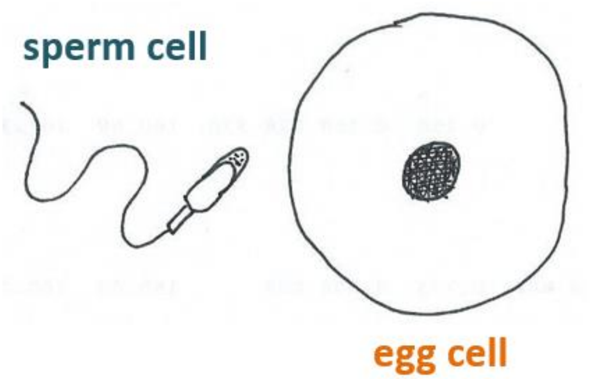
Anatomy Lecture Notes Section 1: The Tissue Level of Organization

The Three Primary Germ Layers

The word **germ** or **germinate** means a portion of an organism that is capable of developing or growing into a new part or a new whole. Like a *seed* from a tomato *germinates* and becomes a tomato plant! Therefore, the germ layers of the human body are like the seeds, or stem cells, for the body, they are responsible for generating all of the tissues, organs and structures that are created in the body.

A germ layer is a collection of cells that are formed during **embryogenesis** or during the phases of **reproductive** development of the **embryo**. There are three (3) primary (1^{o}) germ layers in human embryology.

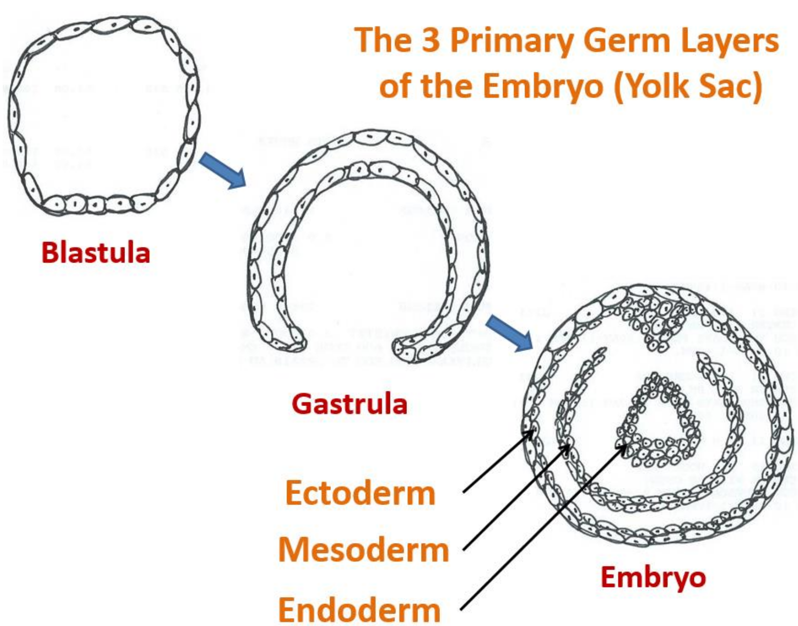
When the male sperm cell unites with the female egg cell this creates a **fertilized egg cell**, also called a **zygote**.



Immediately after this union, the rapid process of cell multiplication begins, as 2 cells become 4, become 8, and onward, until a hollow ball of cells called the **blastula** is generated (see drawing below). The etymology (word origin) means 'little sprout'. From the blastula comes the **gastrula**, which is like a hollow horseshoe-shaped structure that has the start of three distinct cell layers. The etymology of gastrula means 'little stomach'

Finally, there is the formation of the **embryo** (also called the yolk sac) upon which the three primary germ layers can be located. The embryo stage of development starts from about two weeks after fertilization at conception and lasts until week eight of gestation.

Humans are **triploblastic**, this means they have a body that is derived from <u>three embryonic cell layers</u>, which are the **3 primary germ layers**.



The 3 layers (seen on previous page) are called the **endoderm**, the **mesoderm** and the **ectoderm**.

1. The Endoderm is found in the innermost portion of the embryo.
2. The Mesoderm is found in the middle portion of the embryo.
3. The Ectoderm is found in the outermost portion of the embryo.

As illustrated in drawings on the previous page, the 3 primary germ layers are named based on where in embryological development they are derived from. It is these **primary germ layers** that give rise to the **4 primary tissues** and all of the organs and various structures in the human body.

Imagine the blastula is like an inflated balloon of with cells making a spherical 'ball of cells'. The term blastula means 'sprout'. As the blastula continues to grow and develop it becomes the gastrula (which means 'little stomach'), this then becomes the **embryo**. The etymology of embryo is 'something that swells'. It is at 9 weeks after conception the embryo become a **fetus**. In Latin, fetus means pregnancy, childbirth, or offspring.

As we move into **histology** - the study of tissues - it is important to know that these 3 primary germ layers are where the 4 primary tissues are derived from, and of course all of the others organs and structures in the body.

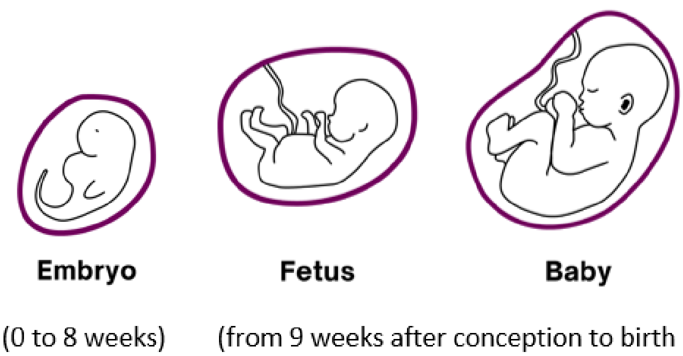


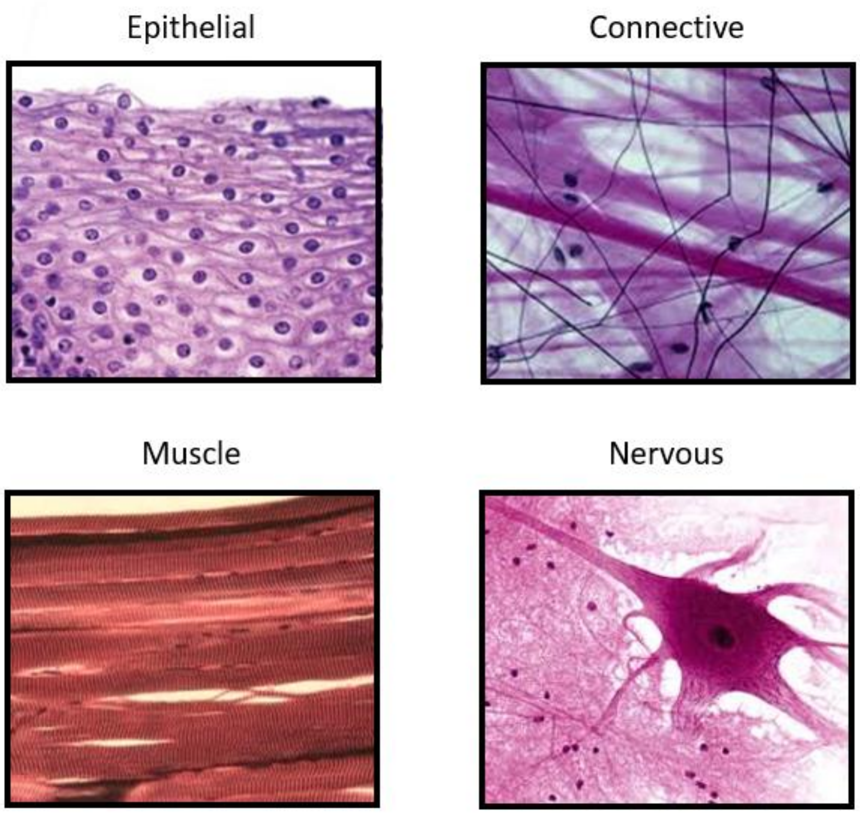
Table showing the tissues and structures that are directly derived from the 3 primary germ layers.

Endoderm	Mesoderm	Ectoderm
Epithelium of pharynx, larynx, trachea, lungs (Respiratory tract).	All Connective tissue: embryonic, mesenchyme, connective tissue proper, cartilage, bone, blood.	Epidermis of skin and epidermal derivatives: Hair, nails, glands of the skin; linings of oral, nasal, anal, and vaginal cavities.
Lining of auditory canal, tonsils, thyroid, parathyroid, thymus.	Endothelium of blood vessels, lymphatic vessels, body cavities, joint cavities, dentin of teeth	All Nervous tissue, special sense organs.
Entire G.I. tract, urinary bladder, and urethra.	Kidneys and ureters Adrenal cortex Internal reproductive organs	Pituitary gland Adrenal medulla lens of eye, enamel of teeth.
Liver and pancreas.	Most Muscle: smooth, cardiac, skeletal.	

The Tissue Level of Organization

In terms of the Levels of Organization in living systems, cells combine to make tissues. To be more specific, let's give a good working definition of tissues. *Tissues are groups of cells and cell products with similar structure and function.* This definition indicates that cells within a specific tissue will have similar anatomy (structure) and physiology (function) and these cells make all the other components of the tissue.

The four (4) **Primary Tissues**: **1)** Epithelial; **2)** Connective; **3)** Muscular; and **4)** Nervous.



Considering there are about 200 different types of cells in the human body, four *Primary Tissues* is a relatively manageable number. It is effective to establish the basic differences between these tissues and be able to clearly distinguish the basic functions and components of each. The images above are examples of histological preparations of the four primary tissues. As we become more familiar with these tissues, their features and characteristics will become more distinct. Below is a very brief overview of the nature and function of the 4 primary tissues. Details of each tissue will be expanded upon in our course, and the tissues are presented in the order that they will be studied.

