Tissues

The human body is composed of only **four basic types of tissue:**

- **Epithelial Tissue**: This tissue type covers body surfaces and lines body cavities providing protection and allowing for the absorption and secretion of substances. ,
- **Connective tissue** serves a connecting function. It supports and binds other tissues in the body.
- **Muscle Tissue**: Excitable cells capable of contraction allow muscle tissue to generate body movement.
- **Nervous Tissue**: This primary tissue of the nervous system allows for communication between various organs and tissues. It is composed of neurons and glial cells.

These tissues, which are formed by cells and molecules of the **extracellular matrix,** exist not as isolated units but rather in association with one another and in variable proportions, forming different organs and systems of the body.

Epithelial tissue

Epithelial tissue is one of the four basic tissue types composed of diverse morphologic and functional subtypes that cover body surfaces, line body cavities, and form a variety of glands. The unique feature of the epithelial tissues is its highly cellular composition with little extracellular matrix (ECM). Epithelial tissues rest on top of the basement membrane, which separates epithelia from underlying connective tissues.

The principal functions of epithelial tissues are:

- Covering, lining, and protecting surfaces (eg, skin).
- Absorption (eg, the intestines).
- Secretion (eg, the epithelial cells of glands).

- Contractility (eg, myoepithelial cells).

Epithelial tissue types

Epithelia tissues can be divided into two main groups according to their structure and function: **covering (or lining) epithelia** and **glandular epithelia.**

(1) Covering or Lining Epithelia

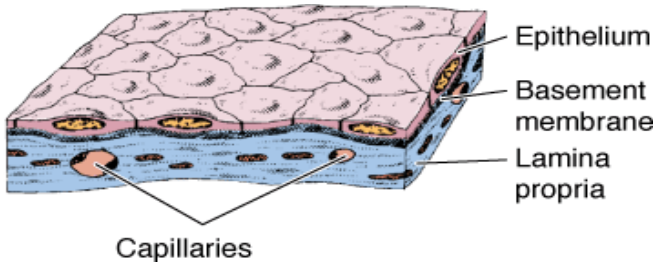
Covering epithelia are tissues in which the cells are organized in layers that cover the external surface or line the cavities of the body. They are classified according to the number of cell layers: **simple epithelia** contain only one layer of cells and **stratified epithelia** contain more than one layer.

A- Simple epithelium

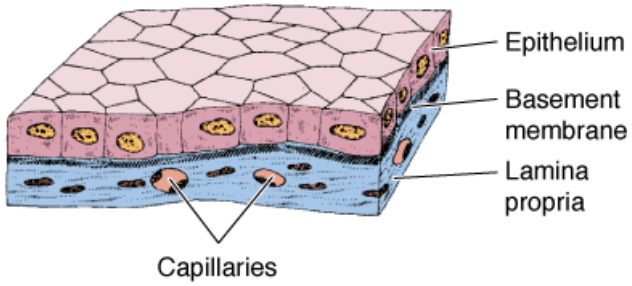
Is a single layer of cells with every cell in direct contact with the basement membrane that separates it from the underlying connective tissue. It is found where absorption and filtration occur. The thinness of the epithelial barrier facilitates these processes.

Simple epithelial tissues are classified by the **shape of their cell** into four major classes:

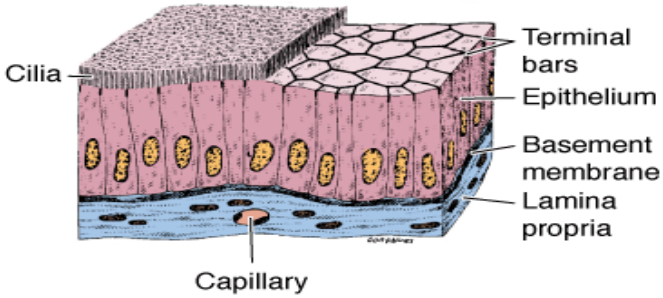
1- Simple squamous: which is found lining areas where passive diffusion of gases occur. Skin, walls of capillaries, linings of the pericardial, pleural, and peritoneal cavities, as well as the linings of the alveoli of the lungs.



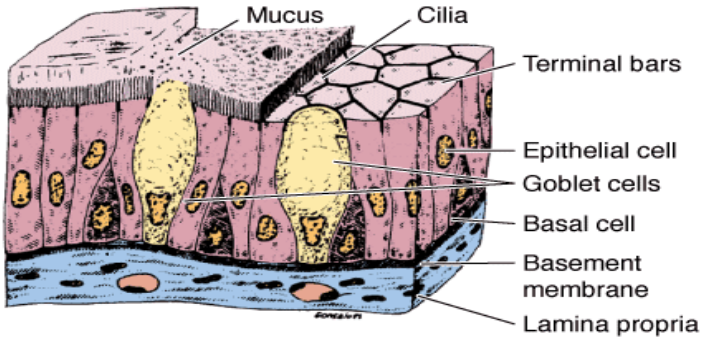
2- Simple cuboidal: these cells may have secretory, absorptive, or excretory functions. Examples include small collecting ducts of kidney, pancreas, and salivary gland.



3- Simple columnar; cells can be secretory, absorptive, or excretory; Simple columnar epithelium can be ciliated or non-ciliated; ciliated columnar is found in the female reproductive tract and uterus. Non-ciliated epithelium can also possess microvilli. Some tissues contain goblet cells. These secrete mucus and are found in stomach, colon and rectum.

