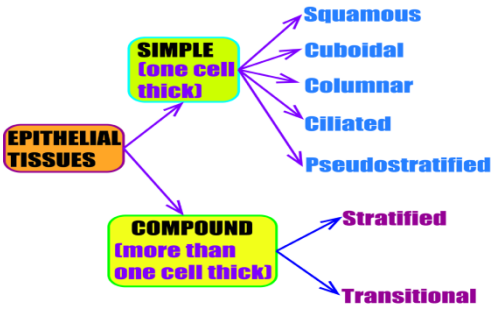
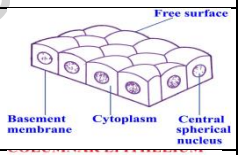
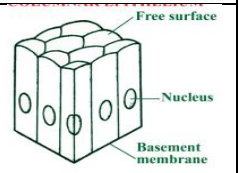
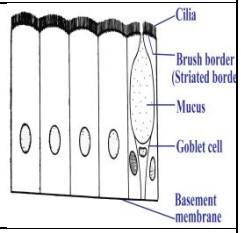
HISTOLOGY (TISSUE ORGANISATION)
A tissue is a group of cells linked together to perform a particular function. These are two main types of tissues i.e. plant and animal tissues.

ANIMAL TISSUES
There are 4 major groups of animal tissues i.e.
i) Epithelial tissue ii) Connective tissue iii) Muscular tissue iv) Nervous tissue

EPITHELIAL TISSUES
comprised of a single or several shifts of cells held together by intercellular substances. The
bottom layer of cells is attached to a basement membrane made up of collagen fibres
Epithelial cover inner and outer surfaces where they always have a protective function



Simple Tissues(Name)	Description	illustration
Squamous	Cells form a single layer attached to a basement membrane. In surface view cell outlines are irregular and closely packed The cells are thin,shallow and flattened. Adjacent cells may be joined by strands of cytoplasm Such epithelia form structures and surfaces over which diffusion can occur . They occer in alveoli of the lungs, Bowman's capsule,in capillary walls,and blood vessels	
cuboidal	It cells are cuboidal and form a single layer attached to a basement membrane. Occer in glands like thyroid, sweat and salivary glands. It also has a non-secretory function e.g. the lining of the kidney collecting tubules, proximal and distal convoluted tubules, pancreatic ducts, etc.	
coloumnar	These are tall and narrow cells with a nucleus near their base. Their surface area is increased by micro villi at the free end. Such cells are mostly found in areas that have an absorptive role. Secretory goblet cells are found within the columnar cells. Occer in digestive system where secretion of mucus and absorption of food takes place. It is also found lining the kidney ducts and the thyroid glands	
ciliated	It comprises of columnar cells with cilia at their free edges. They have many mucus secreting goblet cells present. The combination of mucus and cilia allows substances to move through ducts e.g. in the oviduct, trachea, spinal cord, bronchus and bronchioles where it moves materials from one location to another.	
pseudostratfied	The nuclei of this type of epithelium appear to be at several different levels because not all the cells reach the free surface. Nevertheless, the epithelium is still one layer or one cell thick with each cell attached to a basement membrane. It is found lining the urinary tract and respiratory passages e.g. bronchi.	

Compond tissue	description	illustration
1. Stratified epithelium	It is made of many layers of cells and therefore thicker than the simple epithelium and forms a germinating layer and they undergo cell division. As new cells form, older ones are pushed near to the surface changing shape and flattening to form squamous. The squamous may remain un keratinized as in the oesophagus or may be heavily thickened with keratin (cornified) e.g. the skin where there is a dead layer of cells like those found lining inside the mouth and vagina. Therefore they are for protection from abrasion to areas exposed to wear and tear.	
2. Transitional epithelium	It is found in structures which must stretch e.g. the urinary bladder and parts of the kidney. It comprises of 3 or 4 layers of cells which may be flattened towards the surface which are not shed like those of the stratified epithelium. Transitional epithelium lacks a basement membrane. The functions of transitional epithelium include: - By changing the shape, the transitional epithelium allows the expansion of the organ. - It prevents the loss of water from blood to urine. - Due to its thickness, it prevents the urine from escaping into the surrounding	

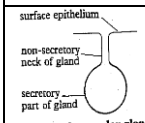
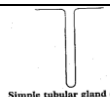
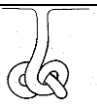
	tissue.	

GLANDS - GLANDULAR EPITHELIUM

1. Based on the kind of secretion and the duct present, glands are of two types;

i) Exocrine glands: these pour their secretions through the ducts to their respective sites of action e.g. salivary, tear intestinal and gastric glands. Their secretions are called enzymes.

ii) Endocrine glands: these do not possess ducts and pour their secretions directly into the blood stream. Their secretions are known as hormones.

1. Simple saccular/alveolar gland	2. Simple tubular gland	3. Simple Coiled tubular gland	4. Simple branched tubular gland	5. Simple branched saccular gland-
 **Simple saccular gland** e.g. mucus glands in the skin of the frog and other amphibia.	 **Simple tubular gland** e.g. crypts of Lieberkühn in the wall of the mammalian small intestine.	 **Coiled tubular gland** e.g. sweat glands in the skin of humans	 **Simple branched tubular gland** e.g. Brunner's glands in the wall of the mammalian small intestine and gastric glands in the wall of the stomach.	 **Simple branched saccular gland** e.g. oil- secreting sebaceous glands in mammalian skin.

2. Based on number of cells, the glands are of 2 types;

i) Unicellular: an individual epithelial cell is modified into a glandular cell as in goblet cells.

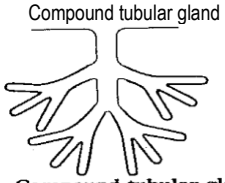
ii) Multicellular: number of glandular cells aggregate to form a multicellular gland. Multicellular glands can further be divided into simple or compound glands e.g. sweat glands.

3. **Based on the shape and complexity, the exocrine glands are of 2 main types**; simple and compound glands which may further be modified.

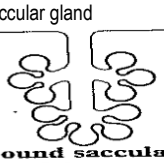
i) **Simple glands:** these have a single unbranched duct. The secretory part could be in the form of (called tubular) or sacs (alveolar). These could be coiled or uncoiled, branched or unbranched. Various forms of simple glands are given below;

ii) **Compound glands**: these have number of ducts forming a branching pattern.

Compound tubular gland . Compound saccular gland



Compound tubular glands e.g. salivary glands.



Compound saccular gland e.g. the part of the pancreas which secretes digestive enzymes, and the mammary glands.

Functions of the epithelial tissue

1. **Protection;** Epithelial tissue basically protects the underlying tissue from injuries by chemicals, pressure abrasion and infection.

2. Secretion; A number of epithelial cells are modified to produce secretions such as mucus, hormones etc.

3. **Excretion;-** The epithelial cells of the kidney tubules and sweat glands remove excessive and toxic metabolic wastes from the body thus helping the body in excretion.

4. **Absorption;-** Cuboidal and columnar epithelia are modified for absorption

5. **Exchange of materials and gases**- Squamous epithelium is extremely thin and flattened promoting exchange of materials and gases by diffusion such as the alveoli of the lungs.

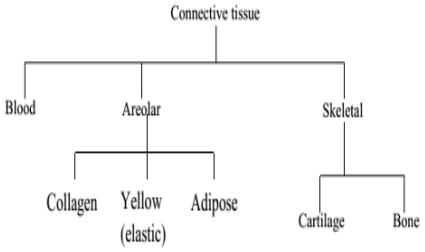
6. **Sensory-** epithelia bearing sensory cells and nerve endings are specialized to receive stimuli as in the skin and retina of the eye.