1) Epithelial – Covers and lines exposed surfaces in the body. For protection, secretion and sensation.

2) Connective – Binds, packages, interconnects, transports and protects various structures in the body.

3) Muscular – Contraction of muscle cells create movement, of specific body part or the entire body.

4) Nervous – Cells provide fast transfer of information for processing and communication.

Epithelial Tissue

A. Functions of Epithelial Tissue

Epithelium is a tissue for covering, lining, secretory, or absorptive functions. This tissue *is always forming a surface of some sort* and always has a basement membrane underneath it to attach it to the tissue deep to it, which is usually connective tissue. Not all epithelial tissue will have all of these functions.

1) Physical Barrier – Provides protection of the exposed surface, either internally (as in a serous membrane) or externally (as in a tract or the superficial layer of the skin). Most often multiple cell layers are present (the tissue is stratified) in order to offer a protective barrier.

2) Regulates (Controls) Exchange – Anything that enters or leaves the body must cross an epithelial lining. This is an important role of epithelium. Most often a single cell layer (simple) is present if permeability (allowing substances to cross) is required. In this way it regulates exchange throughout the entire body.

3) Produces Secretions – Glandular epithelium produces secretions that are delivered to an internal or external surface. Glands such as goblet cells and gastric glands secrete a thick and sticky mucus, while some sweat and salivary glands secrete a thin, watery serous fluid. Oil (sebaceous), ear wax (cerumen) and sudoriferous (sweat) glands are some common types of epithelial glands.

4) Provides Sensations (Nervous Innervation) – This tissue provides much of the body's sensory perception. Epithelium is extensively innervated (has a nervous supply) with general receptors for touch, temperature, pain and pressure. In addition, epithelium also contributes to what are called "special senses" in the body, such as vision, taste, smell, hearing and balance.

B. Characteristics of Epithelial Tissue

There are several different types of epithelia (discussed under 'classification' below), but despite the various types, all epithelial tissue has common characteristics regardless of its specific function. Outlined are the five (5) major characteristics you should be able to describe with regard to epithelium.

1) Cellularity – Most of this tissue is comprised of cells, with very little extracellular material; this is what the term 'cellularity' refers to. Often this tissue looks like a 'wall of cells'. Epithelial tissue cells are distinct in that they often resemble a layer of blocks that create a covering, lining or barrier.

2) Polarity – epithelial tissue has a 'sidedness' to it. There is a superficial or **apical** surface which is exposed, and a bottom or **basal** surface which is attached to the basement membrane. Whether the epithelial tissue is one cell layer thick (simple) or consists of many cell layers (stratified), there is always an apical and basal end of the tissue.

The apical end of epithelial tissue is sometimes specialized, most commonly with either **a) Cilia** or **b) Microvilli**. Cilia are hair-like structures for the movement of substances across the surface of the cell, e.g., mucous. Microvilli are extensions of the plasma membrane that function to increase the surface area, for example, this allows for a faster rate of absorption across surfaces with microvilli.

3) Attachments – The cells in epithelial tissue are physically connected to the cells adjacent to them, including above and below, as well as being attached to the basement membrane. There are several types of attachments, but we will concentrate on four (4) types:

a) *Tight Junctions* – fibrous attachments to neighboring cells at the apical end of the exposed cell layer. It is like a zip-lock seal that goes all the way around the top end of the tissue. Its role is to restrict the passage of unwanted substances (e.g., bacteria or fungi) into the body in between adjacent cells.

b) *Desmosomes* – these are also fibrous (collagen) attachments to neighboring cells, but these are located at the basal end of the cell layer, near basement membrane. These are more like 'spot-welds', they do not go around the entire cell continuously, but are more sporadically located. Their role is to provide mechanical support during distention of the tissue, so cells remain attached to each other at the basal end.

c) *Hemidesmosomes* – fibrous attachments of basal epithelial cells to the underlying basement membrane. Their role is to anchor these deepest basal cells to the basement membrane.

d) *Gap Junctions* – these are little protein channels that provide an open conduit from one neighboring cell to another. This allows for cell-to-cell communication via ions or other substances.

4) <u>Avascularity</u> – Epithelial tissue does not have any blood vessels within it, thus it has no direct blood supply of its own. A = without, and vascular = blood, together meaning 'without a blood supply'. As a consequence of epithelial tissue having no direct blood supply of its own, all epithelial tissue must rely on the nearby connective and other tissues for its oxygen (O_2), nutrient, carbon dioxide (CO_2), and waste exchange. If epithelial tissue is stratified, then only 2-5 cell layers superficial to the basement membrane are living, typically any further layers beyond that are dead or dying cells. This is because they are too far away from the blood supply.

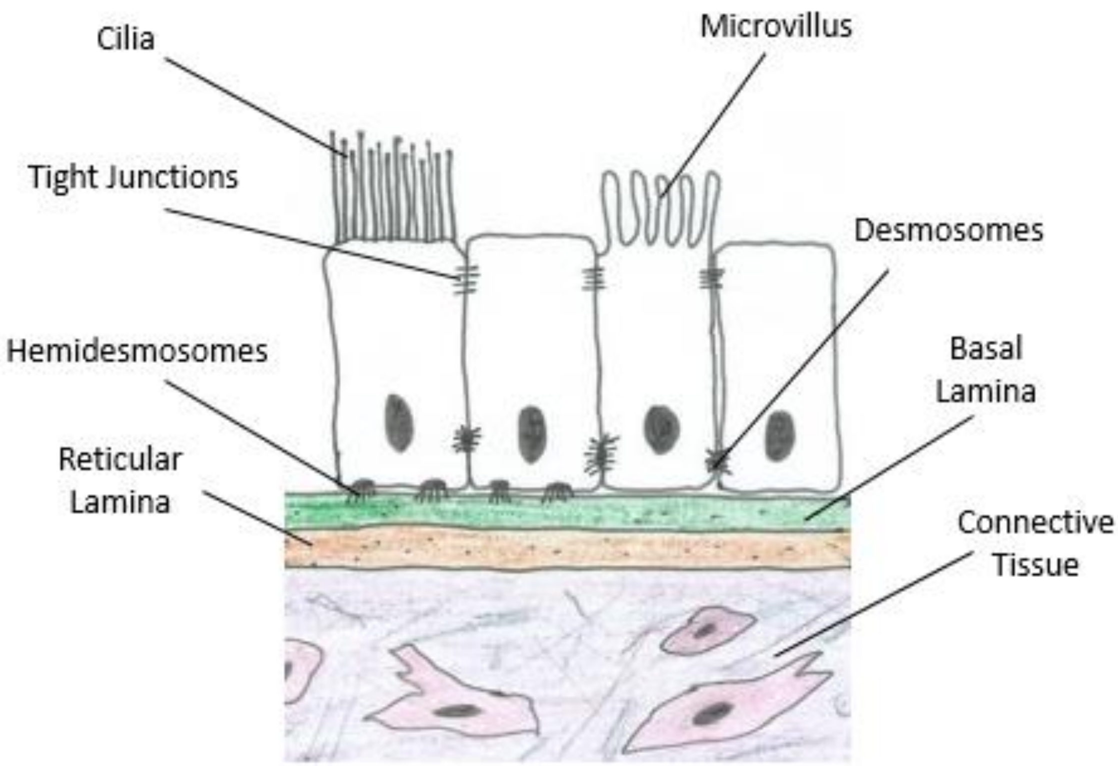
5) <u>Highly Regenerative</u> – epithelial tissue has a high capacity to make more of itself, in other words, it is constantly regenerating to replace itself. Epithelial tissue naturally needs to continuously replace itself because it is continuously lost, as the exposed layers are **sloughed off** constantly in order to provide protection. The basal cell layer, those cells sitting on the basement membrane, are **mitotically** active, meaning they are able to multiply and produce more cells. In this way, these can also be termed 'progenitors' for that specific tissue as they keep the production of epithelial tissue going.

The term **callus** is from Latin meaning 'hardened skin'. Calluses can be found commonly on the hands or the soles of feet. This involves a thickening of the skin as a protective response to repeated stress. More specifically, it is a thickening of the **epidermis** of the skin, especially the stratum corneum; cornu in Latin means 'horn'. A **corn** is a small, tender area of thickened skin on the dorsal (top) aspect, or the side of a toe. People with **bunions** (a bump caused by misalignment of big toe bones) can develop a callus over it due to footwear rubbing against it. Anyone who plays a stringed instrument, such as a guitar, will appreciate the calluses on their fingertips.

C. All Epithelial Tissue is supported by a Basement Membrane

The basement membrane is what epithelial tissue sits on. It is a thin structure that literally connects the superficial epithelium to the deeper connective tissue. The basement membrane is composed of two layers, the **basal lamina** - which is made by the epithelial tissue and underlying that is the **reticular lamina** – which is made by the connective tissue.

The **basal lamina** layer can further be divided into two layers. The clear layer closer to the epithelium is called the **lamina lucida**, while the dense layer closer to the connective tissue is called the **lamina densa**.



The drawing above is a diagrammatic representation of epithelial tissue showing many of the specific structures that are characteristic of the tissue discussed above.

D. Classification of Epithelial Tissues

Epithelial tissue is named and classified by selecting one term from each of two categories below:

1) The **number of cell layers** in the tissue; and

2) The **shape** of the exposed or **apical** cell layer.

There are eight (8) basic classifications of epithelial tissue that will be examined in this course and along with the classification and naming of the tissue, the general functional and specific locations in the body will also be described.

Also included in some epithelial tissue names are the distinct features of a specific tissue:

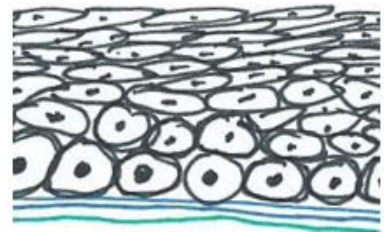
Number of Cell Layers

1) Simple - a single layer of cells.
2) Stratified - more than one layer of cells.

