The structure and functions of the skeleton

Joint action and movements
Different joints allow different types of movement. For example:

- The hinge joints at the knee and elbow can only move in one direction, enabling **flexion** and **extension**.
- The hinge joint at the ankle enables **plantar flexion** and **dorsiflexion**.
- The ball and socket joints at the hip and shoulder enable **rotation**, **adduction**, **abduction**, as well as flexion and extension. The ball and socket joints at the shoulder also enable **circumduction**.

Exam tip
The types of movement that happen at the synovial joints are covered in more detail in Chapter 2, on pages 36–9, but it is important that you see the link between the skeleton, joints and the movements they enable.

Key terms
- **Extension**: increase in the angle of bones at a joint.
- **Flexion**: decrease in the angle of bones at a joint.
- **Abduction**: movement of a bone or limb away from the midline of the body.
- **Adduction**: movement of a bone or limb towards the midline of the body.
- **Circumduction**: movement of a bone or limb in a circular pattern; a combination of flexion, extension, adduction and abduction.
- **Rotation**: a circular movement around a joint or, in other words, a movement around an axis.
- **Plantar flexion**: movement at the ankle joint that points the toes and increases the angle at the ankle joint.
- **Dorsiflexion**: movement at the ankle joint that flexes the foot upwards and decreases the angle at the ankle joint.

Figure 1.6 Running involves flexion and extension at the knee joints, hip joints and elbow joints, and plantar flexion and dorsiflexion at the ankle joints

Figure 1.7 Bowling overarm in cricket involves rotation at the shoulder joint
**Exam tip**

This topic is closely linked to the practical component of the qualification. You need to be aware of the specific movements required in your chosen physical activities.

---

**Activity**

2 a) Mime any normal, everyday physical movement, such as lifting your arm to pour the kettle, turning on a light, or stepping into the bath.

   a) Identify exactly which joints are allowing the movement to take place.
   
   b) For each joint, identify what type of joint it is. Is it a ball and socket joint or a hinge joint?
   
   c) For each joint, identify what type of movement takes place. Is it flexion, extension, adduction, abduction, rotation, circumduction, plantar flexion or dorsiflexion?

---

**Figure 1.8** The breaststroke involves adduction and abduction at the shoulder joint

**Figure 1.9** The arm action in butterfly involves circumduction at the shoulder joint
The short-term effects of exercise

The short-term effects of exercise occur any time up to 36 hours after you finish exercising.

You may feel nauseous.

You may feel light-headed.

You may experience muscle cramps.

Key term

Fatigue: physical fatigue is a feeling of extreme or severe tiredness due to a build-up of lactic acid in the muscles or working for a long period of time.

You will feel tired, possibly very fatigued.

You may experience DOMS if your exercise was of high intensity.

Your muscles will ache a little.

Some of the negative short-term effects of exercise – such as feeling very fatigued, light-headed and nauseous – are quite common until you establish a regular exercise routine, when they are likely to reduce or disappear altogether. Applying the principles of training to your exercise programme will help you avoid the negative effects of exercising.

Exam tip

For more about the principles of training, see pages 66–7.
2.2 Basic movements

Our limbs can move in different directions, depending on the types of joints that are present. There are eight basic movement patterns.

**Flexion**

*Flexion* takes place when the angle of the bones at the joint decreases. It can occur at the shoulder, elbow, hip and knee.

*Figure 2.11* The flexion at the knee gets the foot in the correct position to kick the ball

**Extension**

*Extension* takes place when the angle of the bones at the joint increases. It can occur at the shoulder, elbow, hip and knee.

*Figure 2.12* When full extension at the knee occurs the foot is in the correct position to make contact with the ball

---

Exam tip

Pages 10–13 explain the role of the musculo-skeletal system in these basic movement patterns. You need to have knowledge of both aspects – the role of the musculoskeletal system and basic movement patterns – to be able to carry out movement analysis effectively.

Exam tip

If you are asked to ‘flex your muscles’, you would normally bend your arm at the elbow and display your contracted bicep muscle, performing the movement of flexion!
**Abduction**

*Abduction* is the movement of a limb away from the midline of the body. It can occur at the shoulders and the hips.

*Figure 2.13* When performing a star jump, the outward movement of the arms and legs is abduction and the return movement is adduction.

**Exam tip**

If someone is abducted then they are taken away; it’s a simple way to remember what *abduction* is!

**Adduction**

*Adduction* is the opposite movement to abduction. It takes place when the limb moves towards the midline of the body. It can occur at the hips and shoulders.

