muscle or muscle group to make repeated contractions over a significant period of time (possibly over a number of minutes). To develop muscular endurance you must train the muscle to overcome fatigue. Unlike muscular strength training methods, muscular endurance is not developed by increasing the weight lifted, but by increasing the amount of time a muscle spends contracting against a given resistance. Muscular endurance training should be a progression after several months of training and should come after strength training (low reps and high load) because the greater a muscle's strength, the more force it can exert during endurance training.

Muscular endurance training has similar benefits to muscular strength training. Muscle tone can increase and muscles will experience hypertrophy (although to a lesser extent). The additional benefits happen within the muscle cell. Muscular endurance places stress on the slow-twitch muscle fibres and as a result they can increase in size. This means there is more space for mitochondrial activity. The increase in size and number of **mitochondria** is important because they are the part of the muscle that synthesises aerobic energy. By increasing their size and number, you can increase aerobic performance and the efficiency of **type I muscle fibres** (and some type IIa muscle fibres).

Another important change within muscle fibres is that there is a large increase in **myoglobin** content. This is important for aerobic performance, as myoglobin carries oxygen to the mitochondria. If you have more myoglobin, you can produce more aerobic energy in the mitochondria. These changes can increase VO_2 max by up to 20 per cent. Sports where strength training is key include athletics, football, hockey, boxing, rowing and tennis.

Muscular endurance training helps the body deal with fatigue and increases tolerance to blood lactate. The training uses relatively light to medium loads of 40–60 per cent of 1RM, lifted for a set time or number of repetitions.

Key terms

Mitochondria – organelles (parts of cells) containing enzymes responsible for energy production. Mitochondria are the part of a muscle cell responsible for aerobic energy production.

Type I muscle fibres – slow twitch or slow oxidative fibres containing large amounts of myoglobin and mitochondria. They have a slow contraction velocity and are resistant to fatigue.

Myoglobin – a form of haemoglobin found in muscles that binds and stores oxygen in the mitochondria.

Muscular endurance training can be either long-term or short-term in its approach. Long-term muscular endurance training is suitable for continuous, steady-state sports such as long-distance running, triathlon, rowing and distance swimming. Light resistance or loads are used so that the training can be sustained for a prolonged period. Rest periods are kept to a minimum to reflect the continuous nature of the event. Short-term muscular endurance is suitable for shorter duration events or ones which are continuously stop–start in nature. Light to medium resistance or loads are used and rest periods are short (10–30 seconds) in duration. Free weights, fixed resistance machines and circuits are all suitable methods for training muscular endurance.

- **Repetitions and sets** – muscular endurance training works on the principle of performing many repetitions against a given resistance for a prolonged period of time, or **high reps and low loads**. Depending on the resistance, muscular endurance training reps can range from 15 to 30, and the number of sets from 4 to 6. Muscular endurance is highly (though not entirely) dependent on Type I slow-twitch fibres. Given their resistance to fatigue, exercise should involve a higher number of repetitions than strength training; therefore, lower loads (40–60 per cent of 1RM) are appropriate. An experienced gym user training their shoulders (1RM for dumbbell shoulder press is 25 kg) towards the end of a muscular endurance session might perform the exercise shown in Table 2.20.

Table 2.20: A workout for an experienced gym-user training their shoulders

Exercise	Reps	Sets	Weight (% of 1RM)
Shoulder press	15	4	50% = 12.5 kg

- **Rest periods between sets** – one aim of muscular endurance training is to increase resistance to fatigue and improve tolerance to blood lactate, so rest periods between sets are fewer and shorter than in strength training. Typical rest periods range from 30 to 60 seconds, depending on exercise intensity and the experience of the individual. The shoulder workout shown in Table 2.20 can now be updated (as shown in Table 2.21).

Table 2.21: Updated workout targeting shoulders

Exercise	Reps	Sets	Weight (% of 1RM)	Rest period
Shoulder press	15	4	50% = 12.5 kg	30 seconds

- **Order of exercises to prevent muscle fatigue** – as with strength training methods, a general order of exercise to prevent muscle fatigue is to work the largest muscle groups first and then proceed to the smaller groups (see Table 2.18). Make sure you include all major muscle groups to avoid strength imbalances.

Methods

- **Circuit training** – most sports, whether they are team or individual, largely feature moments of intense exercise lasting 30–120 seconds, followed by periods of less intense aerobic exercise. Examples include football and tennis. Circuits are a suitable muscular endurance training method that aids the training for both intense and less intense periods and replicates the needs of the athlete. The principle of high reps and low loads remains the same, but the rest periods are generally replaced by active recovery periods when the athlete transfers from one station to another. A footballer may undertake a muscular endurance circuit over a period of 6 weeks similar to the one shown in Table 2.22.

Table 2.22: A typical progressive muscular endurance circuit, carried out over 6 weeks

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Intensity	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
Squats with medicine ball	30 seconds	40 seconds	50 seconds	30 seconds	40 seconds	50 seconds
Crunches	15	20	25	15	20	25
Dumbbell lunges	30 seconds	40 seconds	50 seconds	30 seconds	40 seconds	50 seconds
Press-ups	15	20	25	15	20	25
Plank	30 seconds	40 seconds	50 seconds	30 seconds	40 seconds	50 seconds
Back extensions	15	20	25	15	20	25
Calf raises	30 seconds	40 seconds	50 seconds	30 seconds	40 seconds	50 seconds
Changeover time	20 seconds	15 seconds	10 seconds	20 seconds	15 seconds	10 seconds

- **Fixed-resistance machines** – useful during muscular endurance training (either with or without a helper). The risk of injury from repetition failure or over-extending joints is far less with resistance machines than free weights.
- **Free weights** – allow an individual to have constant resistance during exercise, which adds to the 'endurance' element. The use of free weights can increase the risk of injury. For safety reasons, even when using smaller weights compared with strength training, helpers (or 'spotters') should oversee an individual as there is a risk of muscular failure towards the end of the set.
- **Resistance bands/tubing** – these can be used for single muscle exercises, as part of a muscular endurance circuit when the resistance required is light, or for working a specific muscle group (for example rotator cuff) not suited to free weight, body weight exercise or resistance machines.

