13 Let us understand the musculoskeletal system

We are constantly in motion during the whole span of life. Three systems in our body that help us to do this are the skeletal system, muscular system and nervous system. In motion, the skeletal system acts as a lever. The muscular system provides the power and the nervous system provides the stimulus and coordination. As an adolescent you will find the knowledge of these systems useful.

In grade 10 you learnt about the structure and functions of digestive, respiratory, circulatory, excretory and reproductive systems. you also learnt about some diseases that affect these systems and how to prevent them.

In this chapter we will learn about the different systems that help with movements.

Muscular system

Muscles are important for movement of the body as well as for movement of the internal organs.

Anatomy of the muscular system

- Different types of muscles perform specific actions in various parts of the body.
- Different postures can be adapted due to the contraction and relaxation of muscles
- Tendons are attached to bones. They are thick and strong and help with movement.
- The muscles are attached to the bones and help with movements
- The energy needed is stored in the muscles
- The nerves send stimuli for contraction and relaxation of muscles and help with movements
- Special muscles in the face are involved when crying, laughing, showing happiness and sadness

There are three types of muscles classified according to the function and structure

1. Skeletal muscles
2. Smooth muscles
3. Cardiac muscles

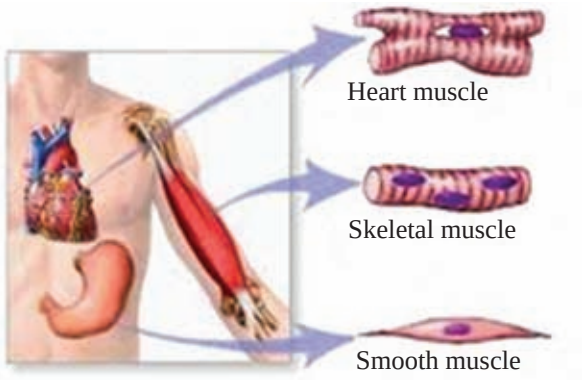


Figure 13.1

Skeletal muscles

These muscles constitute 40% of the body weight. They are long and cylindrical in shape. The two ends are attached to the bone by tendons. They are called striated muscles due to the horizontal striations seen in the muscle. The muscles are controlled by the brain. They contract in a rhythmical manner and get tired. There are more than one nucleus and a large number of mitochondria in a muscle cell. Glycogen is stored as a source of energy in the muscles.

Striated muscles are present in the arms, legs and diaphragm

Smooth muscles

These muscles constitute about 3% of body weight. There is one nucleus in the muscle cell. The muscles are long and the striations are not seen. They contract in a slow, rhythmical manner and do not get fatigued.

Smooth muscles are present in walls of arteries, veins and the digestive tract

Cardiac muscles

The cells branch out. Each cell has one nucleus. A large number of mitochondria are present in the muscle cells. These muscles contract nonstop in a rhythmic manner right throughout one's life.

Cardiac muscles are present only in the heart.

Functions of the muscular system

1. Aids in body movement by contraction and relaxation
2. The heat generated during muscle contraction is used to maintain the body temperature
3. Storage of glycogen needed to generate energy
4. Intercostal muscles and diaphragmatic muscles aid in respiration.

How does muscular system work

Contraction and relaxation of muscles

The skeletal muscles help in movements and to maintain posture. The muscles have a narrow end and a broad middle. They are designed to help with movements that will be efficient.