7. **Movement of materials-** Epithelia may be modified to aid movement of materials e.g Ciliated columnar epithelium lining the inside of the oviduct, ventricles of the brain, spinal canal and respiratory passages bears numerous cilia at their free surface. These are associated with mucus secreting goblet cells producing fluids in which the cilia beat up rhythmically setting up currents which move materials from one location to another.

CONNECTIVE TISSUES

Connective tissues are derived from the embryonic mesoderm.

Summary of the connective tissue



Functions of connective tissues

a) It binds the various tissues together like the skin with muscles and muscles with bones.

b) It is a packing tissue forming sheath like bags around the body organs.

c) Areolar tissue protects the body against wounds and infections.

d) Adipose tissue stores fats, and insulates the body against heat loss.

e) Connective tissue is the major supportive tissue of the body, composed of bones and cartilage which provides the body with a supportive framework.

f) Haemopoitic tissue produces blood.

g) Lymphatic tissue builds body immunity by producing antibodies.

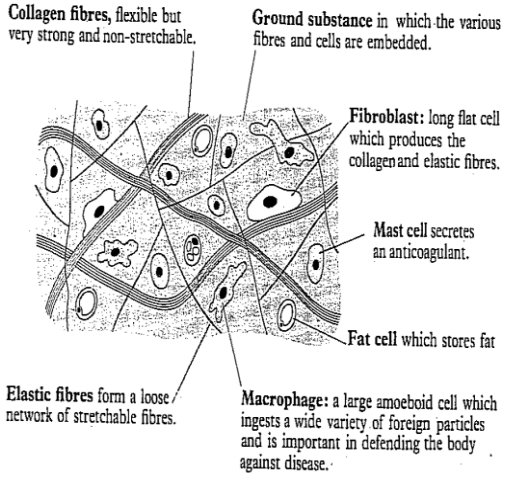
h) Connective tissue separates the body organs, so that they do not interfere with each other's activities.

i) Protects blood vessels and organs where they enter or leave organs.

margins of the periphery.

AREOLAR TISSUE

Transverse section of areolar



Areolar tissue consists of a glycoprotein matrix containing four types of cells and two types of protein fibres.
The areolar cells include:

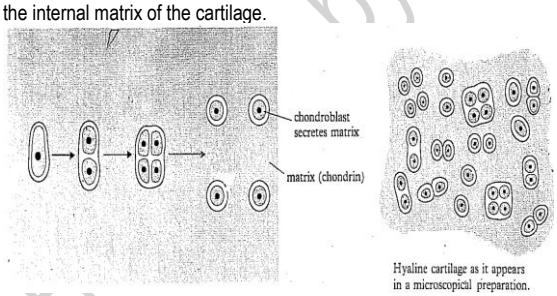
i) Fibroblasts: These are long flat cells which synthesize collagen and elastic fibres.
ii) Mast cells: These are amoeboid in shape or oval shaped and contain granular cytoplasm. They secret
fats filled cells and an anticoagulant or ground matrix or substance and macrophages.
iii) Fat cells: These are fats storing cells which accumulate fats in the body structures to form the adipose
tissue.
iv) Macrophage or histocytes: These are amoeboid cells which are large which ingest a number of
foreign particles hence are important in defense against foreign bodies. The fibres present in areolar
tissue give it its strength and toughness.
There are two types of fibres in areolar tissue:
a) The unbranched collagen fibres/white fibres: these appear parallel to each other and are arranged
in bundles. They are mainly found in tendons.
b) Branched elastic fibres/the yellow fibres: these form a dense network of fibres. They cross the
matrix. The structures are stretchable and are found in ligaments

.**a)Adipose tissue**
It is a type of connective tissue with reduced matrix material and contains enlarged fat cells that are numerous in number. Adipose tissue functions to store energy, insulate the body and provides shock absorption to delicate mammalian organs e.g the kidney. It also occurs beneath the skin, the buttocks.
Adipose tissue occurs in two forms i.e the white and brown adipose tissue.

b)Recticular connective tissue (yellow elastic)
It contains an abundance of recticular fibres. It provides a supporting framework for organs such as those of the lymph nodes, spleen and the liver.

c) Collagen tissue/white fibrous tissue:
This consists of glycoprotein matrix containing densely packed collagen fibres. Collagen tissue has fibres which are inelastic and have a high tensile strength. They are found in the tendons where they attach muscles to bones. They are found in the Dura matter of the brain and also in the cornea of the eye.

SKELETAL TISSUES
CARTILAGE/GRISTLE
This is a connective tissue consisting of cells embedded in a matrix called **chondrin**. The matrix is
deposited by cells called **chondroblasts** and possess many fine fibres mostly collagen. Eventually, the
chondroblasts become enclosed in spaces called **lacunae.** In this state, they are termed as **chondrocytes.**
The margin of a piece of cartilage is enclosed by a dense layer of cells and fibrils called **perichondrium**
in which new chondroblasts are produced and constantly added to the internal matrix of the cartilage.



Cartilage is highly adapted to resist any strains that are placed on it.
The matrix of cartilage is
compressible and elastic. The collagen fibres resist any tensions which may be imposed on the tissue.
The cartilage in adults is restricted to the articular (joints) surfaces of bones that form freely moveable
joints and other specific locations e.g the nose, pinna, intervertebral discs, larynx, etc.
Types of cartilage

There are three types of cartilage ie . hyaline cartilage, yellow elastic cartilage and white fibrous cartilage.

Hyaline cartilage
It is the simplest form of cartilage which is elastic and compressible. It mainly comprises a
semitransparent matrix and chondrocytes. It frequently contains fine collagen fibrils. It has no processes
extending from the lacunae into the matrix and neither are there blood vessels. Therefore, exchange of
materials between the chondroblasts and the matrix is by diffusion.
It is located in the ends of the bones, in the nose and the wall of the trachea and bronchi. It also forms the
embryonic skeleton in many vertebrates.

Yellow elastic cartilage
It has a semi opaque matrix containing a network of yellow elastic fibres. The fibres confer greater
elasticity than found in the hyaline cartilage. Due to high elasticity and flexibility, the tissue quickly
returns to its shape after distortion.
It is located in the external ear, in the epiglottis and cartilages of the pharynx

White fibrous cartilage
In addition to chondrocytes in the matrix, there are large bundles of densely packed collagen fibres. This
gives the tissue a greater tensile strength than hyaline cartilage as well as a small degree of flexibility.
It is located in the discs between adjacent vertebrae which provide a cushioning effect and the
ligamentous capsules surrounding the joints.

