TAMALE COLLEGE OF EDUCATION

DEPARTMENT OF SCIENCE

GENERAL BIOLOGY THEORY/ PRACTICAL II

LEVEL 200

SECOND SEMESTER

COMPLETE COURSE NOTES

UNIT 1

SUPPORTING SYSTEMS IN ANIMALS

SKELETAL SYSTEM IN HUMANS

A skeleton is the hard part of an animal that forms the framework of the body. The skeleton provides support and framework for mammals suitable for their behaviour and function. The skeletal system also provide protection for some delicate organs of the body and makes movement possible. The human skeleton is made up of 206 bones.

Main Parts of the Human Skeleton

There are two main parts of the human skeleton**: axial** and **appendicular** skeleton.

The skeleton which makes the **main axis** of the body is the **axial skeleton** (80 bones). Whilst the **appendicular skeleton** consists of the appendages and their girdles (126 bones).

Axial skeleton consist of three parts

- Skull (cranium)
- Vertebral column
- Ribs and sternum

Appendicular skeleton consist of the limbs and limb girdles

- *Pectoral girdles*: The forelimbs (arms) are attached here.
- *Pelvic girdles*: The hind limbs (legs) are attached here.
- *Limbs* (arms and legs)
  - Hind limbs
  - Fore limbs

All mammals are well adapted for movement (locomotion). Humans move their arms, legs, eyes, hands and jaws by means of muscles. Movement can be of part of the body or the whole body. Locomotion occurs if the whole body is moved from one place to another. The skeleton makes movement possible.

Types of Skeleton

These are the **exoskeleton** and **endoskeleton.** There is a third type of skeleton (hydrostatic skeleton-fluid filled) but this study will only look at endoskeleton and exoskeletons.

- **Exoskeleton-** skeleton on the outside of the body, it is a rigid or hard external covering that supports and protect the bodies of some invertebrates. Example can be seen on animals such as insects, shellfish, and other creatures without bones such as;
    - Mollusc (e.g. snails, octopus)
    - Arthropods (e.g. grasshopper, beetle)
- **Endoskeleton** - internal skeletons made of small, chalky plates. Vertebrates are the only animals that have internal skeletons made of bone. Endoskeleton is found in vertebrates such as:

    - Mammals – e.g. man

    -Reptile – e.g. lizard

    -Amphibians – e.g. toad

    - Birds – e.g. fowl

Mammals and vertebrates have endoskeleton which is made of bones cartilage and ligaments. Bones and cartilage contain non-living mineral substances such as calcium, phosphates and calcium carbonates. Younger individuals have higher numbers of bones because some bones fuse together during childhood and adolescence to form an adult bone.

BONES

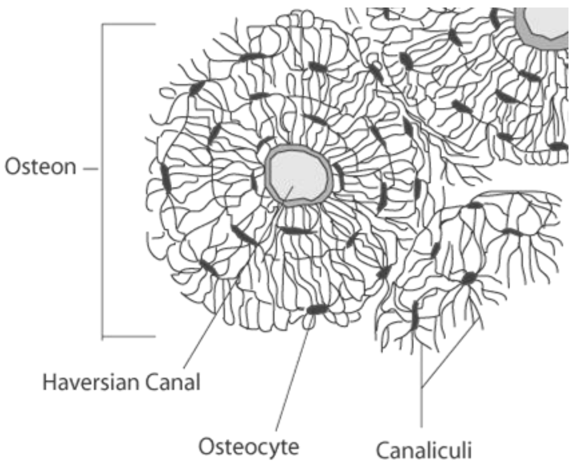
Bones are rigid tissues of a body, mainly made up material like collagen and calcium phosphate. It is made up of connective tissue. These bone tissues assemble to form the bones of the skeletons, the human skeletal system and of the other vertebrates. The human body contains **206** separate bones in the body of an adult. The largest bone is the **femur** or thigh-bone, and the smallest bone is the **stapes**, which is present in the middle ear. Bones are present in five different shapes in the human body which are flat, long, short, irregular and sesamoid.

Another fact is that more than **99 percent** of the body is made up of bones and teeth and the rest **1 percent** is found in the blood. Vertebrates are the only organisms on the earth, whose body consists of bones. Rest among modern vertebrates it is found in bony fish and in higher classes. Bones are of two types namely: **Compact** and **spongy bones**.

STRUCTURE OF BONES

Mammalian limb bones are made up of an outer layer of bone and a hollow inner part containing bone marrow. Its internal structure consists of an organic matrix in which calcium salts, mainly calcium phosphate are deposited. Bones get their strength from these salts. The star shaped cells (osteocytes) secrete the matrix and salts. Around the haverian canal are a series of cell arranged in concentric circles through which blood vessels and nerves pass. This arrangement of the osteocytes forms a compact tissue called compact bone. The space occupied by the central parts of the osteoblast is called **lacunae**. The fine channels called **canaliculi** which connects adjacent cells in the lacunae.

Fig 1.1 Microstructure of compact bone



The Basic Functions of Bones are:

1. It provides the structural support to the soft tissue, internal organs against the various mechanical action performed by them like contraction and relaxation of muscles of heart, lungs, etc.
2. It also acts as a protective site for the special tissues like bone marrow (blood-forming system).
3. It is also responsible for giving shape to the body and act as a mineral reservoir, where it controls the level of calcium and phosphate in the body fluids.

CARTILAGE

Cartilage is a kind of connective tissue, but they are soft, firm tissue and are responsible for the flexibility, bending, and muscles stretching. So these are found at the place where support and flexibility is needed like the joints, ears, nose, as well as between the spinal column.They are the **extracellular matrix** present in the connective tissue. This matrix is produced by specialized cells called as **chondroblasts**. These chondroblasts are found in the matrix of chondrocytes, while lacunae are the space where these cells lie.

The chondrocytes determine the level of flexibility of the cartilage. These are found in the body like the end of the ribs, ears, and nose, bronchial tubes, joints between bones like of elbows, knees, and ankles. Cartilage is also found in cartilaginous fishes.

Cartilage is of three types:
1. **Elastic Cartilage** – This type is found in the ear, as it is the most flexible type.
2. **Hyaline Cartilage** – This type is found at the end of ribs and in the nose, it is the second most flexible type of cartilage.
3. **Fibro Cartilage** – This types found in the knee, as well between the spinal column.

SIMILARITIES BETWEEN BONES AND CARTILAGE

Both protect the delicate organs from internal and external shock also. They are also responsible for movement and locomotion of the body, along with the flexibility. In this content, we will take up the important differences between both along with their functions.

DIFFERENCES BETWEEN BONES AND CARTILAGE

BASIS FOR COMPARISON	**BONE**	**CARTILAGE**
Definition	Bones are the complex structure, made up of connective tissues which are hard and are helpful in providing protection, shape to the body.	Cartilage is the simple structure, made up of connective tissue which is soft and are useful in providing flexibility to the joints and also protect from the external and internal shocks.
Features	They are rigid, non-flexible, and tough. Bones grow in both directions (bidirectional). Haversian system and Volkmann's canals are present.	They are flexible and are soft-elastic. Cartilage grows in single direction (unidirectional). Haversian system and Volkmann's canals are absent.

	Bone marrow is present (it is a kind of haematopoietic tissue from which all blood cells are made). Lacunae possess canaliculi where each lacuna consist of only one cell (osteocyte). These are active participants of blood supply. Matrix consist of the protein called ossein and can be both organic and inorganic. They occur in lamellae and are vascular. They have the deposit of calcium salts largely of calcium phosphate. Bones cells are also known as Osteocytes.	Bone marrow is absent. Lacunae do not possess canaliculi, and each lacuna has two-three chondrocytes. They are not the participants in blood supply, except in perichondrium. The matrix consists of the protein called chondrin, and they are organic. In cartilage, a matrix is said to be as homogenous mass without lamellae. They do not possess calcium salts. Cartilage is found in ear, nose, larynx and trachea
Types	Two types 1. Compact bone. 2. Spongy bone.	Three types 1. Fibrocartilage 2. Elastic cartilage. 3. Hyaline cartilage.

Note that connective tissue maintains the rigidity, shapes, safety of the body’s and its essential parts. Apart from muscles, bones and cartilage act as the main structural components of the body.

ILLUSTRATION OF THE RELATIONSHIP OF SKELETON AND MUSCLES DURING MOVEMENT

Bones and skeletal muscles of the body comprise your **musculoskeletal** system. The primary function of these components working together is to create movement. Other functions include stability, posture and protection. Along with the joints, which act as fulcrums, the bones and muscles work together to create levers in the body. Depending on the location of the load in relation to the joint or fulcrum, muscles and bones create either a mechanical advantage or disadvantage when objects are lifted. The closer the load to the joint and the farther away the muscle, the easier it is to lift the object. Conversely, the farther the load from the fulcrum and the closer the effort to the fulcrum, the more difficult it is to move the objects.

Action of antagonistic muscles of the forearm (voluntary muscles)

The skeletal muscles are attached to the projections of ridges in the bones of the forearm by tendons which are non-elastic cords that anchor muscles to bones. One end of the muscle must be attached to the bone that is to be moved while the other end is anchored to a part of the skeleton to be held stationary with respect to the moving part.

Movement of the forearm is brought about by the alternate contractions and relaxation of a pair of antagonistic muscles. In the forearm, the antagonistic pair of flexor and extensor muscles are arranged in such a way that they contract, they pull in opposite directions.

A summary of the action of the antagonistic muscle in the forearm.

Bending of forearm (flexion)

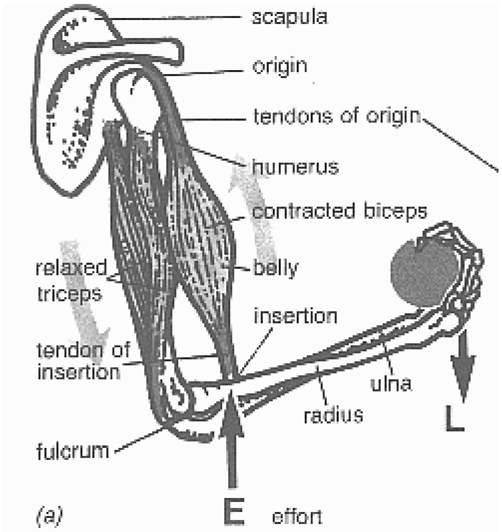
During bending of forearm, biceps (flexor) contract and become shorter and thicker. At the same time triceps (extensor) relax. The ulna and radius pull closer to the humerus and the lower arm is raised.

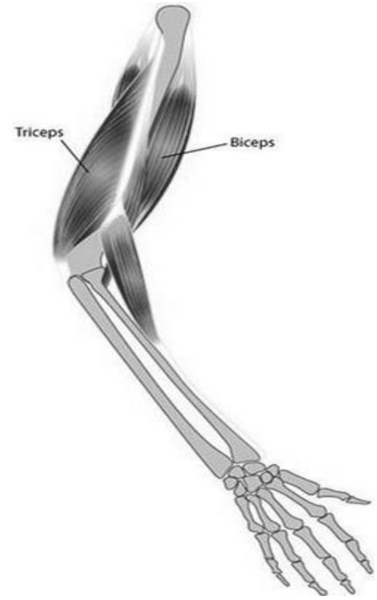
Straightening of forearm (extension)

During straightening of forearm, triceps contract and become shorter and thicker.

Fig 1.1 Movement of Arms

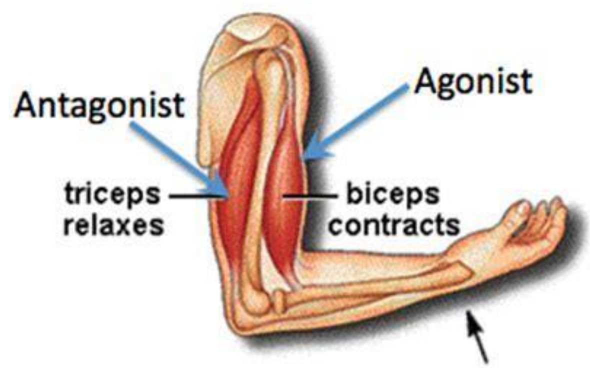
(a) Bending of forearm (Flexion) (b) Straightening of forearm (extension)





C).

D).



<u>Fig 1.2 Movement of Leg</u>

E).

F).

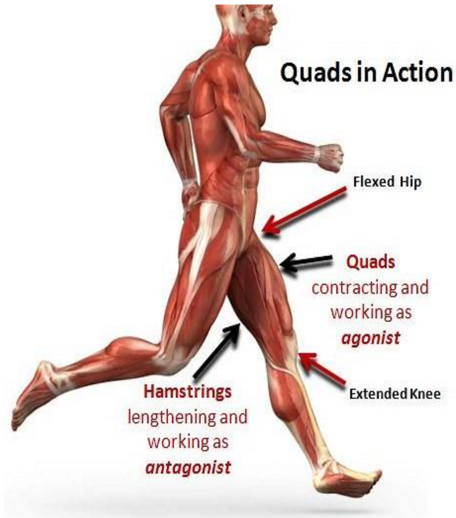


Table 1.1 The human skeleton

The function of the mammalian skeleton

- It forms the framework of the body
- It gives shape to the body
- It provides surfaces for attachment of muscles
- It supports the body
- It provide a series of levers for movement
- Red blood and white blood cells are manufactured in the bone marrow.
- It protects the more delicate parts of the body. E.g. The cranium protects the brain, the rib cage protects the heart and the lungs, the vertebral forming the backbone protects the spinal cord
- It aids in breathing

SHAPES OF BONES IN HUMAN BODY

Bones in the human body come in four main shapes, **long, short, flat and irregular** and are composed of webs of collagen fibers reinforced with calcium and phosphorous.

The collagen provides flexibility while the minerals provide tensile strength. There are **five functions** of the skeletal system in the body, three of which are **external and** visible to the naked eye, and two of which are **internal**. The external functions are: structure, movement and protection. The internal functions are: blood cell production and storage.

FUNCTIONS OF HUMAN SKELETAL SYSTEM

1. STRUCTURE/ SUPPORT

Like the steel framework of a building, the functions of the skeleton and the bones is to provide rigidity, which gives the body shape and supports the weight of body against the force of gravity, and to provide a structure upon which muscles and organs muscles can act to produce movements of the body. Without this structure, the body would collapse-in on itself, compressing the lungs, heart and other organs thus impairing their function.

Some creatures do not have internal skeletons and instead they have external shells (or exoskeletons) with muscle attachments on the interior.

2. MOVEMENT/ LOCOMOTION

There are three major systems involved in the mechanics of movement:

1. Nervous system
2. Muscular system
3. Skeletal system

The nervous system sends the electrical impulses that activate the muscles, the skeletal system provides the levers and anchors for the muscles to pull against. All skeletal muscles have an origin and insertion point.

The origin is the anchor, the bone that remains immobile while the muscle works. The insertion is the bone that moves as the muscle works, which is one of the main functions of the skeleton. So, for example, in the case of the biceps, the upper arm and shoulder are the origins (anchor) and the bones of the forearm are the insertion. Interestingly, the amount of power the muscle needs is directly related to the length of the bone (or lever) and where it is attached. This means that shorter people actually use less power to move than taller people because they have shorter bones, and the point of attachment is closer to the point of origin.

3. PROTECTION

Arguably the most important of the 5 functions of the skeletal system is protection. The most obvious example of the functions of the skeleton's protective properties is the human skull. The vertebrae and ribs also have protective functions by encasing delicate structures like the spinal cord, heart and lungs. The rib cage not only surrounds the organs of respiration, but it’s also very flexible and is constructed to expand and contract with each breath. The bones of the skull are actually several flat plates joined together by sutures. These sutures allow the skull to pass through the birth canal and expand as the brain continues growing. The sutures fuse together in early childhood, forming the classic shape of the skull.

The vertebrae are all irregularly shaped bones in the human body that provide both protection and flexibility for movement. There are also fibrous disks between each vertebra, which provide shock absorption.

4. BLOOD CELL PRODUCTION

Red and white blood cells are made in the red marrow of bones. At birth and in early childhood, all bone marrow is red. As the person ages, about half of the body’s marrow turns to yellow marrow – which is composed of fat cells. In an adult human, a majority of the long bones contain yellow marrow, and the red marrow is only found in the flat bones of the hip, skull and shoulder blades, the vertebrae and at the ends of the long bones.

However, in the event of severe blood loss, the body can convert some yellow marrow back to red marrow to increase blood cell production.

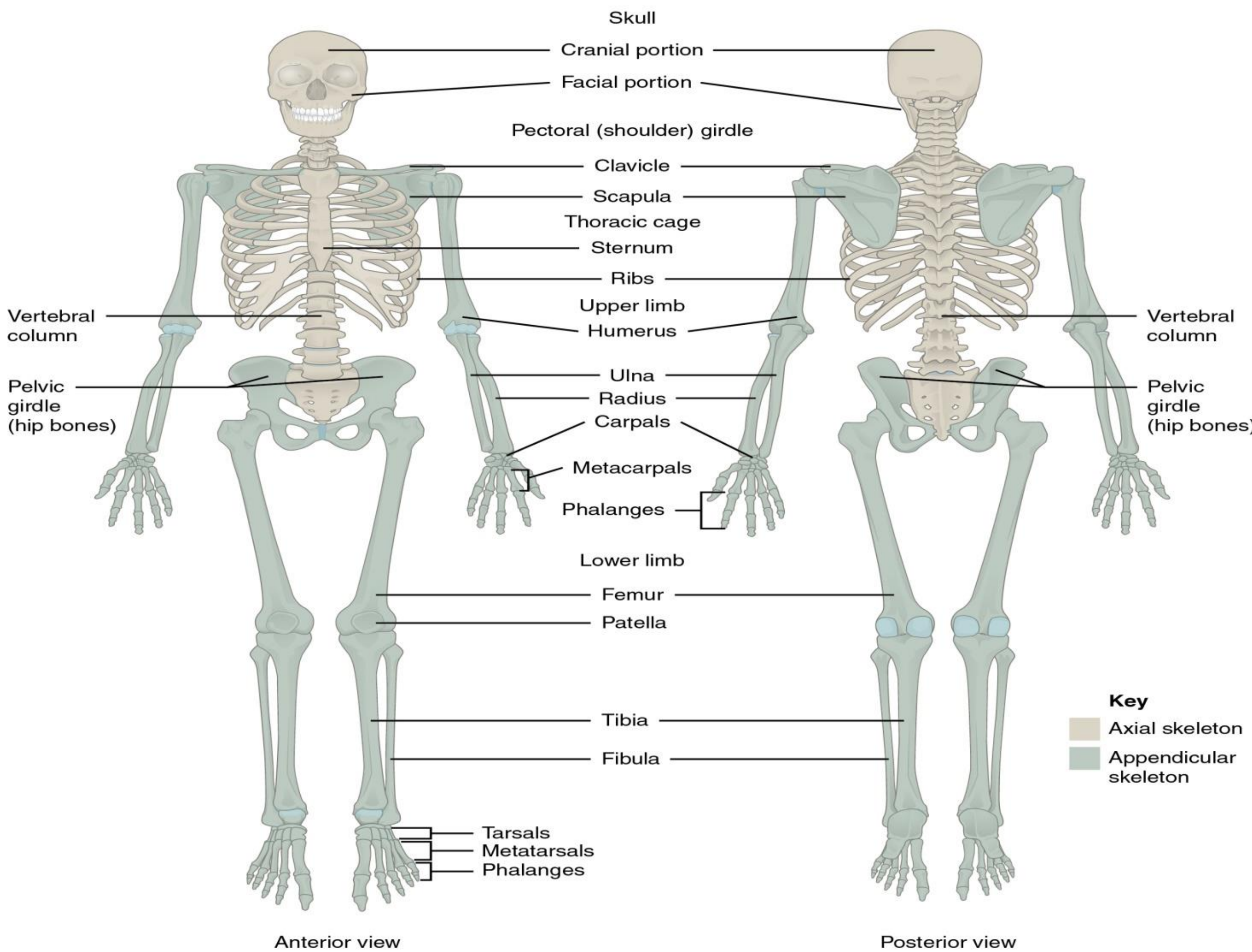
5. STORAGE

The bones of the skeleton serve as the primary storage site for important minerals such as calcium and phosphate. The body uses calcium and phosphorous for bodily processes like muscle contraction. Some of those minerals are found in our diet, but they are also taken from the bones in the human body. When the body needs calcium, if there isn't a ready supply in the blood, the endocrine system releases hormones that initiate the process of taking calcium from bone and releasing it into the bloodstream. When there is a surplus of blood calcium, it's put back into the bones.

This is why dietary calcium and vitamin D are so important. The body uses calcium constantly and, if there isn't enough calcium in the diet, it will consistently take calcium from the bone to compensate – leading to **osteoporosis.** Having enough dietary calcium ensures that there is enough calcium for bodily functions and replenishes the backup stores in the bone.

The bone marrow found within bones stores fat and houses the blood-cell producing tissue of the body.

FIG 2.1 PARTS OF THE AXIAL AND APPENDICULAR SKELETON



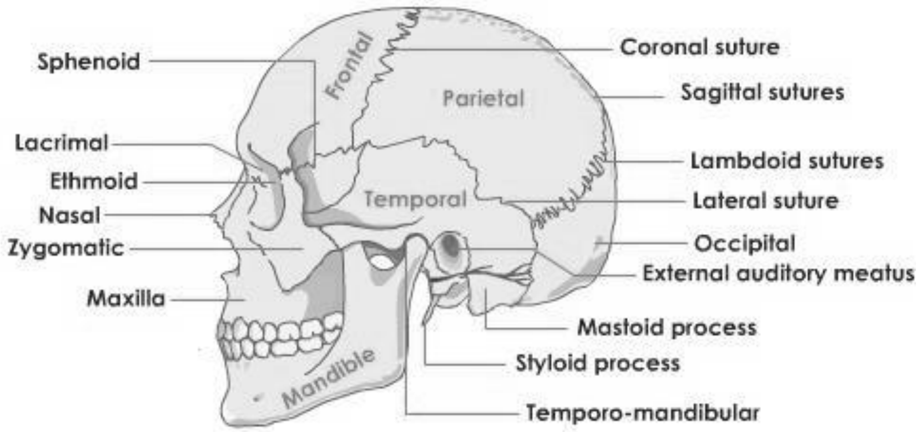
PARTS OF AXIAL SKELETON

1. Skull
2. Vertebral column
3. Rids and sternum

The Skull

The cranium of the skull consists of a number of wide bones that are joined together by irregular edges called **sutures** (immovable joints). It acts like a box, enclosing and protecting the brain. The skull also consist of the upper and lower jaw bones which hold the teeth. Parts of the skull form hollows which protects the eyes (orbits) and ears. The human skull consists of 29 bones, 8 of which forms the forehead and jointly protect the brain. The human face is made of 14 bones with 3 pairs of bones forming the ear ossicles (malleus, incus and stapes) and one hyoid bone.

<u>Fig 2.2 Fixed joint (Suture in Cranium)</u>



The Vertebral Column

A series of bones called vertebrae make up the vertebral column. There are **33 vertebra** in the vertebral column. They are arranged end to end to form a hollow tube through which the spinal cord passes. Pads of fibre called **intervertebral discs** separates but also joins one vertebra to the other. There are five types of vertebrae which are in groups at various regions of the back bone. Including:

(1) Cervical - neck region (7 vertebra)

(2) Thoracic-chest region (12 vertebra)

(3) Lumba - abdominal region (5 vertebra)

(4) Sacral and - tail Region (5 vertebra)

(5) Caudal - tail Region (4 vertebra)

Fig 2.3 Vertebral Column

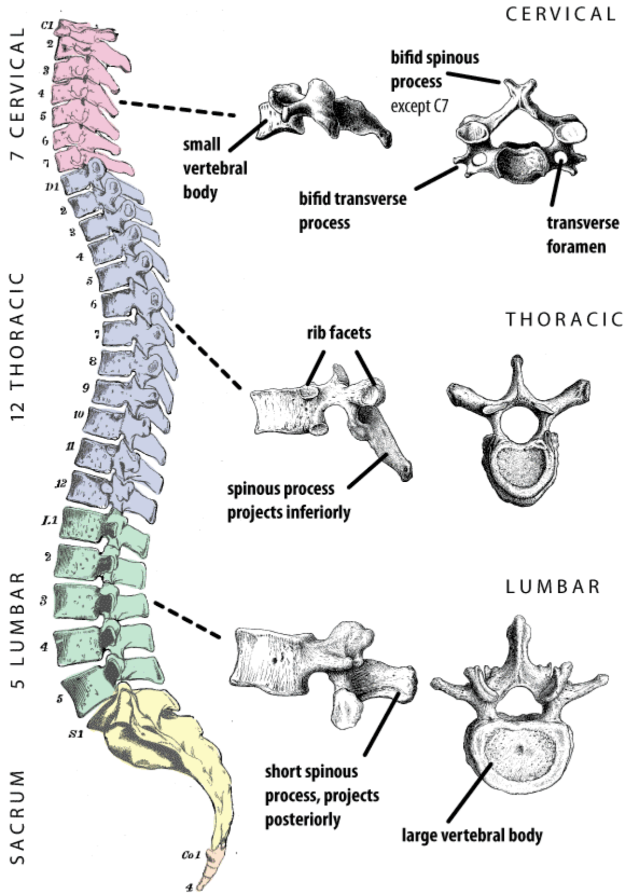
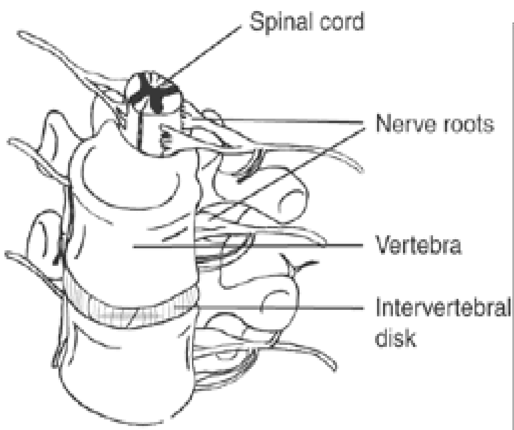
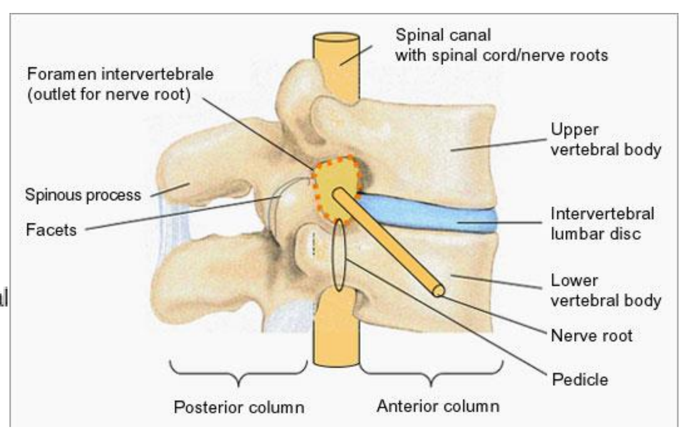


Fig 2.4 The back bone protects the spinal cord





EXTERNAL FEATURES OR COMPONENT OF VERTEBRAE

A. Centrum
B. Neural arch
C. Neural spine
D. Transverse processes
E. Neural canal
F. Anterior facets (zygapophyses)
G. Posterior facets (zygapophyses)

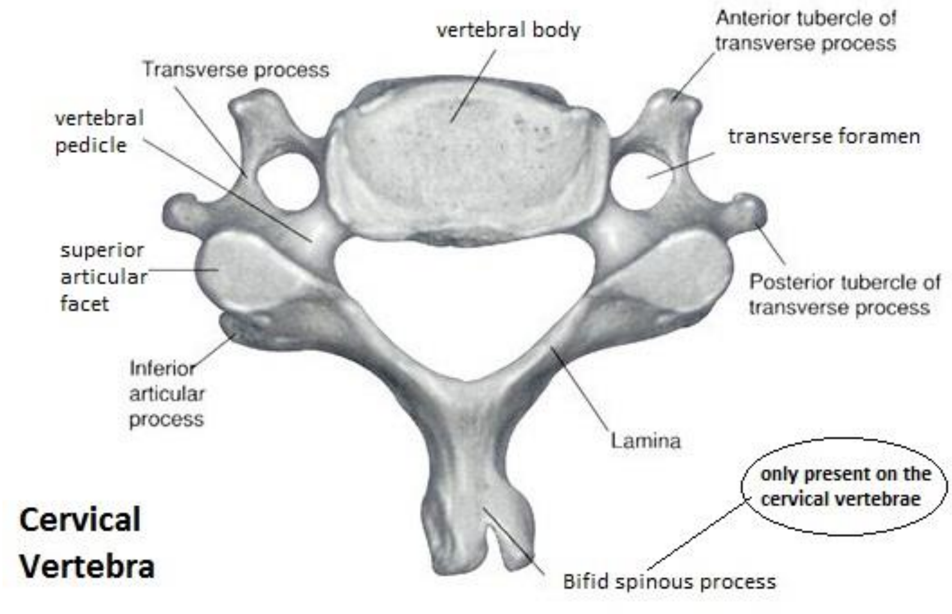
The solid centrum forms the body of the vertebra and provides support and protection for the spinal cord; It carries the **neural arch** and the **neural spine**. The neural arch and neural spine provides a surface for attachment of muscles, the facets are small projections from the neural arch. The smooth surfaces of the anterior and posterior facets articulate with adjacent vertebrae

Cervical Vertebrae

The seven cervical vertebrae are found in the neck region of mammals such as humans, rate, and rabbits. The first cervical vertebrae below the skull are the atlas, followed by the axis. The odontoids process of the axis vertebra fits into the ventral side of the neural canal of the atlas vertebra. This allows rotational movement of the atlas about the odontoid process, which acts as a pivot, allowing side to side movement of the head. Nodding of the head is also made possible so that the mammal can look down and up.

Cervical vertebra supports the head region and protects blood vessels and nerves that pass through their canals. They also provide surface for the attachment of neck muscles.

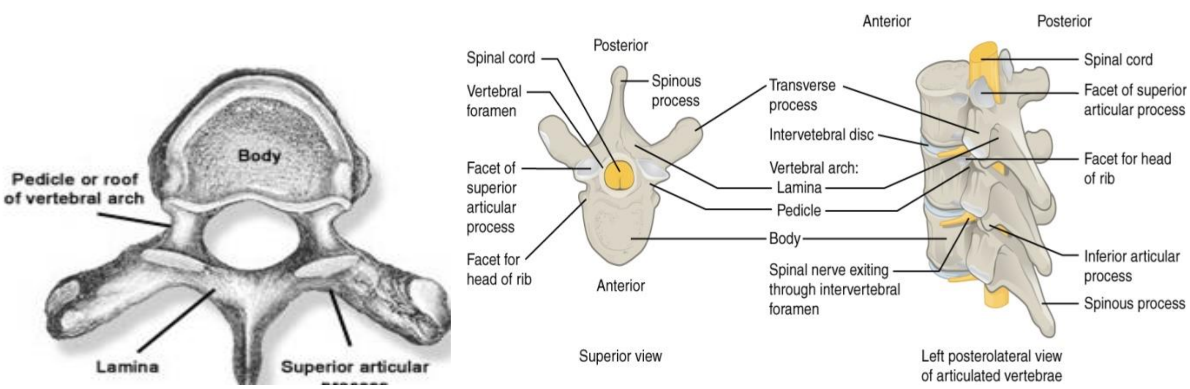
Fig Fig 2.5 Cervical Vertebra



<u>**Thoracic vertebrae**</u>

There are twelve thoracic vertebras in humans. The long neural spines are suitable for attachment of the large thoracic muscles one end of each rib articulates vertebrae to form the ribcage. The large centrums enable – the vertebrae to support the head, neck and shoulder regions of the body.

<u>**Fig 2.6 Thoracic Vertebra**</u>

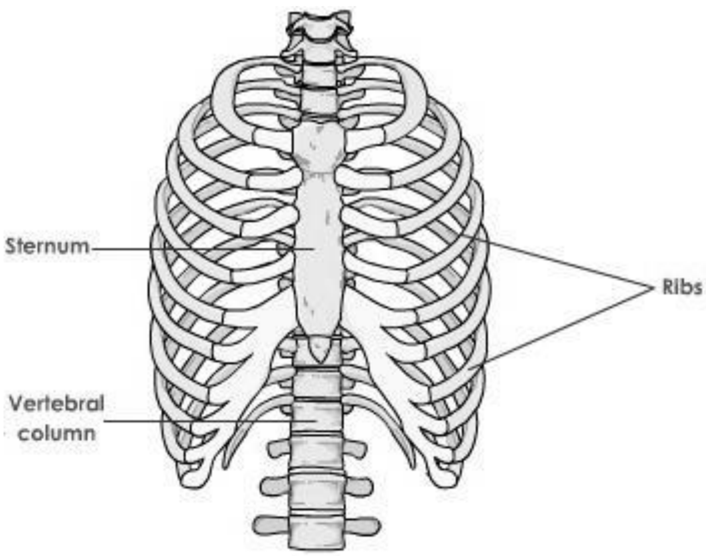


Ribs

There are twelve pairs of long curved bones which lie within the wall of muscles in the thoracic vertebra by two projections. The first nine pairs of ribs have a bar of cartilage at their ventral ends, this joint the eighth and ninth pairs of the ribs to rib above each one. The last three pairs of ribs have no bar of cartilage and so are free at the ventral ends. These are called floating ribs. This arrangement enables a projective cage of bones to be formed which encloses the heart and lungs.

The intercostals muscles between the ribs act on the ribs to bring about breaths movements. The ribs are associated with the axial skeleton

<u>Fig 2.7 Ribs and Sternum</u>



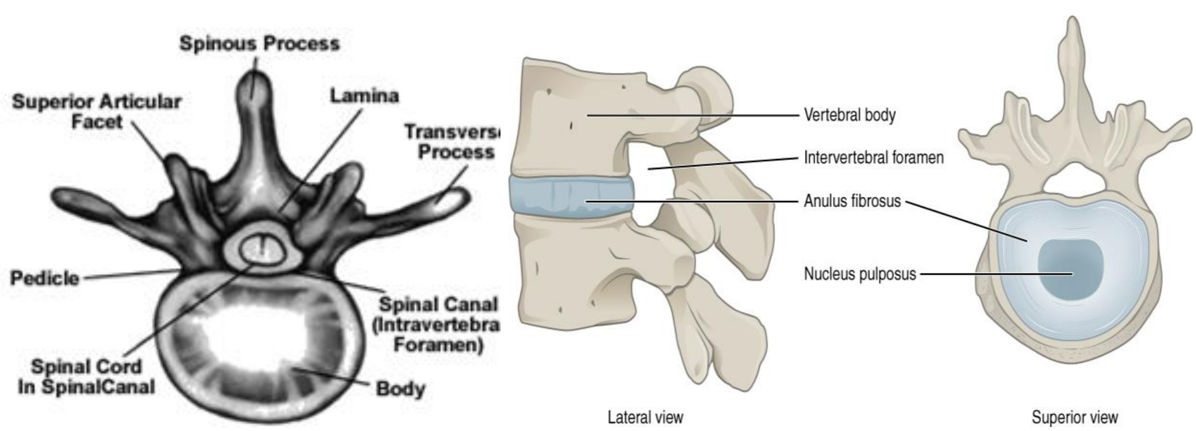
Sternum

The sternum has seven small bones (sternobrae) that run down the centre of the chest region on the vertebrae side. The last sternobrea ends with a plate of cartilage which is fan shaped. The sternum forms part of the rib cage and provide surfaces for attachment of ribs.

Lumbar Vertebra

The human vertebrae have five lumbar vertebras. It has a number of projections that provide surface for attachment of abdominal muscles and muscles of the lower half of the back. The large thick Centrum gives support to the upper half of the body

<u>Fig 2.8 Lumbar Vertebra</u>



SACRAL REGION

The sacral region (sacrum) is at the bottom of the spine and lies between the fifth segment of the lumbar spine (L5) and the coccyx (tailbone). The sacrum is a triangular-shaped bone and consists of five segments (S1-S5) that are fused together.

CAUDAL REGION

This is also known as the tail region of the vertebra.

ARPPENDICULAR SKELETON

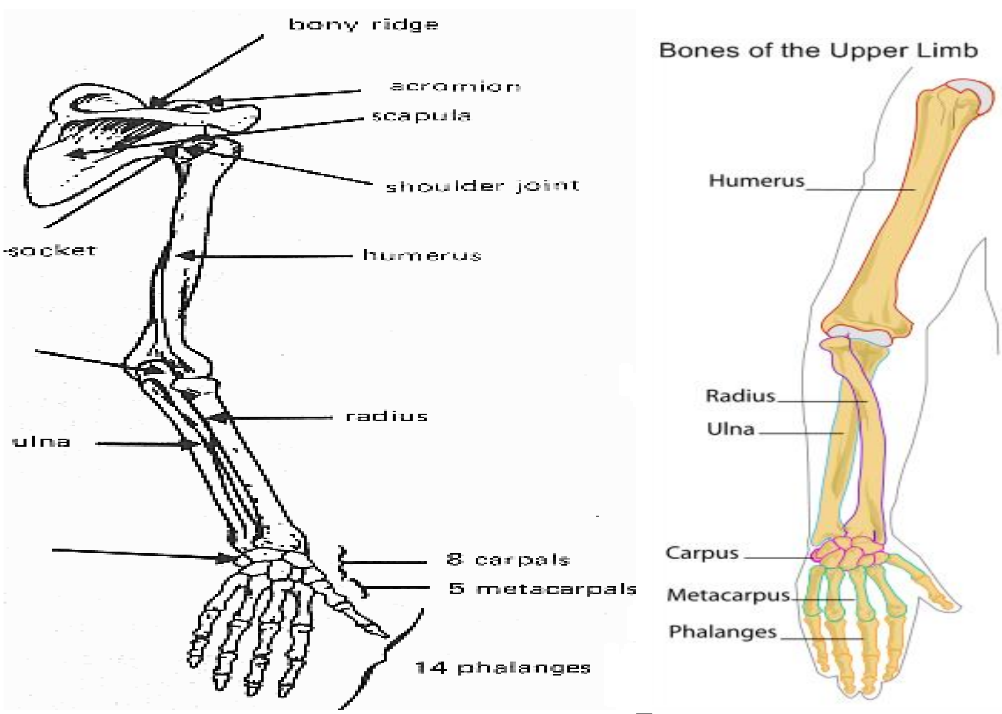
This is made of the limb bones and their girdles.

<u>THE FORE – LIMB BONES</u>

THE STRUCTURE OF THE FOREARM

1. The forearm is made up of the humerus (upper arm), the ulna and the radius.
2. The wrist and the hand are made up of small carpal bones, metacarpal and phalanges.
3. The humerus forms a ball and socket joint with the scapula at the shoulder and a hinge joint is formed between the humerus and the ulna at the elbow.

<u>Fig 2. 9 Skeleton of the forearm</u>



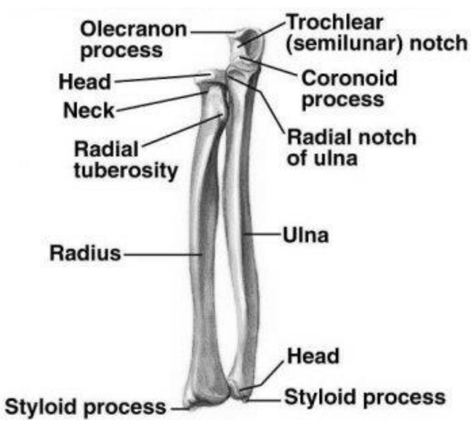
Humerus

It is the long upper arm bone and supports the upper arm and its rounded head fits into the glenoid cavity of the scapula to form the shoulder Joint. Similarly, the trochlea fits into the sigmoid **notch** of the ulna to form the elbow joint.

