Contents

Workbook also available for externally assessed units ISBN 9781292230603

Unit 1 Anatomy and Physiology

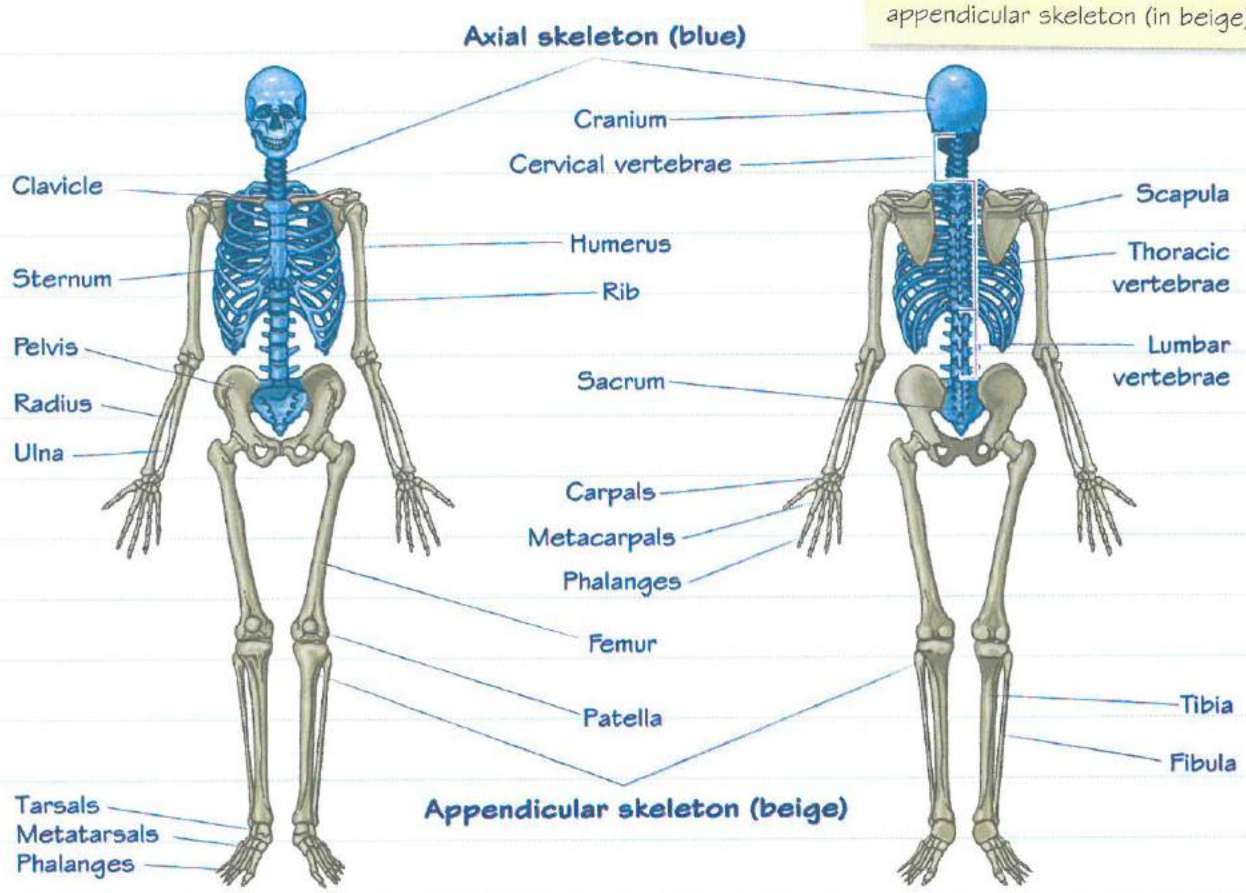
Unit 2 Fitness Training and Programming for Health, Sport and Well-being

A small bit of small print
Pearson publishes Sample Assessment Material and the Specification on its website. This is the official content and this book should be used in conjunction with it. The questions in *Now try this* have been written to help you test your knowledge and skills. Remember: the real assessment may not look like this.

The skeleton

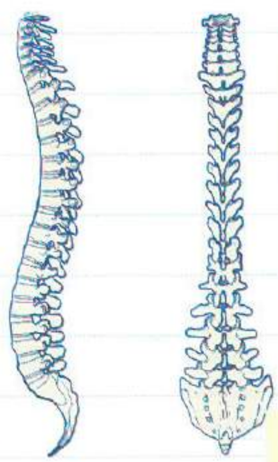
You need to know the names and locations of the major bones of the axial and appendicular skeleton, and the variations of the curvature of the spine.

The bones of the axial (in blue) and appendicular skeleton (in beige)



Neutral spine alignment

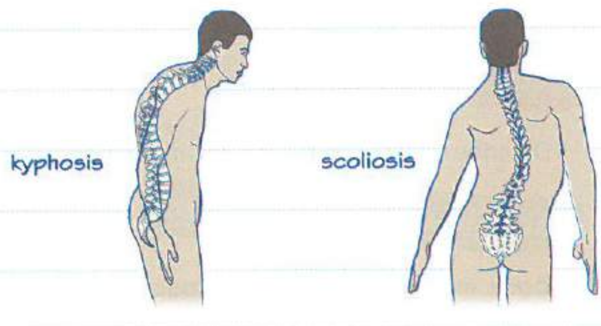
Another name for the vertebral column is the spine.



The spine naturally forms an 'S' shape when viewed from the side (in other words there should be three slight curves). When viewed from the back the spine should be straight.

This is neutral spine alignment.

Postural deviations kyphosis and scoliosis



Kyphosis (hunched back) and scoliosis (abnormal sideways curvature of the spine when viewed from the back).

Now try this

(a) Describe the postural deviation kyphosis.

(b) Explain **one** way that the postural deviation kyphosis could impact on performance in sport.

Had a look ☐ Nearly there ☐ Nailed it! ☐

Bone growth

Strong healthy bones are vital for effective sports performance. You will need to know the process of bone growth and the bone cells that enable it to take place.

Process of bone growth

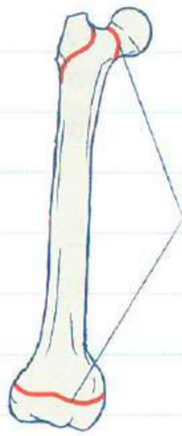
Bone is living tissue. It is formed through a process called **ossification.**

Bone develops in length from infancy to adulthood.

Calcium and phosphate accumulate on the cartilage, trapping it, causing the cells of cartilage to die.

Tiny spaces are left when the cartilage dies. Blood vessels grow in these spaces and transport osteoblasts and nutrients to the developing bone.

The length of your bones can determine your sport. For instance, basketball players are often tall; jockeys, often short.



Bone tissue is naturally added at the epiphyseal plate in children and teenagers to increase the length of the bone.

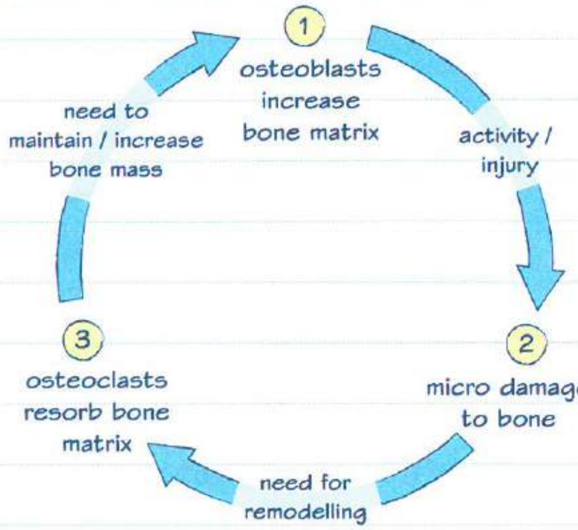
Bone cells

Bone cells comprise:

- **osteoblasts**, which form bone by secreting **collagen**
- **osteoclasts**, which remove bone. Osteoclasts dissolve bone mineral. The degraded bone is then removed.

Growth in diameter of a bone can continue through adulthood.

Bone is continuously being broken down and restructured due to the dynamic relationship between bone cells.



Worked example

Describe how the bone cells maintain bone mass. **4 marks**

Sample response extract

Bone mass is maintained through the action of the osteoblasts and osteoclasts. Osteoblasts are responsible for increasing the bone matrix after the osteoclasts have absorbed bone tissue during growth / repair.

The command word used is '**Describe**' so the points you make must be linked or related to each other.

Start by identifying the relevant bone cells before describing the role of each.

Now try this

Karl broke his arm playing rugby.

Explain the role of bone cells in Karl's recovery.

Make sure you read each question carefully. Tailor your answer to the question context. The context is a broken arm, so make sure you link your response.

Functions of the skeleton

You need to know the functions of the skeleton and be able to apply your knowledge to a range of different sport and exercise situations.

Supporting framework and movement

The skeleton:

- allows the body to maintain its shape
- allows you to stand erect due to the vertebral column
- provides a framework for muscle attachment
- allows movement due to muscle attachment and the formation of joints between the bones
- allows a vast range of movement from intricate precise movements of the hand to the large range of movement possible at the shoulder.

Leverage

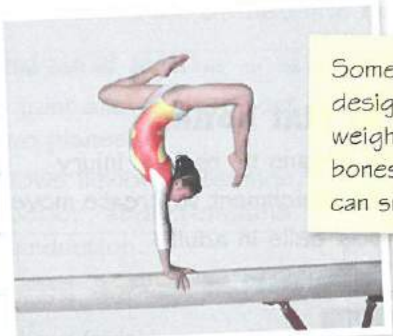
The length of our bones determines our height and the amount of leverage the bones can exert. This will impact on our performance in a range of activities.

It is an advantage for basketball players to be tall.

A tennis player with long arms will be able to exert more force on the ball; improving their service.

Weight bearing

In order to maintain an erect stature, the bones of the pelvis and leg are strong and thick so that they can take the weight of the entire skeleton.



Some other bones are especially designed for strength to allow weight bearing. For instance, the bones at the gymnast's wrists can support her body weight.

Protection

Vital organs are protected from damage due to their position in relation to the bones of the skeleton.

For example:

- the cranium protects the brain
- the vertebrae protect the spinal cord
- the rib cage and sternum protect the lungs and the heart.

Source of blood cell production

The following blood cells develop in the bone marrow:

- red blood cells – important as they carry oxygen to the muscles
- white blood cells – important as they fight infection to keep the performer healthy.

Store of minerals

The bone matrix stores:

- calcium, essential for muscle contraction and bone repair
- phosphorus; too little phosphorus can cause muscle fatigue and joint pain.

The bone marrow stores iron, essential for red blood cell formation.

Now try this

Explain how **two** different bones of the skeleton are used for protection in physical activity.

Give examples for **two** different bones in the skeleton, such as the cranium and the ribs.

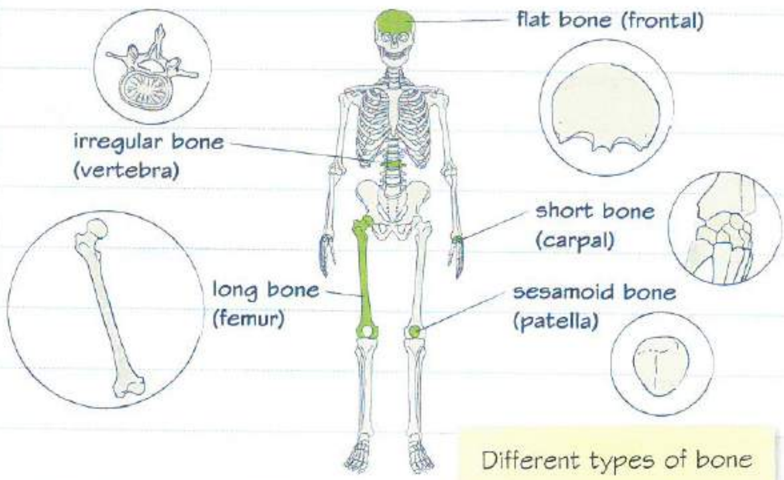
Be clear about how each bone provides protection.

Give a different sporting example for each bone.

Bone types

You need to know and understand how each bone type is related to its function and how these functions aid sporting techniques and actions.

Characteristics and examples of bone types



Different types of bone

- Long – longer than they are wide, such as the femur, ulna and phalanges
- Short – as short as they are wide, such as the carpals and tarsals
- Flat – broad, flat and normally thin bones, such as the pelvis, sternum and ribs
- Sesamoid – held within tendons, covered in cartilage, such as the patella
- Irregular – irregular shape, such as the vertebrae

Function of long bones

- Source of red blood cells production, essential for oxygen delivery
- Enable large movements, allowing increased speed or range in which an object can be moved
- Act as levers to generate more force on an object

Function of short bones

- Increase stability and reduce unwanted movement
- Are weight bearing, helping the body to remain upright or hold balance
- Absorb shock, such as when running

Function of sesamoid bones

- Ease joint movement, meaning more fluid
- Resist friction so movement is not slowed down

Function of flat bones

- Protect vital organs to reduce injury
- Enable muscle attachment to create movement
- Produce blood cells in adults

Function of the bone types applied to sport.

Now try this

Analyse the role of **one** bone type during a game of badminton.

Think of the roles of the different bone types. For example, a long bone acts a lever – how does this help? What will happen to the speed of the racket? What is the impact of this?

Joint classification

The first thing you need to know is that there are different types of joints in the body.

Types of joints

A joint is formed where two or more bones meet. We classify joints according to the amount of movement they allow.

1 Fibrous

These joints are fixed and allow no movement, such as the sacrum and coccyx.

The cranium is also a fibrous joint.

2 Cartilaginous

These joints are slightly moveable joints, such as between the lumbar vertebrae.

The joints between the cervical and thoracic vertebrae also form cartilaginous joints.

3 Synovial

These are freely moveable joints.

They are important in sport because they provide the greatest range of movement.

The shape of the bones at the joint determines the range of movement. For example, due to the shape of the bones forming the knee, we can only bend and straighten the leg at the knee.

Synovial joints

Synovial joints are divided into six groups based on the amount of movement at each joint.

Condyloid joint

This joint allows movement in two planes.

It allows flexion, extension, adduction, abduction, and circumduction.

Pivot joint

There is a pivot joint at the elbow and between the first and second vertebrae. These joints allow twisting or rotation.

Hinge joint

Examples of these are found at the elbow, knee and ankle.

They allow flexion and extension.

Gliding joint

This joint is formed between the bones of the wrist and foot. The bones glide over each other to allow sliding or twisting movements. For example, the hand action in hockey as you dribble the ball.

Saddle joint

This joint is formed between the carpals and metacarpals at the base of the thumb. The movements are the same as the condyloid joint.

The elbow

Classified as a pivot and hinge joint. This is because there are actually two joints in the area of the elbow. Make sure you know which bones form each joint:

- **pivot** – between the radius and the ulna
- **hinge** – between the radius and the humerus and the ulna and the humerus.

Ball and socket joint

These joints give the greatest range of movement.

Ball and socket joints at the hip and shoulder allow flexion, extension, adduction, abduction and rotation.

Now try this

Go back to page 1 to identify the joints of the upper and lower skeleton.

