chromosomes. It involves the following events:

a. The chromosomes at each pole unfold, and become long and slender. Finally, they become indistinguishable as were in an interphase cell.

b. Nuclear envelope is reconstructed around each group of chromosomes gradually. First, the membrane vesicles associate with the individual unfolding chromosomes, partially enclosing each chromosome. Then they fuse to form an envelope surrounding the entire set of chromosomes at each pole. The lamina proteins re-associate simultaneously with the reconstruction of nuclear envelope and form a complete lamina within the nuclear envelope

c. Nucleolar material, composed of partially processed ribosomal subunits and processing enzymes, dispersed into the cytoplasm in the prophase return to the nucleolar organizer site and forms a small nucleolus. Processing of this preexisting material then continues. Transcription of new rRNA also begins at this time; it gradually speeds up until it attains the high level of characteristic of interphase cell. Along with this, the nucleolus grows and attains its normal size. The nucleolus reformed at telophase, thus contains both old and new rRNA and ribosomal proteins.

With the transformation of chromosomes into chromatin and reconstruction of nucleoli, transcription of all the three RNA types gradually becomes normal. The spindle begins to disappear, and the asters become small by depolymerization of microtubules and the

centrioles take up their characteristic interphase position close to the one side of the nucleus. Short spindle microtubules persist for some time at the spindle equator to mark the region where the cytoplasm will later divide.

Cytokinesis:

Cytokinesis is the division of cytoplasm. It encloses the daughter nuclei formed by the karyokinesis in separate cells, thus completing the process of cell division. Cytokinesis is signaled at the metaphase by cytoplasmic movements that bring about equal distribution of mitochondria and other cell organelles in the two halves of the cell. Division occurs differently in animal cells and the plant cells.

Significance of Mitosis:

➢ **Maintenance of Size**- Mitosis helps maintaining the size of the cell. A cell, when full grown, divides by mitosis instead of growing further.

➢ **Growth**- A fertilized egg develops into an embryo and finally into an adult by repeated mitotic cell division.

➢ **Maintenance of Chromosome Number**- Mitosis keeps the number of chromosomes equal in all the cells of an individual. Thus, mitosis provides a complete set of genetic information to each cell, since DNA is duplicated in S phase prior to mitosis.

➢ **Repair**- Mitosis provides new cells to replace the old worn out and dying cells.

➢ **Healing and Regeneration**- Mitosis produces new cells for the healing of wounds and regeneration.

➢ **Reproduction-** Mitosis brings about multiplication in the acellular organisms. In multicellular organisms also, it plays an important role in reproduction, asexual aswell as sexual.

➢ **Evidence of Basic Relationship of Organisms-** Mitosis, being essentially similar in many kinds of organisms, supports the basic relationship of all living things.
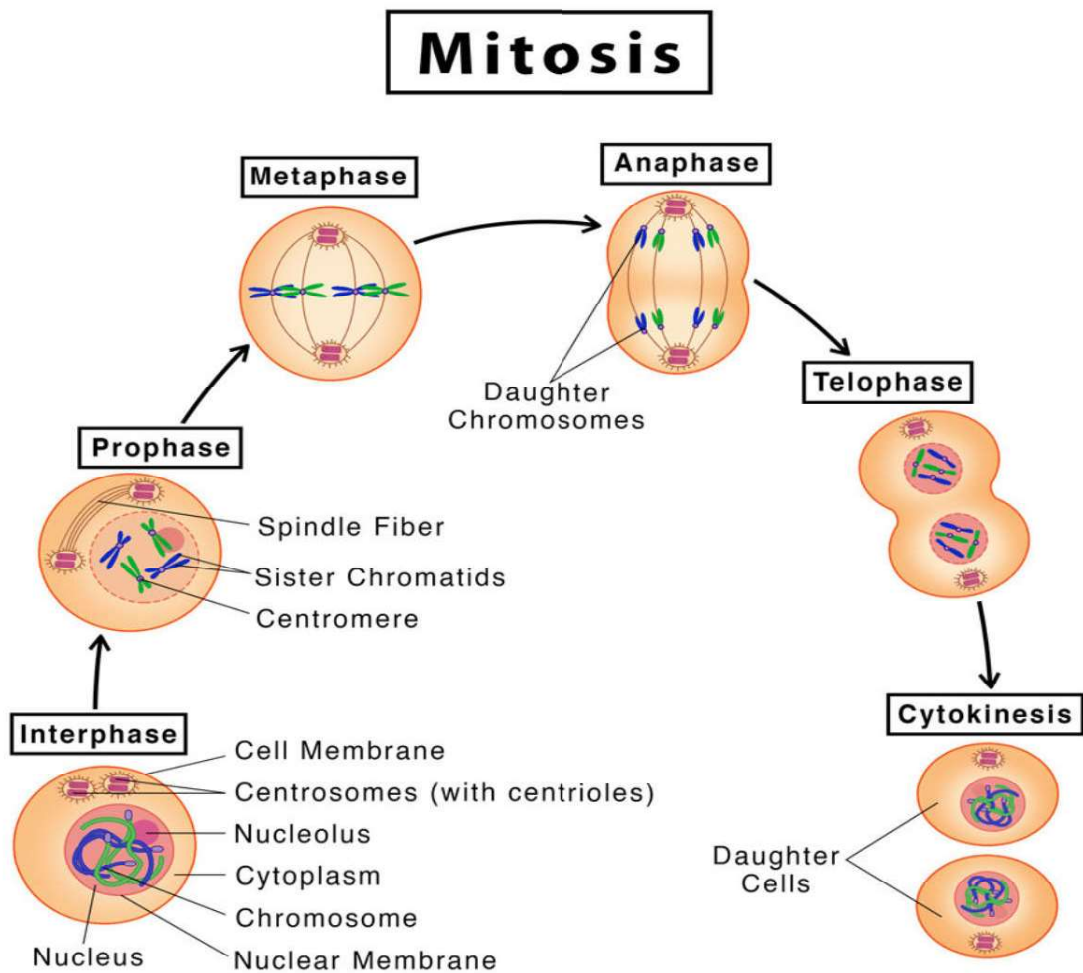

Figure 40: Mitosis division stages.

MEOSIS DIVISION:

Meiosis consists of two divisions that take place in rapid succession, with the chromosomes replicating only once. Thus, a parent cell produces four daughter cells, each having half the number of chromosomes and half of the nuclear DNA amount present in the parent cell. Meiosis is therefore also known as **reduction division**. The two divisions of meiosis are known as the first and the second meiotic divisions or **meiosis-I and meiosis-II**

Meiosis Divisions:

First meiotic division or Meiosis-I:

During the first meiotic division, the two homologous chromosomes of each pair separate from each other and go to separate daughter cells. This reduces the number of chromosomes from diploid to haploid condition. **Meiosis-I** is therefore known as **heterotypic division**. The four phases of this division are called Prophase-1, metaphase-1, anaphase-1 and telophase-1.

1- **Prophase-.** The meiotic prophase-1 is more complex than the mitotic prophase because of the process of recombination that occurs in it. It also lasts much longer than the mitotic prophase in the same organism. It may extend over weeks, months or even years. Although it is more or less a continuous process, it is divided into 5 sub- stages: leptotene, zygotene, pachytene, diplotene and diakinesis (Figure 41).
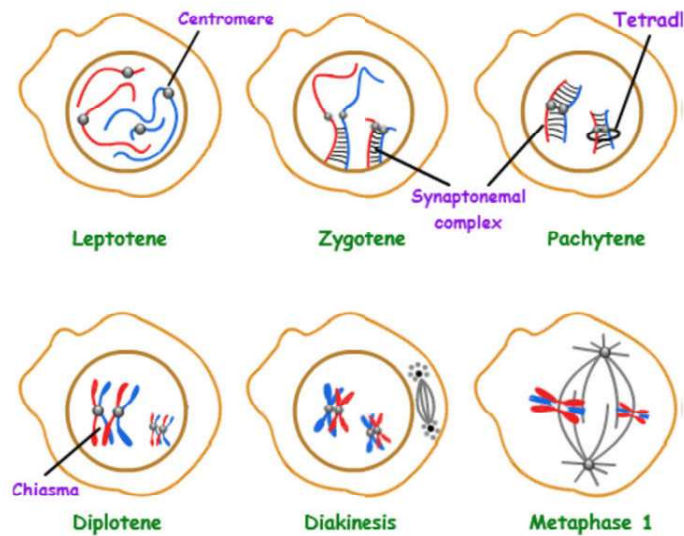
Figure 41: meiotic prophase-1 substages.

2- **Metaphase** I: The spindle shifts to the position that is earlier occupied by the nucleus. The tetrads scattered in the cytoplasm move to the equator of the spindle. Here, they align in two parallel metaphase plates, one formed by chromosomes and other by their homologous. The attachment of the tetrads to the spindle microtubules in metaphase-I is different from that of mitotic metaphase chromosomes. Each homologous chromosome has two kinetochores, one for each of its two chromatids Both the kinetochores of a homologous chromosome connect to the same spindle pole. The two kinetochores of its homologue join the opposite spindle pole.

3- **Anaphase-I**: From each tetrad, two chromatids of a chromosome move as a unit (dyad) to one pole of the spindle, and the other two chromatids of its homologue migrate to the opposite pole. Thus, the two homologous chromosomes of each pair are separated in the anaphase-I of meiosis. The process is also called as **disjunction.** As

a result, half of the chromosomes, which appear in early prophase, go to each pole. Thus, it is during anaphase-I that the real reduction in the chromosome number occurs. Each chromosome at the pole is still double and consists of two chromatids. Thus, the group of chromosomes at each pole though has only one member of each homologous pair still contains twice the haploid amount of DNA.

4- **Telophase I***:* During telophase I, the chromosome at each pole of the spindle partly unfolds and elongate, and form a nucleus with nucleolus and nuclear envelope. The spindle and asters disappear.

   The cytoplasm divides at its middle by constriction in an animal cell and by cell plate formation in a plant cell. This produces, two daughter cells, each with one nucleus. The nucleus of each daughter cell has received only one chromosome from each homologous pair. Thus, it has half the number of chromosomes, but double the amount of nuclear DNA as each chromosome is double.

Second meiotic division or Meiosis-II:

The meiosis-II is similar to mitosis as in this division, the two chromatids of each chromosome separate from each other and go to separate daughter cells. With the result, the number of chromosomes remains the same as produced by meiosis-I. Meiosis-II is, therefore, known as homotypic division. The four stages of this division are called prophase-II, metaphase-II, anaphase-II and telophase-II.

1- **Prophase-I***:* When there is no interkinesis, the telophase-I spindle is replaced by two new spindles; and the centrioles and asters, if present, duplicate and one copy of each comes to lie at each pole of

the new spindles. The telophase-I chromosomes move from the poles of the old spindle to the equators of the new spindles. If decondensation has occurred during telophase-I, the chromosome recondense to short rod lets as they migrate to the metaphase-II spindles.

2- If interkinesis is present, centrioles move apart and asters are formed around them. A spindle is formed between the centrioles. Chromosomes each consisting of two chromatids, appear in the nucleus. They are set free in the cytoplasm by breakdown of the nuclear envelope. Nucleus disappears.

3- **Metaphase-II**: The chromosomes get arranged at the equator of the spindle as a metaphase plate. The chromatids of each chromosome are joined at their kinetochores by chromosomal microtubules extending from the opposite poles of the spindle as in mitosis

4- **Anaphase-II**: The two chromatids of each chromosome separate and move to the opposite poles of the spindles. Here they are called chromosomes. Each pole has **haploid number of chromosomes and haploid amount of DNA**. This amount is one-fourth of the DNA present in the original cell which entered meiosis.