The humerus provides surfaces for attachment of muscles, with the supratrochlear foramen providing a passage for blood vessels and nerves. Red blood cells are manufactured in the bone marrow.

Radius and ulna
They are the long bones of the lower arm. The ulna is slightly longer than the radius. The radius starts from the elbow and leads to the thumb, while the ulna leads from the elbow to the small finger. The ulna and radius support the lower arm and their relative movement allow for rotation. The olecranon process of the ulna prevents the arm from bending backwards, both bones provide for attachment to the lower arm muscles. Red blood cells are also manufacture in the bone marrow.

<u>Fig 2.10 Radius and ulna</u>

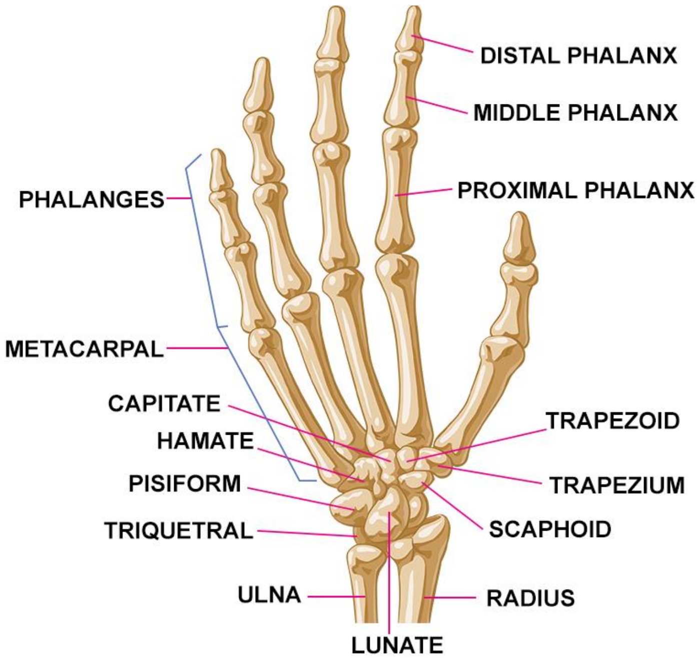


Carpals
There are nine small bones in the wrist which articulate with the ulna and radius at the upper end and the metacarpals at the lower end. Carpals allow free movement of the hand and support the wrist. They also provide surface for attachment of wrist muscles of the palm and also support and maintain the shape of the palm.

Metacarpals
There are five slightly elongated bones are found in the palm, each of them articulate with a phalanges (finger bones). Metacarpals provide surfaces for attachment of muscles of the palm and also support and maintain the shape of the palm.

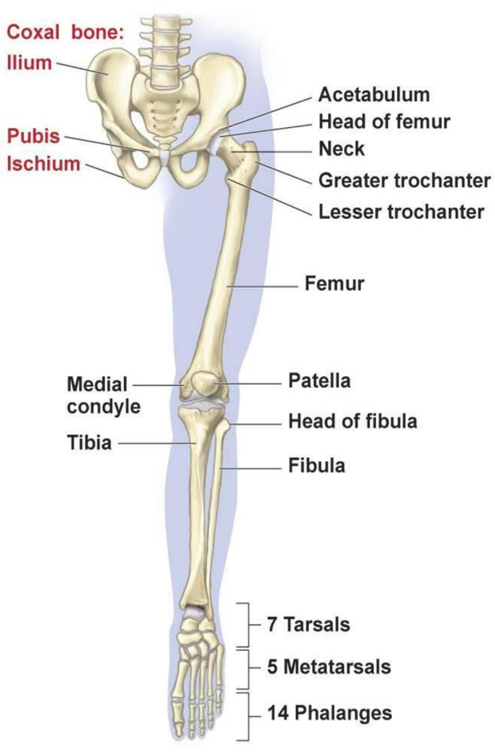
Phalanges
Each of the fingers consists of three short bones with joints between them. But the thumb has two bones. The phalanges support the fingers, joints between the bones allowing for bending movement of the fingers for holding and grasping objects.

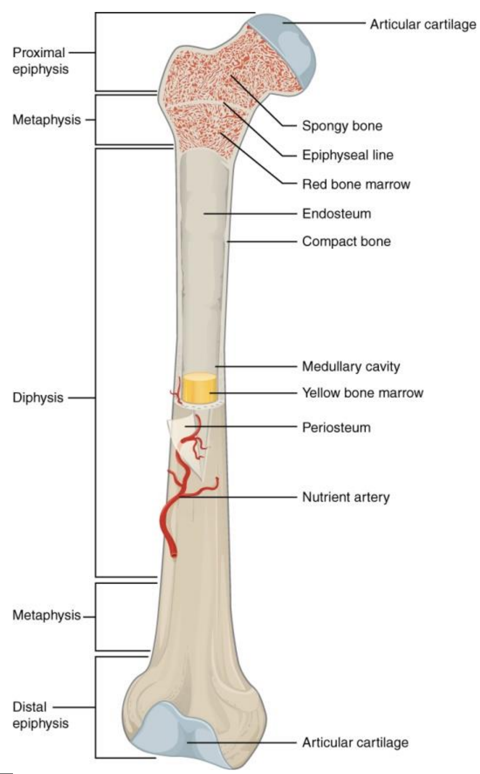
<u>Fig 2.11LABELLED DIAGRAM OF HUMAN HAND</u>



THE HIND LIMB BONES

Fig 2.12 Longitudinal section of a long bone (limb bone)





Femur

They are long bones situated in the thigh or upper leg region. The femur provide surface for the attachment of the leg muscles and support the thigh. The head fits into the **acetabulum** of the pelvic girdle to form the hip joint. The femur articulates with the tibia at the lower end to form the knee joint Red blood cells are manufactured in the bone marrow

Tibia and Fibula

They are long bones of the lower leg. The tibia is a very long bone and may be free from or parly fused to the smaller fibula which lay alongside it. A small round bone called patella (knee cap) lays in front a knee joint. The knee cap prevents the leg from bending upwards at the knee.

The tibia and fibula support the shin and provide surface for attachment of the shin muscles. They articulate with the femur to form the knee joint, and with metatarsals to form the ankle joint. Red blood cells are manufactured in the bone marrow.

Tarsals

They are six small bones in the ankle. Two are elongated and one of these two projects backwards to form the heel bone. The tarsals provide surfaces for attachment of the ankle muscles. The heel bone prevents the food from bending back ward.

Metatarsals

They are elongated bones in the foot. Human have five metatarsal each one leading to a phalange. The metatarsals provides surface for the attachment of the foot muscles. They also support and maintain the shape of the foot.

Phalanges

The phalanges of the hind-limb are made up of three small bones with joints between them which allow bending movement. But the human toe has two bones. The phalanges serve a variety of functions in grasping, climbing, digging and defense or offence.

The limb girdles

The fore and hind – limbs are joined at their upper ends to a girdle of bones, forming a framework for support. The fore-limb are joined to the pectoral girdle while the hind- limb are joined to the pelvic girdle

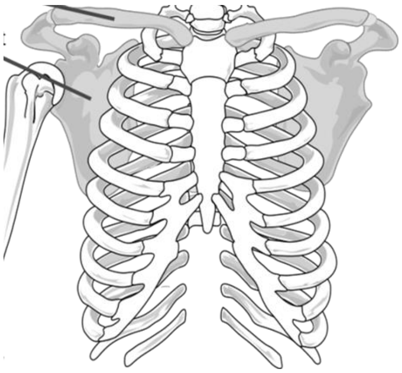
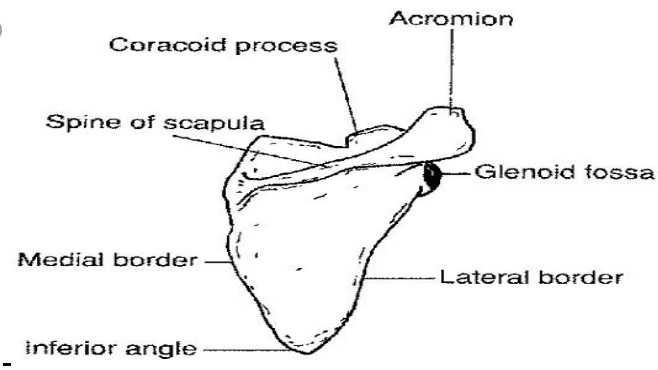
The pectoral girdle

The pectoral girdle has a scapula (shoulder blade) in each half, coracoids and clavicle (collar bone). The scapular is triangular, with a narrow end which lies at the shoulder and a broad base which lies parallel to the vertebral column .

The coracoid fuses with the scapula as a bone one end of which is joined to the scapula the other end being joined by ligaments to the sternum.

The pectoral girdle supports the arm and the scapula provides surfaces for attachment of shoulder muscles. The glenoid cavity provides a socket for the head of the humerus, forming the shoulder joint

Fig 2.13 Pectoral girdle

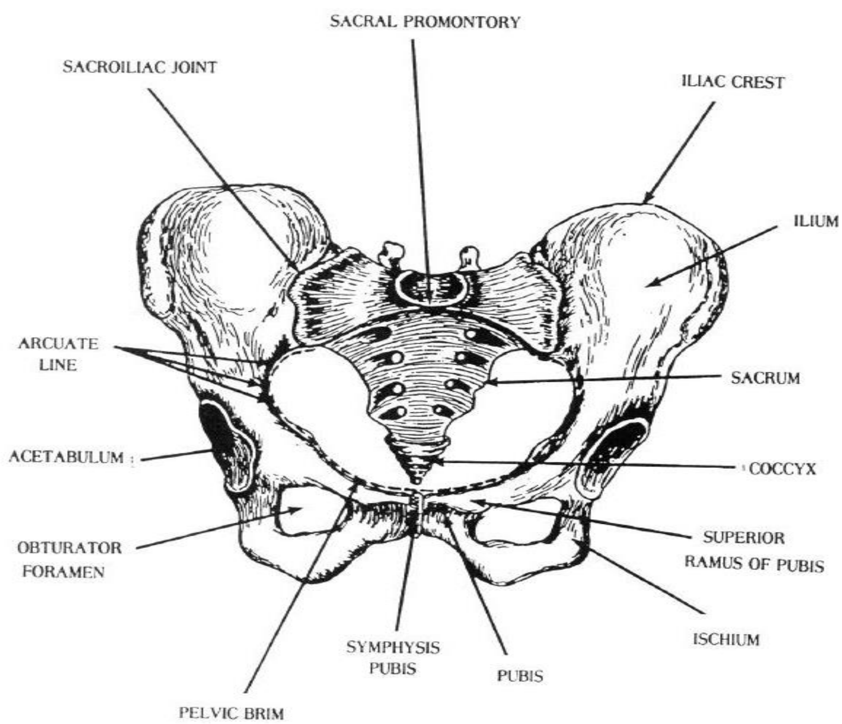
 

The pelvic girdle

The pelvic girdle is made up of several bones which are fused together for greater strength. The bones surround a large hole called the obturator foramen.

The pelvic girdle forms a protective cage around vital organs eg. the female reproductive organs. It supports the legs articulate with the head of the femur to form the hip joint. It articulates with the sacrum and provides support for a tail where present. The obturator formen provides passage for blood vessels and nerves.

<u>Fig 2.14 Pelvic girdle</u>



<u>Table 2.1 Parts of the skeleton and their function</u>

NO	PARTS OF SKELETON	FUNCTION

1	Skull (cranium)	It encloses and protects the brain
2	Vertebral column	It encloses and protects the spinal cord
3	Cervical vertebrae	They support neck, carry skull and allow it to nod or rotate
4	Thoracic Vertebrae	They articulate with ribs and neural spines to provide a large surface areas for the attachment of back and shoulder muscles
5	Lumbar vertebrae	Provide attachment for abdominal muscles bear considerably heavy weight of the lover abdominal region
6	Sacral vertebrae	Together with pelvic girdle gives skeleton rigidity and strength
7	Caudal vertebrae	Support tail and provide attachment for tail muscles
8	Lower and upper jaw bone	They hold the teeth
9	Pectoral girdle	It attaches the arm to the rest of the skeleton and allows them to swing freely
10	Pelvic girdle	It protects the urinary bladder and delicate female reproductive organ
11	Rib cage	It aids in breathing and protects heart and lungs

Joints

Where two or more bones meet, a joint is formed. Joints may be either **immovable** (tightly fixed together so that movement is not possible e.g. Skull bones) or **movable** (where movement is possible e.g. Shoulder joint).

Movable joints generally permit free movement without injury to the bone. **Articulate** surface of the bones are covered with cartilage to prevent wearing of bones. There is the synovial membrane in between the bones, which secretes the synovial fluid to lubricate the joints.

The synovial joints Such as the ball and socket joints and the hinge joint have the greatest movement.

Components of movable joints:

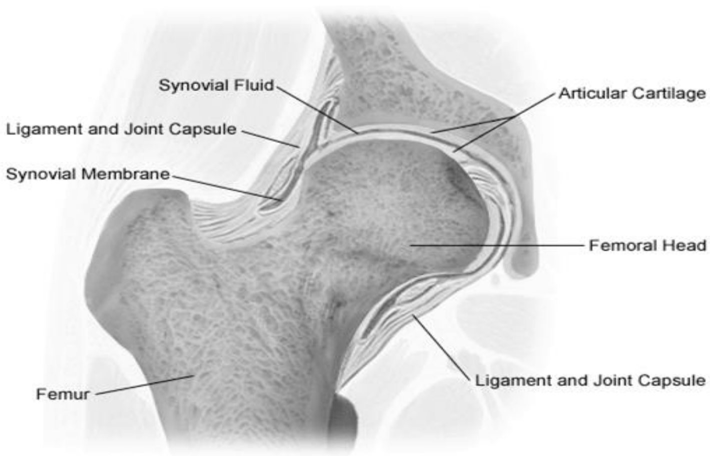
- Bone
- Cartilage
- Ligament
- Synovial membrane
- Synovial fluid

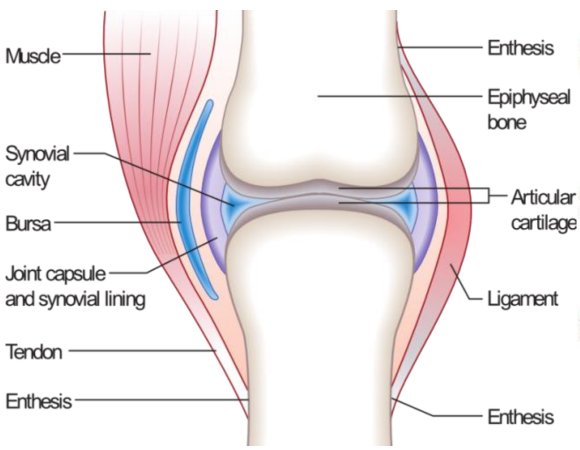
Note: Movable joints are classified based on the degree of movement

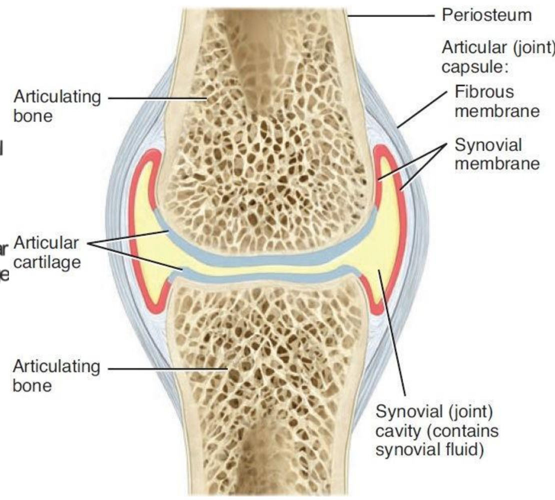
Table 2.2 The different types of joints and their functions

Types of joints	Movement	Location in skeletal system
Fixed joint	No movement permitted	Sutures between the bones of the skill, pelvic girdle
Gliding joint	Limited sliding movement	The vertebrae of the vertebral column, wrist
Pivot joint	Allows nodding and limited rotation of head	Neck
Hinge joint	Allows movement in one plane	Elbow, knee
Ball and socket joint	Allows movement in many plane: back ward, forward etc	Shoulder, hip

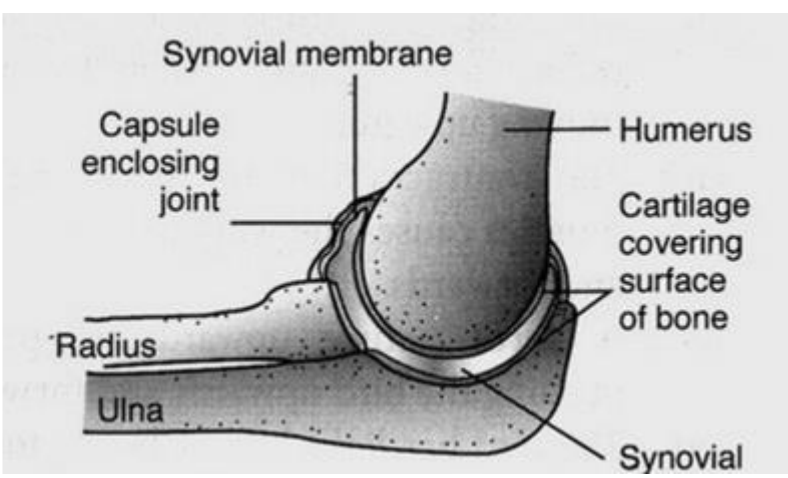
Fig 2.14 Ball and socket joint







<u>**Fig 2.15 Hinge Joint**</u>



fluid

Table 2.3 parts and functions of a typical joint

	Parts of a of Joint	Functions
1	Synovial capsule	A tough, fibrous capsule which holds the joint together. It surrounds the joint, synovial membrane and contains the synovial fluid
2	Synovial membrane	Secretes the synovial fluid and seals in the synovial fluid
3	Synovial fluid	Acts as a lubricant between bones and also provides nutrients to the bone surface
3	Synovial fluid	Acts as a lubricant between bones and also provides nutrients to the bone surface
4	Cartilage Articulate	Soft, slippery, slightly elastic tissue covering the end of the bones allows friction free movement, acts as a shock absorber and prevents wearing of the bones at the joint
5	Ligament	Elastic connective tissue which connects bone to bone. Provides external support and strengthens the joint

<u>Muscles</u>

Most human flesh is muscles. There are three types of muscles:

1) Voluntary muscles
2) Involuntary muscles
3) Cardiac or heart muscles

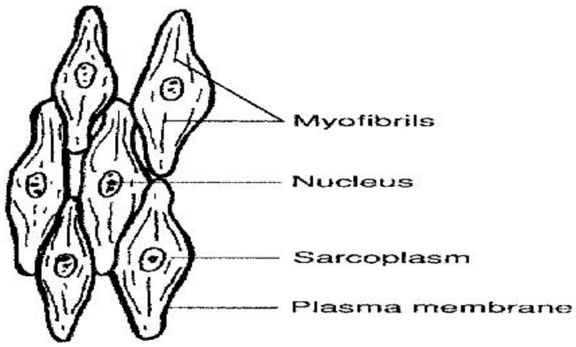
<u>Voluntary muscles</u>

These are also called skeletal or striated muscle and cover the entire skeleton. Tendons attach these muscles to bones. Each muscle is made of fibres which can contract to decrease its length

These fibres have series of transverse bands (Striations) at right angle to the long axis. The fibres occur in bundles bounded by a sheath of connective tissue. Each muscle consists of a number of such bundles together with nerves and blood vessels, all bounded by a further sheath of connective tissue. Voluntary muscles can undergo rapid contraction and are particularly concerned with the movement of skeletal parts of which they are usually connected .

They are under a person's control and can become tired move easily than other types of muscles examples of voluntary muscles include: The Biceps and Triceps of the upper arm

<u>Fig 2.16 Involuntary muscles</u>



Involuntary or smooth muscle

It consists of elongated spindle – shaped cells without striations. These cells are bound together by connective tissue. They occur mainly as sheets of tissue surrounding hollow organs such as the intestine, blood vessel, the urinary bladder, and in the iris diaphragm of the eye.

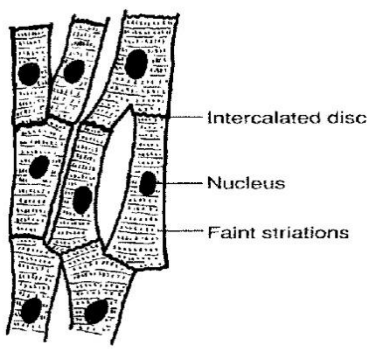
The contraction of involuntary muscles is slow but is capable of remaining contracted for a long time. They are not under a person's conscious control. They do different things. The intestine muscle causes food to be pushed along the organ by peristalsis: While the iris control the amount of light entering the eye

Cardiac or heart muscle

These are found only in the heart and are similar in appearance with the voluntary muscle (striated). They are however joined by cross connections and not as long as voluntary muscles.

The hearts muscles are not under a persons control and contracts rhythmicall throughout life, pumping blood to all parts of the body.

Fig 2.17 CardiacMuscle



TERMS AND THEIR DEFINITION

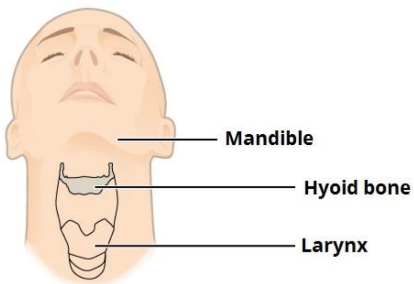
Appendicular skeleton: all bones of the upper and lower limbs, plus the girdle bones that attach each limb to the axial skeleton.

Axial skeleton: central, vertical axis of the body, including the skull, vertebral column, and thoracic cage.

Coccyx: small bone located at inferior end of the adult vertebral column that is formed by the fusion of four coccygeal vertebrae; also referred to as the “tailbone”.

Ear ossicles: three small bones located in the middle ear cavity that serve to transmit sound vibrations to the inner ear.

Hyoid bone: small, U-shaped bone located in upper neck that does not contact any other bone. The hyoid bone is responsible for attachment of the root of the tongue as well as anchors the hyoglossus muscles for creating a depression on the tongue so as to enlarge the oral cavity. For these reasons the hyoid bone is known as the **lingual** and **tongue bone**.



Ribs: thin, curved bones of the chest wall.

Sacrum: single bone located near the inferior end of the adult vertebral column that is formed by the fusion of five sacral vertebrae; forms the posterior portion of the pelvis.

Skeleton: bones of the body.

Skull: bony structure that forms the head, face, and jaws, and protects the brain; consists of 22 bones.

Sternum: flattened bone located at the center of the anterior chest.

Thoracic cage: consists of 12 pairs of ribs and sternum.

Vertebra: individual bone in the neck and back regions of the vertebral column.

Vertebral column: entire sequence of bones that extend from the skull to the tailbone.

UNIT TWO
SUPPORTING SYSTEMS IN PLANTS

SUPPORTING TISSUES IN PLANTS

Plants generally, are knows to possesses supporting tissues which gives them definite shape, strength, rigidity and resistance against external forces such as wind and water to which they are continuously subjected.

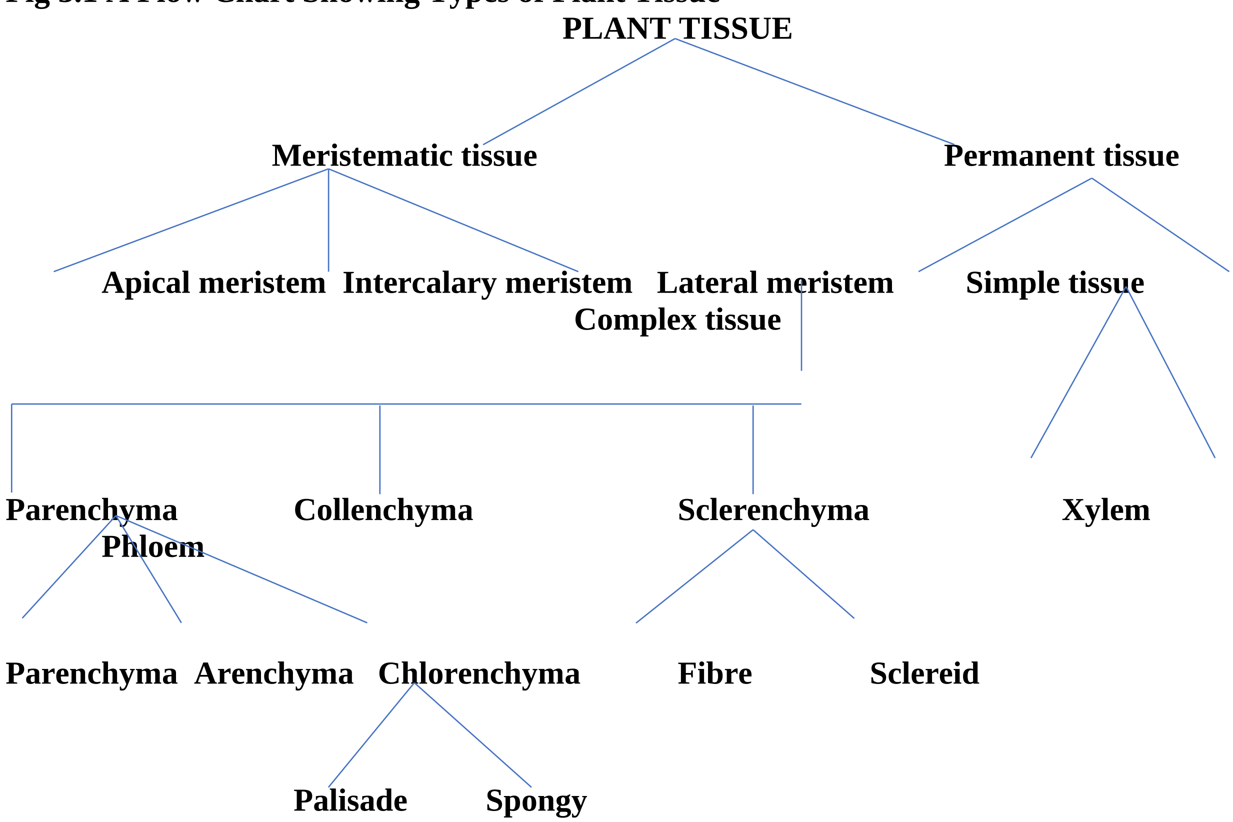
MECHANISMS OF SUPPORT IN PLANTS

The entire body of plants, either internal or external, provides the necessary support to plants. The knowledge of the internal structure of the leaves, stem and roots will assist in the understanding of the mechanisms of support in plants.

TYPES OF SUPPORTING TISSUES IN PLANTS

The main supporting tissues in plants are **parenchyma, collenchyma, sclerenchyma (fibre),** and **wood** or **xylem**. Blow is a flow chart to summarise plant support tissue.

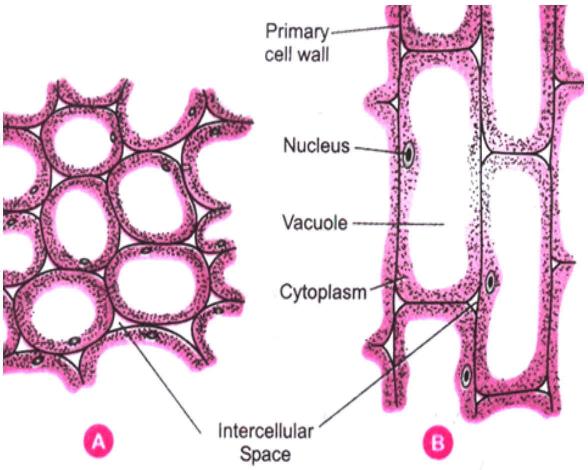
Fig 3.1 A Flow Chart Showing Types of Plant Tissue



PARENCHYMA TISSUES

The parenchyma tissues are found in the cortex of stem, phloem, root, leaf, mesophyll, storage tissues and the xylem of plants. It is about three or four cells thick. The parenchyma is made of large, thin-walled cells with many air spaces. Both cells provides strength and support.

Fig. 3.2 Parenchyma Tissue A) Transverse section B) Longitudinal Section



MESOPHYLL

The mesophylls are composed of cells with large vacuoles and relatively thin wall. They are mainly living cells with cellulose and many air spaces within them. Parenchyma tissues are the most common and in abundant of plants tissues.

FUNCTIONS OF THE PARENCHYMA

The functions of the parenchyma are as follows:

A. When the vacuoles are filled with sap, parenchyma tissues gives firmness and **turgidity** to the stem of herbaceous plants which remain firm and erect as they create pressure within these cells. This provides mechanical strength.
B. The parenchyma can also store food (starch, proteins), water and hormones as well as waste products such as gum, tannin, resin etc.
C. They perform the metabolic activities of the plant.
D. They form packaging tissue between the specialised tissues.
E. They are found in the leaf and mesophyll, functioning mainly in the synthesis of food or photosynthesis (chlorenchyma).

COLLENCHYMA TISSUE

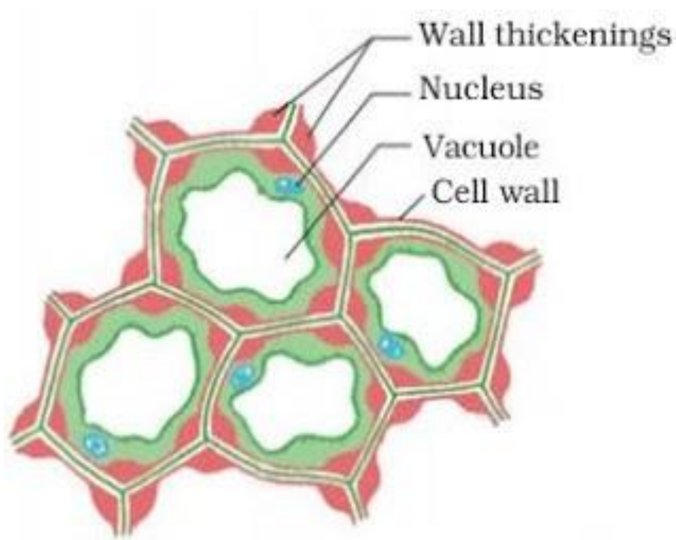
Collenchyma cell are usually located in the Cortex of stem, root and in the hypodermis just beneath the epidermis. The cells of collenchyma tissues are living, elongated and unevenly thickened at the corners. The cells are **flexible** thus allow the bending and twisting strains to which the stem, roots and the leaves of plants are often subjected to.

THE FUNCTIONS OF A COLLENCHYMA

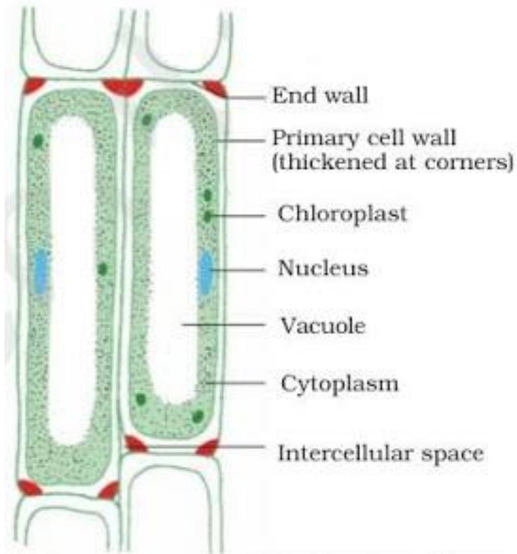
i. Collenchyma cells provide **strength and supports** in young growing plants parts such as the stem, petioles and leaf blade.
ii. The Collenchyma cell gives **flexibility** and resilience to the plant.

They also enable the plant to bend without breaking.

Fig. 3.3 Collenchyma Tissue A) Transverse section B) Longitudinal Section



A



B

SCERENCHYMA

Sclerenchyma cells are found mainly in the pericycle of vascular tissues, cortices of stem and roots. The structure of the Sclerenchyma cells is that they have thicken walls containing lignin in addition to cellulose and other substances. There are two types of sclerenchyma tissues, these are **Fibres** and **Sclereids.**

1. **Fibres** are elongated cells with tapering ends. These help to provide strength and flexibility to plants.
2. **Sclereids** unlike fibres, are not too elongated but have great strength like the fibres too.

Fig. 3.4 Sclerenchyma Tissue A) Longitudinal Section B) Transverse Section

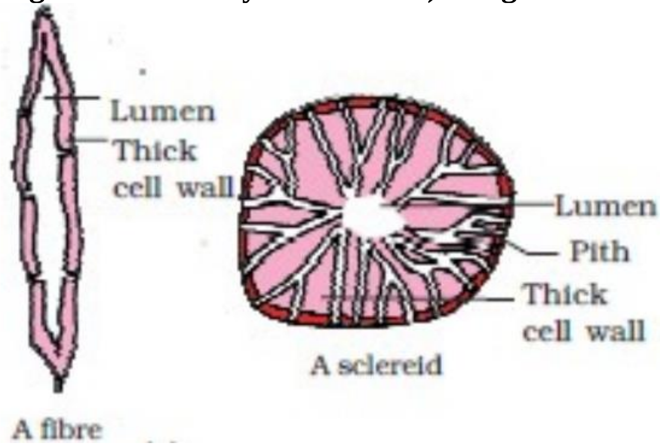
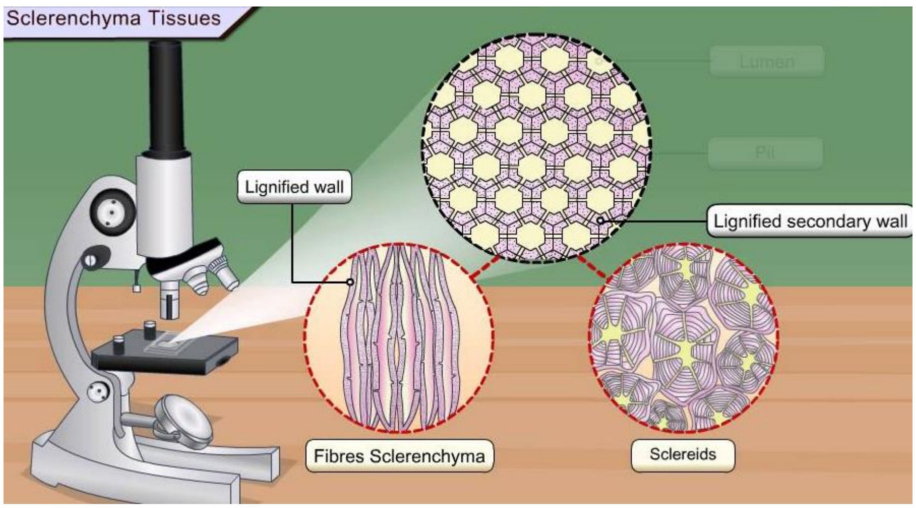


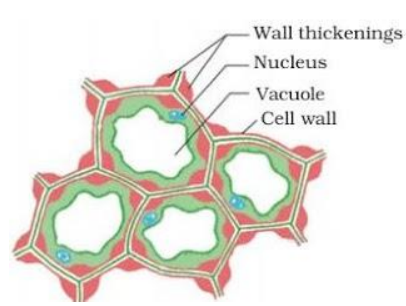
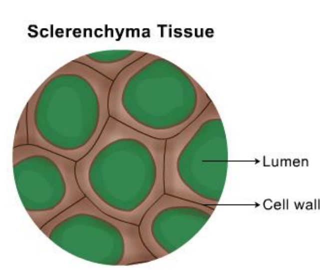
Fig: 3.5 Section of Sclerenchyma under a Microscope



FUNCTIONS OF SCLERENCHYMA

The functions of Sclerenchyma are as follows;
i. The Sclerenchyma fibre type give flexibility to plants and prevent them braking up easily
ii. Sclerenchyma provide strength, **rigidity**, hardness and support to plants

MAIN FEATURES OF SUPPORTING TISSUES AND THEIR DIFFERENCES

<table>
<tr><th>Features</th><th>Parenchyma</th><th>Collenchyma</th><th>Sclerenchyma</th></tr>
<tr><td></td><td></td><td>
</td><td>
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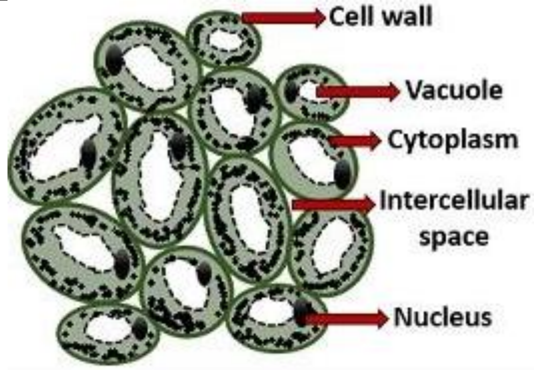
			
Cell shape	Isodiametric cells which are oval, spherical or polygonal in shape.	Circular, oval or polyhedral.	Variable in shape. Fibre and sclereids.
Cell wall	Thin cellulose cell wall	Uneven thickening on their cell wall	Lignified secondary cell wall present
Cytoplasm	Abundant	Present	Absent
Nucleus	Present (living tissue)	Present (living tissue)	Absent (dead tissue)
Vacuole	Large vacuole	Vacuolated	Absent
Intercellular space	Present	Absent	Absent
Occurrence	Basically parking tissue, soft part of plant: pith , cortex and medullary ray.	Dicot stem, petiole and beneath the epidermis, absent in monocots and roots	Dicot hypodermis, bundle sheath, pericycle, seed and pulp of fruit
Function	Food storage and photosynthesis	Provides tensile strength, mechanical support and photosynthesis	Protection from stress and strain as well as give mechanical support

WOOD OR THE XYLEM TISSUES

Then wood or Xylem tissues are mainly in the vascular tissues of stems, roots and leaves.

Structure of the wood or Xylem tissues is made up of many cells. They are:

i. Tracheid’s
ii. Vessels
iii. Fibres and
iv. Xylem parenchyma

TRACHEIDS: Tracheids are non-living elongated, tapering cells with thickened, lignified walls which have piths that aids the passage of water and helps to dissolve mineral salts.

VESSELS: Vessels are long tabular structures that are formed by the fusion of several elongated cells places or stacked one upon another.

FIBRES: fibres are similar to the Sclerenchyma fibres. They are narrow, elongated cells with very thick walls and tapering end walls.

XYLEM PARENCHYMA: these are similar to the parenchyma tissues. They are composed of cells with large vacuoles. The functions of the Xylem parenchyma tissues are as follows
1. The Xylem tissues provides support, strength and shape to the plant.
2. Xylem parenchyma is also a conducting tissue as it helps to conduct water and dissolve mineral salts from the roots to the leaves.

PHLOEM TISSUES

The phloem tissues are closely associated with the major supporting tissues. The tissues are located within the vascular bundles of all plants, be it in the roots, stems or leaves.
The structure of the Phloem tissues are made up of four cells. These are sieve tubes, phloem parenchyma, companion cells and phloem fibres.