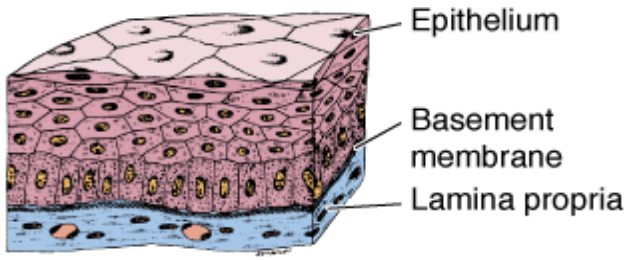


4- **Pseudo stratified**; can be ciliated or non-ciliated. The ciliated type is also called respiratory epithelium of the nasal cavity, trachea and bronchi. Protection, secretion; cilia-mediated transport of particles trapped in mucus out of the air passages.



B- Stratified epithelium

Stratified epithelium differs from simple epithelium in that it is multilayered. It is therefore found where body linings have to withstand mechanical or chemical insult such that layers can be abraded and lost without exposing sub epithelial layers.



Stratified epithelia are classified according to the cell shape of the superficial layers:

1- Stratified squamous

The very thin surface cells of stratified squamous epithelia can be:

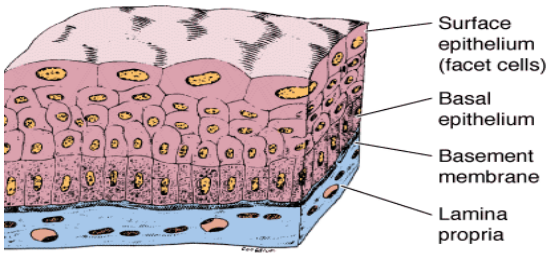
- **Stratified squamous keratinized epithelium** (rich in keratin intermediate filaments) is found mainly in the epidermis of skin. Its cells form many layers, and the cells closer to the underlying connective tissue are usually cuboidal or low columnar. Protection; prevents water loss.

- **Stratified squamous non keratinized epithelium** (with relatively sparse amounts of keratin).lines wet cavities (eg, mouth, esophagus). In such areas where water loss is not a problem. Protection; secretion and prevents water loss.

2- **Stratified cuboidal epithelium** is restricted to large excretory ducts of sweat and salivary glands, where it apparently provides a lining more robust than that of a simple epithelium.

3- **Stratified columnar epithelia** are rare, can be found in the conjunctiva lining the eyelids, where it is protective and secreting.

4-Transitional epithelium or **urothelium**: which lines only the urinary bladder, the ureter, and the upper part of the urethra, is characterized by a superficial layer of domelike cells that are neither squamous nor columnar. These cells, sometimes called umbrella cells, are essentially protective against the hypertonic and potentially cytotoxic effects of urine.



2- Glandular Epithelia

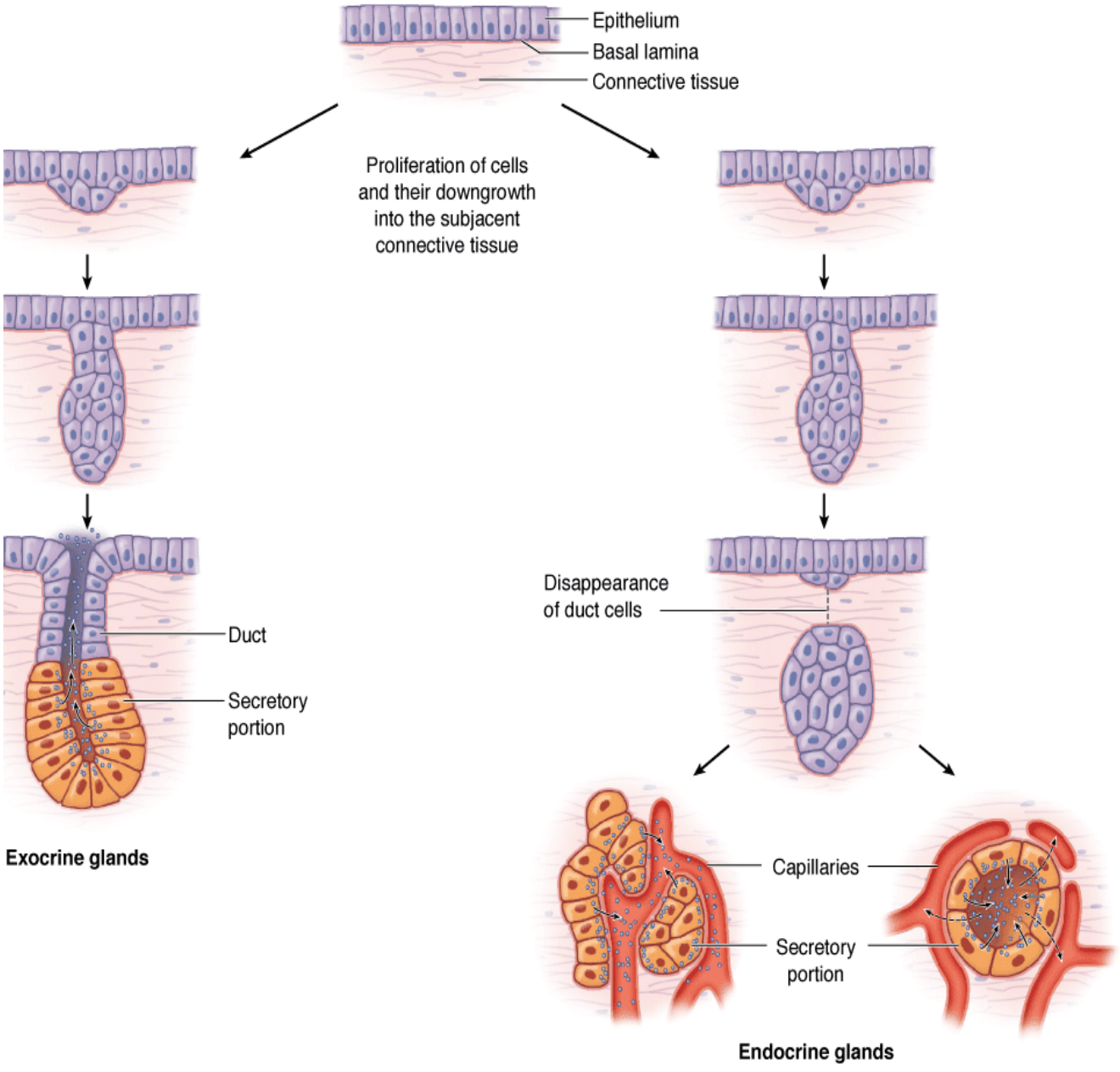
Glandular tissue is the type of epithelium that forms the **glands** .Glandular epithelia are formed by cells specialized to secrete. The molecules to be secreted are generally stored in the cells in small membrane-bound vesicles called **secretory granules.**