Analyse how the synovial joints from the upper skeleton allow a player to serve the ball in a game of tennis.

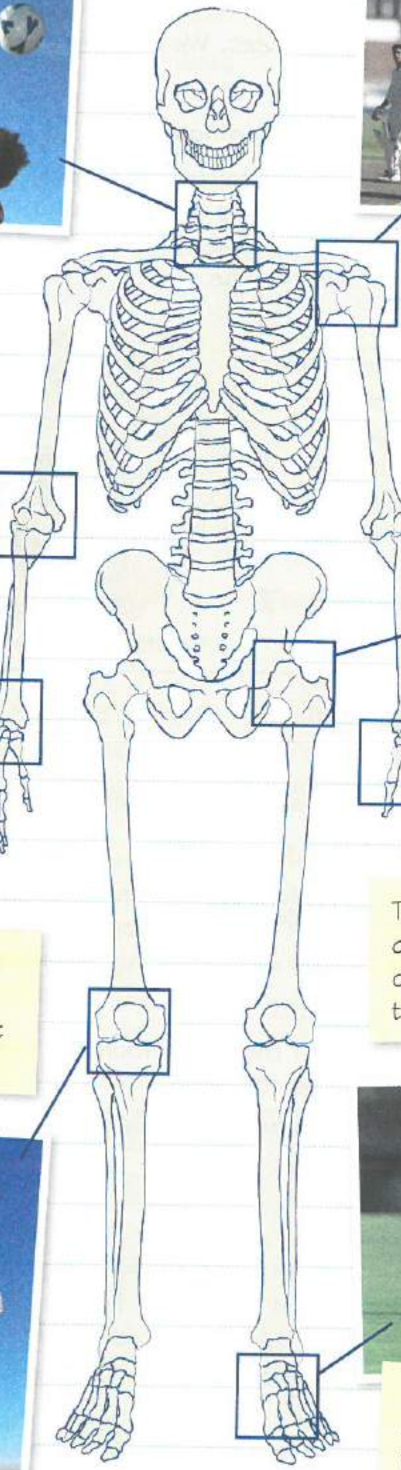
Had a look ☐ Nearly there ☐ Nailed it! ☐

Joints use in sport

You need to understand how the joints of the upper and lower skeleton are used in sporting techniques and actions.

The pivot joint formed between the first and second vertebrae at the neck allows the player to tilt the head back to watch the ball.

The ball and socket joint formed between the scapula and humerus at the shoulder allows the bowler to bowl the cricket ball.

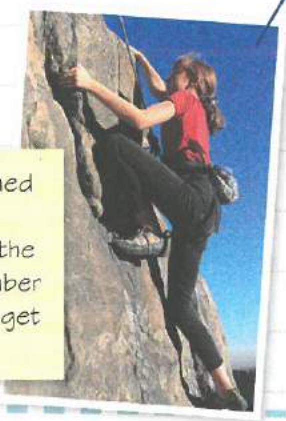


The ball and socket joint formed between the femur and pelvis at the hip allows the hurdlers to lift the leg to clear the hurdle.

The hinge joint formed between the humerus and the radius and ulna at the elbow allows the volleyball player to bend the arm to serve the ball.

The condyloid joint formed between the radius, ulna and the carpals at the wrist allows the gymnast to put their hand flat on to the bar to maintain their weight.

The saddle joint formed between the carpals and metacarpals at the base of the thumb allows the tennis player to grip the racquet and the ball.



The hinge joint formed between the femur, tibia and patella at the knee allows the climber to bend the leg to get a foothold.

The gliding joint formed between the tarsals and metatarsals of the foot increases the flexibility of the foot, allowing the player to turn the foot to kick the ball.

Now try this

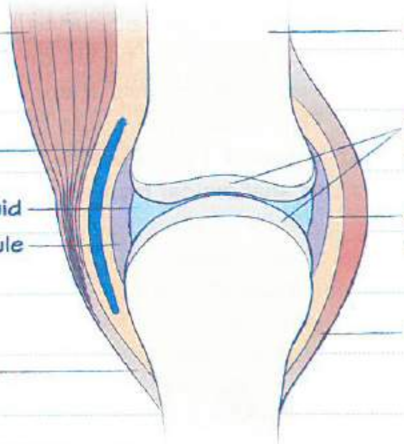
(a) How would the joints between the vertebrae be used in high jump?

(b) The pictures show sporting examples of the use of each type of joint. How else might each of the identified joints be used in sport?

Joint structure

You need to be able to link the function of each component of a synovial joint with its use in sporting techniques and actions.

Components of synovial joints



The general structure of a synovial joint

Function of each component

A joint is formed where two or more **bones** meet. In this example, two bones are meeting to form the synovial joint.

Articular cartilage is a shiny, elastic material, which is designed to reduce friction and absorb shock.

Ligaments connect bone to bone, holding the bones in the correct position. They stabilise the joint.

The **synovial membrane** secretes synovial fluid.

Bursa are found in most major synovial joints. They reduce mechanical friction in the joint. They act as a cushion between bone and another part of the joint, such as tendons or muscles.

Function of each component

The **joint capsule** surrounds the synovial joint. It is attached to the outer layer of the bones forming the joint. It seals the joint and provides stability to the joint.

Synovial fluid:

- lubricates and reduces friction in the joint
- supplies nutrients to the joint
- removes waste products from the joint.

Muscles and tendons

Muscles and tendons are part of the muscular system rather than the skeletal system. They are included on the joint diagram to show they must be present at a joint. Otherwise, there would be no way to move the bones at the joint. The tendon attaches the muscle to the bone and the muscle contracts to bring about movement.

Applied to sporting techniques

The components of the joint aim to keep the joint healthy so that it can continue to function, and you can continue to play sport. The role of the articular cartilage is to protect the bones from wearing out. The bone will be at increased risk of wearing the more you use it. For example, think of the potential wear on the articulating bones at the knee of elite long distance runners who run up to 135 miles in training. Or the importance of the ligaments to maintain the stability of the joint in contact sports such as rugby. The importance of synovial fluid to transport nutrients and lubricate the elbow, (reducing friction at the joint), wrist and shoulder joints of the elite wheelchair athlete who completes 10 miles of road distance training each morning, and sprint training later the same day, is another good example to think about.

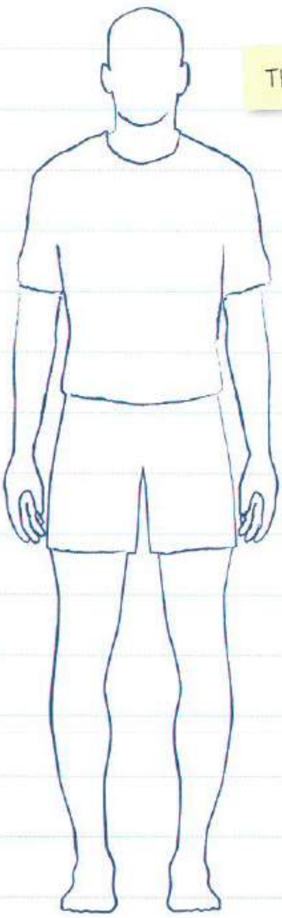
An elite wheelchair athlete relies on the components of the elbow joint to maintain its health, so they can continue to put additional stress on it to allow them to train and compete.

Now try this

How would the bursa aid sporting performance in contact activities such as wrestling or judo?

Anatomical position

You need to know about the ranges of movement possible at joints. When describing any movement, it helps to consider the anatomical position. All ranges of movement start at, or return to, this position.



The anatomical position

Flexion, extension

Flexion means reducing the angle of the bones forming the joint (for example, during a bicep curl there is flexion at the elbow to lift or curl the weights). To lower the weights there is extension at the elbow. This means the angle between the bones at the joint increases and the arm is returned to the anatomical position.

Each range of movement has an 'opposite' to allow the limb to move from the anatomical position and then back towards it.

Plantarflexion and dorsiflexion

This range of movement only occurs at the ankle. During dorsiflexion at the ankle the toes are pulled nearer to the lower leg. To move back to the anatomical position, the ankle plantarflexes. The ankle can plantarflex beyond the anatomical position, such as when pointing the toes in a trampolining routine.

The footballer uses dorsiflexion at the ankle to help control the ball, whilst the diver uses plantarflexion to produce a better dive.

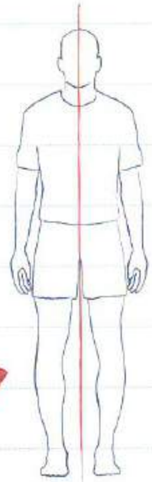
Now try this

Name **three** other movements in sport or physical activity that use flexion and extension.

Abduction and adduction

Abduction

Think of a vertical line passing directly through the body from top to bottom. This is known as the midline of the body. A sideways (lateral) movement of the arms at the shoulder, or a sideways movement of the legs at the hip away from the midline is called abduction.



The midline of the anatomical position

The volleyball player is abducting the arm at the shoulder in preparation to serve as he takes the arm sideways away from the body. He is also abducting the leg at the hip as the limb moves away, sideways, from the anatomical position and the midline of the body.

Adduction

Adduction means bringing the bone at the joint closer to the midline of the body, such as returning to a standing position after a martial art kick out to the side of the body, or the recovery phase of the breaststroke leg action.

The gymnast has adducted the legs at the hip to move to a handstand position on the pommel horse.

Horizontal abduction and adduction

Where the word horizontal is added, it simply gives more detail about the movement taking place. Horizontal means from side to side at shoulder height, so **horizontal abduction** means movement away from the midline of the body but horizontally (parallel to the floor) rather than vertically. For instance, when taking a racket back in the preparatory phase of playing a forehand shot in tennis. Horizontal adduction can occur at the hip and the shoulder.

Horizontal adduction occurs at the shoulder as the tennis player moves the arm forward to play the shot. Note how the elbow is facing downwards.

Now try this

(a) What is the difference between adduction and abduction?

(b) Use an example to explain how horizontal abduction differs from abduction.

If someone is abducted they are kidnapped or taken away. Use this meaning of the word to remind you what the range of movement is.

Had a look ☐ Nearly there ☐ Nailed it! ☐

Other ranges of movement

These are the remaining ranges of movement you need to know and recognise when used in sporting actions.

Horizontal flexion at the shoulder

This is a very similar movement to horizontal adduction **except** the elbows face out to the sides (forcing the palms to face downwards) as the arms are moved to the midline of the body horizontally. For instance, as a discus thrower brings the arm through to release the discus.

Links Go to page 9 to revise horizontal abduction and horizontal adduction.

Horizontal extension at the shoulder

Lateral movement away from the midline of the body horizontally, moving the upper arm away from the chest with elbows at the side. The difference between this movement and horizontal abduction is the position of the upper arm – if the elbow is turned out, it is horizontal extension.

The discus thrower has horizontally extended the arm at the shoulder in preparation to throw the discus. Note the elbow is out to the side.

Hyperextension of the spine

Extension of the spine is movement back to the anatomical position. Hyperextension is a continuation of this movement so that the neck moves further away from the chest (cervical vertebrae) or the spine moves away from the pelvis (thoracic and lumbar vertebrae).

Hyperextension of the spine

Lateral flexion of the spine

This is movement away from the midline of the body so the spine moves from side to side. This can occur at the:

- cervical vertebrae, such as moving the neck sideways towards the shoulder as part of a warm-up routine
- thoracic and lumbar vertebrae, such as moving the upper body sideways towards the pelvis when performing a cartwheel.

Circumduction

This is a conical movement. That is, when circumduction occurs at the shoulder the hand will describe a circle, such as the butterfly arm action as the arms leave the water the hands complete a circular action.

Circumduction can occur at the shoulder, wrist, hip and ankle.

Rotation

This is a circular movement that occurs when the bone at the joint turns around an axis. For example, at the elbow and wrist when playing a topspin forehand drive in tennis, or the rotation at the hip during a golf drive.

Now try this

How can you recognise the difference between horizontal flexion and horizontal adduction?

Responses and adaptations

You need to know the short-term responses of the skeletal system to exercise and the resulting long-term adaptions if regular exercise is carried out.

Responses

These are the **immediate, short-term** ways that the skeletal system reacts when you exercise. The reactions are **short lived**. In other words, when you stop exercising the skeletal system has no need to continue to react in this way and therefore stops.

Responses of the skeletal system to exercise

- Stimulates increase of mineral uptake (calcium) within the bones.
- Stimulates production of collagen due to increased stress on bones as a result of exercise.

Responses of the skeletal system to exercise within the joint

Increased range of movement due to:

- reduction in viscosity of the synovial fluid
- increased pliability of the ligaments.

Increased production of synovial fluid to ensure the articular cartilage does not dry out.

Viscosity – how thick liquid is

Adaptations

These are the **long-term** ways that the skeletal system changes due to regular training. These changes are lasting, provided you do not stop **regular** training. In other words, when you stop exercising, the skeletal system does not immediately change back to how it was before the exercise session.

Adaptations of the skeletal system

- Increased bone density and strength due to increased mineral content and bone cell activity make the bones less susceptible to fractures or breaks.
- Increased ligament strength reduce the risk of dislocation at a joint.
- Increased thickness of articular cartilage protects the ends of the bones from wear and tear.

These adaptations reduce the risk of injury making it possible to continue to train or train harder, provided there is adequate rest built in to the programme.

Links Go to page 2 to revise bone cells and bone growth.

Regular weight-bearing or weight-training exercise makes the areas of the skeleton that are working work harder as they work against gravity, increasing bone strength.

Now try this

Use an example to explain why a warm-up is important to the skeletal system before a hockey match.

When answering a question, make sure you pay attention to the question context and tailor your answer to this, rather than just giving a general response.

Had a look ☐ Nearly there ☐ Nailed it! ☐

Additional factors

You need to understand the potential positive impact of exercise on limiting skeletal disease and the importance to bone growth of waiting until the skeleton has sufficiently matured before taking part in resistance training.

Arthritis

This is a common disease of the skeleton and can affect people of all ages. There are two common types:

- osteoarthritis – mainly develops in those over 40, but can occur at any age
- rheumatoid arthritis – normally develops between the ages of 40–50; women are more susceptible than men to this condition.

However, exercise can delay these conditions by helping the individual maintain a healthy weight and healthy joints.

Types of arthritis

Osteoarthritis causes the articular cartilage to thin, which will cause pain and lack of mobility at the joint. This would make it difficult to continue to exercise.

Rheumatoid arthritis causes inflammation of the joints so they become painful and swollen. The synovial membrane of the joint becomes inflamed, due to a build-up of fluid. Although the inflammation can reduce, the joint capsule has been stretched making the joint less stable. Pain at the joint and, later, the increased risk of deformity at the joint will make activity difficult.

Osteoporosis

This is a reduction in bone density. It can be caused by a lack of calcium, vitamin D and a sedentary lifestyle.

The reduction in bone mass makes the bones more brittle, with increased risk of fracturing a bone from even a minor bump or fall.

Benefits of regular exercise

Higher levels of weight-bearing physical activity can reduce age-related bone loss by putting gentle stress on the bones; not too much that they fracture, but enough so that new bone growth is encouraged.

Links Go to page 2 to revise bone growth.

