

Basic Tissues of the Body

LEARNING OBJECTIVES

After completing the chapter, the readers will be able to:

- Classify the tissue of the body and describe their locations and functions.
- Define epithelial tissues and list their functions.
- Classify the epithelial tissues and describe their location, structure and functions.
- Define and classify the exocrine glands and describe their structure and locations.
- Classify the connective tissue and describe their locations.
- Discuss the structure, location, and functions of different types of connective tissue fibers.
- List the connective tissue cells and discuss their structure, location and functions.
- Correlate the structure of three types of cartilage with their functions.
- List the distribution of three types of cartilages in the different parts of the body.
- Describe the microscopic structure of skeletal muscle based on its function.
- Describe the microscopic structure of cardiac and smooth muscles

CHAPTER OUTLINE

- Introduction
- Epithelial Tissue
- Connective Tissue
- Microscopic Structure of the Muscle
- Microscopic Structure of the Cardiac Muscle
- Microscopic Structure of the Smooth Muscle

INTRODUCTION

Tissues are defined as “group of cells having similar origin, structure and function.” They are aggregates or groups of cells organized to perform one or more specific functions.

Types: There are four types of basic tissues in the body:

1. Epithelial tissue
2. Connective tissue
3. Muscle tissue
4. Nervous tissue

Cartilage and bone are specialized connective tissues.

EPITHELIAL TISSUE

It is a layer of cells, which covers the external surface (skin) of the body or lines the internal surface (lumen) of the tubular structures such as digestive, respiratory,

and urogenital tracts. They are structurally minor but functionally important component of an organ. Glands are epithelial invaginations from the lumen into the underlying connective tissue layer.

Types of Epithelia

Epithelium is classified into simple, pseudostratified and stratified varieties (Fig. 3.1).

1. Simple Epithelium

It consists of single layer of cells resting on a basement membrane.

Simple squamous: The cells are irregular flat, plate-like cells that function as a semipermeable barrier between compartments. These are the cells with a height less than their width (Fig. 3.2A).

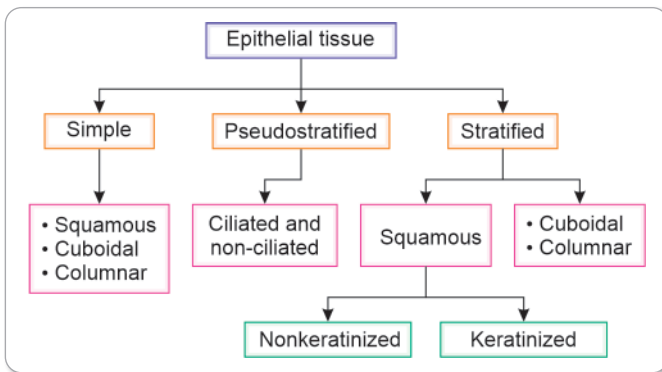


Fig. 3.1: Classification of epithelium

Distribution: Alveoli of the lungs, Bowman's capsule and loop of Henle of kidney, Mesothelium (the lining of the peritoneum, pleura, and pericardial cavities), endothelial cells lining blood vessels.

Simple cuboidal: The height and width of the cell are nearly equal, and nuclei are central in position (Fig. 3.2B).

Distribution: Lining epithelium of proximal convoluted tubules of the kidney, follicles of the thyroid (during moderate activity), walls of the secretory and excretory ducts of salivary glands and surface of the ovary (germinal epithelium). Their functions include protection, regulation

of ion and water concentration (in ducts) or secretion (thyroid follicles) or reabsorption (renal tubules).

Simple columnar: The cells are cylindrical with height is greater than width. Nuclei are elongated and placed toward the base. The apical (free) surface of the cell may be covered by microvilli or cilia or without any surface modifications (Figs 3.2C to F). Its function is absorption, secretion and when ciliated, propulsion of mucus and trapped debris.

Distribution: Nonciliated simple columnar epithelium lines the stomach. Simple columnar epithelium with microvilli lines the intestine. Simple columnar epithelium with cilia lines the bronchioles.

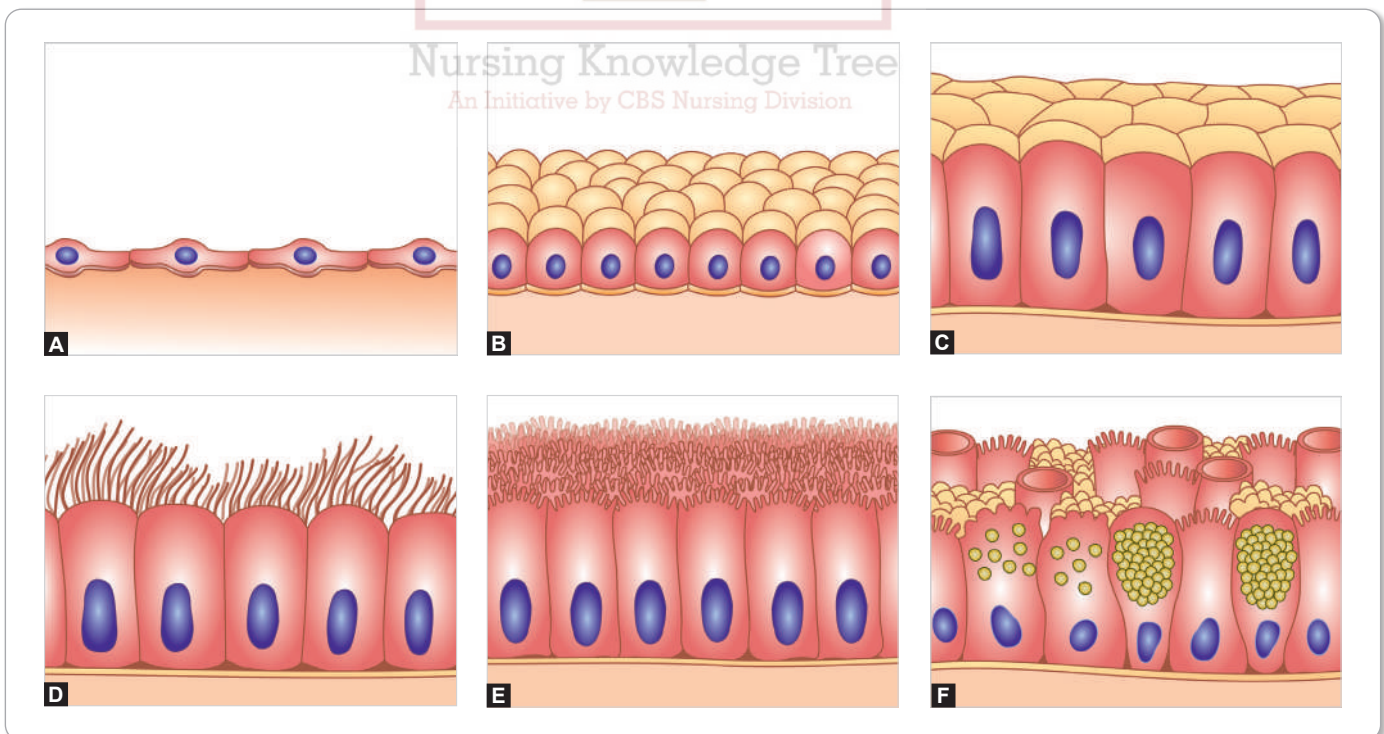
2. Pseudostratified Columnar Epithelium

It is a single layer of epithelial cells resting on a basement membrane. Some cells are shorter and do not reach the lumen, while taller cells reach the lumen. The nuclei of the cells therefore lie at different levels. This gives the impression of stratification (false stratification) (Fig. 3.2G).

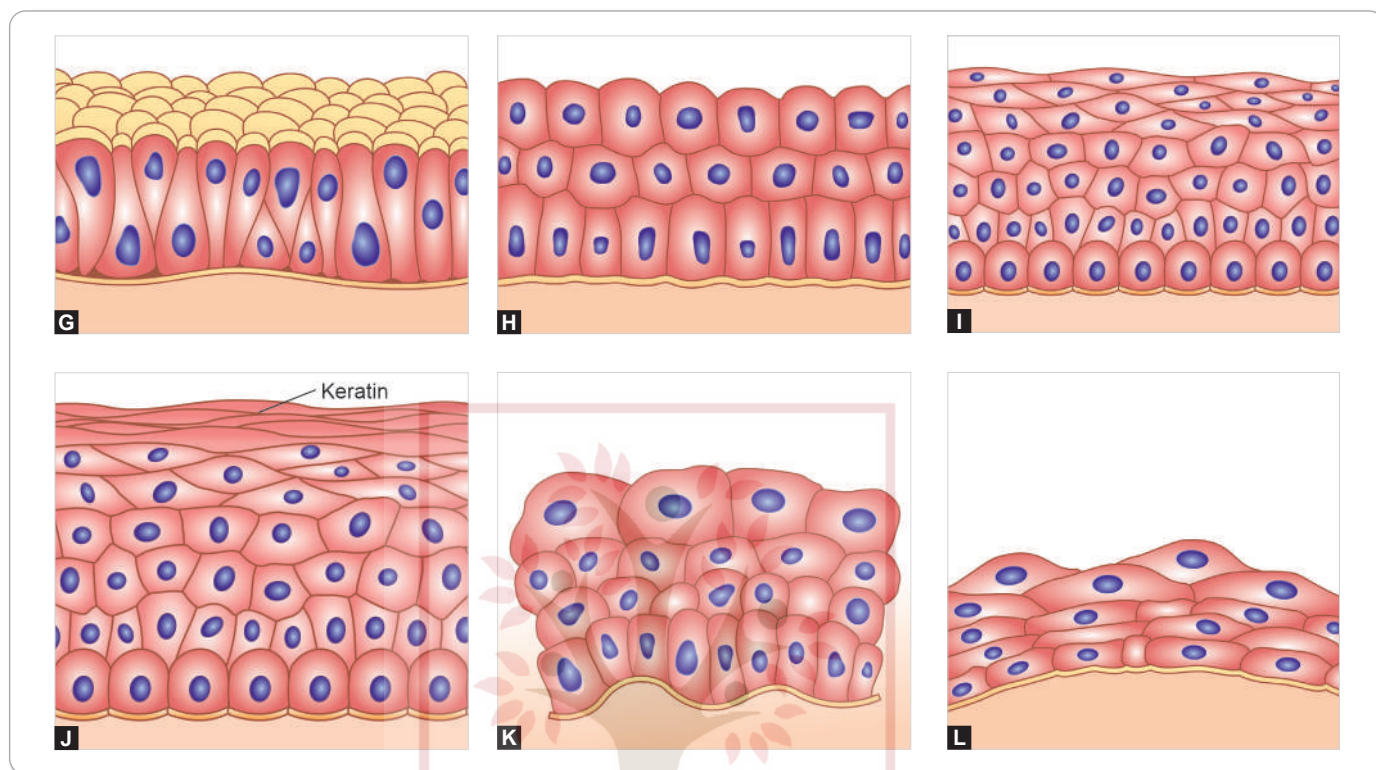
Pseudostratified nonciliated

Distribution: Male urethra (membranous and penile part), auditory tube and Vas deferens

Pseudostratified ciliated: Cells that reach the surface are ciliated.