5- **Telophase-I***:* The chromosome at each pole decondenses, and nuclear envelope develops around them. This produces two nuclei. Nucleolus is formed in each nucleus. Spindle and asters disappear. In cases that lack interkinesis, four nuclei are formed in telophase-II

Cytokinesis:

Cytoplasm divides at its middle by constriction in an animal cell and by cell plate formation in a plant cell. This produces two daughter cells. The later have half the number of chromosomes, and half the amount of nuclear DNA, i.e., in Reduction division is complete when this point is reached. The cells formed by meiosis-II in animals are mature gametes. They do not divide further. A gamete must fuse with another suitable gamete before a new individual can develop. The cells formed by meiosis-II in plants are the spores. The sporescan develop into new individuals without fusing in pairs. In fact the main difference between a spore and a gamete is the ability of the spore to develop directly into a new individual.
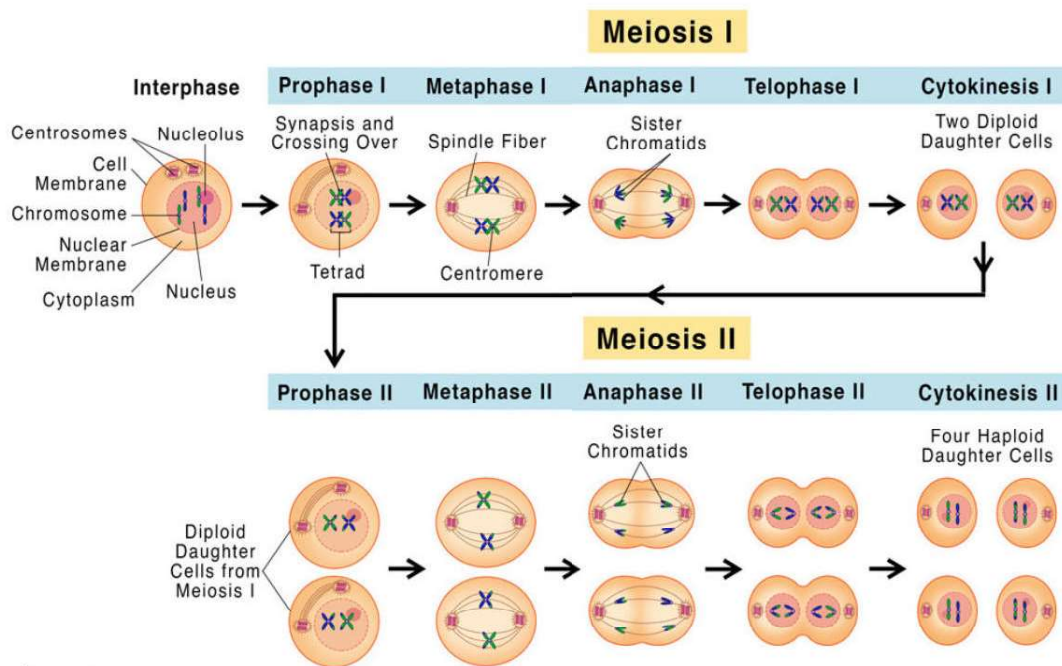

Figure 42: Stages of meiosis division.

HISTOLOGY

TISSUE LEVEL OF ORGNIZATION

The body contains at least 200 distinct cell types. These cells contain essentially the same internal structures, yet they vary enormously in shape and function. The different types of cells are not randomly distributed throughout the body; rather they occur in organized layers, a level of organization referred to as tissue. The human body starts as a single cell at fertilization. As this fertilized egg divides, it gives rise to trillions of cells, each built from the same blueprint, but organizing into tissues and becoming irreversibly committed to a developmental pathway.

Types of Tissues:

The term **tissue** is used to describe a group of cells found together in the body. The cells within a tissue share a common embryonic origin. Microscopic observation reveals that the cells in a tissue share morphological features and are arranged in an orderly pattern that achieves the tissue's functions. From the evolutionary perspective, tissues appear in more complex organisms. For example, multicellular protists, ancient eukaryotes, do not have cells organized into tissues.

Although there are many types of cells in the human body, they are organized into four broad categories of tissues: epithelial, connective, muscle, and nervous. Each of these categories is characterized by specific functions that contribute to the overall health and maintenance of the body. A disruption of the structure is a sign of injury or disease. Such changes can be detected through **histology**, the microscopic study of tissue appearance, organization, and function.

The Four Types of Tissues:

(A)   **Epithelial tissue**, also referred to as epithelium, refers to the sheets of cells that cover exterior surfaces of the body, lines internal cavities and passageways, and forms certain glands (Figure 43)..

(B)   **Connective tissue**, as its name implies, binds the cells and organs of the body together and functions in the protection, support, and integration of all parts of the body (Figure 43)..

(C)   **Muscle tissue** is excitable, responding to stimulation and contracting to provide movement, and occurs as three major types: skeletal (voluntary) muscle, smooth muscle, and cardiac muscle in the heart (Figure 43)

(D)   **Nervous tissue** is also excitable, allowing the propagation of electrochemical signals in the form of nerve impulses that communicate between different regions of the body (Figure 43).

The next level of organization is the organ, where several types of tissues come together to form a working unit. Just as knowing the structure and function of cells helps you in your study of tissues, knowledge of tissues will help you understand how organs function. The epithelial and connective tissues are discussed in detail in this chapter. Muscle and nervous tissues will be discussed only briefly in this chapter.
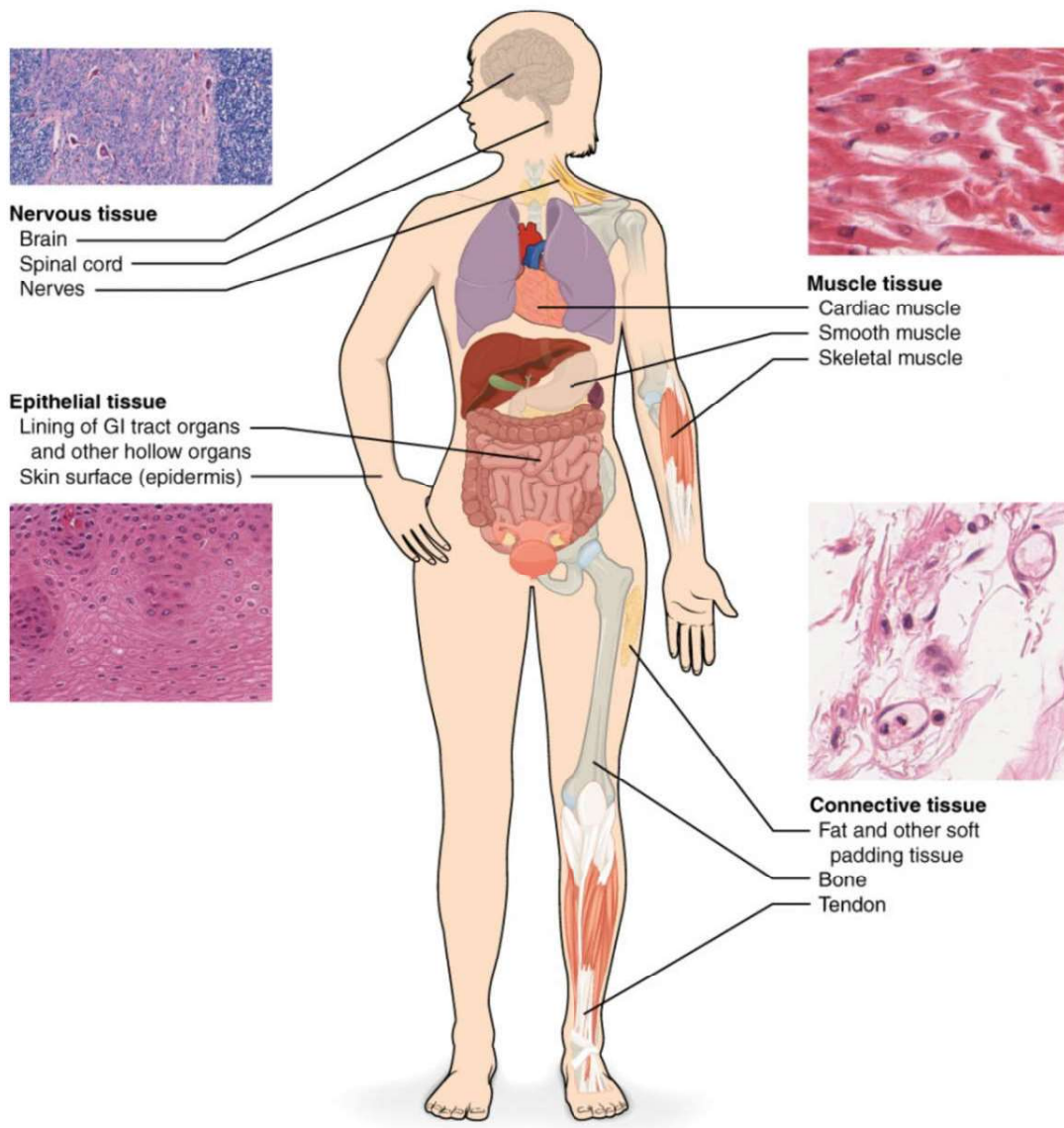
Figure 43: Four Types of Tissues: The four types of tissues are exemplified in nervous tissue, stratified squamous epithelial tissue, cardiac muscle tissue, and connective tissue in small intestine. Clockwise from nervous tissue. (Micrographs provided by the Regents of University of Michigan Medical School © 2012).

(A) PITHELIAL TISSUE

Most epithelial tissues are essentially large sheets of cells covering all the surfaces of the body exposed to the outside world and lining the outside of organs. Epithelium also forms much of the glandular tissue of the body. Skin is not the only area of the body exposed to the outside. Other areas include the airways, the digestive tract, as well as the urinary and reproductive systems, all of which are lined by an epithelium. Hollow organs and body cavities that do not connect to the exterior of the body, which includes, blood vessels and serous membranes, are lined by endothelium (plural = endothelia), which is a type of epithelium. Epithelial cells derive from all three major embryonic layers. The epithelia lining the skin, parts of the mouth and nose, and the anus develop from the ectoderm. Cells lining the airways and most of the digestive system originate in the endoderm. The epithelium that lines vessels in the lymphatic and cardiovascular system derives from the mesoderm and is called an endothelium.

All epithelia share some important structural and functional features. This tissue is highly cellular, with little or no extracellular material present between cells:

1- Adjoining cells form a specialized intercellular connection between their cell membranes called a **cell junction**.

2- The epithelial cells exhibit polarity with differences in structure and function between the exposed or **apical** facing surface of the cell and the basal surface close to the underlying body structures.

3- The **basal lamina**, a mixture of glycoproteins and collagen,

provides an attachment site for the epithelium, separating it from underlying connective tissue.

4- The basal lamina attaches to a **reticular lamina**, which is secreted by the underlying connective tissue, forming a **basement membrane** that helps hold it all together.

5- Epithelial tissues are nearly completely avascular. For instance, no blood vessels cross the basement membrane to enter the tissue, and nutrients must come by diffusion or absorption from underlying tissues or the surface.

6- Many epithelial tissues are capable of rapidly replacing damaged and dead cells. Sloughing off of damaged or dead cells is a characteristic of surface epithelium and allows our airways and digestive tracts to rapidly replace damaged cells with new cells.

Generalized Functions of Epithelial Tissue:

1- Epithelial tissues provide the body's first line of protection from physical, chemical, and biological wear and tear.

2- The cells of an epithelium act as gatekeepers of the body controlling permeability and allowing selective transfer of materials across a physical barrier.

3- All substances that enter the body must cross an epithelium. Some epithelia often include structural features that allow the selective transport of molecules and ions across their cell membranes.

4- Many epithelial cells are capable of secretion and release mucous and specific chemical compounds onto their apical surfaces. The epithelium of the small intestine releases digestive enzymes, for

example. Cells lining the respiratory tract secrete mucous that traps incoming microorganisms and particles. A glandular epithelium contains many secretory cells.

The Epithelial Cell:

Epithelial cells are typically characterized by the polarized distribution of organelles and membrane-bound proteins between their basal and apical surfaces. Particular structures found in some epithelial cells are an adaptation to specific functions. Certain organelles are segregated to the basal sides, whereas other organelles and extensions, such as cilia, when present, are on the apical surface.

Cilia are microscopic extensions of the apical cell membrane that are supported by microtubules. They beat in unison and move fluids as well as trapped particles. Ciliated epithelium lines the ventricles of the brain where it helps circulate the cerebrospinal fluid. The ciliated epithelium of your airway forms a mucociliary escalator that sweeps particles of dust and pathogens trapped in the secreted mucous toward the throat. It is called an escalator because it continuously pushes mucous with trapped particles upward. In contrast, nasal cilia sweep the mucous blanket down towards your throat. In both cases, the transported materials are usually swallowed, and end up in the acidic environment of your stomach.

