

## PLANT HISTOLOGY

Plant tissues are formed from special groups of cells called meristems and may be grouped into two main types depending on their ability to divide, namely

- Meristematic tissues
- Permanent tissues

### MERISTEMATIC TISSUES

A meristem is a group of cells which are able to divide continuously by mitosis to form

new cells. In plants, growth is restricted to meristematic regions only. There are two

main categories of meristems:

a) Primary meristem

- Formed from the initial meristematic cells called primordial cells present in a small region at the apices of roots and shoots. Primordial cells actively divide by mitosis to give rise to primary meristematic tissue. Primary meristems give rise to permanent tissues which form the primary plant body. They are responsible for primary growth which involves increase in length of plant parts. Basing on position, primary meristems can be referred to as:

i) Apical meristem: found at the apex of a growing root and shoot. Divides continuously and brings about increase in length of shoot and root (primary growth) or

ii) Intercalary meristem: Present at regions away from the apical meristem e.g. at base of internodes, at the base of leaves and are capable of forming flower and branches. It is the meristem that enable grasses to regrow lost parts like when eaten by herbivores. The apical meristems are the major primary meristems in all

plants. It is divided into three groups of cells, each giving rise to a different permanent plant tissue:

♣ protoderm: gives rise to epidermal primary tissues which has a protective function.

♣ Procambium: gives rise to primary vascular tissues- primary xylem and primary phloem and vascular cambium.

♣ Ground meristem; gives rise to ground tissues- pith, pericycle, endodermis, and cortex.

b) Secondary meristem; Meristem developed from primary permanent tissues, hence not present at the very beginning of formation of the organ but develops at a later stage and gives rise to secondary permanent tissues (xylem and phloem). Secondary growth (increase in girth/diameter/thickness of plant part) occurs due to the activities of this type of meristem. Secondary growth generally occurs in shrubs and trees (mostly dicots). Secondary meristems are called lateral meristems owing to their function i.e cause lateral growth/expansion of the primary plant body. They include:

- The vascular cambium
- Cork cambium beneath the epidermis.

### **Permanent tissues**

permanent tissues These are plant tissues formed due to division and differentiation of meristematic tissue, and are composed of living or dead cells, which have lost their ability to divide. There are two main types of permanent plant tissues; namely

- Simple permanent tissues: include parenchyma, collenchyma, and sclerenchyma.

- Compound permanent tissues (xylem and phloem)

1. Simple plant tissues: Tissues which are homogenous in nature, consisting of one type of cell, which are structurally and functionally similar. They include:

(1) Parenchyma, (distributed/found in the cortex, pith, medullary rays, packing tissue in xylem and phloem.); for support, secretion, photosynthesis, storage and transport

1. Chloroplast centre for photosynthetic activity.
2. Cells roughly spherical and tightly packed in small spaces for support to non woody parts of the plant.
3. Inelasticity of cellulose cell wall provides support to plant when parenchyma cells are turgid.
4. Large central vacuole containing salts and sugars which make it osmotically active hence able to provide support by turgidity.

Modified/specialized parenchyma: one which is modified to perform a particular function. Below are examples of modified parenchyma.

1. Epidermis; outermost layer (usually one layer of cells) of plant body which has direct contact with external environment,
  - Epidermis consists of parenchyma cells which are elongated, flattened, compactly arranged cells without any intercellular air space forming one cell-thick layer which constitute continuous layer that cover the whole plant body.
  - The cells have a large central vacuole; thin layer of protoplasm;
  - The outer wall of epidermis is thick and usually covered with cuticle-a water proof layer of wax material called cutin (leaves and stems) secreted by the epidermal cells.
  - Epidermal tissue has pores called stomata (leaves); and lenticels on stem epidermis. The pores allow diffusion of gases through them; to allow for gaseous exchange to take place between living cells and the external environment. Each stoma on the leaf epidermis is surrounded by two kidney shaped cell called guard cells. Guard cells differ from typical

epidermal cell in that (i) contain chloroplasts (ii) their inner wall is thicker than the outer wall

- The epidermis may also have epidermal appendages(outgrowths on the epidermis) which vary markedly in shape, structure and function such as: }  
reducing excessive water loss by hairs/trichomes } increase surface area for  
dispersal of fruits and seed by wind } protection against injury by thorns }  
root hairs formed by elongation of the root epidermis play an important  
role of anchoring the plant body firmly in soil; and increasing surface area  
for absorption of water & mineral salts from soil.

2. Chlorenchyma/photosynthetic parenchyma. Chlorenchyma cells which contain chloroplasts; hence function as main site for photosynthesis  
Examples include: leaf Mesophyll tissues, cells in outer cortex of young stem etc. There are two categories of chlorenchyma cells recognized in leaf mesophyll depending on their location in leaf;

Palisade Mesophyll; upper layer made up of compactly arranged column-shaped/rectangular cells with numerous chloroplasts in dicots. In monocots, they are concentrically arranged around bundle sheath cells which also form a ring around the leaf vascular bundle.

Spongy Mesophyll; lower layer of more irregularly oval shaped cells with fewer chloroplasts & large intercellular spaces

3. Endodermis: is the innermost layer of the cortex which completely surrounded by the stele (stele is the whole central mass of vascular tissues with the pith if present. Cells have special thickening called the casparian strip. Endodermal parenchyma cells form a selective barrier to movement of water and mineral salts between the root xylem and cortex.
4. Pericycle: Roughly spherical shaped, elongated cells found in roots between central vascular tissue and endodermis. Pericycle functions to produce lateral roots,
5. Aerenchyma; parenchyma with large air spaces filled with air. In hydrophytes, the parenchyma develops large air spaces to store air in order to provide buoyancy to such aquatic plants

Note: Parenchyma tissues are located in the cortex, pith and as packing tissues in the xylem and phloem.

**Sclerenchyma**; main supportive tissue in plants.

Mature sclerenchyma cells are dead, with thickened highly lignified walls.

The tissue is made of two types of cells: fibres and sclereids

- Fibres: cells elongated; narrow with thick walls and empty lumen, pointed/tapering at both ends, cells have simple/bordered pits/unthickened areas

Sclereids; cells are oval/spherical, have narrow lumen, thickened /lignified walls.

- Both cells have their primary cellulose cell wall thickened with lignin, with tubes of constant width/simple pits where no lignin is deposited owing to the presence of plasmodesmata.

- No intercellular spaces exist between cells

Adaptation of sclerenchyma to their function:

- Cells have highly lignified walls to give the tissue great tensile strength for support.
- Arranged closely into strands or sheets of tissues to that extend for considerable distances longitudinal direction to provide support
- End walls of adjacent cells interlock to provide combined strength.

Distribution of sclerenchyma tissues: fibres are found in the pericycle of the stem, form a layer in the cortex below the epidermis of the stems or roots (form a hollow cylinder that contains the rest of the cortex and vascular tissues. Fibres also occur in both xylem and phloem; Sclereids are scattered singly or in groups any where in a plant; more common in the cortex, pith, phloem, fruits and seeds.

### **Mechanical support in plants**

- **In non wood herbaceous plants; parenchyma is the main mechanical tissue. Parenchyma cells found in the cortex, pith, and xylem and phloem tissue take in water from the surrounding xylem and become turgid.**

**At full turgidity, the cells form a rigid structure that enables the stem, leaves and other parts to take up their normal positions; support is also supplemented by**

the smaller amounts of sclerenchyma, collenchyma and xylem especially in the leaf stalk and leaf veins.

- In young woody plants, support is provided by turgidity of cells through their osmotic properties due to the presence of the inelastic cellulose cell walls, after they absorb water by osmosis, cells expand becoming compactly packed and turgid which confers mechanical strength hence supporting the young plant off the ground support is also supplemented by

- In older woody plants mechanical support is provided by the sclerenchyma and collenchyma which have more mechanical strength than parenchyma; Collenchyma is located in the hypodermis (outer region of cortex), while the sclerenchyma is located in the cortex, pith, phloem, and xylem. Hence the mechanical tissue is composed of sclerenchyma, collenchyma and xylem & pith. In roots, generally, the mechanical tissue is distributed around the central stele (pith and xylem) where they exert resistance force to pull of shoots which is often blown from side to side and also resist compression forces from the soil. In stems, mechanical tissues are distributed around the vascular bundles, cortex, pith and pericycle around the periphery of the stem, well positioned to resist compression and expansion of the stem as it bends.

