How can sportspeople train the body systems to ensure there are long term benefits?

Excercise Physiology

Chapter 2

To answer the big question you will need to be able to complete the following tasks:

1. Analyse the structure and function of the muscular-skeletal system (AO3).

2. Analyse the structure and function of cardiovascular system (AO3).

3. Analyse the structure and function of respiratory system (AO3).

4. Assess the use of different energy systems for different activities (AO3).

5. Discuss the short term and long term effects of training (AO3).

Muscular-skeletal system

Analyse the structure and function of the muscular-skeletal system (AO3).

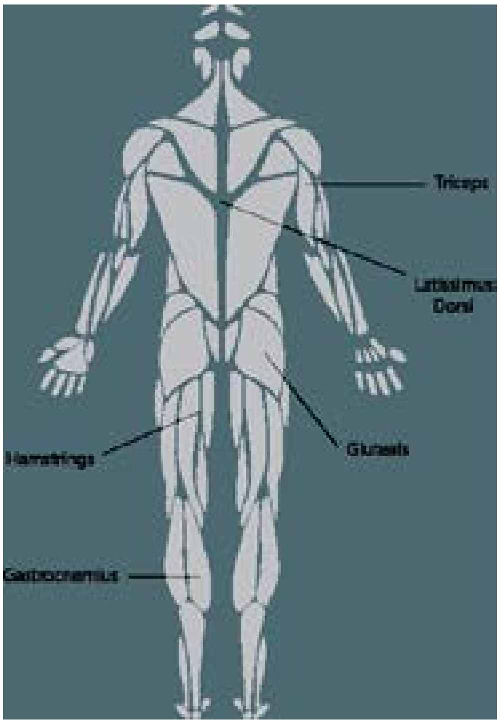
Muscular system

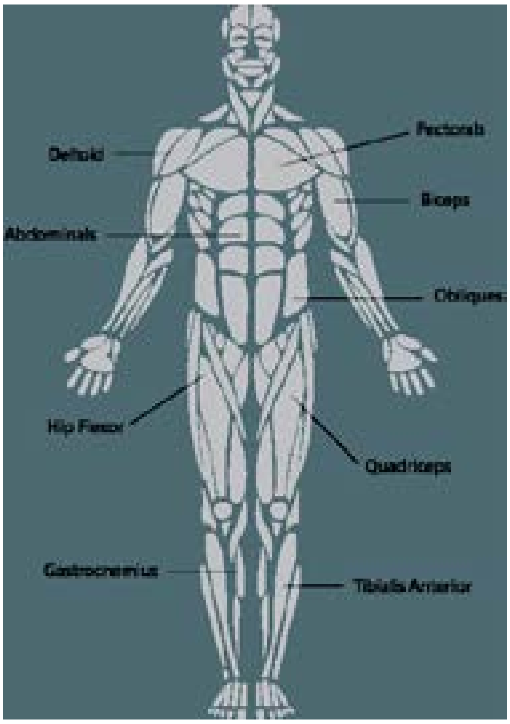
There are three types of muscles in the human body

- Smooth muscle – involuntary muscle (not under our conscious control) found in the internal organs
- Cardiac muscle – involuntary muscles (not under our conscious control) found only in the heart
- Skeletal muscle – voluntary muscles (under our conscious control) attached to the skeleton

Skeletal muscles are the muscles involved with the movement of the body.

Major muscles of the body





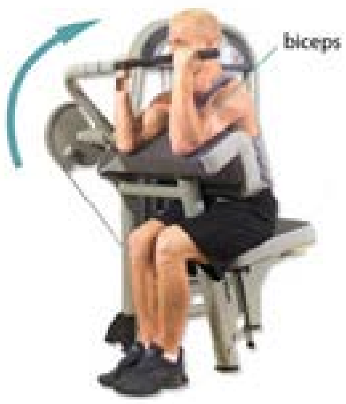
Muscle contractions

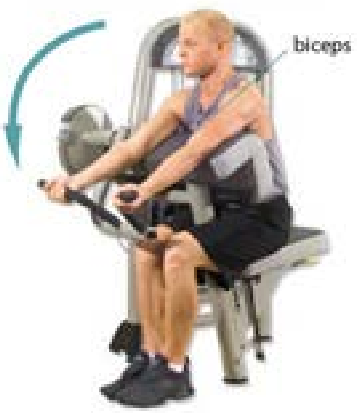
Isotonic contraction - involves the muscle producing tension and controlling the speed of the muscular contraction. This movement can be a concentric or eccentric muscular contraction.