Figure 13.2 - How skeletal muscle is attached to the bones of the arm

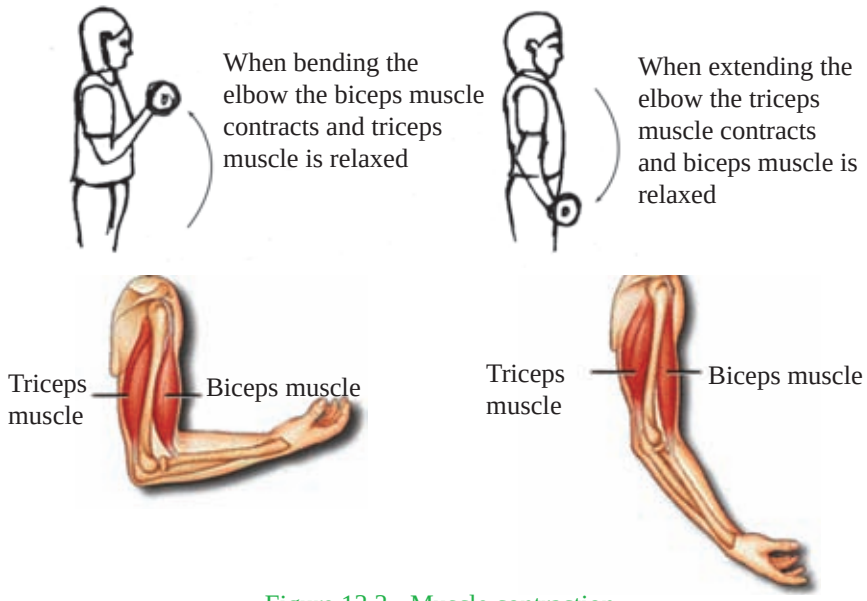


Figure 13.3 - Muscle contraction

In figure 13.2 you can see how a skeletal muscle is attached to a bone. In figure 13.3 see how the muscles contract when the arm is being used.

When the elbow is bent the biceps muscle contracts and triceps is relaxed. When elbow is extended the triceps contracts and the biceps is relaxed.

Activity

Hold a book in your right arm and bend your elbow. Notice how the muscles contract and relax.

To understand how muscles work let us learn how each muscle fibre functions.

The basic structural unit of an organism is a cell. The basic unit of a muscle is known as a muscle fibre. Figure 13.4 shows how multiple muscle fibres make a muscle bundle and many muscle bundles make a muscle.

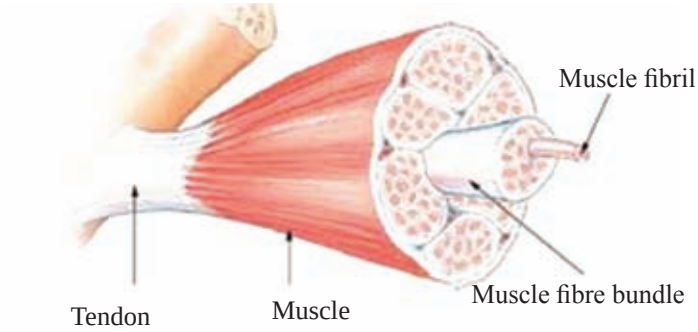


Figure 13.4 - cross section of a skeletal muscle

Activity

Create a cross section of a muscle using drinking straws

Ratio of fibres

You have learnt about the structure and function of muscle fibres. Recall how your friends play in the grounds. One friend can run very fast but gets tired soon and another can run slowly for a long period without getting tired. Various types of muscle fibres help in these situations.

For extra knowledge

The energy needed to perform a task generated by a muscle is known as muscle energy.

The muscles of the student who runs fast will contract and relax very quickly. Whilst the muscles of the student who runs slowly for a long period will contract and relax slowly.

Sports medicine has helped the progress of sports immensely. Two types of fibres have been identified. They are slow twitch fibres and fast twitch fibres. The fast twitch fibres are further categorized into two. In this grade you are expected to study the slow twitch and fast twitch fibres only.

You are born with a particular ratio of these twitch fibres. The friend who runs very fast

has a higher ratio of fast twitch fibres to slow twitch fibres whilst the friend who runs slowly has a higher ratio of slow twitch fibres to fast twitch fibres.

1. Slow twitch fibres- STF; Type 1
These fibres are also known as red fibres as oxygen is utilized to generate energy (red blood corpuscles transport oxygen). These fibres have a lot of capillaries. The sportsmen with a high ratio of these fibres have the ability to run long distances successfully.

2. Fast twitch fibres FTF; Type 11
Oxygenation (need to use oxygen) in these fibres is low. These fibres do not utilize oxygen to generate energy. Therefore the ability to contract is more in these fibres.

Sports persons with a higher ratio of these fibres can perform events that require speed such as sprints, jumps, throws and excel at them.

Identify the differences between these two fibres

Table 13.1- Differences in fast and slow twitch fibres

Characteristics	Fast twitch fibres	Slow twitch fibres
Colour	white	red
Storage food (glycogen)	more	less
Speed of contraction	more	less
Aerobic respiration	less	more
Anaerobic respiration	more	less
Resistant to fatigue	less	more
Involved in high impact sports	more	less
Involved in long duration	less	more

Uses of skills training in sports

By suitable training we can make a few changes to the fibres we are born with.