Strength training

Whilst strength training can be appropriate for all ages, young children should not engage in weight lifting as it can negatively affect bone growth.

Now try this

(a) Why is arthritis likely to stop you from playing sport?
(b) How can exercise improve bone health?
(c) Why shouldn't young children take part in weight training?

Read every question carefully. Part (c) is about weight training; this is different from strength training.

Muscle types

You need to know the characteristics and functions of the three muscle types and their relevance to sport and physical activity.

1 Cardiac muscle

Location:

- only found in the walls of the heart.

Function:

- to circulate blood through and out of the heart.

Characteristics:

- unconsciously controlled by the nervous system
- myogenic (has a set rhythm of contraction)
- does not fatigue.

Relevance to sport

The heart keeps the blood circulating, picking up oxygen from the lungs and dropping off waste products. At rest, approximately 5 litres of blood is pumped out of the heart per minute. When we exercise, we have a much greater demand for oxygen and so need to circulate more blood. The cardiac muscle of the heart achieves this by contracting at a quicker rate. Elite endurance athletes can circulate more than 30 litres of blood a minute during exercise. The heart ensures increased oxygen delivery to allow the performer to continue.

2 Skeletal muscle

Location:

- attached to the bones of the skeletal system.

Function:

- movement plus support and posture.

Characteristics:

- consciously controlled
- contract by impulse from brain
- muscle fibres work together in motor units.

Relevance to sport

Without skeletal muscle we would be unable to move our skeleton and therefore unable to participate in sport.

Skeletal muscle is responsible for large body movements such as running, but also precision movements such as a short putt in golf or releasing an arrow in archery.

3 Smooth muscle

Location:

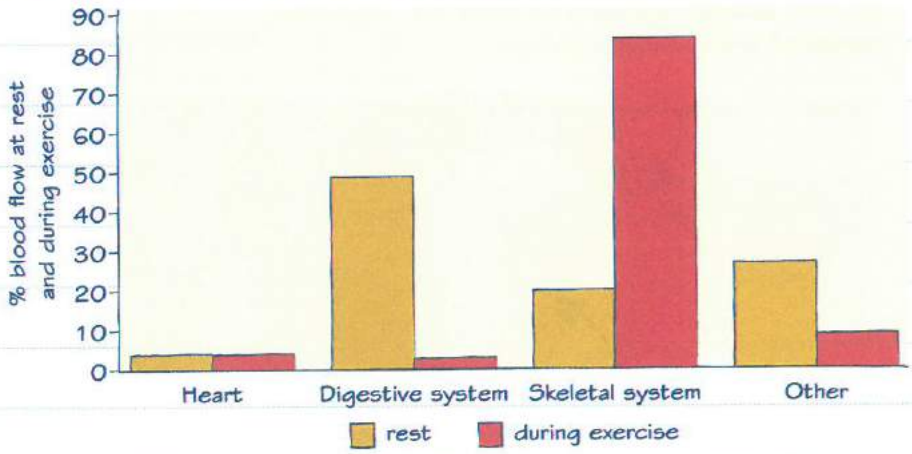
- found in the walls of hollow organs, such as in the digestive and circulatory system.

Function:

- controls body functions, such as movement of food through the body, the passage of urine from the bladder and the movement of blood through the circulatory system.

Characteristics:

- unconsciously controlled by the nervous system.



During exercise, the smooth muscle in the blood vessels can restrict or increase blood flow through the blood vessel so that more blood carrying oxygen can go to the skeletal muscle. Therefore performers get the oxygen their muscles need whilst exercising.

Now try this

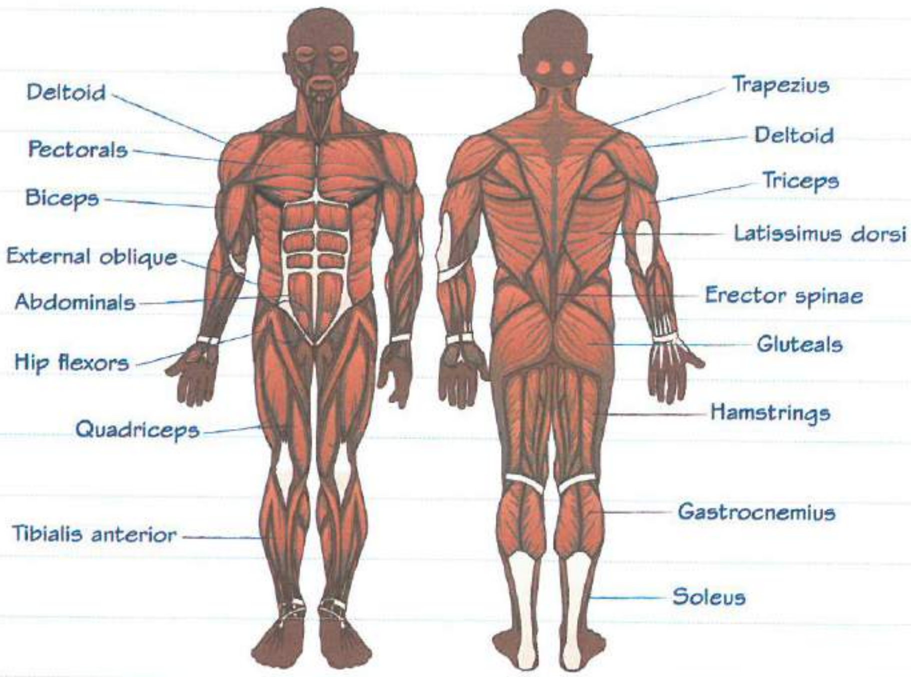
How does each muscle type aid performance?

Make sure you know about each muscle type.

Had a look ☐ Nearly there ☐ Nailed it! ☐

The muscular system

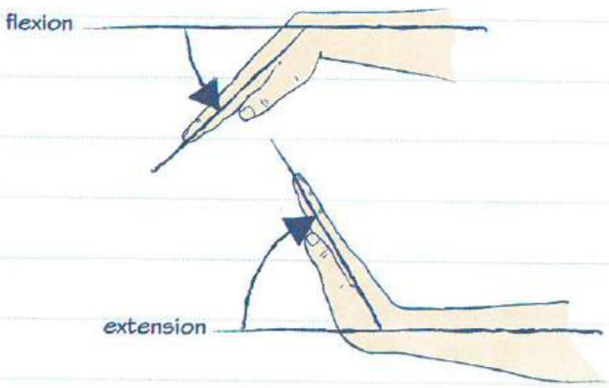
You need to know the names and locations of the major skeletal muscles.



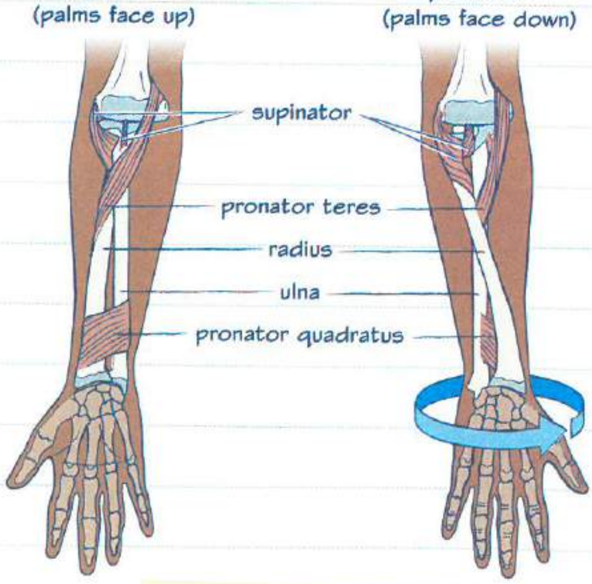
The names and locations of the major skeletal muscles

Movement of the hand at the wrist

Many different muscles control the movement of the wrist. Some are grouped together based on their action. You need to know the collective names of these muscle groups.



Wrist flexors and **wrist extensors** are responsible for flexing and extending the wrist.



Supinators turn the palm upwards. **Pronators** turn the palm face down.

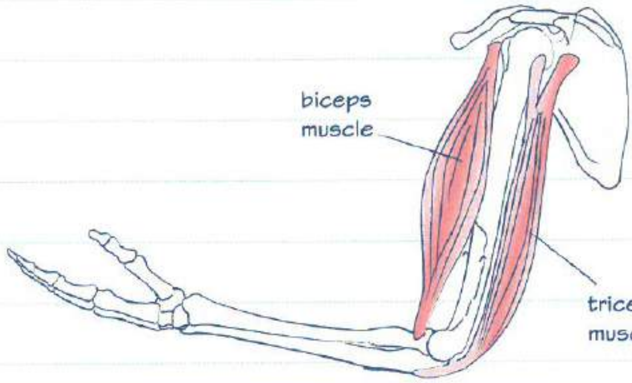
Now try this

What is the collective name given to the muscles that enable a cricketer to 'cup' their hands (palms up) to catch a ball?

Antagonistic muscle pairs

Muscles work together to bring about movement by taking on different roles, depending on the movement required. You need to know the roles of the muscles and their combined use in a variety of sporting actions.

Muscles work in **antagonistic pairs**. When one muscle in the pair is contracting, the other muscle is relaxing. This is so the full range of movement can be achieved at a joint. The contracting muscle is called the **agonist**, and the relaxing muscle, the **antagonist**. When the movement at the joint needs to be reversed the muscles switch roles, the agonist becomes the antagonist, the antagonist becomes the agonist.



The antagonist (triceps) must relax to allow the agonist (biceps) to contract and flex the arm at the elbow. When the arm needs to extend at the elbow, the bicep becomes the antagonist and relaxes, allowing the tricep (now the agonist) to contract.

Synergists

A **synergist** cooperates with the agonist in two ways:

1. Supporting its action by neutralising any undesired action at the joint so that the force generated by the agonist works to bring about the desired action. For example, the latissimus dorsi acts as a synergist for the pectorals when the upper arm is adducted at the shoulder.
2. Assisting the agonist muscle to perform the desired type of movement. For example, the soleus acts as a synergist to the gastrocnemius in dorsiflexion of the ankle.

Fixators

Fixators are muscles that stabilise a joint by eliminating unwanted movement. For example, some of the muscles at the ankle work to stabilise the joint as we stand so that we can balance effectively. During a biceps curl the trapezius will stabilise the movement by preventing the scapula from moving.

The anterior and posterior deltoids work antagonistically to adduct and abduct the arm at the shoulder.

The hip flexors and gluteals work antagonistically to allow flexion and extension of the hip.

The quadriceps and the hamstrings work antagonistically to allow flexion and extension of the leg at the knee.

The tibialis anterior and the gastrocnemius work antagonistically to allow the foot to move from dorsiflexion to plantarflexion.

Now try this

Review the muscles shown on page 14. Identify **five** different antagonistic muscle pairs.

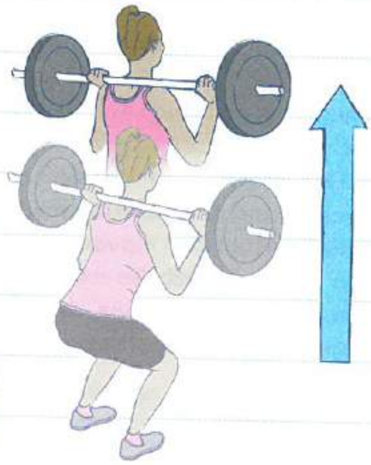
Had a look ☐ Nearly there ☐ Nailed it! ☐

Muscle contraction

You need to know about three different types of muscle contractions. When a muscle contracts, it is working: it is either supporting or moving a load or resistance, or is static under tension.

Concentric contraction

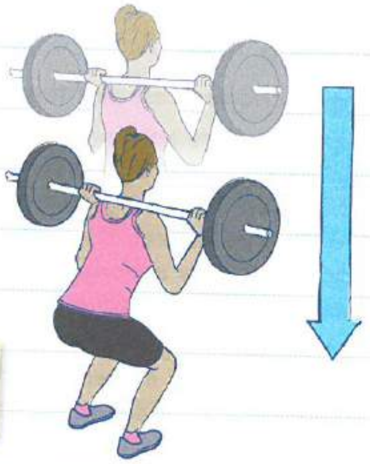
When a muscle contracts and **shortens** it is called a concentric contraction. Concentric contractions are common in power sports or sports where you need explosive force. They cause movement at the joint as the force exerted by the muscle is greater than the resistance. For example, when serving a ball in tennis, the triceps contracts and shortens when you extend the arm to bring the racket through quickly to add pace to the ball.



The quadriceps contract concentrically during the **upward** phase of the squat.

Eccentric contraction

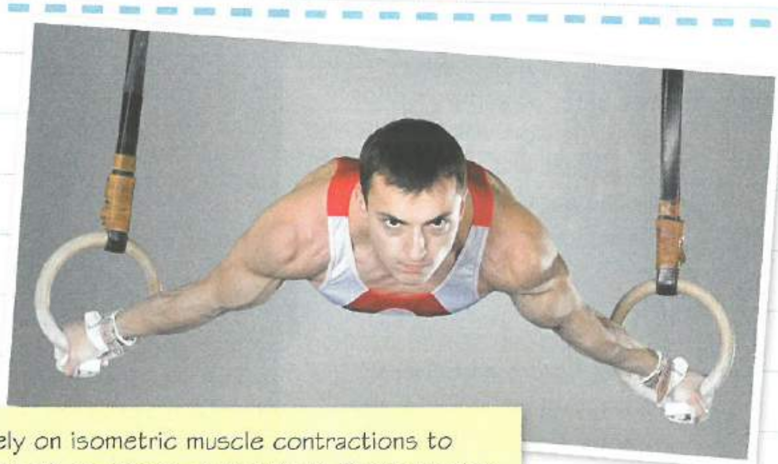
When a muscle contracts it can also **lengthen** under a load or tension. This is often when the muscle is working against gravity, trying to control a movement. For example, running down hill or when lowering the body in a press-up the triceps muscle is still working hard to control the rate of descent so that the body doesn't fall to the floor. In this example, the triceps are contracting but lengthening; therefore they are working eccentrically.



The quadriceps contract eccentrically during the **downward** phase of the squat.

Isometric contraction

When a muscle works isometrically there is little or **no movement** in the muscle or joint. The muscle doesn't shorten or lengthen. For instance, when holding the 'set' position at a sprint start or when weightlifters hold the weights still above their heads for a qualifying lift in the clean and jerk. The muscles are working but there is no movement.



Gymnasts rely on isometric muscle contractions to maintain strength positions on the rings. Their muscles are working but are not shortening or lengthening.

Now try this

Give an example of an exercise activity or technique that would use each type of muscle contraction. Give **one** example for each type of muscle contraction.

Fibre types

You need to know about the different muscle fibre types and their recruitment for a range of exercises and sports.

All or none law

The muscular system works with the nervous system to bring about muscle contraction. Impulses are sent to the muscle via **motor neurones** (nerves). The motor neurone is attached to a number of muscle fibres in the muscle. Together, these are called a **motor unit**. The muscle fibres within a motor unit will be of the same type. When the motor neurone receives the signal to contract, **all** the muscle fibres attached to that neurone will contract (all or none law). The force the muscle produces is altered by adjusting the number of motor units stimulated to contract.