The tissues involved herein provide/achieve mechanical support to wood plants in following way

1. Sclerenchyma tissue has cells with thick lignified cellulose cell walls giving rigidity/ great tensile strength to the plant.
2. The walls of the xylem vessels and tracheids are thick and lignified which keeps them hard thus giving mechanical support to the plant.
3. The central distribution of the xylem significant in that it helps the root to withstand the tugging strains of the aerial parts when the shoot is blown or bend sideways.
4. The peripheral distribution of most mechanical tissues in the stem with the xylem existing as a separate rod throughout the entire stem offers maximized support to shoot against bending.

**5. Secondary thickening in the xylem cells deposits more wood/ xylem tissue to provide greater support.**

**In non vascular plants support is provided by turgidity of cells through osmotic properties due to inelasticity of the cell walls.**

### **COMPOUND PLANT TISSUE**

These are made of more than one type of cells performing specific function. They are generally called vascular tissues; which include the xylem and phloem.

The xylem/ wood tissue

Structure of Tracheids

- A Tracheid is a single non living/dead cell that is highly elongated /tube-like cell with hard, thick lignified walls & posses empty lumen. They have tapering ends that overlap with adjacent tracheids.
- secondary wall of Tracheid posses various kinds of thickenings and can be identified as annular/inform of rings, spiral, reticulate, Scalariform or pitted (simple pitted or bordered)
- Xylem vessel; these, are long tubular structure formed by fusions of many cells end to end. Each cell forming xylem vessel is equivalent to a Tracheid and is called vessel element.
- Just like in the Tracheid, xylem vessel is composed of conducting cells (equivalent to Tracheid) which nonliving highly elongated, tube-like with hard, thick and lignified walls. Cells lack end walls and are connected end to end to form continuous pipeline with large lumen for conducting water and mineral salts.
- secondary wall of vessel element posses various kinds of thickenings and can be identified as annular/inform of rings, spiral, reticulate, Scalariform or pitted (simple pitted or bordered) just like the case with Tracheid
- Vessel element are better at conducting water because their arranged in longitudinal series in which the transverse wall/endplate are perforated.

NB. (i) Tracheid occurs alone in ferns but in wood of ferns and gymnosperms while in angiosperms, they occur with vessels. (ii) Vessels occur in some pteridophytes and gymnosperms however they occur almost all angiosperms.

Scalariform thickening is similar to reticulate but with fewer interconnections between the bars of thickenings. It less commonly seen because it usually grades into reticulate thickening by further lignification. Xylem parenchyma;

- Xylem parenchyma cell has thin cell wall and living contents just like a typical parenchyma cell, xylem parenchyma cells are more common in the primary xylem than in the secondary xylem.

- Xylem parenchyma cells of the primary xylem are thin-walled and made up of cellulose while xylem parenchyma of the secondary xylem cells are thick-walled and lignified,

Function

- (i) Conduction of water and mineral salts,
- (ii) Storage of water/food.
- Xylem fibres. Sclerenchymatous cells associated with the xylem are called xylem fibres. Xylem fibres are long, slender/narrower, thick and lignified.

Adaptations of xylem tissue to its functions

1. End walls of vessel elements breakdown during development; forming vessel tubes; for continuous movement of water;
2. Xylem vessels are hollow/lack protoplasm; to allow water to move continuously without obstruction/ to allow unimpeded flow of water.
3. Tracheids have tapering /sloping/ overlapping end wall for firm connection between adjacent cells; and the end walls contain bordered pits; to allow movement of water from one cell to another;
4. Tracheids are long and narrow; to increase capillarity;
5. The cell walls of the vessels elements and tracheids are highly lignified; to make them impermeable such that water does not escape/leak during transport;

lignification (annular and spiral thickening) also increases mechanical strength of the tissue; hence preventing collapse during transport of water; and provides structural support to the whole plant;

6. The side walls of both xylem vessels and tracheids; are perforated/have numerous pits; to allow water and mineral salts to move sideways between the cells.

B. THE PHLOEM The phloem resembles the xylem in presenting tubular structures modified for translocation of organic substance. However, phloem tubes are composed of living cells with cytoplasm and have no mechanical function.

Structure of phloem; • Vascular conducting tissue composed of 4 (or 5) types of cells; namely,

1. Sieve tube elements,
2. Companion cells
3. Phloem parenchyma
4. Phloem fibres

- Sieve tubes are living, long, tubular, connected end to end. their cell walls are thin and made up of cellulose material. They have large cavities with transverse walls lying obliquely and perforated with many sieve pits to form sieve plates. Though without the nucleus, sieve tubes are living layers of protoplasmic strands connected through sieve pits from one cell to another.

- Companion cells are living, elongated, thin-walled cells with prominent dense and very active cytoplasm lying close and parallel to sieve tubes. Companion cells have a nucleus; and it the nucleus of companion cell that control activities of adjacent sieve tube.

- Phloem parenchyma: cylindrical sub spherical with dense nucleus and cytoplasm.

- Phloem fibres are long unbranched with pointed apices. At maturity, they lose their protoplasm and become dead.

Adaptation of the phloem to it functions;

1. The sieve tube cells are long, tubular and arranged end to end to form continuous channel for the translocation of organic materials.
2. Large cavities in sieve tubes for mass flow of material.
3. Sieve plate perforated by pores to for continuous flow of organic substances from one sieve tube element to the next.
4. Sieve tube cells have no nuclei to avail more space for translocation of organic substances
5. Companion cells are very metabolically active to sustain the metabolic needs of sieve tubes
6. Companion cells have numerous mitochondria hence is chief respiratory centre releasing energy for active uptake of organic materials
7. Sieve tube lye very close and parallel to companion to allow for functional association between cells of the phloem.
8. Phloem parenchyma for storage of organic substances and slow conduction
9. Phloem fibres provide mechanical support to the phloem

## ANIMAL HISTOLOGY

Animal tissues are divided into:

- Epithelial tissues
- Areolar tissues
- Connective tissues
- Skeletal tissues

### EPITHELIAL TISSUES

**Epithelial Tissue** is one of the four types of tissue (epithelial, muscular, connective, and nervous) in animals which consists of closely aggregated polyhedral cells adhering firmly to one another, forming cellular sheets that line the interior of hollow organs and cover the body surface. An epithelial tissue or epithelium (plural is epithelia) consists of cells arranged in continuous sheets, in either single or multiple layers.

#### **Characteristics of Epithelial Tissue**

- Even though epithelial tissue present in different parts of the body might differ in structure and function, they all have some common characteristics.
- Some of these characteristics are given below:
  1. **Shape and Size**
    - The shapes and sizes of epithelial cells are variable, ranging from tall columnar to cuboidal to low squamous.
    - The cell's size and morphology are generally based on their function.
  2. **Polarity**
    - Epithelial cells generally show polarity, with organelles and membrane proteins distributed unevenly within the cell.
    - The apical (free) surface of an epithelial cell is present towards the body surface, the body cavity, the lumen of an internal organ, or a gland duct that receives cell secretions. Apical surfaces may contain cilia or microvilli.

- The lateral surfaces of an epithelial cell, facing the adjacent cells on either side, may contain intercellular adhesion and other junctions.
- The basal surface of an epithelial cell adheres to extracellular materials such as the basement membrane, which is an inert connective tissue made by the epithelial cells themselves.

### **3. Basement Membrane**

- The basement membrane is a thin extracellular layer that commonly consists of two layers, the basal lamina, and the reticular lamina.
- The basal lamina is closer to and secreted by the epithelial cells and contains proteins like laminin and collagen as well as some glycoproteins and proteoglycans.
- The reticular lamina is closer to the connective tissue, present underneath, and contains collagen protein produced by connective tissue cells called fibroblasts.

### **4. Intercellular Adhesion and Other Junctions**

- Several membrane-associated structures provide adhesion and communication between cells.

### **5. Avascular**

- Epithelial tissue is avascular, relying on the blood vessels of the adjacent connective tissue to bring nutrients and remove wastes.
- The exchange of substances between epithelial tissue and connective tissue occurs by diffusion.

### **6. Innervated**

- Epithelial tissue is innervated; that is, it has its own nerve supply.

### **7. Renew and Repair**

- Epithelial cells have a high rate of cell division which allows the epithelial tissue to continually renew and repair itself by sloughing off dead or injured cells and replacing them with new ones.

## Functions of Epithelial Tissue

Based on the location, epithelial tissue performs a bunch of functions. Some of which are:

### Protection

- One of the most critical functions of epithelial tissue is protection. It protects the cells present below against radiation, desiccation, invasion by pathogens, toxins, and physical trauma.
- The absence of blood vessels in the epithelial tissue thus prevents bleeding in the tissue during abrasion.

### Transportation

- Epithelial tissue also functions in the transportation of different molecules in and out of the cells with different pumps present in the epithelial tissue.
- Besides, in the [digestive](#), respiratory, and urinary system, it allows the exchange of molecules between the underlying cells and the body cavity, capillaries, and ducts.