Sieve tubes: these are made up of elongated rows of cylindrical cells arranged vertically. The cells are living and mainly conducts food

Phloem parenchyma: these are similar to the parenchyma cells earlier discussed. They provides strength and support to the plant. The cells also helps in food storage

Phloem fibres: these are special cells which are concerned with the strenghtening of the organs in which they are found

Companion cells: they are small and short cells which are vertically elongated like the sieve tube. They assist in the conduction of food substances

FUNCTIONS OF THE PHLOEM TISSUES

i. The general function of the phloem tissues is to conduct manufactured food from the area of synthesis to the Areas where they are mainly needed.
ii. Secondly, the Phloem tissues assists to provide support to the entire plant
NOTE
The vascular tissues which is the xylem and phloem tissues, are found mainly in the roots, stems, and leaves of plants

EPIDERMIS OR THE PILIFEROUS LAYER

The epidermis is the outer covering of the leaves and stem while that of the roots is called piliferous layer. The epidermal layer is one-cell thick. Their function is mainly protection. They prevent the inner cells from injury, infection and loss of water. In some cases only the guard cells of the leaves that has chloroplast are the only cells that can carry out photosynthesis.

CORTEX

The Cortex is mainly found between the epidermis and the vascular bundles of the dicotyledonous stem. The cortex is made up of three tissues which are collenchyma on the outside, parenchyma on the middle and endodermis on the inner.

THE ENDODERMIS

It is a single layered cell which is often regarded as the starch sheath. It stores starch hence when stained with iodine solution will always turn blue black.

SCLERENCHYMA

This layer is found on the outer part of vascular bundles. It consists of dead, lignifies cells. It aids to strengthen the stem.

VASCULAR BUNDLES

Vascular bundles are found in the inner parts of the stem. It consist of xylem, phloem and cambium tissues.

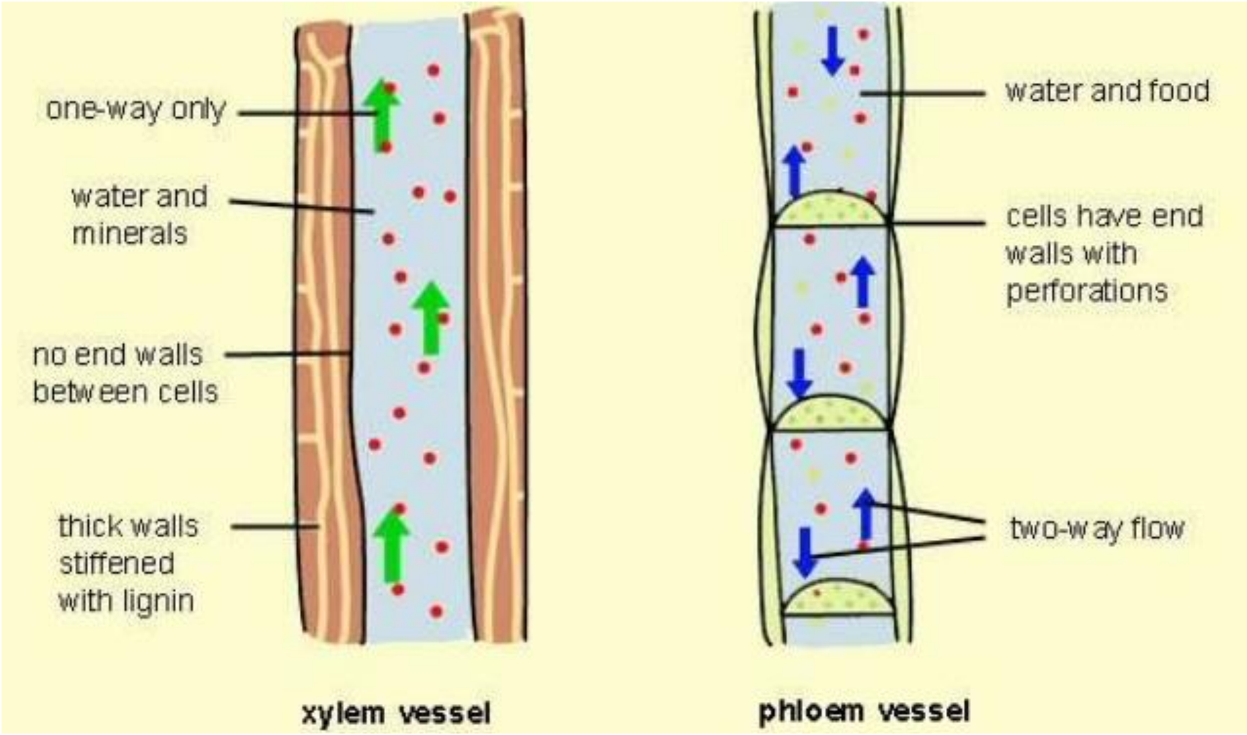
XYLEM

Xylem is responsible for the conduct of water and dissolved mineral salts from the soil to the roots through the roots and stem.

PHLOEM

Phloem is responsible for the transportation or conduction of manufactured food from the areas of synthesis to the where they are needed within the plant.

Fig: 3.6 Section of Vascular Bundles



CAMBIUM

Cambium which almost look like the **bone marrow** in animals is found between the xylem and the phloem. The cambium cells are constantly dividing cells which are called secondary thickening and is responsible for the increase in size of the stem of so many trees.

PITH

The pith is the central part of the stem. It is large and is made of the parenchyma and extends between the vascular tissues. In flowering plants, strength and rigidity are achieved by a combination of tugor pressure and supporting tissues. The parenchyma cells of the Pith when fully turgid, push outside and this force is restrained by the inelastic epidermis.
Hence when the cells of the parenchyma tissues are fully expanded, with water-turgid, they give rigidity and strength otherwise known as **HYDROSTATIC SUPPORT.**
In the vascular bundles, the xylem vessels and fibres which are lignified, adds mechanical strength to the stems and roots of the plant. The function of the cambium, which contributes to the growth of trees trunks in width, provides the necessary support and strength to plants. The wood fibres generally make stems strong and rigid. Other supporting tissues such as the parenchyma, collenchyma and sclerenchyma provides necessary strength needed by plants.

USES OF FIBRES TO PLANTS

Sclerenchyma fibres known simply as fibres provides flexibility and strength.
Two of the special function of the fibres in plants.

The fibres gives mechanical functions that is the necessary strength, rigidity, flexibility and elasticity to the plant body and also enables it to withstand various strains. Plants like Hibiscus, jute and sisal are known to contain some of the strongest plant fibres hence they are used in making ropes, mats, clothes and sacks.

FUNCTIONS OF THE SUPPORTING TISSUES IN PLANTS

The functions of the supporting tissues in plants include:

1. Strengthening
2. Rigidity
3. Resilience and flexibility
4. Protection
5. Distinct shape and
6. Conduction

How support is provided for in Herbaceous plants: Herbaceous stems are soft. The fluid in the plant cells support the stem of these plants by having;

i. Turgidity, water is preserved,
ii. Presence of water, vacuoles inside the parenchyma cells/living cell.
iii. Thickening of the walls of collenchyma cells.

How support is provided for in woody plants: **Woody stems** are hard and rigid. Woody stem have an outer layer of material called bark which provide support.

A. Sclerenchyma in the Cortex
B. The xylem strengthened the deposited ligning in their walls
C. Secondary growth provides extensive xylem and bark

How support is provided for in aquatic plants

Aquatic plants, unlike land plants need little supportive tissue. They often have numerous **air sacs** in their stems, leaves and roots. These air sacs provide buoyancy to help them to stay afloat or upright in water.

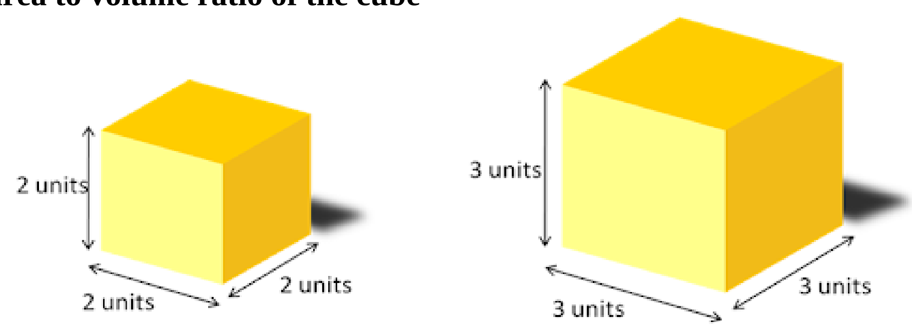
TRANSPORT IN PLANTS AND ANIMALS

Plants and animals are multicellular organisms therefore require complex means of transport of material from one part of the organism to the other. This is because unlike unicellular organisms which are much smaller, plants and animals are much larger thus use different transport system or a combination of two or more of the transport systems unicellular organisms use. Note that as the size of an organism increases, its surface area to volume ratio decreases. This means the **surface area to volume ratio** of a multicellular organism is a lot **smaller** than a unicellular organism thus it has relatively less surface area available for substances to diffuse through, so the rate of diffusion may not be fast enough to meet its cells requirements. Large multicellular organisms therefore cannot rely on diffusion alone to supply their cells with substances such as food and oxygen and to remove waste products.

Therefore, to increase surface area to volume ratio, multicellular organisms develop a complex system of tubes and a channel that delivers solutions from their external environment to the cells buried deep inside them. This system of tubes and channels becomes what is known as the **TRANSPORT SYSTEM** in these organisms. In plants, the transport system is known as the **vascular system** which includes **xylem** and **phloem** tissues. In animals, the transport system is known as the **cardiovascular or circulatory system** which includes the **heart, arteries, veins** and **capillaries**. Both systems serve to deliver fluids rich in oxygen and nutrients to cells found deep in the body of the multicellular organism, as much as removing the wastes produced by them.

SURFACE AREA TO VOLUME RATIO DEMONSTRATION

Fig. 3.1 Increasing the surface area of a cube, increases its volume, but decreases the surface area to volume ratio of the cube



Surface Area = 6 X 2^2 = 24 units^2
Volume = 2^3 = 8 units^3
SA/V Ratio = 24/8 = 3

Surface Area = 6 X 3^2 = 54 units^2
Volume = 3^3 = 27 units^3
SA/V Ratio = 54/27 = 2

The larger box has 1½ the height, length and width of the smaller box, but only has almost half the relative surface. So the larger SA/V ratio of the smaller box would allow more efficient diffusion and exchange of materials.

The significance of surface area to volume ratio on living organisms can be explained when one considers each cube as though they were cells. Diffusion, osmosis or active transport occurs between the external environment and the cell, moving substances across the cell membrane. If a cell has a very large surface area and a small volume, this would suggest that there is **more cell membrane (surface area)** through which diffusion, osmosis and active transport may take place, and the substances will reach the internal volume of the cell **quickly**. Moving substances quickly into or out of a cell is critical for life processes. If food takes too long to get across the membrane and reach the internal volume, then the cell will starve. Likewise, if toxins cannot be removed out of the cell quickly, and accumulates in its internal volume, the cell will die.

Large multicellular organisms like you and I have very small surface area to volume ratio. There is a lot of volume that forms the bulk of our bodies, but the surface area (our skin that is) cannot provide for the rapid transport of materials into and out of the deepest recesses in our bodies. Cells that are buried under layers of other cells cannot rely on simple diffusion, osmosis or active transport for the exchange of substances simply because this will take too long!
So how do we solve this problem?
The solution is simple.... if SA/V ratio is small, that means.... surface area is small.... volume is large....
And if we were to solve the problem of having a small SA/V ratio.... we will therefore increase...? Or decrease....? Think about it and try to solve this problem with your partners...

Work out and fill up the values in the table below and answer the questions that follow

Length of sides of a regular cube	4 cm	5 cm	6 cm	10 cm	15 cm	30 cm
Total Surface Area/cm^2						
Volume/ cm^3						
Surface Area to Volume Ratio						

1. What can you say about the length of the sides of a regular cube in relation to its total surface area? Does it increase, decrease or remain the same as the length of each side of the cube increases?
2. What can you say about the length of the sides of a regular cube in relation to its volume? Does it increase, decrease or remain the same as the length of each side of the cube increases?
3. What can you say about the length of the sides of a regular cube in relation to its total surface area to volume ratio? Does it increase, decrease or remain the same as the length of each side of the cube increases?

TRANSPORT IN PLANTS

In plants, the transport system is known as the **vascular system** which consists of **xylem** and **phloem** tissues.

XYLEM

Xylem is responsible for the conduct of water and dissolved mineral salts from the soil to the leaves through the roots and stem

PHLOEM

Phloem is responsible for the translocation or conduction of manufactured food from the leaves or areas of synthesis to the where they are needed within the plant.

Fig 3.2 Transverse section of a stem

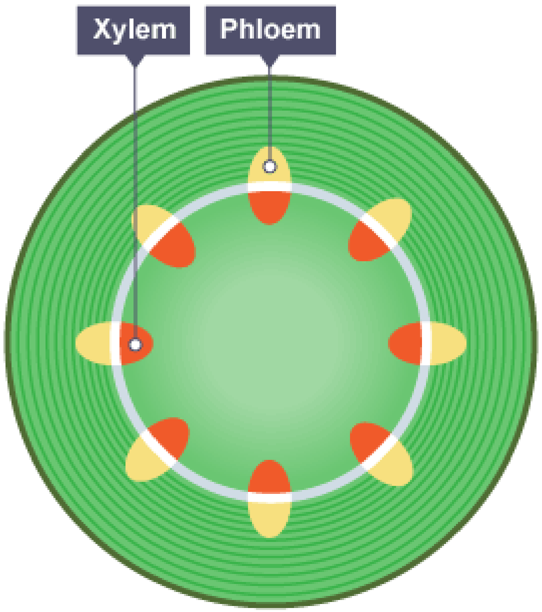
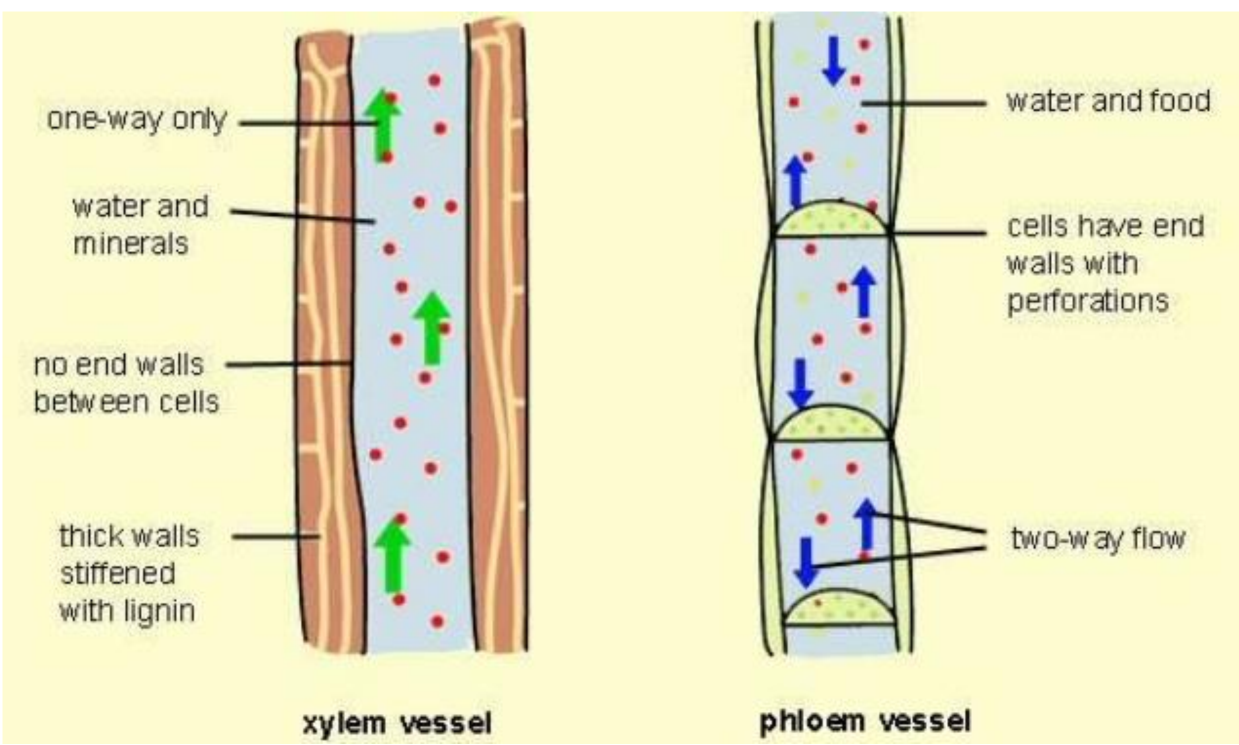


Fig: 3.3 Longitudinal Section of Vascular Bundles



MOVEMENT OF WATER IN PLANTS

- Water moves into the root from the soil and then steady it moves into the root xylem, creating a column of water, which is progressively pushed upwards.
- Evaporation of water molecules from the cells of a leaf creates a suction process, which pulls water from the xylem cells of roots; this process keeps going on.
- The loss of water in the form of vapor from the leaves (i.e. aerial parts) of the plant is known as **transpiration**.
- Transpiration, likewise, helps in the absorption and upward movement of water and minerals dissolved in it from roots to the leaves.
- Transpiration also helps in the temperature regulation (in plants).
- The transport of soluble products of photosynthesis is known as **translocation**, which occurs in the part of the vascular tissue known as **phloem**.
- Along with photosynthesis products, the phloem also transports amino acids and other substances, which are ultimately delivered to roots, fruits, seeds, and to growing organs.

TRANSPORT IN PLANTS

This consists of transport of water, minerals salts and translocation of organic solutes or products of photosynthesis.

A. Transport of Water

Water gets absorbed by the root hair and gets transported inwards by different pathways till it reaches the xylem vessels. This continuous uptake of water creates ***a root pressure*** which pushes the water upwards**.** The pull created due to transpiration of water through the leaves causes the rising of water in the tall trees.

- Phloem Transport
- Transpiration

B. Transport of Minerals

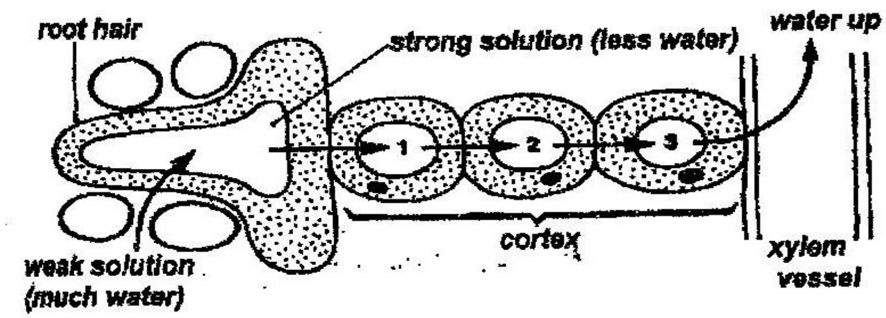
Minerals are also absorbed by the roots and transported upwards through the xylem along with water. Meniral salt is transported in plants by diffusion.

ABSORPTION AND CONDUCTION OF WATER IN PLANTS

Absorption of water by roots of plants

The young root hairs of flowering plants have direct contact with water in the soil. The cell sap in the root hairs is more concentrated then the soil water, hence water is able to pass from the soil into the root hairs by osmosis. The water passes through the thin larger of cytoplasm or cell membrane which is semi-permeable into the vacuole of root hairs.

The extra water raises the tugor pressure of the vacuole or reduces the osmosis pressure and forces water out into the cell walls towards the cortex. The cell next to the root hair cell on the inside has a lower tutor pressure or higher osmotic pressure, hence water will pass into it by osmosis. In this way, the water absorbed will get to the xylem vessels.



TRANSPORT OF WATER IN THE XYLEM TISSUE

Transport of water in xylem tissue is due to the following processes

(i) Root pressure and suction pressure

Root pressure is the pressure that forces water, absorbed from the soil to move through the roots and up the stem of a plant. Root pressure is due to both the osmosis of water from the soil into the root cells, and the active pumping of salts into the xylem tissue, which maintains a concentration gradient along which the water will move.

The root pressure can be demonstrated by cutting a stem, from which water will exude. A manometer can then be attached to the cut stem to measure the root pressure.

To show root pressure

Material required:

- Well-watered young plan
- Rubber tubing
- Manometer
- Clamp stand and champ

Method:

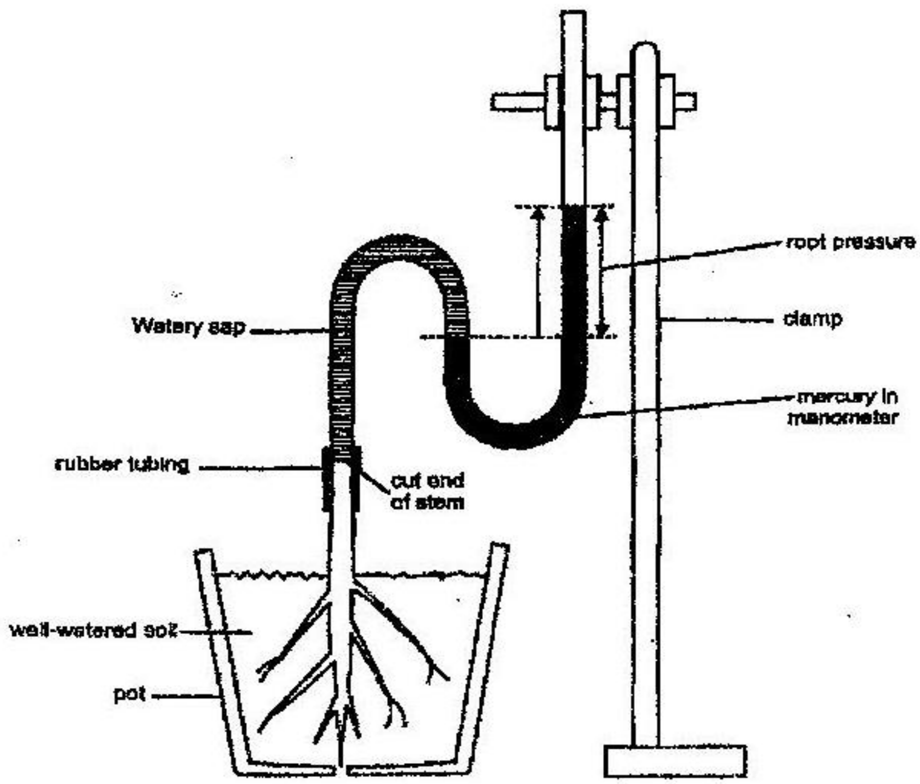
Cut the stem of a well watered as young plant about ten centimetres from the ground.

Notice that watery sap comes out from the cut surface.

Attach a manometer to the stump by means of rubber tubing.

This is due to root pressure, and the amount of root pressure can be determined by measuring the difference in the levels of mercury in the two limbs of the manometer

The pressure can be express in mm of mercury.



To show root pressure

Suction pressure is the total force by which the cell absorbs water from its surroundings. The suction pressure is normally created when water is lost in the form of transpiration through the stomata of the leaves.

(ii) Capillary Action: The upward movement of water through the xylem is mainly achieved through capillary action. The xylem vessels that extend from the roots to the leaves form very fine capillary tubes. Water then rises up such tubes as a result of capillary action. Capillary action is due the attraction of the water molecules and the walls of the xylem vessels.

(iii) Transpiration Pull: The continuous flow of water from the root to the leaves forms the transpiration stream. As water evaporates from the leaf cells, and as photosynthesis is produces more sugar, the osmotic pressure in the leaf cells increase with respect to that in the xylem cells. This causes more water to flow into the leaf cells into the xylem vessels. So there is a pull on the water columns in the xylem vessels and water is drawn up in the plant.

Transpiration

This is the removal of excess water from plants into the atmosphere in the form of water vapour. Plants lose excess water trough:

a) Stomata in the leaves, and this is called stomatal transpiration.
b) The lenticels in the steam and this are called lenticular transpiration.
c) The cuticles of the leaf surface in which is called cuticular transpiration.

To demonstrate Transpiration pull

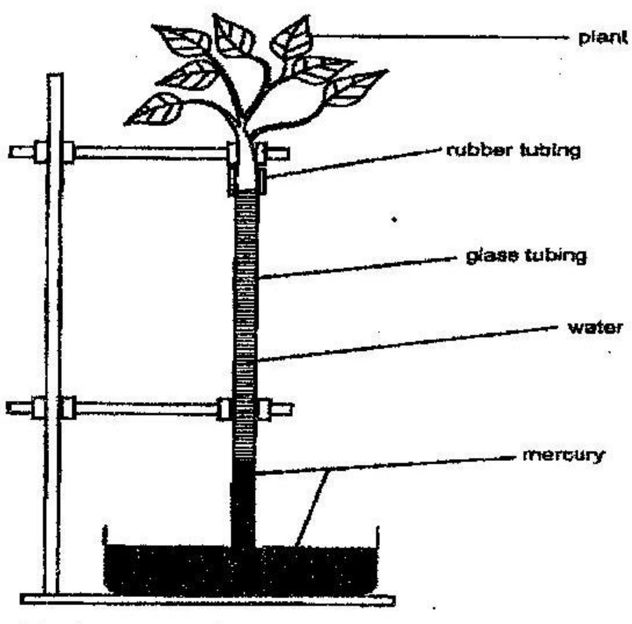
Materials required:

Vigorous young plant, rubber tubing, glass tumbling, mercury, beaker, clamp stand and clamp.

Method:

Cut a young shoot under water to make sure that air does not enter the xylem vessels.

Carefully connect the shoot by means of rubber tubing to a glass tube filled with water while closing the opened lower end of the glass tube with your thump. While still covering the lower end of the tube with your finger, place this lower end below the surface of mercury in a basin. Remove your finger and secure the glass tube with a clamp. Leave the plant to carry on transpiration. As water is lost from the leaves by transpiration, the level of mercury in the tube is seen to rise showing that a pulling force is acting on it. This force is transpiration pull.



Experiment to show transpiration pull

Factors affecting the rate of transpiration

1) **The size of the stomatal pores:** when stomata open due to turgidity of the guard cell, transpiration takes place. Flaccidity of the cells causes the guard sells to close and prevents

transpiration from taking place. The bigger the size of the pores, the higher the rate of transpiration.

2) **Humidity:** the higher the humidity of the atmosphere, the slower the rate of transpiration.
3) **Temperature:** increase in temperature gives rise to high of transpiration while low temperature gives rise to low rate of transpiration.
4) **Light intensity:** high light intensity results in high rate of photosynthesis, due to increase in temperature. This gives rise to high rate of transpiration and vice versa.
5) **Wind:** the higher the speed of the wind, the higher the rate of transpiration and vice versa.
6) **Soil water:** the higher the rate of soil water. The higher the rate of absorption and consequently the higher the rate of transpiration.

Importance of transpiration of plants

a) It enables plants to absorb water and mineral salts from the soil.
b) It helps to remove excess water from the plants
c) The evaporation of water due to transpiration cools the plants.

NOTE: photometer is the instrument which can be used to measure the rate of transpiration.

C. TRANSLOCATION OF ORGANIC SOLUTES

Organic compounds synthesized during the process of photosynthesis gets transported through the phloem sieve tubes. Such a transport of organic solute is called translocation.

TRANSLOCATION OF FOOD IN PLANTS

This is the process by which manufactured food substances are transported from where they are manufactured to tissues were they are needed or stored. Translocation normally begins from the leaves to other parts of the plant. Phloem is the tissue through which these manufactured food substances are translocated. Materials that are commonly translocated include glucose, oil, resins, proteins, alkaloids, hormones, etc.

Experiment to show that translocation takes place in the phloem (ringing experiment).

Material: Two plant, x and y, knife.

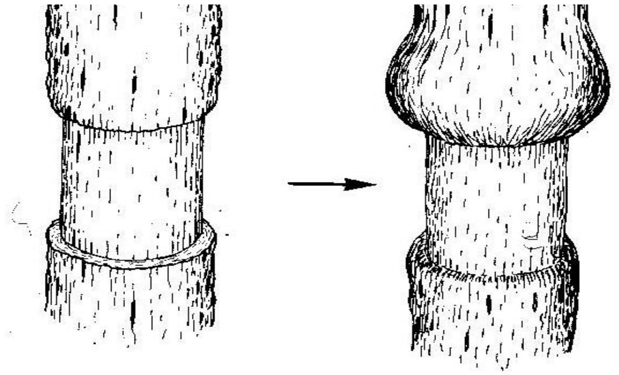
Procedure:

The knife is used to remove the bark and phloem round one of the trees marked **X**, only the bark of the other tree marked **Y** is removed.

The plants are left for about 2 – 5 weeks.

Observations: It will be observed that swelling begins to appear gradually in the bark along the ring in plant **X** but no swelling in that of plant **Y**, the swelling in **X** is due to the accumulation of food substances which has passed down through the phloem from the leaves. After a long period of time, tree **X** will finally die because the root cannot obtain food manufactured in the leaves. There will be no swelling in plant **Y**.

Conclusion: Phloem is responsible for the translocation of manufactured food from the leaves to others parts of the plants.



A A ring of bark is removed from a woody shoot, leaving the xylem undamaged

B After a few weeks the tissue above the girdle has swollen with accumulated substances which have moved down the phloem from the leaves

PROCESSES BY WHICH TRANSPORT IN PLANTS OCCUR

Plant **c**ells are surrounded by watery fluid. The cytoplasm is also surrounded by water; therefore substances pass in and out of the solution. Transportation is an important phenomenon which will take place in all the higher organisms. In plants, materials of transport mainly include gases, water, hormones, minerals, organic material etc. Some of the processes by which water pass in and out of cell are diffusion, osmosis and active transport.

DIFFUSION

It is the process by which molecules or ions of substances move from a region of high concentration to a region low concentration until the molecules become evenly distributed. Substances that can diffuse include solids, liquids and gases.

NOTE

Gases and mineral salt are transported by diffusion whilst liquids are transported by osmosis.

Factors affecting the rate of diffusion

I. **Difference in concentration**

For diffusion to take place in a medium there must be differences in concentration of substances in the two areas. The greater the difference in concentration of the molecules, the greater the rate of diffusion.

II. **Temperature**

More temperature causes increased kinetic energy, hence, the higher the temperature, the faster the rate of diffusion.

III. Nature of the molecules or state of matter i.e. either gas or liquid:

Diffusion varies with the three states of matter. The diffusion of gases is much faster than that of liquids because gas molecules are freer and therefore move faster than liquid molecules.

IV. Size of molecules

The size of the molecules affects the rate of diffusion. In general, the smaller the molecules, the faster the rate of diffusion and vice versa.

V. The density of diffusing substance: Rate of diffusing substances is inversely proportional to the density of diffusing substance.
VI. Medium in which diffusion occurs: Gas diffuses more rapidly through a vacuum than air.

Experiment to Demonstrate Diffusion is liquids

1) Fill a beaker with water
2) Use a pipette to deliver small quantity of potassium permanganate solution gently at the bottom of the beaker. Or a crystal of potassium permanganate can be carefully dropped into the water and allowed to stand for some time.

Observation

i) The purple colour of the potassium permanganate starts to spread.
ii) Eventually, the colour spread evenly throughout the water, so that the water has the same purple colour.

Experiment to Demonstrate Diffusion in Gases

1) Open a bottle containing perfume at the corner of a room.
2) Move to the far corner of the room and wait for some time.

Observation

The odour of the perfume is perceived throughout the room.

Conclusion

The spread of the scent of the perfume shows that diffusion has occurred.

Importance/Roles or Diffusion or Examples of Diffusion in plants

i) Movement of carbon dioxide through the stomata of leaves during photosynthesis.
ii) Water vapour leaving the leaves during transpiration.
iii) Movement of oxygen out the leaves through the stomata during photosynthesis.
iv) Movement of mineral salts from the soil water into root hair cells.
v) Movement of oxygen into the leaves through the stomata during respiration.

Importance/Roles or examples of diffusion in animals

i) The intake of oxygen or nutrients from a mother to the foetus through the placenta during pregnancy.
ii) Gaseous exchange in the lungs of mammals during respiration.
iii) Gaseous exchange in unicellular organism e.g. amoeba.
iv) Absorption of end products of digestion by the villi of the ileum.
v) Gaseous exchange in the gills of fish.
vi) Diffusion of oxygen into the blood and carbon dioxide out of the blood in the lungs of mammals.
vii) Diffusion of hormones out of endocrine glands.

OSMOSIS

Osmosis is the movement of water or solvent molecules from a region of dilute or weaker solution to a region of concentrated or stronger solution through a semi-permeable membrane. It must be noted that osmosis is a special form of diffusion.

Semi-permeable membrane is a membrane which allows some types of substances to pass through it and not others.

Examples of living semi-permeable membranes are goat's bladder, pig's bladder, toads skin, yam tissue, cassava, etc.

Examples of non-living semi-permeable membranes include cellophane and parchment paper.

Conditions necessary for osmosis to take place

i. Presence of a stronger solution. e.g. sugar solution or salt solution.
ii. Presence of a weak solution e.g. distilled water.
iii. Presence of semi or selectively permeable membrane.

Factors that affect the rate of osmosis

i. Concentration gradient:

The greater the difference in concentration between the two solutions, the faster the rate of osmosis.

ii. Temperature:

The higher the temperature, the faster the rate of osmosis.

Experiments on osmosis

Experiment to demonstrate osmosis in non-living tissue.

Materials

Cellophane or parchment paper, beakers, sugar or salt solution, two thistles funnels, restore stand, distilled water.

Method

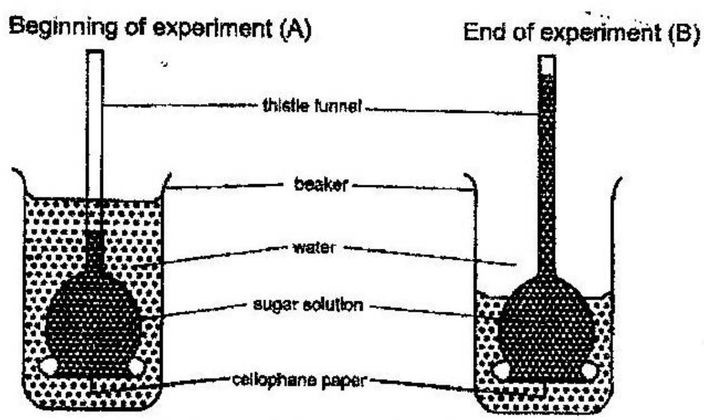
i. Pour equal quantity of water into the beakers.
ii. Cover the mouth of the thistle funnels with cellophane paper.
iii. Pour sugar solution into one of the thistle funnels, and the water into the other thistle funnel. Mark the levels of the water and sugar solutions.
iv. Immerse the two funnels into the beakers containing water.
v. Leave the experiment for about 2 – 6 hours.

Observation

The volume of the sugar solution in the thistle funnel will rise while the water level in its beaker will reduce. The volume of water in the other thistle funnel remains the same.

Conclusion

The rise of sugar solution in the thistle funnel and the decrease in the water level in its beaker shows that osmosis has taken place.



experiment to demonstrate osmosis using a non-living semi-permeable membrane

Experiment to demonstrate osmosis using a living tissue

Materials

Yam or cassava tuber, sugar solution, water, petri dishes, knife.

Method

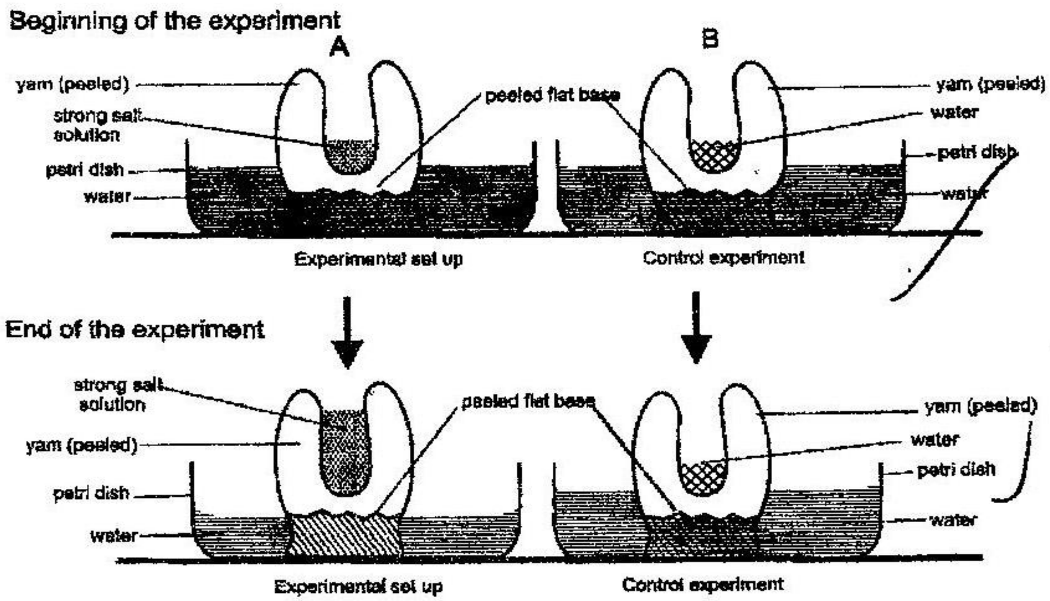
i. A piece of yam is taken and its outer skin is peeled off. The piece is cut into two.
ii. A cavity is made in the centres of each piece with the knife.
iii. Water is poured into two Petri dishes.
iv. Each half of the yam tubers is placed into the Petri dishes, and labeled A and B.
v. Some amount of sugar solution is added into yam tissue A while water is put in the other tissue B.
vi. The setup is allowed to stand for about 4 – 12 hours.

Observation

It will be observed that the level of the solution in setup A will rise and the level of the water in the beaker reduced. In set up B, the water levels in the cavity of the yam and in the beaker remain the same.

Conclusion

Since the sugar solution has risen in yam tissue A, it shows that osmosis has taken place.



Importance/Roles or Examples of Osmosis in plants

i. Absorption of water from the soil by the root hairs.
ii. Movement of water across the cells of leaves and across the cortical cell of the root.
iii. Plasmolysis in plant cells.
iv. Opening and closing of stomata is as a result of water entering and leaving the guard cells.
v. Maintenance of turgor pressure in plants.

Importance/ roles or examples of osmosis in animals

i. Re-absorption of water in the kidney tubules.
ii. Entry of water into unicellular organisms, e.g. amoeba.
iii. Haemolysis of red blood cells.
iv. Absorption of water in the colon in mammals.

Osmotic concentration and osmotic pressure

During osmosis the solution of higher concentration is said to have a higher osmotic concentration. When the water moves across the membrane into a solution of higher concentration, a pressure is created, especially in a living cell. This pressure is called **osmotic pressure**. Osmotic pressure is the force that draws water into the cell. The greater the concentration, the greater the force with which a solution can absorb water molecules when it is contact with water. The pressure which a solution can potentially exert is called its **osmotic potential**.

TYPES OF SOLUTION

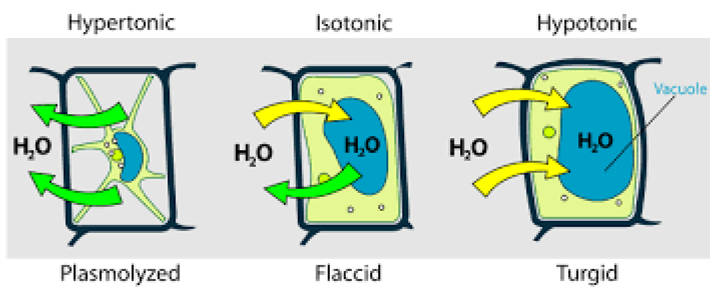
a) **Isotonic solution:** a solution that has the same solutes concentration as the solution with which it is being compared to.