Classification of Epithelial Tissues:

Epithelial tissues are classified according to the shape of the cells and number of the cell layers formed (Figure 44). Cell shapes can be squamous (flattened and thin), cuboidal (boxy, as wide as it is tall), or

columnar (rectangular, taller than it is wide). Similarly, the number of cell layers in the tissue can be one—where every cell rests on the basal lamina—which is a simple epithelium, or more than one, which is a stratified epithelium and only the basal layer of cells rests on the basal lamina. Pseudostratified (pseudo- = "false") describes tissue with a single layer of irregularly shaped cells that give the appearance of more than one layer. Transitional describes a form of specialized stratified epithelium in which the shape of the cells can vary.
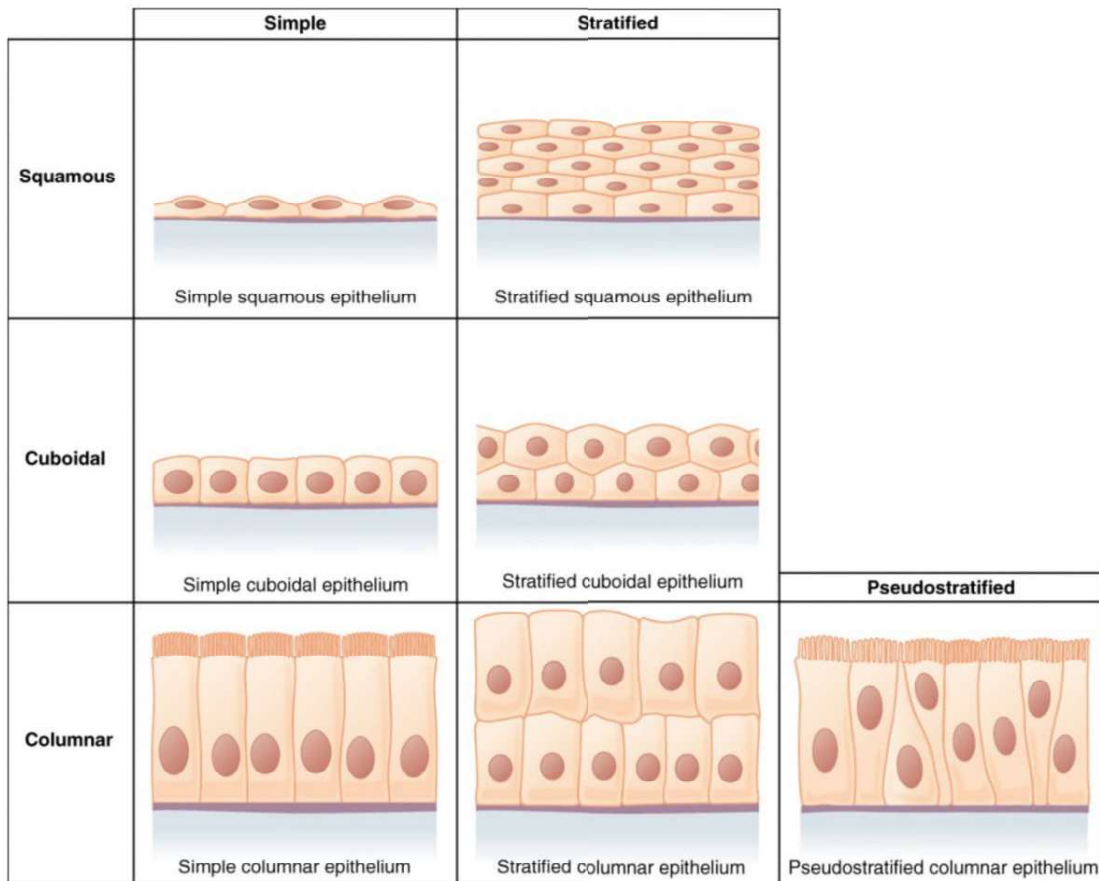
Figure 44: Cells of Epithelial Tissue. Simple epithelial tissue is organized as a single layer of cells and stratified epithelial tissue is formed by several cell layers.

I- Simple Epithelium

The shape of the cells in the single cell layer of simple epithelium reflects the functioning of those cells.

1- **Simple squamous epithelium:** the cells have the appearance of thin scales. Squamous cell nuclei tend to be flat, horizontal, and elliptical, mirroring the form of the cell. The **endothelium** is the epithelial tissue that lines vessels of the lymphatic and cardiovascular system, and it is made up of a single layer of squamous cells. Simple squamous epithelium, because of the thinness of the cell, is present where rapid passage of chemical compounds is observed. The alveoli of lungs where gases diffuse, segments of kidney tubules, and the lining of capillaries are also made of simple squamous epithelial tissue. The **mesothelium** is a simple squamous epithelium that forms the surface layer of the serous membrane that lines body cavities and internal organs. Its primary function is to provide a smooth and protective surface. Mesothelial cells are squamous epithelial cells that secrete a fluid that lubricates the mesothelium.

2- **Simple cuboidal epithelium**: the nucleus of the box-like cells appears round and is generally located near the center of the cell. These epithelia are active in the secretion and absorptions of molecules. Simple cuboidal epithelia are observed in the lining of the kidney tubules and in the ducts of glands.

3- **Simple columnar epithelium**, the nucleus of the tall column-like cells tends to be elongated and located in the basal end of the cells.

Like the cuboidal epithelia, this epithelium is active in the absorption and secretion of molecules. Simple columnar epithelium forms the lining of some sections of the digestive system and parts of the female reproductive tract. Ciliated columnar epithelium is composed of simple columnar epithelial cells with cilia on their apical surfaces. These epithelial cells are found in the lining of the fallopian tubes and parts of the respiratory system, where the beating of the cilia helps remove particulate matter.

4- **Pseudostratified columnar epithelium** is a type of epithelium that appears to be stratified but instead consists of a single layer of irregularly shaped and differently sized columnar cells. In pseudostratified epithelium, nuclei of neighboring cells appear at different levels rather than clustered in the basal end. The arrangement gives the appearance of stratification; but in fact all the cells are in contact with the basal lamina, although some do not reach the apical surface. Pseudostratified columnar epithelium is found in the respiratory tract, where some of these cells have cilia. Both simple and pseudostratified columnar epithelia are heterogeneous epithelia because they include additional types of cells interspersed among the epithelial cells. For example, a **goblet cell** is a mucous-secreting unicellular "gland" interspersed between the columnar epithelial cells of mucous membranes (Figure 45).

II- Stratified Epithelium:

1- A stratified epithelium consists of several stacked layers of cells. This epithelium protects against physical and chemical wear and

tear. The stratified epithelium is named by the shape of the most apical layer of cells, closest to the free space.

2- **Stratified squamous epithelium** is the most common type of stratified epithelium in the human body. The apical cells are squamous, whereas the basal layer contains either columnar or cuboidal cells. The top layer may be covered with dead cells filled with keratin. Mammalian skin is an example of this dry, keratinized, stratified squamous epithelium. The lining of the mouth cavity is an example of an unkeratinized, stratified squamous epithelium. **Stratified cuboidal epithelium** and **stratified columnar epithelium** can also be found in certain glands and ducts but are uncommon in the human body.

3- **Transitional epithelium**, another kind of stratified epithelium is so-called because of the gradual changes in the shapes of the apical cells as the bladder fills with urine. It is found only in the urinary system, specifically the ureters and urinary bladder. When the bladder is empty, this epithelium is convoluted and has cuboidal apical cells with convex, umbrella shaped, apical surfaces. As the bladder fills with urine, this epithelium loses its convolutions and the apical cells transition from cuboidal to squamous. It appears thicker and more multi-layered when the bladder is empty, and more stretched out and less stratified when the bladder is full and distended (Figure 46).
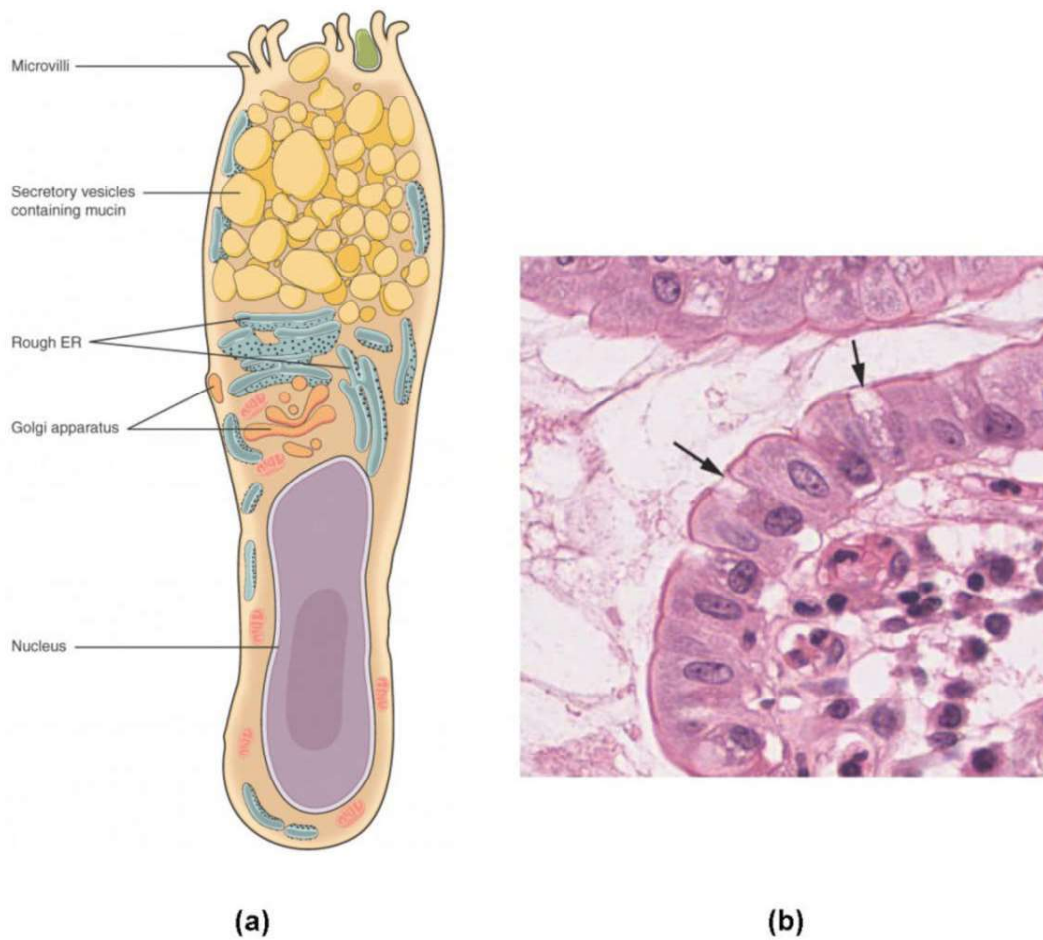
(a)   (b)

Figure 45: Goblet Cell. (a) In the lining of the small intestine, columnar epithelium cells are interspersed with goblet cells. (b) The arrows in this micrograph point to the mucous-secreting goblet cells. (Micrograph provided by the Regents of University of Michigan Medical School © 2012).

Figure 46: Transitional epithelium Lines the bladder, urethra and ureters Allows the urinary organs to expand and stretch.

Glandular Epithelium:

A gland is a structure made up of one or more cells modified to synthesize and secrete chemical substances. Most glands consist of groups of epithelial cells. A gland can be classified as an **endocrine gland**, a ductless gland that releases secretions directly into surrounding tissues and fluids (endo- = "inside"), or an **exocrine gland** whose secretions leave through a duct that opens directly, or indirectly, to the external environment (exo- = "outside").

1- Endocrine Glands:

The secretions of endocrine glands are called hormones. Hormones are released into the interstitial fluid, diffused into the bloodstream, and delivered to targets, in other words, cells that have receptors to bind the hormones. The endocrine system is part of a major regulatory system coordinating the regulation and integration of body responses. A few examples of endocrine glands include the anterior pituitary, thymus, adrenal cortex, and gonads.

2- Exocrine Glands:

Exocrine glands release their contents through a duct that leads to the epithelial surface. Mucous, sweat, saliva, and breast milk are all examples of secretions from exocrine glands. They are all discharged through tubular ducts. Secretions into the lumen of the gastrointestinal tract, technically outside of the body, are of the exocrine category.

Glandular Structure:

Exocrine glands are classified as either unicellular or multicellular. The unicellular glands are scattered single cells, such as goblet cells, found in the mucous membranes of the small and large intestine. The multicellular exocrine glands known as serous glands develop from simple epithelium to form a secretory surface that secretes directly into an inner cavity. These glands line the internal cavities of the abdomen and chest and release their secretions directly into the cavities. Other multicellular exocrine glands release their contents through a tubular duct. The duct is single in a simple gland but in compound glands is divided into one or more branches (Figure 47). In tubular glands, the ducts can be straight or coiled, whereas tubes that form pockets are alveolar (acinar), such as the exocrine portion of the pancreas. Combinations of tubes and pockets are known as tubuloalveolar (tubuloacinar) compound glands. In a branched gland, a duct is connected to more than one secretory group of cells.

Methods and Types of Secretion:

Exocrine glands can be classified by their mode of secretion and the nature of the substances released, as well as by the structure of the glands and shape of ducts (Figure 48).

1- **Merocrine secretion** is the most common type. The secretions are enclosed in vesicles that move to the apical surface of the cell where the contents are released by exocytosis. For example, watery mucous containing the glycoprotein mucin, a lubricant that offers some pathogen protection is a merocrine secretion. The eccrine glands that produce and secrete sweat are another example.

2- **Apocrine secretion** accumulates near the apical portion of the cell. That portion of the cell and its secretory contents pinch off from the cell and are released. The sweat glands of the armpit are classified as apocrine glands. Both merocrine and apocrine glands continue to produce and secrete their contents with little damage caused to the cell because the nucleus and golgi regions remain intact after secretion.

3- **Holocrine secretion** involves the rupture and destruction of the entire gland cell. The cell accumulates its secretory products and releases them only when it bursts. New gland cells differentiate from cells in the surrounding tissue to replace those lost by secretion. The sebaceous glands that produce the oils on the skin and hair are holocrine glands/cells (Figure 49).