BONE
This is very abundant providing support, protection and some metabolic functions. The bone has an organic matrix containing collagen fibres, and is impregnated with small needle shaped crystals of calcium phosphate in form of hydroxyapatite which is brittle but rigid giving bone great strength.
Calcium carbonate is also contained within the matrix.
A bone is a dynamic living tissue that is constantly reconstructed through the life of an individual by bone cells called **osteoblasts.** Osteoblasts secrete the matrix in which calcium phosphate is later deposited.
After calcium phosphate has been deposited, the osteoblasts become less active and are now called

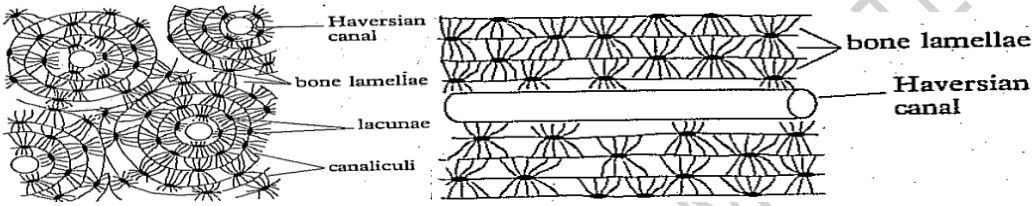
osteocytes and are energized in spaces called **lacunae.**
Another type of bone cells called **osteoclasts** exist in the matrix which play a role in dissolving the bone matrix to enable further reconstruction of a bone during growth. A bone is constructed in thin concentric layers called **lamellae** which are drawn around narrow channels called **haversian canals** that run parallel to the bone length.
Haversian canals contain nerve fibres and blood vessels which keep the osteocytes alive. The concentric lamellae and the encircled canal are termed as the **haversian system/osteon.**
The lacunae have very many fine channels called **canaliculi** containing cytoplasm which link up with the central haversian canal, with other or press from one lamella to another. An artery and a vein run through the haversian canal and capillaries branch from here through the canaliculi. A haversian canal also contains lymph vessels and nerve fibres. Covering the bone is a layer of dense connective tissue called **periosteum.** The inner region of the periosteum has blood vessels and contains cells that can develop into osteoblasts and osteoclasts.

Types of bone

There are two types of bone i.e compact/dense bone and spongy bone

Compact bone/dense bone

They are mainly part of long bones and form the long shape of the bone between two swollen ends. The matrix of compact bones is composed of collagen and calcium phosphate, with large quantities of magnesium, sodium, carbonate, nitrate ions. The combination of organic with inorganic materials produces a structure of great strength. The lamellae are laid down in a manner that is suited to the force acting upon the bone and the load that has to be carried.
A transverse section of a compact boneLongitudinal section of a compact bone



Endochondral ossification

Endochondral ossification is the process of replacement of cartilage by bone. The skeleton of the vertebral embryo consists of mainly hyaline cartilage. Each cartilage element is surrounded by a layer of dense connective tissue, the perichondrium.
Ossification of bones (such as the long bones of the arms and legs) begins when blood vessels penetrate the perichondrium of the cartilage midway along the shaft/diaphysis of the cartilage model.
This stimulates some of the cells of the cartilage perichondrium to become osteoblasts which produce a **collar** of compact bone in the shaft region. The layer of dense connective tissue now surrounding the developing bone is called the periosteum.
A primary ossification centre appears inside the shaft and is progressively invaded by a proliferating number of blood vessels and osteoblasts. The matrix of the cartilage tends to become calcified by deposition of calcium and phosphate, but is eroded by the osteoclasts leaving spaces which eventually fuse to form the **marrow cavity.**
Working in small groups, osteoclasts tunnel through the bone leaving cavities which are invaded by blood capillaries and new bone forming osteoblasts. Within the tunnel, osteoblasts lay down a new bone matrix in concentric rings forming an arrangement called haversian system.
Cartilage continues to grow at either end producing an increase in length. Most of the cartilage is later replaced by a spongy bone.
Inmammals, secondary ossification centres develop in the swollen ends/epiphyses of the cartilage models of long bones. The epiphyses ossify more or less completely except for a thin layer of cartilage called an **epiphyseal plate,** separating each epiphysis from the main shaft.
Increase in diameter of the bone shaft is achieved by continual remodeling and deposition of new bone by osteoblasts of the periosteum. As maturity approaches, the thickness of the epiphyseal plates is reduced and finally the epiphyses and the bone shaft fuse completely leaving a faint **epiphyseal line.** Ossification of all bones in human skeleton is normally completed by the age of 25.

Adaptations of bone to its function

a) A tough fibrous layer of dense connective tissue called periosteum provides a tough and hard covering that surrounds the bone and protects the inner cells.
b) Bundles of collagen fibres from the periosteum penetrate the bone giving more mechanical strength, providing an intimate connection between the underlying bone and the periosteum and acting as a firm base for insertion of tendons, which contribute to movement and locomotion.
c) Osteoblasts are arranged in concentric rings around a series of haversian canals in compact bone thus lay down the matrix in a similar rigid and dense regular pattern to provide uniform mechanical strength.
d) Bone lamellae contain numerous lacunae containing living bone cells called osteoblasts which secrete the matrix of the bone.
e) Mature less active osteoblasts called osteocytes can be reactivated quickly regaining the structure of active osteoblasts and depositing bone matrix, when structural changes in bone are required.
f) Bone cells are embedded in a firm bone matrix which is rendered hard by deposition of calcium salts and other inorganic ions.
g) Bone cells called osteoclasts responsible for dissolving of the matrix as it is laid down enable reconstruction and remodeling of the bone during endochondral ossification.
h) An artery, a vein and a lymph vessel pass through a haversian canal of a compact bone allowing the passage of nutrients, respiratory gases and metabolic wastes towards and away from the bone cells.
i) Each lacuna has fine cytoplasmic extensions called canaliculi which pass through lamellae and

make connections with other lacunae and with the central haversian canal, allowing
communication between the lacunae in different lamellae, and with the central haversian canal.
j) Presence of numerous nerve fibres in the haversian canal allows co-ordination of bone
reconstruction enabling each bone to adapt its structure to meet any change in mechanical
requirement of an animal during its development.
k) Bone releases calcium and phosphate into the bloodstream as required by the body under the
control of the hormones parathormone and calcitonin.
l) Spongy bone has spaces between the trabeculae, reducing the weight of the bone, allowing less
restricted movement and locomotion.

Differences between a cartilage and bone

Cartilage	Bone
No process extended from each lacuna into the matrix.	Lacuna possesses canaliculi that extend into the matrix.
No blood vessels and nerves in the tissue.	Blood vessels and nerves run through the haversian canal.
Exchange of material between chondrocytes occurs by diffusion.	Osteoblasts exchange materials by help of blood capillaries passing through the canaliculi into the lacunae.
Elastic and compressible	Relatively incompressible as the matrix is highly composed of minerals e.g calcium ions, magnesium ions.
Matrix is relatively semi-transparent with hyaline cartilage and semi opaque in yellow elastic cartilage.	Matrix is opaque
The matrix is not calcified.	Matrix is calcified with greater quantities of Mg^{2+}, Na^{+}, Ca^{2+} etc.
No concentric layers of lamellae and no haversian canals present.	Consist of concentric layers of lamellae surrounding the haversian canal.
Rather inactive.	An active tissue with metabolic activity.
Matrix secreting cells are called chondroblasts.	Matrix secreting cells are called osteoblasts.
It is differentiated into hyaline, white fibrous and yellow elastic cartilage.	It is structurally differentiated into compact and spongy bones
It is flexible due to relatively soft and flexible matrix called chondrin.	It is rigid due to solid matrix called osteon.
It is less strong.	It is stronger.
Chondroblasts are randomly scattered in the matrix and occur in singles, pairs or fours.	Osteoblasts are in concentric layers around the haversian canal.
It is mostly found in areas where cushioning is required.	It is located in areas where maximum support is needed.

MUSCLE TISSUE

There are three types of muscular tissue which include: **voluntary muscle**, **involuntary muscle** and **cardiac muscle**.

Basic structure of a muscular tissue

a) All muscle fibres are made up of elongated and thin cells called muscle cells or muscle fibres.
b) The muscle fibres contain a specialized cytoplasm called sarcoplasm that contains a network of membranes called sarcoplasmic reticulum.
c) Muscle fibres may be bound by a cell membrane called sarcolemma.
d) Each muscle may contain numerous thin myofibrils.