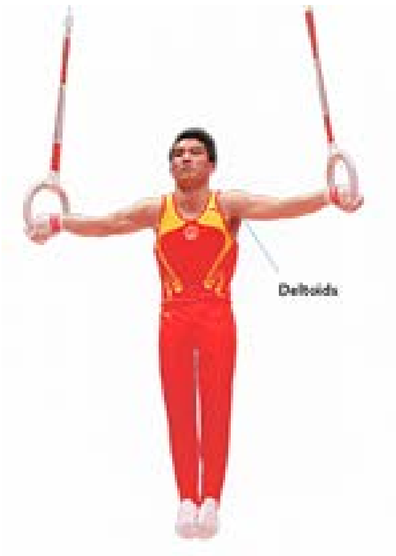
Concentric contraction - involves the muscle shortening under tension. The origin and insertion of the muscle move closer together.

Eccentric contraction - involves the muscle lengthening under tension. The origin and the insertion move further away from each other. An eccentric contraction provides control of a movement in the downward phase and it works to resist the force of gravity.

Isometric contraction – involves a muscle producing tension but staying the same length.







Antagonistic muscle actions

Muscles are attached to bones by **tendons;** they contract by pulling the bones. Muscles work in pairs where one muscle is contracting (the agonist) and an opposite muscle is relaxing (antagonist). The muscle that was relaxed then contracts (becomes the agonist) to return bones to the original position.

The following groups of muscles are antagonistic pairs

Biceps	Triceps
Hamstrings	Quadriceps
Gluteals	Hip flexors
Pectorals	Latissimus dorsi

Muscle fibre types

In simple terms muscle fibres can be classified as slow twitch (Type I) or fast twitch (Type II).

The different types of muscles have different characteristics.

Slow twitch (Type I) – slow contractions, low force, red in colour, fatigues slowly, and needed for endurance events e.g. 10,000 m running.

Fast twitch (Type II) – quick contractions, high force, white in colour, fatigues quickly, needed for power/speed events e.g. sprinting.

Many sports such as hockey and football require performers to have a balance of fast twitch and slow twitch fibres.

Summary

- There are three types of muscles
- Muscles contract in different ways and work in pairs
- There are two main types of muscle fibres

For further discussion:

Give definitions for muscular *hypertrophy* and muscular *atrophy*.

Describe how the antagonistic muscle pairs are working at the elbow during the downwards and upwards phase of a press-up.

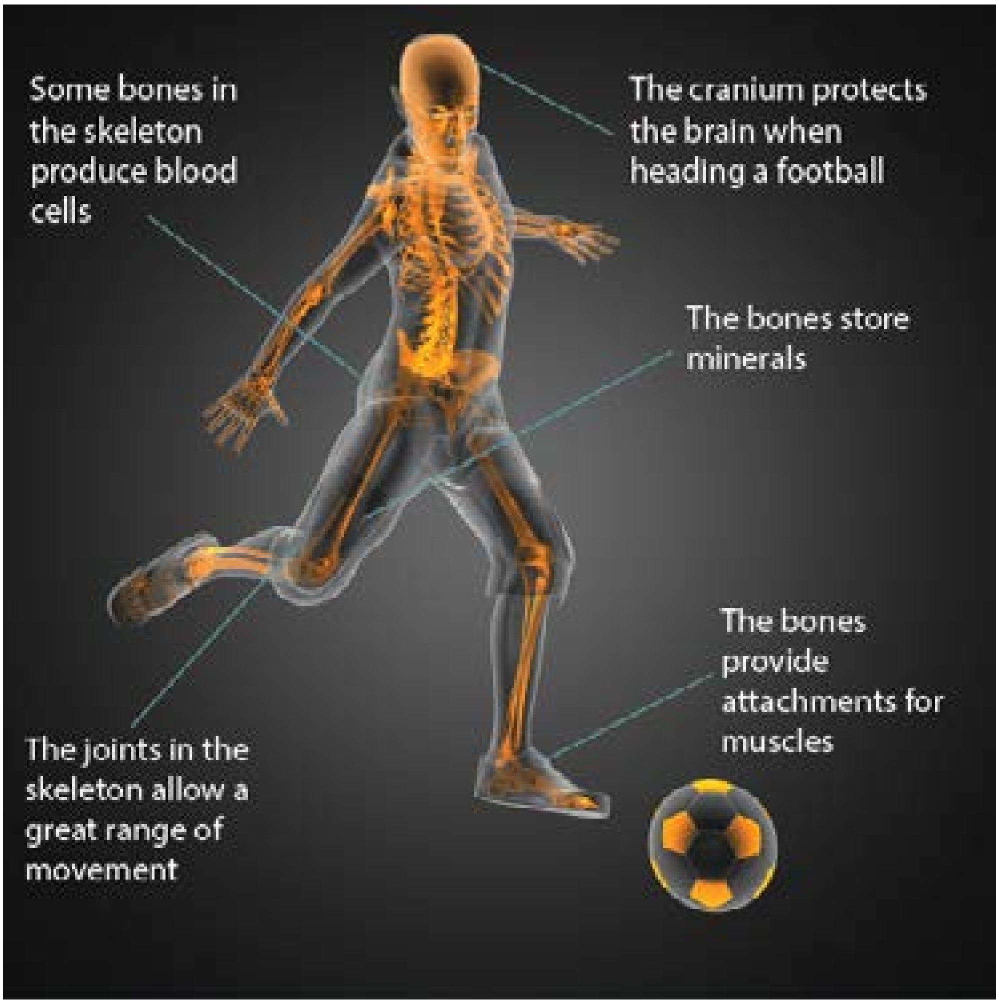
Explain why a long-distance runner requires Type I muscle fibres in order to be successful in their event.