- The area of the cross section of the fibre can be increased. Strength can be developed by doing resistance exercises.
- The number of units in motion are more. Impulses travel to the fibres fast and the velocity is increased. Therefore the fibres contract very fast.
- The number of mitochondria present in fibres increases. The production of ATP and storage increases. Thus one does not get tired quickly.

- The density of blood vessels in the muscles increases. The number of capillaries in the muscles increases. This enables the rapid transport of glucose and oxygen to the muscle cell. Excretory products are also transported out rapidly. Thus performance can continue for a longer period.

The above can be transformed depending on the type of event and training of the sportsman. Therefore suitable measures can be taken to improve the stamina of short and long distant athletes.

The factors that hinder the functioning of the muscular system

1. Nutritional deficiencies
   The development of muscles is affected due to nutritional deficiencies from the time you are a foetus right until you pass the other developmental stages

2. Wrong postures
   Wrong postures tire the muscles and cause muscular ailments. When muscles are not used properly a lot of energy is used. Therefore wrong postures over a long duration can lead to various diseases.

3. Inadequate amount of exercise and rest
   The muscles are affected when the body does not get adequate exercise. Rest is needed for cells to regenerate. A person can have physical ailments if he works for a long period without rest. It is important that you do warm up exercise when you engage in sports or exercises, as the muscles can get damaged.

Protecting the muscular system

1. Good eating habits
   Balanced meal including calories is important to protect the muscular system. It is important to eat at regular times and to eat natural food as much as possible. It is necessary that you eat high quality proteins and non-vegetarian food.
2. Maintain good postures
   Fatigue felt by muscles can be minimized by maintaining a correct posture. Maintaining good postures help to have healthy muscles.

3. Taking adequate exercise and rest
   An adult should engage in at least 30 minutes of exercise daily. Exercise develops the function of muscles , capillaries that are connected to them and

nerve endings. Getting at least six hours of sleep a day regenerates the tired body. The worn out cells are regenerated and muscles remain the original state by rest. It is important that one does warming up exercises before sports or exercises.

Skeletal system

Anatomy of the skeletal system

The shape of your body is maintained by the skeletal system that comprises 206 bones.

Special characteristics of the skeletal system

- The brain is protected by the thick and rounded skull.
- The eyes are protected by the sockets.
- Ball and socket joints help perform a wide range of movements
- The digits in the fingers help with the ability to hold
- The female's pelvic bones are designed to assist with child birth
- Ribs protect the heart and lungs
- The femur is long, broad and strong to bear weight.
- Cartilage at end of bones protects the bones within a joint.
- A bone heals even if it fractures
- Bone marrow manufactures blood corpuscles

The bones cannot function alone. Muscles help in movement.

Human bones are initially formed with cartilage and subsequently replaced by bone cells. The deposition of minerals makes it hard. Most bones are hollow. The marrow in the hollow portion of the bone manufactures blood cells. Bones store calcium and phosphate.

Classification of bones depending on the shape

1. Long bones- present in arms and legs
2. Short bones- present in the fingers and toes
3. Flat bones- skull, ribs, shoulder blades and pelvic bones
4. Irregular bones- spine, some bones in hands and feet

Functions of the skeletal system

- Gives shape to the body
- Bears the weight of the body
- Muscles are attached to bones by tendons for movement of joints
- Manufactures blood corpuscles
- Stores minerals such as calcium
- Protects the internal organs

How does skeletal system work

Joints that help in movements

Hinge joint

- This movement is similar to a door being opened and shut. The joint acts similar to the hinge of a door.
- Movement is not more than 180°
- Examples for this joint are the elbow, knee, and digits of fingers and toes.

