

CHAPTER 6

BLOOD AND HEMOPOIESIS

GENERAL CONCEPTS

- I. In humans, the average blood volume is 5 liters, constituting 7% of the body mass.
- II. Blood is a specialized fluid connective tissue consisting of cells and cell fragments (46% of blood volume) floating in a unique liquid extra-cellular matrix (54% of blood volume).

III. Functions

- A. Delivery of nutrients and oxygen to cells and tissues
- B. Transport of wastes and carbon dioxide away from cells and tissues
- C. Delivery of hormones and other regulatory substances to and from tissues
- D. Maintenance of homeostasis by acting as a buffer
- E. Thermoregulation
- F. Transport of cells of the immune system

IV. Components

- A. Cells and cell fragments
 - 1. **Red blood cells (erythrocytes, RBCs)**, produced in the bone marrow
 - 2. **White blood cells (leukocytes, WBCs)**, produced in the bone marrow; some lymphocytes are also produced in lymphoid tissues and organs.
 - 3. **Platelets**. Cell fragments derived from **megakaryocytes** in the bone marrow; contain granules and function in blood coagulation; 150,000-450,000 per microliter blood
- B. **Plasma**. Constitutes the extracellular matrix of blood
 - 1. Composed of 90% water and 8-9% protein.

- a. Major protein components (plasma proteins)
 - i. Albumin. Main protein component of plasma, synthesized in the liver. Establishes colloid osmotic pressure within vessels and acts as carrier protein for hormones, metabolites and drugs.
 - ii. Globulins. Includes gamma globulins which are antibodies secreted by plasma cells.
 - iii. Fibrinogen. Fiber precursor protein, which is converted into fibrin when blood clots.

2. **Serum**. Yellowish fluid remaining after blood has clotted.

RED BLOOD CELLS

- I. Cells resemble bi-concave discs, 6-8 microns in diameter; 4-6 million per microliter of blood
- II. Cells are non-nucleated. Cytoplasm contains hemoglobin and cytoskeletal elements but lacks other organelles.
- III. Transport oxygen and carbon dioxide

WHITE BLOOD CELLS *(images)*

- I. White blood cells are transported in the blood and migrate through vessel walls (diapedesis) to become active in connective tissues; 5-10 thousand per microliter of blood.

II. Granular leukocytes

A. Neutrophil (polymorphonuclear leukocyte, PMNs)

- 1. 46-81% of circulating WBCs
- 2. Spherical cell, 12-15 microns in diameter; pale or unstained cytoplasmic granules; heterochromatic nucleus with three to five lobes
- 3. Move from the blood to sites of infection
- 4. Phagocytose bacteria and debris

B. Eosinophil

- 1. 1-3% of circulating WBCs

2. Spherical cell, 12-15 microns in diameter; cytoplasmic granules stain with eosin; bi-lobed nucleus
3. Move from the blood to sites of infection
4. Secrete proteins cytotoxic to parasites, neutralize histamine, and internalize antigen-antibody complexes

C. **Basophil**

1. <1% of circulating WBCs
2. Spherical cell, 12-15 microns in diameter; cytoplasmic granules stain dark blue with hematoxylin; nucleus with 2-3 lobes
3. Similar to mast cells; participate in the hypersensitivity reaction by secreting histamine and heparin

III. **Agranular leukocytes**

A. **Lymphocyte**

1. 24-44% of circulating WBCs
2. Spherical cell, 6-8 microns in diameter; scant cytoplasm and a round heterochromatic nucleus often with a small indentation
3. T and B lymphocytes
 - a. **T lymphocytes**. Originate in the bone marrow and mature in the thymus; provide cell-mediated immunity
 - b. **B lymphocytes**. Originate in the bone marrow and are carried in the blood to lymphoid tissues and organs, where they become activated and proliferate, transform into plasma cells in connective tissue, and provide humoral immunity by secreting antibodies

B. **Monocyte**

1. 3-7% of circulating WBCs
2. Large spherical cells, 12-18 microns in diameter; abundant cytoplasm stains gray-blue; large, U-shaped, euchromatic nucleus.
3. Enter connective tissue, where they transform into macrophages; function in phagocytosis and antigen presentation

HEMOPOIESIS (*images*)

I. General considerations

- A. Hemopoiesis is the process of blood cell formation, beginning with a pluripotent stem cell that subsequently goes through a series of cell divisions and differentiation stages to produce all the mature blood cells.
- B. During fetal life, blood cells are first produced in the yolk sac, followed by the hepatic phase when blood cells, mostly erythrocytes, are produced in the liver. The third or bone marrow phase begins during the second trimester and continues until birth.
- C. Postnatal hemopoiesis occurring in red bone marrow located in the spongy bone region of long bones, vertebra, ribs, sternum, and the skull, produces erythrocytes, granular leucocytes, B lymphocytes, monocytes and platelets. Lymphocytes are also generated in lymphoid organs and tissues.
- D. Blood cells have a relatively short life span and, therefore, new cells are formed continuously.
- E. Precursor cell lineage
 - 1. **Stem cells.** Pluripotent cells that give rise to all the blood cells; divide both to renew their own cell population as well as to form progenitor cells, thus beginning the process of blood cell formation. Hemopoietic stem cells generate two major lineages, **myeloid** and **lymphoid**. Cells of the myeloid lineage consist of erythrocytes (erythropoiesis), granulocytes composed of neutrophils, eosinophils and basophils (granulopoiesis), monocytes (monocytopoiesis) and megakaryocytes (thrombopoiesis). The lymphoid lineage includes B and T lymphocytes (lymphocytopoiesis)
 - 2. **Progenitor cells.** Less potentiality than stem cells; committed to the formation of just one or two blood cell lines; have high mitotic activity, dividing to reproduce self and to form precursor cells.
 - 3. **Precursor or blast cells.** Begin morphologic differentiation; display characteristics of the mature blood cells they will form; not self-renewing
 - 4. **Mature blood cells.** Form after several cell divisions of the precursor or blast cells

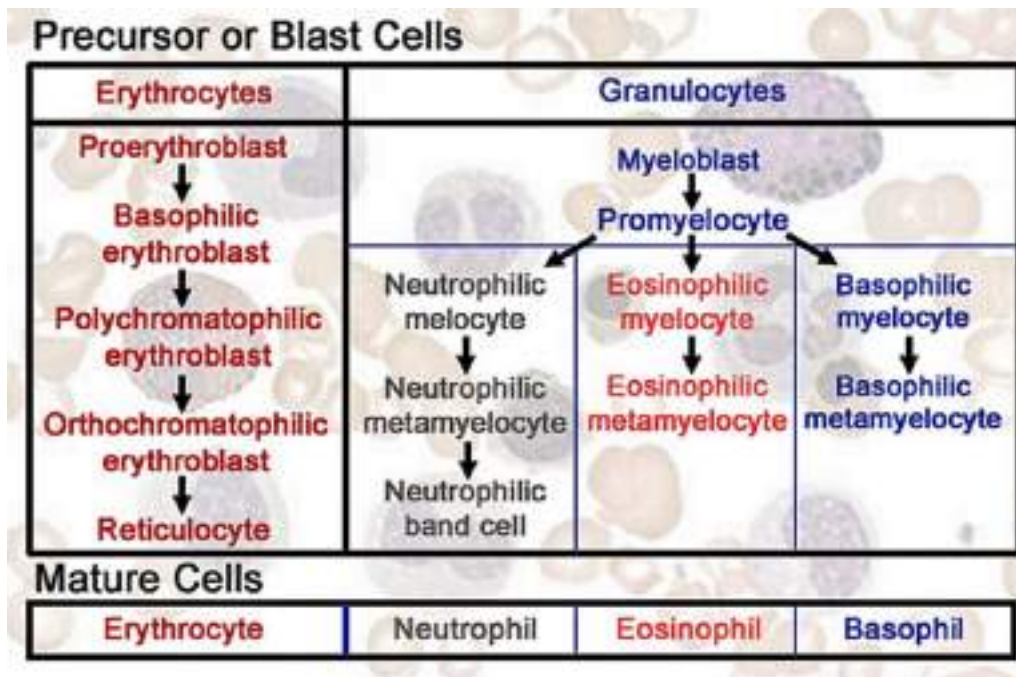


Figure 6.1. Hemopoiesis

II. **Erythropoiesis:** Formation of erythrocytes (*images*)

- A. Process that results in a non-nucleated cell filled with hemoglobin and specialized for transporting respiratory gases
- B. Stages. Cells listed in the order in which they form
 1. **Proerythroblast.** Precursor cell
 2. **Basophilic erythroblast.** Increased numbers of polyribosomes for hemoglobin production results in strong cytoplasmic basophilia; nucleus possesses a "checker-board" chromatin pattern typical of differentiating erythrocytes. The first stage of erythropoiesis that is readily identifiable.
 3. **Polychromatophilic erythroblast.** Number of polyribosomes is reduced as hemoglobin accumulates, resulting in the grayish-stained cytoplasm. No further cell division occurs beyond this stage.
 4. **Orthochromatophilic erythroblast (normoblast).** Smallest cells in the series. Continues condensation of the nucleus; increased eosinophilia of the cytoplasm due to accumulating hemoglobin. Nucleus is small, round and very heterochromatic. Late in this stage, the cell extrudes its nucleus.
 5. **Reticulocyte.** Non-nucleated cell; small number of polysomes form a reticular

network giving the cytoplasm a lilac color. The polysomes and any other organelles are degraded within one day of release forming mature erythrocytes. In normal blood, reticulocytes constitute about 1% to 2% of the total circulating red cells.

6. **Mature erythrocyte.** Biconcave shape which increases the surface to volume ratio, critical for gas exchange. Erythrocytes transport oxygen and carbon dioxide and remain in the blood for about 120 days.

III. **Granulopoiesis:** Formation of granulocytes (**images**)

- A. Process by which cells first produce nonspecific, azurophilic granules (lysosomes) and then synthesize specific granules containing proteins unique for each granulocyte cell type.
- B. Stages. Cells listed in the order in which they form
 1. **Myeloblast.** Precursor cell
 2. **Promyelocyte.** Earliest identifiable stage. Large euchromatic nucleus. Produces azurophilic (blue) granules that contain lysosomal enzymes
 3. **Myelocyte.** Nuclear condensation and the appearance of cell-specific granules containing proteins unique for each of the granular leukocytes. Azurophilic granules still present.
 4. **Metamyelocyte.** Cell-specific granules continue to accumulate and the nucleus changes morphology to resemble that of the mature cell. No further cell division after this stage.
 5. **Band or stab cell.** Nuclear indentation creates a horseshoe-shaped or band-shaped nucleus. Most apparent in the neutrophilic cell line.
 6. **Mature neutrophils, eosinophils, and basophils.** Characterized by lobulation of the nucleus and presence of specific granules unique to each cell type.

IV. **Monocytopoiesis:** Formation of monocytes

- A. **Monoblast.** Precursor cell
- B. **Promonocyte.** Large cell, up to 18 microns in diameter; nucleus becomes indented and the cytoplasm is basophilic with numerous fine azurophilic granules (lysosomes).
- C. **Mature monocyte**

V. **Thrombopoiesis:** Formation of platelets (thrombocytes) (**images**)

- A. **Megakaryoblast.** First recognizable cell, resembles a monoblast.
- B. **Promegakaryocytes.** Undergo endomitosis, a process where chromosome replication occurs but neither nuclear nor cytoplasmic division follows. Produces polyploidy cells, up to 64N.
- C. **Megakaryocytes** are large cells (50-70 microns) with a highly polymorphic nucleus.
- D. **Platelets.** Membrane bound cytoplasmic fragments pinched off from the surface of megakaryocytes that aid in blood clotting.

VI. **Lymphocytopoiesis:** Formation of lymphocytes

- A. **Lymphoblast.** Precursor cell
- B. **Pro-lymphocytes.** Reduction in size from lymphoblast; some remain in the bone marrow to produce B lymphocytes, others leave the bone marrow and travel to the thymus, where they complete their differentiation into T lymphocytes.

BONE MARROW

- I. All spaces within bones contain marrow tissue, a specialized connective tissue.
 - A. **Red marrow.** Blood forming (hemopoietic) red marrow
 - 1. Present in all bone spaces at birth.
 - 2. Converts to yellow marrow with age. Red marrow persists in the pelvic bones, sternum, skull, ribs, and scapulae, as well as in vertebrae. Also occupies the marrow spaces at the proximal ends of long bones such as the femur and humerus.
 - B. **Yellow marrow.** Fat storage
- II. Red marrow releases blood cells and platelets into the circulation throughout life.

CHAPTER 10

CARDIOVASCULAR SYSTEM

GENERAL CONCEPTS

- I. Continuous tubular system for transporting blood, carrying oxygen, carbon dioxide, hormones, nutrients, and wastes
- II. Components of the circulatory system
 - A. **Heart**. Highly modified, muscular blood vessel specialized for pumping the blood. Composed of two atria and two ventricles.
 - B. **Closed circuit of vessels**. The vessels are listed below in the order that blood would follow as it leaves the heart.
 1. **Elastic arteries** (e.g., aorta and pulmonary arteries)
 2. **Muscular arteries** (remaining named arteries)
 3. **Small arteries and arterioles**
 4. **Capillaries**
 5. **Venules and small veins**
 6. **Medium veins** (most named veins)
 7. **Large veins** (e.g., venae cavae, return blood to the heart)
- III. Circuitries of the circulatory system
 - A. **Pulmonary circulation**
 1. Circuit of blood between the heart and lungs
 2. Blood leaves the right ventricle of the heart through the **pulmonary arteries** and proceeds through a series of smaller arteries to supply **pulmonary capillaries** in the lungs. Blood returns through a series of increasingly larger veins to the **pulmonary veins** to the left atrium.
 3. Functions for exchange of carbon dioxide and oxygen between the blood and atmosphere

B. **Systemic circulation**

1. Circuit that distributes blood from the heart to the body tissues
2. Blood leaves the left ventricle of the heart through the **aorta** and proceeds through a series of smaller arteries to supply **systemic capillaries** throughout the body. Blood returns through a series of increasingly larger veins via the **superior and inferior venae cavae** to the right atrium.
3. Functions for exchange of carbon dioxide and oxygen, and nutrients and metabolic wastes between the blood and tissues; distribution of hormones.

- C. **Lymphatic circulation**. Consists of a system of blind-ended lymph vessels positioned throughout the body, which return tissue fluid to the venous circulation.

BASIC STRUCTURAL ORGANIZATION *(images)*

- I. The walls of the entire cardiovascular system, consists of three concentric layers or tunics that are continuous between both the heart and vessels. The constituents and thickness of these layers vary depending on the mechanical and metabolic functions of the vessel.

II. **Inner tunic**

- A. In the heart, this layer is called the **endocardium**; in vessels, it is termed the **tunica intima**.
- B. Composition
1. Simple squamous epithelium (**endothelium**)
 2. Varying amounts and types of connective tissue
 3. In the largest vessels, longitudinally oriented smooth muscle may be present in the connective tissue layer.

III. **Middle tunic**

- A. In the heart this layer is composed of cardiac muscle and is called the **myocardium**.
- B. In vessels this layer is composed of circularly oriented smooth muscle or smooth muscle plus connective tissue and is called the **tunica media**.

IV. **Outer tunic**

- A. In the heart, this layer consists of a serous membrane, called the **epicardium (visceral pericardium)** composed of connective tissue covered with a simple squamous epithelium (mesothelium).
- B. In vessels, this layer is called the **tunica adventitia** and is composed of connective tissue; variable amount of longitudinally arranged smooth muscle is present in this layer in the largest veins.
- C. Possesses blood vessels that supply the wall of the heart or larger blood vessels
 1. **Coronary blood vessels.** Supply the heart wall
 2. **Vasa vasorum.** Consists of a system of small blood vessels that supply the outer wall of larger vessels

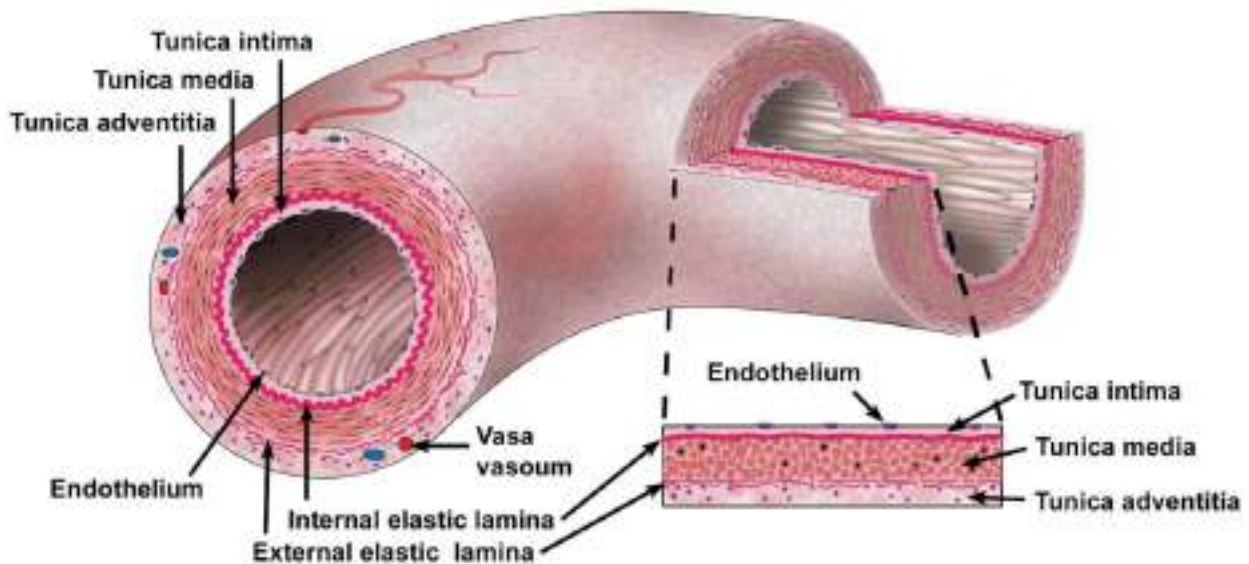


FIGURE 10.1. Structure of a muscular artery.

ARTERIES (images)

- I. General considerations
 - A. Carry blood away from the heart and toward capillary beds
 - B. Have thicker walls and smaller lumens than veins of similar size
 - C. Tunica media is the predominate tunic.

D. Cross-sectional outlines are more circular in arteries than in veins.

II. Types (Only features distinct to each type and different from the Basic Structural Organization are presented)

A. **Elastic (large) arteries (aorta, pulmonary arteries)**

1. **Internal elastic lamina** in the tunica intima adjacent to the tunica media, is present but difficult to distinguish from the elastic tissue of the tunica media.
2. Tunica media is composed of fenestrated sheets of elastic tissue (**elastic lamellae**) and smooth muscle
3. Passively maintain blood pressure by distension and recoil of the elastic sheets

B. **Muscular (medium, distributing) arteries**

1. **Internal elastic lamina.** Prominent, single, fenestrated, elastic sheet located at its border with the tunica media.
2. Tunica media is composed of smooth muscle.
3. **External elastic laminae.** Consists of fenestrated elastic sheets at the junction of the tunica media and tunica adventitia.
4. Regulate blood pressure and blood distribution by contraction and relaxation of smooth muscle in the tunica media

C. **Small arteries and arterioles**

1. Less than 200 microns in diameter
2. Small arteries have an internal elastic lamina and up to eight layers of smooth muscle in the tunica media.
3. Arterioles usually lack an internal elastic lamina and have one to two layers of smooth muscle in the tunica media.
4. Arterioles are the vessels that regulate blood pressure and deliver blood under low pressure to capillaries.

CAPILLARIES

I. General considerations

- A. Site of exchange of metabolites, wastes and gases between the vascular lumen and extravascular tissue.
- B. Lumen is approximately 8 microns in diameter, thus only large enough for RBCs to move through in a single row.
- C. Composed of the endothelium (simple squamous epithelium) and its underlying basal lamina

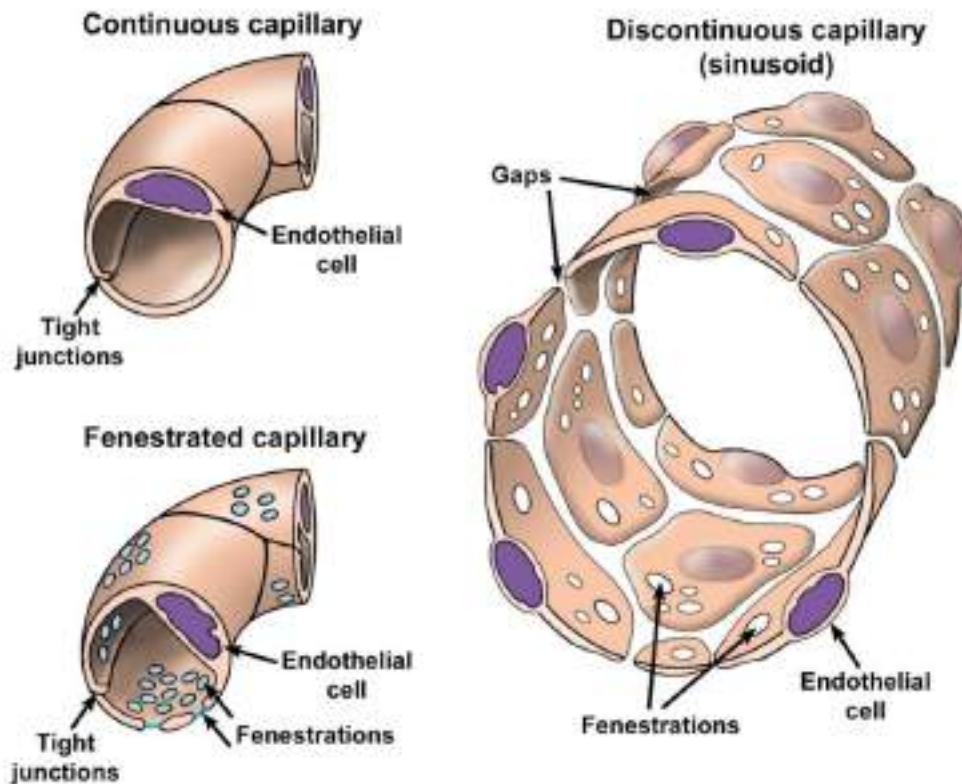


Figure 10.2. Types of capillaries

II. Types (images)

A. **Continuous capillaries**

1. Most common
2. Endothelium is continuous (i.e., has no pores)

B. **Fenestrated capillaries**

1. Endothelium contains pores that may or may not be spanned by a **diaphragm**. If present, the diaphragm is thinner than two apposed

plasma membranes.

2. Pores with diaphragms are common in capillaries in the endocrine organs and portions of the digestive tract. Pores lacking diaphragms are uniquely present in the glomerular capillaries of the kidney.
3. Pores facilitate diffusion across the endothelium

C. **Discontinuous capillaries (sinusoids)**

1. Larger diameter and slower blood flow than in other capillaries
2. Endothelium has large pores that are not closed by a diaphragm.
3. Gaps are present between adjacent endothelial cells.
4. Partial or no basal lamina present.
5. Prominent in spleen and liver

VEINS (*images*)

I. General considerations

- A. Return blood from capillary beds to the heart
- B. Have thinner walls, larger lumens and more irregular cross-sectional outlines than arteries of similar size.
- C. Tunica adventitia is the predominate tunic.
- D. Larger veins possess **valves**, that are extensions of the tunica intima that serve to prevent back-flow of blood.

II. Types (Only features distinct to each type and different from the Basic Structural Organization are presented)

A. **Venules and small veins**

1. Tunica media is absent in venules. Smooth muscle fibers appear in the tunica media as venules progress to small veins.
2. **High endothelial venules**. Venules in which the endothelium is simple cuboidal; facilitate movement of cells from the blood into the surrounding tissues (diapedesis). This type of venule is found in many of the lymphatic tissues.

- B. **Medium veins.** Tunica media is composed of connective tissue and smooth muscle, with the latter increasing to form a more definitive and continuous portion as the vein increases in size. Most named veins are in this category.
- C. **Large veins,** includes superior and inferior venae cavae; have well-developed, longitudinally oriented smooth muscle in the tunica adventitia in addition to the circularly arranged smooth muscle in the tunica media.

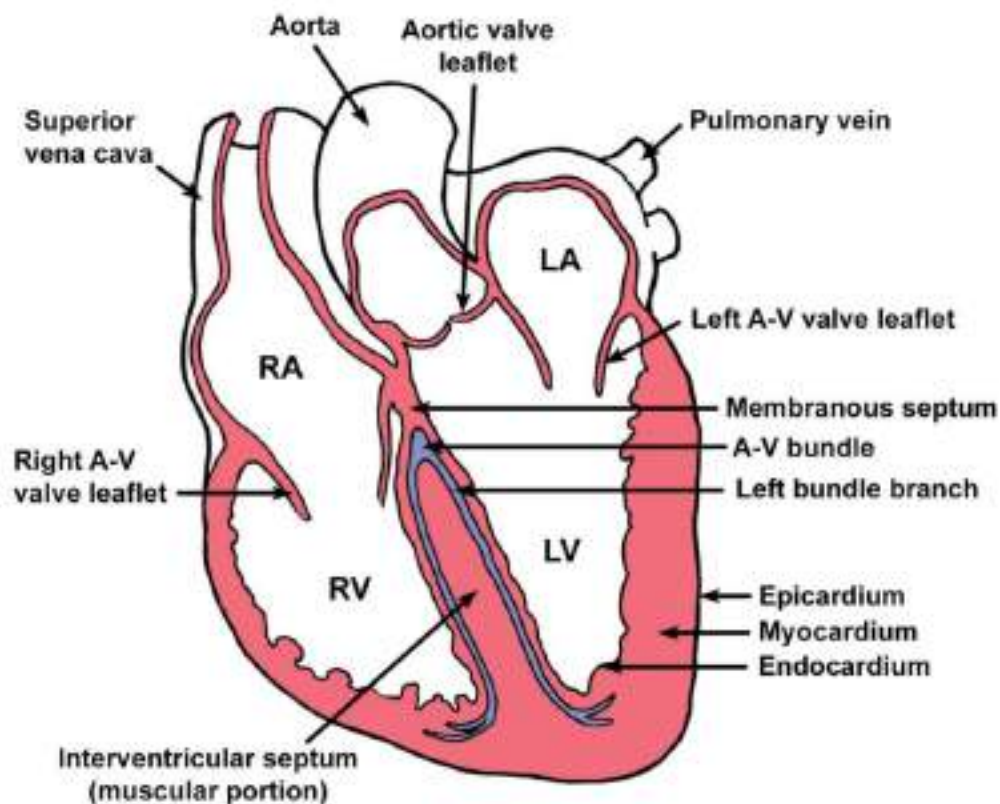


FIGURE 10.3. Diagram of a frontal section of the heart (RA, right atrium; LA, left atrium; RV, right ventricle; LV, left ventricle)

HEART *(images)*

- I. Develops by a vessel folding back on itself to produce four chambers in the adult. Two upper chambers, **atria (singular, atrium)**, receive blood from the body and lungs; two **ventricles** pump blood out of the heart.
- II. Tunics
 - A. **Endocardium**
 - 1. Homologous to the tunica intima of vessels

2. Consists of an endothelium (simple squamous epithelium) plus underlying connective tissue of varying thickness. Smooth muscle may be present in the connective tissue layer.
3. **Cardiac valves.** Folds of the endocardium
 - a. **Semilunar valves** at the bases of the aortic and pulmonary trunks prevent backflow of blood into the heart.
 - b. **Atrioventricular valves (bicuspid and tricuspid)** prevent backflow of blood from the ventricles into the atria.

B. **Myocardium**

1. Composed of cardiac muscle
2. Fibers insert on components of the cardiac skeleton.
3. Thickest layer of the heart
4. Variation in thickness depends on the function of each chamber; thicker in ventricles than atria and thicker in left ventricle than right ventricle

C. **Epicardium (visceral pericardium)**

1. Serous membrane on the surface of the myocardium
2. Consists of a simple squamous epithelium and a loose connective tissue, with adipocytes, adjacent to the myocardium.
3. Coronary blood vessels are located in the connective tissue.

III. **Cardiac skeleton.** Thickened regions of dense connective tissue that provide support for heart valves and serve as insertion of cardiac muscle fibers

- A. **Annuli fibrosi** are connective tissue rings that surround and stabilize each valve.
- B. **Fibrous trigones** regions of connective tissue that connect the annuli fibrosis
- C. **Membranous septum** is a connective tissue partition forming the upper portion of the interventricular septum; this connective tissue also separates the left ventricle from the right atrium.

IV. **Impulse conducting system.** Formed of specialized cardiac muscle fibers that initiate and coordinate the contraction of the heart

- A. **Sinoatrial (SA) node** in the right atrium is the electrical **pacemaker** that initiates the impulse.
- B. Fibers spread the impulse throughout the atria as well as transferring it to the atrioventricular node.
- C. The **atrioventricular (AV) node** is located in the **interatrial septum**.
- D. An **atrioventricular bundle** extends from the AV node in the **membranous septum** and bifurcates into right and left **bundle branches** that lie beneath the endocardium on both sides of the **interventricular septum**.
- E. **Purkinje fibers**, modified, enlarged cardiac muscle fibers leave the bundle branches to innervate the myocardium.

CHAPTER 2

CELL STRUCTURE AND CELL DIVISION

GENERAL CONCEPTS

I. Hierarchy of body organization

- A. Cells
- B. Tissues (epithelium, muscle, connective, nervous)
- C. Organs (stomach, heart, skin, lung, etc.)
- D. Organ systems (digestive, respiratory, excretory, etc.)
- E. Individual

II. Although there are approximately 200 different cell types in the body, cells are more alike than different. Specialization of function, (e.g., glandular cells for secretion or muscle cells for contraction) is really an emphasis of a function that all cells possess to some degree. In some cases, cells have become so specialized that some functions are lost altogether (e.g., cell proliferation).

III. Cells are the structural units of all living organisms.

A. Cells vary in size and shape according to location and function.

1. Cells widely in diameter, from the largest, the mature human ovum (120 microns) to the smallest, the red blood cell (7-8 microns).

2. Cells shapes. *(images)*

- a. **Spherical.** Cells in a fluid environment, e.g., blood cells or some nerve cells
- b. **Squamous.** Flattened cells with a width much greater than height. Found at surfaces where rapid exchanges of gases or fluids occur.
- c. **Cuboidal.** Cells shaped like a cube, roughly equal height and width. Often form tubes or tubules.
- d. **Columnar.** Cells shaped like columns, much taller than they are wide. Often function in absorption.

- e. **Pyramidal**. Cells shaped like a pyramid. Often found comprising spherical glandular structures.
- f. **Stellate**. Star-shaped cells. Possess many slender processes for interaction with multiple cells such as neurons.
- g. **Spindle-shaped**. Elongated shape with tapering ends.

B. Cells vary in internal structure depending upon their function.

1. Specialized cells possess abundant internal structures related to their specific function, e.g., contractile filaments in muscle cells or secretory granules in gland cells.
2. Cell polarity. Polarity is a feature of a cell which is exhibited when the organelles are not homogenously distributed in the cytoplasm. This distribution correlates with the function of the cell, e.g., secretion or absorption.

C. Cells vary in their life history, for example, rates of cell renewal.

IV. Major compartments of the cell

- A. Cytoplasm. Composed of an aqueous matrix containing the internal structures of the cell, thus allowing for the cytosolic metabolic pathways (e.g., glycolysis) to function.
- B. Nucleus

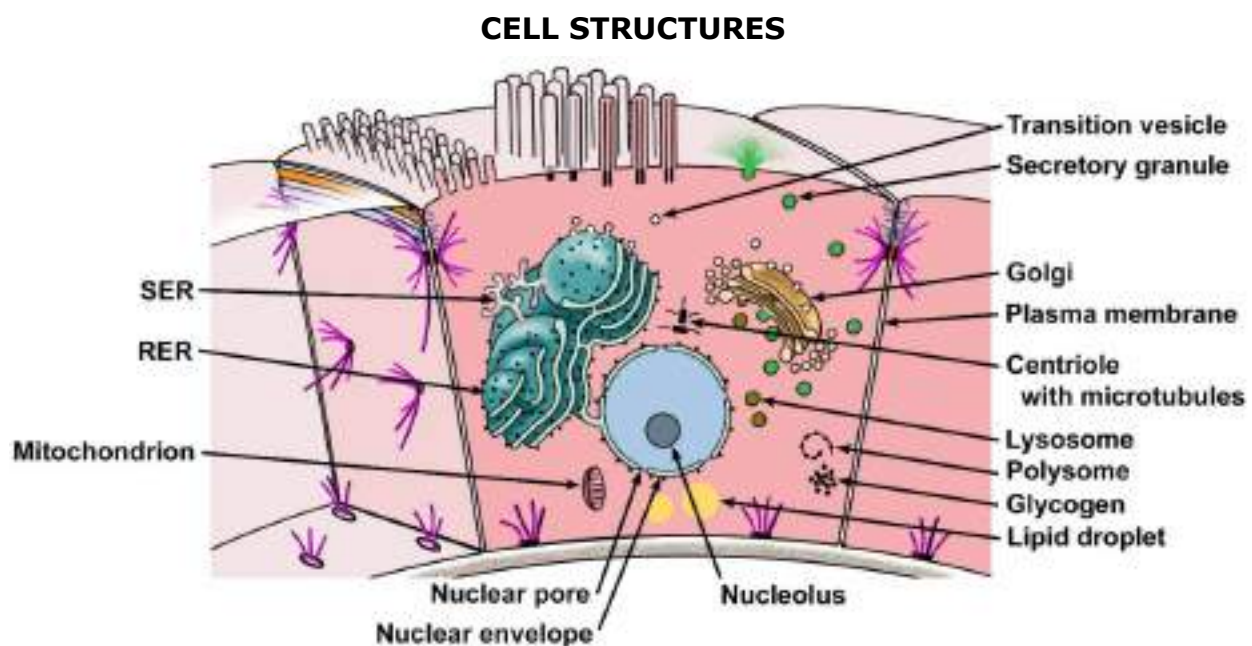


Figure 2.1. Structural features of a typical cell.

CELL MEMBRANES (*images*)

I. All membranes have a similar structure and are referred to as unit membranes. A specialized **unit membrane** forms the surface boundary of the cell and is called the **plasma membrane**. Other membranes are present within the cells, where they form mitochondria, endoplasmic reticulum, or nuclear envelope, for example. The structure of the unit membrane cannot be resolved with the light microscope; however, at high magnification with the electron microscope, it appears as a trilaminar dark-light-dark band.

A. Fluid mosaic model of membrane structure

1. **Phospholipid bilayer** consists of two leaflets of phospholipids.
 - a. The polar, phosphate head groups face the surfaces of the membrane.
 - b. The hydrocarbon tails form the hydrophobic core of the membrane.
2. Membrane proteins
 - a. **Integral membrane proteins** are proteins that extend into one or both of the phospholipid layers. Proteins that extend across both of the phospholipid layers are called transmembrane proteins.
 - b. **Peripheral membrane proteins** are either associated with the polar head groups of the phospholipids or with integral membrane proteins. They do not contact the hydrophobic core of the membrane.
3. **Glycocalyx** is composed of complex carbohydrates on the external surface of the plasma membrane. The carbohydrates are covalently attached to proteins or lipids.

II. Functions of the plasma membrane

A. Membrane transport

1. **Diffusion**
 - a. Passive diffusion
 - b. Facilitated diffusion. Utilizes transmembrane proteins to increase the permeability of the membrane to certain materials.
2. **Active transport**. Energy-requiring process of moving materials across the membrane.
3. **Vesicular transport**

- a. **Endocytosis**. Internalization of small membrane vesicles formed from the plasma membrane
 - i. **Pinocytosis** ("cell drinking"). Uptake of fluid into the cell by a continuous process
 - ii. **Receptor-mediated endocytosis**. Requires receptor-ligand binding for vesicle formation and internalization
 - b. **Phagocytosis** ("cell eating"). Ingestion of large particles (e.g., bacteria) into the cell; prominent in some macrophages and white blood cells.
 - c. **Exocytosis**. Fusion of cytoplasmic vesicles with the plasma membrane and release of the vesicle contents to the outside of the cell
 - i. **Constitutive exocytosis**. Continuous process that renews the plasma membrane.
 - ii. **Regulated exocytosis**. Requires an extracellular signal for vesicle fusion and release (e.g., hormone secretion)
 - d. **Transcytosis**. Uptake of material on one side of a cell followed by transport and release from the opposite surface
- B. Cell adhesion. Proteins provide cell-to-cell attachment and cell-to-extracellular matrix anchorage.
 - C. Intercellular communication. Transmembrane proteins assemble to form pores (gap junctions) between cells.
 - D. Signal transduction. Following interaction with extracellular signals, e.g., hormones and growth factors, receptor proteins initiate intracellular signaling pathways.

NUCLEUS *(images)*

I. Houses the DNA; produces ribosomes and messenger RNA

II. Components

A. **Nuclear envelope**

1. Composed of two unit membranes, **inner and outer nuclear membranes**, which are separated by the **perinuclear space**; outer

membranes and space are continuous with those of the endoplasmic reticulum.

2. Outer membrane possesses ribosomes.
3. **Nuclear pores**. Perforations in the nuclear envelope, provide direct, bidirectional continuity between the contents of the nucleus and the cytoplasm.
 - a. Inner and outer nuclear membranes become continuous at the rim of the pore.
 - b. Pores are surrounded by an octet of proteins with a central granule comprising the **nuclear pore complex**.
4. **Nuclear lamina**. Intermediate filaments on the inner nuclear membrane provide support for the nuclear envelope.

B. **Nucleolus**

1. Site of ribosomal RNA (rRNA) synthesis and initial ribosome subunit assembly
2. Subdivisions of the nucleolus
 - a. **Nucleolar organizing centers (fibrillary centers)**. Pale staining regions containing DNA sequences that encode rRNA
 - b. **Pars fibrosa (dense fibrillar components)**. Electron dense fibrillar regions composed of rRNA transcripts
 - c. **Pars granulosa**. Granular-appearing regions composed of maturing ribosome particles

C. **Chromatin**

1. Composed of DNA plus protein, mostly histone protein
2. Chromatin exists in transcriptionally active and inactive states.
 - a. **Euchromatin**. Refers to the state of chromatin that is transcriptionally active, dispersed, and pale staining
 - b. **Heterochromatin**. Refers to the state of chromatin that is transcriptionally inactive, condensed, and dark staining

- D. **Nucleoplasm**. Similar to cytoplasm, an aqueous matrix with cytoskeletal elements

ENDOPLASMIC RETICULUM (*images*)

I. Intracellular system of membranes

II. Rough endoplasmic reticulum (RER)

- A. Flattened membrane sacs; can occur singly or as multiple, parallel stacks
- B. Continuous with the nuclear envelope
- C. Possesses ribosomes on the cytoplasmic surface
- D. Site of protein synthesis and some phospholipid synthesis

III. Smooth endoplasmic reticulum (SER)

- A. Tubular membranous structures in a meshwork configuration that is continuous with rough endoplasmic reticulum; lack ribosomes
- B. Highly specialized in muscle cells where it is called the **sarcoplasmic reticulum**
- C. Functions
 - 1. Synthesis of triglycerides, cholesterol, and steroid hormones
 - 2. Detoxifies drugs
 - 3. Stores and mobilizes calcium

RIBOSOMES

I. **Ribosomes** are composed of two subunits containing rRNA and proteins.

II. Site of translation of messenger RNA (mRNA) to produce protein

III. Distribution

- A. Free in the cytoplasm. **Polysomes (polyribosomes)**, spiral clusters of ribosomes along a mRNA molecule; synthesize proteins for use in the cytoplasm, mitochondria, peroxisomes, and nucleus
- B. Associated with membranes
 - 1. Attached to the endoplasmic reticulum or outer nuclear membrane

CHAPTER 4

CONNECTIVE TISSUE PROPER

GENERAL CONCEPTS FOR ALL CONNECTIVE TISSUES

I. Connective tissues are unique in that they provide form and framework to organs and the body. The consistency of the framework they contribute varies from a liquid, to the pliancy of a gel, to the rigidity found in bone. Collectively, connective tissues are the only tissues that possess extensive extracellular components (stroma) in addition to parenchymal cells.

II. Functions

- A. Provides substance and form to the body and organs
- B. Defends against infection
- C. Aids in injury repair
- D. Provides a cushion between tissues and organs
- E. Stores lipids
- F. Provides a medium for diffusion of nutrients and wastes
- G. Attaches muscle to bone and bone to bone
- H. Provide support (cartilage and bone)

III. Components

- A. Cells
- B. Extracellular matrix
 - 1. Fibers
 - a. Collagen
 - b. Elastic
 - c. Reticular
- C. Ground substance

IV. Types of connective tissue. Classified by the relative abundance, variety and content of the components

A. Connective tissue proper

B. Cartilage (see Chapter 5)

C. Bone (see Chapter 5)

D. Special. Includes adipose, elastic reticular and mucus connective tissues as well as blood and hemopoietic tissue. (See Chapter 6)

COMPOSITION OF CONNECTIVE TISSUES

I. **Cells**. Each type of connective tissue has its own characteristic complement of one or more cell types. Cells specific to each type of connective tissue will be discussed with each tissue.

II. **Extracellular matrix** is synthesized and secreted by resident "blast" cells specific for each connective tissue type (e.g., fibroblasts and chondroblasts); Extracellular matrix is composed of:

A. **Fibers**. *(images)*

| Fiber type | Composition | Properties |
|------------|----------------|-----------------------------------|
| Collagen | Collagen I, II | Inelastic, eosinophilic |
| Reticular | Collagen III | Inelastic, branched, argyrophilic |
| Elastic | Elastin | Elastic, eosinophilic |

1. Collagen fibers

a. Tropocollagen

- Collagen molecule subunit consisting of three alpha chains intertwined in a triple helix; collagen types are distinguished by their subunit composition.
- Produced by fibroblasts, chondroblasts, chondrocytes and osteoblasts.
- Secreted into the matrix, where they orient themselves into fibrils with a 64 nm repeating banding pattern

b. Major collagen types

- Type I**. Fibrils aggregate into fibers and fiber bundles; most

widespread distribution; Forms a component of the extracellular matrix ("interstitial collagen"), tendons, ligaments and capsules of organs.

- ii. **Type II.** Fibrils do not form fibers; present in hyaline and elastic cartilages
- iii. **Type III.** Fibrils aggregate into fibers; present surrounding smooth muscle cells and nerve fibers. Forms the stroma of lymphatic tissues and organs.
- iv. **Type IV.** Chemically unique form of collagen that does not form fibrils; major component of the basal lamina

2. **Elastic fibers**

- a. Composed primarily of elastin
- b. Elastin forms the central amorphous core of the fiber which is surrounded by microfibrils.
- c. Unique chemical properties of elastin provide for elasticity.
- d. Elastic fibers occur in nearly all connective tissues in varying amounts and are intermixed with collagen fibers. When present exclusively, they constitute elastic connective tissue.
- e. Frequently difficult to differentiate from collagen with conventional stains.

3. **Reticular fibers**

- a. Collagen type III fibers
- b. Highly glycosylated and stain with silver (argyrophilic)
- c. When they are the major fiber type (e.g., in the stroma of lymphoid organs), they constitute reticular connective tissue.

B. **Ground substance**

- 1. An amorphous substance of variable consistencies from liquid to gelatinous (depending on connective tissue type), in which cells and fibers are embedded. Ground substance can also be impregnated with calcium phosphate to form a rigid solid in the case of bone. The differences in the ground substance among the connective tissues confer unique structural qualities to each connective tissue.

2. Functions

- a. Provides a medium for passage of molecules and cells migrating through the tissue.
- b. Contains adhesive proteins that regulate cell movements and provide anchorage.
- c. Retards passage of bacteria
- d. Provides a medium for passage of molecules and cells migrating through the tissue.

3. Components

a. **Glycosaminoglycans (GAGs)**

- i. Long, unbranched polysaccharides composed of repeating disaccharide units, which are usually sulfated.
- ii. Large negative charge of the sugars attracts cations, resulting in a high degree of hydration. The matrix formed ranges from a liquid passageway to a viscous shock absorber.
- iii. GAGs are generally attached to proteins to form **proteoglycans**.
- iv. **Proteoglycan aggregate**. Many proteoglycans are attached to hyaluronic acid, which is itself a glycosaminoglycan.

b. **Adhesive glycoproteins**. For example fibronectin and laminin.

c. **Tissue fluid**. Contains salts, ions and soluble protein.

GENERAL CONCEPTS FOR CONNECTIVE TISSUE PROPER

- I. Connective tissue proper comprises a functionally and structurally diverse group of tissues.

II. Functions

A. Structural functions of connective tissue proper

- 1. Forms a portion of the wall of hollow organs and vessels and the stroma of solid organs
- 2. Forms the stroma of organs and subdivides organs into functional compartments

3. Provides padding between and around organs and other tissues
 4. Provides anchorage and attachment (e.g., muscle insertions)
- B. Provides a medium for nutrient and waste exchange
- C. Stores lipid in adipocytes
- D. Defends the body and provides immune surveillance via lymphoid and phagocytic cells

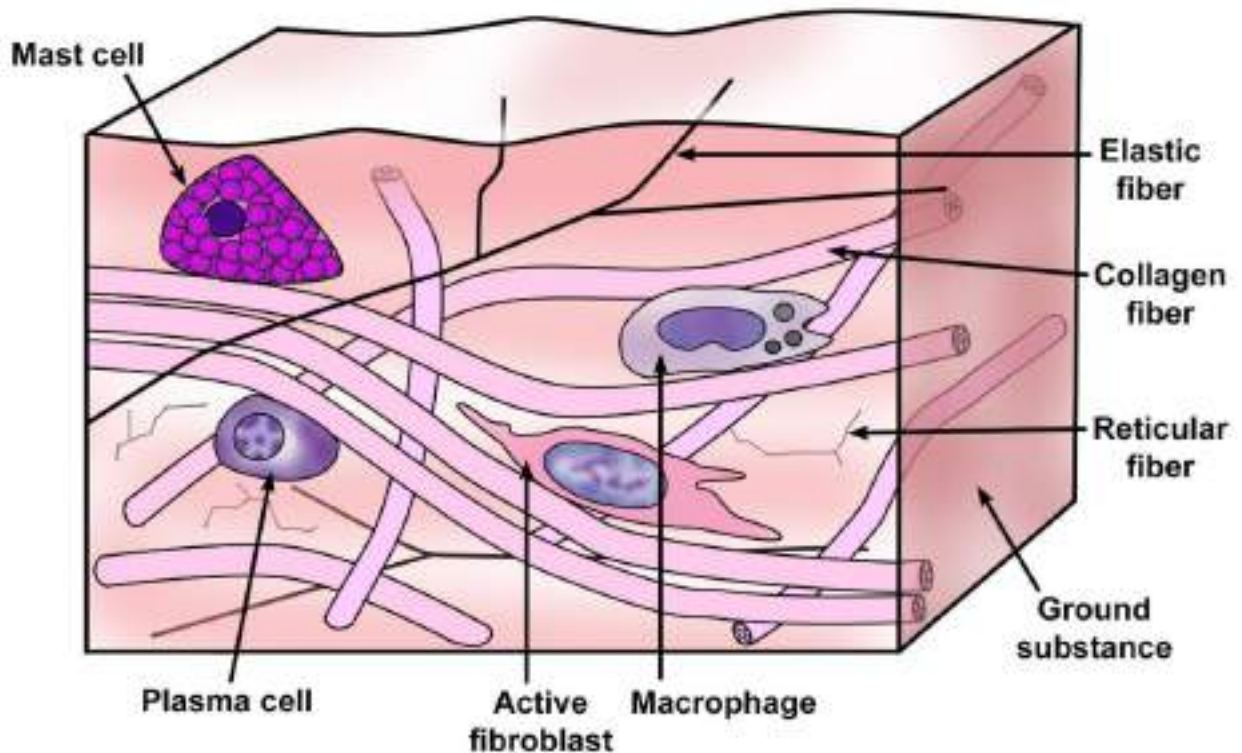


Figure 4.1. Components of connective tissue proper

CELLS OF CONNECTIVE TISSUE PROPER (images)

- I. Connective tissue cells can be grouped into two major groups, resident and migratory.
 - A. **Resident cells** are present in tissues continuously and typically exhibit little movement. They can be regarded as permanent residents of the tissue. They can be derived from mesenchyme (embryonic connective tissue) and hemopoietic (bone marrow) tissue.
 1. Fibroblasts

- a. Synthesize and maintain fibers and ground substance
- b. Major resident cell in connective tissue proper
- c. Active and inactive fibroblasts
 - i. **Active fibroblast**
 - (a). Large, euchromatic, oval nucleus
 - (b). Cytoplasm not usually visible but contains abundant rough endoplasmic reticulum and Golgi
 - (c). Either elongated, spindle-shaped cells or stellate in shape, depending on connective tissue type in which they are located
 - (d). High synthetic activity
 - ii. **Inactive fibroblast**
 - (a). Small, heterochromatic, flattened nucleus
 - (b). Reduced cytoplasm and organelles
 - (c). Low synthetic activity

2. **Adipose cells (adipocytes, fat cells)**

- a. Store lipids
 - i. Types
 - (a). **Yellow fat (unilocular)**
 - 1. Each cell contains a single droplet of neutral fat (triglycerides) for energy storage and insulation.
 - 2. Minimal cytoplasm, present as a rim around the lipid droplet
 - 3. Flattened, heterochromatic, crescent-shaped nucleus that conforms to the contour of the lipid droplet
 - 4. Can occur singly, in small clusters or forming a large mass, which is then referred to as adipose connective tissue
 - (b). **Brown fat (multilocular)**

1. Cells contain numerous, small lipid droplets.
2. Large numbers of mitochondria
3. Present mostly during early postnatal life in humans, abundant in hibernating animals for heat production

3. **Macrophages**

- a. Derived from blood monocytes. Monocytes enter connective tissue from the bloodstream and rapidly transform into macrophages that function in phagocytosis, antigen processing, and cytokine secretion.
- b. Comprise the mononuclear phagocyte system of the body that includes Kupffer cells in the liver, alveolar macrophages in the lung, microglia in the central nervous system, Langerhan's cells in the skin, and osteoclasts in bone marrow.
- c. Structure
 - i. Oval nucleus with an indentation in the nuclear envelope; prominent perinuclear heterochromatin
 - ii. Cytoplasm usually not visible unless it contains phagocytosed material

4. **Mast cells**

- a. Mediate immediate hypersensitivity reaction and anaphylaxis by releasing immune modulators from cytoplasmic granules, in response to antigen binding with cell surface antibodies
- b. Structure
 - i. Round to oval-shaped cells
 - ii. Round, usually centrally located nucleus
 - iii. Well-defined cytoplasm filled with secretory granules containing immune-modulatory compounds (e.g., histamine and heparin)

- B. **Migratory cells.** Migratory or wandering cells are present only transiently and are mobile. They are white blood cells (WBC's leucocytes), derived from hemopoietic tissue in the bone and function primarily in connective tissue. Migratory cells, for the most part, are able to enter and leave the tissue in response to specific, local stimuli.

1. **Lymphocytes (T and B lymphocytes)**. Small spherical cells with sparse cytoplasm and a round heterochromatic nucleus, often with a small indentation
 - a. **B cells**. Enter connective tissue and transform into plasma cells.
 - i. Secrete antibodies to provide humoral immunity
 - ii. Oval-shaped cells with a round, eccentrically located nucleus with heterochromatin clumps frequently arranged like the numerals on a clock face.
 - iii. Basophilic cytoplasm due to large amounts of rough endoplasmic reticulum.
 - iv. Well-developed Golgi complex appears as a distinct, unstained region in the cytoplasm near the nucleus and, for that reason, is often referred to as a "**negative Golgi**".
 - b. **T cells**. Provide cellular immunity and modulate the immune response. Primarily located in lymphatic tissues and organs; however can also be present in connective tissue proper.
2. **Neutrophils (polymorphonuclear leukocytes, PMNs)**
 - a. Spherical cells with a heterochromatic nucleus with three to five lobes
 - b. Pale-staining cytoplasmic granules
 - c. Highly phagocytic cells that are attracted to sites of infection
3. **Eosinophils**
 - a. Spherical cells with a bi-lobed nucleus
 - b. Cytoplasmic granules stain intensely with eosin.
 - c. Modulate the inflammatory process

CLASSIFICATION OF CONNECTIVE TISSUES (images)

I. Connective tissue proper

A. Loose (areolar)

1. Highly cellular, numerous cell types present

2. Fewer and smaller caliber collagen fibers compared with dense
3. Abundant ground substance, allows for diffusion of nutrients and wastes
4. Highly vascularized
5. Provides padding between and around organs and tissues

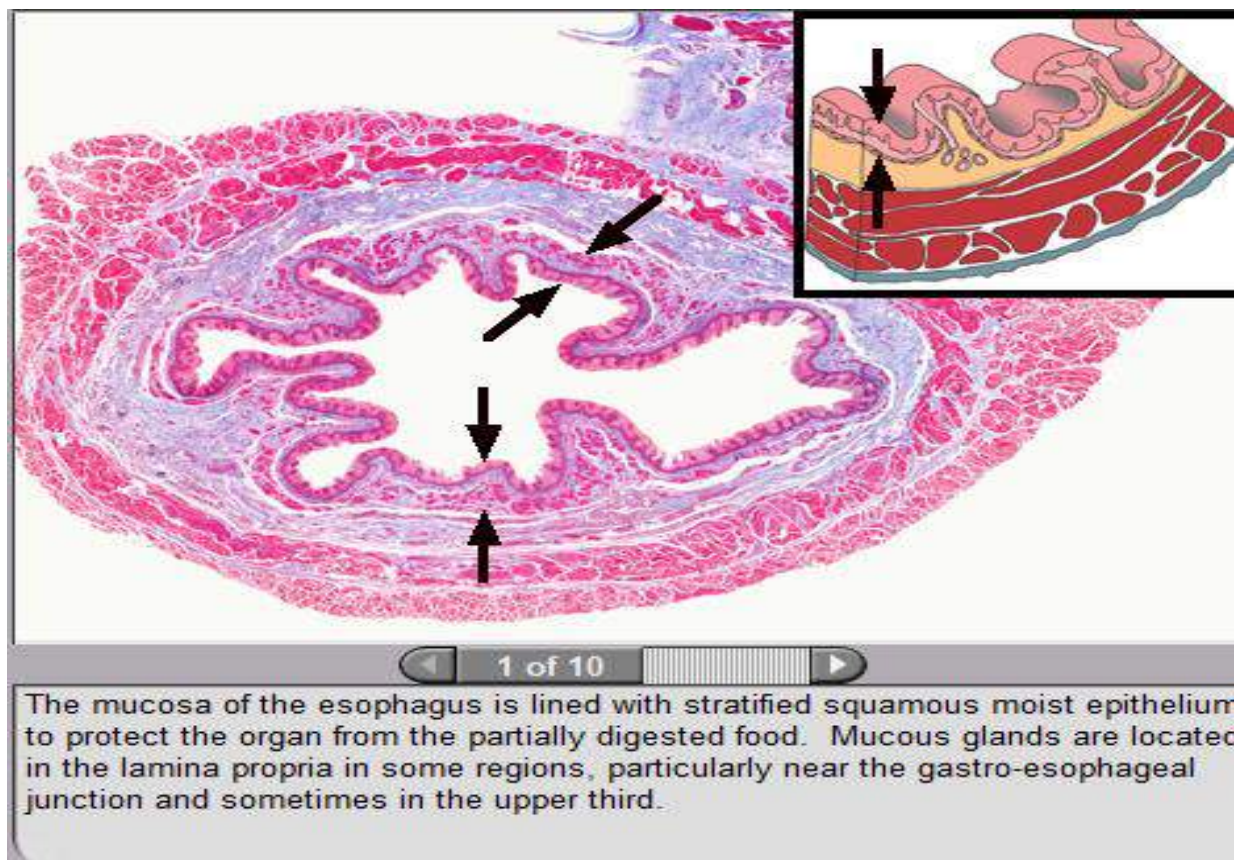
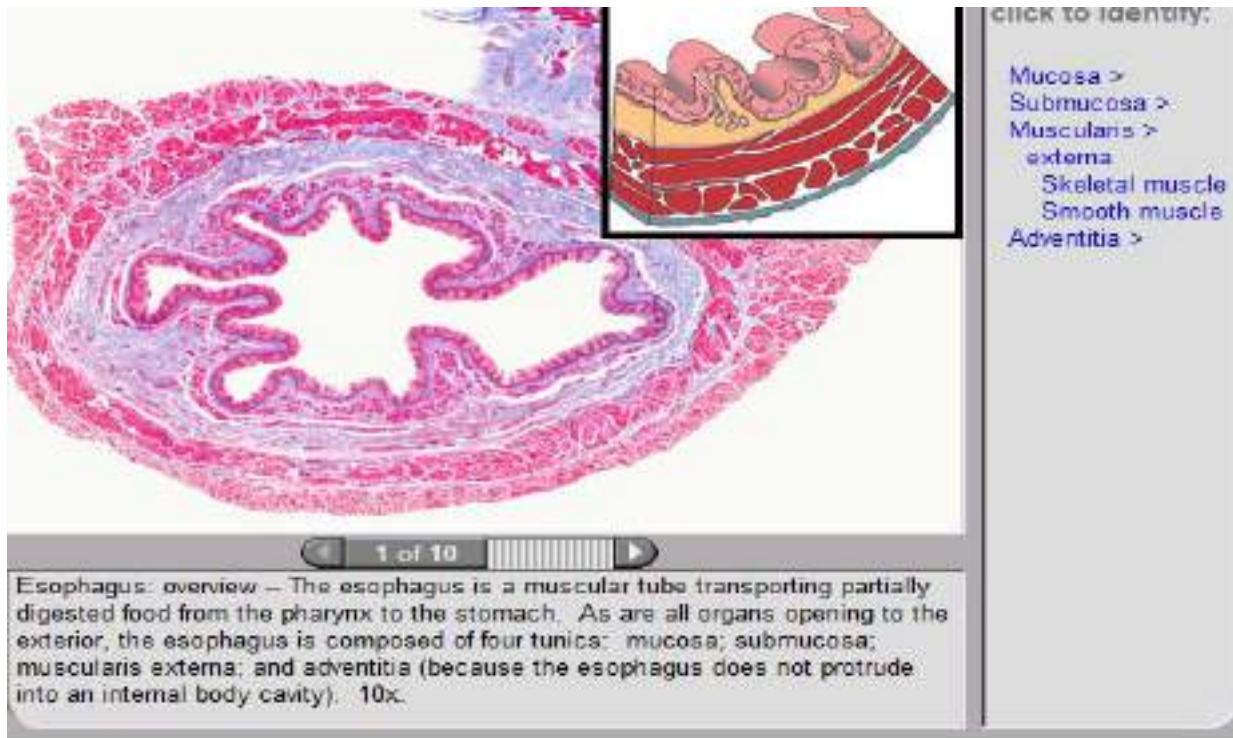
B. **Dense**

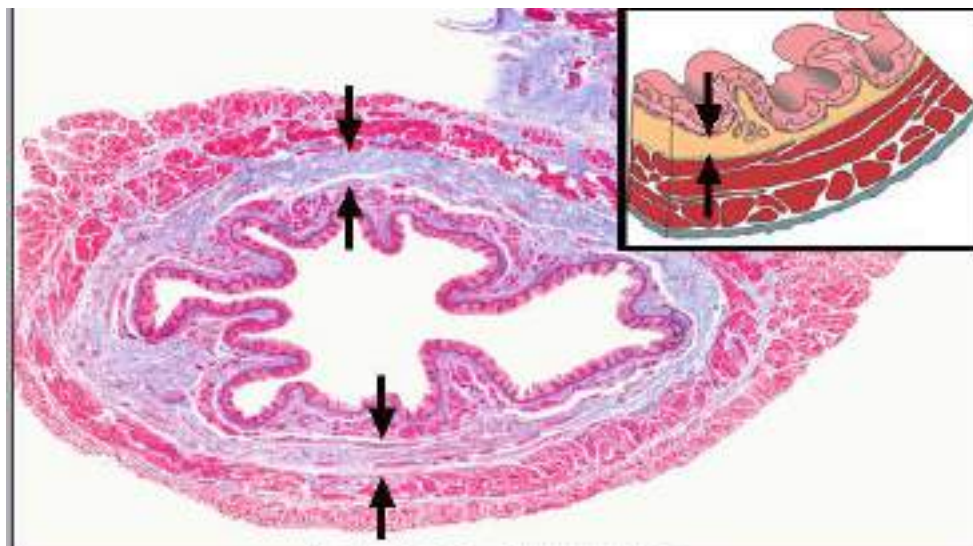
1. Fewer cells, mostly fibroblasts
2. Highly fibrous with larger caliber collagen fibers, provides strength
3. Minimal ground substance
4. Poorly vascularized
5. Types
 - a. **Dense, irregular connective tissue.** Fiber bundles arranged in an interlacing pattern; forms the capsule of organs and the dermis of the skin
 - b. **Dense regular connective tissue.** Parallel arrangement of fiber bundles; restricted to tendons and ligaments

II. Connective tissues with special properties

- A. **Adipose connective tissue.** Consists of accumulations of adipocytes that are partitioned into lobules by septa of connective tissue proper. Provides energy storage and insulation
- B. **Blood and hemopoietic (blood-forming) tissues** (Chapter 6)
- C. **Elastic connective tissue.** Regularly arranged elastic fibers or sheets (e.g., the vocal ligament)
- D. **Reticular connective tissue.** A loosely arranged connective tissue whose fibers are reticular fibers. Forms the stroma of hemopoietic tissue (e.g., bone marrow) and lymphoid organs (e.g., lymph node and spleen).
- E. **Mucus connective tissue.** Embryonic connective tissue with abundant ground substance and delicate collagen fibers; present in the umbilical cord

III. **Supportive connective tissues – Cartilage and Bone** (Chapter 5)



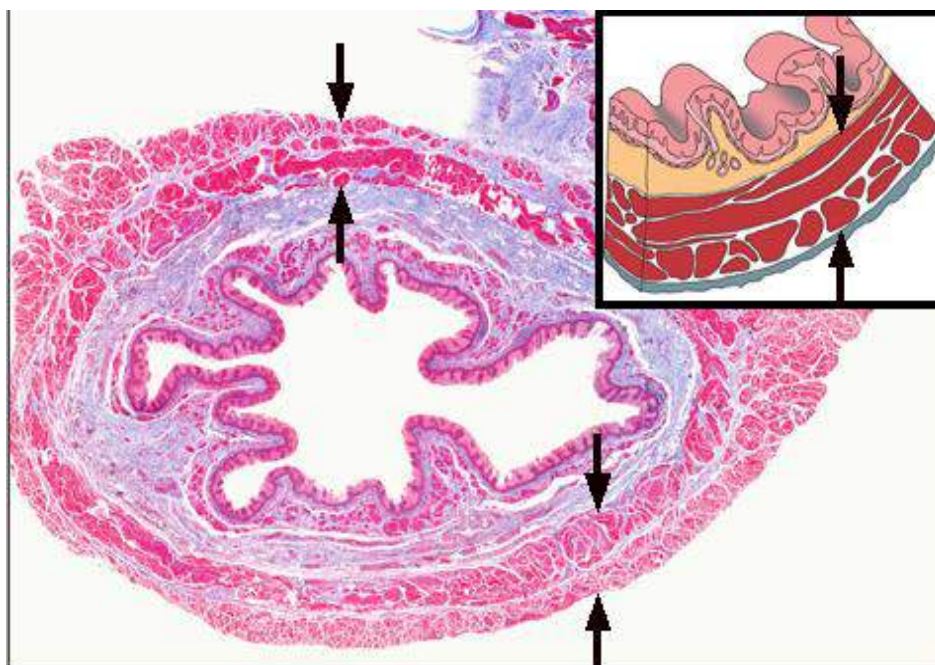


click to identify:

- Mucosa >
- > Submucosa >
- Muscularis >
- externa
- Skeletal mus
- Smooth mus
- Adventitia >

1 of 10

The submucosa possesses compound tubulo-acinar glands, called esophageal glands proper, scattered along the length of the esophagus. These glands, not present in this image, lubricate the esophagus during food transport.

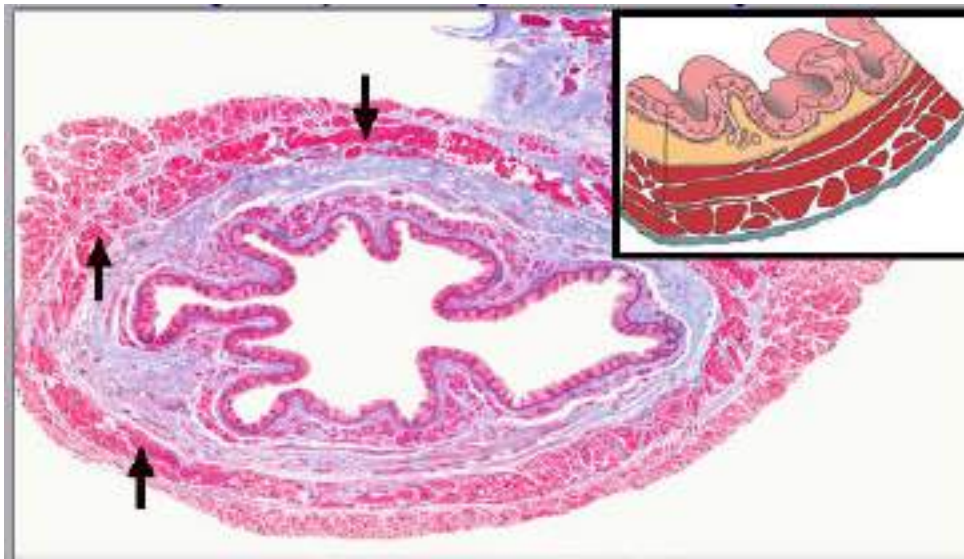


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- > Muscularis >
- externa
- Skeletal muscle
- Smooth muscle
- Adventitia >

1 of 10

Because swallowing is a voluntary action, muscularis externa in the upper one-third of the esophagus is composed of skeletal muscle. Both skeletal and smooth muscle are located in the muscularis externa in the middle third (shown here), and only smooth muscle is found in this tunic in the lower one-third.

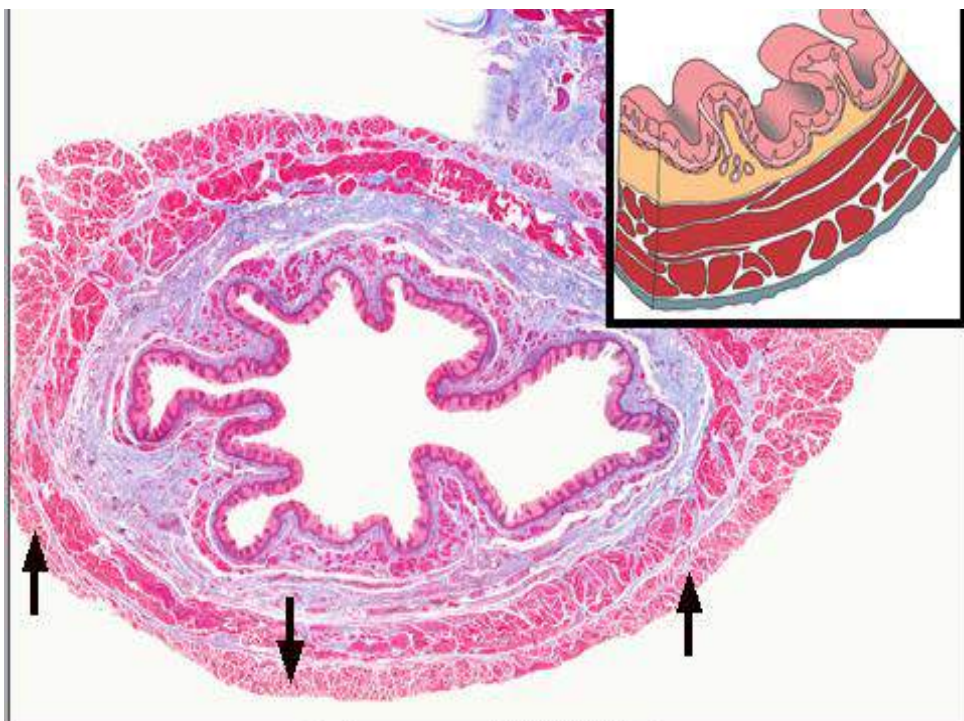


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< 1 of 10 >

Because swallowing is a voluntary action, muscularis externa in the upper one-third of the esophagus is composed of skeletal muscle. Both skeletal and smooth muscle are located in the muscularis externa in the middle third (shown here), and only smooth muscle is found in this tunic in the lower one-third.

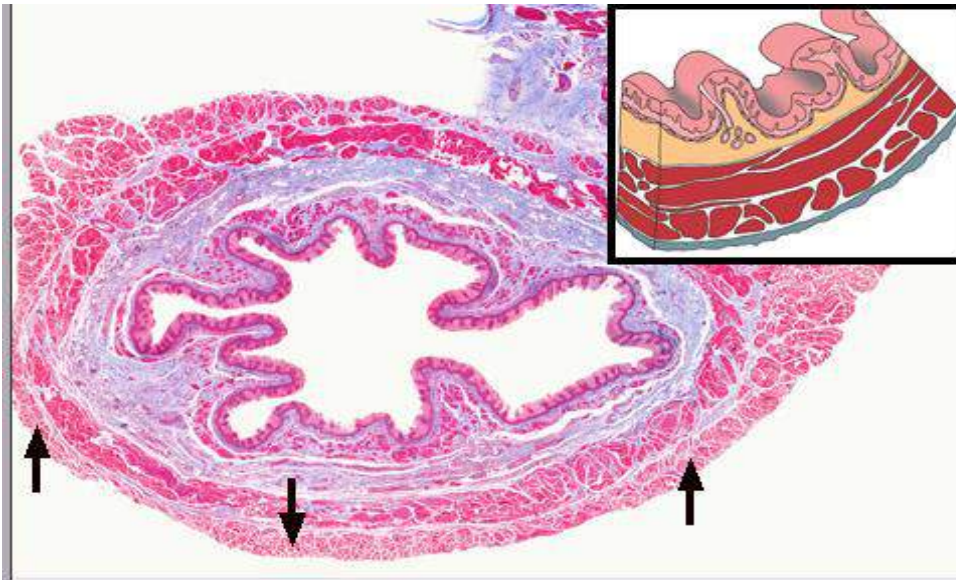


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Because swallowing is a voluntary action, muscularis externa in the upper one-third of the esophagus is composed of skeletal muscle. Both skeletal and smooth muscle are located in the muscularis externa in the middle third (shown here), and only smooth muscle is found in this tunic in the lower one-third.

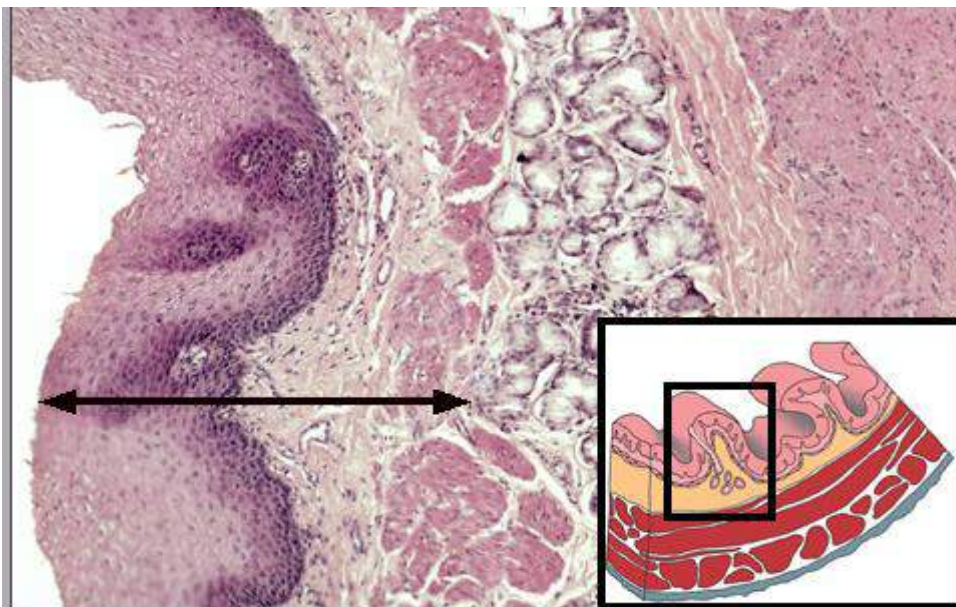


1 of 10

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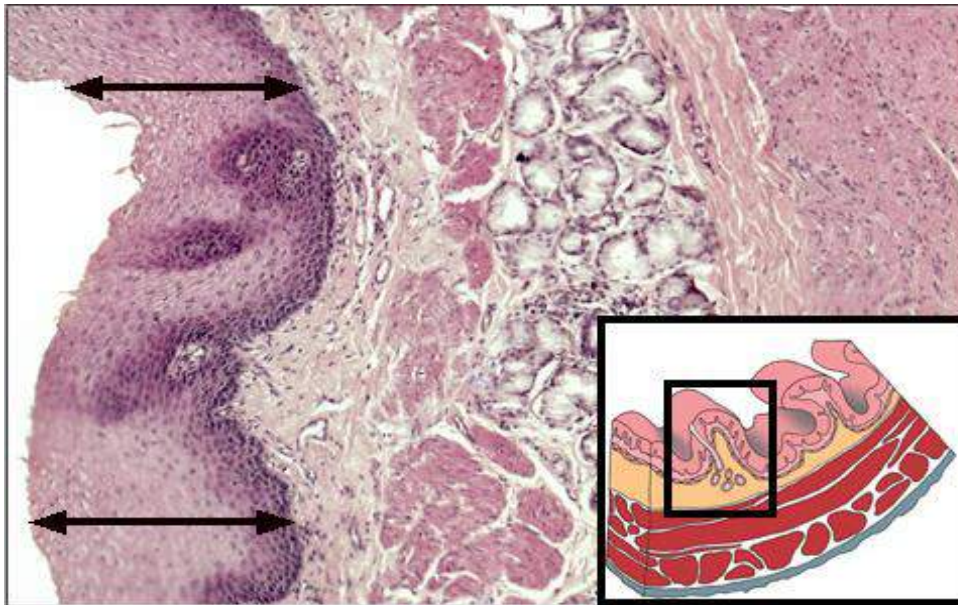


4 of 10

Esophagus -- A thick stratified squamous nonkeratinized epithelium lines the esophagus. The lamina propria underlying the epithelium possesses lymphoid structures and localized mucous glands (not shown here) in the lower third and sometimes in the upper third. Additional tubulo-acinar glands, esophageal glands proper, are located in the submucosa. 100x

click to identify:

- > Mucosa
 - Epithelium
 - Lamina propria
 - Muscularis mucosae
- Submucosa
- Esophageal glands proper
- Muscularis externa



click to identify:

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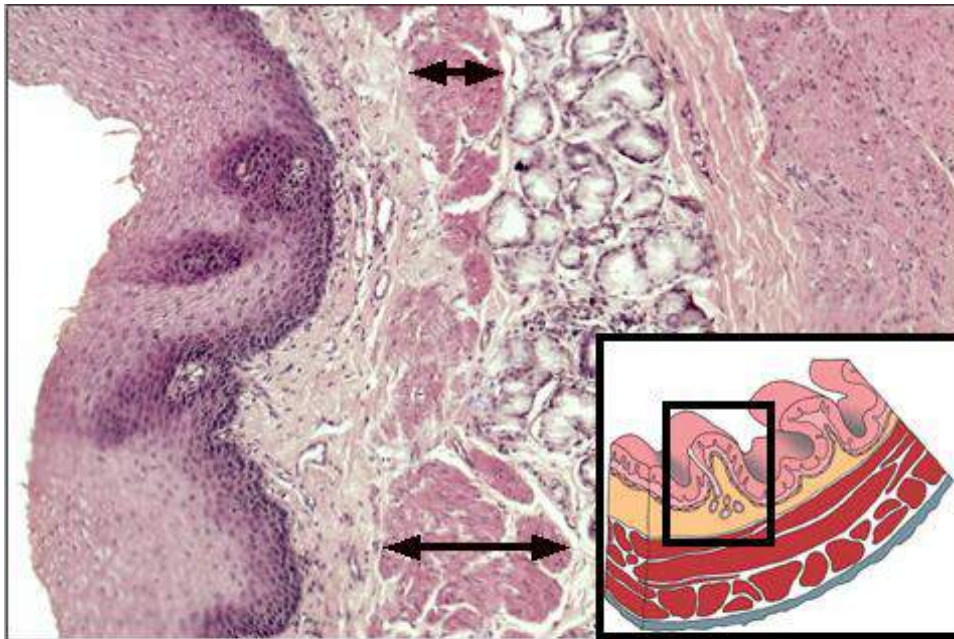


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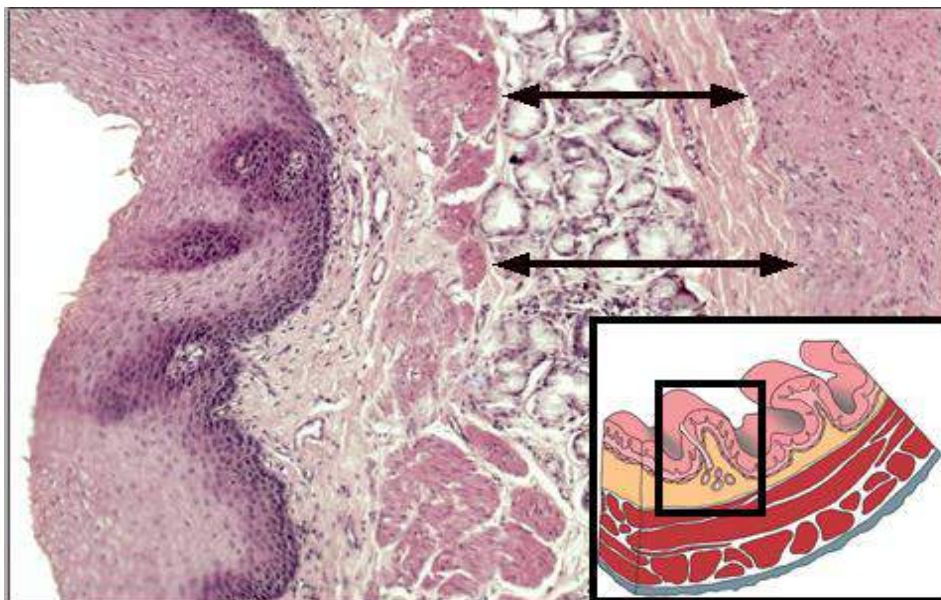


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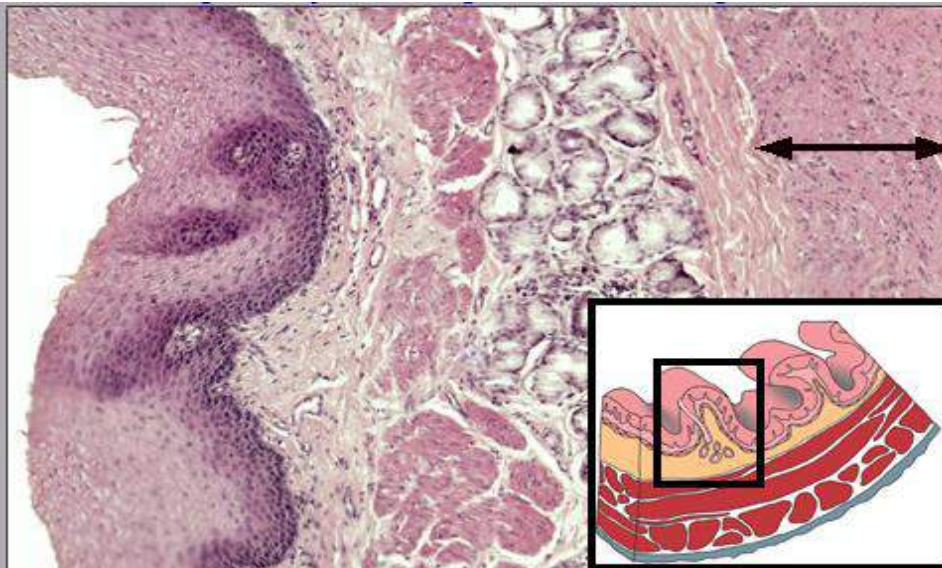


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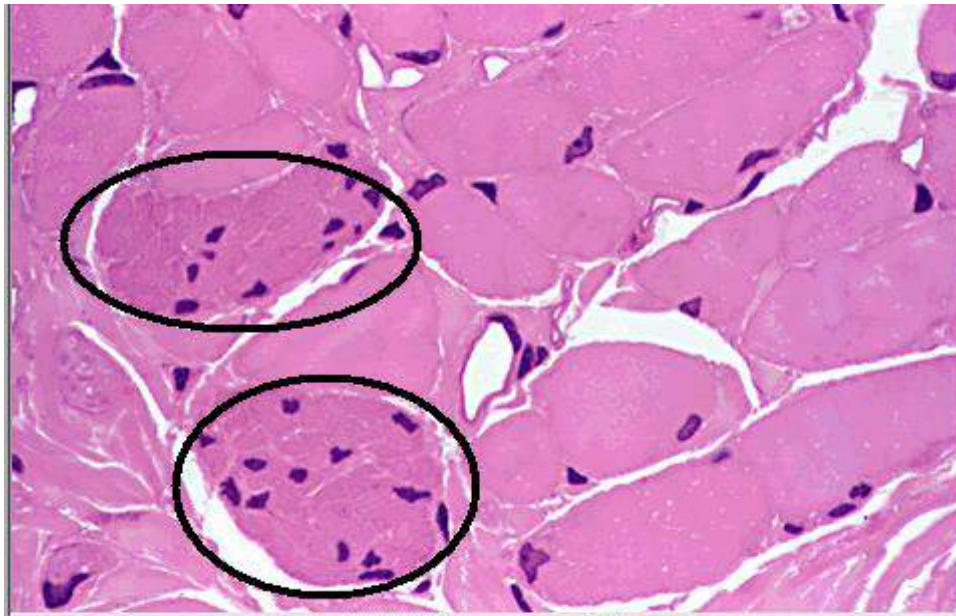


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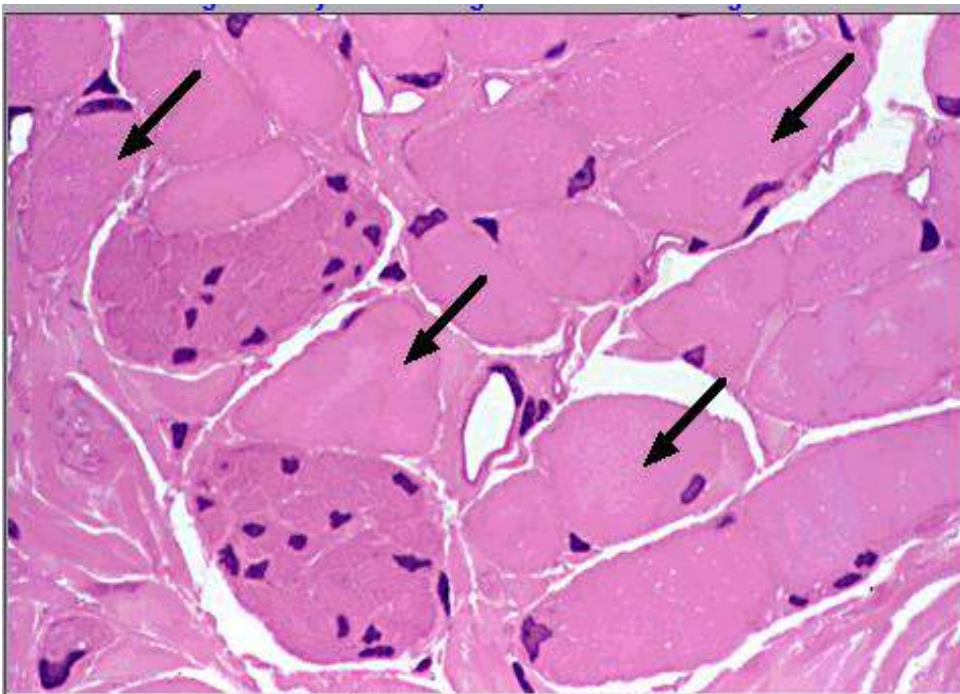


click to identify:

- › Smooth muscle fibers
- Skeletal muscle fibers
- Skeletal muscle nuclei
- Smooth muscle nuclei
- Capillary
- Connective tissue

8 of 10

Esophagus -- In the middle part of the muscularis externa of the esophagus, smooth muscle fibers and skeletal muscle fibers occur together. In this field, compare the size of the fibers and location of the nuclei of these two muscle types. 1000x

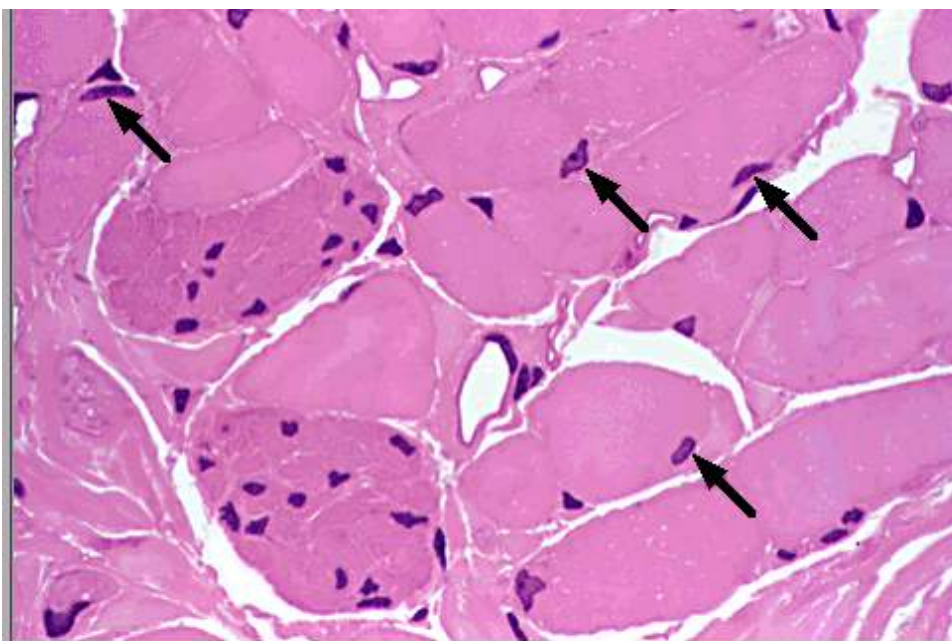


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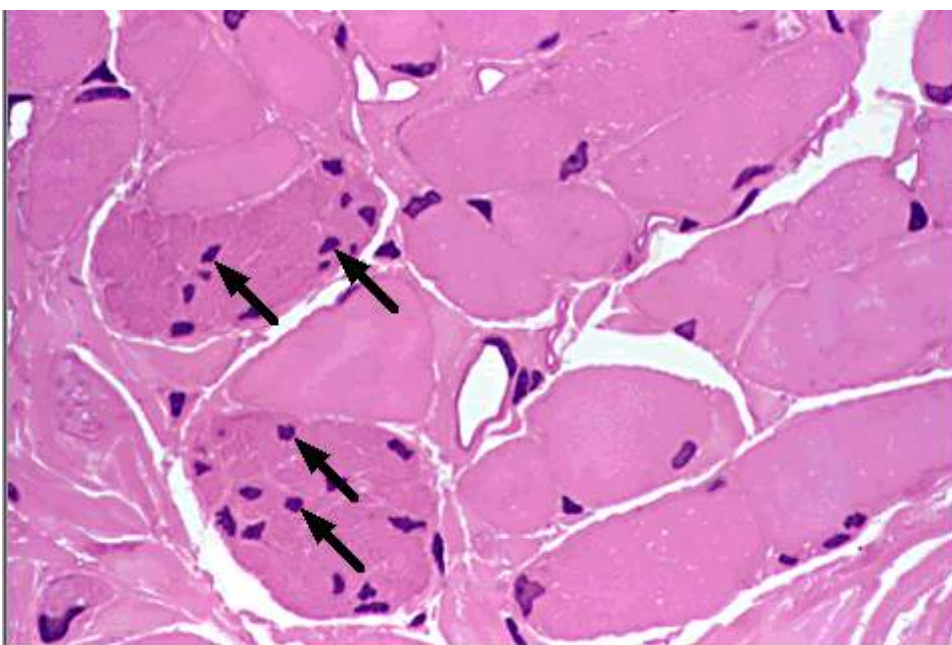


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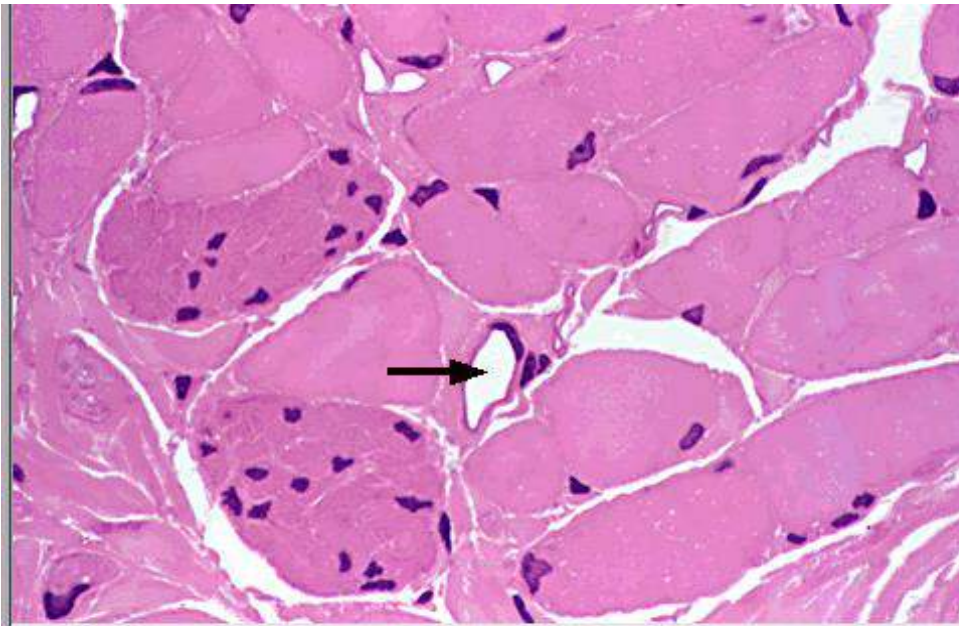


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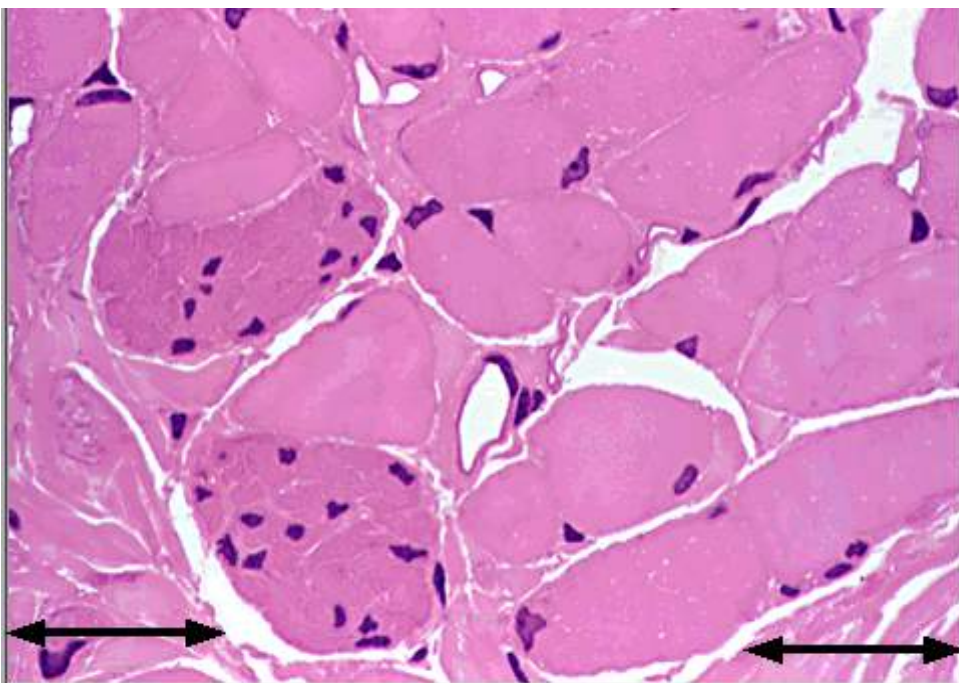


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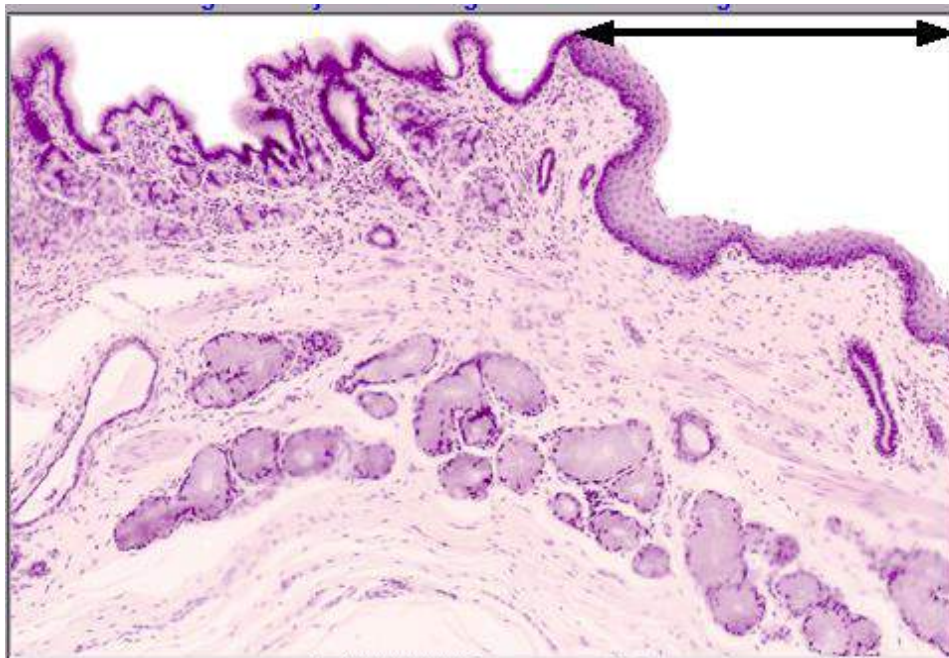


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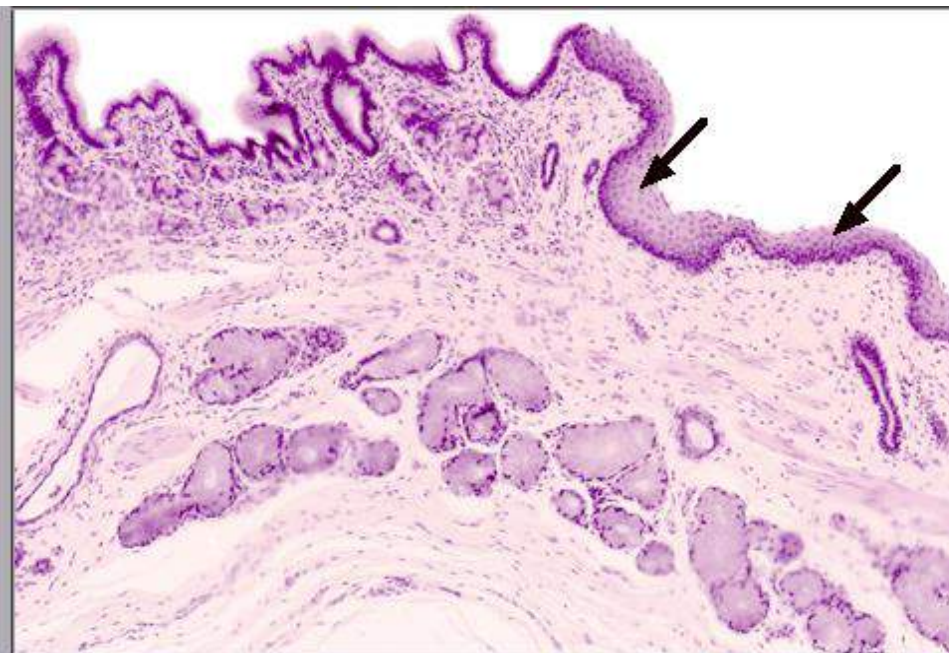


10 of 10

Gastro-esophageal junction -- Stratified squamous moist epithelium (esophagus) changes abruptly to a simple columnar epithelium (sheet gland) of the stomach. Esophageal glands proper, tubulo-acinar glands in the submucosa, continue into the stomach in this section. 100x

click to identify:

- › Esophagus
- Stratified squamous epithelium
- Cardiac stomach
- Sheet gland
- Gastric pits
- Cardiac glands
- Lamina propria
- Muscularis mucosae
- Submucosa
- Esophageal glands proper

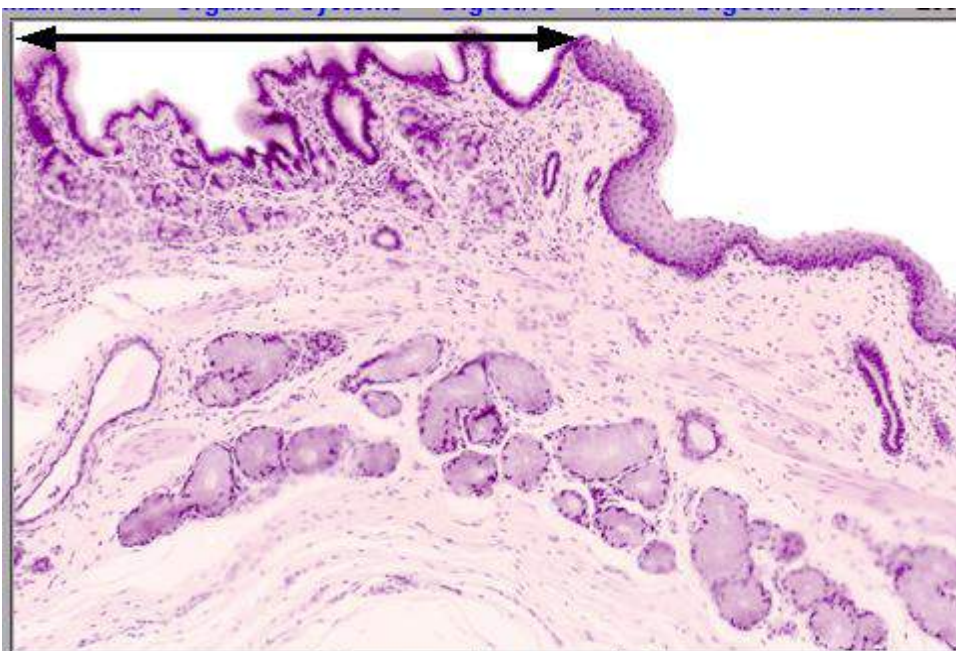


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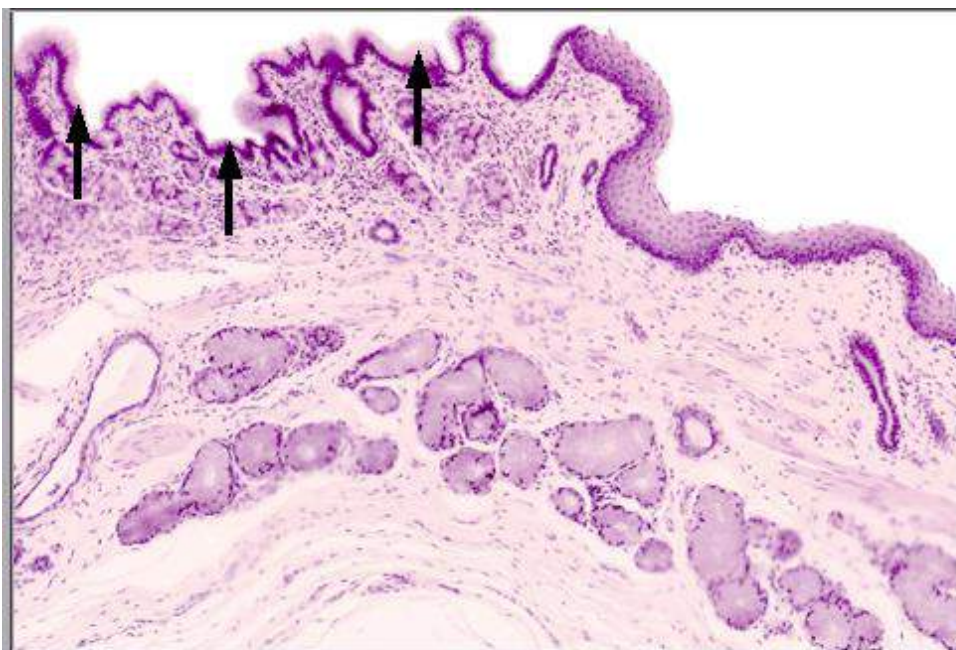