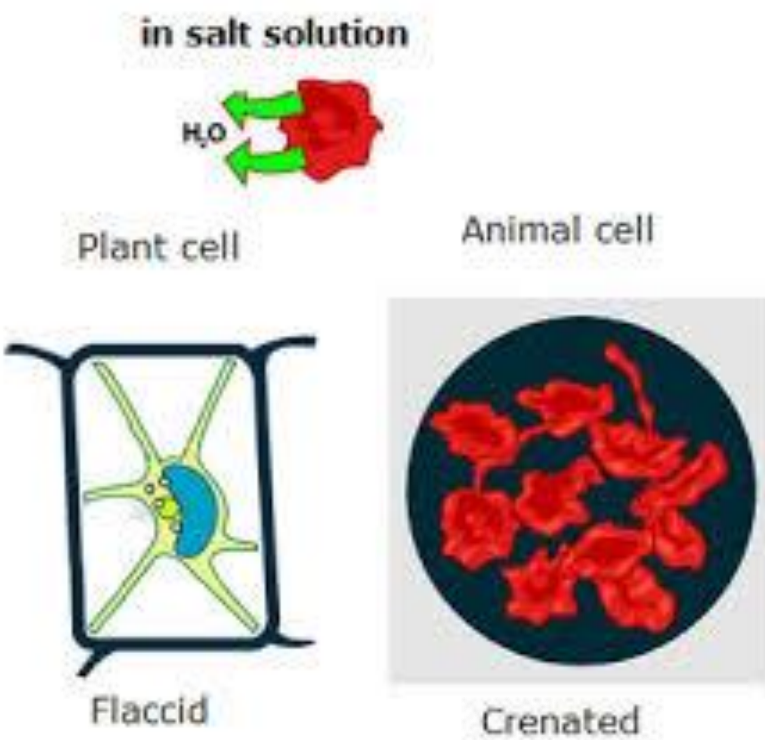
b) **Hypotonic Solution:** a solution having a lower solution solute concentration that the solution with which it is being compared with i.e. weaker solution (e.g. distilled water).

c) **Hypertonic solution:** a solution having higher solutes concentration than the solution with which it is being compared to.

Effects of osmosis on an animal and plant cell

- **Isotonic solution:** There's no net movement of water across the plasma membrane since the concentration is same. The cell retains their normal size and shape for both plant and animal cells.
- **Hypotonic Solution:** Since the concentration of water is higher outside the cell, there is a net movement of water from outside into the cell.
  - **In Animal cell:** Red blood cell gains water, swells and the internal pressure increases. Eventually burst or ruptures to release blood plasma which contains haemoglobin in a process refered to as **HAEMOLYSIS.**
  - **In plant cell:** Cell gains water, swells and the internal pressure increases. Eventually become **TURGID. Plant cells do not contain blood cell so they do not haemolyse nor burst because they have a rigid cell wall.**
- **Hypertonic solution:** This solution contains higher concentration of solutes and less of water than a cell. Since the concentration of water is higher within the cell, there is a net movement of water by osmosis from inside to outside of the cell which causes the cell to shrink as its internal pressure decreases.
  - **In animal cell:** For animal cells the cell will lose water to the hypertonic solution and shrink thereby causing abnormal notches in the edge of the cell. This phenomenon is called **CRENATION.**
  - **In plant cell:** Since the concentration of water is higher within the cell, there is a net movement of water by osmosis from inside to outside of the cell which causes the plasma membrane pulls away from the cell wall as its internal pressure decreases. This is known as **PLASMOLYSIS.** The plant cell becomes flaccid and less turgid. Flaccidity is a state of a cell between turgidity and plasmolysis. Cell wall doesn't shrink because it is strong and rigid. If plasmolysis continues, wilting and death may result. If we placed the plasmolysed plant cell in a hypotonic solution (pure water), water moves into the cell by osmosis and it becomes turgid again. (deplasmolysis).





Application of osmosis and diffusion in preservation of food

The concept of osmosis and diffusion are applied in the preservation of food, such as fruits, fish and vegetables by using preservatives such as (salt, sugar/ vinegar)

1. In salting fish or meat for preservation, the salt diffuses into fish or meat when the fish or meat is placed in the salt solution.
2. In the same process above water moves out of the fish or meat by osmosis. Salt solution of hypertonic to tissue of fish. So water leaves the fish tissue and enter the salt solution by osmosis. Fish become dehydrated and cell crenate. Therefore, bacteria can't grow in fish tissue and bacteria cell will crenate. Preserved fish don't decay so soon and last longer.
3. In prickling, boiled tomatoes are placed in brine. The tomatoes lose water to the brine by osmosis, and salt enters the tomatoes by diffusion. The tomatoes can be then kept for months.
4. Preservation with vinegar: Mangoes are soaked in vinegar which has low pH, vinegar diffuses into the tissues of the mangoes and become acidic. The low pH prevents the growth of microorganism in mangoes and preserved mangoes can last longer.

DIFFERENCES BETWEEN OSMOSIS AND DIFFUSION

No.	OSMOSIS	DIFFUSION
1.	A partially permeable membrane is needed	A partially permeable membrane is not needed.
2.	Takes places in liquids only	Takes places in both liquids and gases
3.	Movement of only solvent (water) molecules	Both solvent and solute move.
4.	Movement of molecules is restricted by semi-permeable membrane	Movement of molecules is free.

PLASMOLYSIS

It is the loss of water by osmosis from a plant cell to the extent that the cytoplasm shrinks away from the cell wall. This happens when the cell is placed in a hypertonic solution.

Active and passive transport are biological processes that move oxygen, water and nutrients into cells and remove waste products. Active transport requires chemical energy because it is the movement of biochemicals from areas of lower concentration to areas of higher concentration. On the other hand, passive trasport moves biochemicals from areas of high concentration to areas of low concentration; so it does not require energy.

ACTIVE TRANSPORT

This is the movement of ions or molecules across a cell membrane into a region of higher concentration assisted by enzymes and requires energy (cellular) against concentration gradient.

FACILITATED DIFFUSION

It is a spontaneous passage of molecules and ions across a membrane through specific carrier proteins without involving energy. Hence facilitated diffusion is also a type of PASSIVE TRANSPORT. This also occurs from an area of more concentration gradient to an area of less concentration gradient.

COMPARISM OF ACTIVE TRANSPORT AND PASSIVE TRANSPORT

	Active Transport	**Passive Transport**
Definition	Active Transport uses ATP to pump molecules AGAINST/UP the concentration gradient. Transport occurs from a low concentration of solute to high	Movement of molecules DOWN the concentration gradient. It goes from high to low concentration, in order to

	concentration of solute. Requires cellular energy.	maintain equilibrium in the cells. Does not require cellular energy.
Types of Transport	Endocytosis, cell membrane/sodium-potassium pump & exocytosis	Diffusion, facilitated diffusion, and osmosis
Functions	Transports molecules through the cell membrane against the concentration gradient so more of the substance is inside the cell (i.e. a nutrient) or outside the cell (i.e. a waste) than normal. Disrupts equilibrium established by diffusion.	Maintains dynamic equilibrium of water, gases, nutrients, wastes, etc. between cells and extracellular fluid; allows for small nutrients and gases to enter/exit. No NET diffusion/osmosis after equilibrium is established.
Types of Particles Transported	proteins, ions, large cells, complex sugars.	Anything soluble (meaning able to dissolve) in lipids, small monosaccharides, water, oxygen, carbon dioxide, sex hormones, etc.
Examples	phagocytosis, pinocytosis, sodium/potassium pump, secretion of a substance into the bloodstream (process is opposite of phagocytosis & pinocytosis)	diffusion, osmosis, and facilitated diffusion.
Importance	In eukaryotic cells, amino acids, sugars and lipids need to enter the cell by protein pumps, which require active transport. These items either cannot diffuse or diffuse too slowly for survival.	It is vital in the preservation of some food items eg. Tomatoes, fish etc

COMPARISON OF DIFFERENT TYPES OF TRANSPORT

Diffusion	**Facilitated diffusion**	**Active transport**
Occurs along the concentration gradient	It occurs along the concentration gradient	Occurs against the concentration gradient
Process is not sensitive to Inhibitors.	This process is sensitive to Inhibitors	Process is sensitive to Inhibitors

Does not require carrier molecules	Require special transport proteins	Require special transport proteins
Energy is not required	The energy is not required	Energy is required
Saturation of transport does not occur	Transportation saturates when all the carrier proteins are being used	Transportation saturates when all the carrier proteins are being used

UNIT THREE

TRANASPORT SYSTEMS IN ANIMALS AND PLANTS

TRANSPORT IN ANIMALS

In animals, the transport system is known as the **cardiovascular or circulatory system** which includes the **heart, arteries, veins** and **capillaries**. This system serve to deliver fluids rich in oxygen and nutrients to cells found deep in the body of the multicellular organism, as much as removing the wastes produced by them.

CIRCUITRY SYSTEM IN HUMANS

The circulatory system in man consists of the blood (medium of transport), the blood vessels (route) and the heart (pump). The blood is circulated by the muscular contraction of the heart. They distribute essential substances to the body cells and collect their metabolic wastes.

A circulatory system is required because the human body is multicellular and has a small surface area to volume ratio.

Diffusion alone is far too slow to transport adequate oxygen and dissolved food substances to cells and the removal of waste from cells. Blood is the main transporter of materials in humans.

STRUCTURE AND FUNCTION OF THE CIRCULATORY SYSTEM

The heart is the organ that controls the circulation of blood in the body.

The heart is large hollow and muscular organ which has two sides; the right and left. It is pear-shaped, lying in the thorax between the lungs and is slightly displaced to the left. It is protected by the muscle of the chest walls, the ribs, the sternum and the diaphragm.

In longitudinal section, four chambers can be seen:

-The right side chambers

- Right atrium
- Left atrium

-The left side chambers

- Left atrium
- Left ventricle.

The right side chambers are separated from the left side chambers by a wall called septum to ensure that oxygenated and de-oxygenated blood do not mix together.

The walls of the left ventricle is thicker than that of the right ventricle because, the left ventricle pumps blood to all parts of the body whereas the right ventricle pumps blood to the lungs only. The left and right ventricles are thicker than the right and left atria because the ventricles pumps blood under high pressure whereas atria receive blood under low pressure.

There are one-way valves between each atrium and ventricle which ensure blood flow in correct direction. These valves are supported by **tendons**. Separating the right atrium and right ventricle is the **tricuspid valve** (three flaps) whilst separating the left atrium and ventricle is the **bicuspid valve** (two flaps). Non-return (semi-lunar) valves are found at the base of the pulmonary artery and aorta.

Oxygenated blood that is the blood carrying oxygen is carried into the left atrium from the lungs by the pulmonary vein.

However, deoxygenated blood that is the blood without oxygen is carried by the two vena cava from the body tissues into the right atrium. From each atrium the blood flows into its corresponding ventricle, and the ventricle pumps it out into the arteries, it must be noted that the artery which carries oxygenated blood to the body from the left ventricle is the aorta, and whiles the pulmonary artery conveys deoxygenated blood from the right ventricle to the lungs.

<u>Fig 3.1 external structure of the mammalian heart</u>

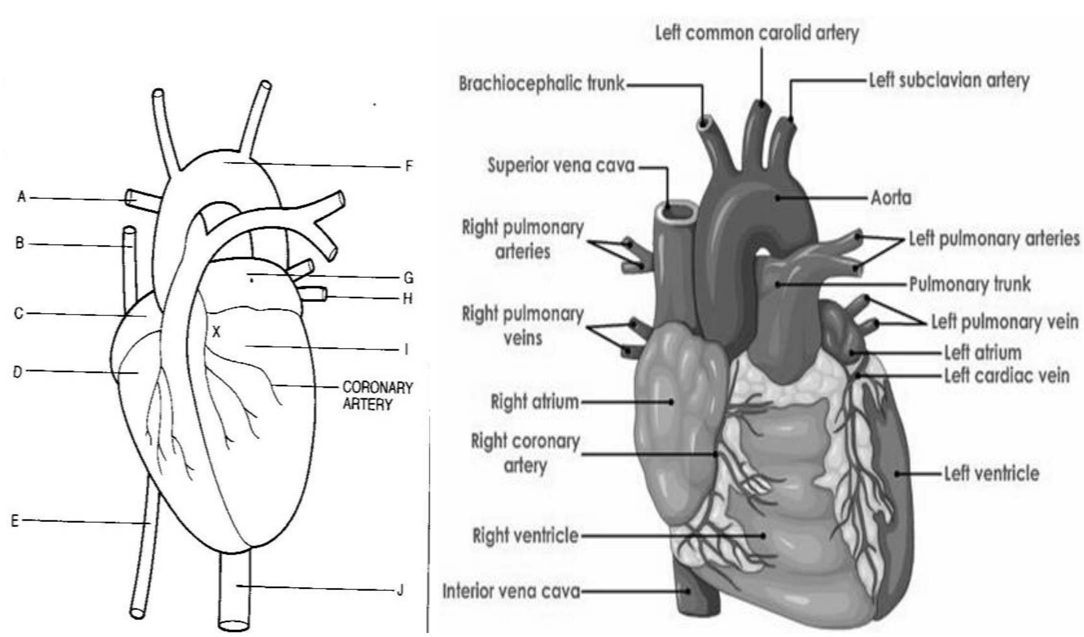


FIG 3.2 THE CIRCULATION OF BLOOD THROUGH THE MAMMALIAN HEART

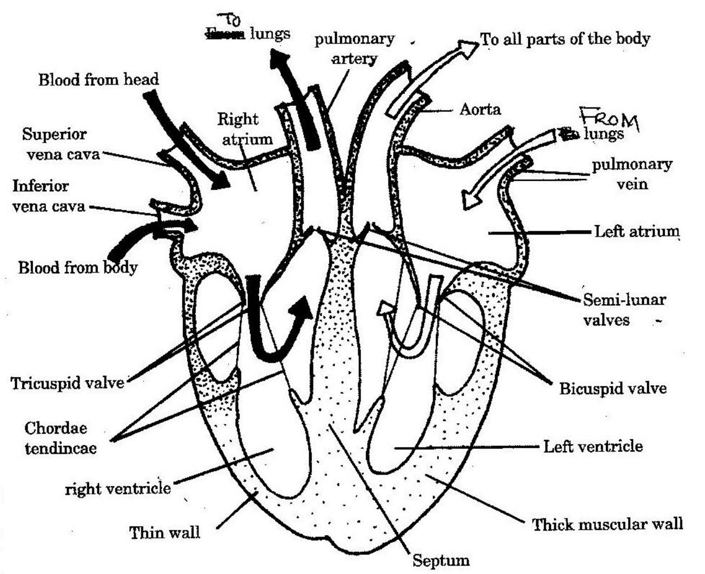


Table 3.1 functions of the parts of mammalian heart

Structure	Position in the heart	Functions
Superior vena cava	Main vein which empties at the top of the right atrium	Return deoxygenated blood from the head and upper limbs to the heart
Inferior vena cava	Main vein which empties at the bottom of the right atrium	Return deoxygenated blood from the lower limbs and organs to the heart
Right atrium	Upper chamber of the heart	Receives deoxygenated blood from vena cava
Semi-lunar valves	Found at the opening of the pulmonary artery	Prevent backflow of blood from the pulmonary artery into the right ventricle when the right ventricle relaxes
Tricuspid valve	Between right atrium and right ventricle. Consists of three flaps	Prevent backflow of blood to the right atrium when the right ventricle contracts.
Right ventricle	Lower chamber of the heart	Pumps blood to the lungs via pulmonary artery.

Septum	Muscular wall separating the left and right chamber	Prevent the mixing of deoxygenated blood in the right of the heart with the oxygenated blood from the left side of the heart
Bicuspid valve	Between left atrium and left ventricle. Consists of two flaps	Prevent backflow of blood to the left atrium when the ventricle contract
Chordae tendineae	Elastic tendons which attach valve flaps to the papillary muscles.	Tendons become taut and prevent the valve from flapping back into the atrium under the blood pressure generated during the contracting of the ventricle
Left ventricle	Lower chamber of the heart, the most muscular part.	Pumps blood to all parts of the body (except the lungs) via the aorta.
Left atrium	Upper chamber of the heart	Receives oxygenated blood from the lungs via pulmonary vein.
Pulmonary artery	Arises from the top of the right ventricle	Carries deoxygenated blood to lungs.

THE ACTION OF THE HEART (CIRCULATION OF BLOOD IN THE HEART)
As soon as the blood is being pumped, the muscles in the walls of the artria and ventricle contract and relax respectively; first the walls of the atria initiate the action by contracting and pushing the blood into the two ventricles with force. The next stage in the process is for the ventricle to respond by contracting to send blood into the arteries. The four set of valves which are placed to divide the heart into upper and lower parts, stop blood from flowing backwards.

Blood is prevented from returning to the atria by the blood pressure built up by the contracting of the ventricles.

This pressure forces the tricuspid or bicuspid valve to close. When the ventricles relax, the blood pressure in the arteries closes the semi-lunar valves so preventing the return of blood to the ventricles.

DOUBLE CIRCULATION OF BLOOD
This is referred to as the dual circulatory system, because, in one complete circulation, blood passes twice through the heart but once through the body.

This is possible because of the two main systems which are connected at the heart to transport blood in humans; the two systems are **pulmonary circulation** and **systemic circulation** (the main circulation)

Pulmonary Circulation; Here the blood circulation is to and from the lungs at low pressure.

Systemic Circulation; Here the blood circulation is to and from all other body parts.

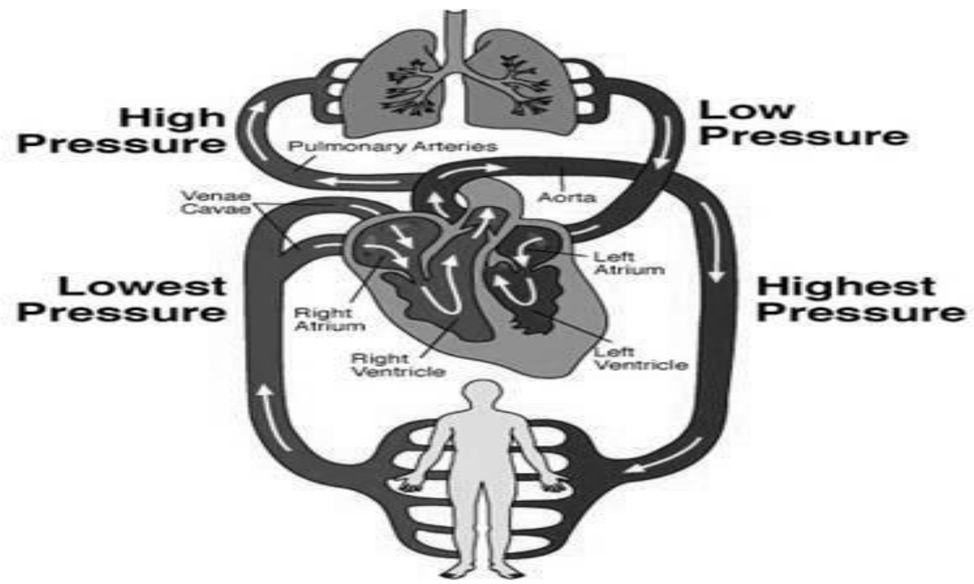
The heart is the pumping station which power these two systems,

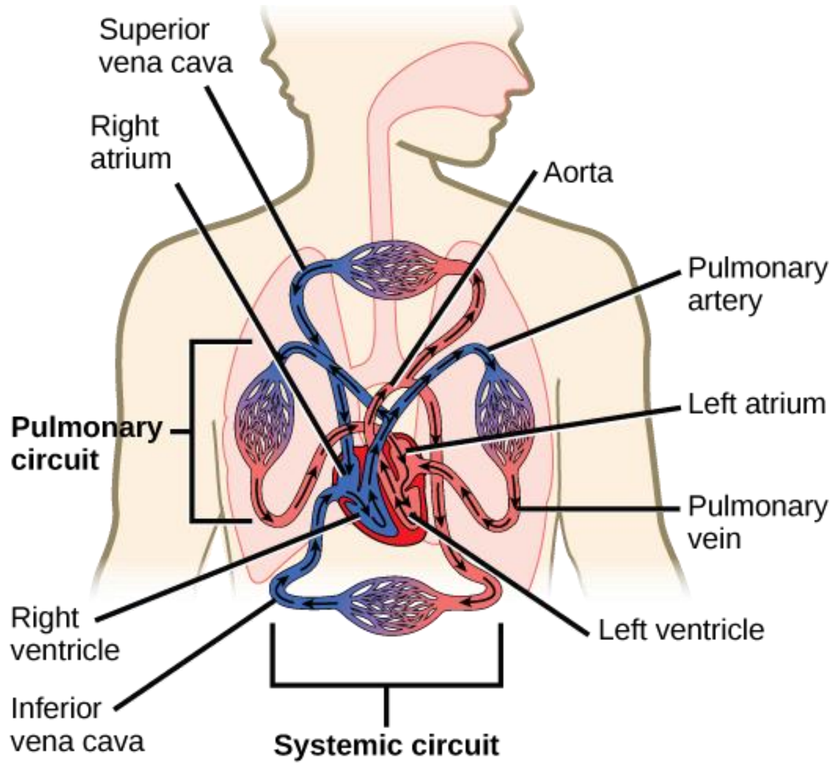
Double circulation begins when blood enters the right atrium after going around the body except the lungs and is deoxygenated. The blood in the atrium is forced into the right ventricle and then forced into the pulmonary artery to the lungs capillaries to absorb more oxygen.

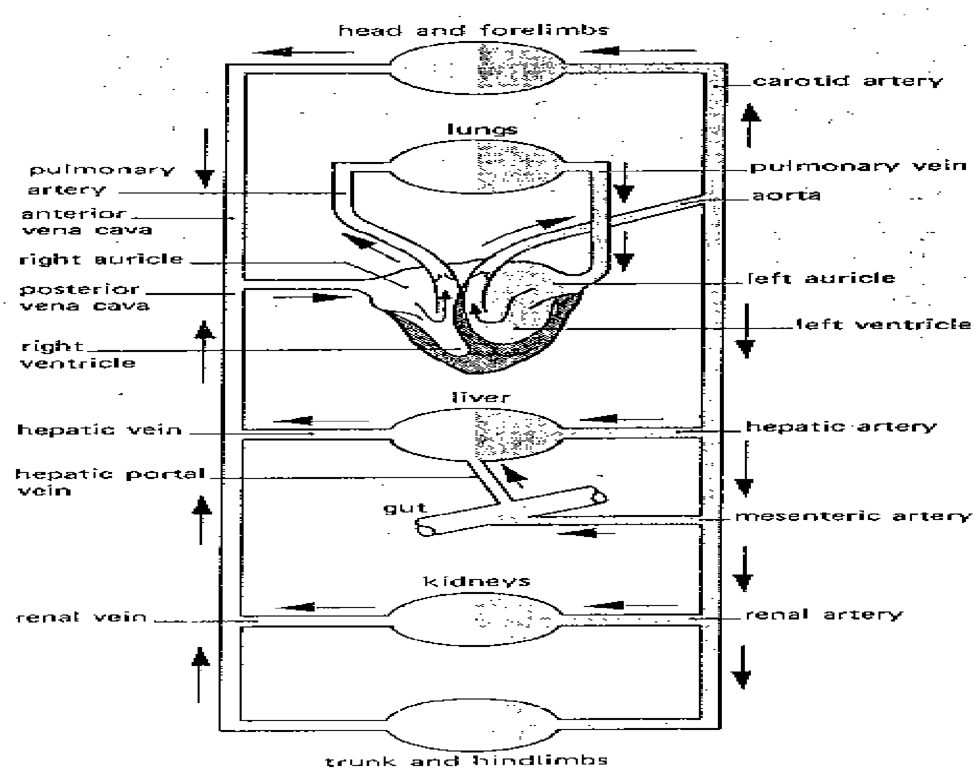
From the lungs the blood is forced through the pulmonary vein which empties into the left atrium. The atrium contract to send blood into the left ventricle which intern contract to push the blood into the main artery called **AORTA**.

The return of deoxygenated blood to the right atrium through the superior and inferior vena cava completes the double circulation.

Fig 3.3 Double circulatory system in humans





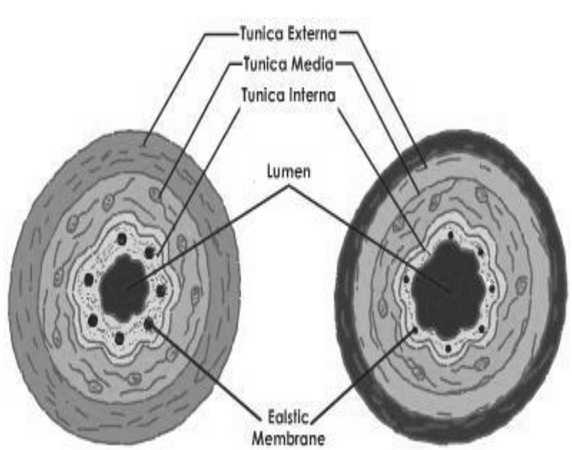


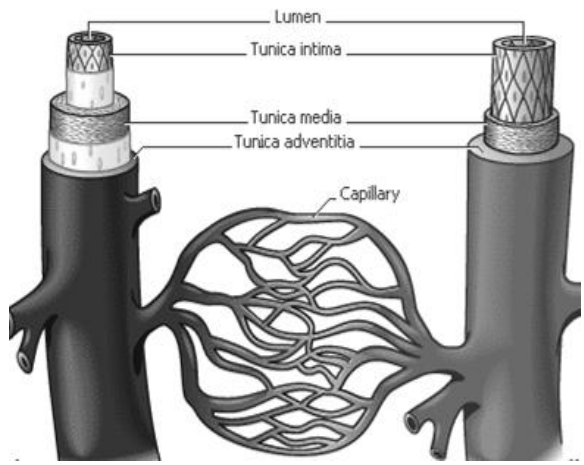
BLOOD VESSELS AND CIRCULATION

Blood vessels are branched tubes transporting blood to every part of the body. Depending on their functions, they vary in appearance. There are however three main blood vessels such as;

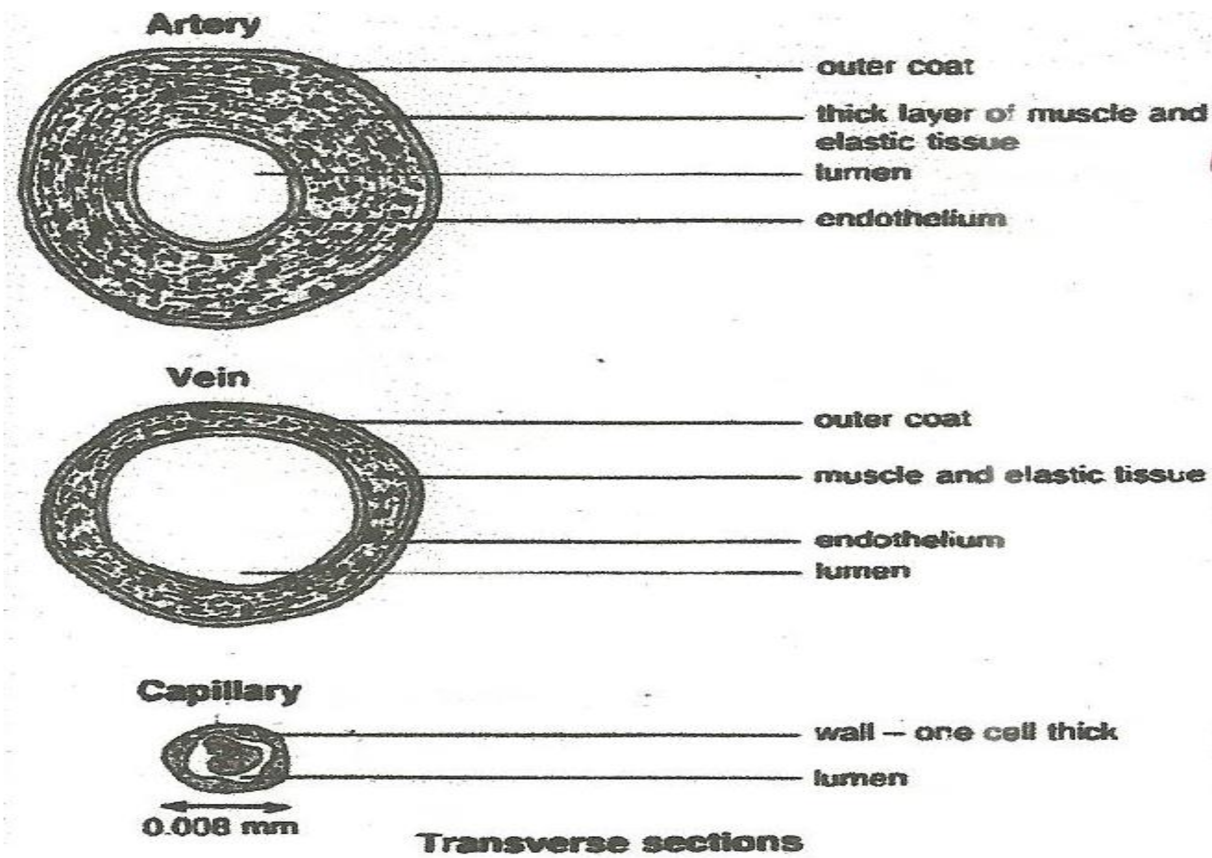
1. Artery
2. Capillary
3. Vein

Fig 3.4 Transverse section of Artery, capillary and vein





Artery **vein** **Artery** **capillary** **vein**



Arteries

Vessels caring bloods away from the heart are Arteries.

All arteries except pulmonary artery carries oxygenated blood. Arteries have three main layered walls which have elastic out layer and thicker muscle layer. The outer layer consists of fibrous connective tissue which functions to prevent extreme expansion of the wall.

The elastic and muscle layers absorb high pressure of blood that is pumped through them by the heart. The muscles layers squeezes blood to help move it along. Arteries divide into very small thin walled vessels called Arterioles within the organs. This further divides into capillaries where exchange of substances occurs. The capillaries lead into venules, which lead into veins which carry blood back to the heart,

Blood flows through arteries in pulse or surges. Each pulse is the result of the contraction of the left ventricle causing expansion of the aorta. Each time the left ventricle contract, blood is pumped into the aorta, and its walls are stretched by the blood. This stretching passes down the aorta and the arteries branching from it in a wave. Each arterial pulse indicate a **heartbeat.**

VEINS

They carry blood back to the heart under low pressure. They have walls much thinner than arteries and have valves present. The valves stop blood flowing backward due to the low pressure. The blood they carry is mainly de-oxygenated.

The veins outer layers are fibrous tissue just like arteries. Beneath it is a layer of smooth muscle and elastic tissue, thinner than in an artery. The innermost layer is made up of endothelium. The lumen of the vein is layer than that of arteries of the same size.

Unlike arteries, veins have cup-shaped valves at intervals along their length, which allows blood under pressure to flow in only one direction. Veins are aided by skeletal muscles of the body squeezing the veins.

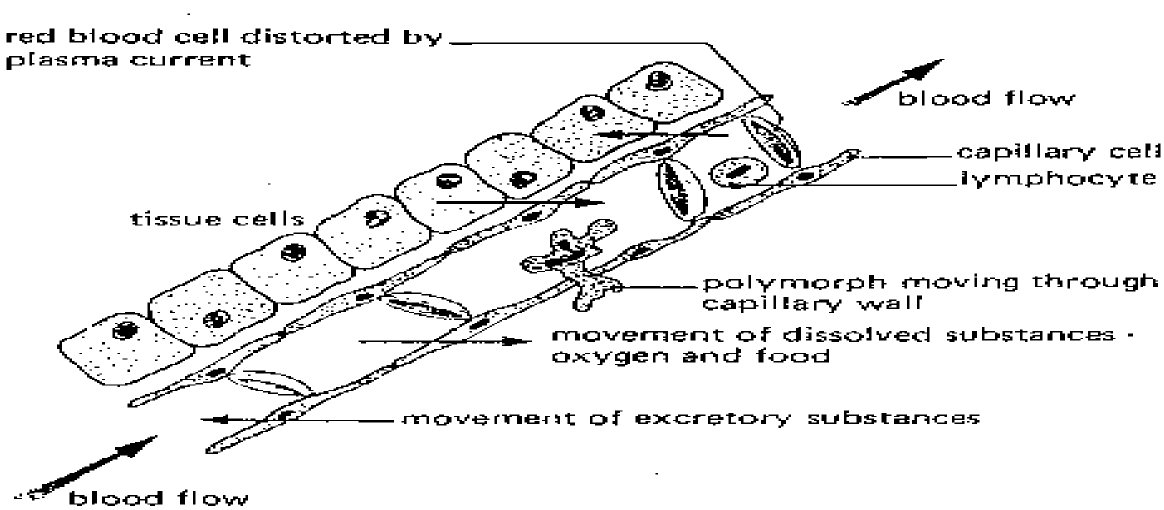
Gravitational pull also helps the blood flow from parts of the body above the heart. Small vessels called venules lead from capillaries and joint to form veins.

CAPILLARIES

Capillaries are present in all tissue of the body, lying very close to the cells. Each capillary network is formed between and arteriole and a venule. They are microscopic blood vessels with very thin walls (only one cell thick) continues with the endothelium of the arteriole and a venule on the other side with holes (pores) in the m. The thin walls allow useful products and waste a short distance to travel since blood in the capillaries is slow running to allow maximum time for exchange of material over a large surface area.

It is only through the walls of the capillaries that exchange of nutrient, gases, and waste products between blood and cells can take place. Foods such as glucose and gases such as oxygen pass from the capillary blood into the tissue fluid surrounding the cells and then into the cells. The pores allow fluid to leave blood. The capillaries connect veins to arteries making circulation of blood possible.

Fig 3.5 exchanges of materials between capillaries, blood and cells



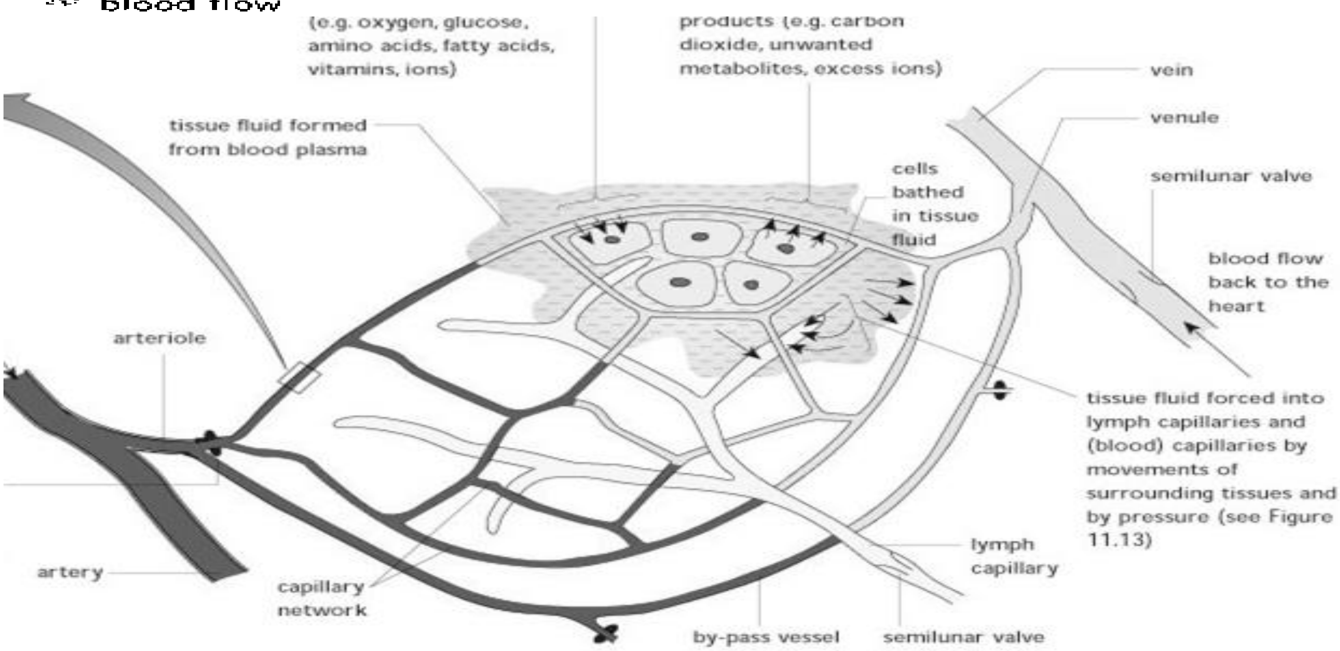


Table 3.2 comparing arteries, veins and capillaries

(Similarities and differences)

Basis of comparison	**Arteries**	**Veins**	**Capillaries**
1. thickness	Thick muscular, elastic wall	Thinner inelastic endless muscular wall	Thin, one cell thick walls. No muscle and elastic tissue
2. location in the body	Usually located deeper in the body	Superficial in location, movement of blood by action of	Located all over the body

		body muscles and valves.	
3. presence of valves	Have no valves except at base of arteries carrying blood away from the heart	Valves present	Have no valves throughout at intervals to prevent backflow of blood
4. chemical nature of blood carried	Usually carry oxygenated blood except in pulmonary artery	Usually carry de-oxygenated blood except in pulmonary vein.	Allow passage of O_2, CO_2 and white blood cells.
5. permeability of the Wall	Walls are not permeable	Walls are not permeable	Walls are permeable to tissue fluid and phagocytes
6. direction of blood Flow	Away from the heart	Towards the heart	Carry blood in different direction to cells
7. blood flow (pulse)	Blood flow in strong pulse under high pressure	Blood flow is smooth and slow (no pulse) under low pressure	Blood flow is slow and smooth (on pulse) and pressure is falling
8. shape of cross-section	Circular cross-section	Oval cross-section	Circular cross-section
9. size of lumen	Relatively small lumens	Relatively large lumen	Very small lumens (smallest blood vessels)

The main organs through which blood circulates in the human body

- Heart; It pumps blood through the body system
- Lungs; The lungs allow the blood to pick up oxygen and get rid of carbon dioxide
- Intestines; Supply digested food to the blood
- Liver; Processes and store some of the food carried by the blood
- Kidney; Removes waste products
- Rest of the body; (brain, muscles etc) takes food and oxygen from the blood and produce wastes products which are carried away by the blood.

Activity 4.1 To identify the circulatory system of a mammal

- Obtain the following materials; rabbit, dissection board, cotton wool, chloroform, sharp scarpel, pins, scissors, alcohol.
- Dissect the mammal and display the heart and the main blood vessels.
- Observe and identify the heart and the main blood vessels.
- Make a simple drawing of the dissection and label the heart, main organs and the main vessels.