Ball and socket joint

- This is similar to a ball in a corresponding cavity
- Movement is 360°
- Examples are shoulder joint and hip joint

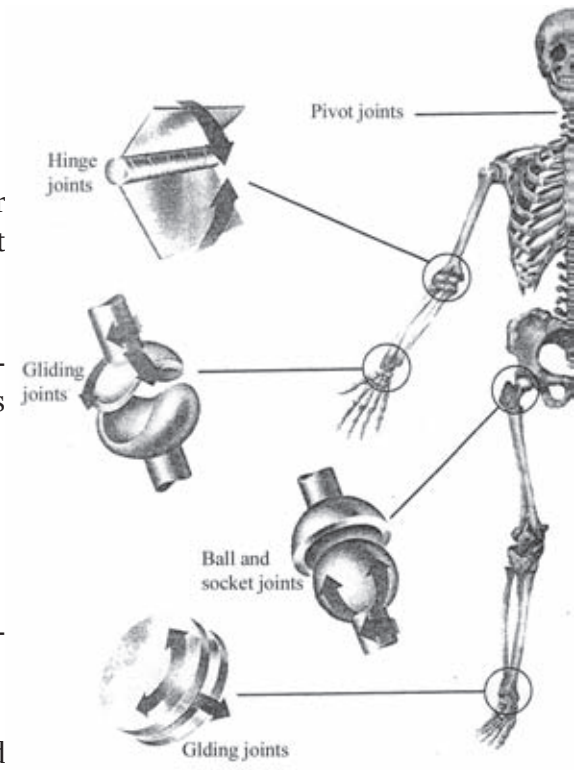


Figure 13.5

Pivot Joint

- The joint where the Atlas (1st vertebrae) and Axial vertebrae (2nd vertebrae) meet in the vertebral column
- This joint has been designed so that the head can be moved from side to side and up and down

Gliding Joint

- Ankle and wrist joints have gliding joints
- Movements can be performed to the front and back left and right

Bones and muscles act as levers during movements. A lever is a rod that can be moved around a stable point. This bone is similar to the rod.

- Fulcrum or pivot is the fixed point in a lever. Joints in our body are examples of this
- The effort is the power on the lever. It is done by muscles.
- The resistance on the lever is the load. A mass raised by the arm is an example.

The movements in our body due to muscle and bones are similar to one of three types of levers

Type 1 lever

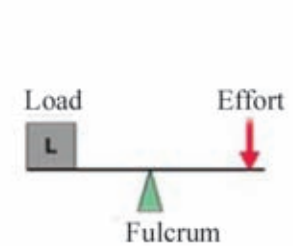


Figure 13.6

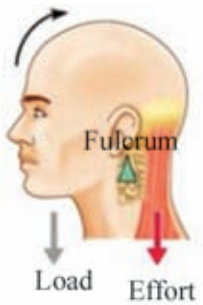


Figure 13.7

Figure 13.6 shows how the load and effort are on either side of the fulcrum

See Figure13.7 for example of above type of lever in the body.

Effort - energy is supplied by contraction of muscle
Fulcrum - Atlanto - Axial joint between 1st and 2nd vertebrate
Load - weight of head

Type 11 levers

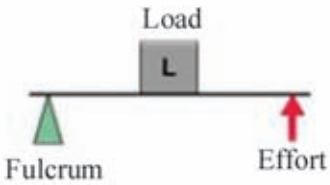


Figure 13.8

Figure 13.9

Figure13.8 shows the fulcrum and effort being on either side of the load. An example for this type of lever is a sports man standing on his toes. See figure 13.9

Fulcrum - the toes on the floor
Effort - the gastrocnemius and soleus muscles of leg contracting
Load - the weight of the body being directed down along the line of gravity

Lever type 111

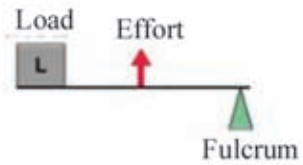


Figure 13.10

Figure 13.11

Figure13.10 shows the fulcrum and the load on either side of the effort.
An example for this type of lever in the body is a sportsman holding a put shot in the hand and bending the elbow to raise the put shot. Refer figure 13.11

Fulcrum - elbow
Load - put shot
Effort - biceps contracting to get the power

Factors that hinder the functioning of the skeletal system

1. Accidents
2. Congenital bone diseases
3. Poor posture
4. Nutritional deficiencies and obesity
5. Arthritis

Ways of protecting the skeletal system

1. Good nutrition
2. Healthy life style
3. Maintaining a good posture
4. Exercising daily
5. Obtaining adequate amount of calcium from food

Nervous system

Impulses needed for movements to occur are supplied by the nervous system. We can understand the function of this system by learning about it.