Figs 3.2A to F: Schematic illustration of the epithelium: **A.** Simple squamous epithelium; **B.** Simple cuboidal epithelium; **C.** Simple columnar epithelium; **D.** Simple columnar ciliated epithelium; **E.** Simple columnar epithelium with microvilli and **F.** Simple columnar epithelium with goblet cells



Figs 3.2G to L: Schematic illustration of the epithelium: **G.** Pseudostratified columnar epithelium; **H.** Stratified cuboidal epithelium; **I.** Stratified squamous nonkeratinized epithelium; **J.** Stratified squamous keratinized epithelium; **K.** Transitional epithelium—relaxed and **L.** Transitional epithelium—stretched

Distribution: Upper part of the respiratory tract (trachea and larger bronchi).

Goblet cells are mucus-secreting (unicellular glands) cells located in between the simple columnar cells of the intestine or pseudostratified columnar epithelium of the respiratory tract. They have narrow bases and wide apex with basal nucleus. The apical part of the cell shows mucin vesicles. They protect and lubricate the epithelial surfaces of the respiratory and digestive tracts by producing mucus.

3. Stratified Epithelium

The epithelium is made up of many layers of cells. They are found in areas which are subjected to friction.

Stratified cuboidal epithelium: It consists of few (2–3) layers of cuboidal cells.

Distribution: Ducts of sweat glands (Fig. 3.2H)

Stratified columnar epithelium: It consists of two or more layers of cells. The basal cells are polyhedral, while superficial cells are columnar.

Distribution: Larger ducts of some glands, conjunctiva, over the respiratory surface of the epiglottis.

Stratified squamous nonkeratinized: Epithelium is made up of many layers of cells. Basal cells resting on

the basement membrane are columnar or low cuboidal. The superficial cells are squamous and flat, hence called stratified squamous epithelium. It is less resistant to water loss than the keratinized type (Fig. 3.2I).

Distribution: Epithelium lining mouth, pharynx and esophagus (*oesophagus*), anal canal, vagina and cornea.

Stratified squamous keratinized epithelium: The superficial layer consists of non-living cells with keratin in their cytoplasm (Fig. 3.2J). They are tough and water-resistant.

Distribution: Epidermis of the skin.

Transitional epithelium (Urothelium):

This is a stratified epithelium with three to four layers of cells. The deepest cells are columnar or cuboidal. The middle layers are made up of polyhedral or pear-shaped cells. The cells of the surface are large and are shaped like an umbrella (Figs 3.2K and L).

The surface cells are often binucleated. It mainly lines the urinary bladder. When the bladder is empty, the surface cells appear dome-like, giving the epithelium a 'cobblestone' appearance; when the bladder is full, the surface cells stretch and flatten. Transitional epithelium can be stretched

TABLE 3.1: Summary of different types of epithelium, their location and functions

Type	Location	Function
Simple squamous	Alveoli of the lung, lining cells of the blood vessels	Diffusion, filtration, osmosis
Simple cuboidal	Lining of the renal tubules in the kidney, linings of the ducts of the glands, outer covering of the ovary	Absorption, secretion
Simple columnar	Lining of the stomach	Absorption, secretion and protection
Simple columnar with microvilli	Lining of the intestine	Absorption, secretion and protection
Simple columnar with cilia	Lining of bronchioles of lung	Protection
Pseudostratified columnar	Lining of the upper respiratory passage (trachea)	Movement of mucus, protection, secretion
Stratified squamous—nonkeratinized	Lining of the oral cavity, pharynx, esophagus, anal canal, vagina	Protection
Stratified squamous keratinized	Outer layer of the skin (epidermis)	Protection
Stratified columnar	Lines part of the male urethra	Protection and secretion
Transitional	Lines the urinary bladder, ureter and part of the urethra	Distensibility and protection
Glandular epithelium	Endocrine, salivary and sweat glands	Secretion

considerably without being damaged. When stretched the cells become flattened. Presence of a glycoprotein membrane on the surface cells is believed to protect the underlying tissue from toxic substances present in the urine.

Distribution: Renal pelvis, ureter, urinary bladder and proximal part of the urethra.

A summary of the epithelium is tabulated in Table 3.1.

Functions of Epithelium

Mechanical protection: It protects the body surface from drying or bacterial invasion. Epithelium covering the skin is called epidermis which protects the body.

Transport: Transport of materials or cells along the surface of an epithelium is propelled by motile cilia or transport of materials across an epithelium (pinocytosis or endocytosis) to and from connective tissue.

Secretion: The cells secrete the product synthesized, either to the lumen (e.g., lining epithelium of stomach) or blood.

Excretion: May excrete metabolic waste products.

Absorption: It absorbs essential substances from the lumen of the gastrointestinal tract and kidney tubules (where it is called reabsorption).

Lubrication: The epithelium lining the body cavities (mesothelium) serves this function.

Sensory: In the skin (touch sensation), nasal mucosa (smell sensation) and tongue (taste sensation), it serves as a sensory organ.

Epithelioid Tissue

Cells are closely opposed to one another in such a way that they lack apical free surface. They rest on a basement membrane. They are derived from progenitor mesenchymal cells (undifferentiated cells of embryonic origin).

Distribution: Interstitial cells of Leydig in the testis, lutein cells of the ovary, the islets of Langerhans in the pancreas, parenchyma of the adrenal gland, cells of the anterior pituitary.

Endothelium: The epithelial lining of the blood vessels and lymphatic vessels.

Endocardium: The epithelial lining of the atria and ventricles of the heart.

Mesothelium: The epithelium that lines the walls and covers the outer surfaces of closed cavities of the body (pericardial, pleural and peritoneal cavities).



CLINICAL NOTES

Barrier and infection: When epithelium is damaged (e.g., burns or wounds), the body loses protection, increasing the risk of infection and fluid loss.

Cancer (carcinoma): Most common cancers arise from epithelium and are called carcinomas (e.g., skin cancer, lung cancer).

Absorption disorders: Damage to intestinal epithelium can lead to poor absorption of nutrients (e.g., diarrhea, malabsorption).

Ciliary dysfunction: In the respiratory tract, damaged cilia (e.g., due to smoking) impair mucus clearance, leading to respiratory infections.

Specialization of the Epithelial Cells

Each cell has three surfaces when viewed from the lateral side: (1) An apical (free) surface, (2) Lateral surfaces that bound neighboring cells, and (3) A basal surface attached to the basal lamina.

Basal Surface Specialization

The basal surface contacts the basal lamina. Because it is the surface closest to the underlying blood supply, it often contains receptors for blood-borne factors such as hormones.

Basal lamina: The basal lamina is a very thin, sheet-like layer located beneath epithelial cells. It provides support and helps anchor these cells to the underlying connective tissue (Fig. 3.3).

It is mainly composed of type IV collagen fibers. The basal lamina has two layers—the lamina lucida, which is the clear layer, and the lamina densa, which is the dense layer. Epithelial cells are attached to the basal lamina by proteins called integrins, which help maintain the connection between the cells and the underlying tissue.

Hemidesmosomes: They are located on the inner surface of the basal lamina in epithelia exposed to extreme stress (e.g., stratified squamous) (Fig. 3.3)

Sodium-potassium ATPase: It is a plasma membrane bound enzyme localized preferentially in the basal and basolateral regions of the epithelial cells. It transports sodium out and potassium into the cell.

Apical Surface Specialization

The cell's apical surface is on the organ's external or internal (lumen) surface. It is specialized to carry out functions that occur at these interfaces, including secretion, absorption, and movement of luminal contents.

Cilia: They are common surface modification of cells. They are hair-like extensions of the apical plasma membrane

containing microtubule protein-axoneme. In general, cilia are classified as motile and primary.

- **Motile cilia** have an internal structure that allows them to move. Ciliated epithelia are found in upper respiratory tract, where they move mucus and trapped epithelium.
- The **primary cilia** are also called monocilia. Only single cilium per cell is present. They are **immotile**. They function as chemosensors, osmosensors and mechanosensors (glomerulus and tubular cells of kidney).

Flagella: They are concerned with movement. Spermatozoa formed inside the seminiferous tubules of the testes are an example.

Microvilli: They are extensions of plasma membrane from the apical surface of the cell. Inside each microvillus, there are about 20–30 actin microfilaments. In the epithelium lining the intestine it is referred as striated border or brush border.

Stereocilia: They are not cilia but elongated microvilli. They are located in epididymis and vas deferens of male reproductive tract where they have absorptive function. They are also present in hair cells of internal ear where they have sensory in function.

Lateral Surface Specialization

Epithelial cells attach tightly to one another by specialized intercellular junctions.

There are four types of junctional complexes (Fig. 3.3). They are as follows:

1. **Tight junction (zonula occludens):** A seal between cells near the top that prevents substances from leaking between them and forms a protective barrier.
2. **Adherens junction (zonula adherens):** A belt-like junction that holds cells together and gives strength by linking their internal structures.
3. **Desmosome (macula adherens):** A spot-like strong attachment between cells that prevents them from pulling apart.
4. **Gap junction (communicating junction):** A channel between cells that allows small molecules and signals to pass directly from one cell to another.

Glandular Epithelium (Glands)

The epithelial cells are specialized to perform secretory function. Such epithelial cell in-groups constitute glands (single epithelial cell can also be a gland-unicellular).

There are two main types of glands (Fig. 3.4): (1) Exocrine and (2) Endocrine.

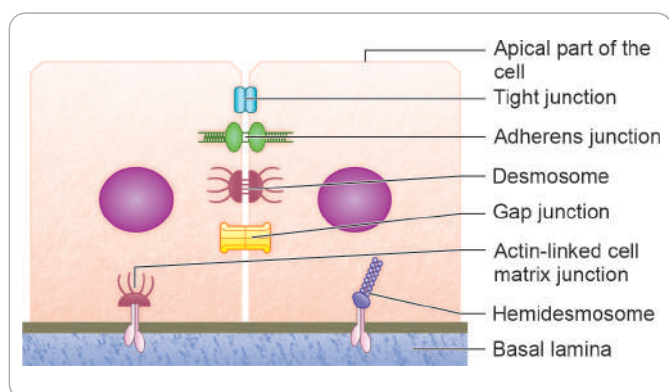


Fig. 3.3: Types of intercellular junction (schematic)

Exocrine Glands

When the secretion from the gland is poured through duct system, they are called exocrine glands. Examples: Salivary glands (parotid and submandibular glands). Exocrine glands are classified as either unicellular or multicellular.