Glands are also named after the products they produce. The **serous gland** produces watery, blood-plasma-like secretions rich in enzymes such as alpha amylase, whereas the **mucous gland** releases watery to viscous products rich in the glycoprotein mucin. Both serous and mucous glands are common in the salivary glands of the mouth. Mixed exocrine glands contain both serous and mucous glands and release both types of secretions.
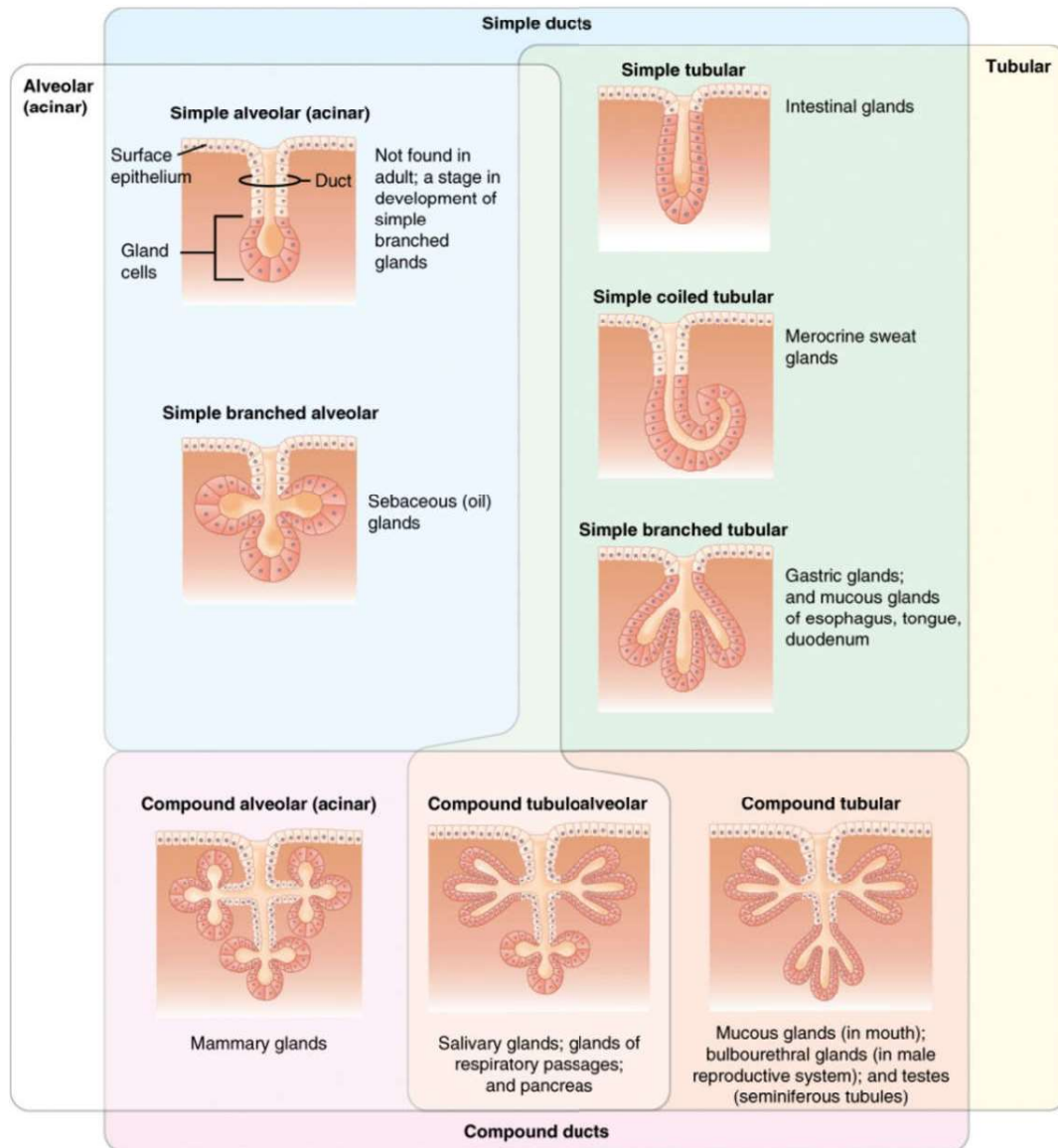
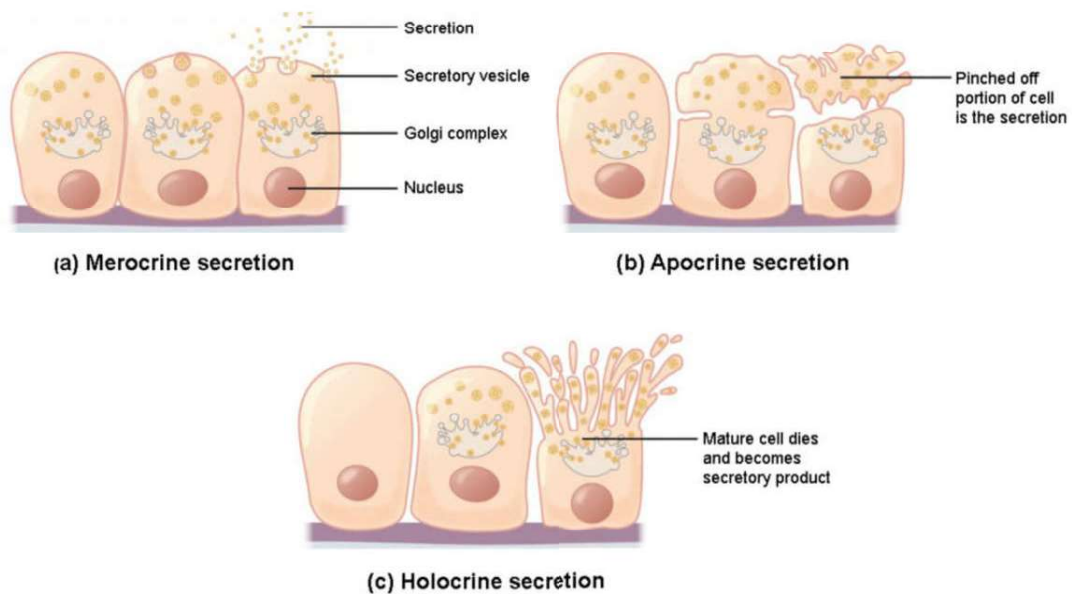**Figure 47:** Types of Exocrine Glands. Exocrine glands are classified by their structure.

(a) Merocrine secretion

- Secretion
- Secretory vesicle
- Golgi complex
- Nucleus

(b) Apocrine secretion

- Pinched off portion of cell is the secretion

(c) Holocrine secretion

- Mature cell dies and becomes secretory product

Figure 48: Modes of Glandular Secretion. (a) In merocrine secretion, (b) In apocrine secretion (c) In holocrine secretion.
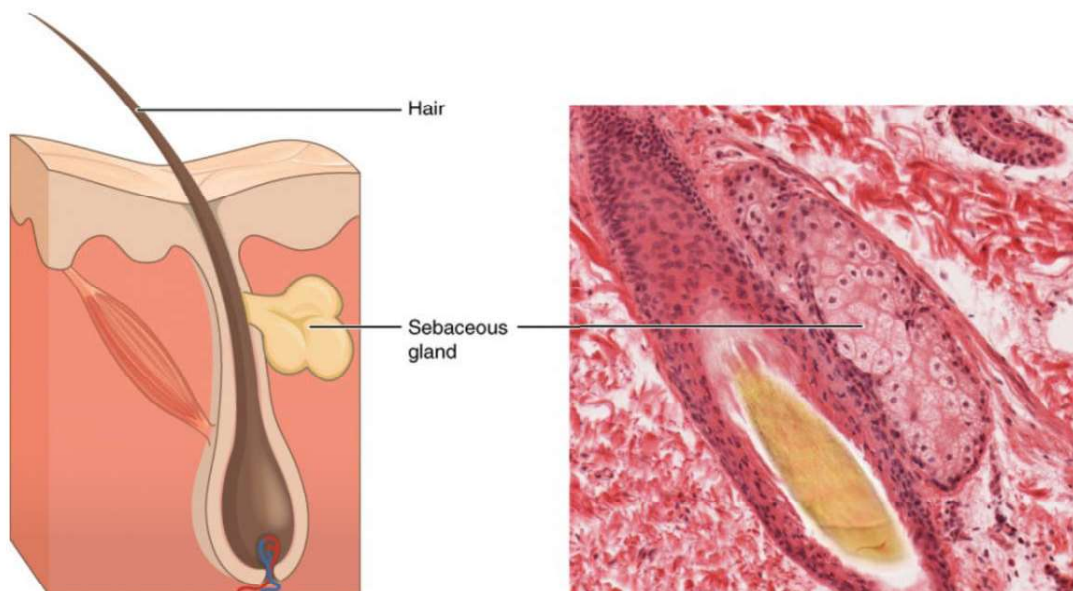

- Hair
- Sebaceous gland

Figure 49: Sebaceous Glands. These glands secrete oils that lubricate and protect the skin. They are holocrine glands, and they are destroyed after releasing their contents. New glandular cells form to replace the cells that are lost. (Micrograph provided by the Regents of University of Michigan Med. School 2012).

(B) CONECTIVE TISSUE:

Connective Tissue Supports and Protects:

As may be obvious from its name, one of the major functions of connective tissue is to connect tissues and organs. Unlike epithelial tissue, which is composed of cells closely packed with little or no extracellular space in between, connective tissue cells are dispersed in a **matrix**. The matrix usually includes a large amount of extracellular material produced by the connective tissue cells that are embedded within it. The matrix plays a major role in the functioning of this tissue. The major component of the matrix is a **ground substance** often crisscrossed by protein fibers. This ground substance is usually a fluid, but it can also be mineralized and solid, as in bones. Connective tissues come in a vast variety of forms, yet they typically have in common three characteristic components: cells, large amounts of amorphous ground substance, and protein fibers. The amount and structure of each component correlates with the function of the tissue, from the rigid ground substance in bones supporting the body to the inclusion of specialized cells; for example, a phagocytic cell that engulfs pathogens and rids tissue of cellular debris.

Functions of Connective Tissues:

Connective tissues perform many functions in the body:

1- The most importantly, they support and connect other tissues; from the connective tissue sheath that surrounds muscle cells, to the tendons that attach muscles to bones, and to the skeleton that supports the positions of the body.

2- Protection is another major function of connective tissue, in the form of fibrous capsules and bones that protect delicate organs and, of course, the skeletal system. Specialized cells in connective tissue defend the body from microorganisms that enter the body.

3- Transport of fluid, nutrients, waste, and chemical messengers is ensured by specialized fluid connective tissues, such as blood and lymph. Adipose cells store surplus energy in the form of fat and contribute to the thermal insulation of the body.

Classification of Connective Tissues:

The three broad categories of connective tissue are classified according to the characteristics of their ground substance and the types of fibers found within the matrix.

I- **Connective tissue proper** includes **loose connective tissue** and **dense connective tissue**. Both tissues have a variety of cell types and protein fibers suspended in a viscous ground substance. Dense connective tissue is reinforced by bundles of fibers that provide tensile strength, elasticity, and protection. In loose connective tissue, the fibers are loosely organized, leaving large spaces in between.

II- **Supportive connective tissue**—bone and cartilage— provide structure and strength to the body and protect soft tissues. A few distinct cell types and densely packed fibers in a matrix characterize these tissues. In bone, the matrix is rigid and described as calcified because of the deposited calcium salts.

III- Fluid connective tissue, in other words, lymph and blood, various specialized cells circulate in a watery fluid containing salts, nutrients, and dissolved proteins.

I- Connective tissue proper:

Fibroblasts are present in all connective tissue proper (Figure 50). Fibrocytes, adipocytes, and mesenchymal cells are fixed cells, which means they remain within the connective tissue. Other cells move in and out of the connective tissue in response to chemical signals. Macrophages, mast cells, lymphocytes, plasma cells, and phagocytic cells are found in connective tissue proper but are actually part of the immune system protecting the body.
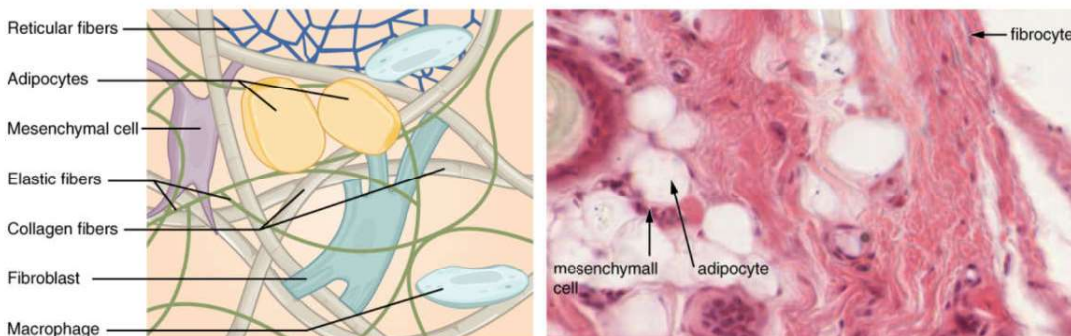
Figure 50: Connective Tissue Proper. Fibroblasts produce this fibrous tissue. Connective tissue proper includes the fixed cells fibrocytes, adipocytes, and mesenchymal cells. (Micrograph provided by the Regents of University of Michigan Medical School © 2012).

Cell Types:

The most abundant cell in connective tissue proper is the **fibroblast**. Polysaccharides and proteins secreted by fibroblasts combine with extra-cellular fluids to produce a viscous ground substance that, with embedded fibrous proteins, forms the extra-cellular matrix. As you

might expect, a **fibrocyte**, a less active form of fibroblast, is the second most common cell type in connective tissue proper.