Type I (slow twitch)

Characteristics:

- utilise the aerobic energy system due to dense capillary network and high levels of myoglobin
- contract slowly
- exert the least amount of force of the fibre types
- have the highest resistance to fatigue; allowing the muscles to continue to contract for long periods of time.

Type I fibres are ideal for endurance activities, such as long distance running.

Links Go to page 35 to revise energy systems.

Type IIa (fast twitch)

Although these are classified as fast twitch fibres, they can develop type I characteristics through endurance training. Therefore, they can utilise either aerobic or anaerobic energy systems depending on the training the performer undertakes. Type IIa fibres have a greater resistance to fatigue than type IIx fibres, but less resistance than type I. They can produce a medium force of contraction. They are ideal for middle distance events.

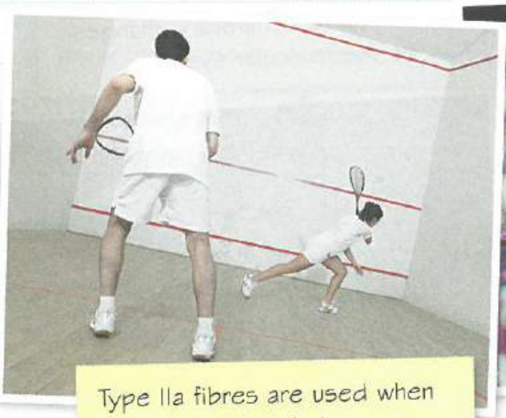
Type IIx (fast twitch, formerly type IIb)

Characteristics:

- utilise the anaerobic energy system
- produce a strong force of contraction
- consist of larger motor neurones
- the motor units normally have more muscle fibres in them compared to slow twitch motor units
- the muscle fibres tend to be larger and thicker than other fibre types.

These fibre types are ideal for power activities, such as sprinting.

Type I fibres are used in marathon running



Type IIa fibres are used when pace is needed, but over a sustained period of time, such as in squash.

Type IIx fibres are used to generate force to achieve a greater height.

Now try this

How does having a range of muscle fibre types allow 10 000 m runners to perform well in their sport?

Responses

You need to know these five short-term responses of the muscular system to exercise.

Responses

These are the **immediate, short-term** ways that the muscular system reacts when you exercise. The reactions are **short lived.** When you stop exercising, the muscular system has no need to continue to react to exercise, and therefore stops and slowly recovers back to its pre-exercise state.

1 Increased blood supply

During exercise there is an increased need for oxygen to be transported to the working muscles so that energy production is high enough. Oxygen is carried via the red blood cells. The blood supply to the muscles increases by a process called **vascular shunting.** The lumen of the arterioles in the muscles **vasodilates,** to allow an increased passage of blood to the muscles, whilst the arterioles in areas such as the digestive system **vasoconstrict** to reduce blood flow.

Links Go to page 32 to revise redistribution of blood flow.

Vascular shunting provides the oxygen for exercise.

Whatever the sport, exercise will cause temporary changes to the muscular system.

2 Increased muscle temperature

When we exercise heat is given off as a by-product of energy production. The more intense the level of exercise, the greater the heat produced.

3 Increased muscle pliability

As muscle temperature increases with exercise the muscle becomes more pliable. It has more 'give' so reduces the chance of injury.

4 Lactate accumulation

Lactate is a by-product of energy production. If enough oxygen is available lactate can be broken down as it is produced. However, as exercise intensity increases lactate builds in the muscles as it is being produced faster than it can be broken down due to insufficient oxygen.

5 Microtears

Each muscle is made up of bundles of muscle fibres. Each muscle fibre is made up of bundles of myofibrils. As a result of resistance exercise these myofibrils can sustain microscopic tears, which will need time to repair before exercising the muscle again. These microtears are thought to be the reason for delayed onset of muscle soreness (DOMS).

Now try this

Jermaine is a middle distance runner and Jill is a weightlifter. How would their muscular systems respond to exercise?

Aerobic adaptations

You need to know the **long-term** changes to the muscular system due to regular aerobic training. These changes are lasting, provided you do not stop **regular** aerobic training.

Regular aerobic training includes activities that involve the use of large muscle groups, for example jogging, swimming, cycling, dancing and cross-country skiing.

regular aerobic exercise → muscular system adapts due to extra work → body finds it easier to complete exercise → can increase training load as can now work harder for longer → regular aerobic exercise

As the muscular system adapts, the aerobic training load can be increased.

Mitochondria

Mitochondria are found in the muscle cells and, with the use of oxygen, generate energy. Regular aerobic training increases the size and number of mitochondria. This means that even more energy can be produced aerobically, allowing the performer to sustain exercise for longer.

Improved use of energy sources

Greater amounts of energy can be released to the muscles for physical work due to increased:

- activity of enzymes that break down our food
- use of glycogen
- use of fat
- stores of glycogen
- stores of triglycerides.

Increased myoglobin content

Myoglobin is similar to haemoglobin, but rather than in the blood it is found in the muscle cells. Its job is to act as an oxygen store in the muscle. With more myoglobin, more oxygen can be transported to the mitochondria, improving aerobic energy production.

Function of adaptations

Most of these adaptations increase the muscles' ability to produce and utilise energy aerobically, in other words, the adaptations allow the performer to work harder, for longer, improving their performance in aerobic, endurance-based activities.

Links You can revise energy systems on page 35.

Now try this

Becky is often substituted in the final quarter when she plays netball. Explain **one** way aerobic training could reduce the likelihood of Becky being substituted in a netball match.

Had a look ☐ Nearly there ☐ Nailed it! ☐

Anaerobic adaptations

You need to know these five **long-term** changes to the muscular system. These changes are lasting, provided you do not stop **regular** anaerobic training.

Anaerobic training

Adaptations as a result of anaerobic training will target the fast twitch muscle fibres:

- type IIa
- type IIx.

This is because these will be the fibres being used to complete the training. Slow twitch muscle fibres would remain unchanged.

Muscle hypertrophy of fast twitch fibres can be brought about by resistance training using heavy loads and few repetitions.

Links You can revise fast twitch fibres on page 17.

1 Hypertrophy of fast twitch muscle fibres

As the muscle is stressed during exercise, microtears form in the myofibrils. This stimulates specialised muscle cells called satellite cells to multiply and to fuse with the existing myofibril, helping to repair the damage. As these cells fuse to the existing cells the fibre increases in size rather than generating new fibres. The increased size of the muscle means it becomes stronger and able to apply greater force.

2 Increased tendon strength

As the muscles become larger and stronger, the tendons that attach the muscle to the bone also have to adapt so that they can manage the increased force of the contraction of the larger muscle, otherwise the player will become injured. This is achieved by an increase in collagen, adding to the existing collagen fibres that make up the tendon.

3 Increased tolerance to lactate

Lactate threshold is the point at which lactate starts to accumulate in the blood – the moment that the body switches from working aerobically to anaerobically. Therefore, the longer you can remain under this threshold the longer you can use the aerobic energy system. Anaerobic training at about 85 to 90 per cent of maximum heart rate for 30 minutes will improve your body's ability to tolerate lactic acid / lactate (enhancing aerobic performance).

4 Increased energy stores

Increased levels within the muscles of:

- ATP
- PC.

ATP is our way of storing small amounts of energy in the muscle so that it can contract when we need it to. We can break down PC to rebuild ATP once it has been used. By increasing the stores of these, we increase the muscles' ability to work quickly.

5 Improved use of energy sources

The muscles get better at breaking down glycogen (even without oxygen) so they can exercise at a high intensity for longer. This is helped by their ability to **buffer** (neutralise) lactic acid more effectively.

Note the references to energy. The muscular and energy systems work together; the training causes adaptations to both of these systems.

Now try this

Igor uses interval training to improve his time in the 200 metres sprint. Explain **one** way Igor's muscle adaptations to this type of training could help him increase his speed.

Additional factors

You need to understand the additional factors affecting the muscular system and their impact on exercise and performance.

Age

Muscle deteriorates with age. As we get older we lose a percentage of our strength. This varies from person to person, but the average loss of muscle mass is approximately 30 per cent between the age of 50 and 70. The rate of loss increases after this age.

Implications for performance

Loss of muscle is accelerated by a sedentary lifestyle. If we remain active and follow an appropriate strength training programme, the effects of aging can be reduced. Clearly if our performance relies on strength, it will deteriorate due to reduced muscle as we age.

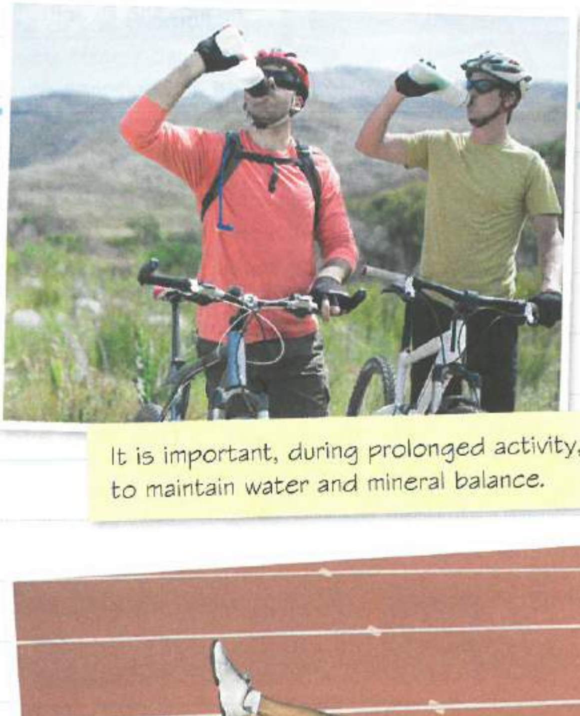
Cramp

Cramp is a sudden, strong contraction of a muscle. It can last for a few seconds or minutes and is very painful. You have no control over the muscle whilst it is experiencing cramp. Because the muscle fibres have contracted and shortened, a hard mass of muscle fibres will form under the skin.

Causes of cramp

Possible causes of cramp include:

- overuse of the muscle, such as during extra time in a football match
- dehydration, such as a lack of fluid intake during a long run
- holding a position for a long time, such as a balance in gymnastics
- mineral depletion, such as a lack of calcium in the diet.



It is important, during prolonged activity, to maintain water and mineral balance.

Implications for performance

In order to avoid cramp, performers must make sure they:

- remain hydrated
- maintain an appropriate electrolyte balance.

It is important to maintain the correct level of minerals. Performers need to factor this in to their training and performance, especially if they take part in endurance activities.

It is important to stretch before and after exercise to reduce the risk of cramp. If a performer suffers with cramp during an activity they will need to:

- stop exercising due to the discomfort
- stretch
- massage the affected muscle.

This should relieve the cramp so they are able to start exercising again.

Cramp often occurs in the legs, but can occur in any skeletal muscle.

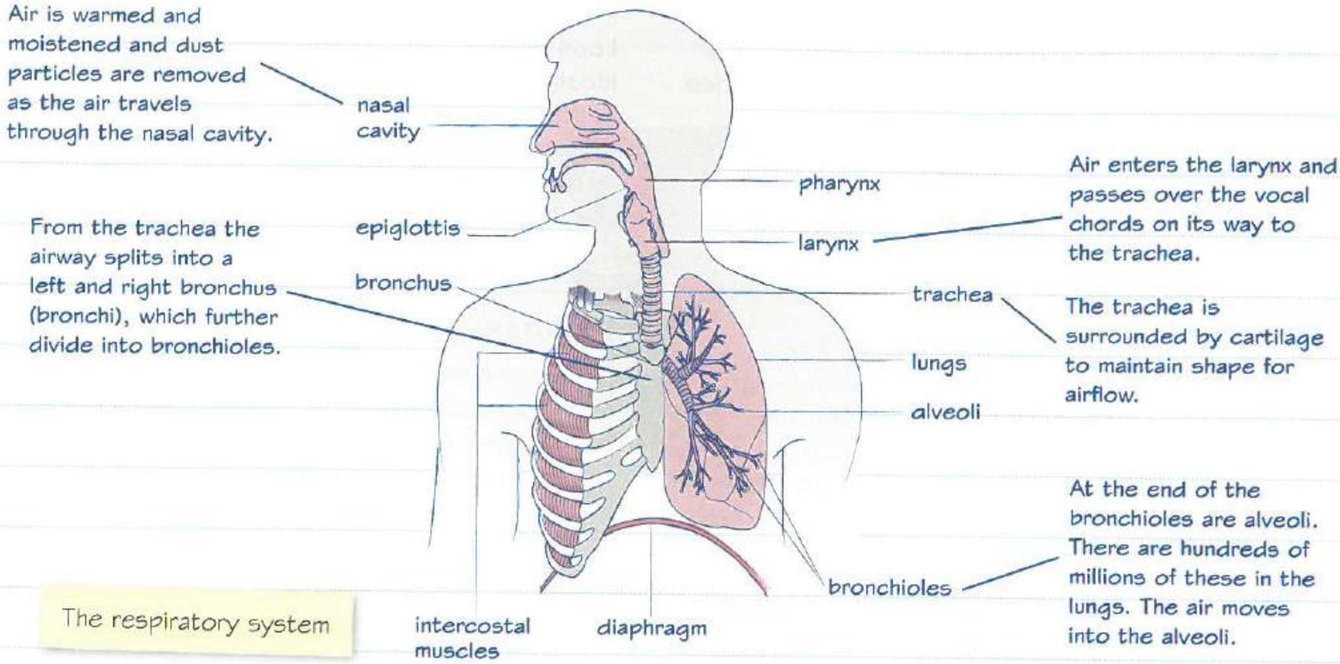
Now try this

How can you reduce the likelihood of cramp occurring in a long distance race?

Had a look ☐ Nearly there ☐ Nailed it! ☐

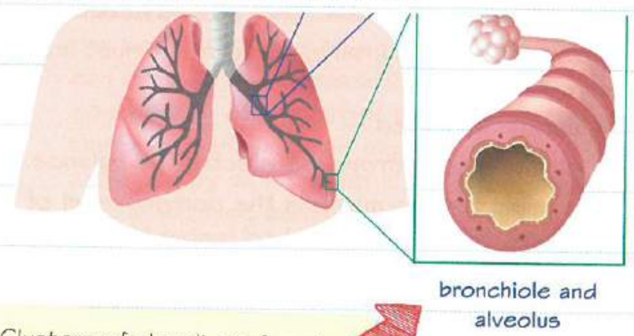
The respiratory system

You need to know the names and location of the main components of the respiratory system. These are vital in ensuring we can exercise.

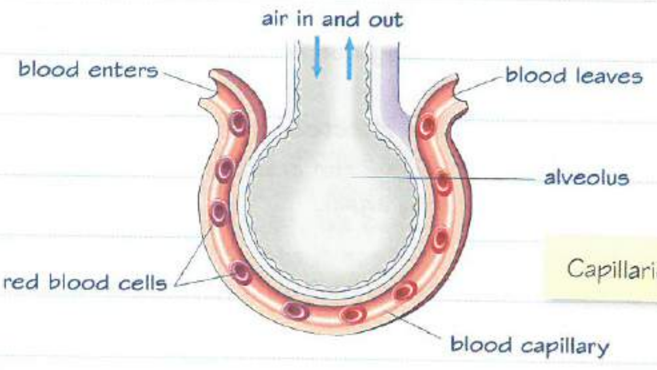


The respiratory system

Bronchiole and alveoli



Clusters of alveoli are found at the end of each bronchiole.