*Exam tip*

If you *add* something, you bring it back or in, so it is *adduction*!

**Circumduction**

*Circumduction* is a combination of flexion, extension, adduction and abduction. It can occur at the shoulder joint, as the arm moves in a circle.

When performing the butterfly stroke, a swimmer’s arms circumduct at the shoulder joint.
Basic movements

**Dorsiflexion**

*Dorsiflexion* takes place at the ankle joint when the foot flexes upwards.

![Figure 2.14 When you perform a squat, dorsiflexion takes place at the ankles](image)

**Plantar flexion**

*Plantar flexion* takes place at the ankle joint when the foot flexes downwards.

![Figure 2.15 When a basketball player jumps, plantar flexion takes place at the ankle](image)
Rotation

Rotation is a circular movement where part of the body turns while the rest remains still. It can occur at the hips and shoulders.

Figure 2.16 When overarm bowling, a cricketer’s arm rotates at the shoulder joint

Exam tip

The blades of a helicopter are called rotors because they go round and round; because rotation takes place.

Key terms

Extension: increase in the angle of bones at a joint.
Flexion: decrease in the angle of bones at a joint.
Abduction: movement of a bone or limb away from the midline of the body.
Adduction: movement of a bone or limb towards the midline of the body.
Circumduction: movement of a bone or limb in a circular pattern; a combination of flexion, extension, adduction and abduction.
Plantar flexion: movement at the ankle joint that points the toes and increases the angle at the ankle joint.
Dorsiflexion: movement at the ankle joint that flexes the foot upwards and decreases the angle at the ankle joint.
Rotation: a circular movement around a joint or, in other words, a movement around an axis.

Activity

2 Observe a practical session and carry out some basic movement analysis by identifying examples of extension, flexion, abduction, adduction, rotation, circumduction, plantar flexion and dorsiflexion. If you are able to, recording the action using a video analysis app, a camera or your phone and playing it back will make this task slightly easier.

3 Look at these photographs and use your knowledge of basic movements and levers to describe:

a) what is happening at the elbow and shoulder joints.

b) what is happening at the hip, knee and ankle joints.

Figure 2.17

Figure 2.18
When carrying out fitness testing it is important to recognise that fitness testing has its limitations.

- The tests are often general and not sport specific. For example, the Sit and Reach Test measures the flexibility of the hamstring group and lower back, but if you are, say, a swimmer, flexibility in your upper body is also important.

- The tests do not replicate the movements used in most sports and physical activities. For example, the Stork Stand Test is used to measure balance but involves a pose that does not feature in many sports that require good balance.

- The tests are usually conducted in isolation, with few distractions, and do not replicate competitive conditions. In contrast, the weather, a noisy crowd or anxiety might affect your ability to perform at your best in a competitive environment.

- Many do not use direct measuring/sub-maximal testing and are, therefore, inaccurate. For example, the Vertical Jump Test requires maximum force in order to drive upwards from the ground when taking off in the jump phase and it can be difficult to ensure that the performer is putting in maximum effort at all times.

- Some of the tests need quite high levels of motivation and can produce unreliable results if the person being tested isn’t fully committed. For example, the Multi Stage Fitness Test requires you to work until you are exhausted, but some people might find the test boring and give up before they reach this point.

- Some tests have questionable reliability because they do not consistently give the same result when they are repeated over and over again. For example, your muscles become progressively fatigued as you complete the One Rep Max test so the result may not reflect your true one rep max.

- A fitness test must be carried out using the correct procedure to ensure it is valid; to ensure it measures exactly what it sets out to measure.
3.5 Measuring balance: The Stork Stand Test

Objective
To measure a person’s ability to maintain a state of balance on one leg.

Equipment required
- A stopwatch
- An assistant

Method
1. Start by standing on both feet with your hands on your hips.
2. Lift one leg and place the toes of your raised foot against the knee of your standing leg.
3. Raise the heel of your standing leg so that you are standing on your tiptoes.
4. Balance for as long as possible without letting either the heel touch the ground or the other foot move away from the knee.
5. Your assistant should measure and record the total time in seconds that the balance is maintained.
6. Compare the results with the national averages.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&gt; 50 seconds</td>
<td>&gt; 30 seconds</td>
</tr>
<tr>
<td>Above average</td>
<td>41–50 seconds</td>
<td>23–30 seconds</td>
</tr>
<tr>
<td>Average</td>
<td>31–40 seconds</td>
<td>16–22 seconds</td>
</tr>
<tr>
<td>Below average</td>
<td>20–30 seconds</td>
<td>10–15 seconds</td>
</tr>
<tr>
<td>Poor</td>
<td>&lt; 20 seconds</td>
<td>&lt; 10 seconds</td>
</tr>
</tbody>
</table>