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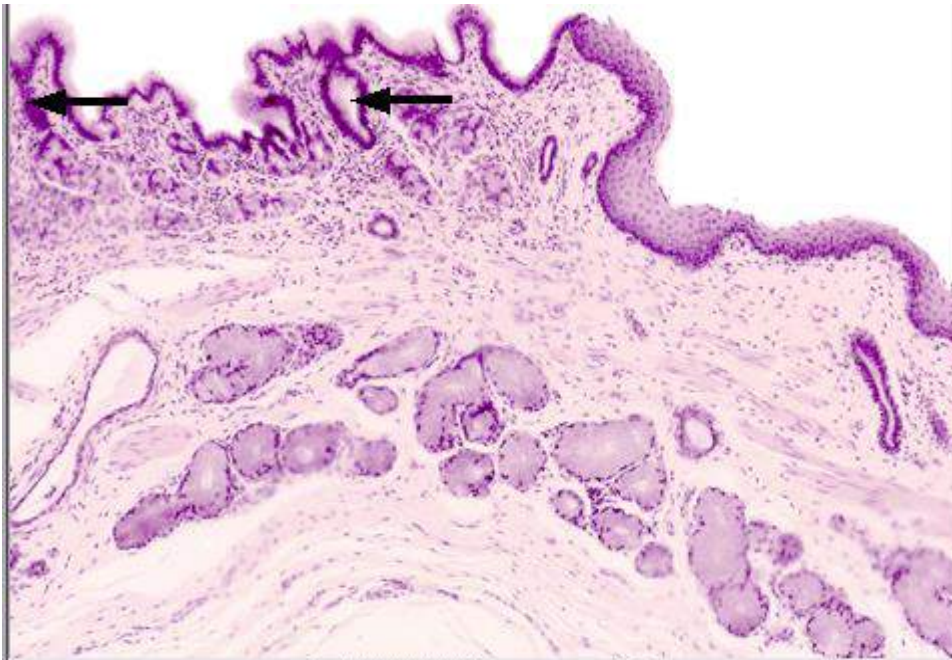


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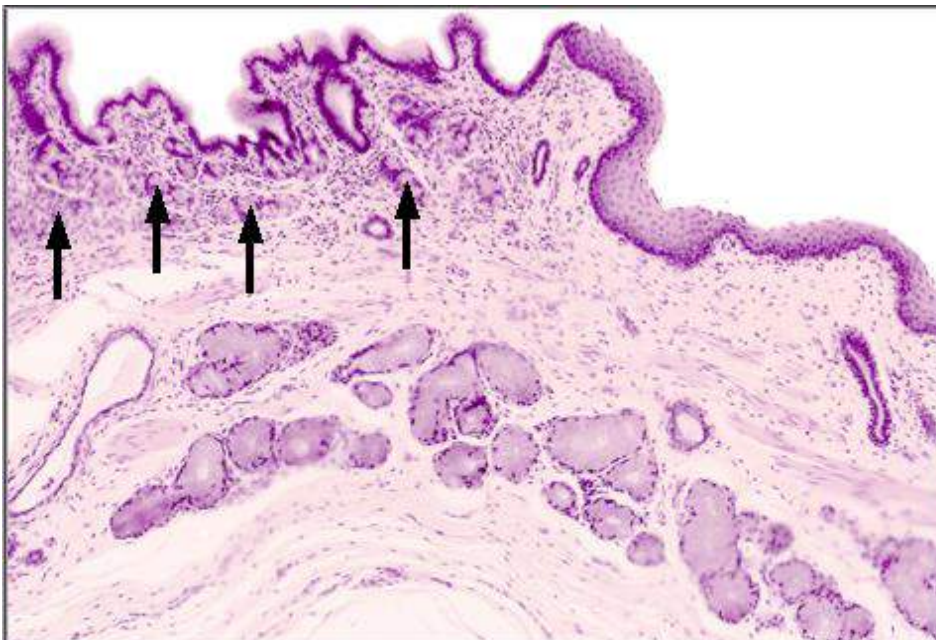


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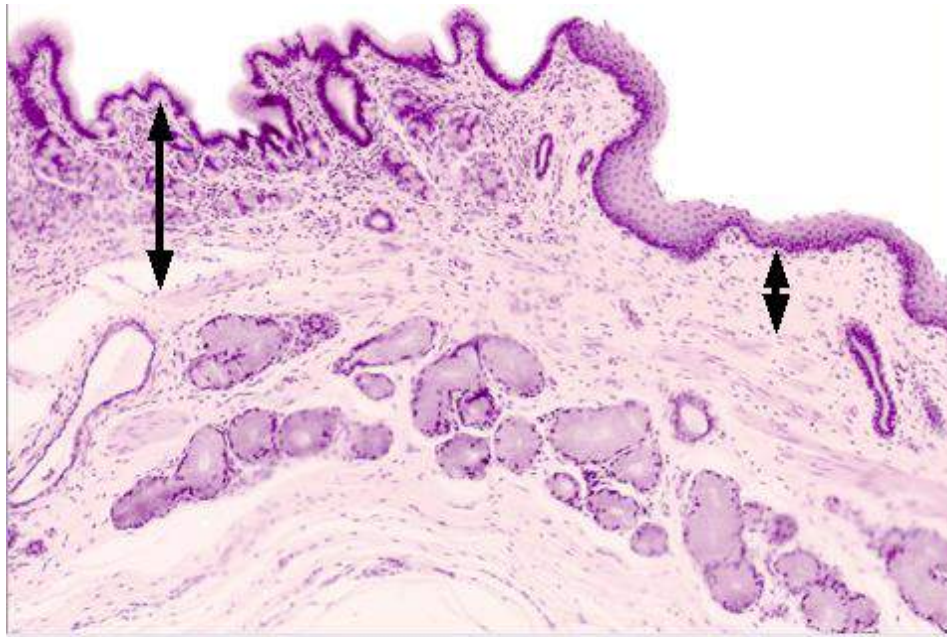


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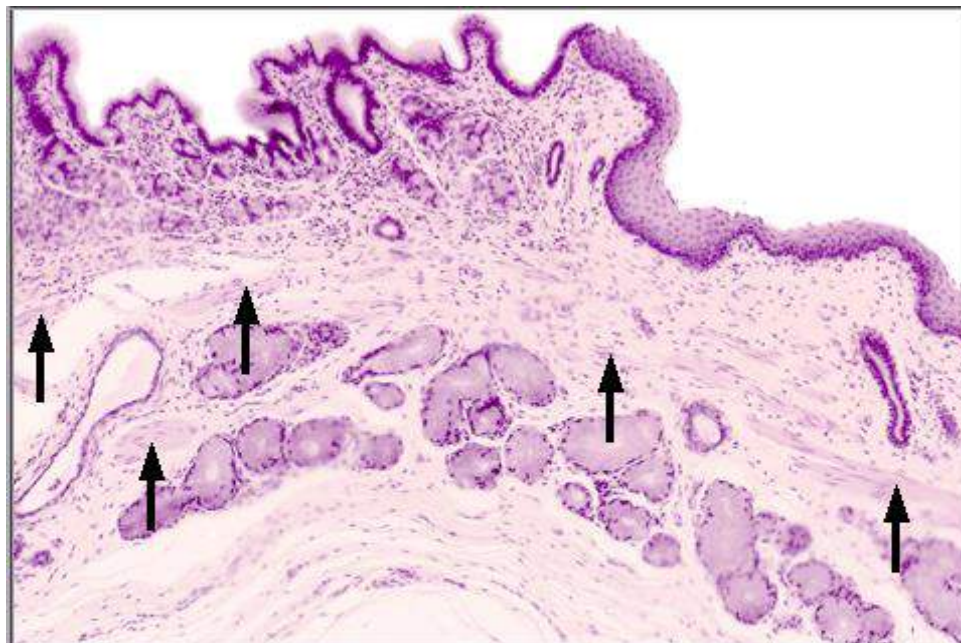


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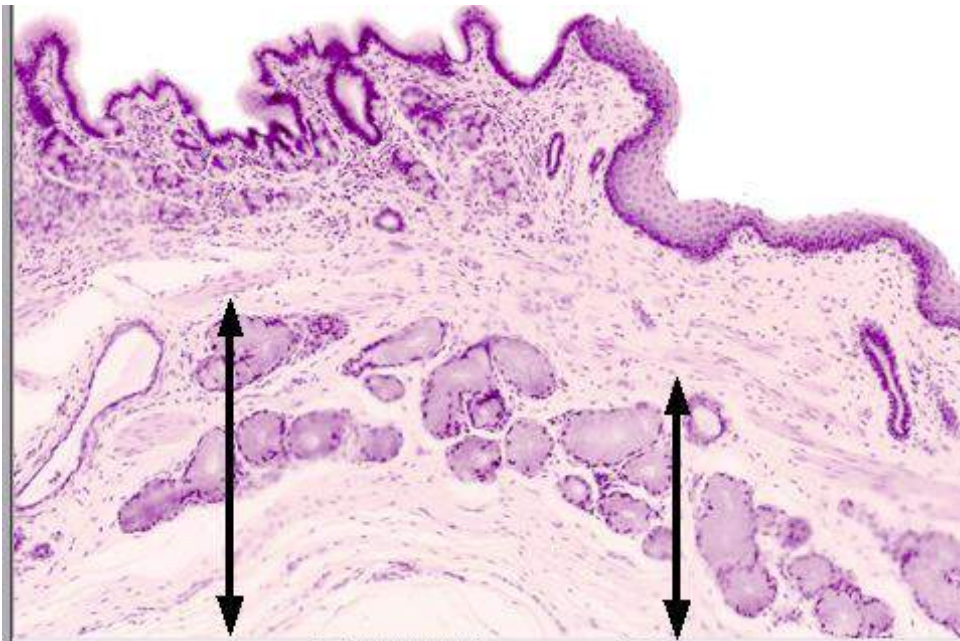


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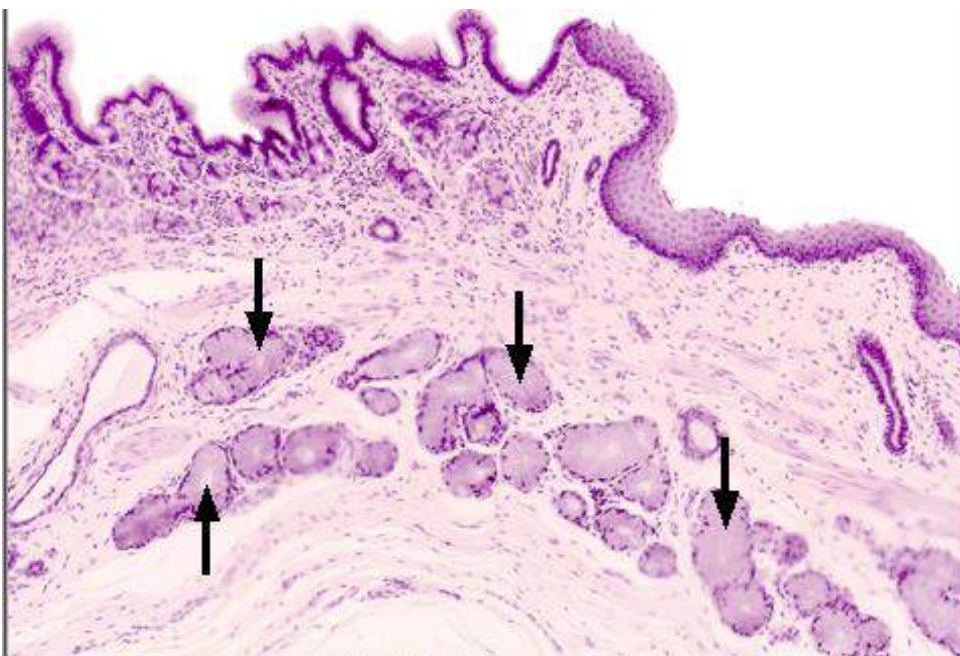


10 of 10

Gastro-esophageal junction -- Stratified squamous moist epithelium (esophagus) changes abruptly to a simple columnar epithelium (sheet gland) of the stomach. Esophageal glands proper, tubulo-acinar glands in the submucosa, continue into the stomach in this section. 100x

click to identify:

Esophagus
Stratified
squamous
epithelium
Cardiac stomach
Sheet gland
Gastric pits
Cardiac glands
Lamina propria
Muscularis
mucosae
Submucosa
Esophageal glands
proper

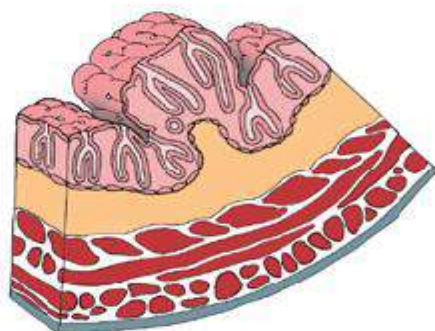
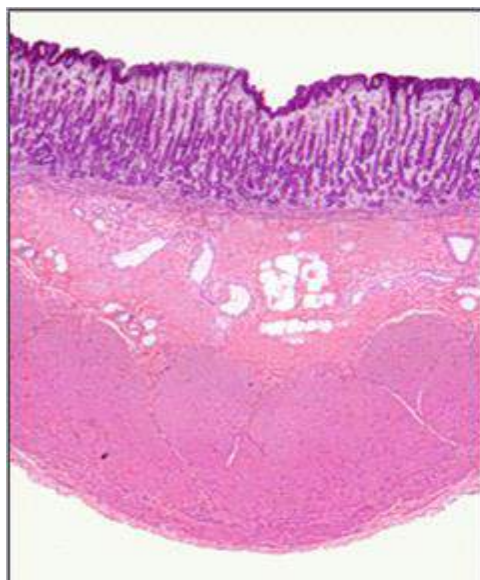


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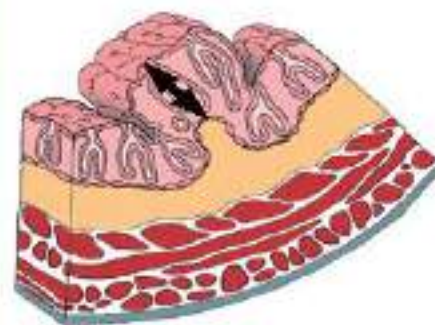
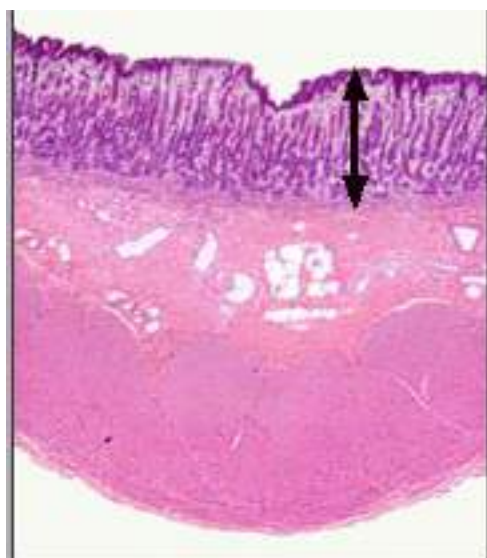


click to identify:

- Mucosa >
 - Sheet gland
 - Lamina propria
 - Muscularis mucosae
 - Gastric pits
 - Gastric glands
- Submucosa >
- Muscularis externa
- Serosa

1 of 6

Overview -- The four stomach regions comprise three functional units (cardia, body and fundus, pylorus), each composed of the expected four tunics. The stomach continues digestion by secreting pepsin to aid in protein digestion, by producing an acidic fluid, and by churning via the thick muscularis externa. Hormones secreted by enteroendocrine cells modulate digestion. 10x

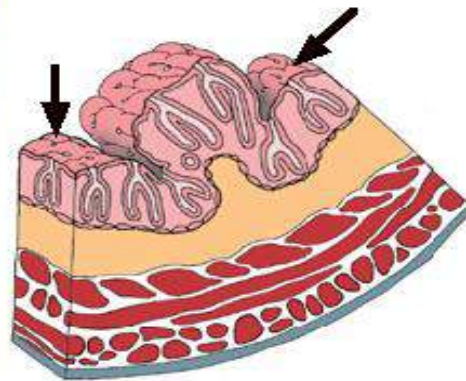
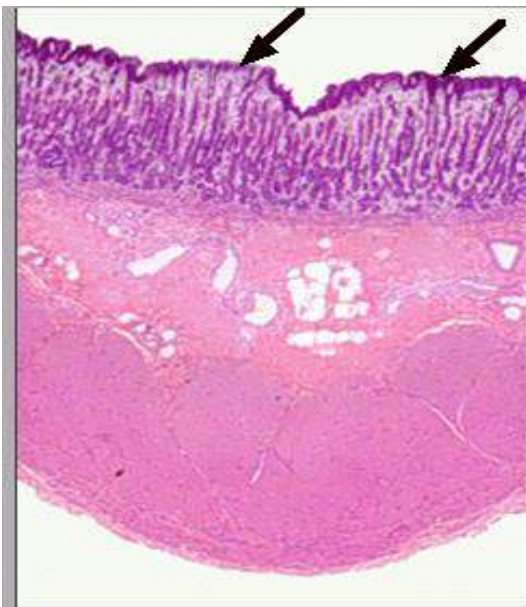


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The mucosal epithelium of the stomach is modified to form a sheet gland that invaginates into lamina propria, forming gastric pits. Gastric glands begin at the bases of these pits and extend to muscularis mucosae.

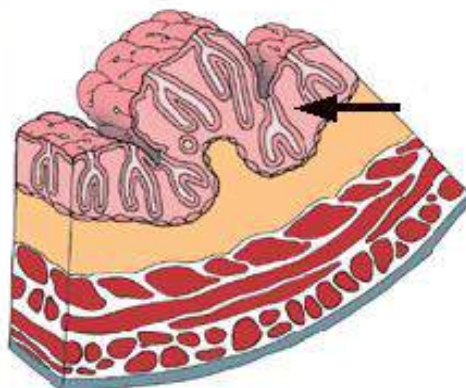
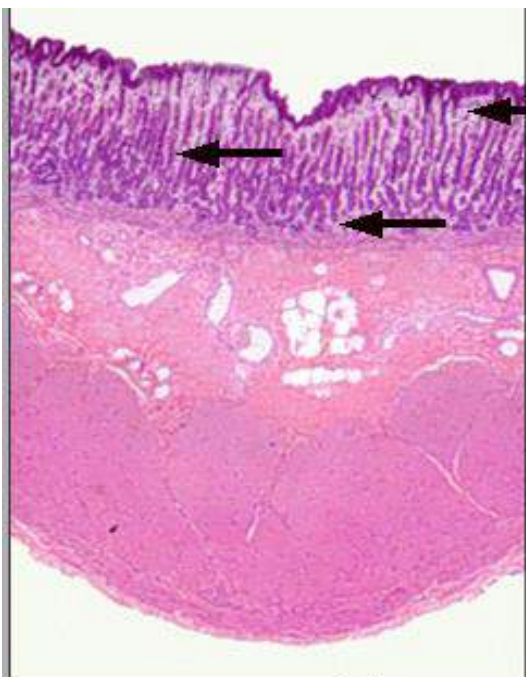


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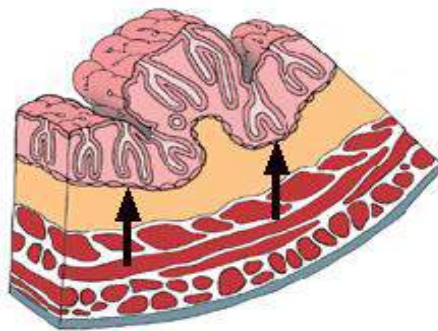
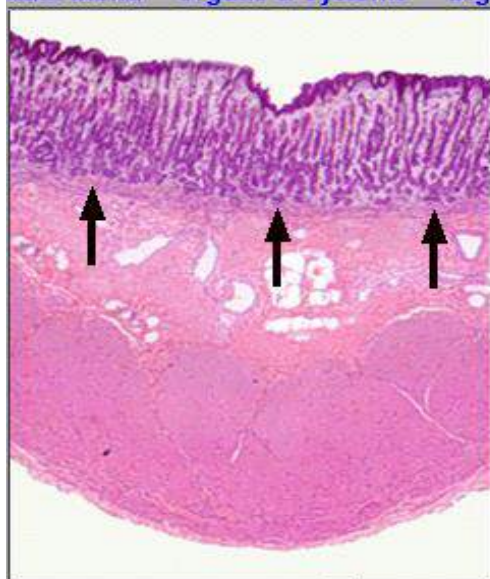


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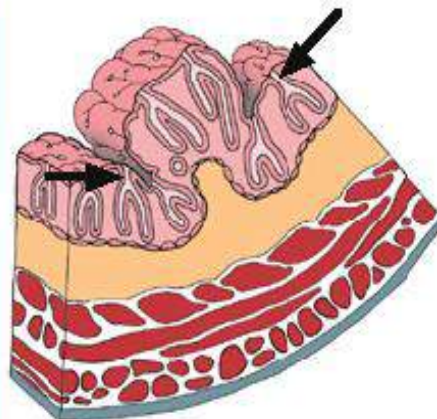
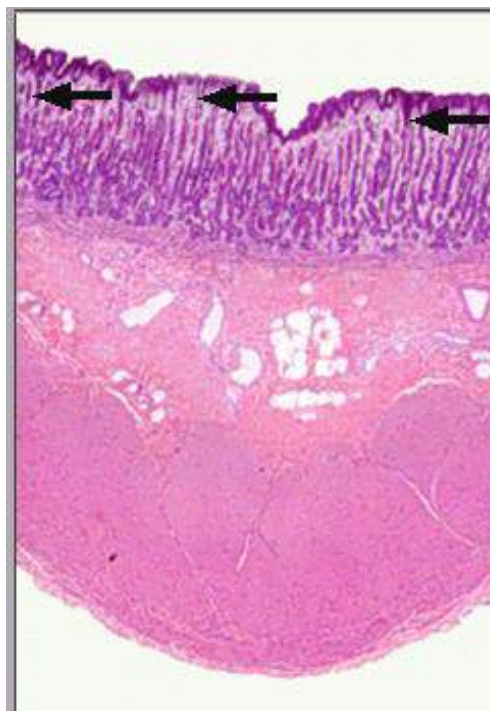


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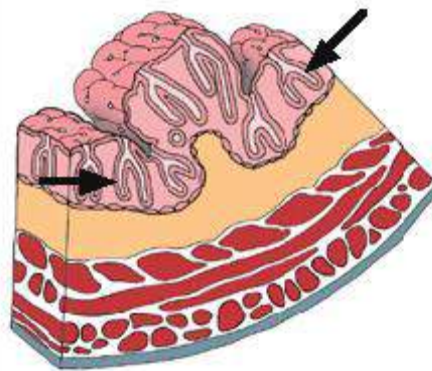
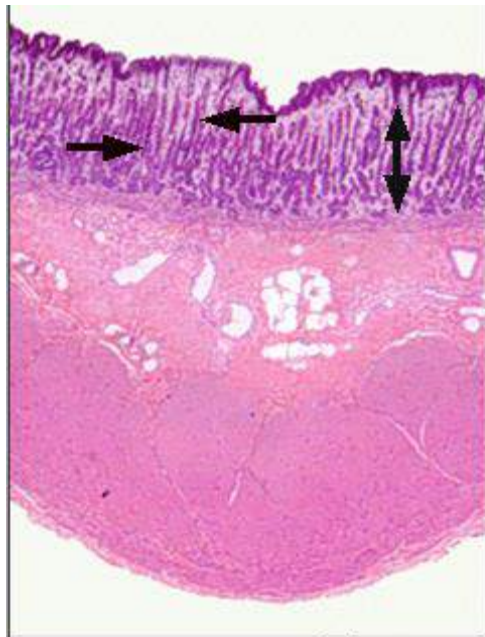


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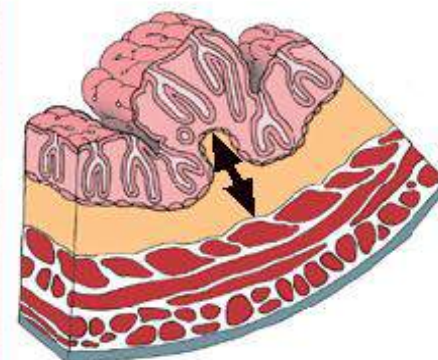
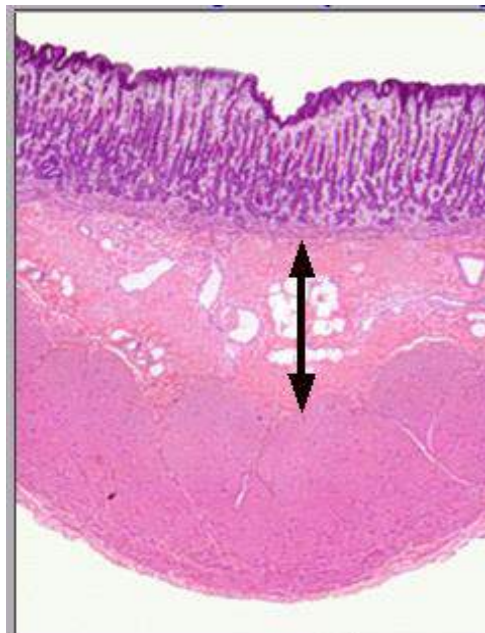


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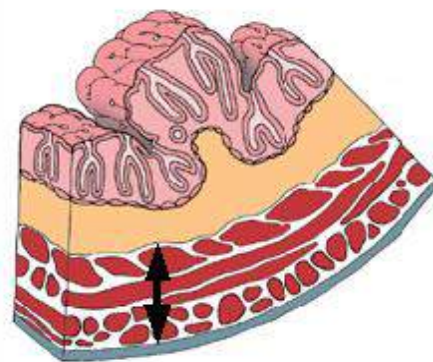
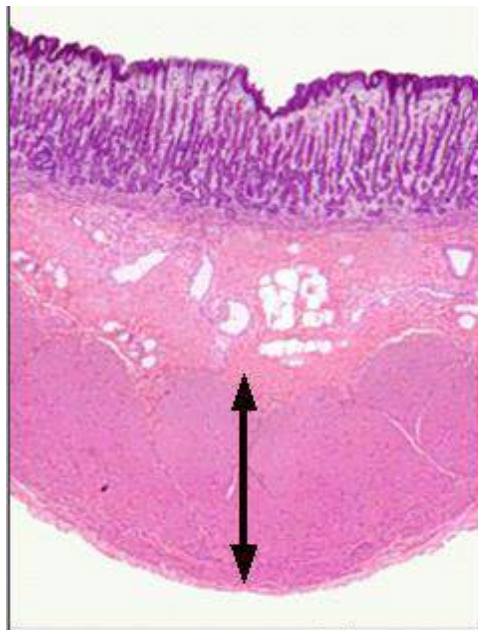


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1 of 6

The submucosa is composed of dense connective tissue. Although muscularis externa is composed of three layers of smooth muscle instead of the usual two, the additional internal oblique layer is inconsistently present. The stomach is covered on its exterior surface by an serosa because this organ protrudes into the peritoneal cavity.

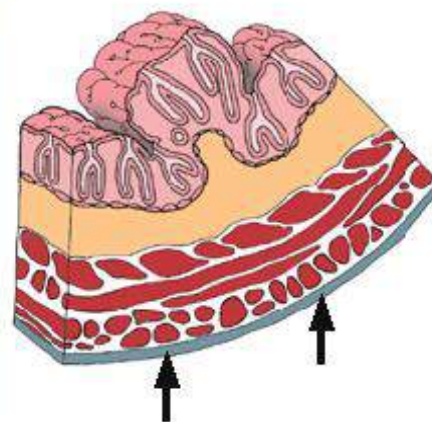
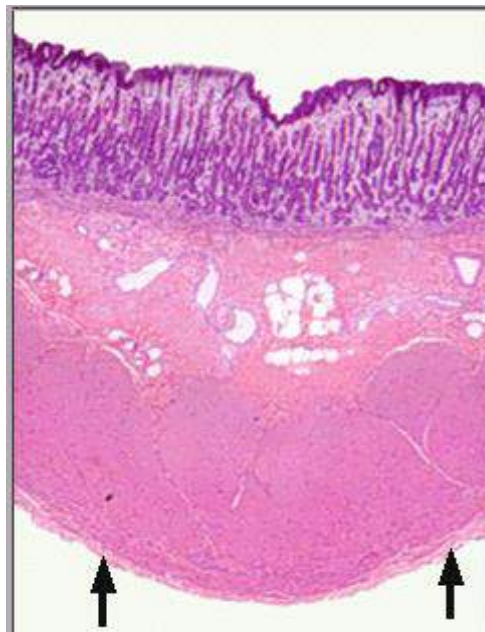


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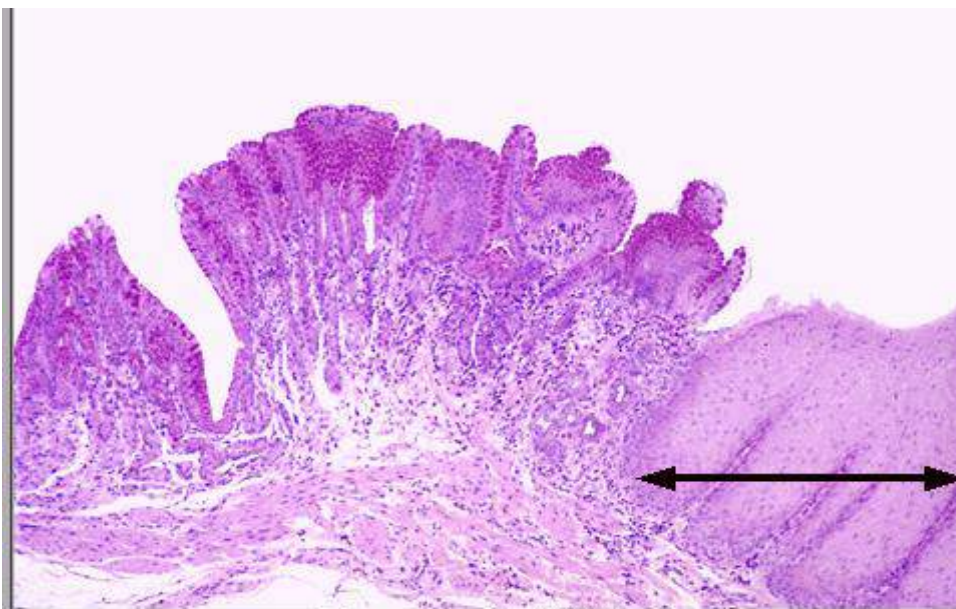


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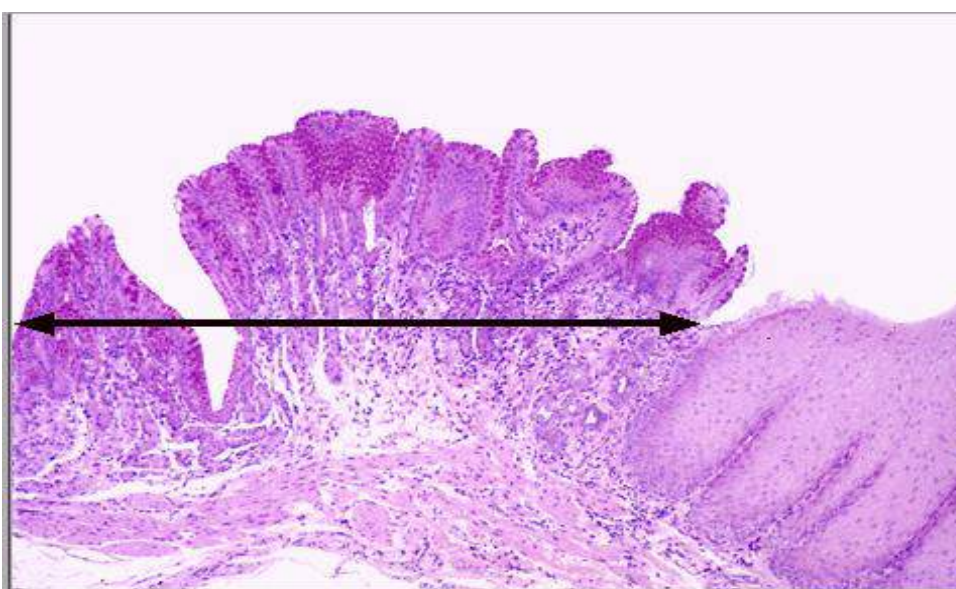


1 of 13

Stomach: cardiac region -- A sharp transition in the epithelium, from stratified squamous moist (esophagus) to simple columnar (stomach), marks the transition of these two organs. The depth of the gastric pits (foveolae) is about equal to the length of the glands in the cardiac region (a diagnostic feature for the cardiac region of the stomach). 40x

click to identify:

- › Esophagus
- Cardiac stomach
- Gastroesophageal junction
- Opening of pits
- Gastric pits
- Cardiac glands

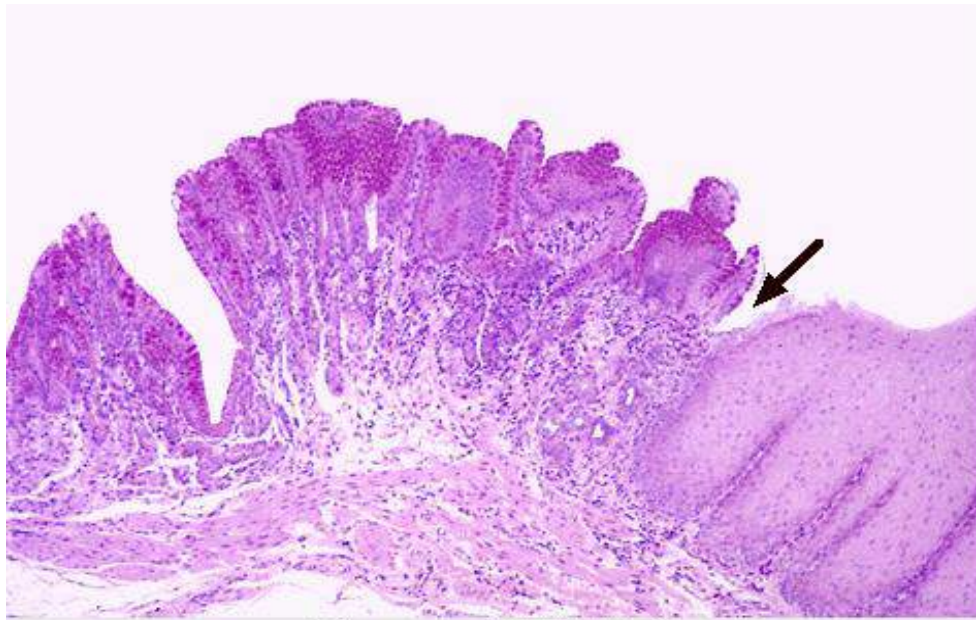


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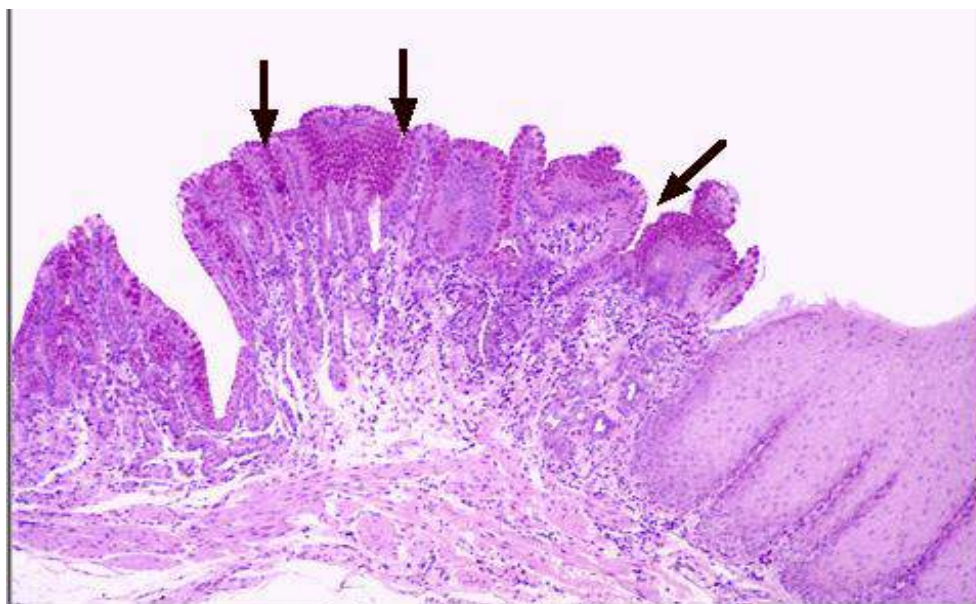


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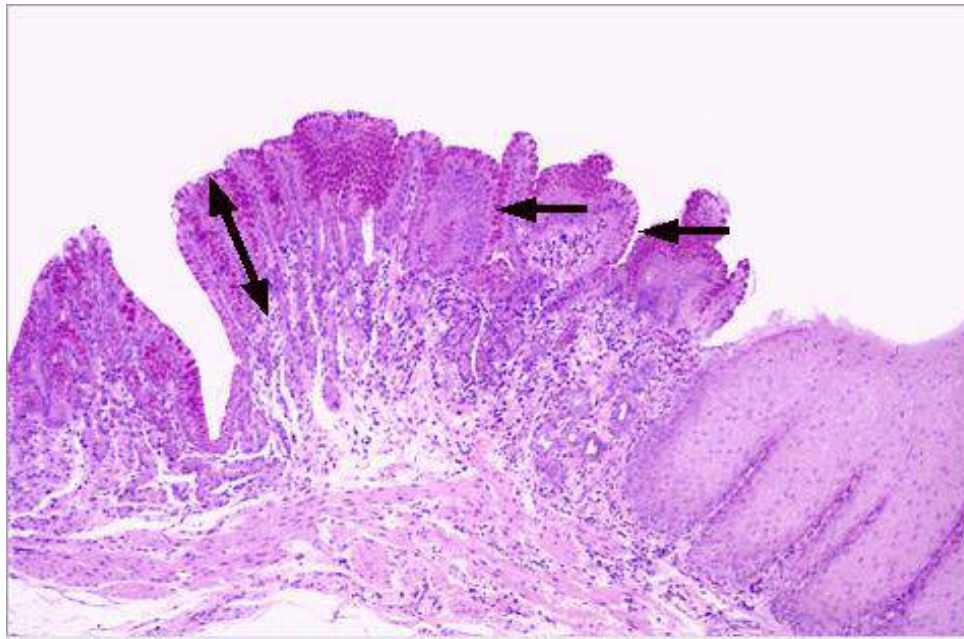


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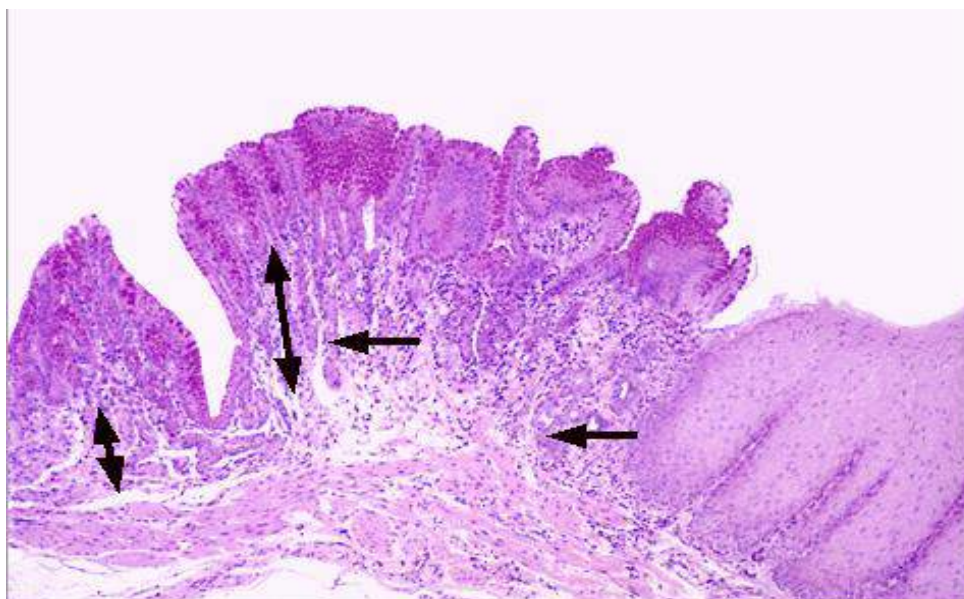


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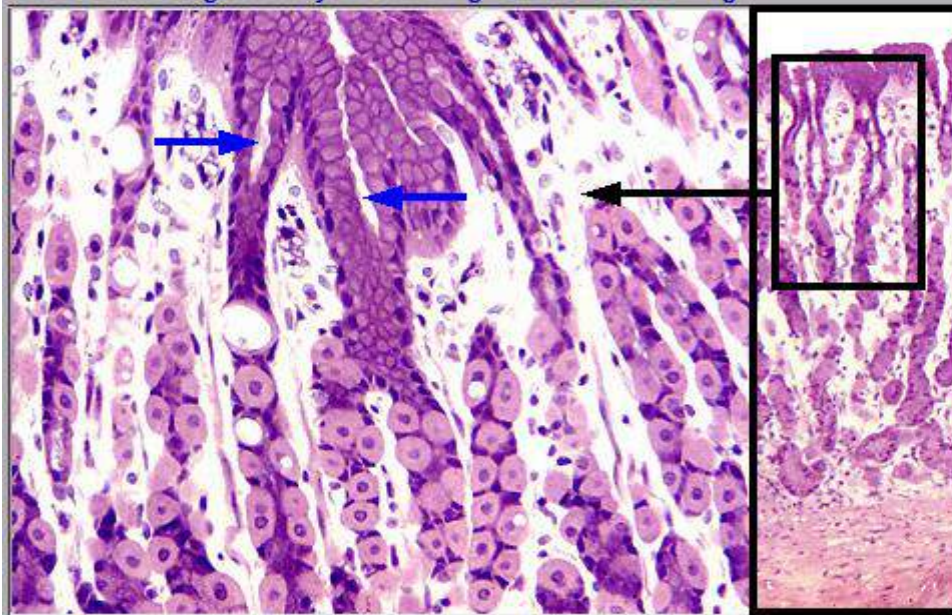


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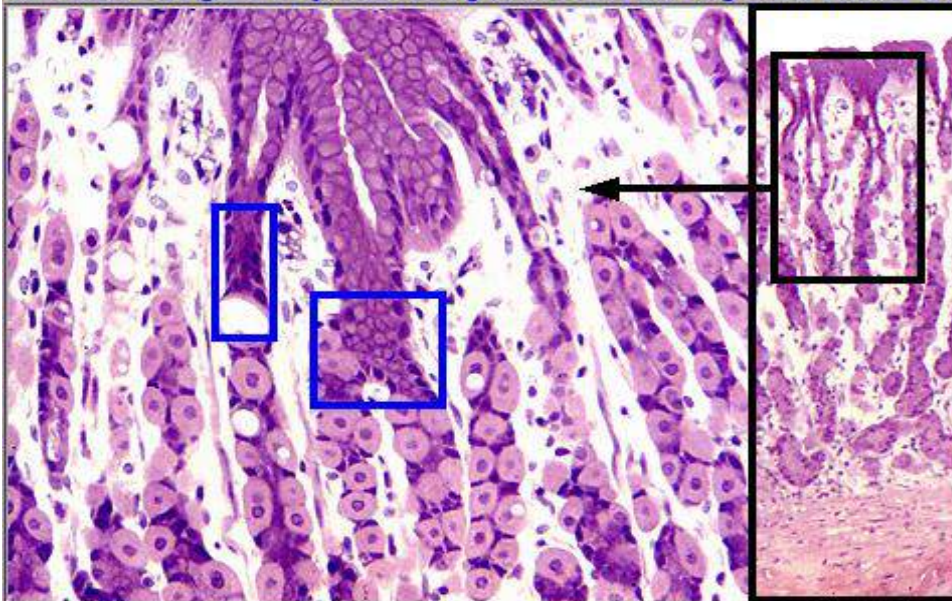


5 of 13

Stomach: fundus and body -- The neck, the first part of fundic glands, contains mucous neck cells (darkly staining cells) and parietal cells. Mucous neck cells secrete a mucus different from that of the surface mucous cells. Parietal (oxyntic) cells, large, spherical and eosinophilic, are responsible for the HCl production in the stomach and also secrete gastric intrinsic factor. 200x, 100x

click to identify:

- > Gastric pits
- Necks of glands
- Bodies of glands
- Mucous neck cells
- Parietal cells

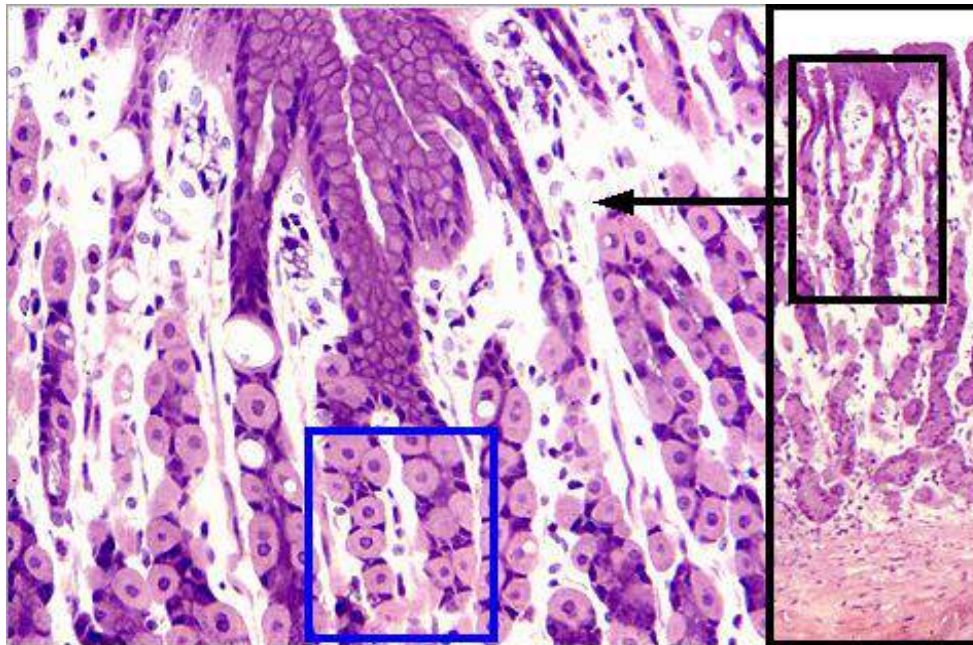


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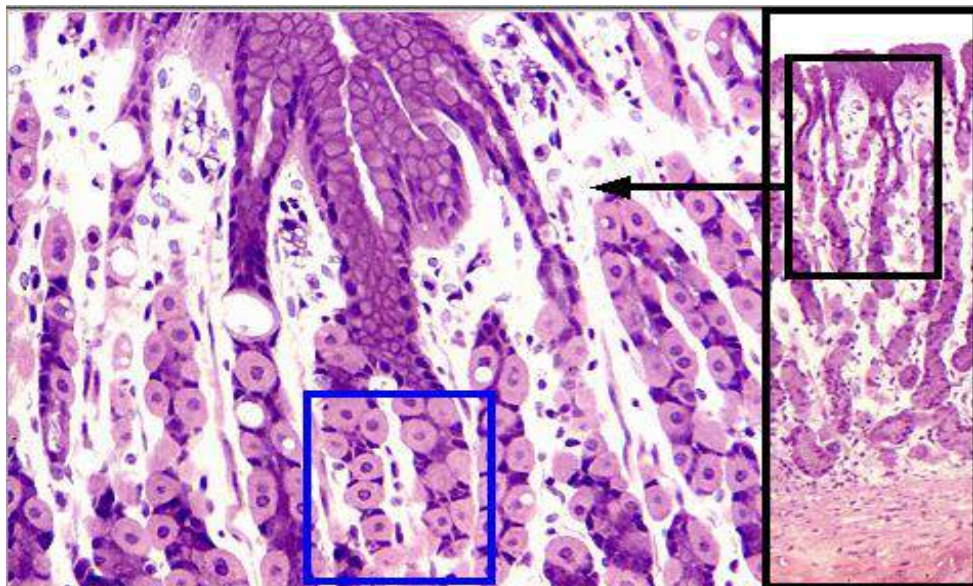


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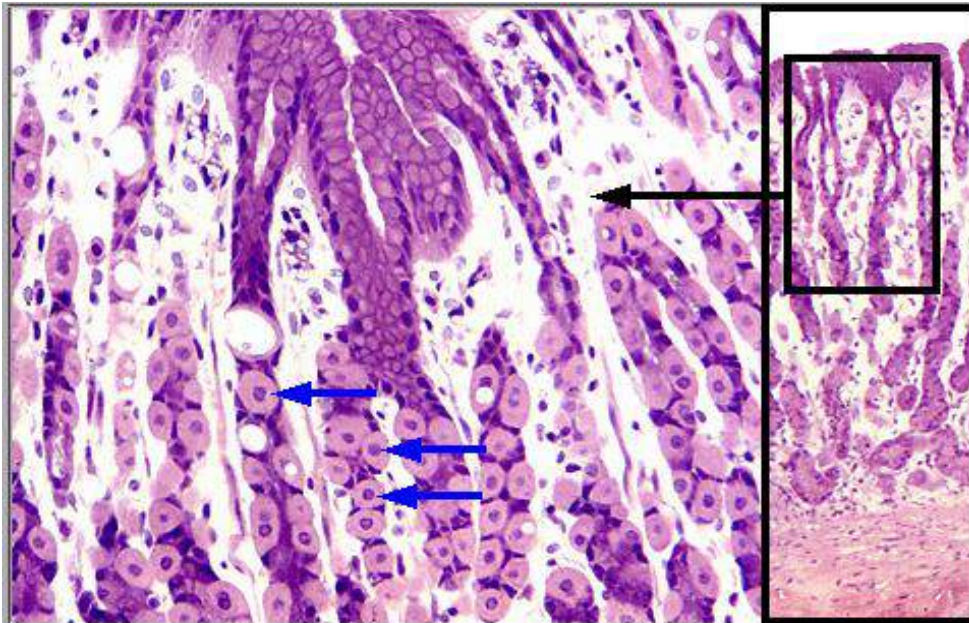


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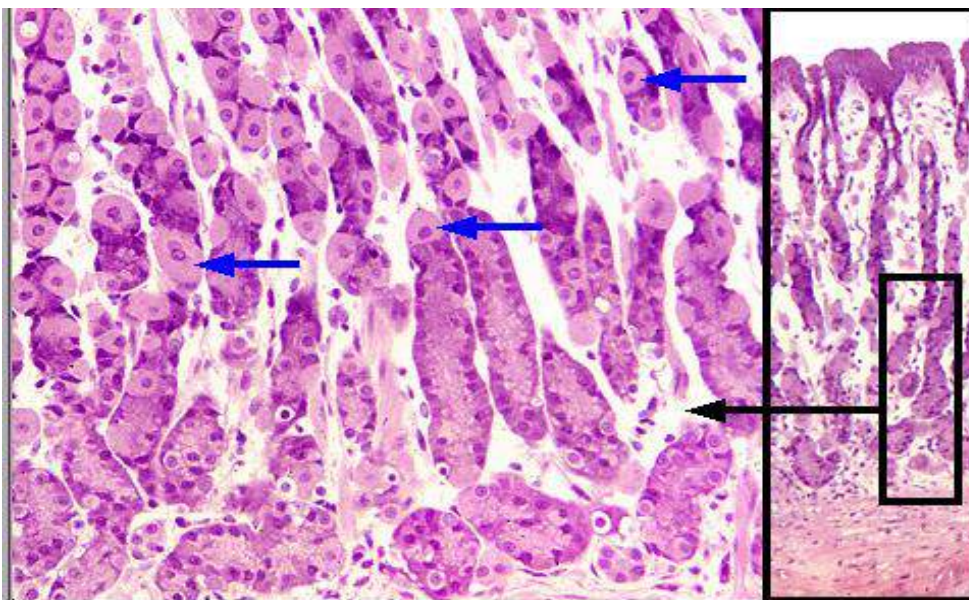


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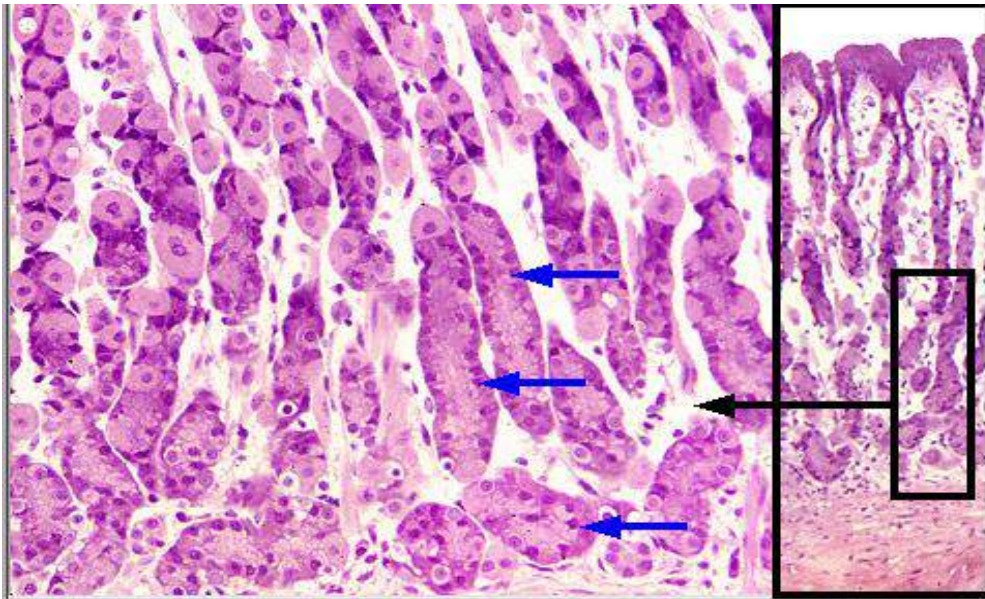


6 of 13

Stomach: fundus and body -- The bases of fundic glands, resting on the muscularis mucosae, are embedded in the loose connective tissue of the lamina propria. Although parietal cells are located here too, chief cells and enteroendocrine cells predominate in this area. 200x

click to identify:

- > Parietal cells
- Chief cells
- Enteroendocrine cells
- Next image

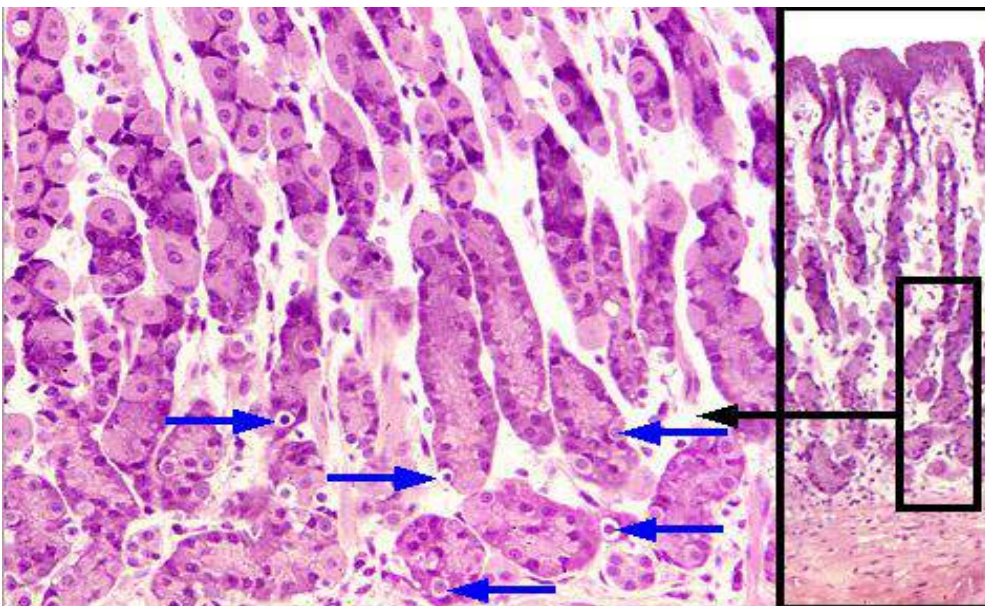


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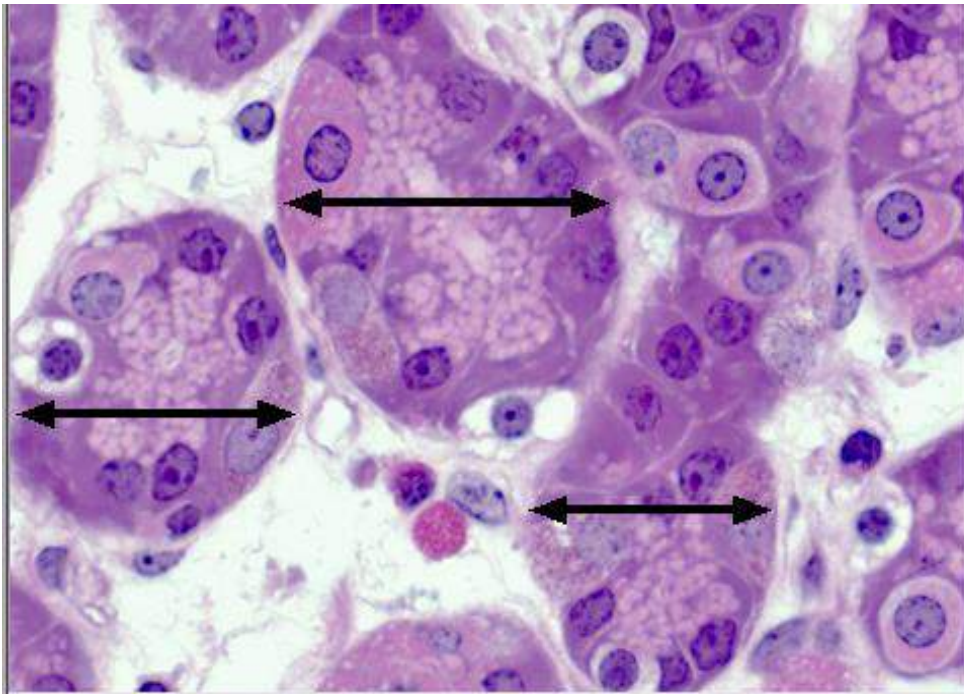


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- Chief cells
- Enteroendocrine cells
- Next image

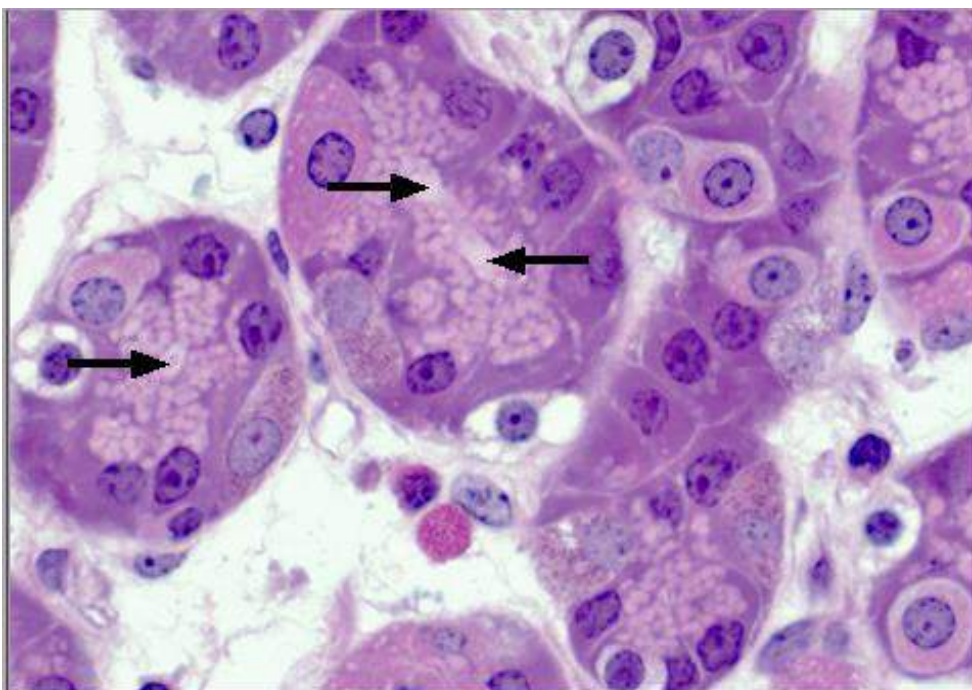


click to identify:

- › Fundic glands
- Lumens of glands
- Lamina propria
- Parietal cell >
- Chief cells >
- DNES cells >
- Secretory >
- granules

8 of 13

Stomach: fundus and body -- Bases of gastric glands in the fundic region of the stomach demonstrate several cell types. 1000x

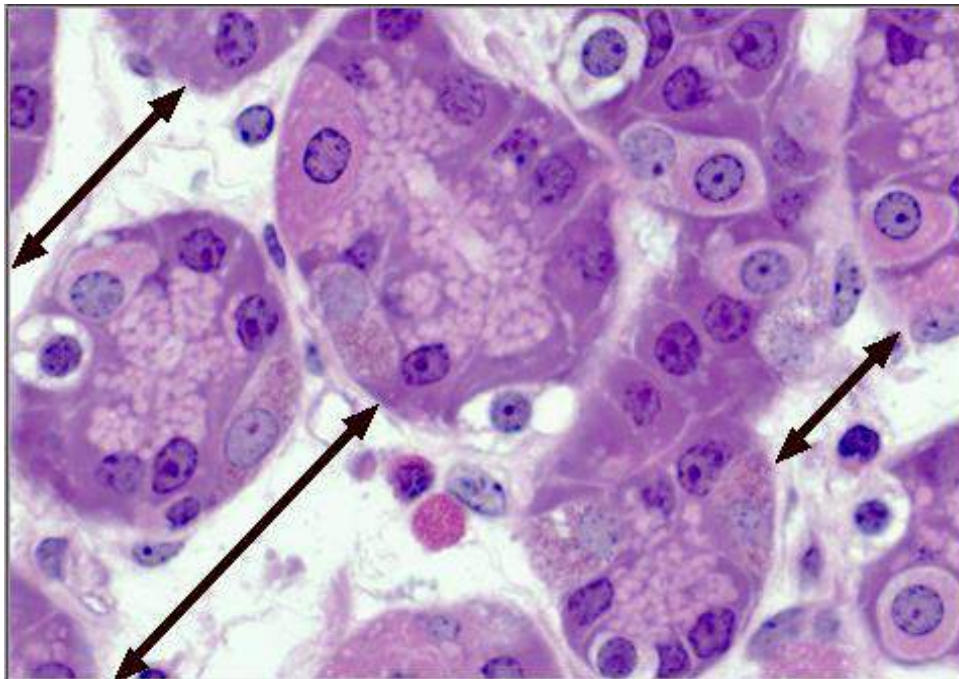


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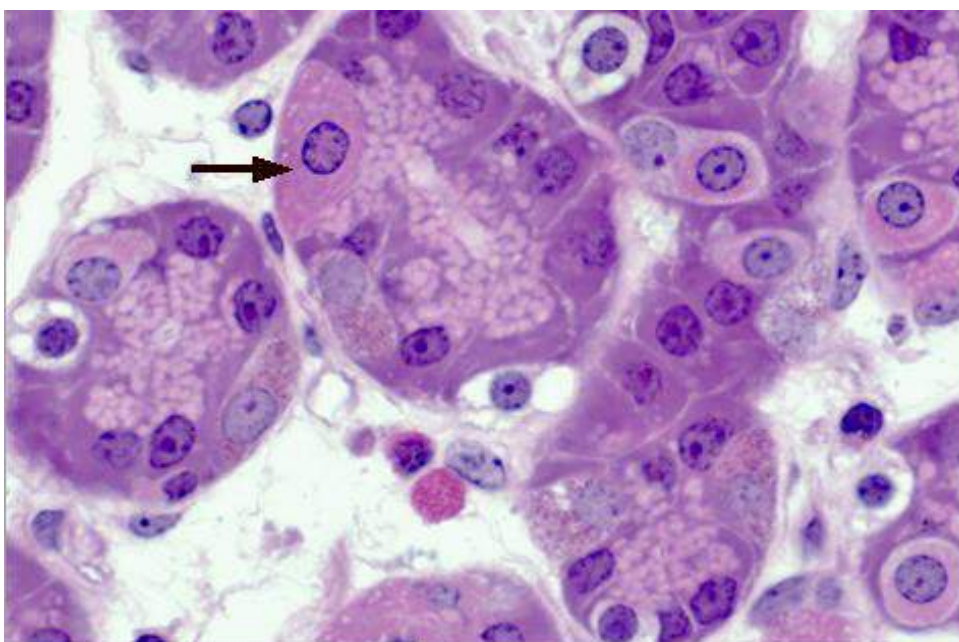


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- Secretory >
- granules

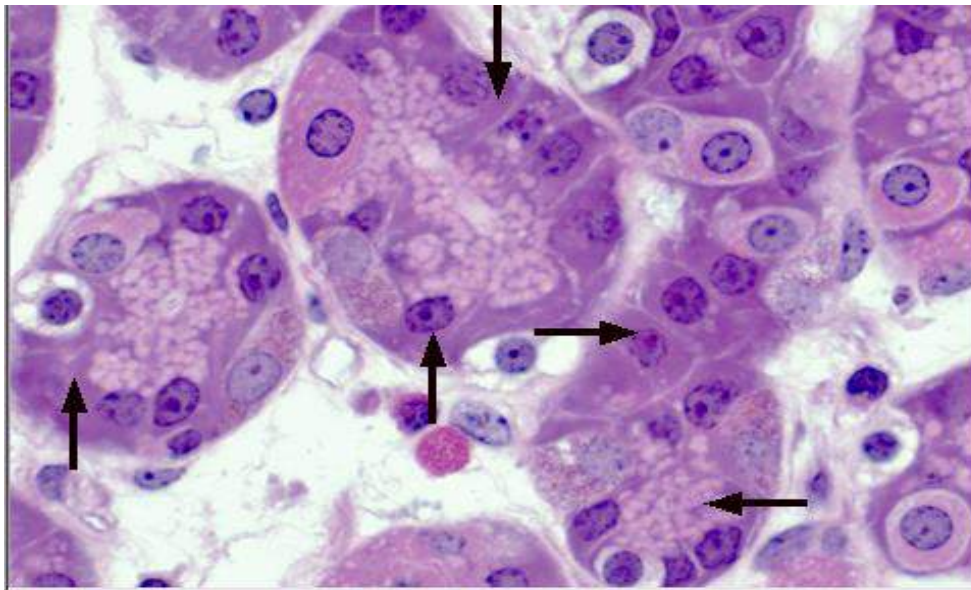


8 of 13

Although more numerous closer to the lumen of the stomach, parietal cells are also seen deep in the glands. They secrete HCl, which aids in digestion, converts pepsinogen into the active pepsin, and is bacteriostatic. Parietal cells resemble fried eggs, with abundant eosinophilic cytoplasm and a centrally located nucleus.

click to identify:

- Fundic glands
- Lumens of glands
- Lamina propria
- > Parietal cell >
- Chief cells >
- DNES cells >
- Secretory >
- granules

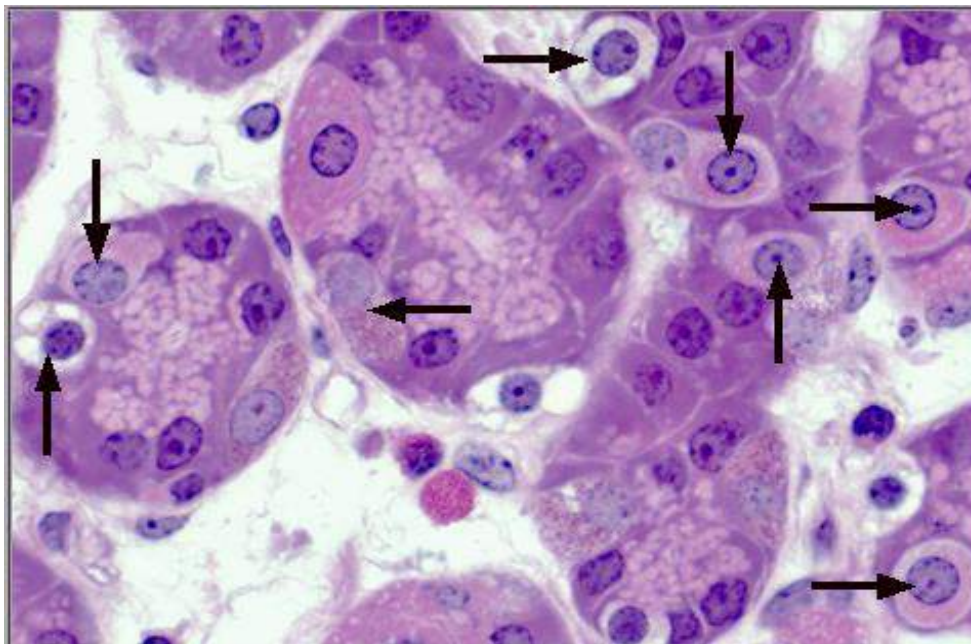


click to identify:

- Fundic glands
- Lumens of glands
- Lamina propria
- Parietal cell >
- > Chief cells >
- > DNES cells >
- Secretory >
- granules

8 of 13

Chief cells secrete the enzyme precursor pepsinogen and, therefore, as protein-secreting exocrine cells, have basally located RER and apically located secretory granules. These cells are most numerous in the bases of the fundic glands, as seen here.

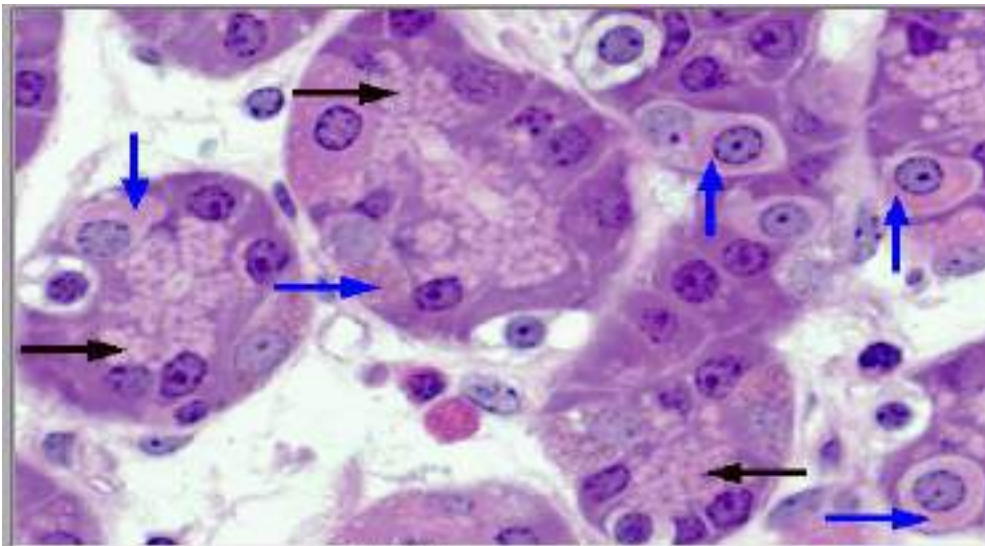


click to identify:

- Fundic glands
- Lumens of glands
- Lamina propria
- Parietal cell >
- > Chief cells >
- > DNES cells >
- Secretory >
- granules

8 of 13

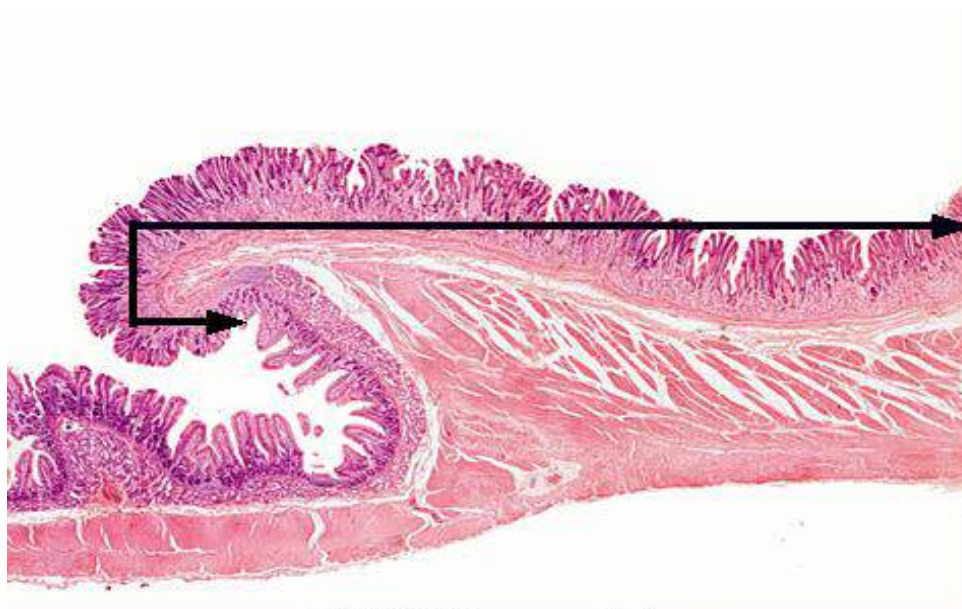
DNES (diffuse neuroendocrine system) cells are called enteroendocrine cells in the digestive system. They do not secrete their hormones into the lumens of the glands but into the surrounding connective tissue. Therefore, these cells are located at the periphery of the glands with their granules positioned away from the lumen and adjacent to the basement membrane.



click to identify:

- Fundic glands
- Lumens of glands
- Lamina propria
- Parietal cell >
- Chief cells >
- DNES cells >
- > Secretory >
- granules

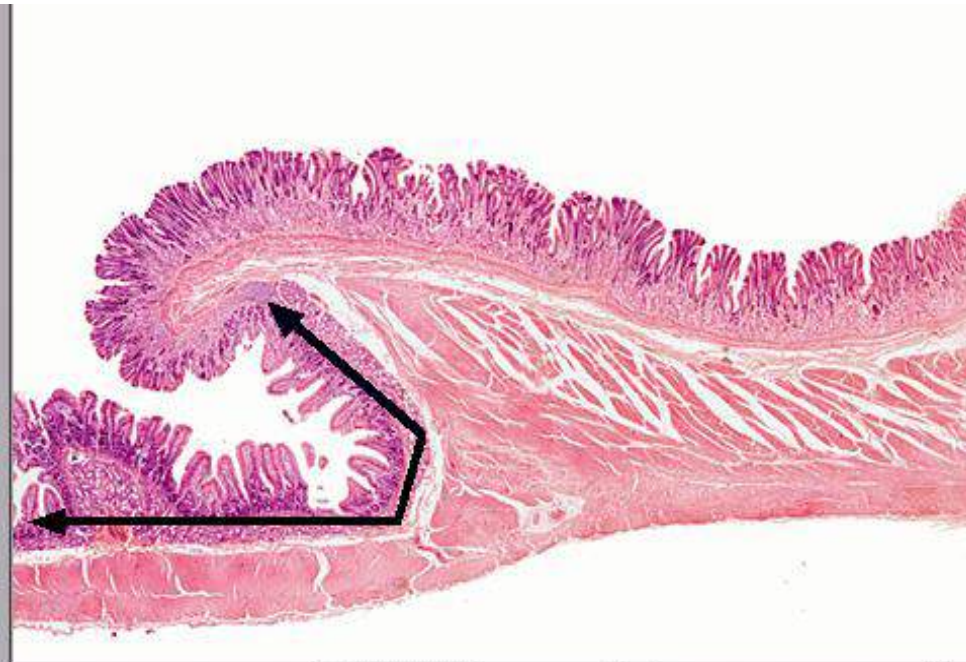
Secretory granules of chief cells (black arrows) lie adjacent to the glandular lumens into which they are released (exocrine secretion). Conversely, the secretory granules (blue arrows) of enteroendocrine cells are located adjacent to the basement membrane of fundic glands because their secretory product is released into the lamina propria (endocrine or paracrine secretion).



click to identify:

- > Pyloric stomach
- Duodenum
- Gastric pits
- Pyloric glands
- Villi
- Intestinal glands
- Brunner's glands
- Muscularis externa
- Pyloric sphincter

Gastro-duodenal junction -- Several criteria differentiate the transition of pyloric stomach to duodenum of the small intestine. As denoted by their names, gastric pits and gastric glands occur only in stomach. Villi, intestinal glands and Brunner's glands are present in the duodenum. The inner circular layer of muscularis externa in stomach is modified to form the pyloric sphincter. 10x

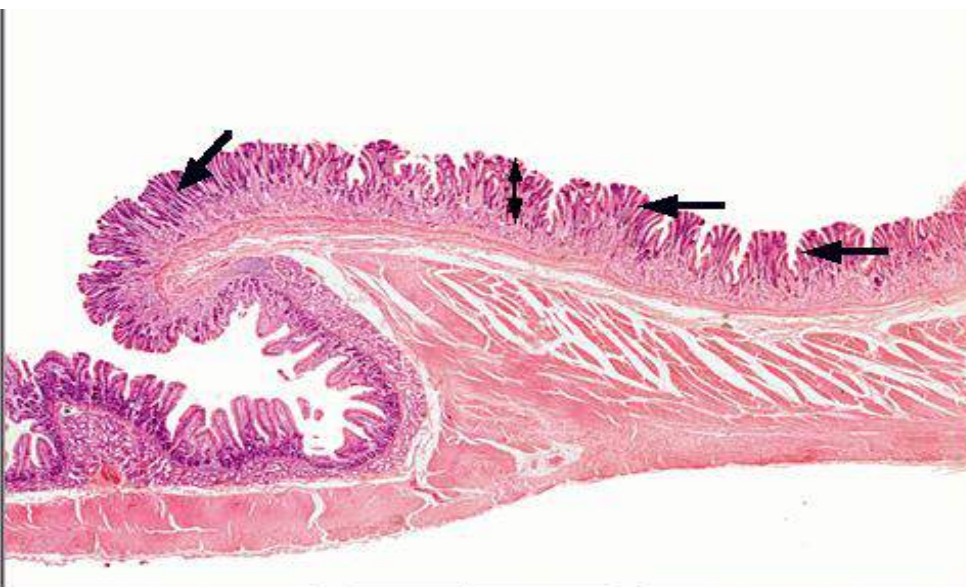


12 of 13

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- Pyloric stomach
- Duodenum
- Gastric pits
- Pyloric glands
- Villi
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- Muscularis externa
- Pyloric sphincter

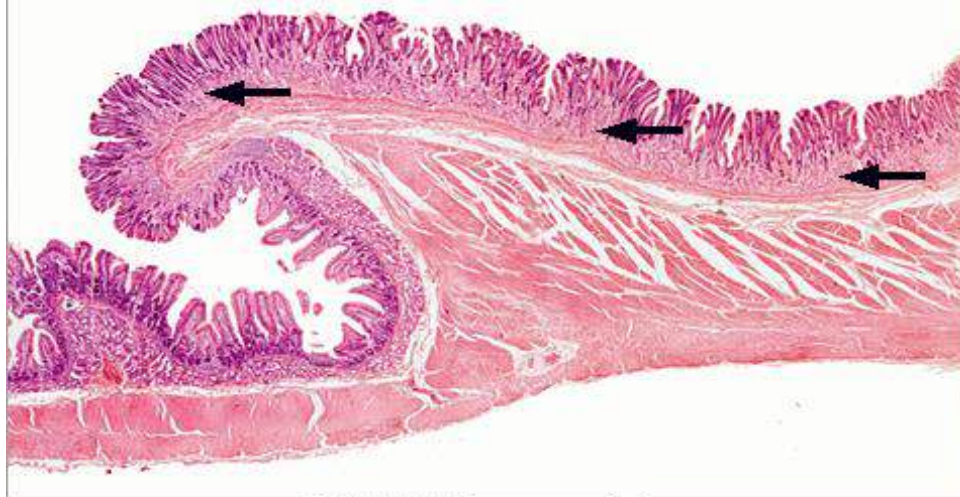


12 of 13

Gastro-duodenal junction -- Several criteria differentiate the transition of pyloric stomach to duodenum of the small intestine . As denoted by their names, gastric pits and gastric glands occur only in stomach. Villi, intestinal glands and Brunner's glands are present in the duodenum. The inner circular layer of muscularis externa in stomach is modified to form the pyloric sphincter. 10x

click to identify:

- Pyloric stomach
- Duodenum
- Gastric pits
- Pyloric glands
- Villi
- Intestinal glands
- Brunner's glands
- Muscularis externa
- Pyloric sphincter

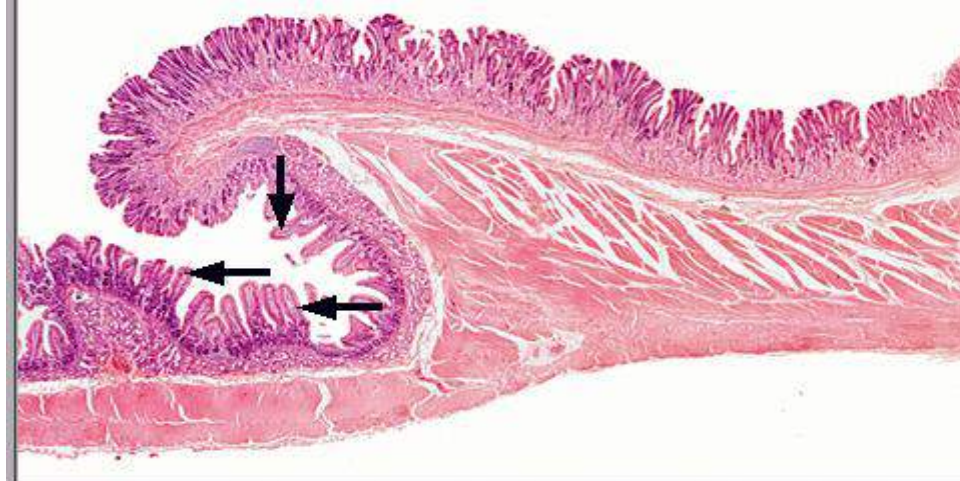


click to identify:

- Pyloric stomach
- Duodenum
- Gastric pits
- Pyloric glands
- Villi
- Intestinal glands
- Brunner's glands
- Muscularis externa
- Pyloric sphincter

12 of 13

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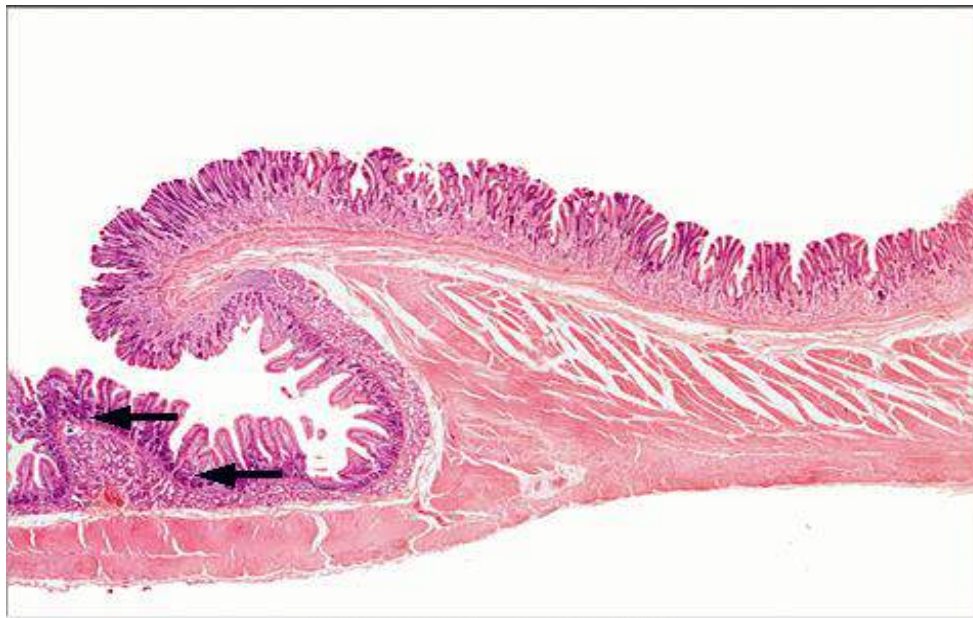


click to identify:

- Pyloric stomach
- Duodenum
- Gastric pits
- Pyloric glands
- Villi
- Intestinal glands
- Brunner's glands
- Muscularis externa
- Pyloric sphincter

12 of 13

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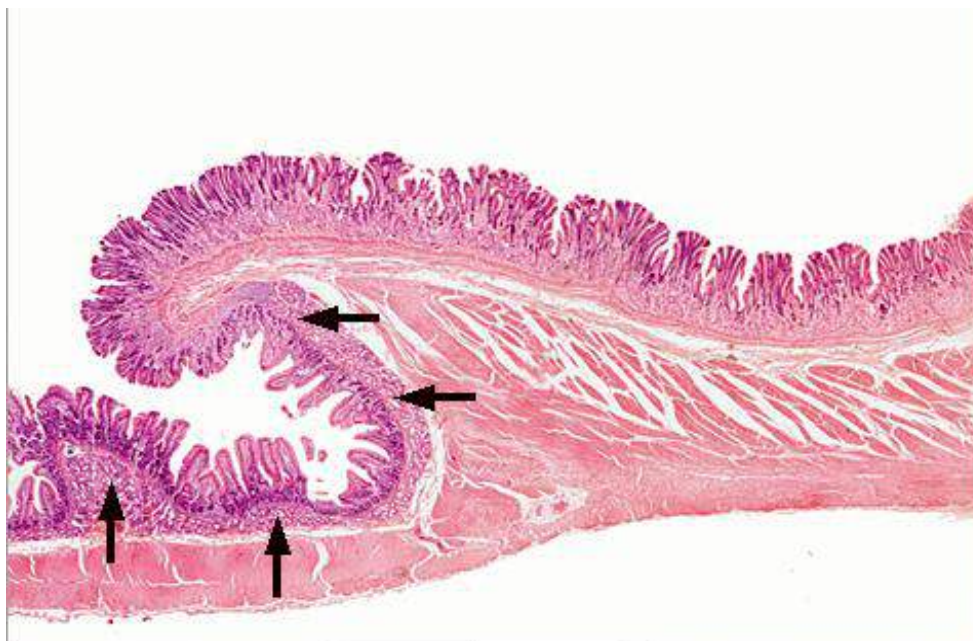
12 of 13

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Pyloric stomach
Duodenum
Gastric pits
Pyloric glands
Villi

► Intestinal glands
Brunner's glands
Muscularis externa
Pyloric sphincter



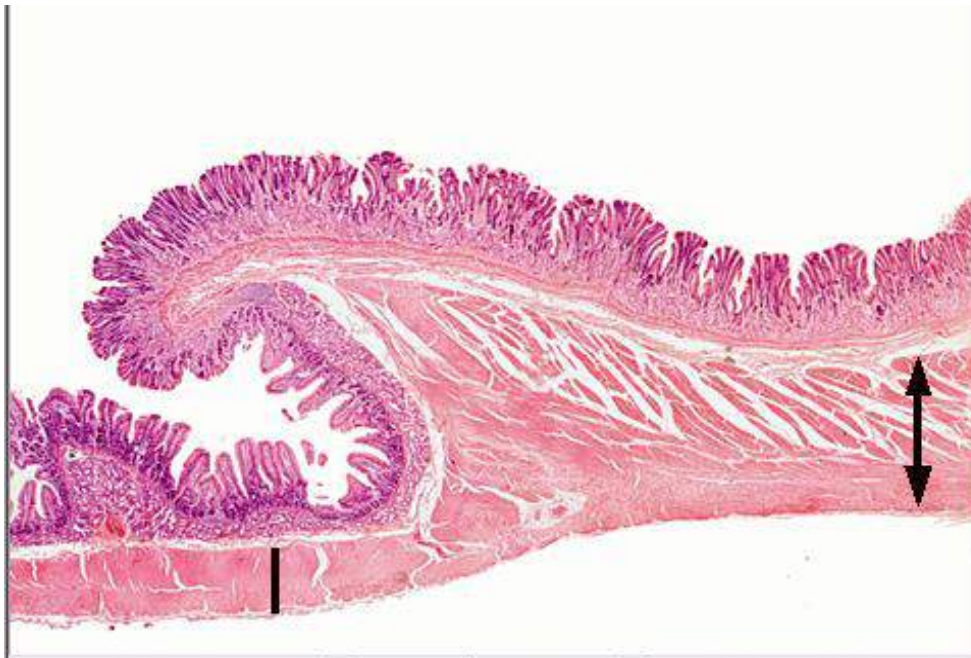
12 of 13

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click to identify:

Pyloric stomach
Duodenum
Gastric pits
Pyloric glands
Villi

► Intestinal glands
Brunner's glands
Muscularis externa
Pyloric sphincter

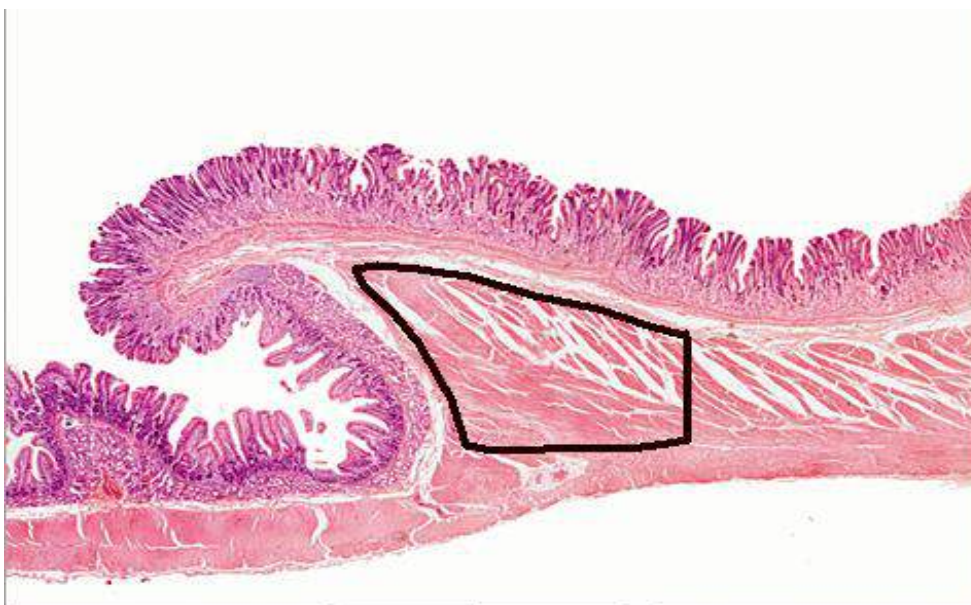


click to identify:

- Pyloric stomach
- Duodenum
- Gastric pits
- Pyloric glands
- Villi
- Intestinal glands
- Brunner's glands
- > Muscularis externa
- Pyloric sphincter

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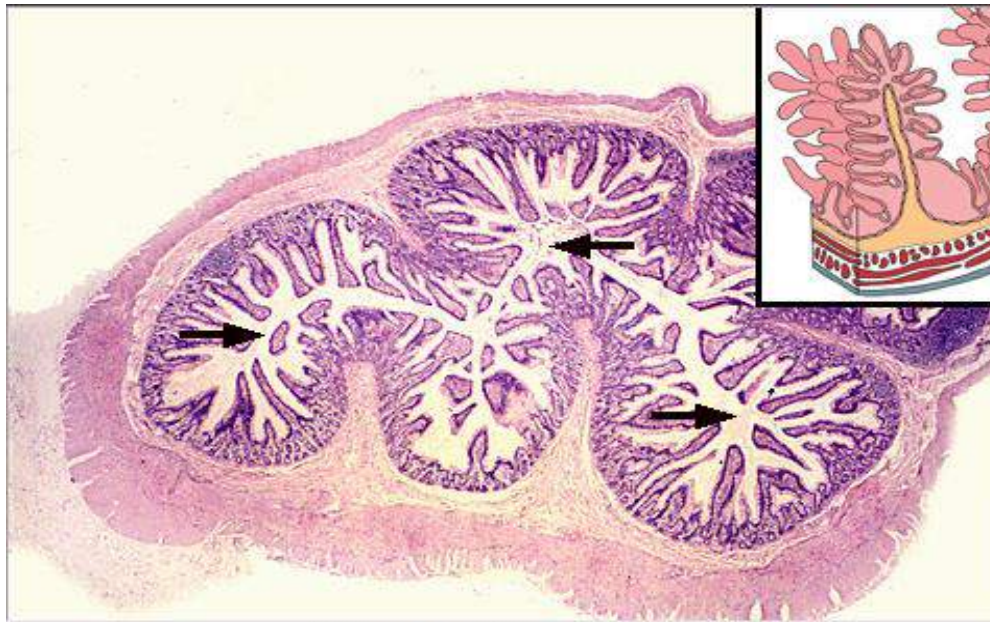


click to identify:

- Pyloric stomach
- Duodenum
- Gastric pits
- Pyloric glands
- Villi
- Intestinal glands
- Brunner's glands
- Muscularis externa
- > Pyloric sphincter

12 of 13

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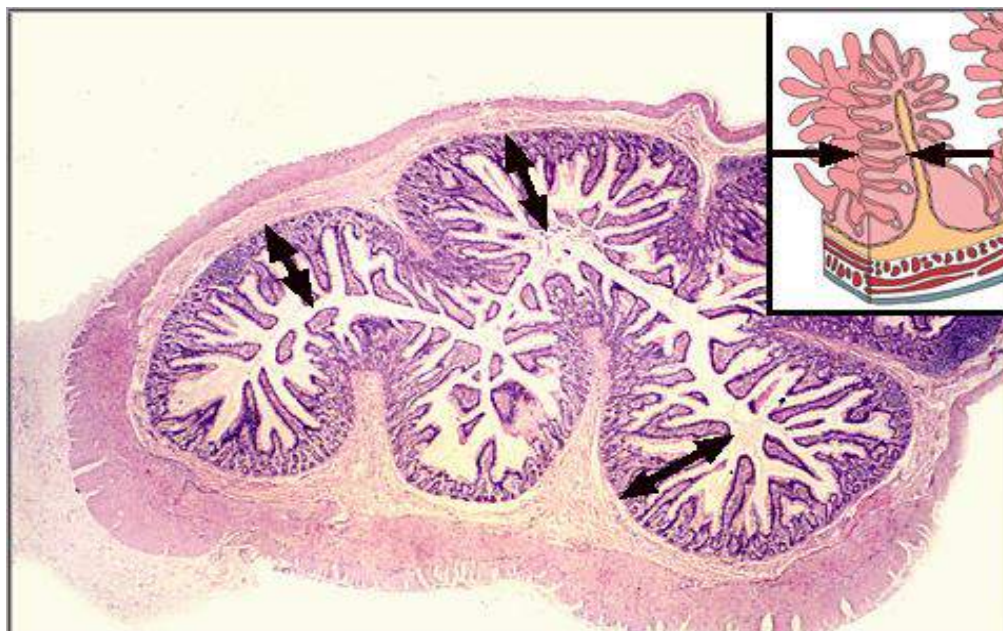


1 of 9

Overview -- Digestion is completed and metabolites are absorbed in the small intestine. The small intestine, composed of a mucosa, submucosa, muscularis externa and usually a serosa, is subdivided into duodenum, jejunum and ileum. The exocrine secretions of the pancreas and liver are released into the duodenum. 10x

click to identify:

- > Lumen
- Mucosa
- Submucosa
- Muscularis > externa
- Serosa >
- Villi >
- Plicae circulares >
- Mesentery >
- Next image

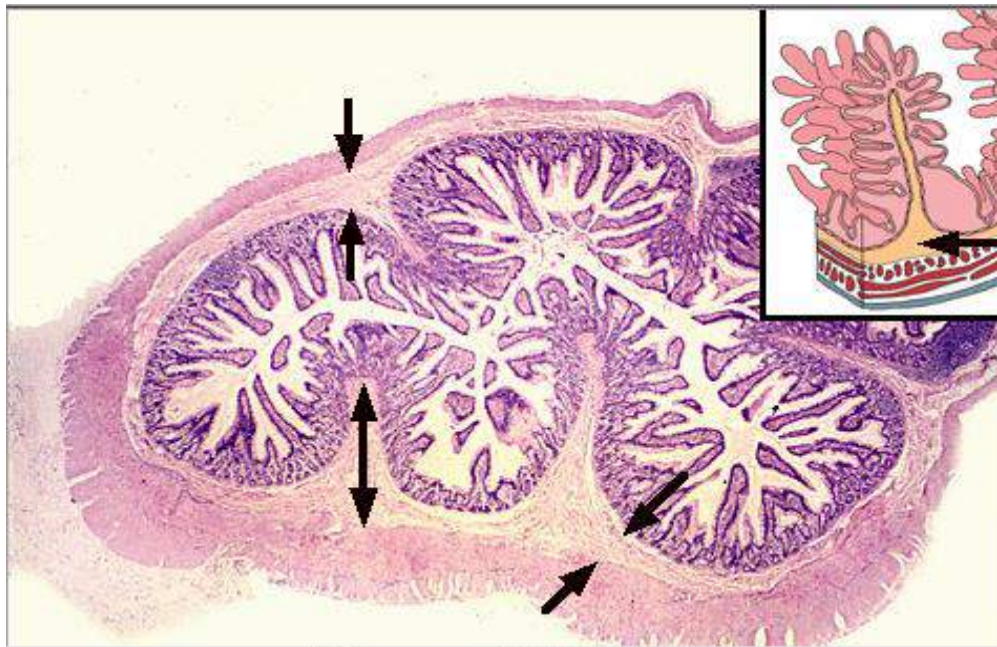


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- Submucosa
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- Serosa >
- Villi >
- Plicae circulares >
- Mesentery >
- Next image

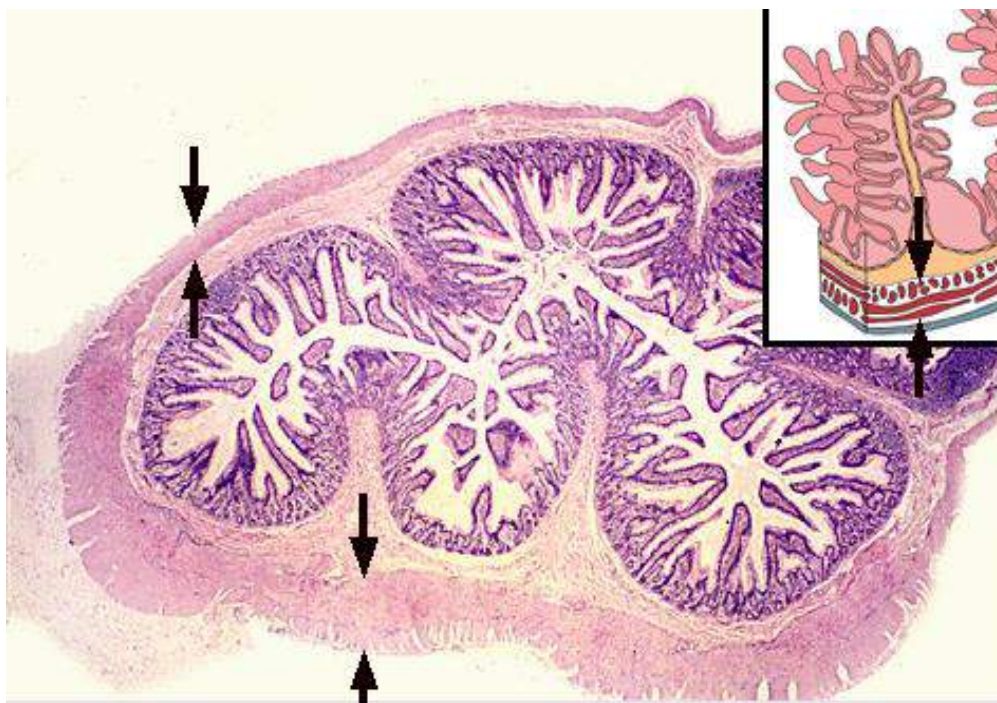


click to identify:

- Lumen
- Mucosa
- > Submucosa
- Muscularis > externa
- Serosa >
- Villi >
- Plicae circulares >
- Mesentery >
- Next image

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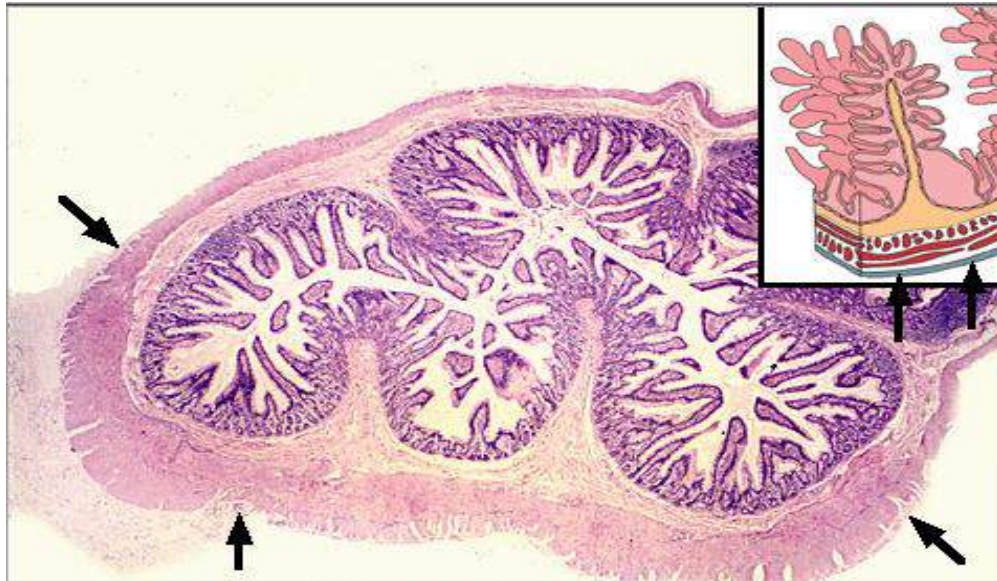


click to identify:

- Lumen
- Mucosa
- Submucosa
- > Muscularis > externa
- Serosa >
- Villi >
- Plicae circulares >
- Mesentery >
- Next image

1 of 9

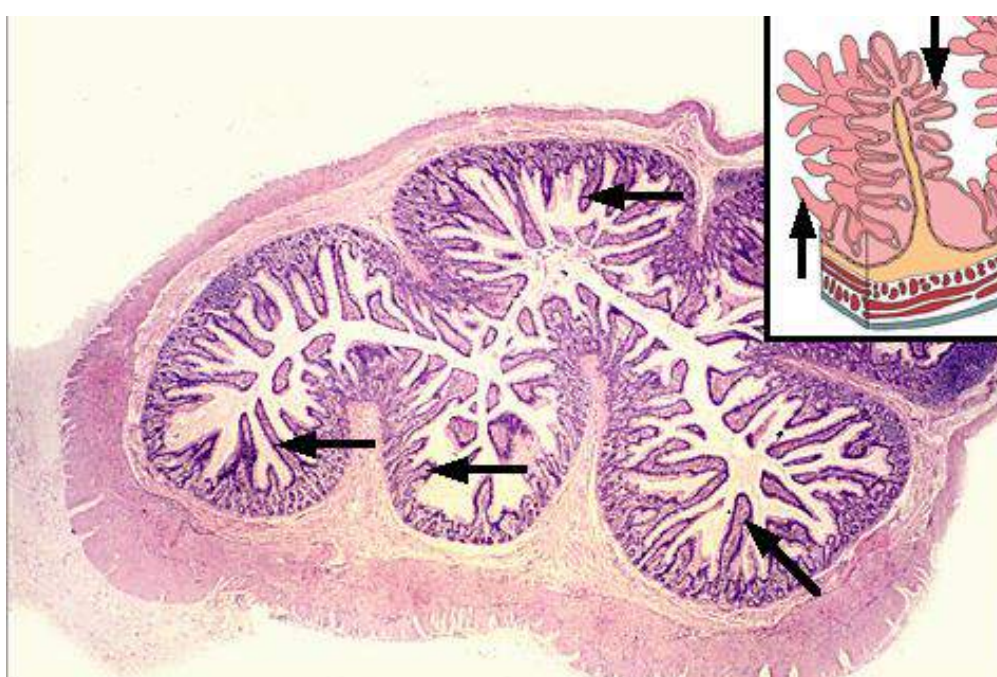
The muscularis externa of the small intestine is composed of inner circular and outer longitudinal layers of smooth muscle.