The epithelia that form glands can be classified according to various criteria. **Unicellular glands** consist of large isolated secretory cells and **multicellular glands** have clusters of cells. The classic unicellular gland is the **goblet cell** in the lining of the small intestine or respiratory tract. The term "gland" is used to designate large aggregates of secretory epithelial cells.

There are two major classifications of glands: endocrine glands and exocrine glands:

Endocrine glands have lost their connection to the surface from which they originated during development. These glands are therefore ductless and their secretions are picked up and transported to their sites of action by the bloodstream rather than by a duct system. Endocrine glands are the producers of **hormones**.

Exocrine glands retain their connection with the surface epithelium, the connection taking the form of tubular ducts lined with epithelial cells through which the secretions pass to the surface. Exocrine glands have a **secretory portion,** which contains the cells specialized for secretion, and **ducts,** which transport the secretion out of the gland.

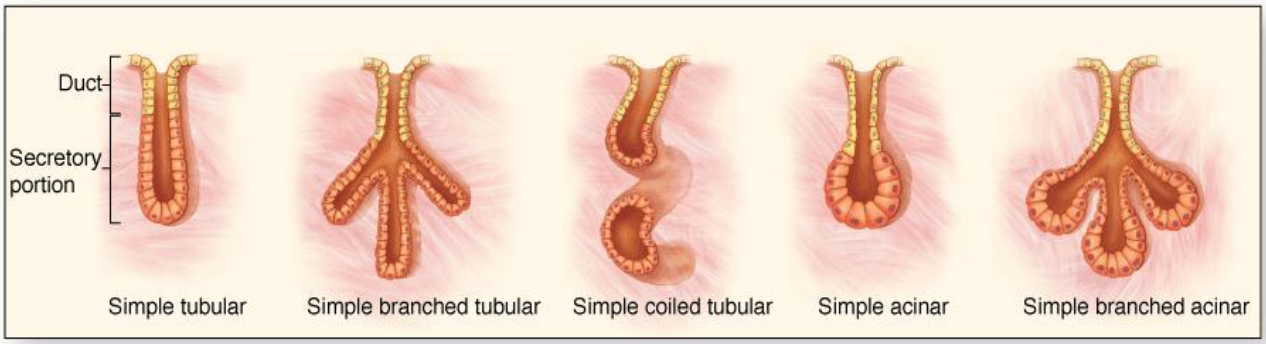


The morphology of these components allows the glands to be classified according to the scheme

- **Simple gland**

Ducts can be simple (un branched)

1- Simple tubular, mucous secretion, ex. small and large intestine.
2- Simple branched tubular, mostly mucous secretion, ex. stomach pylorus.
3- Simple coiled tubular, sweat secretion, ex. skin sweat glands.
4- Simple acinar, mucous secretion, ex. glands of penile urethra.
5- Simple branched acinar sebum secretion, skin sebaceous glands.

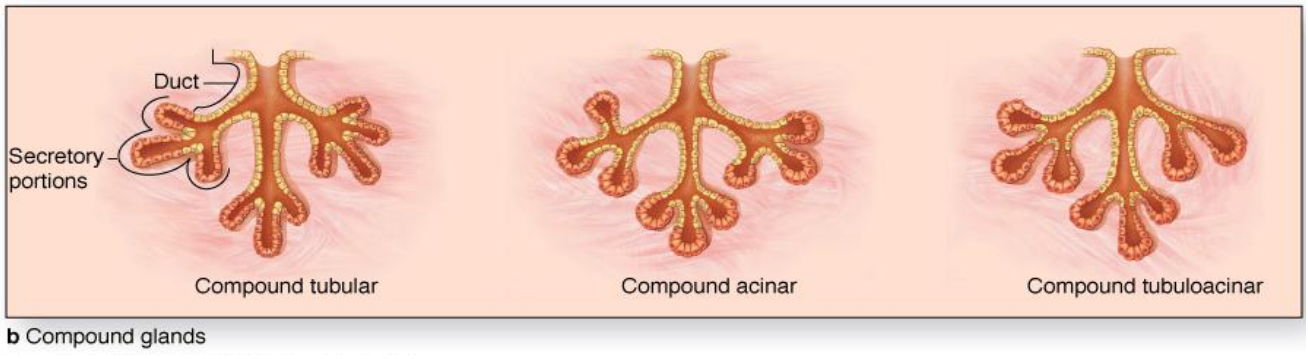


a Simple glands

- **Compound glands**

Duct with two or more branches

1- Compound tubular, mucous secretion, Brunner glands of duodenum
2- Compound acinar, watery protein - aceous secretion, Parotid glands, pancreas, and mammary glands.
3- Compound tubule acinar. Mucous and serous secretion Submandibular and sublingual salivary glands.



b Compound glands

Connective Tissue

As the name implies, **connective tissue** serves a connecting function. It supports and binds other tissues in the body. Unlike epithelial tissue, which has cells that are closely packed together, connective tissue has cells scattered throughout an extracellular matrix of fibrous proteins and glycoproteins attached to a basement membrane. The primary elements of connective tissue include a ground substance, fibers, and cells.