Unicellular glands: Single secretory cells scattered among other epithelial cells (e.g., Goblet cells).

Multicellular glands: They are composed of more than one cell. Their structural organization allows further classification according to the arrangement of secretory cells (parenchyma) and presence or absence of branching of the duct element (Fig. 3.4). The secretory part of the gland (end piece) may be in the form of rounded sac (or acini) or flask-shaped tube (alveoli). If the duct part of the gland is unbranched, it is called simple, if the duct is branched, it is called compound. If the secretory portion is shaped like tube, the gland is called tubular; if it is shaped like a flask or grape, the gland is alveolar or acinar and if the tube ends in a sac-like dilation, the gland is tubuloalveolar. Exocrine glands may be in the form of (Figs 3.5A and B).

Simple tubular gland: Secretory portion of the gland is a straight tube formed by the secretory cells (e.g., intestinal glands).

Simple coiled tubular: Coiled tubular structure is composed of the secretory portion located deep in the dermis (e.g., eccrine sweat gland).

Simple branched tubular: Branched tubular glands with wide secretory portion are formed by the secretory cells and produce a viscous mucus secretion (e.g., mucus-secreting glands of stomach pylorus, endometrial glands of uterus).

Simple acinar (alveolar) gland: It represents a stage in the development of simple branched glands.

Branched acinar (alveolar) gland: The secretory portions are formed by mucus-secreting cells, the short single duct portion opens directly into the lumen (e.g., Mucus-secreting

glands of cardiac end of the stomach, sebaceous glands of the skin).

Compound tubular gland: Compound tubular glands with coiled secretory portions are located deep in the submucosa of the duodenum (e.g., duodenal submucosal glands of Brunner).

Compound acinar (alveolar) gland: Compound acinar glands with alveolar shaped secretory units are formed by pyramid-shaped serous-secreting cells (exocrine portion of pancreas).

Compound tubuloacinar (alveolar) gland: Compound tubuloacinar glands can have both mucous branched tubular and serous branched acinar secretory units; they have serous end caps (submandibular salivary gland).

Depending upon the nature of secretion, the exocrine glands may be classified into mucous glands and serous glands. The mucous glands secrete 'mucopolysaccharide' and secretions of serous glands are watery in nature rich with proteins.

Glands are also classified (on the basis of type of secretory product) into:

1. **Apocrine gland:** The luminal part of the cell disintegrates as a part of secretion. The basal part will regenerate. E.g., Mammary gland.
2. **Holocrine gland:** The cell itself will be disintegrated as a part of secretion. E.g., Sebaceous gland.
3. **Merocrine gland (epicrine gland):** The secretion is discharged without disintegrating the cell. Most of the glands belong to this type.

Endocrine Glands

These glands are 'ductless' and pour their secretion directly into the blood stream. Their secretion is called 'hormone'. The cells of the endocrine glands are usually arranged in cords or in clumps with rich network of blood capillaries around them. Examples: Pituitary gland, Thyroid and parathyroid glands, Suprarenal glands.

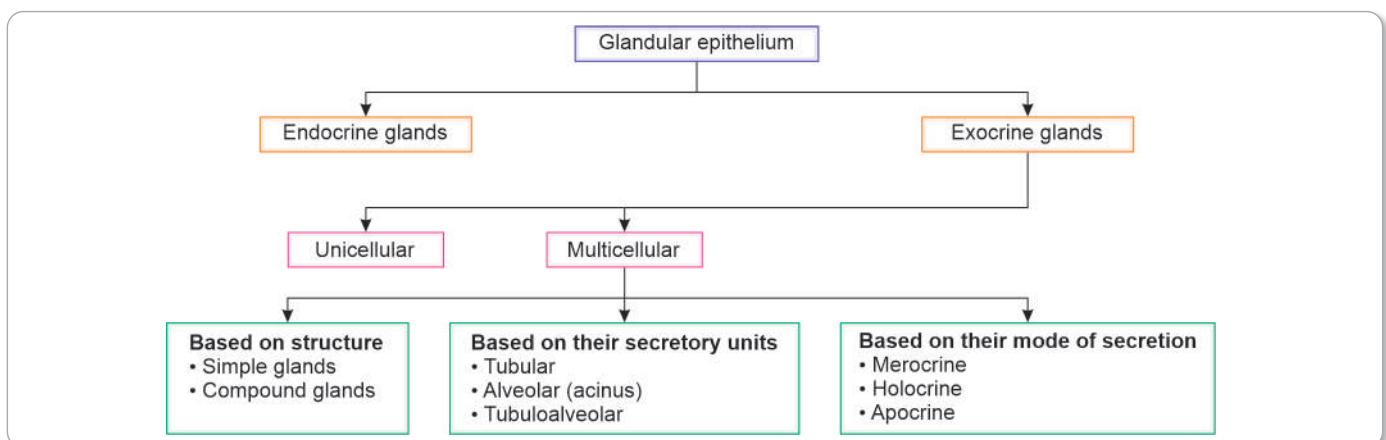
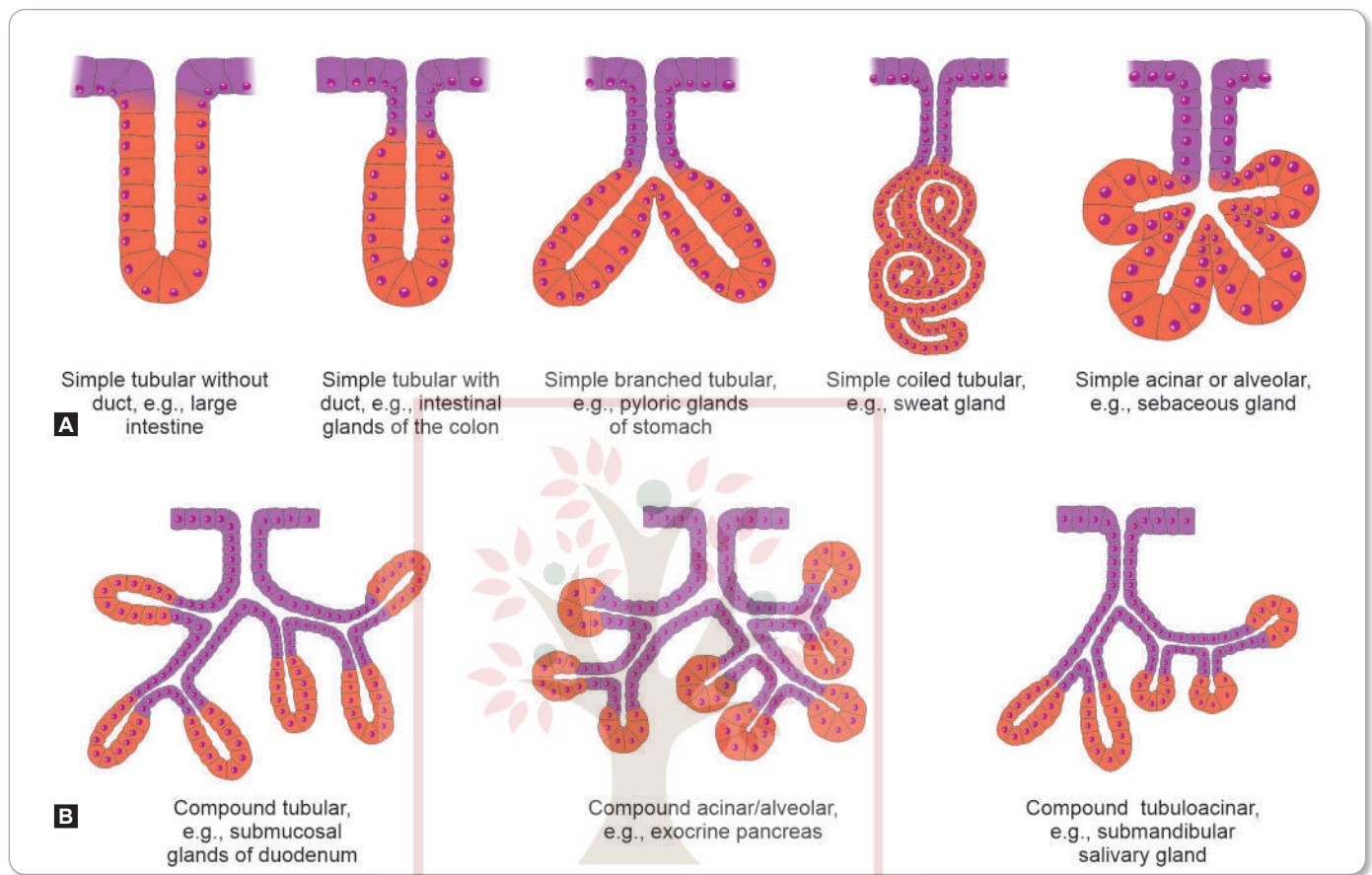


Fig. 3.4: Classification of glandular epithelium



Figs 3.5A and B: Classification of epithelial glands

CONNECTIVE TISSUE

Connective tissue is one of the main types of tissues in the body. It supports, connects, and protects different parts of the body such as organs, muscles, and blood vessels. Unlike epithelial tissue, connective tissue has cells that are widely spaced and are embedded in a material called the extracellular matrix. Connective tissue comprises cells and extracellular matrix. The extracellular matrix includes protein fibers (collagen, elastic and reticular) and ground substance (amorphous component containing proteoglycans, glycoproteins and glycosaminoglycans) (Fig. 3.6).

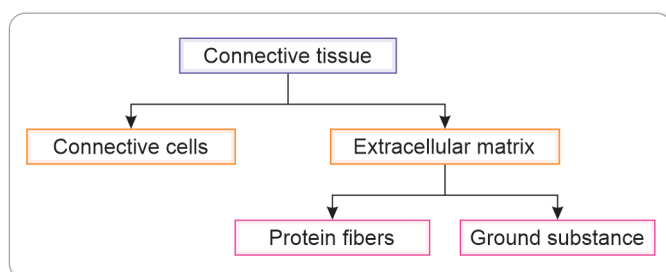


Fig. 3.6: Components of connective tissue

They perform variety of functions depending on type of the connective tissue. They bind various other tissues of the body, provide physical and immunological protection and also helps in storage. Connective tissue is classified on the basis of composition and organization of its extracellular components and on its functions (Fig. 3.7).