Capillaries surround the alveoli.

The capillaries

The capillaries are part of the cardiovascular system. They work with the alveoli in the respiratory system to make sure that oxygen from the air is transported to the working muscles so that energy can be released for exercise. If there were no way to get air into the body, the cardiovascular system would not have any oxygen to transport and therefore could not release aerobic energy for exercise.

Links Go to pages 28–34 to revise the cardiovascular system.

Now try this

Describe the passage of air through the respiratory system.

Respiratory function

You need to know the function of the respiratory system in supporting exercise and sporting performance.

Thoracic cavity

The thoracic cavity is the area inside the chest from the base of the neck to the diaphragm. It contains the heart and lungs, protected by the ribs and sternum.

The diaphragm and the internal and external intercostal muscles attach to the ribs. Therefore, when these muscles contract they move the rib cage. This means that the volume of the thoracic cavity can be altered.

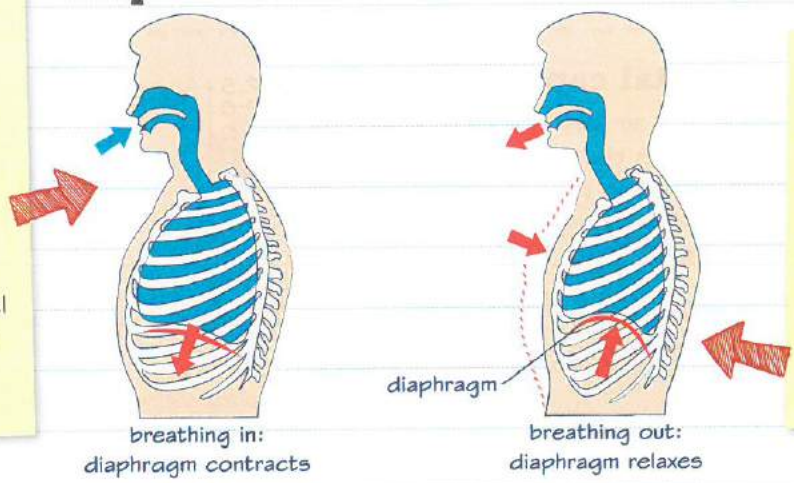
Inspiration and expiration

During **inspiration**, the thoracic cavity increases in size allowing the lungs to expand and the pressure within them to drop compared to outside. Inspiration causes air to enter the lungs.

During **expiration**, the thoracic cavity decreases in size, reducing the size of the lungs so the pressure increases in the lungs, compared to outside. Expiration causes air to leave the lungs.

Respiration

During inspiration the diaphragm and external intercostal muscles **contract** to increase the area of the thoracic cavity. Note how the diaphragm flattens as it contracts, and how the external intercostal muscles raise the ribs and sternum to allow the lungs to expand.

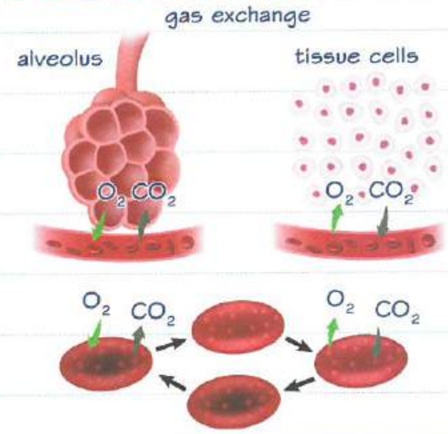


During forced expiration, the diaphragm and external intercostal muscles relax, and the internal intercostal muscles contract. This causes a decrease in the size of the thoracic cavity and lungs.

Gas exchange

In order to generate energy for sustained activity we need oxygen to get to the muscles. We also need to remove the carbon dioxide that has been produced by the muscles. We need to exchange gases:

- in – oxygen
- out – carbon dioxide.



Oxygen concentration in the alveolus is high, but it is low in the blood, so the oxygen leaves the area of high concentration for the area of low concentration. Carbon dioxide levels are high in the blood so leave for the alveolus where concentration is lower.

Gases exchange when there is a diffusion gradient; when there is a difference in concentration in one area compared to another. Gas moves from an area of high concentration to low concentration.

Now try this

(a) Why is there a higher concentration of oxygen at the alveolus?

(b) What would you expect to happen to the diffusion gradient during exercise?

Lung volumes

You need to know about the different lung volumes and the changes that occur to some lung volumes in response to exercise and physical activity.

Pulmonary ventilation (VE)

In order to exercise we need oxygen.

↓

We get the oxygen from the air we breathe.

↓

It is the job of the respiratory system to:

↓ take air into the body ↓ extract some of the oxygen from it.

↓

The process of moving air into and out of the lungs is called pulmonary ventilation.

Lung volumes

You need to be aware of four different lung volumes:

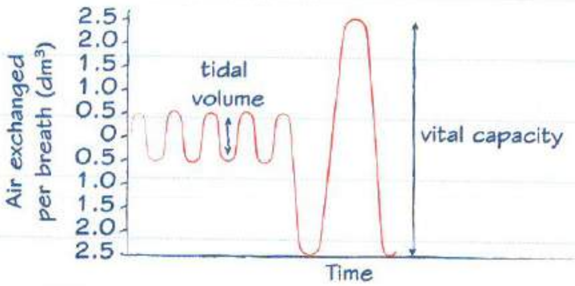
- tidal volume
- vital capacity
- residual volume
- total lung volume.

Each type of lung volume is used to describe the capacity of the lungs at a particular time.

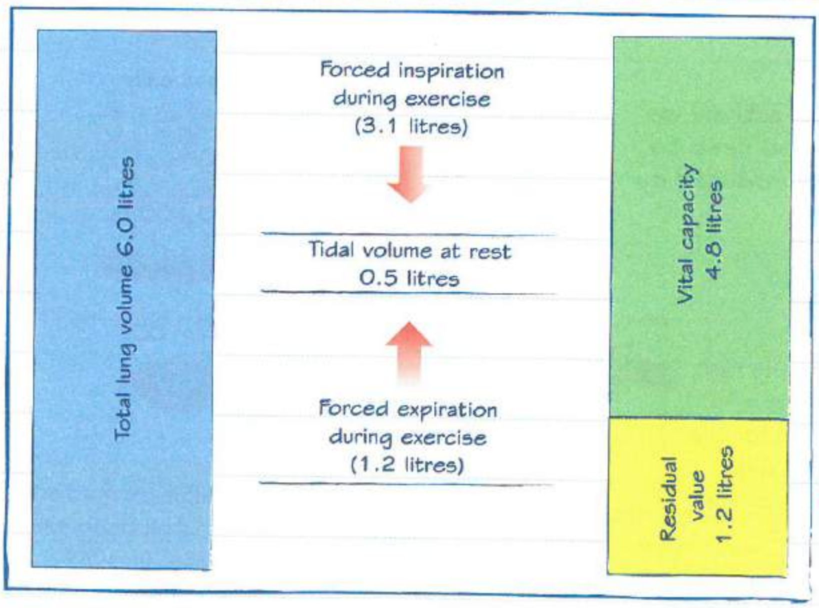
Tidal volume and vital capacity

Tidal volume is the amount of air inspired or expired in a normal breath when the person is at rest. It is the amount of air the person can breathe in or out without forcing their breathing. On average this is 0.5 litres.

Vital capacity is the volume of air that can be inspired or expired per breath, including forced breathing. Vital capacity can be as much as 4.8 litres.



Vital capacity is greater than tidal volume.



Lung volumes at rest and during exercise

Residual volume and total lung volume

Residual volume is the amount of air left in the lungs even after forced breathing out. This volume of air cannot be breathed out. It prevents the lungs from collapsing. The average residual volume is approximately 1.2 litres.

Total lung volume is vital capacity and residual volume, therefore on average 6.0 litres.

Now try this

Which lung volumes alter when a performer begins to exercise?

Control of breathing

You need to understand how you control your breathing rate in response to exercise.

Oxygen for energy production

When you exercise you need more oxygen than at rest for increased energy production. Therefore, you need a way to control your breathing rate so that you can:

✓ increase it when you need more oxygen, such as when you exercise

✓ slow it down when there is no longer an increased demand, after you have recovered from exercise.

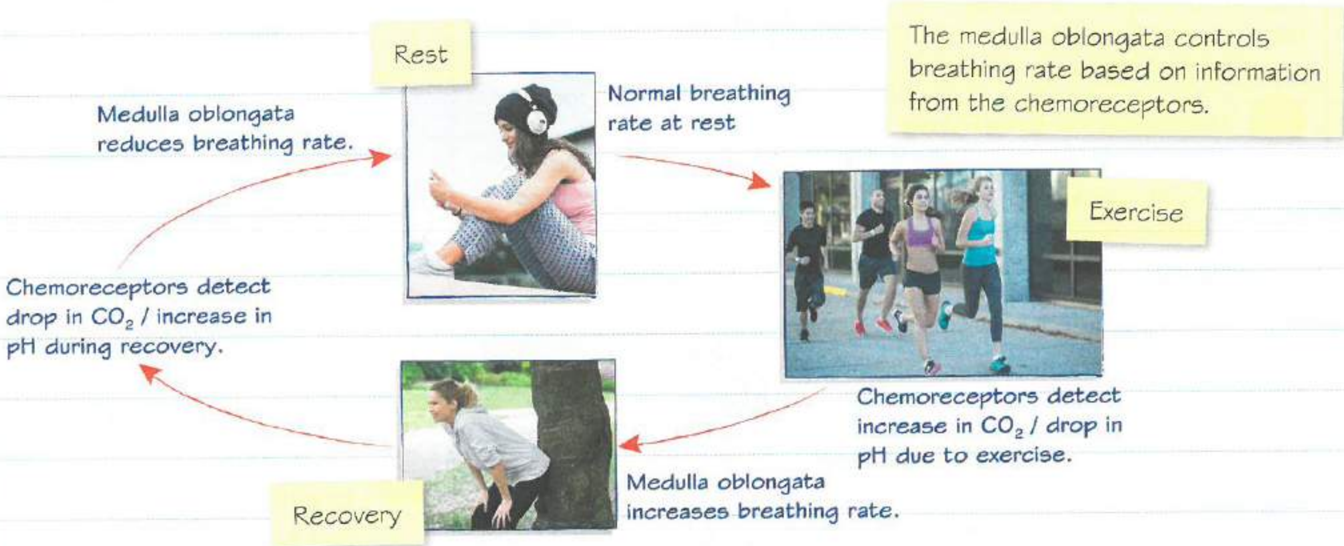
You control your breathing rate through neural and chemical control.

Links Go to page 23 to revise the role of the diaphragm and intercostal muscles.

The medulla oblongata

- is found in the brain stem, just above the spinal cord
- contains nerve fibres
- is responsible for autonomic nervous activity (i.e. things we do not consciously control such as breathing rate and sneezing)
- is the respiratory centre transferring messages to and from the spinal cord and the brain.

These messages control the action of the diaphragm and intercostal muscles, and therefore the rate of breathing.



Inspiration and expiration

During inspiration nerve impulses are sent to:

- the external intercostal muscles and
- the diaphragm.

This causes the muscles to contract, increasing the size of the thoracic cavity so that air enters the lungs. During expiration nerve impulses are no longer sent to these muscles, so they stop contracting and relax; decreasing the size of the thoracic cavity.

Adjusting breathing rate

The medulla oblongata knows when to alter breathing rate based on information from the chemoreceptors. Chemoreceptors monitor the chemical content of the blood; in particular, levels of carbon dioxide (CO_2) and the acidity (pH) of the blood.

During exercise, nerve impulses may also be sent to the **internal** intercostal muscles to speed up expiration.

Now try this

Jus and Jo run the 100 metres sprint. After the event their breathing rate is twice as high as it normally is at rest. How was their breathing rate controlled to bring about this increase?

Responses and adaptations

You need to know the short-term responses and long-term adaptations of the respiratory system to exercise.

Impact on sport and exercise performance

The respiratory system responses and adaptations increase oxygen availability and carbon dioxide removal to make participation in physical exercise and sport possible.

Short-term responses

These are the **immediate, short-term** ways that the respiratory system reacts when you exercise. The reactions are **short lived**: when you stop exercising, the respiratory system has no need to continue to react to exercise and therefore stops and slowly recovers back to its pre-exercise state.

1 Increase in breathing rate

During normal breathing, whilst at rest, we breathe in and out approximately 12 times per minute, but this can increase to 45 times per minute during intense exercise, or as much as 70 times per minute for an elite athlete.

2 Increase in tidal volume

At rest, our tidal volume (air taken in per breath) is approximately 500 ml but this can increase during exercise.

A combination of increased rate of breathing and tidal volume means we can increase the volume of air moving into and out of the lungs from approximately 6 litres per minute at rest to 60 litres per minute whilst performing moderate exercise. This is higher if exercise is more intense.

The increased air means that plenty of oxygen is available for transport to the muscles.

Short-term responses and long-term adaptations provide performers with more oxygen for exercise or a quicker recovery period after exercise.

Long-term adaptations

These are the long-term, sustained changes to the respiratory system resulting from the additional stress placed on the respiratory system due to regular exercise.

1 Increased strength of the respiratory muscles

Through increased use, the diaphragm and the external intercostal muscles will become stronger. This means they will be able to contract more forcibly, increasing the size of the thoracic cavity so that a greater volume of air can be taken in to the lungs.

2 Increased vital capacity

Due to the increase in size of the thoracic cavity, vital capacity increases.

3 Increase in oxygen and carbon dioxide diffusion rate

This is due to an increase in the number of capillaries, as a result of training, allowing more efficient gaseous exchange.

Links Go to page 24 to revise lung volumes.

Now try this

How does the respiratory system respond to a single exercise session?

Unless further detail is given in a question, a 'single exercise session' is a general description of any training session.

Additional factors

You need to understand the additional factors affecting the respiratory system and their impact on exercise and performance.

Asthma

Asthma is a health condition that affects the lungs, in particular the bronchi. The airways into the lungs are inflamed and easily irritated by a variety of asthma triggers, such as smoke, pollen, dust or stress. When this happens:

- the smooth muscle around the walls of the airways tightens, reducing the size of the airway
- the lining of the airway becomes more inflamed and starts to swell
- phlegm can build up to narrow the airway further.

These reductions in the size of the airway make it difficult to breathe and will lead to wheezing, coughing and tightness in the chest.

Asthma: impact on exercise

✓ Exercise can induce an asthma attack.

✓ There is reduced oxygen delivery to the muscles due to reduction in air getting to the lungs, and a drop in aerobic performance or speed of recovery.

Impact of regular exercise on asthma

The performer would benefit from the training adaptations caused by regular training, in particular:

✓ increased strength of the respiratory muscles

✓ increase in vital capacity

✓ increase in oxygen and carbon dioxide diffusion rate.