The ground substance acts as a fluid **matrix** that suspends the cells and fibers within the particular connective tissue type. Connective tissue fibers and matrix are synthesized by specialized cells called **fibroblasts**.

Functions of connective tissue cells:

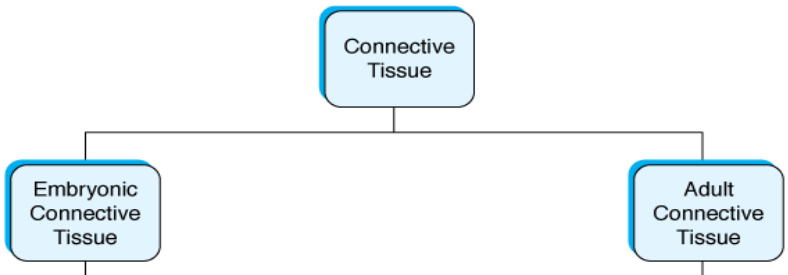
Cell Type	**Representative Product or Activity**	**Representative Function**
Fibroblast, chondroblast, osteoblast, odontoblast	Production of fibers and ground substance	Structural
Plasma cell	Production of antibodies	Immunologic (defense)

Lymphocyte (several types)	Production of immunocompetent cells	Immunologic (defense)
Eosinophilic leukocyte	Participation in allergic and vasoactive reactions, modulation of mast cell activities and the inflammatory process	Immunologic (defense)
Neutrophilic leukocyte	Phagocytosis of foreign substances, bacteria	Defense
Macrophage	Secretion of cytokines and other molecules, phagocytosis of foreign substances and bacteria, antigen processing and presentation to other cells	Defense
Mast cell and basophilic leukocyte	Liberation of pharmacologically active molecules (eg, histamine)	Defense (participate in allergic reactions)
Adipocyte	Storage of neutral fats	Energy reservoir, heat production

Fibers

The connective tissue fibers are formed by proteins that polymerize into elongated structures. The three main types of connective tissue fibers are **collagen, reticular,** and **elastic fibers.** Collagen and reticular fibers are both formed by the protein **collagen,** and elastic fibers are composed mainly of the protein **elastin.** These fibers are distributed unequally among the types of connective tissue and the predominant fiber type is usually responsible for conferring specific properties on the tissue.

Types of connective tissue



There are three main groups of connective tissues:

- **Loose connective tissue** holds organs in place and attaches epithelial tissue to other underlying tissues.
- **Dense connective tissue** helps attach muscles to bones and link bones together at joints.
- **Specialized connective tissue** encompasses a number of different tissues with specialized cells and unique ground substances. Some are solid and strong, while others are fluid and flexible. Examples include adipose, cartilage, bone, blood, and lymph.

Loose Connective Tissue

Is a very common type of connective tissue that supports many structures which are normally under some pressure and low friction. It usually supports epithelial tissue, forms a layer around small blood and lymphatic vessels, and fills the spaces between muscle and nerve fibers. Loose connective tissues provide support, flexibility, and strength required to support internal organs and structures such as blood vessels, lymph vessels, and nerves.

Loose connective tissue, sometimes called **areolar tissue**, has all the main components of connective tissue (cells, fibers, and ground substance) in roughly equal parts.

Three main types of **loose connective fibers** include collagenous, elastic, and reticular fibers.

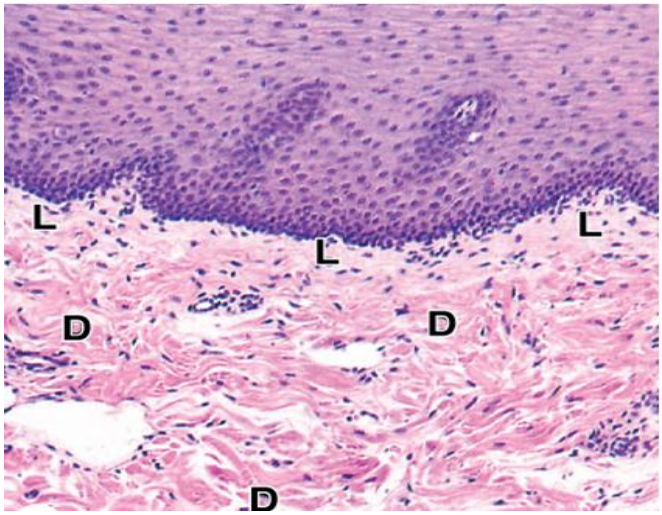
- **Collagenous fibers** are made of collagen and consist of bundles of fibrils that are coils of collagen molecules. These fibers help to strengthen connective tissue. Collagen fibrils are thin, elongated structures they have transverse striations. The striations are caused by the regular, overlapping arrangement of the collagen molecule subunits.
- **Elastic fibers** are made of the protein elastin and are stretchable. They help to give connective tissue elasticity. Elastic fibers are thinner than the average collagen fiber and form sparse networks interspersed with collagen bundles in many organs subject to much bending or stretching, such as the wall of large arteries.
- **Reticular fibers** join connective tissues to other tissues, are now known to consist mainly of collagen type III, which forms extensive networks of extremely thin and heavily glycosylated fibers in certain organs.