Activity 3.2 Examine the heart of a mammal

a) External Features

1. Take a close look at the heart of the sheep and goat with the main blood vessels still attached.

2. Describe the shape of the heart

3. Distinguish between the two atria and the ventricle and describe their appearance

4. Examine the cut ends of the main blood vessels and identify the arteries and veins. The arteries have thicker walls.

5. Find the coronary artery and vein spread's round the ventricles.

What is the function of the vessels?

b) Internal Features

1. Insert's a pair of scissors into the aorta and cut through it together with the ventral wall of the left ventricle.
2. pull the cut end apart
3. Find the semi lunar valves (pocket valves) situated at the base of the aorta and the thick ventricle wall, the bicuspid valve, the tendons and the papillary muscles.
4. Insert the scissors into the bicuspid valve and cut up through the ventral wall of the left artrium
5. Find the walls of the atrium and the valve which open it.
6. Insert the scissors into the pulmonary artery, cut down along the ventral wall of the right ventricle. Open and flatten out the pulmonary artery and pull the cut ends of the right ventricle apart
7. Insert the scissors into the tricuspid valve and cut up along the ventral wall of the atrium.

- Have you observed any passage between the left and right sides of the heart?
- Have the left ventricle and thicker wall than the right ventricles?
- How do you explain this?
- What is the function of

i. The semi lunar valves?

ii.The tendons and the capillary muscles?

iii.Why is there no passage between the left and right side of the heart?

Composition and Function of Blood

Blood account for 10% of the body weight. There is about six litres of blood in an adult. Blood consist of fluid called **plasma** in which are suspended red blood cells (erythrocytes), white blood cells (leucocytes) and platelets.

Plasma in nature is a straw-coloured fluid and consists of the following components:

- **Water** constitutes 90% of plasma and serving as a solvent for 10% dissolved substance.
- **Blood proteins** constituting 7% of plasma. Which include fibrinogen which is used in the clotting of blood and antibodies as a defense against disease causing organisms.
- **Dissolved food**: the end products of digestion are set free from storage areas. Examples include, amino acids, glucose, fat droplets.
- **Mineral salt**: in the form of ions e.g. Na+, Cl^-, Ca+2 and HCO^{-3}(hydrogen carbonates) the major form in which carbon dioxide is transported in blood
- **Waste substance**: urea
- **Gases**: these are nitrogen and oxygen
- **Hormones**: e.g. Adrenalin and insulin in extremely small quantities

The Cellular Components of blood are divided into three categories

- The red blood cells (erythrocytes)
- The white blood cells (leucocytes)
- Platelets (thrombocytes)

Red blood cells (erythrocytes)

They are very small (0.008mm) biconcave discs numbering between 4.5 – 5million per milliliter of blood. People living in regions of low atmospheric (high altitude) oxygen happen to have large numbers of red blood cells as a result of **Acclimatization**.

Red blood cells are made in **Red Marrow** of all bones in infants but in the principals bones such as sternum, scapulae, ribs, vertebrae and pelvis in adults.

These cells are able to squeeze through tiny blood capillaries and regain their shape after emerging from them because they lack nuclei and the presence of supply membrane.

Erythrocytes have a cell surface membrane which is permeable to gases, particularly oxygen. In the cytoplasm, is an iron– containing protein, **haemoglobin,** which has affinity for oxygen which allows it to combine readily with oxygen in high oxygen concentration in the lungs to form a bright red compound, **oxyheamoglobin** that readily breaks down in areas with low oxygen concentration to free oxygen. The cytoplasm contains enzymes such as carbonic anhydrate which catalyses the combination of carbon dioxide and water to form carbonic acid.

Thus the blood can transport carbon dioxide as hydrogen carbonate ions from the tissue to the lungs.

Each blood cell has a life span of 90 to 120 days. Red blood cells are broken down in the liver and their iron stored for re use. New cell are manufactured at the same time. The decomposition of the erythrocytes produces **two bile pigments** which are excreted in bile in the gut.

White blood cells (Leucocytes)
These are larger than the red blood cells. They have nuclei but no haemoglobin in their cytoplasm. They are produced in red blood cells in the ratio of 600:1. There are two types of white blood cells:
- Granulocytes

-Agranulocytes.

The granulocytes have granular cytoplasm and lobed nuclei. They are all amoeboid. There are three types of granulocytes. One type of granulocytes called **phagocytes** can engulf and digest foreign particles (bacteria) they can pass out of blood capillaries into intercellular spaces where they can engulf pathogens.

There are two types of Granulocytes one variety of agranulocyte called **Lymphocytes** secrete proteins known as antibodies.

Platelets thrombocytes
These are fragments of cells produced in the red bone marrow and have no nucleus

Fig. 3.6 THE DIFFERENT TYPES OF MAMMALIAN BLOOD CELLS

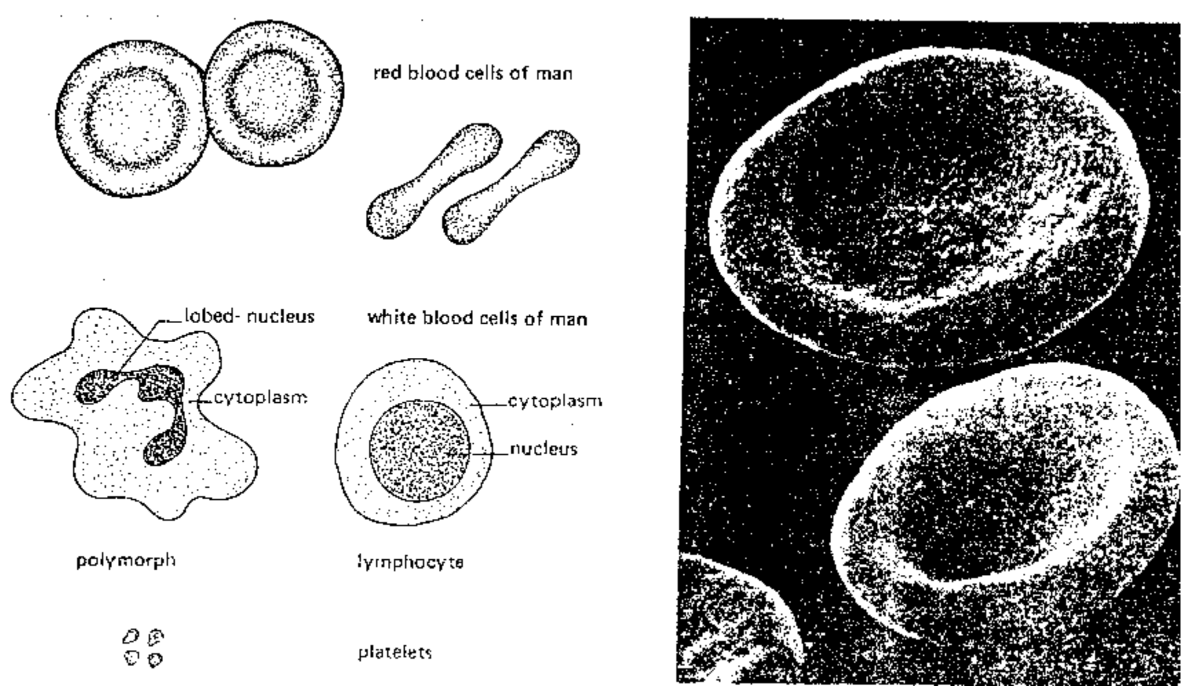


Table 4.6 modification in blood composition in the human body

Part of body	**What is taken up by the body**	**Water ,carbon dioxide, glucose (some stored as glycogen) excess amino acids, worn out erythrocytes**
Kidneys		Water, urea, salts

Small intestine	Sugars, amino acids, water, salts, Vitamin	
Spleen	Erythrocytes (from storage)	Worn out erythrocytes
Skin	Vitamin D	Water, salts, urea, heat
Thyroid gland	Thyroxine	Iodine

Table 4.8 Transport by the blood system

Substance	**From**	**To**
Oxygen	Lungs	Whole body
Hormones	Glands	Target organs
Digested food	Intestine	Whole body
Heat	Liver and muscles	Whole body
Carbon dioxide	Whole body	Lungs
Urea	liver	Kindneys

Functions of Blood

Blood has four main functions:

(1) Transport
(2) Regulatory
(3) Defense or protective
(4) Reproduction

(1)Transport of blood

(a) Oxygen: This is carried by the haemoglobin in the red blood cells as oxyhaemoglonbin

(a) Carbon dioxide: This is carried combined with haemoglobin. Most as hydrogen carbonate in the plasma from other organs to lungs.
(b) Foods: Simple foods or soluble end products of digestion from small intestines to tissues to be stored or used from storage to the whole body. (Foods glucose, and amino acid)
(c) Urea: This is made in the liver by break down of protein and carried to the kidney where it is excreted.
(d) Hormones: Endocrine (ductless) organs secrete these into the bloodstream to target tissues or glands or the whole body to trigger other organs to act. Example, adrenalin and insulin.

(e) Heat: Mammals are warm blooded; that is they keep a constant body temperature. The heat from liver and muscles are carried to and away from all parts so as to maintain this temperature.
(f) Antibodies/Antitoxins: White blood cells and antibodies to all body parts to help prevent diseases.
(g) Platelets and blood proteins.
(h) Red blood cells carrying oxygen form lungs to the whole body.
(i) Water and inorganic salts which maintain the balance of the body fluid.

(2) Regulation

(a) It regulate the concentration of cell cytoplasm

(b) Regulate body temperature

(3)Defense or protective function of blood

Disease – Causing organisms (pathogens) enter the body and are attacked by white blood cells. Some work by phagocytosis, some produce antibodies and some produce antitoxin. Platelets are used for clotting.

- Phagocytes engulf and digest disease causing bacteria.
- Lymphocytes produce antibodies which attack bacteria and foreign bodies.
- Platelets aid in clotting of blood to prevent entering of germs after injury.
- Toxins produced by bacteria or germs are neutralized.

(4)REPRODUCTIVE FUNCTION OF BLOOD

Blood is essential in mammals to make the penis erect so that sexual intercourse can take place.

Tissue fluid and lymph

Capillaries are minute tubes. Their wall is one cell thick and minute gaps between them allows small substances such as water, gases, glucose, amino acids to filter out of the capillaries into the spaces surrounding the cells or tissues to form **inter cellular** or **tissue fluid**.

This fluid surrounding the cells is the **tissue fluid (interstitial fluid).** From it, cells obtain nutrients and into it they excrete waste products. This means that substances can move in and out of the cells.

Excess tissue fluid drains into another series of tubes known as lacteals. These join up and form the **lymph system** which drains into the blood stream in the neck region.

Lymph: Is a colourless fluid and as well as taking excess tissue fluid back into the blood, it also transport fats and excretory compounds and produces types of white blood cells (in the lymph nodes).

Lymph capillaries join to form larger **lymph vessels**. There are no pumps to drive these vessels but lager lymph vessels like veins, have cup-shaped, non-return valves so that lymph, flow in one direction only.

Lymph moves through the vessels at low pressure by the contraction of the skeletal muscles through which they pass.

The thoracic duct that opens into the left subclavian vein in the base of the neck is the main lymphatic vessel conducting lymph. The lymphatic vessel is made from the merger of lymphatic vessels of the leg and the abdominal region of the body. From the right side of the head, neck and the right arm.

Lymph returns to the blood stream in the right subclavian vein through the right lymphatic duct. This system of capillaries and vessels is called the **Lymphatic system**.

Lymphocyte a type of white blood cell is produced in the lymphatic system. The stationary granulocytes (phagocytes) are also contained in the lymphatic system and they attack, engulf and digest foreign bodies such as bacteria in the lymph.

One important feature of the lymphatic system is the presence of glands or nodes at intervals along its vessels.

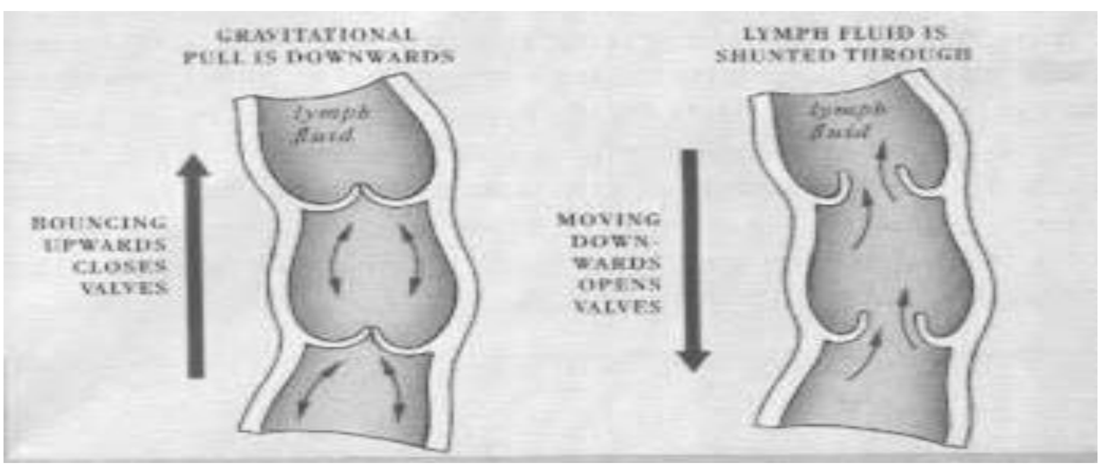
Painful, swollen glands at the onset of infection are the result of large number of white blood cells collecting in the lymph nodes.

Lymph Nodes

There are lymph nodes along the lymphatic vessels. It is in such nodes that lymphocytes are stored. Phagocytes are also to be found in the lymph nodes. Bacteria which are not killed are carried in the lymph into the lymph nodes to be ingested.

The lymph nodes form part of the body's defense system against infection

<u>Lymphatic vessel</u>



<u>Fig. 3.9 The position of the main lymph glands and vessels</u>

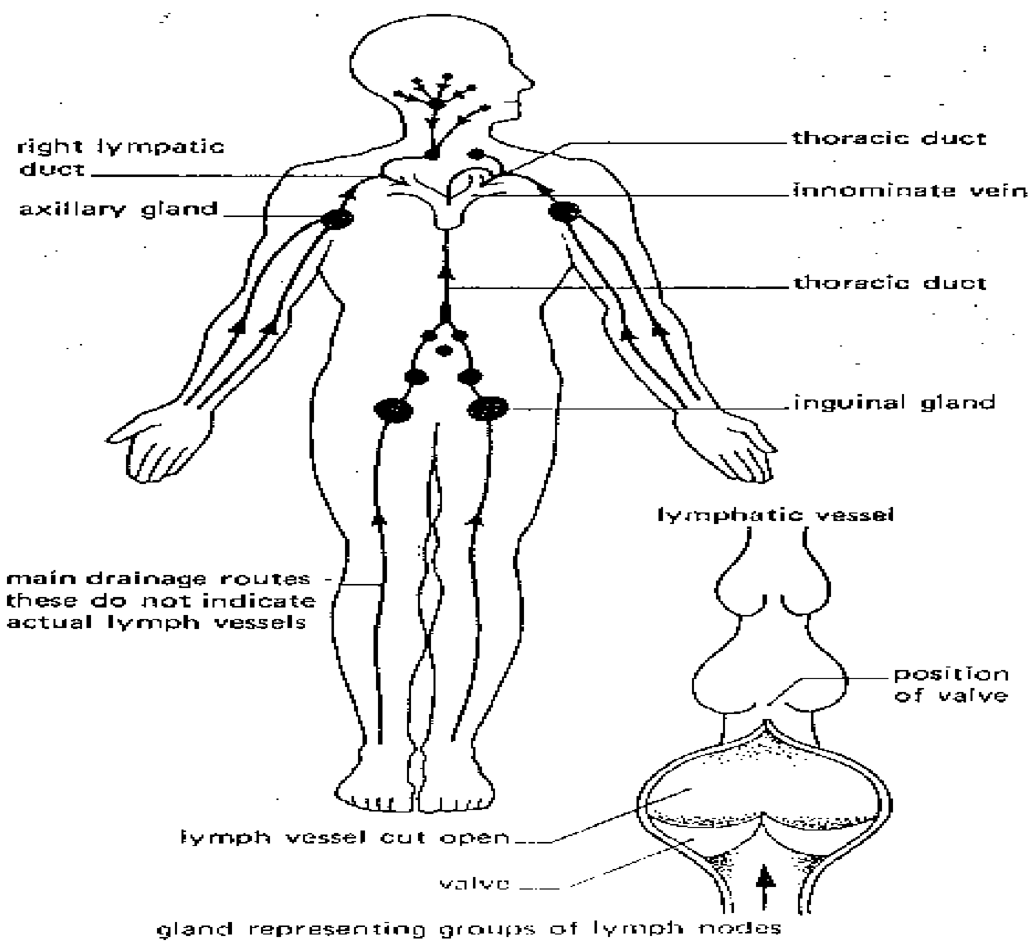


Table 3.9 comparing blood plasma, tissue fluid and lymph

Blood plasma	Tissue fluid	Lymph
Straw coloured liquid	Colourless watery liquid	Colourless, watery liquid
The liquid part of blood in blood vessels	Forced out of the thin walls of capillaries due to high blood pressure. Surrounds all cells of the body and fills the spaces between them	Excess tissue fluid surrounding cells drains into lymphatic capillaries as lymph
Contains plasma proteins such as fibrinogen prothrombin etc	Same composition as blood plasma but has no plasma proteins	Contains more waste products and less food substances than tissue fluid

UNIT FOUR

RESPIRATION IN ANIMALS

RESPIRATORY SYSTEM

Respiration is the sum total of the chemical processes that release energy from food substances within cells, with or without the participation of molecular oxygen.

Energy is the most essential requirement to support all activities and processes of living organisms. Thus all plants and animals need energy for survival. Humans get their required energy stored in the food they eat. Energy is set free from food for use of the body cells by the process called respiration. This process usually requires molecular oxygen from the external environment for the chemical component of the food to release energy from carbohydrates. While the cells of the body make use of the energy released, carbon dioxide is got rid of as a waste product. The oxygen is obtained from the air through the lungs. From here the oxygen dissolves in the blood and is carried to the cells by the circulatory system. However energy can be released in the absence of oxygen under certain circumstances.

Respiration can be divided into two kinds;

- Internal (tissue or cellular) respiration.
- External (gas exchange or breathing) respirations.

GASEOUS EXCHANGE

This is the exchange of respiratory gases between the organism and the environment. It takes place across specialized surfaces called respiratory surfaces. Gaseous exchange helps an organism to get rid of CO2 produced during respiration within cells and at the same time obtain oxygen needed for aerobic respiration to occur.

NOTE: Breathing is an active process involving movement of air in and out of the body whereas gaseous exchange is a passive process involving passage of air through respiratory surfaces/gaseous exchange surfaces.

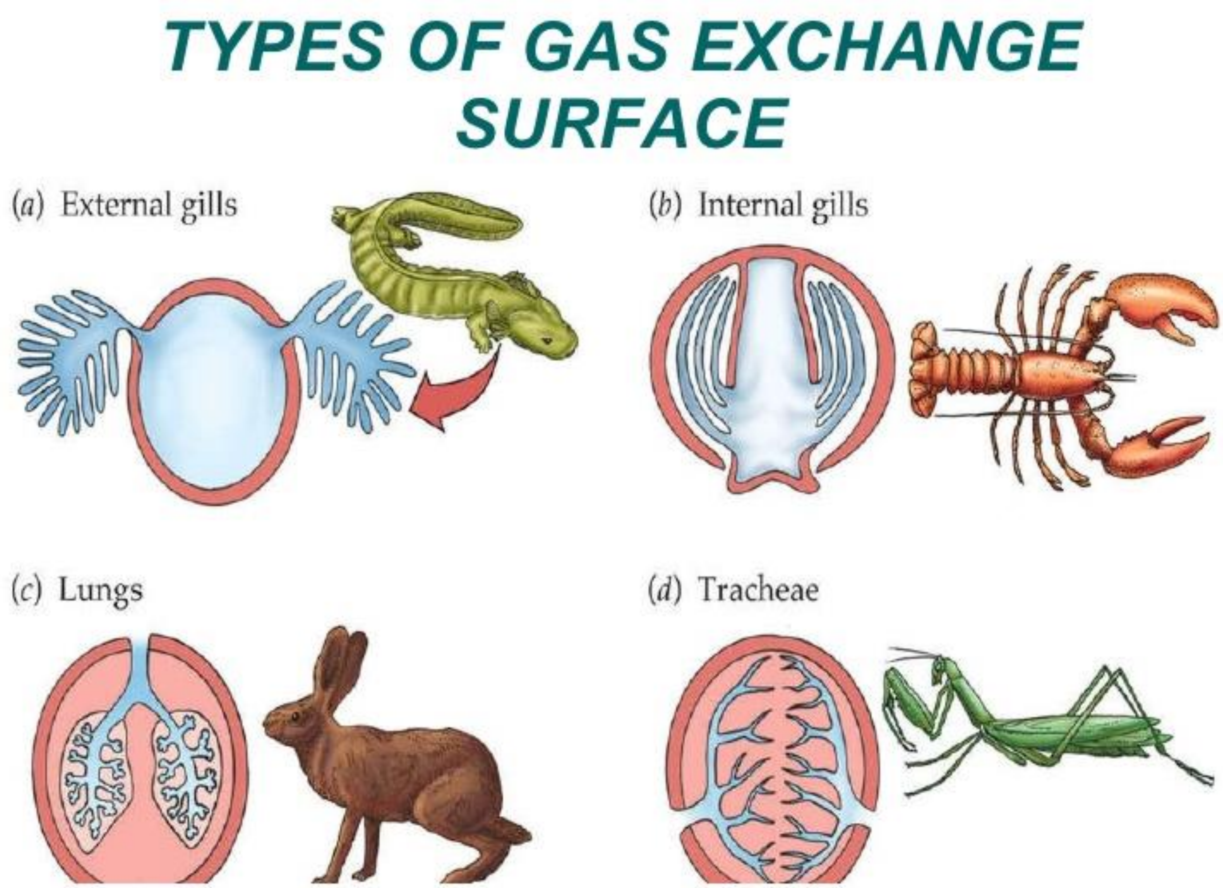
CHARACTERISTICS OF A GOOD RESPIRATORY SURFACE

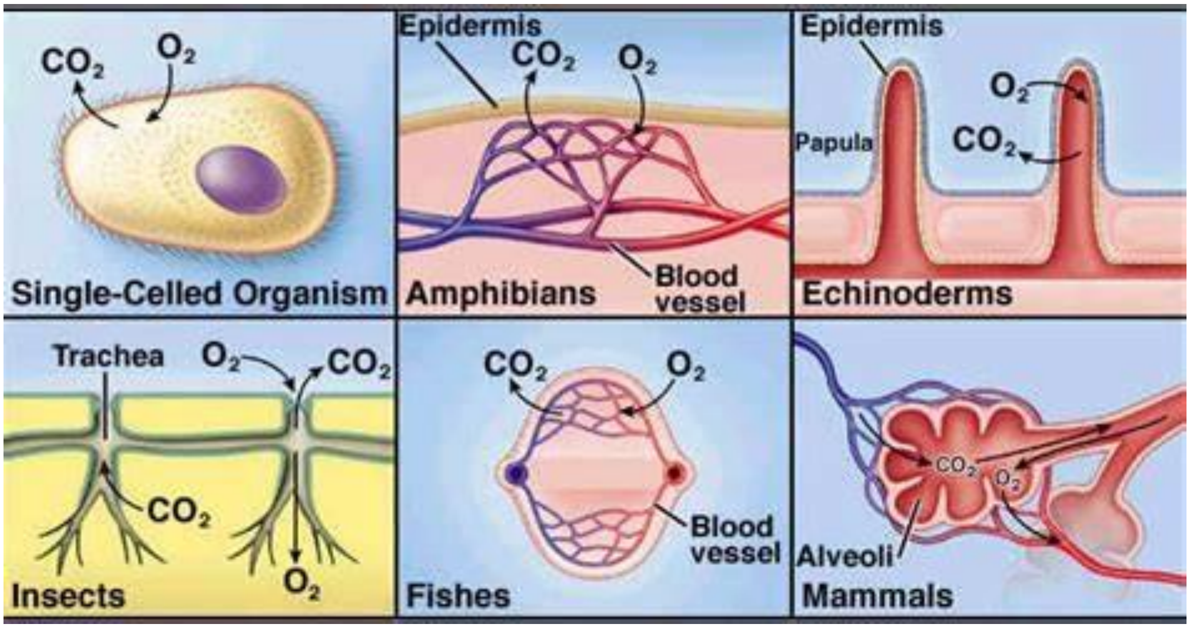
Respiratory surfaces are sites where gaseous exchange takes place in the body of the organism. Respiratory surfaces possess the following characteristics:

1. They have a large surface area to volume ratio to enable rapid diffusion of gases. This is achieved by folding or branching of structures to form alveoli in lungs, gill filaments in the gills and tracheoles in insects.
2. They are moist to allow easy diffusion of gases.
3. They are thin walled to reduce on the distance over which diffusion has to take place.
4. They have a good network of blood capillaries for easy transportation of gases to the respiring tissues.

5. They are well ventilated to maintain a high concentration gradient that favours diffusion of gases.

Note: respiratory surfaces of insects are not supplied with a network of blood capillaries because the blood of insects does not transport gases. The gases are transported in the tracheole tubes.





HOW ARE RESPIRATORY SURFACES ADAPTED FOR THEIR FUNCTIONS

I. They have a thin layer of moisture to dissolve gaseous for easy diffusion.
II. They have a thin wall to reduce on the distance for faster diffusion of gases.
III. They have a network of capillaries to supply blood for transporting gases to maintain a concentration gradient.
IV. They are folded to increase on surface area for easy diffusion of gases.

GASEOUS EXCHANGE IN SIMPLE ORGANISMS

Small organisms like amoeba, paramecium, hydra and jellyfish have a large surface area to volume ratio. In such organisms gaseous exchange takes place over the whole body surface. Because of their small body volume, diffusion alone is enough to transport oxygen and Carbon dioxide into, around and out of their bodies.

Larger organisms such as insects and vertebrates have a small surface area to volume ratio. In these organisms, gaseous exchange takes place in a specialized region of the body known as a respiratory surface. The respiratory surface is part of the respiratory organ. It is the actual site where gaseous exchange takes place.

EXAMPLES OF RESPIRATORY SURFACES AND CORRESPONDING RESPIRATORY ORGANS

Animal	**Respiratory organ**	**Respiratory surface**
Amphibians	Lungs	Alveolus
Amphibians	Skin	Skin surface (cutaneous)
Amphibians	Buccal cavity	Buccal cavity epithelium

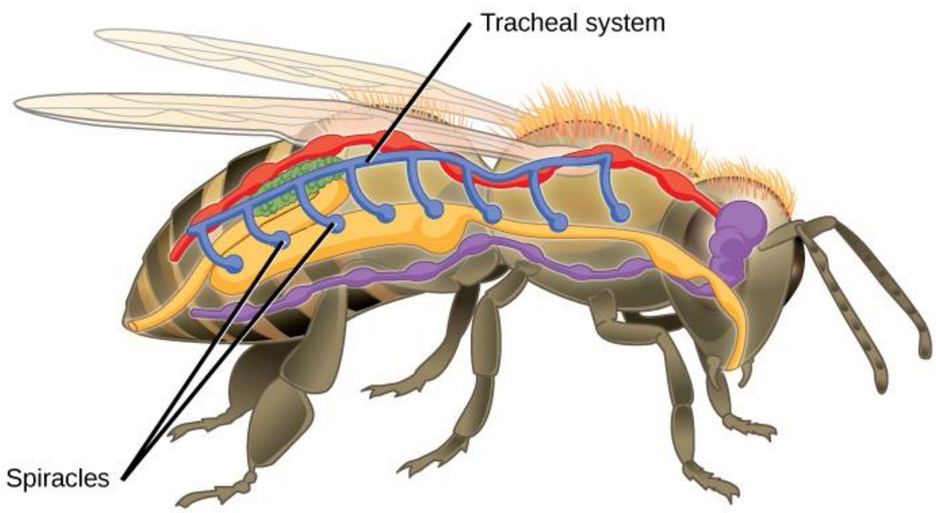
Birds	Lungs	Alveolus
Fish	Gills	Gill filaments
Insects	Tracheal system	Tracheoles
Mammals	Lungs	Alveolus
Tadpoles	Gills	Gill filaments

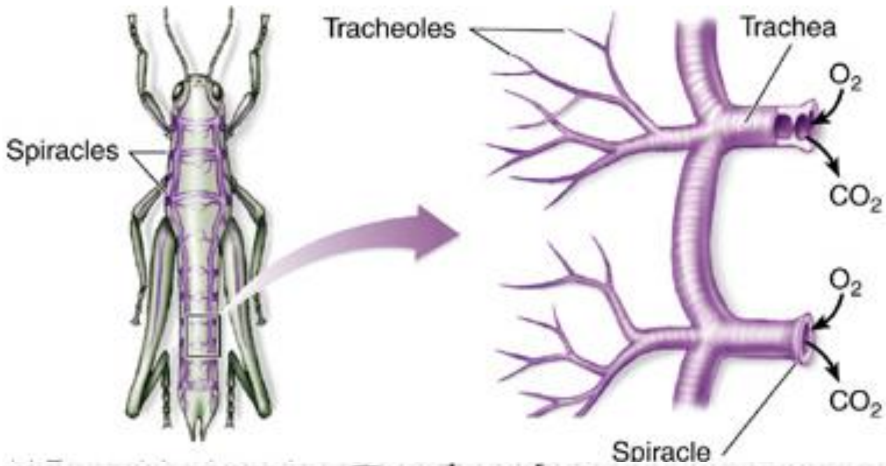
NB: the movement of gases and water to and from respiratory surface is called ventilation (breathing).

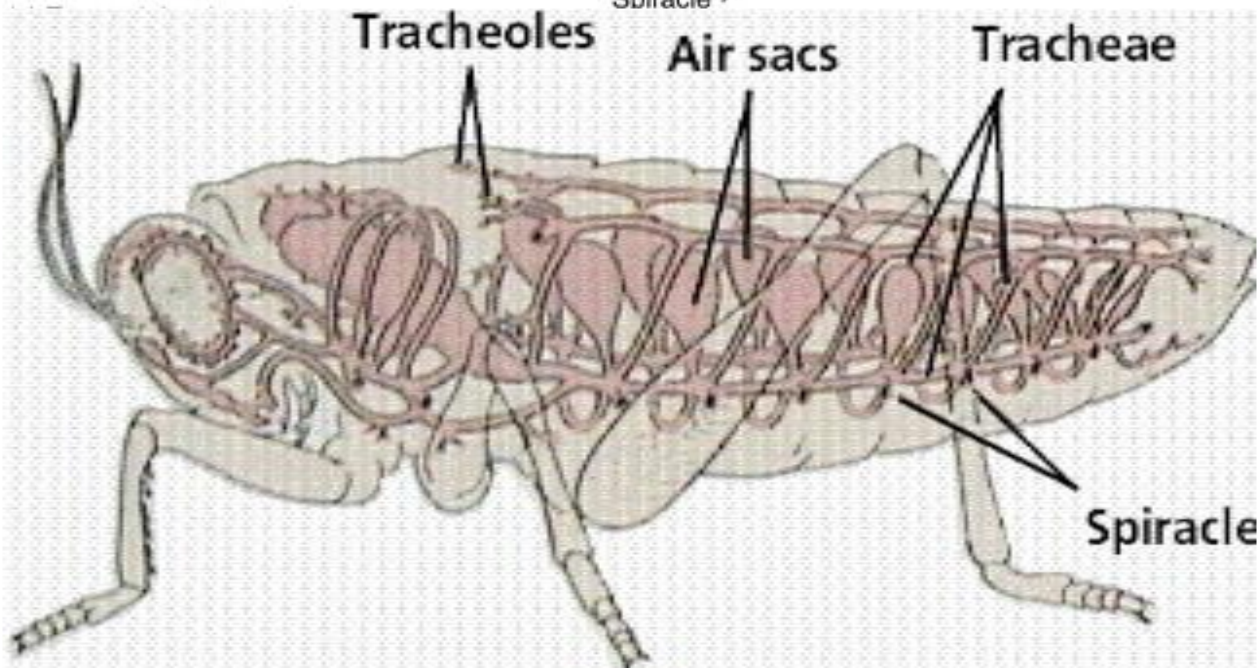
GASEOUS EXCHANGE IN INSECTS

The respiratory organs of insects consist of a network of tubes known as tracheal tubes, which make up the tracheal system. These tubes reach all the body tissues like the capillaries.

THE TRACHEAL SYSTEM OF INSECTS







VENTILATION MECHANISM

Inhalation:

- ✓ When the abdominal wall expands, the internal pressure reduces and the volume increases.
- ✓ This forces air containing oxygen in to the insect through the spiracles, to the trachea and then the tracheoles.
- ✓ Between the tracheoles and muscles of the insect, gaseous exchange occurs with oxygen entering in to the tissues and CO2 released from tissues, diffusing into the fluid in the tracheoles

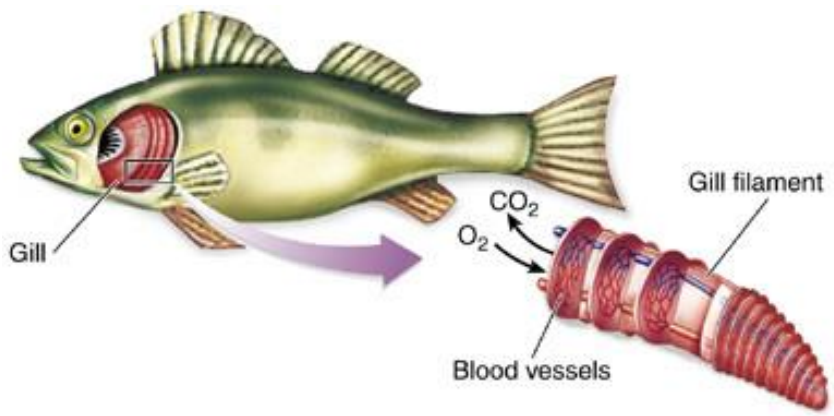
Exhalation:

Abdominal wall contracts, internal volume decreases while pressure increases, forcing air with a high concentration of carbon dioxide in the tracheoles out of the insect through the spiracles.

GASEOUS EXCHANGE IN FISH

Fish uses water as a medium of gaseous exchange and their respiratory surface is the internal gill. Fish absorb dissolved oxygen from water by use of gills. In most fish there is a pair of gills on each side of the body and in bony fish the gills are covered by a gill plate also called the operculum.

STRUCTURE OF THE GILL



Parts of the gill:

1) **Gill bar:** this provides an attachment and support to the gill filaments.
2) **Gill raker:** These are hard projections from the gill bar.
    a. They trap food suspended in water.
    b. They protect the gill filament by filtering out sand particles in water before reaching the gill filament.
3) **Gill filaments**: These are sites of gaseous exchange in the fish.
    a. They are finger-like projections that increase the surface area for gaseous exchange.
    b. They have a network of capillaries whose blood moves in the opposite direction with water (counter current flow) to maintain a high concentration gradient by carrying away the diffused gases.
    c. Filaments have a thin membrane.
    d. They are well ventilated.
    e. They are numerous to increase the surface area.

MECHANISM OF VENTILATION IN BONY FISH

Ventilation in bony fish occurs in two phases i.e. inhalation and exhalation.

Mechanism of inhalation

i. The operculum and glottis close.
ii. Floor of the mouth is lowered so that volume of the mouth cavity increases and pressure decreases below that of the surrounding water.
iii. Mouth opens.
iv. Water enters the mouth

Mechanism of exhalation

a. Mouth is closed.
b. Floor of the mouth is raised.
c. Volume of mouth cavity is reduced but pressure is increased.
d. Water moves from the mouth cavity into the gill.
e. As water passes over the gill filaments, oxygen diffuses into the water
f. Operculum opens and water containing carbon dioxide is expelled.

Out ward movement of water:

a) For water to flow out after gaseous exchange the operculum muscle relaxes then water flows out.
b) Meanwhile the buccal floor is still raised and the mouth is still closed.
c) The buccal floor then lowers to repeat the cycle.

GASEOUS EXCHANGE IN AMPHIBIANS

A. Tad pole

- Tad poles first use external gills and later internal gills as surface of gaseous exchange.
- The tad pole takes in water through the mouth and the water passes over the gills and then out of the body through the gill slit.
- The oxygen diffuses from the water into the blood while CO2 diffuses from blood into water.

B. Adult amphibians (Toad)

In adults gaseous exchange takes place through the;

1) Skin/ cutaneous.
2) Lining of the mouth cavity.
3) Lungs.

Amphibians depend mostly on their skin and buccal cavity for their gaseous exchange while they are in water. Lungs are only used when on land or when the water dries and the amphibian has to remain in mud.

1) The skin or cutaneous of Toad

Cutaneous respiration

Cutaneous respiration, or **cutaneous gas exchange**, is a form of respiration in which gas exchange occurs across the skin or outer integument of an organism rather than gills or lungs. Cutaneous respiration may be the sole method of gas exchange, or may accompany other forms, such as ventilation. Cutaneous respiration occurs in a wide variety of organisms, including insects, amphibians, fish, sea snakes, turtles, and to a lesser extent in mammals.

The skin is thin walled, moist and has a good network of blood capillaries. The skin acts as a respiratory surface when the amphibian is in and out of water. It's used when the oxygen need is low.

On land, the atmospheric oxygen dissolves in the layer of moisture and then diffuses across the skin into the blood. At the same time, CO_2 diffuses from the blood into the atmospheric air. In water, the oxygen dissolved in it, diffuses from the water across the skin into blood. CO_2 diffuses from blood into water.

Gas exchange in cutaneous respiration is controlled by three factors:

- Ventilation: the rate of delivery of respiratory medium (water or air) to the respiratory surface
- Diffusion: the passage of gases through the skin
- Convection: the carrying of dissolved gases towards or away from the lungs

2) **The buccal cavity**

The buccal cavity has a thin lining which is kept moist. It also has a good network of blood capillaries. The cavity is ventilated in the following ways.

During inhalation:

- The mouth floor lowers when it closes.
- This increases the volume of the buccal cavity reducing the pressure within.
- This forces the air from the atmosphere through the nostrils into the buccal cavity.
- Oxygen diffuses through the thin cavity membrane into blood while Carbon dioxide diffuses from blood into the buccal cavity.

During exhalation:

- The muscles of the floor of the buccal cavity relax raising the floor of the mouth.
- This leads to a reduction in volume and an increase in pressure within the mouth cavity.
- Air then moves out to the atmosphere through the nostrils.

3) **The lungs**

- The lungs consist of sacs supplied by a good network of blood capillaries.
- They have a large surface area.
- It is supplied with a lot of blood capillaries
- It is thin walled.
- Ventilation of the lungs occurs in the following stages;

Inspiration:

- The mouth closes and the nostrils open.

- Muscles of the floor of the buccal cavity contract to lower the mouth floor. This increases the volume and reduces the pressure within the buccal cavity.
- Air enters through the nostrils into the buccal cavity.
- The nostrils close, the muscles of the floor of the buccal cavity relax to raise the floor of the buccal cavity, while those of the abdominal cavity contract.
- This causes the volume of the buccal cavity to reduce and that of the abdominal cavity to increase.
- Pressure in the buccal cavity increases and that in the lungs decreases.
- It opens the glottis and air moves from the mouth cavity into the lungs through the trachea.
- Oxygen diffuses from the lungs into blood and Carbon dioxide from the blood into the lungs.