Structure of the nervous system

- Impulses obtained from the environment can be converted to electrical impulses
- Impulses are transmitted in a very short time
- Reactions can occur with or without thinking
- The brain controls our actions and is able to memorise them

The nervous system can be divided into two

1. Central nervous system
2. Peripheral nervous system

Central nervous system

brain :

The brain and the spinal cord are the components of this system. The prominent part of the brain is the cerebrum. This constitutes left and right hemispheres that are divided by a sulcus. Cognitive functions such as memory, intelligence, responsibility, analysis, decent behaviour and learning are controlled by the cerebrum. Perceptions such as vision, hearing, taste, smell, touch, pressure , pain, warmth and cold are also identified by the cerebrum

Figure 13.12 - Cerebrum

Spinal cord :

The spinal cord is a cylindrical bundle of nerves that runs down from the brain through the vertebral column.

The spinal nerves arise from both sides of the spinal cord in pairs. There are 31 pairs of spinal nerves.

Peripheral nervous system

The 12 cranial nerves starting from the brain and the 31 spinal nerves arising from the spinal cord constitute the peripheral nervous system.

Nerve cells are known as neurons. There are three types of neurons

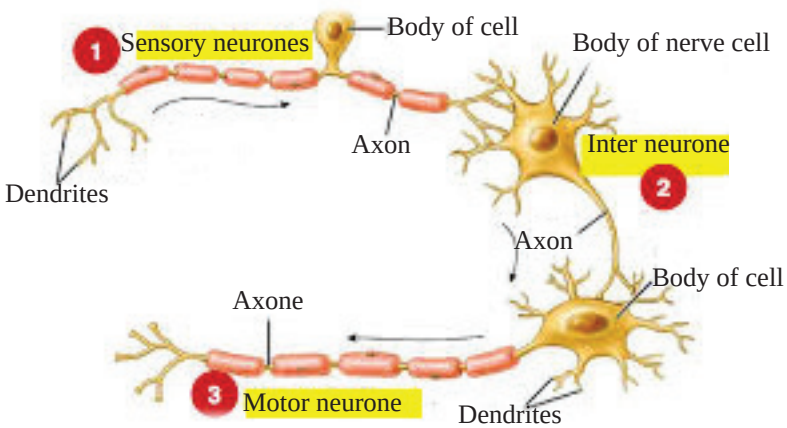


Figure 13.13

1. Sensory neurons
These nerves transmit impulses from sensory organs to the central nervous system

2. Motor neurons
These nerves transmit impulses from the central nervous system to the muscles

3. Inter neurons
Neurons that transmit impulses between sensory neurons and motor neurons

Functioning of the nervous system

Motor and sensory functions
The dendrites of sensory neurons start from sensory organs. The stimulus is taken up by the dendrites in the sensory organ. The axons of these neurons are situated in the central nervous system. The path of the impulses is directed from the organ towards the brain. The impulses in the motor neurons travel from the central nervous system to the effector which is the muscle.

The sensory organs such as the eyes, ears, nose, tongue and skin receive the stimulus and impulses are sent via the sensory neurons to the central nervous system as messages. The central nervous system send back a message with regards to the action that should take place via the motor neurons to the effector.

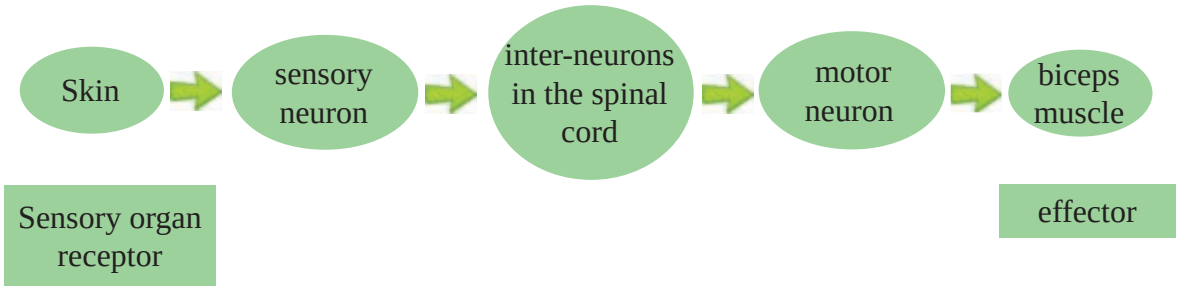
Reflexes

In sports we think of the action needed to perform. Sometimes we react to an impulse instantly without having to think. This is known as a reflex.