All of these would help to reduce the effects of asthma.

Partial pressure

Partial pressure tells us how much of a particular gas is present. Oxygen moves from high pressure (in the alveoli) to low pressure (in the capillaries), until the pressures are equal. Provided the concentration of oxygen is greater in the alveoli than the capillaries, oxygen will leave the lungs for the blood stream. The greater the difference in concentration, the faster the rate of diffusion.

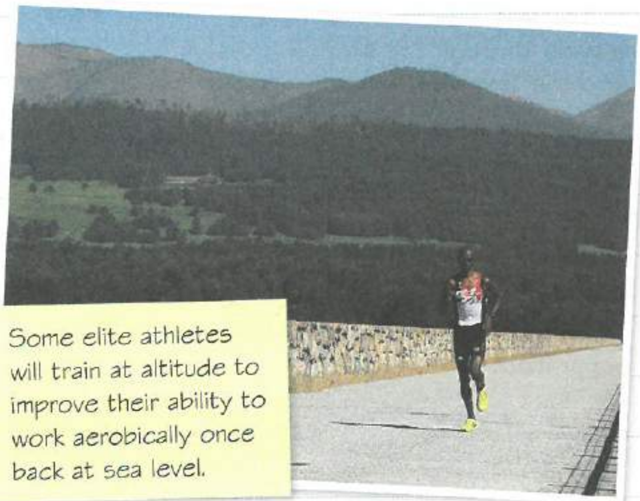
Effects of altitude

At 2400 m above sea level we are said to be at high altitude. At high altitude the partial pressure of oxygen is less than at sea level, so, although we will breathe in the same quantity of air, there will be less oxygen available in this air for our bodies to extract and transport to the muscles. As the partial pressure of oxygen drops, the amount of oxygen carried by the haemoglobin in red blood cells also drops.

Altitude: impact on exercise

With less oxygen available, the body cannot work at the same level of intensity, therefore performance levels will drop as athletes will experience muscle fatigue more rapidly.

This is why elite athletes will train at altitude (or mimic training at altitude) before major competitions so that their bodies can adapt, increasing the body's red blood cell count. This allows the athlete to transport more oxygen, off-setting muscle fatigue so they may work harder for longer in aerobic events.



Some elite athletes will train at altitude to improve their ability to work aerobically once back at sea level.

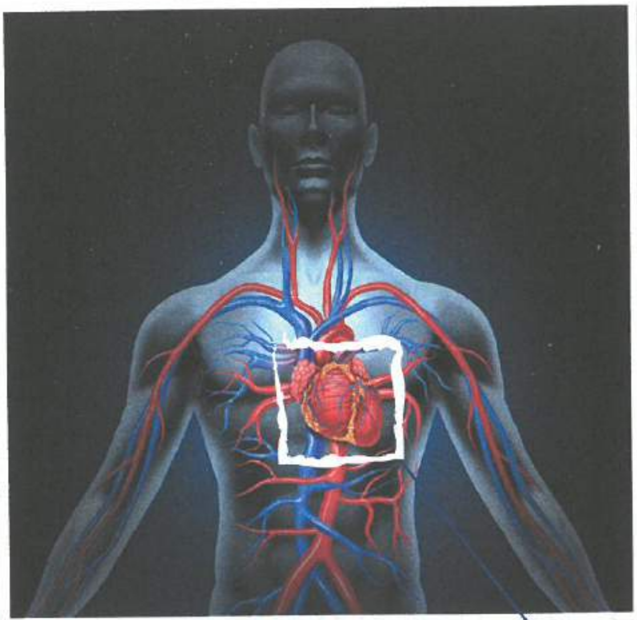
Now try this

Why would sports performers train at altitude before a major competition at altitude?

Had a look ☐ Nearly there ☐ Nailed it! ☐

The cardiovascular system

You need to know the names and location of the main components of the cardiovascular system as these are vital in ensuring we can exercise.



The cardiovascular system

- The cardiovascular system is made up of the heart, blood vessels and the blood.
- Blood is circulated around the body due to the pumping action of the heart.
- The heart is a muscle and therefore requires a blood supply. Blood is transported to the heart muscle via the coronary arteries, which cover the surface of the heart.
- The valves in the heart prevent the backflow of blood within the heart.

Blood flow

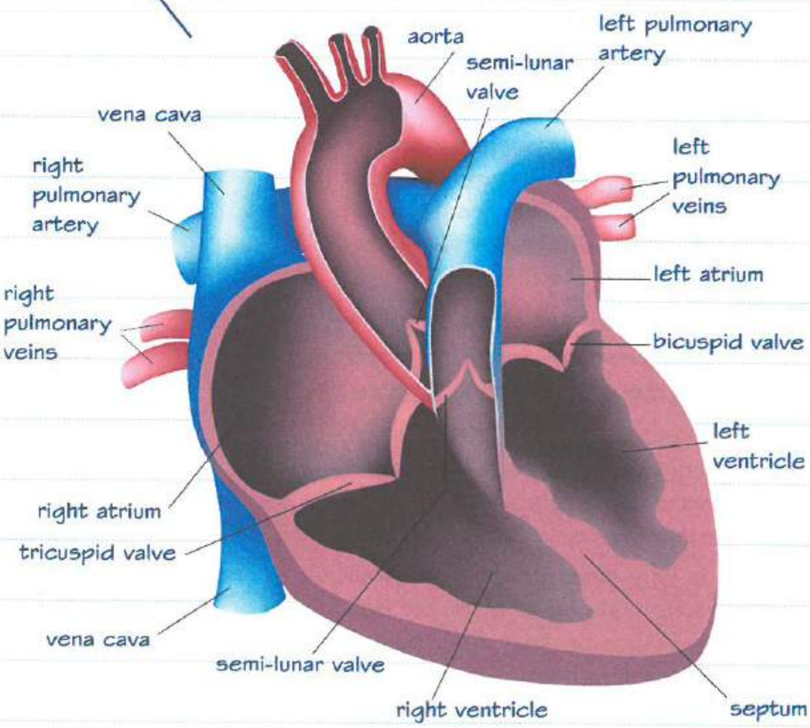
Deoxygenated blood passes from the **vena cava** to the **right atrium**. From here it travels through the **tricuspid valve** into the **right ventricle.** Deoxygenated blood leaves the right side of the heart, passing through the **semi-lunar valves** into the **pulmonary artery** to travel to the lungs.

Oxygenated blood from the lungs passes through the **pulmonary vein** to the **left atrium**. From here it travels through the **bicuspid valve** into the **left ventricle.**

Oxygenated blood leaves the left side of the heart, passing through the **semi-lunar valves** into the **aorta** to travel to the body.

The septum divides the heart into left and right sides, keeping the blood in these areas of the heart separated.

Internal anatomy of the heart



Blood flow is controlled by the pumping of the heart and the use of valves.

Now try this

Describe the passage of blood from the vena cava through the right side of the heart towards the lungs.

Blood and blood vessels

You need to know about the components of blood and the structure and function of the different blood vessels.

Blood

Blood is composed of plasma, red blood cells, white blood cells and platelets. Blood travels around the body through the blood vessels.

Blood vessels

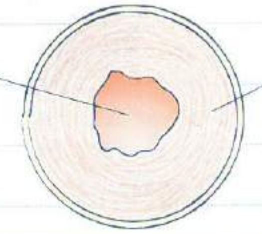
Each type of blood vessel is designed so that it can perform its function effectively. The blood vessel types you need to know are: arteries, arterioles, capillaries, venuoles and veins.

1 Arteries:

- always carry blood **away** from the heart
- always carry oxygenated blood, with the **exception** of the pulmonary artery, which takes deoxygenated blood away from the heart to the lungs
- are elastic, so they can accommodate changing volumes of blood passing through them
- have muscular walls that can contract to maintain blood pressure when there is a reduction in blood flow.

2 Arterioles

Arterioles link arteries with capillaries. They have similar properties and functions to arteries. However, they have thinner muscular walls as blood is not at such a high pressure as they are further from the force of contraction of the heart. Their muscular walls allow the arteriole to control blood flow into the capillary, vasodilating to increase blood flow during exercise and vasoconstricting to reduce blood flow when resting.

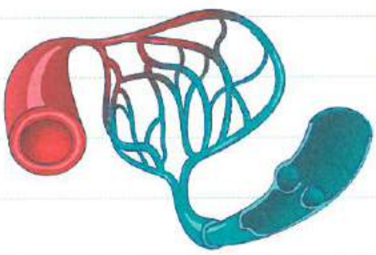


Arteries have thick muscular walls as the blood they carry is at high pressure. The pressure of the blood is high as it has just been expelled from the heart.

Links Go to page 30 to revise vasoconstriction and vasodilation.

3 Capillaries

Capillaries are one cell thick, allowing exchange of gases, nutrients and waste products between the blood in the capillary and the surrounding tissue. Blood pressure in the capillary is lower than in arterioles, but higher than venuoles.



Capillaries link the arterioles and venuoles.

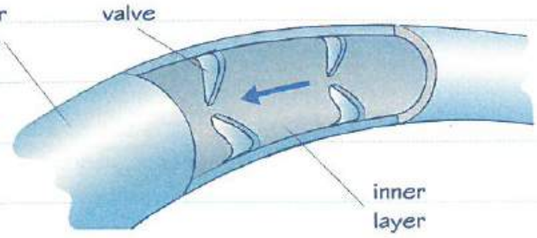
4 Venuoles

Although small, these are larger than capillaries. They carry deoxygenated blood and take the carbon dioxide from the capillary and transport it to the veins.

5 Veins

Return deoxygenated blood to the heart (with the exception of the pulmonary vein, which carries oxygenated blood). Blood flows slowly through veins. Blood is moved along the vein via the skeletal-muscle pump.

Blood in veins is under low pressure so they need valves to stop the back flow of blood.



Now try this

Which type of blood vessel controls blood flow to the capillaries?

Had a look ☐ Nearly there ☐ Nailed it! ☐

Functions of the cardiovascular system

Many of the functions of the cardiovascular system are carried out by the components of the blood. You need to know the function of plasma, red blood cells, white blood cells and platelets, and how they support sport and exercise performance.

The functions of the cardiovascular system are:

- the delivery and removal of nutrients and waste
- thermoregulation
- vasodilation and vasoconstriction
- to clot blood
- to fight infection.

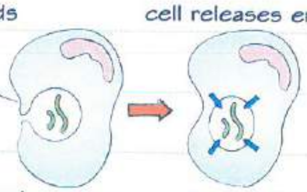
Plasma is needed to transport essential nutrients to the muscles so there is energy for exercise.

Functions of the blood

Plasma is the liquid part of blood. It is 90 per cent water. Plasma makes it possible to carry the blood cells, nutrients, gases and waste products around the body. Without plasma, these rugby players would not be able to:

- circulate the required oxygen, carried by the red blood cells, that is vital in energy production for exercise
- transport carbon dioxide and lactate, produced during exercise. Carbon dioxide is transported to the lungs to be breathed out of the body. Lactate is transported to the liver.

White blood cells



White blood cells keep the performer healthy by fighting infection so they do not need a break from training.

Platelets

Platelets prevent blood loss. During contact sports such as rugby and boxing, players may receive a cut. Blood will flow from a cut until the site is blocked. Platelets will gather, sticking to each other to form a plug at the site of the injury. The platelets also stimulate fibrin (a blood protein) to form a sticky net trapping red and white blood cells, so a clot is formed and the skin is resealed, stopping blood loss. As soon as blood loss is stopped, the player is allowed to re-join the game.

Thermoregulation

It is important that we keep our body temperature at, or close to, 37°C. This is so the reactions in our body, for example those required for energy production, can work at an optimum level. During exercise, when we need efficient energy production, we generate heat. The cardiovascular system helps us lose this excess heat through vasodilation.

The vessels do not move or increase in size; it is the space within the vessel that alters.

Vasoconstriction and vasodilation

Smooth muscle in the walls of the arterioles near to the surface of the skin relax, causing the arteriole to vasodilate. This increases blood flow through these vessels so that a greater amount of blood can pass near the skin and lose heat.

If we need to maintain heat, for example, if exercising in a cold environment, the blood vessels near the surface of the skin will vasoconstrict, reducing blood flow and heat loss.

Now try this

State **four** functions of the cardiovascular system.

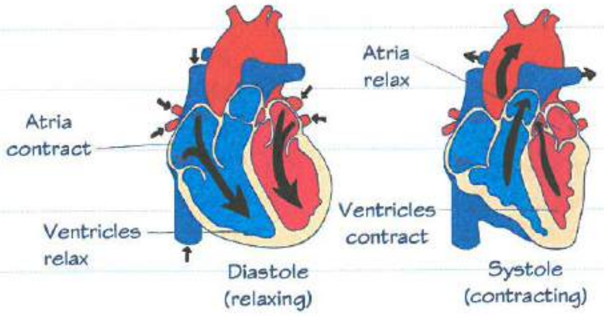
Cardiac cycle

You need to know about the cardiac cycle and its control to allow changes in heart rate during sport and exercise.

Blood movement through the heart

Blood movement through the heart is controlled by muscular contraction of the walls of the chambers of the heart and one-way valves.

The atria contract, forcing blood through the bicuspid and tricuspid valves, into the ventricles, which are relaxing so they can fill with blood. This is diastole.



The atria relax, the bicuspid and tricuspid valves close, the ventricles contract, forcing blood through the semi-lunar valves, out of the heart into the main arteries (the pulmonary artery or aorta). This is systole. During this time the atria are refilling with blood for the next cardiac cycle.

Cardiac cycle is the term given to the events that take place in the heart each time the heart beats. It includes diastole and systole.

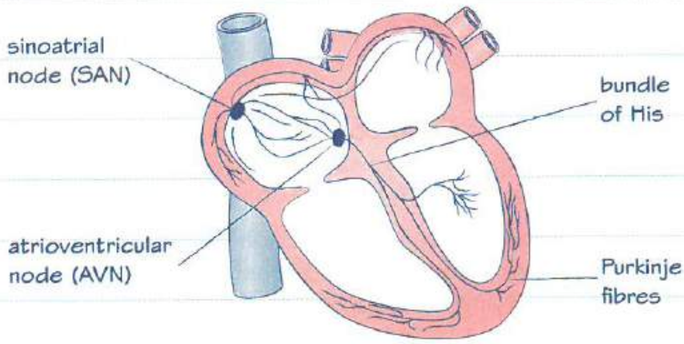
Varying the cardiac cycle

Each heartbeat contains a cardiac cycle. The rate the heart beats is controlled by the nervous system. We need to regulate our heartbeat so our cardiovascular system can carry out its functions. The sympathetic nervous system causes the heart rate to increase during exercise; after exercise the heart rate slows down due to the parasympathetic nervous system.

We need to be able to vary heart rate depending on the intensity of exercise.

Control of the cardiac cycle

The sinoatrial node acts as a pacemaker; it initiates the heartbeat. It transmits electrical impulses causing the atria to contract. Each electrical impulse is detected by the atrioventricular node and passed to specialised cardiac muscle fibres called the bundle of His. These muscle fibres conduct the impulse throughout the muscular walls of the ventricles. The Purkinje fibres receive these electrical impulses and signal both ventricles to contract.