PAUSE POINT

Is it difficult to further overload specific muscle groups as part of a muscular endurance programme?

Hint

In sets you can use different exercises, one after another, within the same set, so long as they target the same muscle group.

Extend

Research the training methods known as 'super sets' and 'super giant sets'. What level of athlete uses these methods?

Core stability training methods

Core stability training exercises the deep muscles of the torso all at the same time. It is vital to most sports because the core muscles stabilise the spine and provide a solid foundation for movement in the arms and legs. The core is the centre point for all sporting actions – it reduces postural imbalance and plays an important role in injury prevention.

Methods

- **Yoga** – an ancient form of exercise focusing on strength and flexibility combined with breathing techniques to enhance physical and mental wellbeing. It is one of the best ways to build core stability, strength and flexibility in your muscles, as it focuses on the abdominal and back regions. Yoga can be performed using light free

weights which create additional forces on the muscles and joints, increasing the overall strength and core stability requirements of each exercise or pose. Resistance bands can also target areas requiring precision movement while applying an additional resistance. Yoga exercises are varied but can target every area required for core stability. Exercise examples are shown in Figure 2.7 and are described below.

- **Side plank** strengthens the obliques, while abdominal muscles stabilise the body.
- **Floating triangle** lengthens and strengthens the obliques, abdominals and back muscles.
- **Boat** engages all the abdominal muscles.
- **Dolphin** works the abdominals while flexing the spine.
- **Locust** strengthens the muscles around the spine and is ideal to counter all previous exercises and maintain an exercise balance.

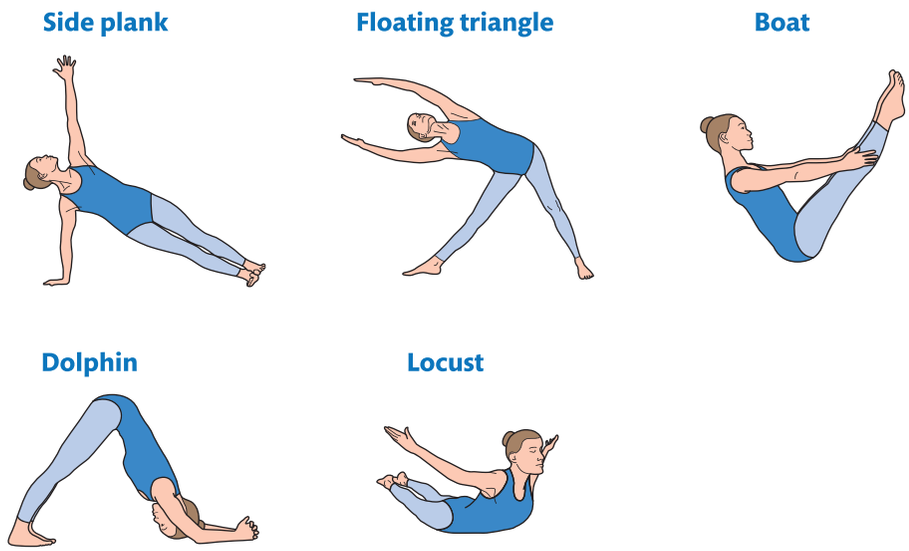

Figure 2.7: Yoga positions

- **Pilates** – developed by Joseph Pilates, who believed mental and physical health were interlinked. His method was influenced by other forms of exercise, including gymnastics, boxing and wrestling. Pilates is similar to yoga and aims to strengthen the body with particular focus on the body's core to improve strength, general fitness and well-being. Resistance bands can also target areas requiring precision movement while applying additional resistance. Pilates develops whole-body strength, flexibility, coordination, balance, and good posture, with a decreased risk of injury compared with other forms of exercise.
- **Gym-based exercises** – because core stability training methods tend to use body weight exercises (for example, yoga and Pilates), they can also be performed on a gym mat. Exercises such as plank, bridge and V-sit can also be done on a mat and there are various resistance machines (for example, back extension machines and abdominal crunch machines) that work aspects of core stability. Gym-based core stability exercises can incorporate a variety of equipment to aid training, such as resistance bands. A stability ball will further engage the core muscles by introducing the need for additional coordination and balance due to the 'wobble' effect. Kettle bells engage your core muscles with almost every lift, and free weights can add additional resistance to an exercise. All can be combined for a core stability circuit training programme.

Key terms

Static flexibility – the range of movement that a muscle or joint can achieve.

Dynamic flexibility – the range of movement that a muscle or joint can achieve when in motion.

Flexibility training methods

Both **static flexibility** and **dynamic flexibility** can be developed using a range of training methods. The main methods of flexibility training are:

- static stretching
- dynamic stretching
- proprioceptive neuromuscular facilitation (PNF) stretching.

The general principle of flexibility training is to overload a specific muscle group by stretching the muscles beyond what they are used to. The aim is to increase the range of movement, and work must be targeted towards the joints and muscle groups requiring improvement. The movement should not exceed the tolerance level of the tissue. For improvements in flexibility, an individual should increase the time (duration) of stretching and the number of repetitions to allow overload to take place.

As flexibility is significantly affected by the temperature of muscles and connective tissues, flexibility training is best completed at the end of a training session or after some form of aerobic training. If using stretching activities as part of a warm-up, you should make sure the stretching is low-intensity and does not stretch the muscle or joint too far, too soon.

Stretching is a key way to improve flexibility

The three main types of stretch are:

- **Maintenance stretches** – used to return a worked muscle to its normal length. They are performed after an exercise session. They should be held for 10–15 seconds. Stretching after an exercise session is one of the most neglected areas of fitness training. Research shows individuals who regularly stretch after training reduce the risk of injury, reduce muscle tension and improve muscle coordination.
- **Developmental stretches** – used to increase muscle length or muscle flexibility. They are performed at the end of an exercise session. They should be held for an initial 6–10 seconds, then developed slightly further for another 20–30 seconds. They are a key method of increasing muscle flexibility and an individual's range of movement. However it is not solely about achieving more flexibility, but should be considered a specialised area of stretching designed to aid and improve posture and general well-being.
- **Pre-activity stretches** – used to get the muscle ready for exercise. They should be performed standing and held for 8–10 seconds and be performed after the warm-up phase of your exercise programme. Pre-activity stretches should focus on the muscles or muscle groups that the exercise programme will target.