Recall how you reacted when your hand touched a hot electric iron. You may remember removing your hand immediately? That is a reflex action.

The stimulus is the heat. It feels to the skin slowly. Impulses travel from the skin through the sensory neurons in the spinal cord. The inter-neurons in the spinal cord sends impulses to the hand along the motor neurons. The hand is removed immediately. The message reach the brain little later and after the immediate response the person will realize the incidence that occurred. The harm is minimized as the action is done very fast.

The hand is taken off without our knowledge. It is known to us only after the reflex action. This pathway that impulses travel is called a reflex arc.



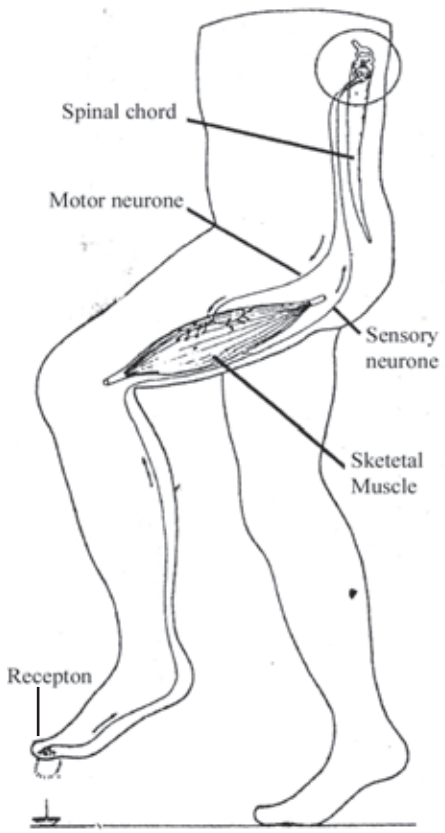


Figure 13.14

Conditioned reflexes

Scientists say that other than the innate reflexes we are born with, experience can develop reflexes. Reflexes that are developed from experience are known as conditioned reflexes. The pathway to these new reflexes is via the brain. Complex conditioned reflexes compared to the simple conditioned reflexes may not last

throughout life. Conditioned reflexes could be developed by systematic training. Thereby complex sports skills can be performed in the correct manner without difficulty.

Factors that cause harm to the nervous system

1. Smoking
2. Using illicit drugs and alcohol
3. Congenital diseases
4. Illnesses that occur during pregnancy and birth
5. Nutritional deficiencies that occur during pregnancy

Protecting the nervous system

1. Refrain from smoking
2. Abstaining from using illicit substances
3. Providing pregnant mothers and adolescent females proper nutrition
4. Exercising
5. Leading a stress free life and being happy
6. Getting adequate sleep and rest
7. Protecting the eyes, ears, nose, tongue and skin

How energy is supplied during movements

We learnt, there is a function of contraction and relaxation of muscles. For this action energy is needed. The energy is generated from ATP (Adenosine triphosphate) in mitochondria that is present in the muscle.

ATP molecule

Adenosine – Phosphate – Phosphate – phosphate

One adenosine molecule is attached to three phosphate molecules. Energy is generated when a bond between two phosphate molecules is broken. This energy is used for the contraction of muscles.

When ATP gets broken repeatedly ATP gets depleted. After energy is generated adenosine and 2 phosphate groups remains together to form Adenosine diphosphate.

ATP ⟶ ADP + P + Energy → For muscle contraction

ADP cannot generate energy again till it is converted to ATP. For that the released phosphate should get attached. Energy needed for the production of ATP occurs in two ways.

1. Anaerobic method
2. Aerobic method

1. Anaerobic method

The glycogen stored in the muscles are used for this purpose. In speed events energy is produced without utilizing oxygen. Under this method while producing energy it produces lactic acid. This energy is utilized to convert ADP to ATP.

Glycogen ⟶ Lactic Acid + Energy

This method can generate only a small amount of energy and also it can be supplied for a short period only. Lactic acid gets accumulated in the muscles and they get fatigued. In the presence of oxygen, the lactic acid is cleared and relieved the muscle from fatigue.