Shape of Exposed Layer

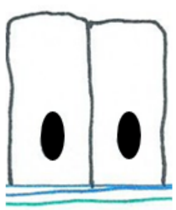
The important thing to remember is that it is the shape of the ***apical*** cell that is what matters when naming epithelial tissue. The descriptions of cell shapes below cover the basic cell morphologies that will be encountered in the classification of epithelial tissue.

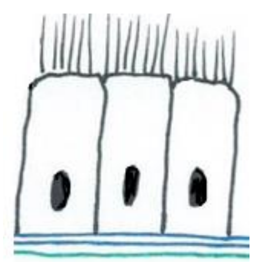
1) Squamous (flat, think of "squashed") cells are flattened in the plane perpendicular to the basement membrane, therefore their appearance when examined down a microscope looks very much like tiles or compacted ribbons. The nucleus of these cells is flat and centralized, as in the sketch at left illustrating simple (one cell layer) squamous (flat) epithelium. Squamous epithelium is frequently seen in a stratified arrangement, meaning many cell layers thick, this offers protection. That arrangement is shown by the sketch to the right. Keep in mind, that only the outermost (exposed) layer, away from the basement, is used to determine the cell shape.



2) Cuboidal cells look like cubes, as their name describes. The cell shape is very regular and usually has a rounded and centrally located nucleus. More often in the body these are found as simple tissue (one cell layer thick), as opposed to stratified. However, both simple and stratified cuboidal tissues are commonly seen lining the ducts of glands. This is shown in the sketch to the left, as a duct (tube) being viewed cut in cross section (across its length). In all of these tissues (and the sketches of them) the deepest layer of epithelial cells, whatever their shape, are sitting on a basement membrane, seen as the two layered lines underneath all of the epithelial tissue in these drawings.

3) Columnar cells are tall and column-shaped (perpendicular to the basement membrane). They are often simple but can also be stratified, though this is not very common in the human body. This epithelial tissue can also *pseudostratified*, meaning it gives the false appearance of stratification when in reality it is only one cell layer, with every cell attached to the basement membrane. It is only the columnar cells that can have this 'pseudostratified' arrangement because of their height. Columnar cells can be specialized at their apical (top or exposed) end with cilia (seen in the drawing to the right) and microvilli. The function of cilia is to move substances (like mucus) across the surface of the cell, whereas microvilli are actually extensions of the plasma membrane of the cell and they function to increase the surface area of the cell to augment absorption.





4) Transitional epithelium has cells that are atypical in shape, meaning they are irregular and often larger near the free edge than at the basement membrane, which is the opposite of most epithelium. This type of tissue is always stratified (found in several layers) and is found in the urinary system, such as the inner lining of the bladder, and the ureters, plus other structures. This tissue allows for expansion and contraction, and as such, the cell's shape 'transitions' depending on whether the region, like the bladder, is contracted or distended.

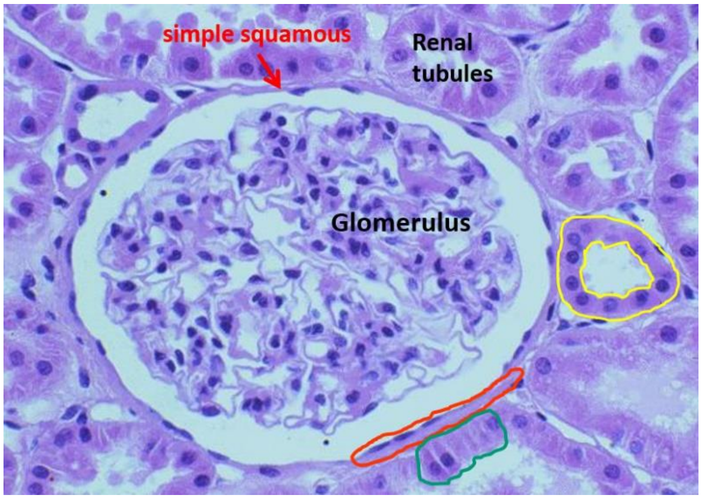
Summary of Epithelial Tissue Histology – Let's see how it looks down the Microscope

On the next pages are specific examples of the 8 Categories or Classifications of Epithelial Tissue. There are 4 epithelial tissues that are **Simple** (meaning 1 cell layer thick), and 4 epithelial tissues that are **Stratified** (have more than one cell layer). Becoming familiar with the photographic images of the histological slides of epithelial tissues is very useful for becoming more skilled at identifying them down the microscope in lab.

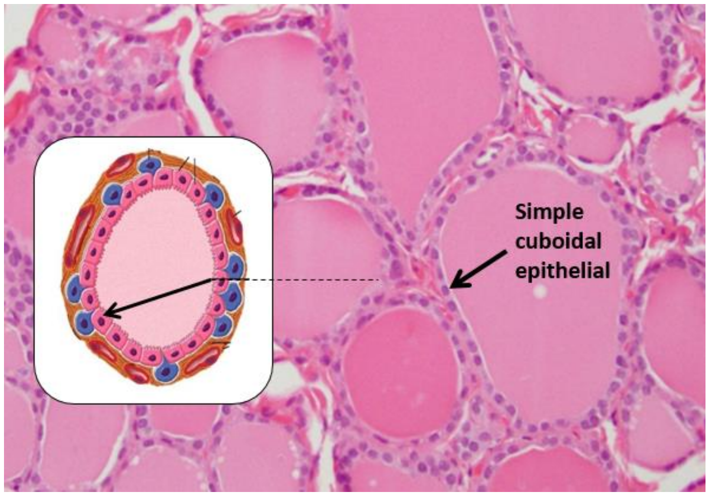
The 4 Types of Simple Epithelium

1) Simple Squamous Epithelium
2) Simple Cuboidal Epithelium
3) Simple Columnar Epithelium
4) Pseudostratified Ciliated Columnar Epithelium

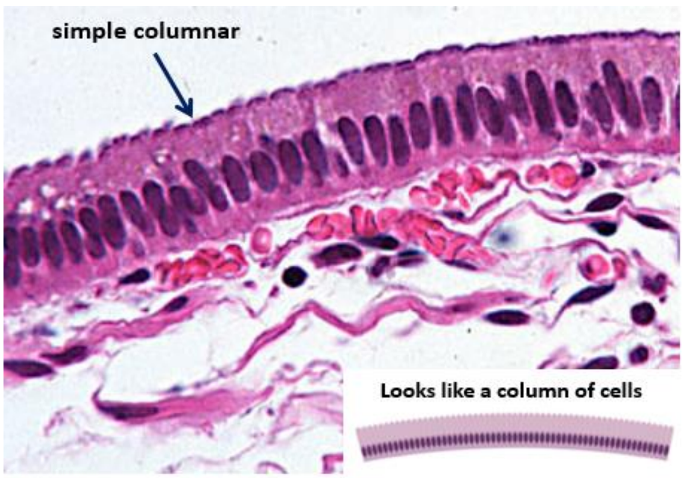
1) Simple Squamous Epithelium
The structure below is the glomerular capsule, found in the kidney. Red arrow and red circle = simple squamous epithelium. Note: the green = simple columnar and yellow = simple cuboidal.



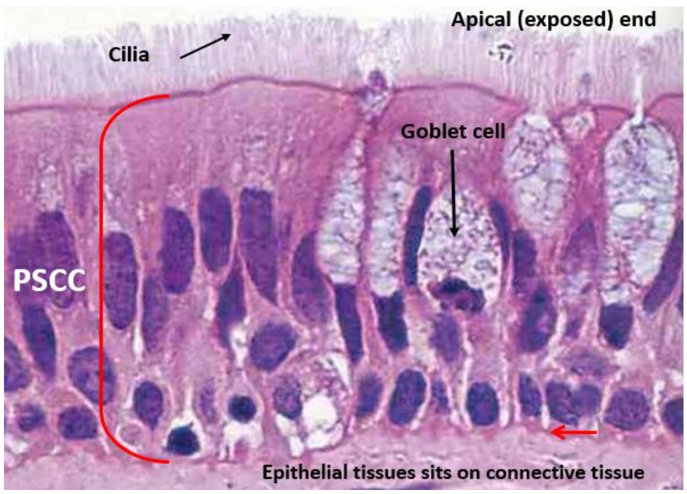
2) Simple Cuboidal Epithelium
In our lab slides, simple cuboidal is found in thecal follicles of thyroid gland, they line where the colloid is stored. The inset (left) is a drawing of the same follicle structure.



3) Simple Columnar Epithelium
In our lab slides, simple columnar is found lining the small intestine. Notice the nuclei of the columnar cells are lined up in a single layer.



4) Pseudostratified Ciliated Columnar Epithelium
This tissue if found in the trachea. Notice how there appears to be several layers of nuclei in this tissue, but all cells are attached to the basement



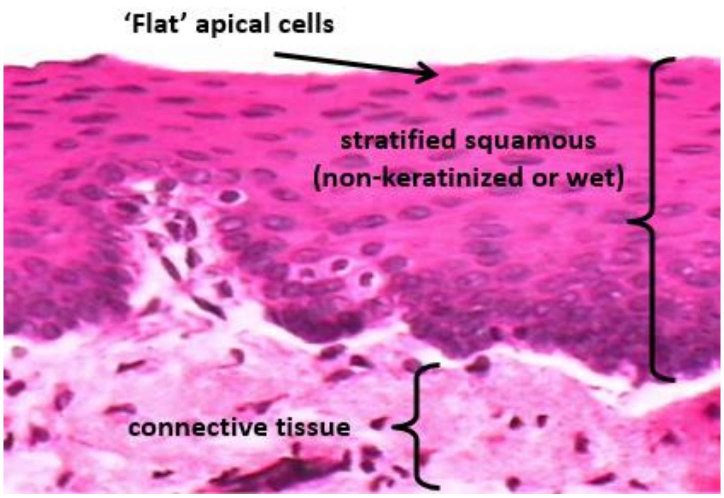
Below are photographs of histological slides showing a specific example of each of these stratified epithelial tissues.