Skeletal system

Function of the skeletal system.

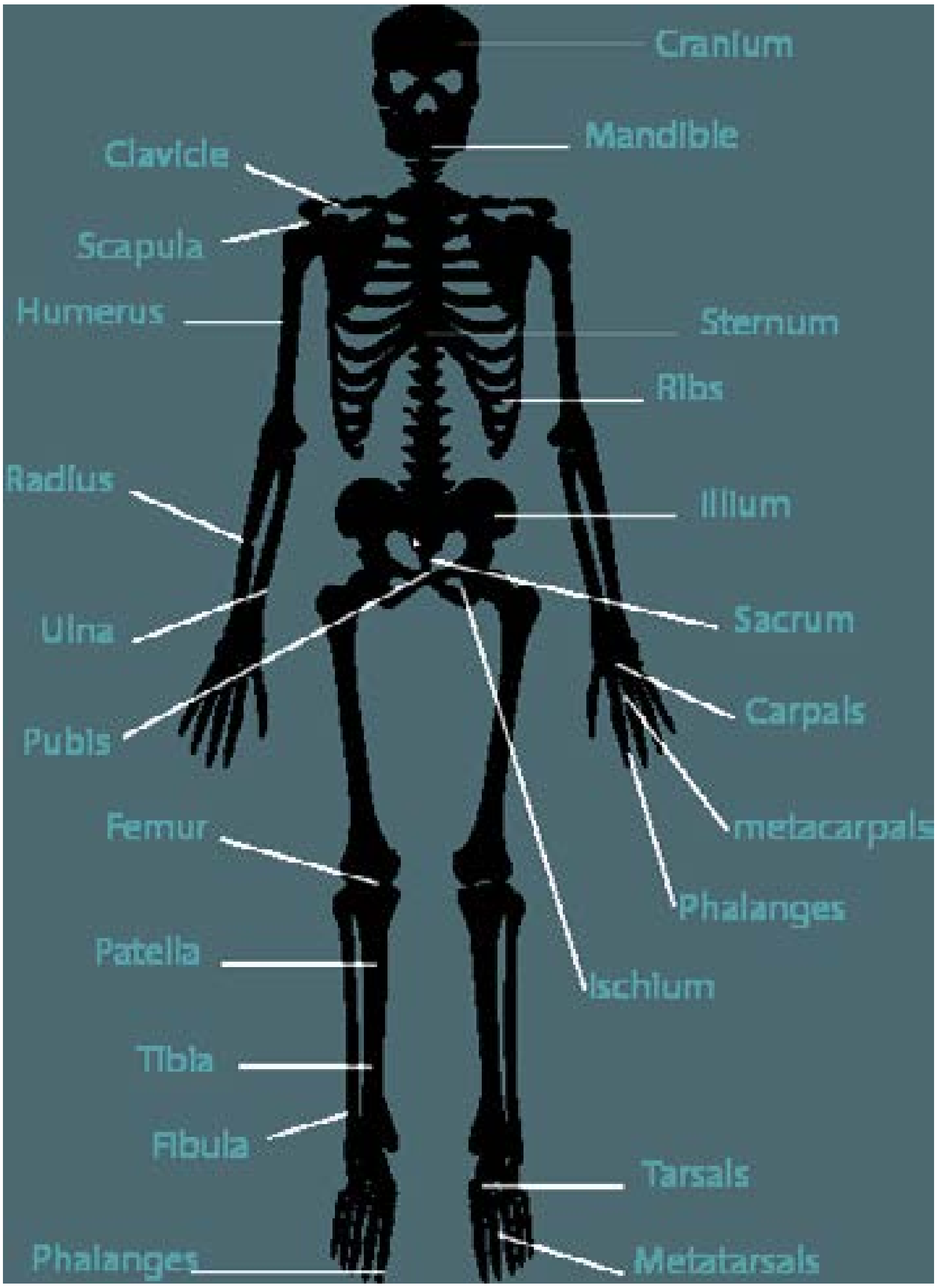
The skeleton has the following functions:

1. Movement – The bones act as levers around joints. Muscles pull on the bones to produce movements. The bones of the skeleton provide surfaces for the attachment of muscles. Bones have bony points and grooves to provide attachment points.
2. Support and protection – support for the body and protect the vital organs. For example, the cranium protects the brain and the ribs protect the heart and lungs'
3. Blood cell production– bone marrow produces red blood cells, white blood cells and platelets.
4. Storage of minerals – act as a mineral store for calcium and phosphorous, which are available to the body if needed for other functions.



Structure of the skeleton

There are 206 bones in the human body. The main ones involved in movement in sport and physical activity can be seen in the diagram below.



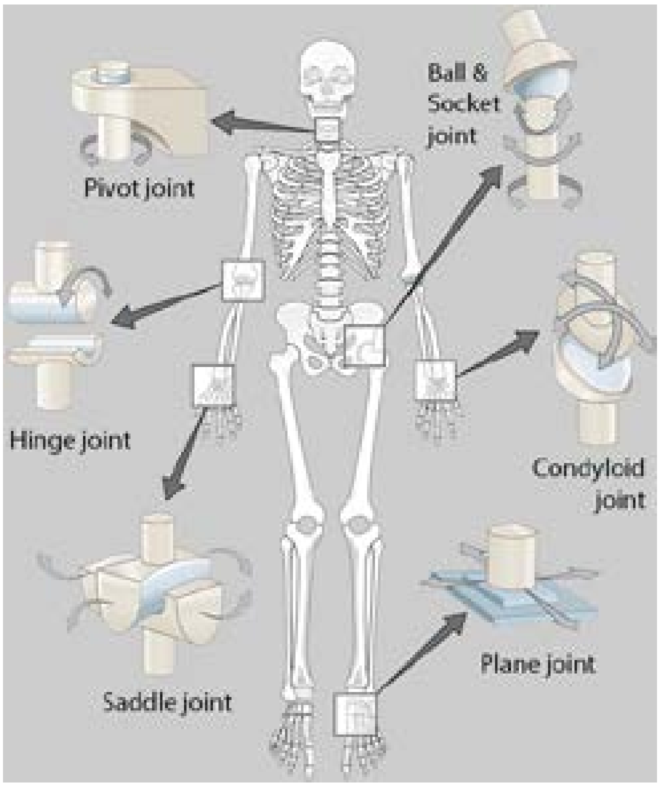
Structure of synovial joints

- A joint is a place where two or more bones meet. Bones are connected around the joint.
- Connective tissues consist of ligaments, cartilage and tendons.
- Ligaments hold the joint together which give the joints their stability.
- Cartilage is found at the ends of bones and where joints meet.
- Tendons attach muscles to the skeleton.

Types of synovial joints

Different types of synovial joints allow varying degrees of movement, these include:

1. Hinge – found in the elbow and knee. Hinge joints allow you to move the elbow and knee in only one direction. They allow flexion and extension of a joint.
2. Ball and socket – found in the shoulder and hip and allow movement in almost every direction. A ball-and-socket joint is made up of a round end of one bone (ball) that fits into a small, bowl-like area of another bone (socket).
3. Pivot – found in the neck, between the top two vertebrae. It allows only rotational movement, such as moving your head from side to side.