Figure 3.13 The stork stand pose should be held for as long as possible

National averages for 16- to 19-year-olds for the Stork Stand Test
There are a number of factors to take into account when setting up a circuit:

- The space available dictates how big or complex the circuit can be.
- The equipment available also dictates what can be set up at each station.
- The number of stations can vary. Commonly, a circuit will contain six to ten, or sometimes, 12 stations.
- A circuit should contain a variety of exercises chosen to train the required component(s) of fitness. To avoid muscle fatigue, it is important to ensure that exercises that train the same muscle group, such as sit-ups and leg raises, are not placed one after the other.
- It is essential that the exercise at each station is performed using the correct technique, to ensure that the performer receives the maximum benefit from the training session.
- The work:recovery ratio must meet the needs of the performers. Performers must have adequate time to recover in order to perform effectively at the next station, but they must not rest for too long or they will not experience overload.

How the circuit is organised affects which component of fitness is trained:

| Timed circuits – where the performer completes as many repetitions of an exercise as possible in a set time – will improve muscular endurance. |
| Fixed load circuits – where the performer has to complete a set number of repetitions of an exercise before moving on – will improve strength and muscular endurance. |
| Varied circuits – where the speed of a timed circuit and the work:recovery ratio changes from circuit to circuit – will improve cardiovascular endurance. |

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Would benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit training is very flexible and can be used to train a range of components of fitness.</td>
<td>Circuit training is not really suitable for individual training.</td>
<td>The majority of games players, and is often used by footballers and rugby players.</td>
</tr>
<tr>
<td>Large groups can train at the same time.</td>
<td>Quite a large space is required.</td>
<td></td>
</tr>
<tr>
<td>Circuits are relatively easy to set up.</td>
<td>Technique can be affected by fatigue when performing as many reps as possible in a set amount of time. This can also increase the risk of injury.</td>
<td></td>
</tr>
</tbody>
</table>

**Activity**

7  a) Design a circuit, with between six and ten stations, to develop cardiovascular endurance.

b) Choose a sport and identify one component of fitness that is essential to that sport. Now add two stations to your circuit that would train that component of fitness.
**Interval training and high intensity interval training**

Interval training involves alternating between periods of work and periods of rest.

High intensity interval training (HIIT) involves alternating between short periods of intense work in the anaerobic training zone and periods of active recovery in the aerobic training zone.

The two most common forms of HIIT are:

- Long-interval training, with work periods of 15 seconds to three minutes at about 80–85 per cent of maximum heart rate and active recovery periods of the same length.

- Short-interval training, with short periods of work of no more than 15 seconds at as close to maximum heart rate as possible and longer periods of active recovery, possibly up to two minutes.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Would benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Good for inexperienced performers and beginners.</td>
<td>● Can put a lot of pressure on the body’s systems, which can lead to injury if they have not been conditioned correctly.</td>
<td>● Long-interval HIIT benefits games players and middle-distance athletes.</td>
</tr>
<tr>
<td>● Good for overall fitness.</td>
<td>● Because HIIT is a high intensity workout, your recovery period between training sessions should be at least 48 hours.</td>
<td>● Short-interval HIIT benefits racket sports players and sprinters.</td>
</tr>
<tr>
<td>● Trains aerobic and anaerobic fitness.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fartlek training**

Fartlek is a Swedish word meaning ‘speed play’. It involves periods of fast work with intermittent periods of slower work, and is, therefore, a form of interval training. It is usually completed in an outdoor environment, so the varied terrain can be used by the performer to help them vary the speed and work:recovery ratios. It is often used in running, with the performer changing between sprinting, jogging and walking.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Would benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>● No specialist equipment is required.</td>
<td>● Not suitable for groups or teams as it must be tailored to the individual.</td>
<td>● Experienced endurance athletes, especially marathon runners.</td>
</tr>
<tr>
<td>● Ideal for someone training on their own.</td>
<td>● It is an advanced form of training because the performer has to be experienced to ensure the workout is intense but not too intense.</td>
<td></td>
</tr>
<tr>
<td>● Helps a performer learn how to pace themselves and to understand their physical responses to changes in pace.</td>
<td>● It can be difficult to keep going so you need self-motivation and self-discipline.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Bad weather may be problematic!</td>
<td></td>
</tr>
</tbody>
</table>

**Component of fitness trained**

Cardiovascular endurance

---

8. Take part in a continuous training session, an interval training session and a Fartlek training session. Can you add any more advantages and disadvantages to the lists above?
**Abduction** movement of a bone or limb away from the midline of the body.