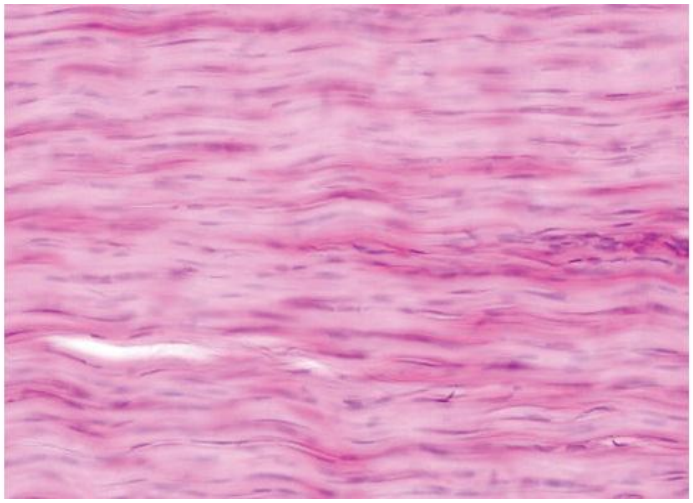
Dense Connective Tissue

Another type of connective tissue is dense or fibrous connective tissue, which can be found in tendons and ligaments. These structures help attach muscles to bones and link bones together at joints. Dense connective tissue is composed of large amounts of closely packed collagenous fibers. In comparison to loose connective tissue, dense tissue has a higher proportion of collagenous fibers to ground substance. It is thicker and stronger than loose connective tissue and forms a protective capsule layer around organs such as the liver and kidneys.

Dense connective tissue can be categorized into **dense regular**, **dense irregular** connective tissues.

- **Dense regular:** Tendons and ligaments are examples of dense regular connective tissue. The collagen bundles of **dense regular** connective tissue are arranged according to a definite pattern, with collagen fibers aligned with the linear orientation of fibroblasts in response to prolonged stresses exerted in the same direction, this arrangement offers great resistance to traction forces.
- **Dense irregular:** The dermis layer of the skin is composed of dense irregular connective tissue, the membrane capsule surrounding several organs is also dense irregular tissue. Collagen fibers are arranged in bundles without a definite orientation, the collagen fibers form a 3-dimensional network in dense irregular tissue, providing resistance to stress from all directions. Dense irregular connective tissue is often found closely associated with loose connective tissue.





Specialized Connective Tissues

Specialized connective tissues include a number of different tissues with specialized cells and unique ground substances. Some of these tissues are solid and strong, while

others are fluid and flexible. Examples include adipose, cartilage, bone, blood, and lymph.

Adipose Tissue

Adipose tissue is a specialized type of connective tissue in which **adipocytes** or fat cells predominate. These cells can be found isolated or in groups within loose or irregular connective tissue, often in large aggregates where they are the major component of adipose tissue.

The primary cells of adipose are **adipocytes**. These cells store fat in the form of triglycerides. Adipocytes appear round and swollen when fat is being stored and shrink as fat is used.

Adipose lines organs and body cavities to protect organs and insulate the body against heat loss. Adipose tissue also produces endocrine hormones that influence activities such as blood clotting, insulin sensitivity, and fat storage.

There are two types of adipose tissue with different locations, structures, colors, and pathologic characteristics.

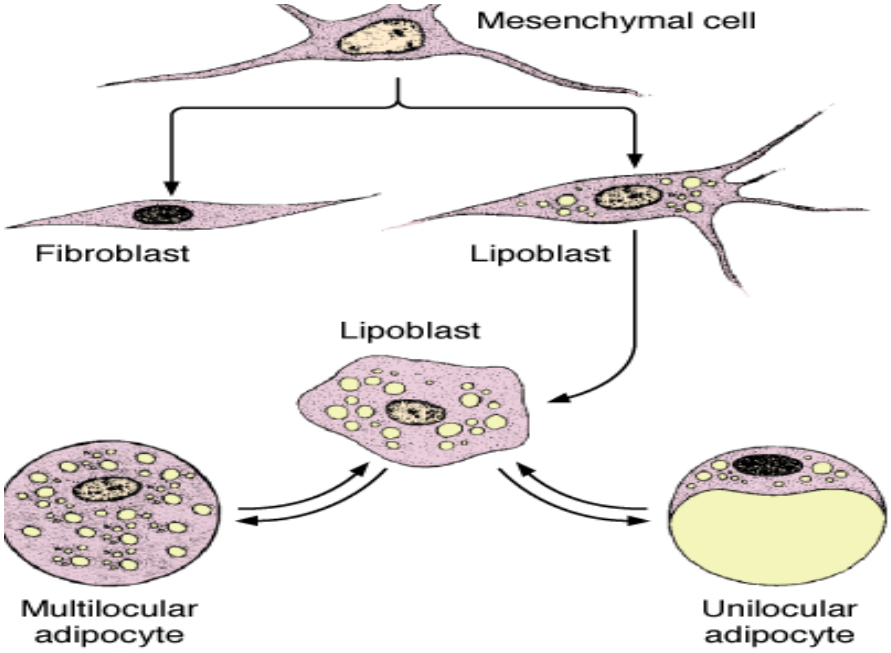
- **White Adipose Tissue**

The more common type, is composed of cells that contain one large central droplet of whitish-yellow fat in their cytoplasm. white adipose cells are spherical when isolated but are polyhedral when closely packed in adipose tissue. White adipocytes are called **unilocular** because triglycerides are stored in a single locus**.** The large droplet causes these cells to have eccentric and flattened nuclei. Specialized for energy storage.