Static stretching

To improve flexibility, you can use static stretches, which are controlled and slow. There are two types:

- **Active** – can be done individually. Active stretching involves voluntary contraction of specific muscles. Research shows that this can lead to gains in range of motion and increased functional mobility.
- **Passive** – also known as assisted stretching, it requires the help of another person or an object such as a wall. The other person applies an external force (push or pull) to force the muscle to stretch. Passive stretching is one of the safest methods of stretching and also most helpful for relaxation.

Dynamic stretching

Think about when you have watched football players, rugby players or basketball players going through their warm-up. You will see them performing a range of movements that are like the sports movements they need during the game. These are dynamic flexibility exercises. Dynamic flexibility is important for sports that have high-speed movements and movements that take a muscle or joint past its normal range of static flexibility.

Proprioceptive neuromuscular facilitation (PNF) technique

Proprioceptive neuromuscular facilitation (PNF) stretching is an advanced form of stretching and one of the most effective ways of increasing flexibility. The types of movement vary between different muscles and muscle groups, but the general process is the same:

- Stretch the target muscle group to the upper limit of its range.
- **Isometrically** contract the muscle or muscle group against a partner for 6–10 seconds.
- Relax the muscle or muscle group as your partner stretches it to a new upper limit or range of movement (you should be able to stretch it further this time).

When using this type of stretching remember that pain is the body's signal that you are working out too hard in some way, so when this activity hurts too much you have taken it too far.

Key term

Isometric – an exercise in which an engaged muscle group produces no movement of the joint at which the muscles are attached.

Equipment

- **Towel** – wrapping a towel around, for example, your feet or a stable fixing in a gym, and holding on to both ends of it can help you to stretch a muscle a few centimetres further while keeping the rest of the body stable.
- **Belt** – can be used to maintain correct limb alignment during stretches to increase flexibility and mobility.
- **Band** – resistance bands come in many forms and strengths, and are ideal for adding a resistance or supportive element to a stretch while stabilising the movement.
- **Mat** – an essential piece of kit while stretching. Most stretches are done on the floor so, to aid concentration and support, it is important you remain comfortable throughout, without pressing your bodyweight against a hard floor which may lead to injury.
- **Partner** – important when performing PNF stretching. Partner up with someone who knows your physical abilities or experience so they know your upper-limit range of movement when assisting in a stretch.

Speed training methods

Principles of speed training

Speed is an essential component of fitness in most sports, and good acceleration is vital. Acceleration from a standing position is critical for success in sports such as sprinting and in team-based sports such as rugby league, where a player has to accelerate with the ball past opponents, changing pace rapidly.

Although there are general guidelines for speed-based interval training, the more specific requirements are geared towards the requirements of specific sports and specific positions within those sports. Speed training should take place after a rest period of low-intensity training to reduce the risk of injury or overtraining. Speed training should take place after the warm-up, and any other training within the session should be low-intensity.

- **Training thresholds** – maximum speed training works largely in the anaerobic training zones, while the recovery phases – jogging or walking – work in the aerobic training zones. A general guideline for speed training is that there should be a work–rest ratio of 1:5. If you were to have a 10 second maximal sprint, this would be followed by a 50 second rest period. Interval training is used in aerobic endurance training and speed training, so you can use Table 2.23 to plan a training session targeting different energy systems.

Table 2.23: Guidelines for speed-based interval training

Energy system	Time (min:sec)	Sets	Reps per set	Work : relief ratio	Relief interval type
ATP–PC	0:10 0:20	5 4	10 10	1:3 1:3	Walking
ATP–PC–LA	0:30 0:40 0:50 1:00 1:10 1:20	5 4 4 3 3 2	5 5 5 5 5 5	1:3 1:3 1:3 1:3 1:3 1:2	Jogging
LA–O_2	1:30–2:00 2:00–3:00	2 1	4 6	1:2 1:1	Jogging
O_2	3:00–4:00 4:00–5:00	1 1	4 3	1:1 1:0.5	Walking

- **Percentage of maximum heart rate** – as speed training should achieve maximal sprint speeds, it is working in the anaerobic zone. At peak speed an athlete should be working towards 90–100 per cent of maximum heart rate. However, peak speed is only a small percentage of the total training time – the remainder will be recovery time when an athlete is working towards a heart rate of 60 per cent of maximum.
- **Recovery periods between sets** – depending on the intensity, repetitions and sets used as part of your training programmes, you may require rest periods of 1–3 minutes in between sets. These will be essential for you to replenish energy stores, maintain correct technique and reduce the risk of injury.

Methods

- **Hollow sprints** – team sports such as football or rugby and individual sports such as tennis require participants to vary their speed while competing. This change of pace requires practice, and hollow sprints are designed to do this. Hollow sprints involve sprinting for a set distance, slowing down, and then accelerating again for another set distance. This process helps train the Type IIx and Type IIa fast-twitch muscle fibres and conditions them to accelerate quickly over short distances. The distances should be variable throughout the activity. An example of a hollow sprint programme is shown in Table 2.24.

Table 2.24: A typical hollow sprint training programme

Start	15 m	5 m	10 m	5 m	5 m	5 m	2 minute rest
	Sprint	Jog	Sprint	Jog	Sprint	Jog	

- **Acceleration sprints** – this is an aerobic training method where running speed is gradually increased from an initial jog to **striding** then sprinting at maximum speed. Each section should be approximately 50 metres long (150 metres in total). The speed increase is incremental – this reduces the risk of muscle injury.
- **Interval training** – can improve anaerobic endurance. The work intervals for aerobic endurance training tend to be long in duration and low in intensity in order to train the aerobic system. By contrast, for anaerobic endurance, work intervals will be shorter but more intense (near to maximum). Interval training can help athletes improve speed and anaerobic endurance (speed endurance). Athletes should work at a high intensity. Overload and progression can be brought in by making changes, e.g. decreasing the rest period.
- **Resistance drills** – one of the best methods to increase speed, resistance band exercises place an additional resistance against an accelerating athlete over short distances. This additional resistance makes the muscle work harder during the acceleration phase. When the resistance bands are removed, the athlete will be ready to move and accelerate faster in their role or sport. A similar principle is applied if the athlete trains with a parachute instead of a resistance band, or uses a sled or bungee ropes. An alternative is to simply add resistance by getting the participant to run up a hill.

