College of sciences **Dr. Mahdi Haider**

Microbiology dep. **First lecture**

Anatomy of Human Body

Anatomy:

The study of the structure of body parts and their relationships to one another

Physiology:

The study of the function of the body's structural machinery

Some important anatomical terms:

Superior (Cranial)

Closer to the head

Inferior (caudal)

Away from the head

Anterior (ventral)

Toward the front of the body

Posterior (dorsal)

Toward the back of the body

Medial

Toward the midline of the body

Lateral

Away from the midline of the body

Proximal

Closer to the trunk

Distal

Away from the trunk

Superficial

Toward the surface of the body

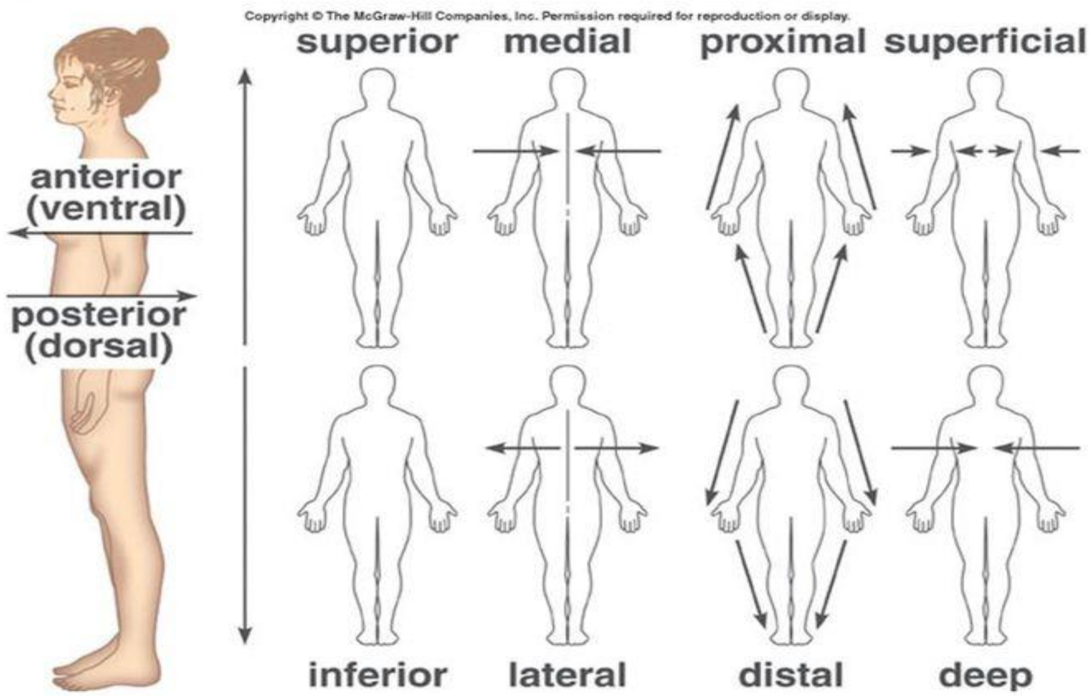
Deep

Away from the surface of the body

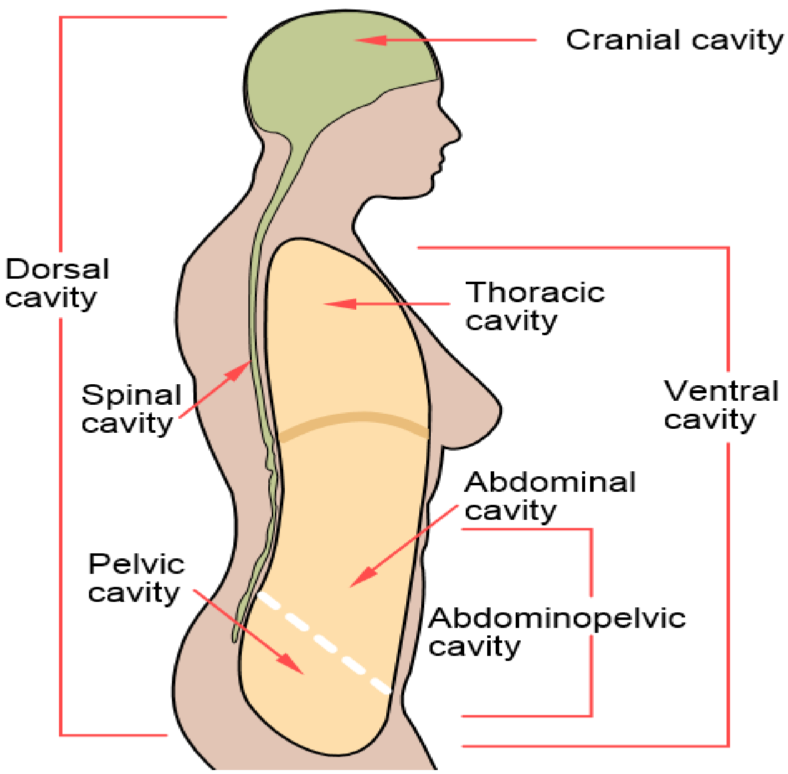
Internal: in side of body

External: outside of body

Fig. 1.2



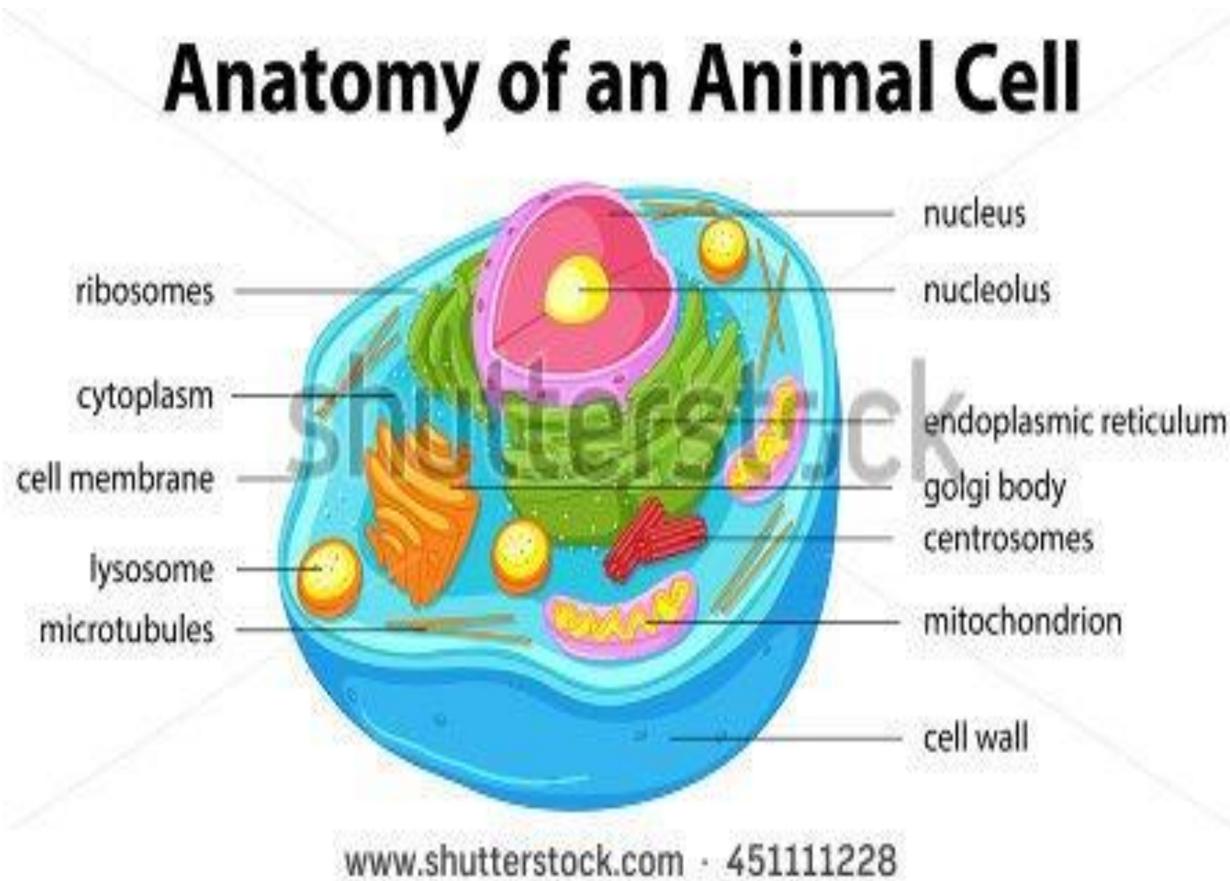
Type of body cavity:

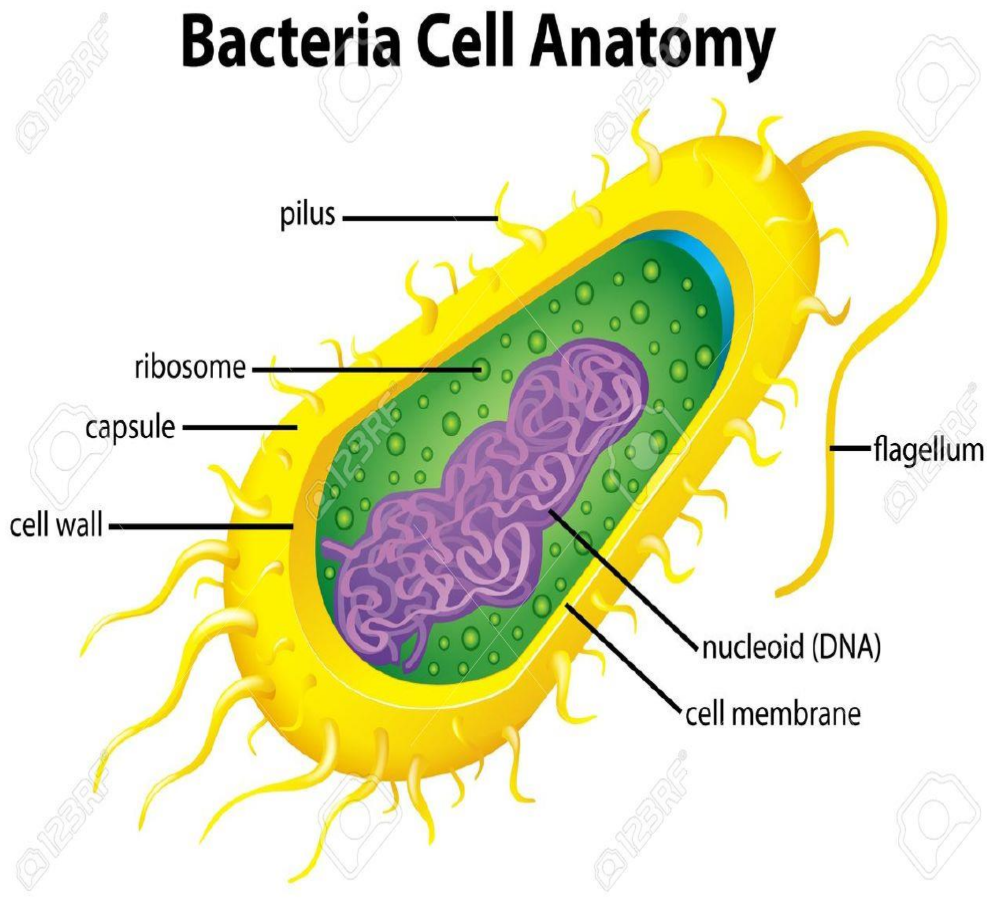


Anatomy of an animal cell

What are the ٣ major parts of the cell?

١. Plasmic Membrane
٢. Cytoplasm
٣. Nucleus





What is the major function of the plasmic membrane?

Binds the cell between the inside and the outside. Also determines what substances leave and enter the cell.

What are the ٢ major fluids which travel within or out of the plasmic membrane?

ECF - extracellular fluid
ICF- intracellular fluid (cytosol)

What are ٣ different types of ECF?

١. Interstitial Fluid
٢. Plasma
٣. Lymph

Interstitial Fluid

Also known as **intracellular fluid** or tissue fluid- located between cells of tissues

Plasma

A liquid component of blood

Lymph

Liquid located in lymphatic vessels.

The structure of the plasmic membrane is described as what? and what is its structure?

Fluid-mosiac Model - a lipid bilayer containing proteins.

Integral proteins

Strongly attached to the membrane

Peripheral Proteins

Loosely attached to the membrane

Diffusion

The way most substances move within the cell.
The way substances move in/out of cell.
spontaneous

Concentration Gradient

Different levels of concentration is the net movement of diffusion.

What happens when the molecules are small enough to pass through the membrane and down the concentration gradient?

The movement requires the cell to do no work.

Simple diffusion

The diffusion of dissolved substances through the lipid bilayer of the membrane

Facilitated Diffusion

The diffusion of dissolved substances through an integral protein gate in the membrane

Osmosis

Water diffusion across the membrane

What happens when the molecules are too large to pass through the plasmic membrane by diffusion?

The cells requires work thus beginning of Active Transport or Vesicular Transport.

What are the ٢ parts of Vesicular transport?

Endocytosis and Exocytosis

Endocytosis

Large molecules enter the cell with the plasmic membrane producing vessels.

Exocytosis

Large molecules exiting the cell.
First they are formed in vesicles which are formed within the cell

Cytoplasm

The part of the cell inside the plasmic membrane , and outside the nucleus

Cytosol (ICF) (cytoplasm)

Contains water, ions, and enzymes.

Ribosomes (cytoplasm)

Particles made of proteins and RNA where protein synthesis occurs. They may float freely or be attached to internal membranes.

Cytoskeleton (cytoplasm)

A network of protein fibers that run throughout the cytosol and supports and moves the cellular structures.

Organelles (cytoplasm)

Membranous structures with distinctive shapes and function

Endoplasmic Reticulum (organelle)

A network of membrane enclosed passage ways that run throughout the cytosol

Rough Endoplasmic Reticulum

Contains Ribosomes

Smooth Endoplasmic Reticulum

Contains no ribosomes. Stores Ca ions and makes or breaks fat.

Golgi Apparatus (Organelle)

A series of flatten membrane-bound sacs stacked upon each other.

What is the name job the the Golgi apparatus?

It receives and sorts products of the rough ER and packages them into vesicles for proper delivery within or out of cell.
Also the production of lysosomes.

Lysosomes (organelle)

Membrane-bound sacs containing digestive enzymes to be secreted or for intracellular digestion

Peroxisomes (organelle)

Membrane-enclosed sacs containing enzymes to destroy various harmful molecules.

Mitochondria (organelle)

Provide the most energy used by the cell

Nucleus

Contains genetic information or DNA

Centrioles (organelle)

A pair of cylindrical organelles located close to the nucleus. Important for cell division.

What is the main function of pores in the nucleus?

Allow for substances in/out of the cell.

College of sciences **Dr. Mahdi Haider**

Microbiology dep. **lecture**

Epithelial Tissue

Epithelial tissue is a sheet of cells that covers a body surface or lines a body cavity. Two forms occur in the human body:

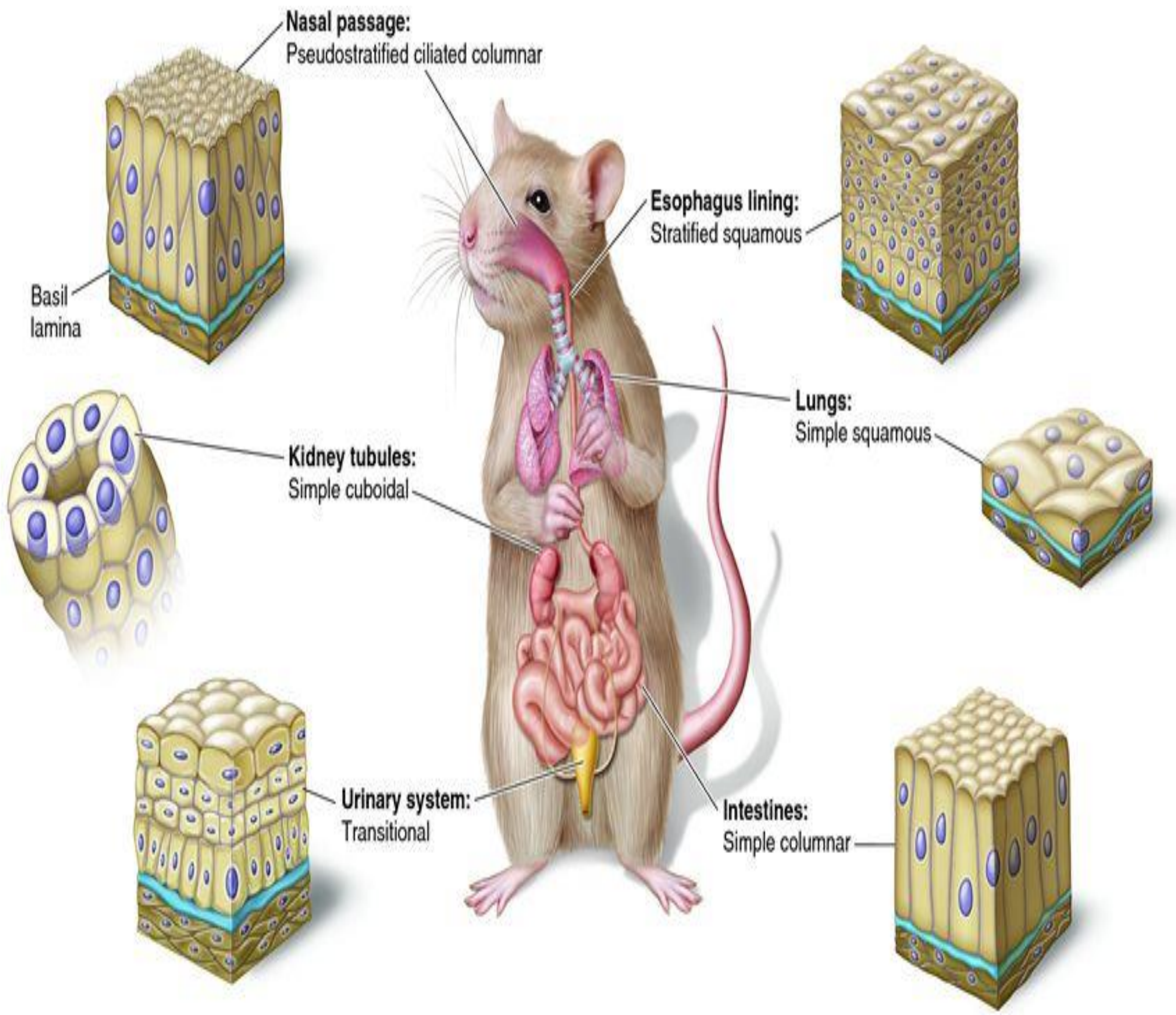
١. *Covering and lining epithelium*– forms the outer layer of the skin; lines open cavities of the digestive and respiratory systems; covers the walls of organs of the closed ventral body cavity.

٢. *Glandular epithelium*– surrounds glands within the body.

Characteristics of epithelium

Epithelial tissues have five main characteristics.

١. Polarity– all epithelia have an apical surface and a lower attached basal surface that differ in structure and function. For this reason, epithelia is described as exhibiting *apical basal polarity*. Most apical surfaces have microvilli (small extensions of the plasma membrane) that increase surface area. For instance, in epithelia that absorb or secrete substances, the microvilli are extremely dense giving the cells a fuzzy appearance called a brush border. Examples of this would include epithelia lining the intestine and kidney tubules. Other epithelia have motile cilia (hairlike projections) that push substances along their free surface. Next to the basal surface is the basal lamina (thin supporting sheet). The basal lamina acts as a filter allowing and inhibiting certain molecules from passing into the epithelium.



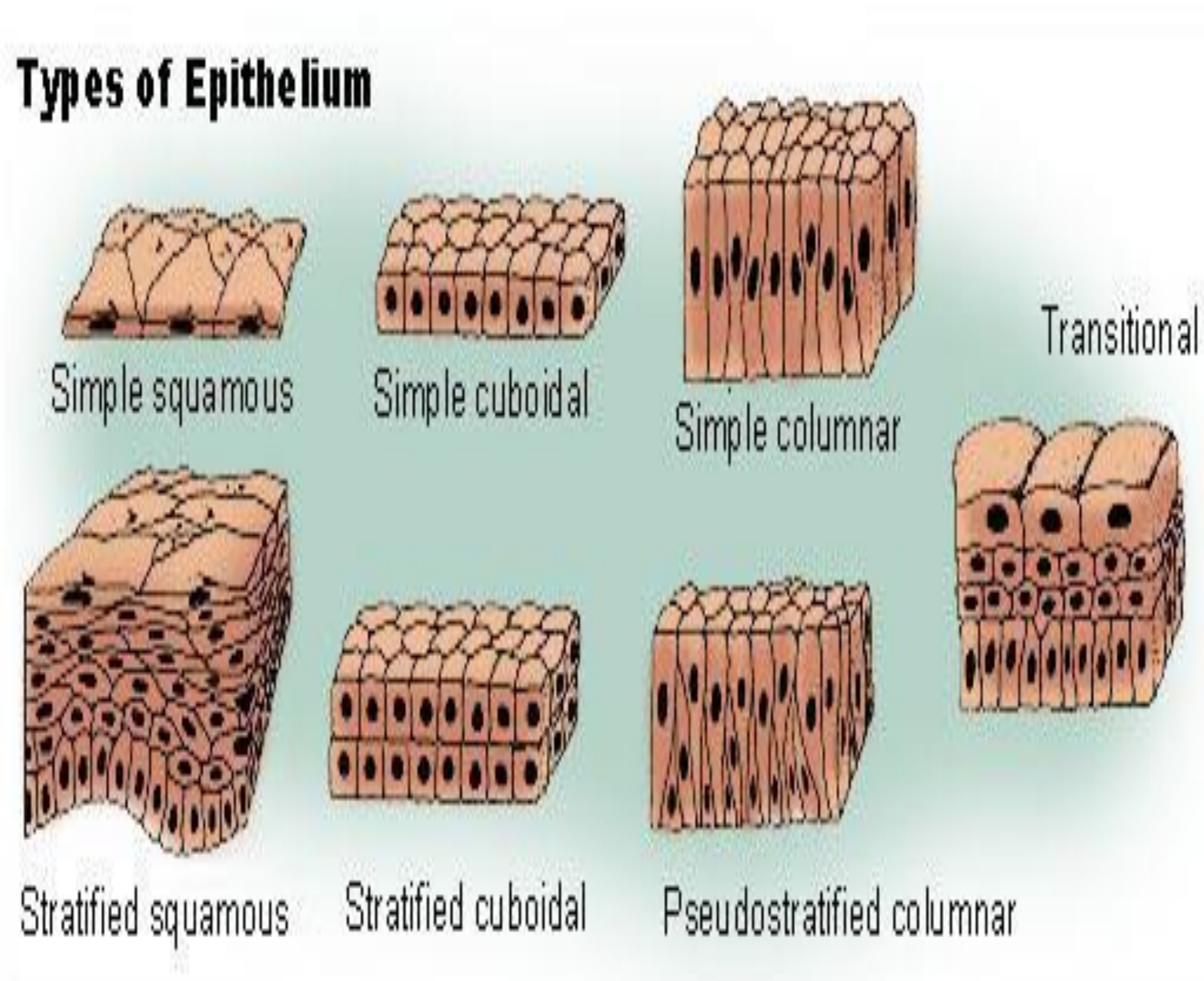
٢. Specialized contacts– epithelial cells fit close together and form continuous sheets (except in the case of glandular epithelia). They do this with t*ight junctions* and *desmosomes*. Tight junctions form the closest contact between cells and help keep proteins in the apical region of the plasma membrane. Desmosomes connect the plasma membrane to intermediate filaments in the cytoplasm.