Types of movement

Each joint allows different types of movement as can be seen in the table below.

Types of movement	Description of movement	Example	Type of joint
Flexion	Bending a joint. This occurs when the angle of a joint decreases.	E.g. the elbow flexes when performing a bicep curl	Hinge
Extension	Straightening a joint. This occurs when the angle of a joint increases.	E.g. when throwing a shot put	Hinge
Abduction	Movement away from the midline of the body.	E.g. at the hip during a splits	Ball and socket
Adduction	Movement towards the midline of the body.	E.g. at the shoulder when hands clasp together before a dive	Ball and socket
Circumduction	Where the limb moves in a circle.	E.g. in the shoulder joint during an overarm tennis serve	Ball and socket
Rotation	Where the limb moves in a circle.	E.g. in the shoulder joint during an overarm tennis serve	Pivot

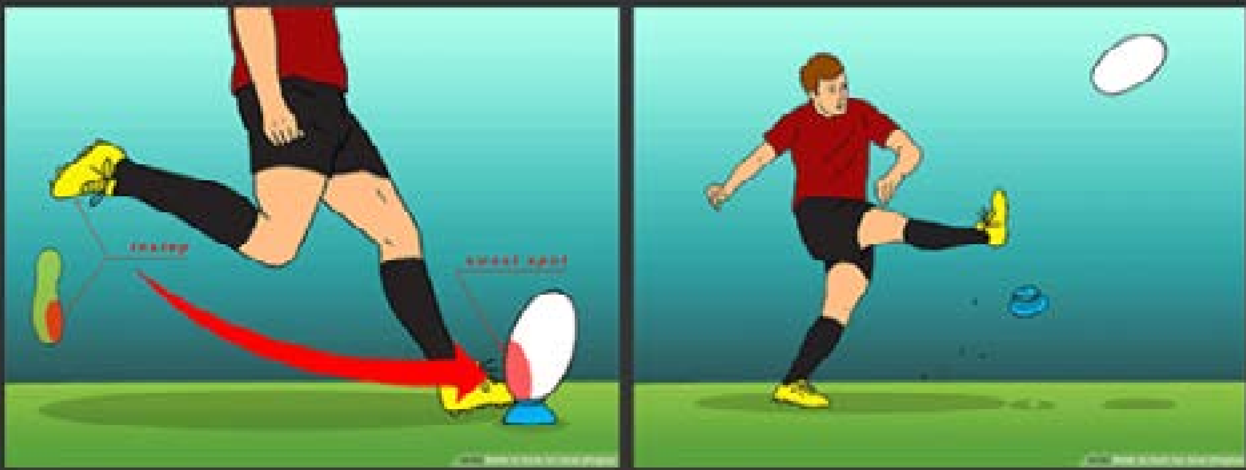
Summary

- The muscular-skeletal system works together to produce movement in the body
- Ligaments and tendons are two main types of connective tissue that help the muscular-skeletal system produce movements
- There are different types of movement at different joints

For further discussion:

Question

Complete the table to analyse a rugby conversion kick.



	Joint	Type of movement	Bones	Muscles	Muscle contraction
Phase 1	Knee				
Phase 2	Knee				

The cardiovascular system

Analyse the structure and function of the cardiovascular system (AO3).

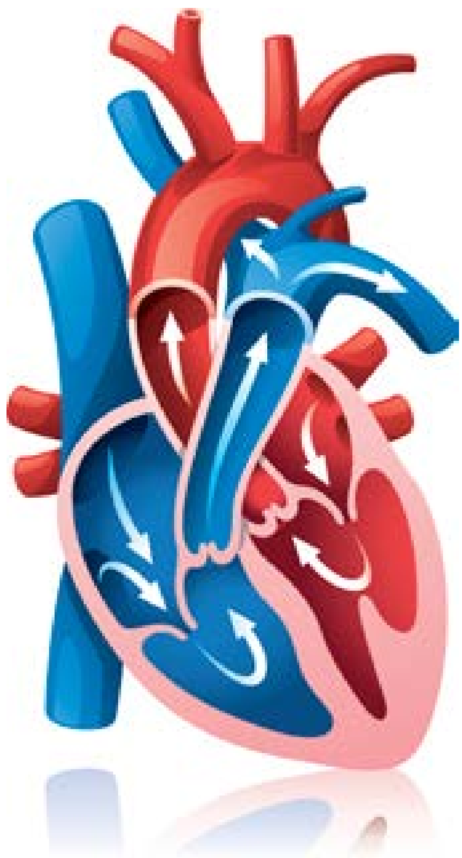
The cardiovascular system is made up of the heart, blood vessels and the blood.

