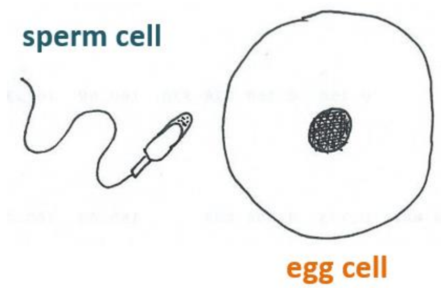
Anatomy Lecture Outline Section 1: The Tissue Level of Organization

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 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. There are three (3) primary (1^{o}) germ layers in human embryology.

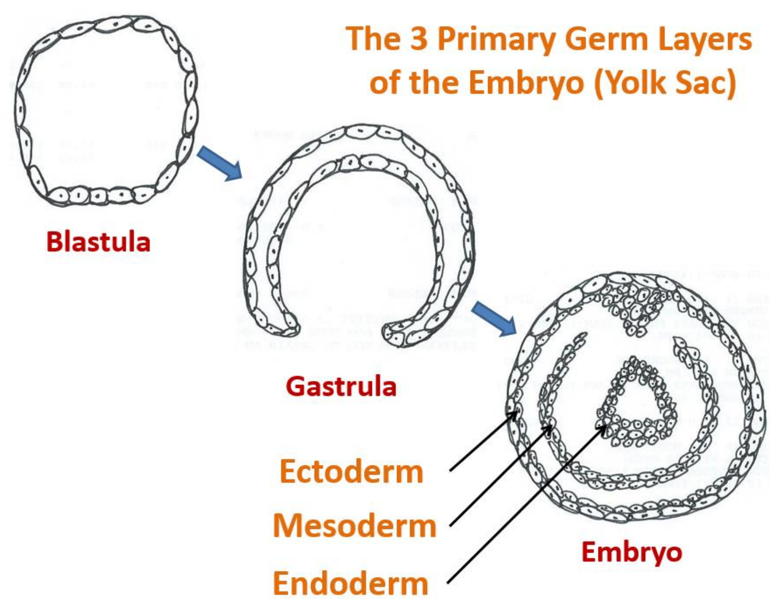


When the male sperm cell unites with the female egg cell this creates a **fertilized egg cell**, also called a **zygote**. Immediately after this time, the rapid process of cell multiplication begins, as 2 cells become 4, become 8, and onward, until a hollow ball of cells called the **blastula** is generated. From the blastula comes the **gastrula**, which is like is a hollow horseshoe-shaped structure that has the start of three distinct cell layers. 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 or conception and lasts until week eight of gestation.

Humans are **triploblastic**, that is, they have a body that is derived from three embryonic cell layers, which are the **3 primary germ layers**. The three are called **endoderm**, **mesoderm** and **ectoderm**.

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

As illustrated in drawings below, the 3 primary germ layers are named depending on where in embryological development they derive from. It is these germ layers that give rise to all tissues and organs in the human body.



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 essentially means that the cells within a tissue have similar anatomy and physiology and these cells make all of the other components of the tissue.

In the human body there are four (4) **Primary Tissues**:
1) Epithelial; **2)** Connective; **3)** Muscular; and **4)** Nervous.

Considering that there are over 200 different types of cells in the human body, four *Primary Tissue* is a relatively manageable number! It will be effective to establish the basic differences between these tissues and be able to clearly distinguish the basic functions and components of each. Below is a very brief overview of the nature and function of the 4 primary tissues. Details of each tissue will be expanded upon 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.

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 require. 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 secret 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 some common types of epithelial glands.

4) Provides Sensations (Nervous Innervation) – This tissue provides much of the bodies 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 epithelium (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) <u>Cellularity</u> – 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) <u>Polarity</u> – 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 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) <u>Attachments</u> – 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. This is because they are too far away from the blood supply.

5) Highly Regenerative – 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**.