٣. Supported by connective tissue– all epithelia are supported by connective tissue. For instance, deep to the basal lamina is reticular lamina (extracellular material containing collagen protein fiber) which forms the basement membrane. The basement membrane reinforces the epithelium and helps it resist stretching and tearing.

٤. Avascular and innervated– even though epithelium is *avascular* (contains no blood vessels), it's still *innervated* (supplied by nerve fibers).

٥. Regeneration– epithelium have a high regenerative capacity and can reproduce rapidly as long as they receive adequate nutrition.

Classification of Epithelia



Epithelium has two names. The first name indicates the number of cell layers, the second describes the shape of its cell. Based on the number of cell layers, epithelia can either be **simple or stratified**.

- **Simple epithelia**– consist of a single cell layer (found where absorption, secretion, and filtration occur).
- **Stratified epithelia–** are composed of two or more cell layers stacked on top of each other (typically found in high abrasion areas where protection is needed).

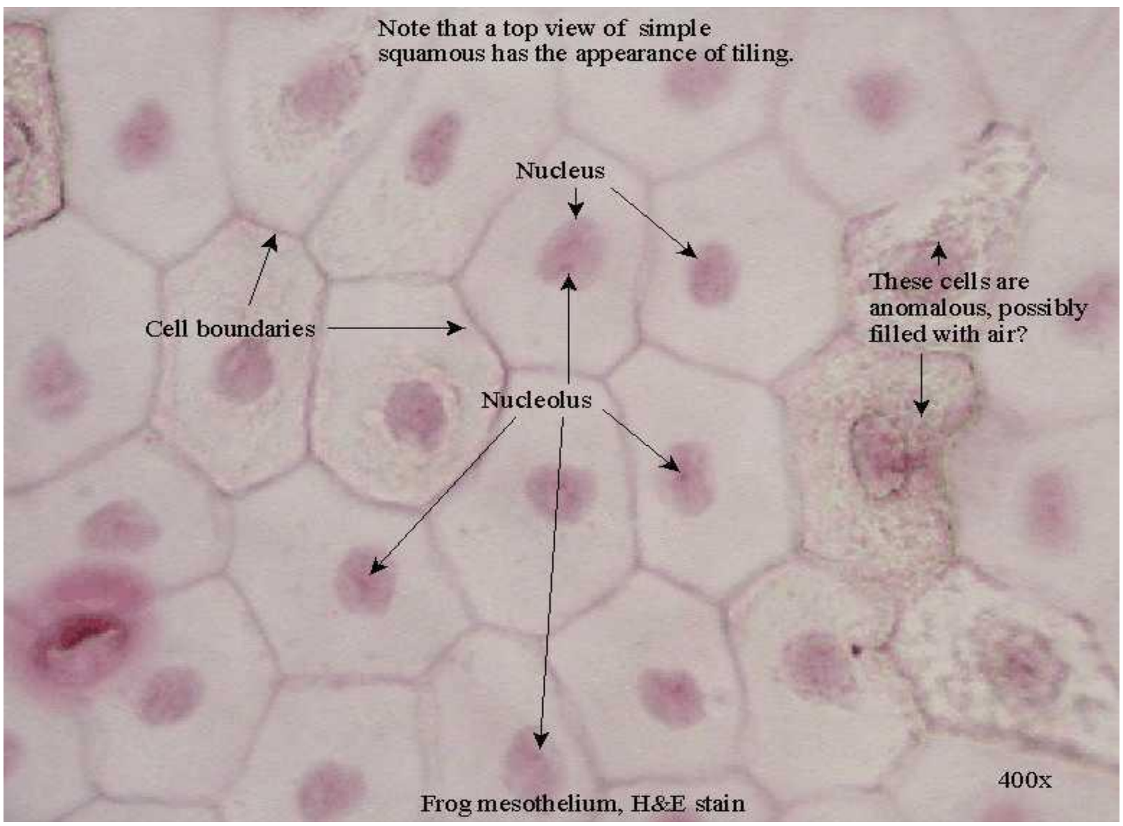
All epithelial cells have six sides but they vary in height. For this reason, there are three ways to describe the shape and height of epithelial cells.

١. Squamous cells– are flat and scale-like.

٢. Cuboidal cells– are box-like (same height and width).

٣. Columnar cells– are tall (column shaped).

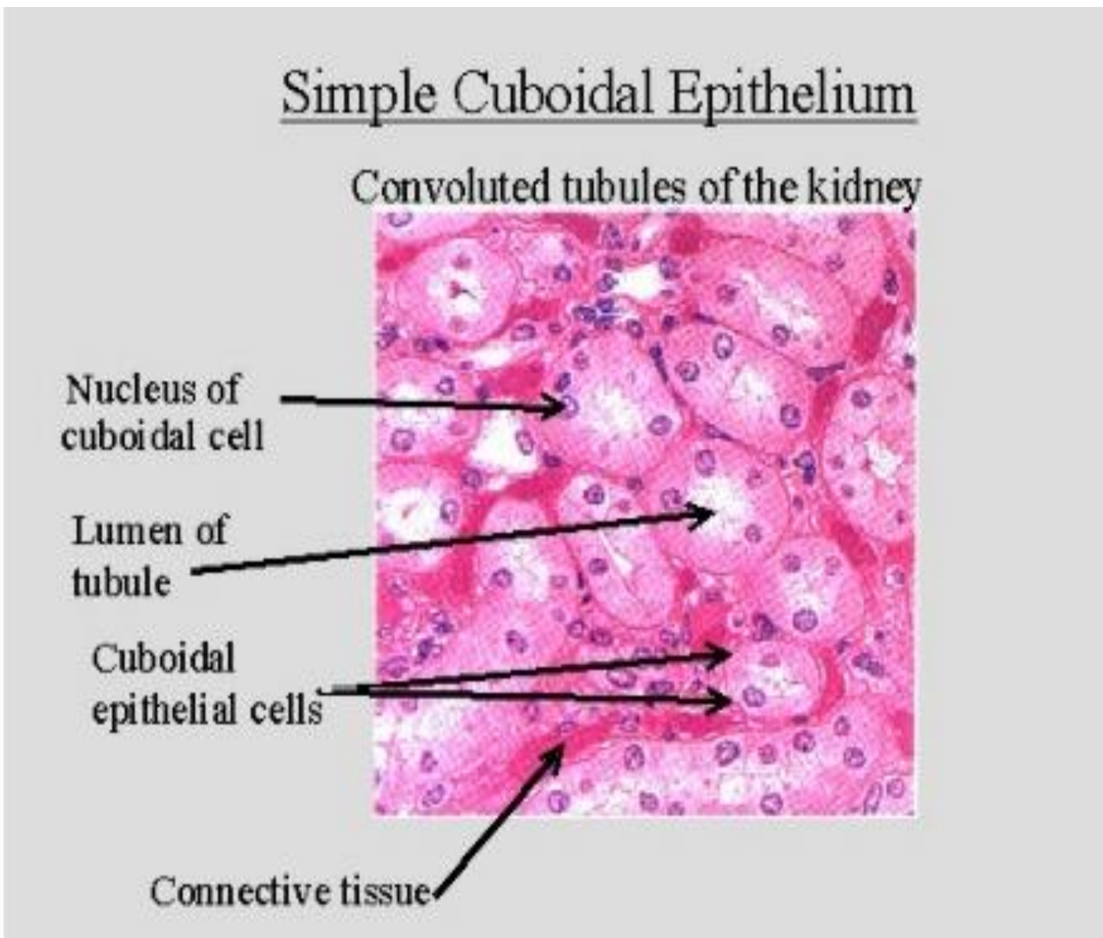
Simple squamous epithelium



Simple squamous epithelium– are close fitting and flattened laterally. They're found where filtration occurs (kidneys, lungs) and they resemble the look of a fried egg. Two simple squamous epithelia in the body have special names reflecting their location.

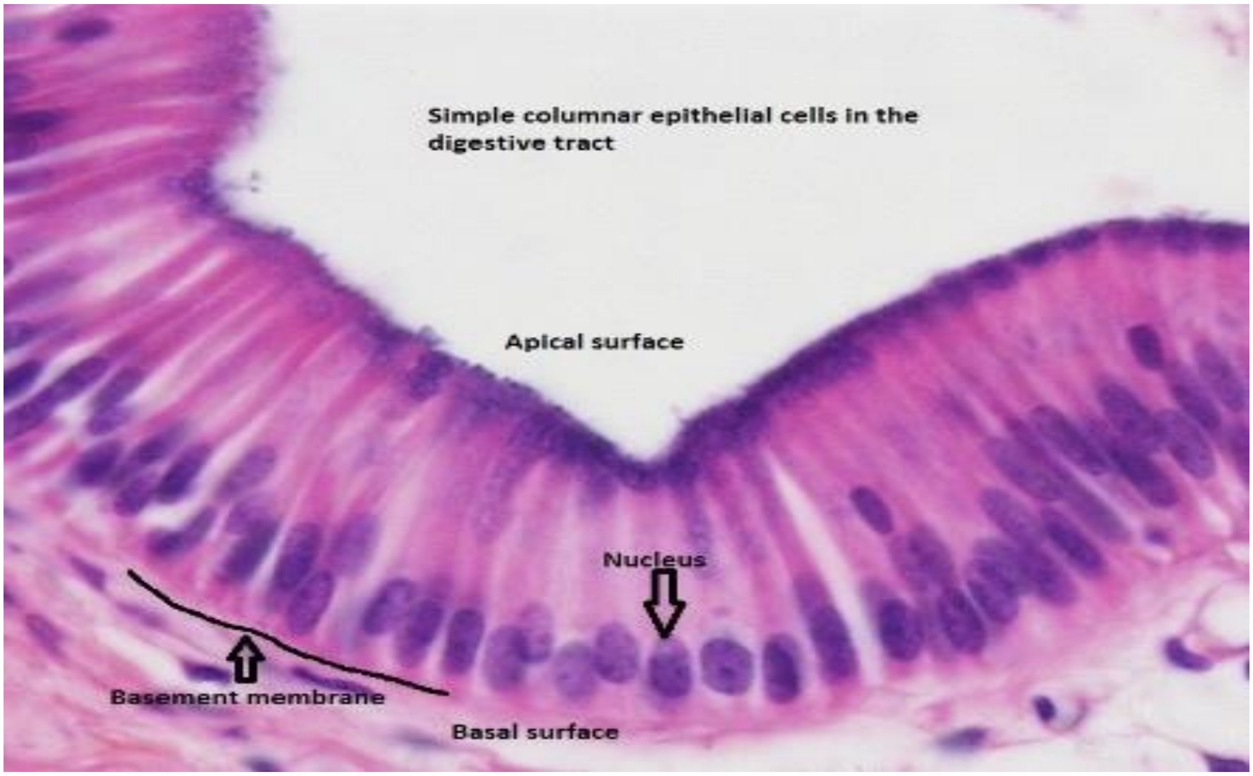
١. Endothelium– provides a friction-reducing ling in lymphatic vessels and all hollow organs of the cardiovascular system (heart, blood vessels, capillaries).

٢. Mesothelium– is the epithelium found in serous membranes (membranes lining the ventral body cavity and covering the organs within it).



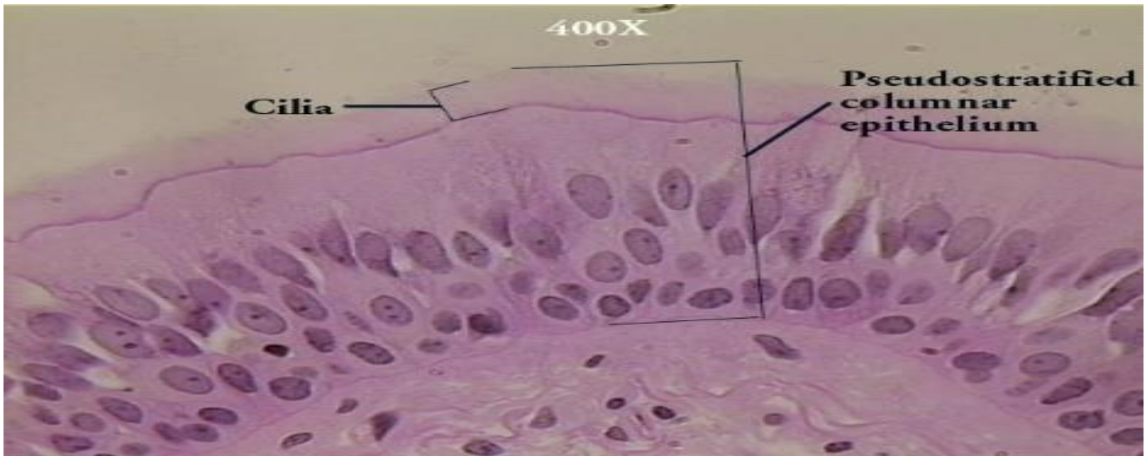
Simple cuboidal epithelium– consists of a single layer of cells with the same height and width. Functions include secretion and absorption (located in small ducts of glands and kidney tubules).

Simple columnar epithelium

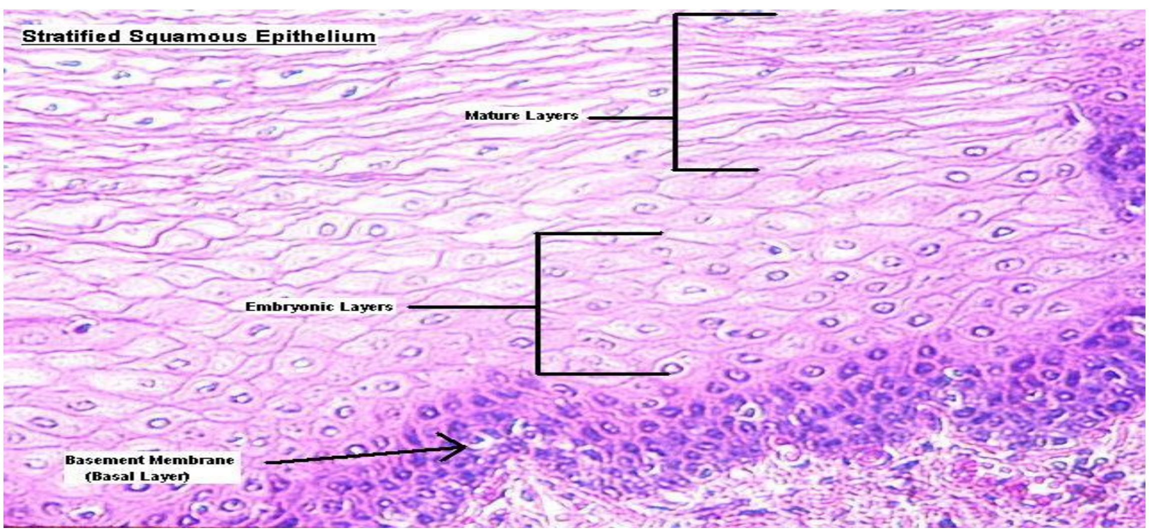


– is a single layer of tall, closely packed cells that line the digestive tract from the stomach to the rectum. Functions include absorption and secretion. They contain dense microvilli on their apical surface. Additionally, some simple columnar epithelia may display cilia on their free surface also.

Pseudostratified columnar

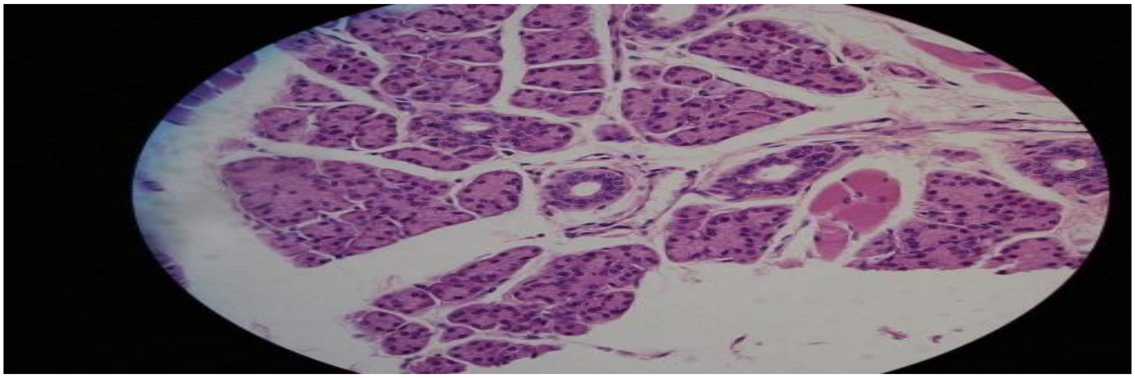


epithelium– vary in height. All of their cells rest on the basement membrane and only the tallest reach the apical surface. When viewing pseudostratified epithelium it may look like there are several layers of cells, but this is not the case. (Because the cells have different heights, it gives the illusion of multiple cell layers). Most pseudostratified epithelia contain cilia on their apical surface and line the respiratory tract.



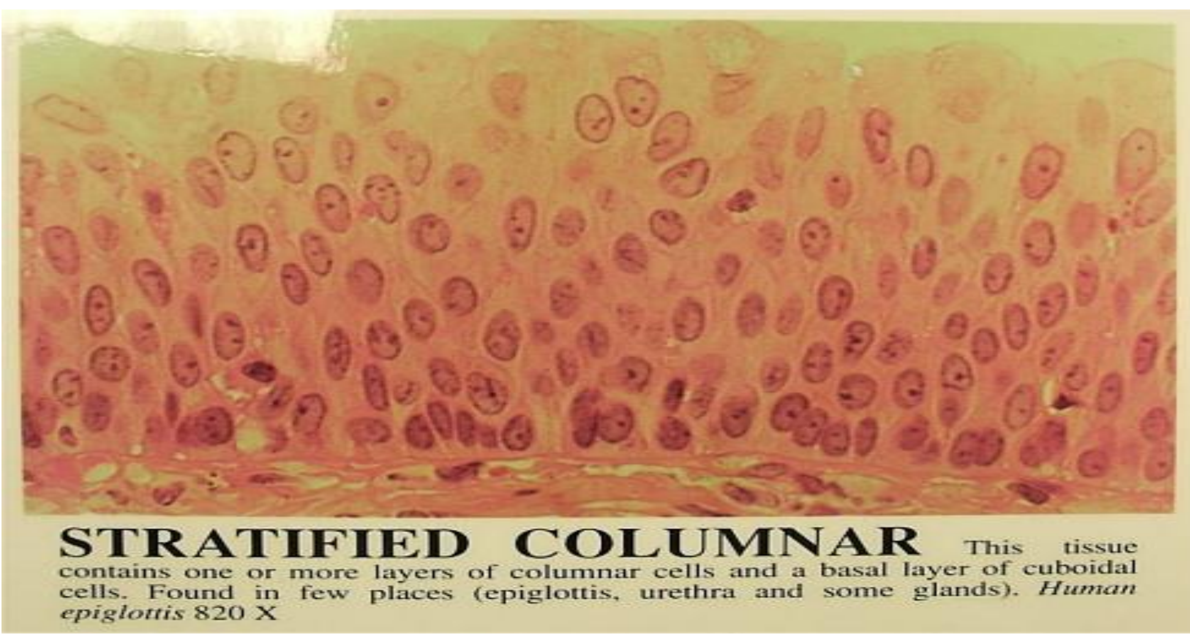
Stratified squamous epithelium– is the most widespread stratified epithelia. It's composed of several layers and is perfect for its protective role. Its apical surface cells are squamous and cells of the deeper layer are either cuboidal or columnar. Stratified squamous forms the external part of the skin and extends into every body opening that's continuous with the skin. The outer layer of the skin (epidermis) is *keratinized* (contains *keratin*, a protective protein). Other stratified squamous in the body is nonkeratinized.