Key term

Striding – long, continuous steps that are quicker than walking but slower than sprinting.

Equipment

The following types of equipment will provide an additional load to speed training. This load works against the athlete over short distances, making the muscles work harder during the acceleration and speed phases of movement.

- **Resistance bands/tubes** – inexpensive equipment used during resistance drills. The resistance can be varied according to the ability of the athlete. Resistance bands are limited to a short distance unless a partner is holding either end and follows the athlete. The tension within the band/tube provides the additional load.
- **Parachutes** – similar to resistance bands but with the advantage that they are not limited to a set distance. Air resistance within the parachute provides the additional load.
- **Bungee rope** – similar to resistance bands but, due to their greater length, bungee ropes allow the athlete to run a greater distance. The tension within the rope provides the additional load.
- **Resistance tyres** – a tyre is attached by a rope to a harness or belt worn by the athlete. This equipment works on a similar principle to parachutes, but friction between the tyre and the ground provides the resistance rather than the air resistance of the parachute.

Speed training can use parachutes to increase the challenge of resistance drills

Training methods for skill-related fitness components

Agility training methods

Agility is the ability to change direction quickly without losing speed or balance. Exercises involve changing the body position quickly and with control and include **SAQ (Speed, Agility, Quickness)**. These combine speed, the maximum velocity an athlete can achieve and maintain, and quickness (rapid and energetic movements). SAQ works over short distances, usually over 5 metres. Each drill is performed as quickly as possible without compromising technique and might involve running between cones in a zig-zag pattern, forcing rapid changes of direction. SAQ is designed to replicate specific movements in sports such as rugby and football.

Balance training methods

Static balance exercises focus on retaining the body's centre of mass above the base of support **when stationary** – if you can stand on one leg without holding onto anything for at least 20 seconds, your static balance is good. Balance training is useful on two fronts. First, a controlled wobble engages your core muscles and second, it can prepare you for a rapid change of direction. An example of static balance training is the one-legged balance. You start with your feet together, raise one foot – knee facing forward or to the side – and hold the position with eyes open, then closed. Switch feet and repeat for four to six reps with each foot.

In contrast, **dynamic balance** exercises focus on retaining the body's centre of mass above the base of support **when moving**. Ideally, balance training requires that both right and left sides of the body allow for an equal range of motion of your body's joints. A wobble cushion or balance board trainer can help if one side of your body is weaker than the other. An example of dynamic balance training is the Plank Progression, which improves your balance of one shoulder at a time. You start in a standard plank position with your elbows on top of the dome and hold for 30 seconds. Then, progress to one elbow at a time and add a rotation if possible.

An effective balance routine progresses from static to dynamic balance moves: for instance, you could move from a basic squat to a squat on one leg, keeping support near in case you lose balance. This type of progression helps improve your functional balance.

Coordination training methods

Coordination training methods are exercises that use two or more body parts at the same time. Coordination training often leads to improved execution of sport-specific skills because continued practice and repetition aid coordination. For example, continued forehand practice in tennis will increase coordination of the forehand shot.

An example of coordination training is the tennis ball toss. Mark a distance from the wall at which you stand facing the wall. Throw a tennis ball from one hand in an underarm action against the wall, and try to catch it with the opposite hand. Throw the ball back against the wall and catch it with the initial hand. By adding a set time limit to complete a number of throws, you can also add the factor of working under pressure.

Reaction time training methods

Reaction time is vital in many sports, especially timed and short-duration sports. Consider how important the start is in the 100-metre sprint. Reaction time to the gun

is often where the race is won and lost. But other sports such as table tennis also call for quick reaction times. The following pieces of equipment may be used:

- **Stopwatch** – used to time the participant's reactions.
- **Whistle** – an excellent stimulus to get athletes to react. Most athletes are used to hearing a whistle.
- **Visual stimuli** – coloured or traffic lights, flags or hand signals are examples of visual stimuli to indicate when athletes should react and carry out a sport-specific skill or move.
- **Auditory stimulus** – shouting or a range of electronically-created sounds can be used to get athletes to react. A good training practice is to have a range of sounds, with each sound followed by a different reaction or movement.
- **Reaction Ball** – a six-sided ball used to enhance reaction time and hand–eye coordination. The random movement of the Reaction Ball requires the athlete to react quickly and seize – or catch – the ball before it bounces and changes direction. Reaction Balls can be used in sports-specific training drills such as those used by cricket fielders.

A Reaction Ball

Power training methods

Plyometric training is designed to improve explosive power. It is a useful training method because it engages and stretches the target muscle or muscle groups during the same exercise movement. Plyometric training is ideal for sports and activities involving explosive actions, such as a slam dunk in basketball or a 100-metre sprint start.

If you stretch a contracted muscle it becomes stronger, and muscles produce more force if they have previously been stretched. Plyometric activities help this process of force production by taking the muscle through an eccentric muscle action followed by a powerful concentric muscle action. This process causes the muscle spindles to cause a stretch reflex, preventing any muscle damage and producing a maximum force at a rapid rate.

Different activities are used in plyometric training sessions. Lower body activities include hurdle jumps, single leg bounds, alternate leg bounds, box drills, and depth jumps. Upper body activities include plyometric press-ups and medicine ball throws.

Equipment that may be used includes the following:

- **Ladders** – these are portable pieces of equipment, 2–10 m in length, ideal for developing speed and agility but also useful for plyometric training. Hops are a basic plyometric exercise that can be adapted using ladders. You lay the ladder out and stand at one end with feet together; get yourself into a squat position and hop down the length of the ladder on both feet from ladder segment to segment. A progression of this exercise is to switch to single foot hops.
- **Cones** – cone routines are simple but effective. Cones are laid out on the ground and a routine or pattern is explained which generally involves a series of one-legged jumps from one cone to another, usually side-to-side. These jump routines can be performed as low-level plyometric exercises but they also develop coordination and balance.
- **Jump ropes** – jump rope routines are flexible and are ideal for developing speed, agility and balance and improving your hand–eye–foot coordination. Jump rope routines can be performed as low-level plyometric exercises: keep both feet together and jump quickly while turning the rope, coming no higher than 5–10 cm off the ground with a slight skip between each jump. Repeat the exercise for 50–100 repetitions depending on fitness and experience.