Adipocytes are cells that store lipids as droplets that fill most of the cytoplasm. There are two basic types of adipocytes: white and brown. The brown adipocytes store lipids as many droplets, and have high metabolic activity. In contrast, white fat adipocytes store lipids as a single large drop and are metabolically less active. Their effectiveness at storing large amounts of fat is witnessed in obese individuals. The number and type of adipocytes depends on the tissue and location, and vary among individuals in the population.

The **mesenchymal cell** is a multipotent adult stem cell. These cells can differentiate into any type of connective tissue cells needed for repair and healing of damaged tissue. The macrophage cell is a large cell derived from a monocyte, a type of blood cell, which enters the connective tissue matrix from the blood vessels. The macrophage cells are an essential component of the immune system, which is the body's defense against potential pathogens and degraded host cells. When stimulated, macrophages release cytokines, small proteins that act as chemical messengers. Cytokines recruit other cells of the immune system to infected sites and stimulate their activities. Roaming, or free, macrophages move rapidly by amoeboid movement, engulfing infectious agents and cellular debris. In contrast, fixed macrophages are permanent residents of their tissues. The mast cell, found in connective tissue proper, has many cytoplasmic granules. These granules contain the chemical signals histamine and heparin. When irritated or damaged, mast cells release histamine, an inflammatory mediator, which causes

vasodilation and increased blood flow at a site of injury or infection, along with itching, swelling, and redness you recognize as an allergic response. Like blood cells, mast cells are derived from hematopoietic stem cells and are part of the immune system.

Connective Tissue Fibers and Ground Substance:

Three main types of fibers are secreted by fibroblasts: collagen fibers, elastic fibers, and reticular fibers. **Collagen fiber** is made from fibrous protein subunits linked together to form a long and straight fiber. Collagen fibers, while flexible, have great tensile strength, resist stretching, and give ligaments and tendons their characteristic resilience and strength. These fibers hold connective tissues together, even during the movement of the body.

Elastic fiber contains the protein elastin along with lesser amounts of other proteins and glycoproteins. The main property of elastin is that after being stretched or compressed, it will return to its original shape. Elastic fibers are prominent in elastic tissues found in skin and the elastic ligaments of the vertebral column.

Reticular fiber is also formed from the same protein subunits as collagen fibers; however, these fibers remain narrow and are arrayed in a branching network. They are found throughout the body, but are most abundant in the reticular tissue of soft organs, such as liver and spleen, where they anchor and provide structural support to the **parenchyma** (the functional cells, blood vessels, and nerves of the organ).

All of these fiber types are embedded in ground substance. Secreted by fibroblasts, ground substance is made of polysaccharides, specifically

hyaluronic acid, and proteins. These combine to form a proteoglycan with a protein core and polysaccharide branches. The proteoglycan attracts and traps available moisture forming the clear, viscous, colorless matrix you now know as ground substance.

a) Loose Connective Tissue:

Loose connective tissue is found between many organs where it acts both to absorb shock and bind tissues together. It allows water, salts, and various nutrients to diffuse through to adjacent or imbedded cells and tissues.

(1) Areolar tissue

Shows little specialization. It contains all the cell types and fibers previously described (Figure 50). and is distributed in a random, web-like fashion. It fills the spaces between muscle fibers, surrounds blood and lymph vessels, and supports organs in the abdominal cavity. Areolar tissue underlies most epithelia and represents the connective tissue component of epithelial membranes, which are described further in a later section.

(2) Adipose tissue:

Consists mostly of fat storage cells, with little extracellular matrix (Figure 51). A large number of capillaries allow rapid storage and mobilization of lipid molecules. White adipose tissue is most abundant. It can appear yellow and owes its color to carotene and related pigments from plant food. White fat contributes mostly to lipid storage and can serve as insulation from cold temperatures and mechanical injuries.

White adipose tissue can be found protecting the kidneys and cushioning the back of the eye.

Brown adipose tissue is more common in infants, hence the term "baby fat." In adults, there is a reduced amount of brown fat and it is found mainly in the neck and clavicular regions of the body. The many mitochondria in the cytoplasm of brown adipose tissue help explain its efficiency at metabolizing stored fat. Brown adipose tissue is thermogenic, meaning that as it breaks down fats, it releases metabolic heat, rather than producing adenosine triphosphate (ATP), a key molecule used in metabolism.
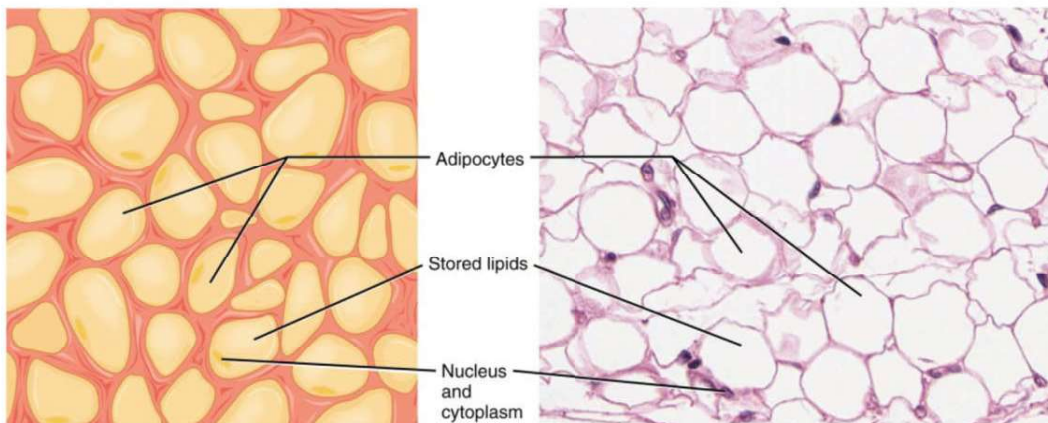
Figure 51: Adipose Tissue. This is a loose connective tissue that consists of fat cells with little extracellular matrix. It stores fat for energy and provides insulation. (Micrograph provided by the Regents of University of Michigan Med. Sch. 2012).

(3) Reticular tissue:

Is a mesh-like, supportive framework for soft organs such as lymphatic tissue, the spleen, and the liver (Figure 52). Reticular cells produce the reticular fibers that form the network onto which other cells attach. It derives its name from the Latin *reticulus*, which means "little net."
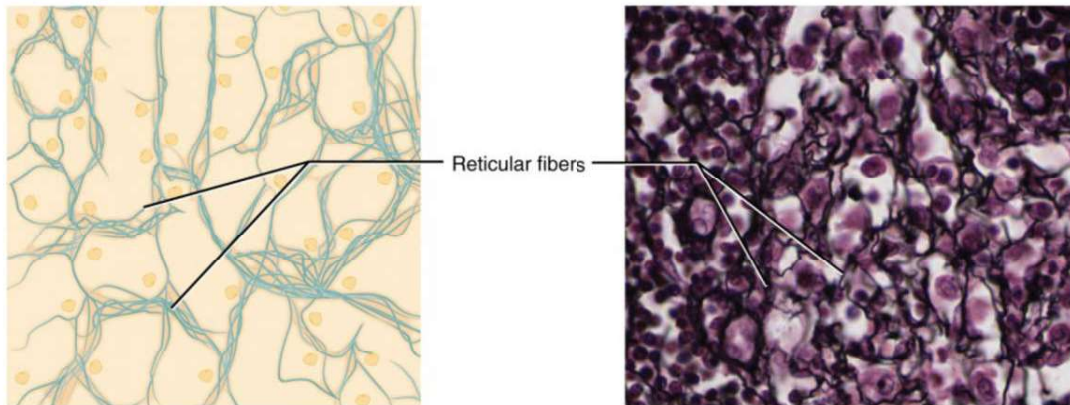
Figure 52: Reticular Tissue. This is a loose connective tissue made up of a network of reticular fibers that provides a supportive framework for soft organs. (Micrograph provided by the Regents of University of Michigan Med.School 2012)

b) Dense Connective Tissue

Dense connective tissue contains more collagen fibers than does loose connective tissue. As a consequence, it displays greater resistance to stretching. There are two major categories of dense connective tissue: regular and irregular.

(1) Dense regular connective tissue:

Fibers are parallel to each other, enhancing tensile strength and resistance to stretching in the direction of the fiber orientations. Ligaments and tendons are made of dense regular connective tissue, but in ligaments not all fibers are parallel. Dense regular elastic tissue contains elastin fibers in addition to collagen fibers, which allows the ligament to return to its original length after stretching. The ligaments in the vocal folds and between the vertebrae in the vertebral column are elastic (Figure 53).

(2) Dense irregular connective tissue:

The direction of fibers is random. This arrangement gives the tissue greater strength in all directions and less strength in one particular direction. In some tissues, fibers crisscross and form a mesh. In other tissues, stretching in several directions is achieved by alternating layers where fibers run in the same orientation in each layer, and it is the layers themselves that are stacked at an angle. The dermis of the skin is an example of dense irregular connective tissue rich in collagen fibers. Dense irregular elastic tissues give arterial walls the strength and the ability to regain original shape after stretching (Figure 53).
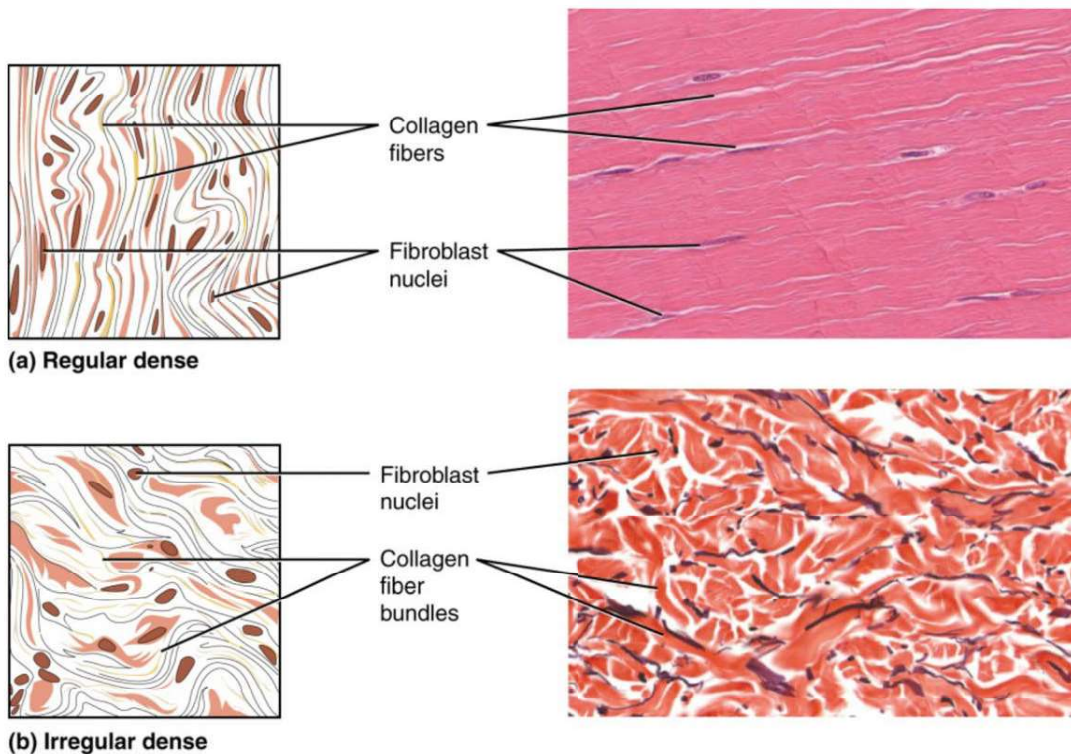
Figure 53: Dense Connective Tissue. (a) Dense regular connective tissue consists of collagenous fibers packed into parallel bundles. (b) Dense irregular connective tissue consists of collagenous fibers interwoven into a mesh-like network. From top, (Micrographs provided by the Regents of University of Michigan Medical School © 2012).

II- Supportive Connective Tissues:

Two major forms of supportive connective tissue, cartilage and bone, allow the body to maintain its posture and protect internal organs.

(a) Cartilages:

The distinctive appearance of cartilage is due to polysaccharides called chondroitin sulfates, which bind with ground substance proteins to form proteoglycans. Embedded within the cartilage matrix are **chondrocytes**, or cartilage cells, and the space they occupy are called **lacunae** (singular = lacuna). A layer of dense irregular connective tissue, the perichondrium, encapsulates the cartilage. Cartilaginous tissue is avascular; thus all nutrients need to diffuse through the matrix to reach the chondrocytes. This is a factor contributing to the very slow healing of cartilaginous tissues.

The three main types of cartilage tissue are hyaline cartilage, fibrocartilage, and elastic cartilage (Figure 54).

(1) **Hyaline cartilage**, the most common type of cartilage in the body, consists of short and dispersed collagen fibers and contains large amounts of proteoglycans. Under the microscope, tissue samples appear clear. The surface of hyaline cartilage is smooth. Both strong and flexible, it is found in the rib cage and nose and covers bones where they meet to form moveable joints. It makes up a template of the embryonic skeleton before bone formation. A plate of hyaline cartilage at the ends of bone allows continued growth until adulthood.