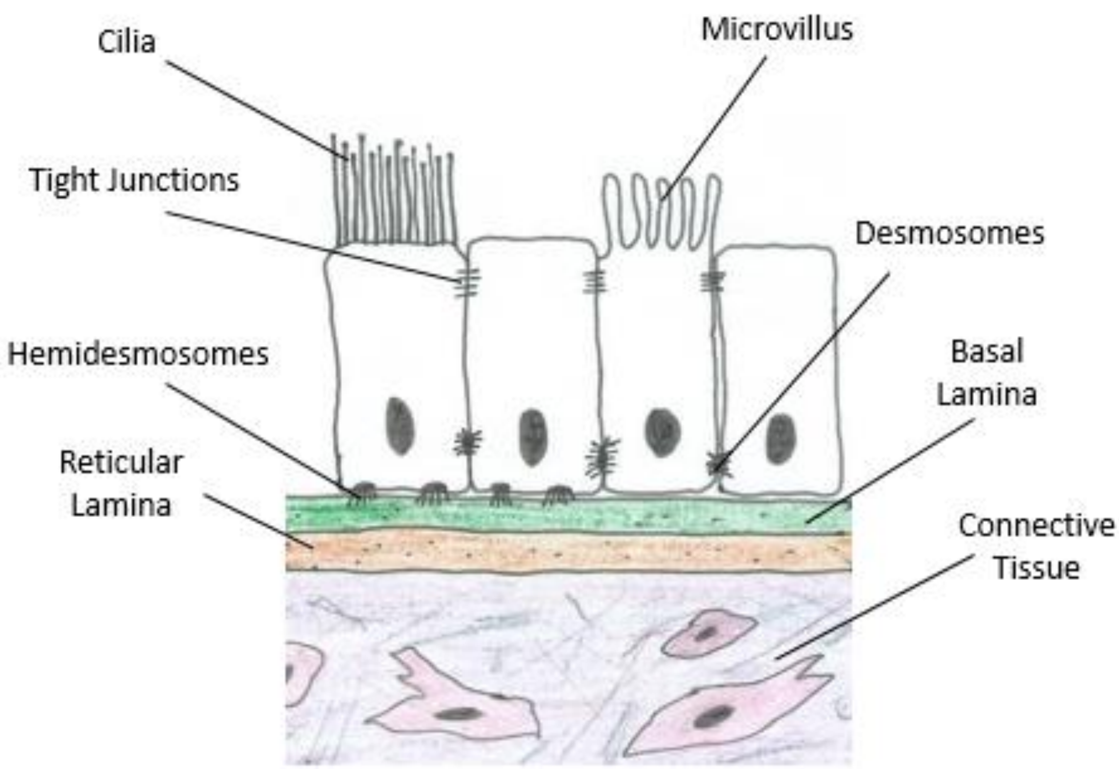


Figure 1. This shows a diagrammatic representation of epithelial tissue with many of the specific structures discussed above.

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 as 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. Squamous epithelium is frequently seen in a stratified arrangement for protection. The nucleus is of these cells is flat and centralized. Keep in mind, that only the outermost (exposed) layer, away from the basement, is used to determine cell shape.

2) Cuboidal cells look cubed, like their name. The cell shape is very regular with a rounded and centrally located nucleus. More commonly these are found in simple tissue as opposed to stratified.

3) Columnar cells are tall and column-shaped (perpendicular to the basement membrane). They are often simple but can also be pseudostratified (meaning a giving false appearance of stratification). Only columnar cells can have this arrangement because of their height. Columnar cells can be specialized with cilia and microvilli.

4) Transitional epithelium is found in the urinary bladder and associated structures and allows for expansion. The cells are atypical in shape, irregular and often larger near the free edge than at the basement, which is the opposite of most epithelium. The cells shape transitions depending on whether a structure, like the bladder, is contracted or distended.

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.

Here is some additional information on the various ways to **Classify Exocrine Glands**

1. Unicellular (e.g., goblet cells) or multicellular.

2. Structure of multicellular glands:
- **i.** Simple (one duct)
- **ii.** Compound (many ducts)
- **iii.** Tubular (tube shaped)
- **iv.** Acinar or alveolar (bag shaped)

3. Mode of secretion:
- **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 accumulate and the entire cell is shed as a product.