- **Medicine ball** – the chest push using a medicine ball is a plyometric exercise.
  - From a kneeling position, hold a medicine ball with both hands against the chest.
  - Carry out the pass by pushing the medicine ball in an explosive, rapid movement outwards from the chest, pushing as far forward as possible.
  - Allow the body to fall forward with the momentum and catch yourself on the floor with the palms of your hands.
- **Hurdles** – can be used to perform a variety of exercises that are simple to set up and adapt. A simple yet effective leg exercise is hurdle jumps with a bounce. With feet together, you jump over one hurdle. After landing, bounce once then jump the next hurdle. Continue this sequence until you reach the final hurdle.
- **Benches** – bench jumps are a highly effective exercise designed to increase leg power and strength. Difficulty can be increased by using a taller bench, but care must be taken to ensure the bench is stable, otherwise injury may occur.

PAUSE POINT Can you think of any potential safety concerns when doing plyometric exercise?

Hint The intense movements used in repetition increase the stress on joints and the potential for injury.

Extend How might you go about implementing low-intensity variations to make plyometrics safe and effective for more people?

Assessment practice 2.4

The fitness coach calls you into his office. He tells you that in 3 months' time he is going to Spain to work with the National Tennis Academy. He has agreed with the general manager that you should undertake a Level 2 gym instructor award, just in case you have to take over his duties while he is away. The tennis club has kindly agreed to pay for this course on condition that you prove you have existing knowledge of different training methods and different components of fitness, and how these can be used at the tennis club.

The fitness coach suggests that you produce an article for the next issue of the tennis club's magazine that covers all the components of fitness to be trained. Where possible you should apply each component using tennis as the sporting example. If this is not possible, he suggests you choose any other sport of your choice, but remember to give each component a sporting context.

If this article is of a good standard, the general manager has promised to publish it in the next issue of the magazine, so all members will have the opportunity to read it.

Plan

- What is the task? What am I being asked to address in the article?
- Are there any fitness training components I am not comfortable with?
- The article may be published in a magazine, so the design and its impact are important. Is this something I may struggle with?

Do

- I know all the components of fitness, and will include all the necessary information, with sporting examples, and explain why this information is important. I will make sure details are brief and to the point, without too much detail to overload the readers.
- I can identify where my article may have gone wrong and adjust my thinking/approach to get myself back on course.

Review

- I can explain what the task was and how I approached the construction of my article.
- I can explain how I would approach the more difficult parts differently next time.

E Understand training programme design

Reflect

Consider your own training or coaching experiences. How might you have adapted that coaching and training if you were planning the programme now? How would you analyse the training requirements for your sport? What training methods might you now employ and what nutritional requirements would you consider?

Link

This section will provide useful knowledge that you can apply if you are studying *Unit 4: Sports Leadership* and are asked to develop a session.

Principles of fitness training programmes

When designing training programmes, there are two key questions:

- What am I trying to improve?
- How am I going to improve it?

You need detailed knowledge of different components of fitness, and the different training methods used to improve them, to answer these questions.

Before you can design a training programme, you will need to set individual goals. Without these, you will not know what to direct your training towards. The programme must be flexible but capable of meeting these goals and personal needs. Each individual has different ambitions and aspirations, and your programme should reflect these.

The athlete's aims and objectives should be broken down into short-term (up to one month), medium-term (one to three months) and long-term goals (three months to one year). Goals should be SMARTER targets:

- **Specific** – they say exactly what you mean (e.g. to improve flexibility in the hamstring muscle group)
- **Measurable** – you can prove you have reached them (e.g. increase flexibility by 5 cm using the sit and reach test)
- **Achievable** – they are actions you can achieve (e.g. practise and improve flexibility through training)
- **Realistic** – you will be able to achieve them but they will still challenge you (e.g. the increase in flexibility must be manageable – a 20 cm increase in two weeks is not achievable)
- **Timed** – they have deadlines (e.g. to reach the target within six weeks)
- **Exciting** – ensure you look forward to and never get bored with your training programme
- **Recordable** – keep accurate records of everything you do in a training diary. This will be an excellent resource and source of inspiration to keep you fit and healthy.

You must also consider the resources you will need for the training programme. The range you could choose from is huge, including free weights, resistance machines, cardiovascular machines, mats, resistance bands, kettle bells, suitable clothing and footwear, etc. The training location should also be considered and might have a considerable impact on the equipment available.

Principles of training

One of the most important principles when planning individual sessions and full training programmes is the **FITT principle**. FITT stands for Frequency, Intensity, Time, Type.

- **Frequency** of a training session or programme refers to the number of training sessions per week. While the frequency of sessions is important, intensity and duration of training are more important. Novice trainers should not train more than three times per week until their levels of fitness can cope with the increased training load. Once your levels of fitness have increased, you could progress to five times per week.
- **Intensity** of a programme is closely linked with the training principle of overload – it is how hard you are working during your training. Intensity is one of the most important factors when designing a training programme and relates to factors such as weight, distance, heart rate percentages and speed.
- **Time** relates to the length of each training session, how long the session(s) will last for.
- **Type** of exercise you complete will be related to your individual needs. It is the mode of training you will complete, for example free weight training.

Additional principles of training

There are also other principles to consider in planning a training programme.