- **Brown Adipose Tissue**

The color of brown adipose tissue or **brown fat** is due to both the numerous mitochondria (containing colored cytochromes) scattered through the adipocytes and the large number of blood capillaries in this tissue. Adipocytes of brown fat contain many small lipid inclusions and are therefore called **multilocular** . The many small lipid droplets, abundant mitochondria, and rich vasculature all help mediate this tissue's principal function of **heat production**. In comparison with white adipose tissue, which is present throughout the body, brown adipose tissue has a much more limited distribution.

Cells of brown adipose tissue cells are polygonal and generally smaller than cells of white adipose tissue but their cytoplasm contains a great number of lipid droplets of various sizes. These adipocytes have spherical and central nuclei and the numerous mitochondria have abundant long cristae.



Cartilage

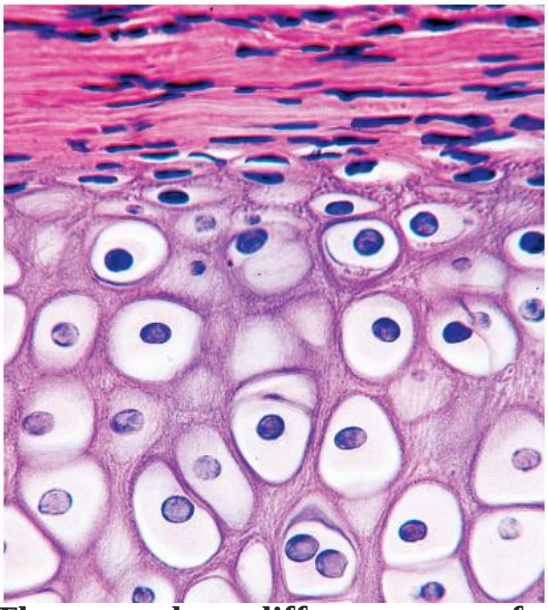
Cartilage is a specialized form of connective tissue in which the firm consistency of the extracellular matrix (ECM) allows the tissue to bear mechanical stresses without permanent distortion.

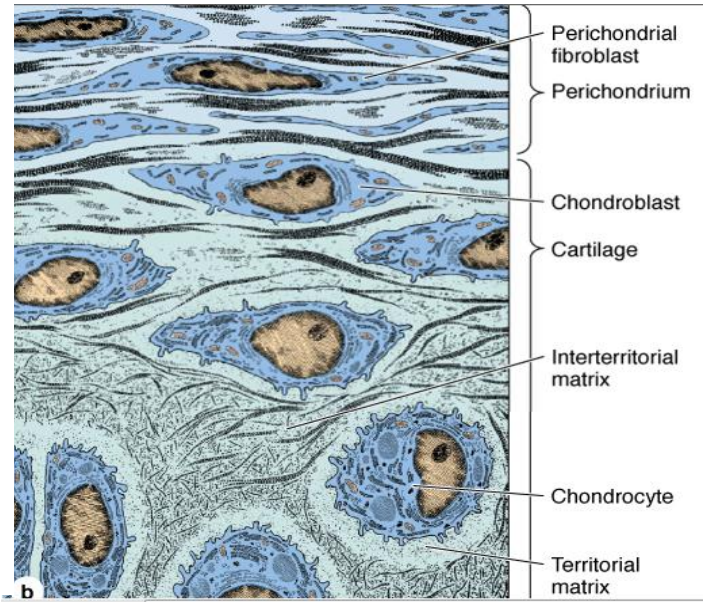
Cartilage consists of cells called **chondrocytes** and an extensive **extracellular matrix** composed of fibers and ground substance. Variations in the composition of these matrix components produce three types of cartilage adapted to local biomechanical needs.

Chondrocytes synthesize and secrete the ECM and the cells themselves are located in matrix cavities called **lacunae.**

Cartilage also provides flexible support for certain structures in adult humans including the nose, trachea, and ears.

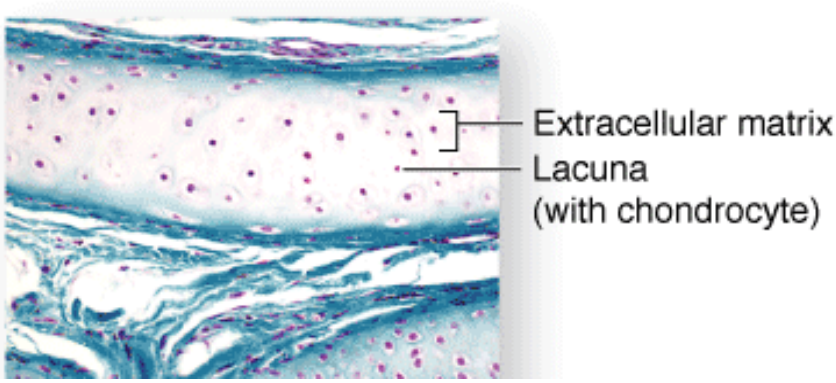
The **perichondrium** is a sheath of dense connective tissue that surrounds cartilage in most places, forming an interface between the cartilage and the tissue supported by the cartilage.



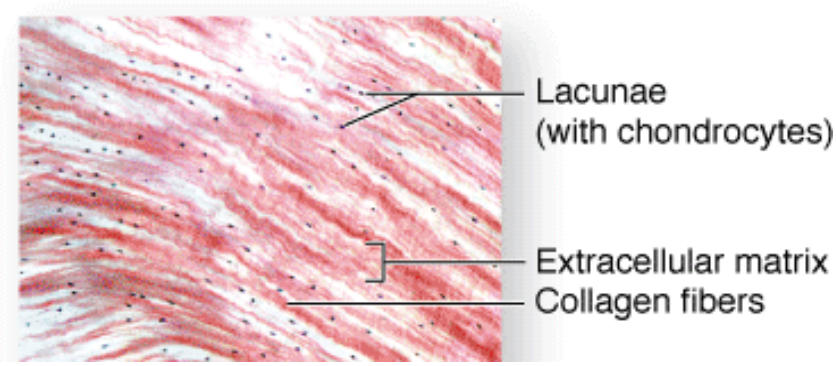


There are three different types of cartilage, each with different characteristics.