The 4 Types of Stratified Epithelium

- **5)** Stratified Squamous Epithelium
- **6)** Stratified Cuboidal Epithelium
- **7)** Stratified Columnar Epithelium
- **8)** Transitional Epithelium

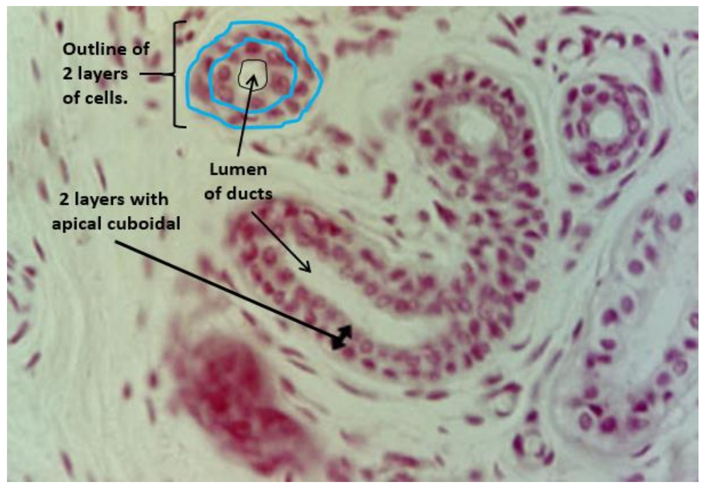
5) Stratified Squamous Epithelium

This is non-keratinized (wet) stratified squamous. This lines the esophagus giving protection and keeping moisture.



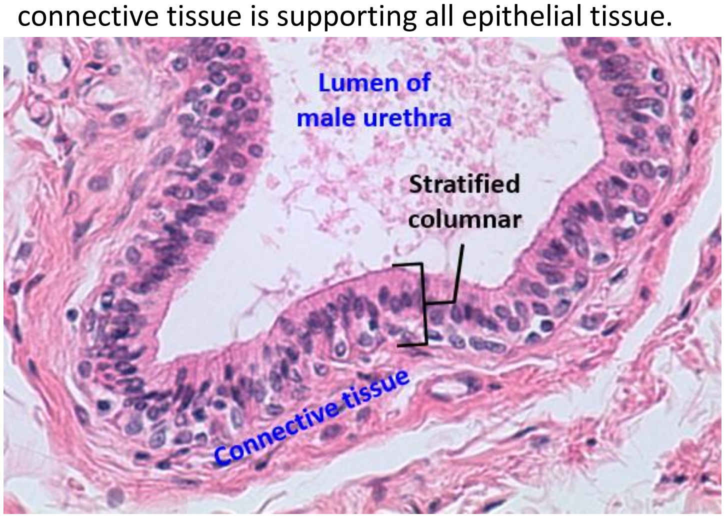
6) Stratified Cuboidal Epithelium

In our lab slides, stratified cuboidal is seen lining the duct of this sweat gland. Notice the 2 distinct layers (blue lines) and that the shape of the apical cells are cuboidal.



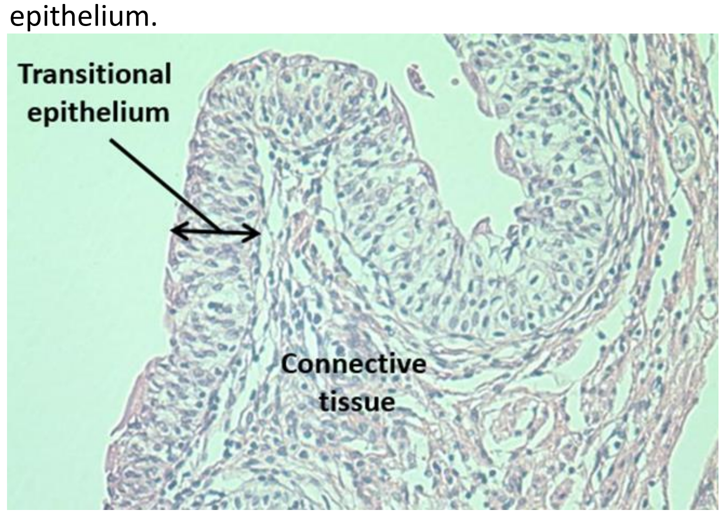
7) Stratified Columnar Epithelium

The stratified columnar epithelium is found lining the male urethra. Notice 2 layers with the apical cells being columnar in shape. Notice that connective tissue is supporting all epithelial tissue.



8) Transitional Epithelium

This tissue if found lining the urinary bladder. It is clearly stratified (has many layers) but the apical layer has many different shapes, thus it is called transitional epithelium.



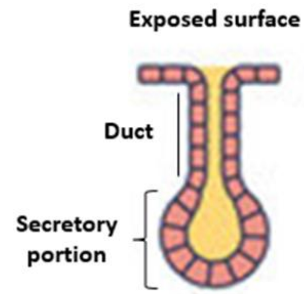
Notice that connective tissue is supporting all epithelial tissue.

Special Features: Epithelial tissue is often specialized for various functions on the apical surface of the tissue. These include such structures as **cilia**, **microvilli** and **goblet cells**. Almost all of these are exclusively associated with columnar cells.

E. Glandular Epithelia – found in glands that secrete substances. There are two types of glands:

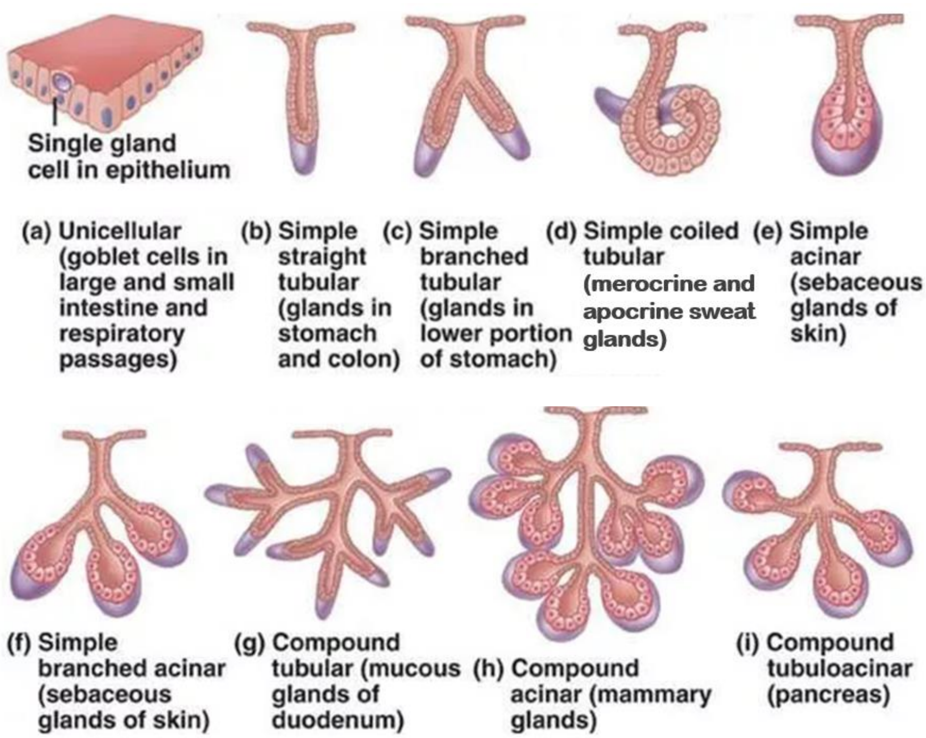
1. **Endocrine** – secretes hormones directly into body fluids, usually blood.
2. **Exocrine** – secrete products by way of duct onto an exposed surface.

At this point in anatomy, our focus will be on the various ways to **Classify Exocrine Glands**. There are three main ways that exocrine glands are classified, 1) the number of cells and their structural arrangement; 2) the mode of secretion or way that substances are released; and the type of secretion. How many cells are involved? Unicellular glands contain 1 cell. The only example is the goblet cell. Most of the exocrine glands are multicellular.



1) The **structure** of multicellular glands can be classified by 2 elements:
a) whether it has a single main duct (simple) or has many branching ducts (compound); and **b)** the shape of the secretory portion of the gland. See the image to the right which shows the duct and secretory portions of a gland.

i. Simple (one duct)
ii. Compound (many ducts)
iii. Tubular (tube shaped)
iv. Acinar or alveolar (bag shaped)



2) Mode of secretion: The mechanism by which the glands products are released from the gland.
i. Merocrine - secretion by exocytosis (of vesicles), cell stays intact.
ii. Apocrine - exocytosis of thicker, lipid-rich product (*tip of the gland is shed*).
iii. Holocrine - vesicles of substances accumulate and the entire cell is shed as a product.

3) Type of secretion:
i. Serous – watery secretion. Slippery and not viscous.
ii. Mucous – thick sticky viscous secretion.
iii. Mixed – contains both serous and mucous solutions.

Connective Tissue

In comparison to epithelial tissue, connective tissue is highly variable in its structure. There are, however, some basic commonalities shared by all connective tissue. All connective tissue is characterized by the presence of specialized **cells**, **fibers** and various types of **ground substance**.

A. Functions of Connective Tissue

1) Structural Framework – Provides internal interconnecting material, like scaffolding. It packs and binds one tissue to another.

2) Protection – Insulates vital organs, think of the boney skull and rib cage, adipose buffers and cushions internal organs, areolar and reticular cover and bind many organs.

3) Storage within Body – Adipose tissue stores energy in the form of triglycerides (fats) and bone stores the minerals calcium and phosphate and many trace minerals in its calcified matrix, which the body can have access to.