- **Specificity** – the principle of specificity means that you should plan your training programme around the needs of the sport or activity (such as specific muscle groups, components of fitness or sporting actions) and your individual needs (such as targets that are specific to you rather than just general targets).
- **Progression** – this is important because your body will only adapt to training if you keep making the training progressively harder (increasing the levels of overload). Without correct levels of overload and progression, your training gains will start to level off or 'plateau'. Be careful when planning progression, because poor performances may result from too little progression or a training programme that overloads the system. As well as poor performance, excessive overloading may lead to injury or illness through over-training.
- **Overload** – overload is stretching the body systems beyond their normal functional level and is an essential aspect of gaining training effects. The following areas can be adapted (increased or decreased) to control the level of overload:
  - frequency: the number of sessions a week, for example, increasing from two to four
  - intensity: the amount of energy needed to perform a particular exercise or activity
  - duration: the total time an exercise session or activity takes, for example, one 20-minute session could be increased to a 30-minute session.
- **Reversibility** – the loss of training benefits and adaptations when you stop training.
- **Rest and recovery** – the need for adequate time to recover from training or competition. Your ability to recover from training is just as important as the workout itself.
- **Adaptation** – the way the body 'programmes' the muscles to remember movements or skills. The process of repeating these movement or skills encourages the body to adapt so they become easier to perform.
- **Variation** – regular changes in training intensity, duration or volume often yield increased gains in performance.

- **Individual needs** – the personal fitness needs based on age, motivation, fitness level and gender, and/or the aims or requirements of a specific sport, all form part of a successful training programme.

During your training, you will normally be trying to progress the overload to make sure that you keep seeing training effects, but there are times when you will want or need to reduce the overload. These include:

- signs of over-training or burnout, such as injury, illness or severe decrease in motivation
- different times of the season (for example, off season or close to a major competition).

PAUSE POINT What risks are involved with overload?

Hint: Consider the difference between constructively overloading a client and pushing them beyond their capabilities.

Extend: How can you control the level of overload so that your client makes progress rather than suffering injury or burnout?

Periodisation

Most people in sport use a training programme based on a structured cycle. This is known as 'periodisation'. Periodisation can benefit you because it ensures continued physiological and psychological changes, it prevents over-training injuries and boredom, and it helps to achieve peak performance for key events.

The training cycle is split into **macrocycles**, **mesocycles** and **microcycles**.

Macrocycles

The first layer of a training programme may be based on a 1-year to 4-year cycle, which is known as a macrocycle. For example, a football player will train based on a 1-year cycle, from June to May, aiming to peak for a weekly or bi-weekly match, whereas an Olympic athlete will have a 4-year macrocycle, aiming for peak performance to coincide with the Olympic Games.

Mesocycles

The macrocycle is divided into a number of mesocycles, usually lasting 4–24 weeks. The mesocycle is the main method of controlling the work-to-rest ratios. For example, if you have a work-to-rest ratio of 3:1, you will have a four-week mesocycle with three working weeks followed by one active rest week. If you are an inexperienced trainer, you may have a ratio of 2:1, but if you are an advanced trainer, you could have a ratio of up to 6:1.

Mesocycles can be **step loaded**. This technique uses a repetitive work-to-rest ratio; for example, with a 4-week mesocycle, you could have a ratio of 3:1 and repeat this cycle three times but increase the intensity of the work weeks at the start of each cycle.

Microcycles

Each mesocycle is divided into a number of microcycles. The microcycle is planned with a specific adaptation in mind and should follow the principles of FITT training. Microcycles typically last for one week, but can range from 5–10 days. A typical periodised training programme is shown in Table 2.25.

Table 2.25: A typical periodised training programme.

Macrocycle											
Mesocycle 1				Mesocycle 2				Mesocycle 3			
Microcycle 1	Microcycle 2	Microcycle 3	Microcycle 4	Microcycle 5	Microcycle 6	Microcycle 7	Microcycle 8	Microcycle 9	Microcycle 10	Microcycle 11	Microcycle 12
Work	Work	Work	Rest	Work	Work	Work	Rest	Work	Work	Work	Rest

PAUSE POINT

What factors or events might disrupt the periodisation of a training programme?

Hint

Injuries, illness and unforeseen circumstances happen all the time. We cannot plan for them, only adapt to them.

Extend

How would you get a client back on track after a 6-week injury? Would you re-write or adapt their training programme?

Case study

Sports Scientist: Jack Donnelly and the fitness training challenge

Jack is now well established as the football club's new sports scientist. Having performed a number of tasks throughout the club over the year, Jack has now been asked to work on the more specific training and fitness requirements of the under-16 boys' squad.

Jack found this a step-up in terms of the required sports-specific knowledge. Therefore, Jack has taken it upon himself to gain a Personal Trainer qualification to aid his role at the football club and help the under-16s in their aim to be fitter and stronger. Jack has identified the following steps to achieve his aim:

- **Step 1** – Be realistic: are you in good shape and able to demonstrate or perform exercises in front of trained athletes? Before you start, make sure you are reasonably fit, have an interest in fitness training and programming and are comfortable in a gym setting.
- **Step 2** – Undertake a Level 2 Gym Instructor qualification. This is the first step into fitness training and the fitness industry, and it is the foundation for further progression to becoming a Personal Trainer or Athletic Trainer.
- **Step 3** – Once qualified as a Level 2 Gym Instructor, consider progressing to a Level 3 Diploma and Advanced Diploma in Personal Training. These courses will provide you with advanced knowledge and the development of your gym skills. You may even want to run your own business from this point.
- **Step 4** – The knowledge gained from your academic qualifications combined with a start at Level 2 Gym Instructing will help you carry out and supervise fitness programmes.

Take a look at the websites of some local health and fitness clubs and see if they are advertising for gym instructors. See what their work might be like and compare it to the other health and fitness clubs. There are also opportunities for fitness trainers, personal trainers and strength and conditioning coaches at professional sports clubs. What differences are there between these jobs and those in health and fitness clubs?

Assessment practice 2.5

The fitness coach has a six-month contract to work at a tennis academy in Spain. The general manager has asked if you will fill in until his return. Naturally, you said yes!

However, you have taken over the fitness training duties at a busy time and the general manager has asked you to put together a general training programme for a typicala competitive adult tennis player. This 'off the shelf' training package will help you free up more time to devote to training the rising stars of the under-16s group.

This programme can be written in whichever format you wish, but it must include the following information to ensure the club continues to offer the best training advice possible:

- fitness training programme design: aims and objectives; SMARTER goals; resources required
- principles of training: FITT; specificity; overload; progression; rest and recovery
- periodisation (6 months): macrocycles; mesocycles; microcycles.

The programme should be geared towards the annual tennis club tournament which is in 6 months' time, when the fitness coach will be returning.

Plan

- What is the task? What does the training programme need to address?
- How confident do I feel in my own abilities to complete this task? Are there any areas of fitness training programme design and its impact that I think I may struggle with?