### Secretion

- Glandular epithelium secretes various macromolecules like hormones responsible for multiple bodily functions.
- Many endocrine and exocrine glands also help maintain the body surfaces (skin) as well as support the functions of various organs (digestive system).

### Absorption

- By the function of various specialized structures like cilia and microvilli on the surface of cells, epithelial tissue also aids in the absorption of multiple molecules by increasing the surface area.
- In the digestive system, columnar cells of the small intestine help in the absorption of water and various other nutrients.

### Receptor function

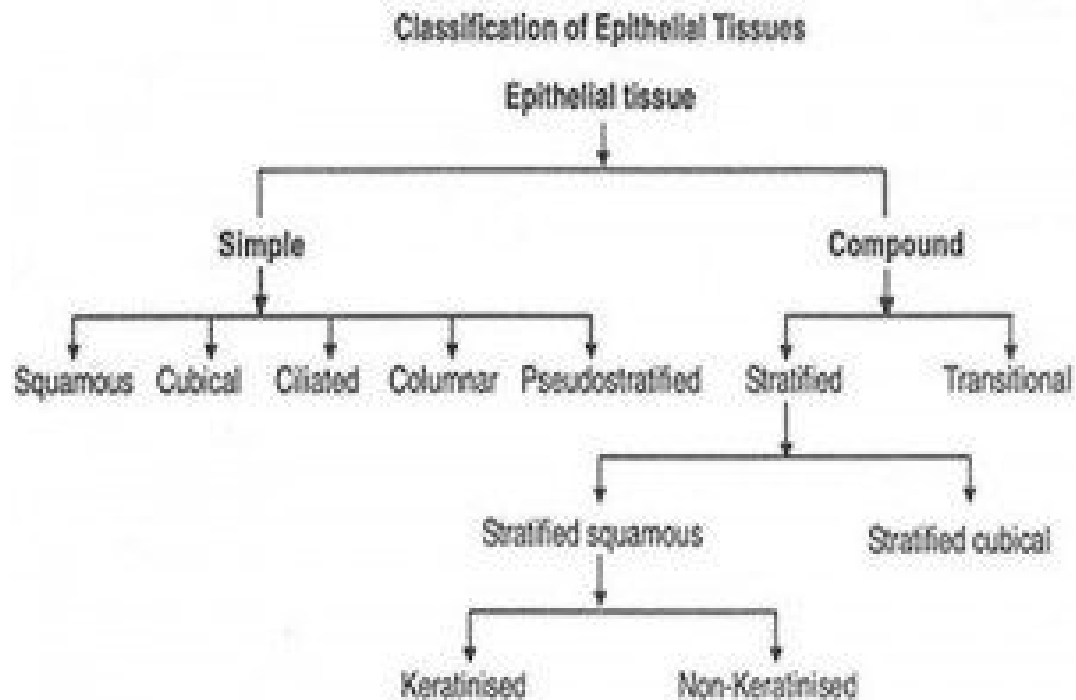
- Some cells in the epithelial tissue are specialized to perform sensory functions that can detect the sensory information and convert them into neural signals.
- Cells in epithelial tissue like the pseudostratified columnar epithelium of the olfactory mucosa contain apical cilia that allow the sensation of odor.

### **Types / Classification with examples and location**

Epithelial tissue is divided into two types:

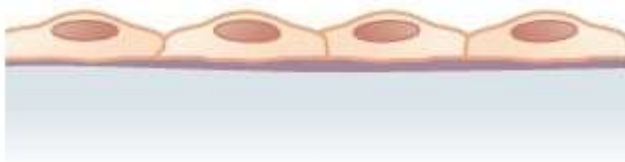
1. **Covering and lining epithelium**, also called the surface epithelium, that forms the outer covering of the skin and some internal organs and also forms the inner lining of blood vessels, ducts, body cavities, and the inner lining of the respiratory, digestive, urinary, and reproductive systems.
2. **Glandular epithelium** that makes up the secreting portion of glands such as the thyroid gland, adrenal glands, sweat glands, and digestive glands.

Further, types of covering and lining epithelial tissue are classified according to the arrangement of cells and the shapes of those cells.



## Simple epithelium

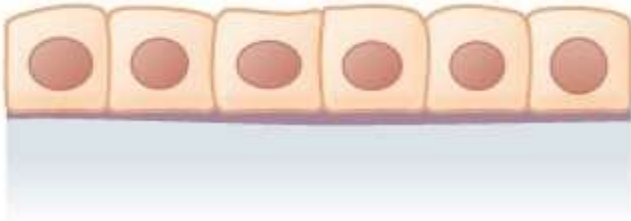
- Simple epithelium is made up of a single layer of identical cells, which are usually found on secretory and absorptive surfaces, where the single layer enhances these processes.
- Simple epithelium is divided into three main types, and these are named according to the shape of the cells, which differ based on their functions.
- The simple squamous epithelium consists of a single layer of flat cells that resembles the tiles on a floor when viewed from the apical surface with a centrally located nucleus that is flattened and oval or spherical.
- This epithelium most commonly lines the cardiovascular and [lymphatic system](#) (heart, blood vessels, lymphatic vessels), where it is known as **endothelium** and forms the epithelial layer of serous membranes (peritoneum, pleura, pericardium), where it is called
- It is also found in air sacs of lungs, glomerular (Bowman's) capsule of kidneys, and the inner surface of the tympanic membrane (eardrum).



Simple squamous epithelium

## Simple cuboidal epithelium

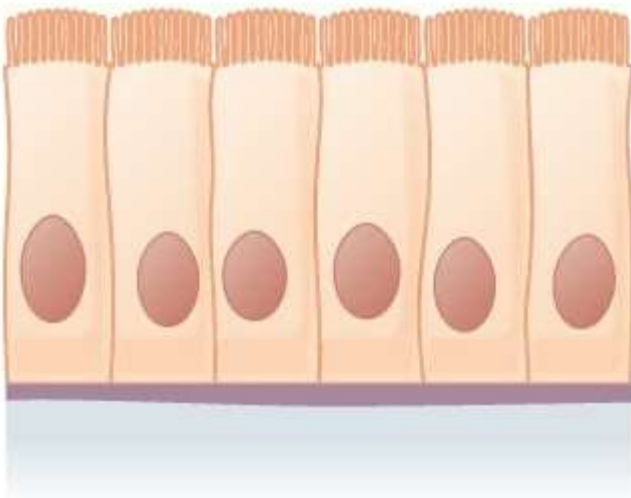
- Simple cuboidal epithelium is a single layer of cube-shaped cells that are round and have a centrally located nucleus.
- It covers the surface of the ovary, lines the anterior surface of the capsule of the lens of the eye, forms pigmented epithelium at the posterior surface of retina of the eye, lines kidney tubules and smaller ducts of various glands, makes up secreting portion of some glands like the thyroid gland and ducts of some glands such as the pancreas.



Simple cuboidal epithelium

### Simple columnar epithelium

- The columnar epithelium is made by a single layer of cells, rectangular in shape, on a basement membrane.
- This epithelium lines many organs and is often derived to make it well suited for a specific function.
- Columnar epithelium lines the stomach without any surface structures. However, the free surface of the columnar epithelium lining the small intestine is covered with microvilli, which provide a vast surface area for the absorption of nutrients from the small intestine.
- In the trachea, the columnar epithelium is ciliated. Also, it contains goblet cells that secrete mucus, and in the uterine tubes, ova are propelled along by ciliary action towards the uterus.

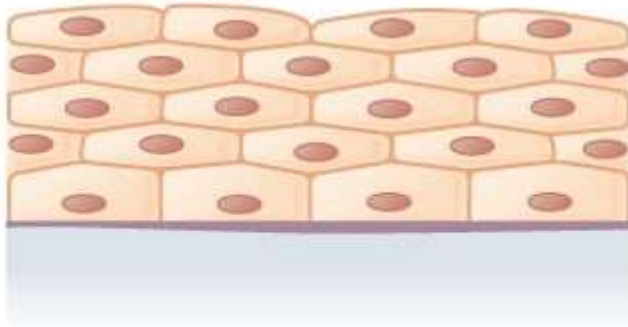


Simple columnar epithelium

### Stratified epithelium

- A stratified epithelium consists of several layers of cells of various shapes, and basement membranes are usually absent.
- As basal cells divide, daughter cells arising from cell divisions are pushed older cells upward toward the apical layer.
- As they move toward the surface and away from blood supply in underlying connective tissue, they become dehydrated and less metabolically active.
- Tough proteins predominate as cytoplasm is reduced, and cells become tough, hard structures that eventually die.
- At the apical layer, after dead cells lose cell junctions, they are sloughed off, but they are continuously replaced as new cells emerge from basal cells.
- There are two main types of stratified epithelium: stratified squamous, stratified cuboidal, and stratified columnar epithelium.