Exhalation:

- For exhalation, the abdominal muscles relax to reduce the volume of the lungs while the floor of the mouth cavity is lowered to increase its volume.
- This creates a higher pressure in the lungs and low pressure in the buccal cavity.
- Waste air is forced from the lungs into the buccal cavity
- The valve to the lungs (glottis) closes and nostrils open.
- Muscles of the floor of the mouth cavity relax raising the floor and increasing pressure in the buccal cavity.
- Waste air is forced from the cavity through the nostrils to the atmosphere.

GASEOUS EXCHANGE IN MAMMALS

Mammals are endotherms, ("warm-blooded") and have higher metabolic demands than ectothermic ("cold-blooded") vertebrates, and the skin is thicker and more impermeable than other vertebrates, which preclude the skin as a major source of gas exchange. However, small amounts of respiration may occur, and in bats, the highly vascularized wings may account for up to 12 percent of carbon dioxide excretion. In humans and most other mammals, a cutaneous respiration account for only 1 to 2 percent but most of the respiration is by the lung.

Gaseous Exchange in Humans

The respiratory organs in man are lungs and the respiratory surfaces are the sac like structures called ***alveoli***. The respiratory tract (air passage). Air enters through the nostrils into the nasal cavity where it is warmed to body temperature.

It begins from the nostrils into the back of the mouth, then into the pharynx from which it goes into the larynx and then to the trachea. From here, it travels through the bronchus, bronchioles and lastly to the alveolus.

The membrane of the nasal cavity is covered with cilia between which are goblet cells, which produce mucus.

Dust and germs inhaled from the atmosphere are trapped in mucus and are carried by the beating action of cilia towards the back of the mouth where they are swallowed.

This helps to prevent dust and germs from entering the lungs. Therefore, by the time air reaches the lungs it is dust and germ free, warm and moist. It is drawn from the nasal cavity into the trachea (wind pipe).

THE TRACHEA

This is a tube running from the pharynx to the lungs. It is always kept open by the circular rings of cartilage within it. The cartilage prevents the trachea from collapsing in case there is no air.

Cilia and goblet cells extend into the trachea to draw germs and dust out of trachea into the mouth where they are lost.

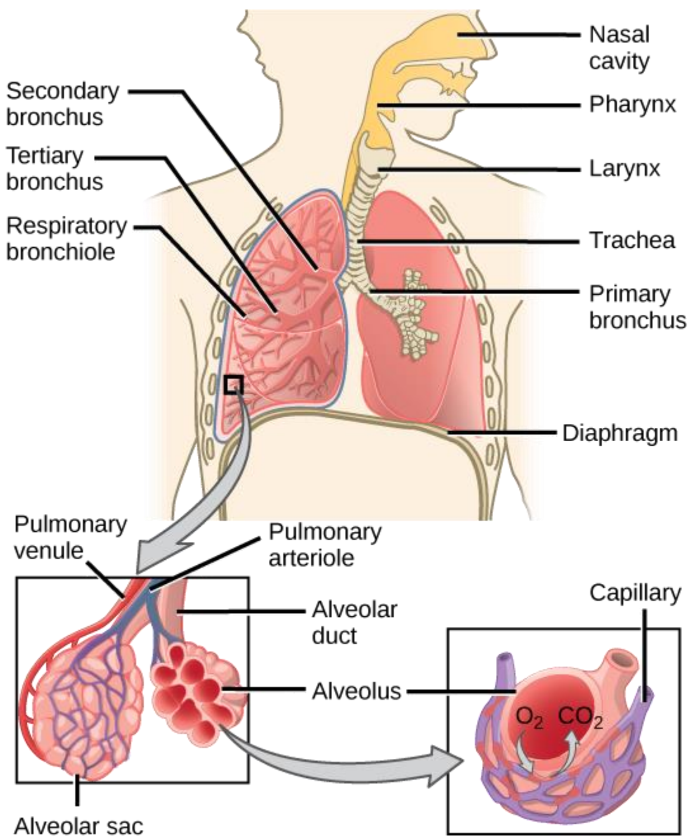
At the lower end, the trachea divides into sub tubes called bronchi, which penetrate further into the lungs and divide repeatedly to form small tubes called bronchioles.

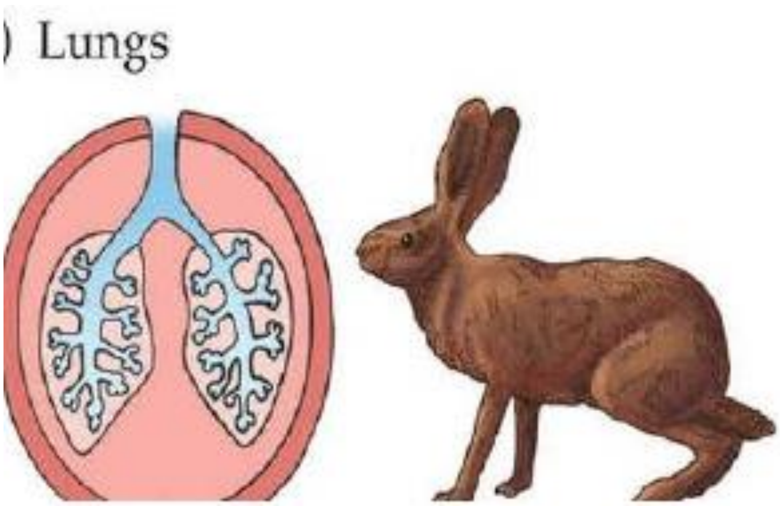
The bronchioles divide into many small tubes called alveolar ducts, which end in air sacs called alveoli.

The alveoli are the respiratory surfaces of mammals. There are about 300 million alveoli in a human lung. This increases the surface area over which gaseous exchange takes place.

LOCATION OF THE LUNGS IN THE BODY

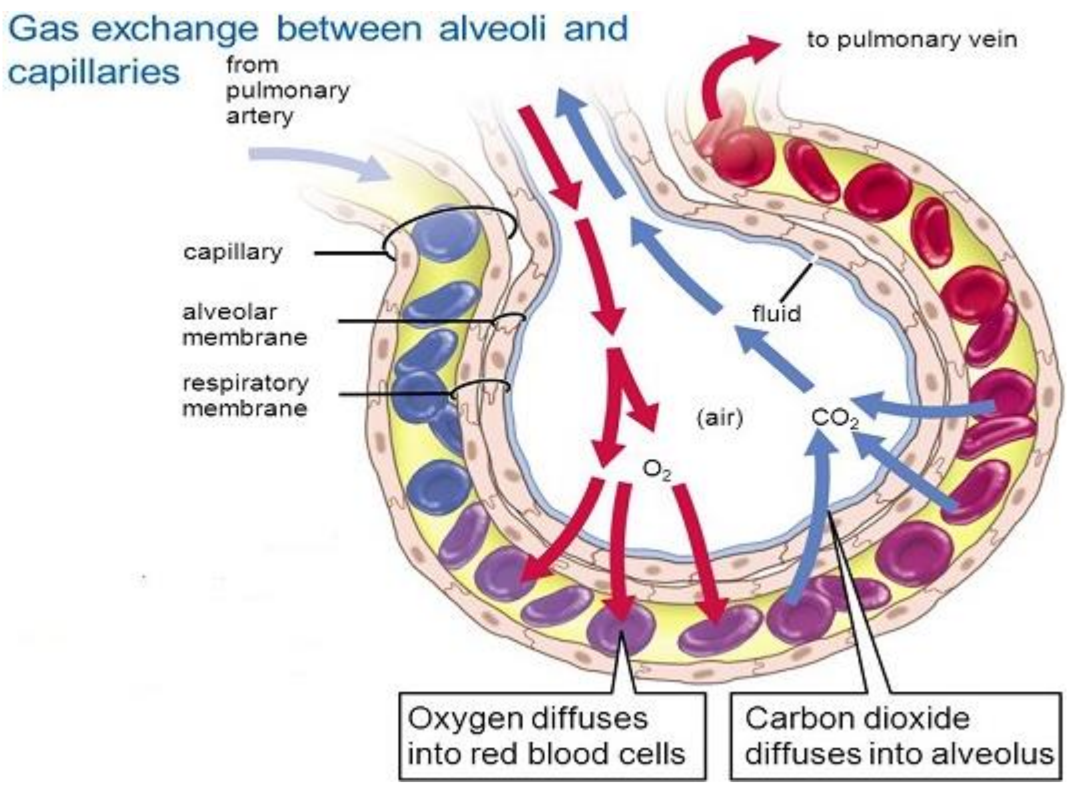
They are located in the thoracic cavity, enclosed by thorax wall and diaphragm.





The alveoli

An alveolus is a sac-like structure. The outer surface of the alveolus is covered with a network of blood capillaries. The alveolus is moist and thin walled. The oxygen in the alveolus diffuses into blood in the capillaries and it is carried around the body. At the same time, Carbon dioxide diffuses from blood into the alveolus and travels through the alveolar duct to the bronchioles then to the bronchi and trachea and out through the nostrils.



The mammalian lung

These are two elastic spongy-like structures located within the thoracic cavity and protected by the rib cage. Between the ribs are intercostal muscles, which move the rib cage. Below the lungs is a muscular sheet of tissue called the diaphragm.

Breathing mechanism in mammals/ lung ventilation

The breathing mechanism in mammals involves two sub-processes that are

INSPIRATION AND EXPIRATION.

Inspiration:

- The external intercoastal muscles contract while the internal intercoastal muscles relax. This involves the ribs outwards and downward movements.
- The diaphragm muscles contract and cause the diaphragm to move downwards and flatten
- these increase the volume of the thoracic cavity but reduce pressure in it below the atmospheric pressure.
- Air rushes /enters into the lungs from the atmosphere.

Expiration:

- The internal intercostal muscles contract while the external intercostal muscles relax. This causes the ribs to move downwards and inwards.
- The diaphragm muscles relax and cause the diaphragm to become dome-shaped.
- The volume in the thoracic cavity reduces but the pressure in it increases above the atmospheric pressure.
- Air is forced out of the lungs.

GASEOUS EXCHANGE IN THE ALVEOLUS

This take place across walls of alveoli and blood capillaries by diffusion.

During inspiration, air is taken into the lungs filling the alveoli. This air contains more oxygen and low CO2 concentration. Oxygen in inspired air dissolves in the moisture of the alveolar epithelium and diffuses across this and capillary walls into the red blood cells of blood. Inside the red blood cell, oxygen combines with haemoglobin to form oxyhaemoglobin and carried in this form. At the same time, CO2 which was carried as bicarbonate ion in blood diffuses from it through the capillary walls into the alveoli. It leaves the lungs in expired air.

Changes in the composition of gases in blood across the alveolus

Volume of gas carried by 100cc of blood

Gas	**Entering lungs**	**Leaving lungs**
Nitrogen	0.9cc	0.9cc
Oxygen	10.6cc	19.0cc

Carbon dioxide	58.0cc	50.0cc

The blood that flows towards the lungs contains a larger volume of carbon dioxide and less oxygen. But as it leaves the lungs, oxygen is added into it and some CO_2 is given off in the lungs. This indicates exchange of gases within the lungs.

CHANGES IN APPROXIMATE AIR COMPOSITION DURING BREATHING

Component	**Inhaled**	**Exhaled**
Nitrogen	**79%**	9%
Oxygen	21%	17%
Carbon dioxide	0.03%	4%
Water vapour	Less saturated (variable)	Saturated
Temperature	Atmospheric temperature	Body temperature

Although nitrogen is exchanged within the lungs and blood plasma, it plays no part in chemical reactions of the body hence its composition remains the same in inspired and expired air.

Inhaled air has more oxygen compared to exhaled air because it is taken up for the process of respiration, which produces out CO_2. Hence exhaled air contains more CO_2 than inhaled air. However the process of gaseous exchange in alveoli does not remove all the carbon dioxide and oxygen in air.

GASEOUS EXCHANGE IN PLANTS

Plants do not have a special respiratory surface for gaseous exchange. They use simple pores i.e. stomata of the leaves and lenticels of the stems for gaseous exchange.

Gases circulate in the plant by simple process of diffusion due to abundant large intercellular spaces that make diffusion faster.

Plants do not need special respiratory surfaces and blood transport system because:

- They utilize CO_2 produced by the plant cells for photosynthesis thus preventing accumulation.
- Plants produce oxygen as a bi-product of photosynthesis which is then used in respiration.
- Plants have numerous stomata and lenticels that favour fast gaseous exchange.
- They have large intercellular spaces that favour fast circulation of gases without blood.

- They have low demand for oxygen due to their low metabolic rate because they are less active since they are immobile.

UNIT FIVE
EXCRETORY SYSTEMS AND MECHANISMS

This unit will look at excretory systems in animals and in plants.

EXCRETORY SYSTEM OF HUMANS

Excretion is the removal of the waste or toxic products of metabolism from the body and substances in excess of requirement (carbon dioxide, urea, mineral salt, water etc).

Metabolism is the name given to the many hundreds of chemical reactions going on inside each of our cells. If these waste are allowed to accumulate they would prevent the maintenance of a constant internal environment and could act as poisons or toxins, and in time the poison may kill the organism.

This constancy of the internal environment despite external environment changes is known as **homeostasis**, and mechanisms contributing to homeostasis, including excretion are called homeostatic mechanism.

Mammals have four main excretory organs.

1) Lungs - Remove carbon dioxide and water from aerobic respiration. Excretory product; Carbon dioxide and water.
2) Liver – Removes bile pigments from the breakdown of haemoglobin in worn out red blood cells. This is lost in the faeces. Excretory product: Bile pigment and urea.

a) Surplus **amino acids** in the bloodstream cannot be stored, thus they are removed by the liver and broken down into the **urea** (which is the nitrogen-containing part of the amino acid) and a **sugar** residue, which can be respired to release energy. The breakdown of amino acids is called **deamination**.

3) Skin – Removes salts, water and traces of urea via the sweat glands. Excretory product: Excess water, mineral salts (NaCl) and urea.
4) Kidney – Remove large quantities of urea, a compound containing nitrogen.

Excretory products: Water, urea, mineral salts, and uric acid.

The common waste products which mammals produce are: Water, carbon dioxide, mineral salts, nitrogenous compounds such as urea. Uric acid and ammonium compound may be produced, but are not directly excreted as such.

Two processes which need to be distinguished from excretion are

i. Egestion
ii. Secretion

Egestion is the removal of undigested food (i.e. most materials in faeces). Most egested materials have not been absorbed by cells and so have not been involved in metabolism

Secretion is the production and release of a useful chemical e.g. secretion of saliva from salivary glands, gastric juice and mucus from gastric glands in the stomach wall and endocrine secretions.

Differences between Excretion and Egestion

Excretion	**Egestion**
Removal of metabolic body waste products from the body	Removal of undigested food from the body
Waste products are removed through the lungs, skin, kidney and liver	Waste products are removed through the anus
excretory products include excess water ,carbon dioxide, urea , bile pigments, etc	Egestion product are faeces and water
Waste substances are removed from the cells and tissues	Egested substances are removed from the alimentary canal

Table 3 .1 Excretory products and their sources

Excretory product	Site of production	Source / from
Urea	Liver	Protein metabolism
Carbon dioxide	Body tissue	Aerobic respiration
Excess water and mineral salts	Body tissue	Dietary intake and bile pigments and salts from the breakdown of red blood cells
Bile pigment	liver	Red blood cells

Importance Of Excretion

(1) It helps to maintain water and salt balances in the body
(2) If excretory waste products are not removed, it can interfere with normal metabolic activities of the body.
(3) The excretory waste products are harmful to the body and so must be remove.

STRUCTURE AND FUNCTION OF THE EXCRETORY ORGANS

The kidney: Usually there are two kidneys in humans. The kidney is a dark red, bean shaped organs in the dorsal part of the abdominal cavity. They are at waist level in people.

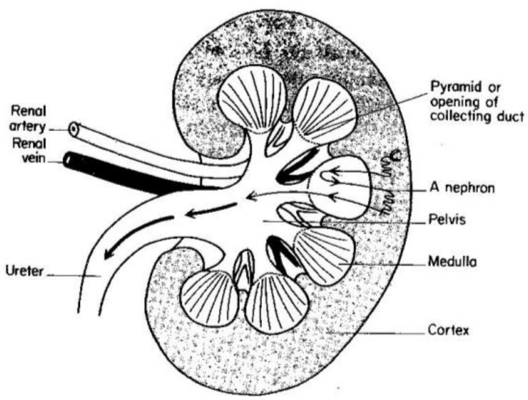
The right kidney is slightly anterior to the left and both are usually covered with a deposit of fat. Blood supply to the kidney is from the dorsal aorta via the renal artery.

Its capillaries unite to form the renal vein. The narrow white muscular tube which emerges from the inner concave surface is called the ureter. This carries a continues flow of unine from the kidney to the urinary bladder.

There are **two main sections or zones** in a vertical section through a kidney:

(1) Cortex ---- outer zone composed of the tubules (dark)
(2) Medulla ---- The inner zone containing several cone – like extensions called pyramids (lighter). The pyramids project into a space, the renal pelvis, from which the ureter arises.

Fig 3.1. Vertical section through a mammalian kidney

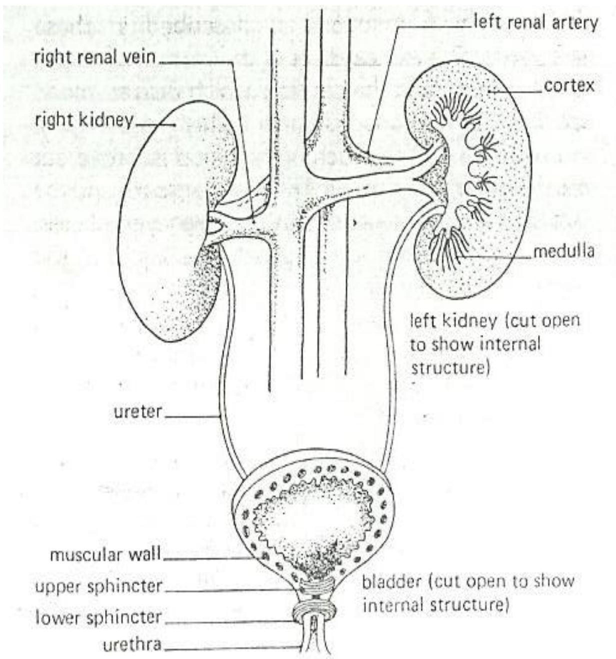


- Capsule – found around the cortex
- Pelvis - The ureter is swollen to form the pelvis
- Pyramid is the rigid inner border of the medulla.

Functions of Kidney:

A. Regulation of fluid balance: The kidney controls osmotic pressure of extra cellular body fluids by regulating the amount of water lost from body.
B. Regulation of electrolyte concentrations: The concentration of electrolytes like Sodium, Potassium, Chloride, Bicarbonates etc in blood also regulated. It is performed by selective tubular reasbsorption process in proximal tubule.
C. Maintenance of acid-base balance.
D. Removal of other substances like mineral salts, iodides, drugs, arsenic and bacteria are recovered of the blood by kidney only.
E. Kidney secretes rennin which is an enzyme but acts as hormone which changes the plasma protein.
F. Kidney secretes erythropoietin which stimulates the formation of RBC.

Fig. 3.2 STRUCTURE OF THE KIDNEY AND BLADDER IN MAN



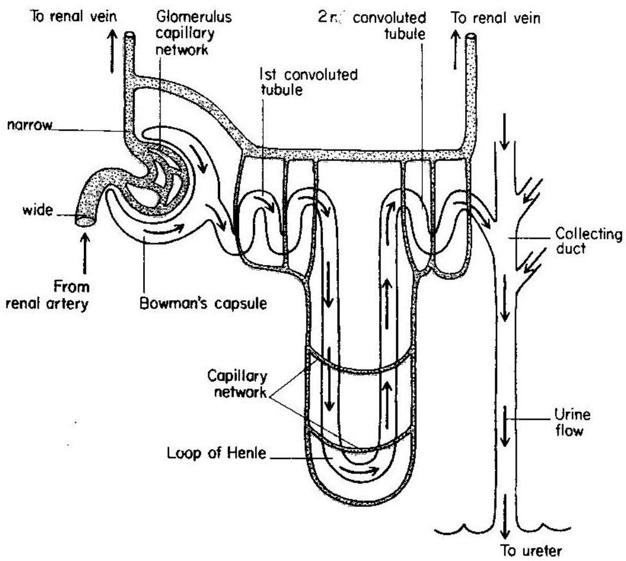
INTERNAL STRUCTURE OF THE KIDNEY

The nephron is the basic unit of the kidney. There are about three million nephrons (Kidney or renal tubules) in the kidney. The tubule has a number of defined regions.

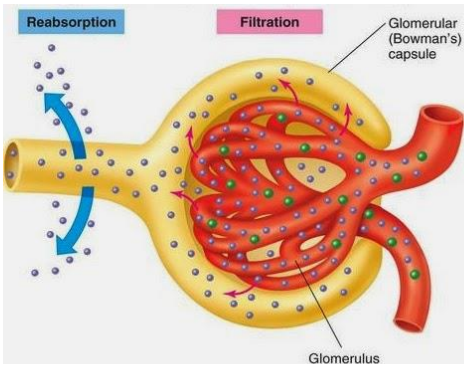
Beginning in the renal cortex is the Malpighian corpuscle, made up of the cup-shaped Bowman's capsule, and a knot of blood capillaries called the glomerulus. From the capsule emerges a tube that coils on itself many times before descending into the medulla. This coiled region of the tubule is called the first or **proximal convoluted tubule.** On entering the medulla, the tubule makes an upward U-turn to return to the cortex. This U-shaped, very narrow region is called the loop of Henle. The tubule makes a second set of coils on returning to the cortex called the second or **distal convoluted tubule.** It then joins a common collecting duct which opens into the renal pelvis.

Each tubule is supplied with blood from a branch of the renal artery called the **afferent arteriole**. These branches into about 50 parallel capillaries which form the glomerulus. The glomerulus is drained by a narrower vessel called the efferent arteriole which coils back to form capillaries around the convolutions and the loop of Henle, before finally joining up with other vessels to form the renal vein. About 25% of blood leaving the left ventricle at every systole passes through the two kidneys.

Fig 3.3 Diagram of one renal tubule showing the blood supply and the main areas of reabsorption (nephron/uriniferons tubule)



Function of the kidney include filtration and reabsorption



The function of the kidney is to filter blood, **removing** urea and excess H_2O, **reabsorbing** glucose, some H_2O and some mineral salts.

Mechanism of urine formation
The processes involved in the formation of urine occur in three phases which are:

- Ultrafiltration (Pressure filtration)
- Selective reabsorbtion
- Hormonal secretion

Ultrafiltration (glomerular filtration)
This takes place between the capillaries in the glomeruli and the bowman's capsule.

In the first phase, blood is brought to the kidney by renal arteries, as it circulates through the capillaries or glomerulus of each Bowman's capsule, water, urea, nitrogenous compounds, mineral salts, sugar, glucose and plasma solutes are filtered into the capsule. This is possible because the efferent arteriole of the glomerulus is narrower than the afferent arteriole and creates high pressure in the glomerulus. This process of filtering material from the glomerulus in to the Bowman's capsule under pressure is called **ultrafiltration or pressure filtration.**

This is possible because the glomerulus and Bowman's capsule is one cell thick and have special structures to allow small molecules through but most or the blood protein and blood cells do not pass through as they are too large.

SELECTIVE REABSORPTION

The fluid from ultrafiltration in the capsule or glomerular filtrate now moved into the first coiled tubule where 75% of the water in the filtrate is reabsorbed into the blood by osmosis or active transport. All useful metabolic products (glucose, amino acid, etc) are reabsorbed from the glomerular filtrate. This happens as the filtrate passes along the first convoluted tubule. The process involved in reabsorption is passive diffusion and active transport.

Active transport requires energy from ATP. The microvilli of the cells lining the lumen of the tubule provide a large surface area which aids reabsorbtion. This process of reabsorbing useful materials back into the blood is called selective reabsorbtion.

The concentrated filtrate now passes into the loop of Henle and the second convoluted tubule in which reabsorption of salts and water is regulated according to the body's needs. If a person has been excercing and losing a lot of water through pespiration, the more water will be reabsorbed from the urine and its colour will be dark. The reverse occurs if the body is water- rich.

Hormonal secretion

At this stage the fluid in the tubule becomes more concentrated as its flows through the distal tubule where more water is reabsorbed by the action of the hormone ADH (anti – diuretic hormones) and urine finally formed. The filtrate gradually tickles into the collecting duct by the time it reaches the renal pelvis and propelled by peristalsis through the ureter into the urinary bladder, when the bladder is full, it contracts and discharges the urine through the urethra.

Note: selective reabsorption is a means of regulating the level of water and dissolved substances to maintain a constant osmotic pressure in the blood and tissue fluid. Thus, both excretion and osmo-regulation are carried out by the kidney.

Summary urine production

Blood enters the kidney through the renal artery. The artery divides into smaller and smaller blood vessels, called arterioles, eventually ending in the tiny capillaries of the glomerulus. The capillary walls here are quite thin, and the blood pressure within the capillaries is high. The result is that water, along with any substances that may be dissolved in it—typically salts, glucose or sugar, amino acids, and the waste products urea and uric acid—are pushed out through the thin capillary walls, where they are collected in Bowman's capsule. Larger particles in the blood, such as red blood cells and protein molecules, are too bulky to pass through the capillary walls and they remain in the bloodstream. The blood, which is now filtered, leaves the glomerulus through another arteriole, which branches into the mesh-like network of blood vessels around the renal tubule. The blood then exits the kidney through the renal vein. Approximately 180 litres (about 50 gallons) of blood moves through the two kidneys every day.

Urine production begins with the substances that the blood leaves behind during its passage through the kidney—the water, salts, and other substances collected from the glomerulus in Bowman's capsule. This liquid, called glomerular filtrate, moves from Bowman's capsule through the renal tubule. As the filtrate flows through the renal tubule, the network of blood vessels surrounding the tubule reabsorbs much of the water, salt, and virtually all of the nutrients, especially glucose and amino acids that were removed in the glomerulus. This important process, called tubular reabsorption, enables the body to selectively keep the substances it needs while ridding itself of wastes. Eventually, about 99 percent of the water, salt, and other nutrients is reabsorbed.

At the same time that the kidney reabsorbs valuable nutrients from the glomerular filtrate, it carries out an opposing task, called tubular secretion. In this process, unwanted substances from the capillaries surrounding the nephron are added to the glomerular filtrate. These substances include various charged particles called ions, including ammonium, hydrogen, and potassium ions.

Together, glomerular filtration, tubular reabsorption, and tubular secretion produce urine, which flows into collecting ducts, which guide it into the microtubules of the pyramids. The urine is then stored in the renal cavity and eventually drained into the ureters, which are long, narrow tubes leading to the bladder. From the roughly 180 liters (about 50 gallons) of blood that the kidneys filter each day, about 1.5 liters (1.3 qt) of urine are produced.

Table 3.2 Part of the human urinary system and their functions

Structure	Functions
Kidney	Filters blood and excretes nitrogenous waste, excess salts and water as urine
Renal artery	Branching from the aorta, the renal artery carries oxygenated blood to the kidney
Renal vein	Carries deoxygenated blood away from the kidney to the vena cava
Ureter	Peristaltic waves of contraction in the thin tube carries urine produced by the kidneys to the urinary bladder through the ureter
Sphincter Muscle	Voluntarily relaxes to release urine from the bladder
Urethra	Passage of urine out of the body is through the urethra

Table 3.3 Functions of the parts of the human kidney

Region in the kidney	Function
Outer cortex (dark colour)	Contains the Bowman's capsules and glomeruli of the nepherons

Inner medulla (light colour)	Contains the U-shaped loop of Henle and the collecting ducts
Pyramids	Cone-shaped areas in medulla where urine produced by the kidney tubules drain into the pelvis of the ureter
Pelvis	Funnel – shaped spaces formed by the top of the ureter, collects urine
Ureter	Peristaltic waves of contraction in the thin tube carry urine produced by the kidney to the bladder.

Urine content

95% water

2.5% urea and other nitrogenous waste

1.5% salts etc.

Table 3.4 concentration of substance in blood plasma and urine

Substance	Percentage (%) in plasma **A**	Percentage (%) Filtrate/Bowman's capsule **B**	Percentage (%) in urine **C**	Concentration factor **D**
Water	90 – 93	90-93	95.0	
Protein	7.0	0	0	
Glucose	0.1	0.1	0	
Sodium	0.3	0.3	0.35	*1.0
Chloride	0.4	0.4	0.6	*1.5
Urea	0.03	0.03	2.0	*60.0
Uric acid	0.004	0.004	0.05	*12.0
Creatinine	0.001	0.001	0.075	*75.0
Ammonia	0.001	0.001	0.04	* 40.0

Exercise (1) From the table above list the substance present and those absent from the urine of a normal person

Disorders of urinary system in human

- Bed wetting
- Nephritis
- Kidney stones
- Diuresis
- Urine retention

Abnormal functions of the kidney

A close examination of the constituents of urine is important in diagnosis certain disorders in the body. For example if on analysing urine, it is found to contain glucose; the diseases called diabetes mellitus is evident. This happens when the pancreas is not secreting the hormone insulin from the **islet** of Langerhans to convert sugar in blood to glycogen. Occasionally when people are unable to secrete sufficient ADH they tend to excrete large amount of urine. The sufferers therefore tend to drink enormous quantities of water to replace the loss in urine. This condition is known as Diabetes insipidus. Thus can be remedied by regular nasal spraying with ADH. Another disease which the analysis of urine can give an indication of is NEPHRITIS, This afflicts people when the glomeruli become faulty and allow proteins to filter through with the glomerular filtrate. Ultimately appearing in the urine.

People occasionally suffer from kidney failure. This might happen suddenly due to severe infection or low blood pressure. Or gradually as a result of high blood pressure. It is possible to live with one kidney only, but it is fatal when both fail, partial kidney failure can be treated by controlled diet (eating less protein rich food), by dialysis uses a kidney machine, or by kidney transplant.

The skin as an excretory organ

The skin excretes substances within a fluid called sweat.

Sweat glands are coiled tubes which continue as sweat duct opening at the surface of the skin as sweat pores. A network of blood capillaries surrounds each sweat gland. As blood flows through these capillaries, waste products such as water, urea sodium a chloride and carbon dioxide are absorbed by the sweat glands to pass through the sweat ducts and out through the sweat pores,. Thus the sweat glands enable the skin to function as an excretory organ. When the body is exposed to temperature in excess of the internal body temperature, sweat containing a large quantity of water, mineral ions and small percentage of urea. As the sweat passes up the sweat duct, the water component absorbs heat from the skin cells. If the external environment is sufficiently hot and dry, the water evapourates; if not it wets the skin surface. In the way some excretory products are removed incidentally.

The lung as an excretory organ

The lungs a part from having respiratory function also acts as organs of excretion and homeostasis. In considers the process of gas exchange in the alveoli, it was observed that every 100cm^3 of blood plasma entering the lungs contains 58cm3 of carbon dioxide: the amount of carbon dioxide leaving the lungs is 50cm^3/ 100cm^3 of blood. These figures indicate that part of the body's carbon dioxide is "unloaded" in the lungs

The other excretory product of the lungs is water vapour.

The liver as an excretory organ

The liver is a large and vital organ concerned with excretion and homeostasis among several other functions.

It **excretes** bile pigments and excess cholesterol. The pigments are waste products of haemoglobin (erythrocyte) destruction. They are excreted in bile into the duodenum of the alimentary canal

As a homeostatic organ, the liver stores excess glucose as glycogen which it can convert back as glucose when needed. In this way it regulates the blood sugar lever. The liver also de-aminates excess amino acids to urea and glycogen. It stores their iron for later use; It also stores vitamins A and D as well as blood.

Another important function of the liver is to render harmless such poisons as ethanol (ethyl alcohol) and toxins produced by bacteria in the gut.

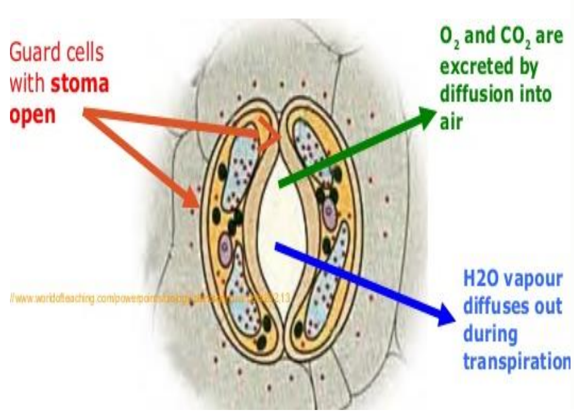
EXCRETORY SYSTEM IN PLANTS

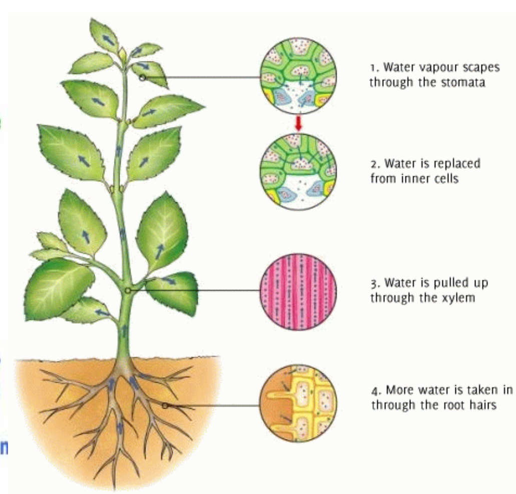
Plants have no special excretory organs for removal of waste. The waste products of respiration and photosynthesis are used as raw materials for each other. Oxygen gas produced as a by-product of photosynthesis is used up during respiration and carbon dioxide produced during respiration is used up during photosynthesis.

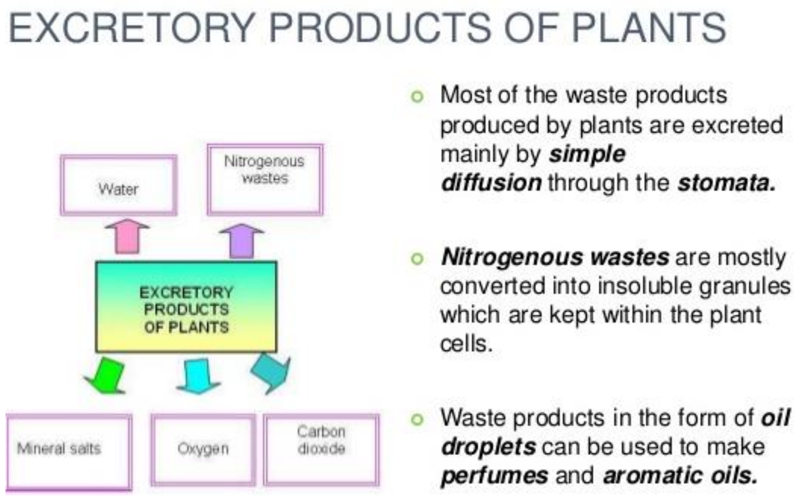
Excretion in plants is carried out in the following ways:

i. The gaseous waste such as oxygen, carbon dioxide and water vapour are removed through stomata of leaves and lenticels of stems.
ii. Some waste products collect in the leaves and bark of tress. When the leaves fall and the bark are shed, the waste is eliminated.
iii. Some waste products are rendered harmless and then stored in the plant body as, raphides, tannins, resins, gum, rubber and essential oils are some such wastes.

EXCRETION THROUGH STOMATA







UNIT SIX

HOMEOSTASIS

Homeostasis is the maintenance of constant internal environment in response to fluctuations in outer or external environment. Internal environment refers the interstitial fluids surrounding individual cells while external environment refers to the environment in which organisms live. Maintaining a dynamic equilibrium between body's internal environment and changing external environment requires constant monitoring and adjustments. This adjusting of physiological systems within the body is called homeostatic regulation. The liver, the kidneys, and the brain (hypothalamus, the autonomic nervous system and the endocrine system help maintain homeostasis. An inability to maintain homeostasis or fluctuation in temperature, water levels and nutrient concentrations may lead to death or a disease, a condition known as **homeostatic imbalance.** Other diseases which result from a homeostatic imbalance include **diabetes,**

dehydration, hypoglycemia, hyperglycemia, gout, hypothermia etc. Medical intervention can help restore homeostasis and possibly prevent permanent damage to the organs.

Homeostasis Control System

The control system for regulation of homeostasis is an open system, which involves stimulus as input and response as output.

THE HYPOTHALAMUS COORDINATES TEMPERATURE CONTROL

The **hypothalamus** (part of brain) acts like a **censor** or thermostat. It detects temperature (t^o) of the blood running through it. If t^o > or < 37^0C, it sends electrical impulses, along nerves, to parts of the body which function in regulating body t^o. Any deviation from the means temperature value is corrected by either switching on the heating mechanism or the heat loss mechanism. The thermo receptors in the brain detect high or low body temperature.

Temperature regulation

Temperature regulation is one homeostatic function. Mammals and birds are warm-blooded thus they maintain a constant body temperature despite external environment changes. For instance humans maintain a body temperature of 37^0C. We have mechanisms to lose heat when we get too hot, and ways of retaining heat when we get too cold. Enzyme reacting and physiological processes occur most efficiently at this temperature and death occurs when the body temperature falls as low as 30^oC or rises above 42^oC for any length of time.

The mechanism that keeps the body temperature constant despite fluctuation in the environmental temperature is called **temperature regulation** or **thermoregulation** like excreting and maintenance of the water and salt content of the body, temperature regulation contributes to homeostasis.

In temperature regulation, heat lost form the body is balanced by the amount of heat gained by the body. The body temperature remains constant at about 37^oC when these two are in equilibrium.

Heat is gained by the body through

- Absorption by the skin of heat energy from the sun, hot objects, drinking hot drinks
- Metabolic reaction, especially in the liver and muscular contraction in exercise and shivering.

Ways of losing heat include:

- Coming into contact with a cold environment
- Profuse sweating
- Heat loss through urine and faeces.

The heat gain mechanism

In cold weather or when you are feeling cold, the body gains and saves more heat through;

A. **Shivering:** muscles contract and relax spontaneously to produces heat and warms blood.
B. **Vasoconstriction:** arterioles near skin become narrower so little blood can flow through them (the blood flows through the deep-lying capillaries instead) this conserves heat loss through radiation.
C. **Metabolism may increase; this** releases energy.
D. **Hair stands up**. In human, the erector muscles contract, raising the hair to stand on their ends (this produces ‘goose pimples’) and trapping air around skin to prevent heat loss, . But in hair animals (cat), it acts as an insulator: trap a thicker layer of warm air next to the skin, prevent skin from loosing more warmth.

The heat loss mechanism

In hot weather or when you are feeling hot, the body loses more heat through;

i. **Vasodilatation occurs;** more blood flows near skin surface to lose heat when the blood vessels in the skin dilate, thereby allowing heat loose by radiation.
ii. **Hair lies flat:** Erector muscles relax and hair lies flat and heat is lost.
iii. **Sweating**: also brings about loss of heat through evaporation of the sweat.

NOTE
COMMON MISCONCEPTIONS
Remember that the process of vasodilatation and vasoconstriction happen only in arterioles – they do **not** happen in capillaries or veins. When writing about the process, make sure you refer to arterioles.

OSMOREGULATION

Osmoregulation is a process that regulates the osmotic pressure of fluids and electrolytic balance in organisms. In animals, this process is brought about by **osmoreceptors**, which can detect changes in osmotic pressure. Humans and most other warm blooded organisms have osmoreceptors in the hypothalamus. Besides the brain, osmoregulators are also found in the kidneys.