The sympathetic nervous system sends messages to the SAN to increase heart rate, for example during exercise.

Now try this

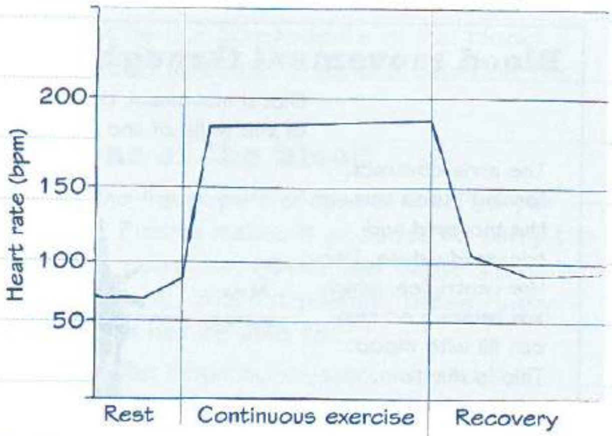
What effects do the sympathetic and parasympathetic nervous systems have on heart rate?

Responses

You need to know these five short-term responses of the cardiovascular system to exercise.

Changes in heart rate when exercising

- **Anticipatory rise** – an increase in heart rate just before the start of physical activity. It is caused by the release of adrenalin into the blood.
- **Increased heart rate** – to speed up oxygen delivery and carbon dioxide removal during exercise.



Resting, working and recovery heart rates, before, during and after exercise.

Increased blood pressure

Blood will be flowing at a faster rate due to the increase in heart rate. Also, the heart will contract more forcibly to squeeze more blood out. This will cause a temporary increase in systolic blood pressure.

Links Go to page 34 to revise blood pressure.

Increased cardiac output

Cardiac output is the amount of blood leaving the heart per minute. It is calculated by multiplying heart rate by stroke volume.

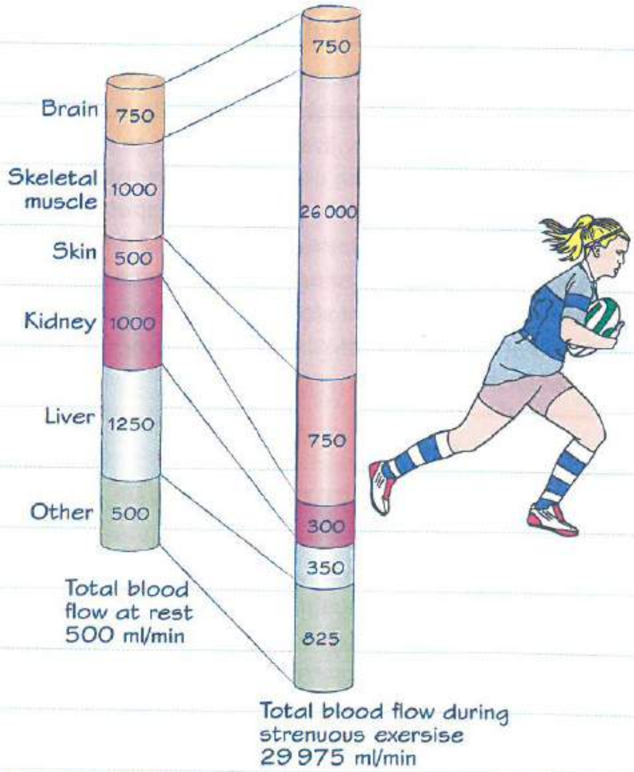
Stroke volume is the amount of blood leaving the heart per beat. If either heart rate or stroke volume increase, cardiac output will increase.

Redirection of blood flow

When we exercise we need more oxygen for greater energy production. This increase in energy production increases waste products that need removing from the body. The body satisfies these demands by:

- increasing cardiac output
- redirecting blood flow so that the majority of the circulating blood goes to the areas of the body that need it most.

This is achieved through vasodilation of arterioles supplying active areas and vasoconstriction of arterioles supplying inactive areas.



Increased cardiac output and redirection of blood flow allows a much greater flow of blood to the working muscles during exercise.

Links Go to page 30 to revise vasoconstriction and vasodilation.

Now try this

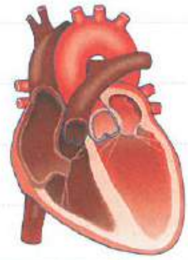
Why does the body redirect blood flow during exercise?

Adaptations

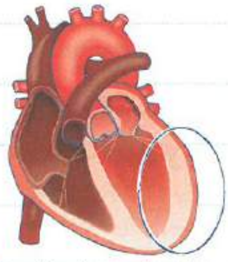
You need to know the long-term adaptations of the cardiovascular system to regular exercise and the impact of these adaptations on subsequent performance.

1 Cardiac hypertrophy

Hypertrophy means muscle cell enlargement, i.e. an increase in the size of a muscle. Cardiac hypertrophy means this increase is taking place in heart muscle.



Untrained heart



Cardiac hypertrophy

Cardiac hypertrophy will increase the thickness of the left ventricle wall, allowing the heart to contract with greater force.

2 Stroke volume increases

Stroke volume increases as the muscular walls of the heart undergo cardiac hypertrophy. Therefore, more blood can be ejected from the heart per beat. This is true at rest and during exercise.

3 Resting heart rate decreases

If we increase our resting stroke volume, we do not need the heart to beat as often to achieve the required cardiac output at rest.

4 Decreased heart rate recovery time

Heart rate remains elevated after exercise to aid recovery. However, due to an increased stroke volume, a high level of blood can still be circulated without the need for a very high heart rate. Therefore, heart rate will return to resting levels sooner.

5 Capillarisation

This is the development of the capillary network in the body. Capillary density is increased in skeletal muscle and around the alveoli in the lungs. The increase in capillary density means that a greater volume of blood can flow through the body, ensuring a good supply of oxygen and nutrients to the tissues, and removal of carbon dioxide.

7 Reduction in resting blood pressure

This is one of the reasons why exercise is said to be good for us. By dropping resting blood pressure, we reduce the risk of heart-related ill health. Several factors contribute to a drop in resting blood pressure:

- cardiac hypertrophy
- increased nitric oxide release, which vasodilates the blood vessels
- increased plasma volume.

6 Increase in blood volume

Blood volume is a measure of the amount of plasma and red blood cells circulating around the body. Initial increases in blood volume are due to an increase in plasma, although maintenance of training can also result in an increase in red blood cells. The increase in blood volume improves oxygen delivery and temperature regulation.

As the volume of blood plasma increases to a greater extent than the number of red blood cells within it, the viscosity of the blood will not increase; it may even reduce. If blood viscosity does reduce it will decrease its resistance to blood flow, therefore contributing to a reduction in resting blood pressure.

Viscosity – how thick a liquid is.

Now try this

Why does resting heart rate decrease if resting stroke volume increases?

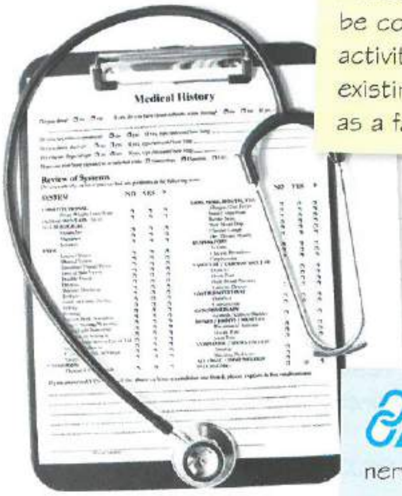
Energy systems: additional factors

You need to understand the additional factors affecting the cardiovascular system and their impact on exercise and performance.

Sudden arrhythmic death syndrome (SADS)

SADS results in sudden death, normally in people under the age of 35. It is caused by cardiac arrhythmia. Cardiac arrhythmia is a condition caused by an irregular heartbeat, it means that the normal rhythm of the heart is altered causing cardiac arrest.

Most cases of cardiac arrhythmia do not result in sudden death. However, as there are often no clear symptoms of SADS, people are likely to have the condition and not know. When these people participate in strenuous exercise, even though they appear fit and healthy, they can die due to SADS.



A medical history form should be completed before increasing activity level. This checks for existing health conditions such as a family history of SADS.

Links Go to page 31 to revise nervous control of the heart.

Blood pressure

As blood passes through the blood vessels it exerts a pressure against the walls of the blood vessel.

The amount of pressure exerted will vary depending on:

- the rate of blood flow
- the size of the internal diameter of the blood vessel.

The faster the blood flows, and the less space available to flow in, the greater the blood pressure.

Blood pressure readings

Blood pressure is expressed as two figures. **Systolic**, when the heart contracts and **diastolic**, when the heart is relaxing.

- normal blood pressure – 120/80 mmHg
- high blood pressure (hypertension) – 140/90 mmHg
- low blood pressure (hypotension) – 90/60 mmHg.

High blood pressure increases the risk of heart attack or stroke. Exercise increases blood pressure during the activity.

Hyperthermia

Hyperthermia is an increase in core body temperature. It can lead to heat cramps, heat exhaustion or heat stroke. When we exercise, we generate heat, which we can normally lose through thermoregulation. However, if we are in a hot environment this becomes more difficult, although appropriate clothing can help.

Hypothermia

Hypothermia is a drop in core body temperature below 35°C. It can occur when exposed to cold, or cold and wet conditions for long periods of time without adequate clothing. In these conditions performers will lose their ability to make decisions or move quickly.

Links Go to page 30 to revise thermoregulation.

Now try this

Why is it important to complete a medical history questionnaire when joining a new sports or fitness club?

The role of ATP

You need to understand the role of ATP for muscle contraction for exercise and sports performance.

Energy

Energy cannot be created or destroyed, but we can change its form. The fats and carbohydrates we eat contain energy. They are our food fuel sources. Once eaten, our body begins to digest these foods, breaking them down into useable forms of energy.

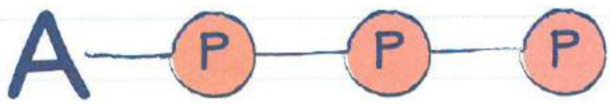
Energy systems

There are three energy systems: ATP-PC, lactic acid system and aerobic system.

Each works in a slightly different way to produce energy from our food fuel sources. All three systems resynthesise (rebuild) ATP.

ATP

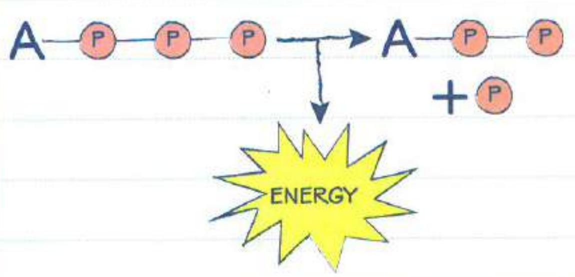
ATP is the accepted abbreviation for adenosine tri-phosphate. It is the chemical form of energy that our body uses for all muscle contractions. Without ATP we would have no energy for movement. A small store of ATP is found in muscle cells so that it is available instantly. It is an immediately accessible form of energy for exercise. ATP stores in the muscle last for approximately two to three seconds so the body needs to find a way to resynthesise ATP so we can work for longer. It does this by using one of the three energy systems.



ATP is made up of one molecule of adenosine and three molecules of phosphate. A for adenosine, T for tri (meaning three), and P for phosphate. Each molecule is bound to another as shown by the blue line.

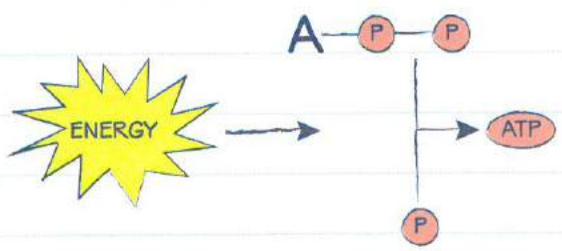
ADP means adenosine di-phosphate. Di means two.

Breakdown of ATP for muscle contraction



The bond joining the final phosphate in the ATP chain breaks, releasing energy, ADP and a single phosphate.

Resynthesis of ATP for future muscle contraction



Energy is provided by one of the three energy systems to rebuild the bond between ADP and a single phosphate to resynthesise ATP.

Now try this

(a) What is ADP?

(b) How long does ATP last in the muscle?

(c) What are the three energy systems used to resynthesise ATP?

The ATP-PC system

You need to understand the role of the ATP-PC system in energy production for exercise and sports performance.

Aerobic and anaerobic activity

Sport and exercise activities are often described as aerobic, anaerobic or a mixture of both. This relates to how much the sport or exercise activity relies on the presence of oxygen for energy production. Those activities requiring oxygen are said to be aerobic, those that depend on energy production without the presence of oxygen are said to be anaerobic.

Anaerobic activities

These types of activities:

- are short in duration
- require the use of fast twitch muscle fibres
- rely on strength, speed or power.

Activities where the performer needs to jump or sprint are anaerobic activities.

ATP-PC

ATP is the chemical form of energy that our body uses for all muscle contractions. There is sufficient ATP in the muscles for approximately 2–3 seconds of work; after this more ATP needs resynthesising (rebuilding). In the ATP-PC system the energy required to resynthesise ATP is provided by phosphocreatine (PC).

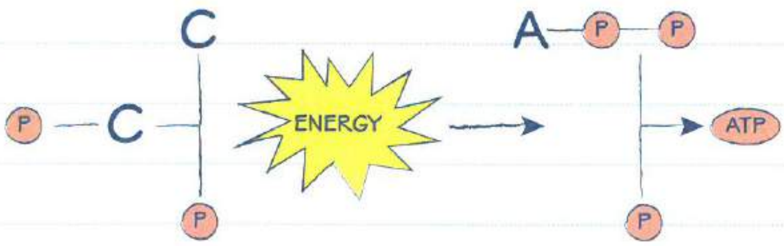
PC is made up of a molecule of phosphate and a molecule of creatine. There is enough PC in the muscle cell to continue to resynthesise ATP for approximately 8–10 seconds of physical work.

Advantages / disadvantages

The advantages of this system are that energy is released quickly and no waste products are formed. The disadvantages are the limited stores of PC and the 2–3 minutes required to fully recover these stores. This means there is insufficient recovery time during play in many sporting situations to recover the PC stores once they have been used.

Recovery time

Once the supply of PC has been broken down to resynthesise ATP, energy is needed from another energy system to resynthesise the PC stores. This energy is provided from the aerobic system.



The chemical bond between the phosphate and creatine molecule breaks, releasing energy that is then used to resynthesise ATP.

Now try this

What type of activity would allow performers a 2–3 minute rest so they could use the PC system again during their competition?

The lactate system

You need to understand the role of the lactate system in energy production for exercise and sports performance.

The lactate system

The lactate system of energy production is anaerobic. This means that oxygen is **not** used in the process. This system produces energy relatively quickly, so it is good for short-duration, high-intensity activities.

The food fuel source carbohydrate is broken down by the body to form glucose. Some of this glucose goes into the blood stream, some is converted to glycogen and stored in the muscle cells and liver.