In events like 400 running this method is used to produce energy. In the final stages of 800m and 1500m events this method is used. Untrained athletes run the last few stages of a 400m event at a slow speed due to the accumulation of lactic acid.

2. Aerobic method

Glucose and fatty acids are used to generate energy in this method. Glucose or fatty acid in the presence of oxygen produce energy. The energy generated is used to convert ADP to ATP. Carbon dioxide and water are the by-products of this process.

Glucose + CO_2 ⟶ CO_2 + H_2O + energy

Fatty acid + O_2 ⟶ CO_2 + H_2O + energy

As oxygen is used in this method, it is known as aerobic method.

This method produces large amounts of energy. Energy generated by this method in not available very fast. Energy produced in this method is used in sports that take long duration of time such as Marathon, 10000m run etc.

Other than above methods there is an another method known as creatine phosphate method.

Creatine phosphate (CP) also known as **Phosphocreatine (PCr)**, is a molecule that serves as a rapidly mobilizable reserve of high-energy phosphates in skeletal muscles. When energy has to be supplied immediately, breakdown of creatine phosphate will provide the required.

Creatine phosphate $\longrightarrow$ creatine + Phosphate + Energy

This energy will be used to convert ADP to ATP. This method can function with or without the use of oxygen. As it does not use oxygen, sometimes it is referred to as the Anaerobic Alactic method.

Events such as 100m, 200m, 100m x 4 relay, jumps, throws and carrying weight, which require a burst of energy instantly, specially at the beginning (first 2-3 seconds) is supplied by this method.

Involvement of the different systems during exercise

Involvement of the muscular system during exercise

- There are many ways that energy is generated for the muscles to act. During high impact exercise and low impact exercise energy is produced in different ways.
- In movements, muscles that are used more and use more force are stronger and bigger. It is due to the cross section being larger,
- By exercising, the endurance and flexibility can be improved.
- The number of mitochondria are increased and ATP increases.
- During training the lactic acid breakdown becomes fast.
- By exercising the activity becomes more efficient depending on the type of muscle fibres you posses

- Larger and stronger muscles are situated in places where there is a lot of strain on the body.
- To prevent muscle injury during strenuous activities muscles get fatigued.
- By training the density of capillaries are increased.
- The time taken to produce lactic acid can be lengthened by training
- By training, cardiac muscles get strengthen

Involvement of the skeletal system during exercise

- The limb bones are strong and long to bear the weight of the body and get stronger when exercising
- Presence of ball and socket joints help to increase the range of movements
- The natural position of the atlas vertebra help in a range of movements of the head.
- Muscles are attached to joints which aid in movements and get stronger with exercise.
- The natural position of the vertebral columns helps in the ease and efficiency of movements.
- Presence of arches in the feet help in efficient walking and running.
- The joints in the feet help to absorb the impact of vibration.

Involvement of nervous system during exercise

- Conditioned reflexes are developed
- Unnecessary movements are reduced due to the impulses being directed appropriately
- The parasympathetic nervous system works more during rest
- During exercise the sympathetic nervous system works more
- The organs work more efficiently eg: heart and lungs
- Thirst makes us drink water to compensate for the volume of water that gets excreted as sweat during exercise.
- Fainting attacks occur as a measure to regain oxygen lost during exercise to the brain.

Summary

Three systems are involved for movement. The structure of these system have been designed to help with these actions efficiently.

The muscles help in movement by contraction and relaxation .

The skeletal system acts as a lever through the connection of joints.

The nervous system generates the required impulses for movements.

The energy needed for movement is obtained by the breakdown of ATP to ADP. The ADP broken down is converted to ATP from energy obtained by the aerobic and anaerobic systems.

When the systems do not function as desired, the efficiency of the movements are reduced. By preventing this we are able to maintain good postures for good productivity and efficiency.

Exercise help in strengthening the muscular, skeletal and nervous systems.

Exercise

1. Name three functions for each of the muscular and skeletal system
2. Name three ways of protecting the nervous system
3. Find out the ratio of muscle fibres in a 100m sprinter and a Marathon runner
4. Describe how your body functions as the three different levers function, giving examples
5. Describe how the muscular, skeletal and nervous system function during exercise