1 of 9

The outermost layer of the small intestine may be either an adventitia (in the part of the duodenum that is retroperitoneal) or a serosa, in the remainder of the duodenum and in the jejunum and ileum (shown here). (See serosa and adventitia in the General Concepts chapter to review where each is present.)

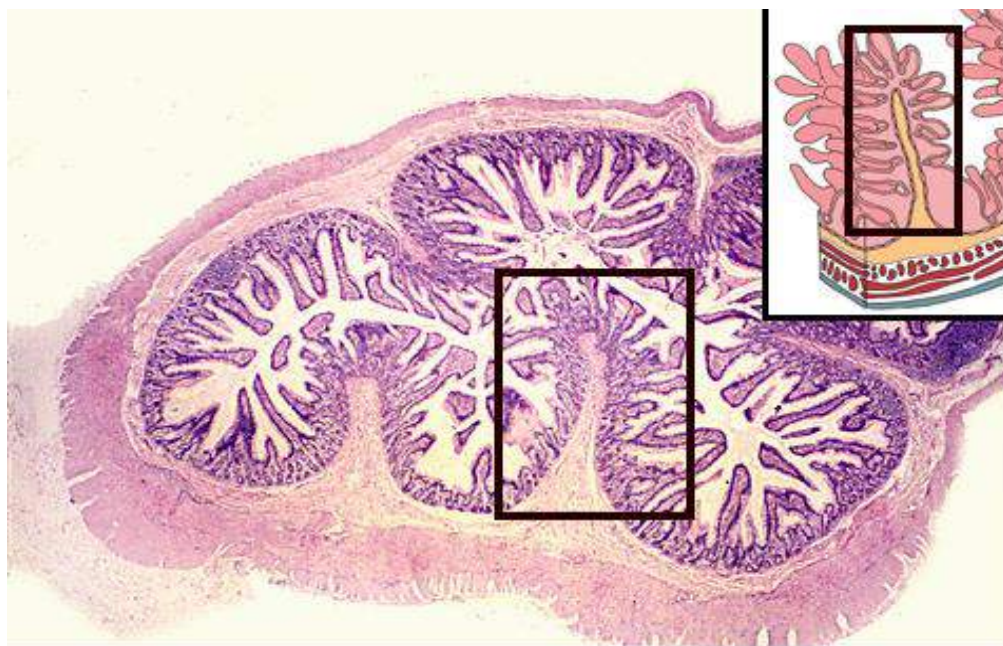
- click to identify:
- Lumen
 - Mucosa
 - Submucosa
 - Muscularis > externa
 - > Serosa >
 - Villi >
 - Plicae circulares >
 - Mesentery >
 - Next image



1 of 9

Villi are finger-like projections from the surface of the small intestine into the lumen of the organ. Villi are composed of a central core of lamina propria covered by its overlying surface epithelium. The presence of villi are diagnostic for the small intestine.

- click to identify:
- Lumen
 - Mucosa
 - Submucosa
 - Muscularis > externa
 - Serosa >
 - > Villi >
 - Plicae circulares >
 - Mesentery >
 - Next image

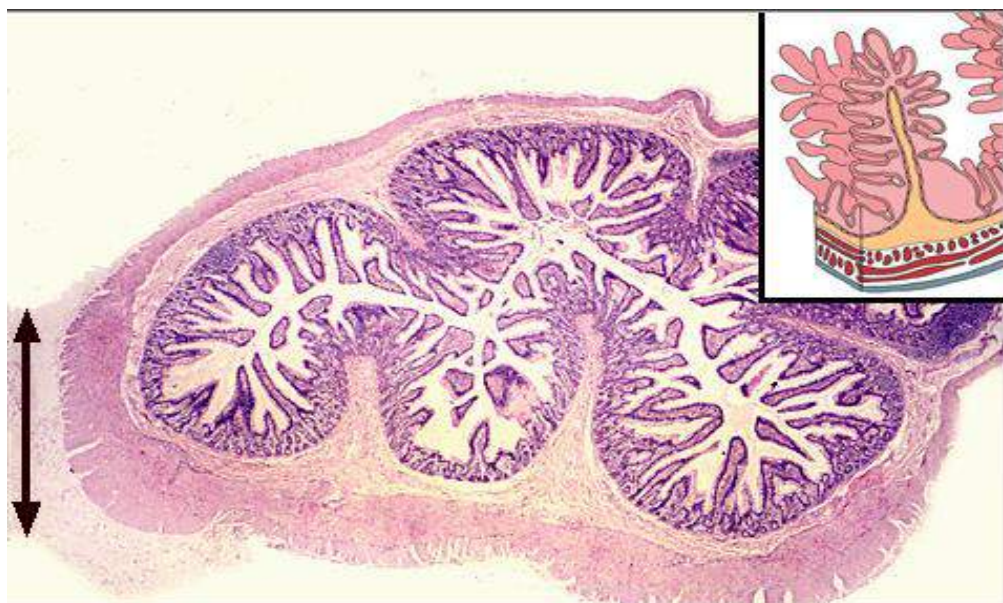


click to identify:

- Lumen
- Mucosa
- Submucosa
- Muscularis > externa
- Serosa >
- Villi >
- > Plicae circulares >
- Mesentery >
- Next image

1 of 9

Plicae circulares are circular folds extending around the inner circumference of the small intestine. The central core of each plica, formed by the submucosa, pushes up all the overlying layers. Therefore, the entire mucosa (including villi and glands) overlying the submucosal core is included in each plica.

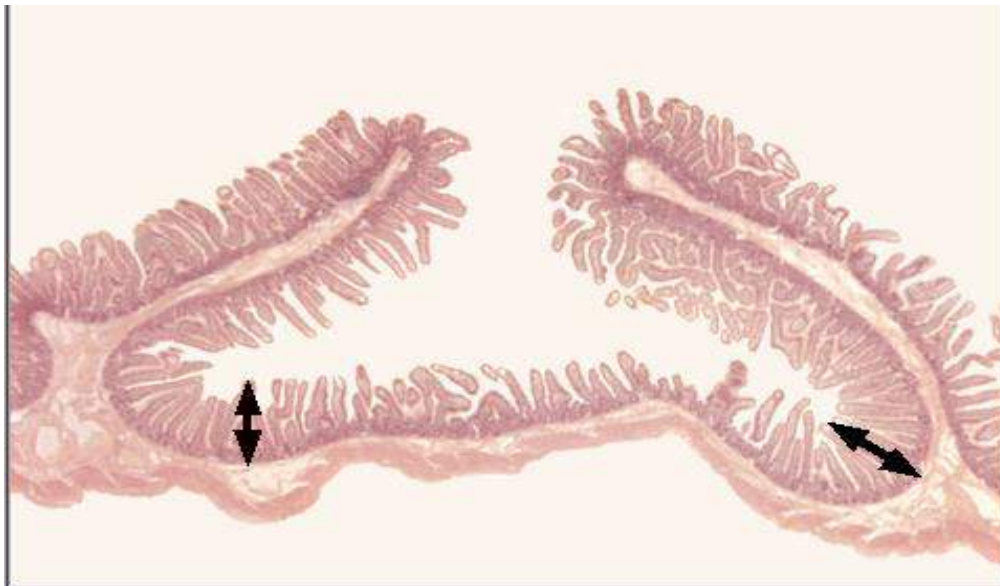


click to identify:

- Lumen
- Mucosa
- Submucosa
- Muscularis > externa
- Serosa >
- Villi >
- Plicae circulares >
- > Mesentery >
- Next image

1 of 9

The mesentery suspends most of the small intestine from the dorsal body wall. It is composed of two serosal layers and an intervening layer of loose connective tissue.

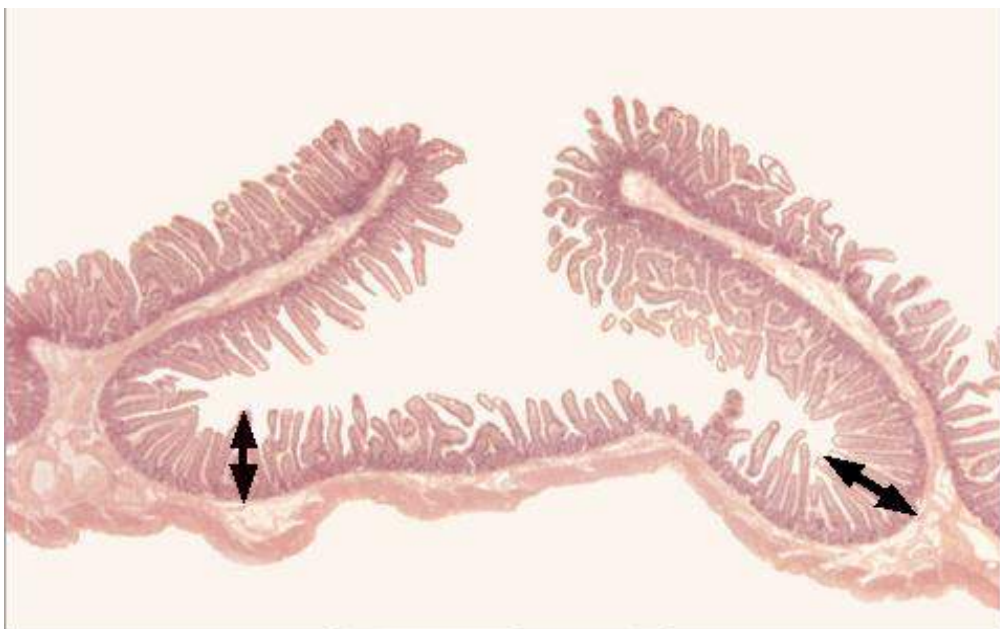


2 of 9

Overview -- A longitudinal section of the small intestine displays the four layers of this organ as well as structures that aid to increase surface area, plicae circulares and villi. Each plica has a core of submucosa that is overlain by all mucosal layers, including villi. Villi have a core of lamina propria covered by the intestinal epithelium, including microvilli. 10x

click to identify:

- › Mucosa
- Submucosa
- Muscularis externa
- Serosa
- Villi
- Intestinal glands
- Plicae circulares
- Next image

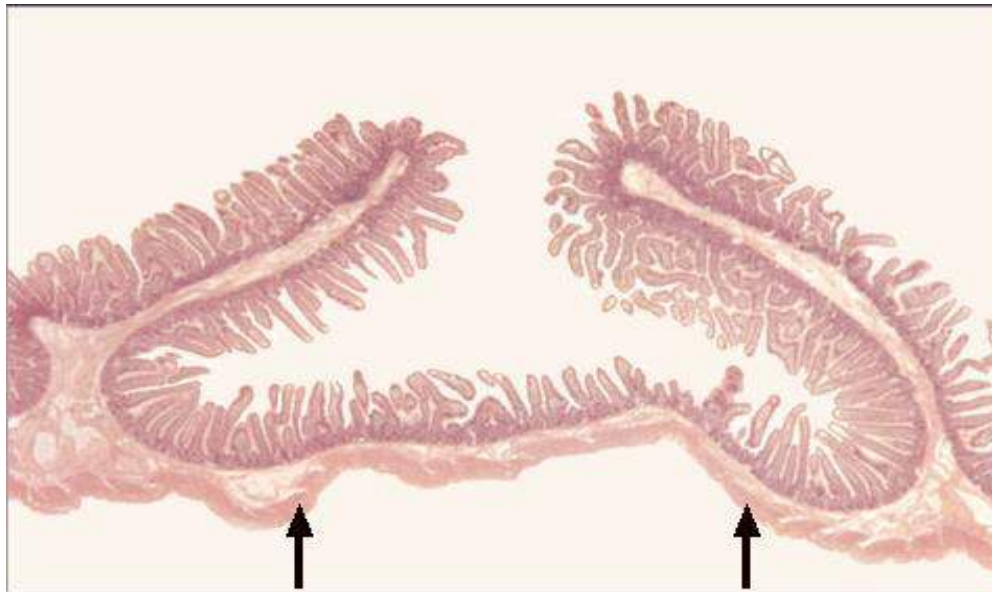


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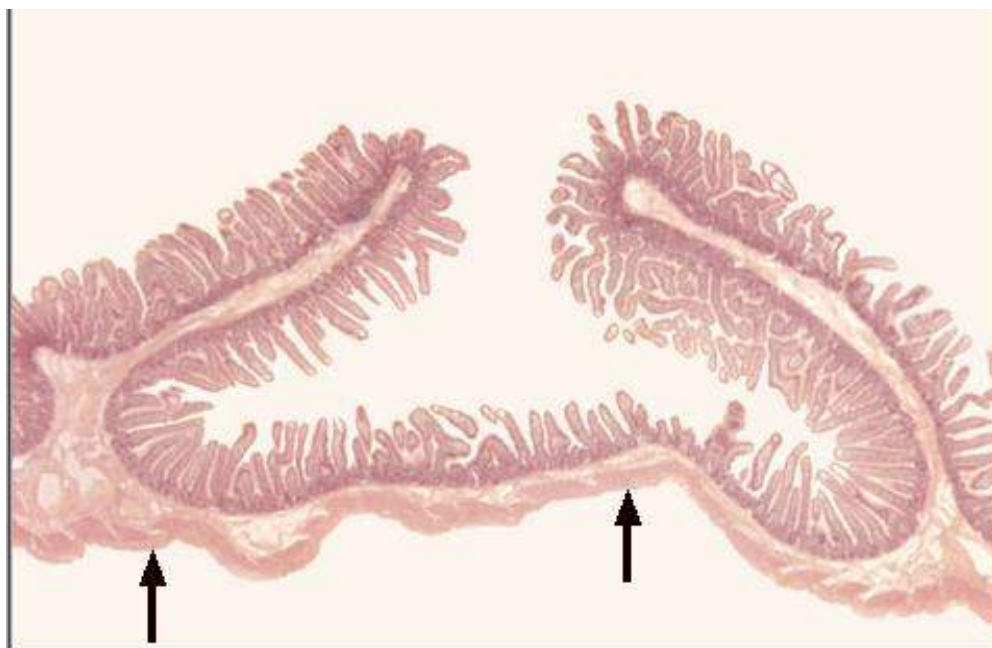
- › Mucosa
- Submucosa
- Muscularis externa
- Serosa
- Villi
- Intestinal glands
- Plicae circulares
- Next image



click to identify:

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- Submucosa
- Muscularis externa
- Serosa
- Villi
- Intestinal glands
- Plicae circulares
- Next image

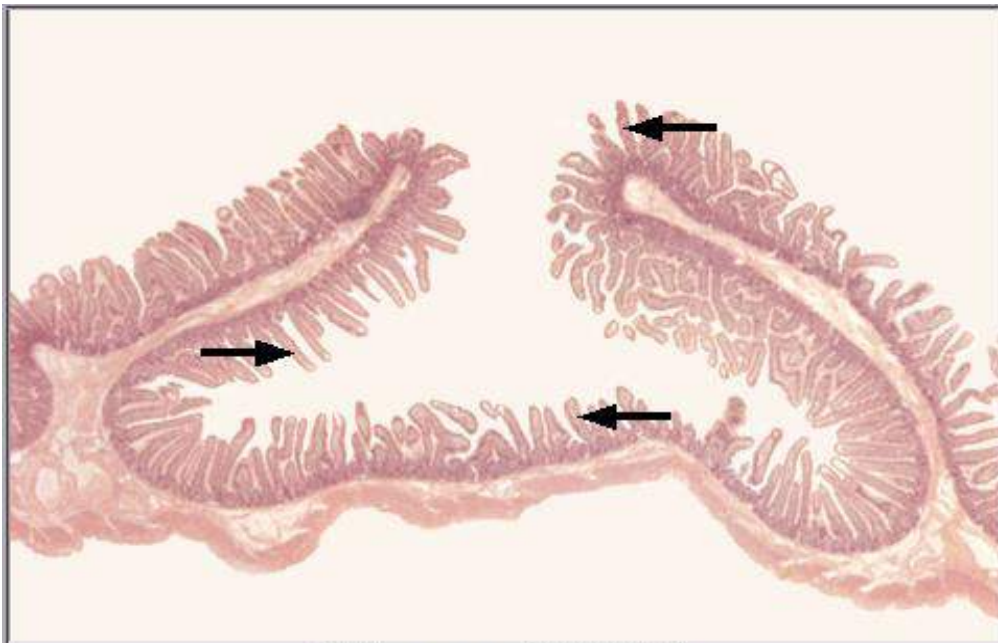
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- Submucosa
- Muscularis externa
- Serosa
- Villi
- Intestinal glands
- Plicae circulares
- Next image

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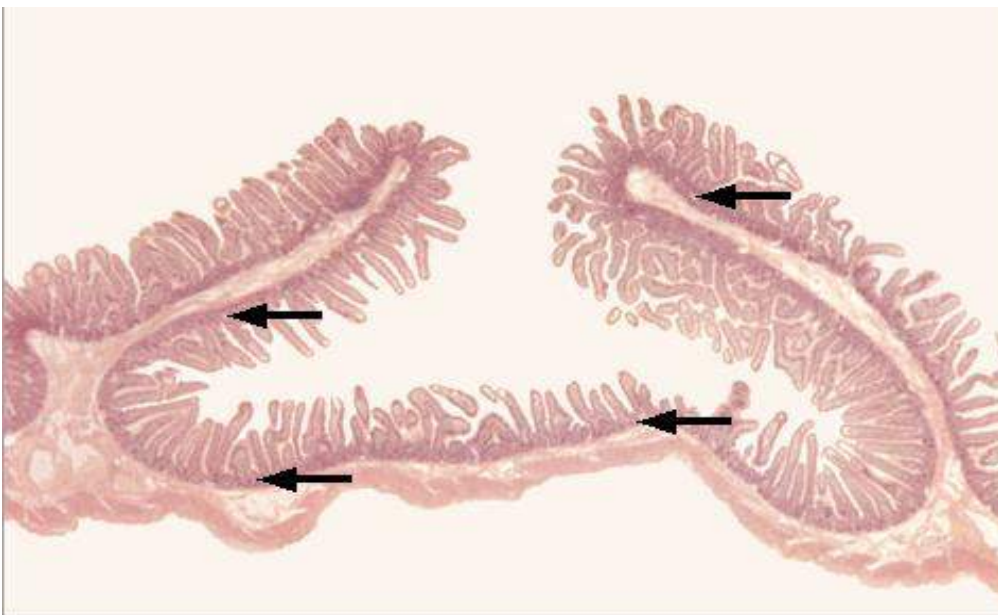


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- Submucosa
- Muscularis externa
- Serosa
- > Villi
- Intestinal glands
- Plicae circulares
- Next image

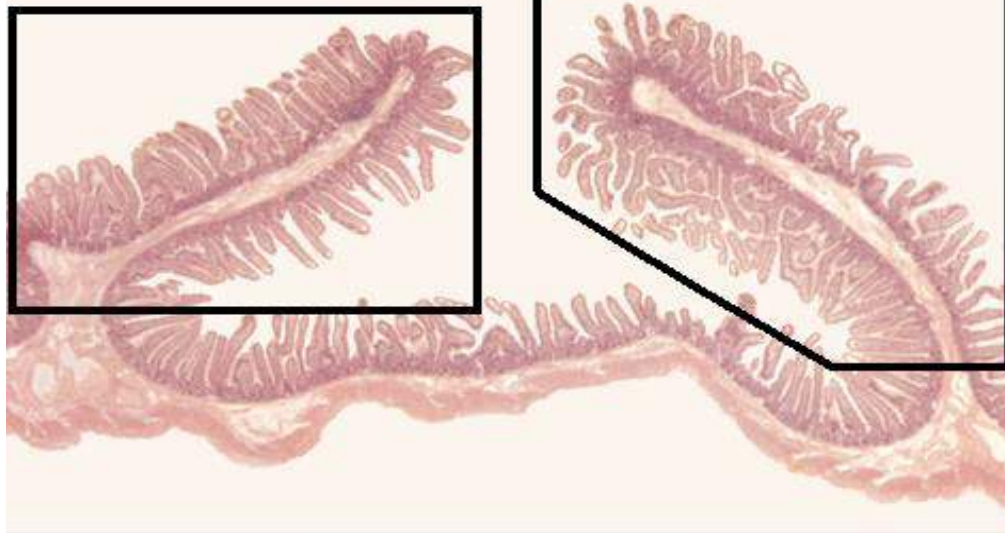


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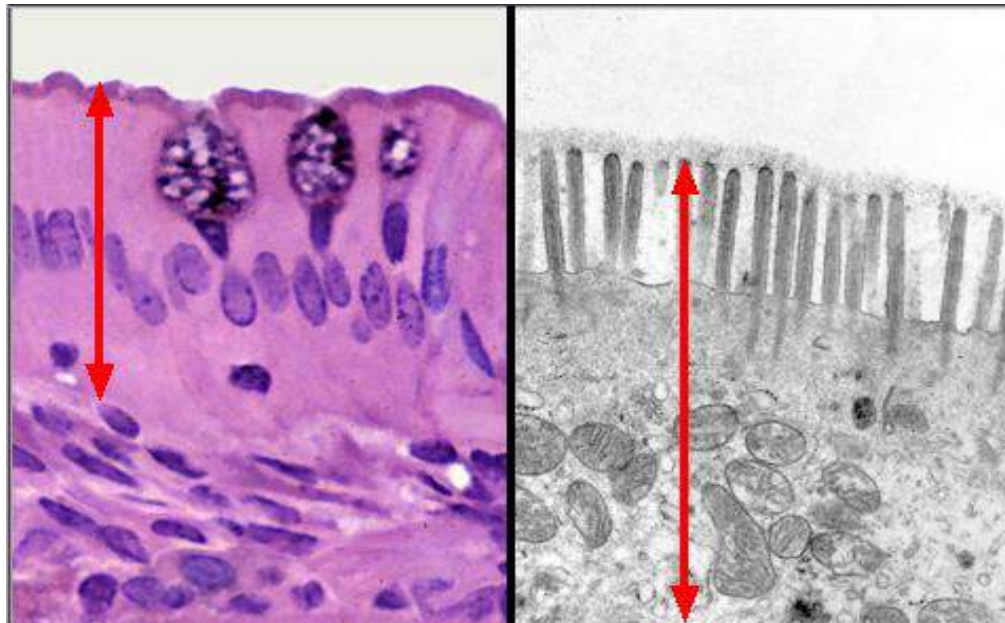
- Mucosa
- Submucosa
- Muscularis externa
- Serosa
- Villi
- > Intestinal glands
- Plicae circulares
- Next image



click to identify:

- Mucosa
- Submucosa
- Muscularis externa
- Serosa
- Villi
- Intestinal glands
- > Plicae circulares
- Next image

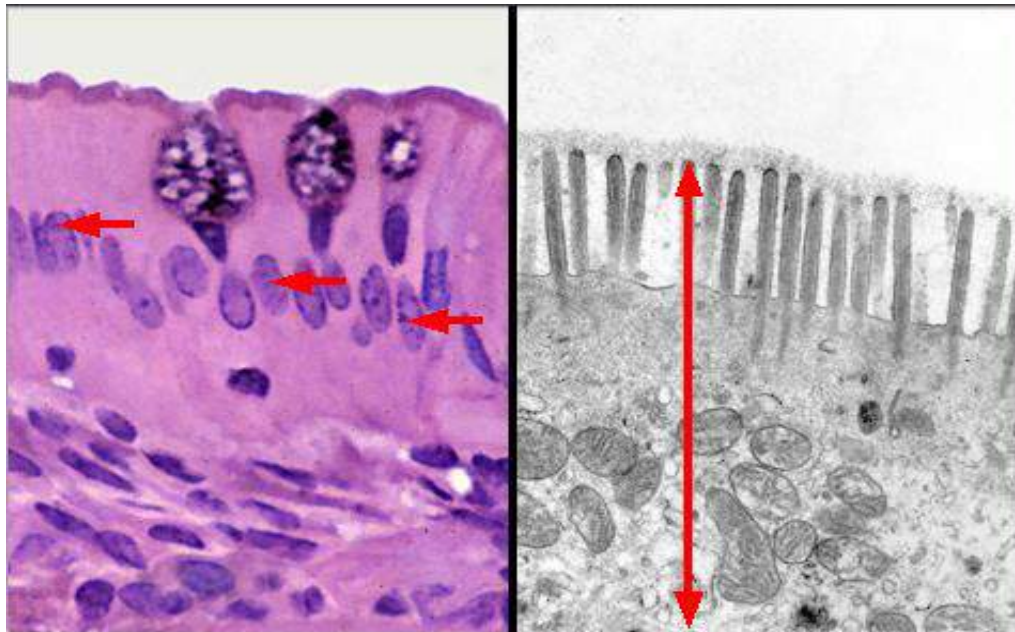
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click to identify:

- > Epithelium
- Enterocytes >
- Microvilli
- Glycocalyx
- Goblet cells >
- Lamina propria >

Overview -- The small intestine is lined by a simple columnar epithelium with microvilli and goblet cells. The majority of these epithelial cells are absorptive cells (enterocytes) involved with the uptake of nutrients from ingested food. 1000x, 10,000x

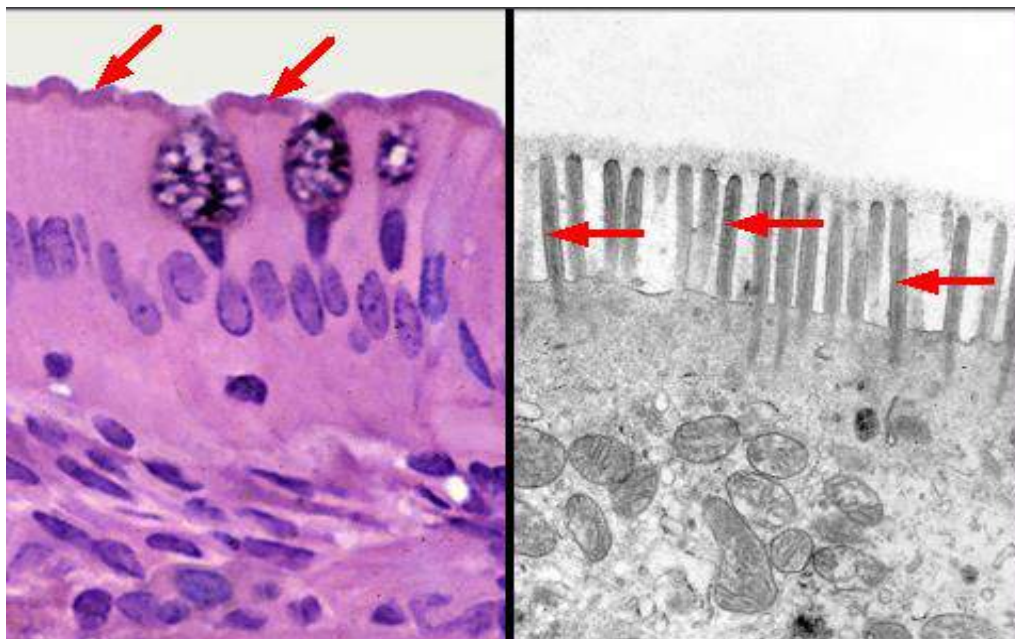


6 of 9

The luminal surfaces of enterocytes, the simple columnar cells of this epithelium, are covered by microvilli that increase the surface area for absorption. A glycocalyx, also located at the extracellular surface, sequesters enzymes important in digestion and in the transport of nutrients.

click to identify:

- Epithelium
- > Enterocytes >
- Microvilli
- Glycocalyx
- Goblet cells >
- Lamina propria >

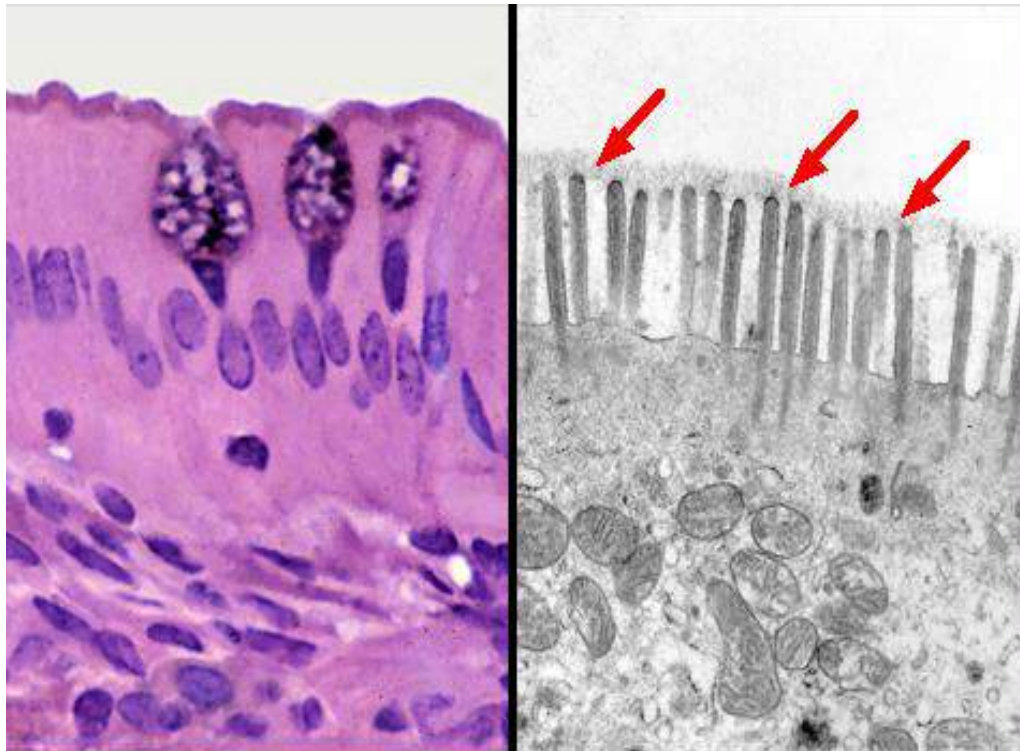


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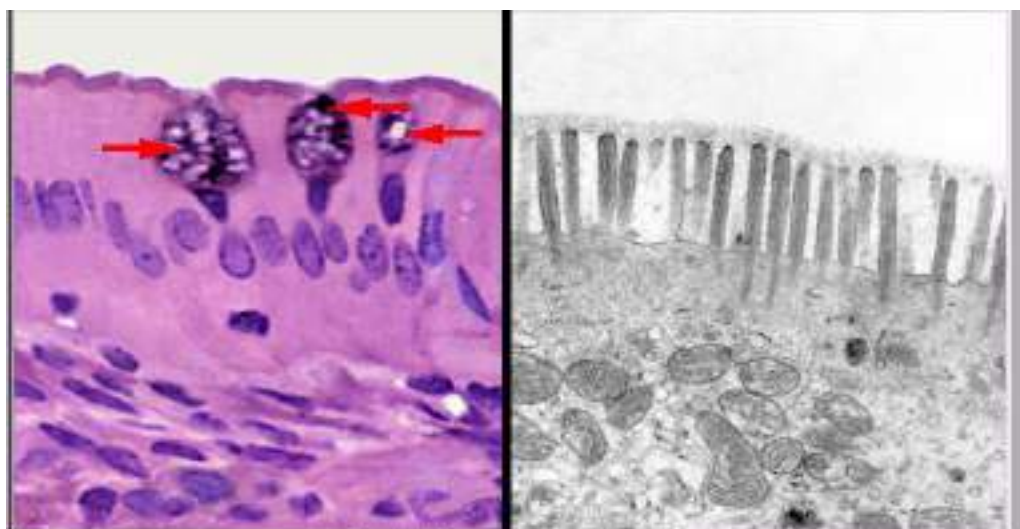
- Epithelium
- Enterocytes >
- > Microvilli
- Glycocalyx
- Goblet cells >
- Lamina propria >



click to identify:

- Epithelium
- Enterocytes >
- Microvilli
- > Glycocalyx
- Goblet cells >
- Lamina propria >

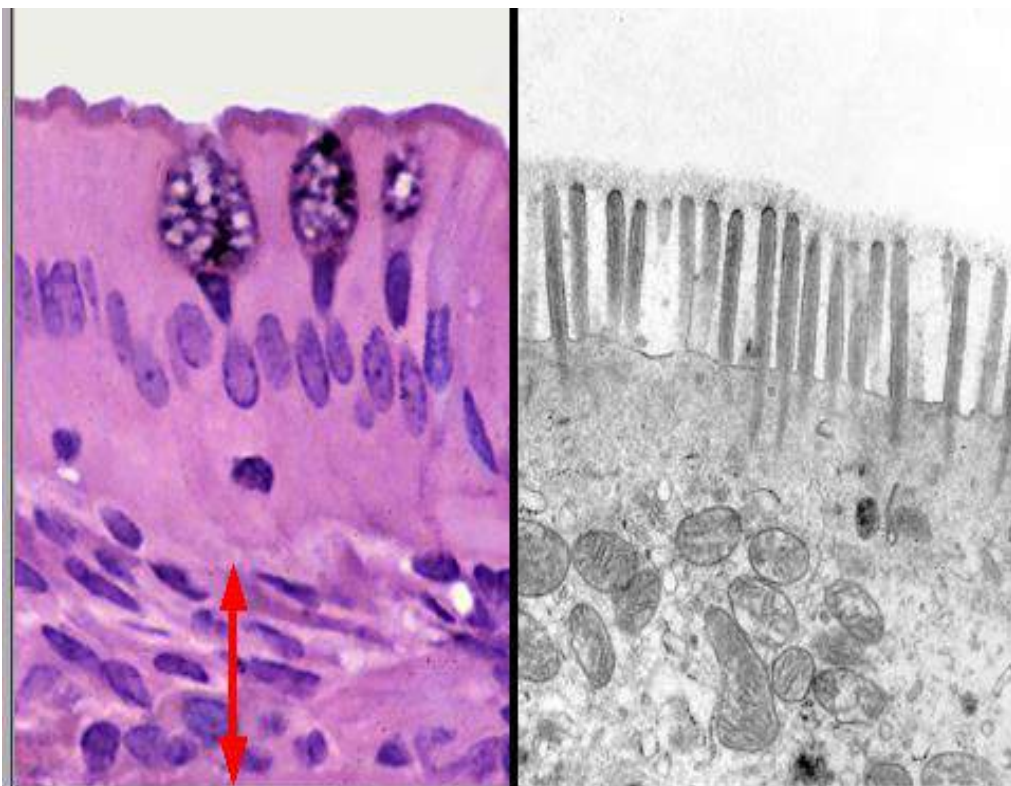
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click to identify:

- Epithelium
- Enterocytes >
- Microvilli
- Glycocalyx
- > Goblet cells >
- Lamina propria >

Goblet cells are the second cell type in the epithelium. Mucin droplets produced by these cells accumulate in the bulging apex, while the nucleus and remaining cytoplasm form the "stem" of the each goblet. Goblet cells, found throughout the small and large intestines, produce mucus that lubricates the surface of the intestines.

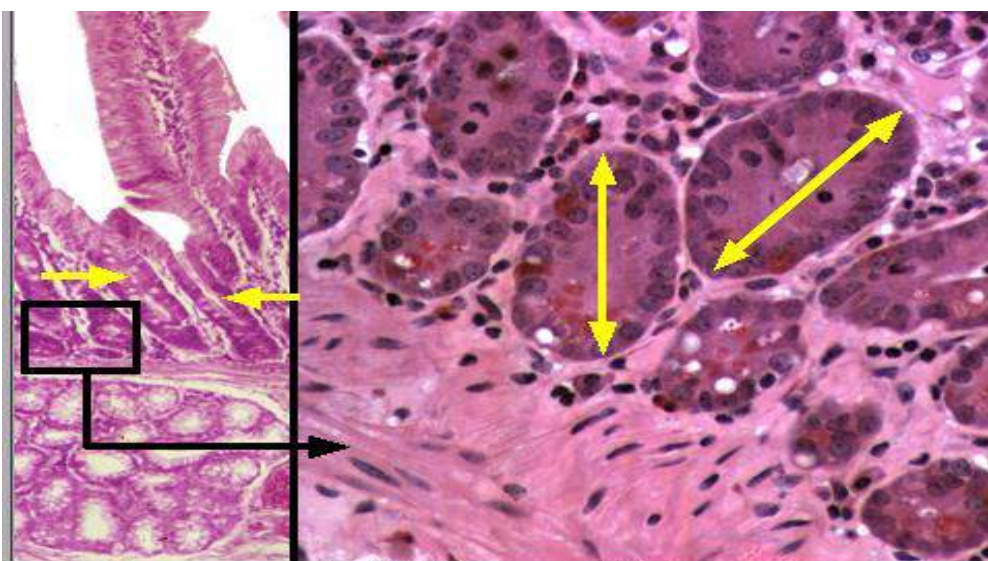


6 of 9

A lamina propria of loose connective tissue underlies the epithelium.

click to identify:

- Epithelium
- Enterocytes >
- Microvilli
- Glycocalyx
- Goblet cells >
- > Lamina propria >

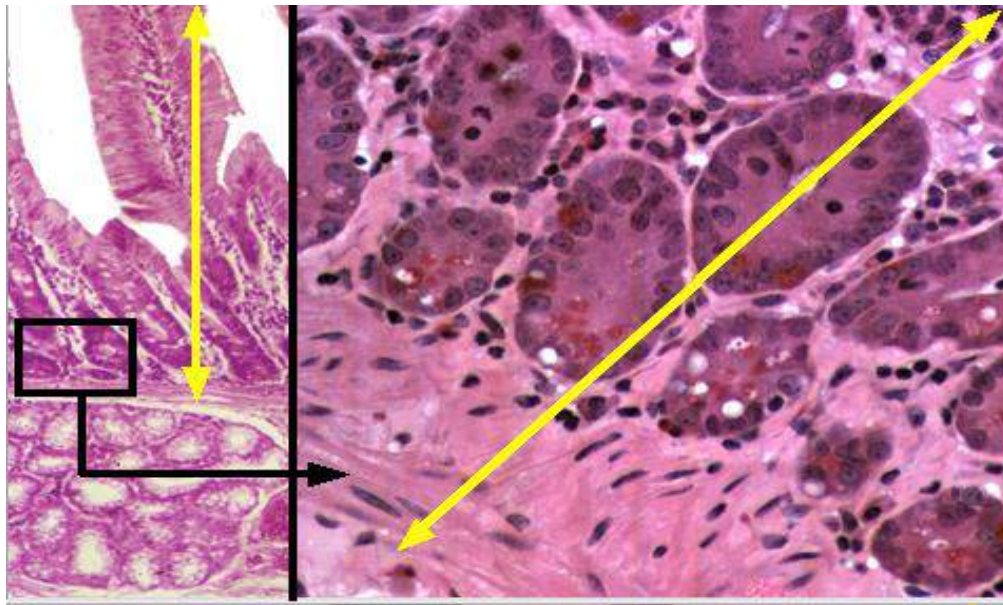


7 of 9

Overview -- Epithelial invaginations into the lamina propria of the small intestine form the intestinal glands, also known as the glands or crypts of Lieberkuhn; the bases of these glands extend down to the muscularis mucosae. Intestinal glands contain goblet cells, some absorptive cells, Paneth cells and enteroendocrine (DNES) cells. 100x, 400x

click to identify:

- > Intestinal glands
- Mucosa
- Lamina propria
- Muscularis mucosae
- Submucosa
- Next image

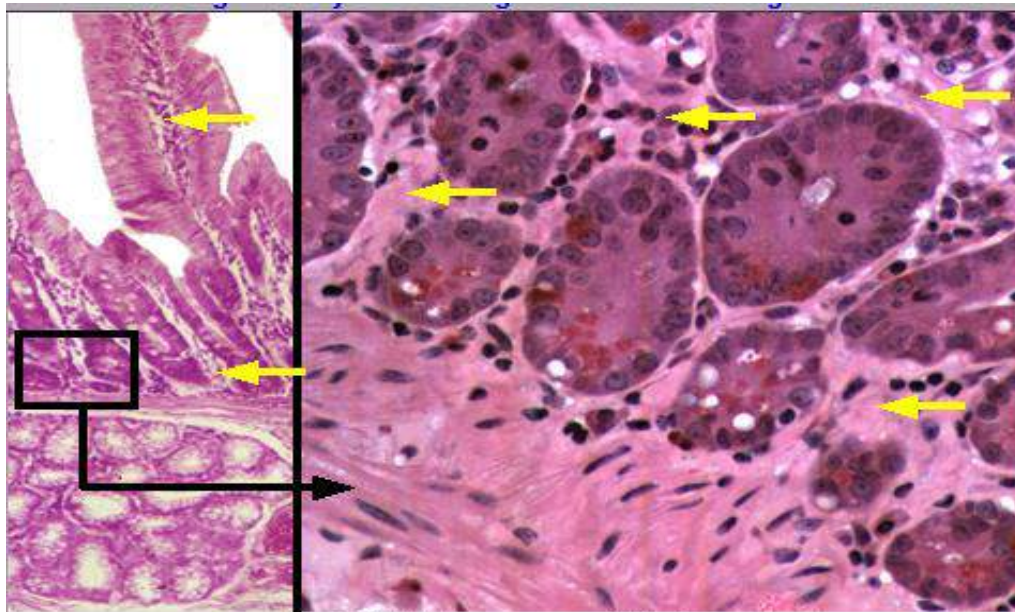


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- Lamina propria
- Muscularis mucosae
- Submucosa
- Next image

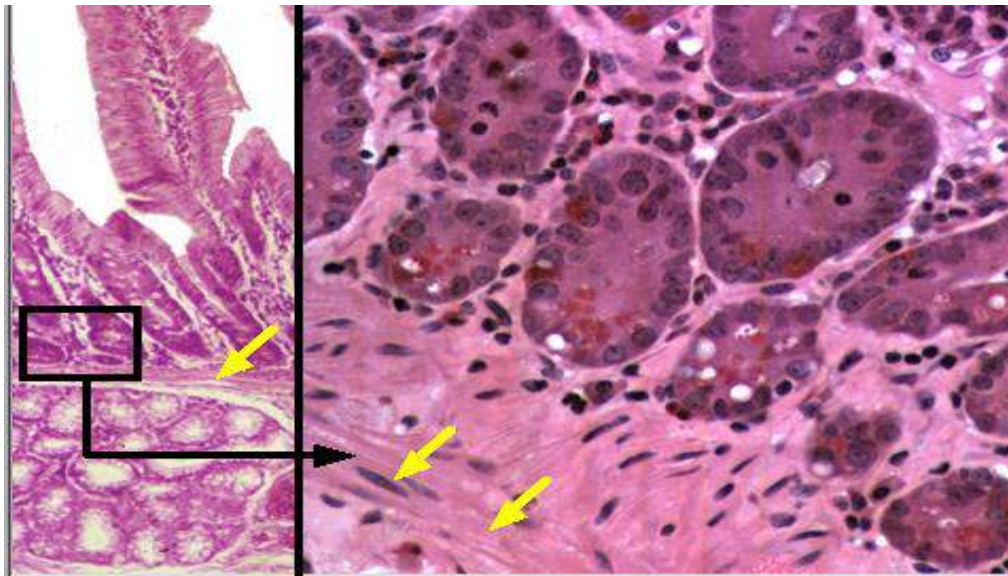


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- › Lamina propria
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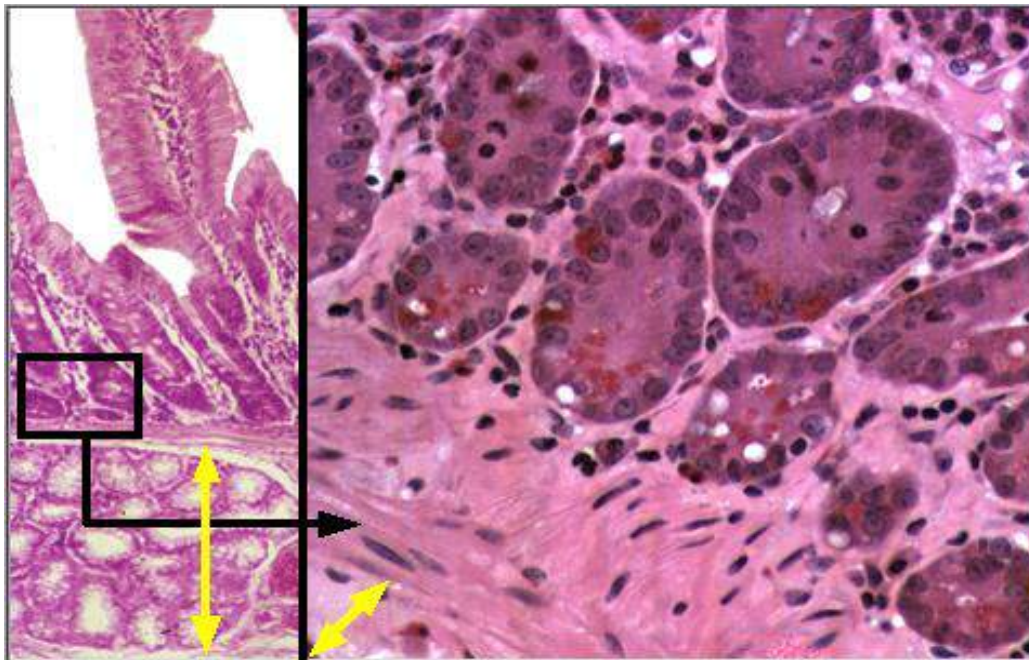


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Intestinal glands
Mucosa
Lamina propria
➤ Muscularis
mucosae
Submucosa
Next image

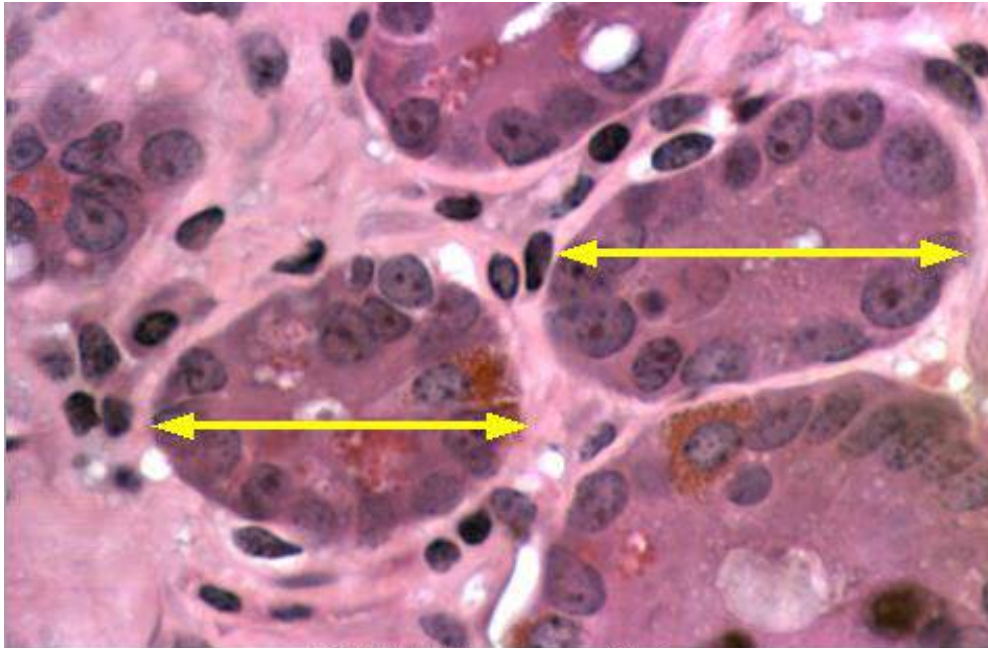


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click to identify:

Intestinal glands
Mucosa
Lamina propria
Muscularis
mucosae
➤ Submucosa
Next image

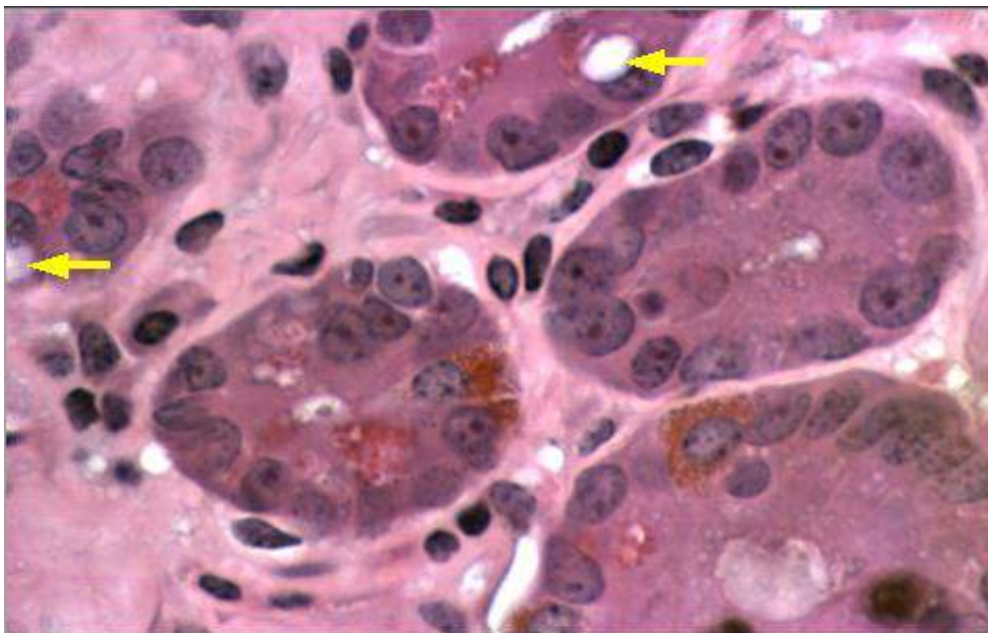


8 of 9

Overview -- Intestinal glands, seen here in cross section, are formed by an epithelium composed of absorptive cells, goblet cells, Paneth cells, precursor cells and enteroendocrine (DNES) cells. 1000x

click to identify:

- > Intestinal glands
- Goblet cells
- Precursor cells >
- Paneth cells >
- Enteroendocrine > cells
- Lamina propria >
- Plasma cell

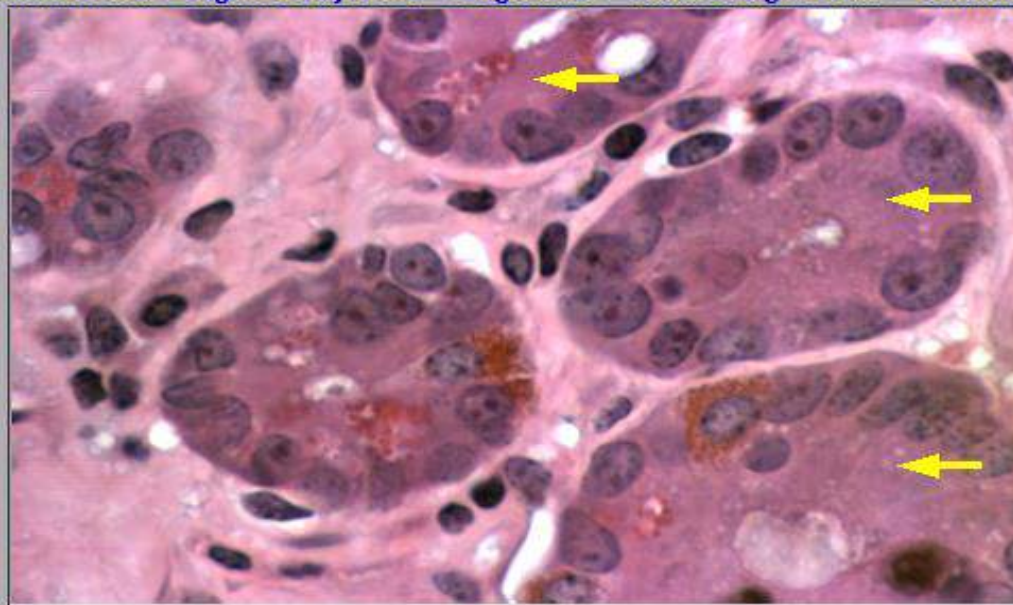


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click to identify:

- Intestinal glands
- > Goblet cells
- Precursor cells >
- Paneth cells >
- Enteroendocrine > cells
- Lamina propria >
- Plasma cell

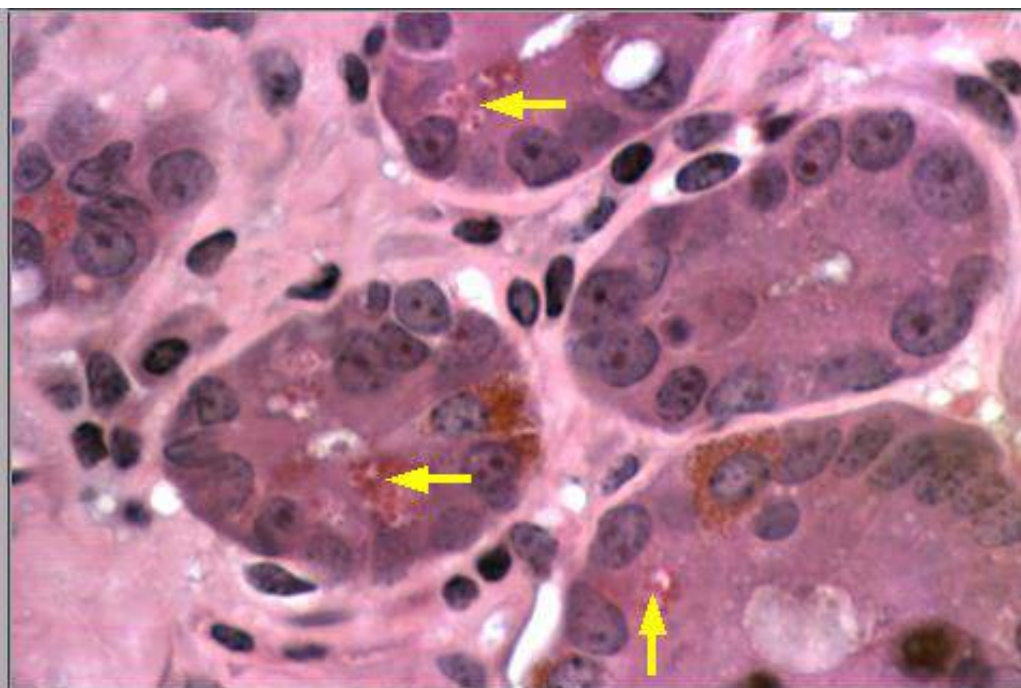


8 of 9

The crypts of Lieberkuhn house precursor cells (stem and intermediate cells) that replenish the supply of both the absorptive and goblet cells. When formed, these differentiated cells migrate up the intestinal glands and villi to be shed from the tips of the villi.

click to identify:

- Intestinal glands
- Goblet cells
- > Precursor cells >
- Paneth cells >
- Enteroendocrine >
- cells
- Lamina propria >
- Plasma cell

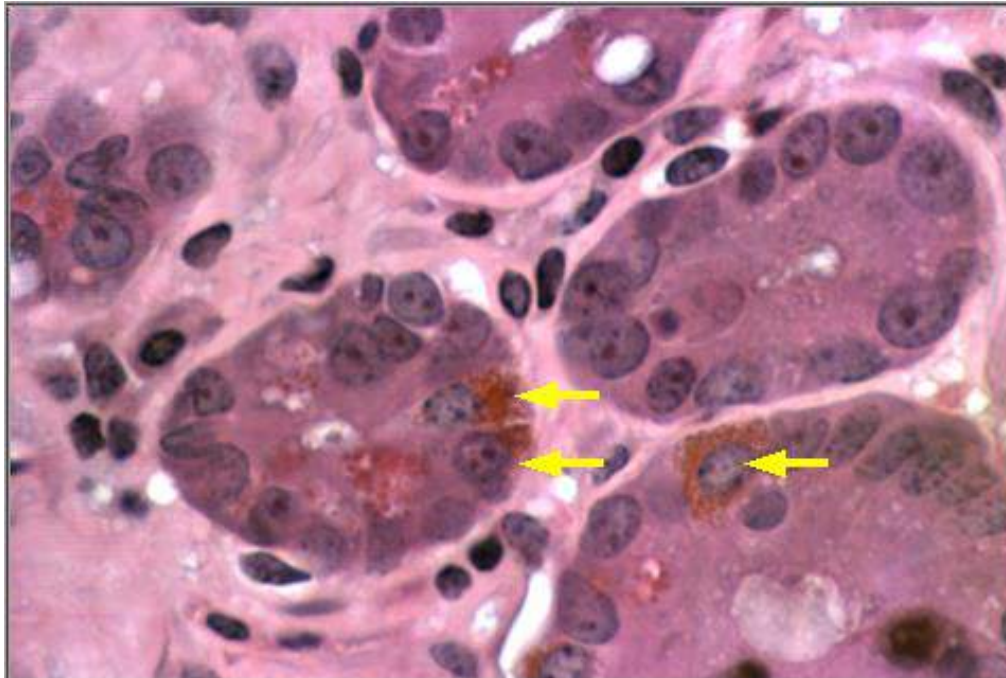


8 of 9

Paneth cells have prominent, eosinophilic granules that face the lumens of the glands. They produce lysozyme, an enzyme that digests bacterial cell walls, and also probably aids in maintenance of healthy intestinal flora.

click to identify:

- Intestinal glands
- Goblet cells
- Precursor cells >
- > Paneth cells >
- Enteroendocrine >
- cells
- Lamina propria >
- Plasma cell

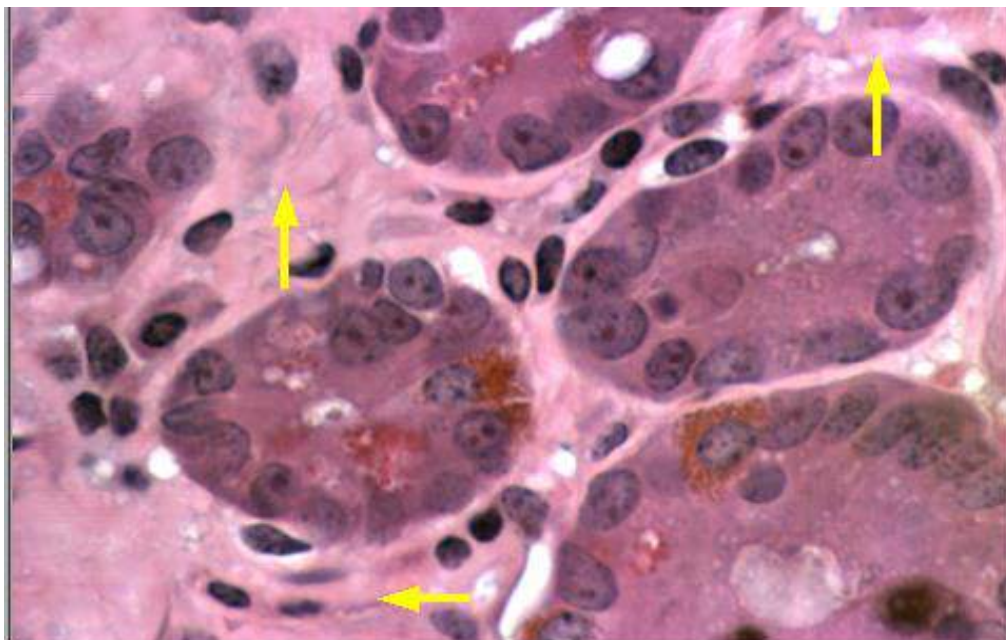


8 of 9

Solitary endocrine cells, enteroendocrine, are also found in the intestinal glands. Because these cells are secreting into the lamina propria, their granules face the basement membrane of the gland rather than the lumen.

click to identify:

- Intestinal glands
- Goblet cells
- Precursor cells >
- Paneth cells >
- > Enteroendocrine >
- cells
- Lamina propria >
- Plasma cell

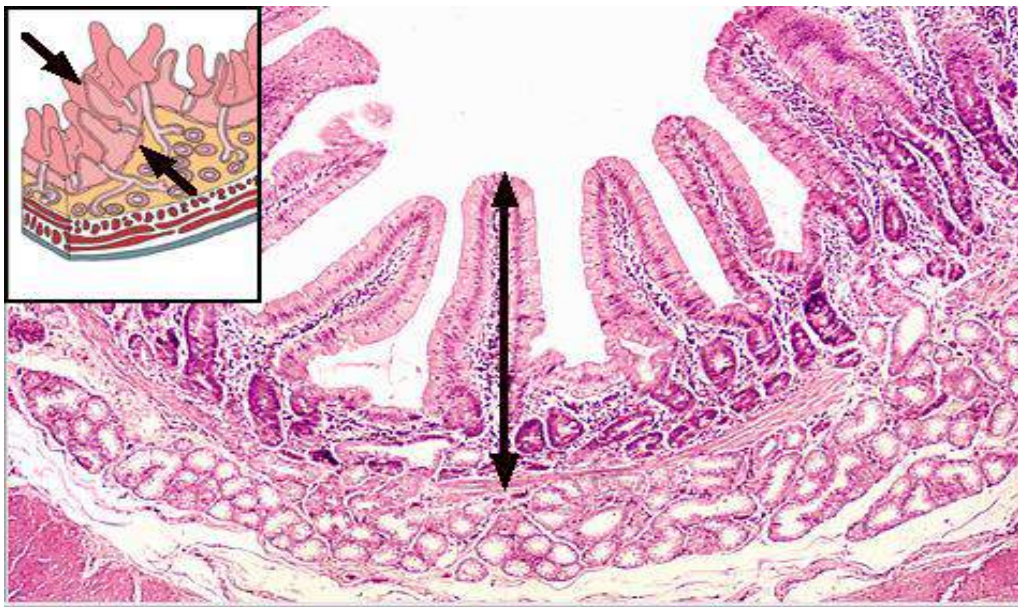
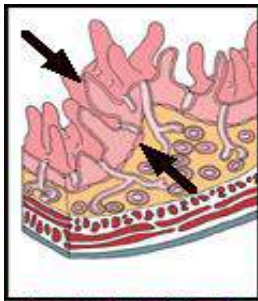


8 of 9

The lamina propria of loose connective tissue surrounds the intestinal glands and possesses a wide variety of cells, such as the immunoresponsive plasma cell seen here.

click to identify:

- Intestinal glands
- Goblet cells
- Precursor cells >
- Paneth cells >
- Enteroendocrine >
- cells
- > Lamina propria >
- Plasma cell

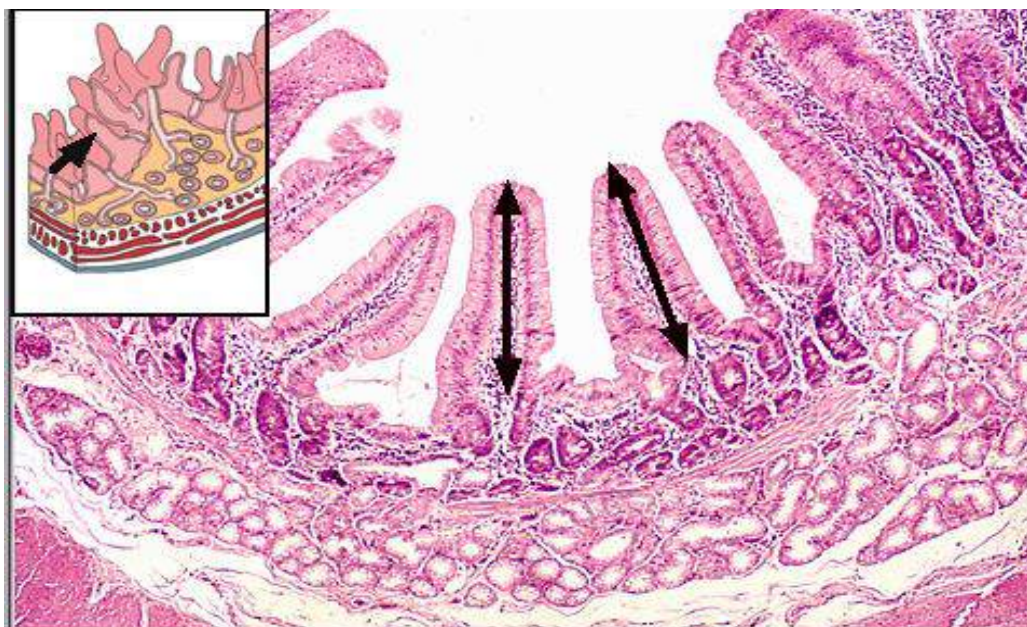
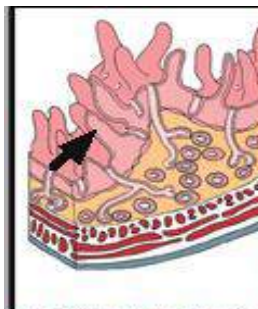


1 of 9

Duodenum -- The duodenum of the small intestine can be differentiated from the remainder of the small intestine primarily by the presence of Brunner's glands in the submucosa. Brunner's glands produce an alkaline mucus that counterbalances the acidity of the chyme entering the duodenum from the stomach. 100x

click to identify:

- > Mucosa
- Villi
- Intestinal glands
- Lamina propria
- Muscularis mucosae
- Submucosa
- Brunner's glands

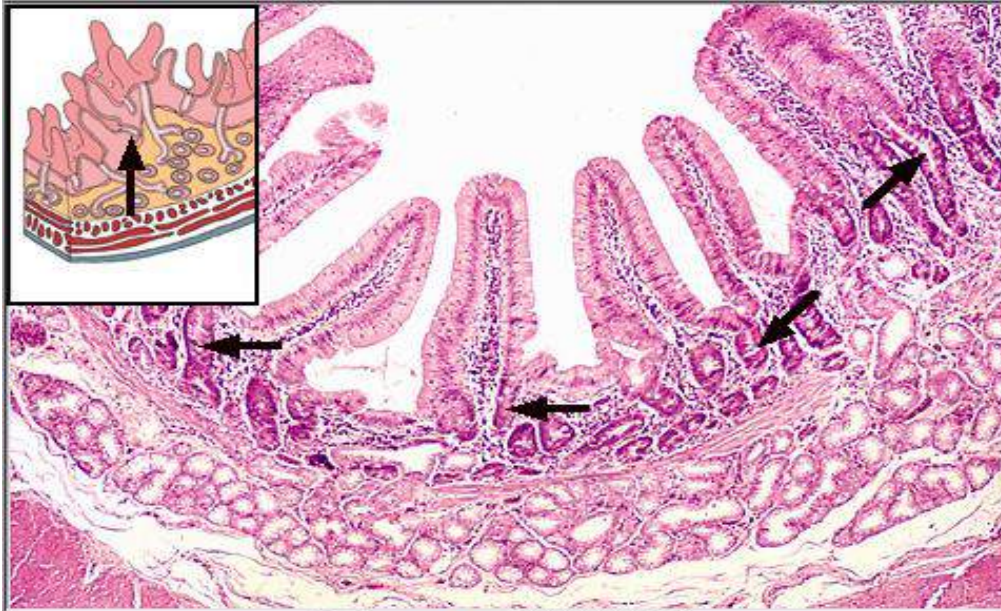


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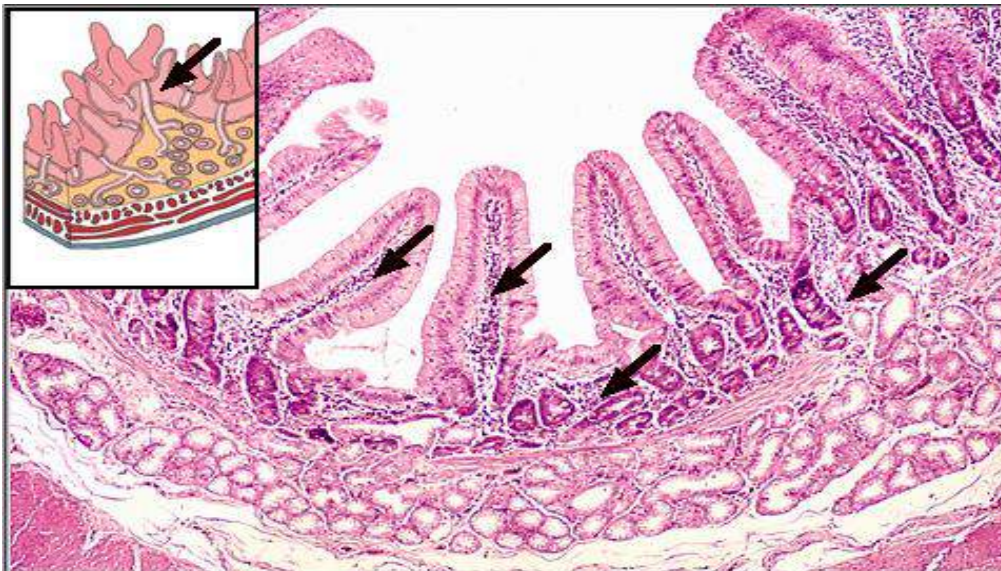


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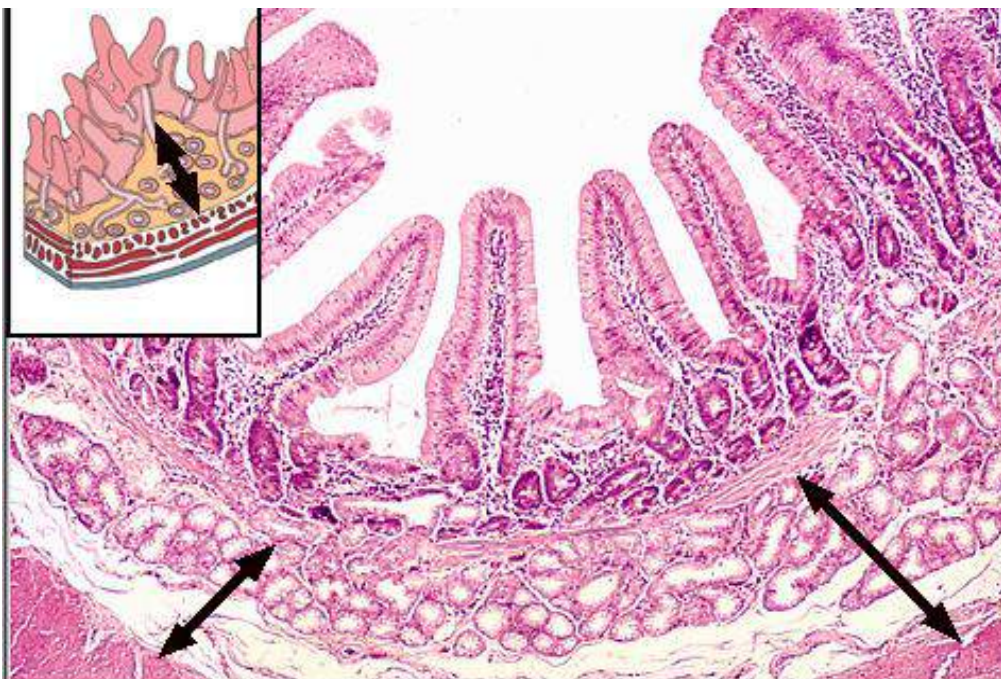


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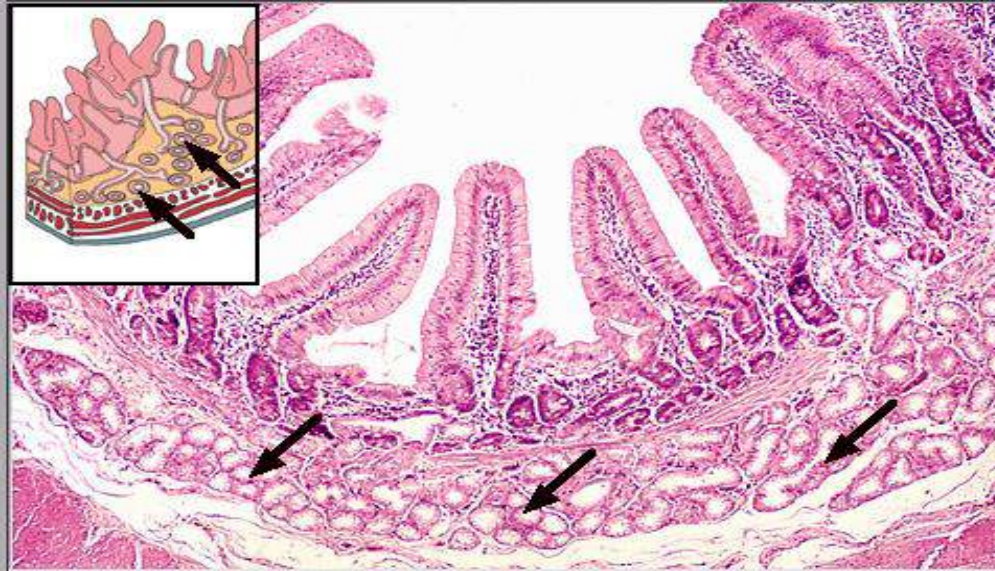


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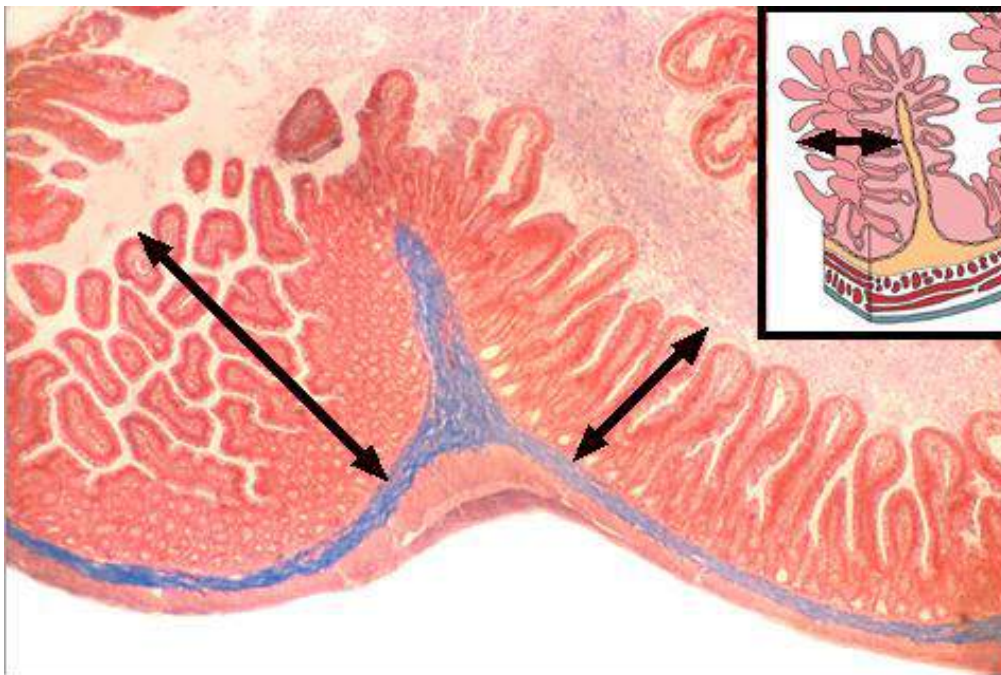


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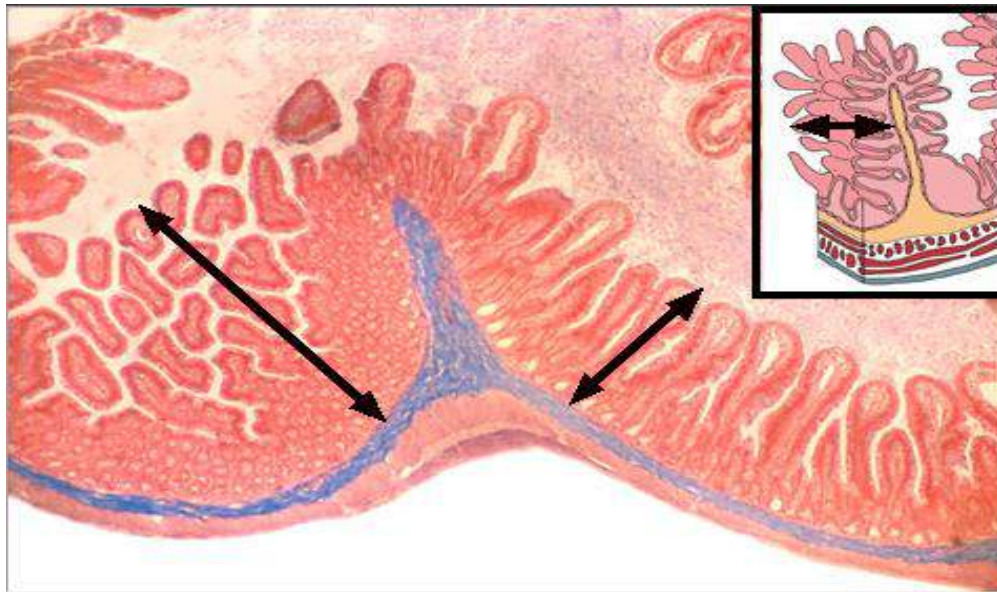


3 of 9

Jejunum or ileum -- The jejunum and ileum (shown here) can be differentiated from the duodenum, primarily by the lack of glands in the submucosa. Villi of the small intestine possess a lacteal that transports absorbed lipids to lymphatic vessels in the submucosa. A plica circularis, a circular fold of submucosa and its overlying mucosa, is centrally located in the image. 40x

click to identify:

- > Mucosa
- Villi
- Intestinal glands
- Lamina propria
- Lacteals
- Submucosa
- Muscularis
- externa
- Plica circularis
- Next image

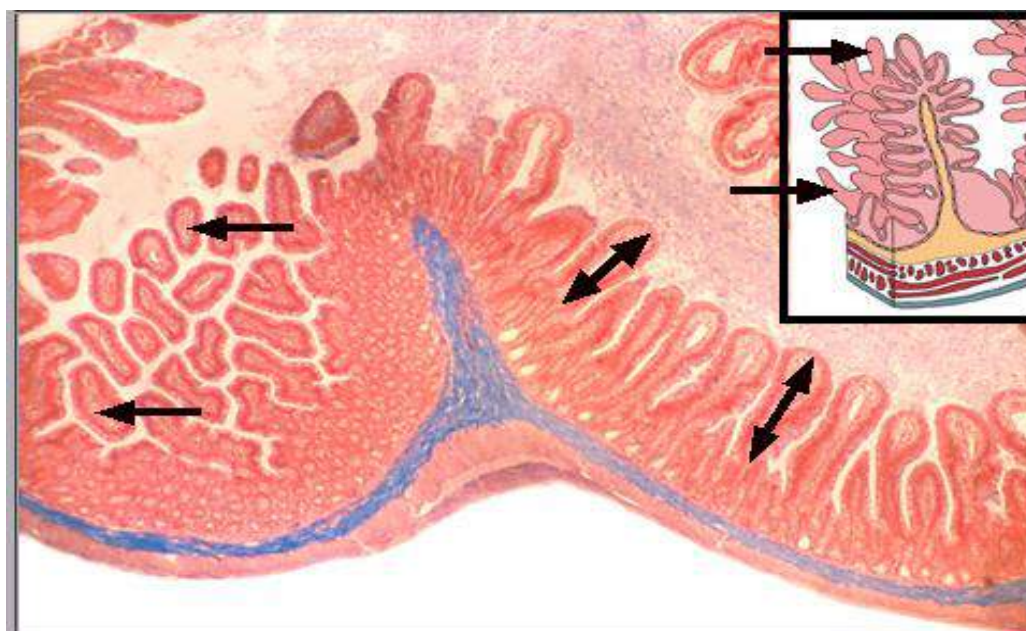


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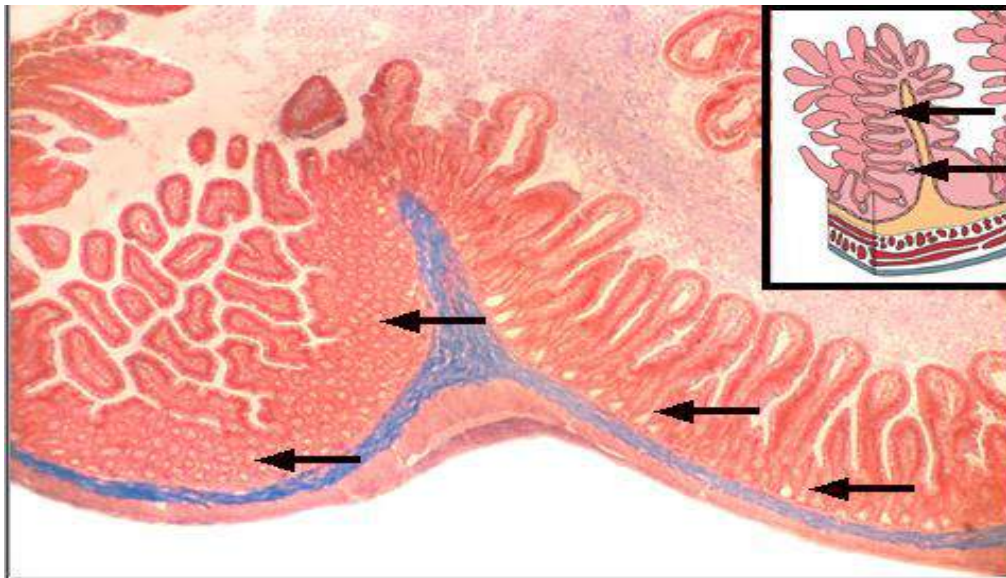


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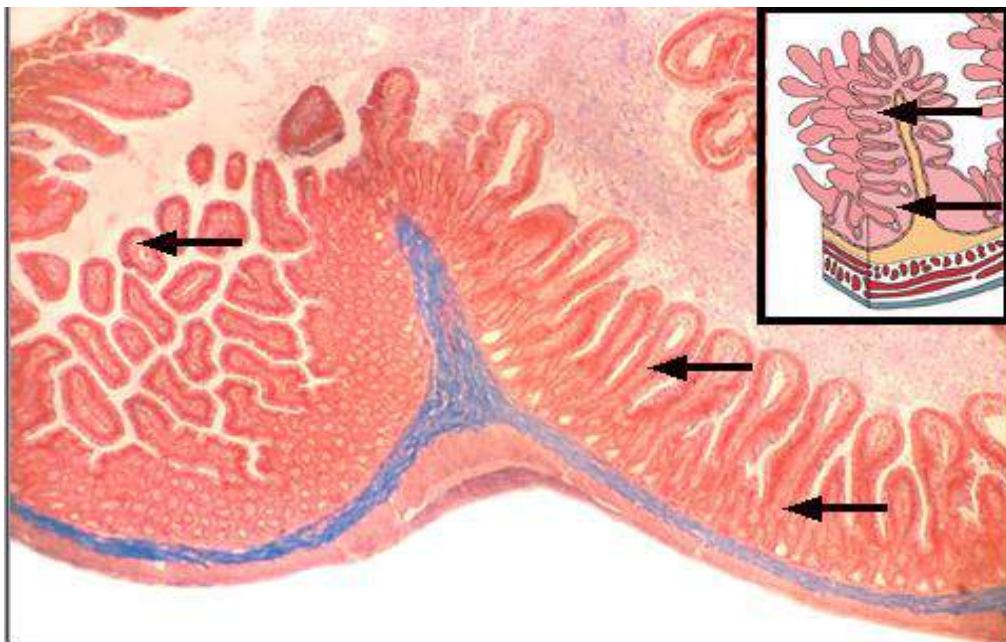


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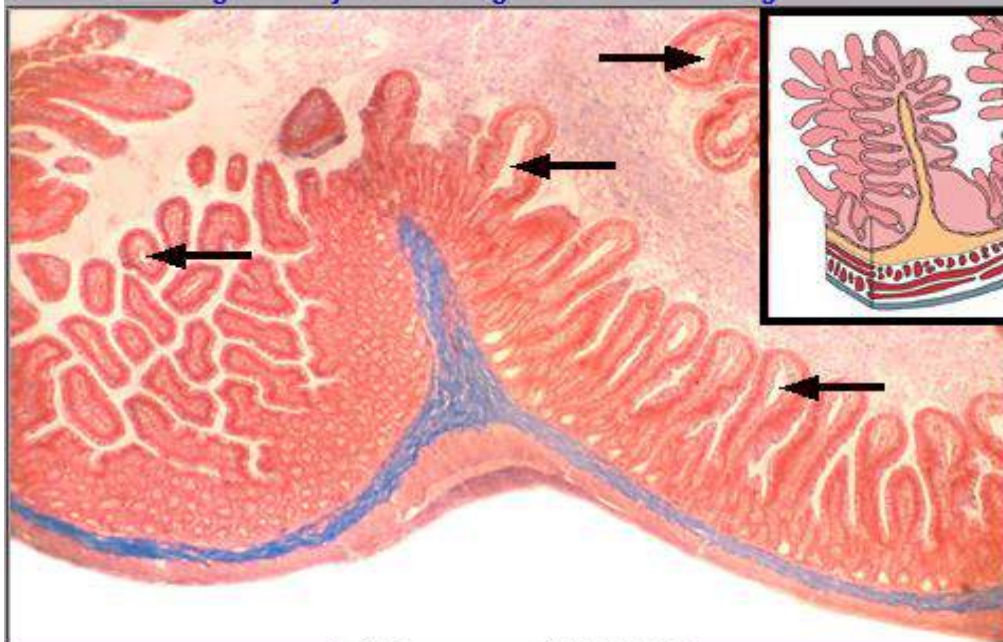


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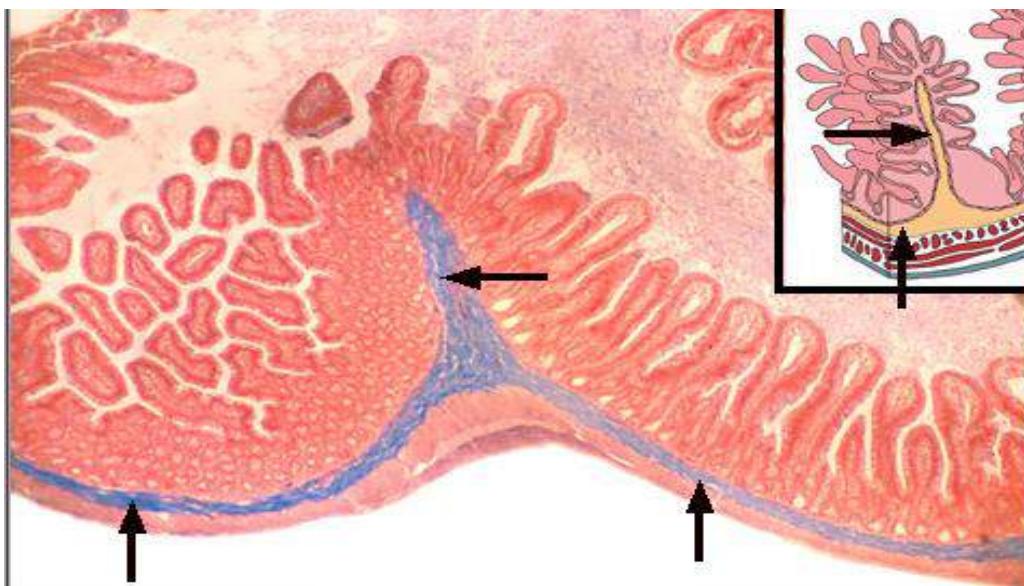


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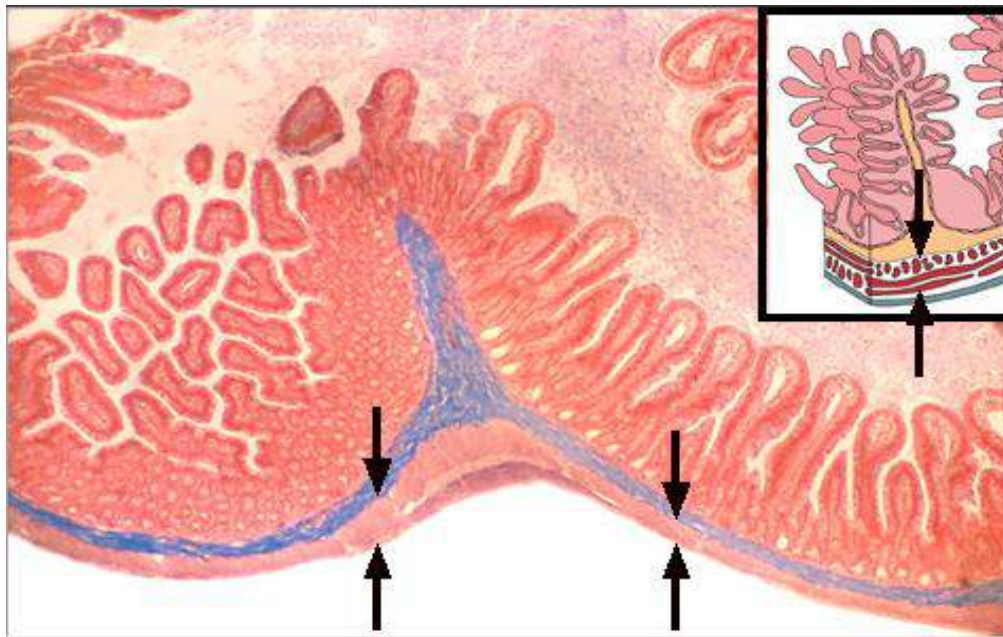


click to identify:

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- Lacteals
- > Submucosa
- Muscularis externa
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- Next image

3 of 9

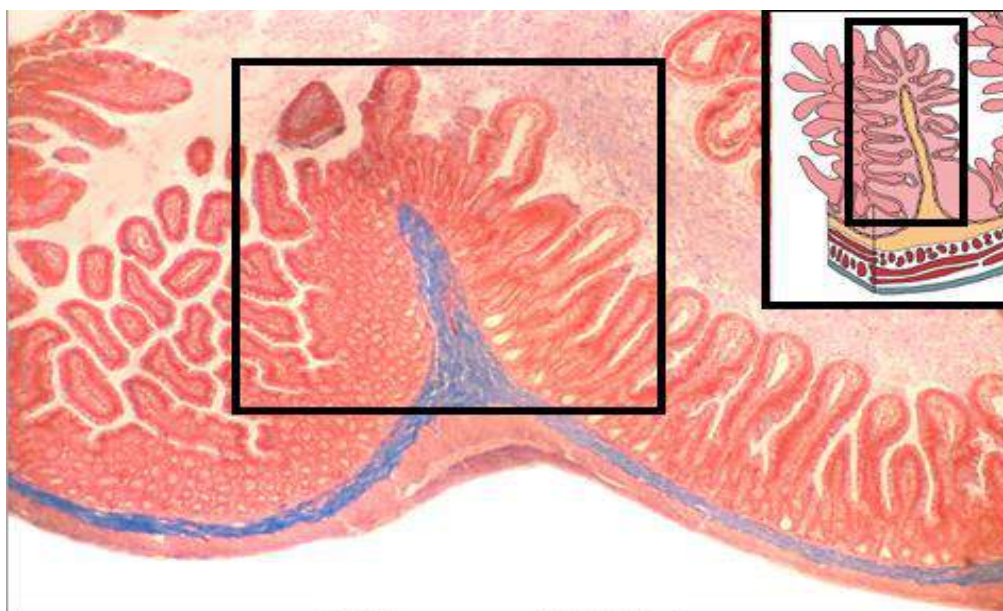
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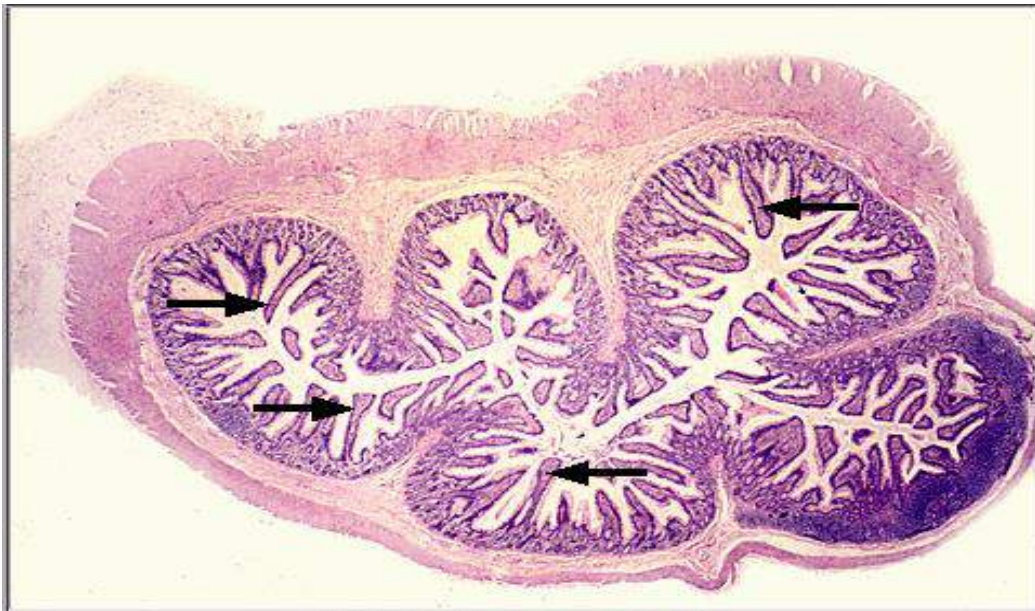
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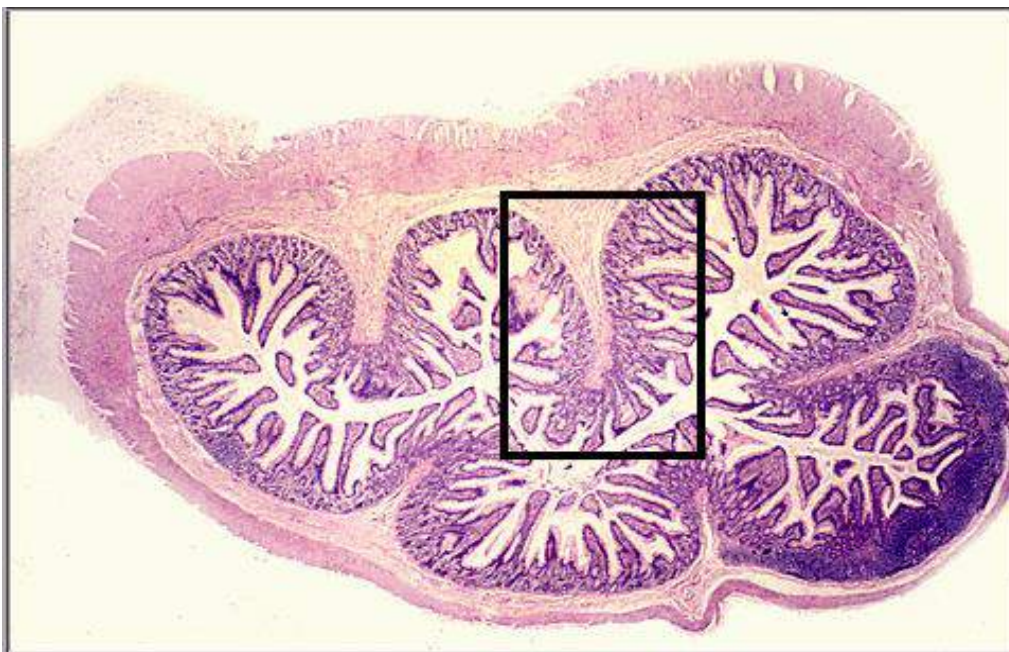


6 of 9

Ileum -- This low magnification image of the ileum shows that the villi of the ileum are tall and are the most finger-like in the small intestine. Diffuse and nodular lymphoid tissues, forming a Peyer's patch, are common in the lamina propria of the ileum on the side opposite the mesentery. Peyer's patches are a part of the mucosa-associated lymphoid tissue (MALT). 10x

click to identify

- > Villi
- Plica circularis
- Peyer's patch
- Mesentery
- Next image

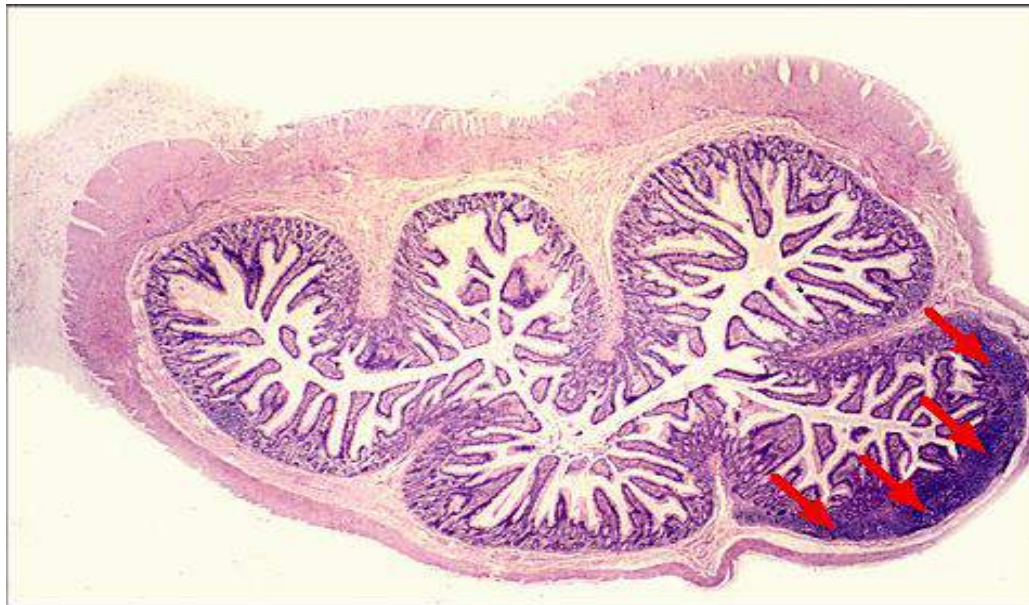


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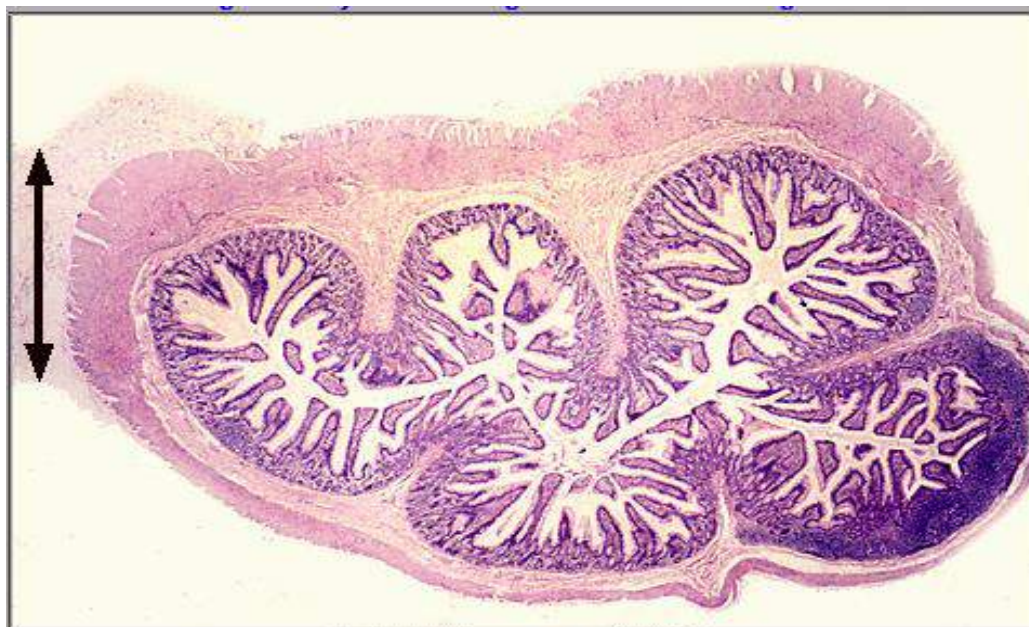


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- Next image

CHAPTER 12

DIGESTIVE SYSTEM

(Oral cavity, tubular tract and glands)

LIP *(images)*

I. Forms the anterior boundary of the **vestibule**, the space between the inner surfaces of the lips and cheeks and the outer surface of the teeth and gums

II. Regions

A. Exterior surface

1. Covered by **thin skin**
2. **Hair follicles** and **sebaceous glands** are present

B. **Vermilion zone**

1. Forms the red-colored portion of the lip
 - a. Covered by a thin, stratified squamous keratinized epithelium
 - b. Mucosa contains numerous, densely packed dermal papillae
 - c. Papillae allow blood vessels close access to the surface
2. Lacks hair follicles

C. Inner surface

1. Lined by **oral mucosa**, stratified squamous moist epithelium
2. **Minor salivary glands (labial glands)** in the submucosa secrete both mucous and serous products.