VOLUNTARY/ SKELETAL /STRIATED OR STRIPED MUSCLE

It is said to be striated because its muscle cells have transverse stripes when viewed in longitudinal section.

Distribution of skeletal muscles

It is found attached to the skeleton in the head, trunk and limbs hence the name skeletal muscle.

Gross structure of a skeletal muscle

Skeletal muscle is composed of bundles of muscle fibres each surrounded by a connective tissue, **endomysium.** Each bundle of muscle fibres is surrounded by **perimysium,** a connective tissue, the various bundles are surrounded by an **epimysium,** a connective tissue sheath.

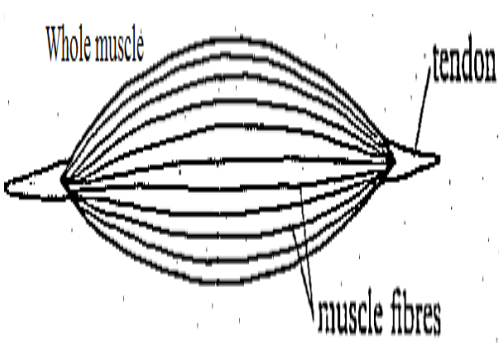
The skeletal muscle is attached to a bone in at least two places namely; the **origin**, a fixed non-moveable part of the skeleton and the **insertion**, a moveable part of the skeleton.

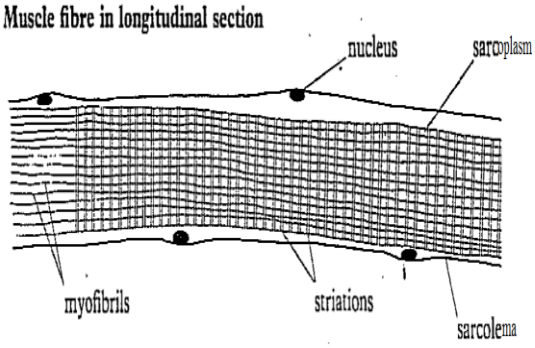
Attachment is by a means of tough relatively inelastic tendons made up of almost entirely collagen fibres. At one end, the tendon is continuous with the outer covering of the muscle while the other end is of the tendon combines with the outer layer of the bone called **periosteum** and forms a very firm attachment.

Histology of a striated muscle (skeletal muscle)

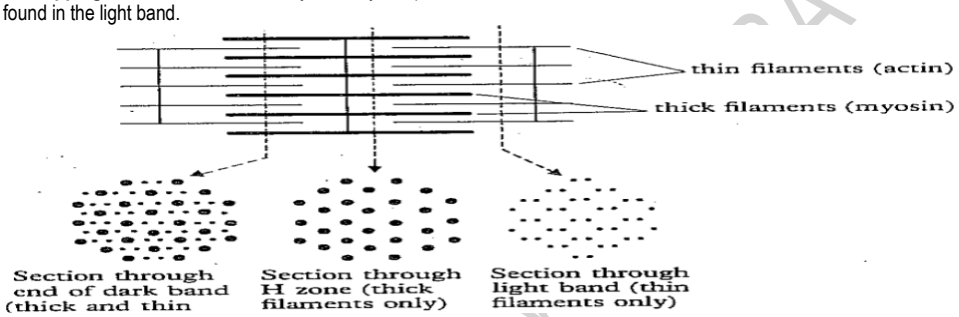
The muscle is made up of many hundreds of long muscle cells called **muscle fibres.** Each muscle fibre is filled with a cytoplasm called **sarcoplasm** in which about 100 nuclei are spaced out evenly just beneath the bounding membrane called **sarcolemma.**

In the sarcoplasm, there are many thin myofibrils which possess characteristic cross striations. The myofibrils line up perpendicular with the cross striations next to each other. The myofibrils are composed of protein filaments called **actin** and **myosin**. **Fine structure of a striated muscle**





Each myofibril is divided into light and dark bands. The dark band has a comparatively light region in the middle called **H- zone,** and it has darker regions on either sides. In the middle of the H- zone is a dark line called the **M- line**.
Running through the light bands in the middle is the **Z- line**. The dark and light bands are called **A** and **I** bands respectively. **I** means isotropic, as it allows light to pass through and so appears lighter. **A** means anisotropic as it does not allow light to pass through, so it appears darker.
The region of a myofibril between two Z-lines is called a **sarcomere** and is described as the basic functional unit of a myofibril. Alternating light and dark bands are due to two types of protein filaments which run longitudinally. These are the **thin actin** and **thick myosin** protein filaments. The thick myosin filaments are confined to the dark band and the thin actin protein filaments occur in the light band but extend in between the thick myosin filaments within the dark band.
The darker segments on either side of the H- zone are due to both thick myosin and thin actin filaments **overlapping**. The H-zone consists only thick myosin protein filaments. The thin actin filaments alone are found in the light band.



Within each muscle fibre, there is an internal membrane system, the **sarcoplasmic reticulum** surrounding the myofibrils. The sarcoplasmic reticulum includes a system of **transverse tubules** (the **T- system**) which run into the muscle fibre from the sarcolemma at positions corresponding to the Z- lines.
Connected with the T- system are vesicles containing calcium ions in high concentration. Ca2+helps in hydrolysis of ATP. After muscle contraction, calcium ions are actively removed into the longitudinal tubules thereby lowering the concentration to a level below that at which ATP hydrolysis can occur.

Adaptation of skeletal muscle tissue for its function/relationship between structure and function of a striated muscle

It consists of elongated fibres, allowing considerable contractile length.
- Its fibres are parallel to give it maximum contractile effect and to allow each fibre to be controlled individually which gives ability to vary the length of the whole muscle contraction necessary for proper control of skeletal movement.
- The ends of the muscle fibre are tapered and interwoven with each other to provide adequate mechanical strength during muscle contraction.
- Its cells contain a large number of mitochondria to provide large amounts of ATP for muscle contraction.
- In their arrangements, the actin and myosin filaments fit into each other to allow them slide over each other to cause contraction.
- The cells have a rich blood supply to provide adequate supply of oxygen and nutrients
- The muscle cells have myoglobin to store oxygen and release it for respiration when blood oxygen levels are low.
- Has a specialized region called the motor end plate where the axon of a motor neurone divides and forms fine non myelinated branches (dendrites) ending in synaptic knobs running in shallow troughs on the sarcolemma allowing nervous stimulation and control of the muscle.
- The sarcolemma folds inwards and forms a system of tubes called the T- system (transverse tubules) which run parallel through the sarcoplasm to the Z- lines allowing a nerve impulse arriving along a motor neurone at the neuromuscular junction at the surface of a muscle fibre to be propagated as a wave of depolarization (action potential) through the T- system causing release of calcium ions of the sarcoplasmic reticulum to activate the process of muscle contraction.
- The specialized endoplasmic reticulum of the muscle fibre called the sarcoplasmic reticulum forms the vesicles at the Z- line of the sarcomeres which contain calcium ions used to activate the process of muscle contraction.
- Ability to generate ATP using phosphocreatine during anaerobic conditions for a constant supply of ATP in the muscle.
- Ability to respire anaerobically for continued muscle contraction in anaerobic conditions.