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 repairs in the body. If other tissue can't regenerate, the gap or injury will be filled by connective tissue. Scar tissue is the 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) <u>Abundance of Extracellular Material</u> – 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. The main difference between *loose* and *dense* connective tissue is how densely packed the matrix is with fibers.

2) <u>Various Specialized Cells</u> – 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 terms referred to as *differentiation*. A good example of this is how osteoblasts differentiate into osteocytes in bone tissue.

3) <u>Blood Supply Varies</u> – 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 (for example a tendon). One type of connective tissue is *avascular* (has no blood supply, like epithelial) and that is cartilage. All three types of cartilage (hyaline, elastic and fibrocartilage) have no blood supply and thus their ability to repair themselves is limited.

4) <u>Nervous Innervation</u> – 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)** Wandering cells are most associated with blood and lymph (e.g., erythrocytes and leukocytes)
- **2)** Fixed cells, e.g., fibroblasts, adipocytes, macrophages*, mast cells*, chondrocytes (-blasts), osteocytes (-blast), and nerve cells. **these cells can sometimes take a wander.*

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

- **1)** <u>Collagen</u>: thick, strong and unbranched. White in body, stains pink and blue in histology.
- **2)** <u>Reticular</u>: very thin (collagen), fine, branching ('network') and flexible.
- **3)** <u>Elastic</u>: made of elastin, recoils after stretching. Yellow in body, stains dark in histology.

3. Ground Substance is the material in which fibers are embedded.

The most common components of connective tissue ground substance are **1)** hyaluronic acid, **2)** mucopolysaccharides and **3)** glycosaminoglycans. Chondroitin sulfate is also found in cartilage, it is the substance that is responsible for the 'rubbery' quality of cartilage..

A. Loose Connective Tissues

1. Areolar tissue, contains both collagen, elastic and reticular fibers.
2. Adipose tissue (fat tissue) consist of large cells almost entirely filled with fat vacuole (filled with triglycerides) and with very little cellular material visible.
3. Reticular tissue forms a supportive network around other cells in organs.

B. Dense Connective Tissues

1. Dense Regular connective tissue has collagen fibers aligned and tightly bundled like fibers in thread or rope and is consequently very strong. Overall appearance may be wavy.
2. Dense Irregular connective tissue is similar in substance to dense regular but has no particular orientation to the fibers which makes it strong in several directions.
3. Dense Elastic tissue has additional elastic fibers and thus has elasticity in addition to strength.

C. Supporting Connective Tissues

These include cartilage and bone and have much more solid matrix (matrix is = fibers + ground substance). Both bone and cartilage characteristically have lacunae in which chondrocytes or osteocytes as the case may be, reside. In the case of bone the matrix is mineralized and hard in addition to the tough collagen fibers.

1. Cartilage

a. Hyaline cartilage has 'glassy' smooth matrix and may appear 'texture-less'.
b. Elastic cartilage has dark, stringy elastic fibers within the matrix.
c. Fibrocartilage has thick, wavy collagen fibers and fewer chondrocytes.

2. Bone

a. Compact Bone - osteons looks like tree rings or targets.
b. Spongy Bone - has trabeculae, which resembles scaffolding (with blood cells).

** Fluid tissues include blood and lymph in which the matrix is plasma or lymph (~92% water) and the cells are floating structures carried by the matrix. We will examine these more closely later.*

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.
4. **Synovial** - lines joint cavities and produces viscous synovial fluid.

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 - fibrous appearing, it is the "meat" of the body. Its properties are that it is contractile, elastic, extensible, and excitable. In the body, muscle tissue provides movement of the whole or a specific body part.

There are 3 Types of Muscle Tissue

1. Skeletal muscle – striated, long, cylindrical, multinucleated cells. The nuclei are always located in the periphery of the cell. The fibers do not branch.

2. Cardiac muscle – striated, usually a single centrally located nuclei. 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 – tapering cells which are frequently indistinctly seen, single large, well centered nucleus. Striations are never visible (hence the name *smooth* muscle).

Neural tissue - Neural tissue is characterized by two cell populations; **neurons** and neuroglial or **glial** cells. Neurons 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. Glial cells support the neurons and have various shapes and locations.