Stratified cuboidal epithelium

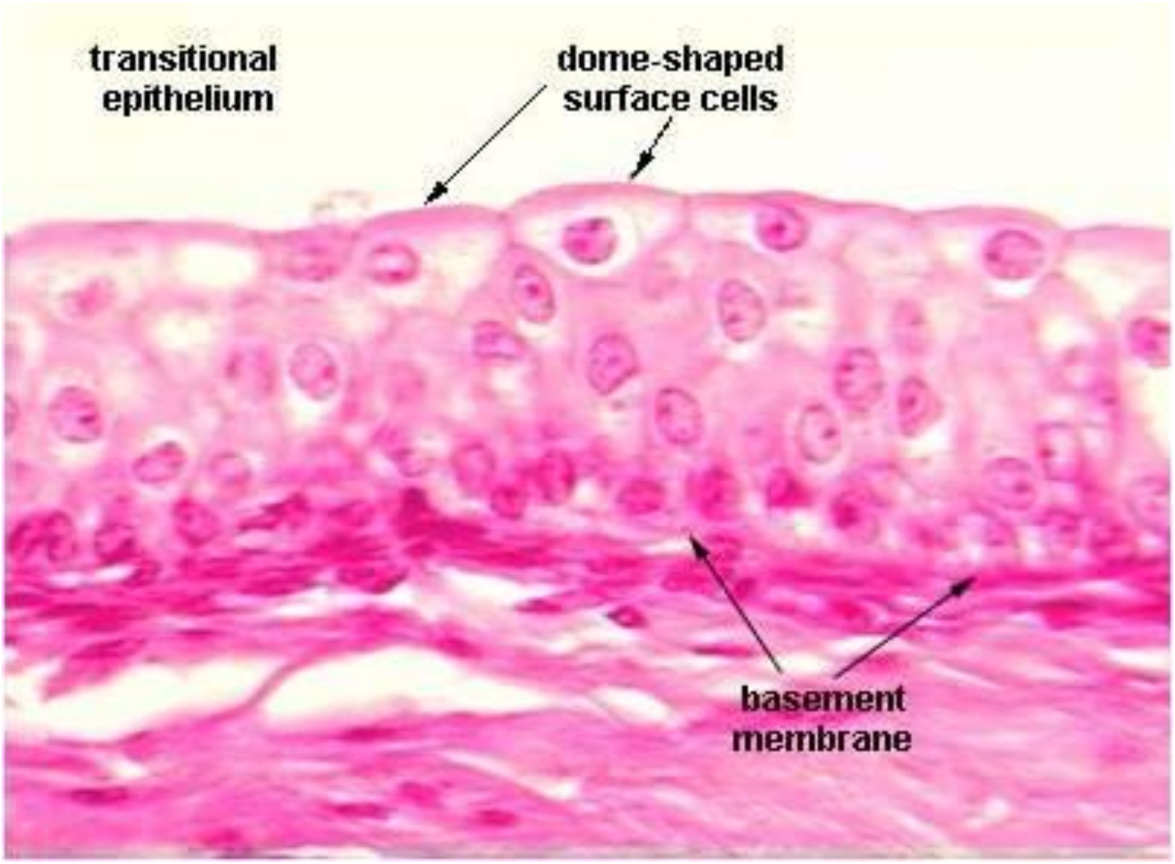


<u>Stratified cuboidal epithelium</u>– is somewhat rare in the human body. It's mainly found in the ducts of glands (sweat glands, mammary glands) and is typically has two layers of cuboidal cells.

Stratified columnar epithelium



<u>Stratified columnar epithelium</u>– is also rare in the human body. Small amounts are found in the pharynx, male urethra, and lining of some glandular ducts. Stratified columnar epithelium occurs in transition areas (junctions) between other epithial types.



Transitional epithelium– forms the lining of hollow urinary organs, which stretch as they fill with urine. Cells in the basal layer are cuboidal or columnar. Cells by the apical surface vary in appearance depending if the organ is stretched at the time. Transitional cells have the ability to change their shape which allows more urine to flow through.

College of sciences **Dr. Mahdi Haider**

Microbiology **Third lecture**

Connective Tissue

Connective tissue provides a matrix that connects and binds the cells and organs and ultimately gives support to the body. (Hence called support tissue also.)

The main constituent of connective tissue is the extracellular matrix. Due to this abundance of extracellular matrix, the cells in connective tissues are widely placed. Other tissues (like epithelium, muscular and nervous) are formed mainly by cells.

The function of connective tissues:

Mechanical function i.e. supporting function as described below:

١. The Loose areolar tissue holds together structures like skin, muscles, blood vessels etc. and binds together the various layers of hollow viscera (stomach, intestine, urinary bladder, uterus).
٢. Reticular tissue forms a framework that supports the cellular elements of various organs like spleen, lymph nodes and glands.
٣. Enables the movement of skin over underlying structure.
٤. Allows mobility and stretching in hollow organs.
٥. Hold the bone at joints (in the form of ligament).
٦. Provide attachment for origin and insertions of many muscles (in the form of deep fascia, intermuscular septa, aponurosis and tendon). Tendon also transmits the pull of muscles to their insertion.
٧. Hold the tendons of muscles at wrist and ankle
٨. Provide planes along which blood vessels, lymphatics and nerves travel (through areolar tissue and fascial membrane).
٩. Provides support and protection to the brain and spinal cord

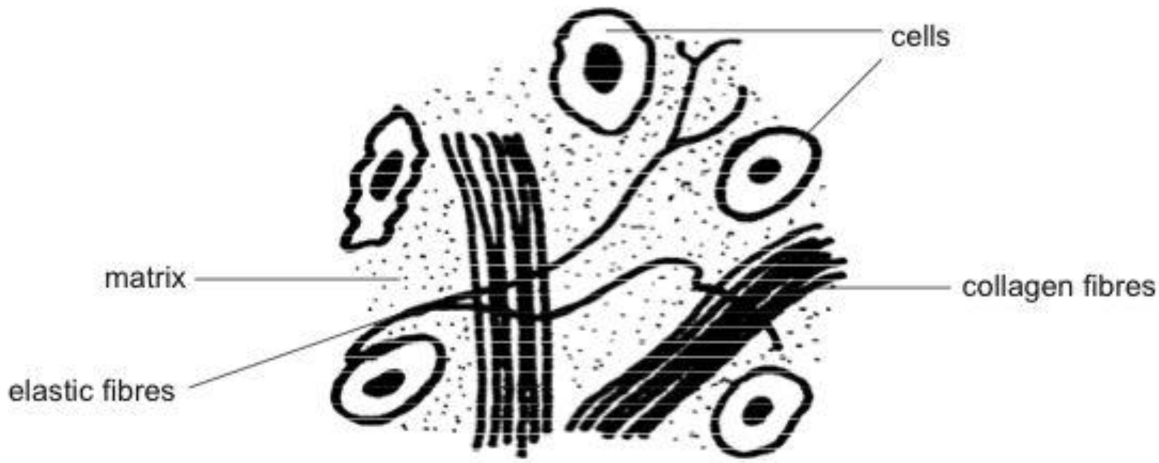
Other functions:

١. The matrix serves as medium through which nutrients and metabolic wastes are exchanged between cells and their blood supply.
٢. Provides immunity: due to presence of cells of immune system - macrophages and plasma cells.
٣. Wound repair: Fibroblast produces the collagen fibres necessary for wound repair.
٤. Adipose tissue stores nutrition
٥. Regeneration of tissues (like cartilage and bone) due to the presence of undifferentiated mesenchymal cells. (Undifferentiated mesenchymal cells are capable of differentiating into specialized cells like **chondroblast**-cartilage forming cells and **osteoblast**- bone forming cells)

Connective Tissues are broadly classified into:

General Connective tissue
Specialized connective tissue (Bone, Blood, cartilage)

General Connective Tissue
The constituents for general connective tissues are as follow:
Cells
Fibres
Ground substance



Cells

Fibroblast- these are the most numerous cells of connective tissue. They are so named because they produce collagen fibers (also reticular and elastic fibers).In tissue sections, these cells appear to be spindle shaped and nucleus appears to be flattened. Fibroblast become very active when there is need to lay down the collagen fibres e. g. during wound repair. Inactive forms are known as fibrocytes.

Mesenchymal cell- Embryonic connective tissue is known as **mesenchyme** which is made up of small cells with slender branching processes that join to form a network. Various components of mature connective tissue are derived from mesenchyme. Mesenchymal cells are capable of differentiating into any specialized cells. It is believed that some undifferentiated mesenchymal cells persist as such and these are the cells from which other types can be formed when required.

Pigment cells- they are easily distinguished as they contain brown pigment (melanin) in their cytoplasm. They are most abundant in the connective tissue of skin, of choroid and iris of eyeball. Of the many cells that contain pigment in their cytoplasm only a few are actually capable of synthesizing melanin. Such cells are called melanocytes, remaining cells are those that engulf pigment released by other cells. Such cells are called chromatophores or melanophore and are probably modified fibroblasts.

Fat cells or adipocytes- some cells store fat in large amounts and become distended with it. These are called fat cells, adipocytes or lipocytes.

Mast cells- these are small round or oval cells. The nucleus is small and centrally placed. The distinguish feature of these cells is the presence of numerous granules in the cytoplasm. They release various substances when appropriately stimulated e.g. release of histamine is associated with allergic reaction when a tissue is exposed to an antigen to which it is sensitive. They are most frequently seen around blood vessels and nerves.

Macrophages- these cells are part of mononuclear phagocyte system. Macrophage cells of connective tissue are also called histiocytes or clasmatocytes. They have ability to phagocytose unwanted material like bacteria invading the tissue and damaged tissues. Fixed macrophages resemble fibroblast but free or motile macrophages are round. The nuclei of macrophages are small and stain intensely than those off fibroblasts.

Lyhmphocytes-lymphocytes represent one variety of leukocytes and are in aggregation in lymphoid tissues. They reach connective tissue from these sources and are numerous when tissue undergoes inflammation. They have the ability to recognize the substances that are foreign to host body and destroy them by producing antibodies against them. They are of two types B lymphocytes and T lymphocytes.

Plasma cells- very few plasma cells can be seen in normal connective tissue. Their number increases in the presence of certain types of inflammation. These are mature B lymphocyte that have lost their power of further division. Plasma cells is seen to be small and rounded with nucleus having car wheel resemblance. The cytoplasm is basophilic.

Fibers

Collagen –Collagen fibers are most abundant. With light microscopy they are seen in bundles. The bundles are made up of collections of individual collagen fibers which are ١-١٢ micrometer in diameter. In turn collagen fibers are made up of fibrils which are ٢٠-٢٠٠ nm in diameter. Each fibril consists of a number of microfibrils, ٣,٥ nm in diameter.

Bundle of collagen fibers appear white with naked eye. With H & E, they are stained light pink.
Collagen fibers can resist considerable tensile forces without significance increase in their length. They are also pliable and can bend easily.

Chemically collagen fibers are made up of protein called collagen.

Types of Collagen fibers

Type I- they are found in connective tissue, tendons, ligaments, fasciae, aponeurosis, bone, dermis, meninges etc.
Type II- found in hyaline cartilage, vitreous body.
Type III is the reticular fibres
Type IV- in the basal laminae of basement membrane.
Various other types are also recognized.

Elastic fiber- Elastic fibers are made up of a protein called elastin. They run singly (not in bundles), branch and anastomose with other fibers. Elastic fibers are thinner than those of collagen (٠،١-٠،٢ micrometer). In some situation they are thick e.g. ligamentum flava and in other they are fenestrated as in walls of arteries.

Elastic fibers can be stretched (like a rubber band) and returns to their original length when tension is released. They are seen as shining line in unstained preparations.

Reticular fiber- these fibers are variety of collagen fiber (Type III). They are much finer and uneven in thickness. They form a network (or reticulum) by branching and anastomosing with each other. They do not run in bundles. Reticular fibers provide a supporting network in many situations e.g. spleen, lymph nodes and bone marrow; most glands including liver; and the kidneys. They are the essential component of all basement membrane.

Ground substance
The intercellular ground substance is a highly hydrated, complex mixture of glycosaminoglycans, proteoglycans and multiadhesive glycoproteins. The complex molecular mixture of the ground substance is colorless and transparent, it fills the space between cells and fibers of the connective tissue and because it is viscous acts as both a lubricant and a barrier to the invaders.

Types of Connective tissue

Loose areolar- e.g. superficial fascia
Dense irregular – e.g. dermis of the skin
Dense regular- e.g. tendon
Elastic Tissue- e.g. ligamentum flava
Adipose Tissue

Connective tissue is divided into four main categories:

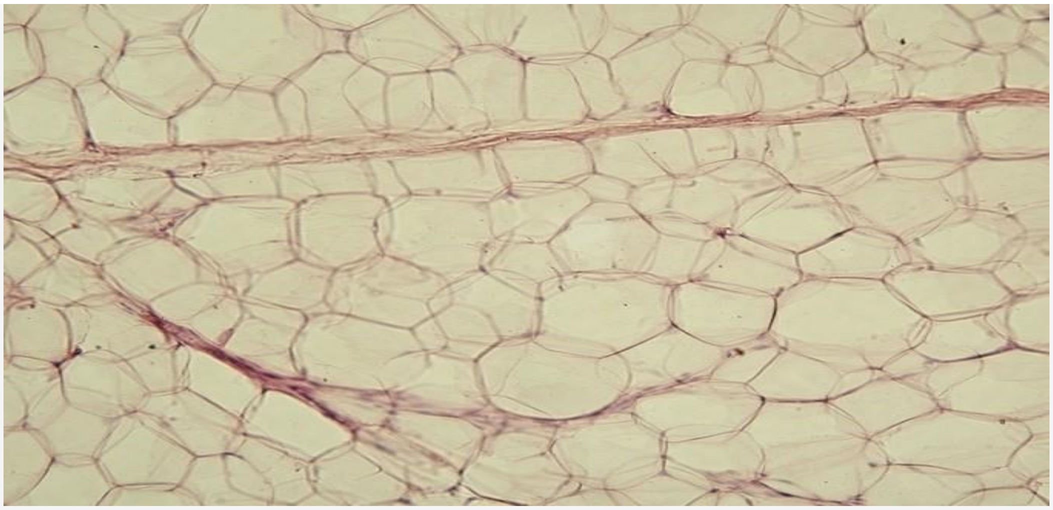
١. Connective proper
٢. Cartilage
٣. Bone
٤. Blood

Connective tissue proper has two subclasses: loose and dense. Loose connective tissue is divided into ١) areolar, ٢) adipose, ٣) reticular. Dense connective tissue is divided into ١) dense regular, ٢) dense irregular, ٣) elastic.

Areolar Connective Tissue

These tissues are widely distributed and serve as a universal packing material between other tissues. The functions of areolar connective tissue include the support and binding of other tissues.
It also helps in defending against infection. When a body region is inflamed, the areolar tissue in the area soaks up the excess fluid as a sponge and the affected area swells and becomes puffy, a condition called edema.

Adipose Tissue or Body Fat



Adipose tissue: Yellow adipose tissue in paraffin section with lipids washed out.

This is loose connective tissue composed of adipocytes. It is technically composed of roughly only ٨٠٪ fat. Its main role is to store energy in the form of lipids, although it also cushions and insulates the body.

The two types of adipose tissue are white adipose tissue (WAT) and brown adipose tissue (BAT). Adipose tissue is found in specific locations, referred to as adipose depots.

Reticular Connective Tissue

This tissue resembles areolar connective tissue, but the only fibers in its matrix are the reticular fibers, which form a delicate network. The reticular tissue is limited to certain sites in the body, such as internal frameworks that can support lymph nodes, spleen, and bone marrow.

Dense Regular Connective Tissue

This consists of closely packed bundles of collagen fibers running in the same direction. These collagen fibers are slightly wavy and can stretch a little bit. With the tensile strength of collagen, this tissue forms tendons, aponeurosis and ligaments. This tissue forms the fascia, which is a fibrous membrane that wraps around the muscles, blood vessels, and nerves.

Dense Irregular Tissue

This has the same structural elements as dense regular tissue, but the bundles of collagen fibers are much thicker and arranged irregularly. This tissue is found in areas where tension is exerted from many different directions. It is part of the skin dermis area and in the joint capsules of the limbs.

Elastic Connective Tissue

The main fibers that form this tissue are elastic in nature. These fibers allow the tissues to recoil after stretching. This is especially seen in the arterial blood vessels and walls of the bronchial tubes.

Blood

This is considered a specialized form of connective tissue. Blood is a bodily fluid in animals that delivers necessary substances, such as nutrients and oxygen, to the cells and transports metabolic waste products away from those same cells.
It is an atypical connective tissue since it does not bind, connect, or network with any body cells. It is made up of blood cells and is surrounded by a nonliving fluid called plasma.

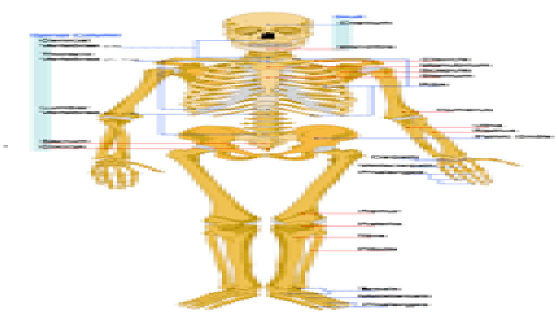
Connective tissue type and characteristics	Functions	Locations
Areolar (loose) connective tissue. Loose array of random fibers with a wide variety of cell types	Nourishes and cushions epithelia, provides arena for immune defense against infection, binds organs together, allows passage for nerves and blood vessels through other tissues	Under all epithelia; outer coverings of blood vessels, nerves, esophagus, and other organs; fascia between muscles; pleural and pericardial sacs
Adipose tissue (fat). Large fat-filled adipocytes and scanty extracellular matrix.	Stores energy, conserves body heat, cushions and protects many organs, fills space, shapes body	Beneath skin; around kidneys, heart, and eyes; breast; abdominal membranes (mesenteries)
Dense irregular connective tissue. Densely spaced, randomly arranged fibers and fibroblasts.	Toughness; protects organs from injury; provides protective capsules around many organs	Dermis of skin; capsules around liver, spleen, and other organs; fibrous sheath around bones
Dense regular connective tissue. Densely spaced, parallel collagen fibers and fibroblasts.	Binds bones together and attaches muscle to bone; transfers force from muscle to bone	Tendons and ligaments
Cartilage (gristle). Widely spaced cells in small cavities (lacunae); rubbery matrix.	Eases joint movements; resists compression at joints; holds airway open; shapes outer ear; moves vocal cords; forerunner of fetal skeleton; growth zone of children's bones	External ear, larynx, rings around trachea, joint surfaces and growth zones of bones, between ribs and sternum, intervertebral discs
Bone (osseous tissue). Widely spaced cells in lacunae; much of matrix in concentric onionlike layers; hard mineralized matrix.	Physically supports body, provides movement, encloses and protects soft organs, stores and releases calcium and phosphorus	Skeleton
Blood. Erythrocytes, leukocytes, and platelets in	Transports nutrients, gases, wastes, hormones,	Circulates in cardiovascular system

Bone Anatomy

Bones are made of active, living cells that are busy growing, repairing themselves, and communicating with other parts of the body. Let’s take a closer look at what your bones do and how they do it.

How many bones are in the human body?

The skeleton of an adult human is made up of ٢٠٦ bones of many different shapes and sizes. Added together, your bones make up about ١٥٪ of your body weight. Newborn babies are actually born with many more bones than this (around ٣٠٠), but many bones grow together, or fuse, as babies become older. Some bones are long and thick, like your thigh bones. Others are thin, flat, and wide, like your shoulder blades.



The adult human skeleton has ٢٠٦ bones.

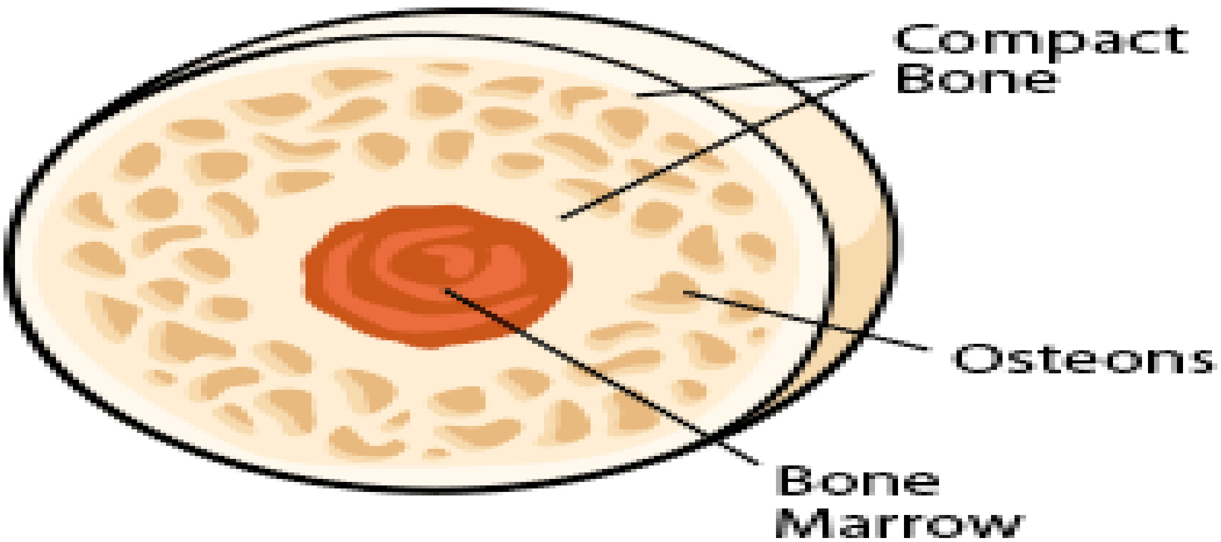
Support: Like a house is built around a supportive frame, a strong skeleton is required to support the rest of the human body. Without bones, it would be difficult for your body to keep its shape and to stand upright.

Protection: Bones form a strong layer around some of the organs in your body, helping to keep them safe when you fall down or get hurt. Your rib cage, for example, acts like a shield around your chest to protect important organs inside such as your lungs and heart. Your brain is another organ that needs a lot of protection. The thick bone layer of your skull protects your brain. For this purpose, being "thick-headed" is a very good thing.