III. **Orbicularis oris muscle**

- A. Skeletal muscle arranged as a sphincter around the mouth.
- B. Forms the core of the lip.

ORAL CAVITY

COMPONENTS

- I. **Vestibule**. Bounded anteriorly and laterally by the lips and cheeks; bounded medially by teeth and gingiva (gums).
- II. **Oral cavity proper**. Bounded anteriorly and laterally by the lingual surfaces of the teeth and gingiva, superiorly by the hard and soft palate, inferiorly by the tongue and floor of the mouth, and posteriorly by the pillars of the fauces leading to the pharynx

ORAL MUCOSA (*images*)

- I. **Oral mucosa**, the mucous membrane (mucosa) lining the oral cavity and vestibule, is continuous with external skin and with the mucous membrane of the pharynx.
- II. Composition
 - A. Epithelium. Stratified squamous keratinized or nonkeratinized depending on location
 - B. Lamina propria
 - C. Muscularis mucosae is not present.
 - D. Although not part of the oral mucosa, a submucosa of dense connective tissue, containing the minor salivary glands, underlies much of the oral mucosa.
- III. Regional variations, depending on function and location
 - A. **Masticatory mucosa**
 - 1. Located where mucosa is exposed to forces of mastication, such as gingiva and hard palate
 - 2. Composition
 - a. Stratified squamous epithelium, keratinized
 - i. **Orthokeratinized epithelium** resembles the epidermis of the skin with a fully keratinized stratum corneum and is located in areas of maximal trauma.
 - ii. **Parakeratinized epithelium** does not fully keratinize, retaining

pyknotic nuclei and organelles in the surface cells. This epithelium is found in areas of reduced trauma.

b. Underlying submucosa is lacking in some locations.

B. **Lining mucosa**

1. Located where mucosa is not exposed to forces of mastication (minimal trauma), such as lining of lips and cheeks, soft palate, alveolar mucosa, undersurface of tongue, and floor of mouth
2. Epithelium. Stratified squamous epithelium, nonkeratinized (moist)

C. **Specialized mucosa**

1. Named "specialized" due to the presence of **taste buds**
2. Located on the dorsum of the tongue where it forms **papillae**
3. Epithelium
 - a. Stratified squamous keratinized, modified to form **filiform papillae** that facilitate the movement of food posteriorly
 - b. Stratified squamous moist, covering **fungiform** and **circumvallate papillae**

TONGUE (***images***)

I. The subdivisions of the **tongue** are based on embryologic origins: anterior two-thirds (body) and posterior one-third (root) are separated by the sulcus terminalis.

II. Composition

- A. **Mucosa**. Dorsum of the tongue is covered by a specialized oral mucosa, modified to form papillae. (See "Specialized mucosa" above.) The ventral surface of the tongue is covered by a lining mucosa
- B. The **submucosa** possesses **minor salivary glands** that are mucus-secreting except for those associated with the circumvallate papillae, which are serous-secreting

III. **Papillae**. Each consists of a connective tissue core covered by a stratified squamous epithelium.

A. **Filiform**

1. Most numerous; cover body of tongue
2. Cone-shaped protrusions angled so that they aid in movement of food toward the pharynx

B. **Fungiform**

1. Less numerous than filiform but also located on anterior two-thirds of tongue
2. Mushroom shaped, possess taste buds on superior surface

C. **Circumvallate**

1. Eight to twelve papillae located just anterior to the sulcus terminalis
2. Mushroom shaped and surrounded by a narrow moat; lateral wall of each papilla possesses taste buds
3. **Serous glands of von Ebner** open into the base of the moat and flush the moat for reception of new tastes.

D. **Foliate**. Parallel folds on the posterolateral surface of the tongue; not well developed in humans

IV. **Taste buds** are onion-shaped structures embedded in the surface of the fungiform and circumvallate papillae. Taste buds contain taste-receptor cells that communicate with the surface of the papilla through a **taste pore**. Depolarization of the taste cells leads to the stimulation of gustatory nerve fibers and the discrimination of sweet, salty, bitter, and sour sensations.

V. **Intrinsic tongue muscles**. Skeletal muscle bundles are arranged in three separate planes, with connective tissue bands from the lamina propria separating the bundles and firmly anchoring the muscle to the mucous membrane.

TEETH *(images)*

I. Overview of the **teeth**

- A. **Anatomic crown**. The portion of the tooth covered by enamel.
- B. **Anatomic root**. The portion of the tooth covered by cementum.
- C. **Cervix**. Region where enamel abuts cementum

- D. **Pulp cavity** is the central core of a tooth and is divided into a pulp chamber in the crown and a root canal in the root. An apical foramen at the tip of the root allows passage of nerves and blood vessels into and out of the pulp cavity.
- E. **Gingiva**. Oral mucosa (masticatory) encircling the cervical region of the tooth and providing support for the tooth

II. Components

- A. **Enamel** is the hardest tissue in the body, consisting of a mineralized tissue that is 96% hydroxyapatite. Enamel covers the anatomic crown of the tooth. During tooth development, enamel deposition by **ameloblasts** begins on the surface of dentin and progresses away from this **dentinoenamel junction**. No additional enamel can be formed after the tooth erupts, as the ameloblasts die on exposure to the oral cavity.
- B. **Dentin**
 - 1. Comprises the bulk of the tooth, underlying both enamel and cementum; dentin is a connective tissue that is 70% mineralized with hydroxyapatite.
 - 2. Dentin is formed continuously throughout life by **odontoblasts** whose cell bodies line the pulp cavity.
 - 3. Odontoblast processes extend through the dentin in S-shaped dentinal tubules radiating from the odontoblasts toward the **dentinoenamel** or **dentinocemental junctions**.
- C. **Cementum**, a connective tissue mineralized with 50% hydroxyapatite, covers the anatomic root of the tooth. Cementum is formed continuously throughout life by activity of **cementoblasts** lying on the surface of the root at the interface of the cementum with the periodontal ligament.
- D. The **pulp cavity** is lined by odontoblasts and filled with loose connective tissue, blood vessels, nerves, and lymphatics.
- E. The **periodontal ligament**, collagen fiber bundles interconnecting cementum with the surrounding alveolar bone, suspends and supports each tooth in its alveolar socket.

MAJOR SALIVARY GLANDS (*images*)

I. Overview

- A. All major salivary glands are compound, exocrine glands, and all open into the oral cavity.

B. Functions

1. Produce saliva to wet, lubricate, and buffer the oral cavity and its contents
2. Produce amylase for the initial digestion of carbohydrates
3. Produce lysozyme to control bacteria in the oral cavity

II. Major cell types

A. **Serous cells**

1. Synthesize, store, and release a thin, protein-rich secretion containing digestive enzymes, primarily amylase
2. Are pyramidal in shape and possess all organelles necessary for protein production and secretion (e.g., basal rough endoplasmic reticulum, Golgi, and apical secretory granules)
3. Are arranged into either:
 - a. **Acini** (singular, **acinus**) or **alveoli** (singular, **alveolus**). Flask-shaped sacs with tiny lumens
 - b. **Serous demilunes**. Half moon-shaped caps positioned over the ends of mucous tubules

B. **Mucous cells**

1. Synthesize, store, and release mucus, a viscous, thick, glycoprotein secretion that protects and lubricates epithelia
2. Have flattened nuclei that are located at the bases of the cells along with the rough endoplasmic reticulum. Abundant **mucigen droplets** are located in the apex of each cell, giving it a frothy, vacuolated appearance.
3. Are organized in test tube-shaped **tubules** with relatively wide lumens

- C. **Myoepithelial cells** are stellate-shaped epithelial cells with contractile functions that lie between the secretory or duct cells and the basement membrane. These cells contract to aid in movement of the secretory product.

III. Duct system conducts secretions to oral cavity.

- A. Ducts are more numerous with serous acini than with mucous tubules because the tubules can act as their own ducts.

1. **Intralobular ducts**

- a. **Intercalated ducts** exit from secretory acini and are smaller in diameter than the acini they drain. These ducts are lined by simple cuboidal epithelia.
 - b. **Striated ducts** continue from intercalated ducts and are larger in diameter than the secretory units they drain. They are lined by simple columnar epithelia. Numerous mitochondria and infoldings of the plasma membrane in the basal region of the cells give the duct a striated periphery. Striated ducts alter the content and concentration of the saliva.
2. **Interlobular ducts** form by the anastomosis of striated ducts and are located in the connective septa between lobules. Interlobular ducts are lined with simple columnar to stratified columnar epithelia.
 3. The **main excretory duct(s)** is formed by the union of interlobular ducts. An excretory duct (s) is lined by a stratified epithelium that becomes stratified squamous moist just prior to its junction with the epithelium of the oral cavity.

IV. Major salivary glands

A. **Parotid glands**

1. Compound acinar glands producing only serous products; their secretions account for 25% of the saliva
2. Possess the most highly developed duct system of the major salivary glands

B. **Submandibular glands**

1. Compound tubulo-acinar glands producing both serous and mucous products, although serous acini predominate. Their secretions account for 70% of the saliva.
2. Serous cells are present as both acini and **serous demilunes**.

- C. **Sublingual glands** secrete approximately 5% of the saliva. These are compound tubulo-acinar glands, producing both mucous and serous products, although mucous tubules predominate

TUBULAR DIGESTIVE SYSTEM

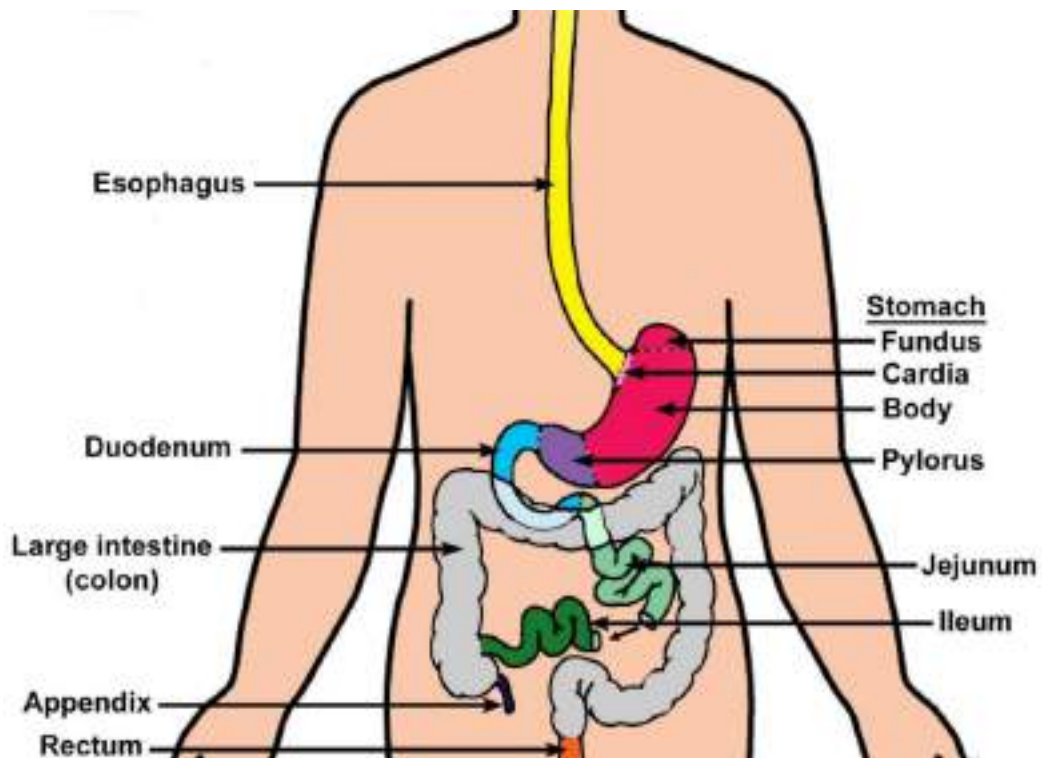


FIGURE 12.1. Organs comprising the tubular digestive tract.

COMPONENTS

- I. Pharynx
- II. Esophagus
- III. Stomach
- IV. Small intestine
- V. Large intestine
- VI. Anus

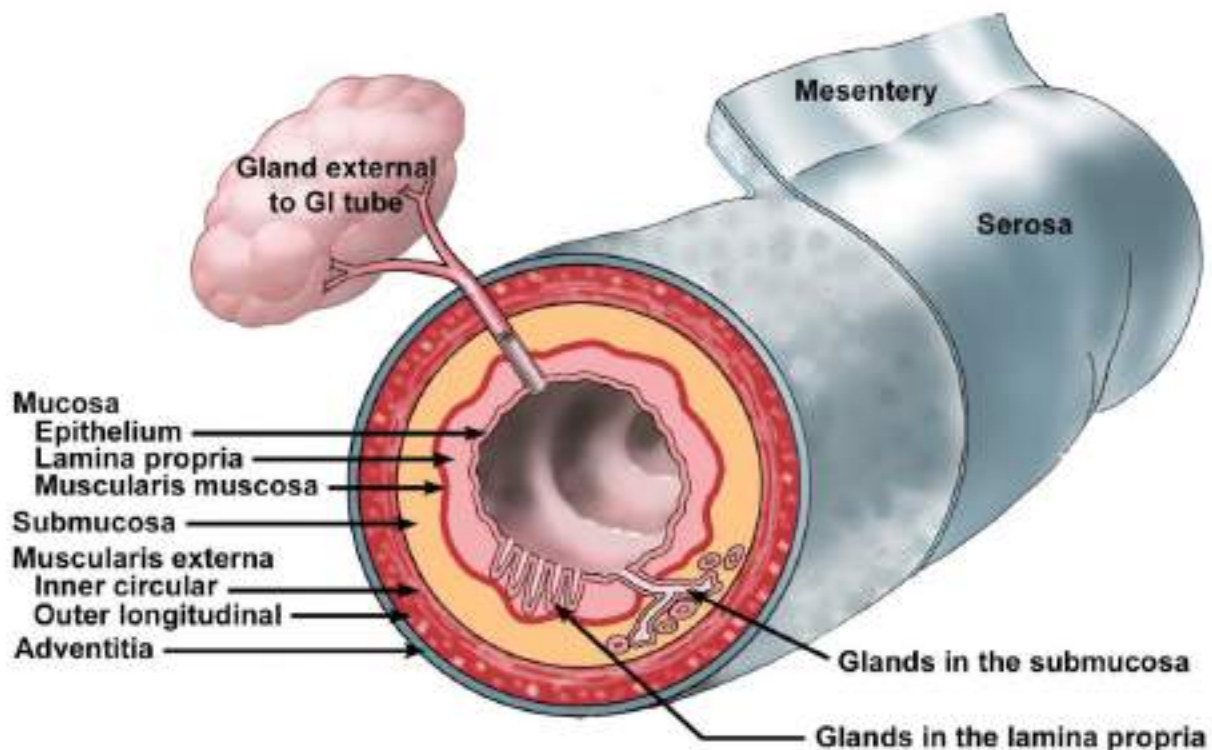


FIGURE 12.2. Overview of the layers and components of the tubular digestive tract.

BASIC HISTOLOGICAL ORGANIZATION

I. Layers

- A. **Mucosa (mucous membrane)**. Innermost layer facing the lumen
 1. **Epithelium**. Either a stratified squamous moist or a simple columnar epithelium
 2. **Lamina propria**. Loose connective tissue; usually possesses digestive glands
 3. **Muscularis mucosae** of smooth muscle is usually present.
- B. **Submucosa**. Denser connective tissue than the lamina propria. The submucosa possesses **Meissner's nerve plexus** that supplies innervation to the muscularis mucosae and to digestive glands in the mucosa and submucosa. The submucosa possesses glands in the esophagus and duodenum.

- C. **Muscularis externa** of smooth muscle is usually arranged into inner circular and outer longitudinal layers. **Auerbach's nerve plexus** is located between the two muscle layers and provides innervation to this smooth muscle.
- D. **Serosa** (serous membrane) is present if the organ protrudes into the peritoneal cavity, or an **adventitia** (only the connective tissue portion of the serosa) is present if the organ is retroperitoneal.

II. Glands

- A. Exocrine glands, aiding in digestion and/or lubrication, are located in:
 - 1. Epithelium (e.g., goblet cells throughout the intestines)
 - 2. Lamina propria (e.g., gastric glands)
 - 3. Submucosa (e.g., Brunner's glands in the duodenum)
 - 4. Glands located external to the digestive tract that open into the system (e.g., liver and pancreas)
- B. Endocrine and paracrine cells, belonging to the diffuse **neuroendocrine system (DNES)**, are located throughout the mucosa of the gastrointestinal tract, influencing the secretion of glands and the motility of the gut.

VARIATIONS THAT DISTINGUISH EACH ORGAN FROM THE BASIC ORGANIZATIONAL PLAN

I. **Esophagus** (*images*)

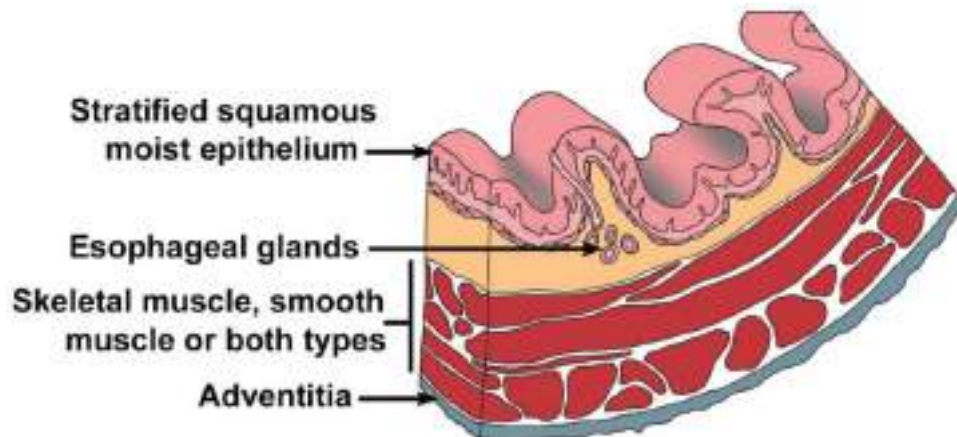


FIGURE 12.3. Cross-section of the esophagus.

- A. Epithelium. **Stratified squamous nonkeratinized epithelium**

- B. Lamina propria possesses **esophageal cardiac glands** that resemble the mucus-secreting glands of the cardiac portion of the stomach. These glands are particularly prominent near the junction of the esophagus with the stomach and are sometimes located in the beginning of the esophagus.
- C. Submucosa has mucus-secreting, **esophageal glands proper**.
- D. Muscularis externa is composed of **striated muscle** in the upper portion of the esophagus, skeletal, and smooth muscle in the middle portion, and smooth muscle in the lower portion.
- E. Adventitia. Composed of loose connective tissue.

II. **Stomach** (*images*)

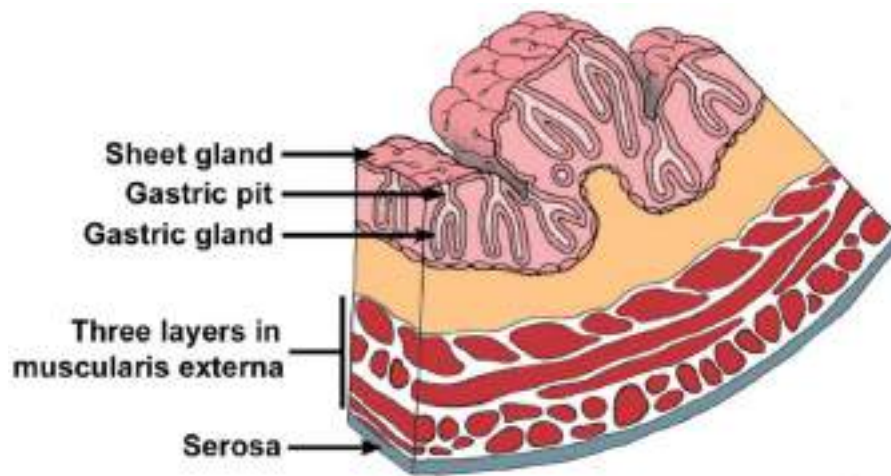


FIGURE 12.4. Cross-section of the stomach.

- A. Structures present throughout the stomach
 - 1. Surface epithelium
 - a. Simple columnar epithelium facing the lumen is modified so that all cells secrete mucus, forming a **sheet gland** that protects the stomach from its acidic environment.
 - b. **Gastric pit**. A channel formed by the invagination of the surface epithelium into the underlying lamina propria; connects the sheet gland with the gastric glands. The length of the gastric pit varies with each stomach region.
 - 2. **Gastric glands**
 - a. Simple, branched tubular glands begin at a gastric pit and extend

through the lamina propria to the muscularis mucosae.

- b. The region of the gland that attaches to the gastric pit is called the **neck region**; the base region of the gland is located adjacent to the muscularis mucosae.
 - c. Secretory cells in these glands vary in each region of the stomach.
 3. Muscularis externa. Subdivisions of this smooth muscle layer frequently interdigitate, making it difficult to distinguish one layer from another.
 - a. Internal oblique layer
 - b. Middle circular layer that is modified in the pyloric region to form the pyloric sphincter
 - c. Outer longitudinal layer is separated from the inner circular layer by Auerbach's plexus, nerve fibers from the autonomic nervous system that supply
 4. Serosa
 5. **Rugae**. Longitudinal folds of the mucosa and submucosa in the undistended stomach allow for expansion.
- B. Variations specific to the **cardiac region** (narrow region adjacent to the esophagus)
 1. Abrupt transition of epithelium from stratified squamous moist of the esophagus to a sheet gland lining the cardiac stomach
 2. Length of gastric pits is about equal to the length of cardiac glands
 3. **Cardiac glands** primarily secrete mucus, although other products are also produced. Glands are frequently coiled.
 4. Cardiac glands of the stomach extend into the lower esophagus, forming the esophageal cardiac glands.
- C. Variations specific to the **fundic and body regions** (Glands in both regions are called fundic glands.)
 1. **Fundic glands** are about twice as long as their gastric pits.
 2. Cell types present in fundic glands:
 - a. **Stem cells** replenish both the surface epithelial cells and cells of the glands. Stem cells are located in the neck region.

- b. **Mucous neck cells** are irregular in shape and stain basophilically. They secrete mucus and are located in the neck region.
- c. **Parietal cells** are large, spherical, eosinophilic cells that secrete hydrogen and chloride ions and gastric intrinsic factor. They possess numerous mitochondria. An umbrella-shaped canaliculus indents the luminal surface, increasing surface area. Although present throughout the gland, parietal cells are more numerous in the upper regions.
- d. **Chief or zymogen cells**, typical protein-producing cells, predominate in the bases; stain blue with hematoxylin and secrete pepsinogen.
- e. **Enteroendocrine cells** (part of the diffuse neuroendocrine system, DNES) are located on the basement membrane and do not usually reach the lumen of the gland. This population of cells secretes a variety of hormones with endocrine and paracrine influences on digestive activity. Secretory granules cluster toward the basement membrane for their subsequent release into the lamina propria. Most common at the bases of the glands.

D. Variations specific to the **pyloric region**

- 1. Pits are longer in pylorus than in the cardiac region.
- 2. **Pyloric glands**, not as coiled as in the cardiac region; primarily secrete mucus.
- 3. Enteroendocrine cells are also present here.
- 4. Circular layer of muscularis externa is greatly thickened to form the **pyloric sphincter**.

III. **Small intestine** (*images*)

A. Subdivided into **duodenum**, **jejunum**, and **ileum**

B. Common features of the small intestine.

- 1. Structures that increase the surface area of the small intestine
 - a. **Microvilli**. Increase surface area of absorptive cells and, collectively, form a brush or striated border
 - b. **Villi**. Finger-like protrusions of the lamina propria and overlying epithelium into the lumen

- i. Villi assume different shapes in each of the three intestinal subdivisions.
 - ii. A **lacteal** (blind-ending lymphatic capillary) is located in the center of each villus to absorb digested fat.
 - iii. Individual smooth muscle cells lie parallel to the long axis of each villus, "milking" the lacteal contents to the periphery.
- c. **Plicae circulares**. Permanent circular folds formed by an up-welling of the submucosa and its overlying mucosa into the lumen. Villi protrude from the plicae.

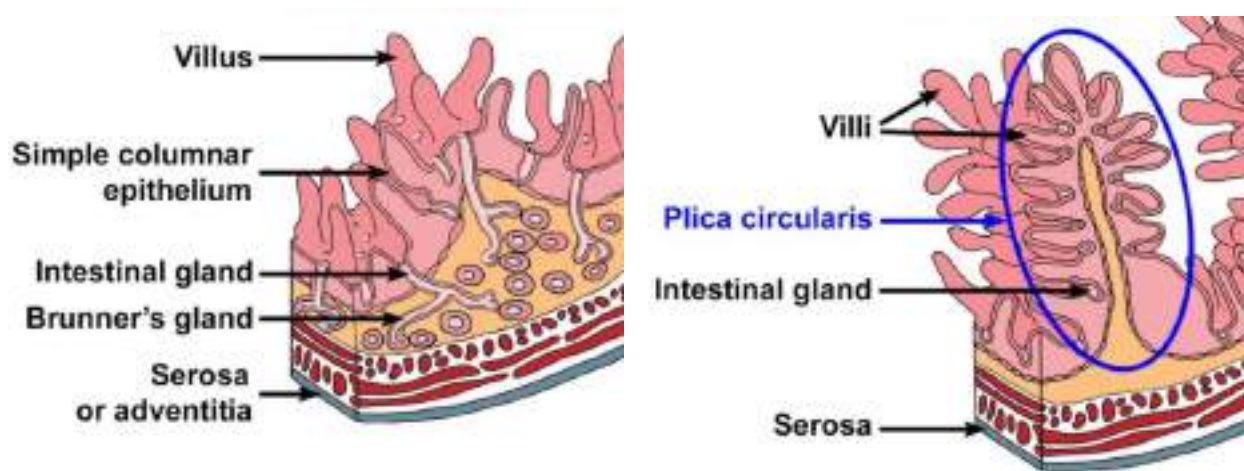


FIGURE 12.5. Longitudinal section through the duodenum (left) and the jejunum/ ileum (right). Note the orientation of the layers of muscularis externa when sectioned longitudinally.

2. Mucosal epithelium is composed of:
 - a. **Absorptive cells (enterocytes)**, forming a simple columnar epithelium with microvilli, absorb digested food
 - b. **Goblet cells** (unicellular glands) are interspersed among absorptive cells and secrete mucus. These cells increase in number from duodenum to rectum.
3. **Intestinal glands (crypts of Lieberkuhn)** are simple tubular glands that begin at the bases of the villi in the mucosa and extend through the lamina propria to the muscularis mucosae. Possess:
 - a. Absorptive cells

- b. Goblet cells
 - c. **Paneth cells** possess large, eosinophilic granules whose contents, e.g, lysozyme, digest bacterial cell walls.
 - d. **Enteroendocrine cells**
4. Muscularis externa of inner circular and outer longitudinal layers with an intervening Auerbach's nerve plexus
 5. Serosa covers all of small intestine except for the beginning of the duodenum, which is retroperitoneal and possesses an adventitia.
- C. Variations specific to the intestinal subdivisions
1. **Brunner's glands** in the submucosa are present only in the duodenum. These compound tubular glands open into the bases of the intestinal glands and secrete an alkaline mucus to neutralize the acidity of the stomach contents.
 2. **Peyer's patches** are clusters of 10-200 lymphoid nodules located primarily in the lamina propria of the ileum. Each cluster is positioned on the side of the intestine away from the mesentery and forms a bulge that may protrude into the lumen as well as into the submucosa.

IV. Large intestine (colon) (images)

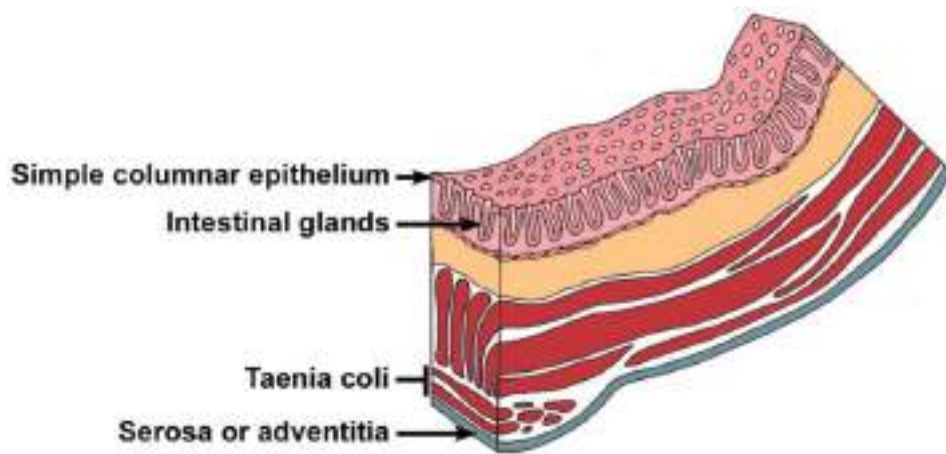


FIGURE 12.6. Cross-section of the large intestine.

- A. Layers and structures forming the wall of the large intestine.
1. Mucosal epithelium:

- a. Absorptive cells form a simple columnar epithelium with microvilli.
 - b. Goblet cells increase in number toward the rectum and provide lubrication.
 - c. A reduced number of enteroendocrine cells is present.
 2. Intestinal glands (crypts of Lieberkuhn) are very straight in the large intestine.
 3. No villi or plicae circulares are present in the large intestine.
 4. Muscularis externa
 - a. Inner circular layer is complete around the circumference of the tube
 - b. Outer longitudinal layer is segregated into three longitudinal bands, the **taeniae coli**, that are placed equidistantly around the tube. The contraction of the taenia produces permanent sacculations in the large intestine, termed **haustreae**.
 5. Either an adventitia or a serosa is present, depending on the particular portion of the large intestine.
- B. The **appendix** resembles the large intestine except that the outer longitudinal smooth muscle layer is complete. Additionally, abundant lymphoid tissue is present in the lamina propria to protect against invading microorganisms.
- C. Regions
1. **Ascending colon**. Rises on the right side of the abdominal cavity.
 2. **Transverse colon**. Horizontal region that passes across the abdomen from right to left below the stomach.
 3. **Descending colon**. Descends on the left side of the abdominal cavity.
 4. **Sigmoid colon**. "S"-shaped
 5. **Rectum** is a 12-cm-long tube continuing from the sigmoid colon. The mucosa of the rectum is similar to that of the majority of the large intestine. The rectum narrows abruptly to become the anal canal.
- D. **Anal canal**. The terminal portion of the intestinal tract is about 4 cm long.

1. The intestinal glands disappear and the epithelium undergoes an abrupt transition from simple columnar to stratified squamous with sebaceous and apocrine sweat glands.
 2. The inner circular portion of the muscularis externa expands to form the internal anal sphincter. The external anal sphincter is composed of skeletal muscle.
- V. The **anus** is located at the level of the external anal sphincter and is covered by stratified squamous keratinized epithelium (skin).

MAJOR DIGESTIVE GLANDS

PANCREAS (*images*)

OVERVIEW

- I. Located in the abdomen in the curve of the duodenum and divided into a **head**, **body**, and **tail**
- II. Is both an exocrine and an endocrine gland
 - A. The exocrine portion produces an alkaline secretion containing digestive enzymes that empties into the duodenum.
 - B. The endocrine portion secretes insulin, glucagon, and somatostatin that regulate blood glucose levels.

STRUCTURE

- I. **Exocrine pancreas**
 - A. Compound acinar gland; the acinar cells secrete numerous digestive enzymes that break down proteins, carbohydrates, lipids, and nucleic acids.
 - B. Cells show polarity with basal rough endoplasmic reticulum and apical secretory granules.
 - C. Duct system
 1. Ducts begin as **centroacinar cells** located within the acini.
 2. Intercalated ducts are lined with simple cuboidal epithelium. Centroacinar cells and cells of the intercalated ducts secrete bicarbonates to neutralize the acidity of the stomach contents (chyme) entering the duodenum.
 3. Striated ducts are not present.

4. Interlobular ducts lead into one or more excretory ducts that empty into the duodenum.
- D. Resembles the parotid gland except the pancreas has centroacinar cells and fewer ducts.
- E. Secretion is regulated by cholecystokinin and secretin from enteroendocrine cells in the small intestine

II. **Endocrine pancreas (islets of Langerhans)**

- A. Small clusters of cells, richly supplied by fenestrated capillaries, are scattered throughout the exocrine pancreas; these clusters show no orderly arrangement of secretory cells within the cluster.
- B. Predominate cell types and secretions
 1. **A cell (alpha cell)**. Secretes glucagon, which elevates glucose levels in the blood
 2. **B cell (beta cell)**. Secretes insulin, which lowers blood glucose levels; predominant cell type
 3. **D cell (delta cell)**. Secretes somatostatin, which modulates release of the other two major hormones
- C. Individual cell types cannot be distinguished with routine hematoxylin and eosin staining.

LIVER *(images)*

OVERVIEW

- I. Located in right, upper quadrant of abdominal cavity under the diaphragm
- II. Both an exocrine and an endocrine gland
 - A. Exocrine secretion (bile) is stored in the gall bladder and released into the duodenum. This secretory product contains bile acids that aid in the emulsification of lipids, bilirubin (the breakdown product of hemoglobin), phospholipids, and cholesterol.
 - B. Endocrine function is the synthesis of plasma proteins, including albumin, clotting factors, and lipoproteins that are released into the liver sinusoids.
- III. Additional functions include the metabolism of digested food, storage of

glucose as glycogen, and detoxification of hormones and drugs.

CYTOARCHITECTURE OF THE CLASSIC LIVER LOBULE

- I. The classic **liver lobule** resembles a column similar to a stack of covered-wagon wheels.
- II. Spokes of the wheels are cords or plates of **hepatocytes** radiating out from a central axis.
- III. Spaces between the spokes are occupied by **liver sinusoids** (discontinuous sinusoidal capillaries).
- IV. Central axis of the lobule is a **central vein** into which sinusoids drain (i.e., blood is flowing from the periphery of the lobule to the center). The central vein runs parallel to the long axis of the lobule.
- V. The perimeter of the lobule (the wheel rim) is difficult to distinguish in the human. The perimeter is denoted by the position of three to six **portal canals (hepatic portal triads)** situated at intervals around the lobule.
 - A. Portal canals run parallel to the long axis of the lobule.
 - B. Portal canals contain branches of the
 1. **Hepatic portal vein**. Lined with simple squamous epithelium; has the largest diameter of the three structures
 2. **Hepatic artery**. Lined with simple squamous epithelium and two-three layers of smooth muscle
 3. **Bile duct**. Lined with simple cuboidal epithelium; multiple branches may be present

BLOOD SUPPLY AND DRAINAGE OF THE LIVER

- I. Blood supply is from two sources
 - A. **Hepatic portal vein**
 1. Supplies about 75% of the blood
 2. Carries blood drained directly from the gastrointestinal tract, which, therefore, is deoxygenated and high in absorbed nutrients.
 - B. **Hepatic artery**. Supplies oxygenated blood

- II. Branches from both vascular sources continue into smaller branches located in the portal canals. Portal canal branches supply the hepatic sinusoids that drain into a central vein. Multiple central veins anastomose to eventually form the three hepatic veins that empty into the inferior vena cava.

FUNCTIONAL MICROANATOMY

I. Sinusoids

- A. A variation of discontinuous capillaries, in that gaps exist between endothelial cells and the fenestrations lack diaphragms
- B. The basal lamina is lacking beneath the fenestrations.
- C. Fenestrations open into a subsinusoidal space, the **space of Disse**, separating the sinusoids from the hepatocytes beneath the space.
- D. **Kupffer cells**, liver macrophages, span the sinusoids, filtering debris from the blood.

II. Hepatocytes (liver cells)

- A. Arranged as walls one to two cells thick that radiate out from the central vein like the spokes of a wheel
- B. Histology
 - 1. Cells are polyhedral in shape.
 - 2. Cells possess one or two nuclei.
 - 3. Cells contain abundant smooth and rough endoplasmic reticulum, Golgi apparatus, mitochondria, and lysosomes. They also contain large accumulations of electron-dense glycogen granules that stain strongly with PAS. Numerous peroxisomes, along with smooth endoplasmic reticulum, carry out detoxification.
 - 4. At intervals between adjacent cells, the plasma membranes bulge inward to form a bile canaliculus, the beginning of the bile transport system.
 - 5. Microvilli project into the space of Disse, increasing surface area of the cells.

FLOW OF BILE FROM LIVER

- I. Bile is produced by hepatocytes in the liver and released into **bile canaliculi** located between two adjacent hepatocytes.
- II. Bile canaliculi form a meshwork configuration that continues into bile ducts lying in portal canals. These **bile ducts** anastomose to form the left and right **hepatic duct**.
- III. The hepatic ducts exit from the liver and fuse to form the **common bile duct**. The bile it contains can either:
 - A. Travel directly to the duodenum
 - B. Be transported via the **cystic duct** to the gall bladder where it is stored until needed

GALL BLADDER *(images)*

OVERVIEW

- I. Stores and concentrates bile produced in the liver
- II. Connects, via the **cystic duct**, with the hepatic duct from the liver to form the common bile duct that empties into the duodenum

MICROANATOMY

- I. Mucosa
 - A. Composed of:
 1. Simple columnar epithelium with short microvilli. Accumulations of mitochondria and glycoprotein-filled secretory vesicles, particularly in the apices of the cells, are prominent.
 2. Lamina propria
 3. Muscularis mucosae is not present.
 - B. Is thrown into complex, irregular folds that are particularly evident when the gall bladder is empty.
- II. Submucosa
- III. Smooth muscle is arranged in an irregular network surrounding the gall bladder.

IV. A serosa covers most of the gall bladder; an adventitia surrounds the portion that is attached to the liver.

CHAPTER 20

EAR

COMPONENTS *(images)*

- I. **External ear.** Receives sound waves, transmitting them to the tympanic membrane
- II. **Middle ear.** Transmits movement of the tympanic membrane by three ear ossicles to fluid in the inner ear
- III. **Inner ear.** Contains a receptor that responds to these fluid vibrations for the perception of sound. Additional receptors in the inner ear respond to the effects of gravity and motion of the head to maintain equilibrium.

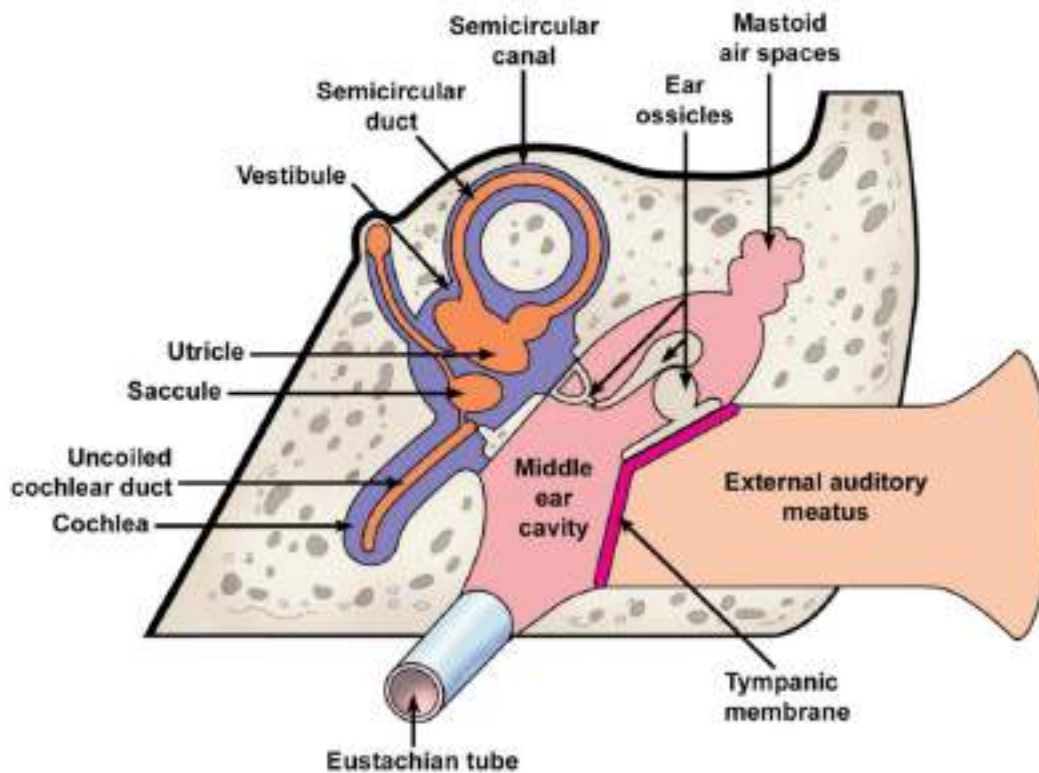


FIGURE 20.1. Schematic illustration of the three subdivisions of the ear embedded in the temporal bone.

EXTERNAL EAR *(images)*

- I. **Auricle** or **pinna.** Shallow appendage on the lateral surfaces of the head that is

formed by thin skin covering a framework of elastic cartilage

II. **External auditory meatus.** Short tube leading to the tympanic membrane

- A. The thin skin, lining the meatus, possesses ceruminous glands. Their secretions combine with those of adjacent sebaceous glands to form cerumen, a thick, waxy product.
- B. Support provided by:
 - 1. Elastic cartilage in the outer portion
 - 2. Temporal bone in the inner portion

III. **Tympanic membrane** (ear drum) separates external from the middle ear.

- A. Composition (from exterior to interior). Thin skin, two layers of collagen and elastic fibers with radial then circular arrangements, and a mucous membrane that is continuous with that lining the middle ear
- B. Attachment of the malleus, an ear ossicle, to the inner surface pulls the tympanic membrane into a flattened, cone shape.

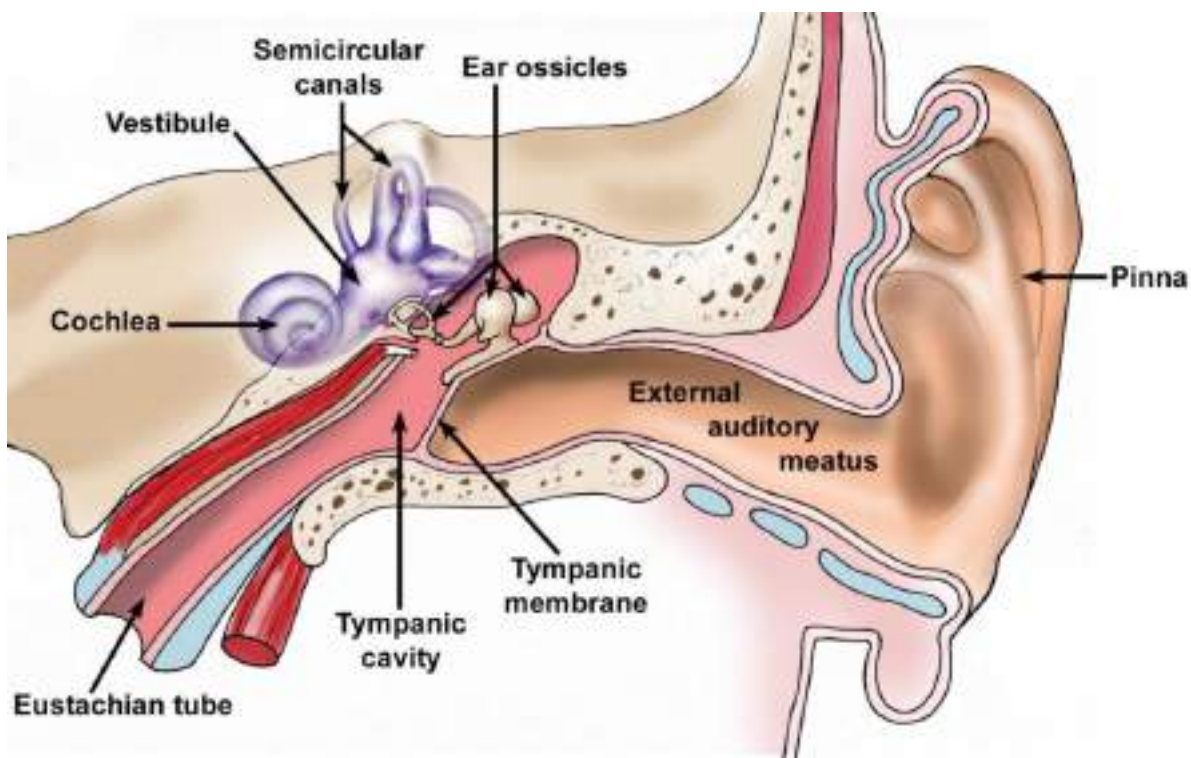


FIGURE 20.2. Coronal section through the skull showing the three subdivisions of the ear in the temporal bone.

MIDDLE EAR (TYMPANIC CAVITY) *(images)*

- I. The **middle ear** or **tympanic cavity** is a cavity within the temporal bone that is bounded by the tympanic membrane laterally and the bony wall of the inner ear medially. It communicates with the mastoid air cells posteriorly, and with the nasopharynx, via the Eustachian tube, anteriorly.

II. Structure

- A. Lined by a mucous membrane whose epithelium is predominately simple squamous

- B. Ear ossicles, small bones, transmit vibrations from the tympanic membrane to the inner ear.

1. Components

- a. **Malleus**. Attached to the tympanic membrane
- b. **Incus**. Interconnects malleus with stapes
- c. **Stapes**. Footplate of the stapes fits into the oval window of the inner ear

2. Ossicles are connected to each other by ligaments and are covered with mucosa.

3. Small muscles attached to malleus (**tensor tympani**) and stapes (**stapedius**) modulate vibrations of these ossicles.

C. **Eustachian tube** (auditory tube)

1. Connects middle ear with the nasopharynx
2. Is lined by a mucous membrane whose epithelium becomes pseudostratified near the nasopharynx. Cilia associated with this epithelium beat toward the pharynx.
3. Is supported first by bone and then by cartilage and fibrous tissue as it nears the nasopharynx
4. Is usually collapsed but opens during swallowing to equilibrate air pressure

D. **Oval window** and **round window**

1. Openings in the petrous portion of the temporal bone that forms the medial wall of the middle ear

2. The oval window is occupied by the footplate of the stapes.
 3. The round window is covered by a membrane that bulges to relieve pressure in the cochlea that originates from motion of the stapes at the oval window.
- E. **Mastoid air spaces**, located in the mastoid process of the temporal bone, communicate posteriorly with the middle ear.

INNER EAR (*images*)

I. The **inner ear** is located in the **petrous portion of the temporal bone**.

II. Components

- A. **Osseous labyrinth**. Series of interconnected tubular and cavernous spaces in the petrous portion of the temporal bone that are lined with periosteum and filled with perilymph fluid
1. **Vestibule**. Centrally located chamber; communicates with middle ear via the oval window
 2. **Semicircular canals**
 - a. Are three tubular spaces that communicate with and lie posterolaterally to the vestibule
 - b. Are oriented in three mutually perpendicular planes
 - c. An enlargement at one end of each canal, adjacent to the vestibule, houses the ampulla of the semicircular ducts.
 3. **Cochlea**. An osseous tube that connects with and lies anteromedially to the vestibule
 - a. Tube is coiled into a spiral shape with 2.5 turns, resembling a snail shell.
 - b. The tube's spiraling in the temporal bone results in the formation of a central, bony axis for the cochlea called the **modiolus**, which resembles a screw. The threads of the screw project into the cochlea and are called the **osseous spiral lamina**.
 - c. The modiolus houses the cochlear division of **cranial nerve VIII** and its sensory ganglion, the **spiral ganglion**.

- B. **Membranous labyrinth.** Series of interconnected ducts and chambers that are suspended within the osseous labyrinth. Contain the fluid, endolymph. These ducts and chambers contain receptors for hearing and for static and kinetic senses.
1. **Utricle** and **sacculle**. Suspended within the vestibule. A receptor, the **macula**, in each of these two chambers responds to stimuli of linear acceleration and gravitational forces.
 2. **Semicircular ducts** (three). One duct is suspended in each of the semicircular canals; both ends of each duct connect with the utricle. An enlargement, the **ampulla**, at one end of each duct is located in the enlargement of each semicircular canal and contains a receptor, the **crista ampullaris**, for angular acceleration.
 3. **Cochlear duct**. Located in the center of the cochlea. The cochlear duct communicates indirectly with the sacculle. The receptor in the cochlear duct, the **organ of Corti**, responds to sound vibrations.
 4. **Endolymphatic duct**. Formed by union of small ducts from the utricle and sacculle; extends toward the brain where it terminates as an enlargement, the endolymphatic sac, between layers of the meninges. Probably functions to absorb **endolymph**.
- C. Sensory innervation is provided by **cranial nerve VIII, the vestibulocochlear nerve**.

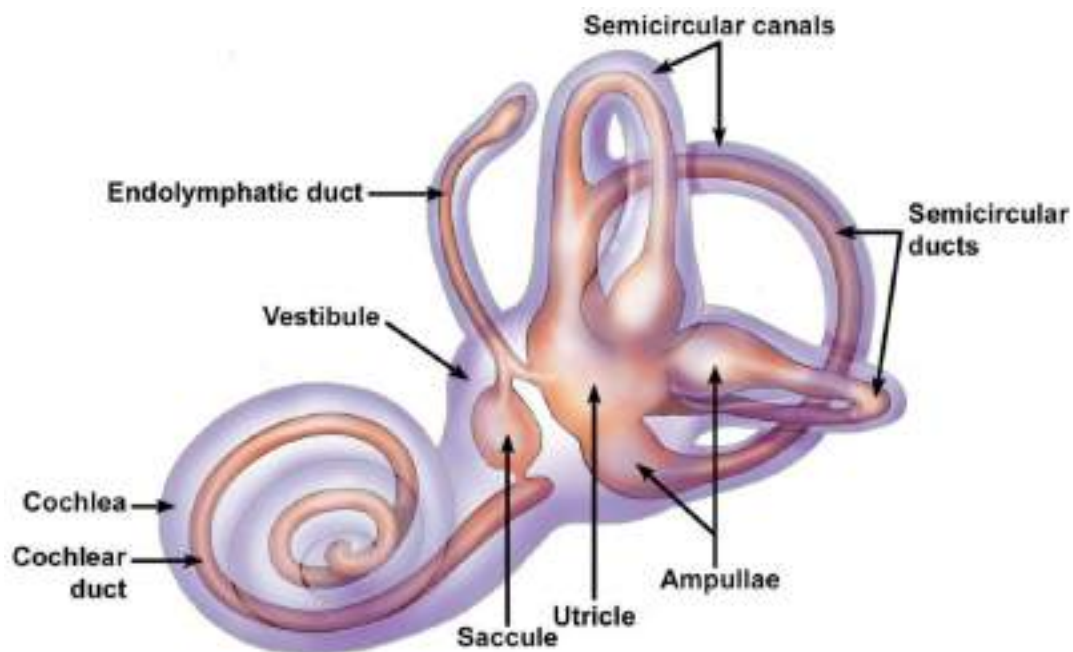


FIGURE 20.3. Inner ear: the membranous labyrinth is suspended in the osseous labyrinth.

III. **Utricle** and **saccul**e

- A. Portions of the membranous labyrinth that are connected to each other and are suspended in the osseous vestibule
- B. **Macula**. Receptor in both the utricle and saccul

 - 1. Thickening in the wall of the utricle and saccul composed of:
 - a. **Supporting cells**
 - b. **Hair cells** with stereocilia and a cilium (**kinocilium**) that are embedded in the gelatinous layer
 - c. **Gelatinous layer** is produced by supporting cells and covers both these and the hair cells.
 - d. **Otoliths (otoconia)**. Calcium carbonate crystals that are suspended at the top of the gel
 - 2. Linear acceleration and the force of gravity displace the otoliths, stimulating the stereocilia and kinocilia and initiating a neural, sensory impulse in the vestibular division of cranial nerve VIII.

IV. **Semicircular ducts** (three)

- A. Portions of the membranous labyrinth suspended in the osseous semicircular canals; both ends of each semicircular duct connect to the utricle.
- B. **Crista ampullaris**. Receptor in the ampullary enlargement of each semicircular duct
 - 1. Ridge-like structure that lies perpendicular to the long axis of each duct. Internal cell structure is similar to that of a macula except:
 - a. Gelatinous layer, called the **cupula**, is shaped like a cone and extends across the ampulla to the opposite wall, thus spanning the duct.
 - b. Otoliths are absent.
 - 2. Angular acceleration displaces the cupula that deflects the stereocilia and kinocilia and initiates a neural, sensory impulse in the vestibular division of cranial nerve VIII.
 - 3. Orientation in three distinct planes allows for complex detection of motion.

V. Cochlear duct

- A. Wedge-shaped duct of the membranous labyrinth suspended in the middle of the tubular, osseous cochlea. Position of the cochlear duct separates the bony cochlea into three subdivisions.
1. **Scala vestibuli**. This subdivision of the cochlea is continuous with the vestibule and lies above the cochlear duct, separated from it by the vestibular membrane.
 2. **Cochlear duct**. Contains the receptor for sound. The cochlear duct is located in the middle of the cochlea and is continuous with the saccule through a small duct. Its roof is the vestibular membrane separating it from the osseous scala vestibuli. Its floor is formed by the basilar membrane that is continuous with the osseous spiral lamina; both separate the cochlear duct from the scala tympani.
 3. **Scala tympani**. Subdivision of the bony cochlea lying beneath the cochlear duct. The scala tympani is continuous with the scala vestibuli at the **helicotrema**, located at the tip of the cochlea. The scala tympani terminates at the round window where pressure on the perilymph in this scala, initiated at the oval window and transported through scala vestibuli to scala tympani, is released.
- B. **Organ of Corti**. Receptor for sound in the cochlear duct; positioned on the floor of the cochlear duct, resting on the basilar membrane
1. Structure
 - a. **Supporting cells**. Several varieties, including pillar cells that form the boundary of a triangular space called the inner tunnel. Provide support for the hair cells, among other functions.
 - b. Inner and **outer hair cells**. Receptor cells located on either side of the inner tunnel possess stereocilia that are embedded in the tectorial membrane.
 - c. **Tectorial membrane**. This gelatinous membrane extends over the hair cells and is secreted by the cells of the spiral limbus, resting on the osseous spiral lamina. Stereocilia of the hair cells are embedded in the tectorial membrane.

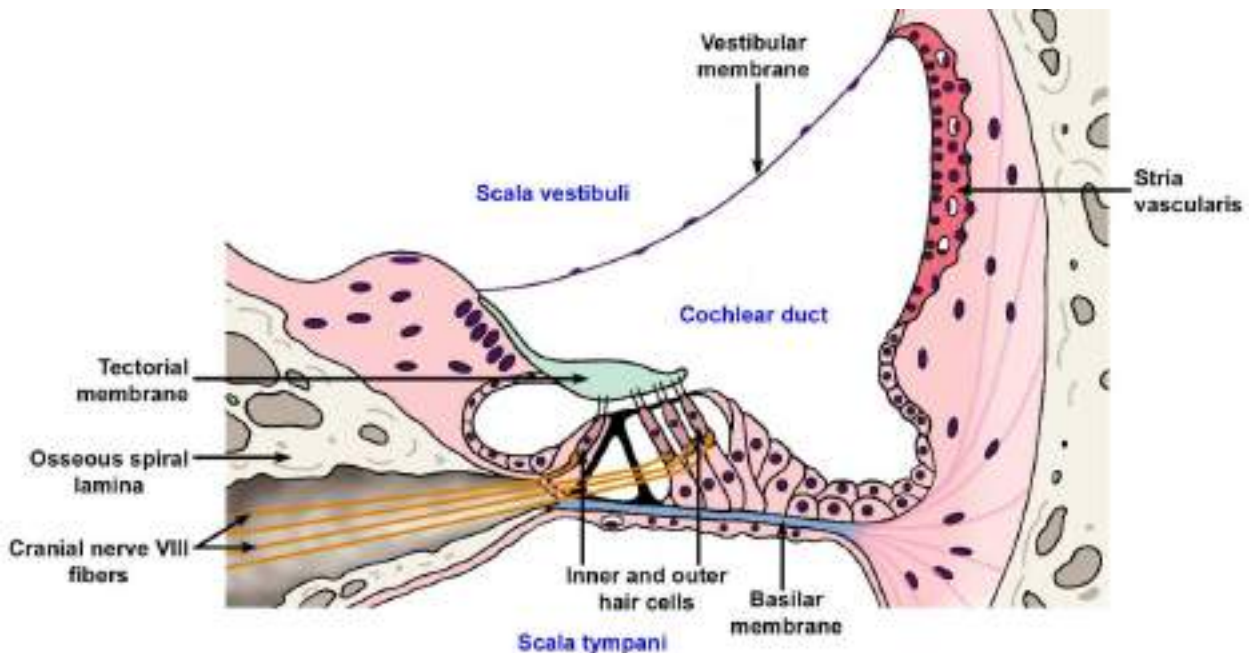


FIGURE 20.4. Cochlear duct, the receptor for sound, is a part of the membranous labyrinth in the inner ear.

2. Functions to discriminate sound

- a. Inward movement of the stapes at the oval window generates pressure on the perilymph in the vestibule that is transmitted into the scala vestibuli.
 - b. From the scala vestibuli, pressure is conducted, by deflection of the vestibular membrane, to the endolymph of the cochlear duct and to the basilar membrane. Movement of the basilar membrane into scala tympani and away from the tectorial membrane causes a shearing force on the stereocilia embedded in this membrane and initiates a neural, sensory response in the cochlear division of cranial nerve VIII.
 - c. Sound vibrations in the scala vestibuli also continue into the scala tympani at their junction at the **helicotrema**.
 - d. Sound vibrations in scala tympani are relieved by the bulging of the round window into the middle ear.
3. **Stria vascularis** is a vascularized epithelium located on the outer wall of the cochlear duct that produces endolymph.

CHAPTER 16

ENDOCRINE SYSTEM

GENERAL CONCEPTS

- I. Endocrine cells release their secretory products, called hormones, into the surrounding extracellular space. Hormones can affect adjacent cells (**paracrine secretion**) or diffuse into capillaries to be transported in the blood (**endocrine secretion**). Although exposed to all cells, Hormones act only on selected cells, called **target cells**, which express specific receptors to mediate the hormone signal.
- II. Endocrine organs are highly vascularized with fenestrated capillaries and, with the major exception of the thyroid gland, their cells do not show polarity. The nervous and endocrine systems combine to coordinate functions of all body systems and are functionally integrated as the neuroendocrine system.

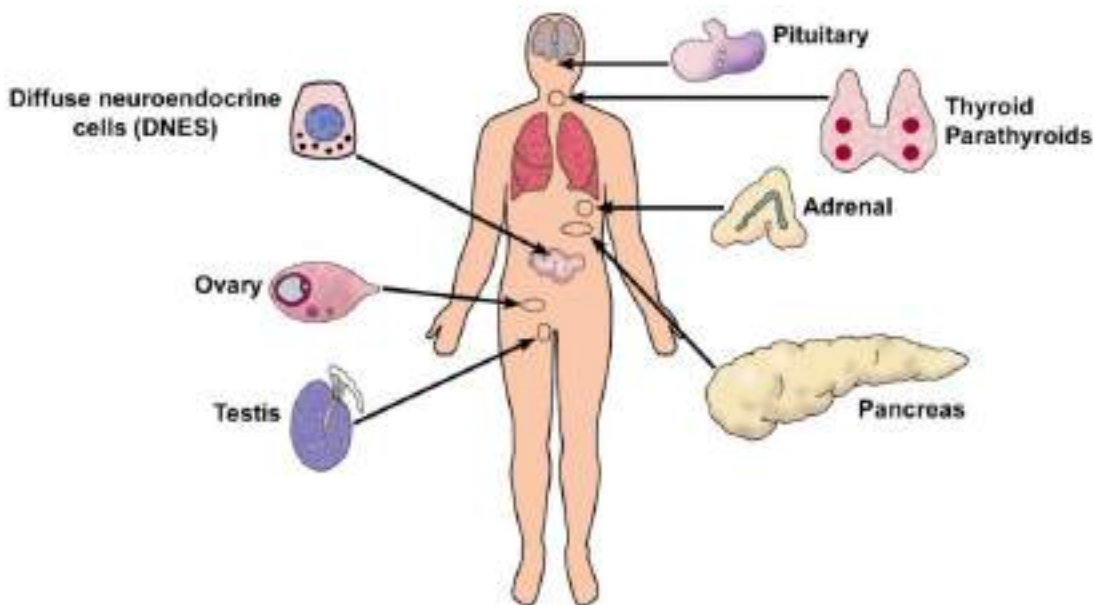


FIGURE 16.1. Components of the endocrine system.

COMPONENTS

- I. Individual cells (enteroendocrine cells) (***images***)
- II. Clusters of cells
 - A. Islets of Langerhans (pancreas)
 - B. Theca interna (ovary)

- C. Interstitial cells (testis)

III. Organs

- A. Pituitary
- B. Thyroid
- C. Parathyroid
- D. Adrenal
- E. Pineal

HORMONE TYPES

- I. Steroids and fatty acid derivatives (cortisol, testosterone)
- II. Amino acid derivatives (thyroxine, epinephrine)
- III. Peptides and proteins (insulin, growth hormone)

PITUITARY GLAND (HYPOPHYSIS) *(images)*

ORIGINS OF THE PITUITARY GLAND

- I. The pituitary gland consists of two different glands, the adenohypophysis and the neurohypophysis, which are derived embryologically from two distinct tissues.

A. **Adenohypophysis**

1. The adenohypophysis develops from a hollow evagination, **Rathke's pouch**, an outgrowth of ectoderm from the roof of the mouth
2. Rathke's pouch loses its connection with the oral cavity and ascends toward the base of the brain where it contacts the neurohypophysis, growing down from the hypothalamus of the brain.
3. Subdivisions
 - a. **Pars distalis**. Largest subdivision; forms from the anterior wall of Rathke's pouch, constituting >95% of the adenohypophysis
 - b. **Pars tuberalis**. Forms a collar of cells around the infundibulum of the

neurohypophysis.

- c. **Cystic remnants of Rathke's pouch.** Small cysts persisting from the original cavity of Rathke's pouch
- d. **Pars intermedia.** Forms from the posterior wall of Rathke's pouch at the interface of the adenohypophysis with the pars nervosa of the neurohypophysis; these cells also surround small cystic remnants of Rathke's pouch; this subdivision is rudimentary in humans.

B. Neurohypophysis

1. The **neurohypophysis** develops as an outgrowth from the hypothalamus of the diencephalon of the brain, and retains its connection with the brain, abutting the posterior wall of Rathke's pouch.
2. The subdivisions of the neurohypophysis consist of the **infundibulum** and the **pars nervosa**.

II. Pituitary terminology

| Terminology based on embryonic origin | Pituitary subdivisions | Clinical terminology |
|--|-------------------------------|-----------------------------|
| Adenohypophysis | Pars distalis | Anterior lobe of pituitary |
| | Pars tuberalis | |
| | Pars intermedia | Posterior lobe of pituitary |
| Neurohypophysis | Pars nervosa | |
| | infundibulum | |

ADENOHYPOPHYSIS

I. Cell types

| Hormone(s) | General Cell Type | Specific Cell Type |
|-------------------|--------------------------|---------------------------|
| GH | Acidophil | Somatotrope |
| Prolactin | Acidophil | Mammotrope |
| TSH | Basophil | Thyrotrope |
| FSH/LH | Basophil | Gonadotrope |
| ACTH | Basophil | Adrenocorticotrope |

A. **Chromophils**

1. **Acidophils**. Hormone-containing granules in the cytoplasm stain with acidic dyes, e.g., eosin
 - a. **Somatotropes**. Secrete **somatotropin, (growth hormone, GH)** which promotes growth (anabolic)
 - b. **Mammotropes**. Secrete **prolactin** which stimulates milk production
2. **Basophils**. Hormone-containing granules in the cytoplasm of these cells stain with basic dyes, e.g., hematoxylin
 - a. **Thyrotropes**. Secrete **thyroid stimulating hormone (TSH)** which stimulates thyroid hormone synthesis and release
 - b. **Gonadotropes**. Secrete **luteinizing hormone (LH)** and **follicle stimulating hormone (FSH)** that regulate egg and sperm maturation and sex hormone production. Both hormones are secreted in both males and females. In males LH can be referred to as **interstitial cell stimulating hormone (ICSH)**.
 - c. **Adrenocorticotropes**. Secrete **adrenocorticotrophic hormone (ACTH)** which regulates glucocorticoid secretion by adrenal gland

B. **Chromophobes**

1. Cells with sparse granule content that do not stain with either hematoxylin or eosin
2. May be degranulated cells or reserve, undifferentiated cells

II. Distribution of cell types in the adenohypophysis

- A. Pars distalis contains all five cell types
- B. Pars tuberalis contains gonadotropes only
- C. Pars intermedia contains basophils; however, their secretions in humans are unclear, although ACTH secretion is a possibility.

III. Regulation of adenohypophyseal secretion

- A. Adenohypophyseal hormone secretion is regulated by releasing or inhibitory factors (**neurohormones**) produced by neurons in the hypothalamus. Axons from these neurons terminate on a capillary bed located at the base of the hypothalamus in a region called the median eminence and release their neurohormones into these capillaries.
- B. The capillaries anastomose into the **hypophyseal portal vessels** which

travel down the infundibulum and end in a second capillary network within the adenohypophysis.

- C. Hypothalamic factors exit this second capillary plexus and either stimulate or inhibit the secretion of hormones from their target acidophil or basophil cells.

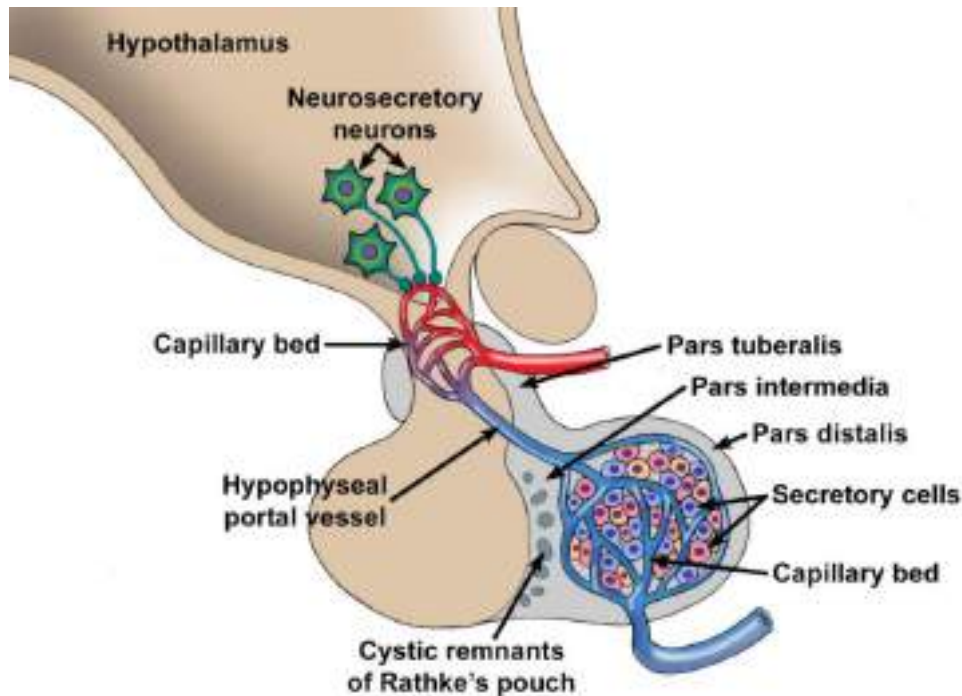


FIGURE 16.2. Structure and regulation of secretion of the adenohypophysis.

NEUROHYPOPHYSIS

I. Components

A. **Infundibulum (hypophyseal stalk)**

1. Extension from the hypothalamus; continuous with the pars nervosa
2. Contains the **hypothalamo-hypophyseal tract** which consists of axons from neurons whose cell bodies are located in the **supraoptic** and **paraventricular nuclei** of the hypothalamus

B. **Pars nervosa**

1. Contains axons and axon terminals of the neurons forming the **hypothalamo-hypophyseal tract**

2. **Herring bodies**. Expanded axon terminals which accumulate secretory granules containing oxytocin or antidiuretic hormone (vasopressin)
 - a. **Oxytocin** causes smooth muscle and myoepithelial cell contraction.
 - b. **Antidiuretic hormone (ADH)** acts on the kidney tubules to prevent water loss.
3. Also contains "astrocyte-like" cells, called **pituicytes**.
4. No secretory cells are present.

II. Regulation of neurohypophyseal secretion

- A. Oxytocin and vasopressin are synthesized by neurons in the hypothalamus, transported down the axons and stored in axons terminals (Herring bodies) in the pars nervosa.
- B. Activity in these neurons, in response to physiological signals, causes hormone release (neurosecretion) in a manner similar to release of neurotransmitters.

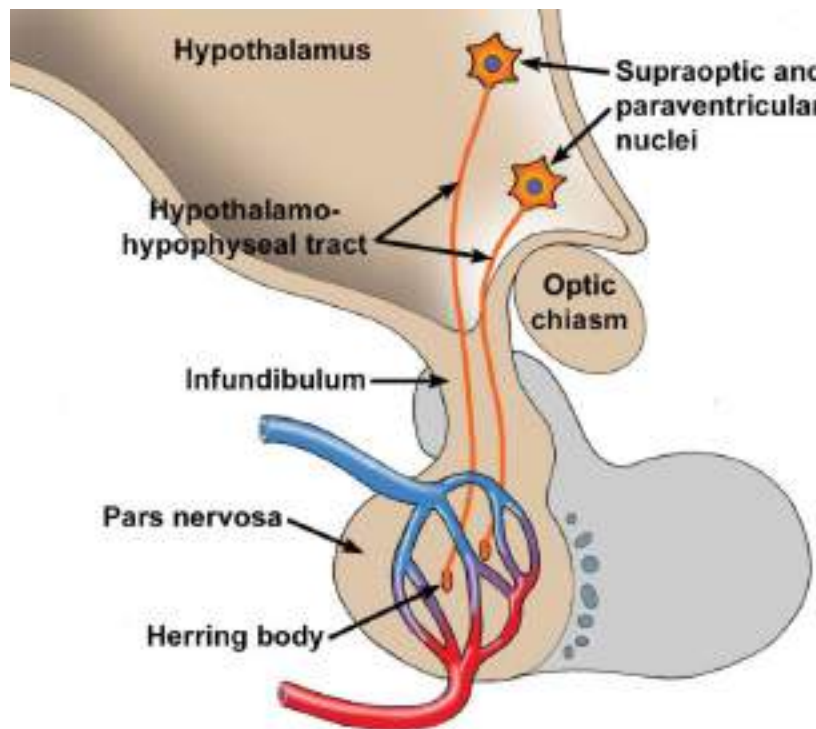


FIGURE 16.3. Structure and regulation of secretion of the neurohypophysis.

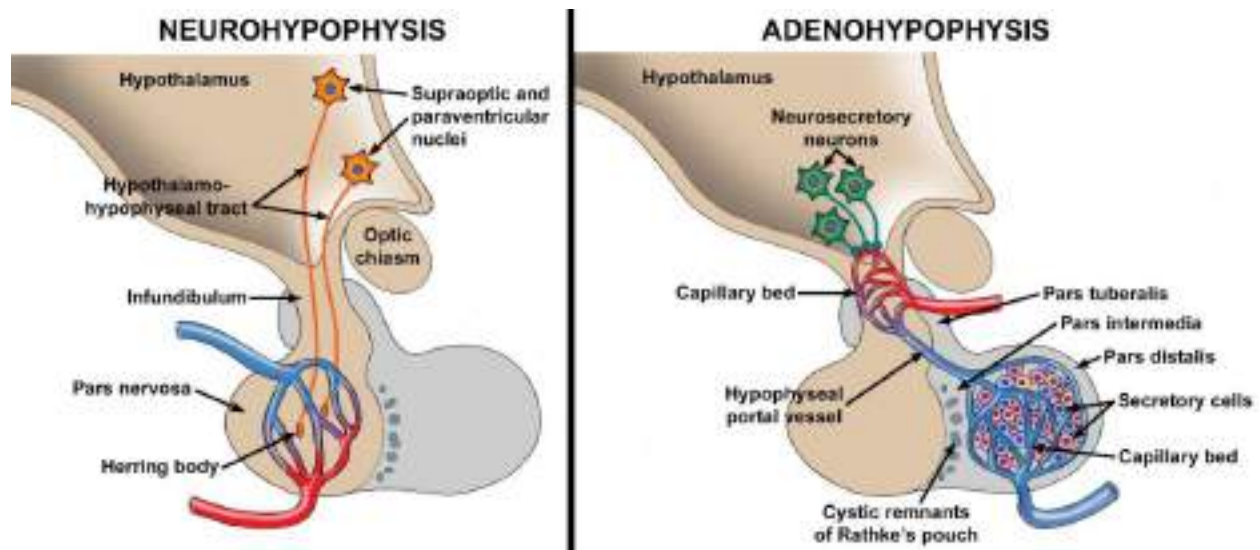


FIGURE 16.4. Comparison of the structure and regulation of secretion of pituitary gland subdivisions.

THYROID GLAND (*images*)

- I. The thyroid gland consists of two unique structural and functional subdivisions, the **thyroid follicles** and **parafollicular cells**.
- II. **Thyroid follicles**
 - A. Spherical cysts whose wall is composed of a single layer of follicle cells surrounding a center gel called colloid. Cells have apical and basal surfaces and demonstrate cellular polarity.
 - B. Follicle cells secrete **thyroglobulin**, a glycoprotein that is stored as colloid in the center of the follicle. The thyroid gland is the only endocrine organ that stores a hormone. When needed, these same follicular cells take up the stored thyroglobulin, transport it across the epithelium and release thyroid hormones into the capillaries surrounding the follicle.
 - C. Thyroglobulin contains modified tyrosine amino acids that constitute the thyroid hormones, **thyroxine (tetraiodothyronine, T_4)** and **triiodothyronine (T_3)**.
 - D. Thyroid hormones regulate the basal metabolic rate.
 - E. The secretion of T_3 and T_4 is controlled by TSH released from the adenohypophysis.

III. Parafollicular cells (C cells, clear cells)

- A. Are located within the follicular epithelium and in small clusters between follicles
- B. Possess secretory granules containing the hormone **calcitonin**, which acts to inhibit bone resorption, lowering blood calcium levels.
- C. Belong to the **diffuse neuroendocrine system (DNES)**
- D. The secretion of calcitonin is controlled by calcium levels in the blood.

SYNTHESIS AND RELEASE OF THYROID HORMONES

- I. Follicle cells synthesize and secrete thyroglobulin from their apical surfaces into the follicle lumen where it is stored. The follicle lumen is an extracellular compartment and, thus, secretion of thyroglobulin constitutes the exocrine secretion of the follicle cells and accounts for the polarity of the cells.
- II. The tyrosines of thyroglobulin are iodinated in the follicle lumen and rearranged to form the thyroid hormones (T_3 and T_4), which are modified tyrosines that are retained in the primary structure of thyroglobulin.
- III. The iodinated thyroglobulin is resorbed by pinocytosis into the follicle cells where it is hydrolyzed, liberating T_3 and T_4 .
- IV. T_3 and T_4 are released from the basolateral surfaces of the follicle cell and enter the blood stream.
- V. Active and inactive follicles
 - A. **Active follicle**. Follicle cells are cuboidal to columnar and are involved with both secretion and resorption of thyroglobulin.
 - B. **Inactive follicle**. Follicle cells are squamous, reflecting the paucity of secretory organelles and the lack of synthetic and uptake activity.

PARATHYROID GLANDS (images)

- I. The **parathyroid glands** are four small, spherical glands that are embedded in the posterior surface of the thyroid gland.
- II. Cell types
 - A. **Chief cell**
 - 1. Major cell type, arranged in cords or clumps

2. Small polyhedron-shaped cells with secretory granules visible only with electron microscope
3. Secrete **parathyroid hormone (PTH)** which increases blood calcium levels, through increased osteoclast activity
4. The secretion of PTH is controlled by calcium levels in the blood.

B. **Oxyphil cell**

1. Large cell may appear singly or in clumps
2. Heterochromatic nucleus and abundant eosinophilic cytoplasm, due to numerous mitochondria
3. No secretory granules
4. Function is unclear.

ADRENAL GLANDS *(images)*

I. Structure

- A. Paired glands, each located at the superior pole of a kidney; consist of two distinct subdivisions with different embryological origins
- B. Subdivisions
 1. **Cortex**. Derived from mesoderm and constitutes the major steroid-producing gland
 2. **Medulla**. Derived from neural crest and is a major source of epinephrine and norepinephrine neurohormones
- C. Surrounded by a dense **capsule**

II. Cortex

- A. Composed of steroid-secreting cells, whose features include:
 1. Abundant smooth endoplasmic reticulum
 2. Mitochondria with **tubular cristae** in the zona fasciculata and the zona reticularis; **shelf-like cristae** in the zona glomerulosa
 3. Numerous lipid droplets filled with cholesterol, precursor for steroid hormones

4. Secretion is by diffusion with no hormone storage.

B. Zonation

1. **Zona glomerulosa**

- a. Located immediately beneath the capsule
- b. Cells arranged in round clusters
- c. Secretes **mineralocorticoids, e.g., aldosterone**

2. **Zona fasciculata**

- a. Middle layer, largest cortical zone
- b. Cells arranged in rows perpendicular to the capsule alternating with wide-diameter, fenestrated capillaries
- c. Secretes **glucocorticoids** and **androgens**
- d. The secretion of glucocorticoids is controlled by ACTH released from the adenohypophysis.

3. **Zona reticularis**

- a. Forms deepest layer of the cortex
- b. Cells arranged as anastomosing cords
- c. Same secretions as zona fasciculata, **glucocorticoids** and **androgens**

III. Medulla

A. Composed of **chromaffin cells**

1. Modified adrenergic neurons without axons or dendrites; represent sympathetic ganglion cells
2. Polyhedral cells containing abundant dense-core, secretory granules

- B. Chromaffin cells synthesize and release epinephrine and norepinephrine, which are routinely released in small quantities. Under stress, the autonomic nervous system stimulates greater production and release.

PINEAL GLAND (EPIPHYSIS CEREBRI) (*images*)

I. Structure

A. Small conical-shaped gland; develops from the roof of the diencephalon and remains attached by a short pineal stalk

B. Surrounded by a **capsule** composed of **pia mater**

1. Connective tissue septa derived from the pia mater penetrate the gland and subdivide it into indistinct lobules.

2. Sympathetic axons and blood vessels enter the gland with the septa.

C. Cells

1. Pinealocytes

a. Major cell type, represent modified neurons

b. Euchromatic nucleus, spherical to ovoid, with a prominent nucleolus

c. Cytoplasm not evident with conventional stains; however, silver staining reveals that the cell generally has two or more extensions similar to neuronal processes.

d. Processes end in association with capillaries.

e. Secrete **melatonin**, an indoleamine hormone

2. Interstitial cells

a. Minor cell type, similar to astrocytes in the brain

b. Nucleus is elongated and more heterochromatic than that of pinealocytes.

c. Possess long processes with intermediate filaments

d. Located among groups of pinealocytes and in the connective tissue septae

D. Corpora araneacea ("brain sand")

1. Globular, basophilic accumulations of calcium phosphates and carbonates in the interstitial space

2. Radio-opaque in X-ray images and, thus, often used as indicators of

midline deflection of the brain resulting from pathological conditions

II. Secretion

- A. Major hormone secreted is melatonin which regulates diurnal (circadian) light-dark cycles and seasonal rhythms.
- B. Melatonin is secreted during darkness; secretion is inhibited by light.
- C. Retinal stimulation by light is relayed to the pineal via sympathetic innervation from the superior cervical ganglion.

CHAPTER 3

EPITHELIAL TISSUES

GENERAL CONCEPTS

I. Classification of epithelial tissues

A. **Lining and covering epithelia**

1. Form the boundary between external environment and body tissues
 - a. Cover body surfaces (e.g., the epidermis of the skin) and lines the lumens of internal organs that open to the exterior of the body
 - b. Line body cavities (e.g., peritoneal cavity) and covers the exterior of organs that project into these cavities
 - c. Line blood and lymph vessels
2. Cell shape and number of layers correlate with the function of the epithelium.

B. **Glandular (secretory) epithelia**

1. Develop from a lining or covering epithelium by invagination into the underlying connective tissue
2. Form exocrine and endocrine glands.

II. General features of all epithelial tissues

- A. Highly cellular (sparse intercellular space)
- B. Numerous intercellular junctions for attachment and anchorage
- C. Avascular
- D. High proliferative capacity, especially in epithelial membranes, to replace continual sloughing of cells from free surface
- E. Most rest on a **basement membrane**. ***(images)***
 1. The basement membrane is composed of a **basal lamina** and a **reticular lamina**.

- a. The basal lamina is secreted by the epithelial cells and consists of the **lamina lucida** and the **lamina densa**. A similar structure is also present in muscle and nervous tissue, where it is referred to as an **external lamina**.
 - b. The reticular lamina is secreted by fibroblasts located in the underlying connective tissue.
 2. Functions of the basement membrane
 - a. Provides support and attachment for the epithelial cells
 - b. Acts as a selective diffusion barrier
- F. Free and basal surfaces of epithelia
1. **Basal surface** contacts the basal lamina of the basement membrane.
 2. **Free surface** interfaces with the external environment or spaces within the body.
 3. **Polarity**. A polarized cell is one that exhibits contrasting properties or structures on opposite sides of the cell. Because epithelial tissues face a free surface, the function of the apical surface is often very different from that at the base of the cell. This diversification is reflected by the non-homogeneous distribution of organelles.

LINING AND COVERING EPITHELIAL TISSUES

METHOD OF CLASSIFICATION

I. Classification by number of layers

A. Simple epithelium

1. One cell layer thick
2. All cells rest on the basement membrane (basal surface) and all cells face the free surface.

B. Stratified epithelium

1. More than one cell layer thick
2. Only the deepest layer of cells contact the basement membrane and only the superficial-most cells have a free surface.

3. Named according to the shape of the cells at the free surface.

II. Classification by shape of surface cells

A. **Squamous**

1. Cells are much wider than tall, resembling a "fried egg."
2. Nucleus is highly flattened.

B. **Cuboidal**

1. Cells are of equal height and width.
2. Nucleus is spherical.

C. **Columnar**

1. Cells are much taller than they are wide.
2. Nucleus is oval shaped, generally located in the mid to lower portions of the cell.

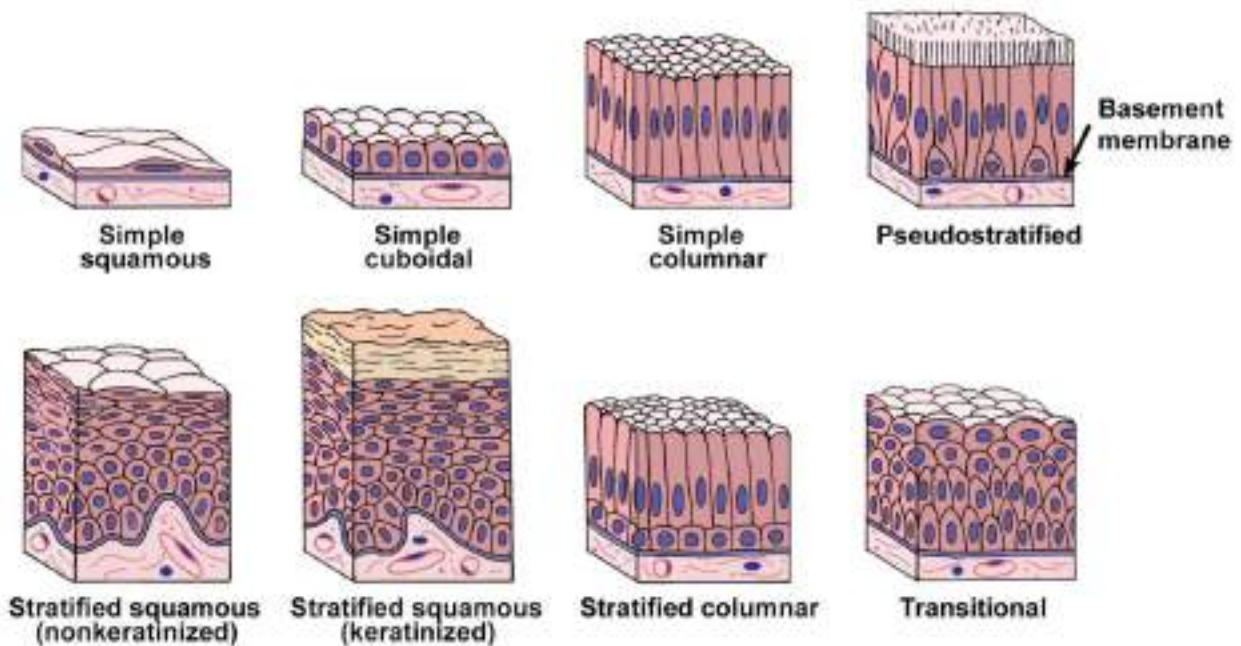


FIGURE 3.1. Types of lining and covering epithelia.

TYPES OF LINING AND COVERING EPITHELIUM

I. Simple epithelial tissues *(images)*

A. **Simple squamous**

1. Allows for rapid diffusion across the epithelium
2. Forms the lining of blood vessels, alveoli of the lungs, and internal body cavities

B. **Simple cuboidal**

1. Lines and absorbs
2. Forms the walls of ducts and tubules

C. **Simple columnar**

1. Lines and absorbs
2. Forms the lining of the intestines and gall bladder

D. **Pseudostratified**

1. Cells are of various heights. All cells rest on the basement membrane, but only the tallest cells reach the free surface. Variation in height of the cells and the location of nuclei give the appearance of a stratified epithelium. Frequently ciliated.
2. Provides protection and surface transport when ciliated
3. Forms the lining of much of the respiratory tract and much of the male reproductive system

II. Stratified epithelial tissues (***images***)

A. **Stratified squamous**

1. Protects from physical abrasion and prevents desiccation
2. Types
 - a. **Nonkeratinized (moist)**. Lining of wet cavities, including the mouth, esophagus, rectum, and anal canal; surface cells are nucleated and living.
 - b. **Keratinized (dry)**. Epidermis of the skin; surface cells are nonliving.

B. **Stratified cuboidal/columnar**. Lines the larger ducts of exocrine glands.

C. **Transitional**

1. Protective function; constructed to expand with distension of the hollow organs it lines
2. Unique to the urinary system; lines the urinary bladder and ureter

SURFACE SPECIALIZATIONS and CELL JUNCTIONS

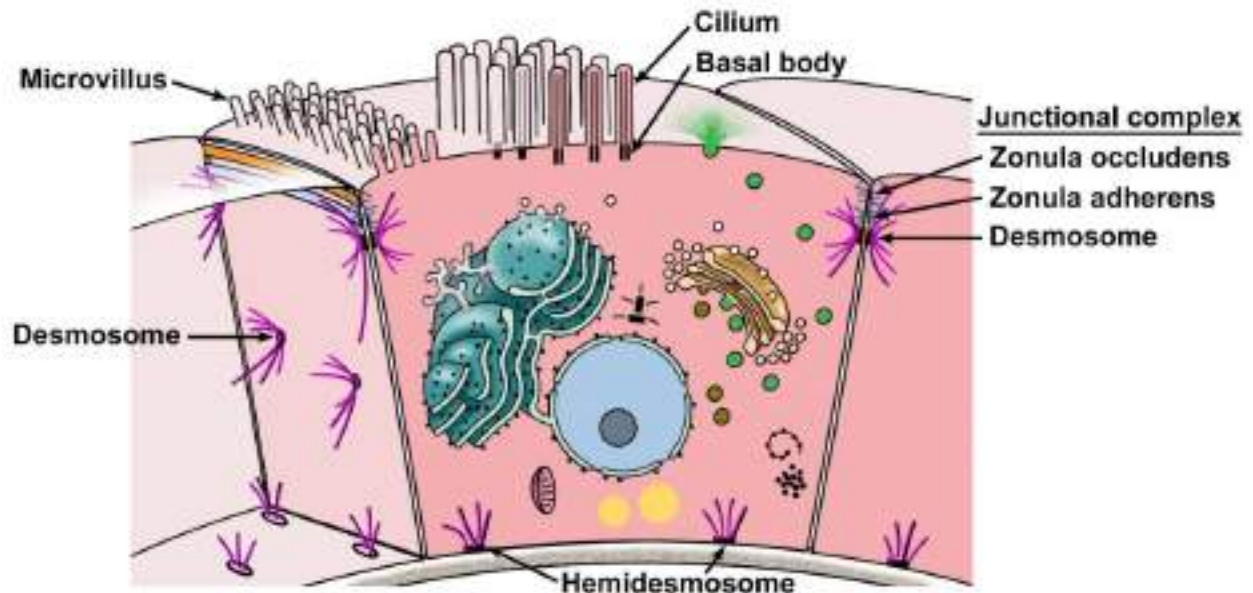


FIGURE 3.2. Cell junctions and surface specializations.

SURFACE SPECIALIZATIONS

I. **Microvilli** (*images*)

- A. Finger-like extensions from the free surface of the cell, about 1 micron in height
- B. Are usually present in large numbers on each cell and, collectively, are called a **brush or striated border**
- C. Contain a core of actin microfilaments
- D. Are relatively non-motile
- E. Increase surface area for absorption
- F. Prominent on cells lining the digestive tract and proximal tubules in the kidney

II. **Stereocilia** (*images*)

- A. Large, non-motile microvilli; not cilia
- B. Contain a core of actin microfilaments
- C. Increase surface area
- D. Present on cells lining the epididymis and ductus deferens in the male reproductive tract

III. **Cilia** (*images*)

- A. Multiple hair-like extensions from free surface of the cell; 7-10 microns in height
- B. Highly motile; beat in a wave-like motion
- C. Function to propel material along the surface of the epithelium (e.g., in the respiratory system and the oviduct of the female reproductive system)
- D. Core of a cilium is called the **axoneme**, in which nine pairs of microtubules surround two central, individual microtubules (9 + 2 arrangement).
- E. The axoneme of each cilium originates from a **basal body** that is located at the apex of the cell and is composed of nine triplets of microtubules.

CELL JUNCTIONS (*images*)

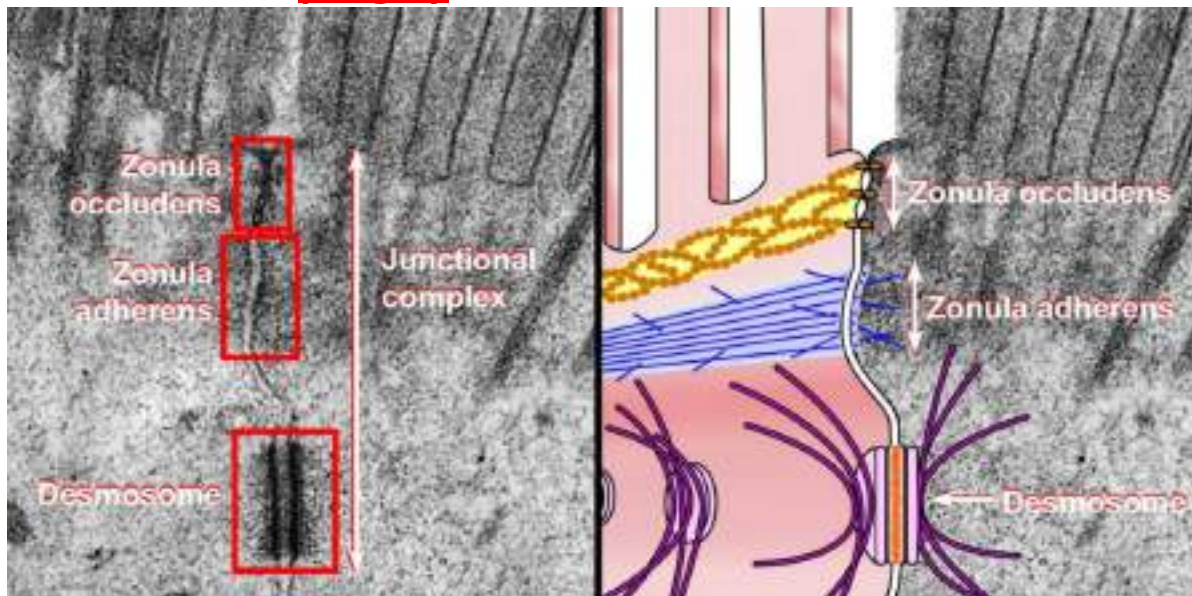


FIGURE 3.4. Cell junctions and surface specializations.

- I. Specialized structures of the plasma membrane that:
 - A. Attach and anchor cells
 - B. Establish apical and basolateral membrane domains by sealing adjacent plasma membranes
 - C. Provide channels for ionic and metabolic coupling
- II. Not restricted to epithelial cells; cell junctions occur, however, in large number in epithelial tissues to resist the physical forces acting on the cells.

III. Types

A. **Tight junction (zonula occludens)**

1. Belt-like, barrier junction around apex of the cell
2. Provides close apposition of adjacent plasma membranes and occludes the intercellular space
3. Functions
 - a. Prevents diffusion of material between the intercellular space and the lumen of the organ
 - b. Establishes apical and basolateral membrane domains in the cell by preventing the lateral migration of proteins in the plasma membrane

B. **Adherent junctions**

1. Attach cells to each other or anchor them to the basal lamina; no fusion of the plasma membrane
2. Types of adherent junctions
 - a. **Belt desmosome (zonula adherens)**. Belt-like junction that encircles the apex of the cell like a barrel strap and is located immediately beneath the zonula occludens; serves to attach adjacent cells together; associated with actin filaments.
 - b. **Spot desmosome (macula adherens)**. Disk-like junctions scattered over the surface of the cell, which are paired with similar structures in adjacent cells; associated with intermediate filaments (e.g., keratin filaments in epithelial cells).

- c. **Hemidesmosome**. Represents a "half desmosome"; these junctions anchor the basal surface of the cell to the basal lamina.
- C. **Junctional complex**. Consists of the zonula occludens, zonula adherens, and desmosomes; because these structures cannot be resolved as separate structures at the light microscopic level, they appear as a single, bar-shaped, dark region at the apical corners of adjacent cells. The term **terminal bar** was used by early microscopists to define the zonula occludens and zonula adherens at the light microscopic level.
- D. **Gap junction**
 - 1. Gap junctions consist of **connexons**, six transmembrane proteins clustered in a rosette that form a central pore. Connexons from adjacent cells abut one another, forming a continuity between cells.
 - 2. Provides metabolic and electrical continuity (coupling) via the pores between cells

GLANDULAR EPITHELIAL TISSUES

GENERAL CONCEPTS

- I. Develop from or within a lining or covering epithelium
- II. Secretory cells may
 - A. Differentiate but remain in the lining epithelium
 - B. Invaginate into the underlying connective tissue and remain attached to the lining epithelium
 - C. Invaginate into the underlying connective tissue but lose their connection to the epithelium

EXOCRINE VS. ENDOCRINE GLANDS

- I. Major classification of glands, which is based on the method by which their secretory product is distributed
- II. **Exocrine glands**
 - A. Secretory products are released onto an external or internal epithelial surface, either directly or via a duct or duct system.
 - B. Secretory cells display polarized distribution of organelles.

III. **Endocrine glands**

- A. No ducts; secretory products are released directly into the extracellular fluid where they can affect adjacent cells (paracrine secretion) or enter the bloodstream to influence cells throughout the body (endocrine secretion).
- B. No polarization of organelles, except the thyroid gland and enteroendocrine cells of the digestive tract
- C. Secretory products are called hormones.

METHODS OF PRODUCT RELEASE FROM GLANDULAR CELLS

- I. **Merocrine**. Secretory product is released by exocytosis of contents contained within membrane-bound vesicles. This method of release is used by both exocrine and endocrine glands. Examples are digestive enzymes from pancreatic acinar cells and insulin from pancreatic islet cells.
- II. **Apocrine**. Secretory material is released in an intact vesicle along with some cytoplasm from the apical region of the cell. This method of release is used by exocrine glands only. An example is the lipid component of the secretory product of the mammary gland.
- III. **Holocrine**. Entire cell is released during the secretory process. Cells that are released may be viable (oocyte or sperm) or dead (sebaceous glands). This method of release is used by exocrine glands only.
- IV. **Diffusion**. Secretory product passes through the cell membrane without the formation of secretory granules. Examples are steroid hormones. This method of release is used by endocrine glands only.

TYPES OF SECRETORY PRODUCTS

- I. Exocrine glands
 - A. **Mucus**. Thick, viscous, glycoprotein secretion
 - 1. Secretory cells are usually organized into tubules with wide lumens.
 - 2. Cytoplasm appears vacuolated, containing mucigen that, upon release, becomes hydrated to form mucus.
 - 3. Nucleus is flattened and located in the base of the cell.
 - B. **Serous**. Thin, watery, protein secretion
 - 1. Secretory cells are usually organized into a flask-shaped structure with a narrow lumen, called an acinus.

2. Cytoplasm contains secretory granules.
3. Nucleus is round and centrally located in the cell.

C. Special

1. **Lipid**. Oily secretion (sebum) from sebaceous glands and lipid portion of milk from the mammary gland.
2. **Sweat**. Hypotonic, serous secretion that is low in protein content.
3. **Cerumen**. A waxy material formed by the combination of the secretory products of sebaceous and ceruminous glands with desquamated epidermal cells in the auditory canal

II. Endocrine glands

- A. **Derivatized amino acids**, e.g, thyroxine and epinephrine
- B. **Peptides and proteins**, e.g., insulin and oxytocin
- C. **Steroids**, e.g., testosterone and cortisol

CLASSIFICATION OF EXOCRINE GLANDS *(images)*

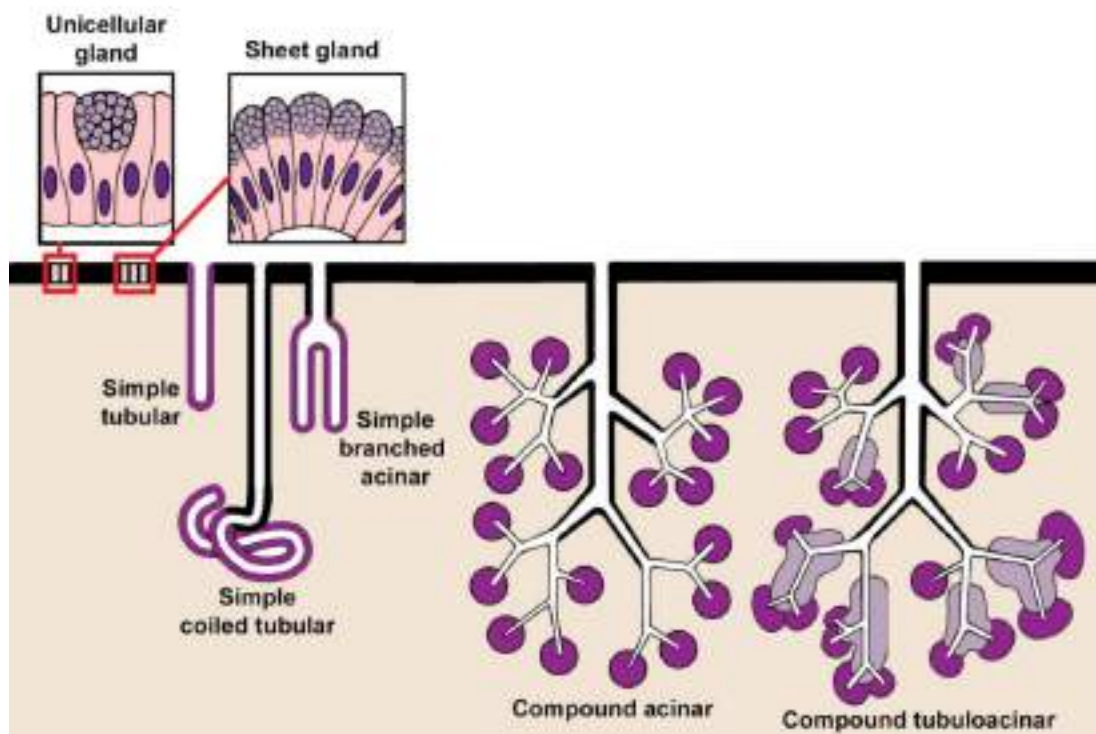


FIGURE 3.4. Types of glands based on their morphology.