Do

- I know how to design a fitness training programme, and will include all the necessary information and explain why this information is important. It is a six-month programme, so I will keep the detail fairly brief – too many details may overload the clients.

Review

- I can explain what the task was and how I approached the design of my fitness training programme.
- I can explain how I would approach the more difficult parts differently next time.

Further reading and resources

Books

Bean, A. (2013) *The Complete guide to Sports Nutrition*, London: Bloomsbury.

Bean, A. (2015) *Which Sports Supplements Really Work*, London: Bloomsbury.

Brooks, D. (2004) *The Complete Book of Personal Training*, Champaign, IL: Human Kinetics.

Coulson, M. (2013) *Complete Guide to Personal Training*, London: Bloomsbury.

Delavier, F. (2013) *Strength Training Anatomy*, London: Bloomsbury.

Websites

www.eis2win.co.uk – English Institute of Sport: information about the nutritional principles used by the EIS to improve athlete performance.

www.uksca.org.uk – UK Strength and Conditioning Association: information and advice about how to become an accredited strength and conditioning coach.

www.bases.org.uk – British Association of Sport and Exercise Sciences: news and other information about sport and exercise sciences.

www.nhs.uk/livewell – NHS Live Well: tips for leading a healthy lifestyle.

THINK FUTURE

Siobhan Barber

Personal Trainer

I studied a BTEC National Sports course and soon took an interest in fitness training and programming. Early in the course, I knew I wanted to be a Personal Trainer. Soon after starting the course, I took my Level 2 gym instructor's award. The BTEC course helped me pass the exam. Soon after passing, I was able to get a part-time job at a local health club while I continued my studies at college. After my BTEC course I had saved up enough money to do a 12-month Level 3 Personal Trainer course. It was hard work, but I am now a fully qualified Advanced Personal Trainer with a list of clients at a health club.

The role is varied and I see many of my clients either early in the morning or later in the evening, as most work regular hours during the day. The free hours during the day are great as they allow me to relax and give me time to plan my weekly schedule, send out invoices, manage my cash flow and ensure all my insurance and administration is up-to-date. When relaxing, I catch up on the latest research and articles for the fitness industry, just to stay one step ahead for the benefit of my clients. The job is very rewarding but it is vital to have a good rapport with clients, to help them feel comfortable and good about themselves. Their health, well-being and achievements are a reflection of my efforts, so I am also very proud of my clients and all they have accomplished in the gym.

Personal training is my dream job. Throughout my BTEC course I knew it was what I wanted to do, and this focus helped me finish that course and all the subsequent courses. I make a good living and I am just about to put down a deposit on a flat as a first-time buyer. Would I change anything about my work? Not a single thing.

Focusing your skills

Conducting health monitoring tests

It is important to follow 'correct protocol' in health monitoring tests. Clients may feel nervous so you need to put them at ease.

- An ability to communicate with clients is important, so treat them with courtesy and respect, and help them to relax.
- Ensure all equipment is clean, hygienic and ready to use, e.g. all monitors have batteries and all cuffs and callipers have been wiped with anti-bacterial wipes.
- Carry out your tests in a suitable environment and in a professional manner. Explain what you are doing and maintain an air of calm authority throughout.
- Emphasise that results are confidential and will not be passed on without the client's consent.
- Explain results in a considered manner and say how they will be used to develop any training programme.
- Ensure the testing area is left exactly as you found it and all testing equipment is safely stowed away.

Fitness knowledge

- A personal trainer requires sophisticated knowledge about how the body moves and functions. This is based on human anatomy, physiology, psychology, nutrition and exercise programming.
- You are both coach and tutor to your clients, and need to combine long-term goals and motivational techniques in a training programme.
- You are tasked with developing individual training programmes, all of which are different and require careful planning, coordination and organisation.

Getting ready for assessment

This section has been written to help you 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 two hours and there is a maximum of 60 marks available. The test is in two parts. Part A will contain a scenario based on an individual who needs guidance on training, lifestyle, and nutrition upon which secondary research is to be conducted. This scenario will be released to you two weeks before Part B. Part B will include supplementary stimulus information building on the scenario information in Part A.

Preparing for the test

To improve your chances during the assessment you will need to revise all the key assessment outcomes that are likely to appear. The assessment outcomes were introduced to you at the start of this unit. To help plan your revision, it is useful to know what type of learner you are. Look at the following table and decide which descritpion sounds most like you.

Type of learner	Visual learner	Auditory learner	Kinaesthetic learner
What it means	• Need to see something or picture it to learn it	• Need to hear something to learn it	• Learn better when physical activity is involved – learn by doing
Helpful ways to prepare for the test	• Colour-code information on your notes • Make short flash cards (so you can picture the notes) • Use diagrams, mind-maps and flowcharts • Use post-it notes to leave visible reminders for yourself	• Read information aloud, then repeat it in your own words • Use word games or mnemonics to help • Use different ways of saying things – different stresses or voices for different things • Record short revision notes to listen to on your phone or computer	• Revise your notes while walking – use different locations for different subjects • Try and connect actions with particular parts of a sequence you need to learn • Record your notes and listen to them while doing chores, exercising etc. – associate the tasks with the learning

- Once you receive the scenario for Part A, you should spend 6–8 hours independently conducting research and making notes over the two weeks before the supervised assessment. Plan a timetable to address each topic contained in the scenario and prepare a set of notes to take into the supervised assessment. Make sure you are familiar with the content by the time you undertake the supervised assessment and Part B.
- Read carefully any instructions and all the content you are given on the day for Part B. Make sure you refer to your prepared notes and consider how the new supplementary stimulus information builds on the scenario in Part A – write down notes on a blank page.

Do not start revision too late! Cramming information is stressful and does not work.

- Most questions contain command words. Understanding what these words mean will help you understand what the question is asking you to do. The command words were introduced at the start of this unit.
- Planning your time is an important part of succeeding on a test. Work out what you need to answer and then organise your time. If you are writing an answer to a longer question, try to plan your answer before you start writing. Have a clear idea of the point you want to make, and then make sure this point comes across in everything you write, so it is all focused on answering the question you have been set.