Connective Tissue Fibers

Connective tissue fibers are protein structures in the extracellular matrix that provide strength, support, and elasticity to tissues. The three main types are collagen fibers (strength), elastic fibers (stretch and recoil), and reticular fibers (supporting network) (Figs 3.8A to C).

Collagen Fibers

Collagen fibers are the most abundant type of connective tissue fibers in the body. Collagen fibers are produced mainly by fibroblasts, and they provide strength and support to tissues.

Structure

Collagen fibers are arranged in bundles. The bundles can branch (split), but the individual collagen fibers themselves

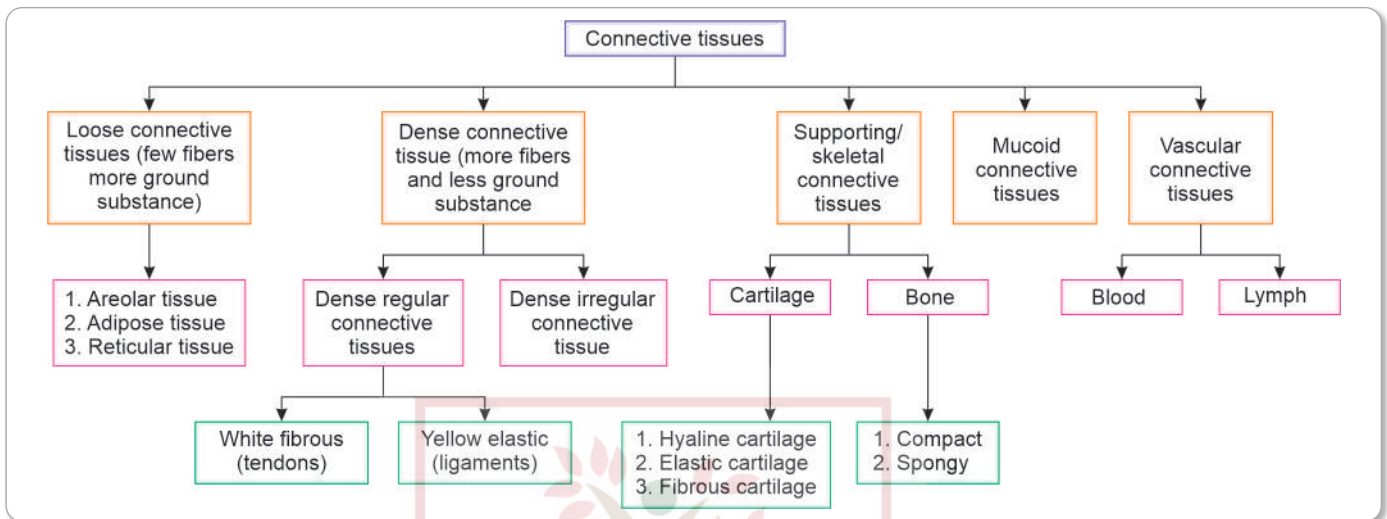
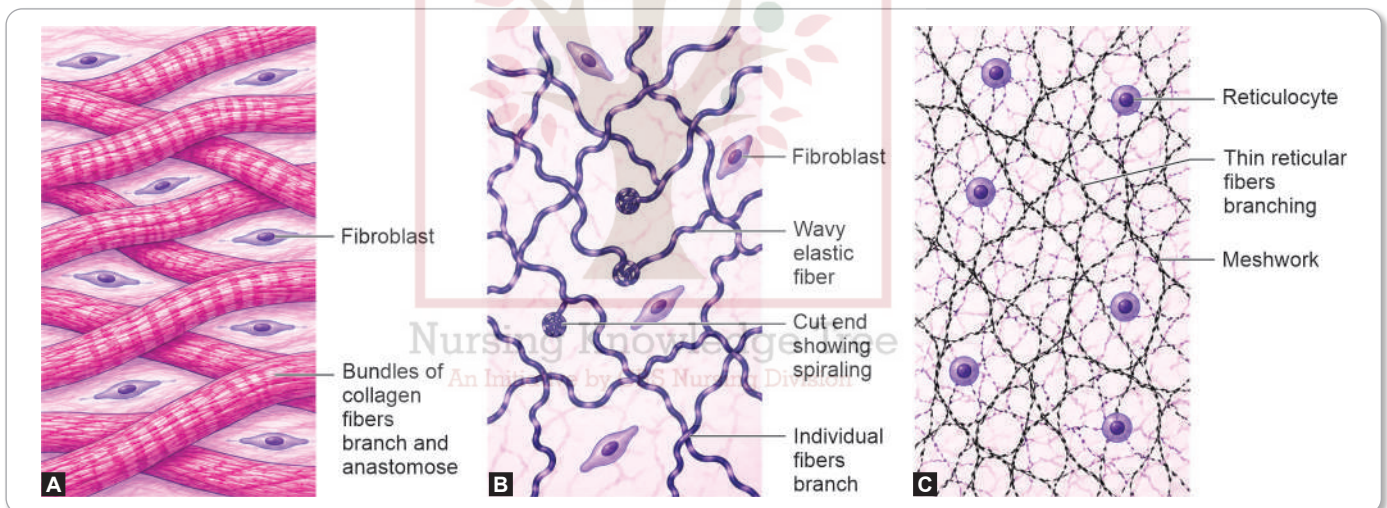


Fig. 3.7: Classification of connective tissue



Figs 3.8A to C: A. Collagen fibers; B. Elastic fibers and C. Reticular fibers

do not branch (Fig. 3.8A). They are made of triple-helix protein molecules (tropocollagen), each consisting of three polypeptide (α) chains, which form strong fibrils that bundle into flexible fibers resistant to pulling forces. In collagen, glycine appears regularly in the chain (every third position), and it is usually surrounded by other amino acids such as proline and hydroxyproline, which help give collagen its strength and stability (Fig. 3.9).

Types and Distribution

There are about 15 major types of collagen, of which Type I (skin, bone, tendon), Type II (cartilage), Type III (reticular fibers), and Type IV (basement membrane for filtration) are most important. These fibers are widely present in skin, bone, ligaments, blood vessels, and supporting tissues of organs.

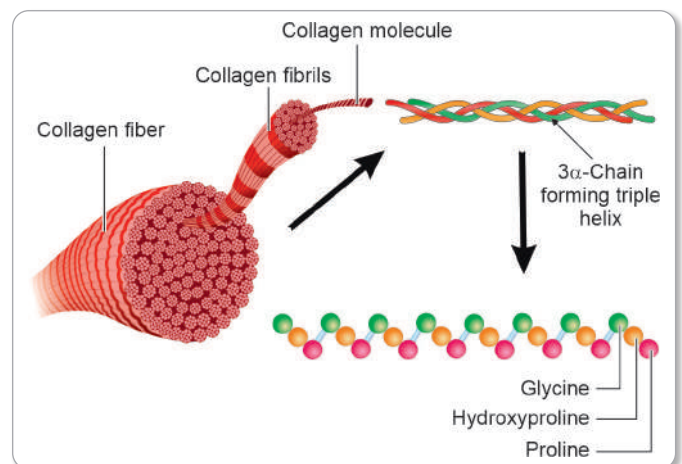


Fig. 3.9: Schematic representation of collagen fiber—collagen fibril, collagen molecule and amino acids

In wound healing, collagen (mainly Type I) is deposited to strengthen and repair damaged tissue. In scurvy (vitamin C deficiency), collagen formation is defective, leading to weak tissues, delayed healing, and bleeding gums, which is clinically important in dental patients.

Reticular Fibers

These are similar to collagen fibers (type-III) in chemical structure. They are thin fibers showing branching and hence form a network or a reticulum. They do not run-in bundles (Fig. 3.8C). These fibers form the skeletal framework of the lymphatic organs. In these organs, a special type of cell called, the **reticular cell** produces the collagen of the reticular fiber. In most places reticular fibers are formed by fibroblasts except in the endoneurium of peripheral nerves, where Schwann cells secrete reticular fibers.

Distribution/Location

They are located in the basement membrane of the epithelial tissue, walls of the blood vessels and lymphatic organs.

Elastic Fibers

Elastic fibers are thin, flexible fibers that allow tissues to stretch and return to their original shape.

Structure

They are yellow in color and are thinner than collagen fibers. Unlike collagen, elastic fibers branch and form networks, but they do not form bundles (Fig. 3.8B).

They are made of a protein called elastin, surrounded by fibrillin fibers, which help give them elasticity. This structure allows the fibers to stretch and recoil easily, such as in the lungs and blood vessels.

Distribution/Locations

Elastic fibers are found in the skin, lungs, blood vessels, and elastic cartilage. They usually work along with collagen fibers to prevent overstretching and tearing.

With aging, elastic fibers decrease, leading to loss of skin elasticity, reduced lung function, and stiff blood vessels.

Cells of the Connective Tissue

Connective tissue cells are of two types—fixed cells and wandering cells. Fixed cells stay in the tissue and include mesenchymal cells, fibroblasts, reticular cells, and fat cells. Wandering cells come from the blood or bone marrow and include mast cells, macrophages, and plasma cells; some of them can move in and out of the tissue. A summary of the connective tissue cells is tabulated in Table 3.2.

Mesenchymal cells: These are small, spindle-shaped embryonic cells with long processes; they are mainly found during development, but some remain in adults as stem cells for repair.

Fibroblasts: These are large, spindle or star-shaped cells with an oval nucleus (Fig. 3.10) and are the most abundant cells in connective tissue; they produce fibers and play a major role in wound healing.

Reticular cells: These are branched cells found in lymphoid organs and bone marrow; they produce reticular fibers that form a supporting network.

Adipocytes (fat cells): These are large round cells filled with fat (Fig. 3.10), mainly found in adipose tissue; they store energy and provide cushioning.

Mast cells: These are large round cells with many granules, commonly found near blood vessels and under mucosa; they release histamine and are important in allergic reactions and inflammation.

Macrophages: These are irregular-shaped cells with a kidney-shaped nucleus (Fig. 3.10), found throughout connective tissue; they engulf bacteria and dead cells (phagocytosis). They also act as antigen-presenting cells, helping activate the immune system by interacting with lymphocytes and releasing cytokines during inflammation.