I. **Unicellular glands**. Individual cells located within an epithelium, such as **goblet cells** that secrete mucus

II. Multicellular glands

A. **Sheet gland**. Composed of a surface epithelium in which every cell is a mucus-secreting cell. A sheet gland is unique to the lining of the stomach.

B. The remaining multicellular glands are classified according to:

1. The shape(s) of the secretory units

a. Presence of **tubules** only

b. Presence of only **acini** (singular, **acinus**) or **alveoli** (singular, **alveolus**) (these two terms are synonymous), which are flask-shaped structures

c. Presence of both tubules and acini

2. The presence and configuration of the duct

a. **Simple**. No duct or a single, unbranched duct is present.

b. **Compound**. Branching duct system

3. Classification and types of multicellular glands

a. **Simple tubular**. No duct; secretory cells are arranged like a test tube that connects directly to the surface epithelium (e.g., intestinal glands).

b. **Simple, branched tubular**. No duct; tubular glands whose secretory units branch (e.g., fundic glands of stomach)

c. **Simple, coiled tubular**. Long unbranched duct; the secretory unit is a long coiled tube (e.g., sweat glands).

d. **Simple, branched acinar (alveolar)**. Secretory units are branched and open into a single duct (e.g., sebaceous glands).

e. **Compound tubular**. Branching ducts with tubular secretory units (e.g., Brunner's gland of the duodenum)

f. **Compound acinar (alveolar)**. Branching ducts with acinar secretory units (e.g., parotid salivary gland)

- g. **Compound tubuloacinar (alveolar)**. Branching ducts with both tubular and acinar secretory units (e.g., submaxillary salivary gland)

SPECIAL FEATURES OF SOME EXOCRINE GLANDS

- I. **Serous demilunes**. Consist of a "cap" of serous cells around the end of a mucous tubule; appear half-moon shaped in section
- II. **Myoepithelial cells**. Resemble smooth muscle cells in their fine structure but are of epithelial origin; prominent in sweat and mammary glands, they surround secretory units, lying inside the basement membrane, and aid in the expulsion of secretory products from the gland.

DUCT SYSTEM OF COMPOUND, EXOCRINE GLANDS *(images)*

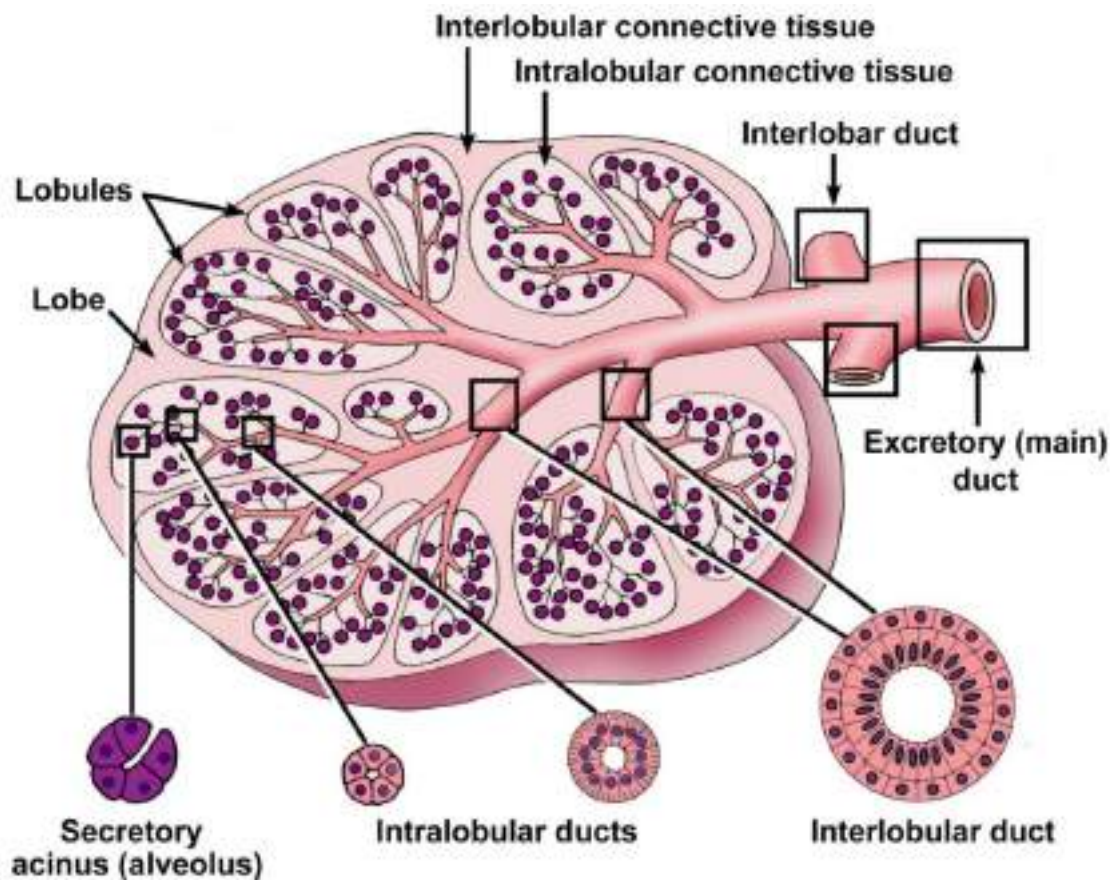


FIGURE 3.5. Structure of a compound gland.

- I. **Intralobular ducts**. Contained within a lobule; simple cuboidal to columnar epithelium
- II. **Interlobular ducts**. Receive numerous intralobular ducts; located in the connective tissue between lobules; stratified columnar epithelium

III. **Excretory (main) duct.** Macroscopic duct draining the entire gland

ENDOCRINE GLANDS (SEE ALSO CHAPTER 16)

I. No ducts; generally cells are not polarized

II. Occurrence

A. Unicellular (e.g., enteroendocrine cells of the digestive tract); these cells do show polarity because they are located within an epithelium and secrete away from the free surface of the epithelium.

B. Small clusters of cells (e.g., islet of Langerhans in pancreas)

C. Organs (e.g., thyroid gland, adrenal gland)

III. Secretory cells of multicellular glands are usually arranged as plates or cords. The thyroid gland, where the cells form fluid-filled spheres, is an exception to this pattern.

IV. Highly vascular with fenestrated capillaries

V. Secretory products are called hormones. Hormones can be:

A. Derived from amino acids (e.g., thyroxine and epinephrine)

B. Peptides and proteins (e.g., insulin and oxytocin)

C. Steroids (e.g., testosterone and cortisol); steroid-secreting cells display mitochondria with tubular cristae and contain large amounts of lipid droplets and smooth endoplasmic reticulum.

VI. Secrete by the merocrine or diffusion methods only

CHAPTER 19

EYE

GENERAL CONCEPTS

- I. The eyes are complex photoreceptive organs located in the bony orbits of the skull. Movement of the eye is accomplished by a set of extrinsic ocular muscles, which insert on the outer surface of the globe.
- II. Each eye consists of image-forming structures, a photoreceptive retina, and a fibrous globe to provide support.
- III. The eye is protected by an eyelid, a moveable fold of skin that covers the anterior surface of the globe.

EYELID (*images*)

- I. Protective covering of the eye.
- II. Components
 - A. Covered on its outer surface by thin skin that possesses eyelashes at the margin of the eyelid
 - B. **Tarsal plate**. Region of dense fibrous and elastic connective tissues within the eyelid that provide support
 - C. Contains the **obicularis oculi muscle**
 - D. **Meibomian glands**. Specialized sebaceous glands embedded in the tarsal plate, whose secretions add to the tear film to reduce evaporation
 - E. **Palpebral conjunctiva**. Lines the inner surface, consisting of a stratified columnar epithelium with goblet cells; the conjunctiva is reflected onto the globe as the bulbar conjunctiva, which is continuous with the **corneal epithelium**.

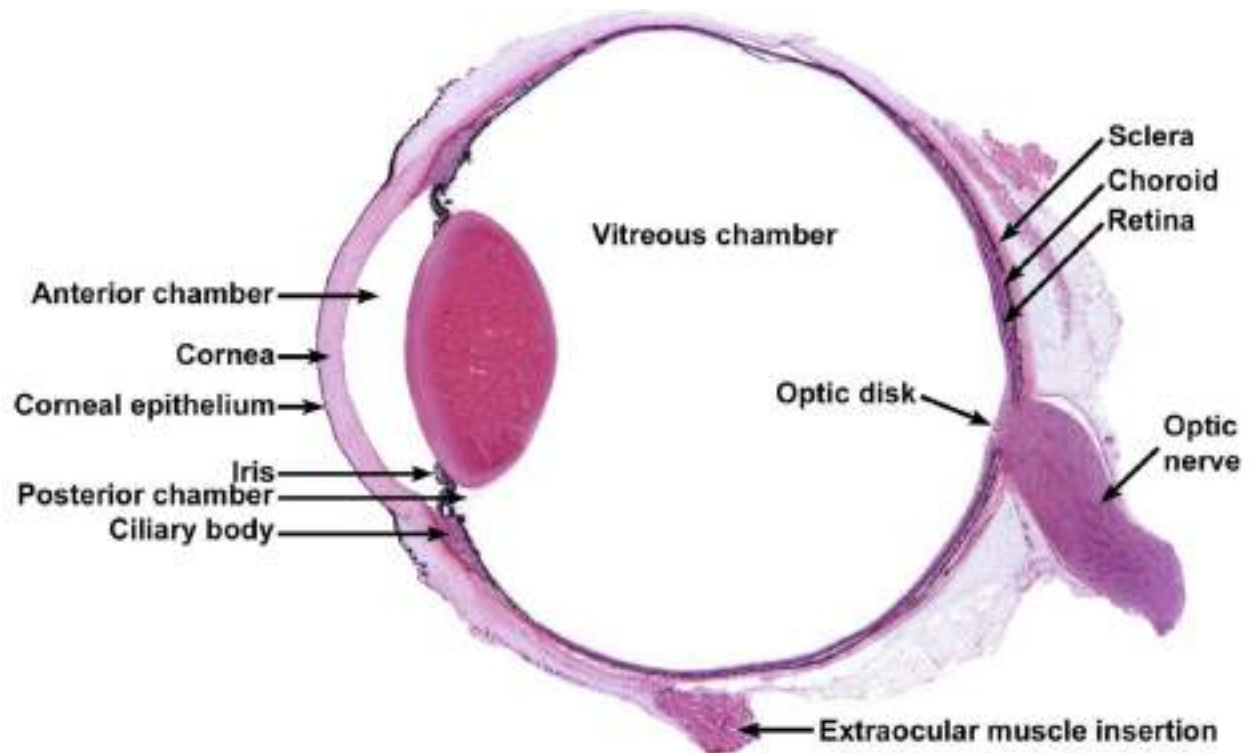


FIGURE 19.1. Midsagittal section of the eyeball.

EYEBALL (GLOBE) (images)

I. Composed of three layers or tunics

- A. **Fibrous tunic** consisting of the sclera and cornea
- B. **Vascular tunic or uveal tract** consisting of the iris, ciliary body, and choroid
- C. **Neural tunic** consisting of the retina

II. Contains three chambers

- A. **Anterior chamber** is the space between the cornea and the iris, filled with *aqueous humor* fluid.
- B. **Posterior chamber** lies between the iris anteriorly and the lens, ciliary body, and zonule fibers posteriorly; filled with aqueous humor
- C. **Vitreous chamber** is located behind the lens and is filled with a gelatinous substance called the **vitreous body**.

FIBROUS TUNIC OF THE EYE (OUTER TUNIC)

I. Sclera

- A. Opaque layer composed of dense, irregular connective tissue; forms the outer layer of the posterior four-fifths of the globe
- B. Gives shape and provides support for the globe
- C. Provides insertion points for extraocular muscles

II. Cornea

- A. Anterior continuation of the sclera, covering the anterior one-fifth of the eye
- B. Transparent and avascular; transparency results from the ordered arrangement of its collagen fibers and low state of tissue hydration.
- C. Convex curvature aids in focusing light (refraction).
- D. Layers (anterior to posterior)
 - 1. **Corneal epithelium**. Covers the anterior surface of the cornea; composed of a moist, stratified squamous epithelium that is continuous with the bulbar conjunctiva at the *limbus*
 - 2. **Bowman's membrane**. Acellular collagenous layer beneath the corneal epithelium
 - 3. **Stroma**. Multiple layers of parallel collagen fibers constitute the majority of the cornea. The collagen fibers in each layer are arranged at about right angles to adjacent layers. The highly ordered arrangement of these fibers contributes to the transparency of the cornea.
 - 4. **Descemet's membrane**. Thickened basal lamina of the corneal endothelium
 - 5. **Corneal endothelium**. Simple squamous epithelium covering the posterior surface of the cornea; regulates the hydration state of the stroma

III. Corneo-scleral junction (limbus)

- A. Transition zone between the cornea and the sclera
- B. Bowman's membrane ends and the corneal epithelium thickens at this junction.

- C. **Trabecular meshwork.** Irregular channels in the stroma that are lined by endothelium. Drains the aqueous humor from the anterior chamber to maintain proper intraocular pressure. The channels of the trabecular meshwork merge to form the **canal of Schlemm**, a ring-like sinus that encircles the limbus and drains into the venous system.

VASCULAR TUNIC (UVEAL TRACT) OF THE EYE (MIDDLE TUNIC)

I. Choroid

- A. Highly vascular, cellular layer lying inside the sclera; this layer is richly pigmented due to its large number of **melanocytes**. Its inner portion is the **choriocapillary layer**, which contains large numbers of small vessels and capillaries and serves a nutritive function for the retina.
- B. **Bruch's membrane.** A thin layer separating the retina from the choriocapillary layer; represents the combined basal laminae of the capillary endothelium and the pigment epithelium of the retina and an intervening network of elastic and collagen fibers

II. Ciliary body

- A. Anterior expansion of the choroid forming a ring that encircles the lens; appears triangular in cross-section
- B. Composed of a core of connective tissue and muscle; lined on its vitreal surface by two layers of columnar cells, an inner pigmented epithelium and an outer layer of non-pigmented cells. These two layers of columnar cells form the non-sensory retina and represent the attenuated anterior part of the sensory layer of the retina.
- C. **Ciliary processes**
 - 1. Ridge-like extensions from the ciliary body
 - 2. **Zonule fibers.** Emerge from between the processes and attach to the lens capsule
 - 3. The aqueous humor is produced by the epithelium of the ciliary processes.
- D. **Ciliary muscles.** Smooth muscle fibers that insert on the sclera and ciliary body; contraction of circularly arranged fibers releases tension on the **zonule fibers**, allowing the lens to assume a more spherical shape, thus providing for focusing on near objects (**accommodation**). Contraction of radially oriented smooth muscle fibers results in flattening of the lens, thus providing for focusing on far objects.

III. Iris

- A. Disc-shaped structure that arises from the anterior margin of the ciliary body; separates anterior and posterior chambers and partially covers the lens
- B. Composed of loose connective tissue that is covered on its anterior surface by an incomplete layer of pigment cells and fibroblasts. Its posterior surface is covered by a double layer of pigmented epithelial cells.
- C. **Pupil**. Central opening in the iris; its diameter is regulated by contraction of two sets of intrinsic smooth muscle in the iris.
 - 1. **Dilator pupillae muscle**. Derived from the more anterior, pigmented epithelial layer; consists of radially oriented cells whose contraction widens the aperture of the pupil
 - 2. **Constrictor pupillae muscle**. Consists of circularly oriented smooth muscle fibers surrounding the pupil; contraction of these fibers decreases the diameter of the pupil.

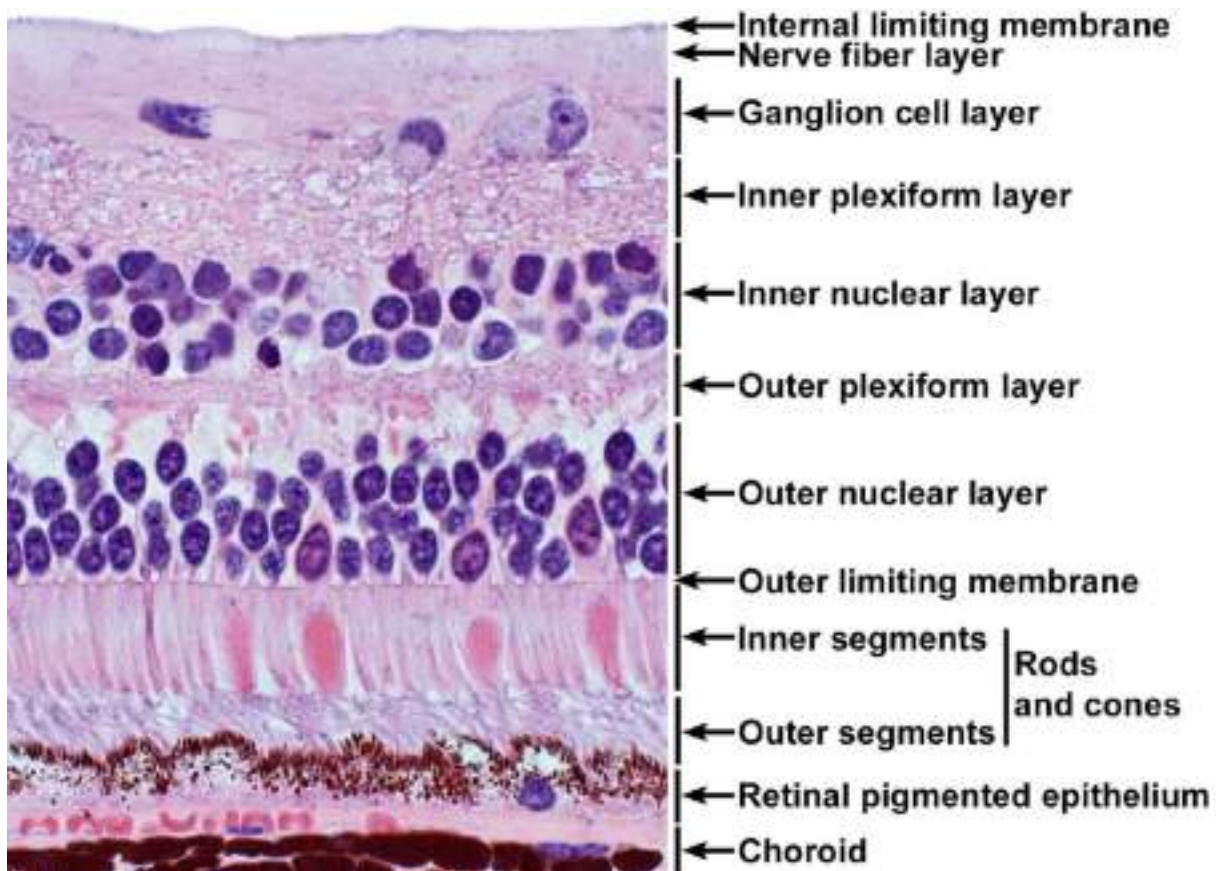


FIGURE 19.2. Layer of the retina

RETINA - INNER TUNIC (*images*)

- I. Inner-most of the three layers, forming a cup-shaped structure. The posterior portion is photosensitive and extends forward to the ciliary body, terminating as the **ora serrata**. The nonphotosensitive anterior portion is reduced in thickness and number of layers and forms the posterior lining of the ciliary body and the posterior lining of the iris.
- II. The photosensitive portion contains the photoreceptors, which transduce light into nervous impulses, and neurons, which perform the initial integration of the visual signals.

III. Overview of retinal cytoarchitecture

A. Basic plan of the **retina** consists of a three-cell pathway

1. **Rods** and **cones**. Photoreceptors that transduce light energy into neural activity and form the **photoreceptor layer**; their nuclei are located in the **outer nuclear layer**.
2. **Bipolar cells**. Synapse with rods and cones; nuclei are located in the **inner nuclear layer**.
3. **Ganglion cells**. Synapse with bipolar cells; cell bodies are located in the **ganglion cell layer**; axons from these cells form the **optic nerve fiber layer** as they pass toward the **optic disc**, head of the optic nerve.

B. Regions of synaptic integration

1. **Outer plexiform layer**. Location of synapses of rods and cones with bipolar cells
2. **Inner plexiform layer**. Location of synapses of bipolar cells and ganglion cells

IV. Layers of the retina—from outer to inner

- A. Composed of 10 layers. The naming of the layers is based on their position relative to the path of neural conduction (from outer to inner), not the path of light (from inner to outer).

B. **Pigment epithelium**

1. Cytoplasm contains numerous **melanin granules** to absorb light and reduce reflection
2. Columnar epithelial cells with apical microvilli whose bases are adherent to

Bruch's membrane

3. Cells form a cylindrical sheath that surrounds the apical tips of the photoreceptors; these sheaths aid in phagocytosis and digestion of membranous discs shed by the photoreceptors.

C. Photoreceptor layer

1. Composed of rods and cones
2. Rods are sensitive to low light intensity, outnumber cones and are located throughout the retina
3. Cones are less numerous than rods, sensitive to high intensity light and respond to color. Cones provide greater visual acuity and are concentrated in the **fovea centralis**.
4. **Outer segment**. Contains flattened, membranous discs that contain the visual pigments rhodopsin (rods) and iodopsins (cones).
5. **Inner segment**. Separated from the outer segment by a constriction, contains the major synthetic and energy-producing organelles.

D. **External limiting membrane**. Not a true membrane; formed by adherent junctions of Mueller cells, modified astrocytes, with the photoreceptors

E. **Outer nuclear layer**. Location of the nuclei of rods and cones

F. **Outer plexiform layer**. Region of synaptic contacts between photoreceptor axons and bipolar cell dendrites

G. **Inner nuclear layer**. Location of cell bodies of bipolar cells. Also present are additional neurons, amacrine and horizontal cells.

H. **Inner plexiform layer**. Location of synaptic contacts between bipolar cell axons and ganglion cell dendrites.

I. **Ganglion cell layer**. Location of cell bodies of ganglion cells

J. **Optic nerve fiber layer**. Layer formed by the unmyelinated axons of the ganglion cell axons that pass toward the **optic disc**, the head of the optic nerve, where they exit to form the **optic nerve** (cranial nerve II).

K. **Internal limiting membrane**. Formed by the basal portions of Mueller cells

V. **Fovea centralis**. Region of the retina providing greatest visual acuity, consists entirely of cones; other retinal layers are displaced centrifugally to allow for an unimpeded path for the light to reach the photoreceptors.

VI. **Optic disc** ("blind spot"). Region composed only of axons from retinal ganglion cells as they exit from the retina through the sclera to form the optic nerve

LENS *(images)*

I. Biconcave, transparent, and elastic

II. Suspended by radially oriented zonule fibers that extend from the ciliary body to insert into the lens capsule

III. Structure of the lens

A. **Lens capsule**. A thickened basal lamina, produced by the subcapsular epithelium, surrounds the entire lens.

B. **Subcapsular epithelium**. Simple cuboidal epithelium, present only on the anterior surface of the lens; apical surfaces of the cells are directed toward the center of the lens.

C. **Lens fibers**. Derived from cells of the subcapsular epithelium primarily in the equatorial region of the lens; lens fibers are highly differentiated cells that lose their organelles and become filled with crystallin proteins.

IV. Contraction of the circularly arranged ciliary muscle releases tension on the zonule fibers, allowing the lens to assume a more spherical shape which provides for focusing on near objects (accommodation). Contraction of the radially oriented ciliary muscles causes the lens to flatten for focusing on distant objects.

CHAPTER 18

FEMALE REPRODUCTIVE SYSTEM

GENERAL CONCEPTS

I. Components

- A. Paired ovaries
- B. Paired oviducts or Fallopian tubes
- C. Uterus
- D. Vagina

II. Functions

- A. Produces female germ cells, ova (singular, ovum)
- B. Produces female sex hormones, estrogen, and progesterone
- C. Receives sperm
- D. Site of fertilization
- E. Transports female germ cells, sperm, and conceptus
- F. Houses and nourishes the developing fetus during pregnancy
- G. Expels baby at parturition

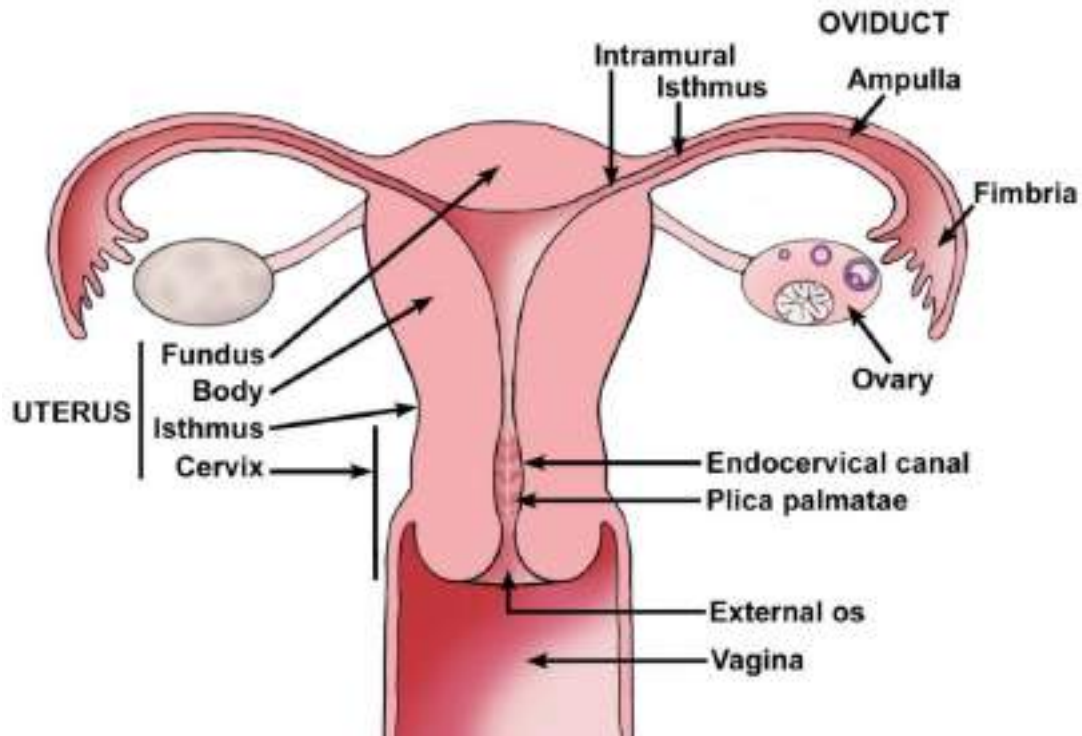


FIGURE 18.1. Schematic representation of the female reproductive system.

OVARY

GENERAL ORGANIZATION *(images)*

I. Flattened, ovoid, paired glands

- A. Exocrine function. Maturation and release of oocytes, developing female germ cells
- B. Endocrine function. Secretion of estrogen and progesterone

II. Subdivisions

A. Cortex

- 1. Covered with a serosa
 - a. **Germinal epithelium.** Simple cuboidal epithelium, unique mesothelium
 - b. **Tunica albuginea.** Underlying, dense connective tissue
- 2. Contents (exact contents depend on age of the ovary and the stage of the ovarian cycle)

- a. **Follicles.** Spheres of epithelial cells surrounding an oocyte. Multiple follicles progress through a series of stages until a single follicle ruptures to release the secondary oocyte at ovulation. Follicles secrete estrogen during the first half of the ovarian cycle.
 - b. **Corpus luteum.** Formed from the wall of the ovulating follicle beginning just before and following ovulation of the oocyte. The corpus luteum secretes progesterone and estrogen and is present during the second half of the ovarian cycle.
 - c. **Atretic follicles.** Degenerating follicles that are not ovulated
 - d. **Corpus albicans.** Degenerating corpus luteum
- B. **Medulla.** Inner region composed of connective tissue, blood vessels, nerves

OÖGENESIS

I. Oogenesis is a multistaged process by which a diploid somatic cell, an oogonium, in the fetal ovary becomes a haploid ovum in the adult after fertilization occurs.

II. Stages

- A. **Oogonia** in the fetal ovary divide mitotically to form diploid, primary oocytes that are located in primordial follicles. Unlike spermatogonia, oogonia reproduce themselves only during early gestation and, thus, no oogonia persist at birth.
- B. **Primary oocytes** immediately begin the first meiotic division, which arrests in prophase. Primordial follicles, each containing a primary oocyte, are the only follicles present from birth until puberty, when selected follicles go through a series of changes during each ovarian cycle, resulting in ovulation.
- C. Formation of a **secondary oocyte**: a primary oocyte in a Graafian follicle completes meiosis I during the hours preceding ovulation in most ovarian cycles, producing a secondary oocyte and a nonfunctional polar body. The secondary oocyte begins meiosis II but arrests in metaphase; this is the oocyte that is ovulated.
- D. An **ovum**, the mature, haploid germ cell, is formed along with a second polar body only if fertilization occurs.

COMPARISON OF OÖGENESIS WITH SPERMATOGENESIS (*image*)

I. Gametogenesis, the formation of haploid (1N) ova and sperm, is a multistaged

process that includes both mitosis and meiosis. While chromosomal events producing sperm (spermatogenesis) and ova (oogenesis) are similar, cytoplasmic stages, the timing of divisions and the number of gametes formed is different between the male and the female.

II. Stages

A. Mitosis

1. Beginning at puberty in males, diploid precursor spermatogonial cells divide to form diploid spermatogonia. Spermatogonia, in turn, divide by mitosis, renewing their own cell line, as well as producing cells that enter meiosis. In contrast in the female, before birth diploid precursor oogonial cells divide to form diploid oogonia. Oogonia divide mitotically, again before birth, forming only cells that enter meiosis, thus depleting their own cell line. Oogonia are not self-renewing and, at birth, no oogonia remain in the ovary.
2. In males, cytokinesis of spermatogonia and primary and secondary spermatocytes is incomplete, and thus, cells remain attached to each other. In females, cytokinesis is complete.

B. Meiosis. In the male, primary and secondary spermatocytes complete both meiotic stages, producing four functional, haploid spermatozoa of equal size from each diploid spermatogonia. In contrast, in the female, when primary and secondary oocytes complete meiosis, only a single, functional, haploid ovum is formed, along with two or three small, nonfunctional satellite cells (polar bodies).

C. Maturation

1. In males, after the completion of meiosis, spermatids undergo morphological changes, transforming themselves from spherical cells to tadpole-shaped spermatozoa, and breaking their cytoplasmic connections. No such maturation process occurs in the female.
2. In females, the completion of meiosis II, with the formation of an ovum, occurs only after fertilization. If fertilization does not occur, the secondary oocyte is destroyed or degenerates.
3. Fusion of the haploid male and female nuclei produces a diploid zygote, reconstituting the full complement of chromosomes.

III. Spermatogenesis occurs throughout the reproductive life of a male, producing millions of sperm during this span. Oogenesis lasts for only 30-40 years in the female and produces only a minimal number of ova, because completion of oogenesis is dependent on fertilization.

FOLLICLES (*images*)

I. Primordial follicle

- A. Contains a **primary oocyte**
- B. **Follicular cells** form a simple squamous epithelium around the oocyte.
- C. Is the only follicle present until puberty

II. Primary follicles

A. Early primary follicle (unilaminar)

- 1. Contains a primary oocyte
- 2. Follicular cells form a simple cuboidal or columnar epithelium around the oocyte.

B. Late primary follicle (multilaminar)

- 1. Contains a primary oocyte
- 2. Follicular cells form a stratified epithelium around the oocyte.
- 3. **Zona pellucida**, formed by both the oocyte and adjacent follicular cells, is a thick glycoprotein band surrounding the oocyte. Forms early in follicle development but easily visualized at this stage.
- 4. **Theca folliculi**, a layer located outside the basement membrane of the follicular cells, is formed by the differentiation of the surrounding multipotential stromal cells.

III. Secondary follicle (antral follicle)

- A. Contains a primary oocyte
- B. Follicle cells increase in size and number and produce a follicular liquid.
- C. Composition
 - 1. Antral spaces form as follicular liquid accumulates between follicular cells. Multiple antral spaces eventually coalesce to form a single **antrum**.
 - 2. The **granulosa layer (granulosa cells or stratum granulosum)** is formed by follicular cells surrounding the antrum. These cells convert androgens, produced in theca interna, into estrogen.

3. The **cumulus oophorus** is a hillock of granulosa cells in which the primary oocyte is embedded. The innermost layer of cumulus cells, immediately surrounding the oocyte, forms the **corona radiata**.

4. **Zona pellucida**

5. Theca folliculi develops into:

a. **Theca interna**, located immediately outside the basement membrane of the follicular cells, is composed of cells that secrete the steroid hormone androgen.

b. **Theca externa**, composed of multipotential connective tissue cells, resembles a layer of flattened fibroblasts and lies outside the theca interna. The theca externa serves as a reserve cell source for the theca interna.

D. Although a group of follicles begins follicular development, usually only a single secondary follicle progresses to the mature follicle stage in a single ovarian cycle.

E. Follicular growth and maturation are influenced by follicle stimulating hormone (FSH), secreted by the pituitary gland, and estrogen, aromatized by granulosa cells from androgen produced by the theca interna.

IV. **Mature (Graafian) follicle**. The follicle that will rupture, ovulating a secondary oocyte. Present only during the day preceding ovulation. Changes occurring during the time it is present include:

A. Increase in follicular liquid greatly increases antral and follicle size; follicle will reach a diameter of about 2.0 cm.

B. Granulosa and theca interna cells begin formation of **corpus luteum**.

C. Enlarged follicle bulges from the ovarian surface, thinning the ovarian tissue covering the follicle and forming a **stigma**.

D. Oocyte and surrounding cumulus oophorus detach from the granulosa layer and lie free in the antral space.

E. Meiosis I is completed with the formation of a **secondary oocyte** and **first polar body**. Meiosis II arrests in metaphase.

F. **Ovulation**. Day 14 of ovarian cycle

1. The Graafian follicle ruptures at the stigma, releasing the haploid secondary oocyte, polar body, cumulus oophorus, follicular liquid, and blood.

2. Oocyte and the surrounding cumulus are transported into the oviduct to the ampulla to await fertilization. Fertilization triggers the completion of meiosis II and the formation of an ovum.
3. The follicle wall and theca interna continue their conversion into a corpus luteum.
4. Ovulation is stimulated by a surge of luteinizing hormone (LH) from the pituitary gland.

V. Atretic follicles

- A. The process of oocyte/follicular atresia begins before birth and continues throughout the life of a woman. Of the 2 million primordial follicles and their primary oocytes present at birth, only about 450,000 oocytes/follicles remain at puberty and only about 450 of those will be ovulated. The remaining follicles degenerate, thereby producing more atretic than "normal" follicles.
- B. Atresia can occur at any stage of follicular development and will begin in different layers of the follicle or oocyte depending on the follicle's stage of development. Therefore, many varieties of atretic follicles can be seen.

CORPUS LUTEUM (*images*)

- I. The **corpus luteum** is a large, spherical, infolded body functional during the second half of the ovarian cycle.
- II. Formation and life span
 - A. Initially, bleeding from capillaries in the theca interna into the follicular lumen leads to formation of the **corpus hemorrhagicum** with a central clot.
 - B. The corpus luteum is formed by differentiation of the granulosa and theca interna cells in the Graafian follicle before and after ovulation.
 - C. Its formation is stimulated by luteinizing hormone (LH) secreted by the pituitary gland
 - D. The life span of the corpus luteum is finite, lasting about 12 days during the average cycle, during days 14-26.
 - E. Composed of:
 1. **Granulosa lutein cells.** Form from cells in the granulosa layer; typical steroid-secreting cells; major component of the corpus luteum

2. **Theca lutein cells.** Form from theca interna cells; typical steroid-secreting cells but smaller than granulosa lutein cells; remain at the outer boundary of the corpus luteum surrounding the granulosa lutein cells and extending into the infoldings of the corpus luteum

F. Secretes progesterone and estrogen

G. If pregnancy occurs, placental hormones maintain the corpus luteum, and it is known as the corpus luteum of pregnancy. This structure is functional for the first trimester of pregnancy.

III. **Corpus albicans.** Degenerating stage.

A. Results from the degeneration of the corpus luteum

B. Consists of a white mass of scar tissue composed of much collagenous material and scattered fibroblasts

CYCLICITY OF OVARY-BASED ON AN AVERAGE 28-DAY CYCLE

- I. **Follicular phase** (days 1-13). Follicles are differentiating and secreting estrogen. Follicles are developing while menstruation (days 1-4) is occurring.
- II. **Ovulation** (day 14). Graafian follicle ruptures, releasing secondary oocyte.
- III. **Luteal phase** (days 15-28). Corpus luteum is the functional ovarian structure, secreting progesterone and estrogen. Hormone secretion diminishes after day 26.

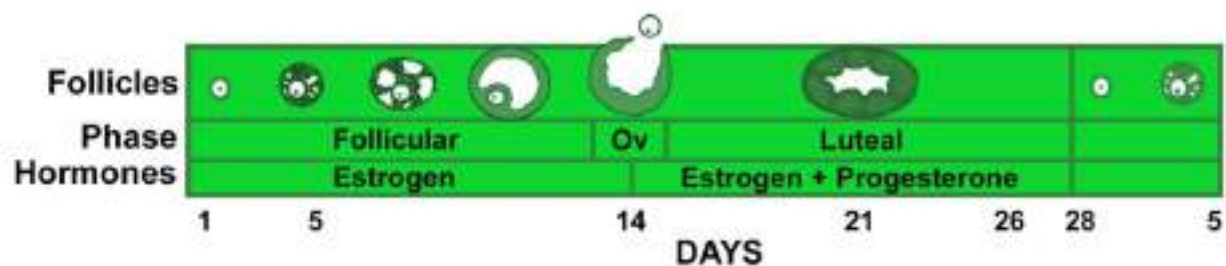


FIGURE 18.2. The ovarian cycle

OVIDUCT *(images)*

I. Subdivisions

A. Paired, 12-cm-long tubes that have four subdivisions.

1. **Infundibulum.** Funnel-shaped, free end with finger-like fimbria embracing the ovary

2. **Ampulla**. Thin walled, lateral two-thirds; fertilization occurs here near its junction with the isthmus
3. **Isthmus**. Thicker walled, medial one-third
4. **Intramural (interstitial)**. Within uterine wall; lumen is continuous with uterine lumen.

II. Structure

A. **Mucosa**

1. Shows gradations from infundibulum to intramural subdivisions
2. Exhibits complex mucosal folds that are most elaborate in the infundibulum and are sparse in the intramural subdivision
3. Epithelium. **Simple columnar** composed of **ciliated cells**, that are most abundant in the infundibulum, and **secretory cells**, that are most abundant in the intramural portion
4. Muscularis mucosae is lacking.

B. **Submucosa** is continuous with lamina propria, forming a continuous connective tissue layer.

C. **Muscularis externa** has poorly defined inner circular and outer longitudinal smooth muscle layers, which are thinnest in the infundibulum and thickest in the intramural portion.

D. **Serosa**. Covers the outer surface except in the intramural portion

UTERUS

GROSS ANATOMY

I. A single, pear-shaped, and pear-sized organ

II. Subdivisions

A. **Fundus**. Domed portion above entrance of oviducts

B. **Corpus or body**. Major portion of the uterus

C. **Isthmus**. Constricted portion at junction of cervix and body

D. **Cervix**. Located above and within the vagina, defining supravaginal and

vaginal portions

HISTOLOGICAL ORGANIZATION OF THE BODY AND FUNDUS (*images*)

- I. **Perimetrium**. Outermost layer, a serosa, covers the upper and posterior regions only; an adventitia surrounds the remaining portions that lie adjacent to the urinary bladder.
- II. **Myometrium**. A thick, well-vascularized band of smooth muscle that is arranged in ill-defined layers. The myometrium forms the major portion of the uterus and is equivalent to a muscularis externa.
- III. **Endometrium**. Mucosa.

A. Components

1. Epithelium is **simple columnar**, some with cilia.
2. **Lamina propria (endometrial stroma)** contains multipotential (stromal) cells and abundant ground substance.
3. Simple tubular glands

B. Zonation

1. **Functional zone (stratum functionalis)**. Luminal two-thirds that is sloughed during menstruation
2. **Basal zone (stratum basalis)**. Firmly attached to the myometrium and retained during menstruation. Cell growth from this zone restores functional zone following menstruation.

ARTERIAL SUPPLY TO ENDOMETRIUM

- I. **Basal (straight) arteries**. Remain in and supply basal zone.
- II. **Spiral arteries**. Located at the junction of the basal and functional zones, spiral arteries extend into and supply the functional zone and a capillary plexus beneath the surface epithelium of the uterus. Early in the menstrual cycle, spiral arteries are nearly straight, but they become highly coiled later in the cycle.
- III. A capillary plexus lies under the surface epithelium.

ENDOMETRIAL CHANGES IN THE BODY AND FUNDUS DURING MENSTRUAL CYCLE

- I. Coordinated with ovarian cycle and controlled by its hormones; approximately 28 days long (*image*)
- II. Phases of uterine menstrual cycle (*images*)
 - A. **Menstrual phase**. Days 1-5, the clinical beginning of the cycle; however, this phase actually marks the end of the cycle. At the end of menstruation the functional zone has been sloughed and only the basal zone remains.
 - B. **Proliferative phase** (estrogenic). Days 6-14
 1. Ovarian follicles are growing and secreting estrogen.
 2. The functional zone proliferates and regenerates from the basal zone.
 - a. Proliferation of epithelial and stromal cells thickens the endometrium.
 - b. Glands are initially straight but become slightly wavy toward the end of the phase.
 - c. Spiral arteries are initially straight, but coil as the endometrium develops and thickens.
 - C. **Secretory phase** (luteal). Days 14-26
 1. Corpus luteum is present and functional.
 2. Uterine glands are actively secreting glycogens and glycoproteins by day 20 or 21 when implantation could occur.
 3. Endometrial changes leading up to day of implantation
 - a. Glands enlarge and become tortuous, coiled, and secretory.
 - b. Spiral arteries lengthen, are highly coiled, and readily visible.
 - c. Stromal cells become **(pre)decidual cells** (about day 24).
 - i. Large, pale cells, with glycogen and lipid, located under the surface epithelium and around spiral arteries
 - ii. If pregnancy occurs, these cells are called **decidual cells** and form the decidua, the maternal placenta.

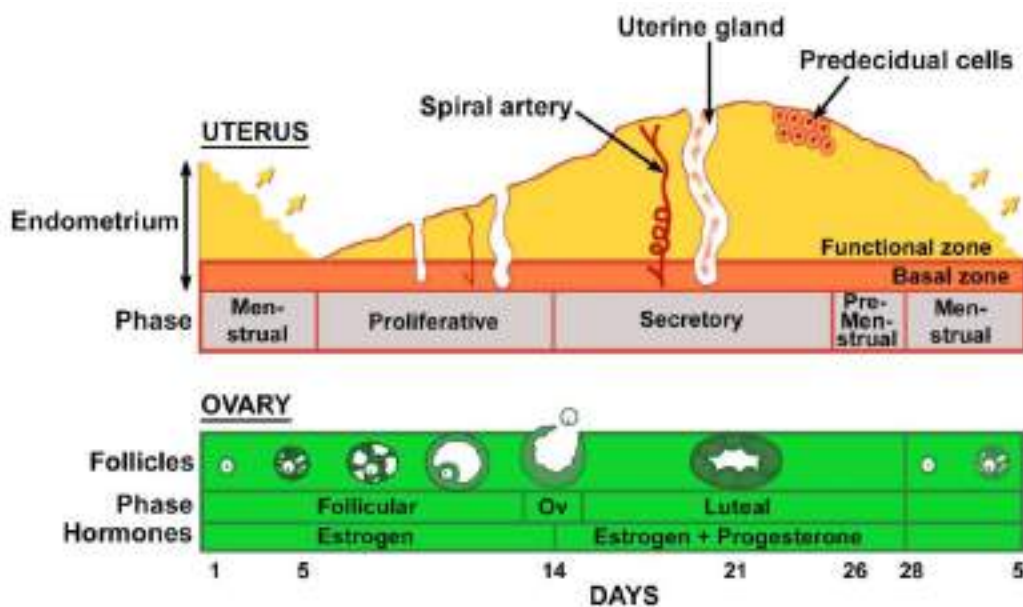
- iii. If pregnancy does not occur, these same cells are called predecidual cells and they are sloughed with menses.

D. Premenstrual phase. (ischemic portion of secretory phase) Days 26-28

1. Estrogen and progesterone secretion from the ovarian corpus luteum decreases.
2. Compression of the endometrium, resulting from lack of hormones from the corpus luteum, causes:
 - a. Constriction of the spiral arteries, which results in ischemia in the overlying tissue in the functional zone.
 - b. The ischemia causes the endometrium to become necrotic and disrupted
 - c. Spiral arteries reopen and blood flows into the ischemic tissue, resulting in bleeding from the spiral arteries into the stroma.
 - d. Cycles of compression and reopening of the arteries leads to degeneration of the functional zone and menstruation.

E. **Menstrual phase.** Days 1-5

1. The functional zone becomes necrotic and is sloughed as menses.
2. Menstrual flow contains blood, tissue fragments, and uterine fluids.
3. Only the basal zone remains, from which the functional zone will be



regenerated.

FIGURE 18.3. Comparison of menstrual and ovarian cycles

CERVIX (*images*)

- I. The cervix is the most inferior portion of the uterus, beginning above and extending into the vagina.

II. Endocervix

- A. Surrounds the **endocervical canal**

A. Structure

1. Mucosa

- a. Simple columnar epithelium with cilia and many mucus-secreting cells
- b. Lamina propria is filled with epithelial folds, the **plica palmatae**, that are lined with mucus-secreting cells.
- c. **Nabothian cysts** occur when a fold becomes occluded.

2. Remainder of cervix consists of connective tissue with some smooth muscle.

B. Cyclic changes and functions of the cervix

1. Mucosa is not sloughed during menstruation. Spiral arteries are absent.
2. Cyclic changes in the cervical mucus
 - a. At mid-cycle, secretions are abundant and the molecules are linearly arranged, facilitating the movement of sperm through the cervix and/or into the plica palmatae for storage. The alkalinity of the cervical mucus neutralizes the low vaginal pH, providing a more favorable environment for spermatozoa.
 - b. At other times during the cycle, cervical mucus is more viscous, making sperm penetration difficult.

III. Ectocervix

- A. Portion of the cervix that protrudes into the vagina

- B. Covered by **moist stratified squamous epithelium**. The junction of this epithelium with the simple columnar epithelium of the endocervical canal is abrupt and is called the squamo-columnar junction

C. **External os**. Opening of the endocervical canal into the vagina.

VAGINA (*images*)

I. Structure

A. **Mucosa**

1. Epithelium. **Stratified squamous nonkeratinized**, cells accumulate glycogen; when shed, it is metabolized by vaginal bacteria to lactic to maintain acidic environment.
2. Lamina propria. No glands present, rich with numerous blood vessels and elastic fibers.
3. Muscularis mucosae is lacking.
4. **Rugae** (folds) allow for expansion.

B. **Submucosa** is continuous with the lamina propria, forming a single connective tissue layer.

C. **Muscle layers**

1. Inner circular and outer longitudinal smooth muscle layers intertwine.
2. Skeletal muscle surrounds the vaginal orifice.

D. **Adventitia** of loose connective tissue

II. Cyclic Changes

- A. The epithelium synthesizes and accumulates glycogen, becoming thick and proliferative by midcycle.
- B. Bacterial breakdown of the glycogen produces lactic acid, creating an acidic environment in the vagina which is protective against bacterial infection.

PLACENTA

GENERAL CONSIDERATIONS (*images*)

- I. An apposition or fusion of membranes of the fetus (chorion) with maternal uterine mucosal tissue (the decidua) to produce hormones and to exchange gases and nutrients

II. Function

- A. Provides exchange of respiratory gases between maternal and fetal circulations
- B. Provides nutrients for and removes wastes from the conceptus
- C. Secretes hormones
- D. Transports some macromolecular materials (e.g., viruses, IgG, alcohol)

BLASTOCYST

- I. A **blastocyst** is the stage of the embryo that implants into the uterus about day 20 or 21 of the menstrual cycle.

II. Composition

- A. **Trophoblast cells** form the peripheral rim of the fluid-filled blastocyst cavity and will develop into the fetal portion of the placenta.
- B. **Inner cell mass**, an eccentrically located cluster of cells inside the trophoblast at one pole of the blastocyst, develops into the embryo.

CHORION, THE FETAL PLACENTA

- I. The **chorion**, derived from trophoblast, is composed of extraembryonic connective tissue and two cell layers derived from the trophoblast, called the cytotrophoblast and the syncytiotrophoblast.

II. Formation of the fetal placenta

- A. Forms within the 23 days following ovulation
- B. **Trophoblast** erodes into the maternal endometrium at implantation and immediately differentiates into:
 - 1. **Cytotrophoblast**. Inner (toward embryo) single layer that gives rise to the syncytiotrophoblast
 - 2. **Syncytiotrophoblast**. Multinucleated, outer syncytium formed from the cytotrophoblast; aggressively invades the uterine endometrium
- C. **Lacunae**, separated by columns of syncytiotrophoblast, develop in the syncytiotrophoblast and coalesce, becoming filled with maternal blood from the spiral arteries. After the formation of villi, lacunae are called

intervillous spaces.

D. Tertiary (definitive) chorionic villi

1. The final in a series of villi that protrude from the syncytiotrophoblast columns into the lacunae, increasing the surface area of the placenta that is exposed to maternal blood.
2. Formed by invasion of syncytiotrophoblast columns by cytotrophoblastic cells and then by fetal connective tissue. Finally, fetal blood vessels invade into and form within the fetal connective tissue.
3. Composition. From internal to external
 - a. Core of **fetal connective tissue** with fetal blood vessels
 - b. **Cytotrophoblast**
 - i. Large, discrete cells with large, euchromatic nuclei form a single layer around the connective tissue core.
 - ii. Changes during pregnancy
 - (a) Early pregnancy. Cytotrophoblast forms a continuous layer beneath the syncytiotrophoblast.
 - (a) Late pregnancy. Cytotrophoblast layer thins and is even lacking in some areas, thus decreasing the thickness of the barrier through which nutrients/wastes must pass.
 - c. **Syncytiotrophoblast**
 - i. Covers outer surface of the villus, facing the intervillous spaces filled with maternal blood.
 - ii. Composed of a single cell (syncytium), possessing multiple nuclei; formed by fusion of cytotrophoblastic cells
 - iii. Possesses microvilli and abundant organelles associated with both protein and steroid hormone production
 - iv. Functions
 - (a) Forms part of the interhemal barrier (barrier between fetal and maternal blood vessels)
 - (a) Secretes a variety of hormones, such as human chorionic gonadotrophin (HCG), human placental lactogen (HPL,

somatomammotropin), human placental thyrotropin (HPT), and estrogen and progesterone

4. Alterations during pregnancy

- a. Early pregnancy. Villi are thick, with a few, thick branches.
- b. Late pregnancy. Villi are much more slender, with profuse branching, thus increasing surface area.

E. **Trophoblastic shell**

1. Outer rind of the fetal placenta abutting the maternal deciduas
2. Composed of cytotrophoblast positioned between the syncytiotrophoblast and the external maternal decidua.
3. Formed by cytotrophoblast cells growing through and then spreading out beneath the syncytiotrophoblast columns

THE DECIDUA, THE MATERNAL PLACENTA

I. The **decidua** is formed from endometrial stromal cells that differentiate into decidual cells beginning about day 24 of the menstrual cycle (about 3 days post implantation).

II. Partitioned into three subdivisions, named according to the position of each in relation to the developing conceptus

- A. **Decidua basalis**. Underlies the implanted conceptus (beneath trophoblastic shell), forming the maternal portion of the functional placenta
- B. **Decidua capsularis**. Covers the luminal surface of the conceptus, separating it from the uterine lumen; will eventually fuse with decidua parietalis of the opposite side of the uterus, obliterating the uterine lumen
- C. **Decidua parietalis** lines the remainder of the uterus.

III. Maternal cotyledons

- A. **Maternal cotyledons** form a "lobe" of the placenta, easily identifiable on the maternal surface of the placenta as domed-shaped protrusions from the placenta.
- B. Up to 35 lobes are present.
- C. Malformations (discrepancies) of these cotyledons, when examined at

delivery, can indicate fetal abnormalities.

PLACENTAL BLOOD FLOW

I. Fetal

- A. **Umbilical arteries** are two in number and travel from the fetus through the umbilical cord to the placenta, carrying blood that is high in carbon dioxide and low in nutrient content. Umbilical arteries branch into capillaries within the tertiary villi.
- B. Fetal capillaries are located in the tertiary chorionic villi (definitive villi).
- C. Fetal veins from the capillaries anastomose to form the single **umbilical vein** that returns oxygen-rich, nutrient-rich blood to the fetus.

II. Maternal

- A. **Spiral arteries** penetrate trophoblastic shell and spurt blood into intervillous spaces, bathing villi.
- B. Branches of uterine veins carry blood away from the intervillous spaces.

III. Placental interhemal membrane

- A. The **placental interhemal membrane** separates maternal (in the intervillous spaces) and fetal blood (in capillaries within tertiary villi) supplies, which normally do not mix.
- B. Beginning in the fetal capillary, this barrier consists of:
 - 1. Capillary endothelial cell (of villus) and its basement membrane
 - 2. Fetal connective tissue of villus (usually lacking in late pregnancy)
 - 3. Cytotrophoblast (may be lacking in late pregnancy) and its basement membrane
 - 4. Syncytiotrophoblast

BREAST

I. Organization of the breast *(images)*

- A. Each breast is a collection of 15-20 separate **mammary glands**, which are modified sweat glands.

- B. Each gland or lobe of the breast is further subdivided into lobules.
- C. Each gland in its functional state is classified as a **compound tubulo-alveolar gland**
- D. Each gland has its own **lactiferous duct**, which empties at the nipple.

II. Organization of mammary glands

A. **Stroma**. Connective tissue framework of the breast

1. **Interlobular connective tissue**, composed of dense, irregular connective tissue with abundant adipose tissue, separates lobules. This tissue is sparsely cellular, containing mostly fibroblasts and adipocytes.
2. **Intralobular connective tissue** is composed of loose connective tissue and lies within lobules and surrounds ducts and alveoli (parenchyma) of the gland. This connective tissue is highly cellular, containing many plasma cells, lymphocytes, and macrophages, as well as fibroblasts

B. **Parenchyma**. Functional components of the breast

1. **Ducts**. Form the majority of an inactive gland and are always present. Consist of an epithelial lining, which can be secretory, and **myoepithelial cells**. Development of the ducts is regulated by estrogen.
2. **Alveoli**. Derived from outgrowths of the ducts and are only present during later stages of pregnancy and lactation. Alveoli consist of alveolar cells and myoepithelial cells. **Alveolar cells** are the major cells responsible for the synthesis and secretion of milk, and their development is regulated by progesterone.

III. Functional stages of the breast

A. **Prepuberty**. Composed entirely of the duct system; no secretory alveolar units are present. At this stage, the breast in the male and female are similar

B. **Puberty (female)**

1. Enlargement of the breast is due primarily to the accumulation of adipose tissue.
2. Rising estrogen levels at this time stimulates the growth and branching of the duct system.
3. No secretory alveoli are present.

C. **Inactive (non-pregnant)**. Minor alveolar development with a slight amount of secretory activity and fluid accumulation may occur during mid to late phases of the menstrual cycle.

D. **Pregnancy**

1. Early to mid-pregnancy

- a. Prominent increase in duct branching induced by estrogen; development of alveoli as evaginations from those ducts is induced by progesterone.
- b. Interlobular connective tissue becomes more cellular with increased numbers of plasma cells, polymorphonuclear leukocytes, and lymphocytes.

2. Late pregnancy

- a. Significant breast enlargement due to hypertrophy of alveolar cells
- b. Lumens of ducts and alveoli widen as secretory products accumulate

E. **Lactation**

1. Alveolar cells secrete by both merocrine and apocrine modes of secretion.

- a. **Apocrine**. Lipid secretion; lipid droplets coalesce in the apical cytoplasm and are released along with some membrane and surrounding cytoplasm
- b. **Merocrine**. Protein secretion; protein, packaged in membrane-bound, secretory vesicles in the Golgi, are released by exocytosis.

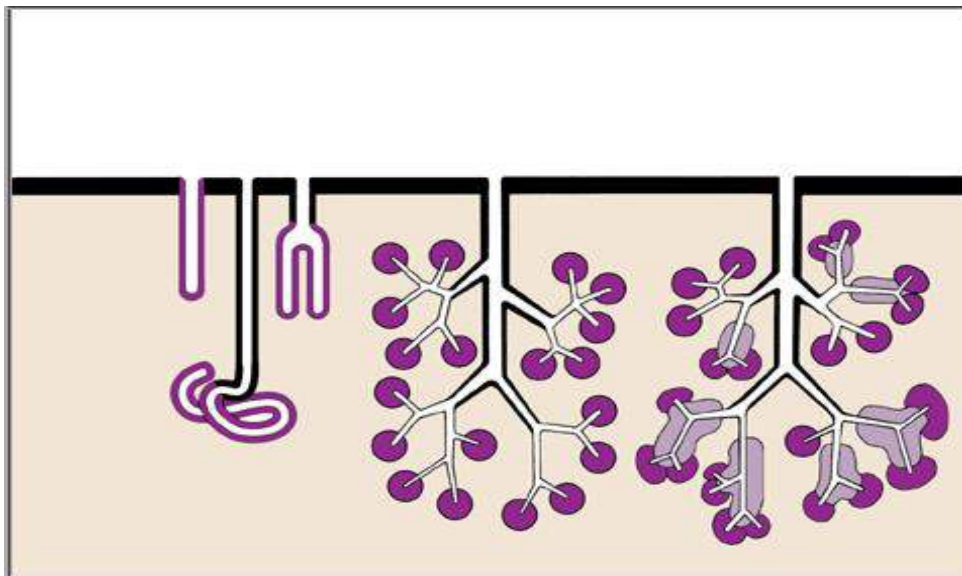
2. Two types of secretory products

- a. **Colostrum**. Secreted for the first few days after birth; protein rich with a high antibody content.
- b. **Milk**. Secretory product released after the colostrum phase; milk has a high lipid content compared with colostrum and also contains protein, carbohydrates, and antibodies.

3. Secretion and ejection of milk is maintained by a **neurohormonal reflex arc**. Infant suckling stimulates sensory nerves, whose activity results in prolactin release from the pituitary gland to maintain milk synthesis and secretion. Similarly, suckling causes oxytocin release, which stimulates the ejection of milk due to contraction of myoepithelial cells.

4. Cessation of suckling results in decreased secretory activity, degeneration

of alveoli, and the end of lactation.

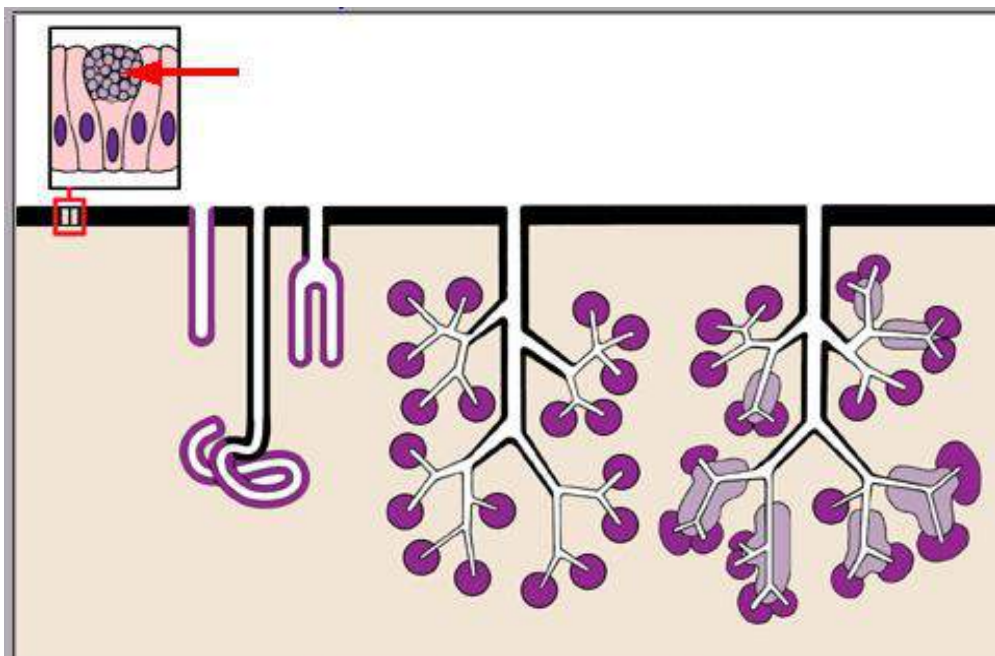


1 of 6

Exocrine glands -- Exocrine secretory cells remain either within or attached to the epithelial surface from which they originate. Secretory cells release their product(s) onto that surface epithelium directly or indirectly via ducts. Units of secretory cells are organized into tubules (test-tube shaped) or grapefruit-shaped acini (sing. acinus). Acini may also be called alveoli (sing. alveolus).

click to identify:

- Unicellular gland >
- Sheet gland >
- Simple glands >
- Tubular >
- Coiled tubular >
- Branched >
- tubular
- Compound >
- glands
- Acinar >
- Tubuloacinar >

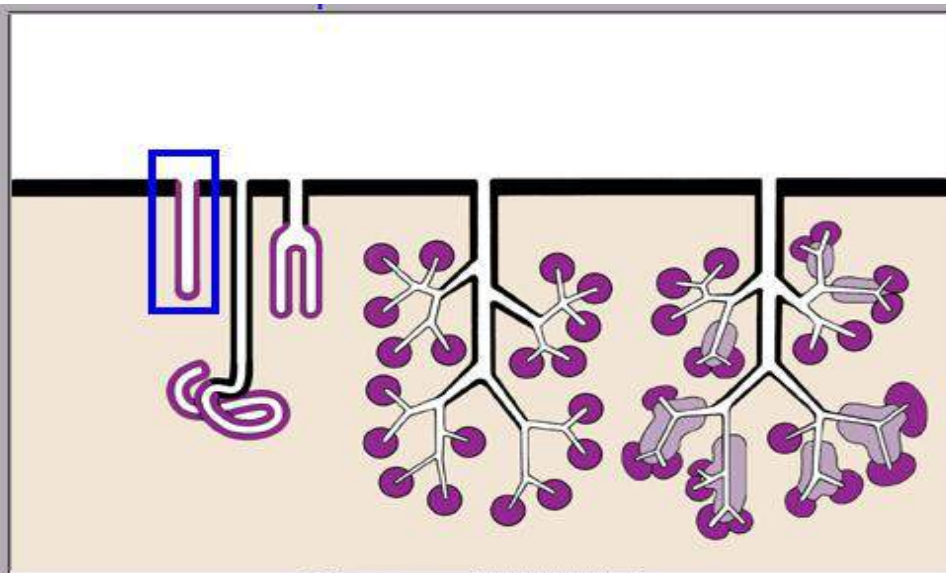


1 of 6

A unicellular gland, the simplest exocrine gland, is a single secretory cell that remains in the epithelium where it forms. Although other examples exist, the most common unicellular exocrine gland is the goblet cell, demonstrated here. Goblet cells secrete mucus to lubricate the surface epithelium.

click to identify

- > Unicellular gland
- Sheet gland >
- Simple glands >
- Tubular >
- Coiled tubular >
- Branched >
- tubular
- Compound >
- glands
- Acinar >
- Tubuloacinar >

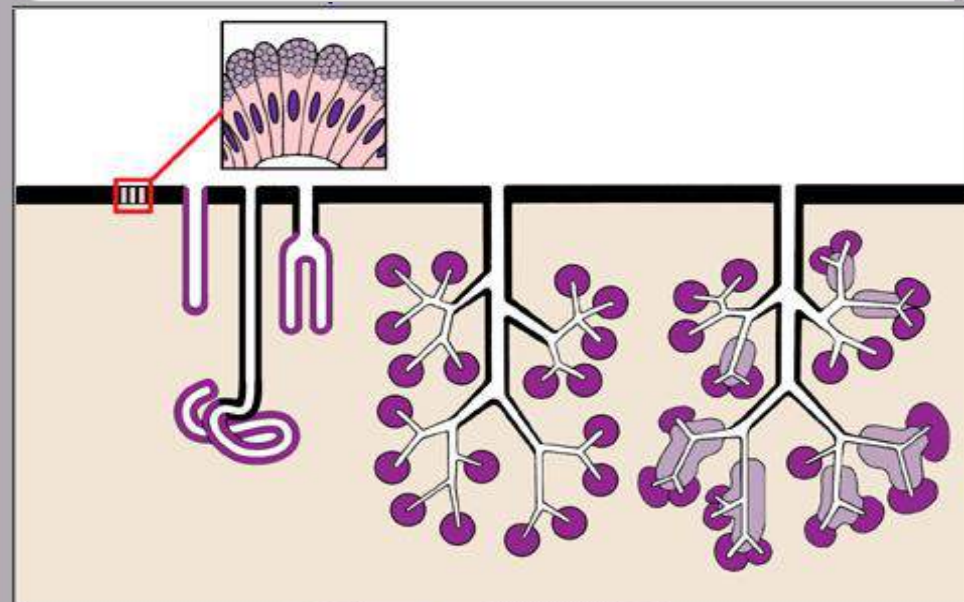


1 of 6

The least complex of the simple tubular glands consists of a secretory unit shaped like a test tube that connects directly to the surface epithelium without an intervening duct. Mucus is a common product of tubular secretory units, so cells of tubular glands frequently appear pale and frothy. Intestinal glands in small and large intestine are simple tubular glands.

click to identify:

- Unicellular gland >
- Sheet gland >
- Simple glands >
- > Tubular >
- Coiled tubular >
- Branched >
- tubular
- Compound >
- glands
- Acinar >
- Tubuloacinar >

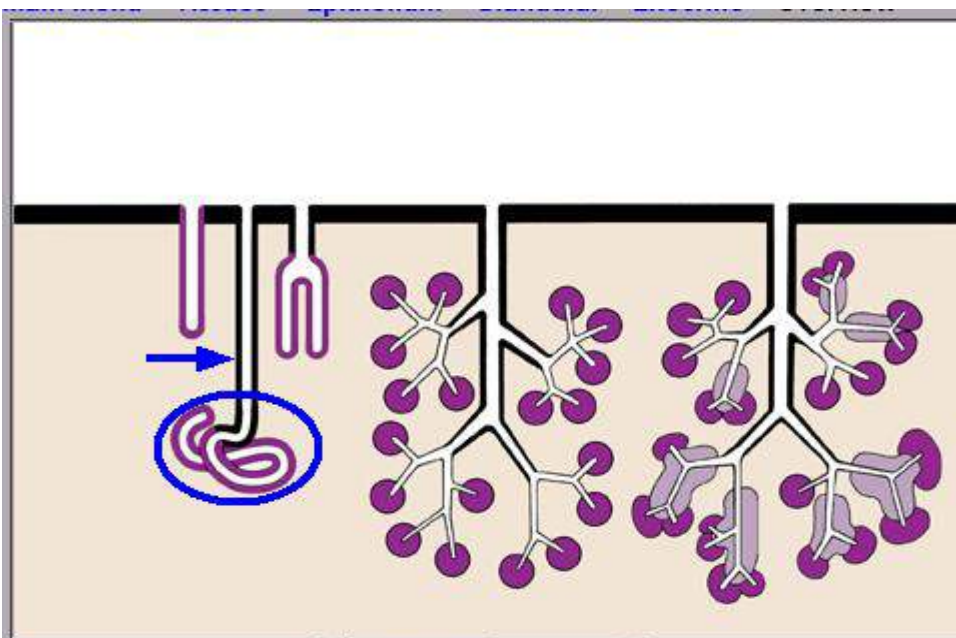


1 of 6

A sheet gland is a little more complex than a unicellular gland in that all cells of a surface epithelium differentiate into secretory cells, forming a secretory sheet. The only sheet gland in the human lines the lumen of the stomach, where the mucus it secretes protects the stomach from gastric acids.

click to identify:

- Unicellular gland >
- > Sheet gland >
- Simple glands >
- Tubular >
- Coiled tubular >
- Branched >
- tubular
- Compound >
- glands
- Acinar >
- Tubuloacinar >

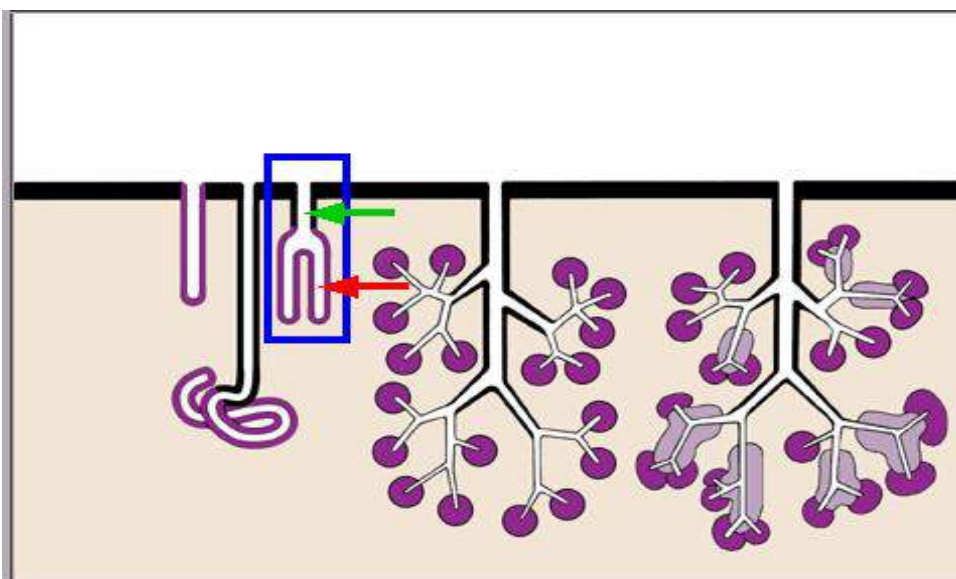


1 of 6

A simple coiled tubular gland has a tubular secretory unit (blue oval) that coils on itself like a ball of yarn; secretory product is conveyed to the surface epithelium by a single duct (blue arrow). The most common simple coiled tubular gland in the human does not secrete mucus, but is specialized to produce sweat.

click to identify:

- Unicellular gland >
- Sheet gland >
- Simple glands >
 - Tubular >
 - > Coiled tubular >
 - Branched >
 - tubular
- Compound >
 - glands
- Acinar >
- Tubuloacinar >

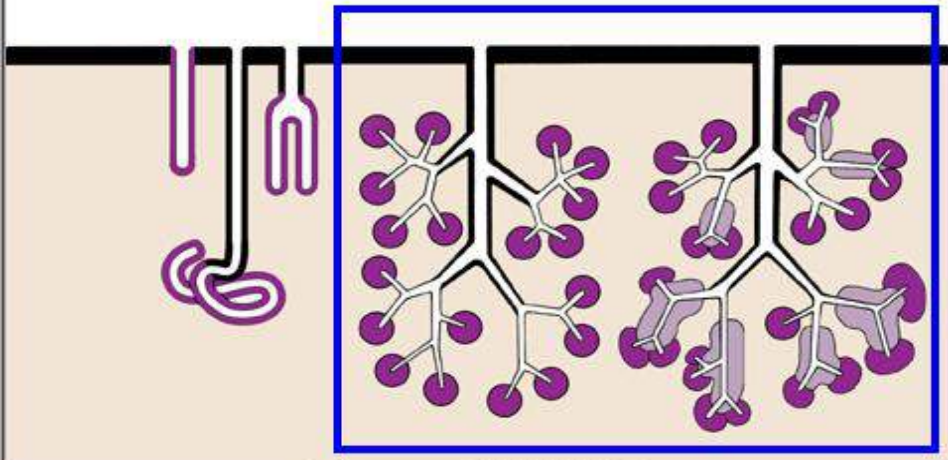


1 of 6

In simple branched tubular glands, secretory tubules (red arrow) branch; if a duct (green arrow) is present, it does not branch. (If the duct branched, this would be a compound gland.) Gastric glands are simple branched tubular glands.

click to identify:

- Unicellular gland >
- Sheet gland >
- Simple glands >
 - Tubular >
 - Coiled tubular >
 - > Branched >
 - tubular
- Compound >
 - glands
- Acinar >
- Tubuloacinar >

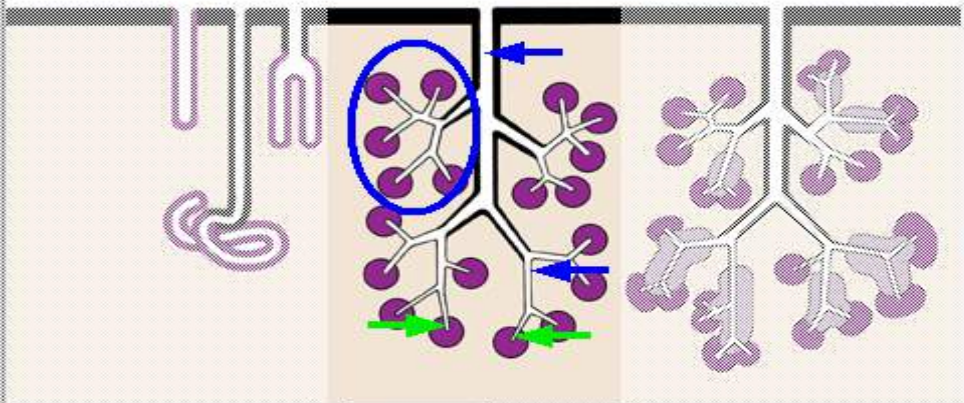


click to identify:

- Unicellular gland >
- Sheet gland >
- Simple glands >
 - Tubular >
 - Coiled tubular >
 - Branched >
 - tubular
- > Compound >
 - glands
 - Acinar >
 - Tubuloacinar >

1 of 6

Compound glands are large, often macroscopic structures with branching ducts. Secretory units may be entirely acinar, entirely tubular or a combination of acinar and tubular. Compound glands can be subdivided into smaller subunits called lobules, each consisting of a duct and its attached secretory units.

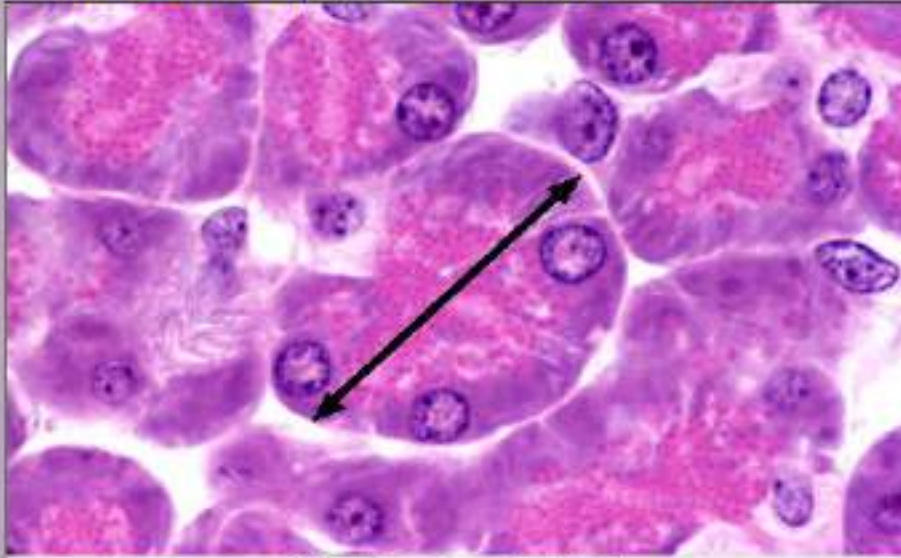


click to identify:

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- Sheet gland >
- Simple glands >
 - Tubular >
 - Coiled tubular >
 - Branched >
 - tubular
- > Compound >
 - glands
 - Acinar >
 - Tubuloacinar >

1 of 6

Compound acinar glands have branching ducts (blue arrows), lobules (oval) and acinar (alveolar) secretory units (magenta spheres). An acinus usually secretes a serous product and resembles a grapefruit; when sectioned, secretory cells resemble grapefruit wedges. Each acinus has a small central lumen (green arrows), sufficient to transport its watery product.

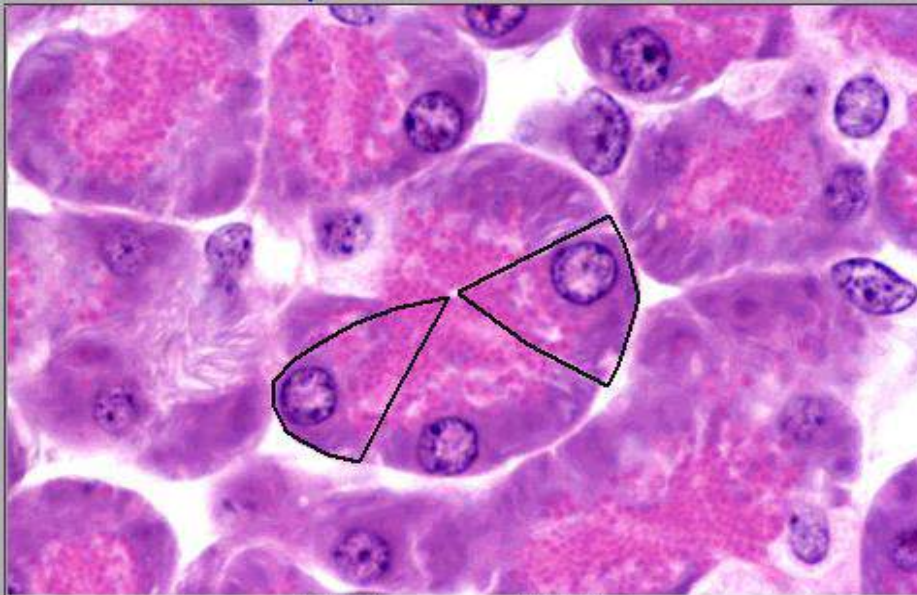


3 of 6

Polarity -- Polarity is the cell feature exhibited when organelles are not homogenously distributed in the cytoplasm. Polarity is a characteristic of exocrine cells. These pyramidal, acinar cells synthesize enzymes in the RER at the base of the cell. The product is stored in secretory granules in the cell apex adjacent to the lumen, into which it will be released. Pancreas 1000x

click to identify:

- > Acinus
- Gland cells
- RER
- Secretory granules
- Lumen

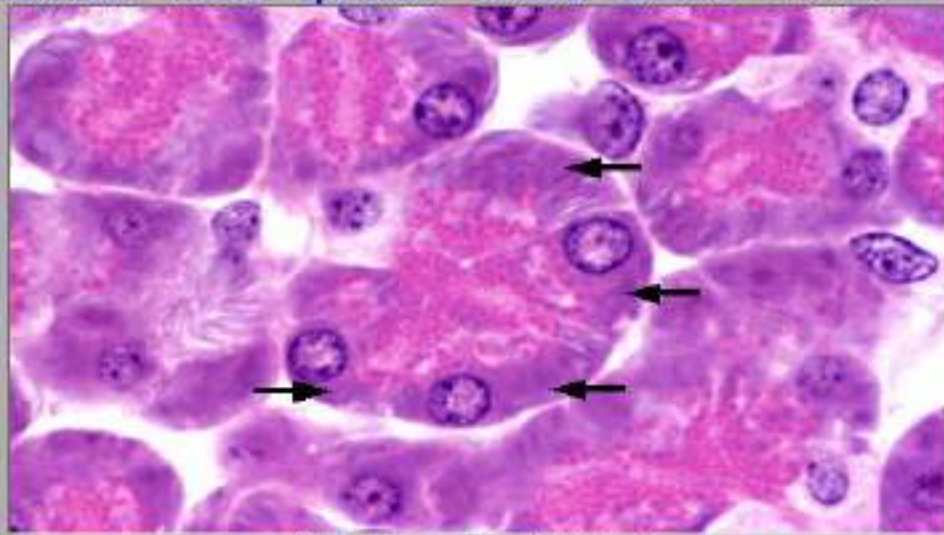


3 of 6

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- Acinus
- > Gland cells
- RER
- Secretory granules
- Lumen

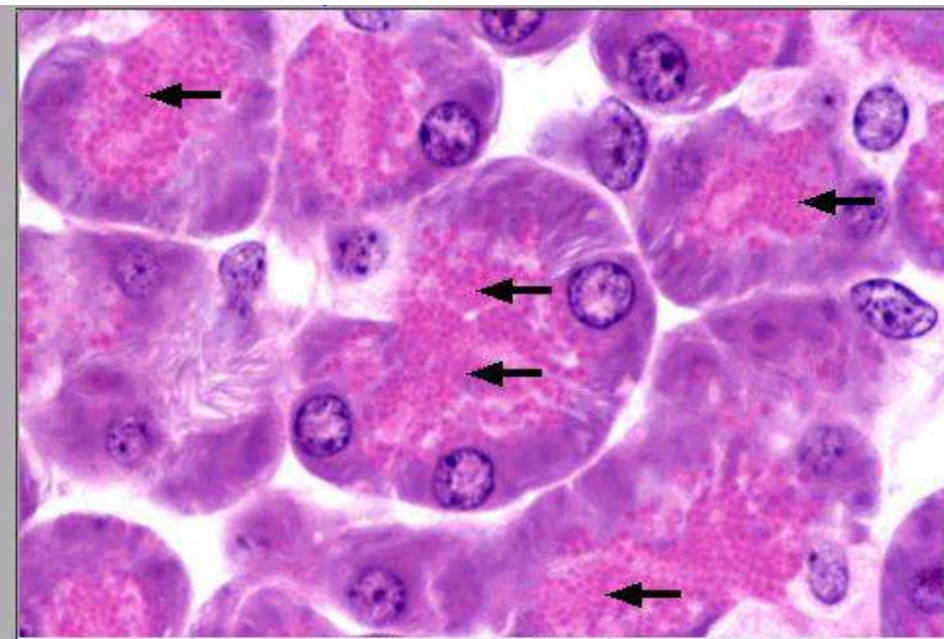


3 of 6

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click to identify:

- Acinus
- Gland cells
- > RER
- Secretory granules
- Lumen

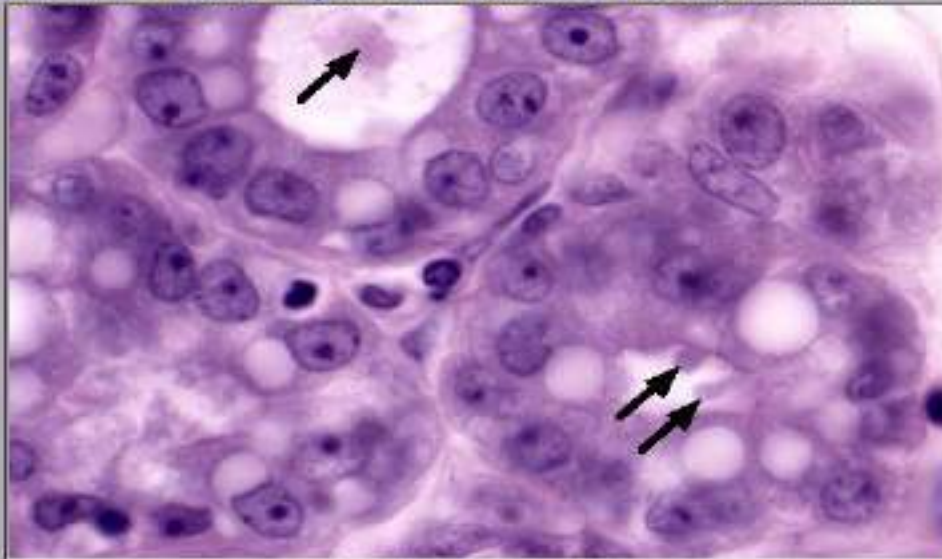


3 of 6

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- Acinus
- Gland cells
- RER
- > Secretory granules
- Lumen

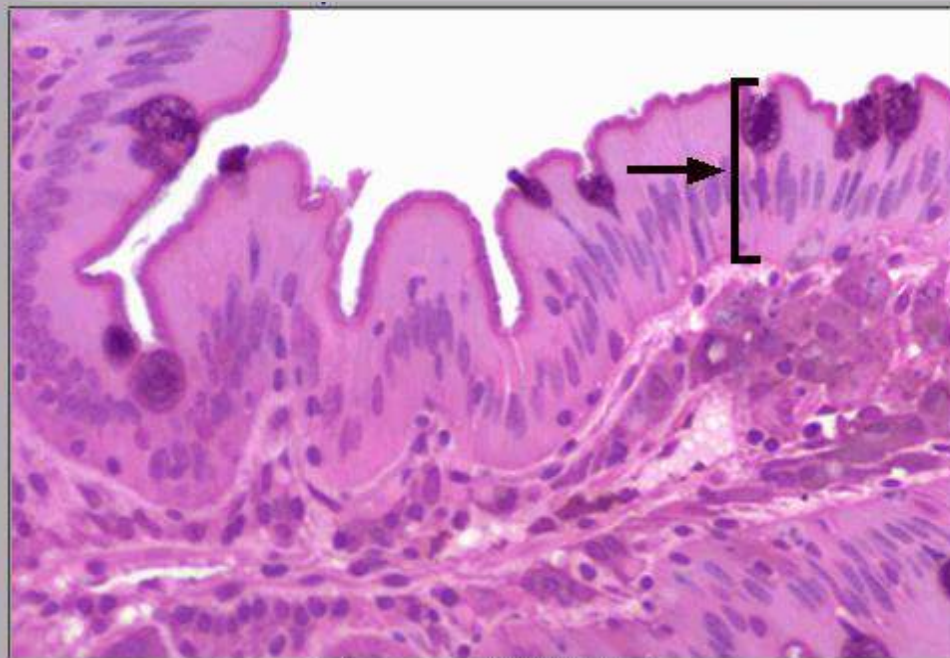


5 of 6

Modes of secretion: apocrine – These secretory cells of the breast secrete by both merocrine (protein) and apocrine (lipid) modes of secretion. Very few glands secrete by the apocrine mode, which involves the loss of surface plasma membrane and a small amount of cytoplasm along with the secretory product. Note the secretory product being released in the lower right of the image. 1000x

click to identify:

- > Secretory product
- Lipid droplet

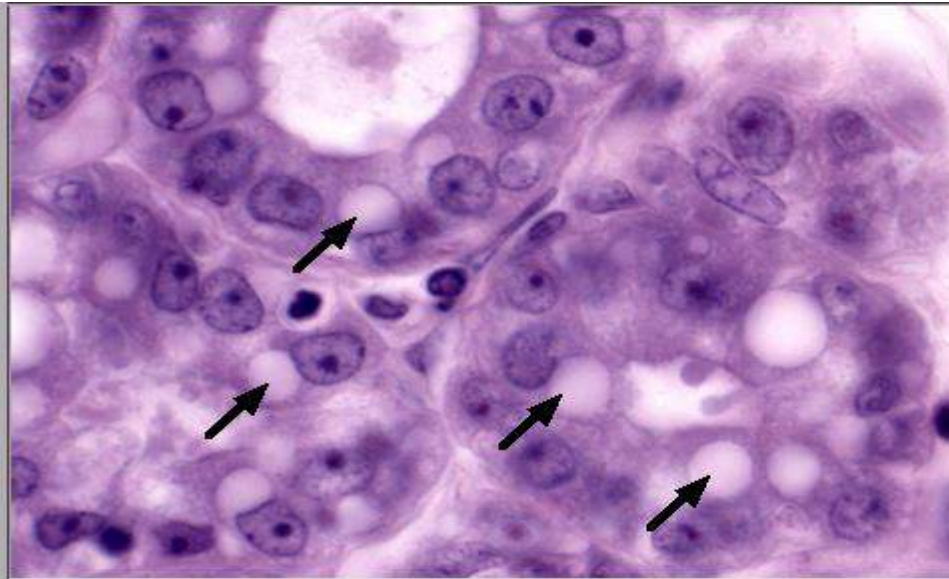


1 of 6

Unicellular gland -- The simplest gland is a unicellular gland, which can be either endocrine or exocrine. The goblet cells shown here represent unicellular exocrine glands that remain in the epithelium from which they originated. These cells secrete mucus and are prominent in the lining epithelium of the gastrointestinal and respiratory systems. Small intestine 400x

click to identify:

- > Goblet cell
- Goblet cell nuclei
- Mucin
- Absorptive cells
- Brush border
- Loose CT

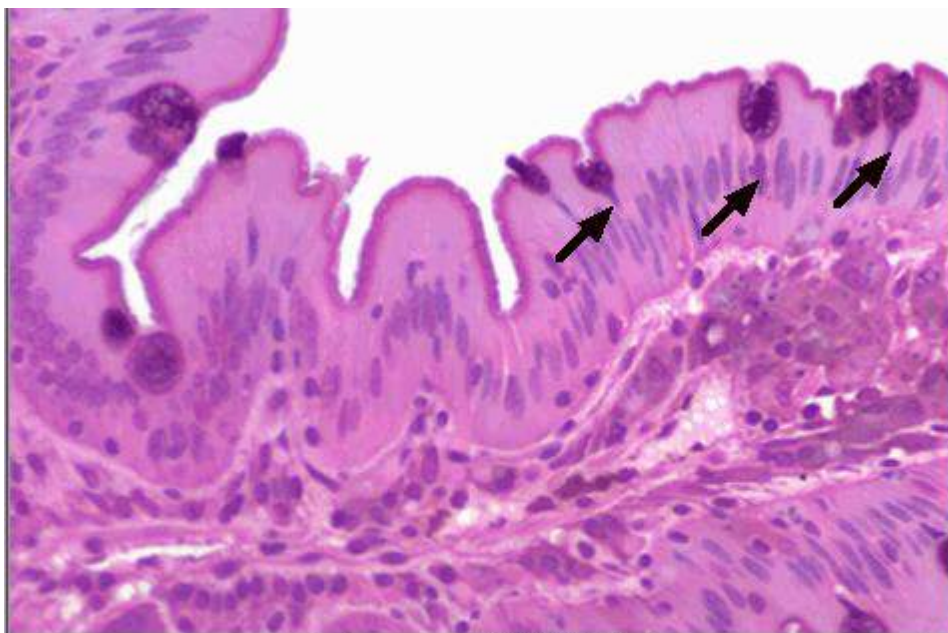


click to identify:

- Secretory product
- › Lipid droplet

5 of 6

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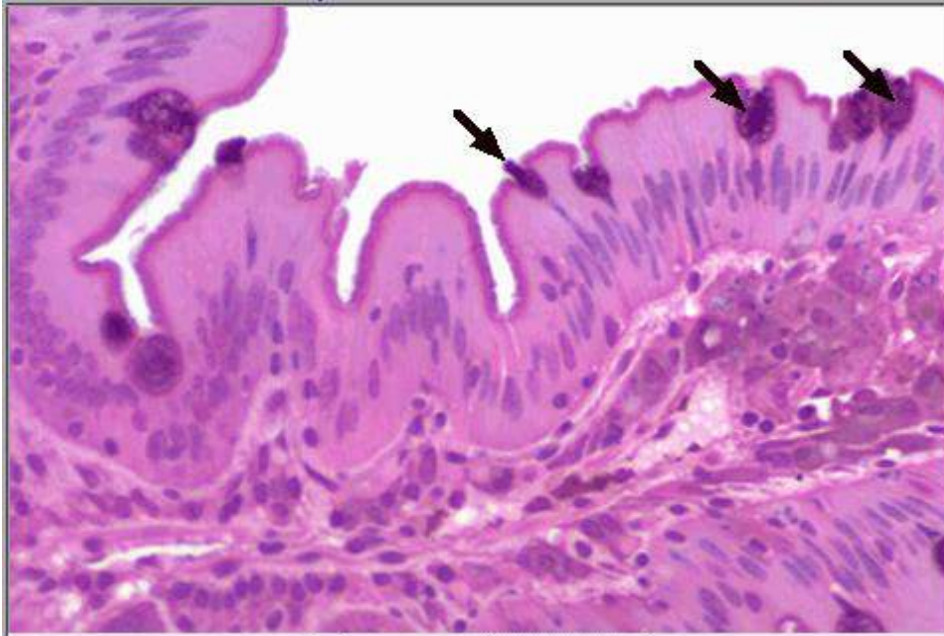


click to identify:

- Goblet cell
- › Goblet cell nuclei
- Mucin
- Absorptive cells
- Brush border
- Loose CT

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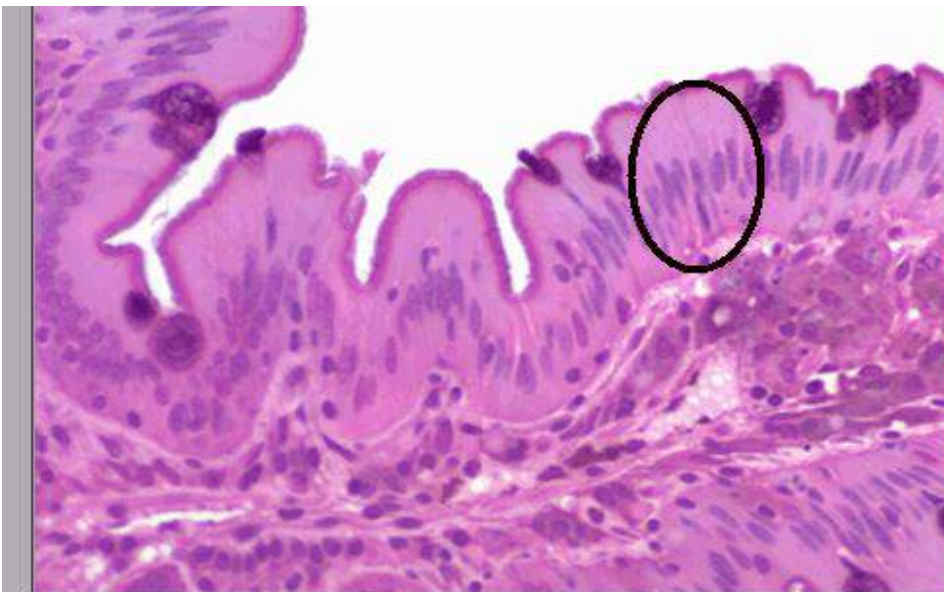


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- Goblet cell nuclei
- > Mucin
- Absorptive cells
- Brush border
- Loose CT

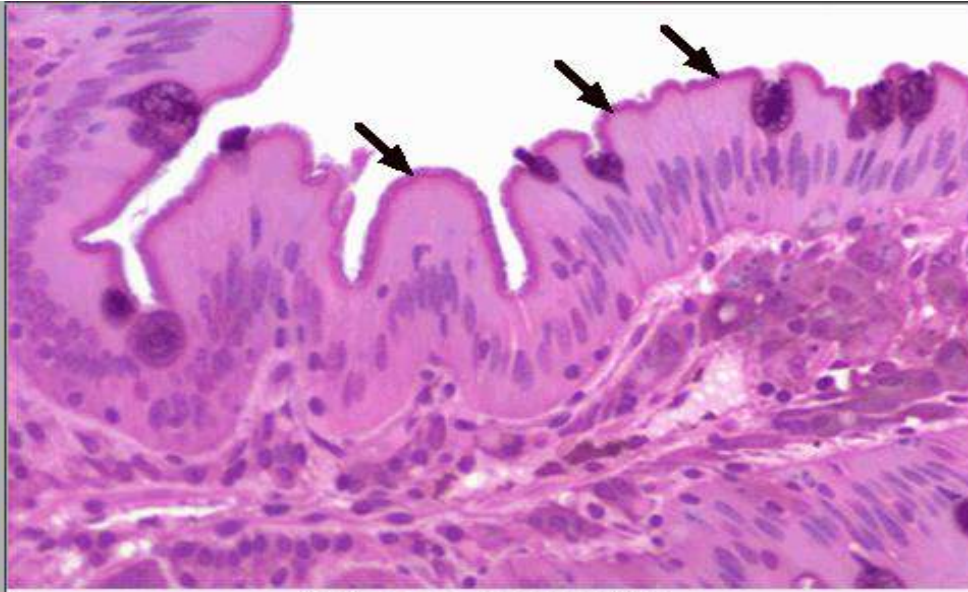


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- Goblet cell
- Goblet cell nuclei
- Mucin
- > Absorptive cells
- Brush border
- Loose CT

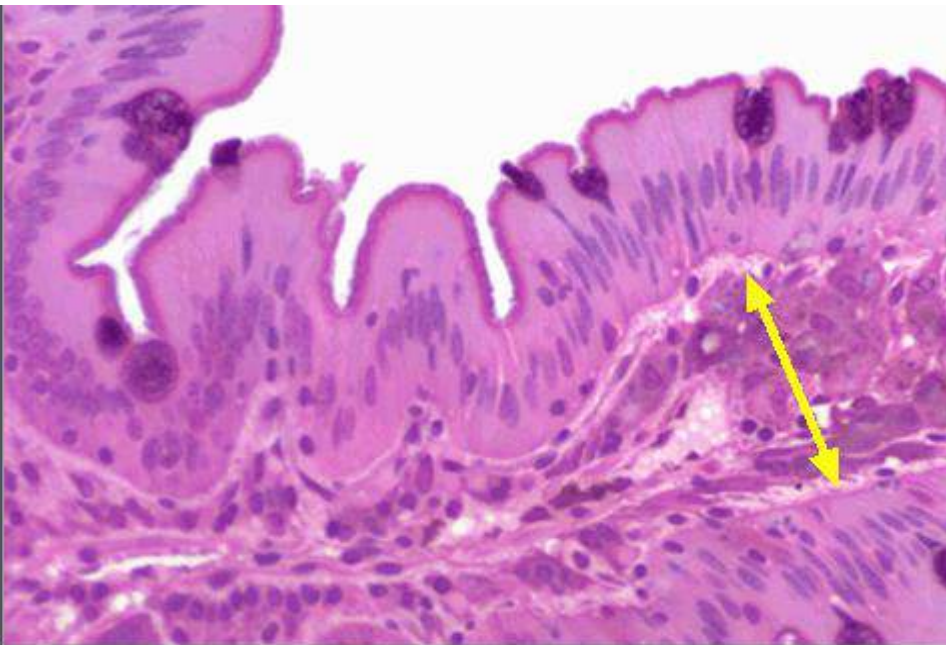


1 of 6

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click to identify:

- Goblet cell
- Goblet cell nuclei
- Mucin
- Absorptive cells
- ▶ Brush border
- Loose CT



1 of 6

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click to identify:

- Goblet cell
- Goblet cell nuclei
- Mucin
- Absorptive cells
- Brush border
- ▶ Loose CT

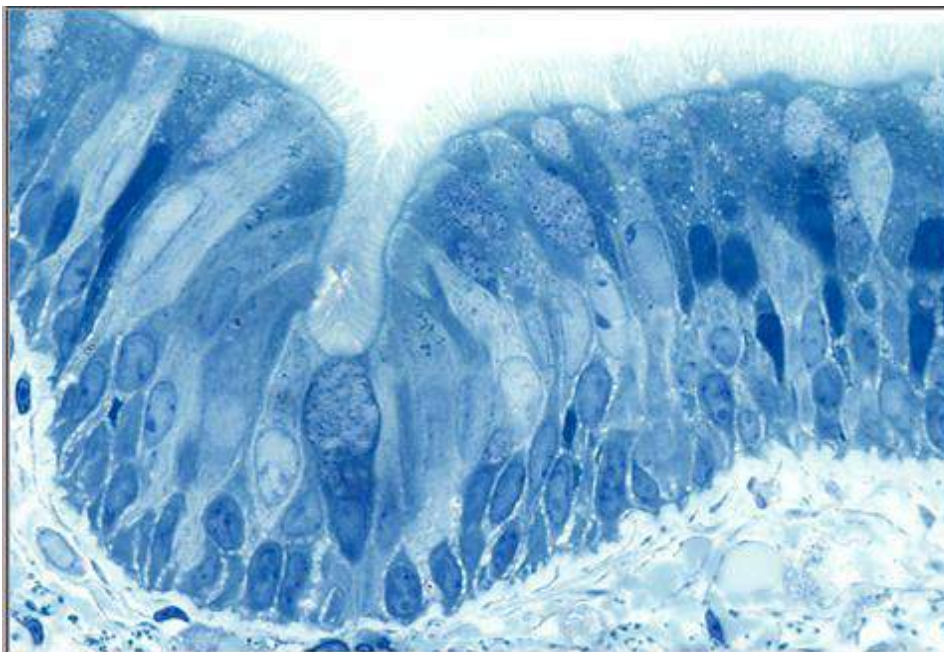


2 of 6

Unicellular gland -- The mucin in these goblet cells is located in the apex of the cell, with the nucleus and remaining cytoplasm located beneath it, creating the goblet-like shape. Goblet cells release mucin proteins which become hydrated, thereby forming mucus. Goblet cells are commonly found in simple columnar epithelia, such as this lining of the small intestine. 1000x

click to identify:

Goblet cell nuclei
Mucin
Absorptive cells
Brush border

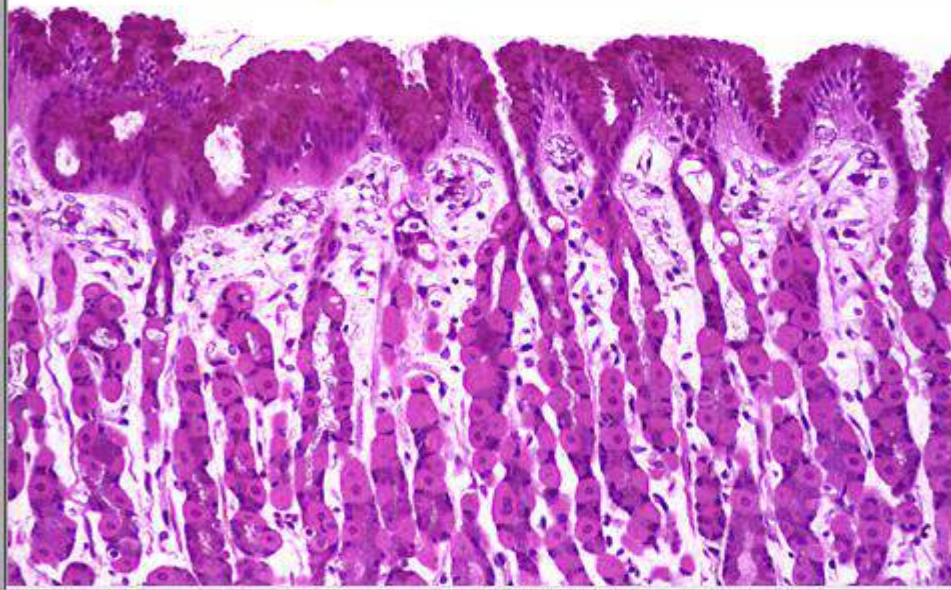


3 of 6

Unicellular gland -- This lining epithelium of the monkey trachea is a pseudostratified epithelium with cilia and goblet cells. Goblet cells release mucin proteins which become hydrated, thereby forming mucus. The mucus traps inhaled particles and the entire mucous sheet is moved upward by the beating action of associated cilia. 1000x

click to identify:

Pseudostratified
epithelium
Cilia
Basal bodies
Goblet cell
Loose CT

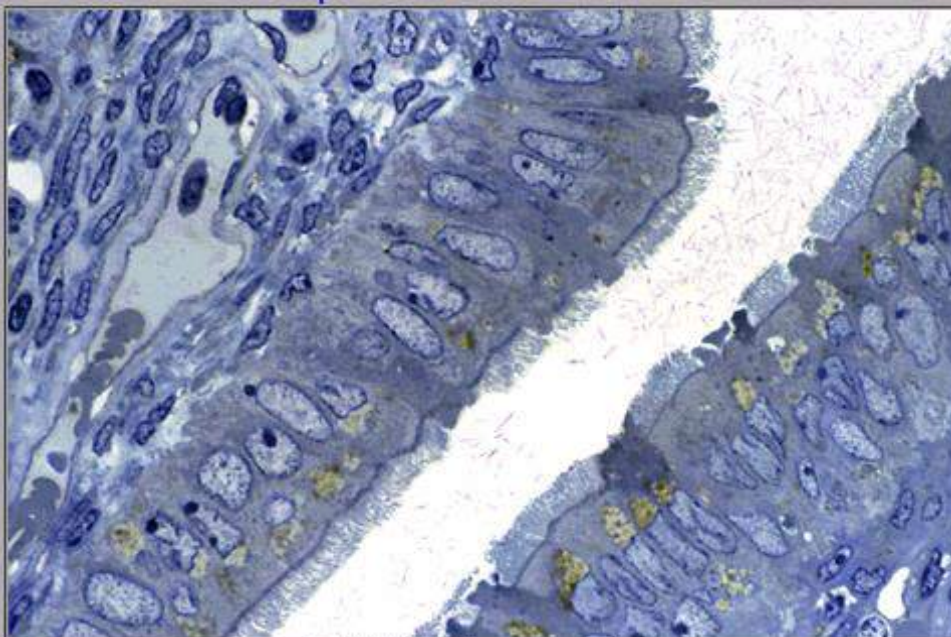


1 of 2

Sheet gland -- This fundic region of the stomach demonstrates a sheet gland, which forms the lining of the stomach. The multicellular sheet gland is an epithelial layer composed entirely of mucus-secreting cells. The mucus produced by this layer protects the stomach tissues from the acidic contents of the organ. 200x

click to identify:

Sheet gland
Tubular glands
Stomach lumen

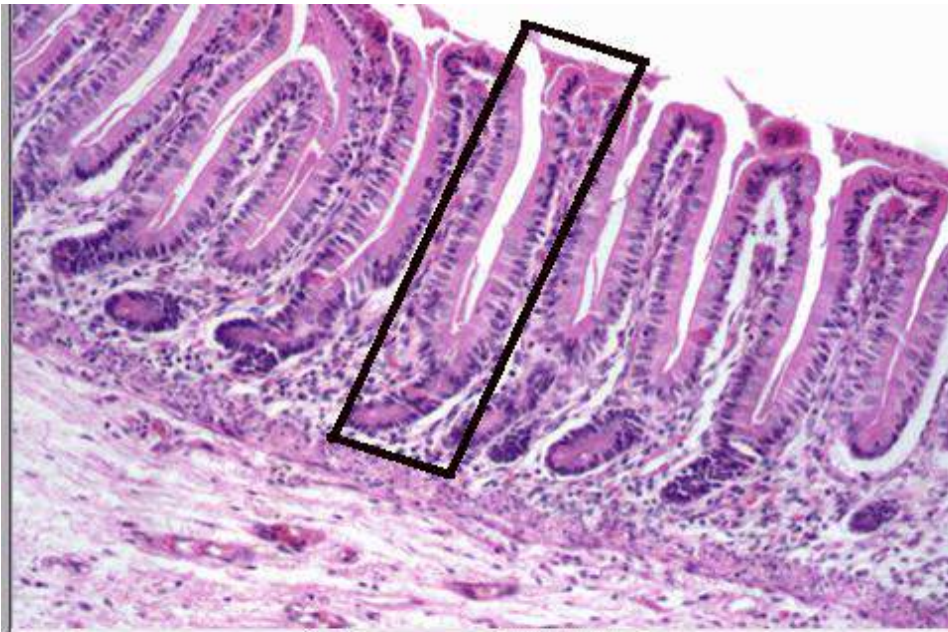


6 of 6

Unicellular gland -- Not all unicellular glands are goblet cells. This simple columnar epithelial lining of the oviduct demonstrates unicellular glands among the ciliated cells. The oviduct is the site of fertilization, and these unicellular glands provide nutrition to the oocyte, sperm and embryo. 1000x

click to identify:

Simple columnar
epithelium
Secretory cells
Cilia
Basal bodies
Loose CT

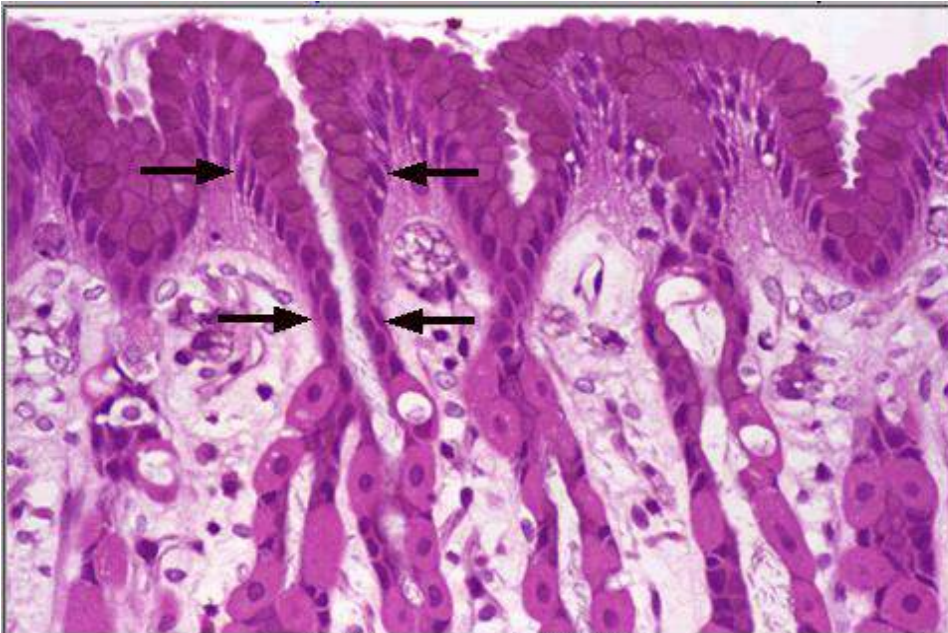


2 of 13

Simple tubular gland -- In this section of the large intestine, the simple tubular glands are slightly longer than the mucosal layer in which they are located. Note that the bases of the glands curve as they reach the muscularis mucosae. These glands are composed primarily of goblet and absorptive cells. 200x

click to identify:

- › Simple tubular gland
- Goblet cells
- Absorptive cells
- Gland lumens
- Intestinal lumen
- Muscularis mucosae

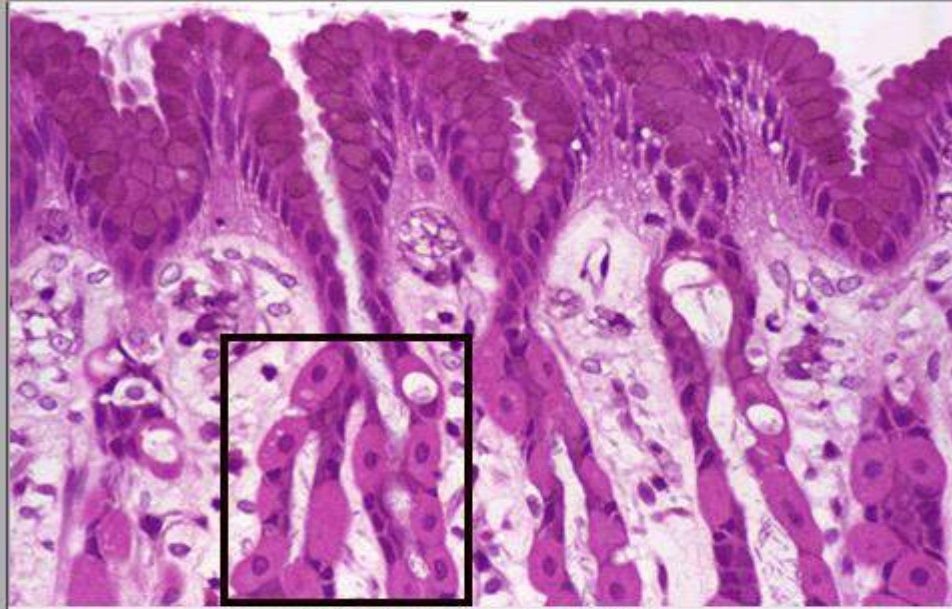


5 of 13

Simple, branched tubular gland -- This image of the stomach shows the structure of a simple, branched tubular gland. The secretory sheet lining the surface invaginates to form a gastric pit that acts as a duct for the gland. The secretory portions of the gland branch at their junction with the gastric pit. 400x

click to identify:

- Simple branched tubular gland
- › Gastric pit
- Secretory tubules
- Sheet gland



5 of 13

Simple, branched tubular gland -- This image of the stomach shows the structure of a simple, branched tubular gland. The secretory sheet lining the surface invaginates to form a gastric pit that acts as a duct for the gland. The secretory portions of the gland branch at their junction with the gastric pit. 400x

click to identify:

- Simple branched tubular gland
- Gastric pit
- Secretory tubules
- Sheet gland

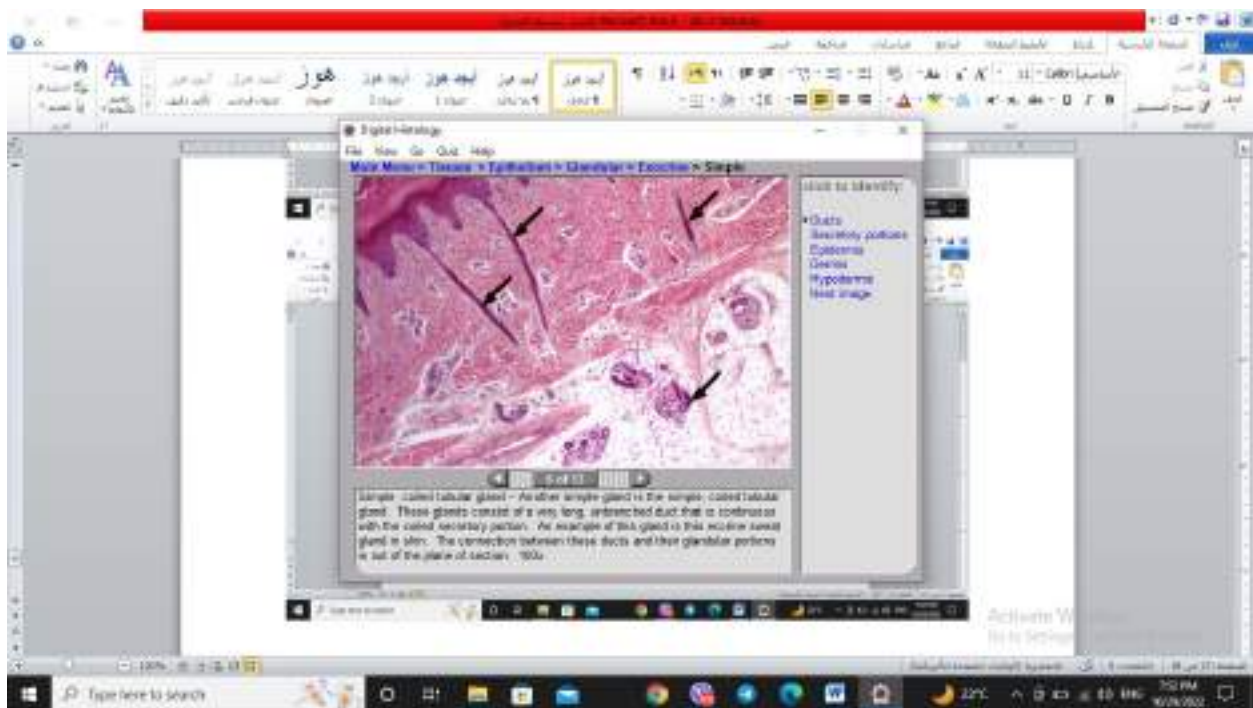
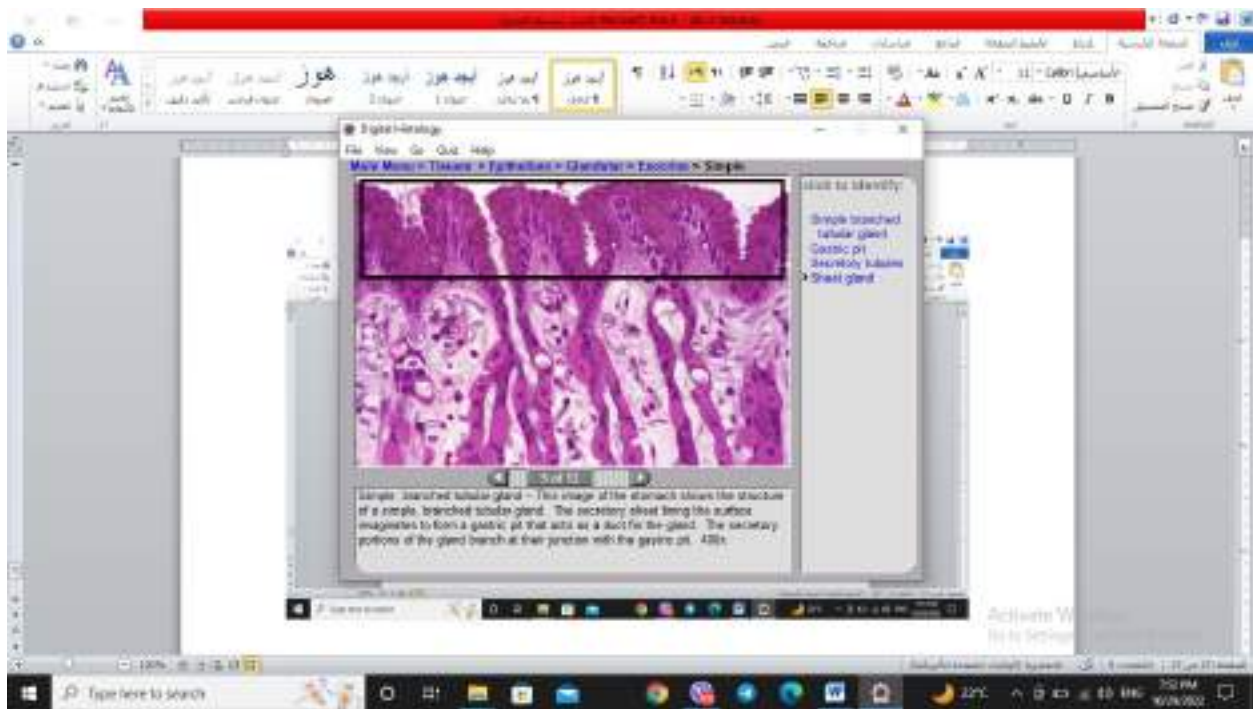


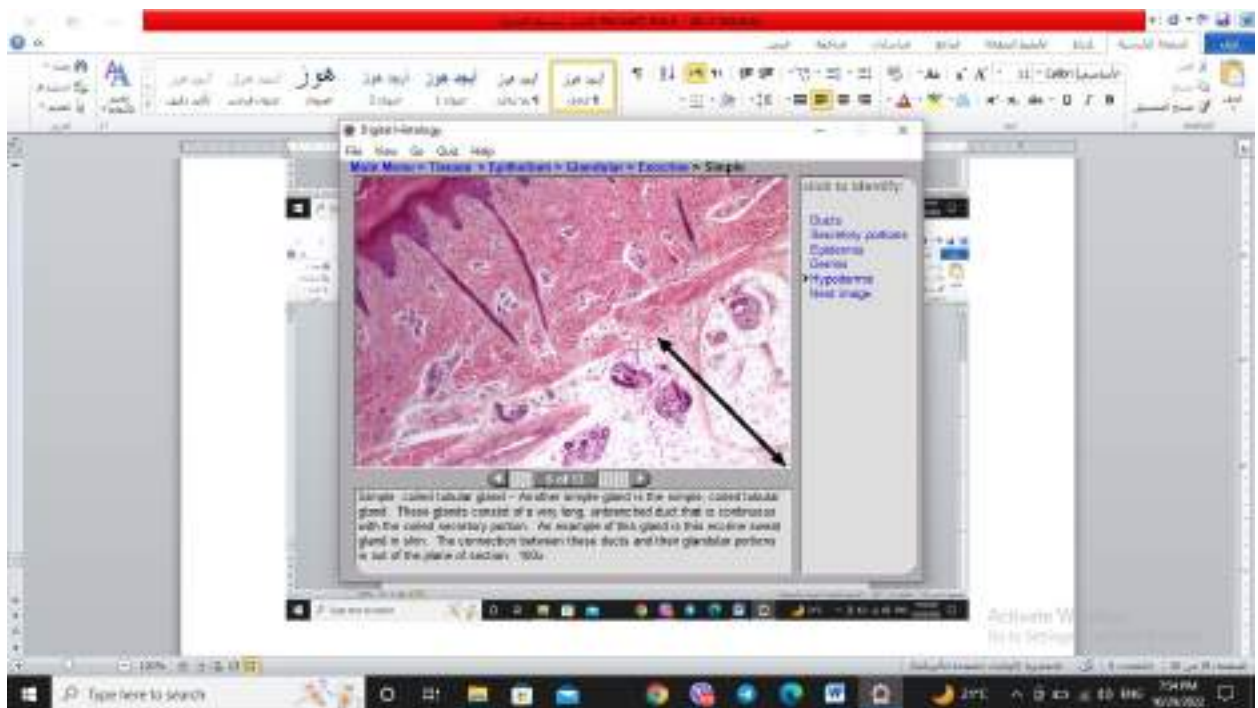
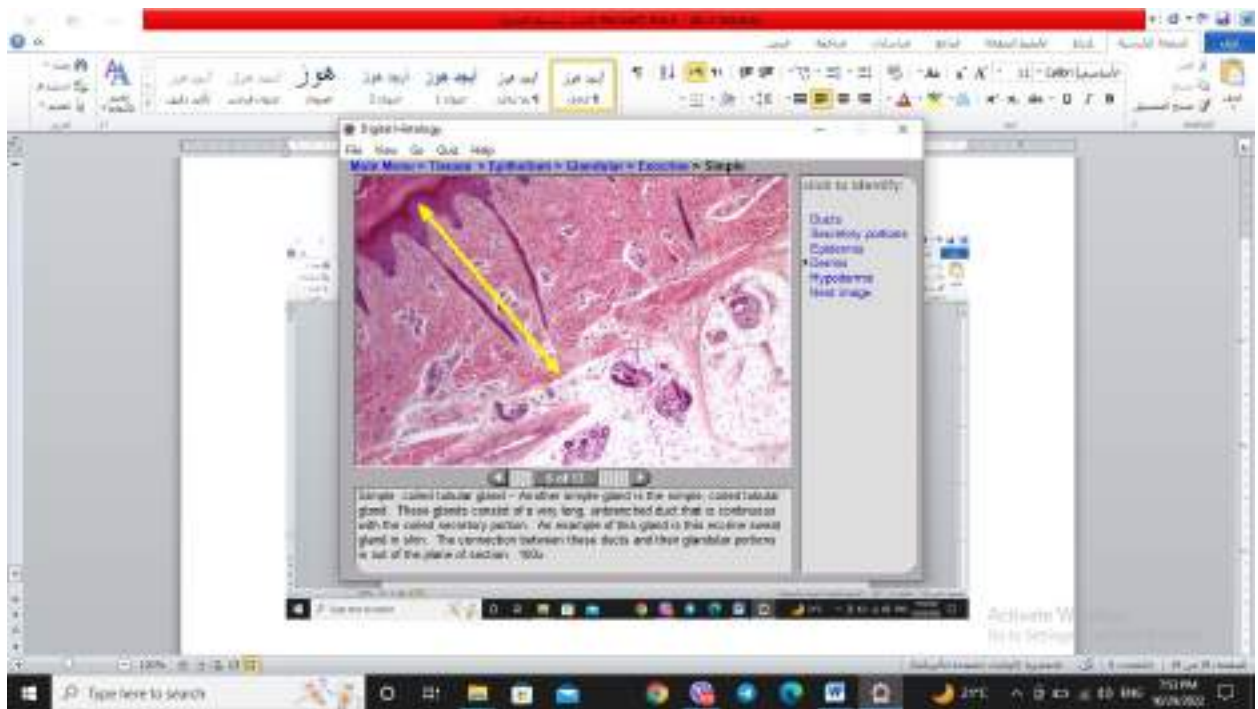
5 of 13

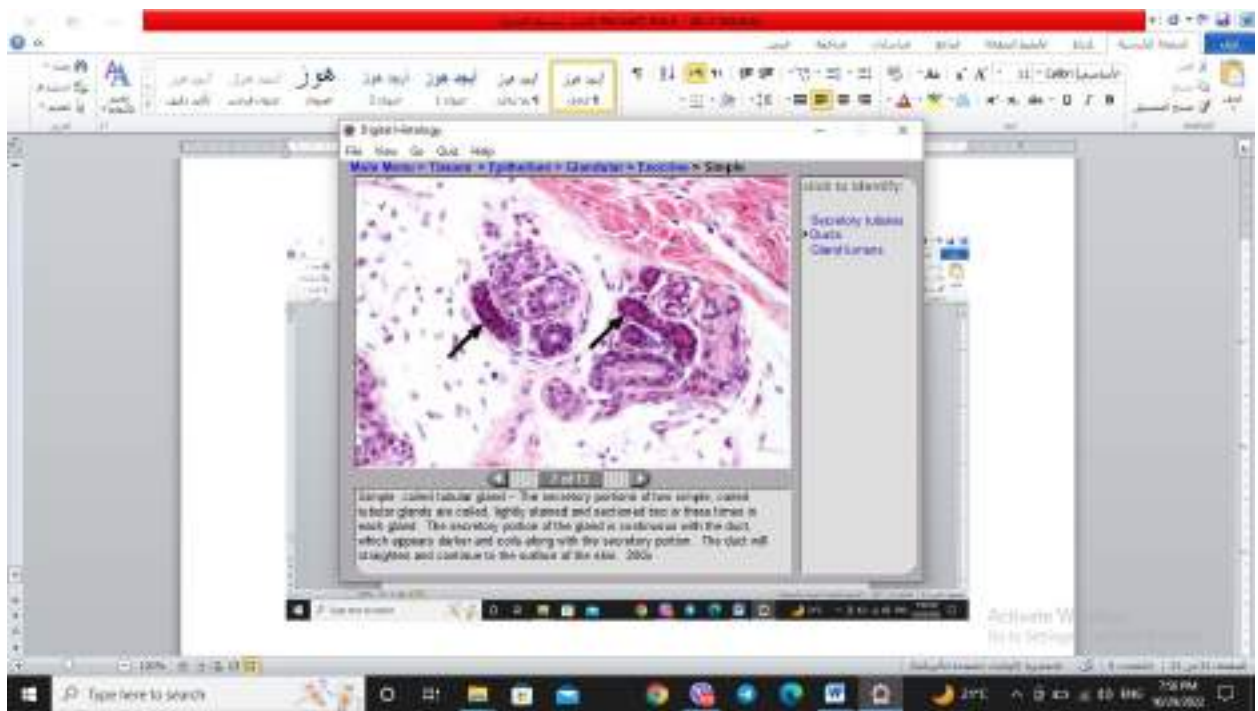
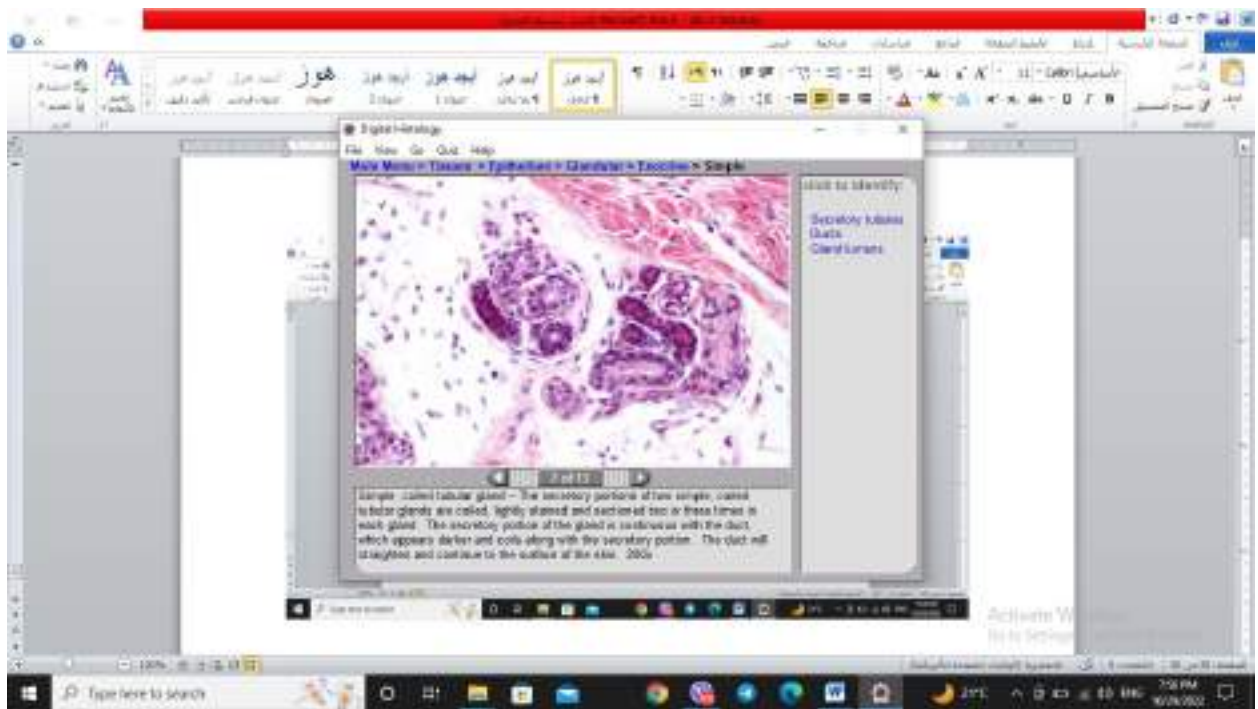
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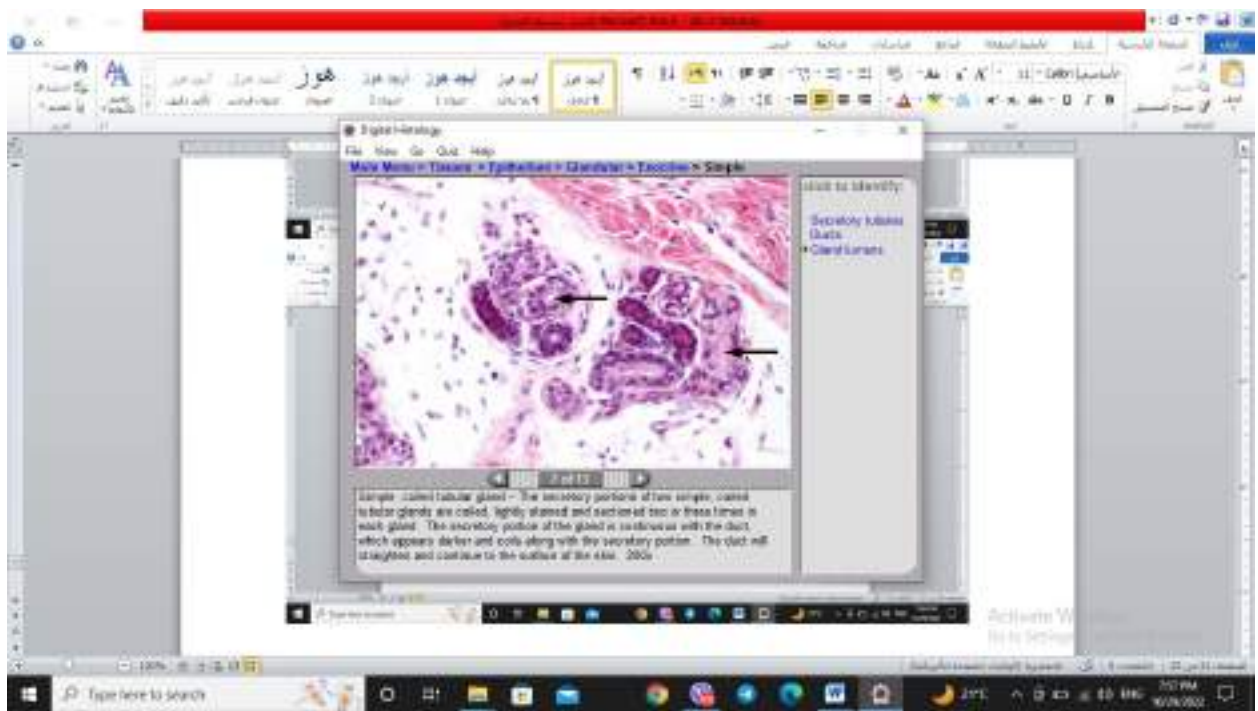
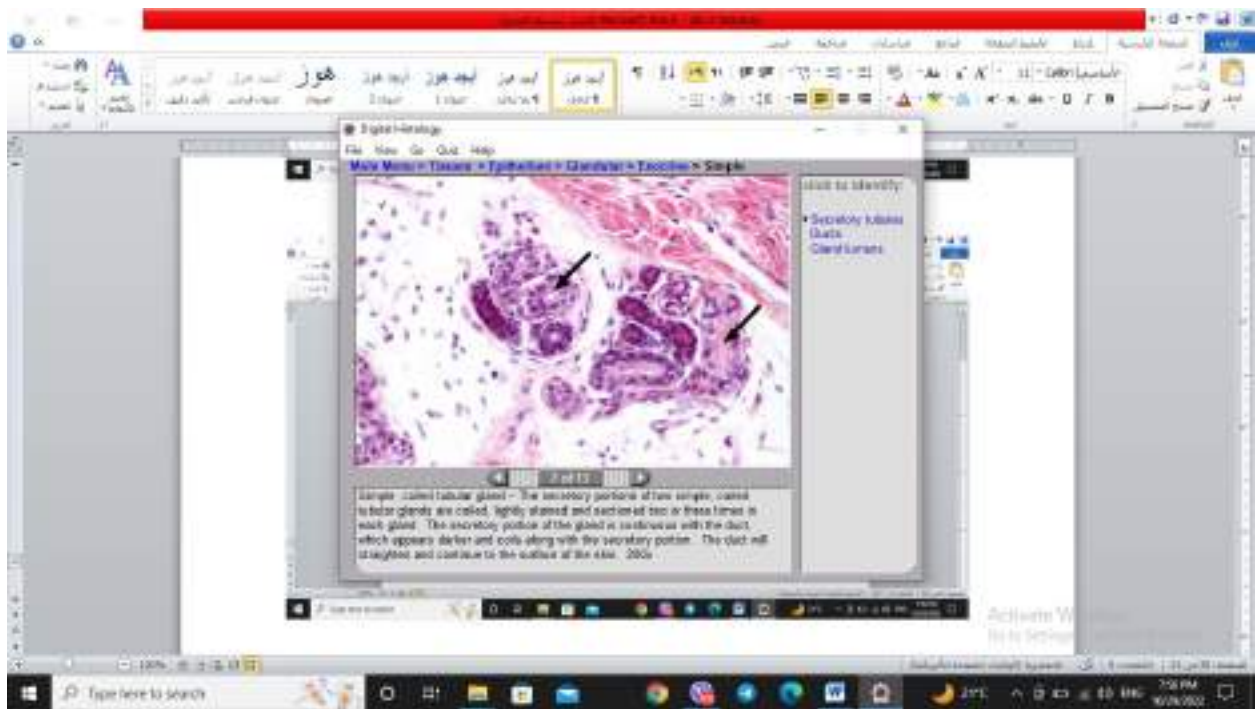
click to identify:

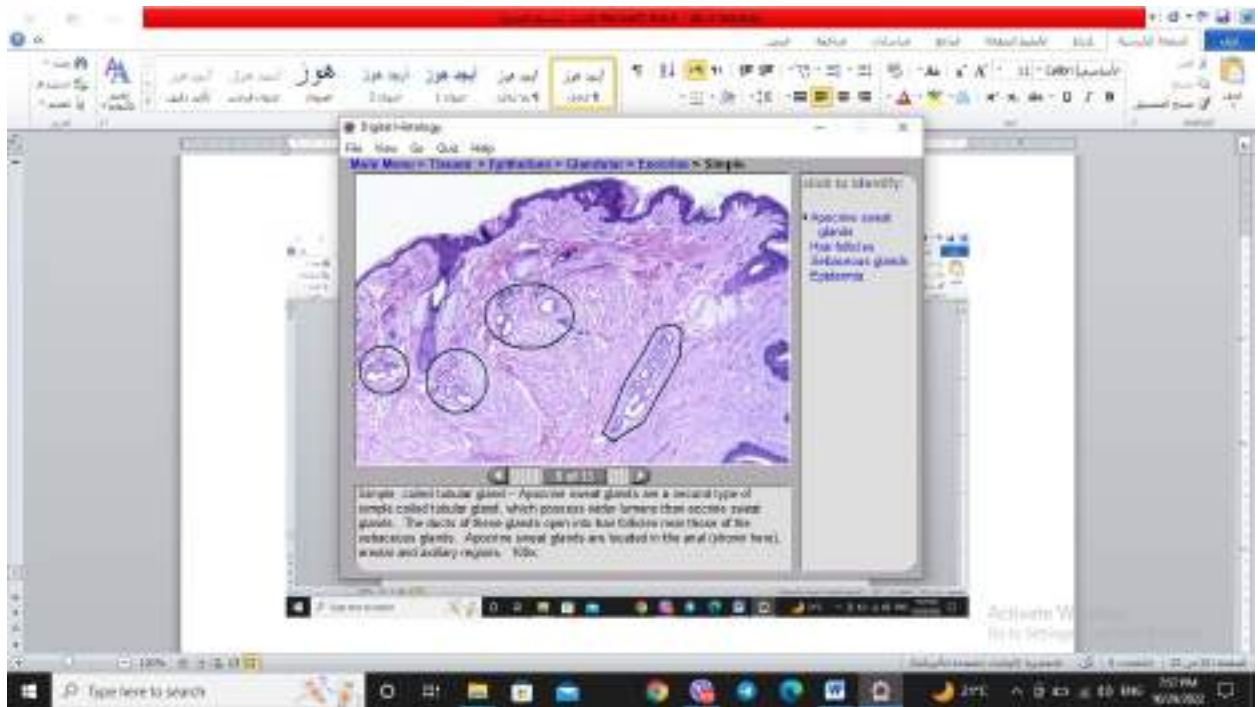
- Simple branched tubular gland
- Gastric pit
- Secretory tubules
- Sheet gland

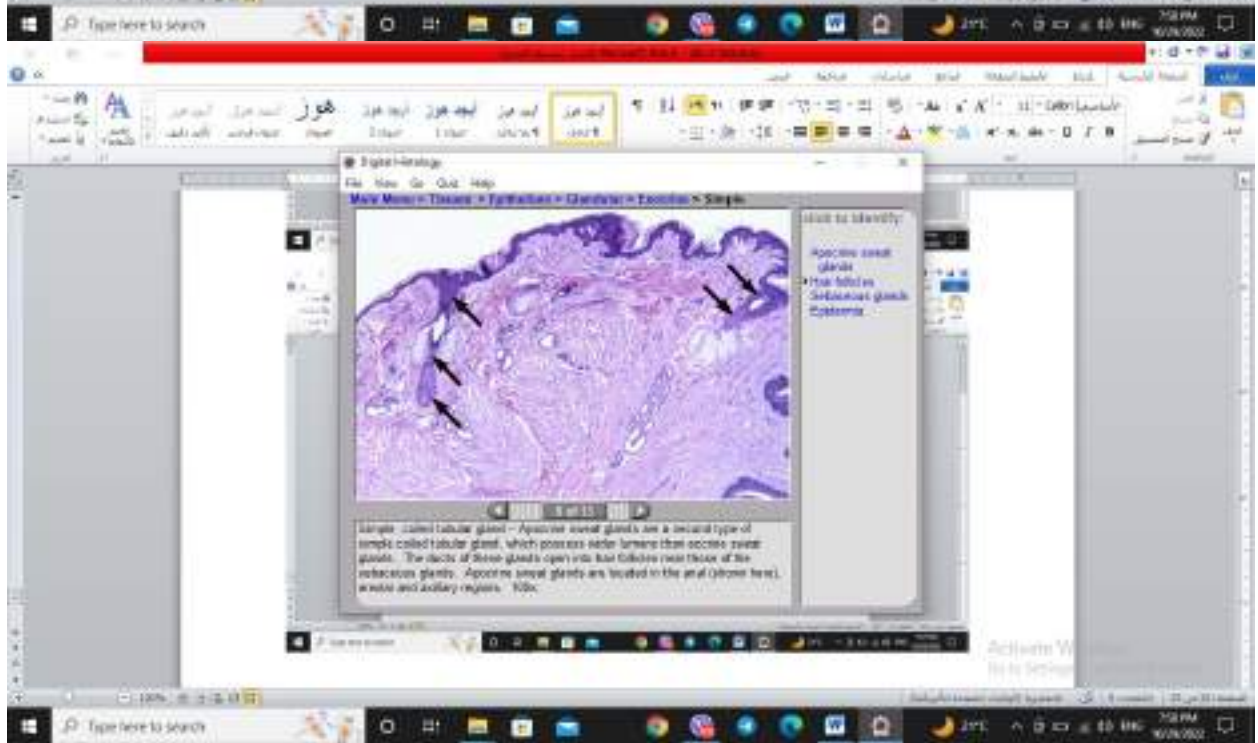
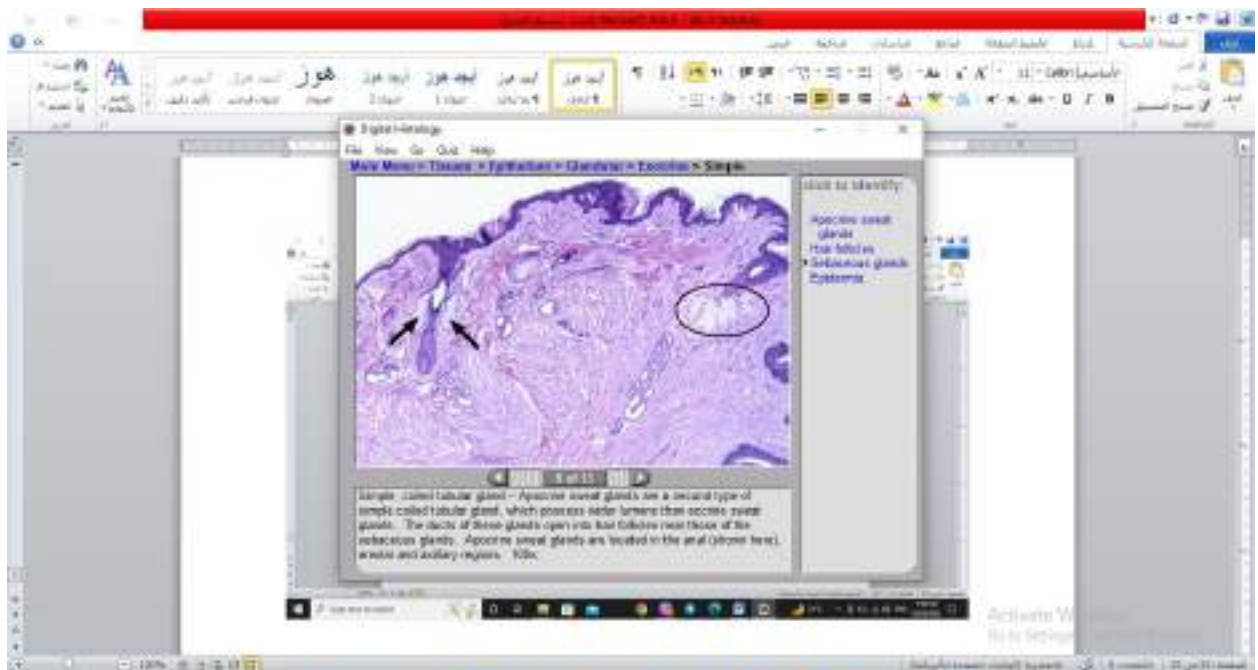


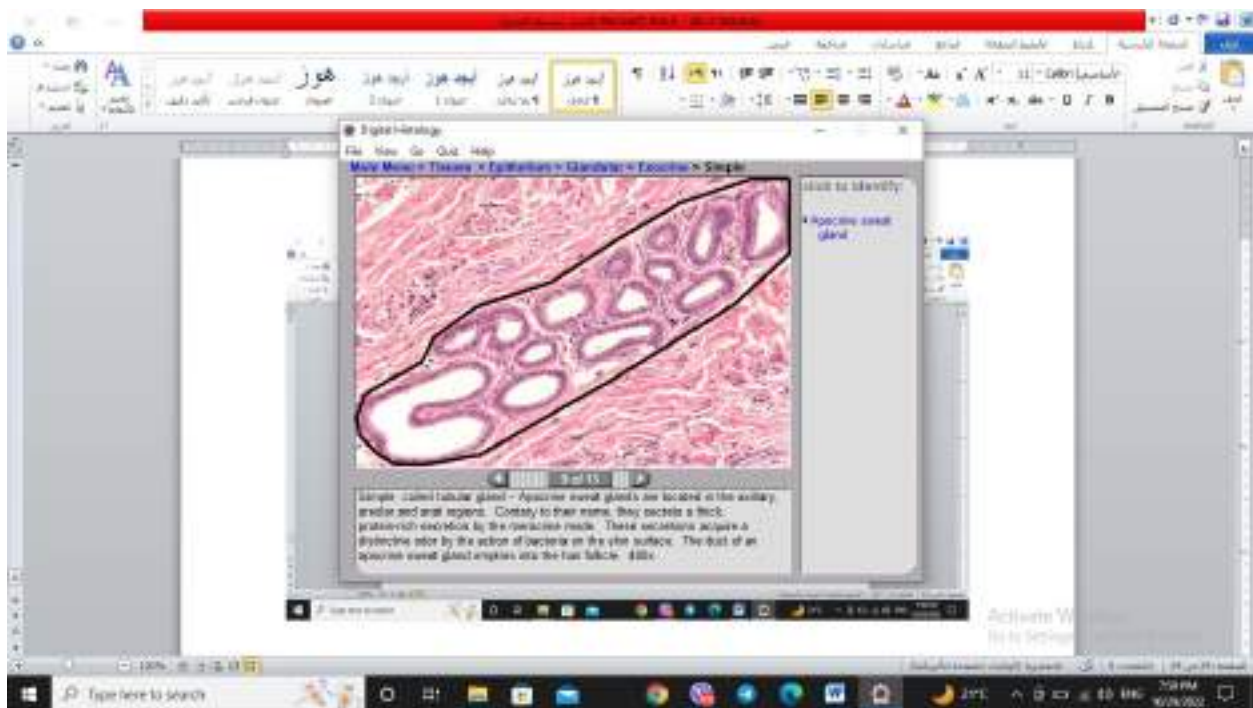
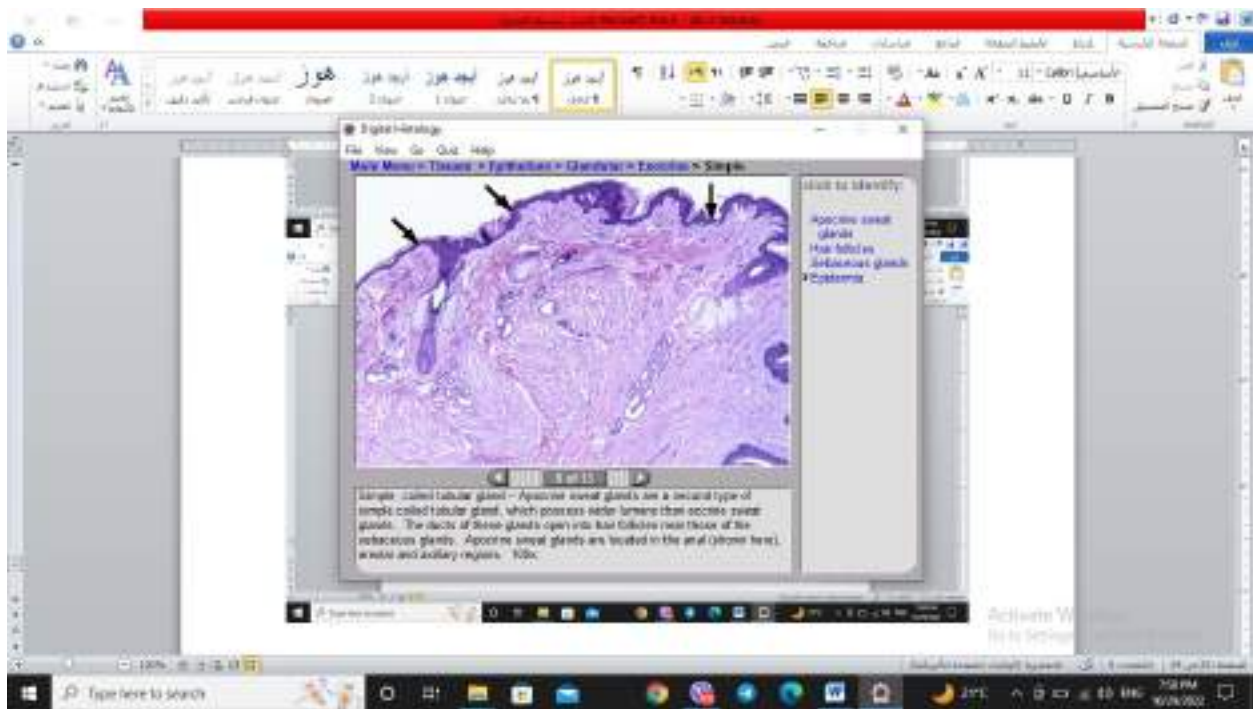


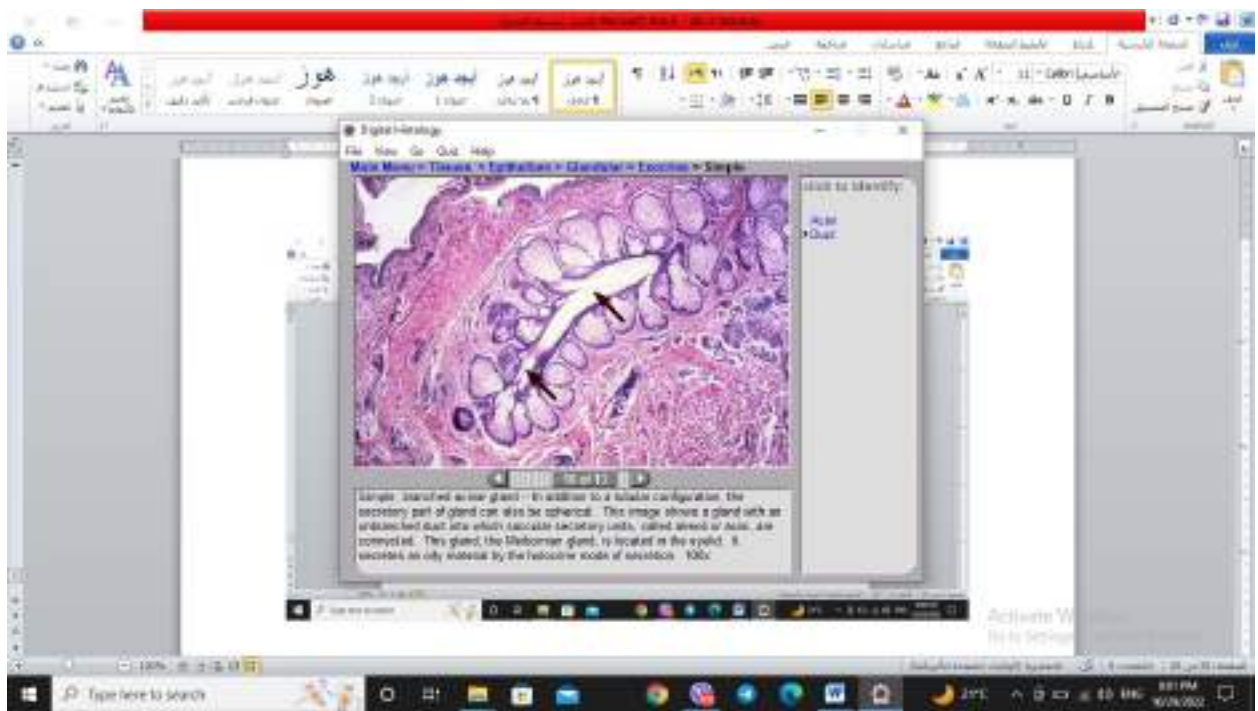
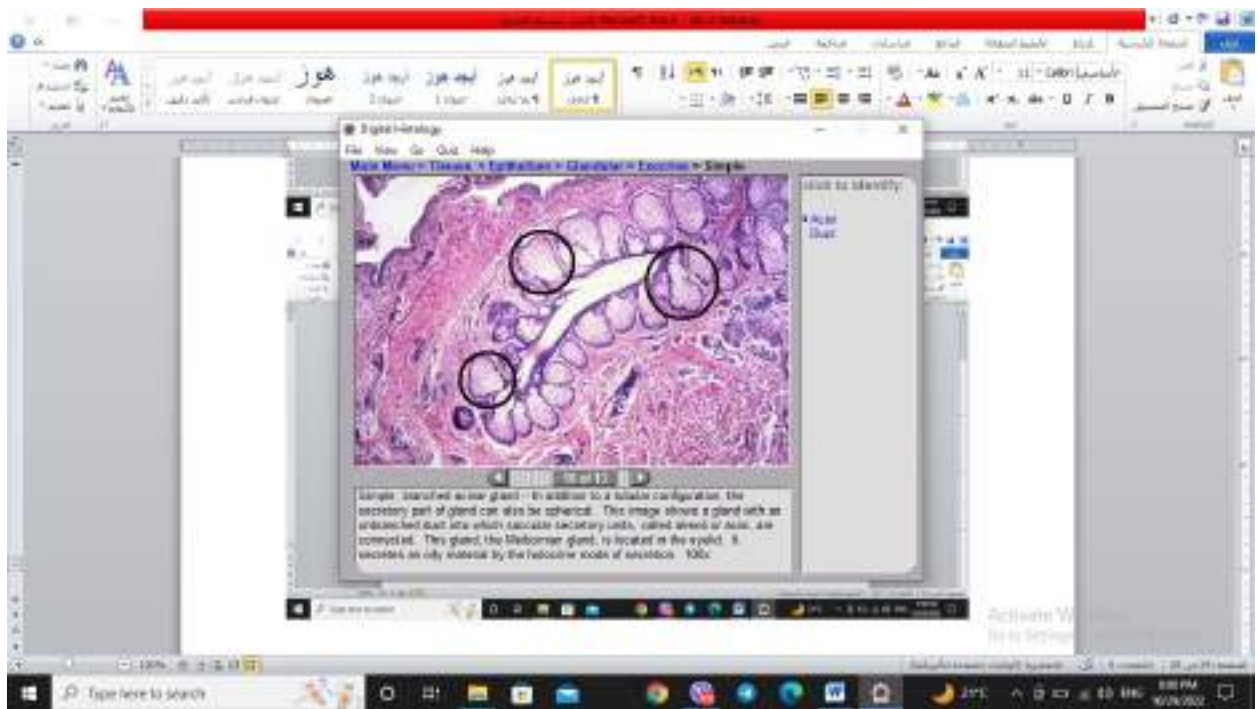


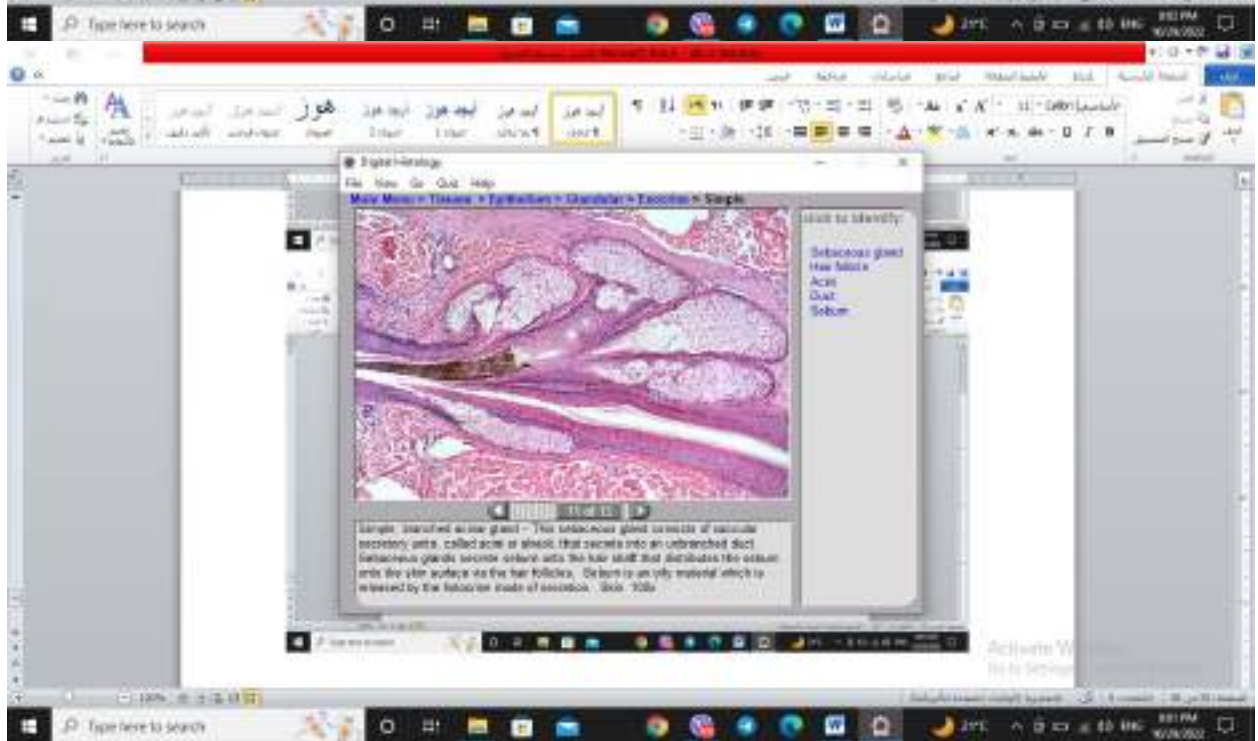
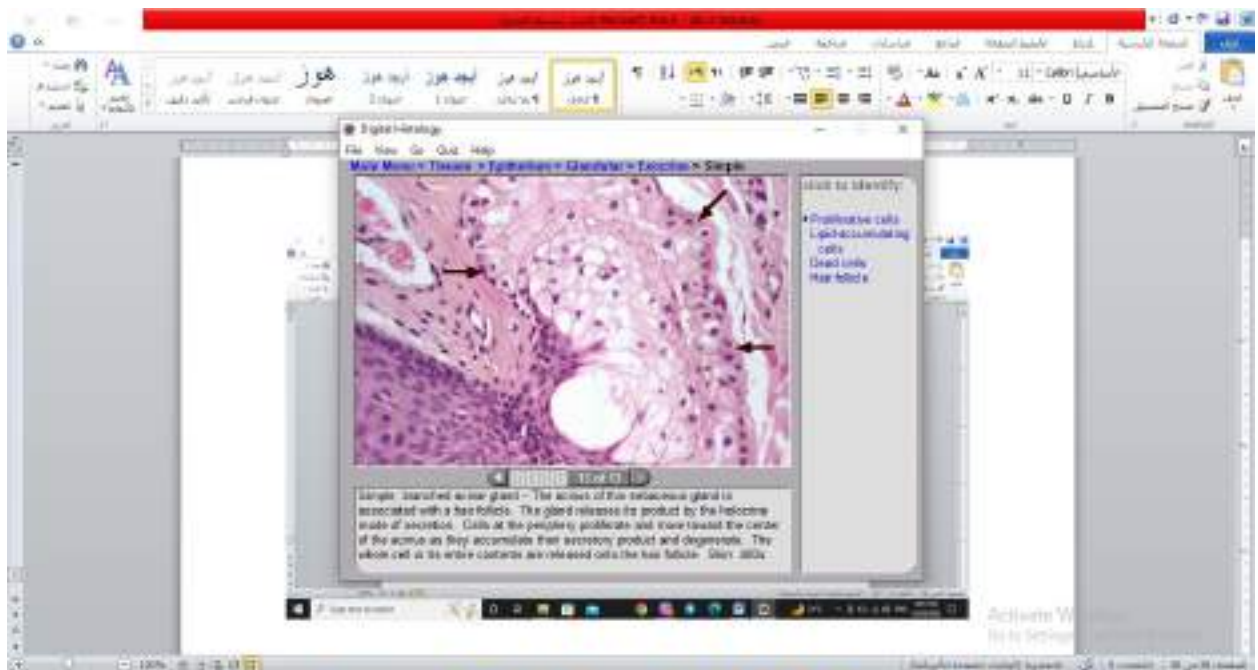


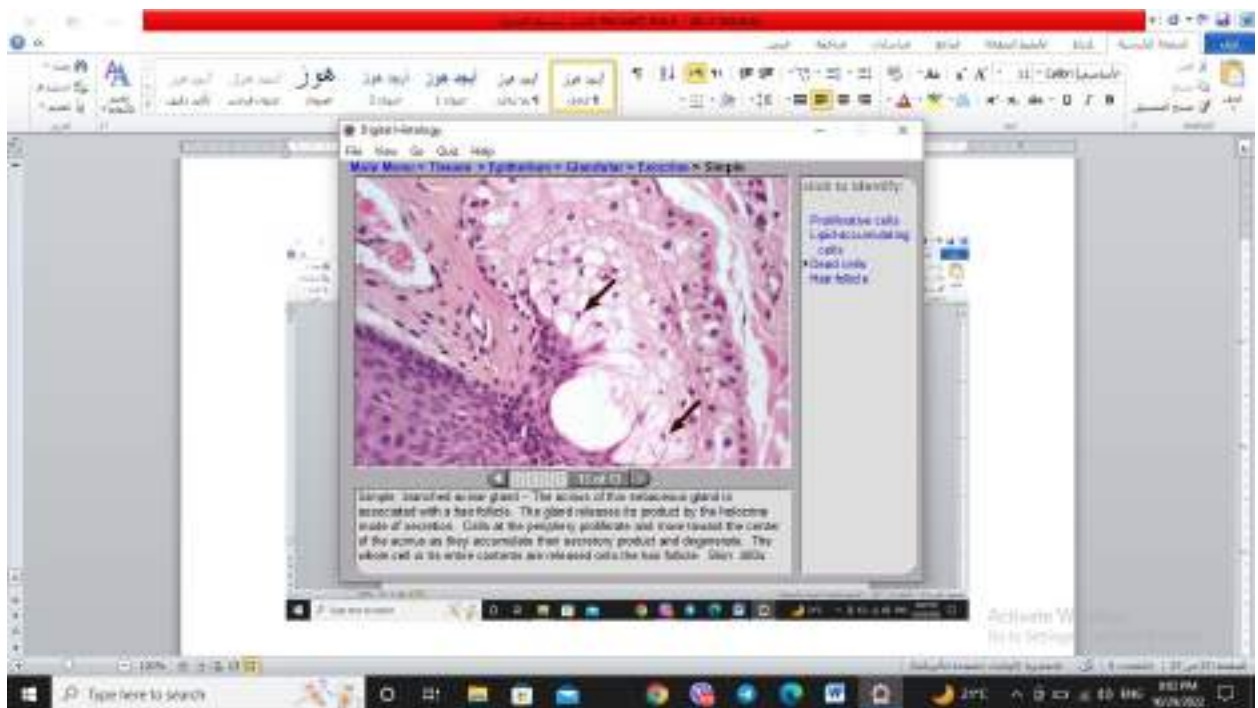
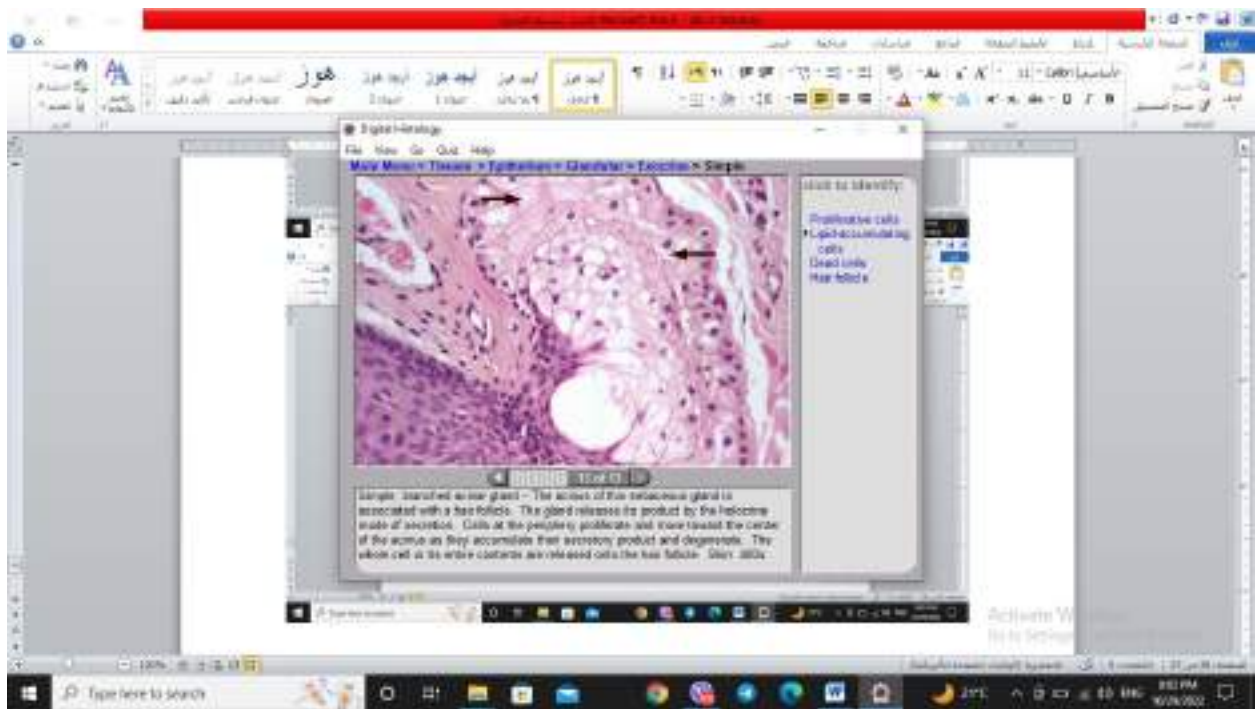


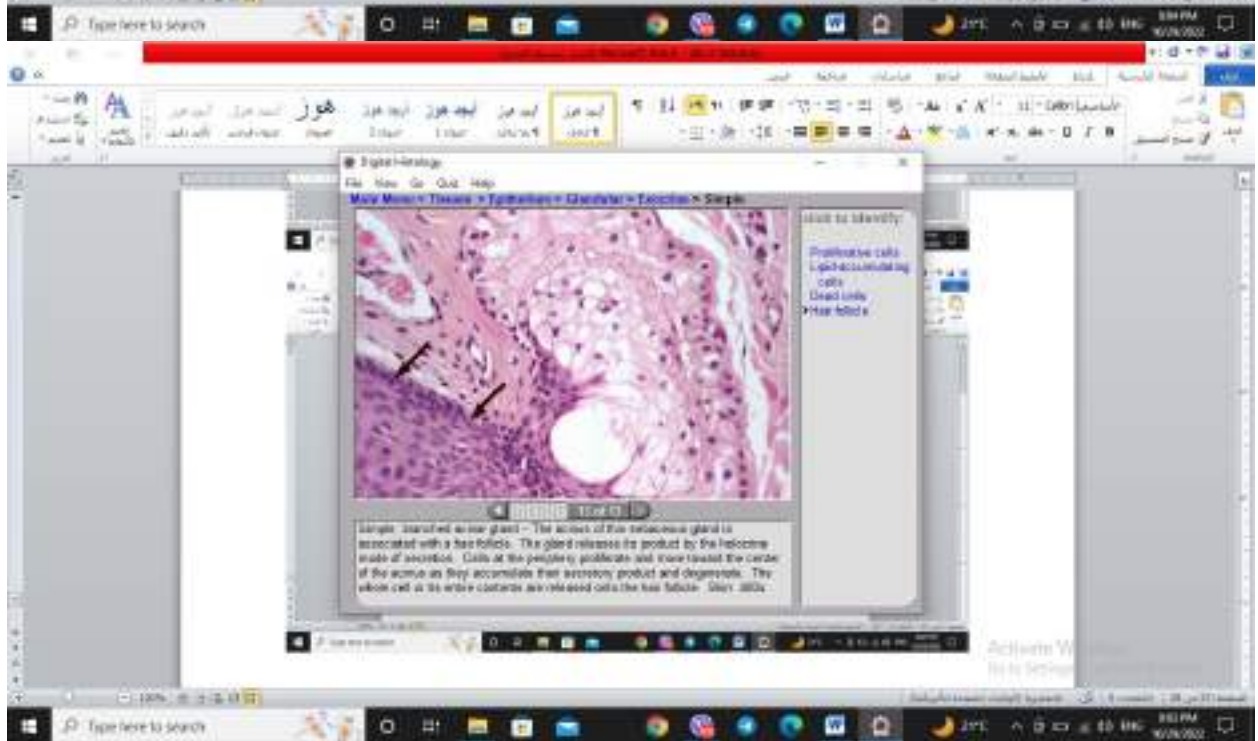
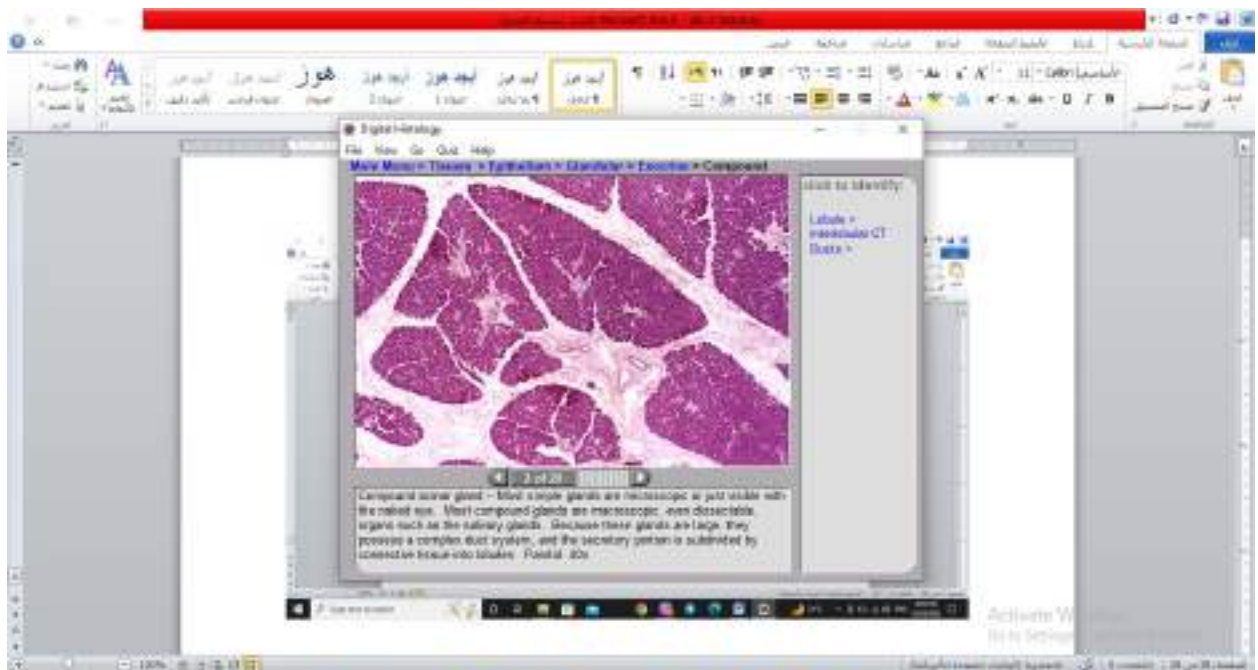


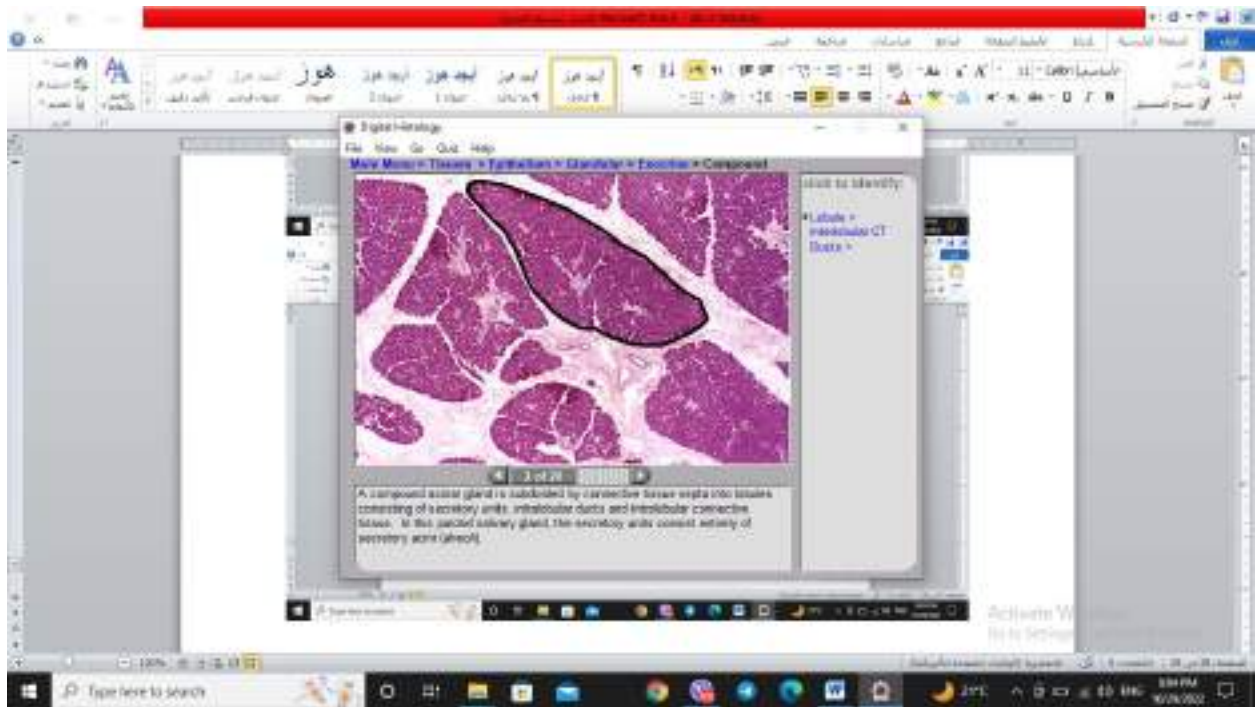


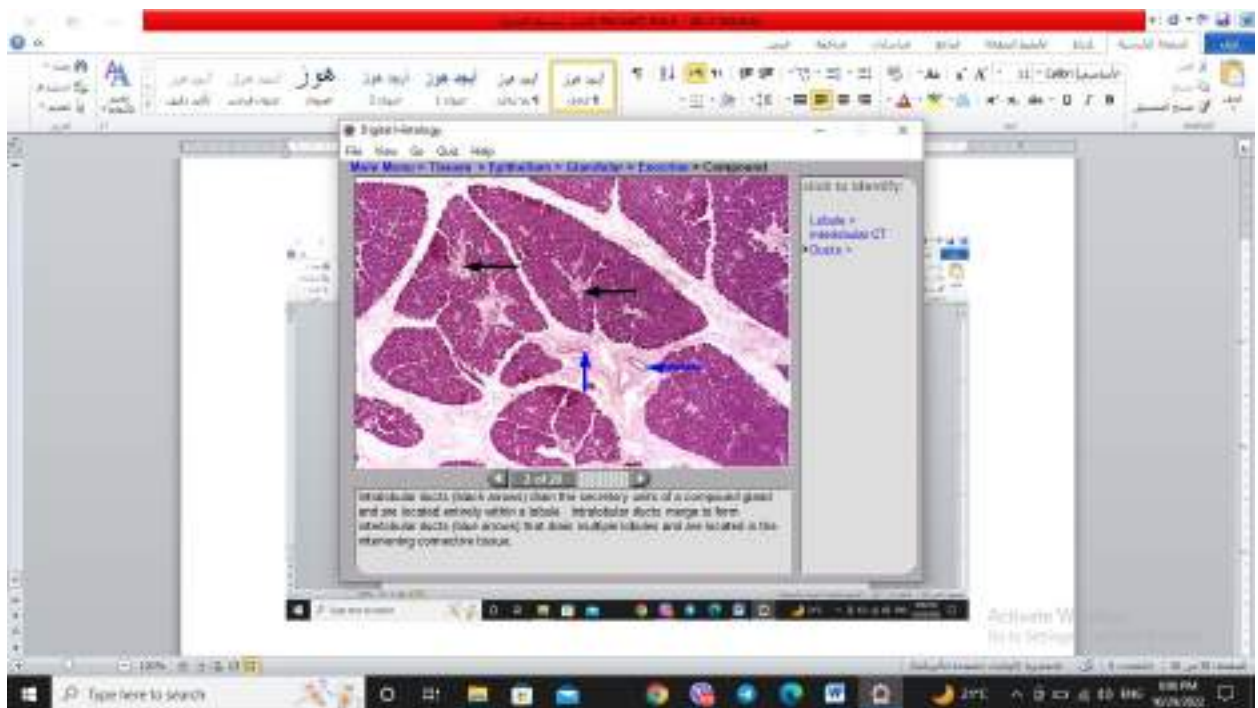
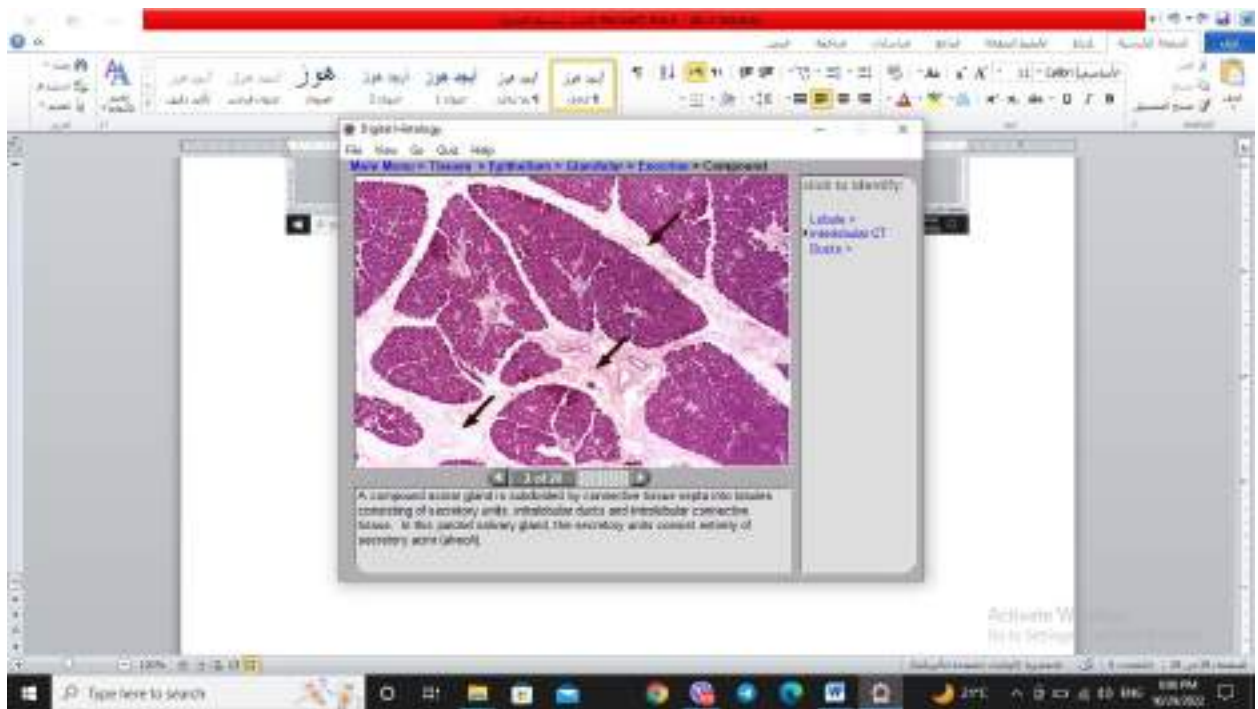


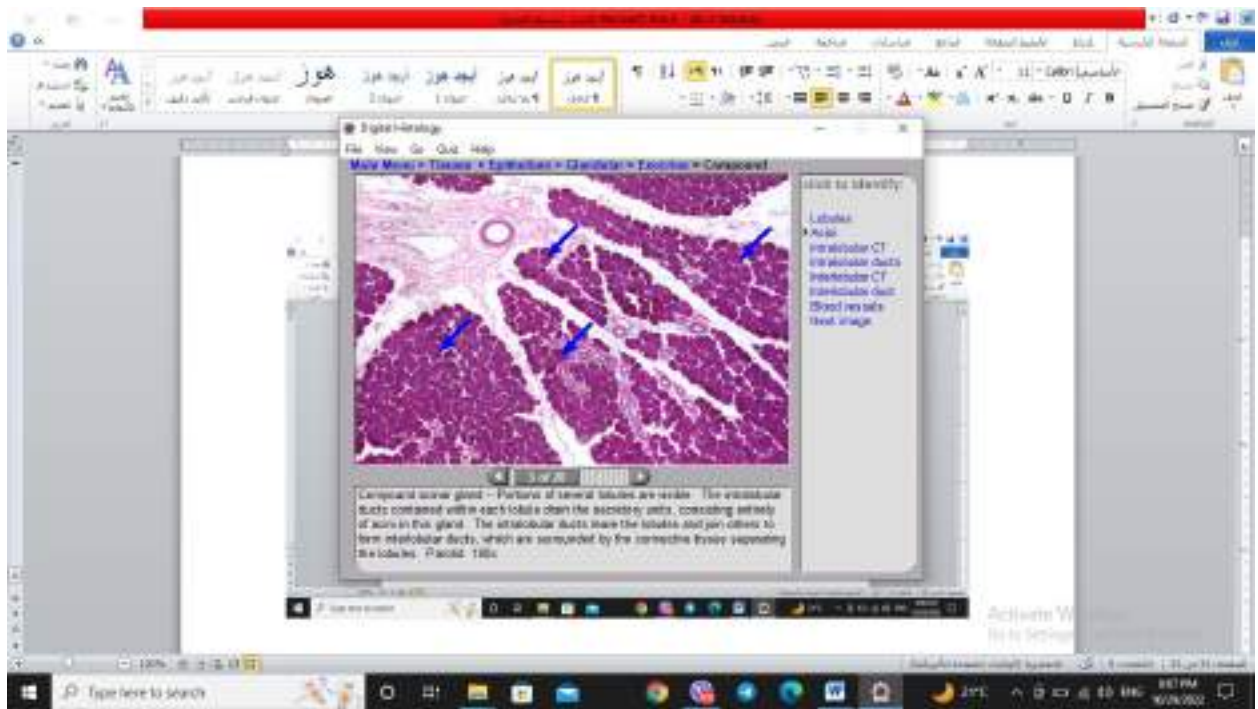
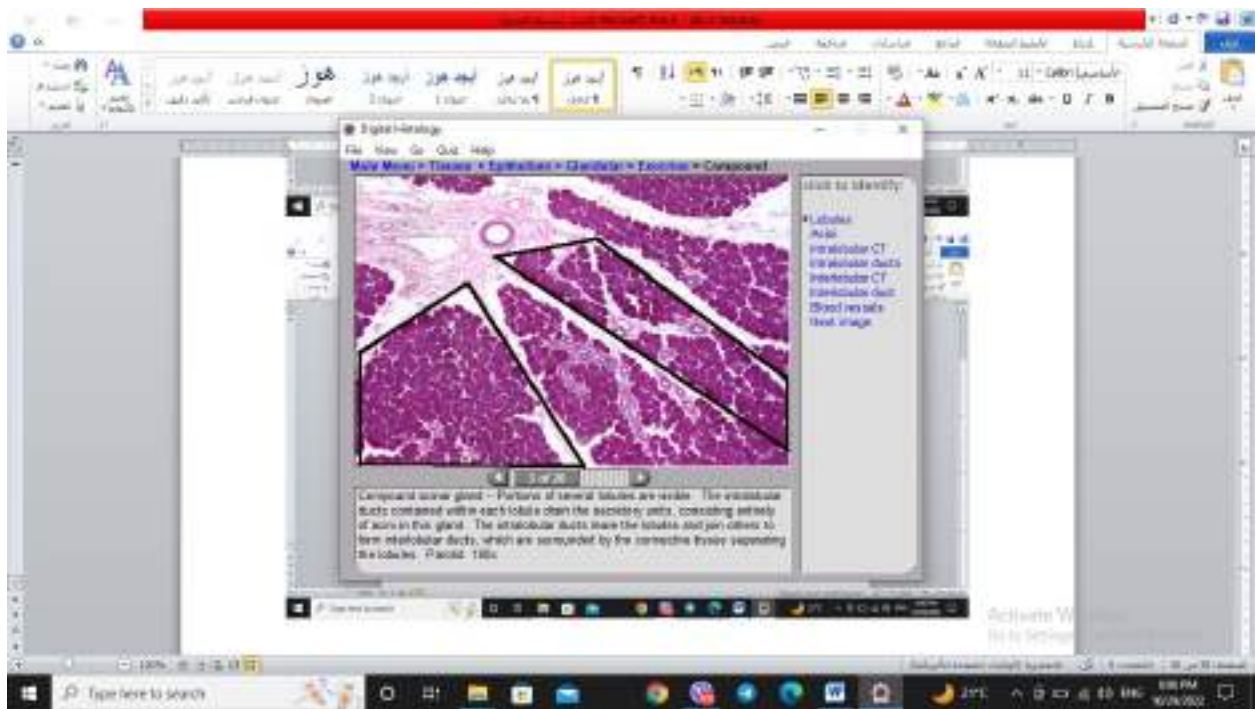


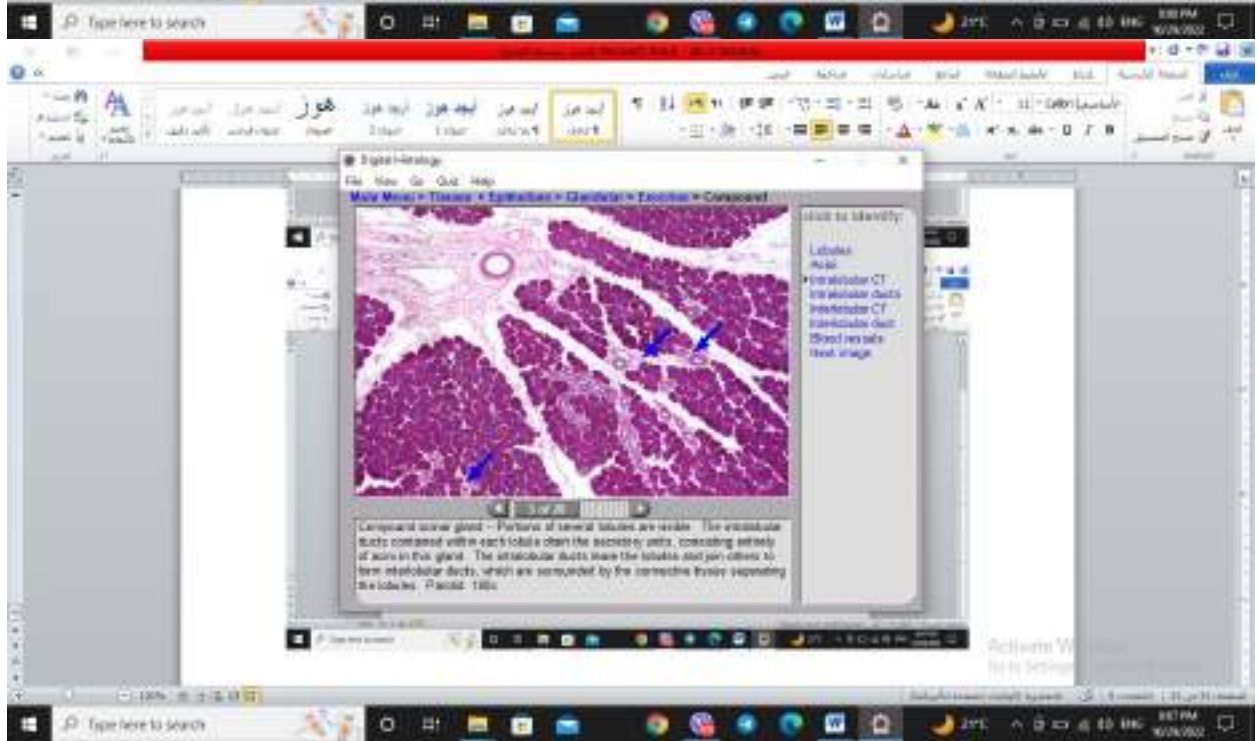
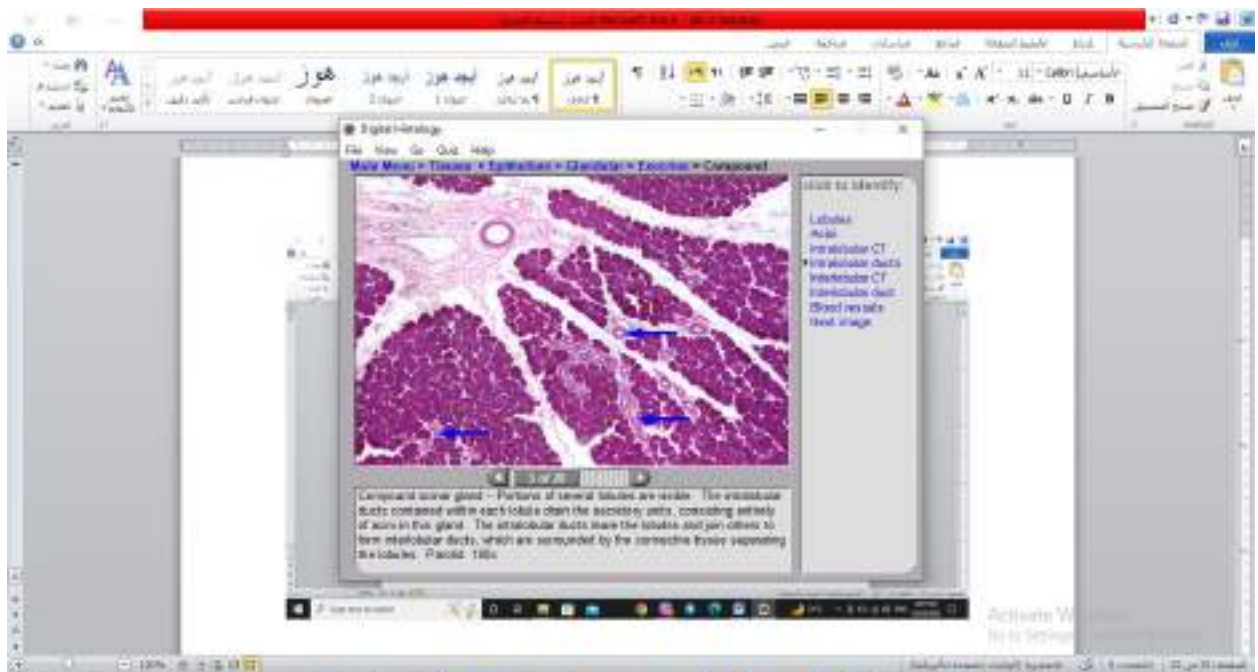


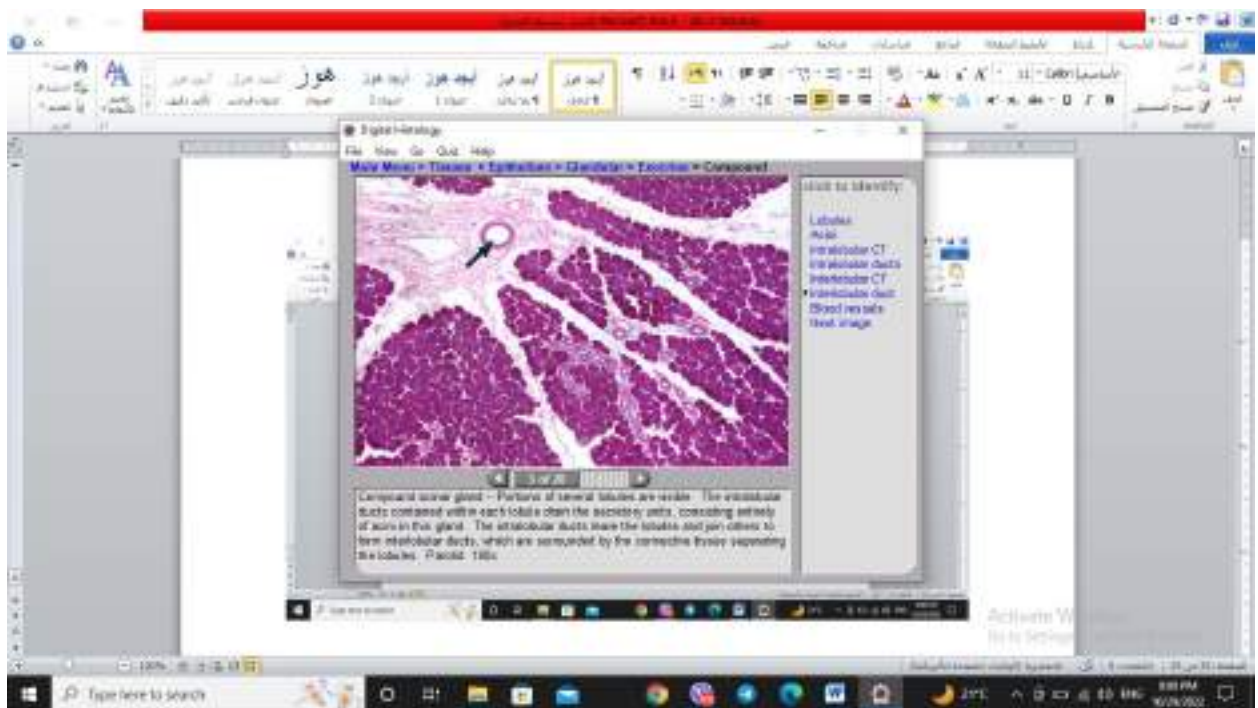
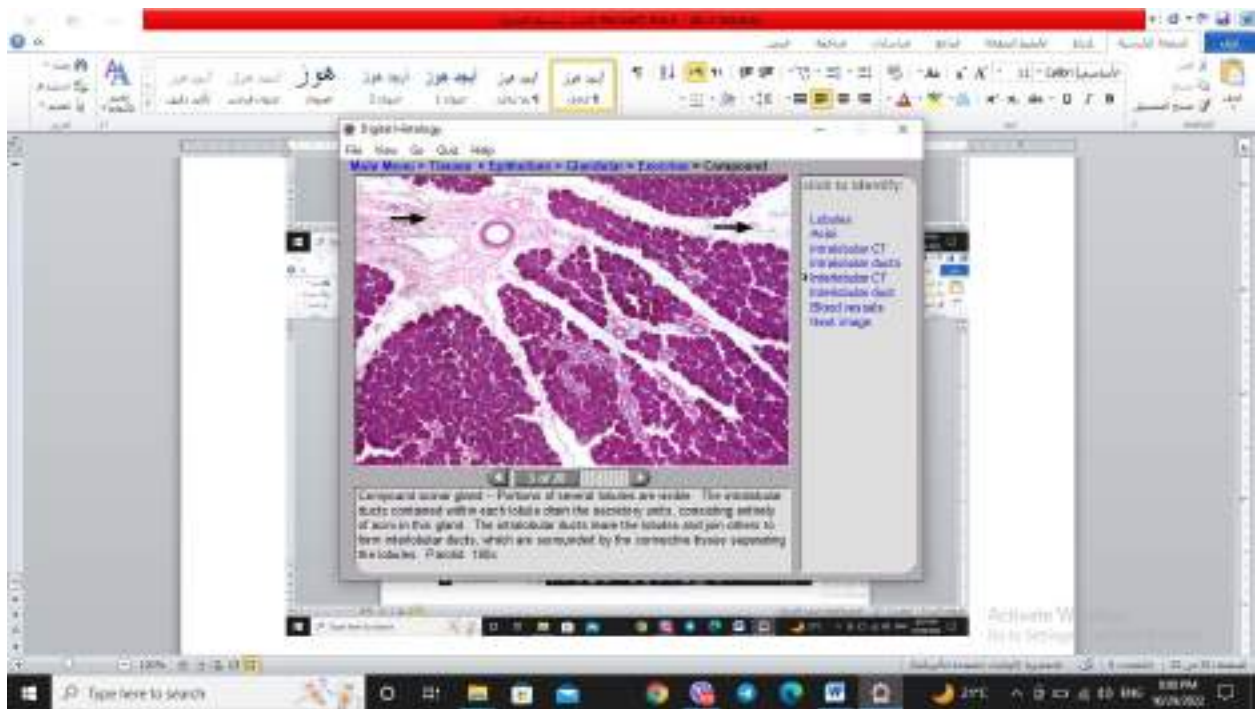


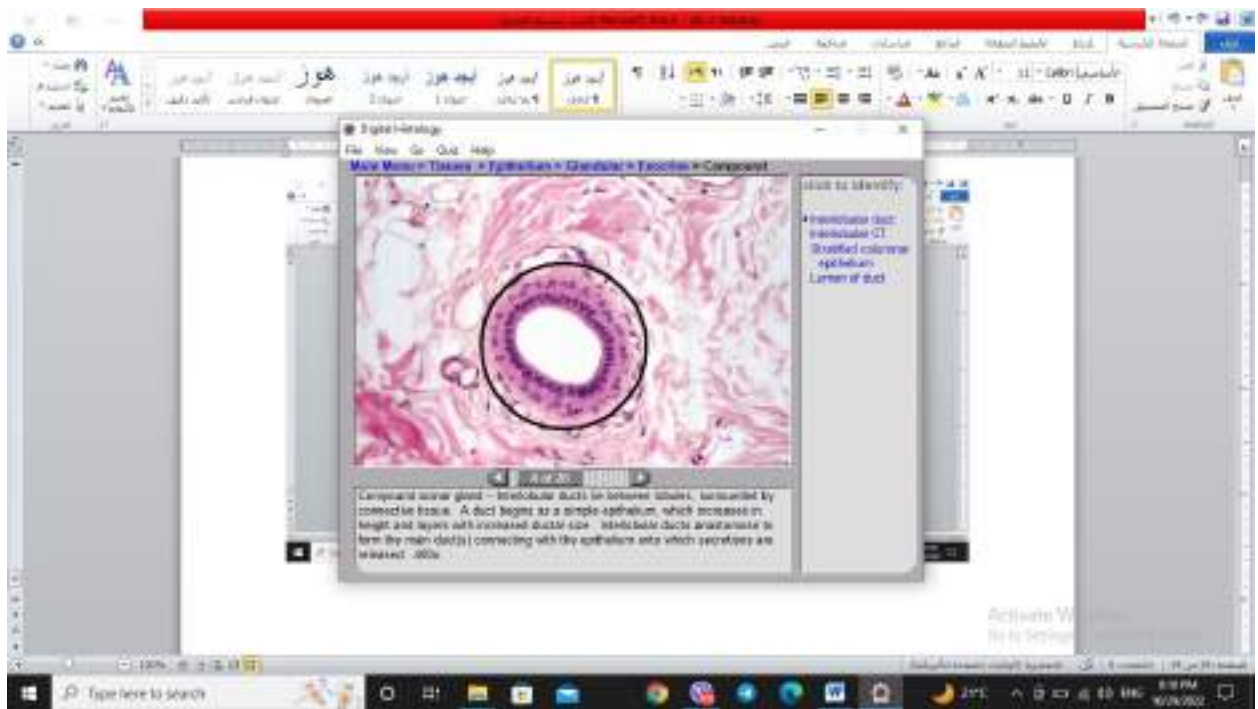
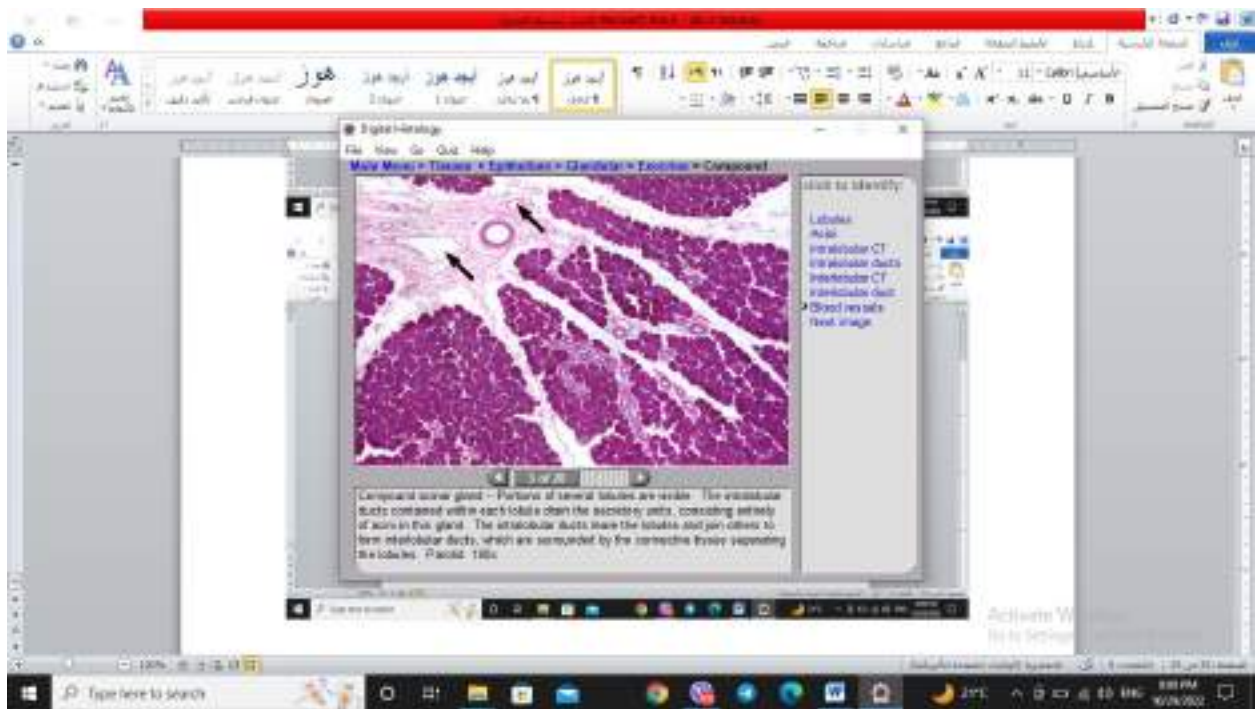