Worked example

David Smith is 30 years old and works a 40-hour week in an office administration role. He has not undertaken any exercise for at least five years. He takes the train to work each day, a journey that last approximately 15 minutes. While on holiday recently, he noticed he had gained weight (10 kg in the last two years). His best friend has suggested that he starts playing football with him and his friends again, but David is worried he will not be able to play like he once could and will suffer on account of his increased weight and obvious lack of fitness.

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

David has decided to join a local gym and undergo a full fitness assessment, so that in the weeks ahead, he may be able to start playing five-a-side football again. He has completed a PAR-Q form and indicated that he has no medical conditions and is fit to take part in physical activity. Consequently, David has been given a 6-week training programme to follow.

Lifestyle questionnaire

Section 1: Personal details			
Name	Mr D Smith	**Date of birth**	01/07/1986
Address	10 The Drive, Milltown		
Phone (home)	01234 566786	**Phone (mobile)**	07785879657
Occupation	Office worker		
Hours worked	9 a.m. to 6 p.m. with a 1-hour lunch break		
How far do you live from your workplace?	Approx. 5 miles		
How do you travel to work?	Train		
Section 2: Current activity levels			
How many times per week do you currently take part in physical activity?	None		
Section 3: Your lifestyle			
How many units of alcohol do you usually consume per week?	16		
Do you smoke?	No		
Do you experience stress on a daily basis?	Yes		
If yes, what causes your stress?	Work deadlines		
On average, how many hours of sleep do you get per night?	6		
Section 4: Health monitoring tests			
Blood pressure	140/90 mm Hg		
Resting heart rate	88 bpm		
BMI	31		
Waist-to-hip ratio	1.3		
Section 5: Physical goals			
What are your physical/sporting goals?	Start playing competitive 5-a-side football again and lose at least 10 kg in weight		
Signed (client): *D. Smith*			

With reference to the lifestyle questionnaire shown, interpret the lifestyle factors and screening information for the client. [12]

Answer: Client is 30 years old and his BMI suggests he is overweight and needs to lose between 8 and 10 kg. His blood pressure is too high and he should drink less alcohol. He has an office job and does not get any exercise during the day or at home. Says he wants to play football again but afraid he will make a fool of himself because he is too fat and not fit enough. Wants to change his lifestyle.

This answer is generally relevant to the client's lifestyle factors but it does not cover some of the information provided by the client (i.e. travel method used, resting heart rate, stress factors, etc.). 5 marks awarded.

Suggest relevant training methods for the client. [8]

Answer: Client's aims are to lose weight and get fit for football. Suggest Week 1 training of 3 days per week concentrating on cardiovascular fitness to underpin later muscular endurance, agility, flexibility and further cardiovascular fitness. To review blood pressure after three and six week intervals. Try to make training football-specific if possible. Initial cardiovascular training to concentrate on low to moderate treadmill exercises to get client's base fitness levels up. Begin Week 1 with low intensity resistance machines with focus on the legs to aid football.

This answer suggests the use of training methods that have specific relevance to the client's requirements. It takes into account his current level of fitness and suggests adaptations to the training programme specific to the client's requirements (football). 7 marks awarded.

Design weeks 1 and 6 of a 6-week training programme for the client. [6]

Answer:

Week 1	
	Physical activity
Monday	Gym: • 5 min CV warm-up on treadmill – low intensity • Static stretch – all major muscle groups • Chest press and leg press on resistance machines (2 × 15 reps – low resistance) • 20 min run on treadmill at 8 km/h • 2 × 10 arm curls – low resistance • 2 × 10 crunches • 5 min CV cool down on exercise cycle • Cool down stretching
Tuesday	Walk to work
Wednesday	Gym: • 5 min CV warm-up on exercise bike – low intensity • Static stretch – all major muscle groups • Seated rows and leg extensions on resistance machines (2 × 15 reps – low resistance) • 20 min row at low intensity • 2 × 10 tricep extensions – low resistance • 2 × 10 leg raises • 5 min CV cool down on treadmill • Cool down stretching
Thursday	Rest

Friday	Gym: • 5 min CV warm-up on treadmill – low intensity • Static stretch – all major muscle groups • Shoulder press and leg extensions on resistance machines (2 × 15 reps – low resistance) • 20 min run on treadmill at 8 km/h • 1 × 5 press-ups • 2 × 10 crunches • 5 min CV cool down on exercise cycle • Cool down stretching
Saturday	30 min walk around local park
Sunday	• Rest

Week 6: Progression	
	Physical activity
Monday	Gym: • 10 min CV warm-up on treadmill – low intensity • Static stretch – all major muscle groups • Chest press and leg press on resistance machines (3 × 15 reps – low resistance) • 30 min run on treadmill at 8 km/h • 3 × 10 arm curls – low resistance • 2 × 10 crunches • 10 min CV cool down on exercise cycle • Cool down stretching
Tuesday	Gym: • 10 min CV warm-up on exercise bike – low intensity • Static stretch – all major muscle groups • Seated rows and leg extensions on resistance machines (3 × 15 reps – low resistance) • 25 min row at low intensity • 3 × 10 tricep extensions – low resistance • 2 × 10 leg raises • 10 min CV cool down on treadmill • Cool down stretching
Wednesday	Walk to work
Thursday	Gym: • 10 min CV warm-up on treadmill – low intensity • Static stretch – all major muscle groups • Shoulder press and leg extensions on resistance machines (3 × 15 reps – low resistance) • 30 min run on treadmill at 8 km/h • 2 × 10 press-ups • 2 × 10 crunches • 10 min CV cool down on exercise cycle • Cool down stretching
Friday	Gym: • 10 min CV warm-up on exercise bike – low intensity • Static stretch – all major muscle groups • Seated rows and leg extensions on resistance machines (3 × 15 reps – low resistance) • 25 min row at low intensity • 3 × 10 tricep extensions – low resistance • 2 × 10 leg raises • 10 min CV cool down on treadmill • Cool down stretching
Saturday	Rest
Sunday	Rest

This answer demonstrates specific relevance to the individual's training requirements with a clear progression from Week 1 to Week 6. It includes appropriate rest periods and exercise periods away from the gym to keep the client interested and motivated. 6 marks awarded.