4) Transportation – Blood and lymph are fluid connective tissues transporting material through the body.

5) Repair and Healing – connective tissue is the ultimate fallback tissue for healing and making repairs in the body. If other tissue can't regenerate, the gap or injury will be filled by connective tissue. Scar tissue is often the result of 'back-filling' with collagen fibers from connective tissue when the wound is deep or significant. Also serves in an immunological role, circulating defense cells in lymph.

B. Characteristics of Connective Tissue

There are several different types of connective tissue, but again this tissue shares some common characteristics regardless of its specific function. Outlined here are the four (4) major characteristics of connective tissue.

1) Abundance of Extracellular Material – generally, the cells of connective tissue are not closely packed as they are in epithelial tissue, and there are fibers and 'ground substance' in various proportions and arrangements. Ground substance is a transparent material with the properties of a viscous solution or a highly hydrated thin gel. The main difference between *loose* and *dense* connective tissue is how densely packed the matrix is with fibers.

2) Various Specialized Cells – The cells of connective tissue are versatile in size, shape and function, depending on the specific type of connective tissue. In general, they are often not 'typical' or consistent as seen in epithelial tissue. Many cell types in connective tissue can also change and become more specialized in structure and function during developmental phases – a term referred to as *differentiation*. A good example of this is how osteoblasts differentiate into mature osteocytes in bone tissue.

3) Blood Supply Varies – Some connective tissue is richly vascularized (has a large blood supply), for instance bone, adipose and areolar tissue are richly supplied with blood. Other tissue is moderately supplied, for example dense irregular and reticular. Scantly supplied connective tissues include dense regular (found in tendons and ligaments). There is one type of connective tissue that is *avascular* (has no blood supply, like epithelial tissue) and that is cartilage. All three types of cartilage (hyaline, elastic and fibrocartilage) have no blood supply of their own and thus their ability to repair themselves is limited.

4) Nervous Innervation – All connective tissue has nervous innervation (supplied by nerves) but most connective tissue is not very richly innervated, and therefore not highly sensitive.

C. Classification of Connective Tissues:

a) Fluid Connective Tissues (blood and lymph).
b) Connective Tissue Proper (loose and dense).
c) Supporting Connective Tissue (bone and cartilage).

1. Cells of connective tissue

1) Fixed cells, e.g., fibroblasts, adipocytes, chondrocytes, chondroblasts, osteocytes, osteoblast, and nerve cells. Macrophages* and mast cells* *can sometimes take a wander.*

2) Wandering cells are most associated with blood and lymph (e.g., erythrocytes and leukocytes)

2. Three kinds of **Fibers** are made within connective tissue:

1) Collagen: thick, strong and unbranched. The most common is type I collagen, replete in skin, tendons, bones, and ligaments. White in body, stains pink and blue in histology. Type II collagen is primarily found in cartilage, type IV collagen is found in basement membranes, and type VI collagen is mostly in the extracellular matrix.

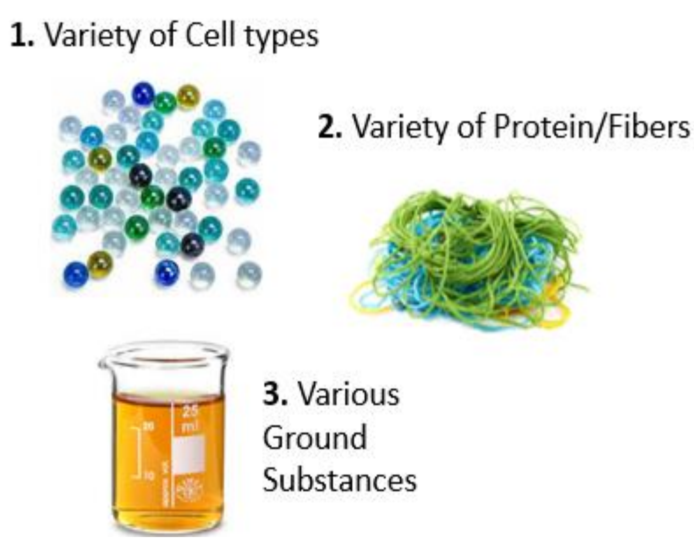
2) Reticular: very thin (type III collagen), fine, branching ('network') and flexible.

3) Elastic: made of elastin, recoils after stretching. Yellow in body, stains dark in histology.

3. The material called **Ground Substance** is what the fibers and cells are embedded in.

The most common components of connective tissue ground substance are **1)** hyaluronic acid and **2)** glycosaminoglycans (mucopolysaccharides). Chondroitin sulfate is also found in cartilage, it is the substance that is responsible for the 'rubbery' quality of cartilage.

The term connective tissue **matrix** is defined as the combination of the **fibers** and the **ground substance**.



It may be helpful to initially visualize the 3 elements of connective tissue, i.e., the cells, the fibers and the ground substance, with everyday objects.

If we had a hand full of marbles (cells), and some strings and threads (fibers) and placed them both into a beaker of honey (ground substance), this could be similar to a generalized concept of connective tissue.

Maybe if we used grapes as the cells, and strips of mango as the fibers, this could be a neat kind of natural snack treat, as well as a good way to contemplate connective tissues.

The Detailed Classification of Connective Tissue

As discussed above, the three broad categories of connective tissue classification are based on those three elements that have been described, that this their cells, the types of fibers found within the tissue, and the characteristics of their ground substance, which helps to make and the matrix of a specific tissue.

The attributes of the 3 elements of the connected tissue are incorporated in order to create broad categories that have 2 to 3 specific types of connective tissue within them (see schema below).

- Consider the cells, are they are dispersed, is there one type or many different types? There are numerous types of cell are found in the various connective tissues, but the most common are fibroblasts (fiber-makers), macrophages (big eaters), and mast cells (for protection and healing).

- Has the tissue got more extracellular material than cells in it? What is the nature of the ground substance? Is it fluid, a gel, rubbery or hard?

- Does it have an extensive network of protein fibers found within the extracellular matrix?

Here is the pattern and the specific names of the categories for the classification of connective tissues.

Fluid Connective Tissue

1) Blood
2) Lymph

Connective Tissue Proper

Loose
1) Areolar
2) Adipose
3) Reticular

Dense
1) Regular
2) Irregular
3) Elastic

Supporting Connective Tissue

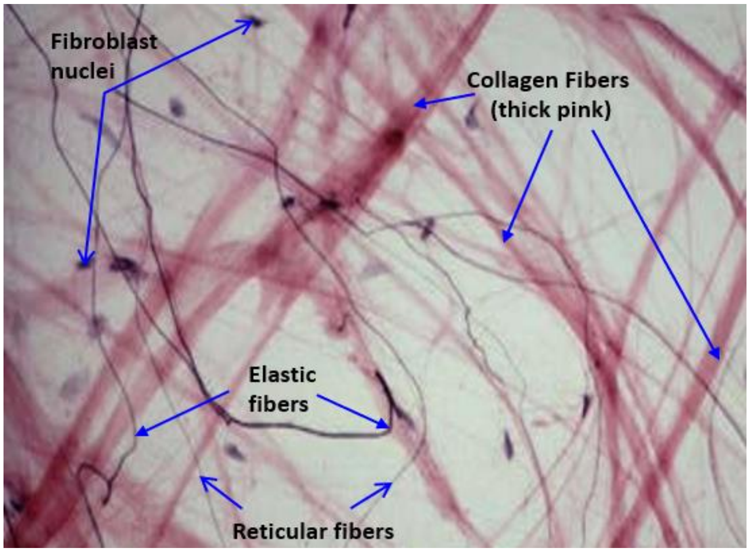
Cartilage
1) Hyaline
2) Elastic
3) Fibrocartilage

Bone
1) Spongy
2) Compact

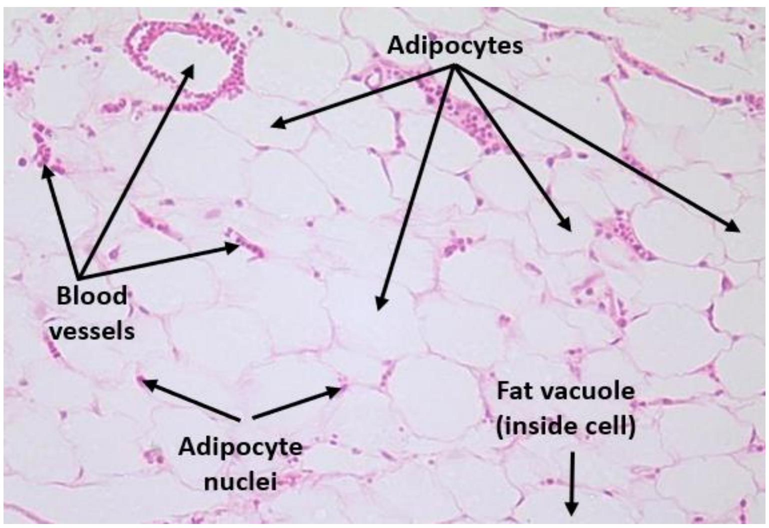
Note: The first category of connective tissue is **Fluid Connective Tissue**. This category includes ***blood*** and ***lymph***. The ground substance of both these are over **90% water** (for plasma and lymph). The cells of these tissues are floating structures carried along by the matrix. For now, we will skip the fluid connective tissues in terms of histological examination, and will examine these more closely later.