(2) **Fibrocartilage** is tough because it has thick bundles of collagen fibers dispersed through its matrix. The knee and jaw joints and the the intervertebral discs are examples of fibrocartilage.

(3) **Elastic cartilage** contains elastic fibers as well as collagen and proteoglycans. This tissue gives rigid support as well as elasticity. Tug gently at your ear lobes and notice that the lobes return to their initial shape. The external ear contains elastic cartilage.
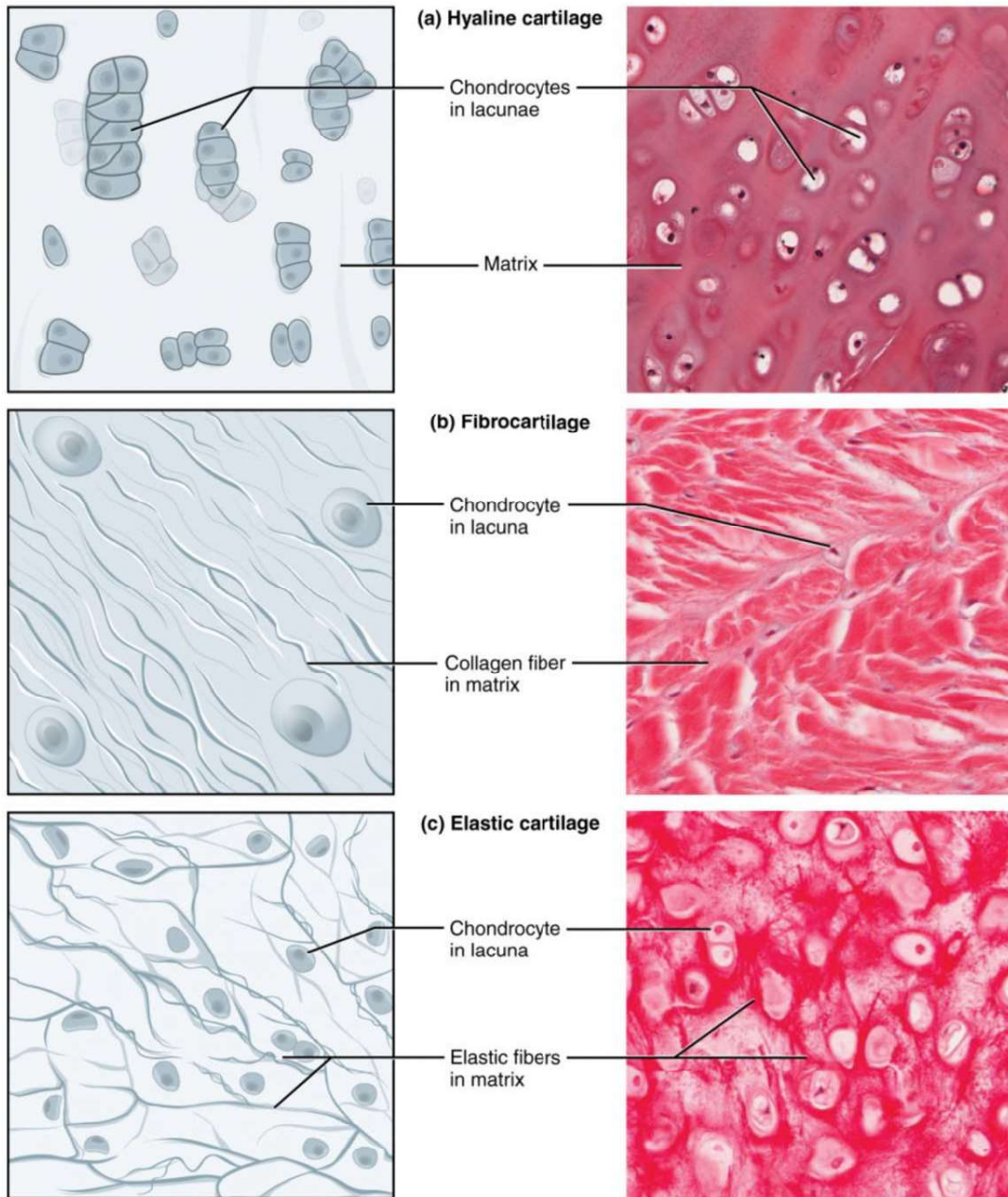
Figure 54: Types of Cartilage. Cartilage is a connective tissue consisting of collagenous fibers embedded in a firm matrix of chondroitin sulfates. (a) Hyaline cartilage provides support with some flexibility. The example is from dog tissue. (b) Fibrocartilage provides some compressibility and can absorb pressure. (c) Elastic cartilage provides firm but elastic support. From top, (Micrographs provided by the Regents of University of Michigan Medical School © 2012).

(b) Bones:

Bone is the hardest connective tissue. It provides protection to internal organs and supports the body. Bone's rigid extracellular matrix contains mostly collagen fibers embedded in a mineralized ground substance containing hydroxyapatite, a form of calcium phosphate. Both components of the matrix, organic and inorganic, contribute to the unusual properties of bone. Without collagen, bones would be brittle and shatter easily. Without mineral crystals, bones would flex and provide little support. **Osteocytes**, bone cells like chondrocytes, are located within lacunae. The histology of transverse tissue from long bone shows a typical arrangement of osteocytes in concentric circles around a central canal. Bone is a highly vascularized tissue. Unlike cartilage, bone tissue can recover from injuries in a relatively short time. There are two types compact and spongy bone, the differences between compact and spongy bone are best explored via their histology. Most bones contain compact and spongy osseous tissue, but their distribution and concentration vary based on the bone's overall function. Compact bone is dense so that it can withstand compressive forces, while spongy (cancellous) bone has open spaces and supports shifts in weight distribution (Figure 55).

(1) Compact Bone:

Compact bone is the denser, stronger of the two types of bone tissue (Figure 56). It can be found under the periosteum and in the diaphyses of long bones, where it provides support and protection. The microscopic structural unit of compact bone is called an osteon, or Haversian system. Each osteon is composed of concentric rings of

calcified matrix called lamellae (singular = lamella). Running down the center of each osteon is the central canal, or Haversian canal, which contains blood vessels, nerves, and lymphatic vessels. These vessels and nerves branch off at right angles through a perforating canal, also known as Volkmann's canals, to extend to the periosteum and endosteum. The osteocytes are located inside spaces called lacunae (singular = lacuna), found at the borders of adjacent lamellae. As described earlier, canaliculi connect with the canaliculi of other lacunae and eventually with the central canal. This system allows nutrients to be transported to the osteocytes and wastes to be removed from them.

(2) Spongy (Cancellous) Bone:

Like compact bone, spongy bone, also known as cancellous bone, contains osteocytes housed in lacunae, but they are not arranged in concentric circles. Instead, the lacunae and osteocytes are found in a lattice-like network of matrix spikes called trabeculae (singular = trabecula) (Figure 57). The trabeculae may appear to be a random network, but each trabecula forms along lines of stress to provide strength to the bone. The spaces of the trabeculated network provide balance to the dense and heavy compact bone by making bones lighter so that muscles can move them more easily. In addition, the spaces in some spongy bones contain red marrow, protected by the trabeculae, where hematopoiesis occurs.
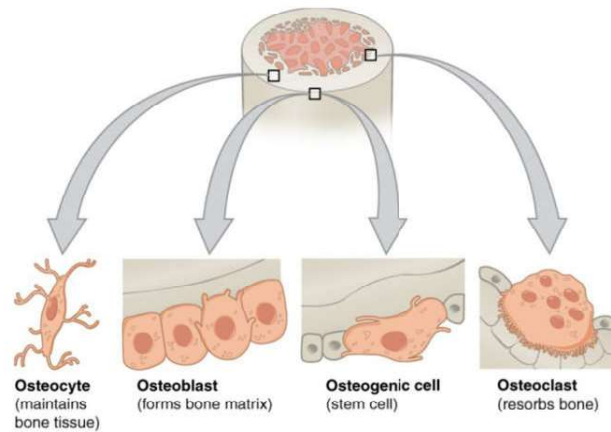
Figure 55: Bone Cells. Four types of cells are found within bone tissue. Osteogenic cells are undifferentiated and develop into osteoblasts.
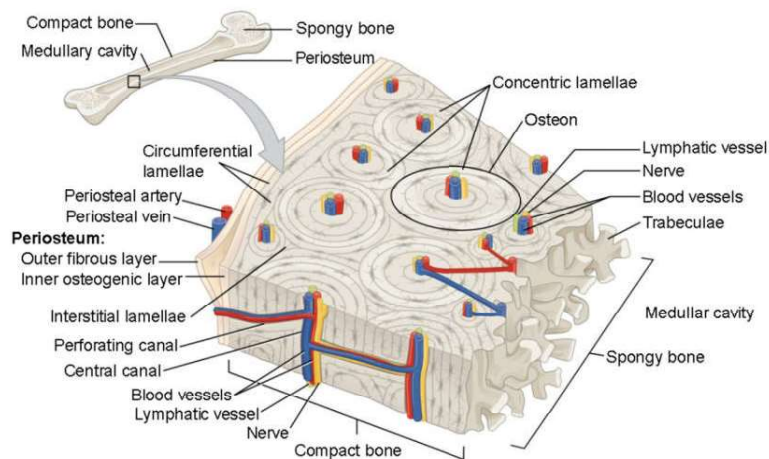

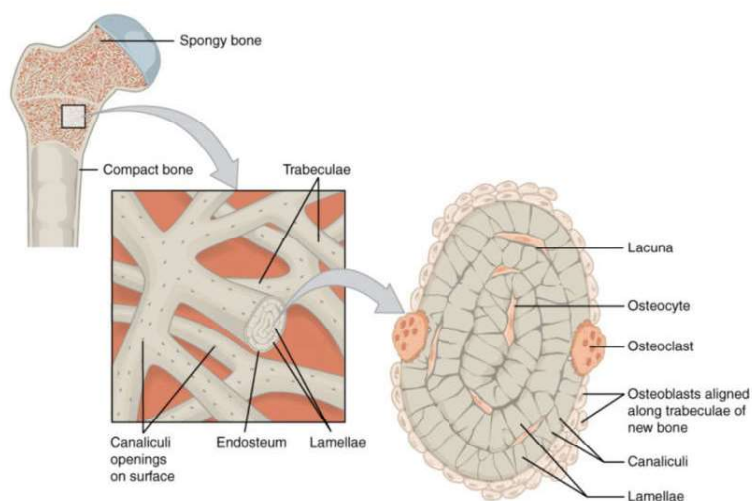**Figure 56:** Cross-sectional of compact bone shows the osteon.

Figure 57: Diagram of spongy bone.

III-   Fluid Connective Tissue:

Blood and lymph are fluid connective tissues. Cells circulate in a liquid extracellular matrix. The formed elements circulating in blood are all derived from hematopoietic stem cells located in bone marrow Erythrocytes (Figure 58)., red blood cells, transport oxygen and some carbon dioxide. Leukocytes, white blood cells, are responsible for defending against potentially harmful microorganisms or molecules. Platelets are cell fragments involved in blood clotting. Some white blood cells have the ability to cross the endothelial layer that lines blood vessels and enter adjacent tissues. Nutrients, salts, and wastes are dissolved in the liquid matrix and transported through the body. Lymph contains a liquid matrix and white blood cells. Lymphatic capillaries are extremely permeable, allowing larger molecules and excess fluid from interstitial spaces to enter the lymphatic vessels. Lymph drains into blood vessels, delivering molecules to the blood that could not otherwise directly enter the bloodstream. In this way, specialized lymphatic capillaries transport absorbed fats away from the intestine and deliver these molecules to the blood.
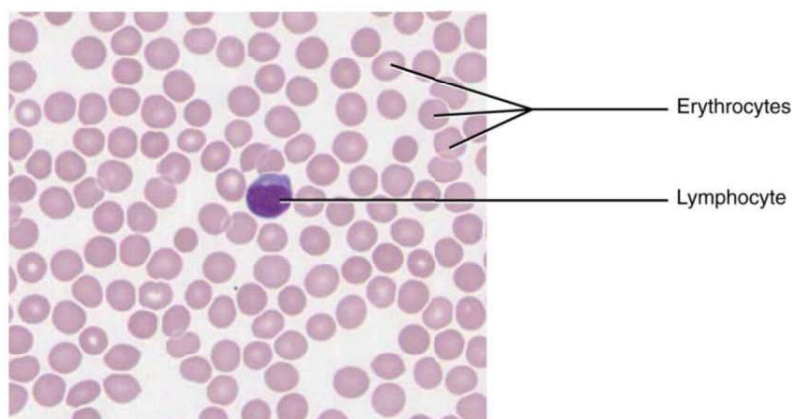

Figure 58: Blood a fluid connective tissue.