VISCERAL/INVOLUNTARY/UNSTRIATED/UNSTRIPED/SMOOTH MUSCLE
- It consists of muscle cells called muscle fibres which are spindle shaped and tapering at both ends

and uninucleated.
 The nucleus is single, elongated in shape, centrally placed and surrounded by little sarcoplasm.
 The muscle fibres lack a sarcolemma.
 Each muscle fibre consists of numerous inconspicuous, fine contractile myofibrils arranged longitudinally.
 The actin and myosin filaments are evenly distributed hence there are no striations or light and dark bands.
 Smooth muscle fibres are shorter than striated muscle fibres.
 Has sarcoplasmic reticulum but less extensive than in striated muscle.
 Has rings of smooth muscle fibres called sphincter muscle fibres for example; pyloric, cardiac and anal sphincters.
 Has prominent mitochondria but less numerous than in striated muscle.

Innervations and activity of the smooth muscle
 Smooth muscle is involuntary in action, so cannot be moved by ones will.
 Innervated by two sets of nerves from the autonomic nervous system (sympathetic and parasympathetic).
 Smooth muscle fibres undergo prolonged and slow, sustained rhythmical contractions and relaxations as in peristalsis, hence fatigues slowly.

The smooth muscle is located in the tracts of the intestines, genitals, urinary and respiratory systems and the walls of blood vessels

Functions of the smooth muscle

ii. The pyloric sphincter controls passage of food from the stomach to the duodenum.
iii. Small sphincter muscle surrounds some blood vessels to control the distribution of blood and regulation of blood pressure.
iv. Control movement of materials with the body visceral organs.

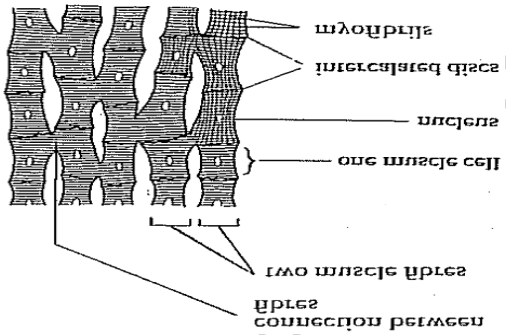
CARDIAC MUSCLE

It is found only in the heart.

The structure of a cardiac muscle

A cardiac muscle consists of a network of interconnected cells called cardiac muscle fibres. Each muscle fibre is short, cylindrical and branched. Each muscle fibre possesses one large mitochondrion, with one nucleus or two nuclei, abundant cytoplasm, glycogen granules, well developed T system and poorly developed endoplasmic reticulum consisting of a network of tubules.

Cardiac muscle fibres are terminally branched and connected to each other by intercalated discs. Actin and myosin filaments are regularly arranged to give faint but regular cross striations. Muscle fibres branch and cross connect with each other to form a complex netlike arrangement.



 The rate of contraction can be influenced by the autonomic nervous system.
 Interconnections between the fibres (intercalated discs) ensure a rapid and uniform spread of the excitation.
 Have rhythmic rapid contractions and relaxation with a long refractory period and so do not fatigue as contraction is not sustained.
 Need a constant supply of large amounts of energy.
 A small number of cardiac muscle fibres and a few nerve endings form the Sino atrial node (SAN) located near the opening of the vena cava which stimulates heart beat on their own

 Cardiac muscle is myogenic meaning that the contractions are developed within the muscle.

. **Adaptations of the cardiac muscle to its function**

a) Cardiac muscle cells are highly branched terminally and connected to each other by intercalated discs to form a network that allows rapid spread of waves of electrical excitation from cell to cell, so that linked muscle cells rapidly contract rhythmically and simultaneously for fast heartbeat.
b) Dense network of blood capillaries ensures adequate supply of oxygen and food nutrients, for fast production of adequate ATP, for continuous rapid muscle contraction and rapid excretion of carbondioxide and other metabolic wastes.
c) Numerous large mitochondria and glycogen granules rapidly provide adequate amounts of energy in form of adenosine triphosphate (ATP) by aerobic respiration for rapid contraction without fatigue.
d) Has the Sino atrial node (SAN) which emits waves of electrical excitation that initiate continuous and rhythmic contraction without fatigue, for continuous heartbeat.
e) Have striations for mechanical strength to support its fast and continuous contractions.
f) Undergoes rapid rhythmic contractions and relaxations with long refractory periods and thus does not fatigue as contraction is not sustained.
g) Well-developed T-system for rapid transmission of impulses thus rapid contraction and relaxation.
h) Branched muscle fibres offer a large surface area for fast spread of waves of electrical excitation for continuous contraction hence continuous heartbeat.

PLANT TISSUES

1) MERISTEMATIC TISSUE

It is a plant tissue consisting of actively dividing cells which give rise to cells that differentiate into new tissues of the plant.

Meristem

A meristem is a group of plant cells which remain with the ability to divide by mitosis producing daughter cells which grow to form the rest of the plant body.

Types of meristems

Apical meristems:- They are found at the shoot tip and root tip. They divide continuously by mitosis leading to primary growth of the plant body that is increase in length of the shoot or root.

Lateral meristems (cambium):- These are found in a cylinder towards the outside of stems and roots. They are responsible for secondary growth and cause an increase in girth.They include the **vascular cambium** which gives rise to secondary vascular tissue including secondary xylem and phloem. They also include the **cork cambium** (**phelogen)** which gives rise to **periderm** which replaces the epidermis and includes the cork.

Intercalary meristems:- These are found at the nodes in monocotyledonous plants. They allow an increase in length in positions other than the tip. Ensures continued growth where tissues are damaged such as when eaten by herbivores in grasses.

SIMPLE PLANT TISSUES

They are tissues consisting of one type of cell. They include the parenchyma, collenchyma and sclerenchyma

2) **PARENCHYMA**

It consists of living cells which are relatively undifferentiated. The cells are either roughly spherical or elongated. The cells have thin cell walls made up of cellulose, pectins and hemicelluloses. The cells also have large sap vacuoles with dense but peripheral cytoplasm.

Parenchyma tissue is located in the cortex, pith and medullary rays of wood. It also serves as a packing tissue in xylem and phloem

Functions of the parenchyma tissue

a) Acts as a packing tissue i.e cells of the parenchyma fill spaces between other specialized tissues e.g in the cortex, pith, between the xylem vessels and phloem.

b) When they are turgid, parenchyma cells become closely packed thus provide support for the organs in which they occur. For example in the leaves and in stems of herbaceous plants.

c) It is a storage tissue due to possession of starch granules and large food vacuoles. Therefore, the tissue is abundant in storage organs eg the Irish potato.

d) It allows transportation of materials through cells by symplast pathway or apoplast pathway.

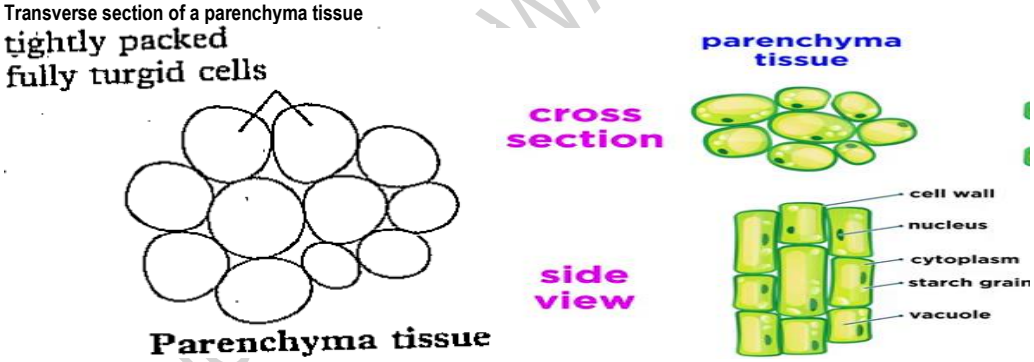
e) The parenchyma tissue is metabolically active as it is composed of living cells for example some parenchyma are photosynthetic.

f) Growth of the pericycle in the roots where it retains the meristematic activity producing lateral roots and contributing to secondary growth.

g) In the endodermis, cells are covered by a fatty substance (suberin) that forms the casparian strip that prevents apoplast transportation of water through the root thus directing the flow of water into xylem.

h) It contains intercellular air spaces which allow gaseous exchange.