TYPES OF OSMOREGULATION

There are two major types of osmoregulation:

- **Osmoconformers**

Osmoconformers are organisms that try to match the osmolarity of their body with their surroundings. In other words, these organisms maintain the same osmotic pressure inside the body as outside water. They conform either through active or passive means. Most marine invertebrates such as starfish, jellyfish and lobsters are osmoconformers.

- **Osmoregulators**

Osmoregulators are organisms that actively regulate their osmotic pressure, independent of the surrounding environment. Many vertebrates, including humans, are osmoregulatory. Most freshwater fish are considered to be osmoregulatory too.

OSMOREGULATION IN DIFFERENT ORGANISMS

Different organisms exhibit different types of osmoregulation. The following are some of the osmoregulation processes in different organisms:

OSMOREGULATION IN FISH

Freshwater fish and marine fish osmoregulate in different ways. The environments which they have varying levels of salinity, hence the process of osmoregulation is different.

- **Osmoregulation in Freshwater Fish**

Freshwater fishes are hypertonic to their surrounding environment, which means that the concentration of salt is higher in their blood than their surrounding water. They absorb a controlled amount of water through the mouth and the gill membranes. Due to this intake of water, they produce large quantities of urine through which a lot of salt is lost. The salt is replaced with the help of mitochondria-rich cells in the gills. These cells absorb salt into the blood from the surrounding water.

- **Osmoregulation in Marine Fish**

Compared to freshwater fish, marine fish face the opposite problem. They have a higher concentration of water in their blood than their surrounding environment. Consequently, it results in the tendency to lose water and absorb the salt. To get around this problem, marine fish drink large quantities of water and restrict urination. Another additional energy expenditure also arises as these organisms actively need to expel salt from the body (through the gills).

OSMOREGULATION IN BACTERIA

Bacteria use a transport mechanism to absorb electrolytes when osmolarity around it increases. The osmotic stress activates certain genes in bacteria that synthesize osmoprotectants.

OSMOREGULATION IN PLANTS

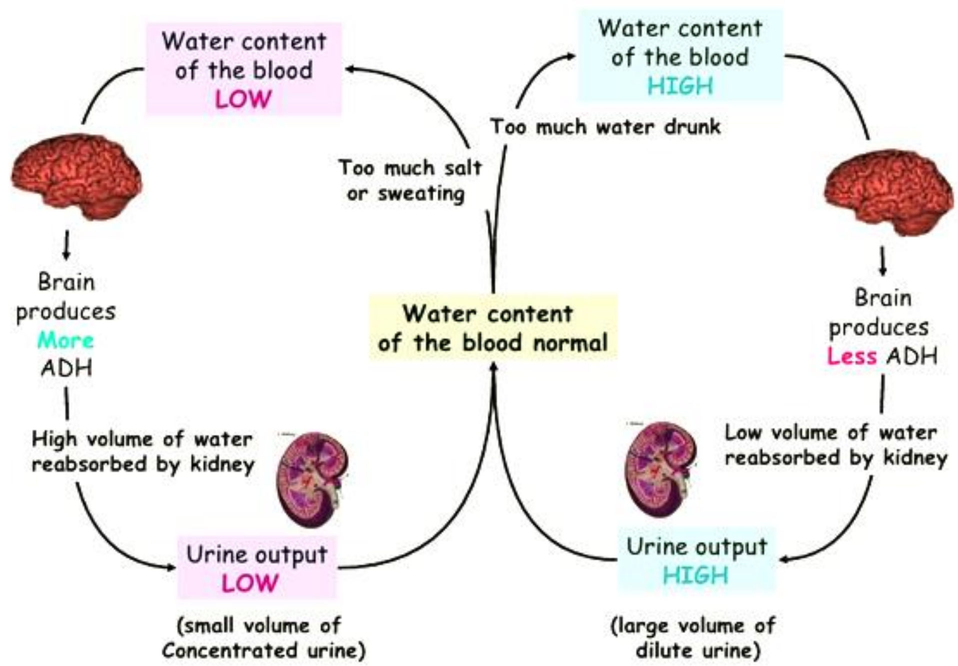
Plants use **stomata** on the lower side of their leaves to regulate water loss. Plants growing in hydrated soils compensate water loss by transpiration by absorbing more water from the soil. The plants that grow in semi-arid areas store water in the vacuoles and have thick and fleshy cuticles to prevent water loss.

OSMOREGULATION IN ANIMALS

Animals have a well-developed excretory system that helps to maintain the water lost from the body, thereby maintaining osmotic pressure.

OSMOREGULATION IN HUMANS

The kidney is the main organ responsible for osmoregulation in humans. Water, amino acids and glucose are reabsorbed by the kidneys. When the water level in the body is high, it releases a large amount of hypotonic urine. When the water level is low, it retains water and produces a low amount of hypertonic urine. Thus, the kidneys maintain the electrolytic balance of the body.



OSMOREGULATION IN HUMANS

Aldosterone, angiotensin II, and antidiuretic hormones **ADH** control the absorption process. Some water and electrolytes are also lost by perspiration.

Osmoreceptors in the hypothalamus of the brain control the thirst and secretion of ADH. ADH opens the water channels of aquaporins allowing the water to flow. Thus, the kidneys keep absorbing water until the **pituitary gland** stops releasing ADH.

MAINTENANCE OF THE ACID-BASE BALANCE OF THE HUMAN SYSTEM

The process by which plants and animals rid themselves of waste products and of the nitrogenous by–products of metabolism are several. But through excretion organisms control osmotic pressure, the balance between inorganic ions and water as well as the maintenance of acid balance. This process thus promotes homeostasis.

Key Points

- The kidneys maintain homeostasis through the excretion of waste products.
- **Acidosis** causes more bicarbonate to be reabsorbed from the tubular fluid, while the collecting ducts secrete more hydrogen to generate more bicarbonate, and more NH_3 buffer is formed.
- **Alkalosis** causes the kidney to excrete more bicarbonate as there is a reduced secretion of hydrogen ions and more ammonium is excreted.

PH, BUFFERS, ACIDS, AND BASES

Acids dissociate into H^+ and lower pH, while bases dissociate into $OH^−$ and raise pH; buffers can absorb these excess ions to maintain pH.

Self-Ionization of Water

Hydrogen ions are spontaneously generated in pure water by the dissociation (ionization) of a small percentage of water molecules into equal numbers of hydrogen (H^+) ions and hydroxide ($OH^−$) ions. The hydroxide ions remain in solution because of their hydrogen bonds with other water molecules; the hydrogen ions, consisting of naked protons, are immediately attracted to un-ionized water molecules and form hydronium ions (H_30^+). By convention, scientists refer to hydrogen ions and their concentration as if they were free in this state in liquid water.

2H2O⇋H3O++OH−2H2O⇋H3O++OH−

The concentration of hydrogen ions dissociating from pure water is 1×10^{-7} moles H^+ ions per liter of water. The pH is calculated as the negative of the base 10 logarithm of this concentration:

$$pH = -\log[H^+]$$

The negative log of 1×10^{-7} is equal to 7.0, which is also known as neutral pH. Human cells and blood each maintain near-neutral pH.

pH Scale

The pH of a solution indicates its acidity or basicity (alkalinity). The pH scale is an inverse logarithm that ranges from 0 to 14: anything below 7.0 (ranging from 0.0 to 6.9) is acidic, and anything above 7.0 (from 7.1 to 14.0) is basic (or alkaline). Extremes in pH in either direction from 7.0 are usually considered inhospitable to life. The pH in cells (6.8) and the blood (7.4) are both very

close to neutral, whereas the environment in the stomach is highly acidic, with a pH of 1 to 2.

Non-neutral pH readings result from dissolving acids or bases in water. Using the negative logarithm to generate positive integers, high concentrations of hydrogen ions yield a low pH, and low concentrations a high pH.

An acid is a substance that increases the concentration of hydrogen ions (H^+) in a solution, usually by dissociating one of its hydrogen atoms. A base provides either hydroxide ions (OH^-) or other negatively-charged ions that react with hydrogen ions in solution, thereby reducing the concentration of H^+ and raising the pH.

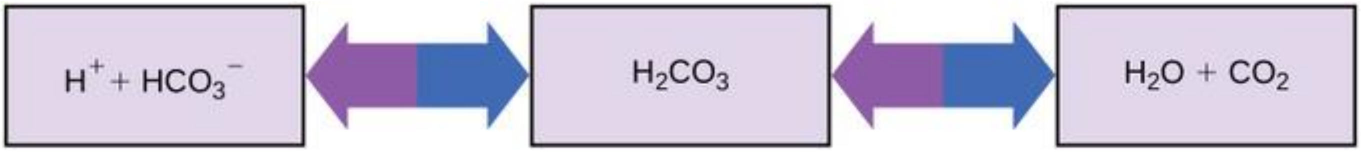
Strong Acids and Strong Bases

The stronger the acid, the more readily it donates H^+. For example, hydrochloric acid (HCl) is highly acidic and completely dissociates into hydrogen and chloride ions, whereas the acids in tomato juice or vinegar do not completely dissociate and are considered weak acids; conversely, strong bases readily donate OH^- and/or react with hydrogen ions. Sodium hydroxide (NaOH) and many household cleaners are highly basic and give up OH^- rapidly when placed in water; the OH^- ions react with H^+ in solution, creating new water molecules and lowering the amount of free H^+ in the system, thereby raising the overall pH. An example of a weak basic solution is seawater, which has a pH near 8.0, close enough to neutral that well-adapted marine organisms thrive in this alkaline environment.

Buffers

How can organisms whose bodies require a near-neutral pH ingest acidic and basic substances (a human drinking orange juice, for example) and survive? Buffers are the key. Buffers usually consist of a weak acid and its conjugate base; this enables them to readily absorb excess H^+ or OH^-, keeping the system's pH within a narrow range.

Maintaining a constant blood pH is critical to a person's well-being. The buffer that maintains the pH of human blood involves carbonic acid (H_2CO_3), bicarbonate ion (HCO_3^-), and carbon dioxide (CO_2). When bicarbonate ions combine with free hydrogen ions and become carbonic acid, hydrogen ions are removed, moderating pH changes. Similarly, excess carbonic acid can be converted into carbon dioxide gas and exhaled through the lungs; this prevents too many free hydrogen ions from building up in the blood and dangerously reducing its pH; likewise, if too much OH^- is introduced into the system, carbonic acid will combine with it to create bicarbonate, lowering the pH. Without this buffer system, the body's pH would fluctuate enough to jeopardize survival.



Buffers in the body: This diagram shows the body's buffering of blood pH levels: the blue arrows show the process of raising pH as more CO2 is made; the purple arrows indicate the reverse process, lowering pH as more bicarbonate is created.

Antacids, which combat excess stomach acid, are another example of buffers. Many over-the-counter medications work similarly to blood buffers, often with at least one ion (usually carbonate) capable of absorbing hydrogen and moderating pH, bringing relief to those that suffer “heartburn” from stomach acid after eating.

Chemical Buffer Systems

Chemical buffers, such as bicarbonate and ammonia, help keep the blood’s pH in the narrow range that is compatible with life.

ACID–BASE HOMEOSTASIS

Acid–base homeostasis concerns the proper balance between acids and bases; it is also called body pH. The body is very sensitive to its pH level, so strong mechanisms exist to maintain it. Outside an acceptable range of pH, proteins are denatured and digested, enzymes lose their ability to function, and death may occur.

BUFFER SOLUTION

A buffer solution is an aqueous solution of a weak acid and its conjugate base, or a weak base and its conjugate acid. Its pH changes very little when a small amount of strong acid or base is added to it. Buffer solutions are used as a means of keeping pH at a nearly constant value in a wide variety of chemical applications.

Many life forms thrive only in a relatively small pH range, so they utilize a buffer solution to maintain a constant pH. One example of a buffer solution found in nature is blood. The body’s acid–base balance is normally tightly regulated, keeping the arterial blood pH between **7.38 and 7.42.**

Several buffering agents that reversibly bind hydrogen ions and impede any change in pH exist. Extracellular buffers include bicarbonate and ammonia, whereas proteins and phosphates act as intracellular buffers.

The bicarbonate buffering system is especially key, as carbon dioxide (CO_2) can be shifted through carbonic acid (H_2CO_3) to hydrogen ions and bicarbonate (HCO^{3-}):

H2O+CO2⇋H2CO3⇋H++CO−3H2O+CO2⇋H2CO3⇋H++CO3−

Acid–base imbalances that overcome the buffer system can be compensated in the short term by changing the rate of ventilation. This alters the concentration of carbon dioxide in the blood and shifts the above reaction according to Le Chatelier’s principle, which in turn alters the pH.

RENAL PHYSIOLOGY

The kidneys are slower to compensate, but renal physiology has several powerful mechanisms to control pH by the excretion of excess acid or base. In response to acidosis, the tubular cells reabsorb more bicarbonate from the tubular fluid, and the collecting duct cells secrete more hydrogen and generate more bicarbonate, and ammoniagenesis leads to an increase of the NH_3 buffer.

In its responses to alkalosis, the kidneys may excrete more bicarbonate by decreasing hydrogen ion secretion from the tubular epithelial cells, and lower the rates of glutamine metabolism and ammonium excretion.

REGULATION OF H+ BY THE LUNGS

Acid–base imbalances in the blood's pH can be altered by changes in breathing to expel more CO_2 and raise pH back to normal.

Acid–base imbalance occurs when a significant insult causes the blood pH to shift out of its normal range (7.35 to 7.45). An excess of acid in the blood is called acidemia and an excess of base is called alkalemia.

The process that causes the imbalance is classified based on the etiology of the disturbance (respiratory or metabolic) and the direction of change in pH (acidosis or alkalosis). There are four basic processes and one or a combination may occur at any given time.

1. Metabolic acidosis
2. Respiratory acidosis
3. Metabolic alkalosis
4. Respiratory alkalosis

Blood carries oxygen, carbon dioxide, and hydrogen ions (H+) between tissues and the lungs. The majority of CO_2 transported in the blood is dissolved in plasma (60% is dissolved bicarbonate).

Expiration: When blood pH drops too low, the body compensates by increasing breathing to expel more carbon dioxide.

A smaller fraction is transported in the red blood cells that combine with the globin portion of hemoglobin as carbaminohemoglobin. This is the chemical portion of the red blood cell that aids in the transport of oxygen and nutrients around the body, but, this time, it is carbon dioxide that is transported back to the lung.

Acid–base imbalances that overcome the buffer system can be compensated in the short term by changing the rate of ventilation. This alters the concentration of carbon dioxide in the blood, shifting the above reaction according to Le Chatelier's principle, which in turn alters the pH. The basic reaction governed by this principle is as follows:

H2O+CO2⇋H2CO3⇋H++CO−3H2O+CO2⇋H2CO3⇋H++CO3−

When the blood pH drops too low (acidemia), the body compensates by increasing breathing to expel more CO_2; this shifts the above reaction to the left such that less hydrogen ions are free; thus, the pH will rise back to normal. For alkalemia, the opposite occurs.

The Role of the Kidneys in Acid-Base Balance

The kidneys help maintain the acid–base balance by excreting hydrogen ions into the urine and reabsorbing bicarbonate from the urine.

Within the human body, fluids such as blood must be maintained within the narrow range of 7.35 to 7.45, making it slightly alkaline. Outside that range, pH becomes incompatible with life; proteins are denatured and digested, enzymes lose their ability to function, and the body is unable to sustain itself.

To maintain this narrow range of pH the body has a powerful buffering system. Acid–base imbalances that overcome this system are compensated in the short term by changing the rate of ventilation.

KIDNEYS AND ACID–BASE BALANCE

The kidneys have two very important roles in maintaining the acid–base balance:

1. They reabsorb bicarbonate from urine.
2. They excrete hydrogen ions into urine.

The kidneys are slower to compensate than the lungs, but renal physiology has several powerful mechanisms to control pH by the excretion of excess acid or base. The major, homeostatic control point for maintaining a stable pH balance is renal excretion.

Bicarbonate (HCO_3^-) does not have a transporter, so its reabsorption involves a series of reactions in the tubule lumen and tubular epithelium. In response to acidosis, the tubular cells reabsorb more bicarbonate from the tubular fluid, and the collecting duct cells secrete more hydrogen and generate more bicarbonate, and ammoniagenesis leads to an increase in the formation of the NH_3 buffer.

In response to **alkalosis,** the kidneys may excrete more bicarbonate by decreasing hydrogen ion secretion from the tubular epithelial cells, and lowering the rates of glutamine metabolism and ammonium excretion.

UNIT SEVEN

THE MAMMALIAN SKIN

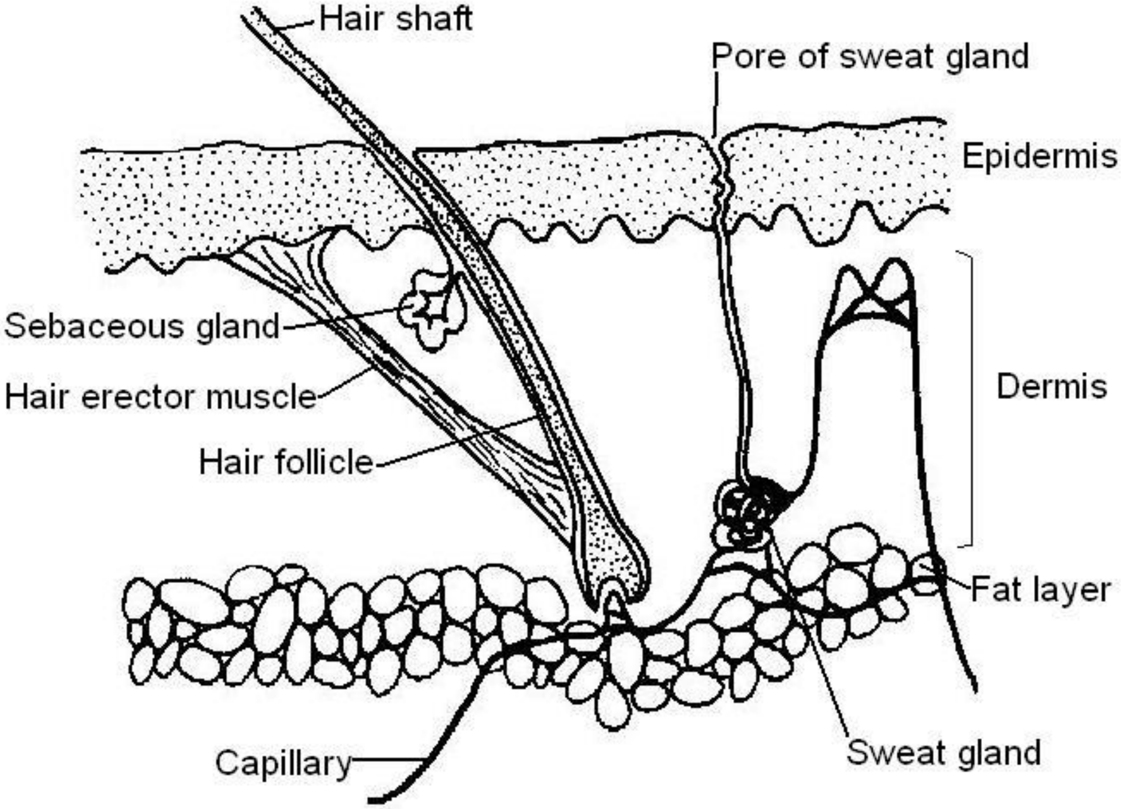
Objective of the lesson

At the end of the lesson the learner should be able to

1. Describe the structures of the human skin
2. Explain the function of the skin
3. Identify the main parts of the skin from a diagram
4. Describe the temperature or homeostatic regulation process in humans

THE MAMMALIAN SKIN

The skin is the largest organ of the body. It covers the entire body. The skin takes on different thickness, coluor, and texture all over your body. For example, your head contains more hair follicles than anywhere else but the soles of your feet have none. In addition, the soles of your feet and the palms of your hands are much thicker than skin on other areas of your body. The skin serves as a protective shield against heat, light, injury, and infection. The skin is made of two layers i.e. Upper epidermis and lower dermis.



EPIDERMIS

Epidermis consists of 3 regions;

1. Cornified/ Squamous/ Horny layer: This consists of flat dead cells forming a tough water proof covering of the cell below. The cells are constantly warn away and replaced from the layer (dead cells) below because it is the outermost layer.
   Functions: Protects the skin from microbial invasion, mechanical injury and reduces water loss from the body
2. Granular/ Basal layer: They are found just under the Cornified/ Squamous/ Horny layer. This consist of living cells produced by the malpighian layer
   Functions: Produces and replaces cells in the cornified layer.
3. Malpighian/ Melanocytes layer: This is made up of living and meristematic cells. Some of the cells contain pigment called melanin which is responsible for skin colour in manand also protein called keratin which is responsible for the toughenss and flexibility of the skin.
   Functions: The cells divide constantly to produce a new epidermal cell. Vitamin D is synthesized in this layer. Melanin also absorbs ultraviolet rays from the sun.

DERMIS

The dermis is held together by a protein called collagen. This layer gives skin flexibility and strength. The dermis also contains pain and touch receptors. This is the inner layer and contains the following tissues

1. Sweat gland: This is a coiled tube which contains a sweat duct opening of the surface of the skin as sweat pore. This gland is surrounded by a network of blood capillaries
   Functions: It produces sweat which is made up of water and urea and salt. Evaporation of sweat on hot days cools the body.
2. Hair follicle: This is a deep pit composed of granular and malpighian layers. The cells multiply to build up a hair inside the follicle and at the base of the follicle is a hair papilla which contains blood vessels and nerves. The papilla supplies materials for hair construction
   Functions: It produces hair which is responsible for temperature regulation of the skin.
3. Erector muscle: This is attached to the hair follicle. When the muscle contract, it caused the hair to stand perpendicular to the surface of the skin
4. Sebaceous gland: This opens into the hair follicle
   Functions: It produces an oily substance called sebum which lubricates the skin and hair
5. Adipose cells: Adipose cells contain fat cells for storage of fat.
   Functions: It insulates the body against heat loss.
6. Nerve endings: These are also called receptors which are sensitive to heat, cold, pain and touch
7. Blood capillaries: Supplies nutrients to the skin.
8. Subcutaneous fat layer: The subcutaneous fat layer is the deepest layer of skin. It consists of a network of collagen and fat cells.
   Function: It helps conserve the body's heat and protects the body from injury by acting as a shock absorber

FUNCTIONS OF THE SKIN

1. It serves as a protective covering around the body; it protects the body against mechanical injury, bacterial and fungal invasion and desiccation.

2. The skin acts as a sensory organ by having sensory nerve endings which can receive stimulus of pain, cold etc.
3. It serves as an excretory organ; its sweat glands eliminate some urea, salt and water in sweat.
4. The skin loosed heat from the body by radiation and evaporation of sweat and so helps it to regulate the body's temperature (thermo regulation)
5. Acts as a barrier between the organism and its environment
6. Helps to make vitamin D when exposed to the sun

TEMPERATURE REGULATION

When the production of heat and the loss of heat are in equilibrium, the body's temperature becomes constant at 37ºC. The body's temperature is constantly monitored by the hypothalamus i.e. the lower part of the brain. It acts like a thermostat switching on the heat production mechanism or the heat loss mechanism where there is any deviation from the mean temperature value. Heat is gained by the body through the following.

1. Activities of the muscle during contraction
2. Metabolic reactions such as tissue respiration and reactions in the liver
3. Absorption of heat by skin from the drinking hot drinks
4. Conduction of heat from the soil into the body

Heat loss processes include

1. Radiation from the sun.
2. Evaporation of sweat.
3. Heat loss through urine, faeces and breathe.

IMPORTANCE OF MAINTENANCE OF COSTANT BODY TEMOERATURE

1. A constant body temperature allows mammals and birds to live in a very wide range of geographical habitat.
2. Maintenance of constant body temperature makes warm blooded animals active at any time of the day compared to cold blooded animals.
3. Maintenance of constant body temperature allows temperature dependent enzymes to work effectively and efficiently

HEAT GAIN MECHANISM

When a mammal is cold, the hypothalamus discharges a nerve impulse to the erector muscle, sweat gland, arterioles of the skin. These parts react as follows

1. The erector muscle contract and the hair stands erect to trap a thicker layer of air which conserves heat.
2. Sweat production decreases to reduce heat loss by evaporation.
3. **Vasoconstriction** i.e. where the sizes of the arterioles of the skin decrease considerably. The volume of warm blood flowing near the surface of the skin decreases and this results in the reduction of heat loss.
4. **Shivering**: muscular contractions occur involuntarily which increases the body's temperature**.**
5. Metabolic rates of the body rise to produce extra heat. This takes place particularly in the liver and muscle

   Behavioural methods include;
   Wearing thicker clothes, taking hot drinks, taking more vigorous exercises, some animals hide in burrows and nests.

<u>HEAT LOSS MECHANISM</u>

1. **Vasodilation**: the arterioles in the skin dilate (expand), more warm blood is brought near to the skin surface and subsequently, more heat is lost to the environment.
2. The erector muscles relax causing hair to lie flat trapping a thin layer of air so that heat is lost more from the body.
3. Sweat production increases and the water evaporating from the surface draws heat from the surface.
4. Metabolic activities of the body decreases like the activities of the liver and kidney decreases. Animals tend to less active in the hoe weather.
5. Shivering stops so that less heat is generated by muscles.

   Behavioural methods include;
   Wearing thinner and light coloured clothes, taking cold drinks, rest in shades, taking cold baths/swimming, using fans or AC.

Progress Assessment
1. Name six parts of the skin and give one function each of the name parts.
2. Describe the protective function of the skin

The Liver

The liver is the largest internal organ of the human body. It forms part of the digestive system. The liver is unique among the body's vital organs in that it regenerates or grows back cells that have been destroyed by short-term injury or disease. But if the liver is damaged repeatedly over a long period of time, it may undergo irreversible changes that permanently interfere with functions.

Functions of the Liver

1) **Detoxification-** conversion of harmful or poisonous substances to harmless chemicals substances.
2) **Stores certain vitamins** e.g. Vitamin A, D, E and K.
3) **Produces certain essential proteins**-fibrinogen, prothrombin and plasma proteins.
4) **Serves as reservoir for blood**
5) **Produces bile**
6) **Destruction of old red blood cells** – It breaks down worn out red blood cells to produce bile pigments and iron from the haemoglobin.
7) **Deamination of excess amino acids** i.e. breaking down excess amino acid into urea and glucose/glycogen. The urea is excreted by the kidneys but the glycogen is stored in the liver cells.
8) **Regulates blood sugar level**. It converts excess glucose to glycogen in the presence of **insulin** to be stored in the liver cells and muscle cells. Glycogen is converted back to glucose for use in the presence of **adrenaline** when the need arises.
9) **Destruction of hormones** – the liver destroys hormones when they enter it, stopping them from an unlimited action.
10) **Excrete excess cholesterol** are excreted in bile into the duodenum. These waste products give the characteristic colour and smell to human faeces.
11) **Metabolism of fats**–It changes excess fats into glycerol and fatty acids. These are oxidized to yield energy for life activities.
12) **Heat production** – the chemical reactions that occur in the liver produce heat, this heat is evenly distributed in the body by the flow of blood.

Function of live as a homeostatic organ

Diseases and Disorders of the Liver

1) **Cirrhosis** – Occurs when the liver cells or tissues are damaged and replaced by useless fibrous tissue which causes the liver to be hardened. It is caused by excessive drinking of alcohol and not eating highly nutritious food. It is also caused by Hepatitis.

Blood vessels leading from the intestines to liver may, branched, causing blood from the small intestine carrying many poisonous substances to by-pass the liver into the body, poisoning the body. This disease can lead to death.

2) **Gallstones** – The various bile substances (calcium, cholesterol and bilirubin) are normally in solution, but sometimes they form solids called gallstones in the gall bladder or bile duct. These may block the bile duct and stop the flow of bile into the duodenum. This cause bile pigments to flow into the bloodstream. One effect of gallstones is that the skin and whites of the eyes turn yellow.

Gallstones can be treatment by surgical removal or taking in drugs that dissolve the stones.

3) **Jaundice** – It is caused by a number of factors. These factors are:

a) Excessive breakdown of red blood cells. This results in high amount of bilirubin in the blood

b) Obstruction of the bile duct

c) Diseases of the liver – these results in the inability of the liver cells to extract bilirubin from the blood.

Symptoms of Jaundice are yellow colouration of the skin and the whites of the eyes.

4) **Amoebic liver abscess** – The parasitic amoeba (Entamoebahistolytica) produce an enzyme that destroys liver tissues and causes an abscess to form.

5) **Hepatitis** – An inflammation and destruction of the liver caused by viruses, bacterial infections or continuous exposure to alcohol, drugs or toxic chemicals. Hepatitis reduces the liver's ability to perform life-preserving functions including filtering harmful agents from the blood.

Symptoms

1) Fever
2) General weakness and fatigue
3) Yellow eyes and skin/Jaundice
4) Loss of appetite
5) Cancer of the liver
6) Abdominal pains and tenderness
7) Nausea

8) Cirrhosis

Causes of Serum /Infectious Hepatitis

1) Unprotected sex with an infected person
2) From mother to child during childbirth
3) Sharing of infected needles or razor blades
4) Transfusion of contaminated blood to uninfected person
5) Eating food or water contaminated with viruses (Hepatitis A)

Causes of Non-Infectious Hepatitis

1) High concentration of bilirubin in the blood tissue
2) Continuous exposure to alcohol drugs or toxic chemicals.
3) Overweight

Progress Assessment
Describe two ways in which the liver act as a homeostatic organ.

UNIT EIGHT

NERVOUS CO- ORDINATION

Nervous System

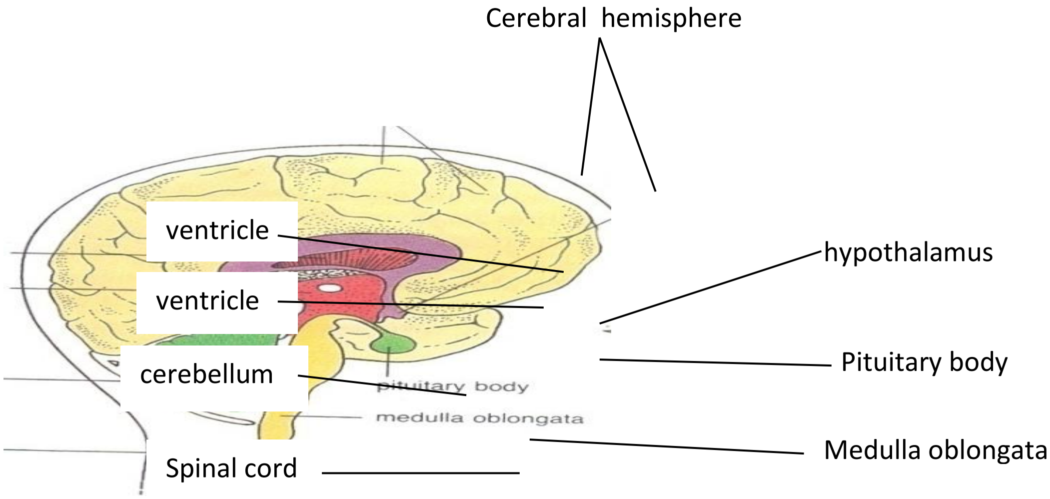
The nervous system is made of neurons or nerve cells. There are two types of nervous systems; these are the

1. Central Nervous System (CNS)
2. Peripheral Nervous System (PNS)

The Central Nervous System (CNS)

The central nervous system (CNS) consists of the brain and the spinal cord. The brain tissue is protected by the bony skull and spinal cord is protected by the backbone or the vertebrae. The brain and spinal cord are linked to the rest of the body by nerves.

The Brain



Longitudinal section of the human brain

The brain is made up of millions of neurons or nerve cells. The main parts of the brain are the

1. Fore brain (Cerebrum)
2. Midbrain
3. Hindbrain (Cerebellum)
4. Medulla Oblongata

Cerebrum (fore Brain)

The cerebrum, the largest part of the brain is made up of two hemispheres, left and right cerebral hemispheres. The two hemispheres are separated by deep depression or fissure. The brain is the anterior part of the CNS. Its outer part is covered by thin grey matter and the inner part is covered by thick white matter. The grey matter forms the cerebral cortex, the outer part of the cerebrum. The grey matter or cerebral cortex is made up of **non-myelinated axons**. The white matter contains nerve cells that have **myelinated axons**. The cortex has **grooves** or **sulci** (**infoldings)** which gives it large surface area. The larger the surface area the more intelligence the person is. The other parts of the cerebrum are;

(a) Hypothalamus
(b) Optic lobes
(c) Pituitary gland

Functions of the Cerebral cortex or Cerebrum

1. It controls learning and storage of information or data

2. It controls intelligence.
3. It interpret sensory impulses
4. It controls thinking/imagination and reasoning
5. It controls voluntary muscular activities/ things we do consciously
6. It controls the acquisition of skills and their development
7. It controls the will-power and the personality of individuals
8. It controls memory and emotion.
9. It for vision, speech, taste, smell and touch

Hypothalamus

The floor of the cerebrum forms the hypothalamus.

Functions of the Hypothalamus

It controls involuntary activities such as;

1. Water and electrolyte balance
2. Carbon dioxide level in the blood
3. Body temperature regulation
4. Sleep and wakefulness
5. Hunger thirst and body weight
6. heart rate and arterial blood pressure

Pituitary Gland

Growth-influencing gland at base of brain: a small oval gland at the base of the brain in vertebrates which produce pituitary hormones.

Functions of Pituitary Hormones

1. They promote growth
2. They control water balance
3. They stimulate and control the functioning of endocrine glands
4. They control sexual maturity and body metabolism

Midbrain

It contains bundles myelinated nerve fibres that join the spinal cord. It contains the centers for certain visual reflexes.

Functions of the Midbrain

1. It controls the movement of the eyes
2. It controls the turning of the head
3. It controls the auditory nerves

Cerebellum

It receives impulses from the semicircular canal of the ear and is involved in balance and posture. Excessive alcohol disturbs the proper functioning of the cerebellum.

Functions of the cerebellum

1. It controls balance and posture during walking, running, lying, riding, driving a car etc.
2. It maintains muscle tone in posture.

Medulla Oblongata

The cerebellum and the medulla oblongata form the midbrain. It controls involuntary and reflex activities of the body.

1. It controls heart beat and breathing
2. It controls blood pressure
3. It controls coughing, sneezing and yawning
4. It controls swallowing and vomiting.

Functions of the Central Nervous System

1. It controls the emotional behavior of humans
2. It controls all reflex actions and conditioned reflexes
3. It co-ordinates the interactions of the body with external environment; e.g. the detection of changes in the external temperature and how the body structures involved with temperature regulation are all co-ordinated by the CNS.
4. The CNS receives information from all parts of the body through the sensory neurons, interprets the information and sends out correct responding information through motor neurones to the effectors and causes them to respond accordingly.

Factors that cause Damage to the Brain and Spinal cord

1. Depression
2. Drug abuse; excessive indulgence in smoking Indian hemp, heroin, etc.
3. Diseases, usually mental disorders and sexually transmitted disease
4. Mainly motor vehicle accidents and to a lesser extent, some domestic accidents

Peripheral Nervous System

The peripheral nervous system (PNS) consists of nerves that branch out from the CNS and connect it to other body parts. The peripheral nervous system consists of the **somatic nervous system (SNS)** and the **autonomic nervous system (ANS).** The SNS consists of motor neurons that stimulate skeletal muscles. The PNS includes the cranial nerves which arise from the brain and the spinal nerves which arise from the spinal cord.

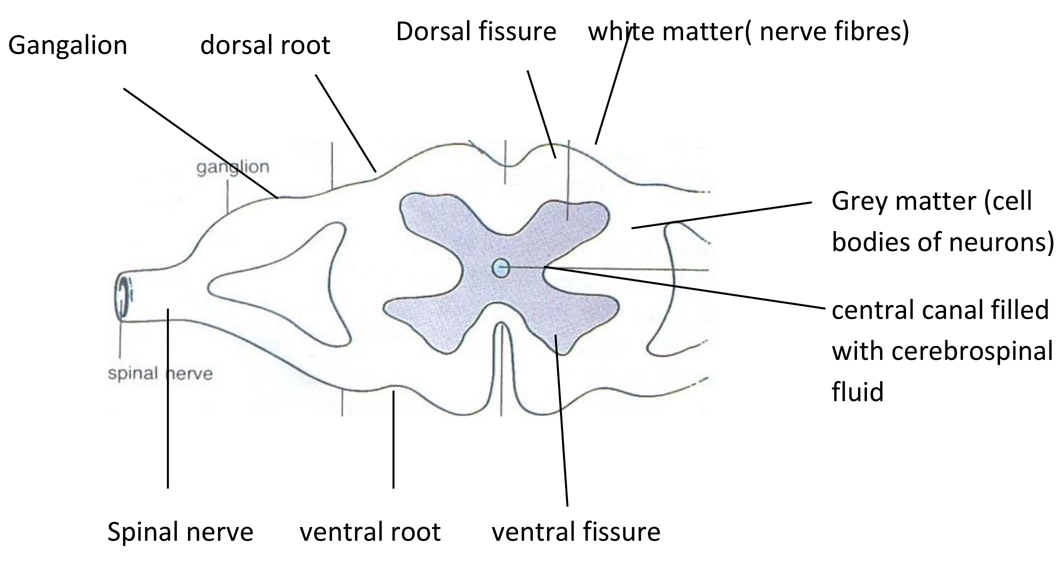
Functions of the Peripheral Nervous System

1. It transmit sensory impulses associated with vision
2. It transmits sensory impulses associated with smell
3. It controls eye movement
4. It controls the tongue's movement
5. It controls hearing
6. It controls the jaws and lips.

The Spinal Cord

1. It controls hearing
2. It controls the jaws and lips.

The Spinal Cord



The spinal cord starts from the medulla oblongata and runs the whole length of the vertebral column. The **vertebral column** protects the spinal cord against mechanical injuries. The central canal of the spinal cord is filled with **cerebrospinal fluid**. The inner layer of the spinal cord is made up of grey matter while the outer layer is made up of white matter. The white matter consists of nerve fibres which give it its colour while the grey matter encloses the spinal canal and consists of neurones which give it the grey colour. There are two narrow grooves called the dorsal (anterior) fissure and the ventral (posterior) fissure situated at the dorsal and the ventral sides.

The spinal cord has thirty pairs of mixed fibres attached to it. All the sensory neurones enter the spinal cord through the dorsal root and the motor neurones leave the spinal cord through the ventral root. The spinal cord controls and co-ordinates all reflex actions. All neurones that are confined to the brain and spinal cord are called **Relay neurones** or **associate neurones.**

Functions

1. It controls all reflex actions
2. It controls nervous impulses (messages) to and the brain.

Autonomic nervous system

The autonomic nervous system operates by receiving information from the environment and from other parts of the body. This part of the nervous system that controls and regulates the internal organs without any conscious recognition or effort by the organism. the ANS consists of motor neurons that control smooth muscles, cardiac muscles, and glands. In addition, the ANS monitors visceral organs and blood vessels with sensory neurons, which provide input information for the CNS. The autonomic nervous system comprises two antagonistic sets of nerves, the sympathetic and parasympathetic nervous systems.

sympathetic nervous system connects the internal organs to the brain by spinal nerves.it originate from the thoracic and the lumber region of the spinal cord. When stimulated, these nerves prepare the organism for stress by increasing the heart rate, increasing blood flow to the muscles, and decreasing blood flow to the skin. Noraldrenaline is the chemical transmitter transmitted at the end of the sympathetic neurone.
parasympathetic nervous system nerve fibres originates from the cranial nerves, primarily the vagus nerve, and the lumbar spinal nerves. Acetylcholine is often used in the parasympathetic system at the end. When stimulated, these nerves increase digestive secretions and reduce the heartbeat.