#### **a. Stratified squamous epithelium**



**Stratified squamous epithelium**

The stratified squamous epithelium has two or more layers of cells. The cells in the apical layer and several layers deep to it are squamous while the cells in deeper layers vary from cuboidal to columnar.

#### **i. Keratinized stratified squamous epithelium**

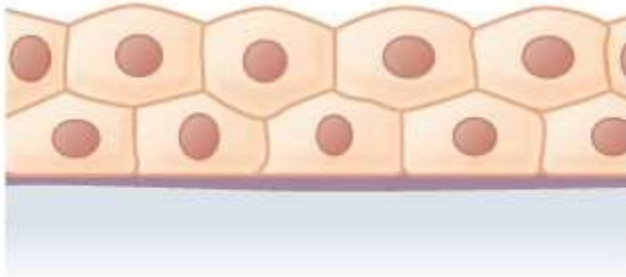
- This epithelium develops a tough layer of keratin in the apical segment of cells and several layers deep to it
- The relative amount of keratin increases in cells as they move away from the nutritive blood supply and the organelles eventually die.

- The keratin forms a tough, relatively waterproof protective layer that prevents drying of the live cells present underneath.
- Keratinized stratified squamous epithelium forms a superficial layer of skin.

### ii. Non-keratinized stratified squamous epithelium

- This epithelium does not contain large amounts of keratin in the apical layer, and several layers deep and is moistened continuously by mucus from salivary and mucous glands.
- Nonkeratinized stratified squamous epithelium lines wet surfaces (lining of mouth, esophagus, part of the epiglottis, part of the pharynx, and vagina) and covers the tongue.

### b. Stratified cuboidal epithelium

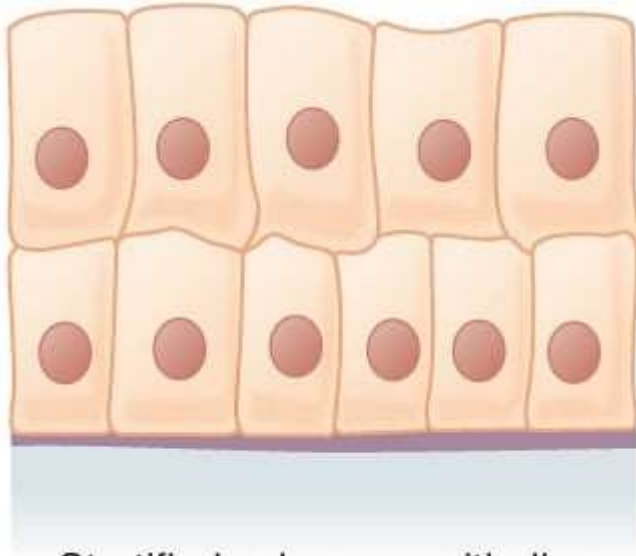


Stratified cuboidal epithelium

Image Source: [Rice University \(OpenStax\)](#)

- Stratified cuboidal epithelium has multiple layers of cells in which the apical layer is made up of cuboidal cells while the deeper layer can be either cuboidal or columnar.
- Stratified cuboidal epithelium is seen in the excretory ducts of salivary and sweat glands.

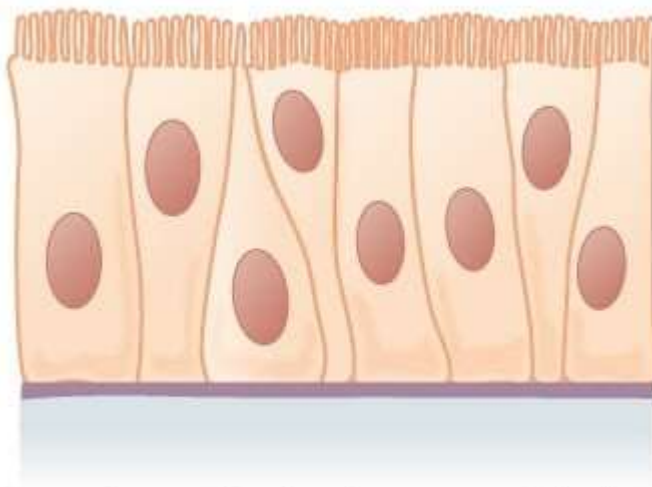
### c. Stratified columnar epithelium



**Stratified columnar epithelium**

- The stratified columnar epithelium has multiple layers of cells in which the apical layer is made up of columnar cells while the deeper layer can be either cuboidal or columnar.
- This type of epithelium is present in the conjunctiva of the eyes, parts of the urethra, and the small area in the anal mucosa.

#### **Pseudostratified columnar epithelium**



**Pseudostratified columnar epithelium**

- Pseudostratified epithelium appears to have several layers because the nuclei of the cells are present at various levels.

- Although all the cells are attached to the basement membrane in a single layer, some cells do not reach the apical surface.
- As a result of these features, it appears as a multilayered tissue, but in fact, is the simple epithelium.
- This epithelium lines epididymis, larger ducts of many glands, and parts of male urethra and airways of most of the upper respiratory tract.

### Transitional epithelium tissue

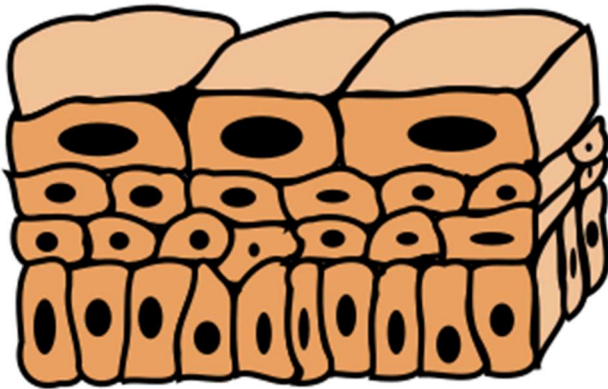


Figure: Transitional epithelium tissue.

- Transitional epithelium (urothelium) has a variable appearance (transitional).
- In a relaxed or unstretched state, looks like stratified cuboidal epithelium, except apical layer cells tend to be broad and rounded.

- As tissue is stretched, cells become flatter, giving the appearance of stratified squamous epithelium. Multiple layers and elasticity make it ideal for lining hollow structures (urinary bladder) subject to expansion from within.

### Glandular Epithelium

- Epithelial cells that function mainly to produce and secrete various macromolecules may occur in epithelia with other significant functions or comprise specialized organs called glands.
- Scattered secretory cells, sometimes called unicellular glands, are common in simple cuboidal, simple columnar, and pseudostratified epithelia.
- Glands develop from covering epithelia in the fetus by cell proliferation and growth into the underlying connective tissue, followed by further differentiation.