A. Loose Connective Tissues

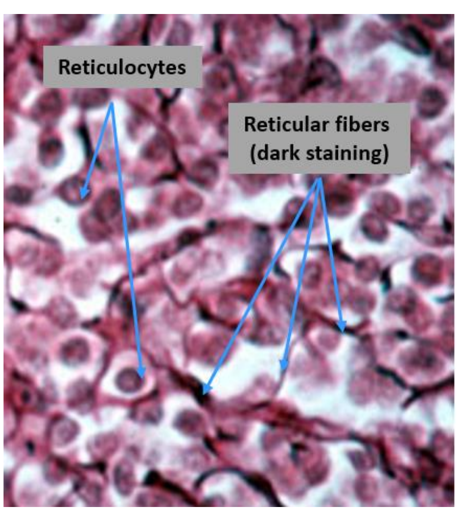
1. Areolar tissue is like the poster-child of connective tissue it that it contains all the fundamental cells and fibers. It has collagen, elastic and reticular fibers within it. Collagen fibers are prominent, they are very large, very thick structures in this tissue, often staining pink. The elastic fibers usually exhibit coiling and are thick, darkly staining structures. The reticular fibers are the thinnest of the three fibers, have a highly branching pattern to them and stain dark. There are many fibroblast nuclei visible in this example. The fibroblasts are the cells that make all the fibers in this tissue. Macrophages and related histiocytes are found in this tissue.

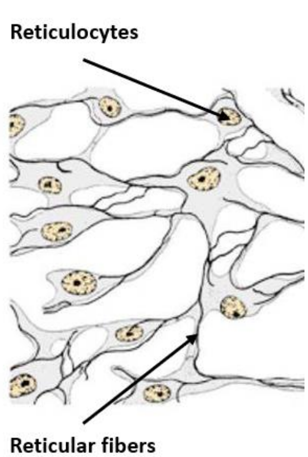


2. Adipose (fat) tissue consists of large cells called adipocytes which are usually very closely packed together and resemble wedged puzzle pieces. Adipocytes are almost entirely occupied by a large fat vacuole (filled with stored lipids called triglycerides). The nuclei of these cells are peripherally located, due to the extensive fat vacuole in the cytoplasm, with very little other cellular material visible. This tissue is highly vascular, and often many blood vessels, including very large one, can be seen in this tissue.



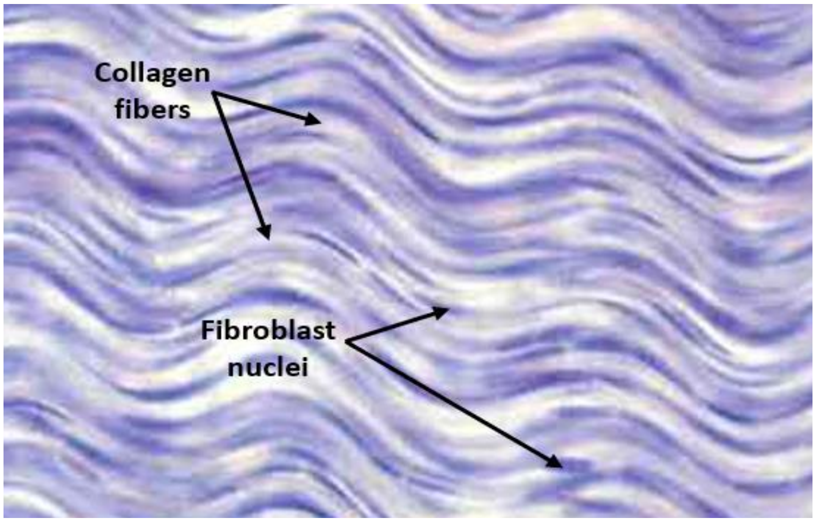
3. Reticular tissue is composed mostly of reticulocytes and reticular fibers. Reticulum = net or network. This tissue forms a supportive network around other cells in organs like the spleen, lymph nodes and tonsils. It's made up of a network of reticular fibers, which are thin, branching structures that form a mesh-like pattern. It is also found around the kidney and liver (in their capsules). Reticular fibers are very thin and usually have an extensive branching pattern. They are made of type III collagen.



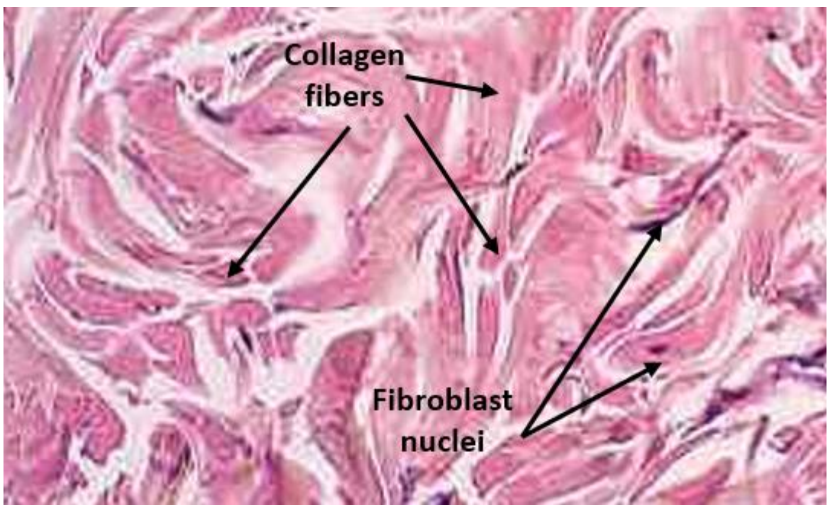


B. Dense Connective Tissues

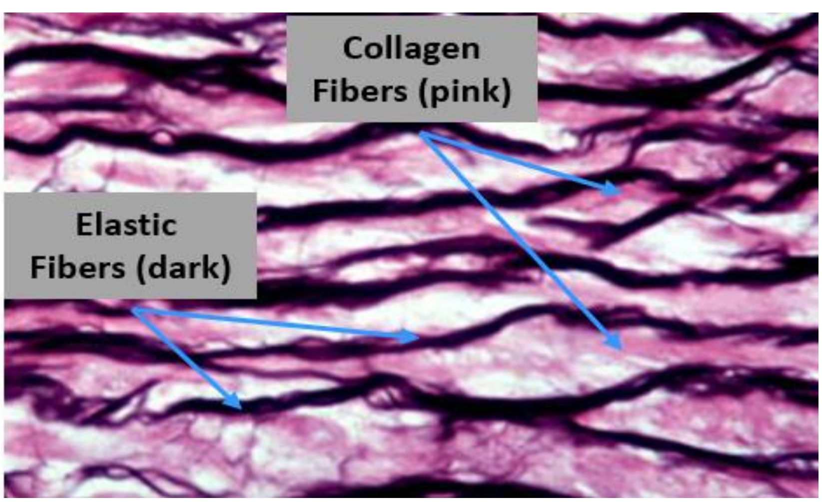
1. Dense Regular connective tissue has thick collagen fibers that are aligned and running parallel to each other, they are densely packed and look like waves of packed fibers in a thread and consequently are very strong due to this. The parallel arrangement of the fibers provides for very effective transmission of force along the direction of the fibers, as seen in tendons and ligaments, where this tissue is predominantly found. Overall, the appearance of this tissue may look wavy under the microscope.



2. Dense Irregular connective tissue has its thick collagen fibers that are arranged in a swirling pattern, set out in all directions, unlike the very organized and ordered dense regular tissue. This irregular orientation of the collagen fibers makes it very resilient to forces that are applied from several different directions. The fibroblasts in this tissue make all the fibers and blood vessels are also abundant in this tissue. A prominent place in the body where this tissue is located is the dermis of the skin.



3. Dense Elastic tissue is essentially like dense irregular tissue (seen above), but with lots of elastic fibers tossed in to give this tissue a lot of elasticity. This adds to its flexibility and strength. It is found in areas of the skin that are highly elastic, such as the face, in elastic ligaments, and it's also found in the walls of arteries (a type of blood vessel). Note: the structure elastin combines to form elastic fibers, which is the structures that is visible under the microscope and responsible for giving recoil to the skin and other structures.

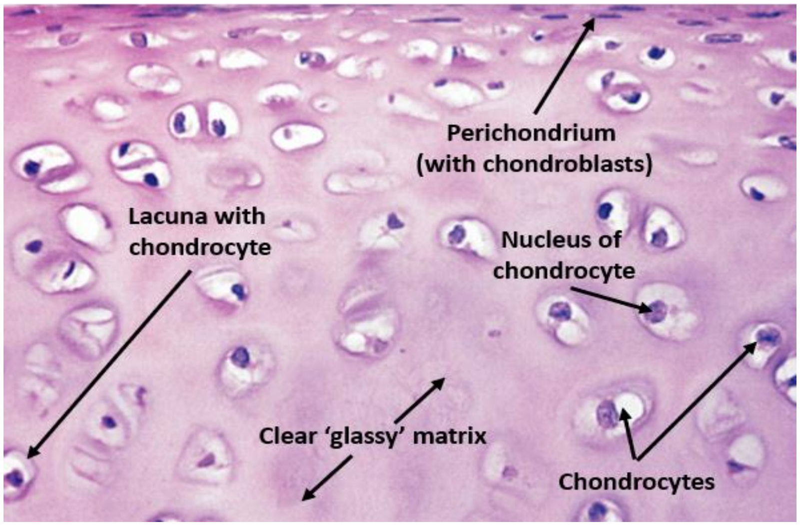


C. Supporting Connective Tissues

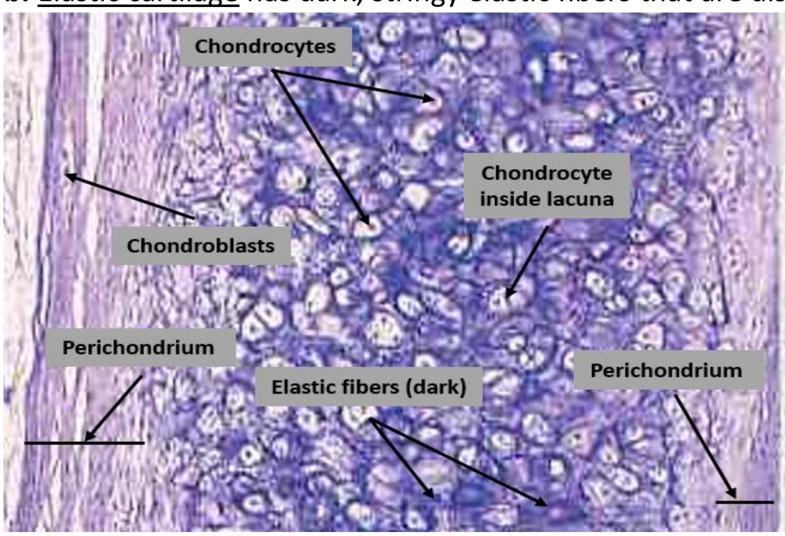
These include cartilage and bone and have much more solid matrix (matrix = fibers + ground substance).