Movement: Many of your bones fit together like the pieces of a puzzle. Each bone has a very specific shape which often matches up with neighboring bones. The place where two bones meet to allow your body to bend is called a joint.

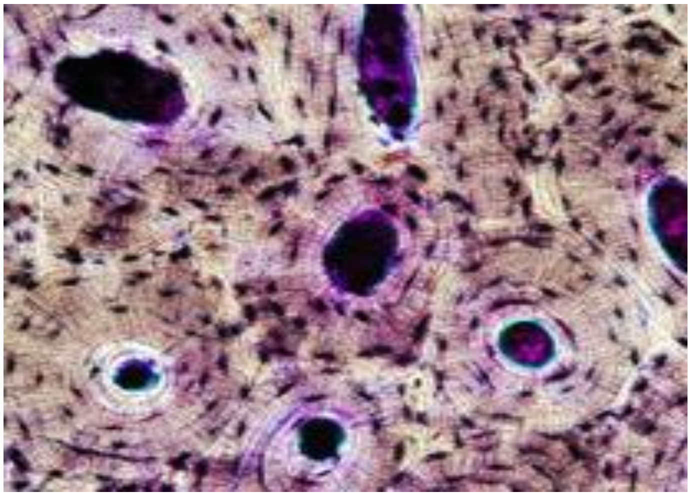
Blood Cell Formation: Did you know that most of the red and white blood cells in your body were created inside of your bones? This is done by a special group of cells called stem cells that are found mostly in the bone marrow, which is the innermost layer of your bones.

Storage: Bones are like a warehouse that stores fat and many important minerals so they are available when your body needs them. These minerals are continuously being recycled through your bones--deposited and then taken out and moved through the bloodstream to get to other parts of your body where they are needed.



What are your bones made of?

Each bone in your body is made up of three main types of bone material: **compact bone, spongy bone, and bone marrow.**

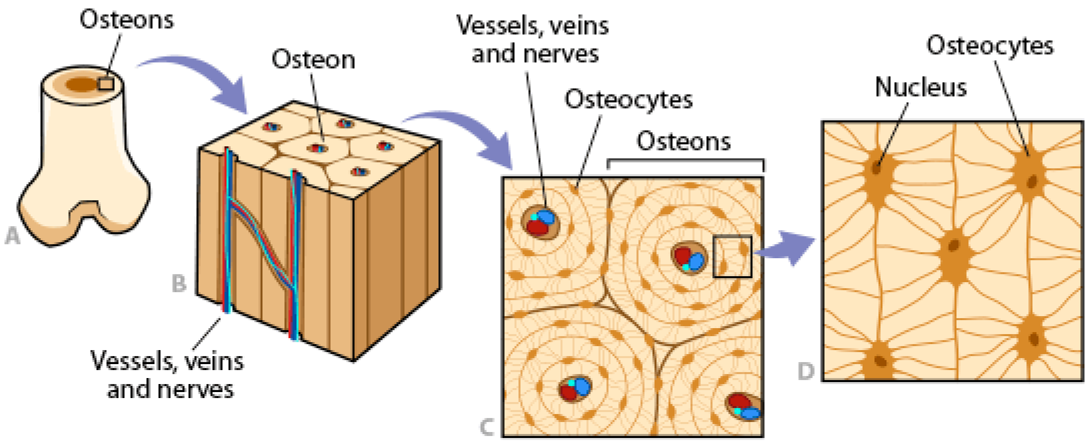


Cross section showing osteons. The large dark spots are passages for blood vessels and neves. The little black spots are osteocytes.

Compact bone

Compact bone is **the heaviest, hardest type of bone**. It needs to be very strong as **it supports your body and muscles** as you walk, run, and move throughout the day. About ٨٠٪ of the bone in your body is compact. It makes up the outer layer of the bone and also helps protect the more fragile layers inside.

If you were to look at a piece of compact bone without the help of a microscope, it would seem to be completely solid all the way through. If you looked at it through a microscope, however, you would see that it's actually filled with **many very tiny passages, or canals**, for nerves and blood vessels. Compact bone is made of special cells called **osteocytes**. These cells are lined up in rings around the canals. Together, a canal and the osteocytes that surround it are called **osteons**. Osteons are like thick tubes all going the same direction inside the bone, similar to a bundle of straws with blood vessels, veins, and nerves in the center.



Looking at the osteons in bone (A) under a microscope reveals tube-like osteons (B) made up of osteocytes (C). These bone cells have long branching arms (D) which lets them communicate with other cells.

Spongy bone:

Close up view of spongy bone.

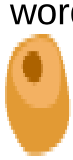
Spongy bone is found mostly at the ends of bones and joints. About ٢٠٪ of the bone in your body is spongy. Unlike compact bone that is mostly solid, spongy bone is full of open sections called pores. If you were to look at it in under a microscope, it would look a lot like your kitchen sponge. **Pores are filled with marrow, nerves, and blood vessels** that carry cells and nutrients in and out of the bone. Though spongy bone may remind you of a kitchen sponge, this bone is quite solid and hard, and is not squishy at all.

Bone marrow

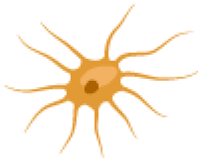
The inside of your bones are filled with a soft tissue called marrow. There are two types of bone marrow: **red and yellow**. Red bone marrow is where all new red blood cells, white blood cells, and platelets are made. Platelets are small pieces of cells that help you stop bleeding when you get a cut. Red bone marrow is found in the center of flat bones such as your shoulder blades and ribs. Yellow marrow is made mostly of fat and is found in the hollow centers of long bones, such as the thigh bones. It does not make blood cells or platelets. Both yellow and red bone marrow have many small and large blood vessels and veins running through them to let nutrients and waste in and out of the bone.

When you were born, all of the marrow in your body was red marrow, which made lots and lots of blood cells and platelets to help your body grow bigger. As you got older, more and more of the red marrow was replaced with yellow marrow. **The bone marrow of full grown adults is about half red and half yellow.**

Bones are made of four main kinds of cells: osteoclasts, osteoblasts, osteocytes, and lining cells. Notice that three of these cell type names start with 'osteo.' This is the Greek word for bone. When you see 'osteo' as part of a word, it lets you know that the word has something to do with bones.



Osteoblasts are responsible for making new bone as your body grows. They also rebuild existing bones when they are broken. The second part of the word, 'blast,' comes from a Greek word that means 'growth.' To make new bone, many osteoblasts come together in one spot then begin making a flexible material called osteoid. Minerals are then added to osteoid, making it strong and hard. When osteoblasts are finished making bone, they become either lining cells or osteocytes.



Osteocytes are star shaped bone cells most commonly found in compact bone. They are actually old osteoblasts that have stopped making new bone. As osteoblasts build bone, they pile it up around themselves, then get stuck in the center. At this point, they are called osteocytes. Osteocytes have long, branching arms that connect them to neighboring osteocytes. This lets them exchange minerals and communicate with other cells in the area.

Lining cells are very flat bone cells. These cover the outside surface of all bones and are also formed from osteoblasts that have finished creating bone material. These cells play an important role in controlling the movement of molecules in and out of the bone.

Osteoclasts break down and reabsorb existing bone. The second part of the word, 'clast,' comes from the Greek word for 'break,' meaning these cells break down bone material. Osteoclasts are very big and often contain more than one nucleus, which happens when two or more cells get fused together. These cells work as a team with osteoblasts to reshape bones. This might happen for a number of reasons:

- When a bone breaks, a thick lump of bone called a hard callus forms around the break in the process of healing. The callus is slowly broken down by osteoclasts until the bone is returned to its original shape.
- When new blood vessels, nerves, and veins are needed in an area, osteoclasts break down bone material to make new passages.
- Bones that are used more often and need to support more weight, such as the bones of athletes, become thicker and stronger over time. Bones that are used less often, such as those that need to be put into a cast for long periods of time, are broken down, becoming smaller and thinner.

It's not completely understood how bone cells in your body are able to work together and stay organized, but pressure and stress on the bone might have something to do with it.

Bone Facts

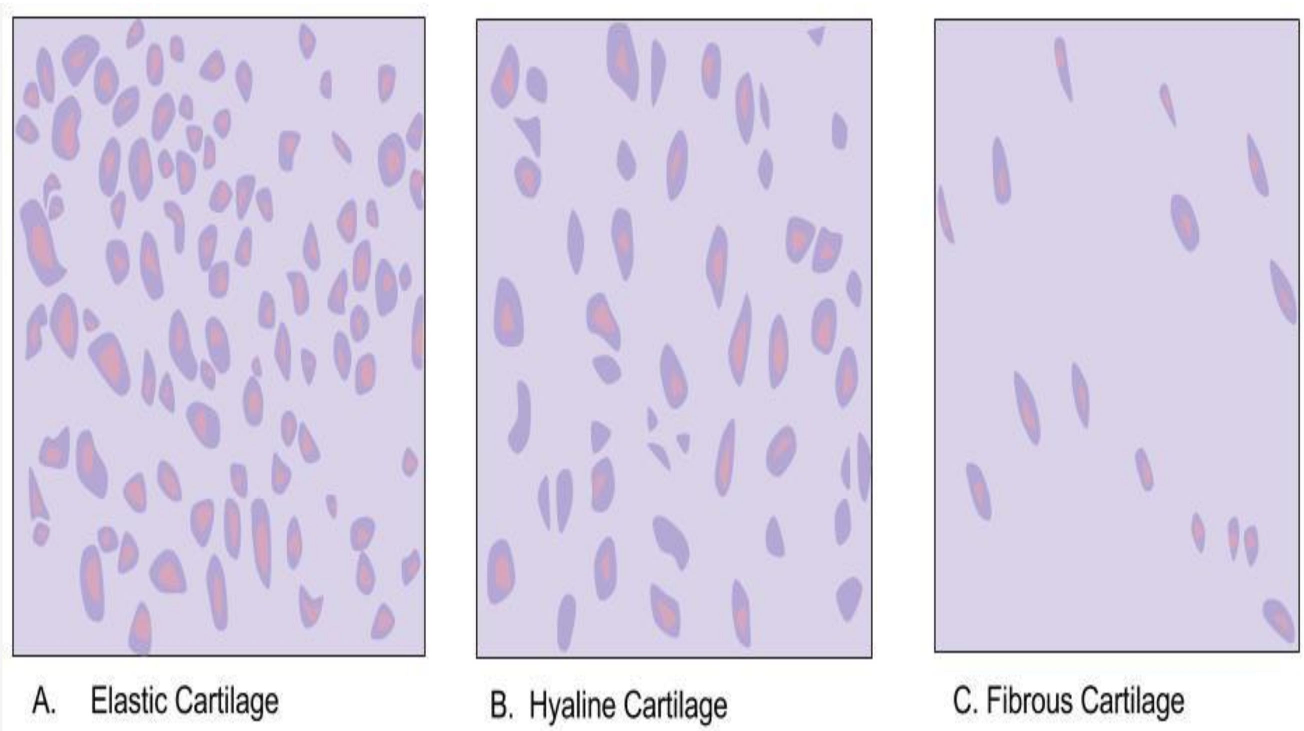
The smallest bone in the human body is called the **stirrup bone**, located deep inside the ear. It's only about ٣ millimeters long in an adult.
The longest bone in the human is called the **femur, or thigh** bone. It's the bone in your leg that goes from your hip to your knee. In an average adult, it's about ٢٠ inches long.

Cartilage :

Cartilage is a flexible connective tissue that differs from bone in several ways. For one, the primary cell types are **chondrocytes** as opposed to **osteocytes. Chondrocytes are first chondroblast cells that produce the collagen extracellular matrix (ECM) and then get caught in the matrix**. They lie in spaces called **lacunae** with up to eight chondrocytes located in each.
Chondrocytes rely on diffusion to obtain nutrients as, unlike bone, cartilage is avascular, meaning there are no vessels to carry blood to cartilage tissue. This lack of blood supply causes cartilage to heal very slowly compared with bone.
The base substance of cartilage is chondroitin sulfate, and the microarchitecture is substantially less organized than in bone. The cartilage fibrous sheath is **called the perichondrium**. The division of cells within cartilage occurs very slowly, and thus

growth in cartilage is usually not based on an increase in size or mass of the cartilage itself.

Articular cartilage function is dependent on the molecular composition of its ECM, which consists mainly of proteoglycans and collagens. The remodeling of cartilage is predominantly affected by changes and rearrangements of the collagen matrix**, which responds to tensile and compressive forces** experienced by the cartilage.



Cartilage types: Images of microscopic views of the different types of cartilage: elastic, hyaline, and fibrous. Elastic cartilage has the most ECM; hyaline a middle amount; and fibrous cartilage has the least amount of ECM.

Types of Cartilage

There are three major types of cartilage: hyaline cartilage, fibrocartilage, and elastic cartilage.

Hyaline Cartilage

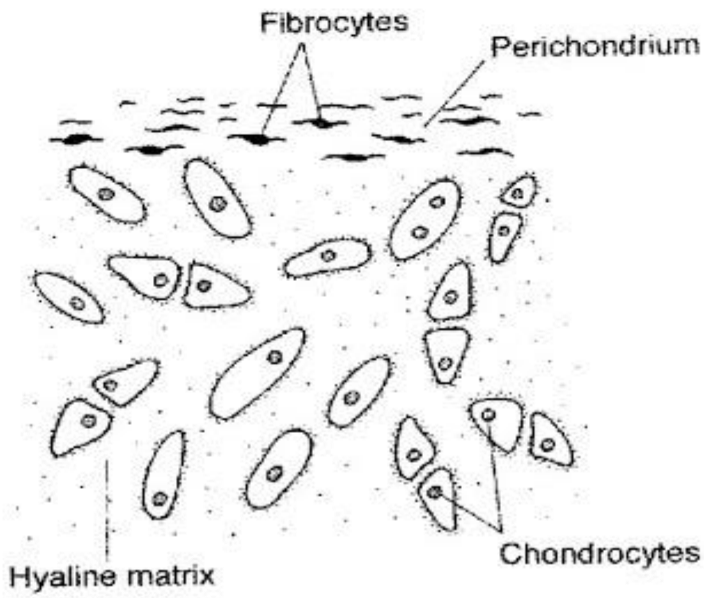
Hyaline cartilage is the most widespread cartilage type and, in adults, it forms the articular surfaces of long bones, the rib tips, the rings of the trachea, and parts of the skull. This type of cartilage is predominately collagen (yet with few collagen fibers), and its name refers to its glassy appearance.

In the embryo, bones form first as hyaline cartilage before ossifying as development progresses. **Hyaline cartilage is covered externally by a fibrous membrane, called the perichondrium**, except at the articular ends of bones; it also occurs under the skin (for instance, ears and nose).

Hyaline cartilage is found on many joint surfaces. It contains no nerves or blood vessels, and its structure is relatively simple.

If a thin slice of cartilage is examined under the microscope, it will be found to consist of cells of a rounded or bluntly angular form, lying in groups of two or more in a granular or almost homogeneous matrix. These cells have generally straight outlines where they are in contact with each other, with the rest of their circumference rounded.

They consist of translucent protoplasm in which fine interlacing filaments and minute granules are sometimes present. Embedded in this are one or two round nuclei with the usual intranuclear network.



Hyaline cartilage

Fibrocartilage

Fibrous cartilage has lots of collagen fibers (Type I and Type II), and it tends to grade into dense tendon and ligament tissue. White fibrocartilage consists of a mixture of white fibrous tissue and cartilaginous tissue in various proportions.
It owes its flexibility and toughness to the fibrous tissue, and its elasticity to the cartilaginous tissue. It is the only type of cartilage that contains type I collagen in addition to the normal type II.
Fibrocartilage is found in the pubic symphysis, the annulus fibrosus of intervertebral discs, menisci, and the temporal mandibular joint.

Elastic Cartilage

Elastic or yellow cartilage contains elastic fiber networks and collagen fibers. The principal protein is elastin.

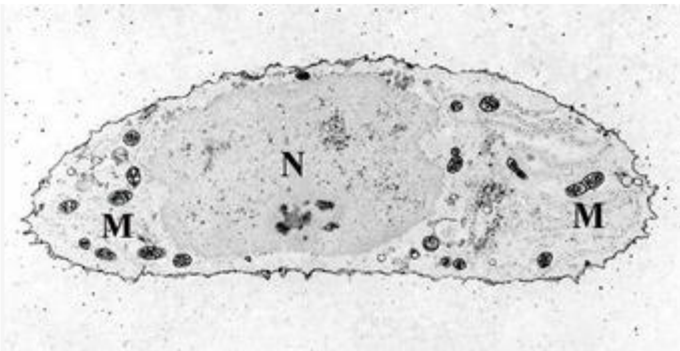
Elastic cartilage is histologically similar to hyaline cartilage but contains many yellow elastic fibers lying in a solid matrix. These fibers form bundles that appear dark under a microscope. They give elastic cartilage great flexibility so it can withstand repeated bending.
Chondrocytes lie between the fibers. Elastic cartilage is found in the epiglottis (part of the larynx) and the pinnae (the external ear flaps of many mammals, including humans).

Cartilage Growth

- collagen matrix: The most abundant protein in the human body and accounts for ٩٠٪ of bone matrix protein content.
- mesenchyme: Undifferentiated cells of the early embryo are able to develop into the different tisue types, including bone and cartilage.
- chondrocyte: A cell that makes up the tissue of cartilage.
- chondrification: The process by which cartilage is formed from condensed mesenchyme tissue.

Formation

Chondrification (also known as chondrogenesis) is the process by which cartilage is formed from condensed mesenchyme tissue.



A chondrocyte: A chondrocyte, stained for calcium, showing its nucleus (N) and mitochondria (M).

Mesenchyme tissue differentiates into chondroblasts and begins secreting the molecules that form the extracellular matrix (ECM). Mesenchymal stem cells (MSCs) are undifferentiated, meaning they can give rise to different cell types. Under the appropriate conditions and at sites of cartilage formation, they are referred to as chondrogenic cells.

During cartilage formation, undifferentiated MSCs are highly proliferative and form dense aggregates of chondrogenic cells at the center of chondrification. These condrogenic cells then differentiate to chondroblasts, which will then synthesize the cartilage ECM.

Cartilage: Hyaline cartilage showing chondrocytes and organelles, lacunae and matrix.

The extracellular matrix consists of ground substance (proteoglycans and glycosaminoglycans) and associated fibers, such as collagen. The chondroblasts then trap themselves in lacunae, small spaces that are no longer in contact with the newly created matrix and contain extracellular fluid. The chondroblast is now a chondrocyte, which is usually inactive but can still secrete and degrade the matrix depending on the conditions.

Growth

The majority of body cartilage is synthesized from chondroblasts that are largely inactive at later developmental stages compared to earlier years (pre-pubescence). The division of cells within cartilage occurs very slowly.
Therefore, growth in cartilage is usually not based on an increase in size or mass of the cartilage itself. Remodeling of cartilage is predominantly affected by changes and rearrangements of the collagen matrix, which responds to tensile and compressive forces experienced by the cartilage. Cartilage growth thus mainly refers to matrix deposition, but can include both growth and remodeling of the ECM.
Early in fetal development, the greater part of the skeleton is cartilaginous. This temporary cartilage is gradually replaced by bone (endochondral ossification), a process that ends at puberty. In contrast, the cartilage in the joints remains permanently unossified during life.

Repair

Once damaged, cartilage has limited repair capabilities because chondrocytes are bound in lacunae and cannot migrate to damaged areas. Also, because cartilage does not have a blood supply, the deposition of new matrix is slow.
Damaged hyaline cartilage is usually replaced by fibrocartilage scar tissue. Over the last few years, surgeons and scientists have elaborated a series of cartilage repair procedures that help to postpone the need for joint replacement.
These include marrow stimulation techniques, including surgeries, stem cell injections, and grafting of cartilage into damaged areas.
However, due to the extremely slow growth of cartilage and its avascular properties, regeneration and growth of cartilage post-injury is still very slow.

College of sciences — Dr. Mahdi Haider

Microbiology — ٤th lecture

Skin Anatomy:

The skin and its accessory structures make up the **integumentary system**, which provides the body with overall protection. The skin is made of multiple layers of cells and tissues, which are held to underlying structures by connective tissue (Figure ١). The deeper layer of skin is well vascularized (has numerous blood vessels). It also has numerous sensory, and autonomic and sympathetic nerve fibers ensuring communication to and from the brain.