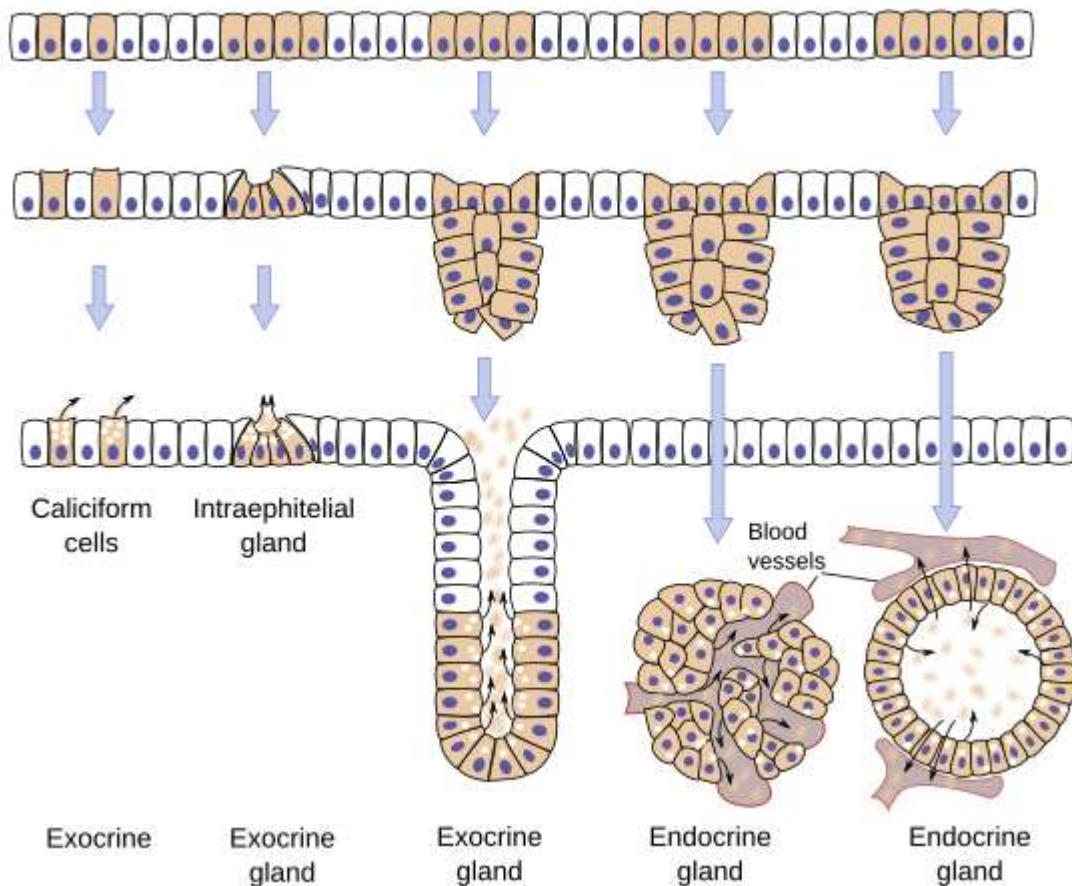


Figure: Main types of glands. Glands differentiate from epithelial tissues during embryo development. Arrows point to the released substances.

### **Endocrine glands**

- The secretions of endocrine glands, called hormones, enter the interstitial fluid and then diffuse into the bloodstream without flowing through a duct.
- Endocrine secretions have far-reaching effects because they are distributed throughout the body by the bloodstream.
- Examples of endocrine glands include pituitary gland at the base of the brain, the pineal gland in the brain, thyroid and parathyroid glands near larynx (voice box), adrenal glands superior to kidneys, pancreas near the stomach, ovaries in the pelvic cavity, testes in the scrotum, thymus in the thoracic cavity.

### **Exocrine glands**

- Exocrine glands secrete their products into ducts that release the secretions onto the surface of organs such as the skin surface or the lumen of a hollow organ.
- The effects of exocrine gland secretions are limited, and some of them would be harmful if they entered the bloodstream.
- Sweat, oil, and earwax glands of the skin, digestive glands such as salivary glands (secrete into mouth cavity) and pancreas (secretes into the small intestine) are the examples of exocrine glands.

## **CARDIAC MUSCLE**

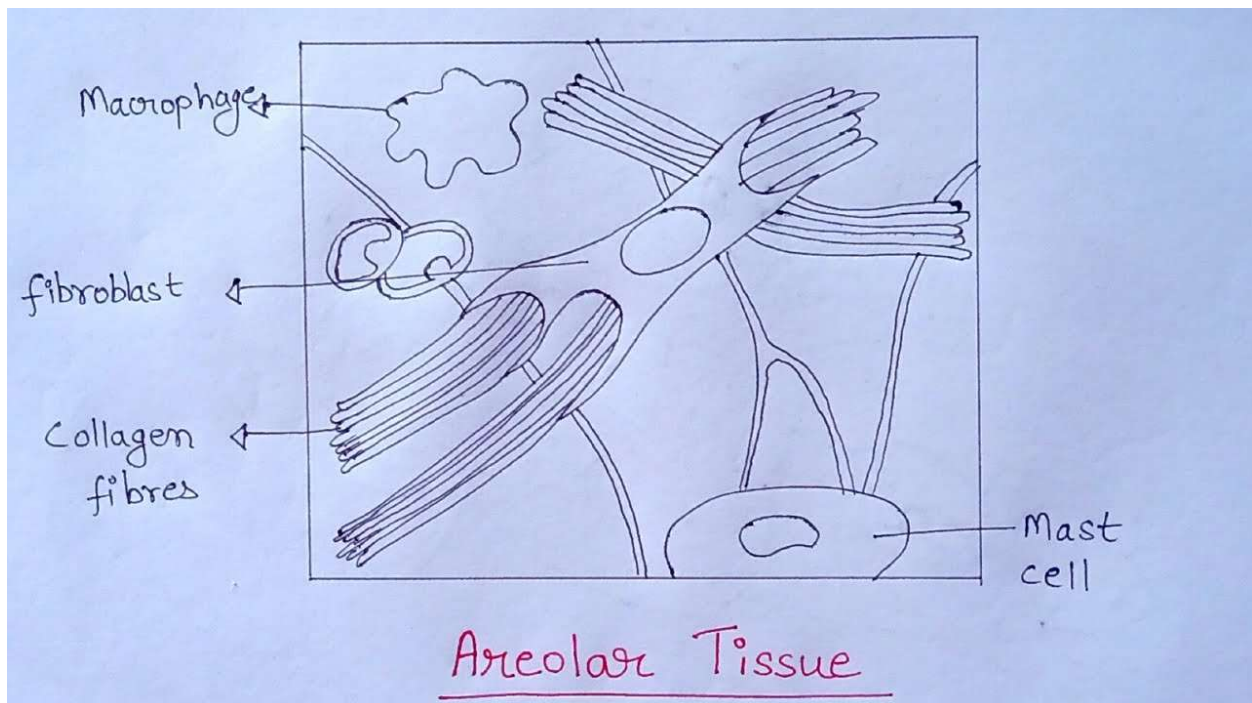
Cardiac muscle tissue, also known as myocardium, is a structurally and functionally unique subtype of muscle tissue located in the heart, that actually has characteristics from both skeletal and muscle tissues. It is capable of strong, continuous, and rhythmic contractions that are automatically generated. The contractility can be altered by the [autonomic nervous system](#) and hormones. In addition, this tissue type has high metabolic, energy, and vascular demands.

Cardiac muscle fibres are long, branched cells, shaped like cylinders joined end-to-end, with one or two nuclei located centrally. The fibres are separated by collagenous tissue that supports the capillary network of cardiac tissue.

The myofilaments of cardiac muscle are arranged in a similar pattern to skeletal muscle, resulting in cross-striations. The fibres are crossed by linear bands called intercalated discs. These structures have two important roles. Firstly, they provide attachment points that provides the tissue with a characteristic branched pattern. Secondly, they allow cardiac muscle tissue to function as a functional syncytium. Essentially, the contractile stimuli is propagated from one cell to the next one, resulting in a synchronous contraction of the entire tissue section.

While the majority of muscle cells within cardiac tissue are physically contracting, there is a special set that performs another role. They are called cardiac conducting cells and they automatically initiate and propagate the contraction impulses.

### AREOLAR TISSUES



The human body relies on diverse tissues to provide structure, support, and protection. Connective tissue is one of the four basic tissue types, and areolar

tissue is the most widely distributed form of loose connective tissue. It functions essentially as the body's flexible packing material, filling spaces between organs and binding different structures together. This tissue provides an open framework that allows for movement and the passage of necessary biological components, making it a generalized support system.

Areolar tissue is classified as a proper loose connective tissue, a term derived from the Latin areola, meaning a small open space. This designation reflects its structural characteristic of having loosely organized protein fibres and cells separated by a significant amount of extracellular material. Unlike dense connective tissues, such as those found in tendons, areolar tissue lacks a highly organized arrangement of fibres. Its sparse, open structure contributes to its flexibility and cushioning ability.

The microscopic structure of areolar tissue is defined by three main components: cells, protein fibers, and the surrounding ground substance. The resident cells are primarily fibroblasts, which secrete the protein fibers and complex molecules that form the extracellular matrix. These cells work to maintain and repair the structural framework of the tissue. The tissue also houses mobile cells, including macrophages and mast cells, which are integral parts of the body's defence system.

Areolar tissue contains an interweaving, random arrangement of all three major fibre types. Thick collagen fibres provide tensile strength, resisting pulling forces across the tissue. Interspersed with these are thin, branching elastic fibres, which allow the tissue to stretch and recoil. Reticular fibres, which are fine collagen strands, form a delicate meshwork that provides subtle structural support for the cells.

Filling the space between these cells and fibres is the ground substance, a viscous, transparent, gel-like fluid. This matrix is composed of water, salts, and large carbohydrate molecules known as glycosaminoglycans. The ground substance acts as the medium through which nutrients, waste products, and gases diffuse efficiently between the capillaries and the surrounding cells.

### **Primary Functions and Locations in the Body**

Areolar tissue is widespread, found in nearly every region of the body where structures need to be bound without sacrificing flexibility. One of its most recognized locations is beneath the skin, forming part of the subcutaneous layer where it anchors the skin to the underlying muscles. This non-rigid attachment allows the skin to slide freely over deeper structures during movement.