Function of the autonomic system including:

- Digestion
- Blood pressure
- Heart rate
- Urination and defecation
- Pupillary response

- Breathing (respiratory) rate
- Sexual response
- Body temperature
- Metabolism
- Electrolyte balance
- Production of body fluids including sweat and saliva
- Emotional responses

Difference between sympathetic and parasympathetic system

Sympathetic	parasympathetic system
Accelerates the heart	Slow the heart
Constricts arteries	Dilate arteries
Dilate pupils	Constricts pupils
Decreases saliva flow	increases saliva flow
Slow down peristalsis	Speed up peristalsis

UNIT NINE

STRUCTURE AND FUNCTION OF NEURONES

Neurones are specialized cells that are modified and adapted to transmit electrical impulses from one part of the body to another. Each neurone has a cell body which contains a nucleus, dendrites that receive or collect information. The information received by the dendrites pass to the cell body in the form of electrical impulses and is conducted along the axon and branch to the end plates of the axon.

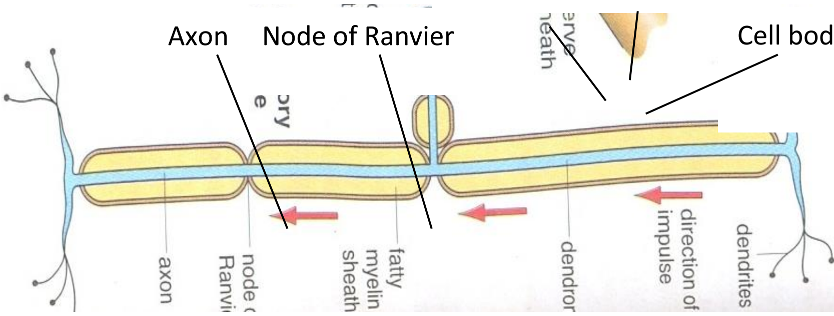
There are three main types of neurones: these are

1. Sensory neurone
2. Relay neurone
3. motor neurone

Sensory Neurone

The body branch at the junction of the Dendron and axon. It has Dendron with long fibre and axon. Sensory neurone has receptor cells. Receptors detect changes, stimuli or signals and pass them on as electrical impulses to sensory neurone.

but some are bipolar.



Sensory Neurone

It conducts impulses fro

Relay Neuron

Relay neurons are only found in the central nervous system (brain and the spinal cord). They are also referred to as associated neurone or intermediate neurone.

Function

It connects sensory neurone to a motor neurone.

Motor neurone

Some axons are covered with a thin sheath of a fat-like substance called myelin. Axon covered with myelin is known as myelinated fibre and those without myelin are known as non-myelinated fibres. The myelin interrupted at short intervals to expose the nerve membrane. The exposed sites are called nodes of Ranvier.

which they synapse with a muscle or gland.

Motor Neurone

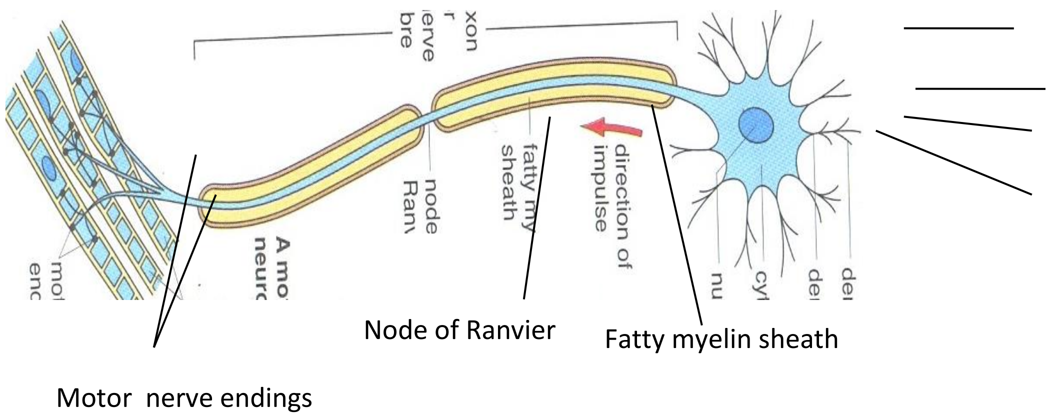
Muscle fibres

Axon or nerve fibre

Dendrite

Dendron

Cytoplasm



Function

It conduct/transmit electrical impulses from the central nervous system to effector organs; e.g. muscles and glands.

Transmission of impulses

Nerve impulses have a domino effect. Each neuron receives an impulse and must pass it on to the next neuron and make sure the correct impulse continues on its path. Through a chain of chemical events, the dendrites (part of a neuron) pick up an impulse that's shuttled through the axon and transmitted to the next neuron. The entire impulse passes through a neuron in about seven milliseconds (faster than a lightning strike). Processes involved in the transmission.

1. Polarization of the neuron's membrane: Sodium is on the outside, and potassium is on the inside. Cell membranes surround neurons just as any other cell in the body has a membrane. When a neuron is not stimulated (it's just sitting with no impulse to carry or transmit) its membrane is polarized. Not paralyzed. Polarized. Being polarized means that the electrical charge on the outside of the membrane is positive while the electrical charge on the inside of the membrane is negative. The outside of the cell contains excess sodium ions (Na+); the inside of the cell contains excess potassium ions (K+). (Ions are atoms of an element with a positive or negative charge.)

   In addition, the K+ is negatively charged protein and nucleic acid molecules also inhabit the cell; therefore, the inside is negative as compared to the outside.

2. Resting potential gives the neuron a break.

3. When the neuron is inactive and polarized, it's said to be at its resting potential. It remains this way until a stimulus comes along.

4. Action potential: Sodium ions move inside the membrane.

   When a stimulus reaches a resting neuron, the gated ion channels on the resting neuron's membrane open suddenly and allow the Na+ that was on the outside of the membrane to go rushing into the cell. As this happens, the neuron goes from being polarized to being depolarized.

5. Repolarization: Potassium ions move outside, and sodium ions stay inside the membrane.

After the inside of the cell becomes flooded with Na+, the gated ion channels on the inside of the membrane open to allow the K+ to move to the outside of the membrane. With K+ moving to the outside, the membrane's repolarization restores electrical balance, although it's opposite of the initial polarized membrane that had Na+ on the outside and K+ on the inside. Just after the K+ gates open, the Na+ gates close; otherwise, the membrane couldn't repolarize.

6. Hyperpolarization: More potassium ions are on the outside than there are sodium ions on the inside.

   When the K+ gates finally close, the neuron has slightly more K+ on the outside than it has Na+ on the inside. This causes the membrane potential to drop slightly lower than the resting potential, and the membrane is said to be hyperpolarized because it has a greater potential. (Because the membrane's potential is lower, it has more room to "grow."). This period doesn't last long, though (well, none of these steps take long!). After the impulse has travelled through the neuron, the action potential is over, and the cell membrane returns to normal (that is, the resting potential).

7. Refractory period puts everything back to normal: Potassium returns inside, sodium returns outside.

   The refractory period is when the Na+ and K+ are returned to their original sides: Na+ on the outside and K+ on the inside. While the neuron is busy returning everything to normal, it doesn't respond to any incoming stimuli. It's kind of like letting your answering machine pick up the phone call that makes your phone ring just as you walk in the door with your hands full. After the Na+/K+ pumps return the ions to their rightful side of the neuron's cell membrane, the neuron is back to its normal polarized state and stays in the resting potential until another impulse comes along.

DAMAGE TO THE BRAIN AND SPINAL CORD

Any damage to brain and the spinal cord is usually permanent and irreversible; this because the nerve cells can never heal (cannot reproduce mitotically). If part of the brain is damage, life activities controlled by that part of the brain become impaired exhibiting an abnormal behavior because of the permanent and irreversible damage. Sometimes other part of the brain takes over the large activities, so there is partial recovering.

Organic illness suchs as brain tumors, infections e.g. meningitis and biochemical changes in the brain cells can cause impaired body function and changes in behavior.

Damage to the nerve cells has an effect on the individual, family and society. The affected person may not be able to:

1. Tolerate behavioural patterns in other people that are different from his or her own.
2. Form and sustain relationships with other people.
3. Take care of his or her own welfare including personal hygiene and feeding.
4. Make rational decision and plan for the future.
5. Adjust to stress.

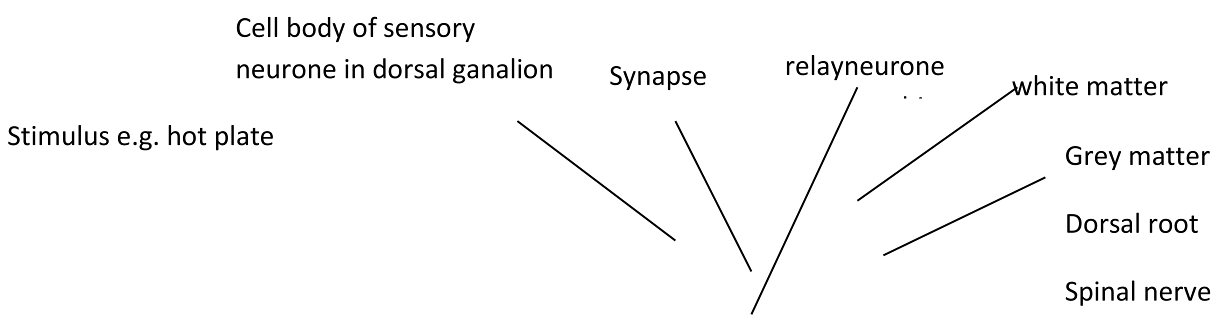
Reflex actions

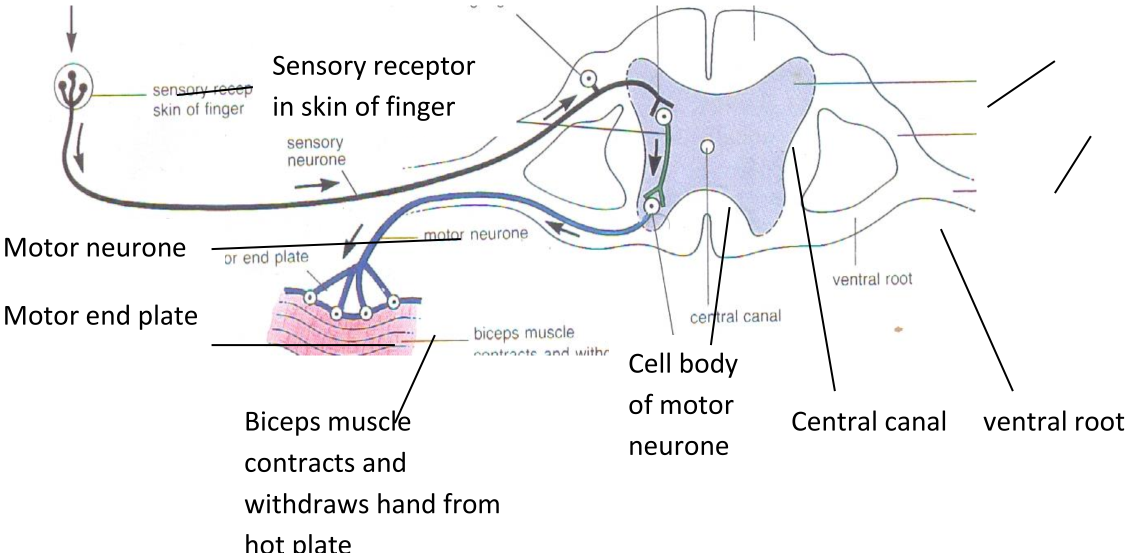
Reflex action is quick, automatic or involuntary responses to stimulus. It is not under the control of the brain but under the control of the spinal cord. Reflex actions are of survival value; it enables us to escape from danger and survive. Reflex action is a defence mechanism of the body against danger. It cannot be controlled or stopped but the individual but the individual may be aware of what is happening.

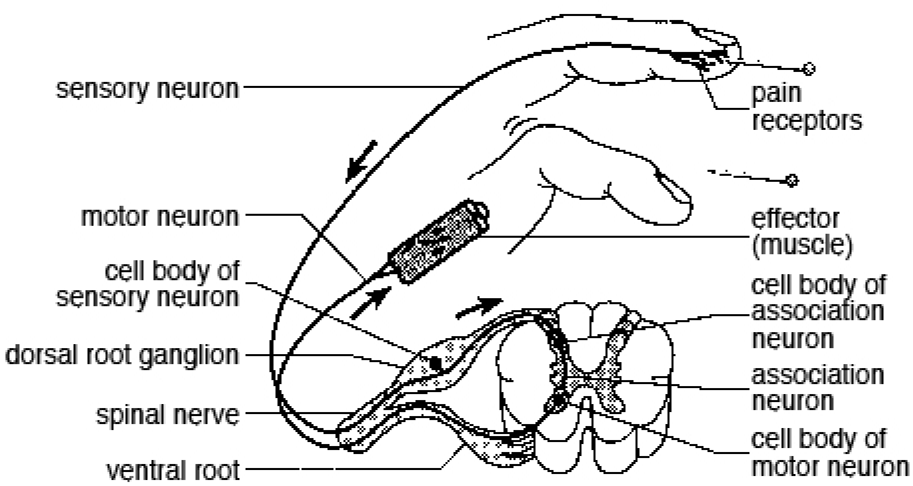
The nervous pathway for reflex action is called a reflex arc. Reflex arc involves **receptor cells, sensory neurone, the spinal cord, relay neurone, motor neurone** and an **effector.**

A reflex arc involves the following components, shown in Figure 1:

- The receptor is the part of the neuron (usually a dendrite) that detects a stimulus.
- The sensory neuron transmits the impulse to the spinal cord.
- The integration center involves one synapse (monosynaptic reflex arc) or two or more synapses (polysynaptic reflex arc) in the gray matter of the spinal cord. In polysynaptic reflex arcs, one or more interneurons in the gray matter constitute the integration center.
- A motor neuron transmits a nerve impulse from the spinal cord to a peripheral region.
- An **effector** is a muscle or gland that receives the impulse from the motor neuron. In somatic reflexes, the effector is skeletal muscle. In autonomic (visceral) reflexes, the effector is smooth or cardiac muscle, or a gland.







A reflex arc.

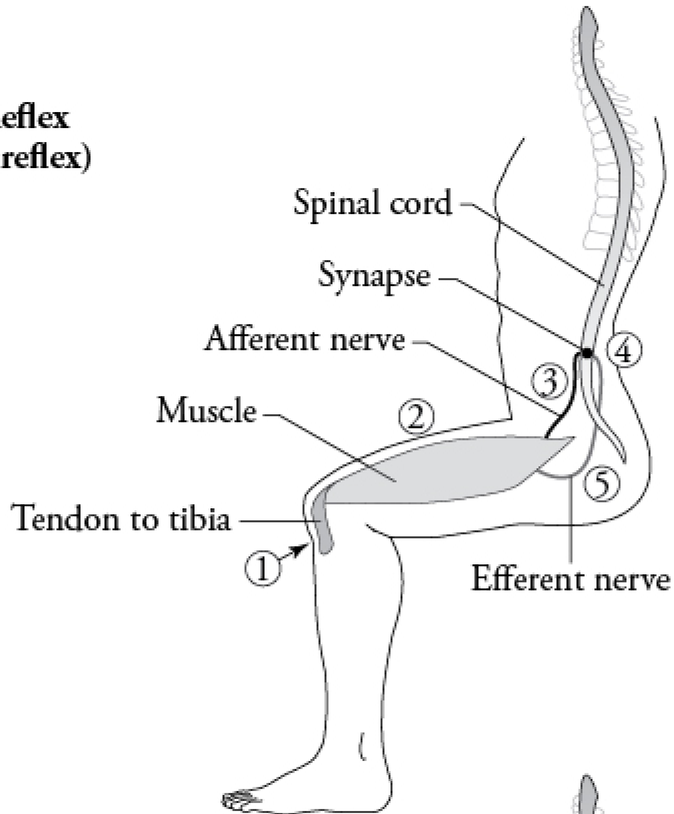
Some examples of reflexes follow:

A stretch reflex is a monosynaptic reflex that is a response to a muscle that has been stretched (the knee-jerk reflex is an example). When receptors in muscles, called muscle spindles, detect changes in muscle length, they stimulate, through a reflex arc, the contraction of a muscle. Stretch reflexes help maintain posture by stimulating muscles to regain normal body position. There is no association neuron in the spinal cord; therefore, information does not go to the brain.

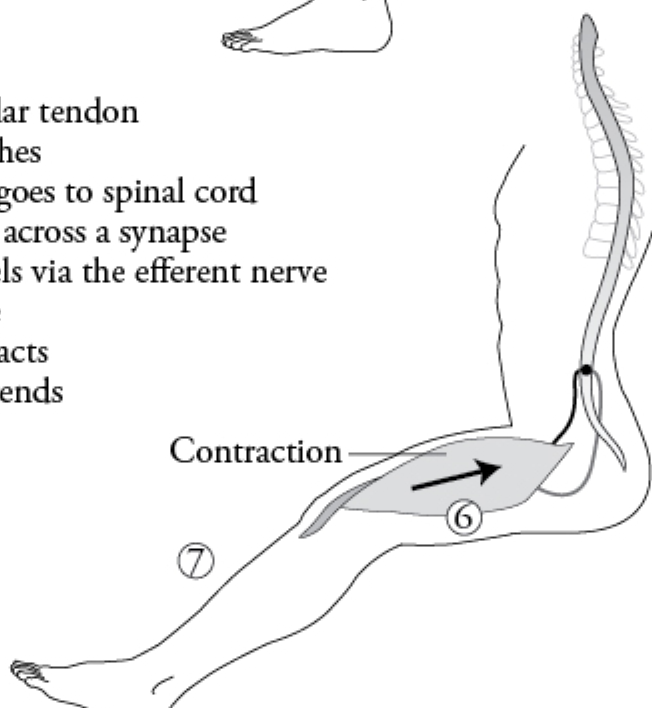
To demonstrate a knee jerk reflex

a. Allow a person to sit on a chair with the right leg crossed over the other knee. The leg should be allowed to dangle in a flexed manner.
b. Strike the right leg sharply just below the knee cap with the edge of your hand
c. The lower right leg automatically jerks away.

The Patellar Reflex
(Monosynaptic reflex)



1. Tap the patellar tendon
2. Muscle stretches
3. Nerve signal goes to spinal cord
4. Impulse goes across a synapse
5. Impulse travels via the efferent nerve to the muscle
6. Muscle contracts
7. Lower leg extends



Examples of **Reflex Actions** are.

1. Withdrawal of the hand from hot object.
2. Watering of the eye when an object falls on it
3. Coughing when something enters the wind pipe
4. Flow of breast milk a baby puts mother's nipple into the mouth
5. Withdrawal of the leg when you step unto a sharp object
6. Sneezing when an irritating gas goes into the nose.
7. Dilation and constriction of the pupil when we go into light of different intensities.

STAGES OF REFLEX ACTION AS ILLUSTRATED BY DIAGRAM

1. Fingers touch hot object.
2. The receptors (nerve endings) detect the extreme heat.
3. The stimulus (heat) is changed into electrical impulses
4. The sensory neurons translate the impulse to the spinal cord using the dorsal root.
5. Spinal cord receives the impulses, explains them and sends out answers.
6. The answers from the spinal cord are translated as electrical impulses along a motor neurone to the effector (the biceps muscles)
7. The biceps response by contracting

CHARACTERISTICS OF REFLEX

1. It is quick, takes place within fraction of a second.
2. It is automatic(involuntary)
3. We are sometimes unconscious of it
4. It is life saving
5. Same response is always given to same stimulus

VOLUNTARY ACTION

It is any activity that can be started and stopped by an individual at any time. Voluntary actions are under the control of the brain i.e. the will of an individual. One can choose to or not to do it, decide how long it must be done.

Examples of voluntary actions are; **walking, singing, shouting, eating, dancing, swimming, jumping, kicking a ball** and **throwing a stone.**

INVOLUNTARY ACTIONS

Involuntary actions include all actions that go on in the body that man has no will or control over. Involuntary actions happen unconsciously; they are not under the control of our will. Such actions occur without being noticed. We cannot choose to do or stop them. Involuntary actions are less complex and involve the control of the spinal cord. Examples of involuntary are:

1. Dilation or constriction of pupil,
2. Heartbeat
3. Breathing
4. Sleeping,
5. Salivation upon smelling the aroma of food
6. Constriction and dilation of the blood capillaries
7. Regulation of the body temperature
8. Blinking of the eye etc.
9. Regulation of water-salt balance of the blood

COMPARISON OF INVOLUNTARY AND VOLUNTARY ACTIONS

Spinal reflex (involuntary actions)	**Voluntary action**
1. Stimulus affect external or internal receptors	1.Initiated from the brain at the conscious level
2. Spinal cord involved-not under conscious control.	2. Forebrain involved under conscious control
3. The impulse travels only up or down the spinal cord	3. The impulse travels from the brain down the spinal cord
4. The path of the nerve impulse is by the shortest.	4. the path of the nerve impulse is much longer
5. The response is immediate	5. The response can be delayed
6. The response is in skeletal or an internal involuntary muscle.	6. The response is in skeletal muscles only

UNIT TEN

ANIMAL HORMONES

Hormone is a chemical substance produce by special endocrine gland/ductless gland and added directly into the blood to enable certain organs function properly. Animal hormones are often produced in specialized hormone-synthesizing glands. The hormones are then secreted from the glands into the blood stream, where they are transported throughout the body. There are many glands and hormones in different animal species.

The endocrine system is made up of ductless glands that release their secretions directly into the blood. Exocrine glands on the other release their secretions into ducts. Pancreas can be both exocrine (releases pancreatic juice) and endocrine by the release of insulin.

ENDOCRINE GLANDS, THE HORMONES THEY PRODUCT AND THEIR FUNCTIONS

Hypothalamus: integrates the endocrine and nervous systems; receives input from the body and other brain areas and initiates endocrine responses to environmental changes; synthesizes hormones which are stored in the posterior pituitary gland; also synthesizes and secretes regulatory hormones that control the endocrine cells in the anterior pituitary gland. Hormones produced include

A. **Growth-hormone releasing hormone**: stimulates release of growth hormone (GH) from the anterior pituitary
B. **Corticotropin-releasing hormone**: stimulates release of adrenocorticotropic hormone (ACTH) from the anterior pituitary
C. **Thyrotropin-releasing hormone**: stimulates release of a thyroid-stimulating hormone (TSH) from the anterior pituitary
D. **Aonadotropin-releasing hormone**: stimulates release of follicle -stimulating hormone and luteinizing hormone from the anterior pituitary
E. **Antidiuretic hormone (vasopressin)**: promotes reabsorption of water by kidneys; stored in posterior pituitary
F. **Oxytocin**: induces uterine contractions labor and milk release from mammary glands; stored in posterior pituitary

Pituitary gland: the body's master gland; located at the base of the brain and attached to the hypothalamus via a stalk called the pituitary stalk; has two distinct regions: the anterior portion of the pituitary gland is regulated by releasing or release-inhibiting hormones produced by the hypothalamus, and the posterior pituitary receives signals via neurosecretory cells to release hormones produced by the hypothalamus. Hormones produced (or secreted) by the gland include:

A. anterior pituitary: the following hormones are *produced* by the anterior pituitary and released in response to hormone signals from the hypothalamus

i. **growth hormone**: stimulates growth factors
ii. **adrenocorticotropic hormone (ACTH)**: simulates adrenal glands to secrete glucocorticoids such as cortisol
iii. **thyroid-stimulating hormone**: stimulates thyroid gland to secrete thyroid hormones
iv. **follicle-stimulating hormone (FSH)** and **luteinizing hormone (LH)**: stimulates production of gametes and sex steroid hormones
v. **prolactin**: stimulates mammary gland growth and milk production

B. posterior pituitary: the following hormones are *produced* by the hypothalamus and *stored* in the posterior pituitary

i. **antidiuretic hormone**: promotes reabsorption of water by kidneys; stored in posterior pituitary
ii. **oxytocin**: induces uterine contractions during labor and milk release from mammary glands during suckling; stored in posterior pituitary

Gland	**Site/location**	**Hormones secreted**	**Functions**	**Effect of under or over production**
Pituitary	Base of brain	Growth, follicle stimulating, anti-diuretic hormones.	1. controls growth 2. Stimulates the production of follicles in females and testis in males. 3. Stimulate the production of other hormones.	Under production causes dwarfism and over production causes giantism.

Thyroid	Neck	Thyroxin	Influences mental and physical development. 2.Increases metabolic rate	Under production causes cretinism (stunted, mental and physical growth) in children and obesity, thick and course hair and premature aging in adults; overproduction causes underweight, resistlessness and mental instability
Parathy-roid	Neck	Parathormone	It regulates blood levels of calcium and phosphorus and stimulates bone reabsorption	
Islets of langer-hans	Pancreas	Insulin	Controls balance of sugar in the blood	Under production causes diabetes mellitus- i.e sugar in urine
Adrenal gland (medulla)	Attached to the kidneys	Adrenaline	Controls response for 'fight or flight'; i.e. increases heartbeat and blood glucose level, dilates coronary arteries etc.	
Ovaries Ovaries	Lower abdomen	Oestrogen and progesterone	Oestrogen controls development of secondary sexual characteristics and thickening of uterus lining. Progesterone maintains the lining of the uterus during pregnancy	
Testes	Lower Abdomen	Testerone	Controls secondary sexual characteristics	

Plant Hormones

Plant hormones are chemical messengers that affect a plant's ability to respond to its environment. **Hormones are organic compounds that are effective at very low concentration;** they are usually synthesized in one part of the plant and are transported to another location. Growth in plants is regulated by a variety of plant hormones, including auxins, gibberellins, cytokinins, and growth inhibitors, primarily abscisic acid and ethylene.

Auxins

An auxin, **indole-3-acetic acid (IAA)**, was the first plant hormone identified. It is manufactured primarily in the shoot tips (in leaf primordia and young leaves), in embryos, and in parts of developing flowers and seeds. Its transport from cell to cell through the parenchyma surrounding the vascular tissues requires the expenditure of ATP energy. IAA moves in one direction only (the movement is polar or downward. Such downward movement in *shoots* is said to be **basipetal** movement, and in *roots* it is **acropetal**. The tips of the growing stems and roots (apical meristem) of a plant is one of the main places where auxin is produced. The apical meristem is also the location that all other parts of a plant grow from - the stem, leaves and flowers.

Function of IAA

- Activates the differentiation of vascular tissue in the shoot apex and in calluses; initiates division of the vascular cambium in the spring; promotes growth of vascular tissue in healing of wounds.
- Activates cellular elongation by increasing the plasticity of the cell wall.
- Maintains apical dominance indirectly by stimulating the production of ethylene, which directly inhibits lateral bud growth.
- Activates a gene required for making a protein necessary for growth and other genes for the synthesis of wall materials made and secreted by dictyosomes.
- Promotes initiation and growth of adventitious roots in cuttings.
- Promotes the growth of many fruits (from auxin produced by the developing seeds).
- Suppresses the abscission (separation from the plant) of fruits and leaves (lowered production of auxin in the leaf is correlated with formation of the abscission layer).
- Inhibits most flowering (but promotes flowering of pineapples).
- Activates tropic responses.
- Controls aging and senescence, dormancy of seeds.

Synthetic auxins are extensively used as herbicides, the most widely known being **2,4-D** and the notorious **2,4,5-T**, which were used in a 1:1 combination as Agent Orange during the Vietnam War and sprayed over the Vietnam forests as a defoliant.

Effect of auxin on lateral bud development

The localized accumulation of auxin in epidermal cells of the root initiates the formation of lateral or secondary roots. when soil moisture is unevenly distributed around the root, auxin preferentially stimulates the development of lateral roots on the moist side.

Auxin also stimulates the formation of **adventitious roots** in many species. Adventitious roots grow from stems or leaves rather than from the regular root system of the plant.

UNIT ELEVEN

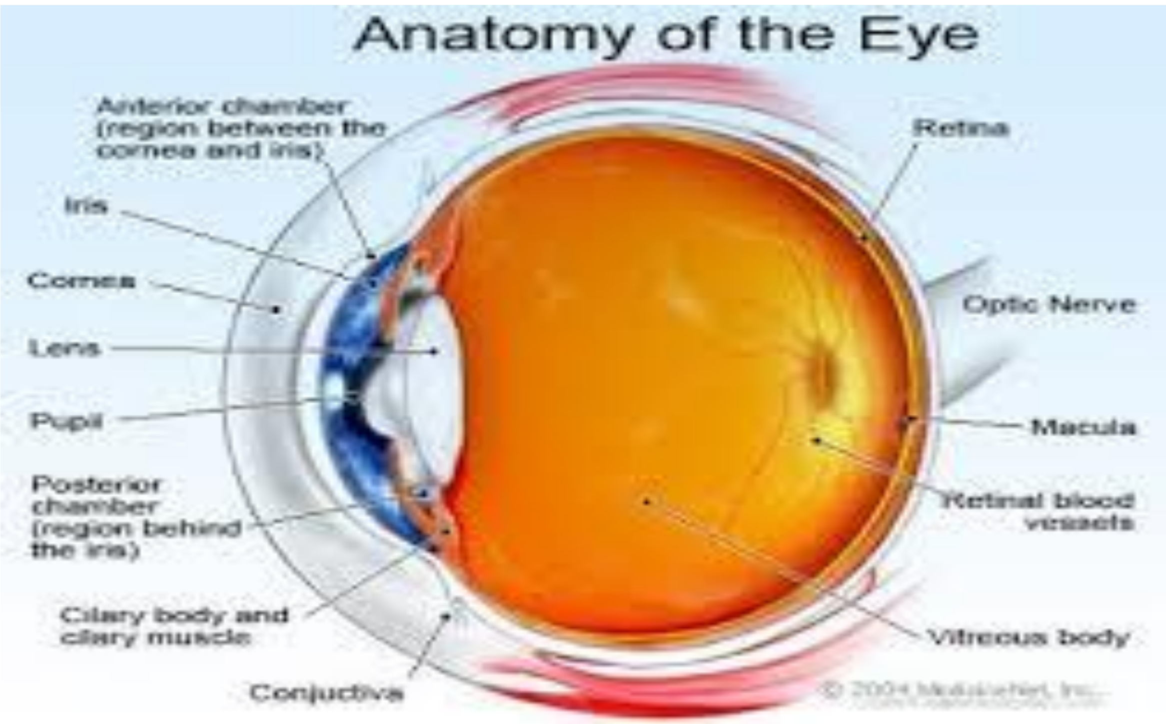
SENSE ORGAN

The structure and function of eye

The eye is comprised of three coats, within which are further three transparent structures. The outermost layer or the fibrous tunic consists of the cornea and sclera. In the middle layer, the vascular tunic or uvea, consisting of the choroid, ciliary body, and the iris. The innermost layer is the retina. It receives its circulation from the vessels of the choroid and also from the retinal vessels.

Within the coats lie the aqueous humor, the vitreous body, and the flexible lens.

The function of the eye is to see or for sight. Vision begins when the light is reflected off a surface and enters the eye through the cornea, which refracts the rays through the pupil. The light rays then pass through the lens which changes shape, bending the rays further and finally focusing it onto the retina.



Parts of Human Eye

Sclera: It is a tough and thick white sheath that protects the inner parts of the eye. We know it as the ‘White of the eye’.

Conjunctiva: It is a thin transparent membrane that is spread across the sclera. It keeps the eyes moist and clear by secreting small amounts of mucus and tears.

Cornea: It is the outermost, transparent layer of skin that is spread over the pupil and the iris. The main role of the cornea is to refract the light that enters the eyes.

Iris: It is a pigmented layer of tissues that make up the coloured portion of the eye. Its primary function is to control the size of the pupil, depending on the amount of light entering it.

Pupil: It is the small opening located in the middle of the Iris. It allows light to come in.

Retina: It is the layer present at the back of the eye where all the images are formed. It is the third and inner coat of the eye which is very sensitive towards the light because of the presence of Photoreceptors. The retina functions by converting the light rays into impulses and sending the signals to the brain through the optic nerve.

Optic nerve: It is located at the end of the eyes, behind the retina. The optic nerve is mainly responsible for carrying all the nerve impulses from the photoreceptors to the **human brain**, without which vision would not be possible.

Aqueous Humour: It is a watery fluid that is present in the area between the lens and the cornea. It is responsible for the nourishment of both the lens and the cornea.

Vitreous Humour: it is a semi-solid, transparent, jelly-like substance that covers the interior portion of the eyes. It plays an important role in maintaining the shape of the eye and also causes refraction of light before it reaches the retina

• **Lens:** It is composed of a fibrous, jelly like material. Provides the focused real and inverted image of the object on the retina. This is convex lens that converges light at retina.

• **Far point:** The maximum distance at which object can be seen clearly is far point of the eye. For a normal adult eye, its value is infinity

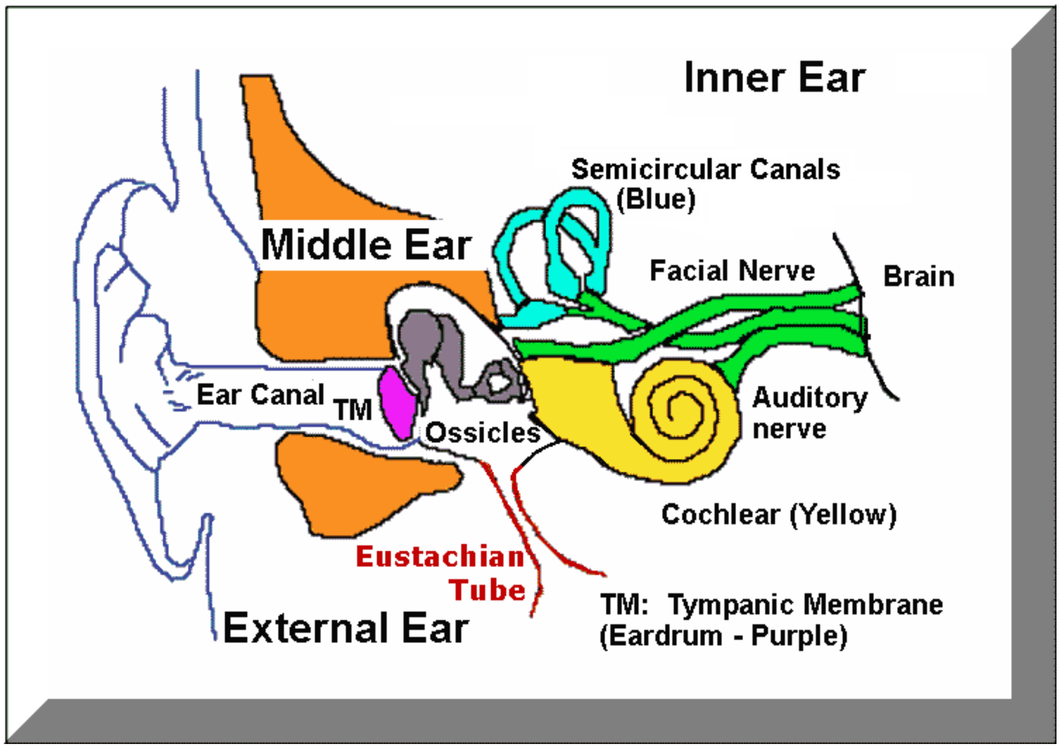
The **rods** are more sensitive in dim light, but cannot distinguish colours. Rods are responsible for night and peripheral (side) vision. Rods are more numerous than cones and much more sensitive to light, but they do not register color or contribute to detailed central vision as the cones do. Rods are grouped mainly in the peripheral areas of the retina.

The **cones** are sensitive to different colours but are not as effective in dim light. Cones are responsible for sharp, detailed central vision and color vision and are clustered mainly in the macula.

The **ciliary muscles and suspensory ligaments** control the shape of the lens in order to focus an image on the retina - see later section on how the eye focuses on near and distant objects. These two systems work together to alter the shape of the lens - important in focussing the image on the retina.

Structure of Ear

The structure of the ear can be broken down into three parts: the outer, inner and middle. The outer ear consists of the auricle or pinna which happens to be the visible portion. It channels the sound waves into the ear canal where it gets amplified from where the waves travel towards a membrane that vibrates. In the middle ear, the vibrations set the ossicles into motion. These sound waves enter the inner ear and then into the cochlea, filled with a fluid that moves with the vibrations. The nerves are set into motion which becomes electrical impulses and travels to the brain where it is interpreted.



The functions of the ear is also responsible for maintaining your equilibrium or balance.

•The outer ear, which includes the complex shell that is the visible ear we see on the outside of our heads. This outside structure, called the “pinna,” acts like a satellite dish or funnel, gathering and focusing sound so that we can hear better.

The pinna is made mostly of cartilage. In some animals, this outer “shell” or “dish” can actually move, rotating enable it to collect sound from different directions. Some breeds of dogs and cats maintain this ability to move their ears to better focus on a sound without moving their whole head.

•The middle ear consists of a series of bony tubes, which contain other bones that are designed to amplify vibrations they receive through the eardrum. This “eardrum” also called the “tympanic

membrane,” vibrates in response to the sounds that enter through the ear canal.

Its vibrations are then transmitted through three tiny bones known as the “ossicles.” These are the malleus (also known as the “hammer”), the incus (also known as the “anvil”), and the stapes (also the “stirrup”).

Unlike most bones which are used for structure and protection, the function of these three delicate bones is to vibrate as much as possible in response to sounds that enter the ear. They concentrate the vibrations from the ear canal and transmit them to the inner ear, where these vibrations ultimately reach the cells that send impulses to the auditory nerve.

•The inner ear contains a series of fluid-filled chambers, which use hair cells to convert fine vibrations into neural impulses for purposes of both hearing and balance. The inner ear receives vibrations that have been amplified and transmitted from the ear canal and through the malleus, incus, and stapes.

Located deep within the head, the hair cells of the inner ear are just what the name suggests: fine cells, shaped like hairs, which are extremely sensitive to vibration. When these hair cells are bent by vibrations, special proteins in the cell membrane cause the hair cells to create electrochemical impulses, very like nerve impulses, which are then carried to the auditory nerve in the brain.

By determining which hair cells are bending in response to vibration, the brain can calculate with a high degree of detail and accuracy the “pitch” or frequency of the sound vibration; the volume; and the location of the sound.

Today, modern medicine allows many people with malformed or damaged cochleas to hear better using devices such as cochlear implants, which artificially produce electrochemical impulses that our auditory nerves can understand.

We will talk in more detail about these parts of the ear in the “Parts of the Ear” section below.

Balance

Within the parts of the ear known as the semicircular canals, hair cells just like those used for hearing have been adapted for a different purpose. This is called the “vestibular system,” and it assists with vision and balance.

In the semicircular canals, these hair cells respond to the movement of otoliths – tiny calcium carbonate crystals which can shift in response to gravity and motion, causing them to press on hair cells and release nerve impulses.