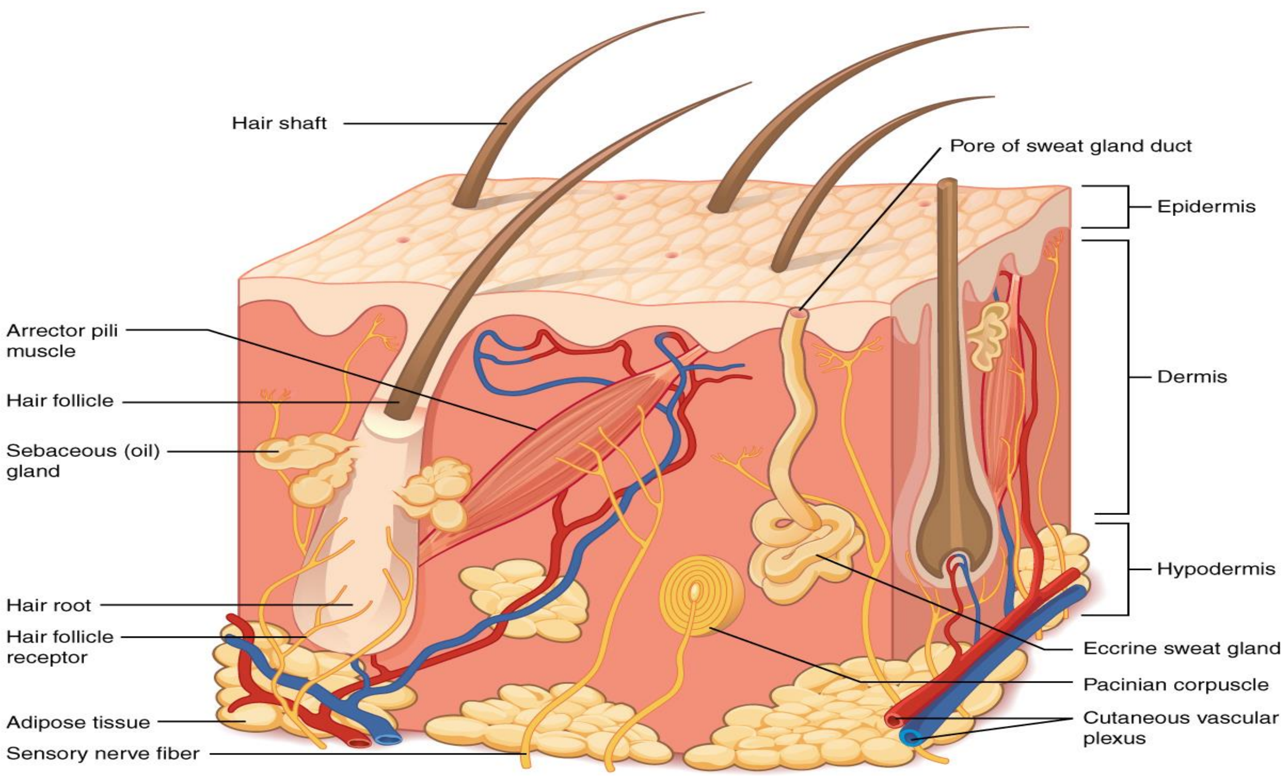


Figure ١. Layers of Skin. The skin is composed of two main layers: the epidermis, made of closely packed epithelial cells, and the dermis, made of dense, irregular connective tissue that houses blood vessels, hair follicles, sweat glands, and other structures. Beneath the dermis lies the hypodermis, which is composed mainly of loose connective and fatty tissues.

The skin consists of two main layers and a closely associated layer.

The Epidermis

The **epidermis** is composed of keratinized, stratified squamous epithelium. It is made of **four or five layers of epithelial cells**, depending on its location in the body. It does not have any blood vessels within it (i.e., it is avascular). Skin that has four layers of cells is referred to as “thin skin.” From deep to superficial, these layers are the **stratum basale, stratum spinosum, stratum granulosum, and stratum corneum.** Most of the skin can be classified as thin skin. “Thick skin” is found only on the palms of the hands and the soles of the feet. It has a fifth layer, called the stratum lucidum, located between the stratum corneum and the stratum granulosum (Figure ٢).

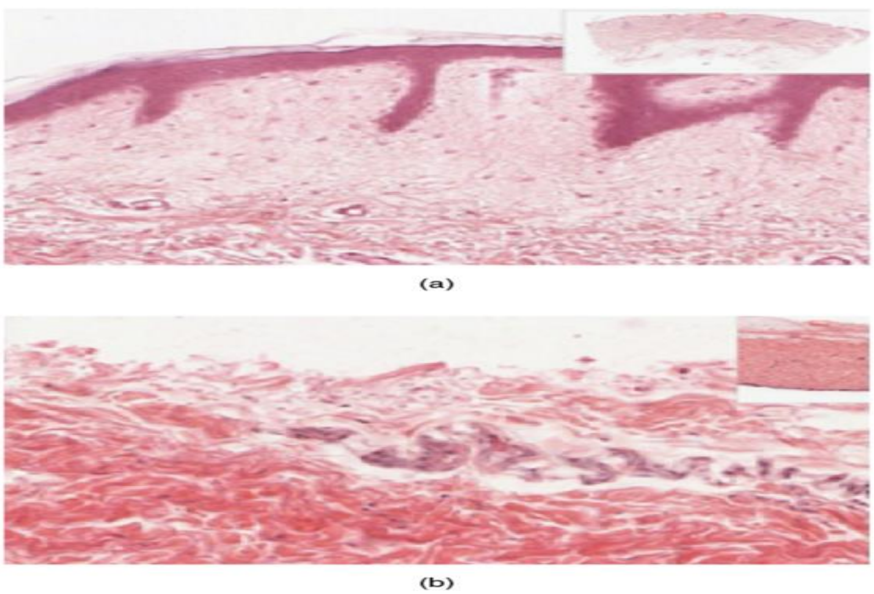


Figure ٢. Thin Skin versus Thick Skin. These slides show cross-sections of the epidermis and dermis of (a) thin and (b) thick skin. Note the significant difference in the thickness of the epithelial layer of the thick skin. From top, LM × ٤٠, LM × ٤٠. (Micrographs provided by the Regents of University of Michigan Medical School © ٢٠١٢)

The cells in all of the layers except the stratum basale are called keratinocytes. A **keratinocyte** is a cell that manufactures and stores the protein keratin. **Keratin** is an intracellular fibrous protein that gives hair, nails, and skin their hardness and water-resistant properties. The keratinocytes in the stratum corneum are dead and regularly slough away, being replaced by cells from the deeper layers (Figure ٣).

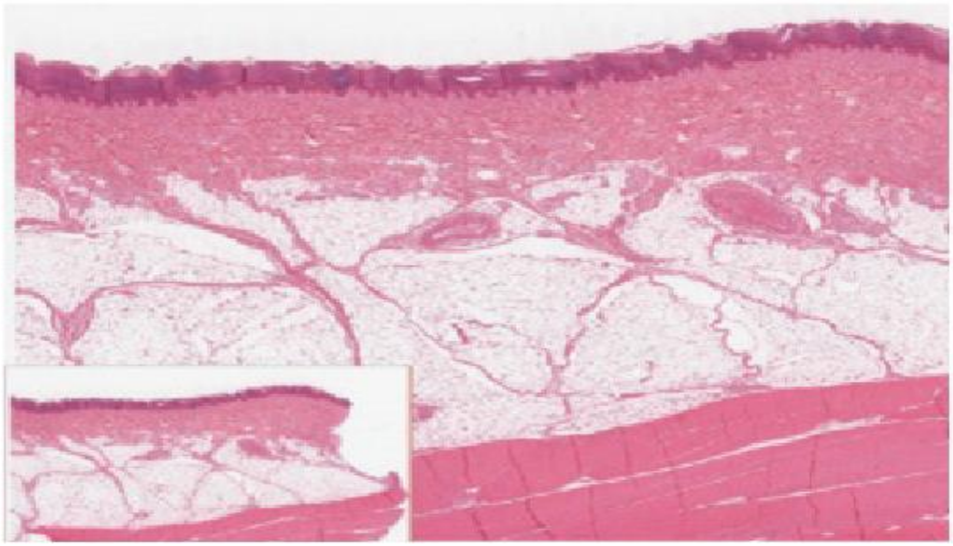


Figure ٣. Epidermis. The epidermis is epithelium composed of multiple layers of cells. The basal layer consists of cuboidal cells, whereas the outer layers are squamous, keratinized cells, so the whole epithelium is often described as being keratinized stratified squamous epithelium. LM × ٤٠. (Micrograph provided by the Regents of University of Michigan Medical School © ٢٠١٢)

Stratum Basale

The **stratum basale** (also called the stratum germinativum) is the deepest epidermal layer and attaches the epidermis to the basal lamina, below which lie the layers of the dermis. The cells in the stratum basale bond to the dermis via intertwining collagen fibers, referred to as the basement membrane. A finger-like projection, or fold, known as the **dermal papilla** (plural = dermal papillae) is found in the superficial portion of the dermis. Dermal papillae increase the strength of the connection between the epidermis and dermis; the greater the folding, the stronger the connections made (Figure ٤).

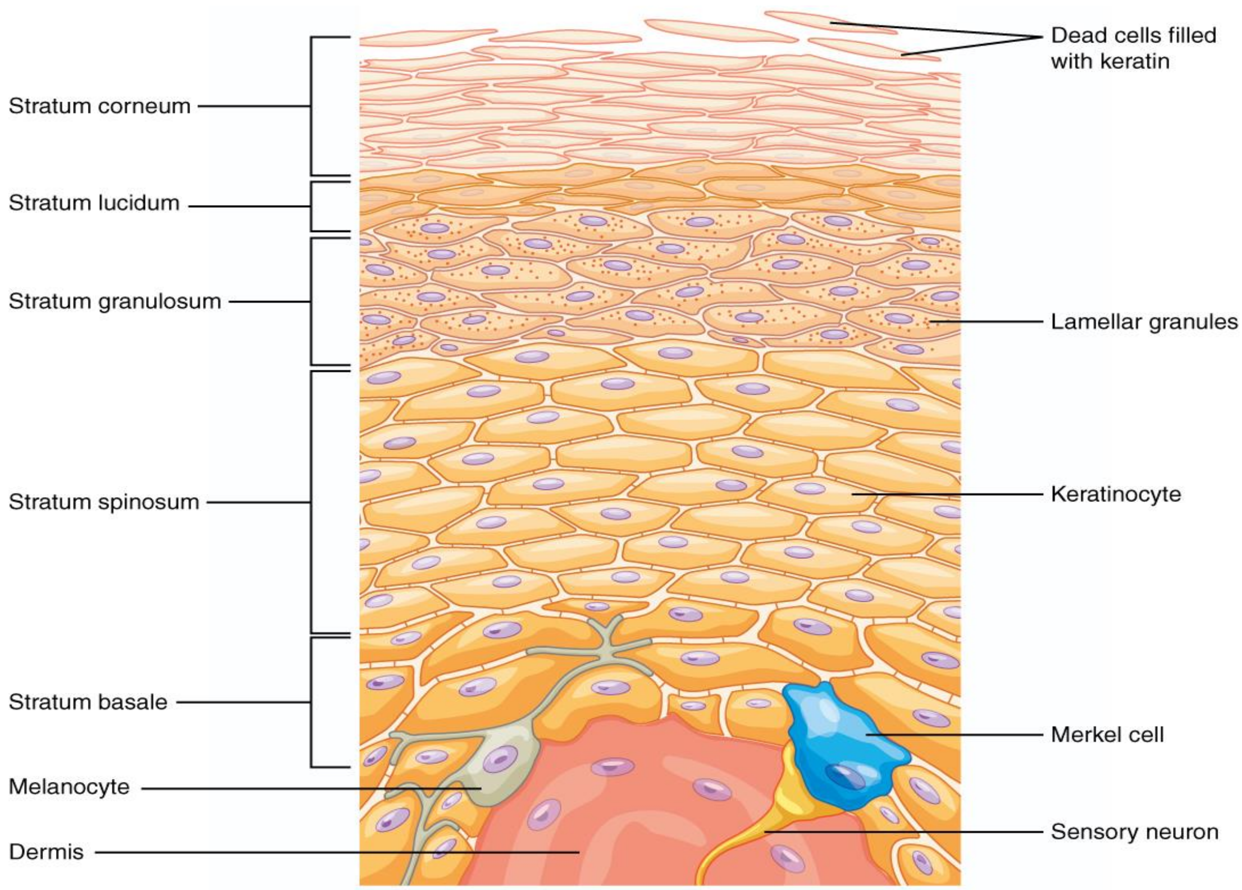


Figure ٤. Layers of the Epidermis. The epidermis of thick skin has five layers: stratum basale, stratum spinosum, stratum granulosum, stratum lucidum, and stratum corneum.

The stratum basale is a single layer of cells primarily made of basal cells. A **basal cell** is a cuboidal-shaped stem cell that is a precursor of the keratinocytes of the epidermis. All of the keratinocytes are produced from this single layer of cells, which are constantly going through mitosis to produce new cells. As new cells are formed, the existing cells are pushed superficially away from the stratum basale. Two other cell types are found dispersed among the basal cells in the stratum basale. The first is a **Merkel cell**, which functions as a receptor and is responsible for stimulating sensory nerves that the brain perceives as touch. These cells are especially abundant on the surfaces of the hands and feet. The second is a **melanocyte**, a cell that produces the pigment melanin. **Melanin** gives hair and skin its color, and also helps protect the living cells of the epidermis from ultraviolet (UV) radiation damage.

In a growing fetus, fingerprints form where the cells of the stratum basale meet the papillae of the underlying dermal layer (papillary layer), resulting in the formation of the ridges on your fingers that you recognize as fingerprints. Fingerprints are unique to each individual and are used for forensic analyses because the patterns do not change with the growth and aging processes.

Stratum Spinosum

As the name suggests, the **stratum spinosum** is spiny in appearance due to the protruding cell processes that join the cells via a structure called a **desmosome**. The desmosomes interlock with each other and strengthen the bond between the cells. It is interesting to note that the “spiny” nature of this layer is an artifact of the staining process. Unstained epidermis samples do not exhibit this characteristic appearance. The stratum spinosum is composed of eight to ١٠ layers of keratinocytes, formed as a result of cell division in the stratum basale (Figure). Interspersed among the keratinocytes of this layer is a type of dendritic cell called the **Langerhans cell**, which functions as a macrophage by engulfing bacteria, foreign particles, and damaged cells that occur in this layer.

to explore the tissue sample in greater detail. If you zoom on the cells at the outermost layer of this section of skin, what do you notice about the cells?

The keratinocytes in the stratum spinosum begin the synthesis of keratin and release a water-repelling glycolipid that helps prevent water loss from the body, making the skin relatively waterproof. As new keratinocytes are produced atop the stratum basale, the keratinocytes of the stratum spinosum are pushed into the stratum granulosum.

Stratum Granulosum

The **stratum granulosum** has a grainy appearance due to further changes to the keratinocytes as they are pushed from the stratum spinosum. The cells (three to five layers deep) become flatter, their cell membranes thicken, and they generate large amounts of the proteins keratin, which is fibrous, and **keratohyalin**, which accumulates as lamellar granules within the cells (see Figure ٤). These two proteins make up the bulk of the keratinocyte mass in the stratum granulosum and give the layer its grainy appearance. The nuclei and other cell organelles disintegrate as the cells die, leaving behind the keratin, keratohyalin, and cell membranes that will form the stratum lucidum, the stratum corneum, and the accessory structures of hair and nails.

Stratum Lucidum

The **stratum lucidum** is a smooth, seemingly translucent layer of the epidermis located just above the stratum granulosum and below the stratum corneum. This thin layer of cells is found only in the thick skin of the palms, soles, and digits. The keratinocytes that compose the stratum lucidum are dead and flattened (see Figure ٤). These cells are densely packed with **eleiden**, a clear protein rich in lipids, derived from keratohyalin, which gives these cells their transparent (i.e., lucid) appearance and provides a barrier to water.

Stratum Corneum

The **stratum corneum** is the most superficial layer of the epidermis and is the layer exposed to the outside environment (see Figure ٤). The increased keratinization (also called cornification) of the cells in this layer gives it its name. There are usually ١٥ to ٣٠ layers of cells in the stratum corneum. This dry, dead layer helps prevent the penetration of microbes and the dehydration of underlying tissues, and provides a mechanical protection against abrasion for the more delicate, underlying layers. Cells in this layer are shed periodically and are replaced by cells pushed up from the stratum granulosum (or stratum lucidum in the case of the palms and soles of feet). The entire layer is replaced during a period of about ٤ weeks. Cosmetic procedures, such as microdermabrasion, help remove some of the dry, upper layer and aim to keep the skin looking “fresh” and healthy.

Dermis

The **dermis** might be considered the “core” of the integumentary system (derma- = “skin”), as distinct from the epidermis (epi- = “upon” or “over”) and hypodermis (hypo- = “below”). It contains blood and lymph vessels, nerves, and other structures, such as hair follicles and sweat glands. The dermis is made of two layers of connective tissue that compose an interconnected mesh of elastin and collagenous fibers, produced by fibroblasts (Figure ٦).

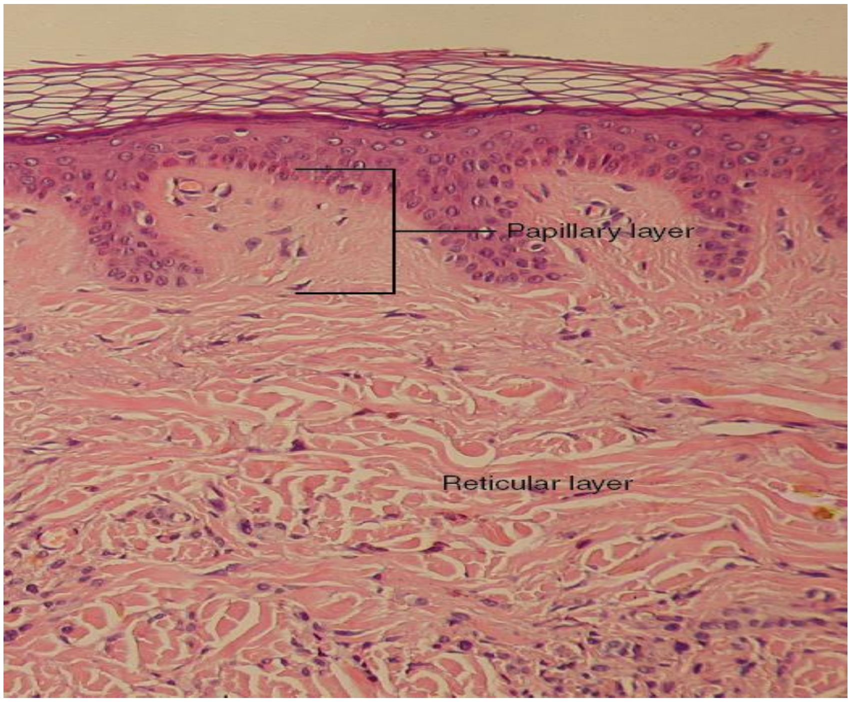


Figure ٦. Layers of the Dermis. This stained slide shows the two components of the dermis—the papillary layer and the reticular layer. Both are made of connective tissue with fibers of collagen extending from one to the other, making the border between the two somewhat indistinct. The dermal papillae extending into the epidermis belong to the papillary layer, whereas the dense collagen fiber bundles below belong to the reticular layer. LM × ١٠. (credit: modification of work by "kilbad"/Wikimedia Commons)

Papillary Layer

The **papillary layer** is made of loose, areolar connective tissue, which means the collagen and elastin fibers of this layer form a loose mesh. This superficial layer of the dermis projects into the stratum basale of the epidermis to form finger-like dermal papillae (see Figure ٦). Within the papillary layer are fibroblasts, a small number of fat cells (adipocytes), and an abundance of small blood vessels. In addition, the papillary layer contains phagocytes, defensive cells that help fight bacteria or other infections that have breached the skin. This layer also contains lymphatic capillaries, nerve fibers, and touch receptors called the Meissner corpuscles.

Reticular Layer

Underlying the papillary layer is the much thicker **reticular layer**, composed of dense, irregular connective tissue. This layer is well vascularized and has a rich sensory and sympathetic nerve supply. The reticular layer appears reticulated (net-like) due to a tight meshwork of fibers. **Elastin fibers** provide some elasticity to the skin, enabling movement. Collagen fibers provide structure and tensile strength, with strands of collagen extending into both the papillary layer and the hypodermis. In addition, collagen binds water to keep the skin hydrated. Collagen injections and Retin-A creams help restore skin turgor by either introducing collagen externally or stimulating blood flow and repair of the dermis, respectively.

Hypodermis

The **hypodermis** (also called the subcutaneous layer or superficial fascia) is a layer directly below the dermis and serves to connect the skin to the underlying fascia (fibrous tissue) of the bones and muscles. It is not strictly a part of the skin, although the border between the hypodermis and dermis can be difficult to distinguish. The hypodermis consists of well-vascularized, loose, areolar connective tissue and adipose tissue, which functions as a mode of fat storage and provides insulation and cushioning for the integument.

College of sciences **Dr. Mahdi Haider**

Microbiology Dep. **٥th lecture**

Anatomy of the Digestive System

The functions of the digestive system are:

١. **Ingestion.** Food must be placed into the mouth before it can be acted on; this is an active, voluntary process called ingestion.

٢. **Propulsion.** If foods are to be processed by more than one digestive organ, they must be propelled from one organ to the next; swallowing is one example of food movement that depends largely on the propulsive process called **peristalsis** (involuntary, alternating waves of contraction and relaxation of the muscles in the organ wall).