1. Cartilage

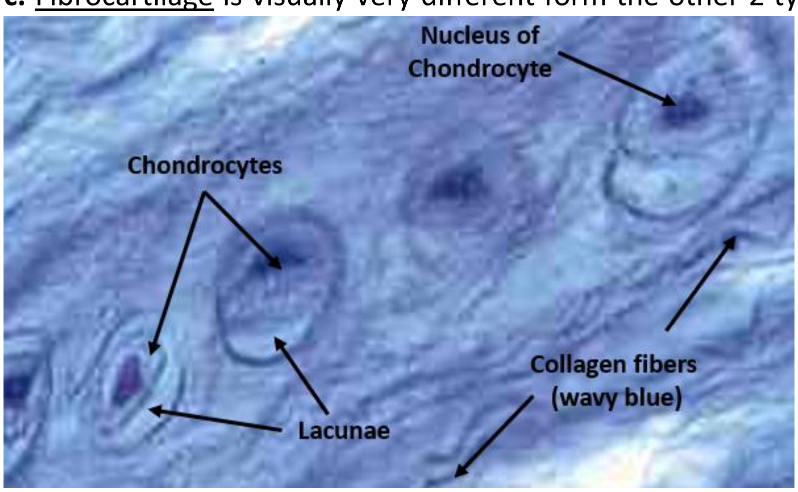
a. Hyaline cartilage has a 'glassy' smooth matrix and visually may appear 'texture-less'. It contains very thin collagen fibers that cannot be visualized in histological preps. It is the most common type of cartilage in the human body, found in the nose, ribs, and at the end of articulating bones. For all cartilage, chondrocytes are the mature cell in this tissue. The chondrocytes In hyaline cartilage reside within lacunae, sometimes 2 chondrocytes will share 1 lacuna. This tissue also has perichondrium surrounding it at the outer edges and this is where the developing cells of cartilage are found, they are called chondroblasts.



b. Elastic cartilage has dark, stringy elastic fibers that are distinctly seen within the matrix, making it look not smooth and not glassy like hyaline cartilage, but more fuzzy from all those fibers. Like hyaline cartilage, elastic cartilage has a matrix that is full of chondrocytes inside of lacunae, and this cartilage tissue is also surrounded by a perichondrium. Like hyaline cartilage, it is in this region is where the chondroblasts are found along with collagen fibers.

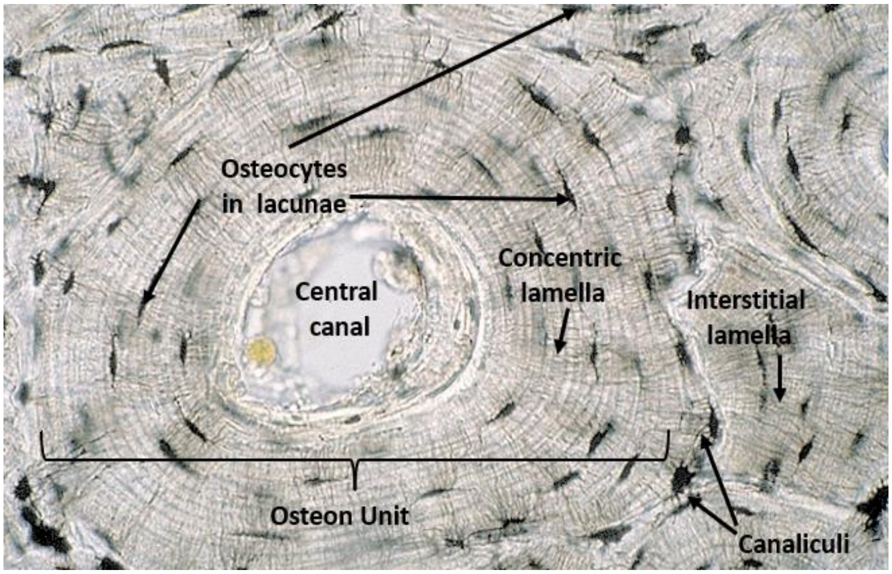


c. Fibrocartilage is visually very different form the other 2 types of cartilage. Mostly because it has very few chondrocytes in its tissue compared to the other 2 cartilage types. It also has an abundance of thick, wavy collagen fibers, as its name indicates. There are many more fibers than chondrocytes like its name indicates. This is the only type of cartilage that does not have a perichondrium.

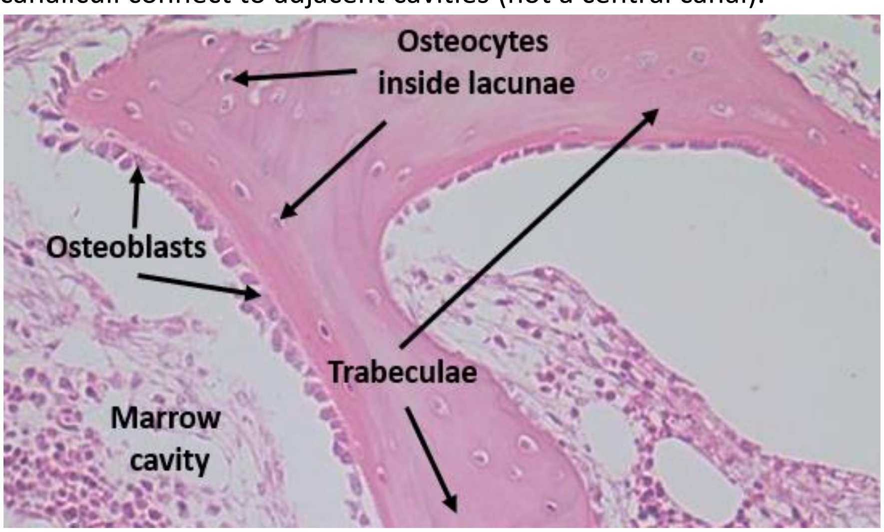


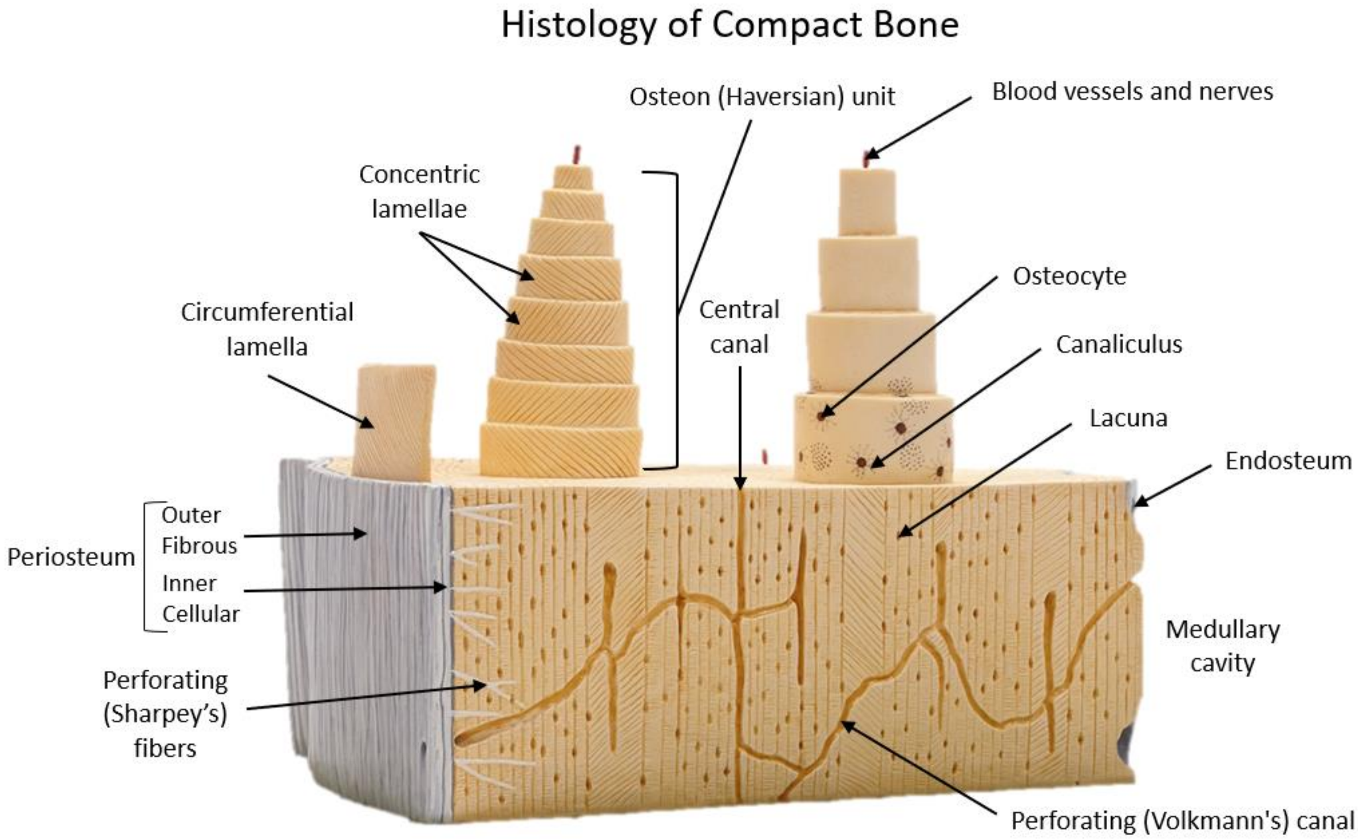
2. Bone

a. Compact Bone – has a mineralized and hard matrix, in addition to robust collagen fibers for flexibility. Compact bone consists of densely packed osteons (Haversian) units, with a central canal in the center of it, surrounded by concentric lamellae, making osteons look like tree rings or targets. Within the rings of matrix, the osteocytes are located within lacunae. Tiny canals radiate out from the osteocyte within the lacuna and these structures are called canaliculi, meaning 'tiny canal'.



b. Spongy Bone - consists of trabeculae (plates or struts) of bone which creating small, irregular cavities containing red bone marrow. The osteocytes are within the lacunae within the trabeculae. Osteoblasts and osteoclasts line the marrow cavity helping to create the endosteum, the inner lining of bone. The canaliculi connect to adjacent cavities (not a central canal).