The tissue also forms thin sheaths that surround and protect blood vessels and nerve bundles, permitting them to move and flex without damage. Furthermore, it is a significant component of the lamina propria, the layer of connective tissue found directly beneath the epithelial lining of mucous membranes. This location is present in systems with external openings, such as the digestive and respiratory tracts.

Functionally, this tissue acts as a reservoir for water and dissolved salts, helping to maintain fluid balance for the surrounding cells. Its open framework provides cushioning and protection for delicate organs by absorbing minor shocks and distributing pressure. Since it is highly vascularized, the tissue also facilitates the rapid exchange of metabolic substances between the bloodstream and neighbouring cells.

## **SKELETAL TISSUES**

These include: the cartilage and the bone tissues.

Cartilage.

### **Structure of Cartilage**

Cartilage consists of 2 main elements:

- Specialised cells
- The extracellular matrix

Cartilaginous tissue is protected and mechanically supported by a fibrous covering termed the perichondrium (which functions similarly to the periosteum in bone).

### **The Specialised Cells**

- Cartilage consists of two main types of specialized cells: chondroblasts and chondrocytes. These cells play distinct roles in the development, maintenance, and repair of cartilaginous tissue.

- In summary, chondroblasts and chondrocytes are the main types of specialized cells found in cartilage. Chondroblasts secrete the extracellular matrix, becoming entrapped within it and transforming into chondrocytes. Chondrocytes, located within lacunae, maintain the cartilage by regulating the composition of the extracellular matrix and participating in its turnover and repair. The coordinated activity of these cell types is crucial for the development, maintenance, and repair of cartilaginous tissues in the body.

### **The Extracellular Matrix**

- The intricate composition of the extracellular matrix in cartilage, with its water, collagen fibres, and elastic fibres, ensures the tissue's unique properties. It provides strength, flexibility, shock absorption, and lubrication, enabling cartilage to perform its essential functions in the body.
- Collagen fibres are responsible for providing the cartilage with high tensile strength. They form a dense network throughout the tissue, creating a scaffold that helps maintain the structural integrity of the cartilage. The arrangement and orientation of collagen fibres contribute to the tissue's resistance to stretching and tearing.
- Elastic fibres provide elasticity and flexibility to cartilage, allowing it to deform and recoil without permanent damage. The ratio of collagen fibres to elastic fibres in cartilage varies depending on its specific function. For example, in weight-bearing cartilage, such as that found in the knees and hips, collagen fibres predominate to provide greater tensile strength. In contrast, cartilage in the outer ear requires more elasticity and flexibility, so the proportion of elastic fibres is higher.

### **Types of cartilage**

There are 3 types of cartilage

- **Hyaline**
- **Elastic**
- **Fibro-cartilage**

### **Hyaline cartilage**

- Hyaline cartilage is the most common form of cartilage in the body, but it is also the weakest type.

- It mainly consists of collagen (type II) with relatively few elastic fibres. It is surrounded by a perichondrium, a layer of connective tissue.
- Hyaline cartilage serves as a precursor for bone formation. It is found in the epiphyseal growth plates of children, where bone growth occurs.
- Hyaline cartilage is found in various parts of the body, including the ribs, nose, larynx, and trachea.
- Hyaline cartilage is translucent, blueish-white, and shiny, giving it a glass-like appearance.
- Hyaline cartilage is usually thin, ranging from 2 to 4 mm, as it lacks blood vessels. Nutrients and oxygen are obtained through diffusion.
- Hyaline cartilage represents the embryonic form of cartilage.
- The collagen fibres in hyaline cartilage are primarily type II, extremely thin, and not visible under a microscope due to their refractory properties similar to the matrix itself.
- Articular Cartilage: It is a specialized type of hyaline cartilage found on the surface of bones in synovial joints. It has a unique structure organized into specific zones.
- In articular cartilage, chondrocytes at the surface are flattened, while in deeper layers, they are stacked in columns within a calcified matrix, increasing their resistance to compressive forces.
- Unlike other hyaline cartilage, articular cartilage does not have an overlying perichondrium. Instead, it is covered by the synovial membrane.

### **Structure of Bone Tissue**

- There are two types of [bone tissue](#): compact and spongy. The names imply that the two types differ in density, or how tightly the [tissue](#) is packed together. There are three types of cells that contribute to [bone homeostasis](#). Osteoblasts are bone-forming [cell](#), osteoclasts resorb or break down bone, and osteocytes are mature bone cells. An equilibrium between osteoblasts and osteoclasts maintains bone tissue.

#### **Compact Bone**

- Compact bone consists of closely packed osteons or [haversian](#) systems. The [osteon](#) consists of a [central](#) canal called the osteonic (haversian) canal, which is surrounded by concentric rings (lamellae) of matrix. Between the rings of matrix, the bone cells (osteocytes) are located in spaces called

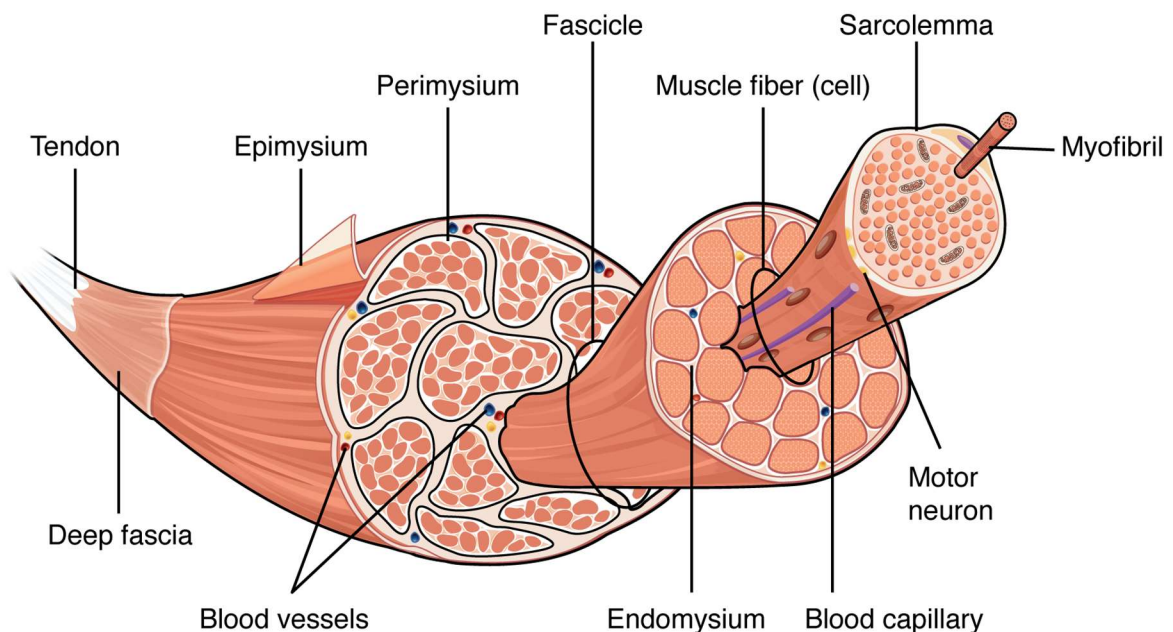
lacunae. Small channels (canaliculi) radiate from the lacunae to the osteonic (haversian) canal to provide passage ways through the hard matrix. In compact bone, the haversian systems are packed tightly together to form what appears to be a solid [mass](#). The osteonic canals contain [blood vessels](#) that are parallel to the long [axis](#) of the bone. These blood vessels interconnect, by way of perforating canals, with vessels on the surface of the bone.

### **Spongy (Cancellous) Bone**

- Spongy (cancellous) bone is lighter and less dense than compact bone. Spongy bone consists of plates ([trabeculae](#)) and bars of bone adjacent to small, irregular cavities that contain red [bone marrow](#). The canaliculi connect to the adjacent cavities, instead of a central haversian canal, to receive their [blood](#) supply. It may appear that the trabeculae are arranged in a haphazard manner, but they are organized to provide maximum strength similar to braces that are used to support a building. The trabeculae of spongy bone follow the lines of [stress](#) and can realign if the direction of stress changes.

## SKELETAL MUSCLES

Each skeletal muscle is an organ that consists of various integrated tissues. These tissues include the skeletal muscle fibers, blood vessels, nerve fibers, and connective tissue. Each skeletal muscle has three layers of connective tissue (called *mysisia*) that enclose it, provide structure to the muscle, and compartmentalize the muscle fibers within the muscle ([Figure 10.2.1](#)). Each muscle is wrapped in a sheath of dense, irregular connective tissue called the **epimysium**, which allows a muscle to contract and move powerfully while maintaining its structural integrity. The epimysium also separates muscle from other tissues and organs in the area, allowing the muscle to move independently.