Anaerobic glycolysis

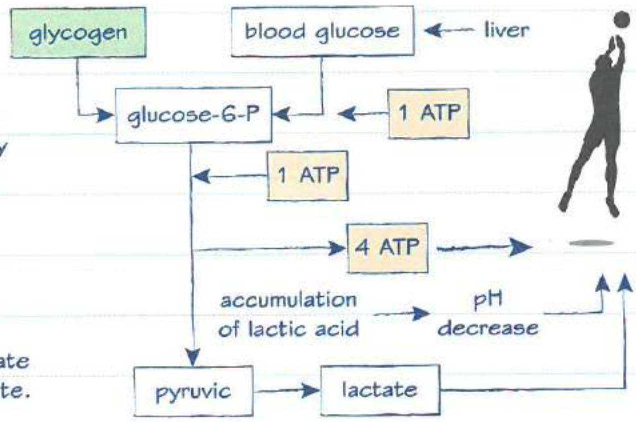
Glucose and glycogen are partially broken down by the lactate system to produce ATP.

ATP is used in this breakdown, but more ATP is produced than used, each molecule of glucose produces two net (additional) molecules of ATP.

Energy can be supplied by the lactate system for approximately 1–2 minutes of intense activity.

Anaerobic glycolysis

Two ATP molecules are used to provide energy for the breakdown of glycogen and glucose (from carbohydrate).



Pyruvate is formed.

Four ATP are produced, giving a net gain of 2 ATP molecules for energy for high-intensity exercise.

Without oxygen, pyruvate is converted into lactate.

Recovery

The lactate produced through this system will accumulate unless there is oxygen available to break it down. As the lactate accumulates it changes the acidity of the blood, reducing the efficiency of muscle contraction, causing muscle fatigue. Therefore, this system can only be used maximally for 1–2 minutes before requiring recovery. A recovery time of approximately 8 minutes will aid the removal of lactate from the muscles and also give time to replace the glycogen stores in the muscles.

Links Go to page 18 to revise lactate accumulation.

The lactate system is used in anaerobic activities that last under 3 minutes but are performed at high intensity, for example a 400 m run or an uphill climb in a cycling race.

Now try this

(a) What is the name of the by-product of anaerobic glycolysis that can lead to muscle fatigue?

(b) Why does this by-product cause muscle fatigue?

Had a look ☐ Nearly there ☐ Nailed it! ☐

The aerobic system

You need to understand the role of the aerobic energy system in energy production for exercise and sports performance.

Aerobic energy production

The aerobic system uses oxygen in energy production. The advantage of this is that it yields large numbers of ATP molecules compared to either of the anaerobic energy systems. This makes it ideal to provide energy for endurance activities. The disadvantage of this system is that releasing the larger quantities of energy involves more chemical reactions. This makes the system slower, and unsuitable for anaerobic activity as it cannot produce the required amount of energy quickly enough for intense activity.

Endurance activities such as long distance cycling, running or swimming rely on the aerobic system for energy production.

Links Go to pages 36 and 37 to revise anaerobic energy production.

The aerobic system

Stored fats and carbohydrates are used as the fuel source for this energy system. They are broken down into glycogen, glucose and fatty acids. There are three main processes within this system.

1. Glycolysis: this is identical to anaerobic glycolysis (see page 37). However, due to the presence of oxygen, pyruvate is broken down later in the process rather than forming lactate. Two net ATP molecules are produced.
2. Krebs cycle (or citric acid cycle) takes place in the mitochondria (see page 19). The pyruvate from anaerobic glycolysis forms Acetyl-CoA, which is broken down, using oxygen to form carbon dioxide and hydrogen. Two ATP molecules are released.
3. Electron transport chain, which is the final part of the process. Hydrogen from Krebs cycle combines with oxygen to form H_2O as a waste product, and 34 molecules of ATP are produced.

Recovery time

The time required for recovery of this system can be a few hours or as long as 2–3 days, depending on the intensity and duration of the exercise and your level of fitness. For example, after a marathon, it may take 2–3 days before your body is ready to run this type of event again.

Energy for exercise

Each energy system is used to generate energy for physical activity. The amount used will depend on the intensity and duration of the activity. For example, in a game of football, the aerobic system provides energy for the majority of the match. However, when a short sprint, a powerful kick or explosive jump is required, one of the anaerobic systems will be used. During a quiet spell in the game where intensity is low the anaerobic systems can be partially recovered from the aerobic system.

Now try this

Why is the aerobic system suited to low-intensity, long-duration activities?

Make sure you consider both parts of the question, low-intensity and long-duration.

Adaptations to energy systems

Regular training will cause adaptations to the energy systems involved in that training. You need to know what the energy system adaptations are and the impact these have on exercise and sports performance.

ATP-PC system adaptations

The ATP-PC system resynthesises ATP through the breakdown of phosphocreatine (PC). Although a very fast energy production system, it is limited by the stores of PC. If the body is able to store more creatine this will allow the ATP-PC system to be used for longer.

A sprinter will be able to delay deceleration in a race, improving their sprint time.

Lactate system adaptations

The lactate system is anaerobic, so produces lactate as a by-product of energy production. Lactate, if left to accumulate, can cause muscle fatigue. This system adapts by building up a tolerance to lactic acid, therefore the muscles do not become fatigued as quickly, extending the length of time this energy system can be used for before needing recovery.

A 400 m runner is able to continue to work at high intensity for longer due to an increased tolerance to lactate. Therefore, they can run faster and for longer, improving their race time.

Aerobic system adaptations

There are three main adaptations:

1. increased ability to use fats as a food fuel source
2. increased storage of glycogen
3. increased number of mitochondria.

Each of these adaptations increases our potential for aerobic energy production. With more fuel available and more sites to break down this fuel aerobically, energy production will be more efficient. This will allow performers to maintain a high level of performance for longer before fatiguing, or a quicker recovery between performances.

Adaptations to the aerobic system allows performers to participate in extreme endurance events, such as the Tour de France where cyclists race approximately 2200 miles in three weeks.

Now try this

(a) How does the aerobic system adapt as a result of long-term training?
(b) Why is this an advantage to the performer?

Had a look ☐ Nearly there ☐ Nailed it! ☐

Energy systems: additional factors

You need to understand the additional factors affecting the energy systems and their impact on exercise and performance.

Diabetes

Diabetes is a common health condition. It is caused by the body's inability to regulate the amount of glucose in the blood.

There is a lack of insulin, or insulin function, so glucose remains in the blood rather than travelling into the cells.

This means blood glucose is too high, and there is insufficient glucose in the cells.

Therefore, diabetes impacts on the amount of energy we can use from the food fuel carbohydrate.

Types of diabetes

1 Type 1 diabetes

This occurs when the body is not able to produce insulin. As the body cannot get energy from glucose it looks elsewhere, breaking down fat and protein. Although those with diabetes are encouraged to exercise, energy production would be limited to the ATP-PC system and the aerobic system unless insulin is injected into the body, or an insulin pump is used.

2 Type 2 diabetes

This is the more common form of diabetes. It develops when not enough insulin is produced by the body, or when insulin is present but is not carrying out its function.

Hypoglycaemic attack

This is when blood sugar falls too low. Although encouraged, participation in sport can increase the risk of having an attack. This is why people with diabetes must monitor glucose levels before and after activity. Those on insulin may need to eat carbohydrates before exercise, during or after to help balance their blood glucose.

Implications for performance

Different sports will have different effects on blood sugar levels. For example, aerobic activity can lower blood glucose, but anaerobic activities can increase it. Having too high or too low blood glucose will negatively affect energy levels and therefore performance.

Diabetes need not impact on sport performance. For example, Sir Steve Redgrave was managing type 2 diabetes when he won his fifth Olympic Gold medal for rowing.

The lactate system in children

This energy system is still developing during childhood, and is not fully developed until around 20 years. This is due to:

- lack of muscle mass
- lower glycogen stores
- fewer essential enzymes required for energy production.

Implications for performance

- Children would not gain much from training anaerobically as their lactate system would not be able to adapt to the training.
- Children are better suited to aerobic exercise as their bodies can adapt and make improvements.

Now try this

Why is it important if you have diabetes to monitor your blood glucose levels before and after activity?

Your Unit 1 exam

Your Unit 1 exam will be set by Pearson and could cover any of the essential content in the unit. You can revise the unit content in this Revision Guide. This skills section is designed to **revise skills** that might be needed in your exam. The section uses selected content and outcomes to provide examples of ways of applying your skills.

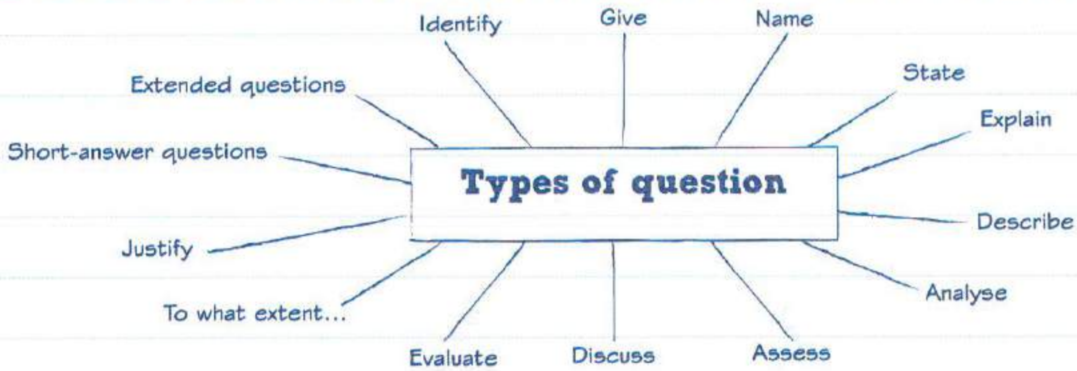
Exam checklist

Before your exam, make sure you:

- ✓ have a black pen you like and at least one spare
- ✓ have double-checked the time and date of your exam
- ✓ get a good night's sleep.

Check the Pearson website

The questions and sample response extracts in this section are provided to help you to revise content and skills. Ask your tutor or check the Pearson website for the most up-to-date **Sample Assessment Material** and **Mark Scheme** to get an indication of the structure of your actual paper and what this requires of you. The details of the actual exam may change so always make sure you are up to date.



Now try this

Visit the Pearson website and find the page containing the course materials for BTEC National Sport. Look at the latest Unit 1 Sample Assessment Material (SAM) to get an indication of:

- the number of papers you have to take
- whether a paper is in parts
- how much time is allowed and how many marks are allocated
- what types of questions appear on the paper.

Your tutor or instructor may already have provided you with a copy of the Sample Assessment Material. You can use these as a 'mock' exam to practise before taking your actual exam.

Had a look ☐ Nearly there ☐ Nailed it! ☐

Command words

Here are some of the skills involved when responding to short-answer and long-answer questions.

Give, name, state, identify, describe

These types of questions are asking for knowledge about a body system, for example, its structure or function, or your ability to apply your knowledge.

As the command word is **'state'**, you do not need to give an explanation, just the name of the muscle responsible for the action.

Worked example

Marvin used free weights to bicep curl as part of his strength training programme.

State the name of the muscle contracting continually during the biceps curl. **1 mark**

Sample response extract

The biceps.

Analyse, assess

These command words can be more demanding, requiring you to look at something in detail, such as the impact of a type of training on a body system, or an analysis of movement.

As the command word is **'analyse'** you must make sure you use the photo, breaking down the movement, identifying how the antagonistic pair work together to allow the diver to achieve the required shape.

Worked example

Analyse how the antagonistic muscle pair at the hip allow the diver to achieve the position shown. **3 marks**

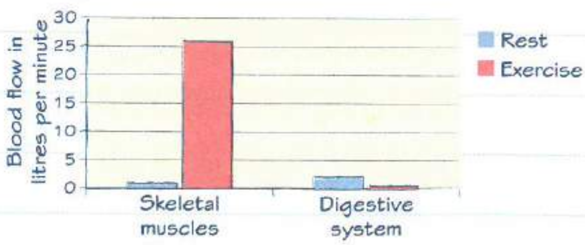
Sample response extract

The muscle pair operating at the hip are the hip flexors and the gluteals. To achieve this shape, the hip flexors are the agonists, contracting to cause flexion at the hip, but this is only possible if the gluteals relax, taking on the role of the antagonistic muscle.

Evaluate, to what extent

These command words require a judgement, based on your knowledge or the information presented in the question, and a conclusion. They are used in long-answer questions.

Graphs and data



Now try this

Using the graph above, explain the changes in blood flow to the muscles and digestive system during physical activity.

Use the information in the graph to help you. Clearly there is an increase in blood flow to the skeletal muscles. Why do we need this increased blood flow during exercise?

Long-answer questions

Here are some examples of skills involved when responding to long-answer questions.

Worked example

Rob plays rugby competitively. Out of season he uses aerobic training to develop his cardiovascular endurance. A sample of Rob's aerobic training programme is shown here. He has three rest days.

Monday	Tuesday	Thursday	Saturday
Fartlek run	Long-distance run	Interval training	Fartlek run

Rob's aerobic training causes adaptations to his muscular system.

Assess the impact of these adaptations on energy production and the effect this will have on his performance in rugby. **8 marks**

Sample response extract

Rob's muscular system will have a greater number of mitochondria in his muscle cells. This is the site of aerobic respiration so his muscles will have more places for energy production, which increases the amount of energy that can be supplied aerobically so that Rob has the supply he needs to continue working to a good level all game.

Rob's myoglobin stores in his leg muscles increase, making oxygen more readily available to the muscle. This oxygen can be used in energy production, delaying the need to switch to anaerobic systems which could lead to muscle fatigue. Rob's muscles will increase their ability to store glycogen and triglycerides, providing further fuel sources for aerobic exercise, limiting the risk of fatigue during the game. These aerobic adaptations will also help Rob recover after high-intensity parts of the game as sufficient quantities of aerobic energy can be used to break down lactate reducing muscle fatigue.

Show your skills

Consider how your response to long-answer questions might include the following qualities:

- ✓ Demonstrate accurate and thorough knowledge and understanding.
- ✓ Apply knowledge to the context of the question.
- ✓ Display a well-developed and logically balanced discussion or analysis, showing an awareness of competing arguments.
- ✓ Contain logical chains of reasoning throughout and the linkages between / within body systems.
- ✓ Use technical language consistently and fluently.

Links Go to pages 68–70 to revise principles of aerobic training.

The question says 'impact on energy production and performance'. Try to apply your knowledge of the adaptations to the impact on **rugby** performance. Make sure you focus on adaptations caused by training aerobically.

For this question you need to demonstrate a good understanding of aerobic adaptations to the muscular system and the aerobic energy system. You also need to show how this knowledge links to performance in a game such as rugby.

The answer could have also talked about capillarisation, or the use of rest days to allow recovery, avoiding overtraining or even injury. Clearly if injured, performance levels would drop.

Links Go to pages 38 and 39 to revise the content needed for this question.

Now try this

Becker is 35 years old and has high blood pressure. He is returning to physical activity after a ten-year gap and has joined a new gym.

Discuss the effects of participating in physical activity on the cardiovascular system for an individual suffering with high blood pressure.

Links Go to pages 33–34 to revise this topic.

'Discuss' means exploring more than one viewpoint.