1. The heart - a fist sized organ found slightly to the left side within the chest. It consists of cardiac muscle and pumps blood around the body. It is divided in to two halves.

The **right-hand side** pumps deoxygenated blood to the lungs from where it gets oxygen.

The **left-hand side** pumps the blood returning from the lungs (oxygenated blood) around the body.

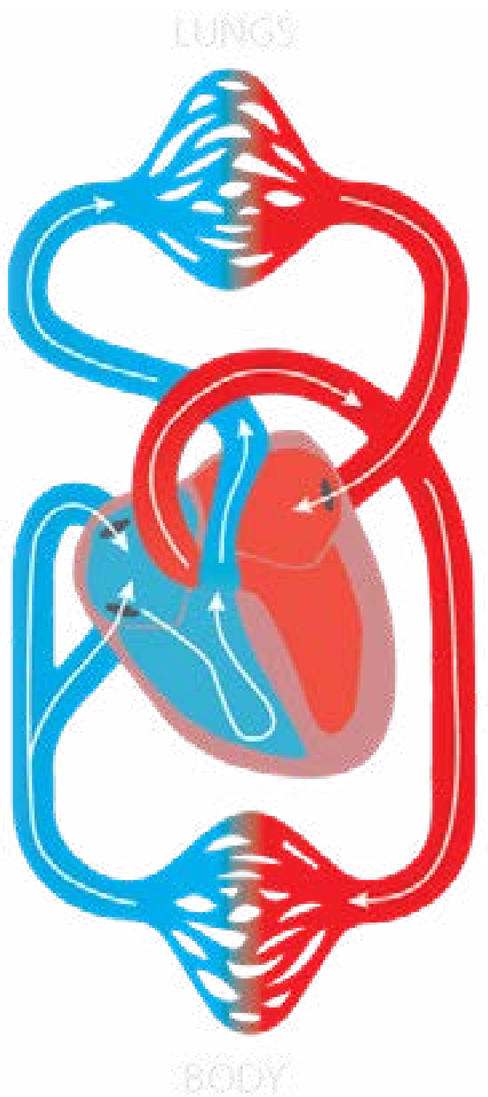
Both sides of the heart contain an atrium and a ventricle.



The atrium is where blood enters the heart.

The ventricles then pump the blood to the lungs or around the body.

There are two valves within the heart to prevent unwanted backflow of blood between sections of the heart - the tricuspid valve prevents backflow from the right ventricle to the right atrium. The bicuspid valve prevents backflow of blood from the left ventricle to the left atrium.



There are four main blood vessels that take blood into and out of the heart.

- The pulmonary artery - carries deoxygenated blood from the right ventricle to the lungs.
- The pulmonary vein - transfers oxygenated blood from the lungs to the heart's left ventricle.
- The aorta – is an artery that carries oxygenated blood to the body from the left ventricle.
- The vena cava – is a vain that carries deoxygenated blood back from the body to the right atrium.

Functions of the cardiovascular system

There are many functions of the heart including:

1. Transporting oxygen and nutrients around the body.
2. Removal of waste products. These waste products are a by-product of exercise including carbon dioxide and lactic acid.
3. Maintenance of appropriate body temperature.
4. Vasodilation – opening of the blood vessels to increase blood flow to tissues that need it most.
5. Vasoconstriction - blood vessels close to help venous return (the return of blood back to the heart).

Cardiac Values

- Heart rate (HR) - the amount of beats per minute. (Average = approx. 70 beats/minute).
- Stroke volume (SV) - the volume of blood pumped by each beat. (Average = 0.7 litres).
- Cardiac output (Q) - the volume of blood pumped per minute.
  Cardiac Output = Stroke volume x Heart rate.
  Or Q = SV x HR (Average = 9 litres/minute i.e. 0.7 litres SV x 70 beats/minute HR).

Cardiac output remains constant even if you become fitter as your stroke volume increases but your heart rate is lowered.

Blood pressure

During contraction of the heart muscles, blood is moved into the blood vessels, creating blood pressure.