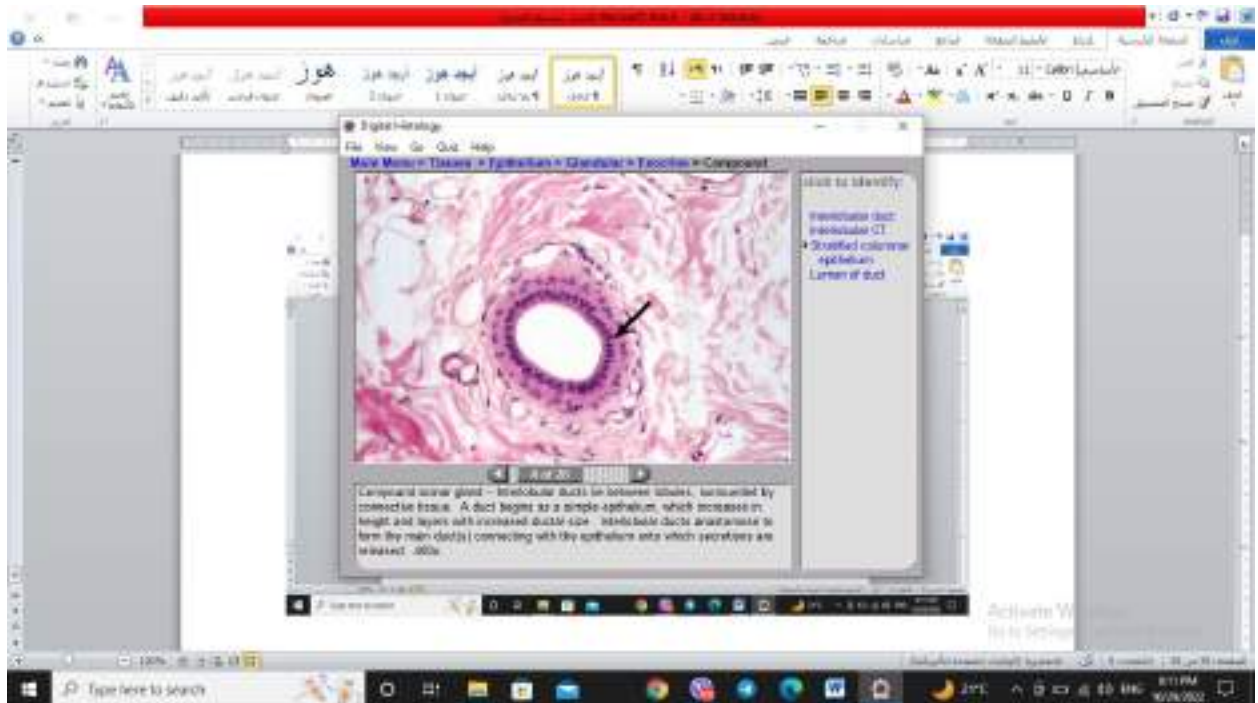
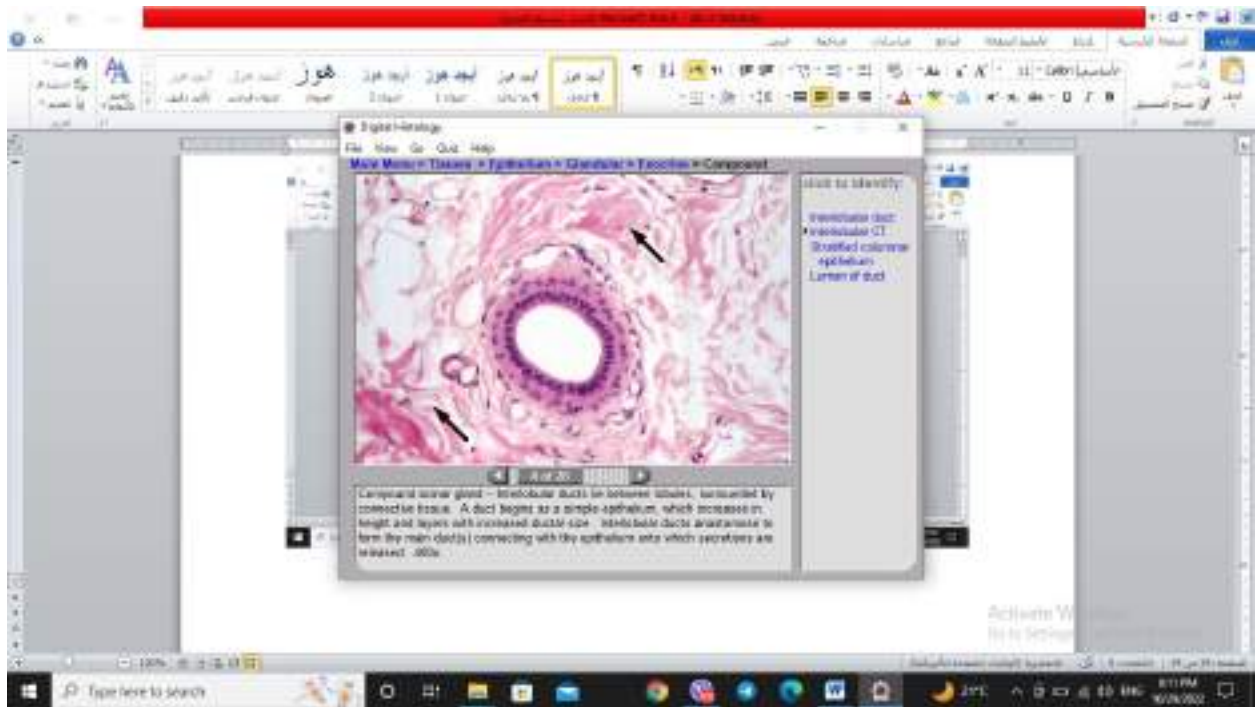


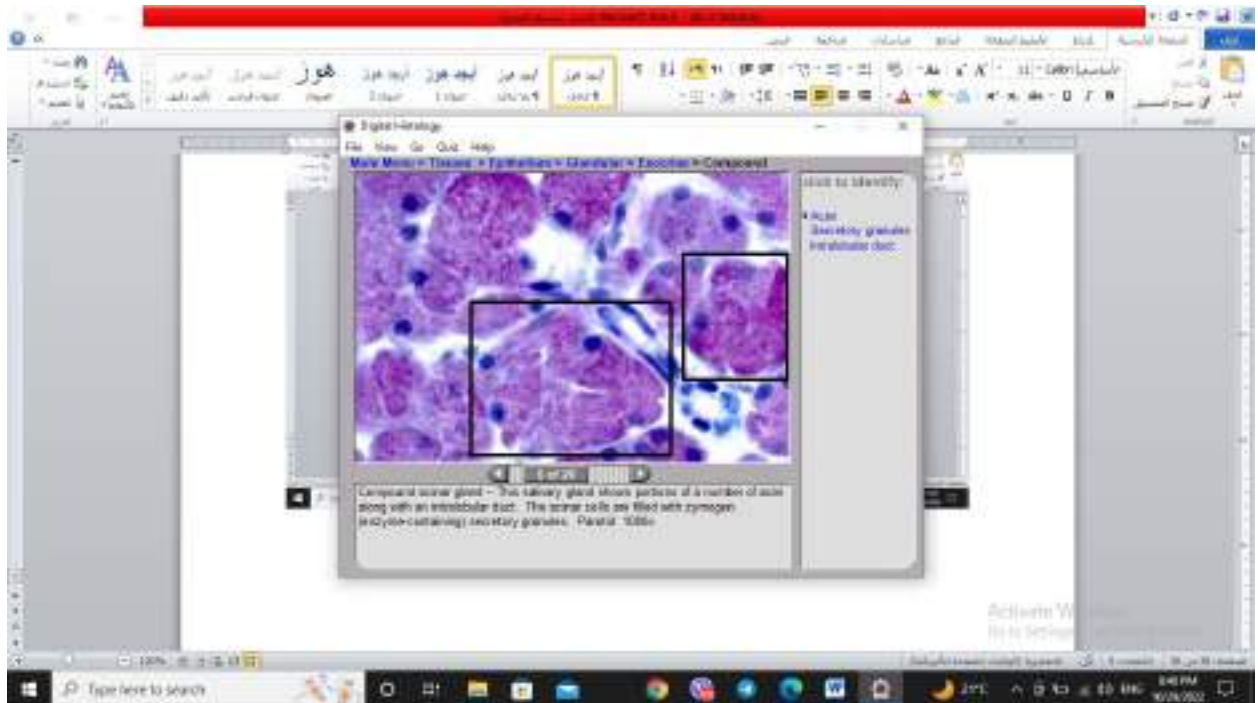
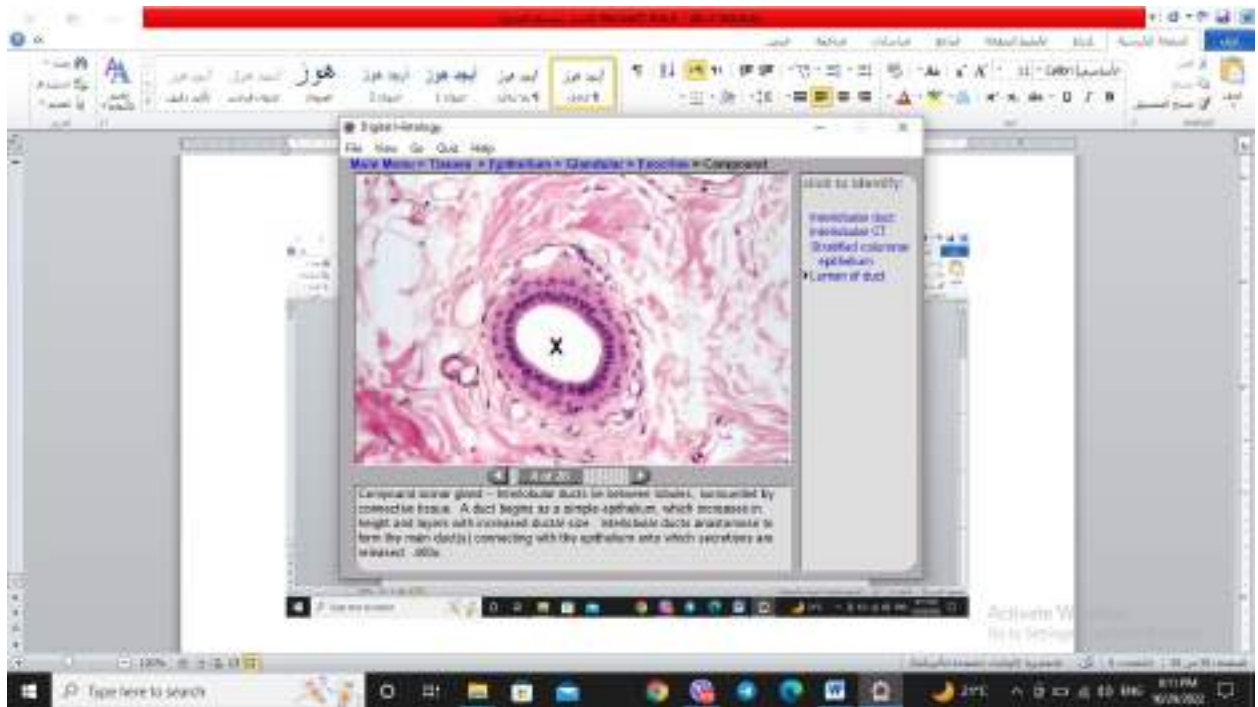


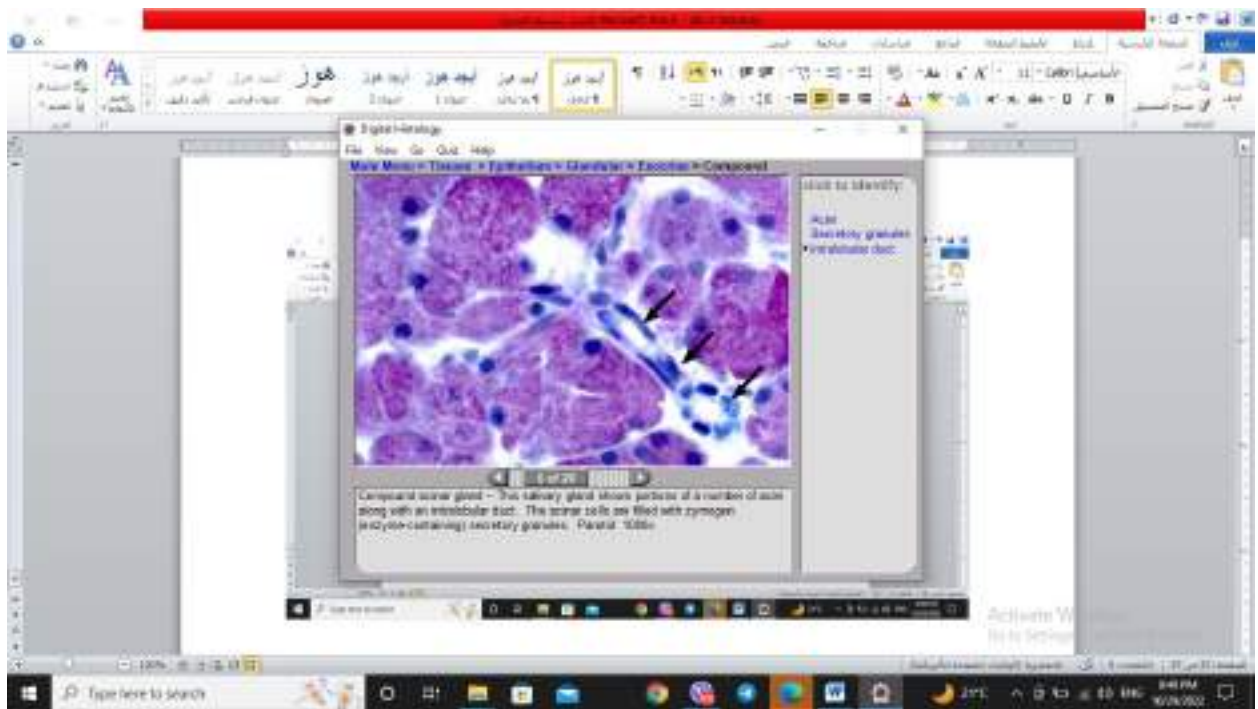
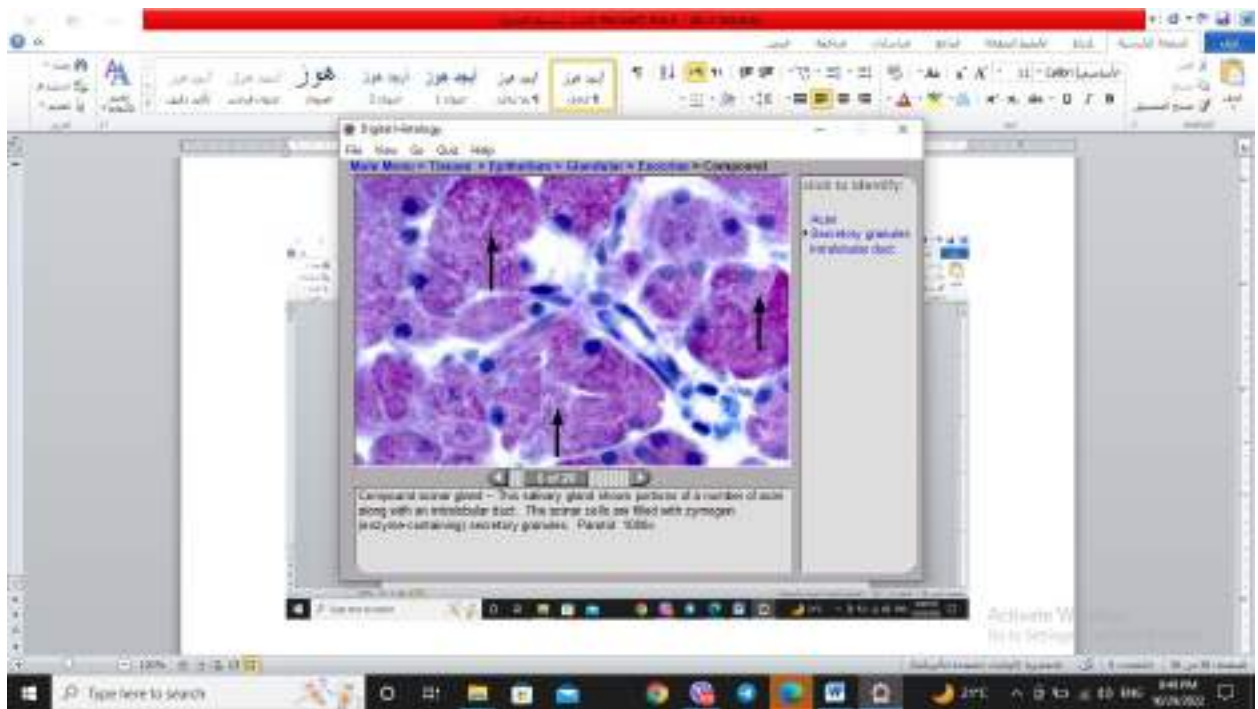


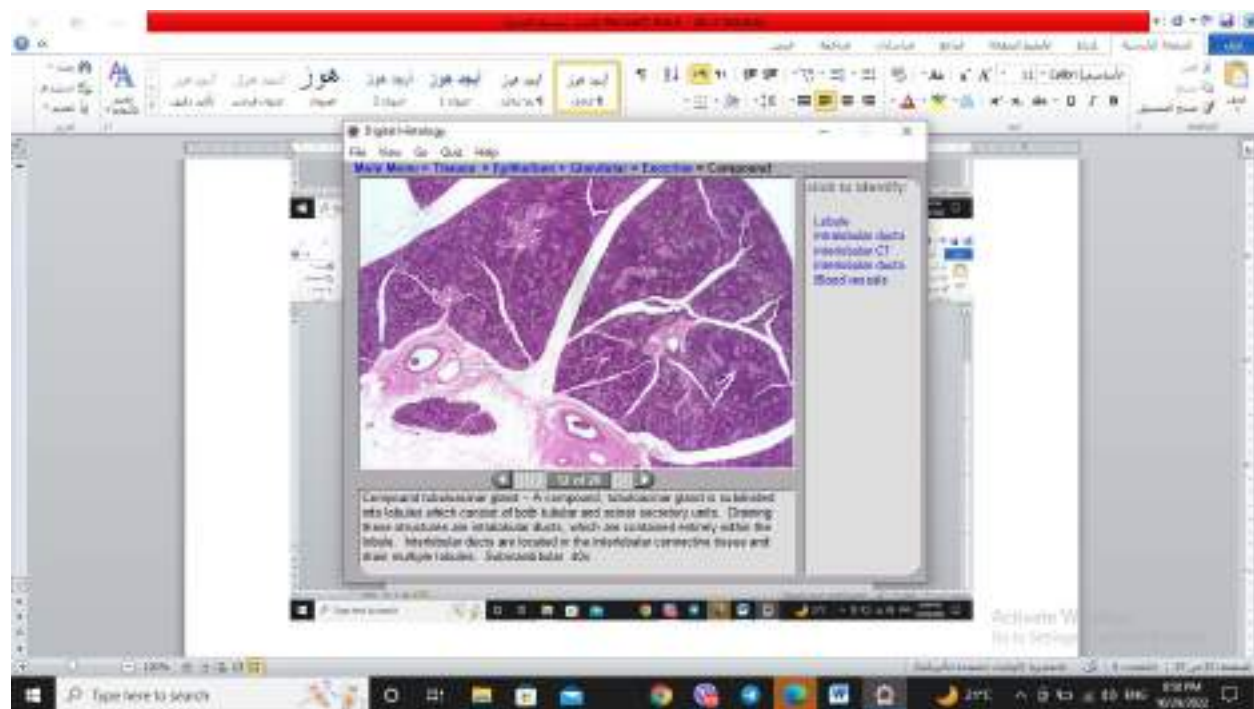


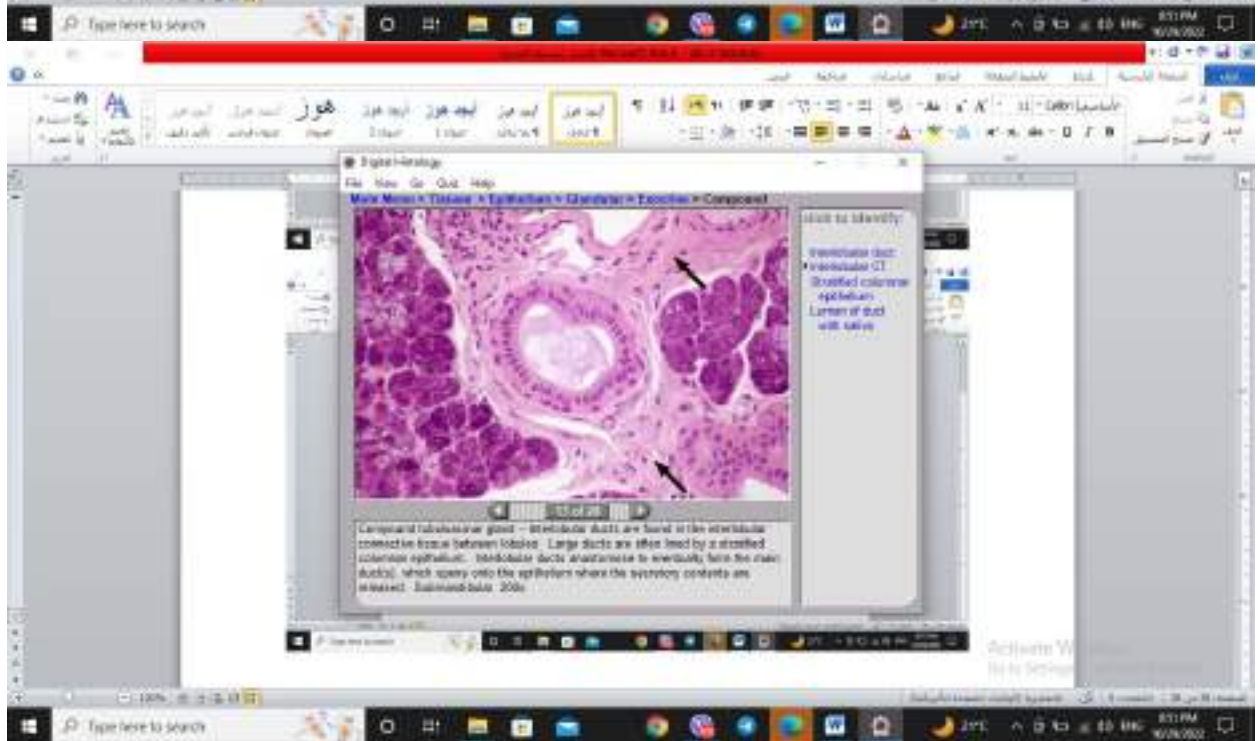
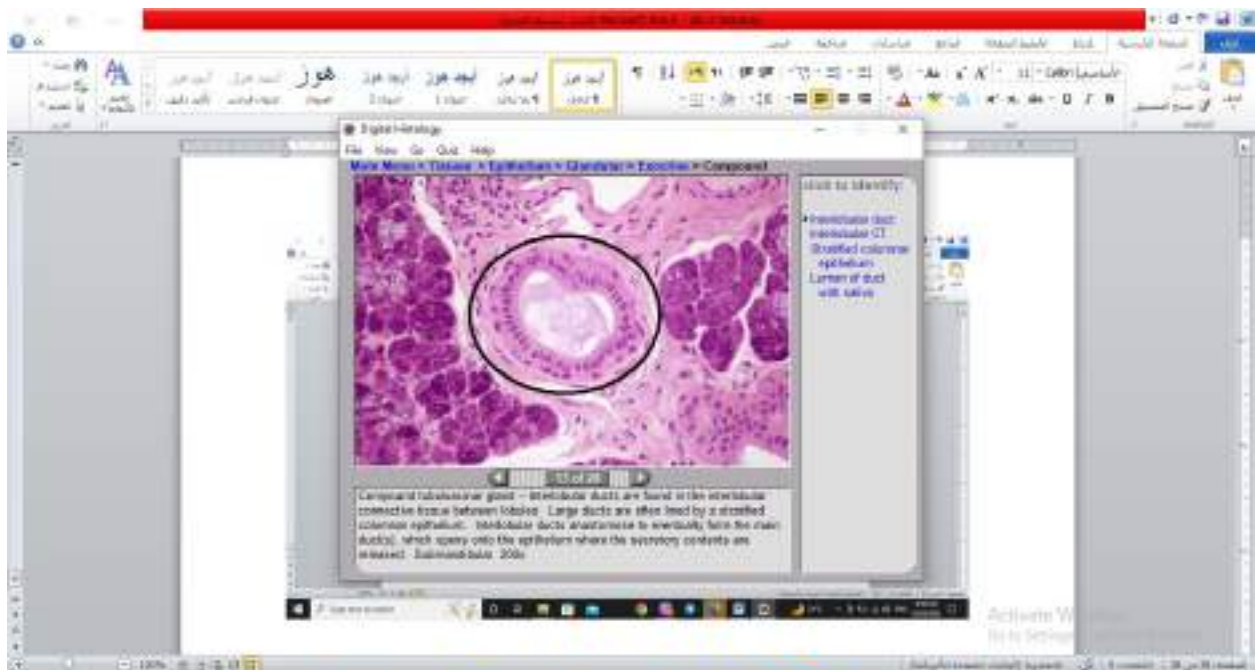


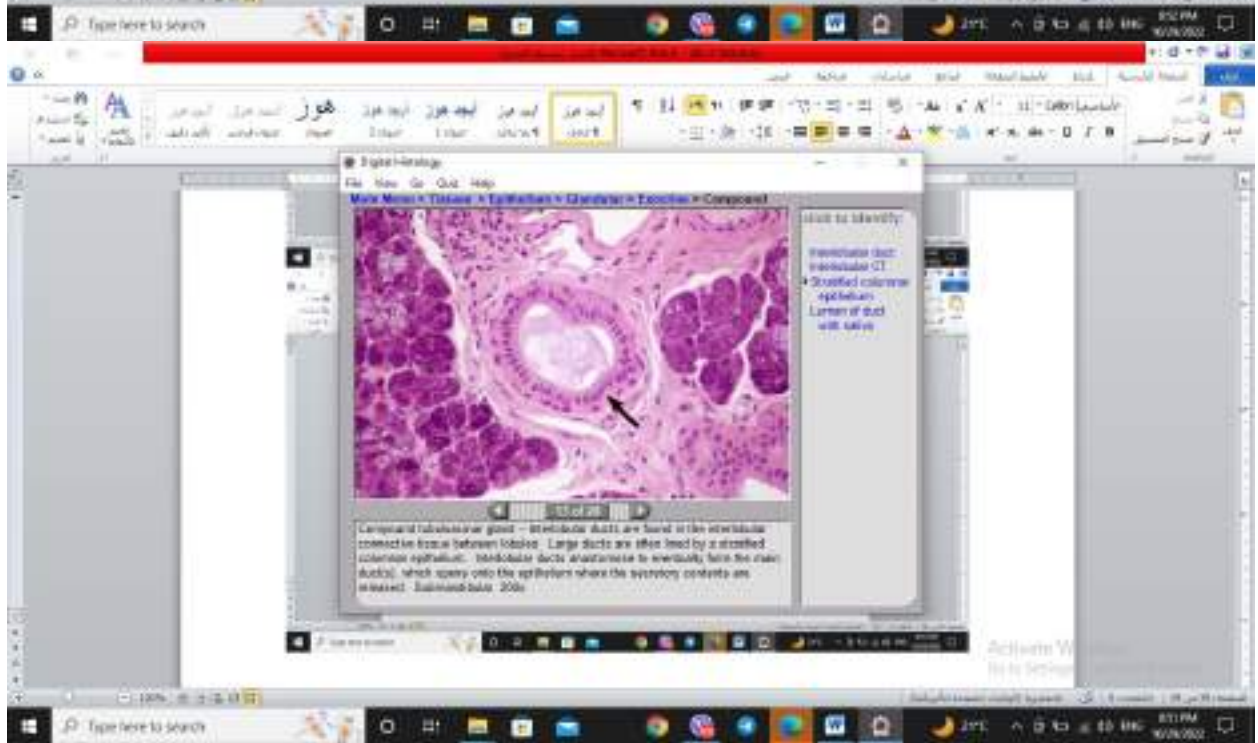
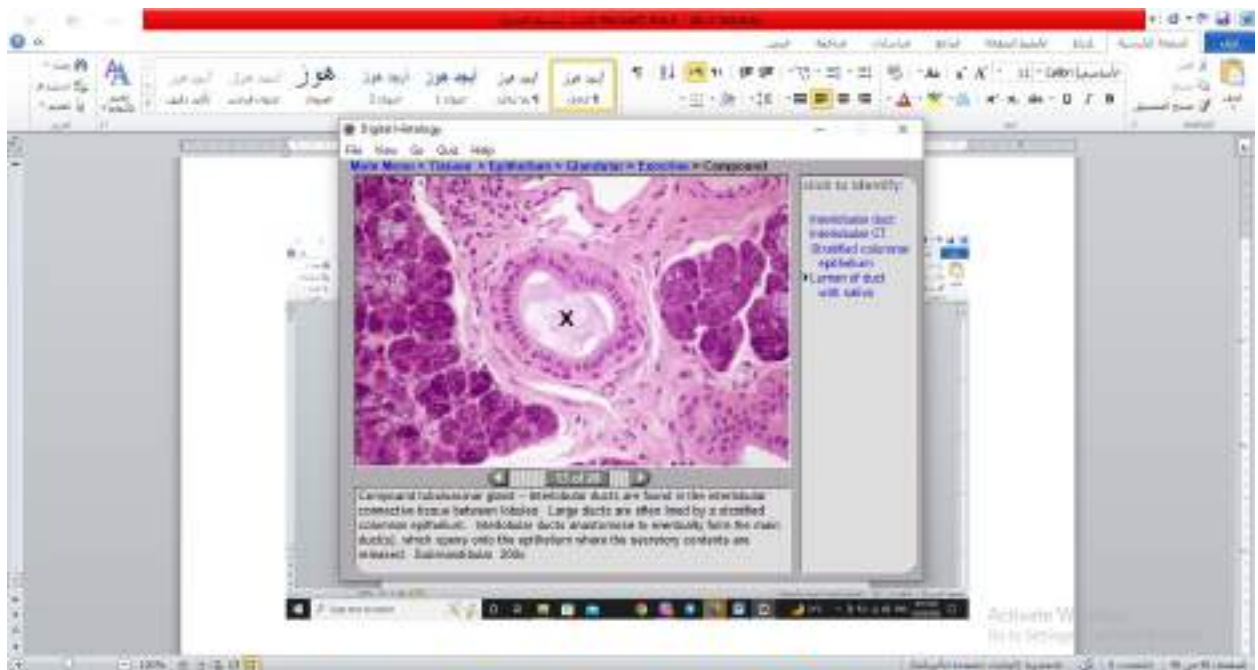


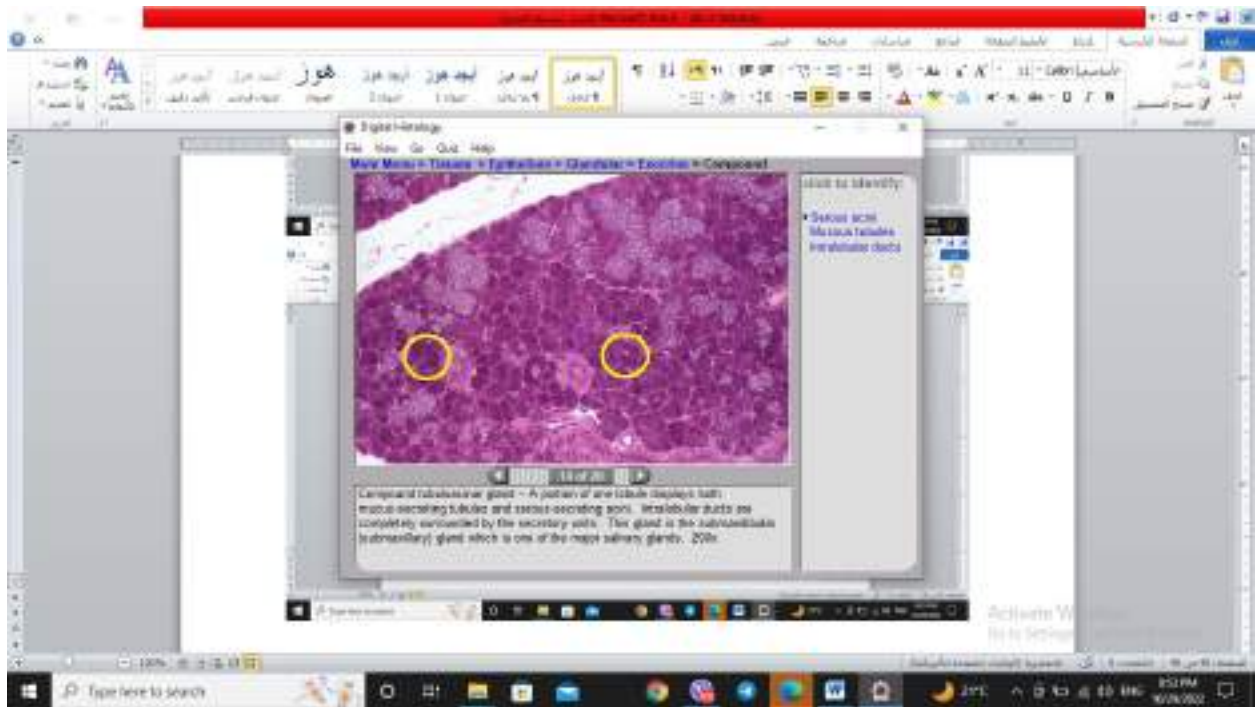


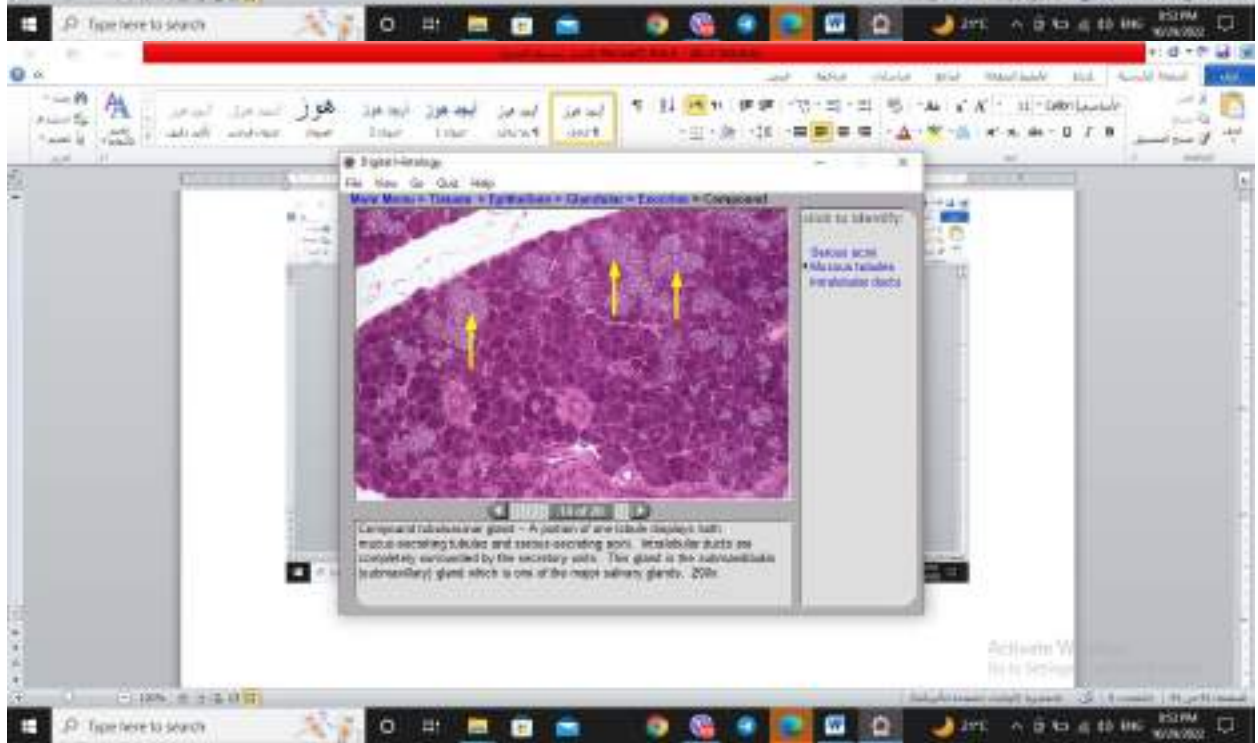
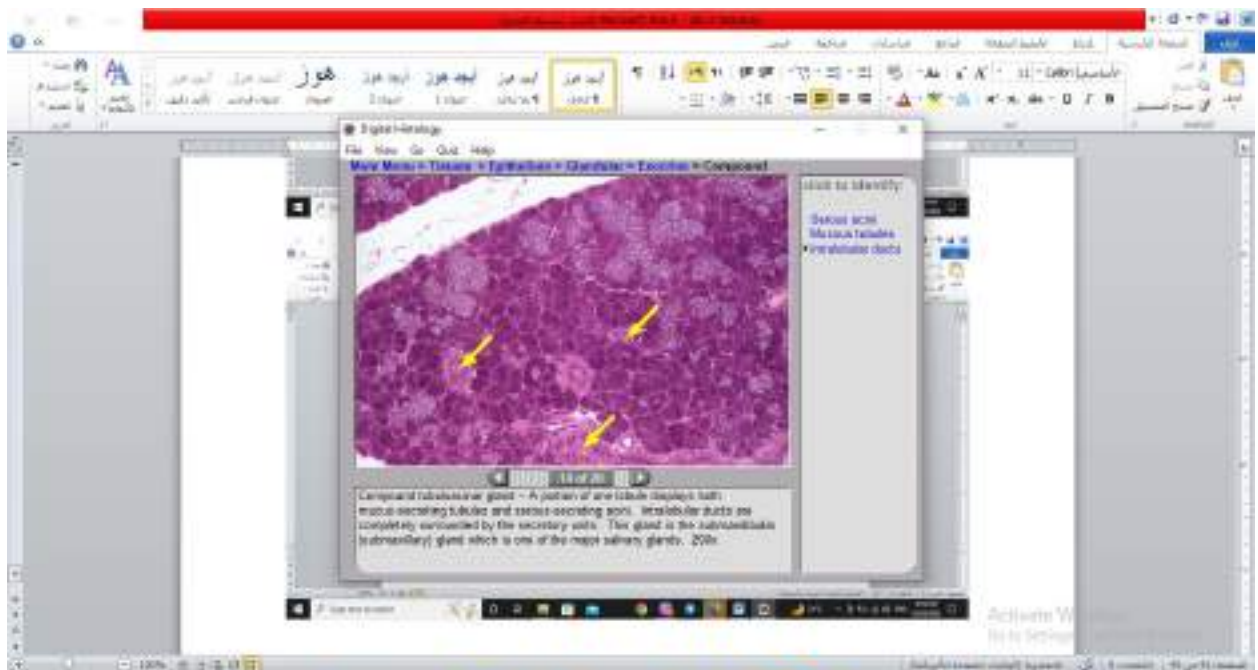


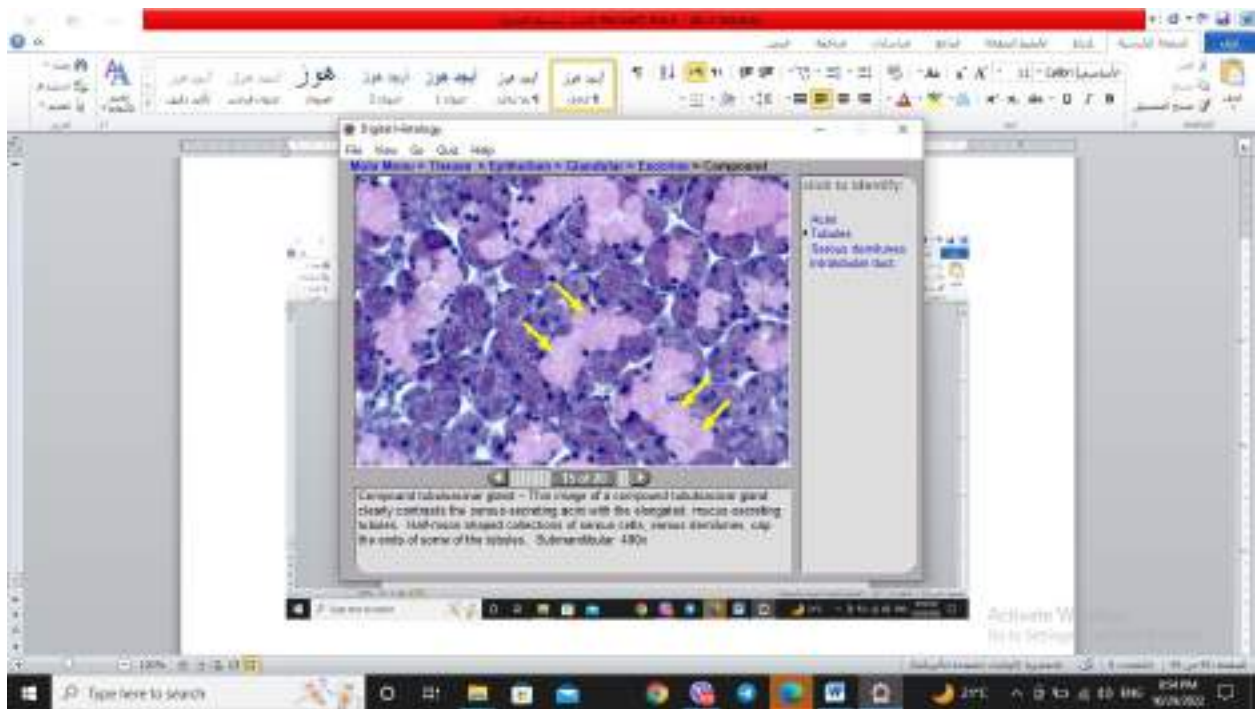
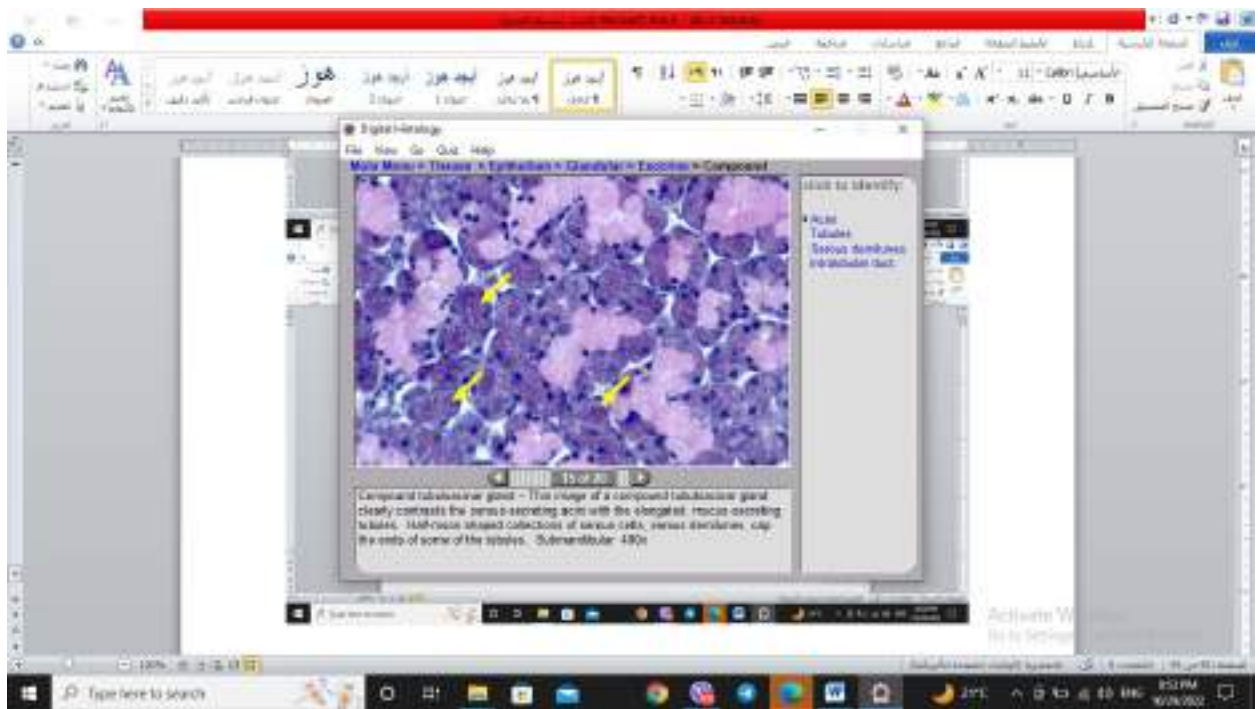


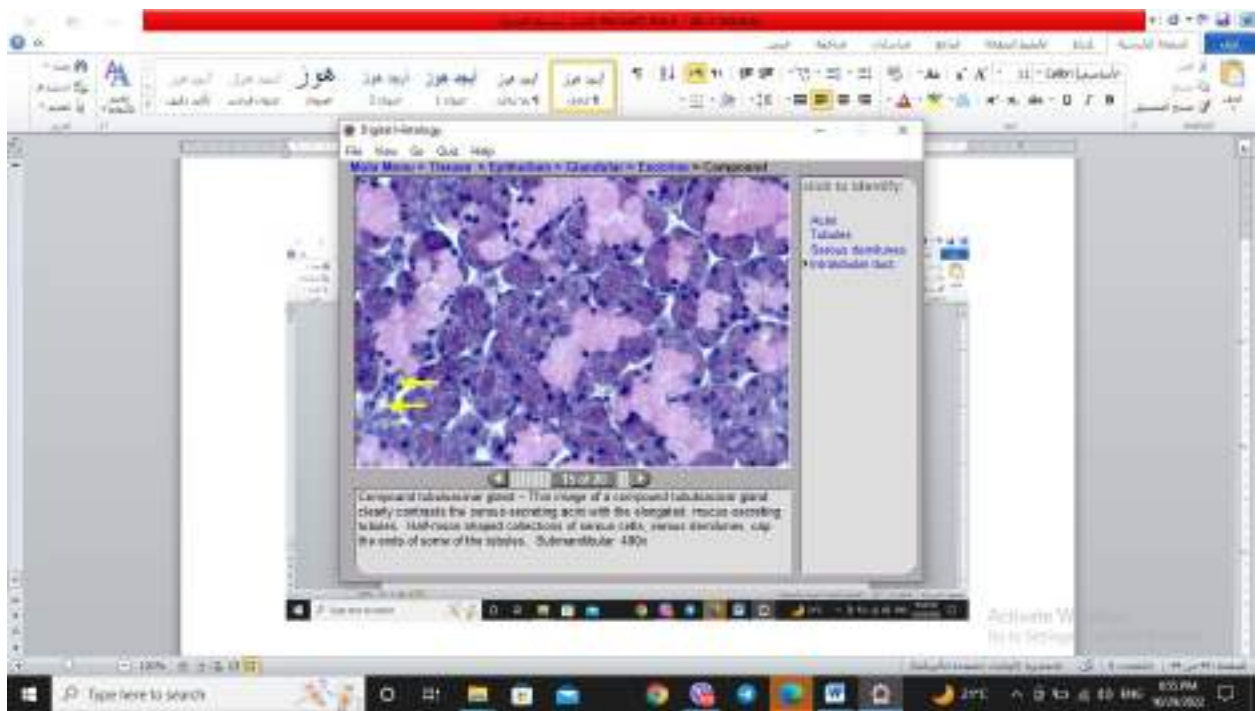
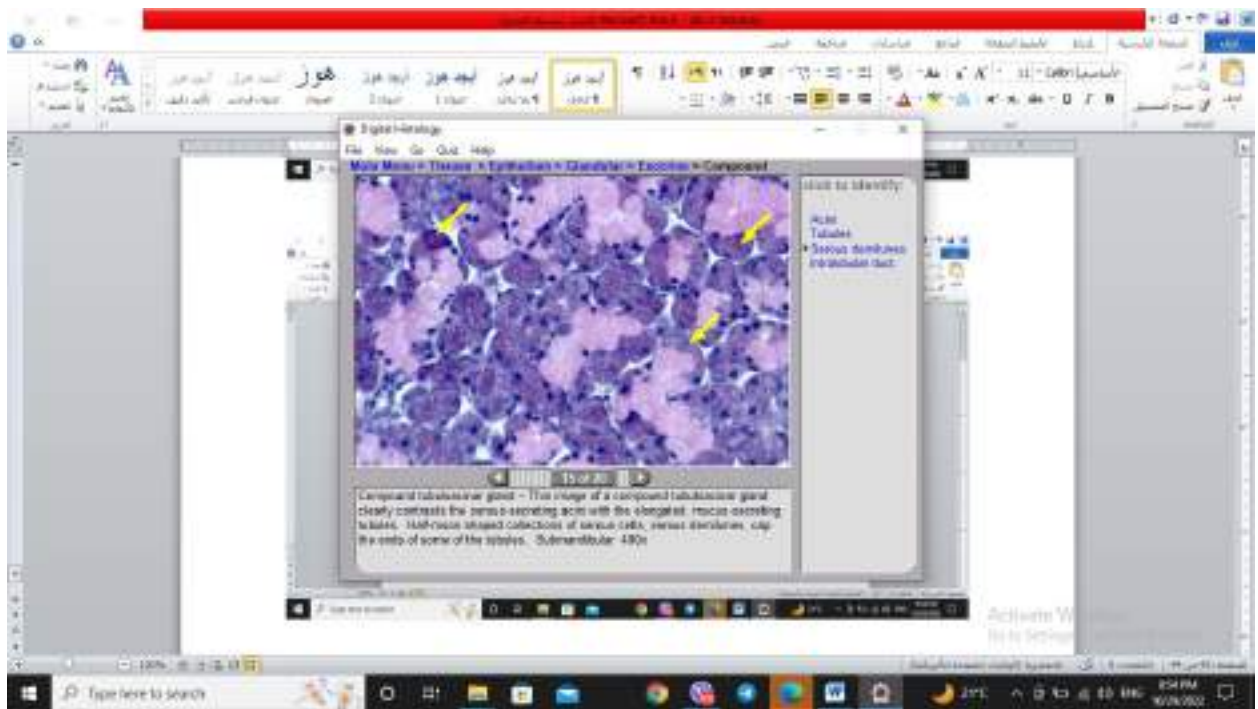


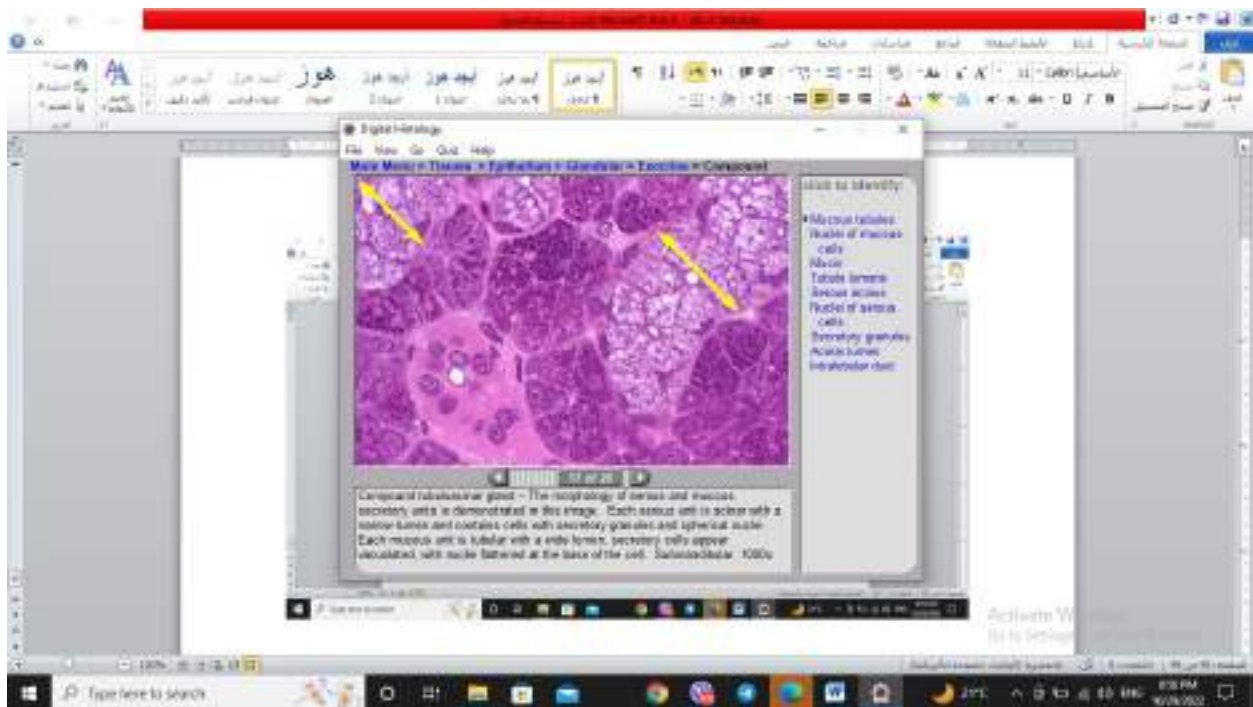
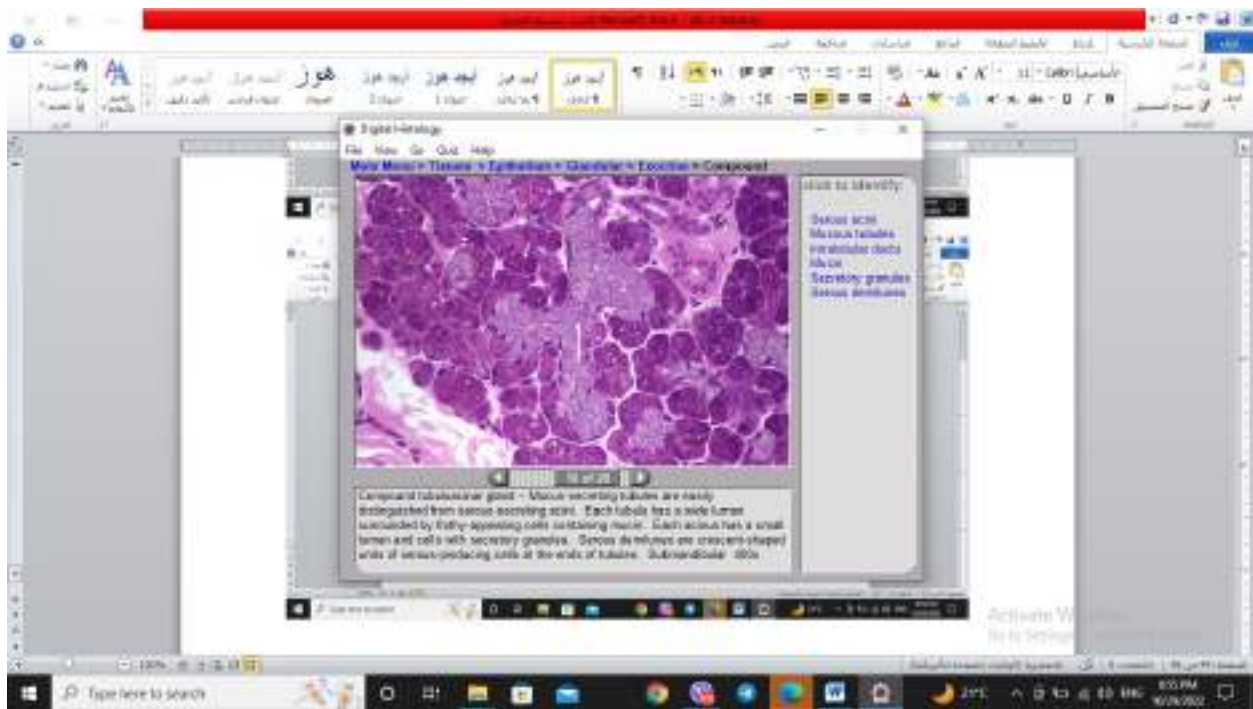


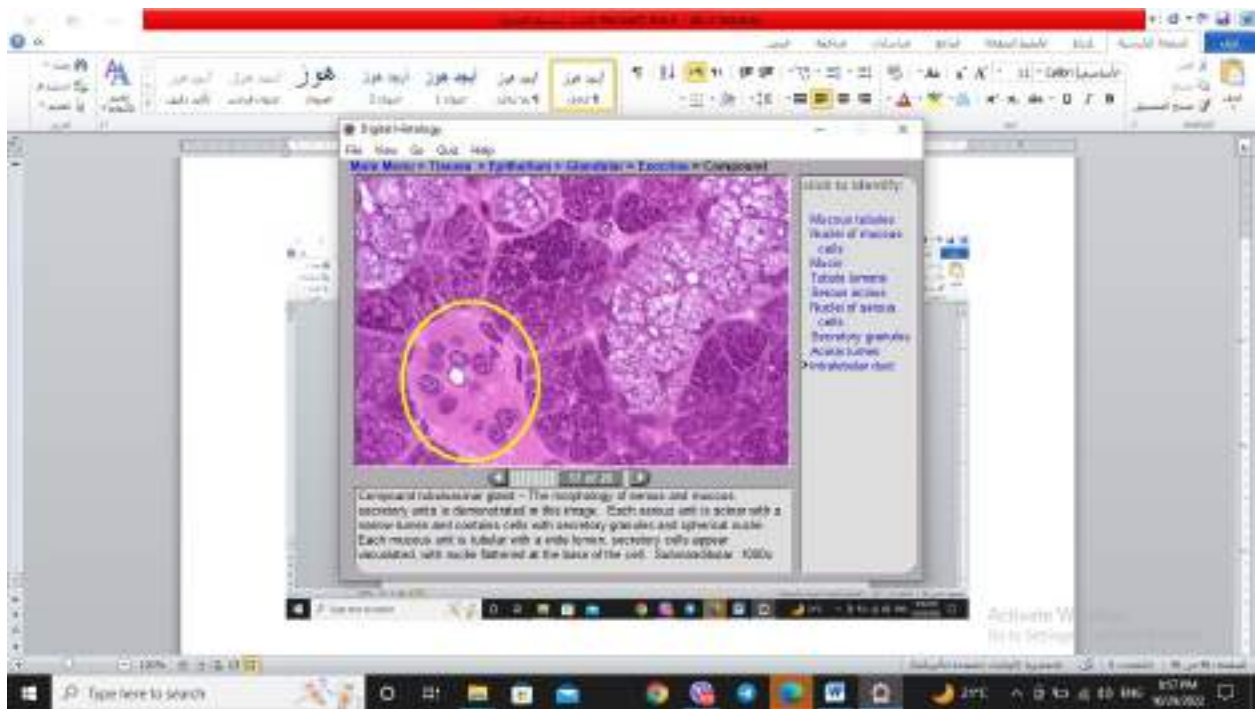
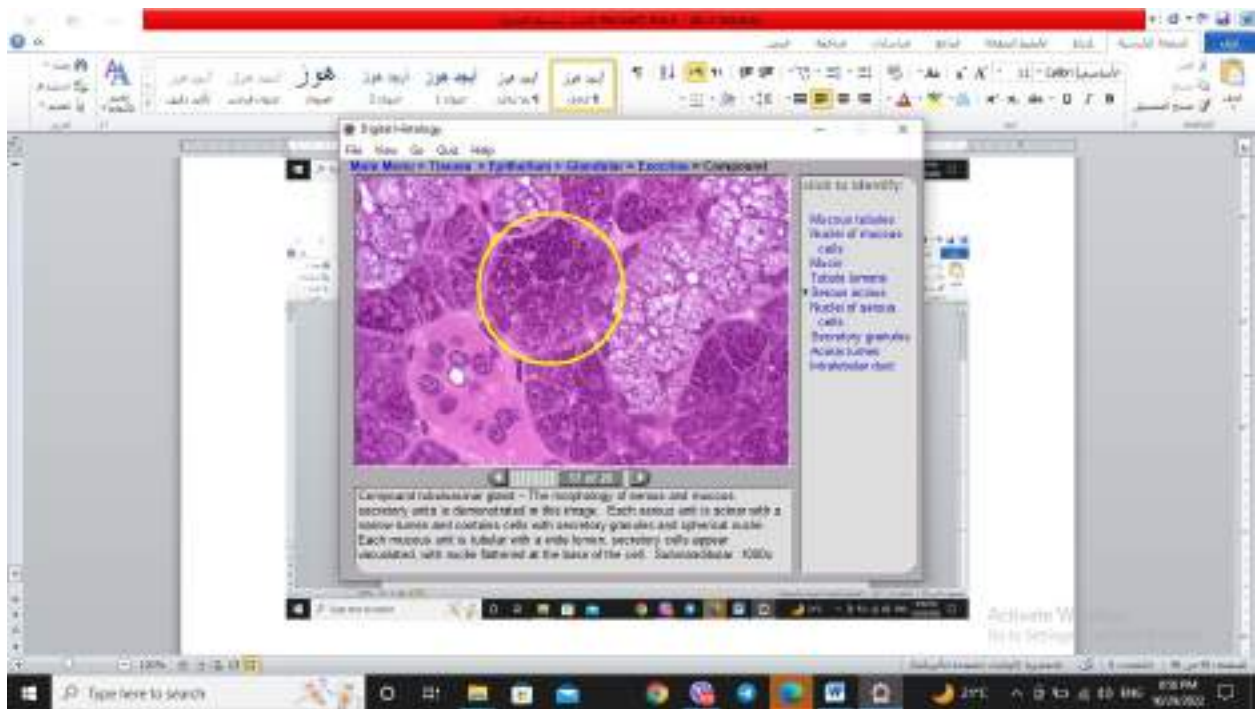


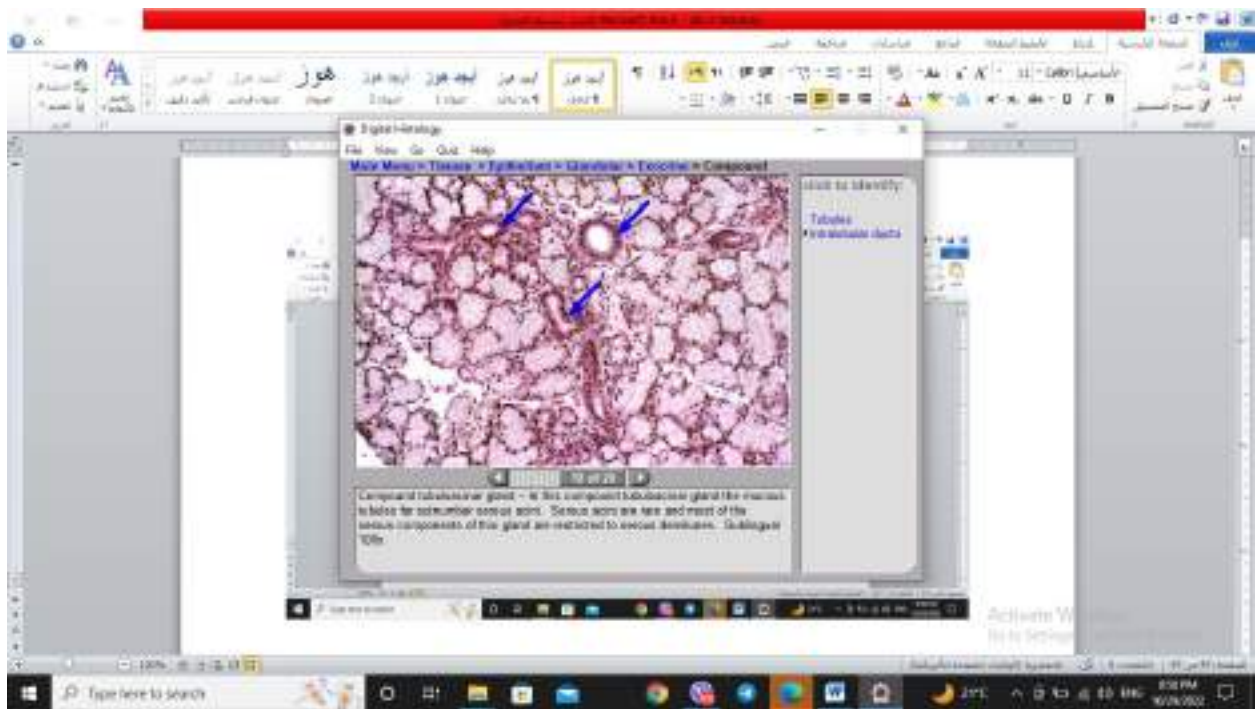
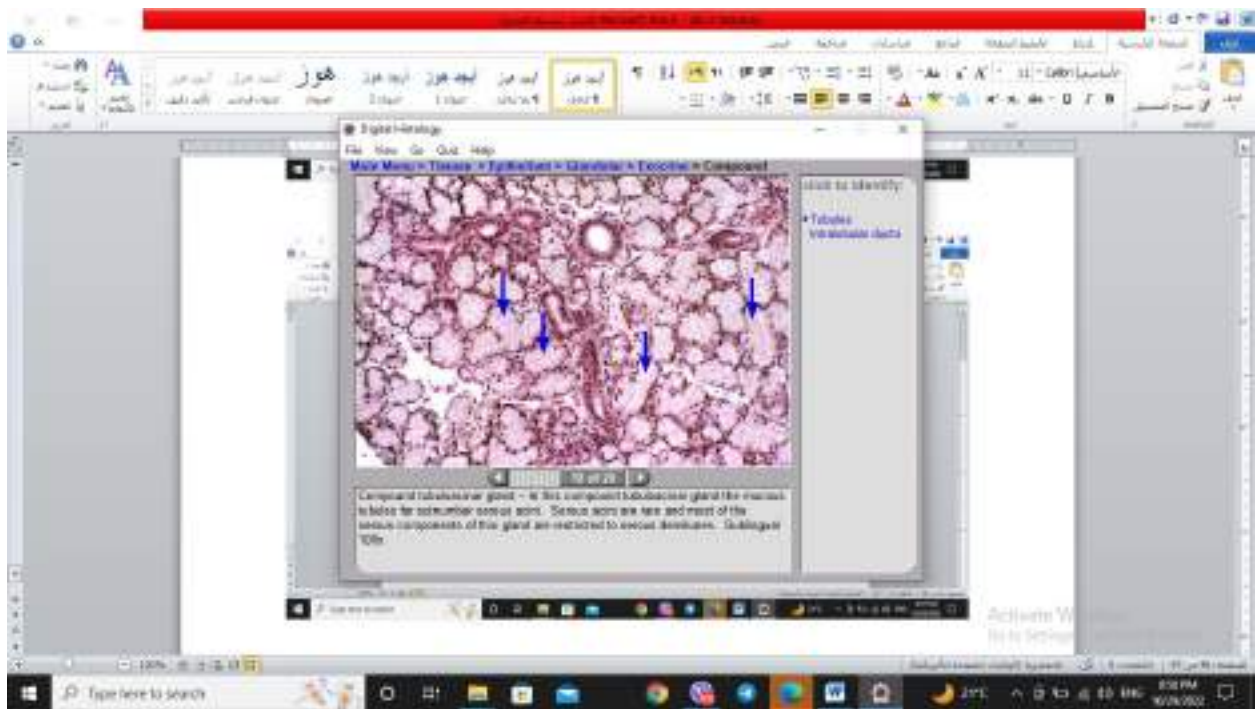


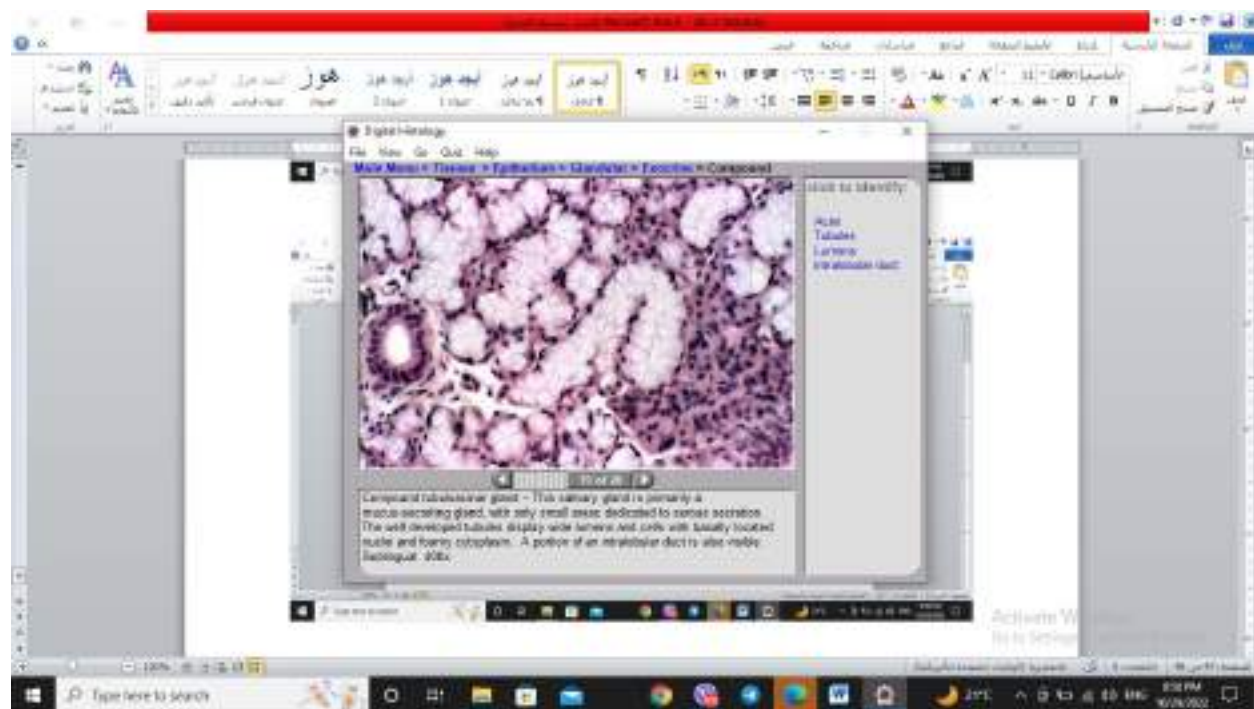








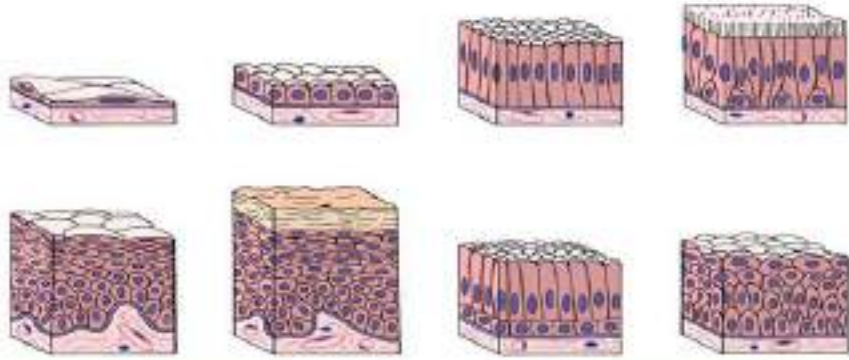




Digital Histology

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Overview



click to identify:

- Simple epithelia >
 - Squamous >
 - Cuboidal >
 - Columnar >
 - Pseudo- > stratified
- Stratified >
 - epithelia
 - Squamous > moist
 - Squamous dry >
 - Columnar >
 - Transitional >
- Basement > membrane

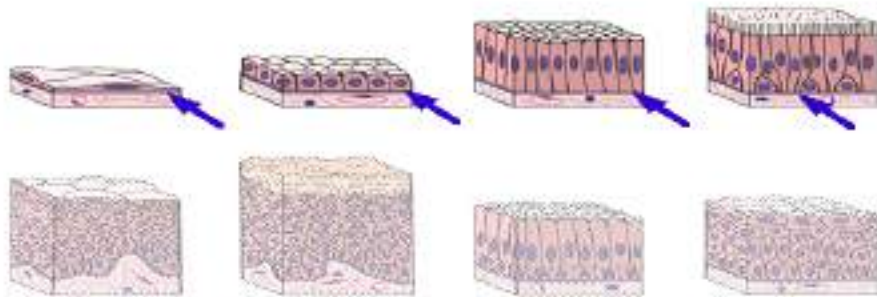
1 of 1

Surface epithelia — Surface epithelia, covering the body exterior and lining all interior surfaces, are classified by the shape of the cells immediately facing the lumen or surface and by the number of cell layers composing the epithelium. All epithelia show polarity, are avascular, and rest on a basement membrane that they produce with the underlying connective tissue.

Digital Histology

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Overview

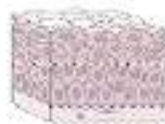
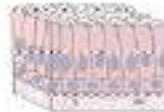


click to identify:

- > Simple epithelia >
 - Squamous >
 - Cuboidal >
 - Columnar >
 - Pseudo- > stratified
- Stratified >
 - epithelia
 - Squamous > moist
 - Squamous dry >
 - Columnar >
 - Transitional >
- Basement > membrane

1 of 1

Simple epithelia consist of a single layer of cells resting on a basement membrane (arrows). The cells may be squamous shaped (like a fried egg), cuboidal, or columnar. Simple epithelia may have surface modifications such as microvilli and cilia.

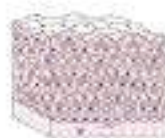


1 of 1

Simple squamous epithelium consists of a single layer of flattened cells with a very thin cytoplasm, resembling the white of a fried egg; the nucleus of the squamous cell, bulging into the lumen, is analogous to the egg yolk. Because of its thinness, simple squamous epithelium lines structures across which rapid transport is required, such as capillaries and lung alveoli.

click to identify:

- Simple epithelia >
- > Squamous >
- > Cuboidal >
- > Columnar >
- > Pseudo- >
- > stratified
- Stratified >
- epithelia
- Squamous >
- moist
- Squamous dry >
- Columnar >
- Transitional >
- Basement >
- membrane

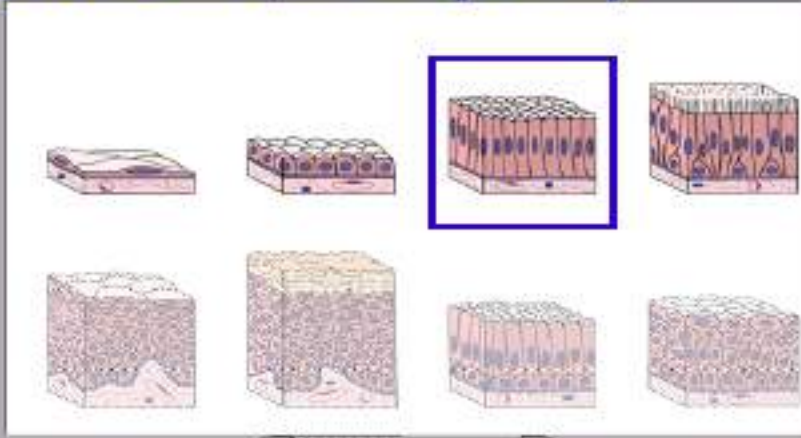


1 of 1

Simple cuboidal epithelium consists of a single layer of cuboidal-shaped cells. Simple cuboidal epithelium lines small ducts and many of the tubules in the kidney that are involved with absorption.

click to identify:

- Simple epithelia >
- Squamous >
- > Cuboidal >
- > Columnar >
- > Pseudo- >
- > stratified
- Stratified >
- epithelia
- Squamous >
- moist
- Squamous dry >
- Columnar >
- Transitional >
- Basement >
- membrane

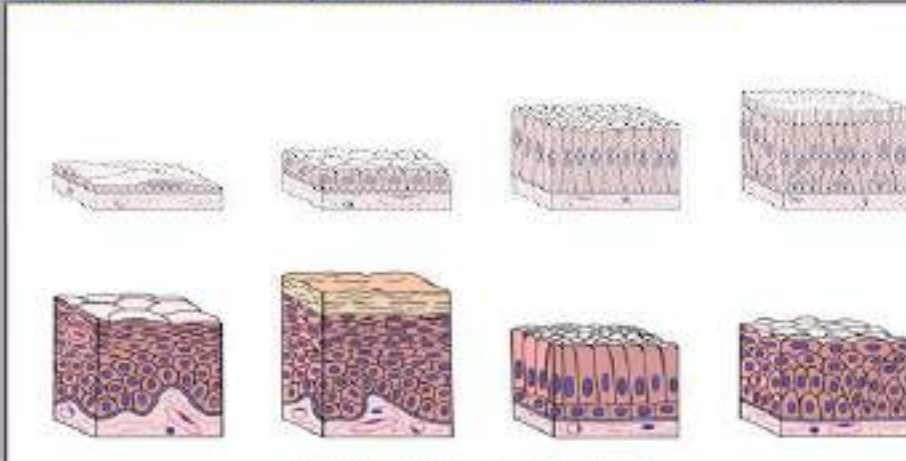


1 of 1

Simple columnar epithelium is composed of a single layer of columnar-shaped cells. The oval nuclei in this epithelium are usually located in the basal half to the center of each cell. Simple columnar epithelium may possess microvilli, such as in the small intestine where they aid in absorption of digested food, or cilia, such as in the oviduct where they transport germ cells.

click to identify:

- Simple epithelia >
- Squamous >
- Cuboidal >
- Columnar >
- Pseudo- >
- stratified
- Stratified >
- epithelia
- Squamous >
- moist
- Squamous dry >
- Columnar >
- Transitional >
- Basement >
- membrane



1 of 1

Stratified epithelia are composed of two or more cell layers and are classified by the shape of the surface layer of cells. Stratified epithelia are not involved with transport or absorption but provide a protective layer to the underlying tissues.

click to identify:

- Simple epithelia >
- Squamous >
- Cuboidal >
- Columnar >
- Pseudo- >
- stratified
- Stratified >
- epithelia
- Squamous >
- moist
- Squamous dry >
- Columnar >
- Transitional >
- Basement >
- membrane

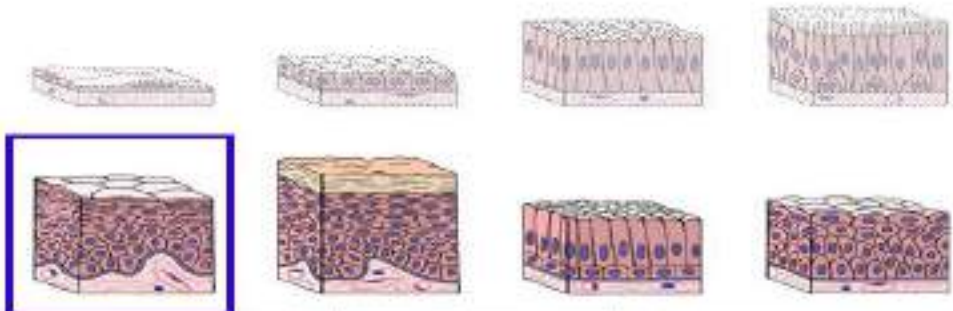
Digital Histology

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Overview

click to identify:

- Simple epithelia >
- Squamous >
- Cuboidal >
- Columnar >
- Pseudo- >
- stratified
- Stratified >
- epithelia
- > Squamous >
- moist
- Squamous dry >
- Columnar >
- Transitional >
- Basement >
- membrane



1 of 1

Stratified squamous moist (or nonkeratinized) epithelium consists of multiple layers; cells in the uppermost layer are living and squamous in shape. This epithelium is designated "moist," because it usually has glands that lubricate and moisturize its surface. This epithelium lines any interior body surface that requires strong protection, such as the esophagus and vagina.

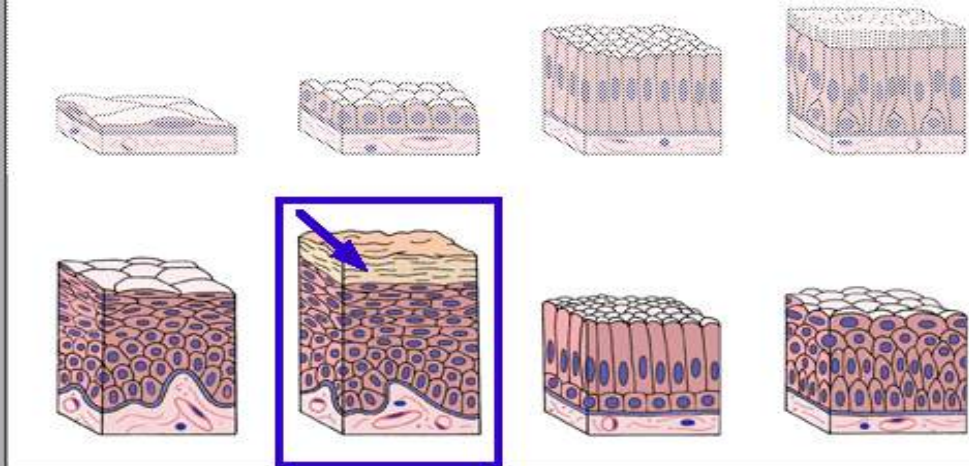
Digital Histology

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Overview

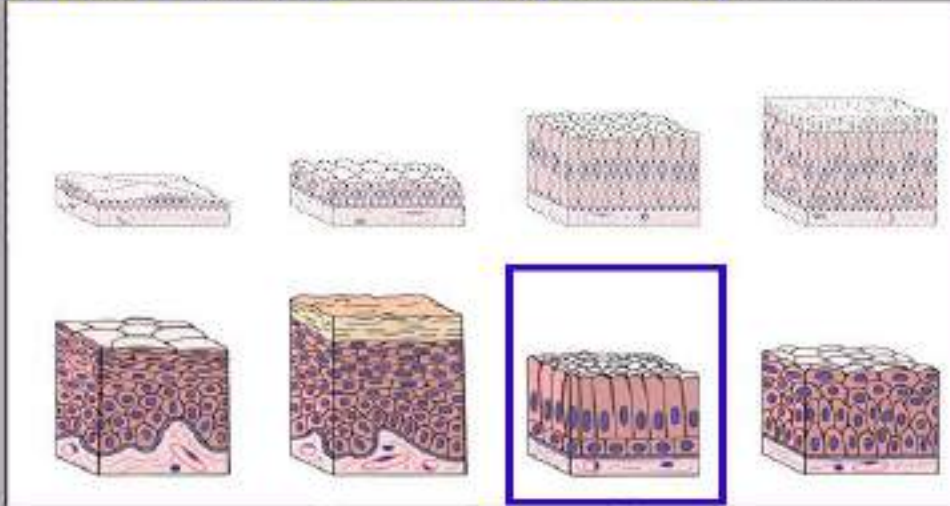
click to identify:

- Simple epithelia >
- Squamous >
- Cuboidal >
- Columnar >
- Pseudo- >
- stratified
- Stratified >
- epithelia
- Squamous >
- moist
- > Squamous dry >
- Columnar >
- Transitional >
- Basement >
- membrane



1 of 1

Stratified squamous dry (or keratinized) epithelium is composed of multiple layers; cells forming this tissue flatten as they approach the surface. These epithelial cells produce a cornified layer at the surface that is composed of flattened, non-nucleated, dead cells filled with keratin (arrow). Stratified squamous keratinized epithelium is part of skin.



click to identify:

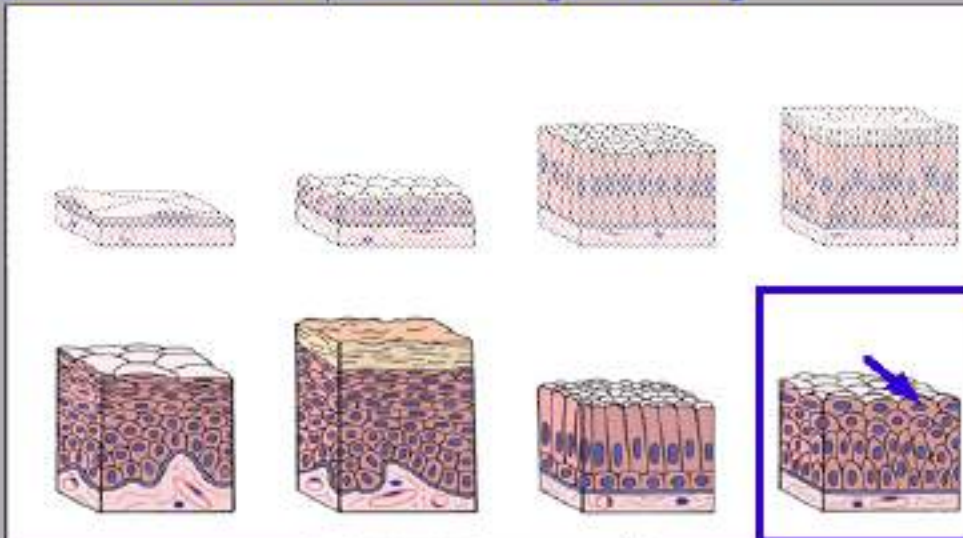
- Simple epithelia >
- Squamous >
- Cuboidal >
- Columnar >
- Pseudo- >
- stratified
- Stratified >
- epithelia
- Squamous >
- moist
- Squamous dry >
- Columnar >
- Transitional >
- Basement >
- membrane

1 of 1

Stratified columnar epithelium is composed of multiple layers, the uppermost of which is columnar-shaped. This epithelium is not found in a definitive location but is frequently seen in areas of epithelial transition, for example, in ducts as their linings are modified from a simple epithelium to a stratified squamous epithelium onto which the gland would secrete.

Digital Histology

File View Go Quiz Help

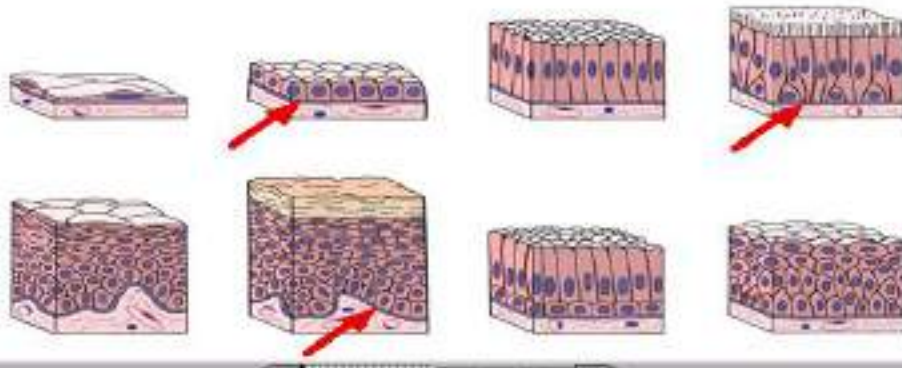


click to identify:

- Simple epithelia >
- Squamous >
- Cuboidal >
- Columnar >
- Pseudo- >
- stratified
- Stratified >
- epithelia
- Squamous >
- moist
- Squamous dry >
- Columnar >
- Transitional >
- Basement >
- membrane

1 of 1

Transitional epithelium is also classified as stratified cuboidal, because its surface cells frequently assume a cuboidal shape. Transitional epithelium lines urinary passages that distend. Surface cells are called dome cells (arrow), because of their bulging shape; these cells, however, flatten to a squamous shape when the epithelium is distended, thus the name transitional.

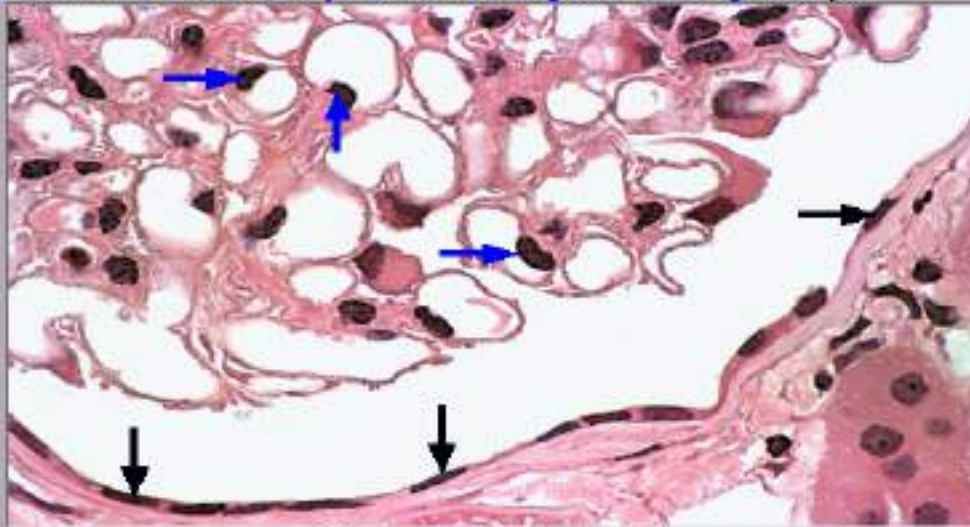


1 of 1

All epithelia rest on a basement membrane, which consists of a basal lamina, produced by the epithelial cells, and a reticular lamina, produced by fibroblasts in the underlying connective tissue. Because the basal lamina and reticular lamina cannot be resolved with the light microscope, the term basement membrane is used in light microscopy to refer to both of these structures, collectively.

click to identify:

Simple epithelia >
 Squamous >
 Cuboidal >
 Columnar >
 Pseudo- >
 stratified
 Stratified >
 epithelia
 Squamous >
 moist
 Squamous dry >
 Columnar >
 Transitional >
 > Basement >
 membrane



1 of 18

The simple squamous epithelium at the black arrows serves a lining function with no transport occurring across its surface. The simple squamous epithelia at the blue arrows line capillaries where much transport does occur.

click to identify:

> Simple >
 squamous
 epithelium
 Capillary lumens

Digital Histology

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple



click to identify:

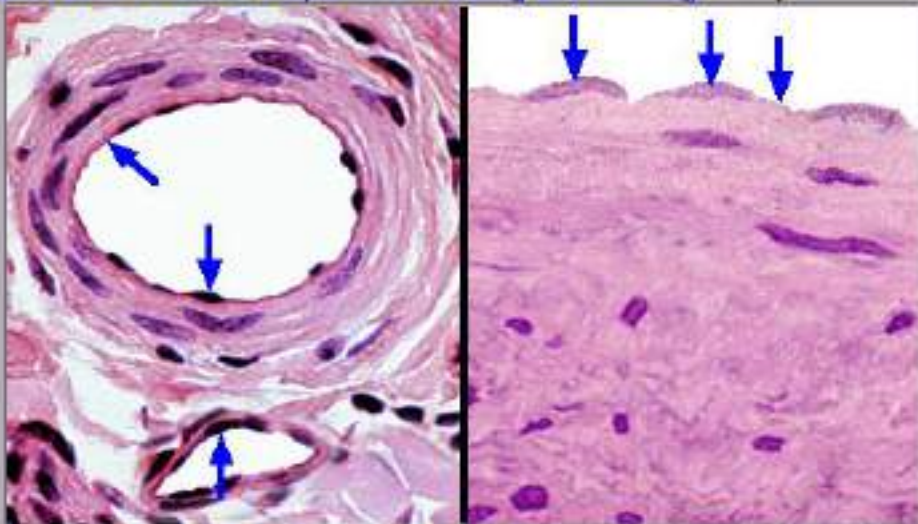
- Simple > squamous epithelium
- > Capillary lumens

1 of 18

The simple squamous epithelium at the black arrows serves a lining function with no transport occurring across its surface. The simple squamous epithelium at the blue arrows line capillaries where much transport does occur.