Transverse section of a parenchyma tissue



Relationship between structure and function of the parenchyma tissue

i) The cells are unspecialized to perform a variety of functions.

j) Many intercellular spaces to allow diffusion and exchange of gases.

k) Thin cellulose cell walls to allow passage of materials for transport.

l) Transparent cell walls to allow light penetration for photosynthesis.

m) The cells are large and contain large vacuoles with a thin layer of cytoplasm to provide storage space for materials of the plant.

n) Have isodiametric, roughly spherical or elongated cells to serve as a packing material between specialized cells.

o) Cells have permeable walls to allow entry of light for photosynthesis.

p) Cells have leucoplasts such as amyloplasts to store food such as starch.

q) Cells have chloroplasts to allow photosynthesis.

r) Cell walls contain cellulose, pectins and hemicelluloses for support.

s) The cells have chromoplasts such as in petals to provide bright colour to attract insects for pollination.

Modified parenchyma

They include; epidermis, mesophyll, endodermis, pericycle, companion cells and transfer cells.

a) Epidermis/epidermal cells

It is a layer of one cell thick that covers the whole primary plant body.

Functions

- The basic function is to protect the plant body from desiccation and infection. This is achieved by secreting cutin and forms the cuticle that is impervious to water.
- Specialized epidermal cells (the guard cells) bound/guard the stomata and are important in

opening and closing of stomata.
 Hair like structures on cuticle (epidermis) serve various purposes for example, root hairs increase on the surface area for absorption of water and mineral salts by the roots.
 Hooked hairs of climbing stems prevent them from slipping off their supports.
 Glandular cells on the cuticle secrete sticky substance that traps and kills insects and they may also secrete scent.
 The epidermal hairs of leaves reduce water loss from the plant as well as reflecting the sun's radiations.
 Being transparent, the epidermis allows passage of light in the mesophyll cells for photosynthesis.

Qn. ***State the various modifications of the epidermis to serve different functions***

b) Mesophyll cells (chlorenchyma)

Mesophyll is a packing tissue located between the upper and lower epidermis of leaves. There are two types of mesophyll cells.
 Palisade mesophyll cells:-They are located in the upper layer called the palisade mesophyll layer. Cells are elongated and columnar in shape. They contain a large number of chloroplasts. The cells are tightly packed with very few and narrow air spaces.
 Spongy mesophyll cells:-They are located in the lower layer called the spongy mesophyll layer. Cells are spherical and irregularly shaped with fewer chloroplasts. They possess large intercellular air spaces between the cells.

The functions of the mesophyll include**: photosynthesis**, **gaseous exchange and Storage of starch.**

Adaptations of the mesophyll to its function

i. Palisade mesophyll cells are column shaped with numerous chloroplasts in a thin layer of cytoplasm to carry out photosynthesis.
ii. Palisade mesophyll cells are tightly packed together forming a continuous layer that traps incoming light.
iii. The chloroplasts within the mesophyll cells can move towards light allowing them to be in the best positions to receive light.
iv. Spongy mesophyll cells are irregularly shaped hence fit together loosely leaving large air spaces to allow efficient gaseous exchange via the stomata.
v. The mesophyll cells contain numerous amyloplasts for storing starch.

c) Endodermis

It is the innermost layer of the cortex surrounding the vascular tissue of the roots and stems. It consists of living, elongated and flattened cells. The cell wall of endodermal cells comprises cellulose, pectins, hemicelluloses and deposits of suberin.

Functions of the endodermis

 Acts as a selective barrier to movement of water and mineral salts between the cortex and xylem in roots.
 In dicot stems, it stores starch forming a starch sheath with a possible role in the gravity response of stems.

Adaptations of the endodermis to its functions

 The endodermis of roots has the casparian strip (made up of suberin) which is impermeable to water and prevents water and solutes from flowing through the air spaces of the cell walls of the endodermal cells (apoplast pathway). This forces water through the cell surface membrane into the cytoplasm of the endodermal cells, hence allowing the endodermal cells to regulate the movement of solutes into the xylem.
 Active pumping of salts by endodermal cells into the xylem allows rapid movement of water by osmosis into the xylem leading to a buildup of root pressure.
 Control of movement of water and solutes by endodermal cells acts as a protective measure against the entry of pathogens and toxic substances into the xylem.
 In dicots, the endodemal cells contain amyloplasts for storing starch grains forming a starch sheath.

d) Pericycle

It is a layer of modified parenchyma, one to several cells thick, located in roots between the central vascular tissue and the endodermis. It consists of one to several layers of living, roughly spherical and elongated cells. Their cell walls are composed of cellulose, pectins and hemicelluloses.

Functions of the pericycle

 Produces lateral roots.
 Contributes to secondary growth

Adaptations of the pericycle to its function

 It retains its capacity for cell division (meristematic activity) to produce lateral roots.
 Due to its meristematic activity, it contributes to secondary thickening of the roots.

e) Companion cells

They are specialized parenchyma cells found adjacent to the sieve tubes.
They have a prominent nucleus, dense cytoplasm with numerous small vacuoles, plastids and the usual cell organelles. They are metabolically very active with numerous mitochondria and ribosomes. Each companion cell is connected to a sieve element by plasmodesmata.

Functions of the companion cells

 Control of the activity of the adjacent metabolically inactive sieve tube elements.
 Provide energy needed for the active processes which occur during translocation of organic solutes in the sieve tubes

Adaptations of the companion cells to their function

 Plasmodesmata connect sieve elements with companion cells allowing communication and exchange of materials between companion cells and sieve tube elements.
 Companion cells have large nucleus to effect metabolic activity of both companion cells and sieve tubes.
 Companion cells contain numerous mitochondria to produce energy for active transport of

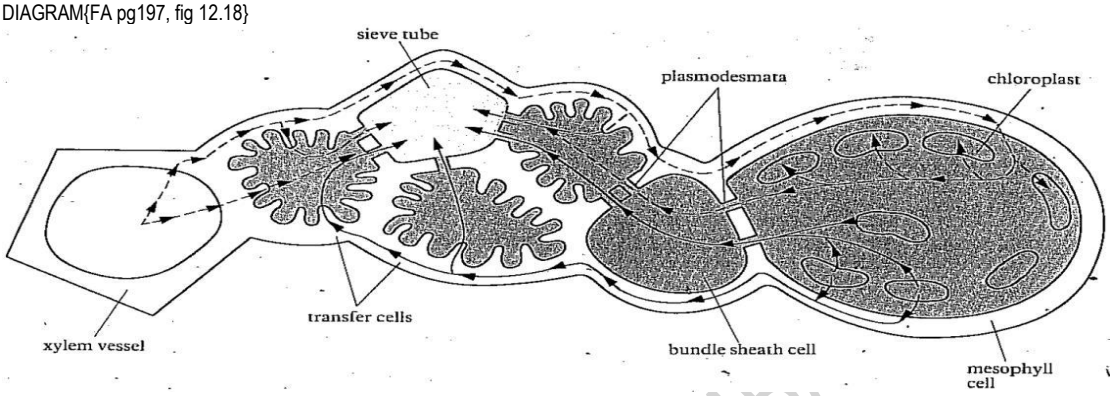
materials in the sieve elements.

f) Transfer cells

They are modified form of parenchyma cells which have numerous internal projections(irregular intuckings) of the primary cell wall and plasma membrane. They posses numerous mitochondria in the dense cytoplasm. Like companion cells, they are associated withphloem sieve tubes. However transfer cells are not confined to the phloem. They are found in a number of places where active transport is thought to occur, forexample in the water-secreting glands(hydathodes) at the edges of certain leaves, and in the secretory tissues inside nectarines. They also occur in salt-secreting glands in the leaves of the saltbush Atriplex, a halophyte which lives in dry, saline soil.