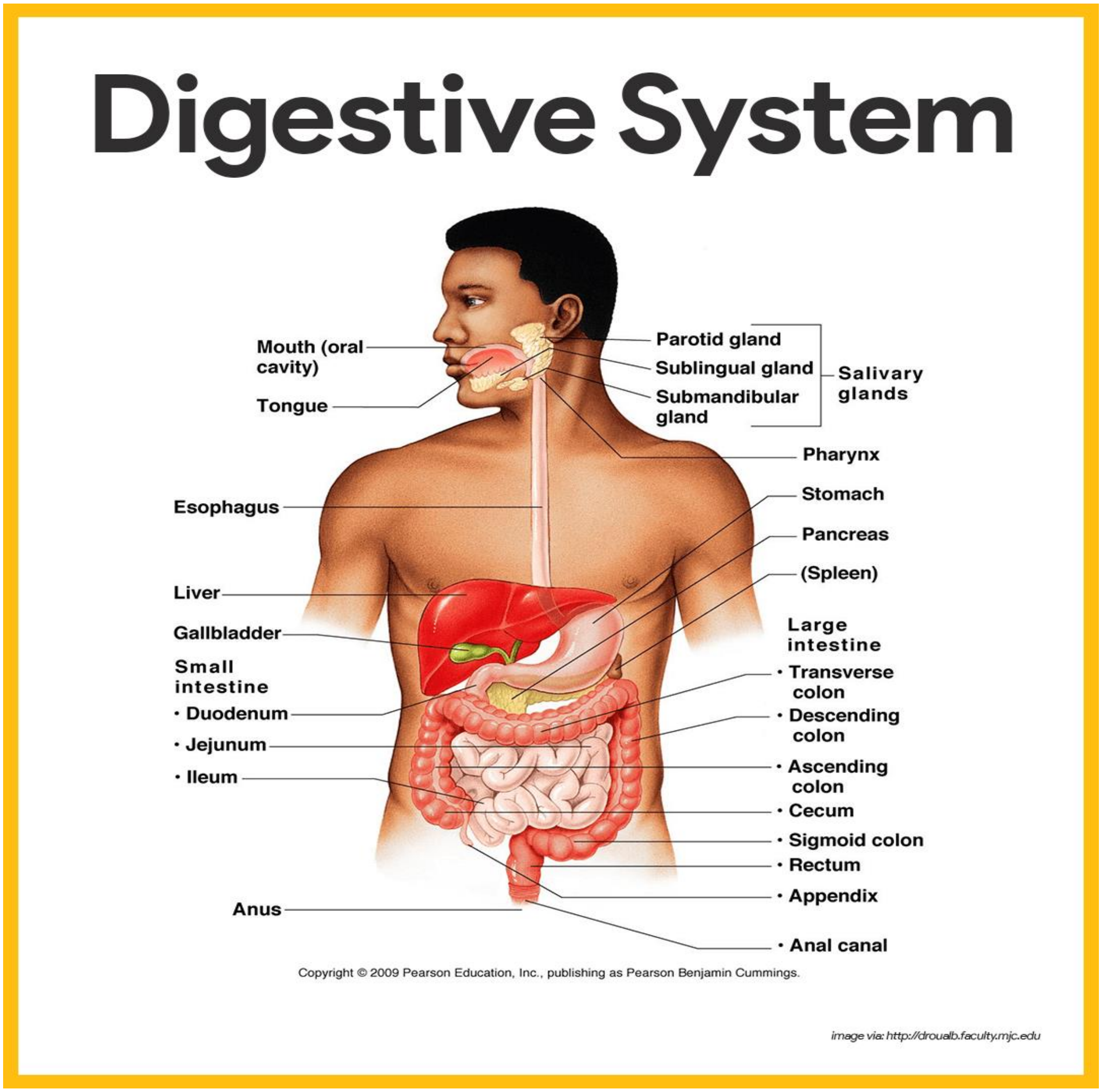
٣. **Food breakdown: mechanical digestion.** Mechanical digestion prepares food for further degradation by enzymes by physically fragmenting the foods into smaller pieces, and examples of mechanical digestion are: mixing of food in the mouth by the tongue, churning of food in the stomach, and segmentation in the small intestine.

٤. **Food breakdown: chemical digestion.** The sequence of steps in which the large food molecules are broken down into their building blocks by enzymes is called chemical digestion.

٥. **Absorption.** Transport of digested end products from the lumen of the GI tract to the blood or lymph is absorption, and for absorption to happen, the digested foods must first enter the mucosal cells by active or passive transport processes.

٦. **Defecation.** Defecation is the elimination of indigestible residues from the GI tract via the anus in the form of feces.

The organs of the digestive system can be separated into two main groups: those forming the **alimentary canal** and the **accessory digestive** organs.



Organs of the Alimentary Canal

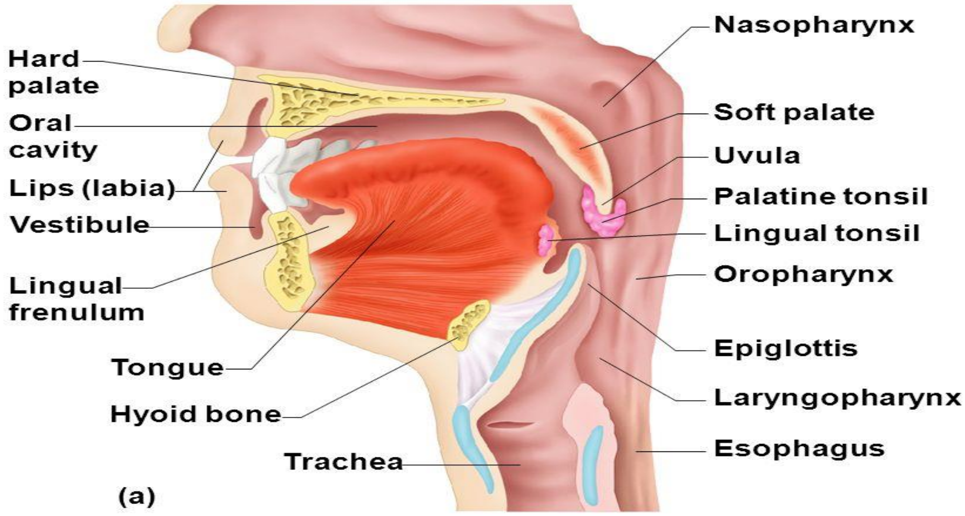
The alimentary canal, also called the gastrointestinal tract, is a continuous, hollow muscular tube that winds through the ventral body cavity and is open at both ends. Its organs include the following:

Mouth

Food enters the digestive tract through the **mouth**, or oral cavity, a mucous membrane-lined cavity.

- **Lips.** The lips (labia) protect its anterior opening.
- **Cheeks. T**he cheeks form its lateral walls.
- **Palate.** The **hard palate** forms its anterior roof, and the **soft palate** forms its posterior roof.
- **Uvula.** The uvula is a fleshy finger-like projection of the soft palate, which extends inferiorly from the posterior edge of the soft palate.
- **Vestibule.** The space between the lips and the cheeks externally and the teeth and gums internally is the vestibule.
- **Oral cavity proper.** The area contained by the teeth is the oral cavity proper.
- **Tongue.** The muscular tongue occupies the floor of the mouth and has several bony attachments- two of these are to the hyoid bone and the styloid processes of the skull.
- **Lingual frenulum.** The lingual frenulum, a fold of mucous membrane, secures the tongue to the floor of the mouth and limits its posterior movements.
- **Palatine tonsils.** At the posterior end of the oral cavity are paired masses of lymphatic tissue, the palatine tonsils.
- **Lingual tonsil.** The lingual tonsils cover the base of the tongue just beyond.

Figure 14.2a Anatomy of the mouth (oral cavity). (a) Sagittal view of the oral cavity and pharynx.



Essentials of Human Anatomy and Physiology, 9e
by Elaine N. Marieb

Pharynx

From the mouth, food passes posteriorly into the oropharynx and laryngopharynx.

- **Oropharynx.** The oropharynx is posterior to the oral cavity.
- **Laryngopharynx.** The laryngopharynx is continuous with the esophagus below; both of which are common passageways for food, fluids, and air.

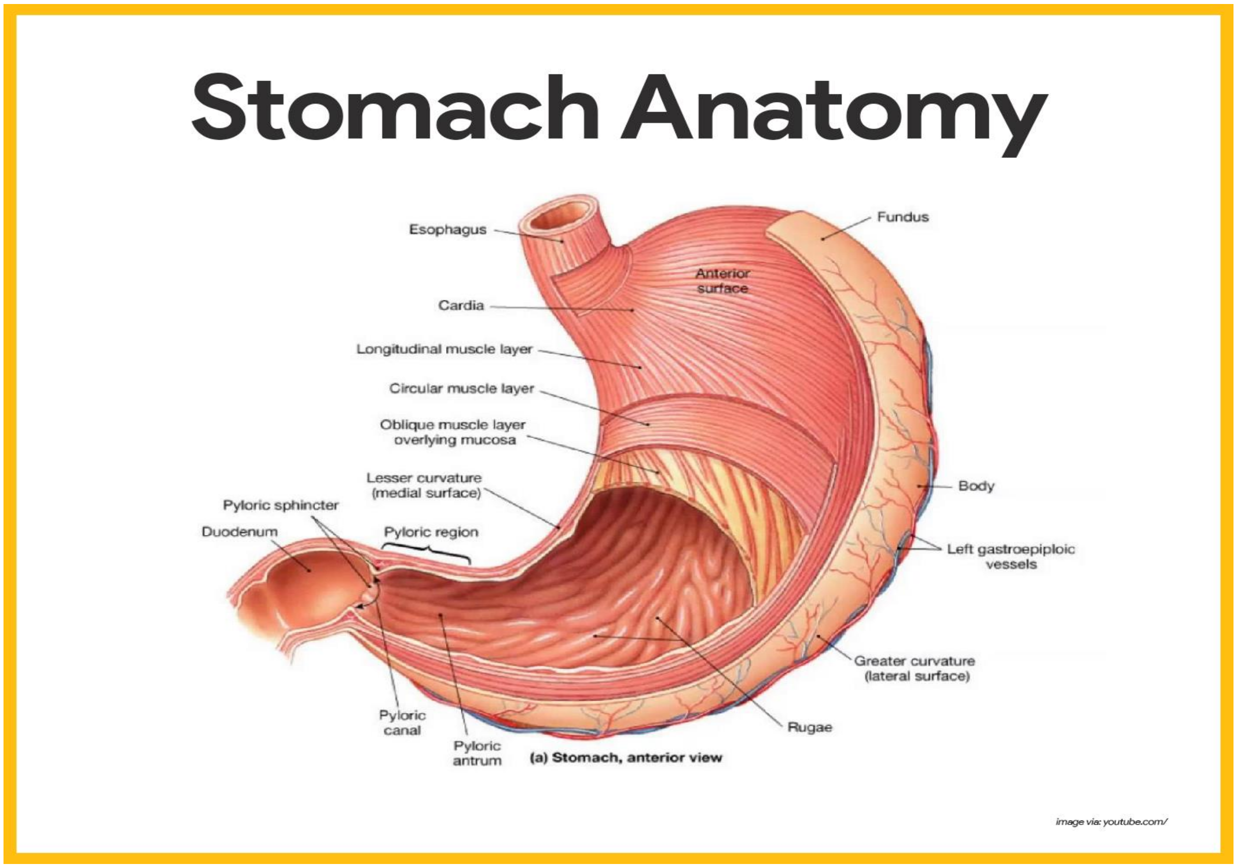
Esophagus

The esophagus or **gullet**, runs from the pharynx through the diaphragm to the stomach.

- **Size and function.** About ٢٥ **cm** (١٠ inches) long, it is essentially a passageway that conducts food by peristalsis to the stomach.
- **Structure.** The walls of the alimentary canal organs from the esophagus to the large intestine are made up of the same **four basic tissue layers or tunics.**
- **Mucosa.** The mucosa is the **innermost** layer, a moist membrane that lines the cavity, or lumen, of the organ; it consists primarily of a surface epithelium, plus a small amount of connective tissue (**lamina propria**) and a scanty smooth muscle layer.
- **Submucosa.** The submucosa is found just beneath the mucosa; it is a soft connective tissue layer containing blood vessels, nerve endings, lymph nodules, and lymphatic vessels.
- **Muscularis externa**. The muscularis externa is a muscle layer typically made up of an inner circular layer and an outer longitudinal layer of smooth muscle cells.
- **Serosa.** The serosa is the **outermost** layer of the wall that consists of a single layer of flat serous fluid-producing cells, the **visceral peritoneum**.
- **Intrinsic nerve plexuses.** The alimentary canal wall contains two important intrinsic nerve plexuses- the **submucosal nerve plexus** and the **myenteric nerve plexus**, both of which are networks of nerve fibers that are actually part of the autonomic nervous system and help regulate the mobility and secretory activity of the GI tract organs.

Stomach

Different regions of the stomach have been named, and they include the following:

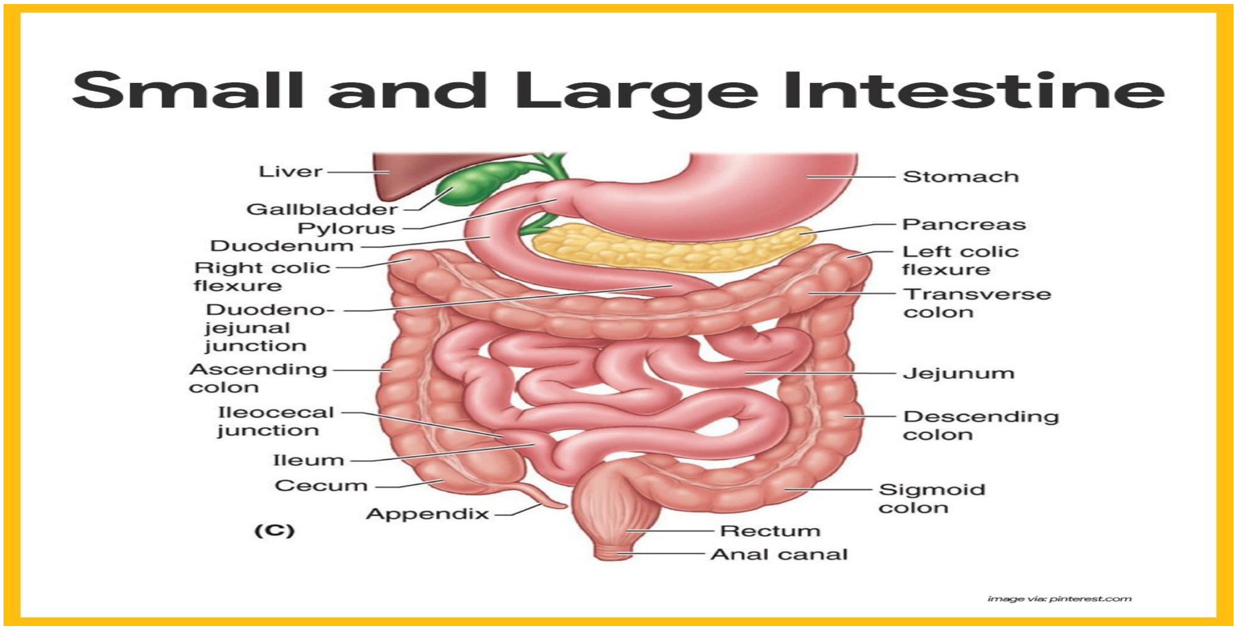


- **Location.** The C-shaped stomach is on the left side of the abdominal cavity, nearly hidden by the liver and the diaphragm.
- **Function.** The stomach acts as a temporary "storage tank" for food as well as a site for food breakdown.
- **Cardiac region.** The cardiac region surrounds the **cardioesophageal sphincter**, through which food enters the stomach from the esophagus.
- **Fundus.** The fundus is the expanded part of the stomach lateral to the cardiac region.
- **Body.** The body is the midportion, and as it narrows inferiorly, it becomes the **pyloric antrum**, and then the funnel-shaped pylorus.

- **Pylorus.** The pylorus is the terminal part of the stomach and it is continuous with the small intestine through the **pyloric sphincter or valve**.
- **Size.** The stomach varies from ١٥ **to** ٢٥ **cm in length**, but its diameter and volume depend on how much food it contains; when it is full, it can hold about ٤ **liters** (١ gallon) of food, but when it is empty it collapses inward on itself.
- **Rugae.** The mucosa of the stomach is thrown into large folds called rugae when it is empty.
- **Stomach mucosa.** The mucosa of the stomach is a simple columnar epithelium composed entirely of mucous cells that produce a protective layer of bicarbonate-rich alkaline mucus that clings to the stomach mucosa and protects the stomach wall from being damaged by acid and digested by enzymes.
- **Gastric glands.** This otherwise smooth lining is dotted with millions of deep **gastric pits**, which lead into **gastric glands** that secrete the solution called **gastric juice**.
- **Intrinsic factor.** Some stomach cells produce intrinsic factor, a substance needed for the absorption of vitamin b١٢ from the small intestine.
- **Chief cells.** The chief cells produce protein-digesting enzymes, mostly **pepsinogens**.
- **Parietal cells**. The parietal cells produce corrosive **hydrochloric acid**, which makes the stomach contents acidic and activates the enzymes.
- **Enteroendocrine cells.** The enteroendocrine cells produce local hormones such as **gastrin**, that are important to the digestive activities of the stomach.
- **Chyme.** After food has been processed, it resembles heavy cream and is called chyme.

Small Intestine

The small intestine is the body's **major** digestive organ.

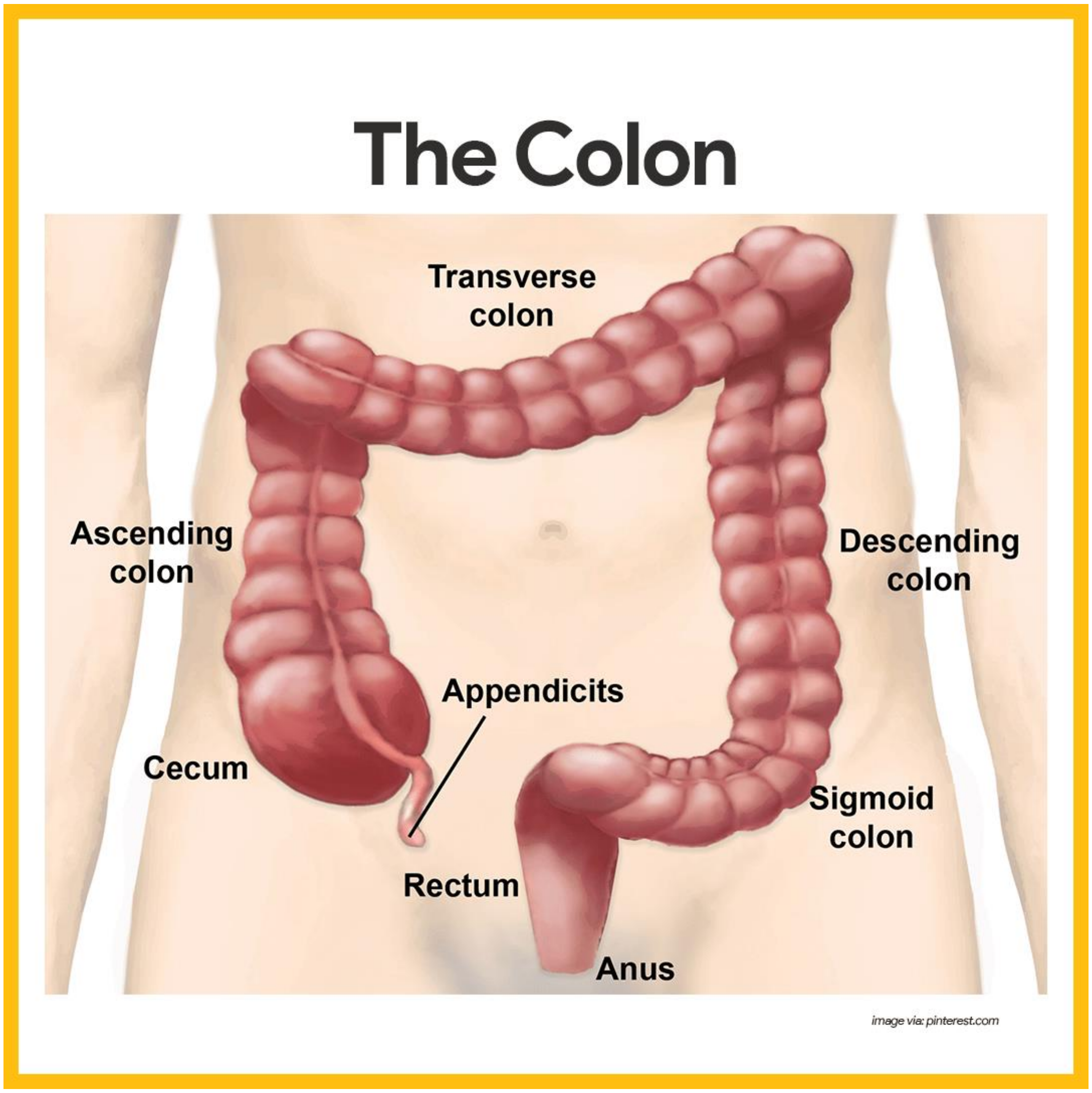


- **Location.** The small intestine is a muscular tube extending from the pyloric sphincter to the large intestine.
- **Size.** It is the longest section of the alimentary tube, with an average length of ٢,٥ **to** ٧ **m** (٨ to ٢٠ feet) in a living person.
- **Subdivisions.** The small intestine has three subdivisions: the **duodenum**, the **jejunum**, and the **ileum**, which contribute ٥ percent, nearly ٤٠ percent, and almost ٦٠ percent of the small intestine, respectively.
- **Ileocecal valve.** The ileum meets the large intestine at the ileocecal valve, which joins the large and small intestine.
- **Hepatopancreatic ampulla.** The main pancreatic and bile ducts join at the duodenum to form the flasklike hepatopancreatic ampulla, literally, the **" liver-pacreatic-enlargement"**.
- **Duodenal papilla.** From there, the bile and pancreatic juice travel through the duodenal papilla and enter the duodenum together.

- **Microvilli.** Microvilli are tiny projections of the plasma membrane of the mucosa cells that give the cell surface a fuzzy appearance, sometimes referred to as the **brush border**; the plasma membranes bear enzymes (brush border enzymes) that complete the digestion of proteins and carbohydrates in the small intestine.
- **Villi.** Villi are fingerlike projections of the mucosa that give it a velvety appearance and feel, much like the soft nap of a towel.
- **Lacteal.** Within each villus is a rich capillary bed and a modified lymphatic capillary called a lacteal.
- **Circular folds.** Circular folds, also called **plicae circulares**, are deep folds of both mucosa and submucosa layers, and they do not disappear when food fills the small intestine.
- **Peyer’s patches.** In contrast, local collections of lymphatic tissue found in the submucosa increase in number toward the end of the small intestine.

Large Intestine

The large intestine is much larger in diameter than the small intestine but shorter in length.



- **Size**. About ١,٥ **m** (٥ feet) long, it extends from the ileocecal valve to the anus.
- **Functions.** Its major functions are to dry out indigestible food residue by absorbing water and to eliminate these residues from the body as feces.