(C)MUSCULAR TISSUE

Muscle Tissue and Motion:

Muscle tissue is characterized by properties that allow movement. Muscle cells are excitable; they respond to a stimulus. They are contractile, meaning they can shorten and generate a pulling force. When attached between two movable objects, in other words, bones, contractions of the muscles cause the bones to move. Some muscle movement is voluntary, which means it is under conscious control. For example, a person decides to open a book and read a chapter on anatomy. Other movements are involuntary, meaning they are not under conscious control, such as the contraction of your pupil in bright light. Muscle tissue is classified into three types according to structure and function: skeletal, cardiac, and smooth (Figure 59).
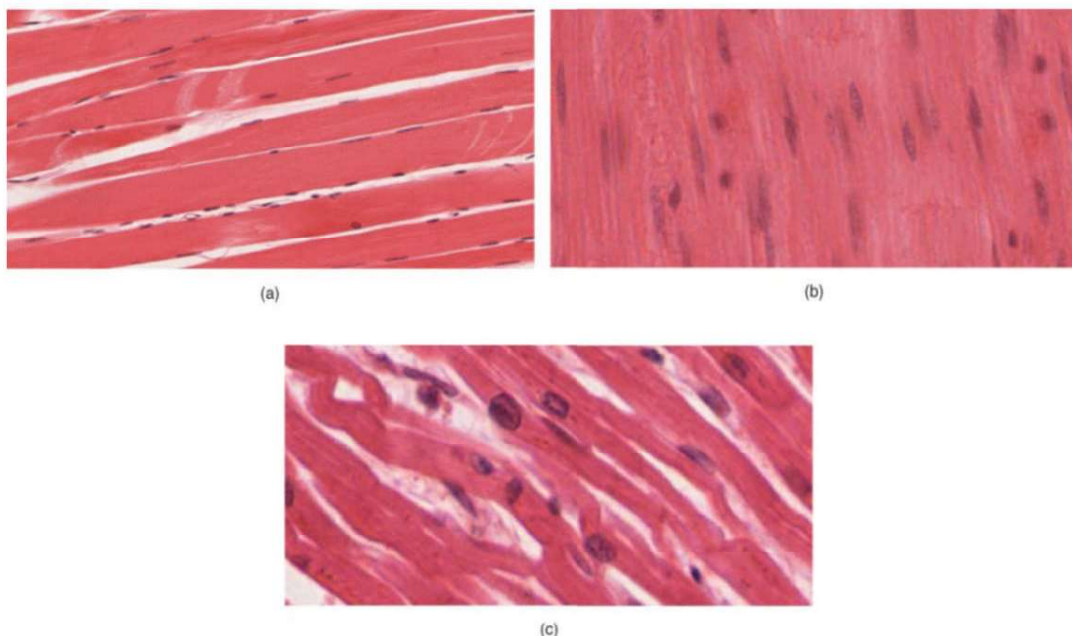

Figure 59: Muscle Tissue. (a) Skeletal muscle cells have prominent striation and nuclei on their periphery. (b) Smooth muscle cells have a single nucleus and no visible striations. (c) Cardiac muscle cells appear striated and have a single nucleus.

(1) Skeletal muscles:

Is attached to bones and its contraction makes possible locomotion, facial expressions, posture, and other voluntary movements of the body. Forty percent of your body mass is made up of skeletal muscle. Skeletal muscles generate heat as a byproduct of their contraction and thus participate in thermal homeostasis. Shivering is an involuntary contraction of skeletal muscles in response to perceived lower than normal body temperature. The muscle cell, or **myocyte**, develops from myoblasts derived from the mesoderm. Myocytes and their numbers remain relatively constant throughout life. Skeletal muscle tissue is arranged in bundles surrounded by connective tissue. Under the light microscope, muscle cells appear striated with many nuclei squeezed along the membranes. The **striation** is due to the regular alternation of the contractile proteins actin and myosin, along with the structural proteins that couple the contractile proteins to connective tissues. The cells are multinucleated as a result of the fusion of the many myoblasts that fuse to form each long muscle fiber.

Skeletal Muscle Fibers:

Because skeletal muscle cells are long and cylindrical, they are commonly referred to as muscle fibers. Skeletal muscle fibers can be quite large for human cells, with diameters up to 100 μm and lengths up to 30 cm (11.8 in) in the Sartorius of the upper leg. During early development, embryonic myoblasts, each with its own nucleus, fuse with up to hundreds of other myoblasts to form the multinucleated skeletal muscle fibers. Multiple nuclei mean multiple copies of genes,

permitting the production of the large amounts of proteins and enzymes needed for muscle contraction. Some other terminology associated with muscle fibers is rooted in the Greek *sarco*, which means "flesh." The plasma membrane of muscle fibers is called the **sarcolemma**, the cytoplasm is referred to as **sarcoplasm**, and the specialized smooth endoplasmic reticulum, which stores, releases, and retrieves calcium ions (Ca_{++}) is called the **sarcoplasmic reticulum (SR)** (Figure 60). As will soon be described, the functional unit of a skeletal muscle fiber is the sarcomere, a highly organized arrangement of the contractile myofilament's **actin** (thin filament) and **myosin** (thick filament), along with other support proteins.
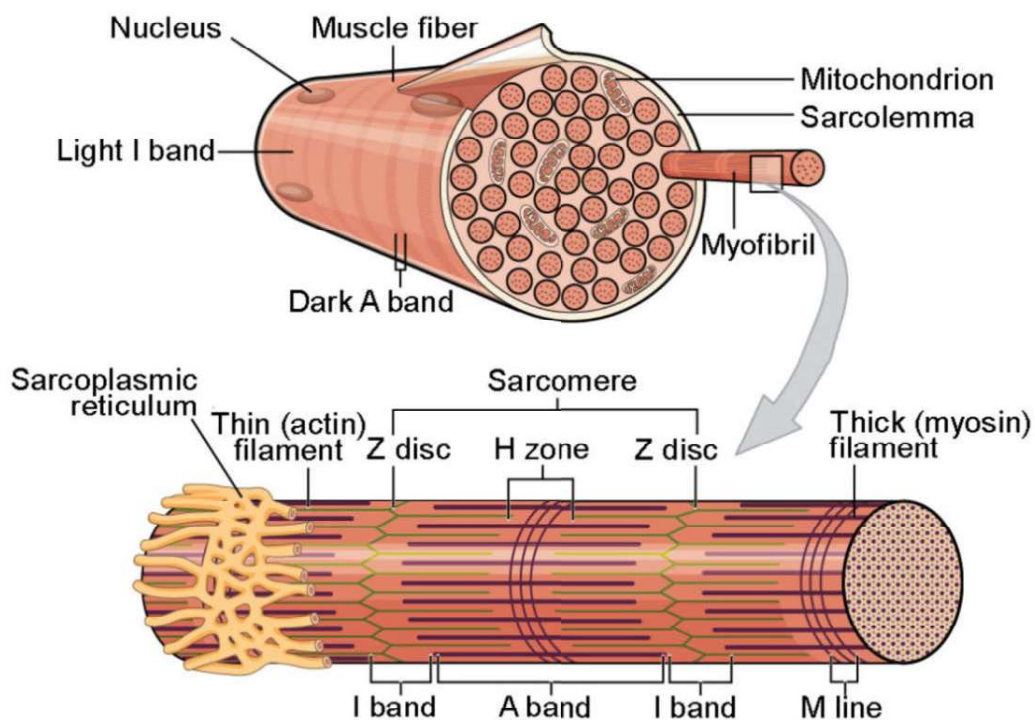

Figure 60: Muscle Fiber. A skeletal muscle fiber is surrounded by a plasma membrane called the sarcolemma, which contains sarcoplasm, the cytoplasm of muscle cells. A muscle fiber is composed of many fibrils, which give the cell its striated appearance.

(2) Cardiac muscles:

Forms the contractile walls of the heart. The cells of cardiac muscle, known as cardiomyocytes, also appear striated under the microscope. Unlike skeletal muscle fibers, cardiomyocytes are single cells typically with a single centrally located nucleus. A principal characteristic of cardiomyocytes is that they contract on their own intrinsic rhythms without any external stimulation. Cardiomyocyte attach to one another with specialized cell junctions called intercalated discs. Intercalated discs have both anchoring junctions and gap junctions. Attached cells form long, branching cardiac muscle fibers that are, essentially, a mechanical and electrochemical syncytium allowing the cells to synchronize their actions. The cardiac muscle pumps blood through the body and is under involuntary control. The attachment junctions hold adjacent cells together across the dynamic pressure's changes of the cardiac cycle

Cardiac muscle fibers

However, cardiac muscle fibers are shorter than skeletal muscle fibers and usually contain only one nucleus, which is located in the central region of the cell. Cardiac muscle fibers also possess many mitochondria and myoglobin, as ATP is produced primarily through aerobic metabolism. Cardiac muscle fibers cells also are extensively branched and are connected to one another at their ends by intercalated discs. An **intercalated disc** allows the cardiac muscle cells to contract in a wave-like pattern so that the heart can work as a pump. Intercalated discs are part of the sarcolemma and contain two structures important

in cardiac muscle contraction: gap junctions and desmosomes. A gap junction forms channels between adjacent cardiac muscle fibers that allow the depolarizing current produced by cations to flow from one cardiac muscle cell to the next. This joining is called electric coupling, and in cardiac muscle it allows the quick transmission of action potentials and the coordinated contraction of the entire heart. This network of electrically connected cardiac muscle cells creates a functional unit of contraction called a syncytium. The remainder of the intercalated disc is composed of desmosomes. A **desmosome** is a cell structure that anchors the ends of cardiac muscle fibers together, so the cells do not pull apart during the stress of individual fibers contracting (Figure 61).
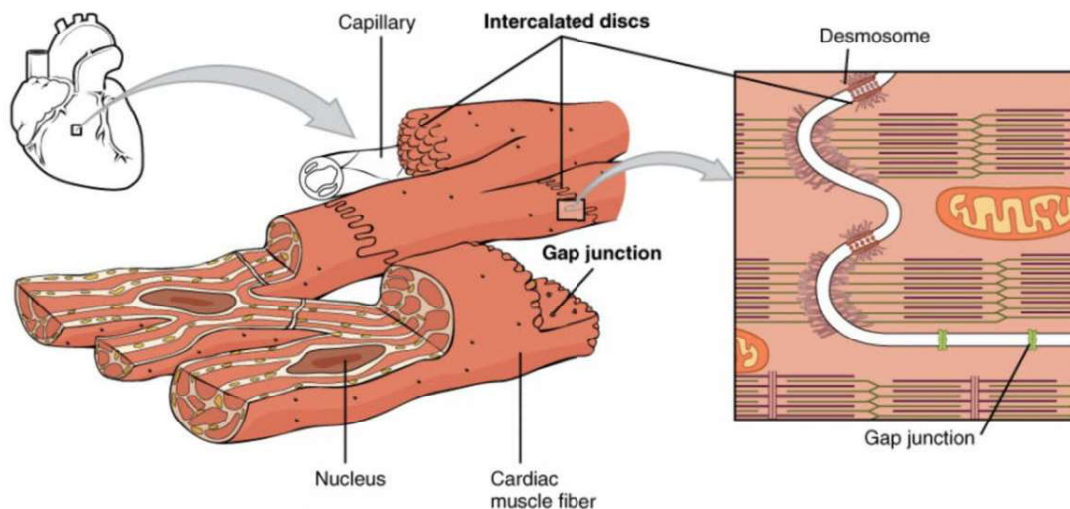

Figure 61: Cardiac Muscle. Intercalated discs are part of the cardiac muscle sarcolemma, and they contain gap junctions and desmosomes.

(3) Smooth muscles:

Tissue contraction is responsible for involuntary movements in the internal organs. It forms the contractile component of the digestive, urinary, and reproductive systems as well as the airways and arteries. Each cell is spindle shaped with a single nucleus and no visible striations.

Smooth muscle fibers:

Smooth muscle fibers are spindle-shaped (wide in the middle and tapered at both ends, somewhat like a football) and have a single nucleus; they range from about 30 to 200 μm (thousands of times shorter than skeletal muscle fibers), and they produce their own connective tissue, endomysium. Although they do not have striations and sarcomeres, smooth muscle fibers do have actin and myosin contractile proteins, and thick and thin filaments. These thin filaments are anchored by dense bodies. A **dense body** is analogous to the Z-discs of skeletal and cardiac muscle fibers and is fastened to the sarcolemma. Calcium ions are supplied by the SR in the fibers and by sequestration from the extracellular fluid through membrane indentations called calveoli (Figure 62).