TABLE 3.2: Cells of the connective tissue—summarized

Connective tissue cells	Function
Fibroblast	Production of collagen, elastic and reticular fibers and also the ground substance
Reticular cells	Production of type III collagen fibers
Adipocytes	Storage of the fat
Mast cells	They secrete heparin (an anticoagulant) and histamine (which cause allergic reactions)
Macrophages	Phagocytosis of the foreign bodies, antigen processing and presenting it to the lymphocytes, secretion of growth factors and cytokines
Plasma cells	Production of antibodies

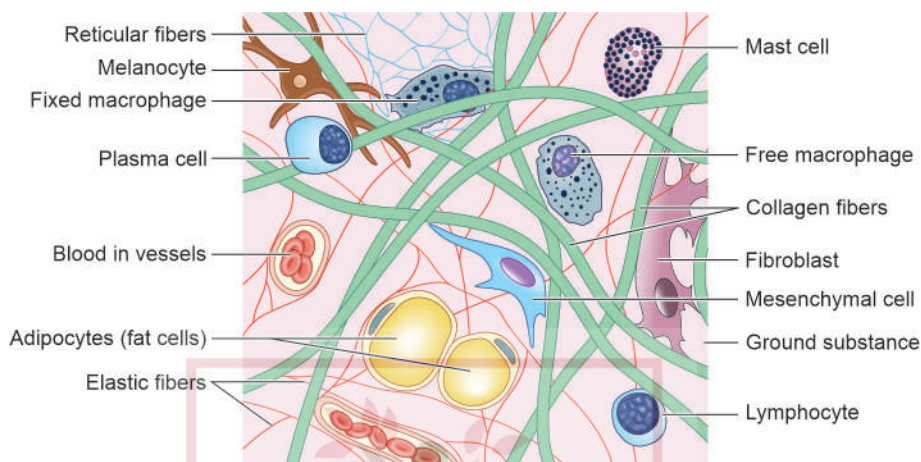


Fig. 3.10: The cells and fibers of connective tissue proper

Plasma cells: These are oval cells with an eccentric nucleus (clock-face appearance), mainly found in mucosal tissues and areas prone to infection; they produce antibodies. They develop from B lymphocytes and play a key role in long-term immune response.

Pigment cells: These cells contain pigment and are mainly found in the eye (iris and choroid).

Connective Tissue Proper

Connective tissue belonging to this group is divided into two general subtypes: (1) Loose connective tissue (areolar tissue) and (2) Dense connective tissue which is further classified into irregular and regular types.

Loose Connective Tissue

Loose connective tissue is primarily subcategorized into three distinct types:

1. Areolar Tissue

Areolar connective tissue has loosely arranged fibers and many cells, with more ground substance (gel-like material) than fibers. It contains all types of fibers and has a soft, jelly-like consistency.

Location/distribution: It is commonly found beneath epithelial tissues, where it helps in the diffusion of oxygen and nutrients from nearby blood vessels. It also supports and surrounds blood vessels and nerves and forms a supporting layer for membranes such as the pleura, peritoneum, and pericardium.

This tissue mainly contains wandering (mobile) cells, which are important for defense. It is a common site for inflammation and immune reactions, and during these conditions, the tissue may swell due to fluid accumulation.

2. Adipose Tissue (Fat Tissue)

Adipose tissue is a type of connective tissue made up of fat cells (adipocytes). Its main function is to store energy (fat), provide insulation, and protect organs. The amount and distribution of fat in the body depend on age, sex, hormones, and nutrition. The tissue is arranged in groups (lobules) separated by connective tissue. There are two types of adipose tissue: (1) White and (2) Brown.

1. **White adipose tissue:** This is the most common type of adipose tissue. White adipose tissue contains cells with one large fat droplet (unilocular), which pushes the nucleus to the side, giving a signet-ring appearance (Fig. 3.11). It stores fat in the form of triglycerides and appears yellow. It helps in energy storage, insulation, and protection.

Location/distribution: It is found mainly under the skin (subcutaneous tissue). In females, additional fat is deposited in the breasts, buttocks, hips and anterior aspect of the thigh. In the abdomen they are bulky in peritoneal folds.

2. **Brown adipose tissue:** Brown adipose tissue contains cells with many small fat droplets (multilocular) and a central nucleus. These cells have many mitochondria, which give the tissue a brown color and help in heat production. It is metabolically more active.

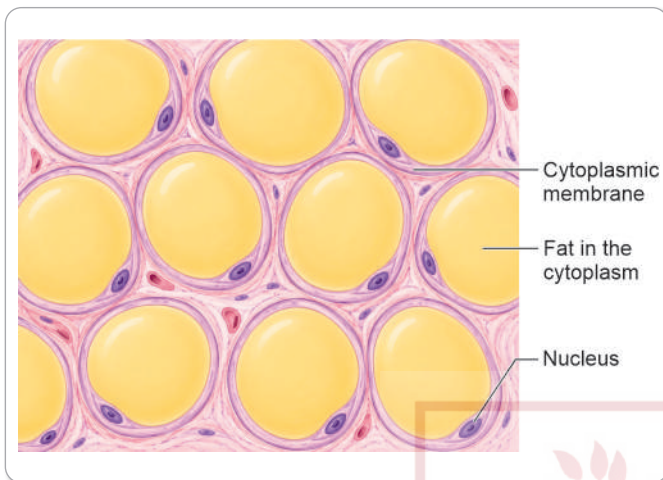


Fig. 3.11: Adipocytes: Note that there is a thin cell membrane that bounds the cytoplasmic lipid, and the nucleus is pushed to the periphery

Location/distribution: Newborns and elderly will have accumulation of these tissue in axilla (arm pit), near the carotid artery and the thyroid gland and around the hilum of the kidney.



CLINICAL NOTES

Obesity: There are two types of obesity – (1) Hypertrophic and (2) Hyperplastic. In hypertrophic obesity the size of the adipose cells increases, which is common in adults. In hyperplastic is characterized by increase in the number of adipose cells due to excessive eating.

3. Reticular Tissue

It consists of network of reticular fibers. These fibers are associated with specialized fibroblasts called reticulocytes. This type of tissue is present in lymphatic organs and bone marrow. It is the main constituent of fascia.

Dense Connective Tissue

Dense connective tissue is a type of connective tissue with closely packed collagen fibers that provides strong support and resistance to stretching.

Dense irregular connective tissue: It mainly contains collagen fibers with little ground substance. The collagen fibers are arranged in bundles oriented in various directions; hence it is called irregular. They resist tensile forces from any direction. The cellular component includes mainly fibroblasts. It is present in the reticular layer of the dermis of the skin.

Dense regular connective tissue: It predominantly consists of collagen fibers which are arranged in parallel array and are

densely packed to provide maximum strength. The volume of the ground substance is less. The fibroblasts are arranged in rows between the fibers. It is found in tendons, ligaments, periosteum, perichondrium, deep fascia and organ covering capsules.

Elastic connective tissue: They resemble dense connective tissue in Hematoxylin and Eosin (H&E) staining. Majority of its fibers are elastic, but few are collagen. Elastic fibers are present in the form of wavy bundles. These bundles are separated by loose connective tissue with fibroblasts. The volume of the ground substance is less compared to its fibers content. The example includes ligamentum flavum of the vertebral column providing flexibility to the spine and elastic cartilage.

Ground Substance (Intercellular Substance)

Ground substance is a soft, gel-like material found between cells and fibers in connective tissue. It is made up of water, proteins, carbohydrates, and small amounts of lipids, and together they form the matrix. It helps in supporting cells and allows the movement of nutrients, oxygen, and waste products between blood and tissues. Ground substance mainly contains:

Proteoglycans: They are large molecules made of proteins and carbohydrates (GAGs) that help retain water and give a gel-like consistency

Glycoproteins: They are smaller molecules that help cells attach to the matrix

Examples of important components include hyaluronic acid (in joints and soft tissues) and chondroitin sulfate (in cartilage).



CLINICAL NOTES

Systemic Lupus Erythematosus (SLE): It is an autoimmune disease in which the body's immune system attacks its own connective tissues, leading to inflammation and damage in organs such as the skin, joints, kidneys, and blood vessels. This causes symptoms like joint pain, skin rashes, and fatigue. It is important clinically because it is a chronic condition that can affect multiple body systems.

Microscopic Structure of the Cartilage

Cartilage is a specialized type of connective tissue (skeletal/supporting) that is firm, flexible, and smooth, and helps support and shape different parts of the body. It is made of cells called chondrocytes embedded in a gel-like matrix and does not have its own blood supply. Cartilages are avascular and nourished by diffusion from nearby tissue. Cartilage is

found in areas such as the nose, ear, joints, and respiratory passages, where it provides support and allows smooth movement. Cartilage is found in areas where support, flexibility, and smooth movement are required, such as joints, respiratory passages, and external structures like the ear and nose. It helps maintain shape, absorb shock, and reduce friction between moving parts.

Perichondrium

Perichondrium is a layer of connective tissue that covers cartilage (Fig. 3.12B). It contains cells similar to fibroblasts, along with a few blood vessels and nerve fibers. When cartilage is growing, the inner layer of the perichondrium forms new cartilage cells (chondroblasts), while the outer layer provides support. The articular cartilages (where bones articulate) do not have perichondrium.

Hyaline Cartilage

Hyaline cartilage is a smooth, glass-like (transparent) connective tissue with a firm, gel-like consistency.

Structure: It is usually covered by a connective tissue layer called the perichondrium, which helps in growth and nutrition (except at joint surfaces). The cells of cartilage, called chondrocytes, are present inside small spaces called lacunae. These cells may be seen alone or in small groups (cell nests), which are formed after cell division. The matrix (background material) looks smooth and homogeneous because the collagen fibers (Type II) are very fine and not easily visible. Chondrocytes near the surface are flattened, while those deeper are round (Figs 3.12A and B).

The ground substance of hyaline cartilage is gel-like and rich in water, which helps it resist pressure and provide

cushioning. It mainly contains glycosaminoglycans (such as chondroitin sulfate and hyaluronic acid), proteoglycans that retain water, and glycoproteins that help bind the cells to the matrix.

Hyaline cartilage grows in two ways: (1) Interstitial growth, in which chondrocytes divide within the tissue, and (2) Appositional growth, in which new cartilage cells are formed from the inner layer of the perichondrium.