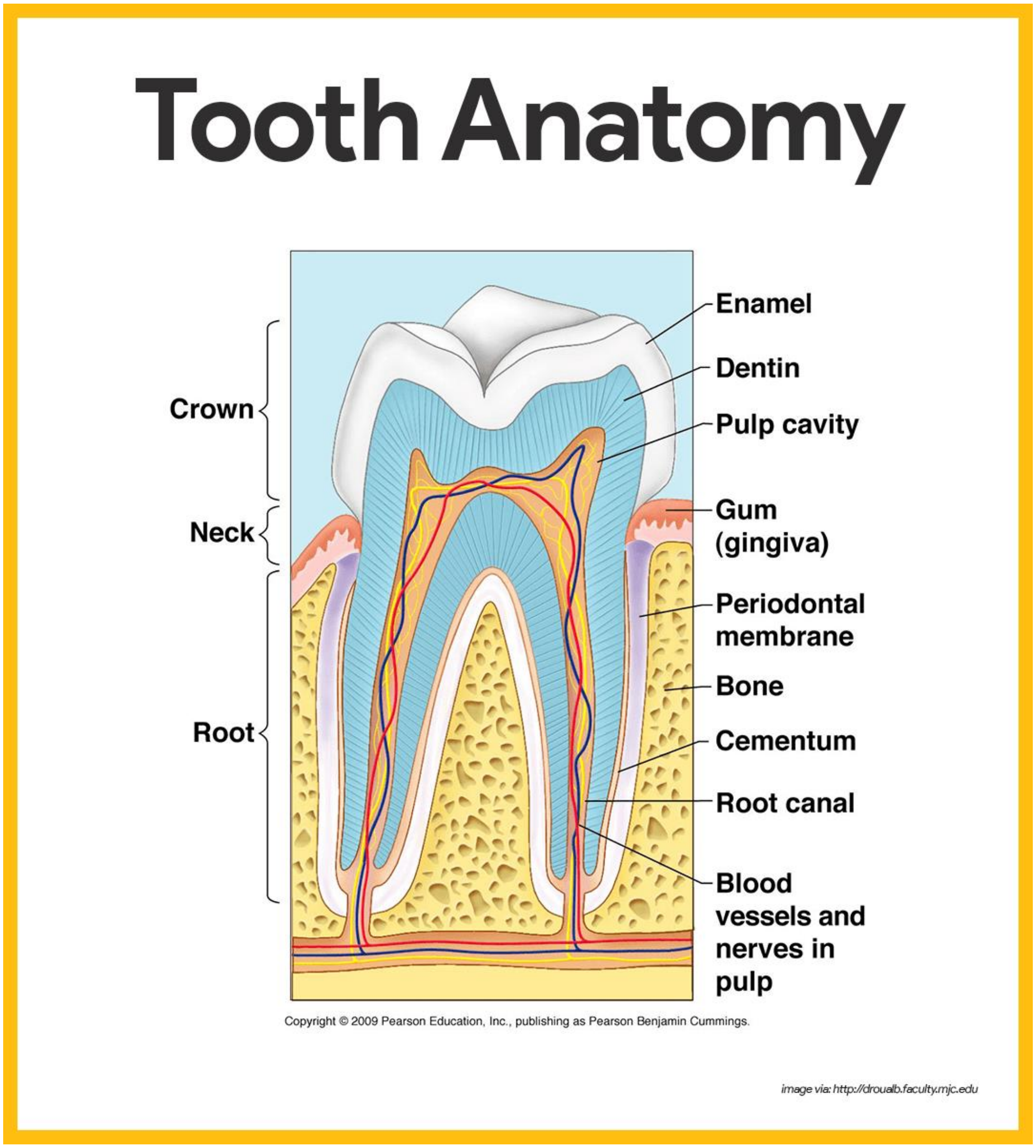
- **Subdivisions.** It frames the small intestines on three sides and has the following subdivisions: **cecum, appendix, colon, rectum, and anal canal**.
- **Cecum.** The saclike cecum is the first part of the large intestine.
- **Appendix.** Hanging from the cecum is the wormlike appendix, a potential trouble spot because it is an ideal location for bacteria to accumulate and multiply.
- **Ascending colon.** The ascending colon travels up the right side of the abdominal cavity and makes a turn, the **right colic (or hepatic) flexure**, to travel across the abdominal cavity.
- **Transverse colon.** The ascending colon makes a turn and continuous to be the transverse colon as it travels across the abdominal cavity.
- **Descending colon.** It then turns again at the **left colic (or splenic) flexure**, and continues down the left side as the descending colon.
- **Sigmoid colon.** The intestine then enters the pelvis, where it becomes the S-shaped sigmoid colon.
- **Anal canal.** The anal canal ends at the anus which opens to the exterior.
- **External anal sphincter.** The anal canal has an external voluntary sphincter, the external anal sphincter, composed of skeletal muscle.
- **Internal involuntary sphincter.** The internal involuntary sphincter is formed by smooth muscles.

Accessory Digestive Organs

Other than the intestines and the stomach, the following are also part of the digestive system:

Teeth

The role the teeth play in food processing needs little introduction; we masticate, or chew, by opening and closing our jaws and moving them from side to side while continuously using our tongue to move the food between our teeth.



- **Function.** The teeth tear and grind the food, breaking it down into smaller fragments.
- **Deciduous teeth.** The first set of teeth is the deciduous teeth, also called **baby teeth** or **milk teeth**, and they begin to erupt around ٦ months, and a baby has a full set (٢٠ teeth) by the age of ٢ years.
- **Permanent teeth.** As the second set of teeth, the deeper permanent teeth, enlarge and develop, the roots of the milk teeth are reabsorbed, and between the ages of ٦ to ١٢ years they loosen and fall out.

- **Incisors.** The chisel-shaped incisors are adapted for cutting.
- **Canines.** The fanglike canines are for tearing and piercing.
- **Premolars and molars.** Premolars (bicuspids) and molars have broad crowns with round cusps (tips) and are best suited for grinding.
- **Crown.** The enamel-covered crown is the exposed part of the tooth above the **gingiva** or gum.
- **Enamel.** Enamel is the hardest substance in the body and is fairly brittle because it is heavily mineralized with calcium salts.
- **Root**. The outer surface of the root is covered by a substance called cementum, which attaches the tooth to the **periodontal membrane (ligament)**.
- **Dentin.** Dentin, a bonelike material, underlies the enamel and forms the bulk of the tooth.
- **Pulp cavity.** It surrounds a central pulp cavity, which contains a number of structures (connective tissue, blood vessels, and nerve fibers) collectively called the **pulp**.
- **Root canal.** Where the pulp cavity extends into the root, it becomes the root canal, which provides a route for blood vessels, nerves, and other pulp structures to enter the pulp cavity of the tooth.

Salivary Glands

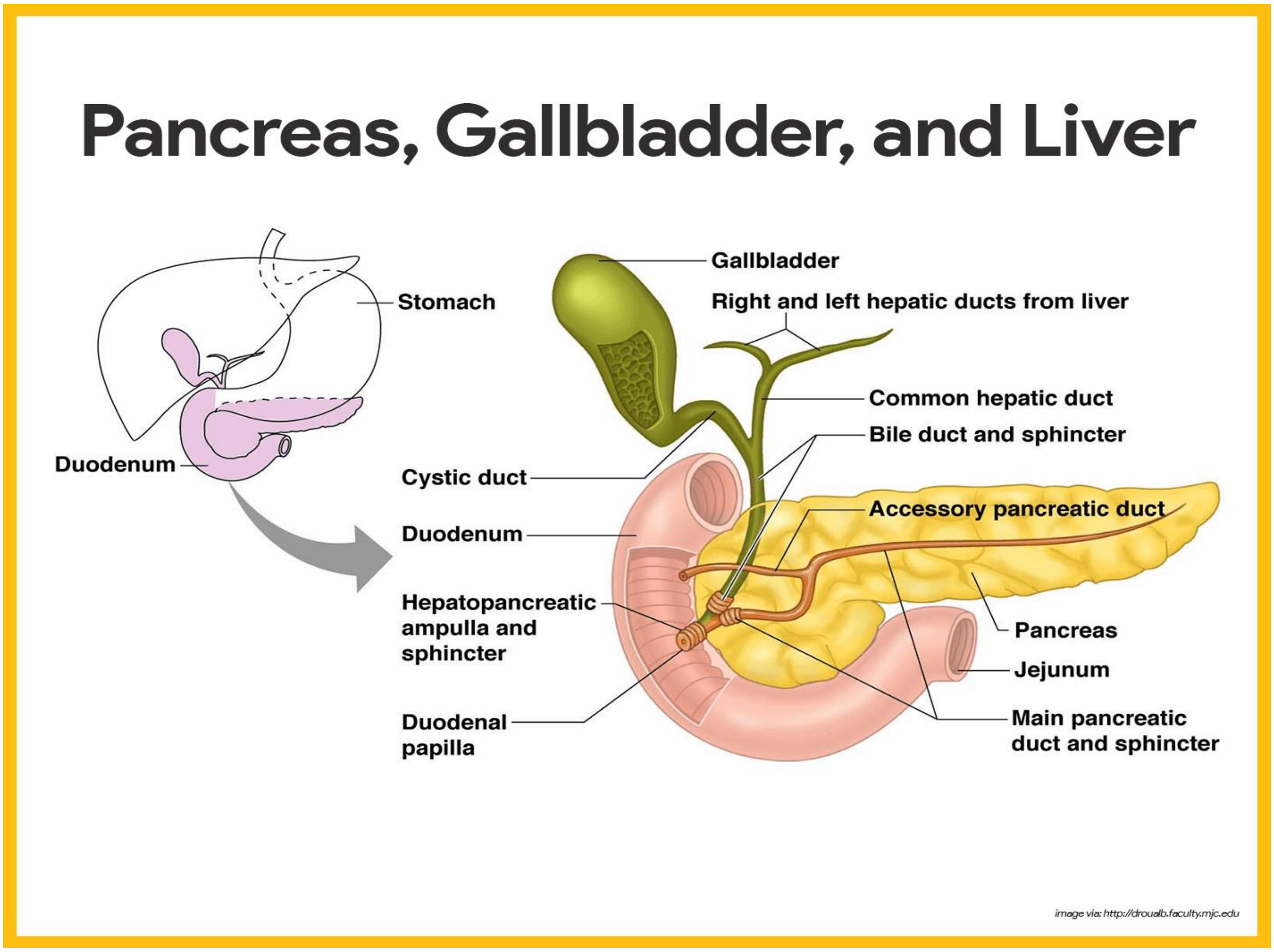
Three pairs of salivary glands empty their secretions into the mouth.

- **Parotid glands.** The large parotid glands lie anterior to the ears and empty their secretions into the mouth.
- **Submandibular and sublingual glands.** The submandibular and sublingual glands empty their secretions into the floor of the mouth through tiny ducts.
- **Saliva.** The product of the salivary glands, saliva, is a mixture of mucus and serous fluids.

- **Salivary amylase.** The clear serous portion contains an enzyme, salivary amylase, in a bicarbonate-rich juice that begins the process of starch digestion in the mouth.

Pancreas

Only the pancreas produces enzymes that break down all categories of digestible foods.



- **Location.** The pancreas is a soft, pink triangular gland that extends across the abdomen from the spleen to the duodenum; but most of the pancreas lies posterior to the parietal peritoneum, hence its location is referred to as **retroperitoneal**.

- **Pancreatic enzymes.** The pancreatic enzymes are secreted into the duodenum in an alkaline fluid that neutralizes the acidic chyme coming in from the stomach.
- **Endocrine function.** The pancreas also has an endocrine function; it produces hormones **insulin and glucagon**.

Liver

The liver is the largest gland in the body.

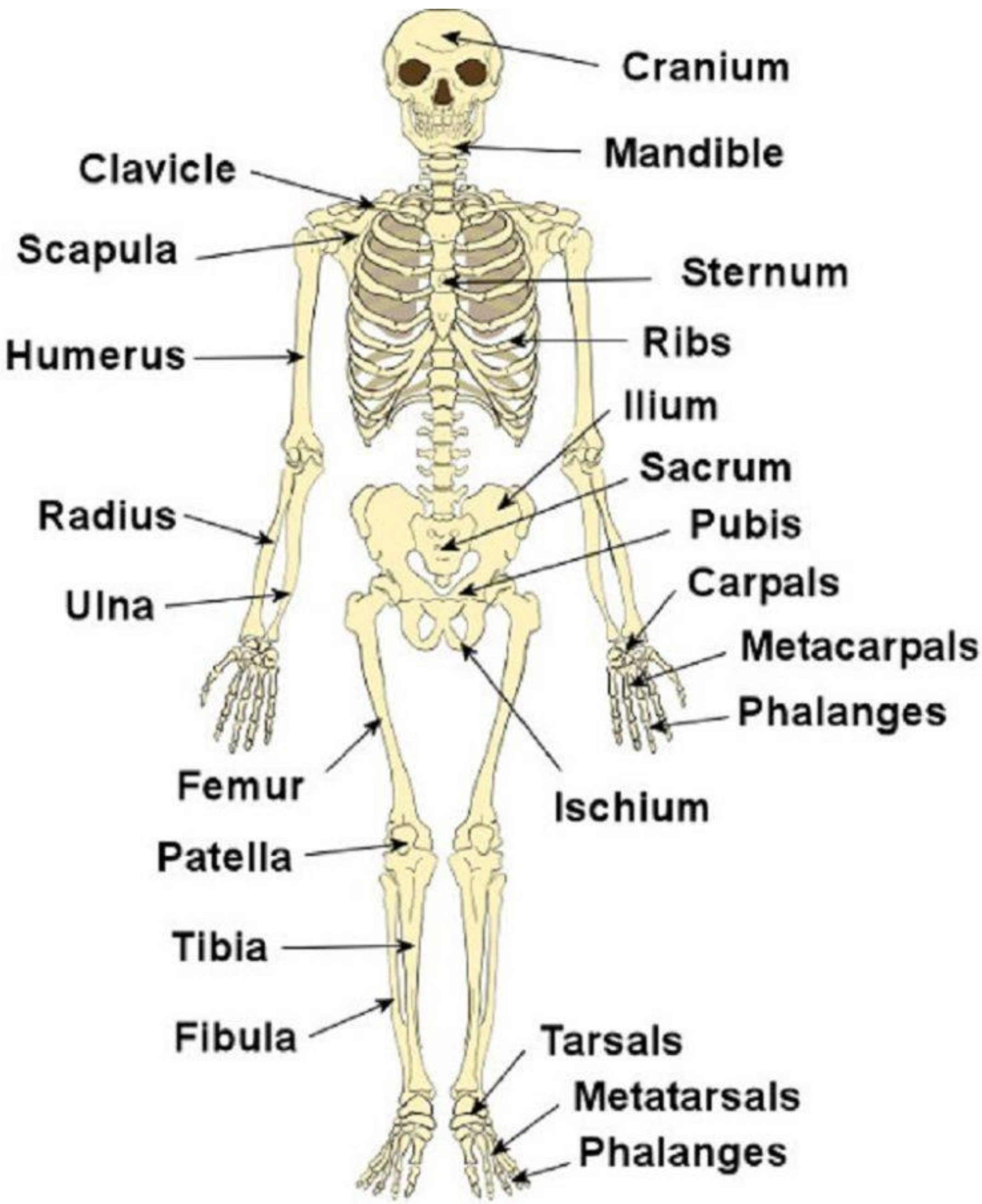
- **Location.** Located under the diaphragm, more to the right side of the body, it overlies and almost completely covers the stomach.
- **Falciform ligament.** The liver has four lobes and is suspended from the diaphragm and abdominal wall by a delicate mesentery cord, the falciform ligament.
- **Function.** The liver's digestive function is to produce bile.
- **Bile.** Bile is a yellow-to-green, watery solution containing bile salts, bile pigments, cholesterol, phospholipids, and a variety of electrolytes.
- **Bile salts.** Bile does not contain enzymes but its bile salts emulsify fats by physically breaking large fat globules into smaller ones, thus providing more surface area for the fat-digesting enzymes to work on.

Gallbladder

While in the gallbladder, bile is concentrated by the removal of water.

- **Location.** The gallbladder is a small, thin-walled green sac that snuggles in a shallow fossa in the inferior surface of the liver.
- **Cystic duct.** When food digestion is not occurring, bile backs up the cystic duct and enters the gallbladder to be stored

Skeletal System Anatomy



The skeletal system in an adult body is made up of ٢٠٦ individual bones. These bones are arranged into two major divisions: the **axial skeleton** and the **appendicular skeleton**. The axial skeleton runs along the body's midline axis and is made up of ٨٠ bones in the following regions:

Skull

Hyoid

Auditory ossicles

Ribs

Sternum

Vertebral column

The appendicular skeleton is made up of ١٢٦ bones in the folowing regions:

Upper limbs

Lower limbs

Pelvic girdle

Pectoral (shoulder) girdle

Skull

The skull is composed of ٢٢ bones that are fused together except for the mandible. These ٢١ fused bones are separate in children to allow the skull and brain to grow, but fuse to give added strength and protection as an adult. The mandible remains as a movable jaw bone and forms the only movable joint in the skull with the temporal bone.

The bones of the superior portion of the skull are known as the cranium and protect the brain from damage. The bones of the inferior and anterior portion of the skull are known as facial bones and support the eyes, nose, and mouth.

Hyoid and Auditory Ossicles

The hyoid is a small, U-shaped bone found just inferior to the mandible. The hyoid is the only bone in the body that does not form a joint with any other bone—it is a floating bone. **The hyoid's function is to help hold the trachea open and to form a bony connection for the tongue muscles**.

The malleus, incus, and stapes—known collectively as the **auditory ossicles**—are the **smallest bones in the body**. Found in a small cavity inside of **the temporal bone**, they serve to transmit and amplify sound from the eardrum to the inner ear.

Vertebrae:

Twenty-six vertebrae form the vertebral column of the human body. They are named by region:

Cervical (neck) - ٧ vertebrae

Thoracic (chest) - ١٢ vertebrae

Lumbar (lower back) - ٥ vertebrae

Sacrum - ١ vertebra

Coccyx (tailbone) - ١ vertebra

With the exception of the singular sacrum and coccyx, each vertebra is named for the first letter of its region and its position along the superior-inferior axis. For example, the most superior thoracic vertebra is called T١ and the most inferior is called T١٢.

Ribs and Sternum

The sternum, or breastbone, is a thin, knife-shaped bone located along the midline of the anterior side of the thoracic region of the skeleton. The sternum connects to the ribs by thin bands of cartilage called the costal cartilage.

There are **١٢ pairs of ribs** that together with the sternum form **the ribcage** of the thoracic region. **The first seven ribs are known as "true ribs**" because they connect the thoracic vertebrae directly to the sternum through their own band of costal cartilage**. Ribs ٨, ٩, and ١٠** all connect to the sternum through cartilage that is connected to the cartilage of the seventh rib, so we consider these to be "**false ribs." Ribs ١١ and ١٢** are also **false ribs**, but are also considered to be **"floating ribs**" because they do not have any cartilage attachment to the sternum at all.

Pectoral Girdle and Upper Limb

The pectoral girdle connects the upper limb (arm) bones to the axial skeleton and consists of **the left and right clavicles and left and right scapulae**.

The humerus is the bone of the upper arm. It forms the ball and socket **joint of the shoulder** with the scapula and forms the **elbow joint** with the lower arm bones. The **radius** and **ulna** are the two bones of the **forearm**. The ulna is on the medial side of the forearm and forms a hinge joint with the humerus at the elbow. The radius allows the forearm and hand to turn over at the wrist joint.

The lower arm bones form **the wrist joint** with the carpals, a group of eight small bones that give added flexibility to the wrist. The carpals are connected to the five metacarpals that form the bones of the hand and connect to each of the fingers. Each finger has three bones known as phalanges, except for the thumb, which only has two phalanges.

Pelvic Girdle and Lower Limb

Formed by the left and right hip bones, the pelvic girdle connects the lower limb (leg) bones to the axial skeleton.

The femur is the largest bone in the body and the only bone of the thigh (femoral) region. The femur forms the ball and socket **hip joint** with the **hip bone** and forms the **knee joint** with the **tibia and patella**. Commonly called the kneecap, the **patella is special because it is one of the few bones that are not present at birth. The patella forms in early childhood to support the knee for walking and crawling.**

The **tibia and fibula** are the bones of the lower leg. The **tibia** is much larger than the fibula and **bears almost all of the body's weight**. The fibula is mainly a muscle attachment point and **is used to help maintain balance**. The **tibia and fibula** form the **ankle joint** with **the talus**, one of the seven tarsal bones in the foot.

The tarsals are a group of **seven small bones** that form the posterior end of the **foot and heel**. The tarsals **form joints** with the five long **metatarsals** of the foot. Then each of the metatarsals forms a joint **with one** of the set of **phalanges** in the toes. **Each toe has three phalanges**, except for the big toe, which only has two phalanges.

Microscopic Structure of Bones

The skeleton makes up about ٣٠-٤٠٪ of an adult's body mass. The skeleton's mass is made up of nonliving bone matrix and many tiny bone cells. Roughly half of the bone matrix's mass is water, while the other half is collagen protein and solid crystals of calcium carbonate and calcium phosphate.

Living bone cells are found on the edges of bones and in small cavities inside of the bone matrix. Although these cells make up very little of the total bone mass, they have several very important roles in the functions of the skeletal system. The bone cells allow bones to:

Grow and develop

Be repaired following an injury or daily wear

Be broken down to release their stored minerals

Types of Bones

All of the bones of the body can be broken down into five types: long, short, flat, irregular, and sesamoid.

Long. Long bones are longer than they are wide and are the major bones of the limbs. Long bones grow more than the other classes of bone throughout childhood and so are responsible for the bulk of our height as adults. A hollow medullary cavity is found in the center of long bones and serves as a storage area for bone marrow. Examples of long bones include the femur, tibia, fibula, metatarsals, and phalanges.

Short. Short bones are about as long as they are wide and are often cubed or round in shape. The carpal bones of the wrist and the tarsal bones of the foot are examples of short bones.

Flat. Flat bones vary greatly in size and shape, but have the common feature of being very thin in one direction. Because they are thin, flat bones do not have a medullary cavity like the long bones. The frontal, parietal, and occipital bones of the cranium—along with the ribs and hip bones—are all examples of flat bones.

Irregular. Irregular bones have a shape that does not fit the pattern of the long, short, or flat bones. The vertebrae, sacrum, and coccyx of the spine—as well as the sphenoid, ethmoid, and zygomatic bones of the skull—are all irregular bones.