When the thin filaments slide past the thick filaments, they pull on the dense bodies, structures tethered to the sarcolemma, which then pull on the intermediate filament's networks throughout the sarcoplasm. This arrangement causes the entire muscle fiber to contract in a manner whereby the ends are pulled toward the center, causing the midsection to bulge in a corkscrew motion (Figure 62).
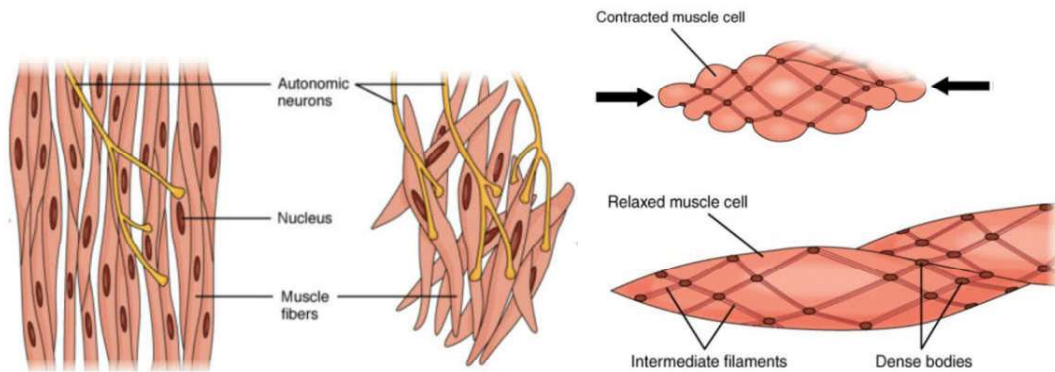
Figure 62: Smooth Muscle Tissue and Muscle Contraction.

(D)NERVOUS TISSUE

Nervous Tissue Mediates Perception and Response:

Nervous tissue is characterized as being excitable and capable of sending and receiving electrochemical signals that provide the body with information. Two main classes of cells make up nervous tissue: the **neuron** and **neuroglia** (Figure 63).

Neurons propagate information via electrochemical impulses, called action potentials, which are biochemically linked to the release of chemical signals. Neuroglia plays an essential role in supporting neurons and modulating their information propagation. Neurons display distinctive morphology, well suited to their role as conducting cells, with three main parts.

Nervous tissue is composed of two types of cells**, neurons** and **glial cells.** Neurons are the primary type of cell that most anyone associates with the nervous system. They are responsible for the computation and communication that the nervous system provides. They are electrically

active and release chemical signals to target cells. Glial cells, or glia, are known to play a supporting role for nervous tissue. Ongoing research pursues an expanded role that glial cells might play in signaling, but neurons are still considered the basis of this function. Neurons are important, but without glial support they would not be able to perform their function.

(1) Neurons:

Neurons are the cells considered to be the basis of nervous tissue. They are responsible for the electrical signals that communicate information about sensations, and that produce movements in response to those stimuli, along with inducing thought processes within the brain. An important part of the function of neurons is in their structure, or shape. The three-dimensional shape of these cells makes the immense numbers of connections within the nervous system possible.

Neuron structure:

The main part of a neuron (Figure 63) is the **cell body**, which is also known as the soma (soma = "body"). The cell body contains the nucleus and most of the major organelles. But what makes neurons special is that they have many extensions of their cell membranes, which are generally referred to as processes. Neurons are usually described as having one, and only one, **axon** a fiber that emerges from the cell body and projects to target cells. That single axon can branch repeatedly to communicate with many target cells. It is the axon that propagates the nerve impulse, which is communicated to one or more cells.

The other processes of the neuron are **dendrites**, which receive information from other neurons at specialized areas of contact called **synapses**. The dendrites are usually highly branched processes, providing locations for other neurons to communicate with the cell body. Information flows through a neuron from the dendrites, across the cell body, and down the axon. This gives the neuron a polarity meaning that information flows in this one direction. Figure 1 shows the relationship of these parts to one another.

Many axons are wrapped by an insulating substance called myelin, which is actually made from glial cells. **Myelin** acts as insulation much like the plastic or rubber that is used to insulate electrical wires. A key difference between myelin and the insulation on a wire is that there are gaps in the myelin covering of an axon. Each gap is called a **node of Ranvier** and is important to the way that electrical signals travel down the axon. The length of the axon between each gap, which is wrapped in myelin, is referred to as an **axon segment**. At the end of the axon is the **axon terminal**, where there are usually several branches extending toward the target cell, each of which ends in an enlargement called a **synaptic end bulb**. These bulbs are what make the connection with the target cell at the synapse.

Neurons are dynamic cells with the ability to make a vast number of connections, to respond incredibly quickly to stimuli, and to initiate movements based on those stimuli.
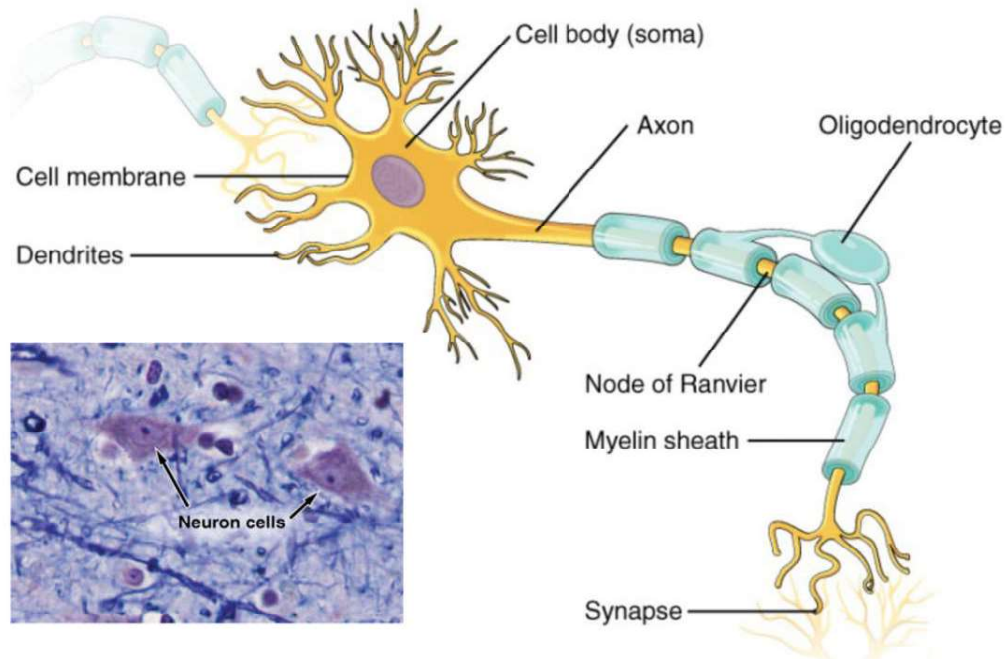
Figure 63: The structure of neuron.

Types of Neurons:

There are many neurons in the nervous system—a number in the trillions. And there are many different types of neurons. They can be classified by many different criteria. The first way to classify them is by the number of processes attached to the cell body.

Using the standard model of neurons, one of these processes is the axon, and the rest are dendrites. Because information flows through the neuron from dendrites or cell bodies toward the axon, these names are based on the neuron's polarity (Figure 64).

1- Unipolar:

Unipolar cells have only one process emerging from the cell. True unipolar cells are only found in invertebrate animals, so the unipolar cells in humans are more appropriately called "pseudo-unipolar" cells.

Invertebrate unipolar cells do not have dendrites. Human unipolar cells have an axon that emerges from the cell body, but it splits so that the axon can extend along a very long distance. At one end of the axon are dendrites, and at the other end, the axon forms synaptic connections with a target. Unipolar cells are exclusively sensory neurons and have two unique characteristics. First, their dendrites are receiving sensory information, sometimes directly from the stimulus itself. Secondly, the cell bodies of unipolar neurons are always found in ganglia. Sensory reception is a peripheral function (those dendrites are in the periphery, perhaps in the skin) so the cell body is in the periphery, though closer to the CNS in a ganglion. The axon projects from the dendrite endings, past the cell body in a ganglion, and into the central nervous system.

2- Bipolar:

Bipolar cells have two processes, which extend from each end of the cell body, opposite to each other. One is the axon and one the dendrite. Bipolar cells are not very common. They are found mainly in the olfactory epithelium (where smell stimuli are sensed), and as part of the retina.

3- Multipolar:

Multipolar neurons are all of the neurons that are not unipolar or bipolar. They have one axon and two or more dendrites (usually many more). Except for the unipolar sensory ganglion cells, and the two specific bipolar cells mentioned above, all other neurons are multipolar. Some cutting-edge research suggests that certain neurons in the CNS do not conform to the standard model of "one, and only one" axon.

Some sources describe a fourth type of neuron, called an anaxonic neuron. The name suggests that it has no axon (an- = "without"), but this is not accurate. Anaxonic neurons are very small, and if you look through a microscope at the standard resolution used in histology (approximately 400X to 1000X total magnification), you will not be able to distinguish any process specifically as an axon or a dendrite. Any of those processes can function as an axon depending on the conditions at any given time. Nevertheless, even if they cannot be easily seen, and one specific process is definitively the axon, these neurons have multiple processes and are therefore multipolar.
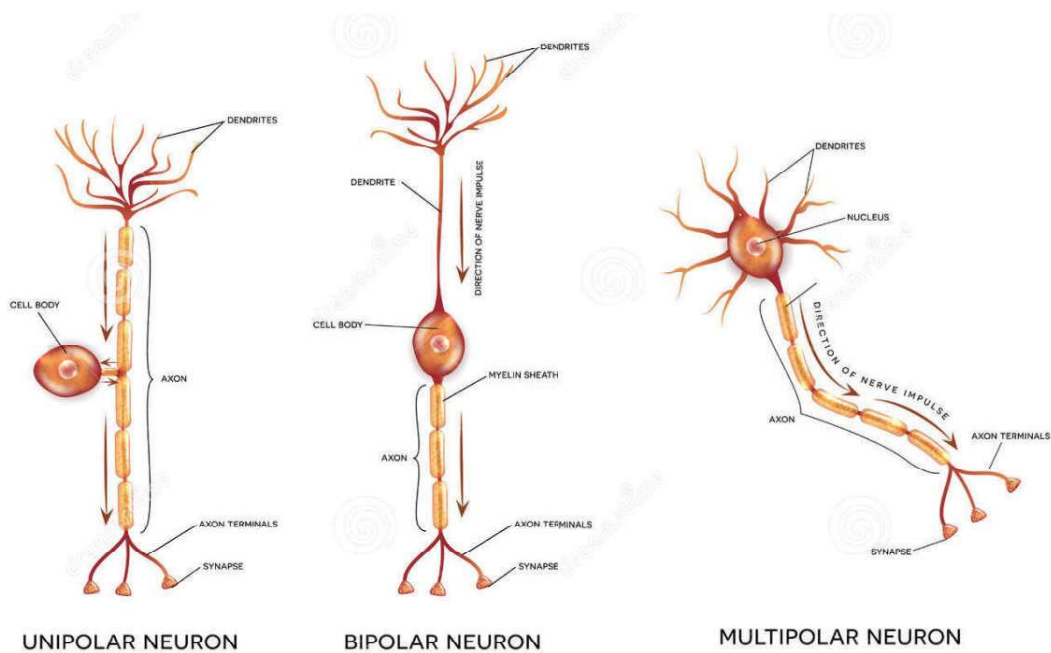

Figure 64: Neuron Classification by Shape. Unipolar cells have one process that includes both the axon and dendrite. Bipolar cells have two processes, the axon and a dendrite. Multipolar cells have more than two processes, the axon and two or more dendrites.

(2) Glial Cells:

Glial cells (Figure 65), or neuroglia or simply glia, are the other type of cell found in nervous tissue. They are supporting cells, and many functions are directed at helping neurons complete their function for communication. The name glia comes from the Greek word that means "glue," and was coined by the German pathologist Rudolph Virchow, who wrote in 1856: "This connective substance, which is in the brain, the spinal cord, and the special sense nerves, is a kind of glue (neuroglia) in which the nervous elements are planted. There are six types of glial cells. Four of them are found in the CNS (Astrocyte, Oligodendrocyte, Microglia and Ependymal cell) and two are found in the PNS (Satellite cell and Schwann cell).
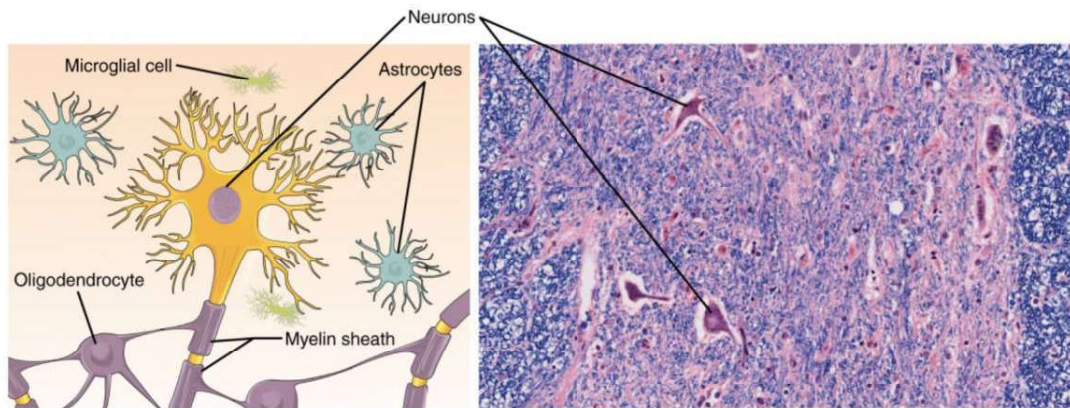

Figure 65: Nervous Tissue. Nervous tissue is made up of neurons and neuroglia. The cells of nervous tissue are specialized to transmit and receive impulses.

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