**Figure 10.2.1 – The Three Connective Tissue Layers:** Bundles of muscle fibers, called fascicles, are covered by the perimysium. Muscle fibers are covered by the endomysium.

Inside each skeletal muscle, muscle fibers are organized into bundles, called **fascicles**, surrounded by a middle layer of connective tissue called the **perimysium**. This fascicular organization is common in muscles of the limbs; it allows the nervous system to trigger a specific movement of a muscle by activating a subset of muscle fibers within a fascicle of the muscle. Inside each fascicle, each muscle fiber is encased in a thin connective tissue layer of collagen and reticular fibers called the **endomysium**. The endomysium surrounds

the extracellular matrix of the cells and plays a role in transferring force produced by the muscle fibers to the tendons.

In skeletal muscles that work with tendons to pull on bones, the collagen in the three connective tissue layers intertwines with the collagen of a tendon. At the other end of the tendon, it fuses with the periosteum coating the bone. The tension created by contraction of the muscle fibers is then transferred through the connective tissue layers, to the tendon, and then to the periosteum to pull on the bone for movement of the skeleton. In other places, the myofibrils may fuse with a broad, tendon-like sheet called an [aponeurosis](#), or to fascia, the connective tissue between skin and bones. The broad sheet of connective tissue in the lower back that the latissimus dorsi muscles (the “lats”) fuse into is an example of an aponeurosis.

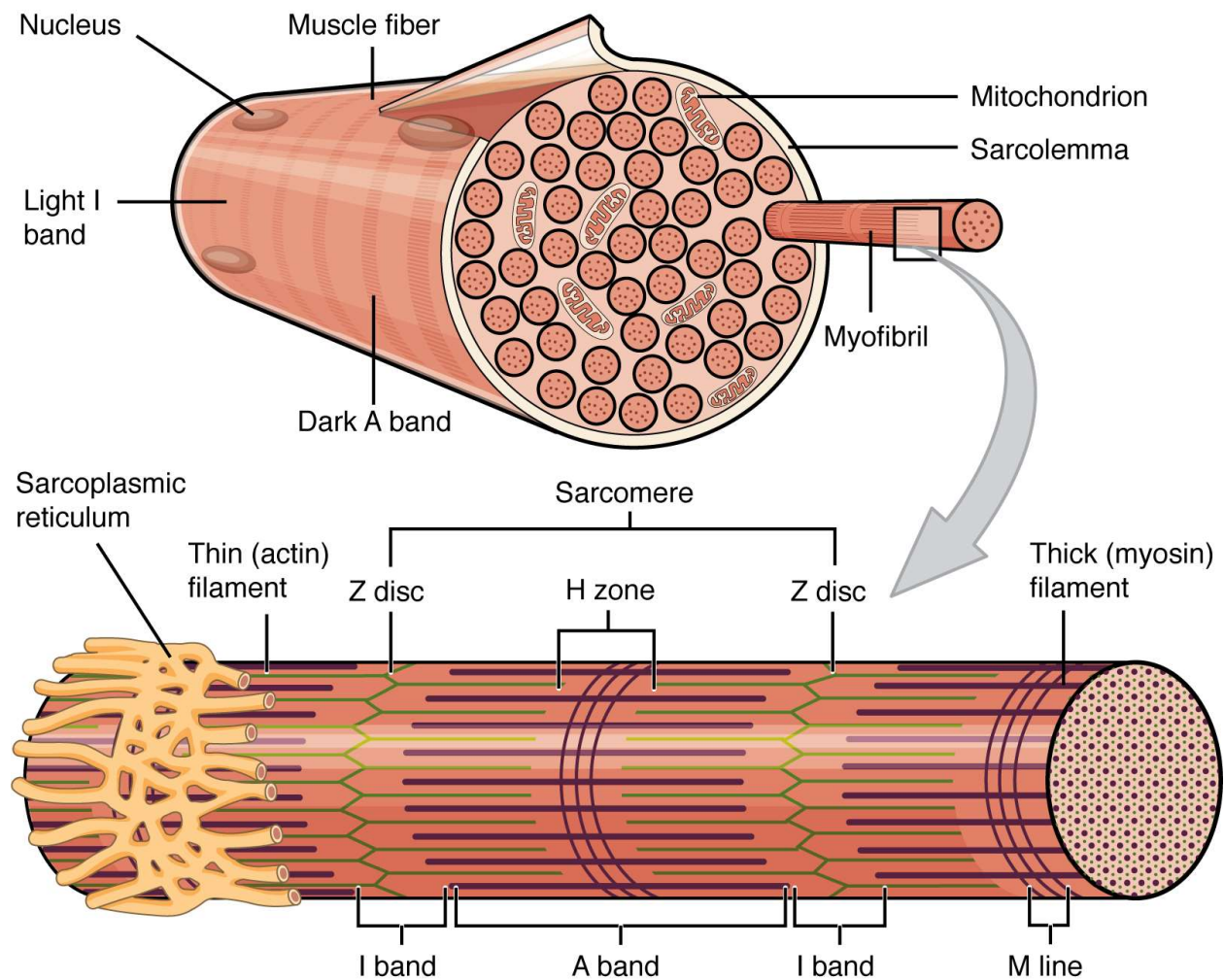
Every skeletal muscle is also richly supplied by blood vessels for nourishment, oxygen delivery, and waste removal. In addition, every muscle fiber in a skeletal muscle is supplied by the axon branch of a somatic motor neuron, which signals the fiber to contract. Unlike cardiac and smooth muscle, the only way to functionally contract a skeletal muscle is through signaling from the nervous system.

### **Skeletal Muscle Fibers**

Because skeletal muscle cells are long and cylindrical, they are commonly referred to as muscle fibers (or myofibers). Skeletal muscle fibers can be quite large compared to other cells, with diameters up to 100  $\mu\text{m}$  and lengths up to 30 cm (11.8 in) in the Sartorius of the upper leg. Having many nuclei allows for production of the large amounts of proteins and enzymes needed for maintaining normal function of these large protein dense cells. In addition to nuclei, skeletal muscle fibers also contain cellular organelles found in other cells, such as mitochondria and endoplasmic reticulum. However, some of these structures are specialized in muscle fibers. The specialized smooth endoplasmic reticulum, called the [sarcoplasmic reticulum \(SR\)](#), stores, releases, and retrieves calcium ions ( $\text{Ca}^{++}$ ).

The plasma membrane of muscle fibers is called the [sarcolemma](#) (from the Greek *sarco*, which means “flesh”) and the cytoplasm is referred to as [sarcoplasm](#) ([Figure 10.2.2](#)). Within a muscle fiber, proteins are organized into

organelles called **myofibrils** that run the length of the cell and contain sarcomeres connected in series. Because myofibrils are only approximately 1.2  $\mu\text{m}$  in diameter, hundreds to thousands (each with thousands of sarcomeres) can be found inside one muscle fiber. The **sarcomere** is the smallest functional unit of a skeletal muscle fiber and is a highly organized arrangement of contractile, regulatory, and structural proteins. It is the shortening of these individual sarcomeres that lead to the contraction of individual skeletal muscle fibers (and ultimately the whole muscle).



**Figure 10.2.2 – Muscle Fiber:** A skeletal muscle fiber is surrounded by a plasma membrane called the sarcolemma, which contains sarcoplasm, the cytoplasm of muscle cells. A muscle fiber is composed of many myofibrils, which contain sarcomeres with light and dark regions that give the cell its striated appearance.

### The Sarcomere

A sarcomere is defined as the region of a myofibril contained between two cytoskeletal structures called Z-discs (also called Z-lines or Z-bands), and the striated appearance of skeletal muscle fibers is due to the arrangement of the thick and thin myofilaments within each sarcomere ([Figure 10.2.2](#)). The dark striated A band is composed of the [thick filaments](#) containing myosin, which span the center of the sarcomere extending toward the Z-discs. The thick filaments are anchored at the middle of the sarcomere (the M-line) by a protein called myomesin. The lighter I band regions contain thin actin filaments anchored at the Z-discs by a protein called  $\alpha$ -actinin. The [thin filaments](#) extend into the A band toward the M-line and overlap with regions of the thick filament. The A band is dark because of the thicker myosin filaments as well as overlap with the actin filaments. The H zone in the middle of the A band is a little lighter in color because it only contains the portion of the thick filaments that does not overlap with the thin filaments (i.e. the thin filaments do not extend into the H zone).