- In the leaf, transfer cells are responsible for moving the products of photosynthesis from the mesophyll cells to the sieve tubes(phloem loading).
- They also carry water and salts from xylem vessels to the mesophyll cells and to the sieve tubes too.

DIAGRAM{FA pg197, fig 12.18}

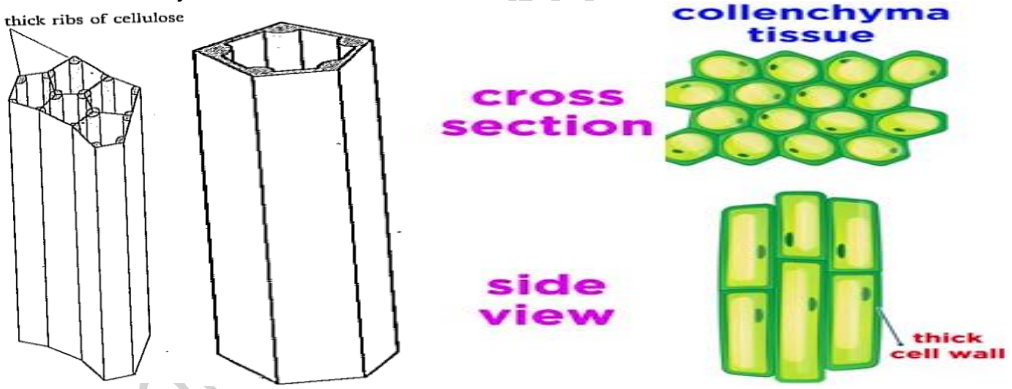


- Numerous internal projections of the cell wall and cell membrane increase the surface area and bring the cell membrane to closer association with the cytoplasm.
- Numerous mitochondria in their cytoplasm provide energy for active transport of organic solutes such as sugars from neighbouring cells.
- Have a large amount of starch granules which are broken down to glucose for aerobic respiration.

3) COLLENCHYMA

Collenchyma consists of living cells modified to give support and mechanical strength. The collenchyma is the first mechanical tissue to develop in the primary plant body.

Structure of collenchyma tissue



Distribution and functions

Collenchyma cells which are relatively flexible provide support for plant organs allowing them to bend without breaking.

It is mainly found in young plants, herbaceous plants and in organs such as the leaves in which secondary growth does not occur.

In the leaves, they are mainly found in the midribs of dicotyledonous leaves.

They are also located at the periphery of the organs usually under the epidermis.

Adaptations of collenchyma to its function

- Deposition of extra cellulose at the corner of the cells leads to development of unevenly thickened cell walls to provide support and mechanical strength.
- Cells are living and can grow and stretch, thus provide mechanical strength without imposing limitations on the growth of the other cells around it, allowing continued growth in young stems and leaves.
- Cells are located towards the periphery of the organ just below the epidermis in the outer regions of the cortex to increase its support value in stems and petiole.

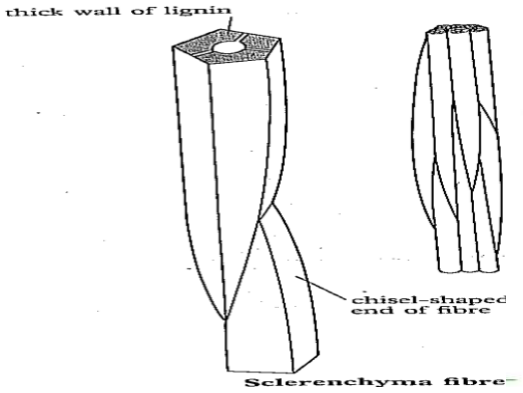
4) SCLERENCHYMA

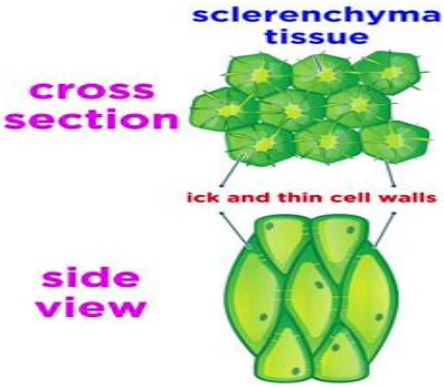
These can only elongate when they are young. The mature cells are dead, incapable of elongation and contain no cytoplasm. The primary cell wall is composed of cellulose, pectins, hemicelluloses and thickened with deposits of lignin. Its thick cell walls contain simple pits, areas where lignin is not deposited on primary wall due to presence of a group of plasmodesmata.

There are two types of sclerenchyma cells that is **fibres** and **sclereids.**

Fibres

The cells are elongated and hollow with narrow lumens. The cells are polygonal in shape with tapering interlocking ends. The fibres are found in the outer regions of the **cortex, pericycle of stems, xylem and phloem**. Its structure is as illustrated below;





Sclereids (stone cells) which are roughly spherical or irregular in shape they are found in the **cortex, pith, phloem, shells and stones of fruits, seed coats**. Its structure is as illustrated below;

Adaptations of sclerenchyma to its function

- Have elongated fibres and spherical sclereids closely packed together to provide mechanical support.
- The primary cell wall is heavily thickened and lignified with heavy deposits of lignin, with great tensile strength and compression strength for support and mechanical protection.
- High tensile strength of lignified walls prevents breakage on stretching.
- High compression strength of the lignified walls prevents buckling or crushing under pressure.
- Fibres are arranged into strands or sheets of tissue that extends longitudinally to provide combined collective strength.
- Ends of cells of fibres interlock with the tapering ends of one another increasing combined supportive strength.

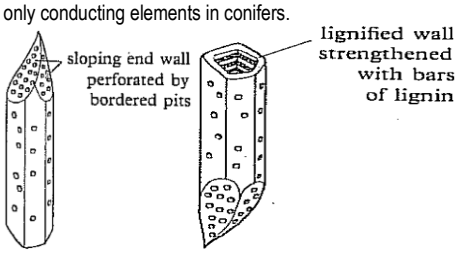
XYLEM

It is a vascular tissue with two main functions; conductance of water and mineral salts and providing mechanical support to the plant. The xylem consists of four types of cells; tracheids, vessels elements, parenchyma and fibres.

Tracheids

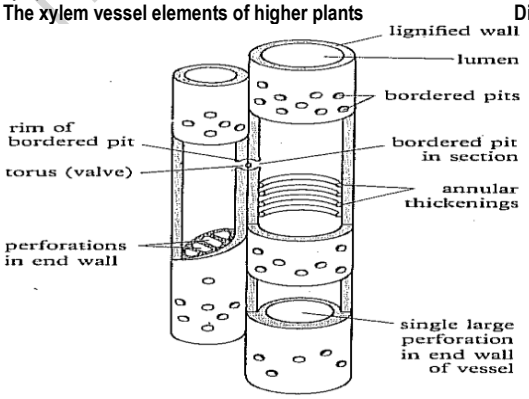
They are single cells with thick walls extensively lignified by heavy deposits of lignin. Some parts are not lignified forming bordered pits. They have tapering end walls that overlap with adjacent tracheids. They are dead with empty lumens when mature. The cells are polygonal in cross section with 5 or 6 sides.