**Ability** an inherited, stable trait that determines an individual’s potential to learn or acquire a skill.

**Adduction** movement of a bone or limb towards the midline of the body.

**Aerobic exercise** working at a low to moderate intensity so that the body has time to use oxygen for energy production and can work for a long period of time.

**Aerobic training zone** training in the aerobic training zone allows the performer to develop their ability to work aerobically. It is 60–80% of your MHR.

**Antagonist** the muscle or group of muscles that relax to allow a movement to take place. The antagonist works in an antagonistic pair with the agonist.

**Arousal** a physical and mental (physiological and psychological) state of alertness/readiness, varying from deep sleep to intense excitement or alertness.

**Articulating bones** bones that meet at a joint to enable movement.

**Axis** an imaginary straight line through the body around which it rotates. There are three types of axis: sagittal, transverse and longitudinal.

**Backflow** the flowing backwards of blood. Valves in the veins prevent backflow.

**Balance** maintaining the centre of the mass over the base of support. Balances can be static or dynamic.

**Balanced diet** a diet that contains the right quantity of food so that you consume only as many calories as you expend each day; and the right mix of different types of foods so that the body receives all the nutrients, vitamins and minerals it needs.

**Basic skill** a simple skill that does not require much concentration.

**Beta blockers** restricted drugs that steady the nerves by controlling the heart rate. They have a calming and relaxing effect.

**Blood doping** a prohibited method that involves removing blood a few weeks before competition and then re-injecting it just prior to competition. It increases the number of red blood cells in the bloodstream, increasing the blood’s oxygen-carrying capacity.

**Blood pressure** the pressure that blood is under. The systolic reading measures the pressure the blood is under when the heart contracts. The diastolic reading measures the pressure the blood is under when the heart relaxes.

**Calorie** a unit of measurement for heat or energy production in the body, normally expressed as Kcal.

**Capillaries** a network of microscopic blood vessels. They are only one cell thick.

**Cardiac cycle** one cycle of diastole and systole is called the cardiac cycle.

**Cardiac output (Q)** the volume of blood ejected from the heart in one minute. Cardiac output \(Q = \text{stroke volume (SV)} \times \text{heart rate (HR)}\).

**Cardio-respiratory system** the name used to describe the respiratory system and the cardiovascular system working together.

**Cardiovascular endurance** also known as aerobic power. The ability of the heart and lungs to supply oxygen to the working muscles.
Circumduction movement of a bone or limb in a circular pattern; a combination of flexion, extension, adduction and abduction.

Closed skill a skill that is not affected by the environment or performers within it. The skill tends to be done the same way each time.

Commercialisation the management or exploitation of a person, organisation or activity in a way designed to make a profit.

Complex skill a skill that requires a great deal of concentration and coordination to perform.

Contract to compete an unwritten agreement between opponents to follow and abide by the written and unwritten rules of the sport.

Coordination the ability to use two or more different parts of the body together, smoothly and efficiently.

Deep breathing taking slow, deep breaths whilst relaxed.

Dehydration excessive loss of water from the body, interrupting the normal functioning of the body.

Deoxygenated blood blood containing a low concentration of oxygen.

Diastole the phase of the heartbeat when the chambers of the heart relax and fill with blood.

Diffusion pathway the distance travelled during diffusion. The diffusion pathway is short in gaseous exchange.

Direct aggression an aggressive act that involves physical contact with others.

Diuretic drugs prohibited drugs that remove fluid from the body by increasing the rate of urination.

DOMS Delayed Onset Muscle Soreness, the pain you feel in your muscles the day after you exercise.

Dorsiflexion movement at the ankle joint that flexes the foot upwards and decreases the angle at the ankle joint.

Ectomorph a somatotype characterised by being tall and thin, with narrow shoulders and narrow hips.

Effort the force required to move the load. It can also be referred to as ‘force’.

Effort arm the distance from the effort to the fulcrum.

Endomorph a somatotype characterised by a pear-shaped body and a tendency towards fatness. Endomorphs have wide hips and narrow shoulders.

Erythropoietin (EPO) a peptide hormone that increases the red blood cell count and, therefore, the oxygen-carrying capacity of the blood.