Because a sarcomere is defined by Z-discs, a single sarcomere contains one dark A band with half of the lighter I band on each end ([Figure 10.2.2](#)). During contraction the myofilaments themselves do not change length, but actually slide across each other so the distance between the Z-discs shortens resulting in the shortening of the sarcomere. The length of the A band does not change (the thick myosin filament remains a constant length), but the H zone and I band regions shrink. These regions represent areas where the filaments do not overlap, and as filament overlap increases during contraction these regions of no overlap decrease.

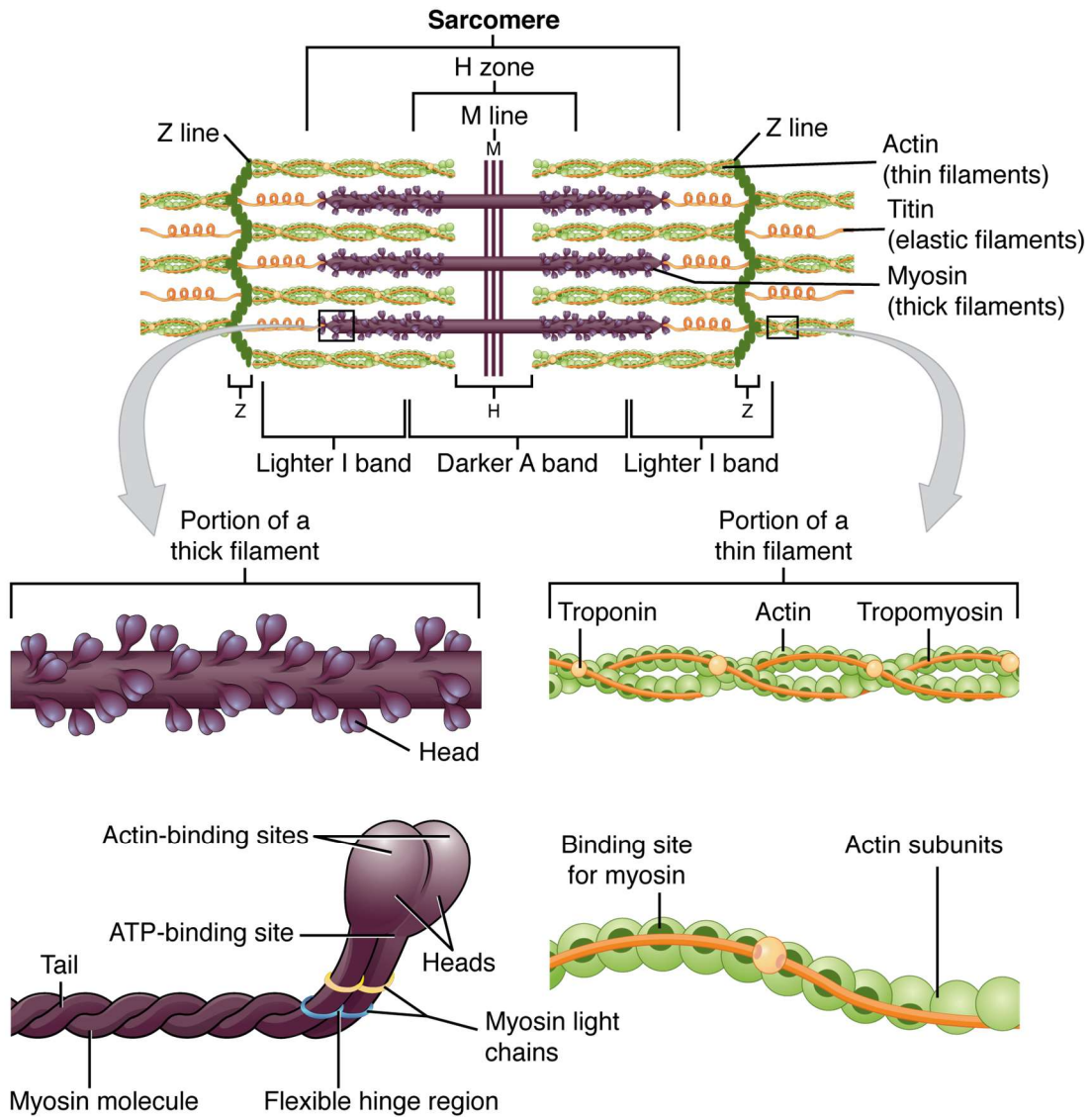
### **Myofilament Components**

The thin filaments are composed of two filamentous actin chains (F-actin) comprised of individual actin proteins ([Figure 10.2.3](#)). These thin filaments are anchored at the Z-disc and extend toward the center of the sarcomere. Within the filament, each globular actin monomer (G-actin) contains a myosin binding site and is also associated with the regulatory proteins, [troponin](#) and [tropomyosin](#). The troponin protein complex consists of three polypeptides. Troponin I (TnI) binds to actin, troponin T (TnT) binds to tropomyosin, and troponin C (TnC) binds to calcium ions. Troponin and

tropomyosin run along the actin filaments and control when the actin binding sites will be exposed for binding to myosin.

Thick myofilaments are composed of myosin protein complexes, which are composed of six proteins: two myosin heavy chains and four light chain molecules. The heavy chains consist of a tail region, flexible hinge region, and globular head which contains an Actin-binding site and a binding site for the high energy molecule ATP. The light chains play a regulatory role at the hinge region, but the heavy chain head region interacts with actin and is the most important factor for generating force. Hundreds of myosin proteins are arranged into each thick filament with tails toward the M-line and heads extending toward the Z-discs.

Other structural proteins are associated with the sarcomere but do not play a direct role in active force production. Titin, which is the largest known protein, helps align the thick filament and adds an elastic element to the sarcomere. Titin is anchored at the M-Line, runs the length of myosin, and extends to the Z disc. The thin filaments also have a stabilizing protein, called nebulin, which spans the length of the thick filaments.



**Figure 10.2.3 – The Sarcomere:** The sarcomere, the region from one Z-disc to the next Z-disc, is the functional unit of a skeletal muscle fiber.

## SMOOTH MUSCLES

Smooth muscle is a type of tissue found in the walls of hollow organs, such as the [intestines](#), [uterus](#) and [stomach](#). You can also find smooth muscle in the walls of passageways, including arteries and veins of the [cardiovascular system](#). This type of involuntary non-striated muscle is also found in the tracts of the [urinary](#), [respiratory](#) and reproductive systems.

In addition to that, you can find smooth muscle in the [eyes](#), where it acts to change the size of the pupil and the shape of the lens. The skin is also contains smooth muscle which allows hair to raise in response to cold temperatures or fear.

### Structure

The smooth muscle cell is 3-10  $\mu\text{m}$  thick and 20-200  $\mu\text{m}$  long. The cytoplasm is homogeneously eosinophilic and consists mainly of [myofilaments](#). The nucleus is located in the center and takes a cigar-like shape during contraction. The cell membrane forms small pouch-like invaginations into the cytoplasm (caveolae) which are functionally equivalent to the T-tubules of the skeletal musculature. The smooth muscle cells are anchored to the surrounding [connective tissue](#) by a basal lamina.

The smooth muscle fibers group in branching bundles. As opposed to [skeletal muscle fibers](#) these bundles do not run strictly parallel and ordered but consist in a complex system. Thus, smooth muscle contracts more slowly and usually with lower peak velocity, but it is more energy efficient and can maintain contraction for much longer than [striated musculature](#). The [actin](#) filaments are stretched between dense bodies in the cytoplasm and attachment plaques at the cell membrane. The myosin filaments lie between the actin filaments.

Furthermore intermediate filaments such as desmin and vimentin support the cell structure.

### Function

Smooth musculature is found in (almost) all [organ system](#) such as hollow organs (e.g. [stomach](#), [bladder](#)), in tubular structures (e.g. vessels, [bile ducts](#)), in sphincters, in the [uterus](#), in the [eye](#) etc. In addition it plays an important role in

the ducts of exocrine glands. It fulfills various tasks such as sealing orifices (e.g. [pylorus](#), uterine os) or the transport of the chyme through wavelike contractions of the intestinal tube. On the one hand smooth muscle cells contract slower than skeletal muscle cells, on the other hand they are stronger, more sustained and require less energy.

Myofibroblasts represent a special type of smooth muscle cell which additionally have qualities of fibrocytes. They produce connective tissue proteins such as collagen and elastin for which reason they are also referred to as fixed (or stationary) connective tissue cells. Myofibroblasts are found, among others, in alveolar septa of the [lung](#) and scar tissue.