Histological Models of Compact Bone

In the anatomy lab there are many very good histological models of various types of tissue. We will encounters histological models throughout the semester in anatomy.

The labeled histological model of **compact** or **ground bone** is shown above.

The **osteon** (Haversian) units are the functional unit of compact bone and can be seen in the models as being 'pulled up' (see image) out of the bone. This is done in order to show how the orientation of the collagen fibers in the **concentric lamella** are arranged perpendicular to the subsequent layer as they radiate out from the central canal. This is an anatomical feature of compact bone that gives it tremendous flexibility and strength. The concentric lamellae are located around a **central canal** which contains the blood vessels, nerves and lymphatics that supply the bone tissue. The **perforating fibers** (also called Sharpey's fibers) help attach the **periosteum** (meaning 'around bone') to the inner calcified bone matrix.

The **perforating** (Volkmann's) **canals** can also be seen interconnecting the central (Haversian) canals within this tissue. There are two others types of lamellae in compact bone. One is **circumferential lamella**, which is seen above (pulled up) traveling around the outer circumference of the bone just deep to the periosteum, and **interstitial lamellae** (not able to be seen here), which is located in between the osteon units. The mature bone cells are called **osteocytes**, they are found inside **lacunae** (plural), and an empty lacuna (singular) is labeled in the image. The osteocytes have tiny processes that radiate out into the bone matrix called **canaliculi** (plural), which means tiny little canals (canaliculus is singular).

Epithelial Membranes

1. **Cutaneous** - which makes up skin, secretes sweat and oil. This is the only "**dry**" membrane.

2. **Serous** - lines sealed cavities within body and produces thin, slippery, watery serous fluid.

3. **Mucous** - lines open or exposed passageways and cavities and secretes thick, sticky mucus.

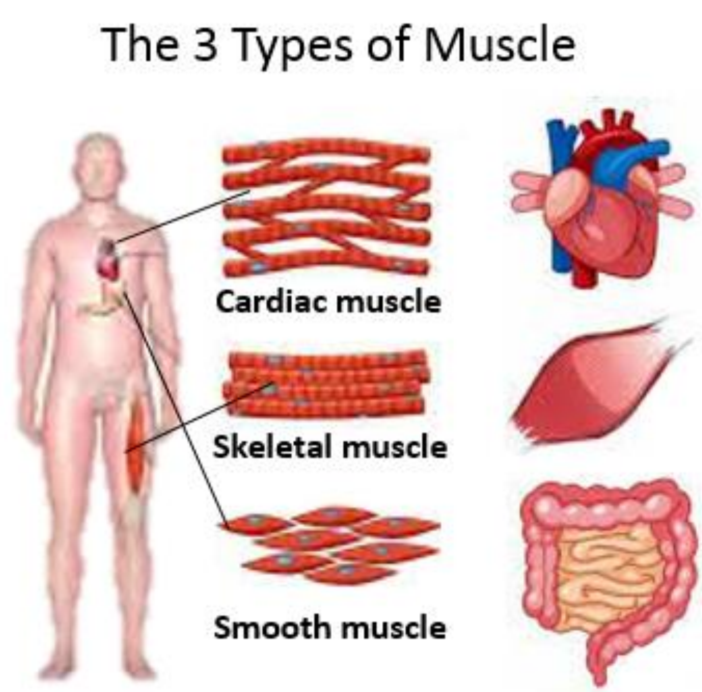
Connective Tissue Framework of the Body

A. Superficial Fasciae - delicate connective tissue just deep to the true skin. It is also known as hypodermis or subcutaneous. Consists mainly of areolar and adipose tissue.

B. Deep Fasciae - layers of collagenous tissue surrounding and separating muscles.

C. Subserous Fasciae - found under the epithelial lining of serous membranes.

Muscle Tissue – This tissue is fibrous in appearance, and in essence it is the "meat" of the body. In fact, muscle cells are called muscle fibers, these two terms are interchangeable for muscle tissue. There are three main types of muscle tissue (see image below right), cardiac, skeletal and smooth muscle. These three tissues have similar properties, yet very different roles in the body.



Regardless of the specific type of muscle, all muscle tissue shares four important properties. They are that muscle is **contractile**, **elastic**, **extensible**, and **excitable**. In the body, muscle tissue provides movement of the whole or a specific body part.

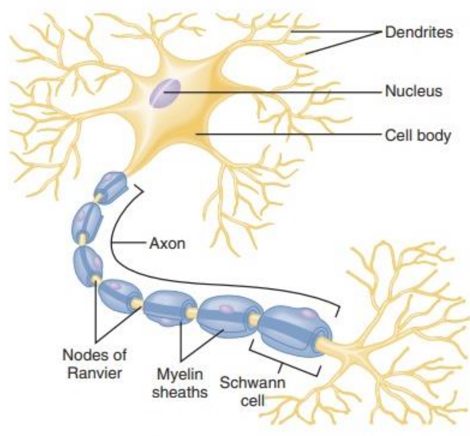
<u>There are 3 Types of Muscle Tissue</u>

1. Skeletal muscle – This muscle tissue has long, cylindrical, multinucleated, striated (has a banding pattern) cells. The nuclei are always located in the periphery of the cell. The fibers do not branch.

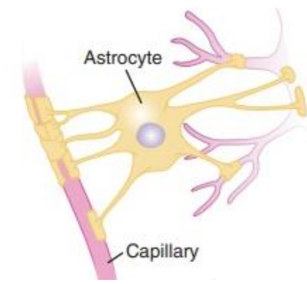
2. Cardiac muscle – This muscle is also striated and usually has a single centrally located nucleus. The fibers (cells) of cardiac muscle often branch and interweave. Distinguishing intercalated discs connect adjacent cells. These intercalated discs contain desmosomes (for cell to cell attachment) and gap junctions (for cell to cell communication).

3. Smooth muscle – This tissue has tapering cells which are frequently indistinctly seen (difficult to visualize) and have a single large, well-centered nucleus. Striations are never visible in this tissue, hence the name *smooth* muscle.

Neural Tissue - Neural tissue is characterized by two cell populations: **Neurons** and **neuroglial** or **glial** cells. Neurons (example seen below) have a large cell body (soma) with a central nucleus and many dendrites (branches) radiating from the soma. They usually have a single elongated process leaving the soma, called an axon.

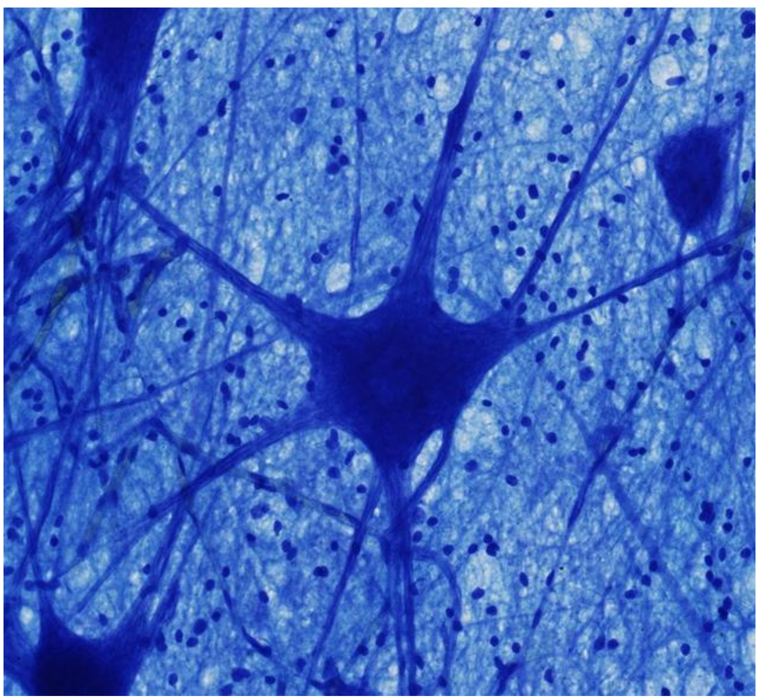


Neuroglia or **glial cells** support the neurons and have various shapes and locations. There are 6 different types of glial cells, each with a specific function, such as the astrocyte shown at right, which adds an additional protective layer over cerebral capillaries, called the blood brain barrier.



Histological Preparation of a Neuron (and Glial cells).

The image below shows a histological stain of a neuron as the central large cell in the image, with many elongated projections extending from the center of it, which is a structure called the soma or cell body of the neuron. The soma is where the dark staining nucleus can be found. One of the long projections coming from the soma is the axon (for outgoing information) and the other structures are the dendrites (for incoming information).



The numerous tiny dark structures also seen in the image are the nuclei of various glia cells that surround and support the neurons. In the entire nervous system, the glial cells outnumber the neurons with a ratio of about 10 to 1.