There are two blood pressure values:

- **Systolic**: The heart **contracts**
- **Diastolic**: The heart **relaxes**

The typical blood pressure is 120/80 mmHg, systolic/diastolic.

Blood pressure is determined by Cardiac Output and also the resistance to blood flow within the blood vessels. The diameter of these blood vessels, which can be influenced by diet, is an important factor in blood flow resistance.

Heart rate

During exercise the heart rate (measured in beats per minute) increases so that sufficient blood is taken to the working muscles to provide them with enough nutrients and oxygen.

Maximum heart rate can be calculated using the formula

Max hr = 220-age

Athletes use percentage of Max HR to help with training e.g. for an intense session to work anaerobically you might work at 90% Max HR.

Summary

- There are three main functions of the cardio-vascular system
- Know the different values

For further discussion:

What is the maximum HR of a 16 year old?

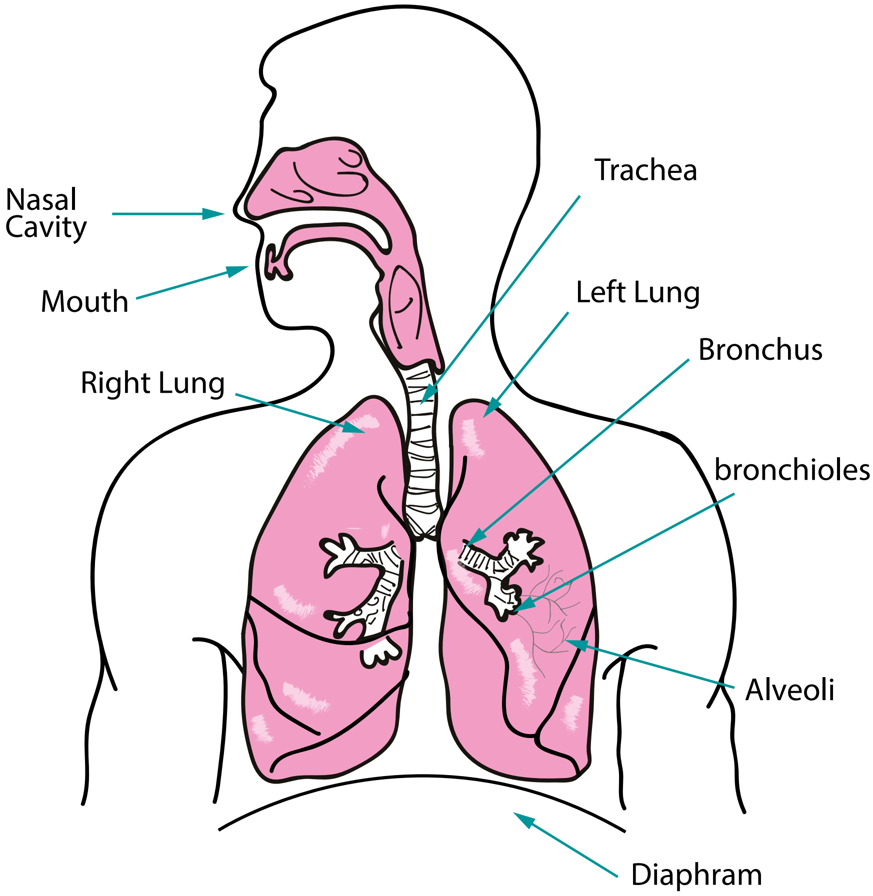
Calculate 90% max HR for a 16 year old.

If you worked at 90% max HR what component of fitness would you probably be improving?

Respiratory system

Analyse the structure and function of respiratory system (AO3).

The function of the respiratory system is to transport oxygen from the air that we breathe through a system of tubes into our lungs and then into the blood stream.



- Air enters the body through the mouth and nose and then enters the trachea
- The air then passes into one of two bronchi. One bronchus enters each lung
- Air then travels into the bronchioles
- At the end of the bronchioles, the air enters one of the many millions of alveoli
- Gaseous exchange occurs in the alveoli in the lungs and takes place by diffusion

Diffusion

The movement of gas from an area of high concentration to an area of low concentration. Oxygen moves into the blood form the alveoli while carbon dioxide moves in the other direction.

When the blood carrying oxygen reaches the muscle the opposite occurs – the carbon dioxide enters the blood and the oxygen enters the muscle. During exercise, the muscles need more oxygen in order to contract and they produce more carbon dioxide as a waste product. To meet this increased demand by the muscles the breathing depth (tidal volume) and breathing rate increase.