Sesamoid. The sesamoid **bones are formed after birth inside of tendons** that run across joints. Sesamoid bones grow to protect the tendon from stresses and strains at the joint and can help to give a mechanical advantage to muscles pulling on the tendon. The **patella and the pisiform bone** of the carpals are the only sesamoid bones that are counted as part of the ٢٠٦ bones of the body. Other sesamoid bones can form in the joints of the hands and feet, but are not present in all people.

Parts of Bones

The long bones of the body contain many distinct regions due to the way in which they develop. At birth, each long bone is made of three individual bones separated by hyaline cartilage. Each end bone is called an epiphysis (epi = on; physis = to grow) while the middle bone is called a diaphysis (dia = passing through). The epiphyses and diaphysis grow towards one another and eventually fuse into one bone. The region of growth and eventual fusion in between the epiphysis and diaphysis is called the metaphysis (meta = after). Once the long bone parts have fused together, the only hyaline cartilage left in the bone is found as articular cartilage on the ends of the bone that form joints with other bones. The articular cartilage acts as a shock absorber and gliding surface between the bones to facilitate movement at the joint.

Looking at a bone in cross section, there are several distinct layered regions that make up a bone. The outside of a bone is covered in a thin layer of dense irregular connective tissue called the periosteum. The periosteum contains many strong collagen fibers that are used to firmly anchor tendons and muscles to the bone for movement. Stem cells and osteoblast cells in the periosteum are involved in the growth and repair of the outside of the bone due to stress and injury. Blood vessels present in the periosteum provide energy to the cells on the surface of the bone and penetrate into the bone itself to nourish the cells inside of the bone. The periosteum also contains nervous tissue and many nerve endings to give bone its sensitivity to pain when injured.

Deep to the periosteum is the **compact bone** that makes up the hard, mineralized portion of the bone. Compact bone is made of a matrix of hard mineral salts reinforced with tough collagen fibers. Many tiny cells called **osteocytes** live in small spaces in the matrix and help to maintain the strength and integrity of the compact bone.

Deep to the compact bone layer is a region of spongy bone where the bone tissue grows in thin columns called **trabeculae** with spaces for red bone marrow in between. The trabeculae grow in a specific pattern to resist outside stresses with the least amount of mass possible, keeping bones light but strong. **Long bones have a spongy bone on their ends** but have a hollow medullary cavity in the middle of the diaphysis. **The medullary cavity** contains **red bone marrow** during childhood, eventually turning into **yellow bone marrow** after puberty.

Articulations

An articulation, or joint, is a point of contact between bones, between a bone and cartilage, or between a bone and a tooth. Synovial joints are the most common type of articulation and feature a small gap between the bones. This gap allows a free range of motion and space for synovial fluid to lubricate the joint. Fibrous joints exist where bones are very tightly joined and offer little to no movement between the bones. Fibrous joints also hold teeth in their bony sockets. Finally, cartilaginous joints are formed where bone meets cartilage or where there is a layer of cartilage between two bones. These joints provide a small amount of flexibility in the joint due to the gel-like consistency of cartilage.

Temporal Styloid Process

The temporal styloid process is located in the posterior portion of the temporal bone. It is one of the two projections situated behind the ear. The temporal styloid process serves as an anchorage for muscles associated with the tongue and pharynx.

Bones of the Leg and Foot

The bones of the leg and foot form part of the appendicular skeleton that supports the many muscles of the lower limbs. These muscles work together to produce movements such as standing, walking, running, and jumping. At the same time, the bones and joints of the leg and foot must be strong enough to support the body's weight while remaining flexible enough for movement and balance.

The femur, or thigh bone, is the largest, heaviest, and strongest bone in the human body. Many strong thigh muscles attach to the femur and pull on the femur during movements of the hip and knee joints.

At the proximal end of the femur is a rounded prominence known as the head of the femur. The head of the femur forms the ball and socket hip joint with the acetabulum of the hip bone. The hip joint gives the leg an incredible range of motion while still providing support to the body's weight.

At the distal end of the femur, two rounded condyles meet the **tibia and fibula**...

Bones of the Pelvis and Lower Back

The bones of the pelvis and lower back work together to support the body's weight, anchor the abdominal and hip muscles, and protect the delicate vital organs of the vertebral and abdominopelvic cavities.

The vertebral column of the lower back includes the five lumbar vertebrae, the sacrum, and the coccyx. These bones work together to provide flexibility to the trunk, support the muscles of the trunk, and protect the spinal cord and spinal nerves of the back. Lumbar vertebrae support much more body weight than the other vertebrae in the body and are therefore the largest and most robust vertebrae in the body. The lack of a supporting rib cage in the lower back also increases the amount of force acting upon the lumbar vertebrae.

The sacrum and coccyx form the inferior end of the vertebral column where it meets the hip bones to form the pelvis. The triangular sacrum forms joints between the lumbar vertebrae and the hip bones. It also contains many passages for...

Bones of the Chest and Upper Back

The bones of the chest and upper back combine to form the strong, protective rib cage around the vital thoracic organs such as the heart and lungs. The rib cage also anchors the bones of the **head, neck, shoulders, and arms** to the trunk of the body. Powerful muscles that move the head and arms attach to these bones as well. The bones of the chest and their joints also support the upper body's weight.

Twelve pairs of ribs extend laterally and anteriorly from the thoracic vertebrae to meet at or near the ***sternum***. The sternum is a thin, flat, blade-shaped bone that is commonly known as the breastbone. **Ribs** are long, flat, curved bones no more than a centimeter or two in width and a few millimeters in depth. The seven superior pairs of ribs connect directly to the sternum via the costal cartilage and are collectively known as the **true ribs**. The five pairs of ribs inferior to the true ribs are considered to be **false ribs** because they do not connect directly to the...

Bones of the Arm and Hand

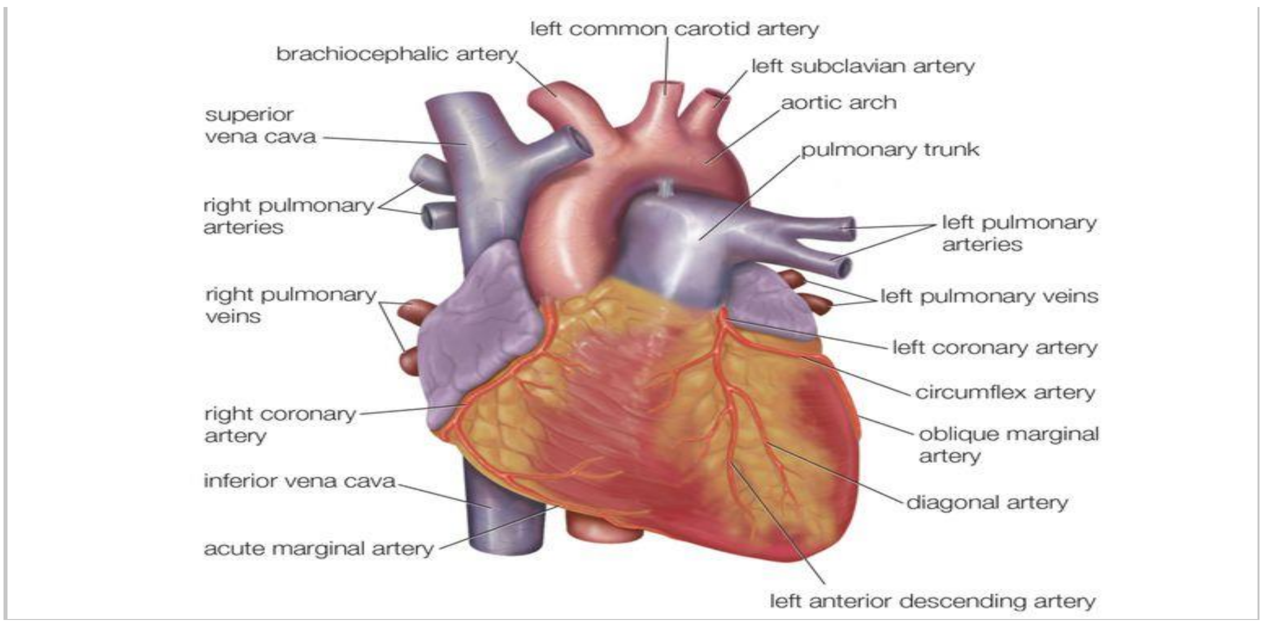
The bones of the arm and hand have the important jobs of supporting the upper limb and providing attachment points for the muscles that move the upper limb. These bones **form joints** that provide a wide range of motion and flexibility needed to manipulate objects deftly with the arm and hand. They also **provide strength** to resist the extreme forces and stresses acting upon the arms and hands during sports, exercise, and heavy labor.

Consisting of the **clavicle (collar bone**) and **scapula (shoulder blade**), the pectoral girdle forms the attachment point between the arm and the chest. **The clavicle**, which gets its name from the Latin word for key, is a long bone that connects the scapula to the sternum (breast bone) of the chest. It is located just under the skin in the thoracic region between the shoulder and the base of the neck. The clavicle is slightly curved **like a letter S** and is about five inches in length. Two joints are formed by the clavicle – the sternoclavicular...

The Anatomy of the Heart

The heart is the organ that helps supply blood and oxygen to all parts of the body. It is divided by a partition or septum into two halves, and the halves are in turn divided into four chambers. The heart is situated within the chest cavity and surrounded by a fluid filled sac called the pericardium. This amazing muscle produces electrical impulses that cause the heart to contract, pumping blood throughout the body. The heart and the circulatory system together form the cardiovascular system

Heart Anatomy



Chambers

- Atria - upper two chambers of the heart.
- Ventricles - lower two chambers of the heart.

Heart Wall

The heart wall consists of three layers:

- **Epicardium** - the outer layer of the wall of the heart.
- **Myocardium -** the muscular middle layer of the wall of the heart.
- **Endocardium** - the inner layer of the heart.

Cardiac Conduction

Cardiac Conduction is the rate at which the heart conducts electrical impulses. Heart nodes and nerve fibers play an important role in causing the heart to contract.

- **Atrioventricular Bundle -** bundle of fibers that carry cardiac impulses.
- **Atrioventricular Node -** a section of nodal tissue that delays and relays cardiac impulses.
- **Purkinje Fibers -** fiber branches that extend from the atrioventricular bundle.
- **Sinoatrial Node -** a section of nodal tissue that sets the rate of contraction for the heart.

Cardiac Cycle

The Cardiac Cycle is the sequence of events that occurs when the heart beats. Below are the two phases of the cardiac cycle:

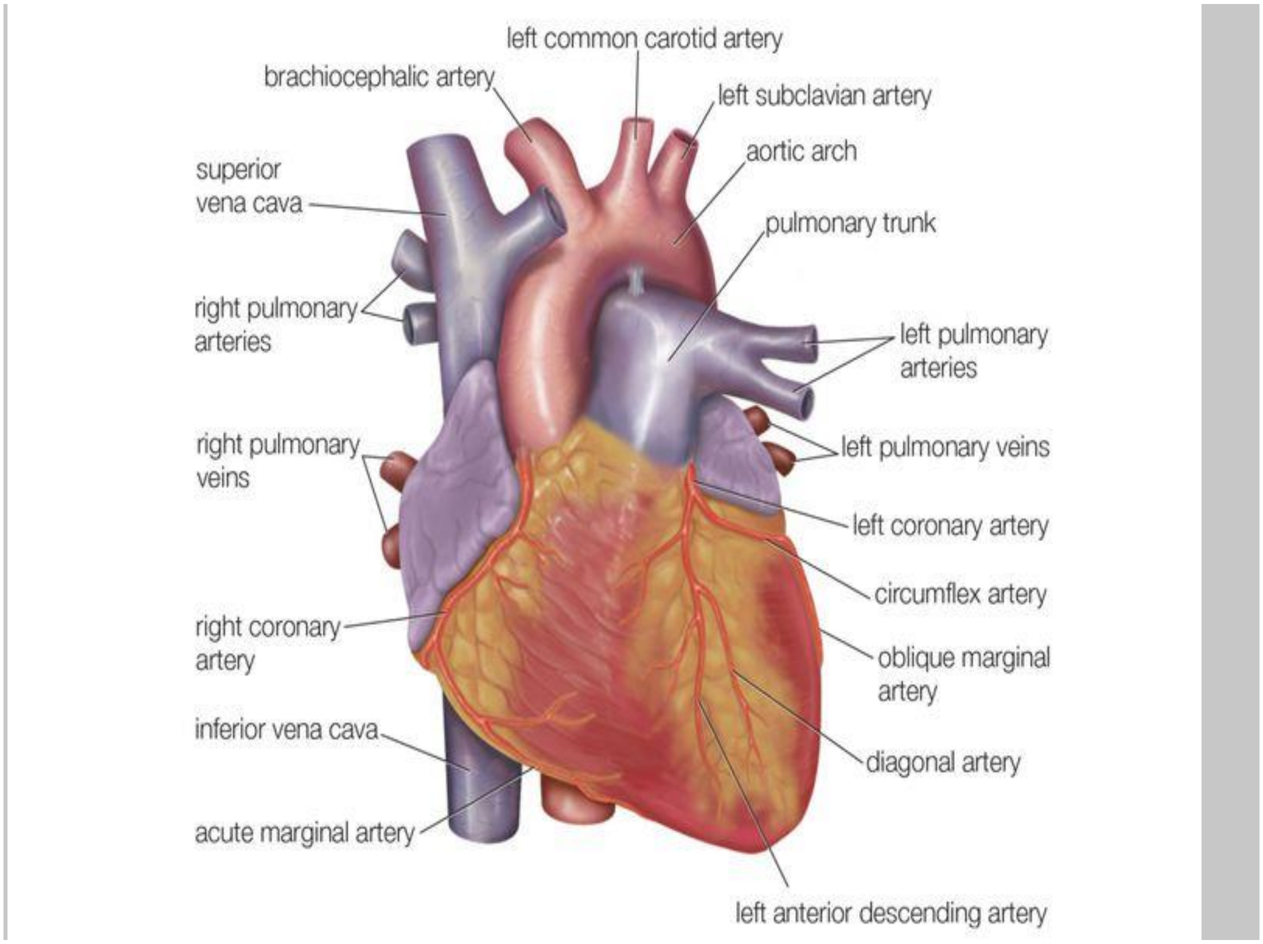
- **Diastole Phase** - the heart ventricles are relaxed and the heart fills with blood.
- **Systole Phase** - the ventricles contract and pump blood to the arteries.

Heart Anatomy: Valves

Heart valves are flap-like structures that allow blood to flow in one direction. Below are the four valves of the heart:

- **Aortic Valve** - prevents the back flow of blood as it is pumped from the left ventricle to the aorta.
- **Mitral Valve** - prevents the back flow of blood as it is pumped from the left atrium to the left ventricle.
- **Pulmonary Valve** - prevents the back flow of blood as it is pumped from the right ventricle to the pulmonary artery.
- **Tricuspid Valve** - prevents the back flow of blood as it is pumped from the right atrium to the right ventricle.

Blood Vessels



Blood vessels are intricate networks of hollow tubes that transport blood throughout the entire body. The following are some of the blood vessels associated with the heart:

Arteries:

- Aorta - the largest artery in the body of which most major arteries branch off from.
- Brachiocephalic Artery - carries oxygenated blood from the aorta to the head, neck and arm regions of the body.
- Carotid Arteries - supply oxygenated blood to the head and neck regions of the body.

- Common iliac Arteries - carry oxygenated blood from the abdominal aorta to the legs and feet.
- Coronary Arteries - carry oxygenated and nutrient filled blood to the heart muscle.
- Pulmonary Artery - carries de-oxygenated blood from the right ventricle to the lungs.
- Subclavian Arteries - supply oxygenated blood to the arms.

Veins:

- Brachiocephalic Veins - two large veins that join to form the superior vena cava.
- Common iliac Veins - veins that join to form the inferior vena cava.
- Pulmonary Veins - transport oxygenated blood from the lungs to the heart.
- Venae Cavae - transport de-oxygenated blood from various regions of the body to the heart.

Cardiovascular System Anatomy

The Heart

The **heart** is a muscular pumping organ located medial to the lungs along the body's midline in the thoracic region. The bottom tip of the heart, known as its apex, is turned to the left, so that about ٢/٣ of the heart is located on the body's left side with the other ١/٣ on right. The top of the heart, known as the heart's base, connects to the great blood vessels of the body: the **aorta**, vena cava, pulmonary trunk, and pulmonary veins.

Circulatory Loops

There are ٢ primary circulatory loops in the human body: the *pulmonary circulation loop* and the *systemic circulation loop*.

١. Pulmonary circulation transports deoxygenated blood from the right side of the heart to the **lungs**, where the blood picks up oxygen and returns to the left side of the heart. The pumping chambers of the heart that support the pulmonary circulation loop are the right atrium and right ventricle.

٢. Systemic circulation carries highly oxygenated blood from the left side of the heart to all of the tissues of the body (with the exception of the heart and lungs). Systemic circulation removes wastes from body tissues and returns deoxygenated blood to the right side of the heart. The left atrium and left ventricle of the heart are the pumping chambers for the systemic circulation loop.

Blood Vessels

Blood vessels are the body's highways that allow blood to flow quickly and efficiently from the heart to every region of the body and back again. The size of blood vessels corresponds with the amount of blood that passes through the vessel. All blood vessels contain a hollow area called the lumen through which blood is able to flow. Around the lumen is the wall of the vessel, which may be thin in the case of capillaries or very thick in the case of arteries.

All **blood vessels** are lined with a thin layer of simple squamous epithelium known as the endothelium that keeps blood cells inside of the blood vessels and prevents clots from forming. The endothelium lines the entire circulatory system, all the way to the interior of the heart, where it is called the endocardium.

There are three major types of blood vessels: arteries, capillaries and veins. Blood vessels are often named after either the region of the body through which they carry blood or for nearby structures. For example, the **brachiocephalic artery** carries blood into the brachial (arm) and cephalic (head) regions. One of its branches, the subclavian artery, runs under the clavicle; hence the name subclavian. The subclavian artery runs into the axillary region where it becomes known as the axillary artery.

١. *Arteries and Arterioles*: Arteries are blood vessels that carry blood away from the heart. Blood carried by arteries is usually highly oxygenated, having just left the lungs on its way to the body’s tissues. The pulmonary trunk and arteries of the pulmonary circulation loop provide an exception to this rule – these arteries carry deoxygenated blood from the heart to the lungs to be oxygenated.

   Arteries face high levels of blood pressure as they carry blood being pushed from the heart under great force. To withstand this pressure, the walls of the arteries are thicker, more elastic, and more muscular than those of other vessels. The largest arteries of the body contain a high percentage of elastic tissue that allows them to stretch and accommodate the pressure of the heart.

   Smaller arteries are more muscular in the structure of their walls. The smooth muscles of the arterial walls of these smaller arteries contract or expand to regulate the flow of blood through their lumen. In this way, the body controls how much blood flows to different parts of the body under varying circumstances. The regulation of blood flow also affects blood pressure, as smaller arteries give blood less area to flow through and therefore increases the pressure of the blood on arterial walls.

   Arterioles are narrower arteries that branch off from the ends of arteries and carry blood to capillaries. They face much lower blood pressures than arteries due to their greater number, decreased blood volume, and distance from the direct pressure of the heart. Thus arteriole walls are much thinner than those of arteries. Arterioles, like arteries, are able to use smooth muscle to control their aperture and regulate blood flow and blood pressure.

٢. *Capillaries*: Capillaries are the smallest and thinnest of the blood vessels in the body and also the most common. They can be found running throughout almost every tissue of the body and border the edges of the body's avascular tissues. Capillaries connect to arterioles on one end and venules on the other.

   Capillaries carry blood very close to the cells of the tissues of the body in order to exchange gases, nutrients, and waste products. The walls of capillaries consist of only a thin layer of endothelium so that there is the minimum amount of structure possible between the blood and the tissues. The endothelium acts as a filter to keep blood cells inside of the vessels while allowing liquids, dissolved gases, and other chemicals to diffuse along their concentration gradients into or out of tissues.

   Precapillary sphincters are bands of smooth muscle found at the arteriole ends of capillaries. These sphincters regulate blood flow into the capillaries. Since there is a limited supply of blood, and not all tissues have the same energy and oxygen requirements, the precapillary sphincters reduce blood flow to inactive tissues and allow free flow into active tissues.

٣. *Veins and Venules*: Veins are the large return vessels of the body and act as the blood return counterparts of arteries. Because the arteries, arterioles, and capillaries absorb most of the force of the heart's contractions, veins and venules are subjected to very low blood pressures. This lack of pressure allows the walls of veins to be much thinner, less elastic, and less muscular than the walls of arteries.

   Veins rely on gravity, inertia, and the force of skeletal muscle contractions to help push blood back to the heart. To facilitate the movement of blood, some veins contain many one-way valves that prevent blood from flowing away from the heart. As skeletal muscles in the body contract, they squeeze nearby veins and push blood through valves closer to the heart.

   When the muscle relaxes, the valve traps the blood until another contraction pushes the blood closer to the heart. Venules are similar to arterioles as they are small vessels that connect capillaries, but unlike arterioles, venules connect to veins instead of arteries. Venules pick up blood from many capillaries and deposit it into larger veins for transport back to the heart.

Coronary Circulation

The heart has its own set of blood vessels that provide the myocardium with the oxygen and nutrients necessary to pump blood throughout the body. The left and right coronary arteries branch off from the aorta and provide blood to the left and right sides of the heart. The coronary sinus is a vein on the posterior side of the heart that returns deoxygenated blood from the myocardium to the vena cava.

Hepatic Portal Circulation

The veins of the stomach and intestines perform a unique function: instead of carrying blood directly back to the heart, they carry **blood to the liver** through the **hepatic portal vein**. Blood leaving the digestive organs is rich in nutrients and other chemicals absorbed from food. The **liver** removes toxins, stores sugars, and processes the products of digestion before they reach the other body tissues. Blood from the liver then returns to the heart through the inferior vena cava.