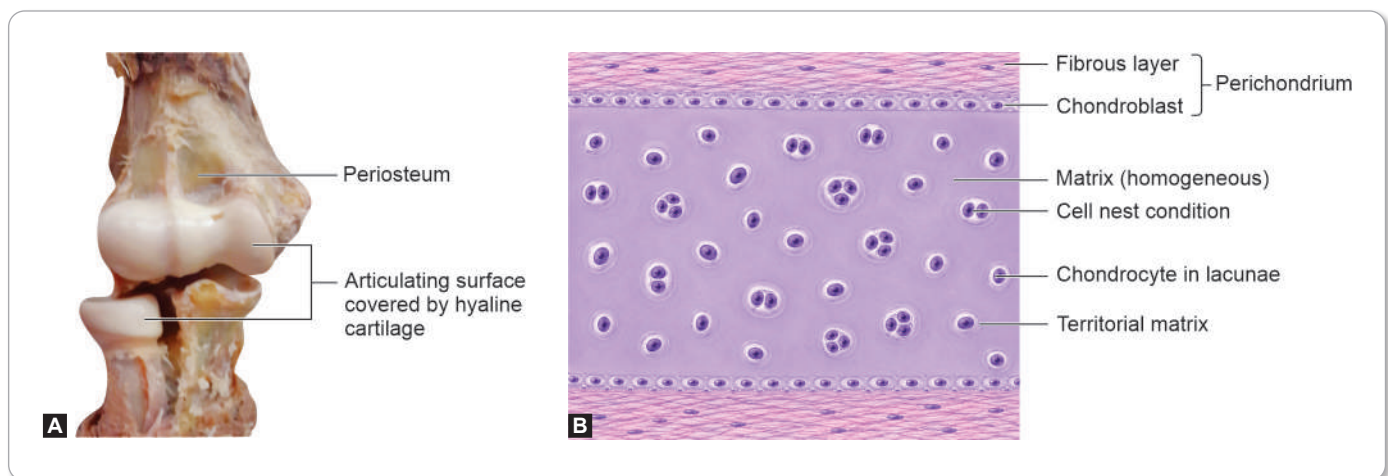
Location/distribution: Costal cartilages of ribs (anterior ends of the ribs), Articular surfaces of joints, Epiphyseal (growth) plates of bones, Larynx (thyroid and cricoid cartilage), Trachea and bronchi.

Elastic Cartilage

Elastic cartilage is a type of cartilage that is yellow in color and very flexible, allowing structures to bend and return to their shape.

Structure: It contains chondrocytes (cartilage cells) present in lacunae and a dense network of elastic fibers along with Type II collagen. These elastic fibers branch and form a network, giving the tissue its flexibility. The cartilage is covered by a perichondrium, which helps in growth and nourishment (Fig. 3.13). Unlike hyaline cartilage, elastic cartilage does not calcify with age. The ground substance is similar to that of hyaline cartilage and is gel-like and rich in water, helping in support and flexibility. It contains glycosaminoglycans, proteoglycans, and glycoproteins, which help maintain the structure and function of the cartilage.

Location/distribution: Elastic cartilage is found in the pinna (external ear), epiglottis, corniculate and cuneiform cartilages of the larynx, and the auditory (Eustachian) tube.



Figs 3.12A and B: A. Articular cartilages of synovial joints; B. A schematic illustration showing microscopic structure of the hyaline cartilage

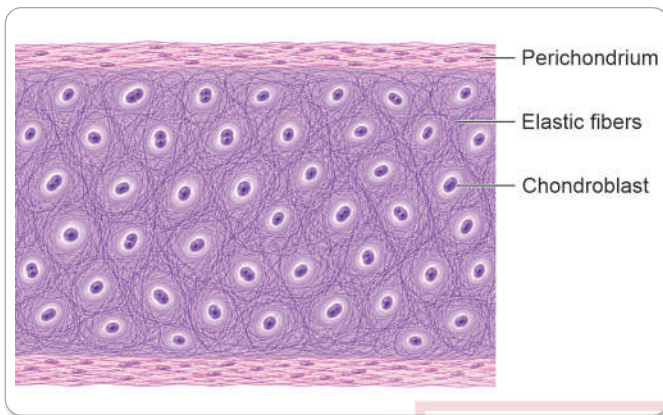


Fig. 3.13: A schematic illustration showing microscopic structure of the elastic cartilage

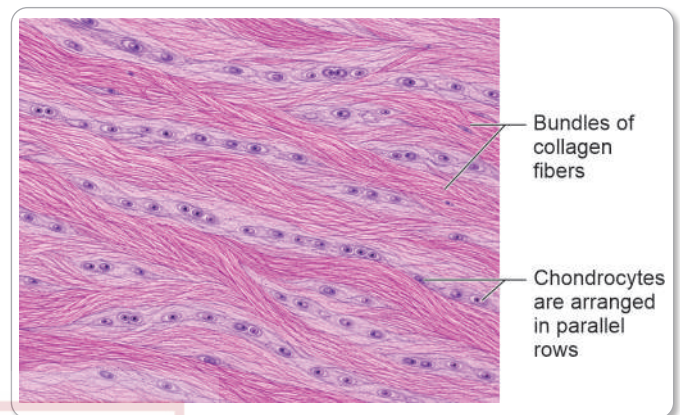


Fig. 3.14: A schematic illustration showing microscopic structure of fibrocartilage

Fibrocartilage (White Fibrocartilage)

Fibrocartilage is a type of cartilage that is very strong and tough and is found in areas where high pressure and stress occur. It has features of both hyaline cartilage and dense connective tissue.

Structure: It contains thick bundles of collagen fibers (Type I) with a few chondrocytes present in lacunae. These cells are arranged in rows between the collagen fibers. Unlike other cartilages, fibrocartilage does not have a perichondrium (Fig. 3.14). The ground substance is less abundant and contains substances like chondroitin sulfate and dermatan sulfate, which provide support and strength.

Location/distribution: Fibrocartilage is found in areas subjected to heavy stress, such as—Intervertebral discs, Menisci of the knee joint, Temporomandibular joint (articular disc), Glenoidal labrum of the shoulder joint and acetabular labrum of the hip joint.

A comparison of three types of cartilages is summarized in the Table 3.3.

Connective Tissue Support of Muscle

Connective tissue coverings help transmit force from muscle to bone and continue at the ends as tendons (Fig. 3.15).

- Endomysium is a thin layer around each muscle fiber and may appear as empty space in sections.

TABLE 3.3: Comparison of three types of cartilages

	Hyaline cartilage	Elastic cartilage	Fibrocartilage
Cell type	Chondrocytes in isogenous groups	Chondrocytes in isogenous groups	Chondrocytes in columnar isogenous groups between bundles of collagen fibers
Fibers type	Type II collagen	Elastic fibers + type II collagen	Type I collagen + type II collagen
Ground substance	Includes GAGs, proteoglycans aggregates and glycoprotein	Same as hyaline cartilage	Similar to hyaline cartilage but equal amount of chondroitin and dermatan sulfates
Organization	Cells occur in isogenous groups. Type II collagen fibers present but difficult to distinguish from ground substance.	Organization identical to that of hyaline cartilage except for presence of a dense elastic fibers	Cross between cartilage and dense regular connective tissues. Chondrocytes usually in row like isogenous groups
Functions	Useful as fetal skeleton, provides support and grows rapidly. Maintains airways in respiratory passages. In joints acts as cushions and provides low-friction surface.	Provides flexible support. Semi rigid: Returns to original shape after being deformed	Attaches bone to bone and provides restricted mobility under great mechanical stress
Locations	Fetal skeleton, articular and costal cartilages, laryngeal, tracheal and bronchial cartilages	External ear, auditory tube, epiglottis, corniculate and cuneiform cartilage of larynx	Intervertebral discs, pubic symphysis, glenoid and acetabular labrum, menisci of knee

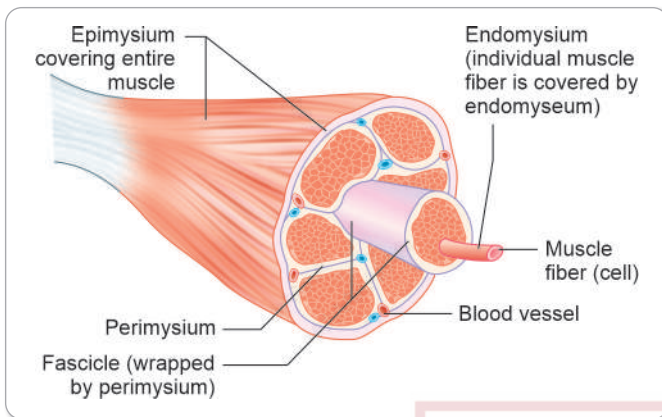


Fig. 3.15: Connective tissue coverings of the skeletal muscle

- Perimysium is a thicker layer around bundles of fibers (fascicles), which act together.
- Epimysium is a dense outer layer around the whole muscle and carries blood vessels and nerves.

MICROSCOPIC STRUCTURE OF THE MUSCLE

- The skeletal muscle is made up of a number of muscle fibers.
- Each muscle fiber (also called myocyte) is elongated, unbranched, cylindrical, multinucleated cell with the length varying from 1 mm to 300 mm.
- The outer plasma membrane of the muscle is called sarcolemma and the cytoplasm is called sarcoplasm.
- The sarcoplasm contains peripherally placed flattened nuclei, and large number of myofibrils, many mitochondria, glycogen granules, sarcoplasmic reticulum (Figs 3.16 and 3.17) and an oxygen binding protein called myoglobin.
- Each muscle fiber is multinucleated and shows striations.
- A muscle fiber is filled with longitudinally arranged structural subunits called myofibrils (Figs 3.16 and 3.17) which extend the entire length of the muscle cell.
- A well-developed smooth surfaced endoplasmic reticulum called sarcoplasmic reticulum forms a highly organized tubular network around myofibrils (Fig. 3.18).
- The transverse tubular system (invagination of sarcolemma) is a network of interconnecting rings, each of which surrounds a myofibril (runs perpendicular to the direction of myofibrils). On each side of the transverse tubule (T-tubule), there is an expansion of the sarcoplasmic reticulum is called terminal cisterna (Fig. 3.18). Two terminal cisternae and intervening transverse tubules comprise a triad. Triads are important in initiating muscle contraction.
- In longitudinal section of skeletal muscle and H&E preparation, the striations are evident, and it is because of alternate dark and light bands of myofibrils (Fig. 3.19).
- The dark bands are known as A bands (anisotropic) and the light bands as I bands (isotropic) (Fig. 3.20A).
- Each myofibril has two protein filaments (myofilaments) called actin (thin) and myosin (thick) filaments (Fig. 3.20B).