Etiquette a convention or unwritten rule in an activity. It is not an enforceable rule but it is usually observed.

Excess Post-exercise Oxygen Consumption (EPOC) the amount of oxygen needed to recover after exercise. It is characterised by an increased breathing rate and deeper breathing after exercise.

Exhalation/Expiration the process of breathing out.

Expiratory reserve volume the amount of air that can be forced out after tidal volume (after a normal expiration). Expiratory reserve volume decreases during exercise.

Extension increase in the angle of bones at a joint.

Externally paced skill a skill that is started because of an external factor. The speed, rate or pace of the skill is controlled by external factors, such as an opponent or the environment.

Extrinsic feedback information a performer receives about their performance from outside themselves, such as from a coach.

Extrinsic motivation the drive to perform well or to win in order to gain external rewards.

Extrovert a sociable, active, talkative and outgoing personality type, usually associated with team sports.

Fatigue physical fatigue is a feeling of extreme or severe tiredness due to a build-up of lactic acid in the muscles or working for a long period of time.

Feedback the information a performer receives about their performance. Feedback can be given during and/or after a performance.

Fine movement skill a skill involving small, precise movements, showing high levels of accuracy and coordination. It involves the use of a small group of muscles.

Fitness the ability to meet, or cope with, the demands of the environment.

FITT principle used to increase the amount of work the body does,
in order to achieve overload. FITT stands for Frequency, Intensity, Time and Type.

**Flexibility** the range of movement possible at a joint.

**Flexion** decrease in the angle of bones at a joint.

**Frontal plane** runs left to right and divides the body into front and back halves.

**Fulcrum** the fixed point at which a lever turns or is supported. It can also be referred to as the ‘axis’.

**Gamesmanship** attempting to gain an advantage by stretching the rules to their limit.

**Gaseous exchange** the process where oxygen from the air in the alveoli moves into the blood in the capillaries, while carbon dioxide moves from the blood in the capillaries into the air in the alveoli.

**Gross movement skill** a skill that uses large muscle groups to perform big, strong, powerful movements.

**Guidance** a method of conveying information to a performer. Guidance can be visual, verbal, manual or mechanical.

**Haemoglobin** the protein found in red blood cells that transports oxygen (as oxyhaemoglobin) and carbon dioxide around the body.

**Health** a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

**Heart rate** the number of times your heart beats in one minute. One heartbeat is one contraction and relaxation of the heart. Heart rate is measured in beats per minute (bpm).

**Home-field advantage** gaining an advantage in a sporting event from being in familiar surroundings, with the majority of the spectators supporting you.

**Hooliganism** the disorderly, aggressive and often violent behaviour by spectators at sporting events.

**Hydration** having enough water in the body to enable it to function normally.

**Hypertrophy** the enlargement of an organ or tissue caused by an increase in the size of its cells. When a muscle is trained, small tears are created. As they heal, they become thicker and increase in size.

**Indirect aggression** an aggressive act that does not involve direct physical contact. It is taken out on an object in order to gain an advantage.

**Information processing** the name given to the process that a performer goes through when they make and act on decisions. There are four steps in the basic information processing model: input, decision-making, output, feedback.

**Inhalation/Inspiration** the process of breathing in.

**Inspiratory reserve volume** the amount of air that can be forced in after tidal volume (after a normal inspiration). Inspiratory reserve volume decreases during exercise.

**Intensity** the amount of energy needed to complete an activity. Working at a high intensity requires a large amount of energy. Working at a low intensity requires less energy.

**Intrinsic feedback** information a performer receives from within.

**Intrinsic motivation** the drive to succeed that comes from within.

**Introvert** a quiet, shy, passive and reserved personality type, usually associated with individual sports performance.

**Isometric contraction** a muscle contraction where the length of the muscle does not change when it contracts. There is no limb movement as a result.

**Isotonic contraction** a muscle contraction where the muscle changes length when it contracts, resulting in limb movement. Isotonic contractions can be concentric (when the muscle contracts and shortens) or eccentric (when the muscle contracts and lengthens).

**Kinaesthetic feedback** received by receptors in the muscles. Physical sensations generated by movements are felt by the performer and provide a form of intrinsic feedback.

**Lactic acid** a mild poison and waste product of anaerobic respiration.

**Lever** a rigid bar that turns about an axis to create movement. All levers contain a fulcrum, load and effort.

**Load** the weight or ‘resistance’ that the lever must move.

**Load arm** the distance from the load to the fulcrum.

**Longitudinal axis** runs vertically through the body, from head to toe.
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