The tracheids represent the original primitive water conducting cells of vascular plants. They are the only cells found in the xylem of the more ancestral vascular plants and are the only conducting elements in conifers.

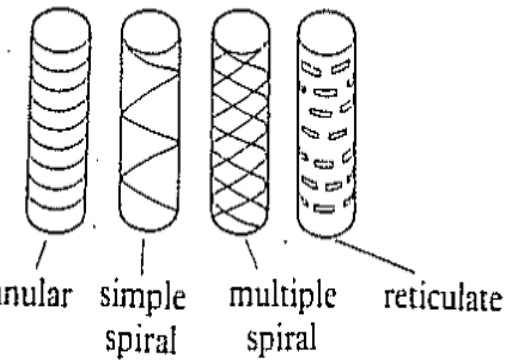


Xylem Vessels ; A vessel is formed from a chain of elongated cylindrical cells (vessel elements) placed end to end. The cellulose side walls of the vessel elements are heavily lignified rendering them impermeable to water and solutes. The lignified walls are perforated by numerous pits called bordered pits where lignin fails to be deposited and only the primary cell wall remains. In the course of development the horizontal end walls of vessel elements break down partially or completely so that the cells are in open communication with each other. Mature vessel elements (cells) lack cell membrane and cytoplasmic contents. Vessel elements are shorter and wider than tracheids.

The xylem vessel elements of higher plants



Different types of thickening found in vessels



Differences between vessels and tracheids

Vessels	Tracheids
They are cylindrical in shape.	They are 5 or 6 sided in cross section
Have open ended walls on either sides	Have perforated closed end walls.
Have no tapering ends.	Have tapering ends.
Offer less resistance towards water passage.	Offer a significant or more resistance to water passage.
Fast conduction of large volume of water.	Conduction of less volume of water.

NB:

1.The xylem fibres provide additional mechanical strength to the xylem.

2. The xylem parenchyma serve functions such as food storage, deposition of tannins, crystals and other chemical compounds, radial transport of food and water and gaseous exchange through intercellular spaces.

Adaptations of xylem to its functions

1. Xylem vessels and tracheids consist of long cylindrical cells joined end to end, hence are continuous with each other ensuring continuous flow of water in a continuous unbroken column.

2. Endwalls of the xylem vessels are completely broken down to form continuous tubes that allow uninterrupted flow of water.

3. Tracheids are perforated with numerous cellulose bordered pits that allow water to pass from one cell to another in lateral directions.

4. During development, the protoplasmic contents of vessels and tracheids die and disappear leaving empty hollow lumens, permitting uninterrupted flow of water without obstruction by living content.

5. Impregnation of cellulose walls with lignin increases adhesion of water molecules to walls thereby facilitating the rise of water by capillarity.

6. Lignifications of walls confer rigidity preventing walls from collapsing under large tension forces set up by the transpiration pull.

7. Narrowness of lumens of vessels and tracheids increases the rise of water by capillarity.

8. Xylem fibres have extremely thick walls which are heavily lignified and with narrow lumens to provide additional mechanical strength and support to the xylem

PHLOEM

It is a vascular tissue modified for translocation of manufactured food. It is composed of five types of cells i.e sieve tube elements, companion cells, parenchyma, fibres and sclereids.

Sieve tubes

They are long tube-like structures formed by end to end fusion of cells called **sieve tube elements/sieve elements.** The sieve elements have walls made of cellulose and pectins, but their nuclei degenerate and are lost as they mature.

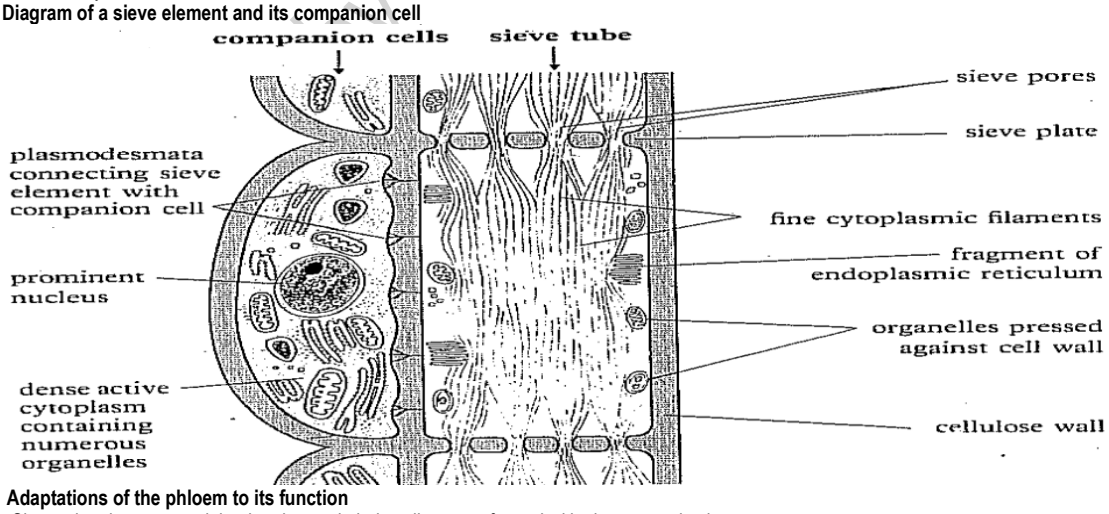
The cytoplasm is confined to a thin layer around the periphery of the cell. Sieve elements are living but metabolically depend on adjacent companion cells. In between the sieve tube elements are **sieve plates**, formed from the two adjoining end walls of neighbouring sieve elements.

The sieve plates are perforated by sieve pores formed by enlargement of plasmodesmata. The sieve plates are made up of a polysaccharide called **callose.**

Companion cells

They have a thin cell wall and dense cytoplasm with a prominent large nucleus, numerous mitochondria, plastids and small vacuoles and extensive endoplasmic reticulum. Companion cells are metabolically active and essential for the survival of sieve elements.

Diagram of a sieve element and its companion cell



Adaptations of the phloem to its function

- Sieve tube elements are joined end-to-end; their walls are perforated with sieve pores in sieve plates allowing passage of materials unimpeded from one cell to another.
- Sieve elements lack nuclei and possess a thin cytoplasm pushed to the sides of the cell, creating room for passage of organic materials in solution with minimal obstruction.
- Plasmodesmata connect sieve elements to companion cells which are metabolically active allowing communication and exchange of materials between sieve elements and companion cells.
- Sieve elements contain cytoplasmic filaments continuous with similar filaments in other sieve elements via sieve pores in the sieve plate, which consist of a contractile phloem protein capable of streaming and sliding organic materials from one sieve element to another by wave like movements of the filaments.

 Companion cells possess numerous mitochondria to provide energy in form of ATP for active transport of materials.
 Modified parenchyma companion cells called transfer cells found next to sieve tubes bear numerous internal projections increasing surface area of the cell membrane and also contain numerous mitochondria producing energy for active uptake of solutes from neighbouring cells during loading of sieve tubes.
 Phloem consist of living cells allowing live active transport of materials since the mechanism of loading sieve tubes and transport of solutes requires energy.
 Sclereids are lignified to provide support to the vascular tissue of the phloem.
 The companion cells are elongated and thin walled to provide a large surface area for diffusion of materials to the neighbouring cells.