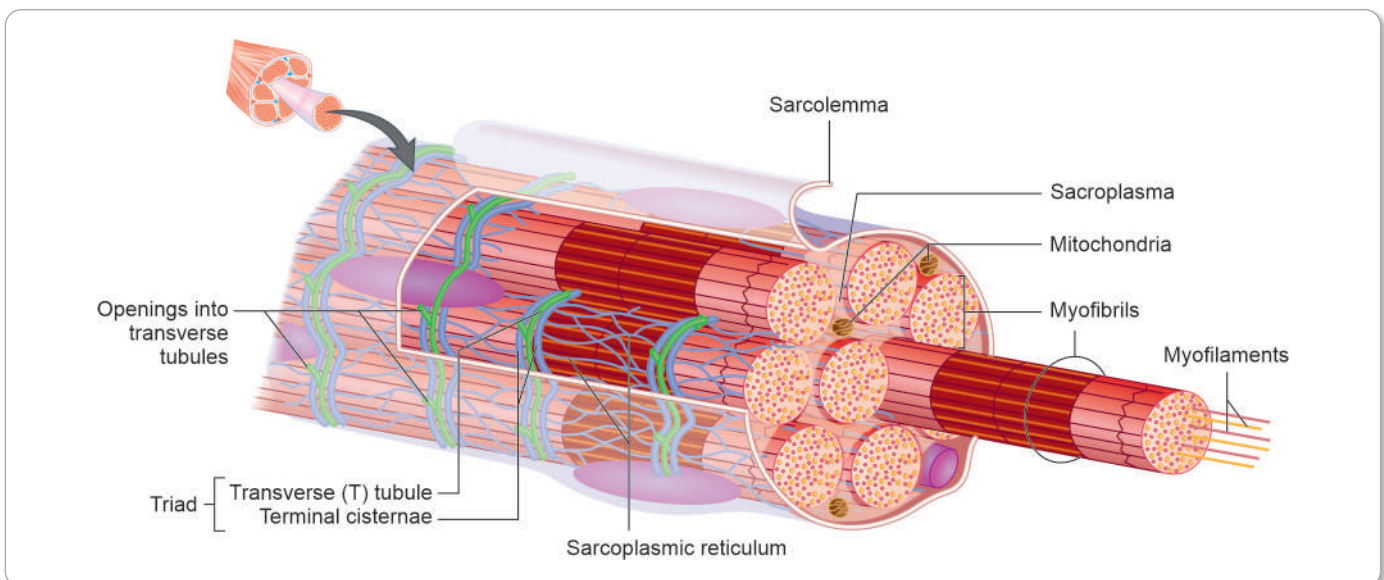


Fig. 3.16: Muscle fiber contains myofibrils, nucleus, sarcoplasmic reticulum

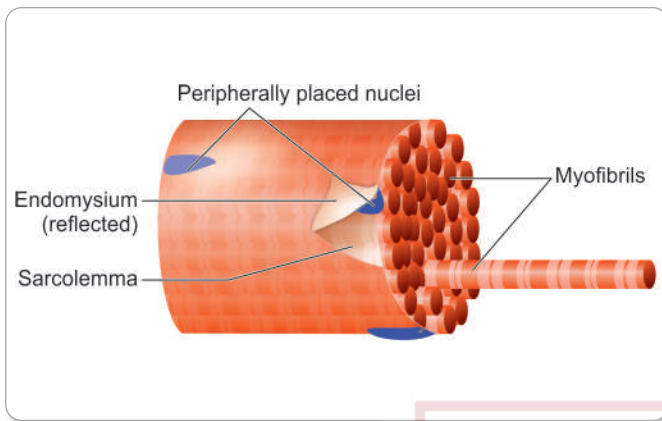


Fig. 3.17: A schematic representation of an individual muscle fibers with peripherally placed nucleus and many myofibrils in its sarcoplasm

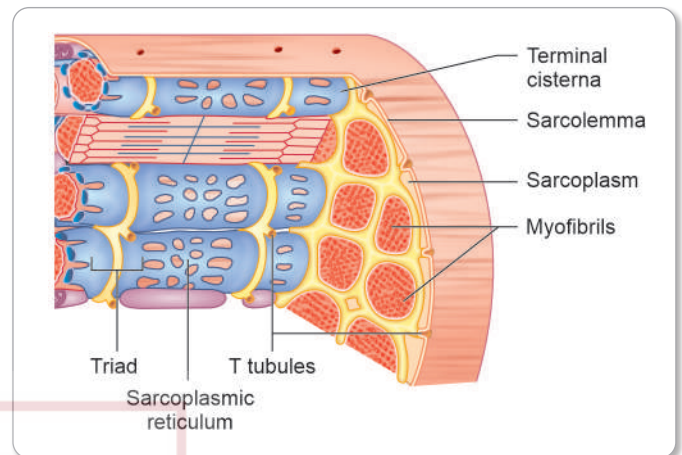


Fig. 3.18: Sarcoplasmic reticulum and sarcolemma forming transverse tubules



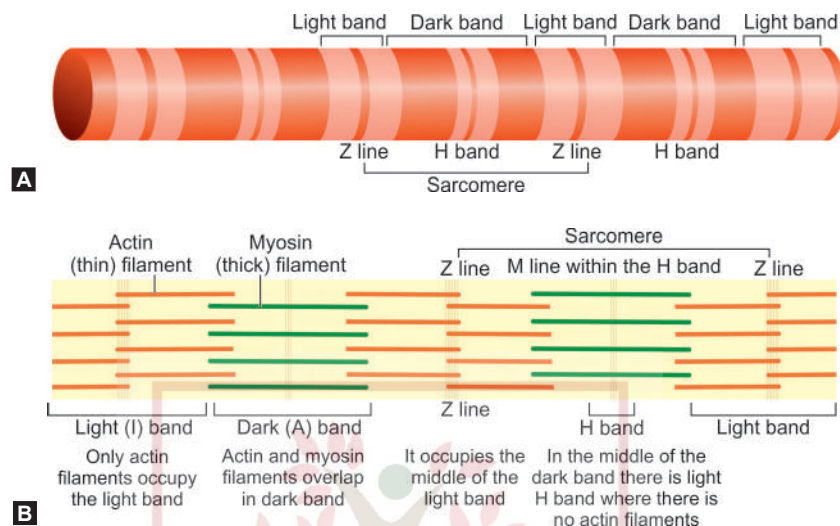
Fig. 3.19: A longitudinal section through a skeletal muscle showing striations/dark light bands (H&E staining)

- The dark band (A-band) is the area where the actin and myosin filaments overlap each other (Fig. 3.20B).
- Only actin filaments occupy the light band (I-band) (Fig. 3.20B).
- This arrangement of actin and myosin filament is responsible for striations (dark and light bands) of skeletal muscle. This banding pattern differs depending on the myofibrils state of contraction.
- In the middle of the dark band there is a light H band where there are no actin filaments (Fig. 3.20B).
- In the middle of the I band there is a dark Z line (Z disc) (Fig. 3.20B).
- The part of the myofibril between two Z line is called sarcomere (Fig. 3.20B). The sarcomere is the basic contractile unit of striated muscles. It may be stretched to $>4\text{ }\mu\text{m}$ and during contraction it may be reduced to $1\text{ }\mu\text{m}$.
- The center of each sarcomere is marked by the M line which holds thick filaments in place (Fig. 3.20B).
- The thick filament bundles lie at the center of each sarcomere and bisected by M line and overlaps the thin filaments free ends (Fig. 3.20B).

Myofilaments

Myofilaments are responsible for muscle contraction and are of two types—(1) Thin (actin) and (2) Thick (myosin).

1. **Thin (actin) filaments:** They are made of actin protein arranged as a double helix. They also contain regulatory proteins: tropomyosin and troponin (Fig. 3.21).
 - Tropomyosin lies along actin and covers binding sites (Fig. 3.21).
 - **Troponin has three parts:** TnT (binds tropomyosin), TnC (binds calcium), and TnI (inhibits contraction).



Figs 3.20A and B: **A.** A schematic representation of a myofibril showing dark and light bands; **B.** A schematic representation of arrangements of actin and myosin filaments responsible for dark and light bands

- Thick (myosin) filament:** They are made of myosin II molecules, arranged with heads projecting outward. The central part lacks heads and forms the H zone. A myosin molecule is a long, golf stick-shaped polypeptide (Fig. 3.21). The myosin head has ATP-binding and actin-binding sites, which are essential for muscle contraction.

Motor Unit

A motor unit is a single motor neuron and all the muscle fibers it supplies. When it is stimulated, all these fibers contract together.

Innervation of the Skeletal Muscle

Motor innervation of a skeletal muscle arises from ventral horn cells of the spinal cord and supplies extrafusal fibers (the ordinary contractile muscle fibers responsible for force production) (Fig. 3.22). The muscle spindle is a specialized sensory receptor located within skeletal muscle that detects stretch and changes in muscle length. It contains intrafusal fibers (modified muscle fibers specialized for sensing stretch), which send signals to the CNS. These sensory impulses are carried by neurons whose cell bodies lie in the dorsal root ganglion, forming the basis of proprioceptive sensation (awareness of body position and movement).

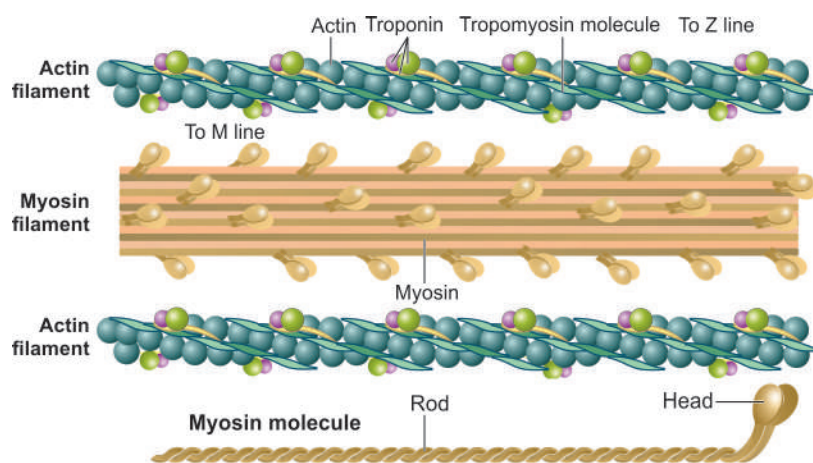


Fig. 3.21: A schematic representation of actin and myosin filaments

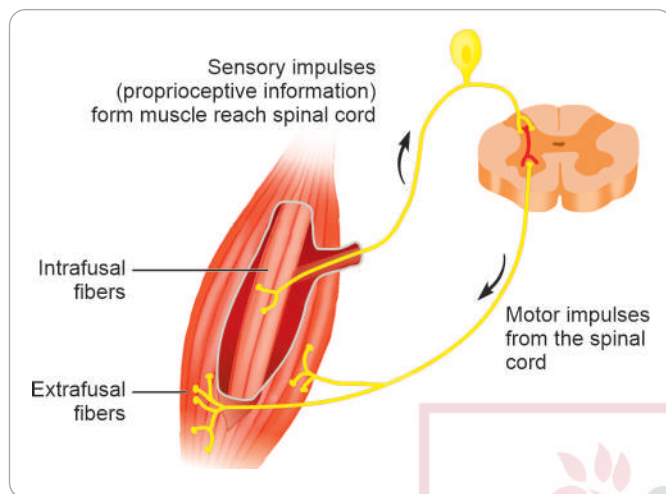


Fig. 3.22: Nerve supply to a skeletal muscle (schematic)

Neuromuscular Junction

A nerve supplying a muscle has motor and sensory parts, and the motor axons branch to supply many muscle fibers. The ends of these axons form motor end plates on the sarcolemma, and together they form the neuromuscular junction. When a nerve impulse arrives, acetylcholine is released, which stimulates the muscle fiber and causes contraction. It has three components (Fig. 3.23).