1- **Hyaline cartilage** is the most common type and is found in areas such as the trachea, ribs, and nose. Hyaline cartilage is flexible, elastic, and surrounded by a dense membrane called perichondrium.

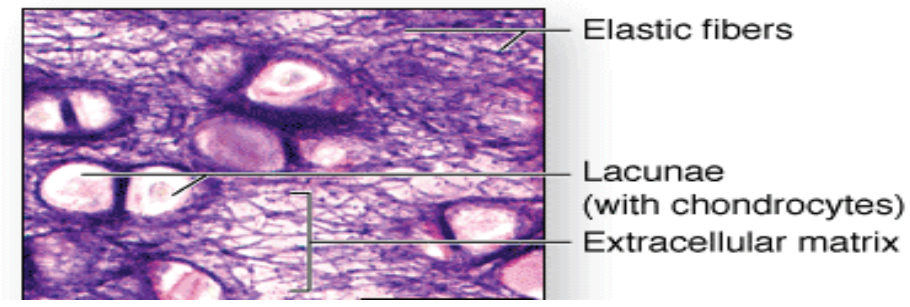


2- **Fibrocartilage** is the strongest type of cartilage and composed of hyaline and dense collagen fibers. It is inflexible, tough, and located in areas such as between vertebrae, in some joints, and in heart valves. Fibrocartilage does not have perichondrium.



3- **Elastic cartilage** contains elastic fibers and is the most flexible type of cartilage. It is found in locations such as the ear and larynx (voice box).

Bone Tissue



As the main constituent of the adult skeleton, bone tissue supports fleshy structures, protects vital organs such as those in the cranial and thoracic cavities, and harbors the bone marrow, where blood cells are formed. Bone also serves as a reservoir of calcium, phosphate, and other ions that can be released or stored in a controlled fashion to maintain constant concentrations of these important ions in body fluids.

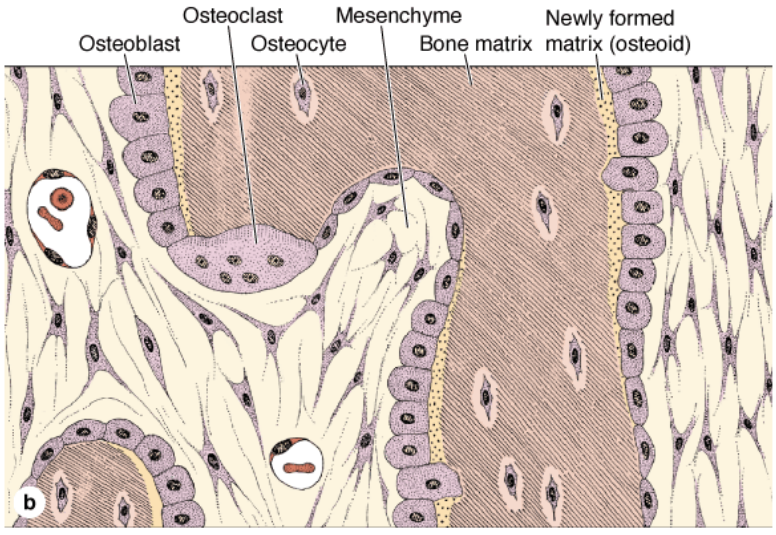
In addition, bones form a system of levers that multiply the forces generated during skeletal muscle contraction and transform them into bodily movements.

Bone is a specialized connective tissue composed of calcified intercellular material, the **bone matrix,** and three cell types:

1- **Osteocytes** which are found in cavities (**lacunae**) between layers (lamellae) of bone matrix, surrounded by calcifying matrix. An osteocyte and its processes occupy each lacuna and the canaliculi radiating from it

2- **Osteoblasts** which synthesize the organic components of the matrix, are located exclusively at the surfaces of bone matrix, usually side by side in a layer somewhat resembling a simple epithelium

3- **Osteoclasts** which are multi-nucleated giant cells involved in the resorption and remodeling of bone tissue.



Because metabolites are unable to diffuse through the calcified matrix of bone, the exchanges between osteocytes and blood capillaries depend on communication through the **canaliculi** , which are very thin, cylindrical spaces that perforate the matrix.

All bones are lined on both internal and external surfaces by layers of connective tissue containing osteogenic cells—**endosteum** on the internal surface and **periosteum** on the external surface.

The **periosteum** consists of a dense fibrous outer layer of collagen bundles and fibroblasts

There are two types of bone tissue: spongy and compact.

Spongy bone, also called cancellous bone, gets its name because of its spongy appearance. The large spaces, or vascular cavities, in this type of bone tissue contain blood vessels and bone marrow. Spongy bone is the first bone type formed during bone formation and is surrounded by compact bone.

Compact bone, or cortical bone, is strong, dense, and forms the hard outer bone surface. Small canals within the tissue allow for the passage of blood vessels and nerves. Mature bone cells, or osteocytes, are found in compact bone.

Microscopic examination of bone shows two types: immature **primary bone** and mature **secondary bone**.