Lung values

Vital capacity = the maximum amount of air that can be breathed out after breathing in as much air as possible. Regular aerobic exercise can increase a person's vital capacity.

Breathing rate (frequency) = the number of breaths in a minute. The average breathing rate is 12 breaths/minute.

Tidal volume = the amount of air breathed in with each normal breath. The average tidal volume is 0.5 litres (500 ml).

Minute ventilation (VE) = the total volume of air entering the lungs in a minute. The average minute ventilation is 6 litres/minute. **Minute ventilation = Breathing rate x Tidal volume.**

Summary

- The function of the respiratory system is to transport oxygen to working muscles and carbon dioxide and other waste products away
- Diffusion of gases occur in alveoli
- Lung values adapt during exercise to cope with increased demands on the body

For further discussion:

Complete the following table

Measure	Rest	Moderate exercise
Breathing rate		
Tidal volume		
Minute ventilation		

Aerobic and anaerobic exercise

Assess the use of different energy systems for different activities (AO3).

In simple terms energy systems for use in sport can be divided into aerobic (with oxygen for moderate exercise) or anaerobic (without oxygen for intense exercise).

Aerobic respiratory system produces the majority of our energy while our bodies are at rest or taking part in low-intensity exercise for long periods of time, such as jogging or long-distance cycling. The energy for aerobic exercise comes mainly from carbohydrates including rice, bread, potatoes and bananas and fats in the form of butter, cheese and milk.

The **anaerobic respiratory system** supplies energy very quickly for sports such as vaulting in gymnastics or throwing a javelin where the activity only lasts a few seconds.

There are two types of anaerobic energy systems. These are:

Creatine phosphate (CP) anaerobic system - supplies energy faster than all other energy systems. It can only supply energy for about ten seconds so used only in explosive, high-intensity contractions, such as in sprinting 100 metres or shot putt.

Lactic acid anaerobic system – used once the CP system has run out. It does not produce energy as quickly as the CP system and produces the majority of energy for high intensity activities for about 1-2 minutes e.g.400 metres run.

The anaerobic exercise systems are inefficient and use energy quickly. The lack of oxygen used and the build-up of lactic acid causes the fatigue. They require oxygen to restore them which results in heavy breathing after the exercise has finished – this is repaying the **oxygen debt**.

Summary

- There are 3 main energy systems
- The one predominantly used depends on the intensity of exercise

For further discussion:

Complete the following table

Energy system	Sporting examples	Justification
Aerobic		
Creatine phosphate (CP)		
Lactic acid		

The short term and long term effects of exercise

Discuss the short term and long term effects of training (AO3).

During any one training session there are **short term** changes to the cardiovascular, respiratory, energy and muscular systems within the body. These changes include:

Muscular system - Increase in temperature of muscles and increased elasticity.

Cardiovascular system - Increase in stroke volume (SV), increase in heart rate (HR), increase in cardiac output (Q) and increase in blood pressure (BP).

Respiratory system - Increase in breathing rate and tidal volume.

Energy system – increased lactate production.

Short term changes are relatively unimportant because as the name suggests these changes do not mean that the body is adapting to the demands made on it. For this to happen there has to be a period of training after which some **long term adaptations** can be seen.

Long term adaptations include:

Muscular-skeletal system - Muscle hypertrophy, increased strength of tendons and ligaments, increased bone density. This is mainly developed using resistance training.

Cardiovascular system - Increase in stroke volume (SV), decreased resting heart rate (HR), increase in cardiac output (Q), increased red blood cells. This is mainly developed using aerobic training.

Respiratory system - Increased vital capacity, increased number of functioning alveoli, increased strength of the respiratory muscles. This is mainly developed using aerobic training.

Energy system - Increased production of energy from the more efficient aerobic energy system and increased tolerance to lactic acid. This can be developed using a combination of aerobic and anaerobic training.

Summary

- There are short term changes
- There are long term adaptations after a period of training (3+ times a week for 6 or more weeks)
- All body systems adapt to exercise

For further discussion:

What is meant by cardiac hypertrophy? Give an example of an exercise that would lead to cardiac hypertrophy.

What is meant by muscular hypertrophy? Give an example of an exercise that would lead to muscular hypertrophy.

Research the term anaerobic threshold. Explain what it is and why it is important.

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