1. **Presynaptic component:** It is the terminal end of the axon (terminal bouton), where the myelin sheath ends. The membrane facing the muscle fiber is called the presynaptic membrane (Fig. 3.23).

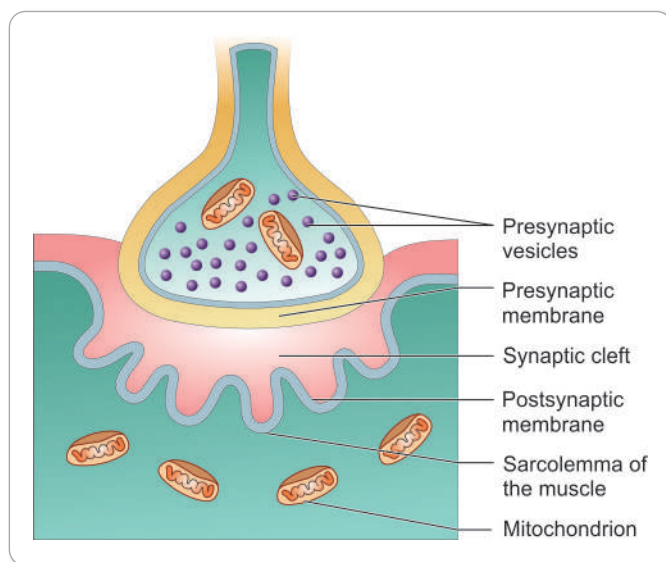


Fig. 3.23: A schematic representation of neuromuscular junction

2. **Synaptic cleft:** It is the gap between nerve and muscle, containing acetylcholinesterase, which breaks down acetylcholine and stops contraction when neural stimulation ends, contraction ends (Fig. 3.23).
3. **Postsynaptic component:** This includes the sarcolemma and underlying sarcoplasm of the muscle fiber. The membrane has acetylcholine receptors and folds, which help in transmitting the signal.

Cascade of Events in Skeletal Muscle Contraction

A nerve impulse travels along the motor neuron to the neuromuscular junction, causing release of acetylcholine, which binds to receptors on the sarcolemma and produces depolarization. This impulse spreads along the sarcolemma and into T-tubules, leading to activation of the sarcoplasmic reticulum and release of Ca^{2+} into the sarcoplasm. The released Ca^{2+} binds to troponin C, causing movement of tropomyosin and exposing binding sites on actin filaments. The myosin heads attach to actin, use ATP, and pull actin filaments toward the center of the sarcomere (sliding filament mechanism). As a result, the sarcomeres shorten (I band shortens, A band remains same), leading to shortening of myofibrils and the entire muscle fiber, producing contraction.

MICROSCOPIC STRUCTURE OF THE CARDIAC MUSCLE

Cardiac muscle has striations like skeletal muscle, but its cells are short, branched (Fig. 3.24) and centrally placed nuclei and contain many mitochondria, glycogen and some pigment.

They show striations due to actin and myosin but have fewer myofibrils and less organized sarcoplasmic reticulum than skeletal muscle.

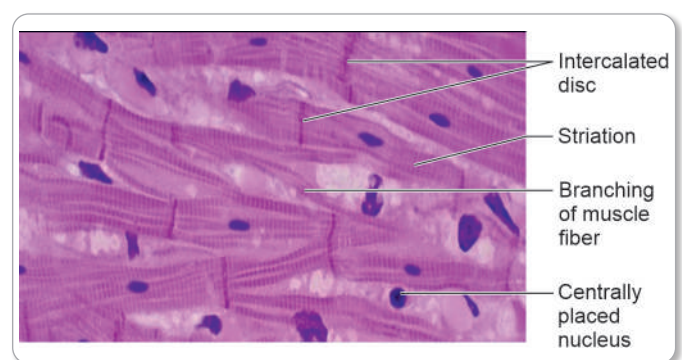


Fig. 3.24: Longitudinal section of cardiac muscle (H&E staining)

T-tubules lie at Z lines and form dyads (one T-tubule + one cisterna) instead of triads.

Intercalated Discs

These are specialized junctional complexes that appear as dark lines (Fig. 3.24) joining cardiac cells and helping them work together. They contain fascia adherens (connect cells), desmosomes (prevent separation), and gap junctions (allow electrical spread).

Cardiac muscle contracts automatically with its own rhythm. The rhythm is initiated by the sinoatrial node and conducted by Purkinje fibers, which are large cells rich in glycogen. The impulse spreads through gap junctions, allowing the heart to act as a single functional unit (syncytium).

MICROSCOPIC STRUCTURE OF THE SMOOTH MUSCLE

- Smooth muscle cells are spindle-shaped with a single central nucleus (Fig. 3.25). They contain mitochondria, rough ER and Golgi, but have no striations.
- They have poorly developed sarcoplasmic reticulum and no T-tubules, triads or dyads; instead, caveolae help in Ca^{2+} movement.
- Actin and myosin filaments are arranged irregularly and overlap more, allowing slow but powerful contraction, and these cells can divide.

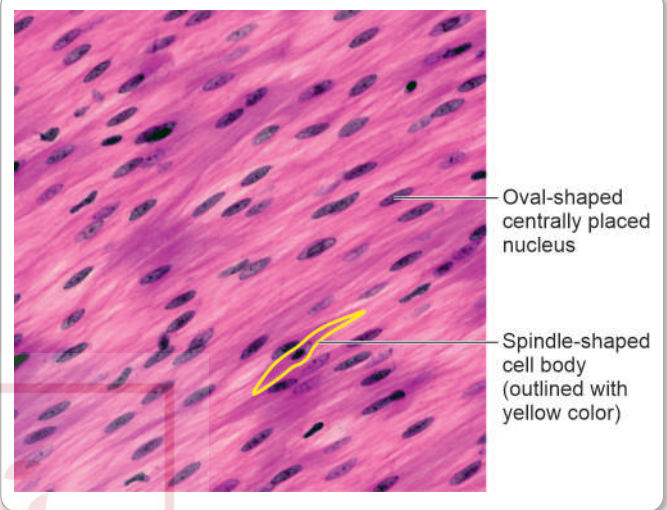


Fig. 3.25: Longitudinal section of smooth muscle (H&E staining)

Types of Smooth Muscle

1. **Visceral smooth muscle:** Found in walls of organs like intestine, uterus and bladder. Cells are connected by gap junctions, contract slowly in waves, and act as a single unit (unitary muscle).
2. **Vascular smooth muscle:** Found in blood vessels and similar to visceral muscle. Contraction is slow but more localized.
3. **Smooth muscle of iris:** Found in the eye (pupil muscles). Cells act individually, have rich nerve supply, and produce precise movements (multiunit muscle).

STUDENT ASSIGNMENTS

ESSAY QUESTIONS

(10 MARKS)

1. Define the epithelial tissue. Describe the various types of epithelium based on their functions and locations.
2. Describe the basal, apical and lateral specialization of the epithelial cells based on their functions.
3. Describe the three types of connective tissue fibers on the basis of their structure, function and distribution.
4. Compare and contrast the three types of cartilages based on their structure, function and distribution.

SHORT ESSAY QUESTIONS

(5 MARKS)

1. Simple columnar epithelium
2. Lateral specialization of epithelial cells
3. Types of multicellular glands

4. Collagen fibers
5. Elastic fibers
6. Hyaline cartilage
7. Adipose tissue
8. Elastic cartilage
9. Fibrocartilage
10. Major cell types of connective tissue fibers

VERY SHORT QUESTIONS

(2 MARKS)

1. Transitional epithelium
2. Holocrine glands
3. Apocrine glands
4. Reticular fibers
5. Elastic fibers
6. Macrophages

7. Fibroblasts
8. Mast cells
9. Perichondrium
10. Locations of hyaline cartilage
11. Locations of elastic cartilage

MULTIPLE CHOICE QUESTIONS

1. Which epithelium is specialized for absorption and is found in the intestine?
 - A. Simple squamous epithelium
 - B. Simple cuboidal epithelium
 - C. Simple columnar epithelium with microvilli
 - D. Stratified columnar epithelium with cilia
2. Which epithelium lines the urinary bladder and can stretch without damage?
 - A. Stratified squamous epithelium
 - B. Transitional epithelium
 - C. Simple columnar epithelium
 - D. Stratified cuboidal epithelium
3. What is the main function of goblet cells?
 - A. Absorption
 - B. Secretion of mucus
 - C. Protection from friction
 - D. Filtration
4. Which type of gland involves complete destruction of the cell during secretion?
 - A. Merocrine gland
 - B. Apocrine gland
 - C. Holocrine gland
 - D. Serous gland
5. Which apical structure is responsible for movement of mucus in the respiratory tract?
 - A. Stereocilia
 - B. Microvilli
 - C. Desmosomes
 - D. Cilia
6. Which type of connective tissue fiber provides strength and resists pulling forces?
 - A. Elastic fibers
 - B. Reticular fibers
 - C. Collagen fibers
 - D. Nerve fibers
7. Which connective tissue cell is mainly responsible for producing fibers and aiding in wound healing?
 - A. Mast cell
 - B. Fibroblast
 - C. Plasma cell
 - D. Adipocyte
8. Which connective tissue cell is responsible for engulfing bacteria and dead cells?
 - A. Macrophage
 - B. Mast cell
 - C. Plasma cell
 - D. Reticular cell
9. Which connective tissue cell plays a key role in allergic reactions by releasing histamine?
 - A. Fibroblast
 - B. Mast cell
 - C. Macrophage
 - D. Plasma cell
10. Which type of adipose tissue is mainly responsible for heat production?
 - A. White adipose tissue
 - B. Dense connective tissue
 - C. Reticular tissue
 - D. Brown adipose tissue

ANSWER KEY

- | | | | | | | | | | |
|------|------|------|------|------|------|------|------|------|-------|
| 1. C | 2. B | 3. B | 4. C | 5. D | 6. C | 7. B | 8. A | 9. B | 10. D |
|------|------|------|------|------|------|------|------|------|-------|