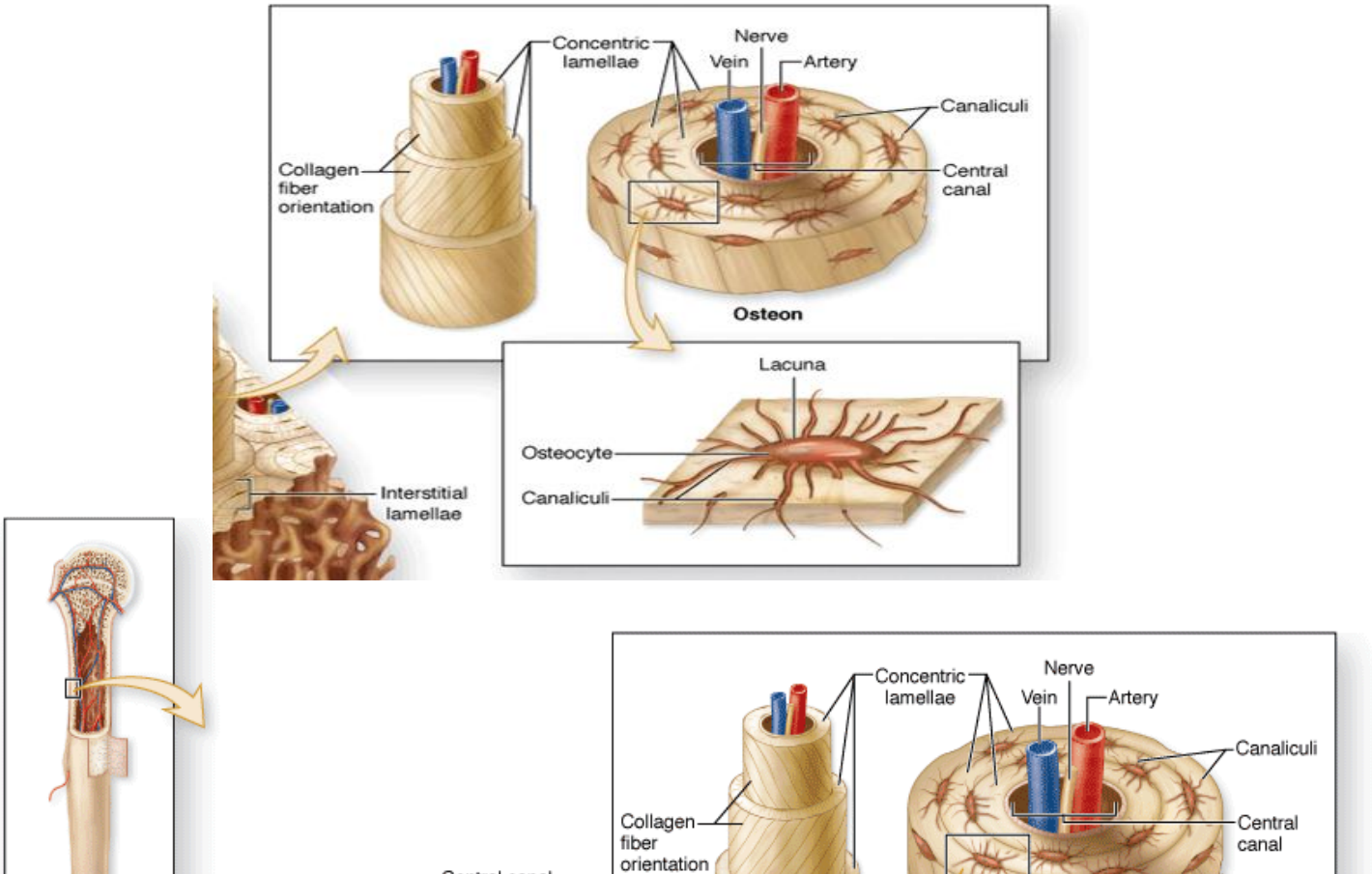
Primary Bone Tissue

Primary bone is the first bone tissue to appear in embryonic development and in fracture repair. It is characterized by random disposition of fine collagen fibers and is therefore often called **woven bone** . Primary bone tissue is usually temporary and is replaced in adults by secondary bone tissue except in a very few places in the body, eg, near the sutures of the calvaria, in tooth sockets, and in the insertions of some tendons.

In addition to the irregular array of collagen fibers, other characteristics of primary bone tissue are a lower mineral content and a higher proportion of osteocytes than that in secondary bones.

Secondary Bone Tissue

Secondary bone tissue is the type usually found in adults. It characteristically shows multiple layers of calcified matrix and is often referred to as **lamellar bone**. The lamellae are quite organized, either parallel to each other or concentrically around a vascular canal. Each complex of concentric bony lamellae surrounding a small canal containing blood vessels, nerves, and loose connective tissue is called an **osteon** (formerly known as **haversian system**). Lacunae with osteocytes are found between the lamellae, interconnected by canaliculi which allow all cells to be in contact with the source of nutrients and oxygen in the osteonic canal. The outer boundary of each osteon is a more collagen-rich layer called the **cement line**.



Reticular Tissue

Individual reticular fibers form delicate three-dimensional networks that support cells in **reticular tissue**. This specialized connective tissue consists of reticular fibers of type III collagen produced by specialized fibroblasts called reticular cells. The heavily glycosylated reticular fibers provide the architectural framework that creates special microenvironments for hematopoietic organs and lymphoid organs (bone marrow, lymph nodes, and spleen). The reticular cells are dispersed along this framework and partially cover the reticular fibers and ground substance with cytoplasmic processes. The resulting cell-lined system creates a sponge like structure within which cells and fluids are freely mobile.

Mucous Tissue

Mucous tissue is found mainly in the umbilical cord and fetal tissues. Mucous tissue has an abundance of ground substance composed chiefly of hyaluronic acid, making it a jellylike tissue containing very few collagen fibers with scattered fibroblasts. Mucous tissue is the principal component of the umbilical cord, where it is referred to as **Wharton's jelly.** A similar form of connective tissue is also found in the pulp cavity of young teeth.