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple

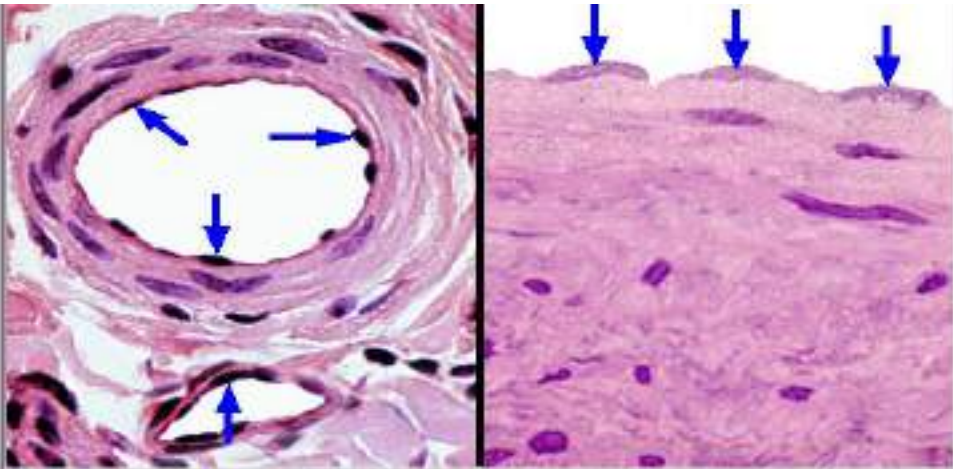


click to identify:

- > Simple squamous epithelium
- Nuclei
- Cytoplasm
- Blood vessels
- Right image >

2 of 18

Simple squamous epithelium – Simple squamous epithelium forms the inner lining of blood vessels, lymphatics, and the heart; in these locations this epithelium is given the proper name of endothelium. Blood vessels 500x, 1000x



click to identify:

- Simple squamous epithelium
- Nuclei
- Cytoplasm
- Blood vessels
- Right image >

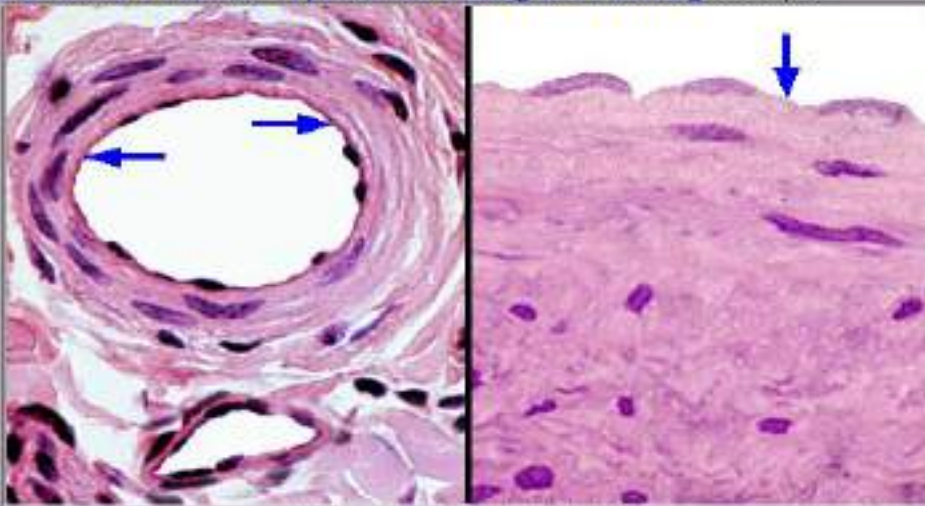
2 of 18

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Digital Histology

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple

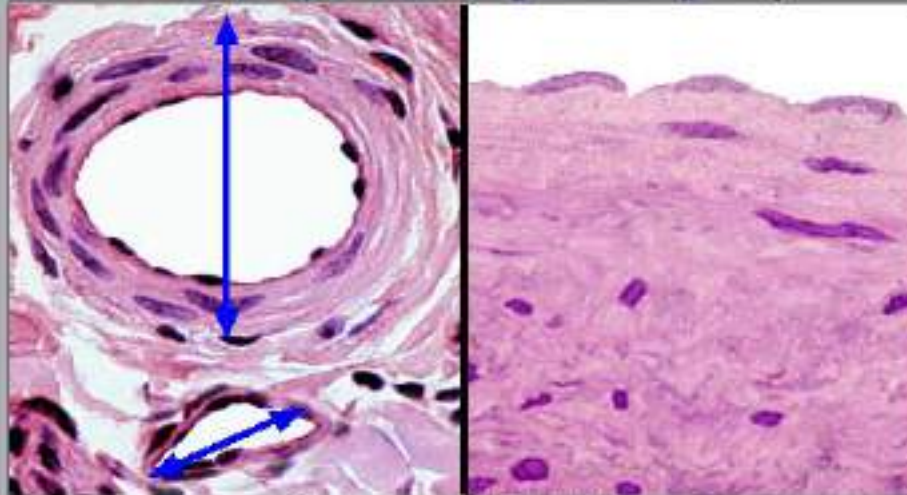


click to identify:

- Simple squamous epithelium
- Nuclei
- Cytoplasm
- Blood vessels
- Right image >

2 of 18

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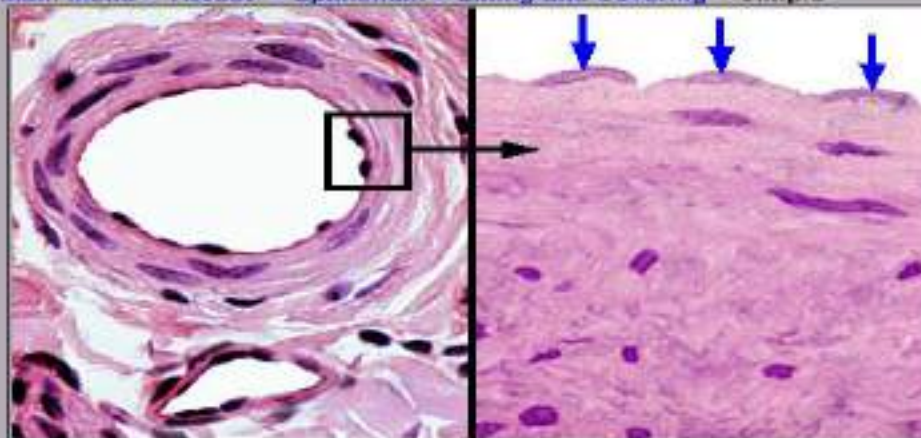


2 of 18

Simple squamous epithelium – Simple squamous epithelium forms the inner lining of blood vessels, lymphatics, and the heart; in these locations this epithelium is given the proper name of endothelium. Blood vessels: 500x, 1000x

click to identify:

- Simple squamous epithelium
- Nuclei
- Cytoplasm
- > Blood vessels
- Right image >



2 of 18

The image on the right is an enlargement of the inner portion of a blood vessel wall that is thicker than that outlined on the left. The right image demonstrates squamous cells (arrows) well: their nuclei are readily visible, but their cytoplasm is too attenuated to be identified.

click to identify:

- Simple squamous epithelium
- Nuclei
- Cytoplasm
- Blood vessels
- > Right image >

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple



click to identify:

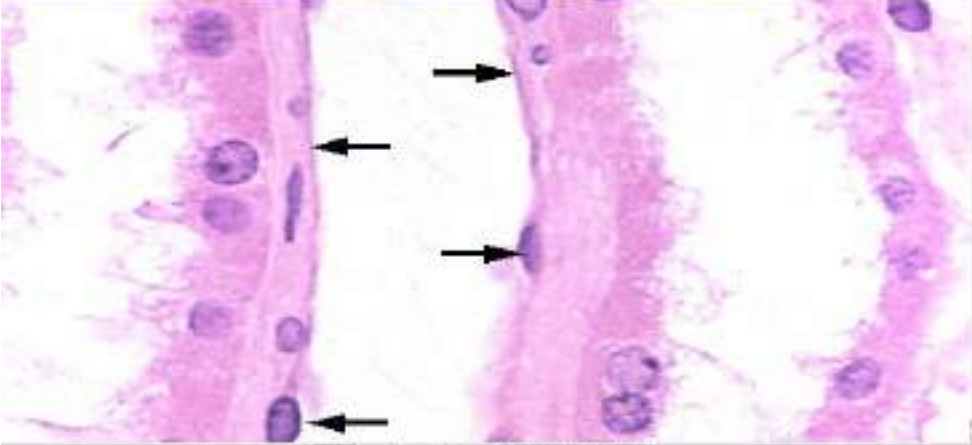
- Simple squamous epithelium
- Lumens
- Simple cuboidal epithelia

3 of 18

Simple squamous epithelium -- Simple squamous epithelium is seen lining one of the tubules in the kidney. In this image a thin band of cytoplasm can be seen extending away from the flattened nuclei. 1000x

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple

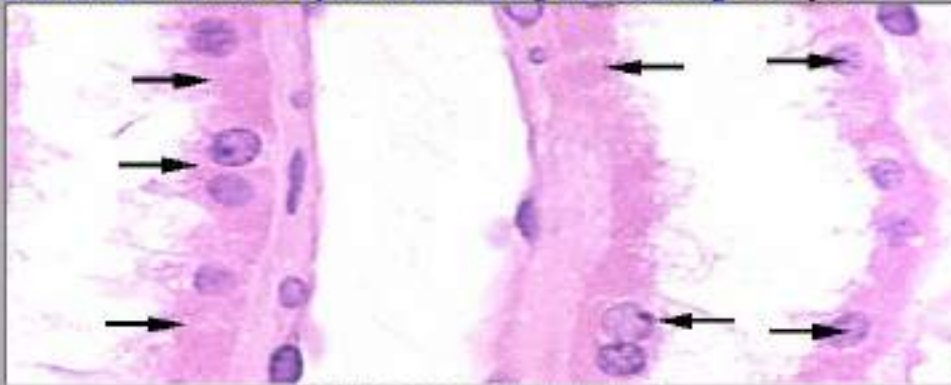


click to identify:

- Simple squamous epithelium
- Lumens
- Simple cuboidal epithelia

3 of 18

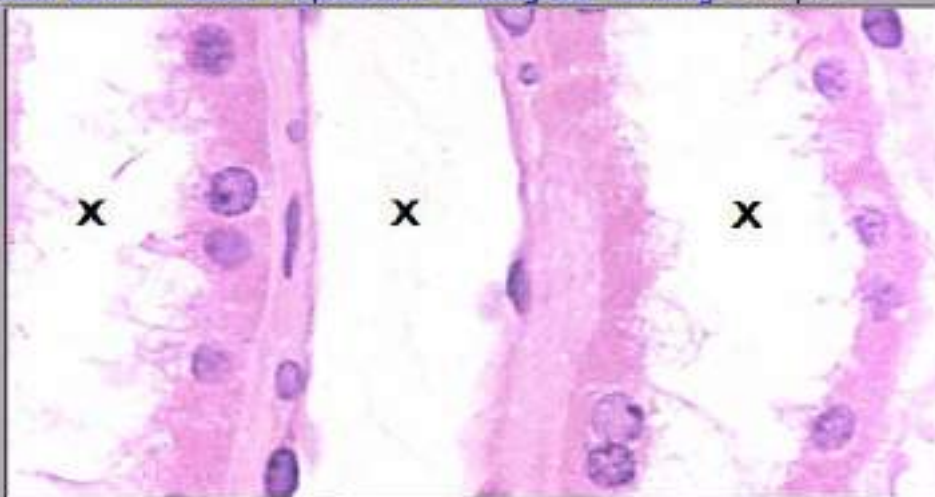
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- Simple squamous epithelium
- Lumens
- Simple cuboidal epithelia



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click to identify:

- Simple squamous epithelium
- Lumens
- Simple cuboidal epithelia

File View Save Open Print

Main Menu > Tissues > Epithelium > Lining and Covering > Simple



click to identify:

- Simple cuboidal epithelium
- Dense irregular CT

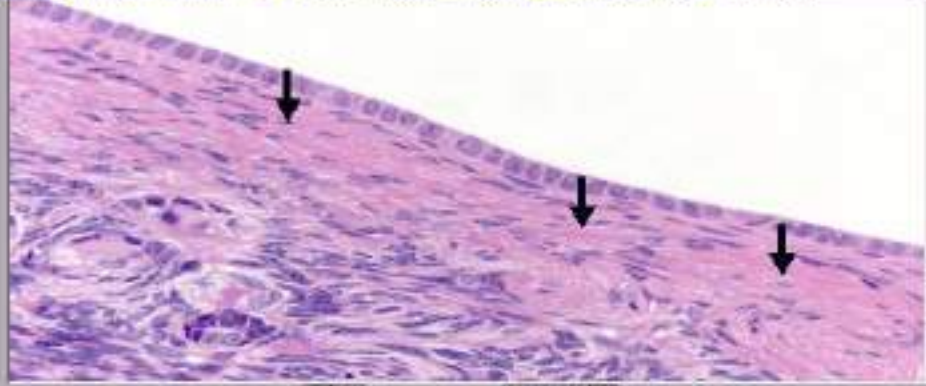
6 of 18

Simple cuboidal epithelium – The surface of the ovary is covered by a simple cuboidal epithelium. Erroneously termed the germinal epithelium, this is one of the few examples of a simple cuboidal epithelium that is not lining a tubular structure. 400x

Digital Histology

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple

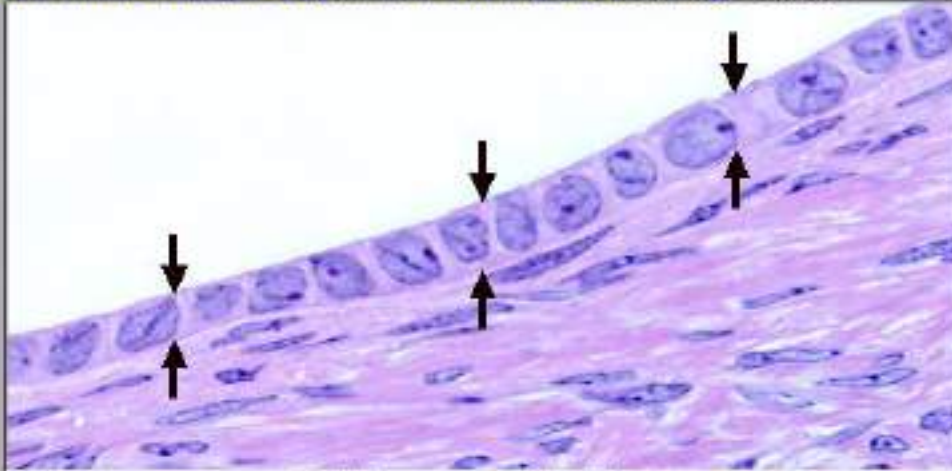


click to identify:

- Simple cuboidal epithelium
- Dense irregular CT

6 of 18

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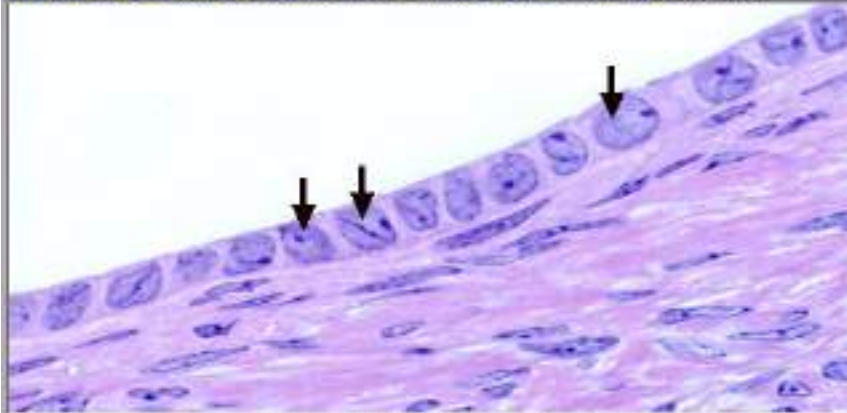


7 of 18

Simple cuboidal epithelium – The ovary is covered by a simple cuboidal epithelium, composed of a single row of box-shaped cells. The nuclei of cuboidal cells are usually spherical, reflecting the equal height and width dimensions of these cells. 1000x

click to identify:

- > Simple cuboidal epithelium
- Nuclei
- Free surface
- Basal surface
- Dense irregular CT

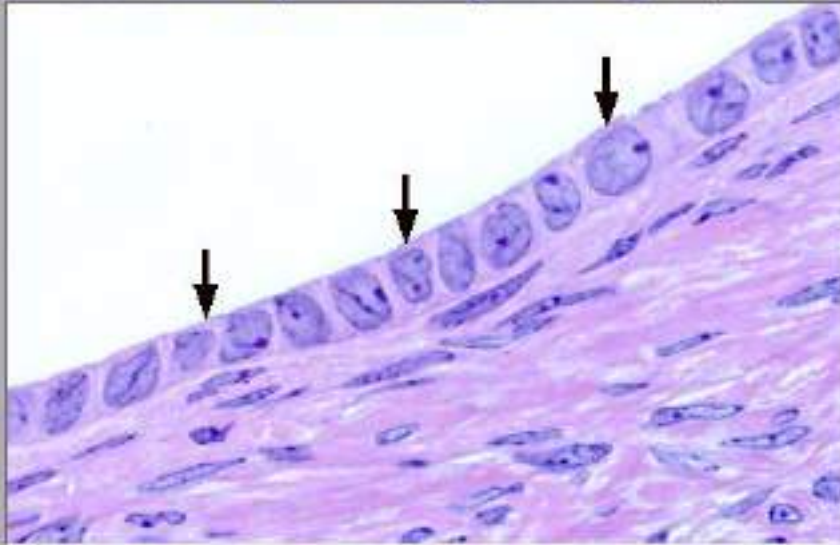


7 of 18

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click to identify:

- Simple cuboidal epithelium
- > Nuclei
- Free surface
- Basal surface
- Dense irregular CT

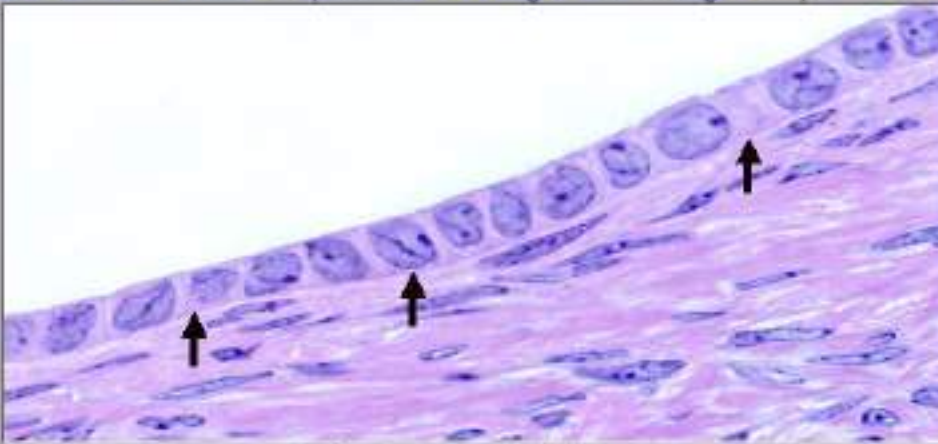


7 of 18

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click to identify:

- Simple cuboidal epithelium
- Nuclei
- Free surface
- Basal surface
- Dense irregular CT

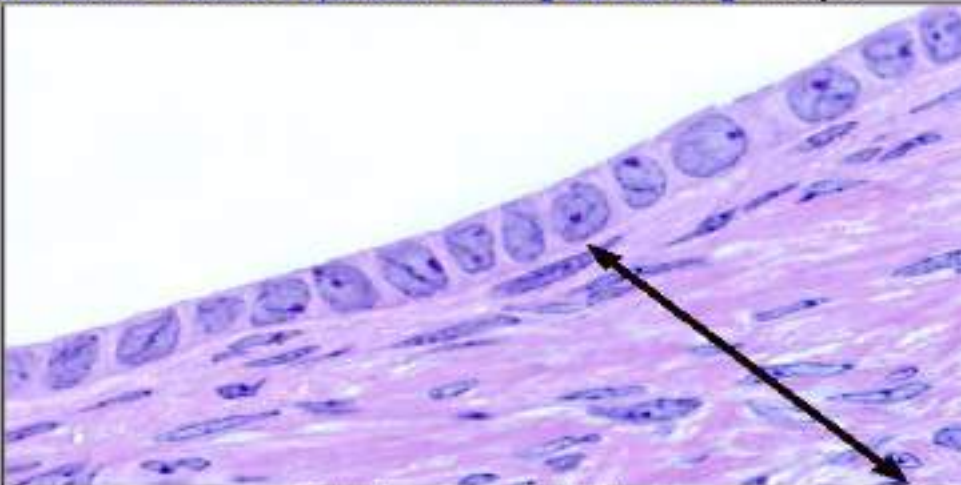


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click to identify:

- Simple cuboidal epithelium
- Nuclei
- Free surface
- > Basal surface
- Dense irregular CT

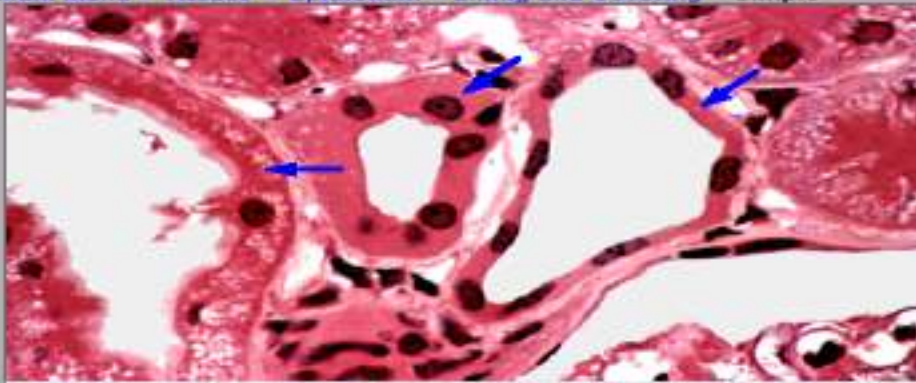


7 of 18

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click to identify:

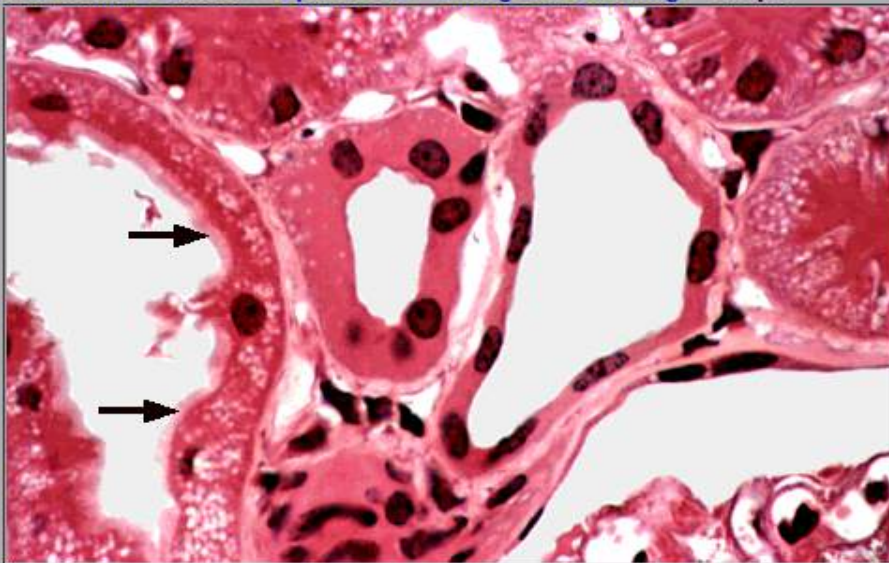
- Simple cuboidal epithelium
- Nuclei
- Free surface
- Basal surface
- > Dense irregular CT



click to identify:

- > Simple cuboidal epithelium
- Brush border
- Simple squamous epithelium

Simple cuboidal epithelia -- Many of the tubules in this image are lined by simple cuboidal epithelia. The cells in each single layer can vary from nearly cube-shaped to rectangular. Due to the plane of section, some cells appear to have no nuclei. Some cells also have a brush border (microvilli) on their free surfaces. Kidney 400x

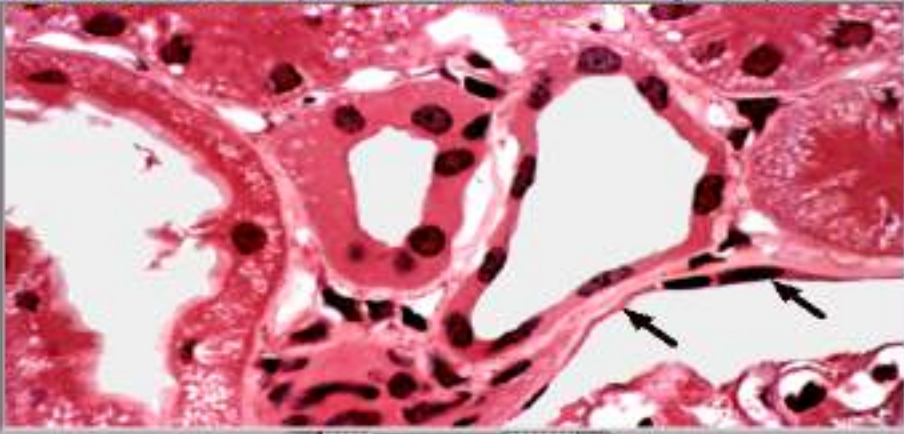


click to identify:

- Simple cuboidal epithelium
- > Brush border
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Home > Tissues > Epithelium > Lining and Covering > Simple



click to identify:

- Simple cuboidal epithelium
- Brush border
- > Simple squamous epithelium

8 of 18

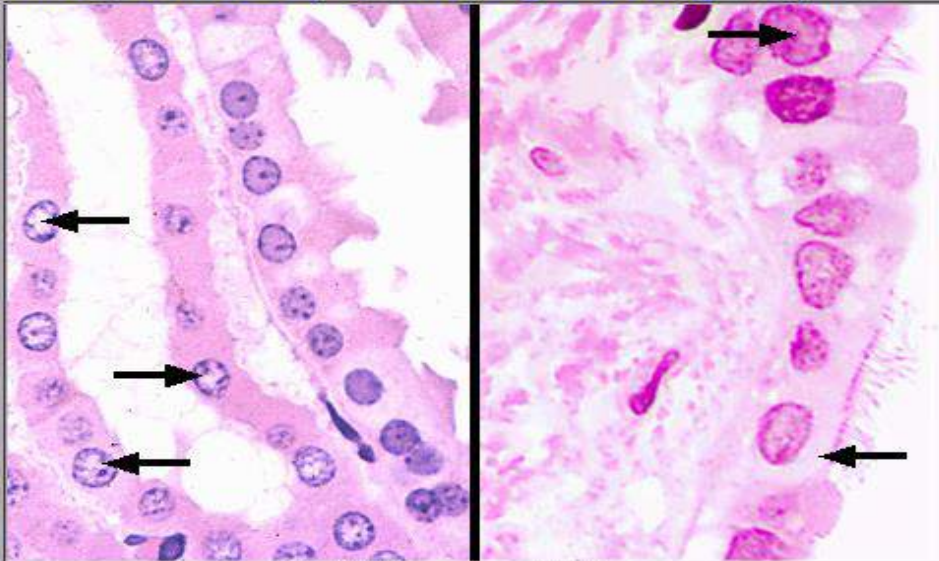
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عنوان 2 عنوان 1 بلا تباعد عادي

Digital Histology

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple



click to identify:

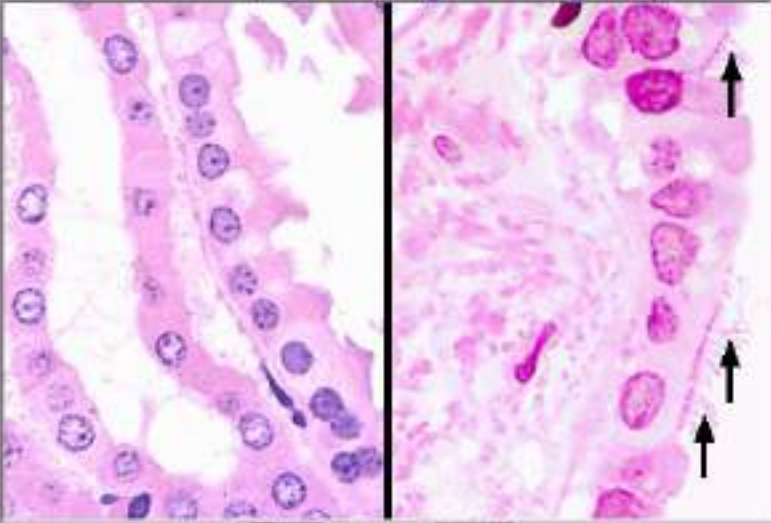
- > Simple cuboidal epithelium
- Cilia
- Basal bodies
- Secretory cells
- Simple columnar epithelium

9 of 18

Simple cuboidal epithelium -- More examples of simple cuboidal epithelia demonstrate the shape of this single layer of cells. In the image on the right, some of the cuboidal cells are ciliated, displaying obvious basal bodies associated with these structures; secretory cells are also dispersed among these cells. Kidney 1000x; Bronchiole 1000x

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple



9 of 18

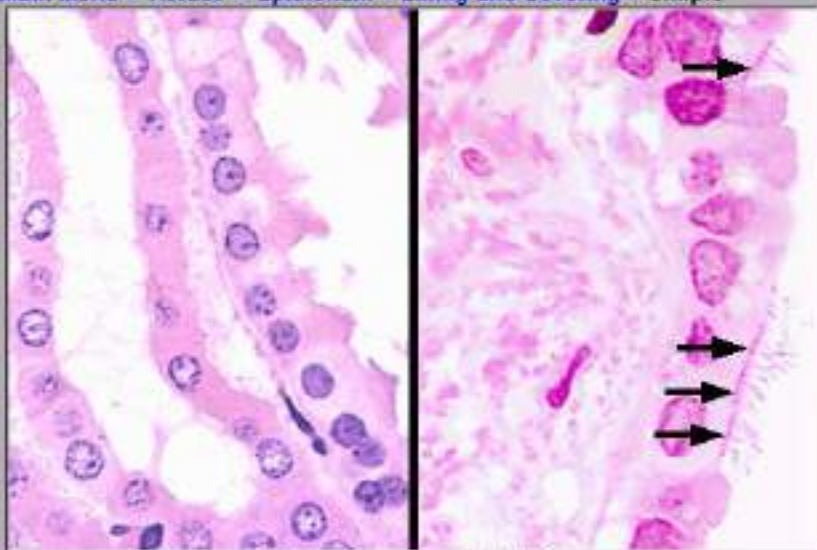
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click to identify:

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- Cilia
- Basal bodies
- Secretory cells
- Simple columnar epithelium

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple

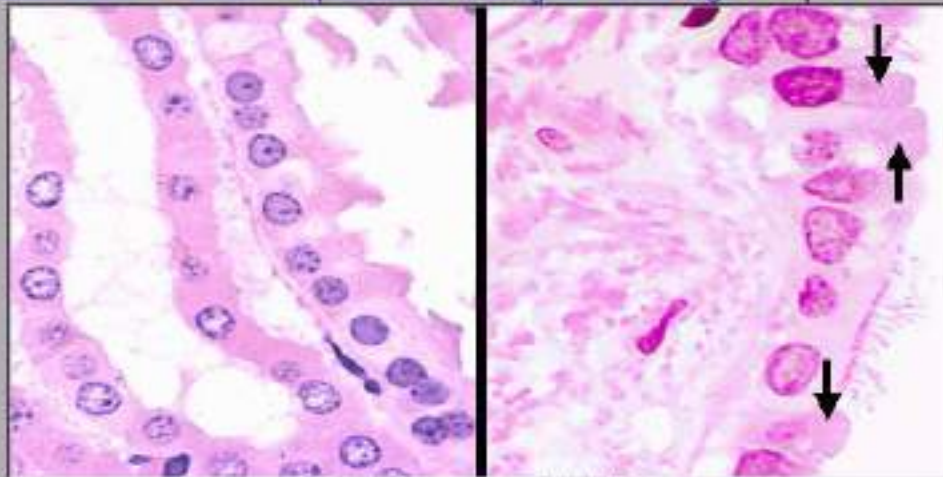


9 of 18

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click to identify:

- Simple cuboidal epithelium
- Cilia
- Basal bodies
- Secretory cells
- Simple columnar epithelium

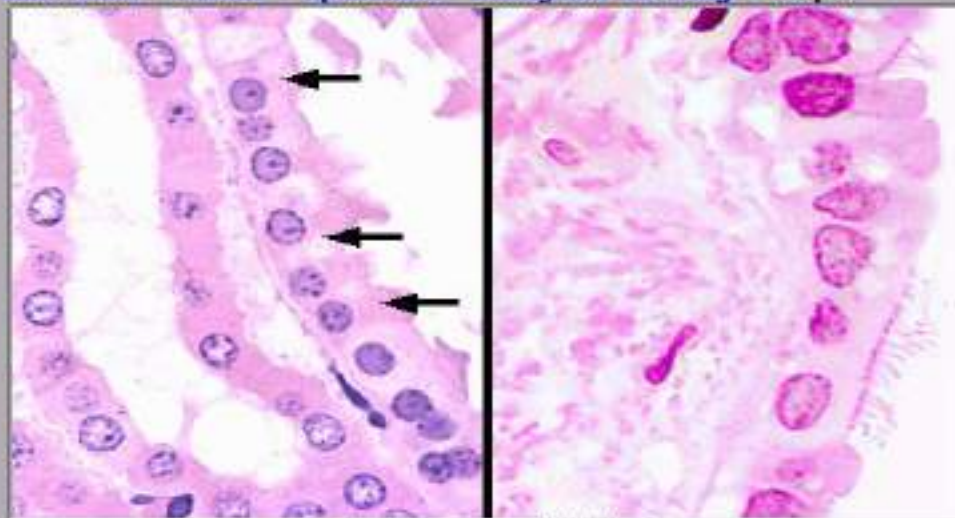


9 of 18

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click to identify:

- Simple cuboidal epithelium
- Cilia
- Basal bodies
- Secretory cells
- Simple columnar epithelium



9 of 18

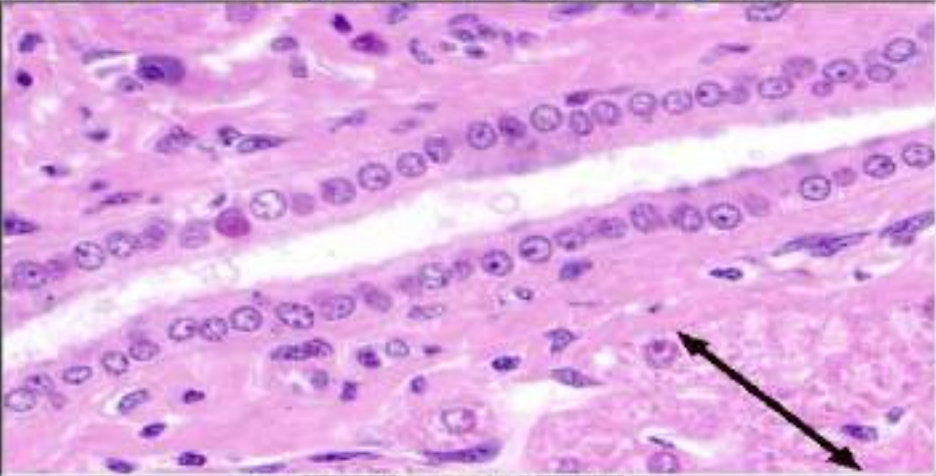
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- Simple cuboidal epithelium
- Cilia
- Basal bodies
- Secretory cells
- Simple columnar epithelium

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple



click to identify:

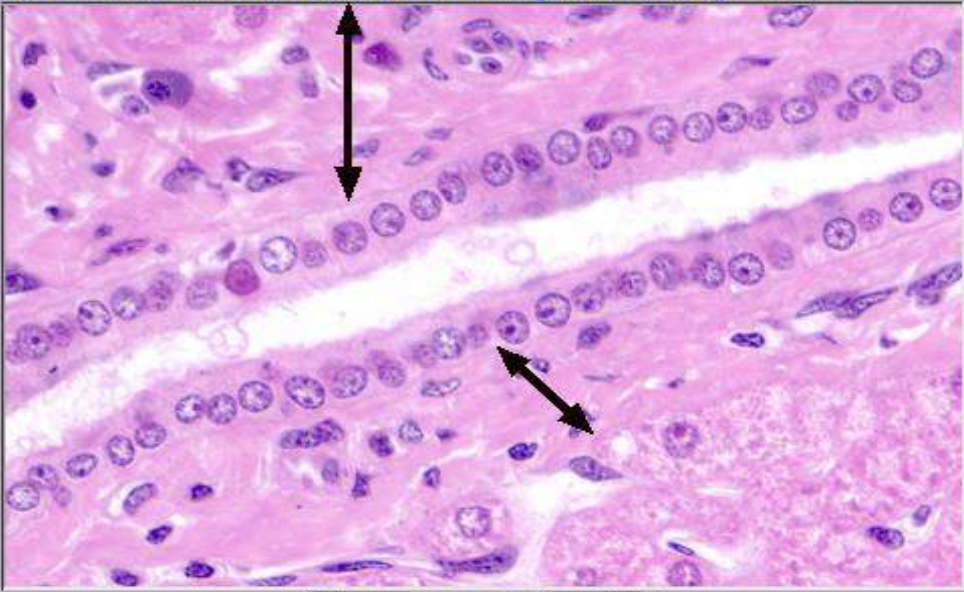
- Simple cuboidal epithelium
- Dense irregular CT
- Liver tissue
- Lumen

10 of 18

Simple cuboidal epithelium – Simple cuboidal epithelia often form the walls of ducts, as seen in this longitudinal section of the bile duct. While the cells in this image are tall cuboidal to low columnar, they are best classified as cuboidal.
Liver 1000x

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple

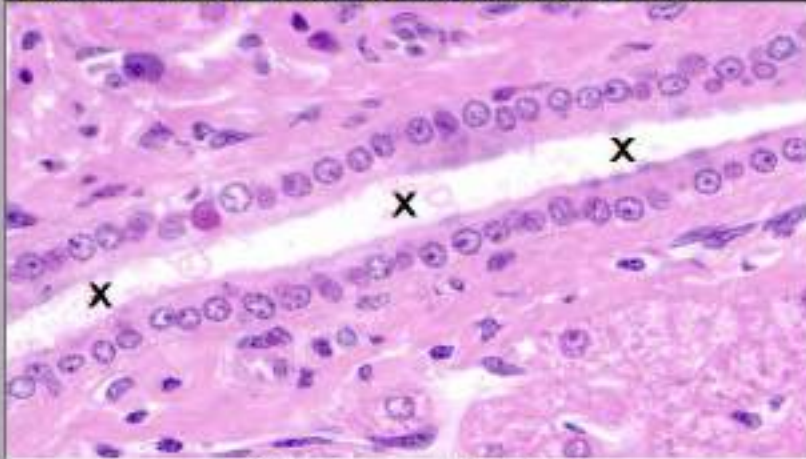


click to identify:

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- Dense irregular CT
- Liver tissue
- Lumen

10 of 18

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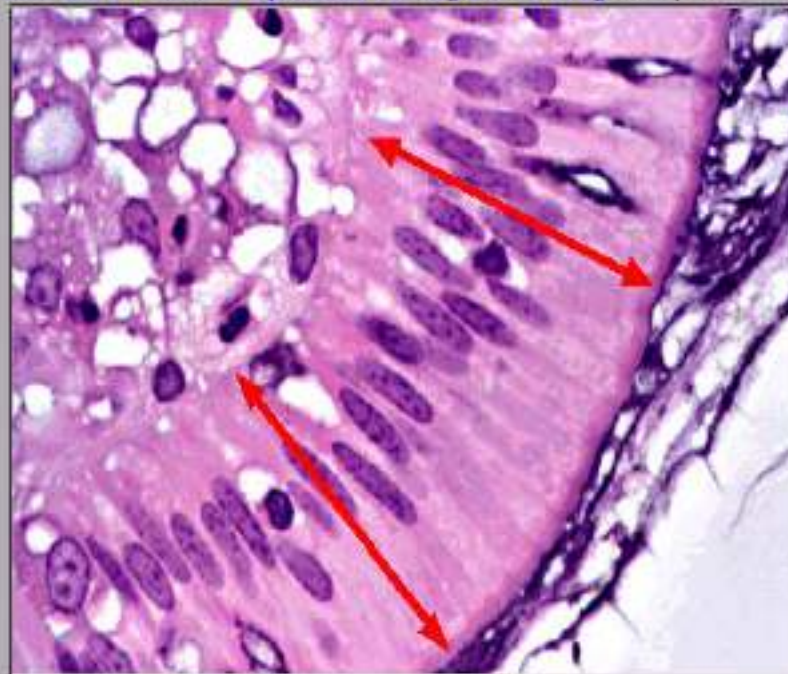


click to identify

- Simple cuboidal epithelium
- Dense irregular
- Liver tissue
- > Lumen

10 of 18

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click to identify

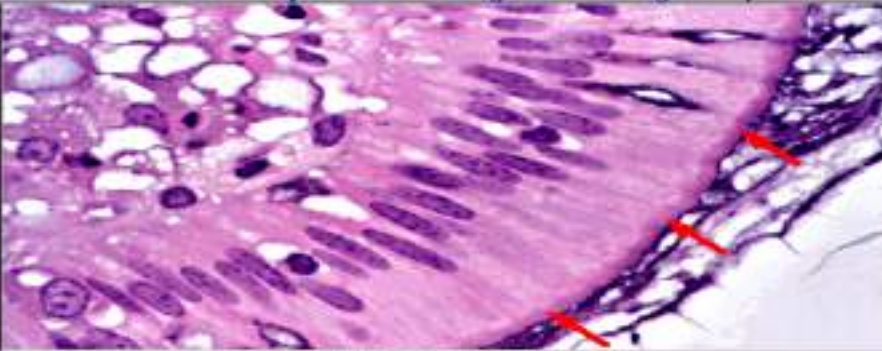
- > Simple columnar epithelium
- Microvilli
- Nuclei
- Loose CT
- Lumen

11 of 18

Simple columnar epithelium – This epithelium consists of a single layer of cells that are taller than they are wide. Nuclei may be basally located but frequently are found in the center of cells. Nuclei usually assume the shape of the cells: oval in taller cells and more spherical if the column is shorter. Microvilli are present as a dark narrow band at the lumen. Small intestine: 1000x

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple



click to identify:

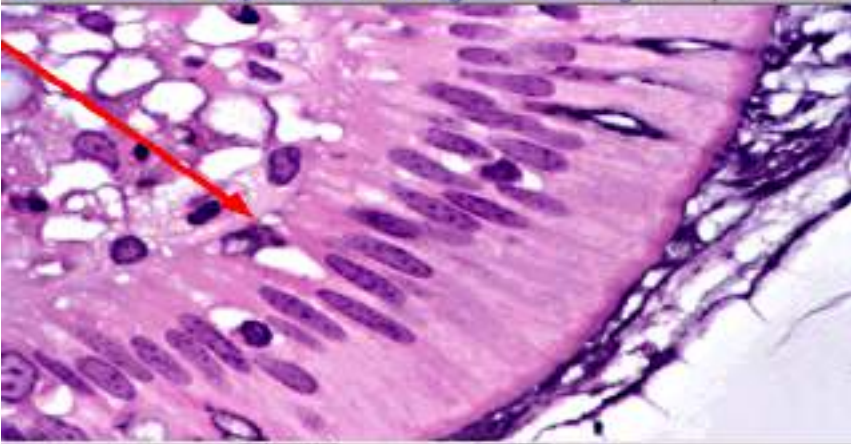
- Simple columnar epithelium
- Microvilli
- Nuclei
- Loose CT
- Lumen

11 of 18

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File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple

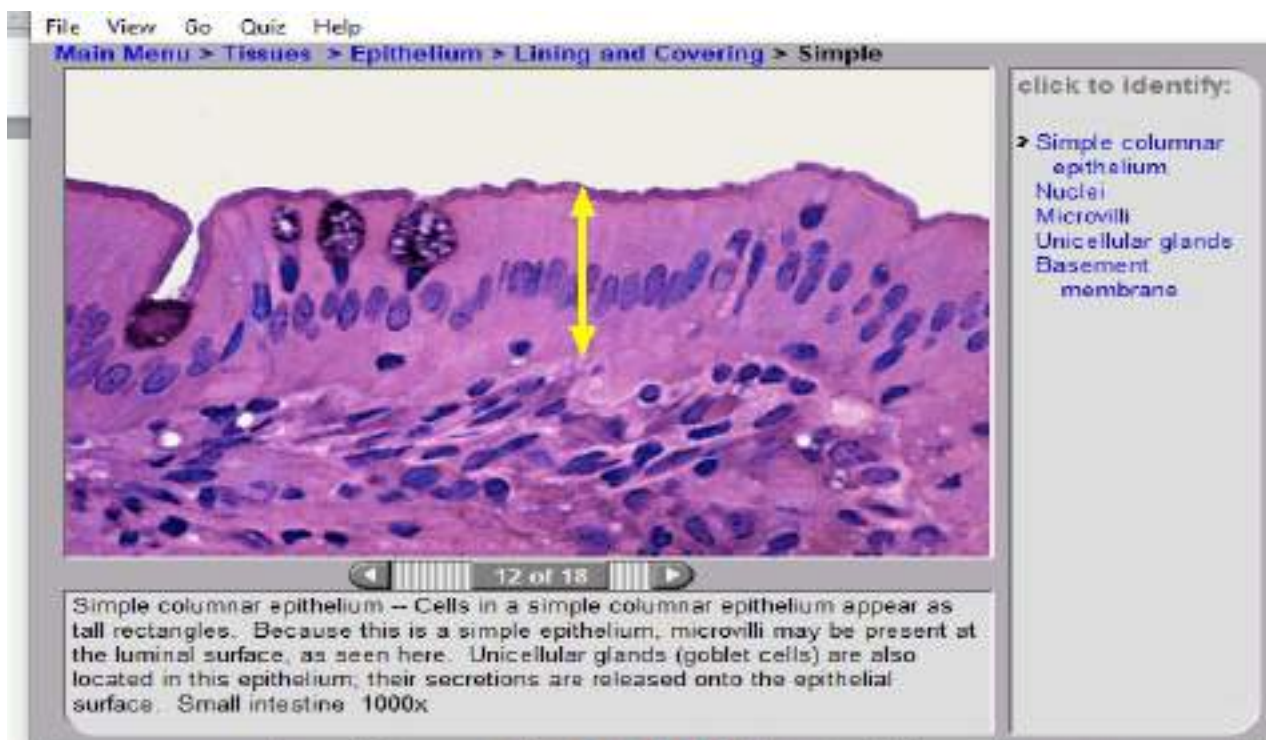
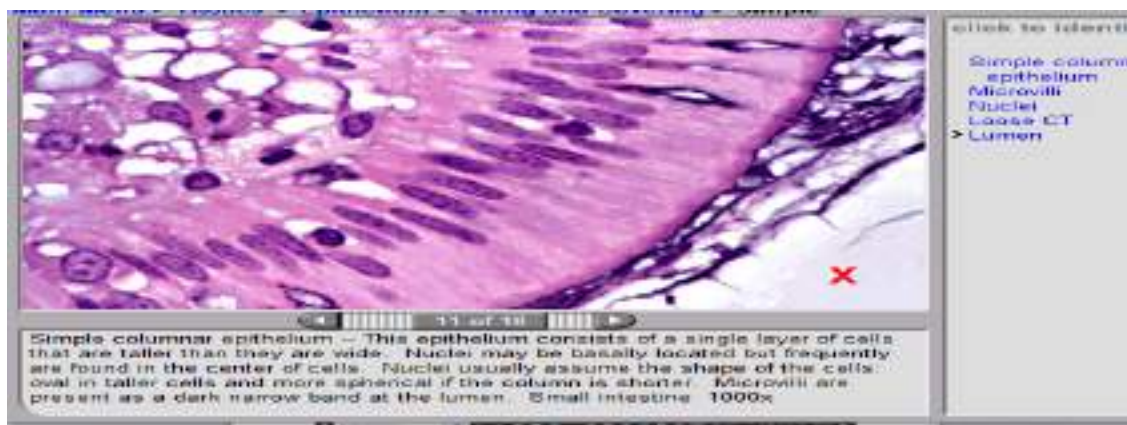


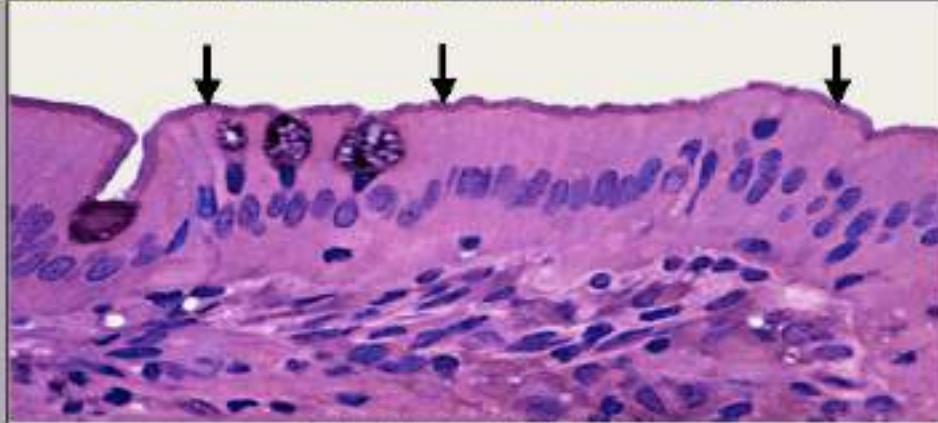
click to identify:

- Simple columnar epithelium
- Microvilli
- Nuclei
- Loose CT
- Lumen

11 of 18

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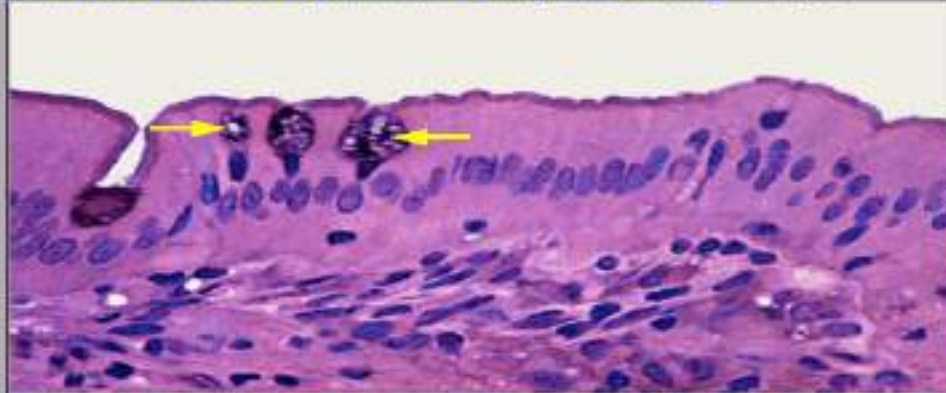


12 of 18

Simple columnar epithelium -- Cells in a simple columnar epithelium appear as tall rectangles. Because this is a simple epithelium, microvilli may be present at the luminal surface, as seen here. Unicellular glands (goblet cells) are also located in this epithelium; their secretions are released onto the epithelial surface. Small intestine 1000x

click to identify:

- Simple columnar epithelium
- Nuclei
- Microvilli
- Unicellular glands
- Basement membrane



12 of 18

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click to identify:

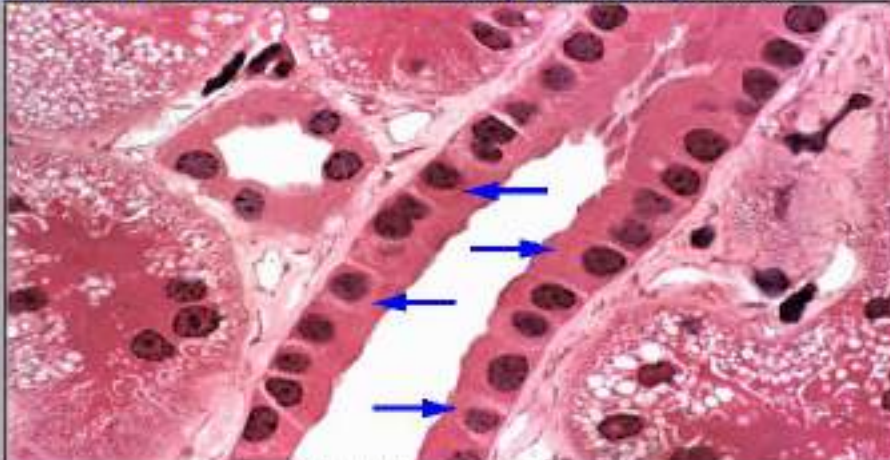
- Simple columnar epithelium
- Nuclei
- Microvilli
- Unicellular gland
- Basement membrane



click to identify:

- Simple columnar epithelium
- Nuclei
- Microvilli
- Unicellular glands
- Basement membrane

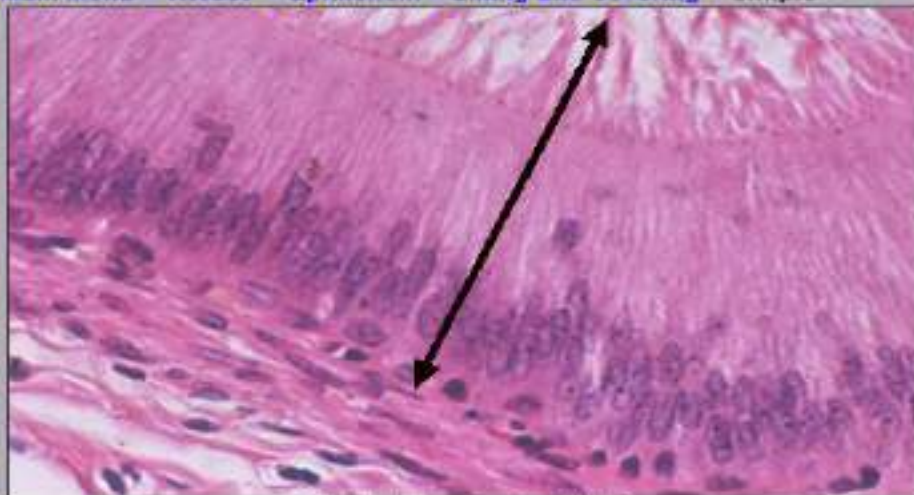
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click to identify:

- Simple columnar epithelium
- Simple cuboidal epithelium

Simple columnar epithelium -- Although this simple columnar epithelium is shorter than those previously seen, its cells are still taller than they are wide. The nuclei of these shorter cells are more spherical and located at the basal surface of the cells. Kidney 1000x

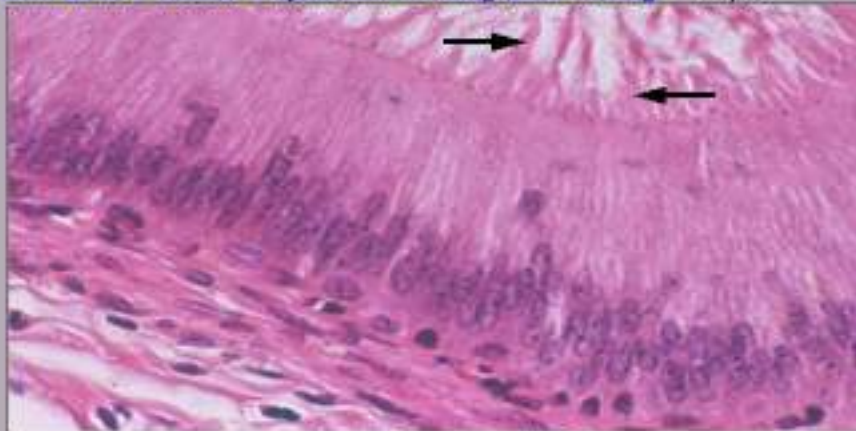


15 of 18

Pseudostratified columnar epithelium -- Pseudostratified epithelium has tall columnar and short basal cells, all of which contact the basement membrane. The layered appearance of the nuclei make this epithelium appear stratified, hence the term, pseudostratified. Because this is truly a simple epithelium, it can possess associated structures, such as stereocilia. Epididymis 1000x

click to identify:

- > Pseudostratified epithelium
- Columnar cells
- Short basal cells
- Stereocilia
- Terminal bar >



15 of 18

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click to identify:

- Pseudostratified epithelium
- Columnar cells
- Short basal cells
- > Stereocilia
- Terminal bar >

Main Menu > Tissues > Epithelium > Lining and Covering > Simple



click to identify:

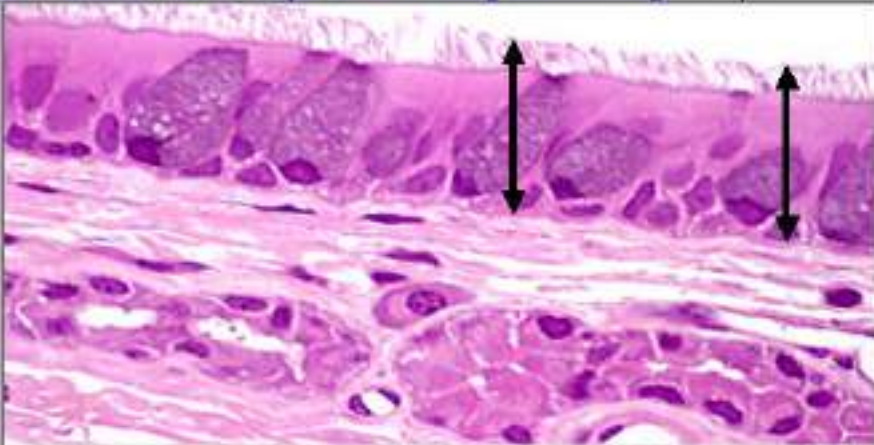
- Pseudostratified epithelium
- Columnar cells
- Short basal cells
- Stereocilia
- > Terminal bar >

15 of 18

The terminal bar is the light microscopic term for the zonula occludens, zonula adherens and desmosome forming the junctional complex. The terminal bar appears as a small, red dot at the luminal surface of adjacent epithelial cells.

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Simple

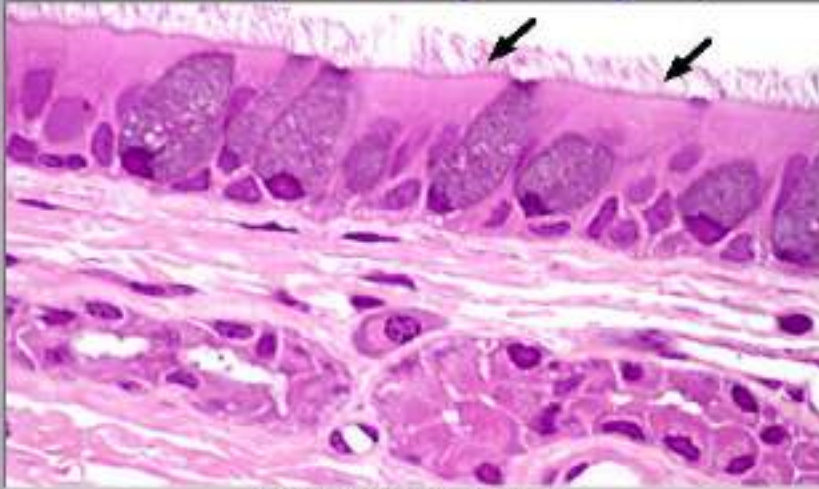


click to identify:

- > Pseudostratified epithelium
- Cilia
- Secretory cells
- Plasma cell

16 of 18

Pseudostratified columnar epithelium – Although pseudostratified epithelium appears stratified, all of its cells rest on the basement membrane. The epithelium pictured here is ciliated and possesses unicellular, secretory (mucus-secreting) cells; both are indications that this is a simple epithelium. Bronchus -400x

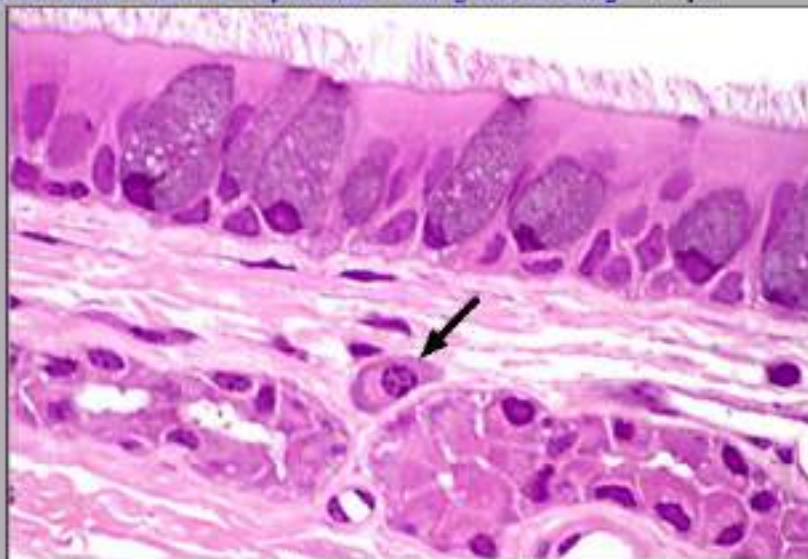


click to identify:

- Pseudostratified epithelium
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- Cilia
- Secretory cells
- > Plasma cell

16 of 18

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[Main Menu](#) > [Tissues](#) > [Epithelium](#) > [Lining and Covering](#) > [Stratified](#)



click to identify:

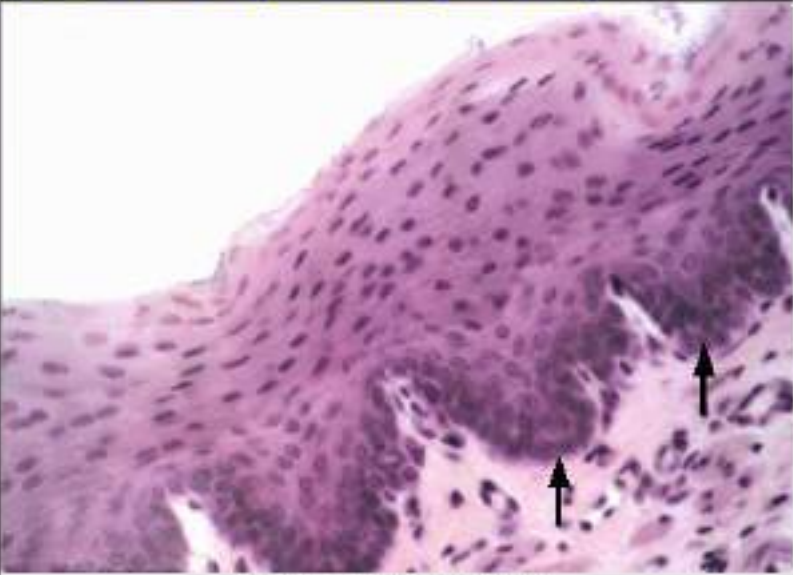
- Stratified squamous nonkeratinized epithelium
- Basal layer
- Squamous cells
- Basement membrane

1 of 12

Stratified squamous, nonkeratinized epithelium – Stratified epithelia have multiple layers and are further classified by the shape of luminal cells. In stratified squamous epithelia, cells flatten as they are pushed from basal to surface layers. When living, nucleated cells are seen at the surface, a layer of keratin has not formed and the epithelium remains moist. Esophagus 400x

File View Go Quiz Help

[Main Menu](#) > [Tissues](#) > [Epithelium](#) > [Lining and Covering](#) > [Stratified](#)



click to identify

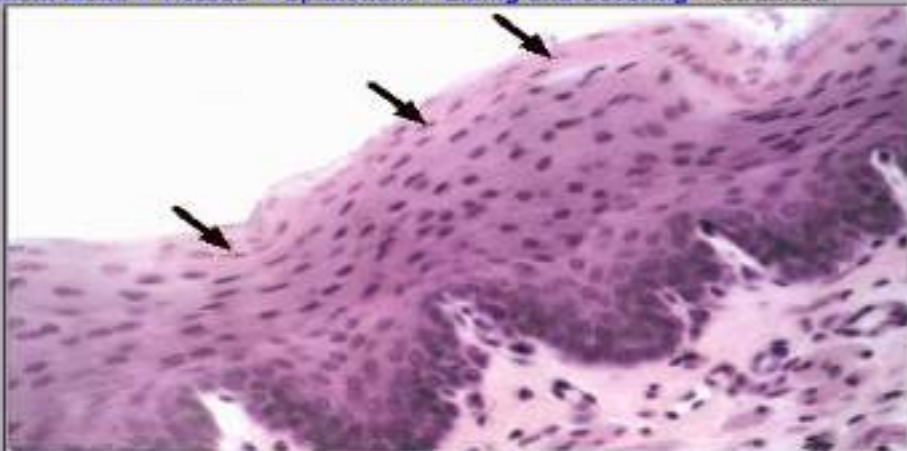
- Stratified squamous nonkeratinized epithelium
- Basal layer
- Squamous cells
- Basement membrane

1 of 12

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File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Stratified



click to identify:

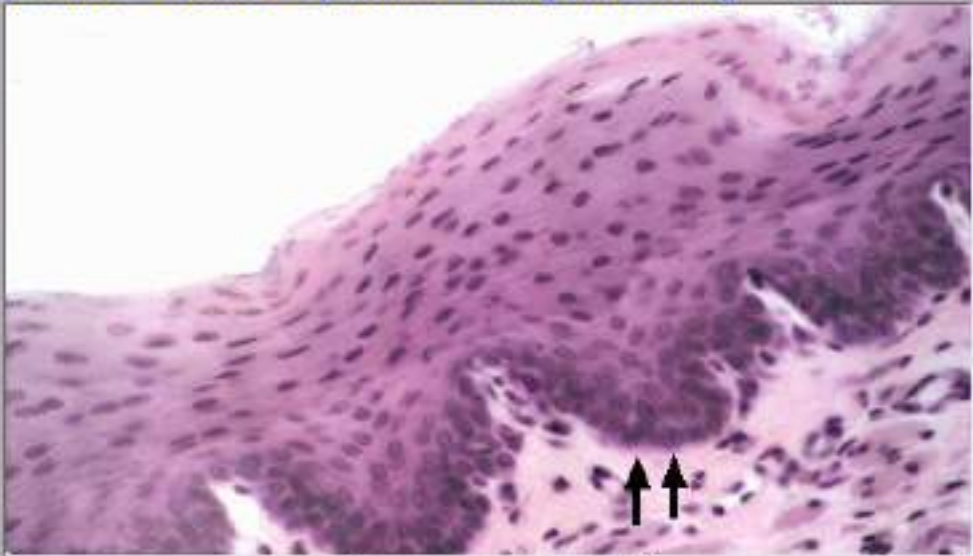
- Stratified squamous nonkeratinized epithelium
- Basal layer
- Squamous cells
- Basement membrane

1 of 12

Stratified squamous, nonkeratinized epithelium -- Stratified epithelia have multiple layers and are further classified by the shape of luminal cells. In stratified squamous epithelia, cells flatten as they are pushed from basal to surface layers. When living, nucleated cells are seen at the surface, a layer of keratin has not formed and the epithelium remains moist. Esophagus 400x

File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Stratified



click to identify:

- Stratified squamous nonkeratinized epithelium
- Basal layer
- Squamous cells
- Basement membrane

1 of 12

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File View Go Quiz Help

Main Menu > Tissues > Epithelium > Lining and Covering > Stratified

click to identify:

- > Stratified squamous nonkeratinized epithelium
- Basal layer
- Squamous cells
- Basement membrane

3 of 12

Stratified squamous, nonkeratinized epithelium – This image demonstrates the transition of epithelial cells from cuboidal at the basement membrane to squamous cells at the surface. Stratified squamous moist epithelium with its multiple layers provides protection against friction and trauma to organs within the body. Esophagus 1000x

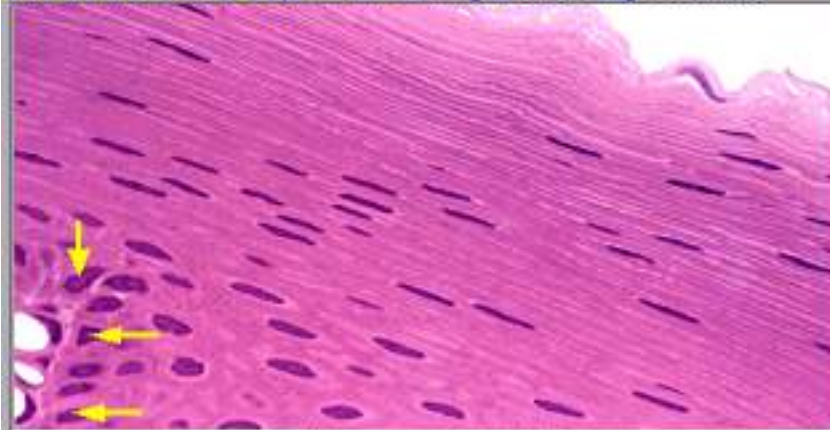
Main Menu > Tissues > Epithelium > Lining and Covering > Stratified

click to identify:

- Stratified squamous nonkeratinized epithelium
- Basal layer
- Squamous cells
- Basement membrane

2 of 12

Stratified squamous, nonkeratinized epithelium – This epithelium covers internal body surfaces which are exposed to some degree of physical trauma. This epithelium shows a basal layer of cuboidal cells; then several layers of polygonal cells that become progressively more flat until they become squamous at the luminal surface. Vagina 400x

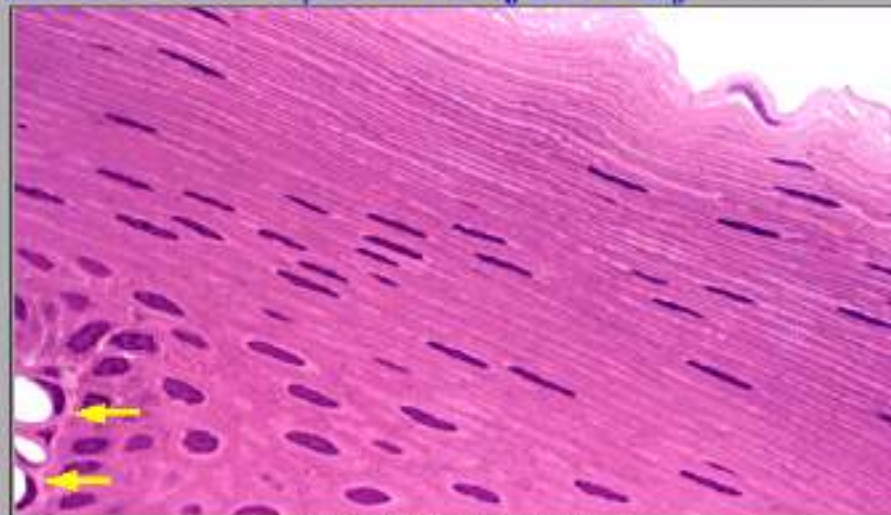


click to identify:

Stratified
squamous
nonkeratinized
epithelium
▶ Basal layer
Squamous cells
Basement
membrane

3 of 12

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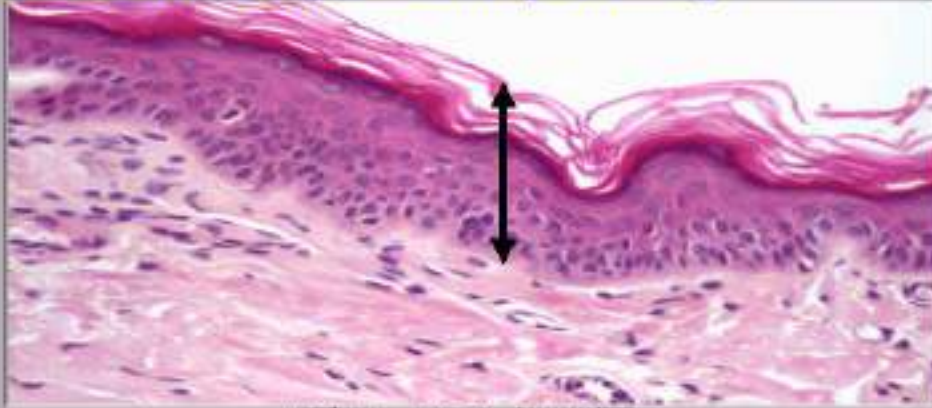


click to identify:

Stratified
squamous
nonkeratinized
epithelium
Basal layer
Squamous cells
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membrane

3 of 12

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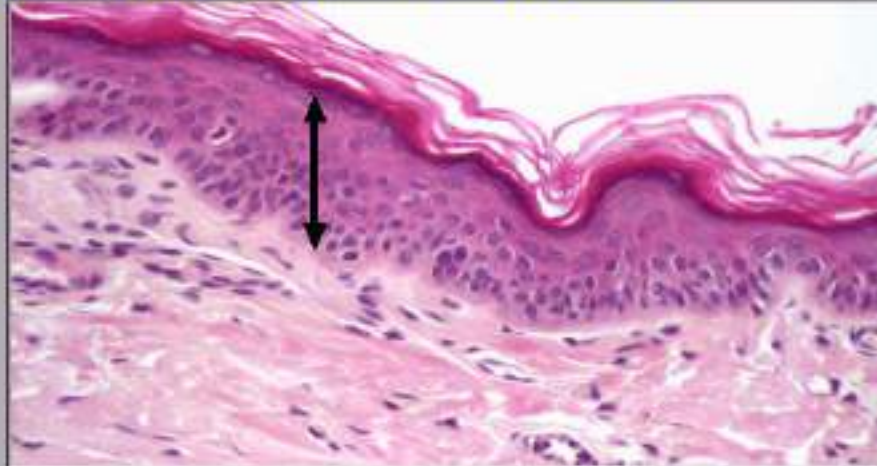


click to identify

> Stratified
squamous
keratinized
epithelium
Living cells
Dead cells

5 of 12

Stratified squamous, keratinized epithelium -- This epithelium, a subdivision of skin, covers the exterior, or "dry," surface of the body that is exposed to the external environment. The basal portion is composed of viable cells, while the outer layer is composed of dead cells made up almost entirely of the protein, keratin. Keratin provides protection against abrasion. 100x

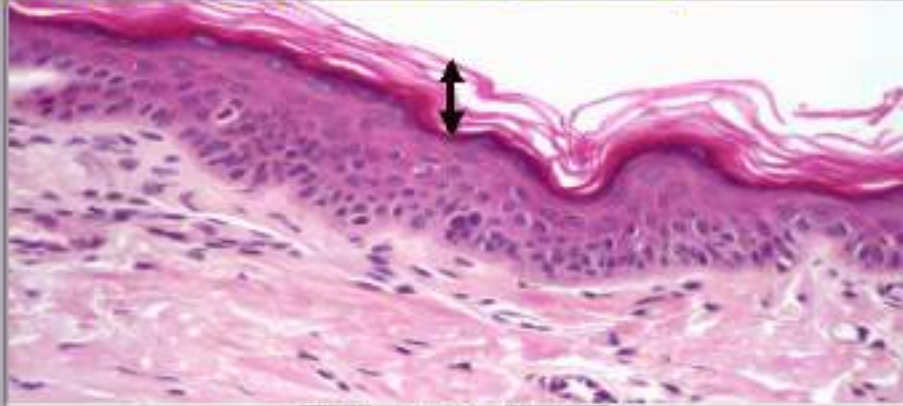


click to identify:

Stratified
squamous
keratinized
epithelium
> Living cells
Dead cells

5 of 12

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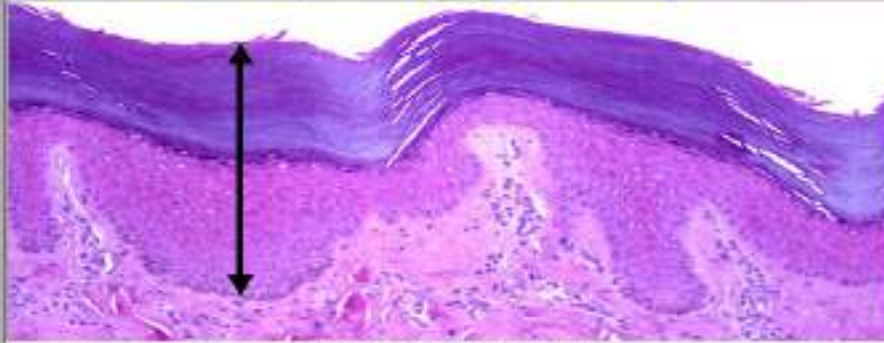


5 of 12

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click to identify:

Stratified
squamous
keratinized
epithelium
Living cells
➤ Dead cells

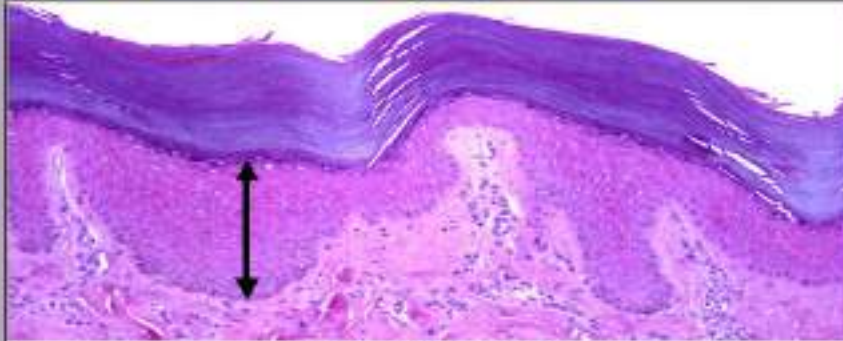


6 of 12

Stratified squamous, keratinized epithelium – Stratified squamous, keratinized epithelium forms the outer layer of the skin on an area of the body that is subjected to a great deal of abrasion. Therefore, its outer protective layer, composed of dead cells forming keratin, is quite thick. 400x

click to identify:

➤ Stratified
squamous
keratinized
epithelium
Living cells
Dead cells



6 of 12

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click to identify:

Stratified
squamous
keratinized
epithelium
➤ Living cells
Dead cells

[Main Menu](#) > [Tissues](#) > [Epithelium](#) > [Lining and Covering](#) > [Stratified](#)



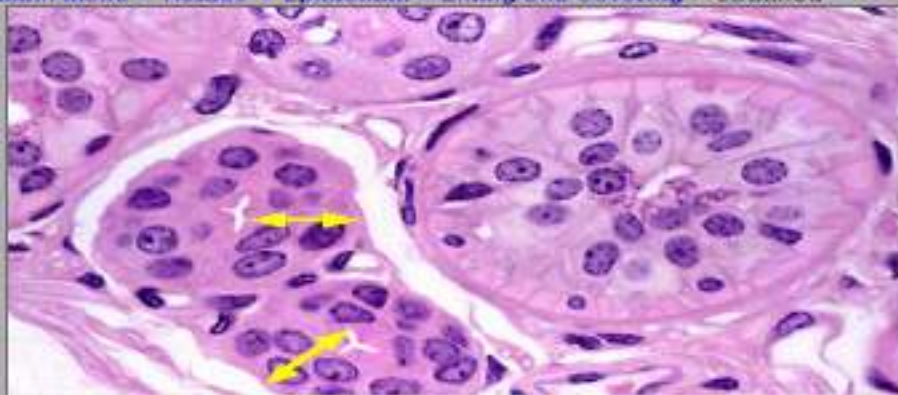
click to identify:

- Stratified squamous keratinized epithelium
- Living cells
- Dead cells

6 of 12

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[Main Menu](#) > [Tissues](#) > [Epithelium](#) > [Lining and Covering](#) > [Stratified](#)

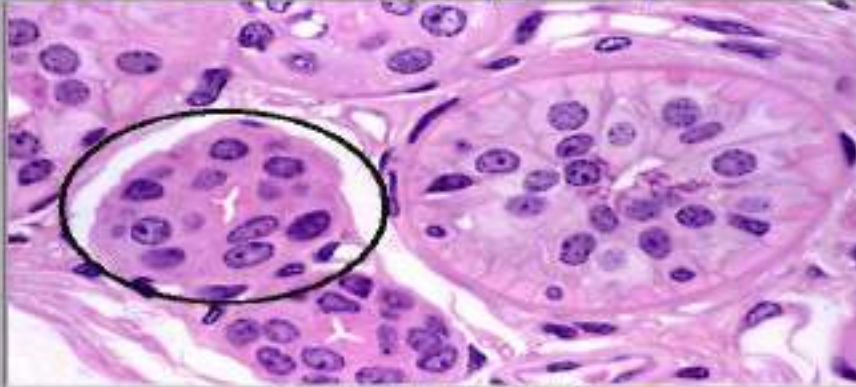


click to identify:

- Stratified cuboidal epithelium
- Duct
- Secretory portion
- Secretory granules

8 of 12

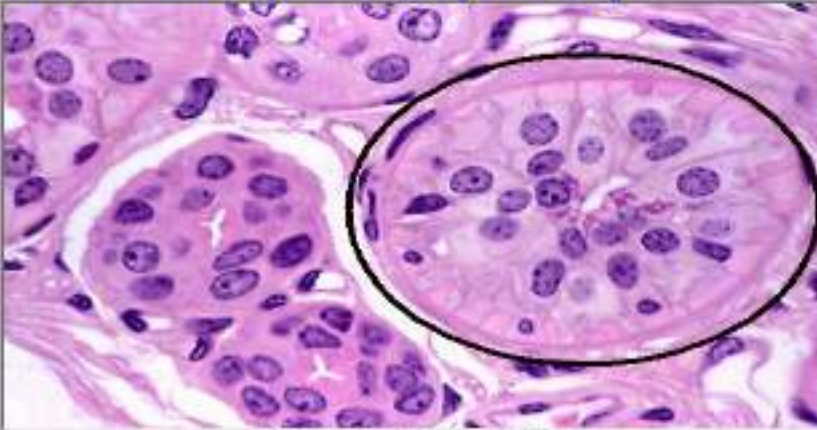
Stratified cuboidal epithelium -- Stratified cuboidal epithelium has a limited distribution but is prominent in ducts of exocrine glands. This image shows a section through a sweat gland and its duct, lined by a stratified cuboidal epithelium. 1000x



click to identify:

- Stratified cuboidal epithelium
- ▶ Duct
- Secretory portion
- Secretory granules

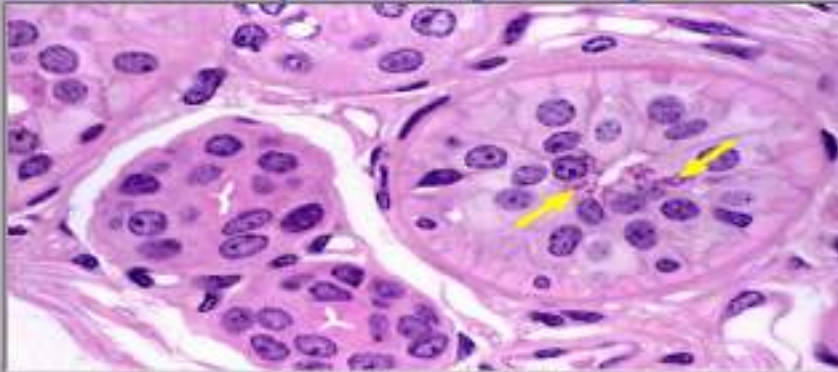
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click to identify:

- Stratified cuboidal epithelium
- Duct
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- Secretory granules

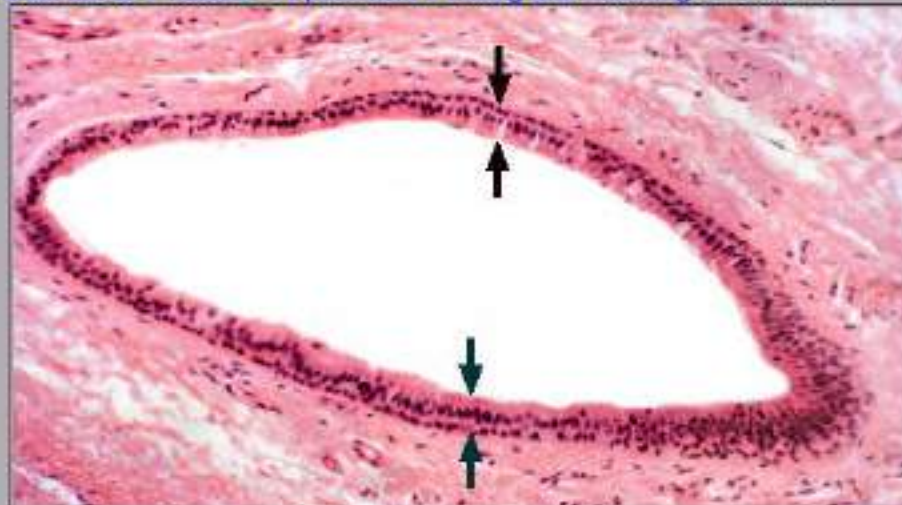
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- Duct
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- Secretory granules

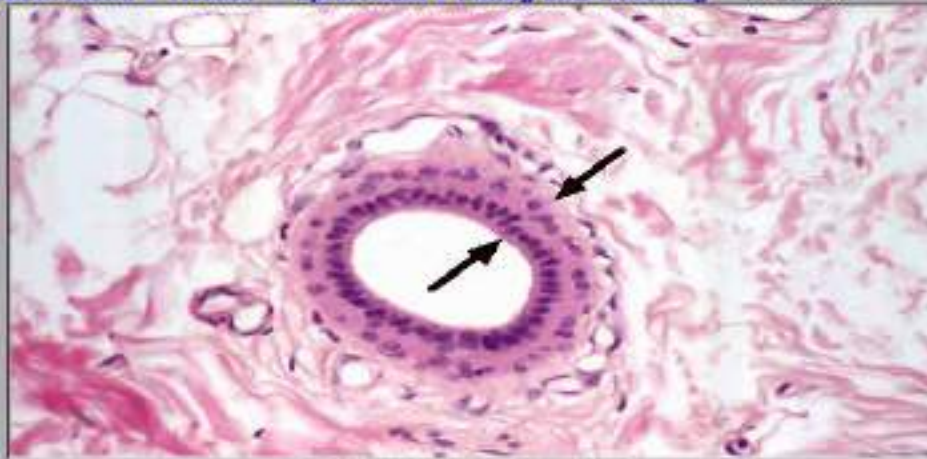
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click to identify:

- Stratified columnar epithelium
- Basal layer
- Surface layer

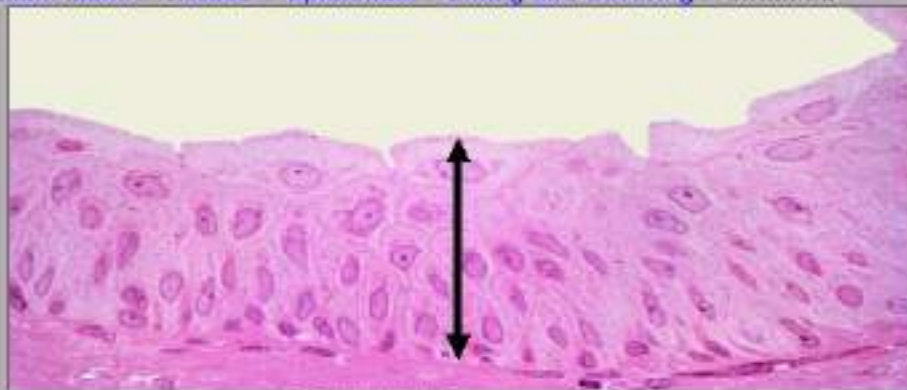
Stratified columnar epithelium – Stratified columnar epithelium is relatively rare, occurring mainly as a transitional form between a simple epithelium and a thicker stratified epithelium; such transitions occur in the ducts of larger glands. The cells of the basal layer are cuboidal, while the cells at the surface are columnar, thus the name stratified columnar. Duct of gland 400x



click to identify:

- > Stratified columnar epithelium
- Basal layer
- Surface layer

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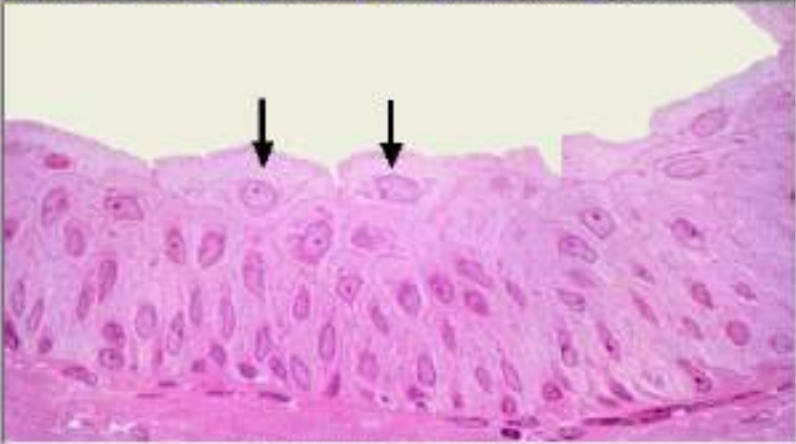


click to identify:

- > Transitional epithelium
- Dome-shaped cells
- Basement membrane

Transitional epithelium -- Transitional epithelium lines the urinary tract and, therefore, must undergo transitions between relaxation and distension. Thus, this epithelium varies between stratified cuboidal and stratified squamous. The dome-shaped cells at the surface of this stratified cuboidal epithelium are characteristic of the urinary bladder when it is not distended with urine. 1000x

File View Favorites Help
Main Menu > Tissues > Epithelium > Lining and Covering > Stratified



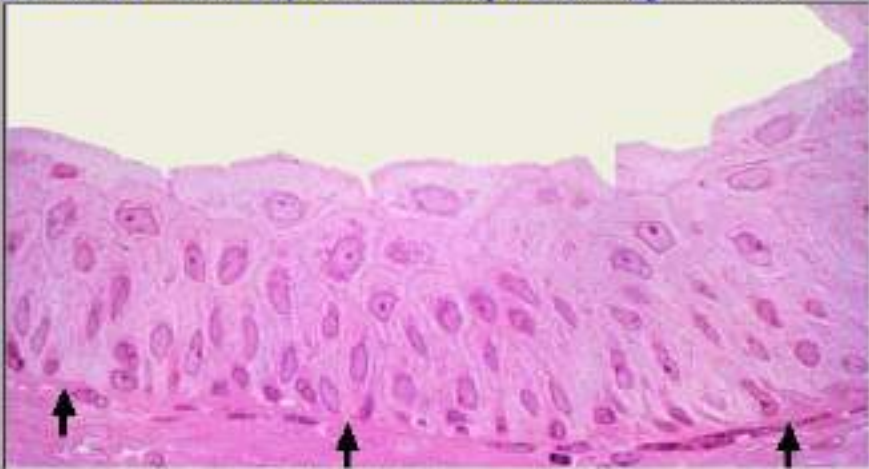
click to identify:

- Transitional epithelium
- ▶ Dome-shaped cells
- Basement membrane

11 of 12

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Main Menu > Tissues > Epithelium > Lining and Covering > Stratified

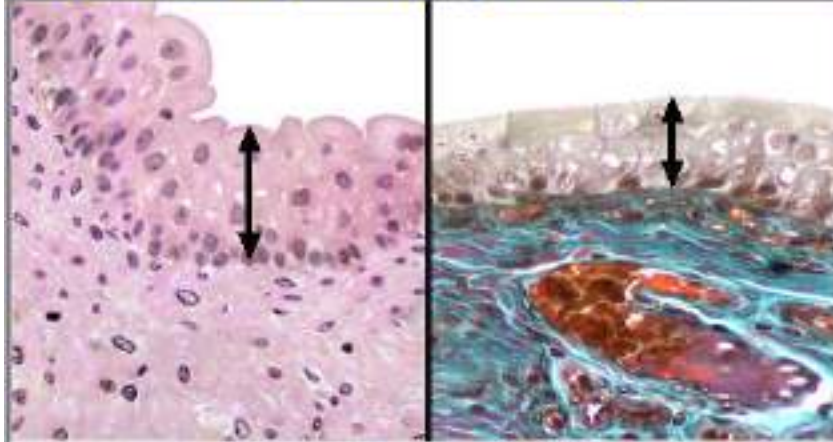


click to identify:

- Transitional epithelium
- Dome-shaped cells
- ▶ Basement membrane

11 of 12

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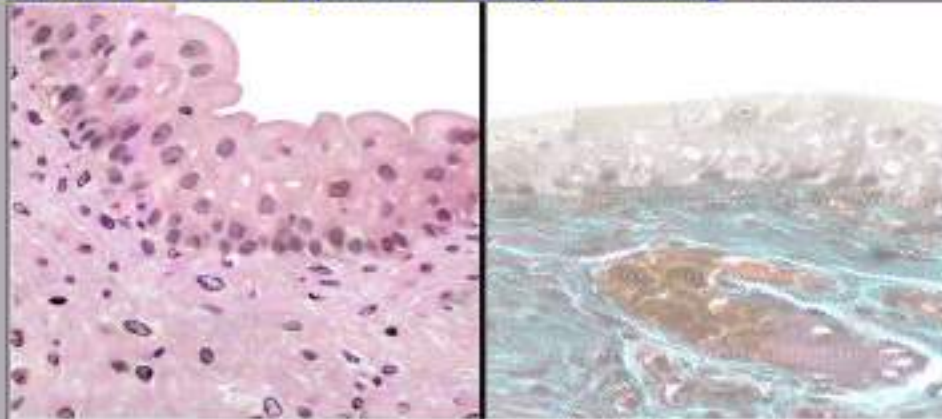


12 of 12

Transitional epithelium -- Changes occur to transitional epithelium as the urinary bladder becomes distended. The epithelium thins and dome-shaped cells flatten to cuboidal (seen here) and eventually to squamous cells when the bladder is fully distended. 400X, 400X

click to identify:

- Transitional epithelium
- Relaxed bladder
- Partial distension
- Dome cells

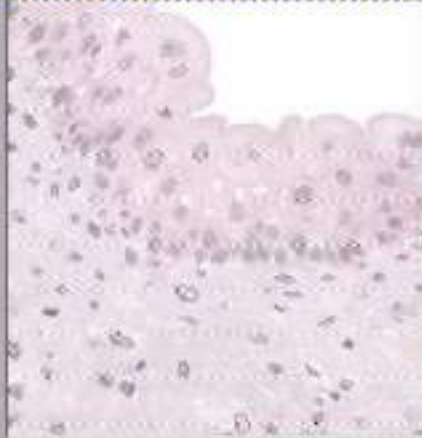


12 of 12

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- Partial distension
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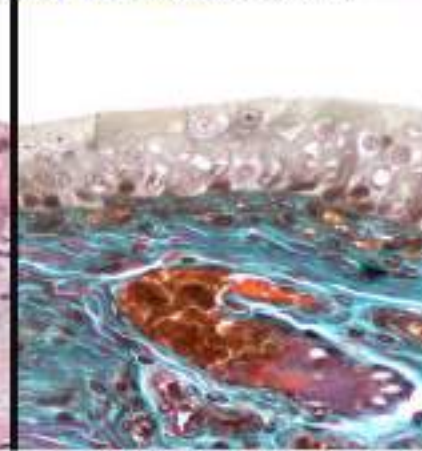
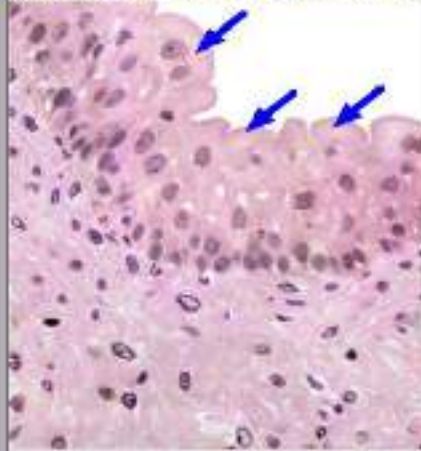


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click to identify:

Transitional
epithelium
Relaxed bladder
> Partial distension
Dome cells

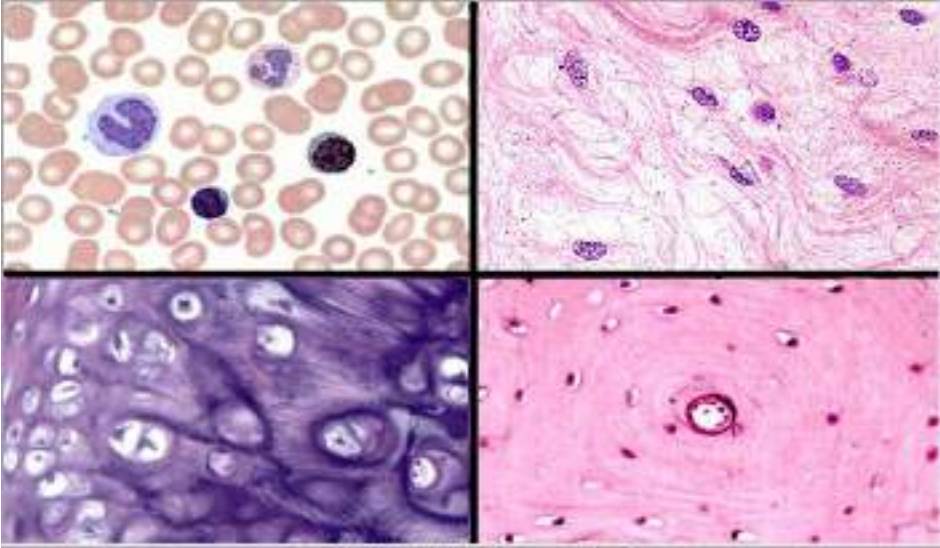


12 of 12

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click to identify:

Transitional
epithelium
Relaxed bladder
Partial distension
> Dome cells



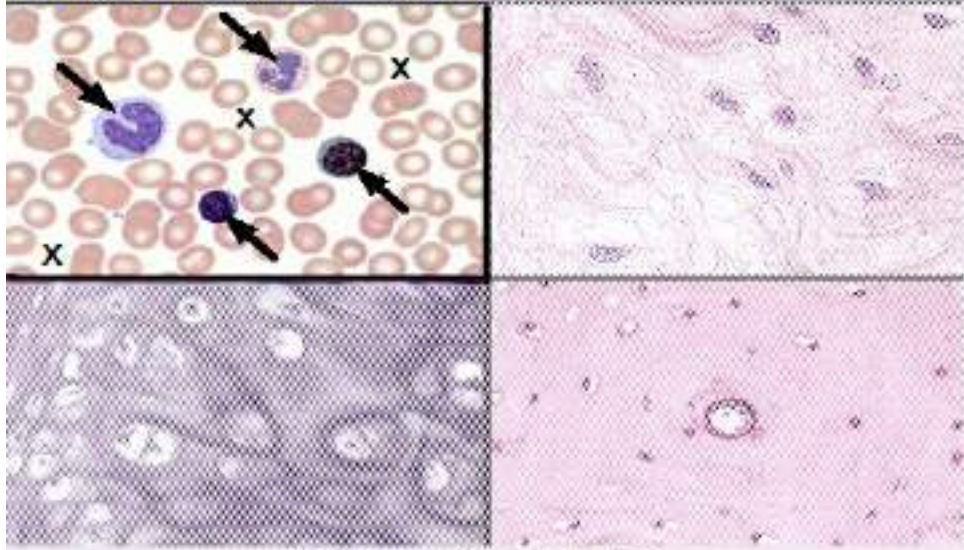
click to identify:

- [Blood >](#)
- [CT Proper >](#)
- [Cartilage >](#)
- [Bone >](#)

<
1 of 1
>

Connective tissue (CT) is characterized by an abundant extracellular matrix surrounding cells. The matrix is composed of fibers, ground substance and tissue fluid. Variation in type, consistency and quantity of these components, in addition to variation in cell type and numbers, imparts characteristics and functions unique to each of the four major connective tissue subdivisions.

[Main Menu >](#) [Tissues >](#) [Connective >](#) Overview

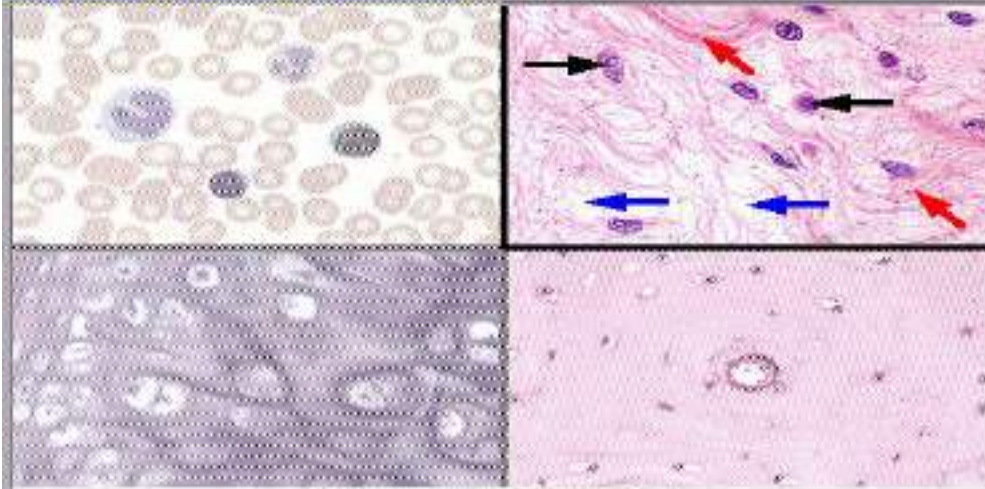


click to identify:

- [> Blood >](#)
- [> CT Proper >](#)
- [> Cartilage >](#)
- [> Bone >](#)

<
1 of 1
>

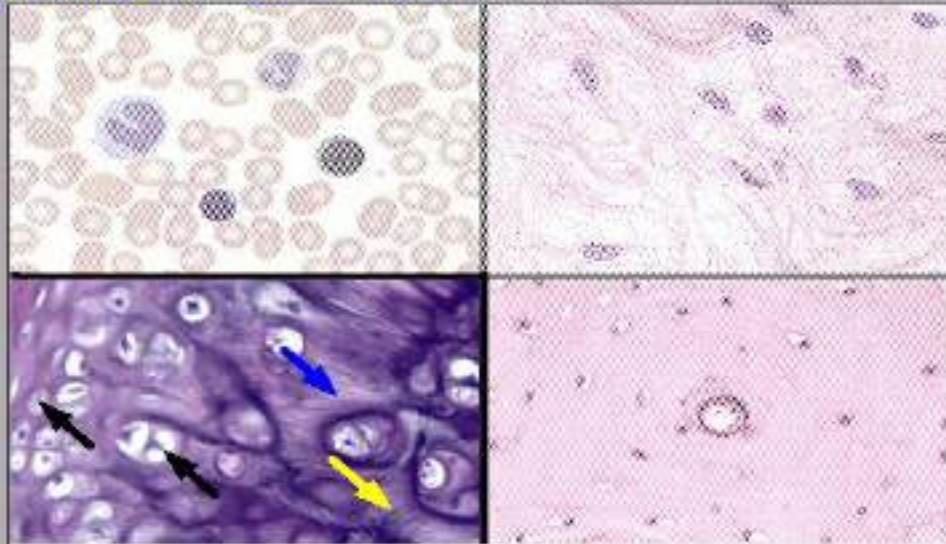
In blood, a specialized connective tissue, the ground substance (X) of the extracellular matrix is a liquid that is not preserved during histological procedures. Fibers, which could impede blood flow, are present only when clotting occurs. The cellular component of blood (arrows) consists of red blood cells, white blood cells and cell fragments called platelets.



click to identify:

- Blood >
- > CT Proper >
- Cartilage >
- Bone >

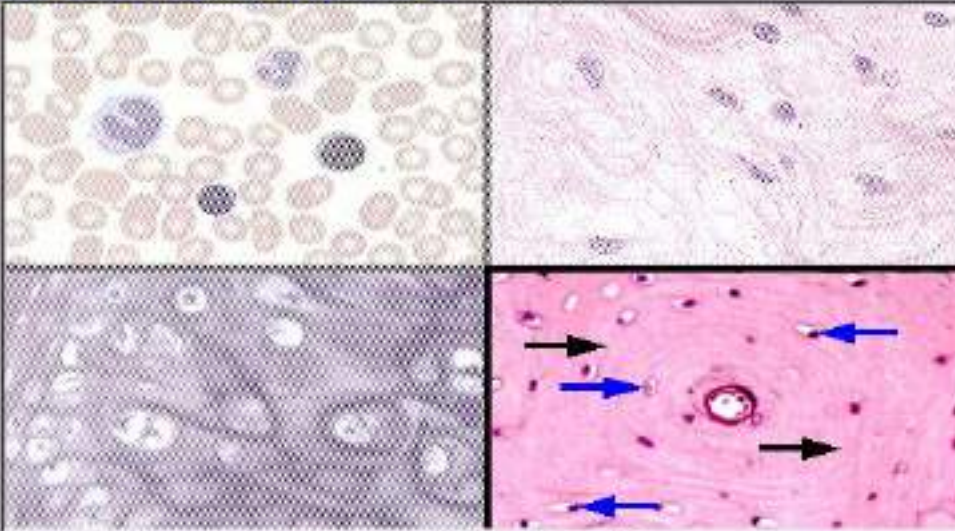
In CT proper the ground substance (blue arrows) is a gel, providing padding qualities to the tissue. Fibers (red arrows), such as collagen, elastic and reticular, provide strength and elasticity. Numerous cells (black arrows) include fibroblasts producing extracellular matrix; white blood cells involved in the immune response; and macrophages, mast cells and adipocytes.



click to identify:

- Blood >
- CT Proper >
- > Cartilage >
- Bone >

In cartilage the ground substance (blue arrow) is a flexible solid, providing deformable support. Fibers (yellow arrow) vary with cartilage type. Cartilage cells (black arrows) are called chondroblasts when they lie on the surface of cartilage and chondrocytes, when they are embedded in the cartilage matrix. Both cell types produce cartilage matrix.

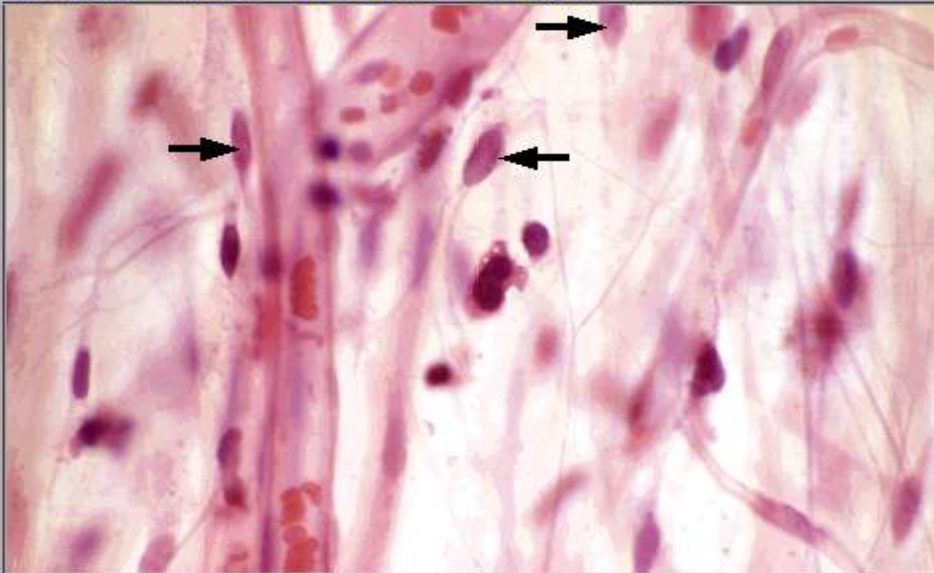


1 of 1

In bone, ground substance is similar to cartilage but is impregnated with calcium phosphate to provide rigidity; collagen is the primary fiber type. This extracellular matrix is indicated by black arrows. Three cell types are present in bone: osteoblasts lie on bone surfaces and produce matrix; osteocytes (blue arrows) are osteoblasts entombed in matrix; osteoclasts break down bone.

click to identify:

- Blood >
- CT Proper >
- Cartilage >
- > Bone >

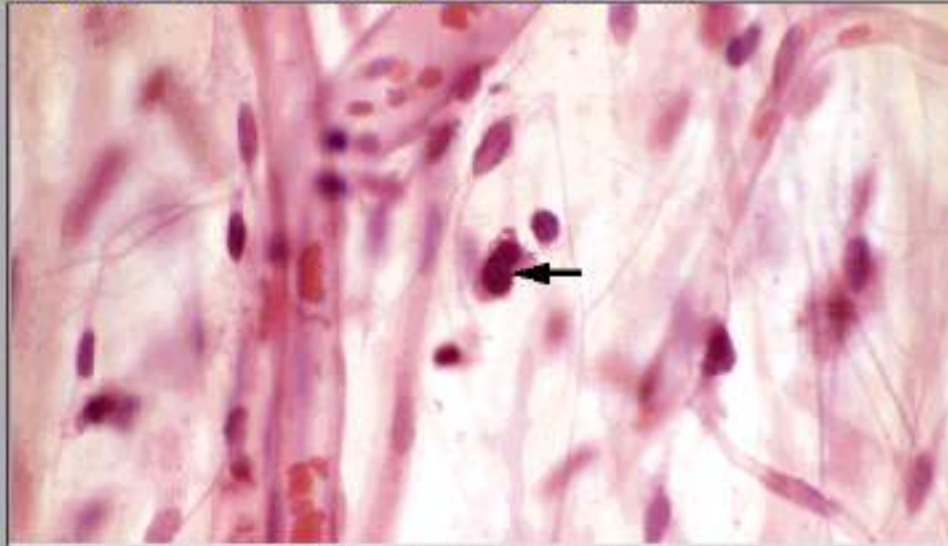


1 of 31

Connective tissue cells -- Cells in connective tissue (CT) proper are either resident cells, such as fibroblasts and fat cells, or migratory cells, which are motile and exit from the blood stream to function in connective tissue. These migratory cells include macrophages and monocytes; mast cells; lymphocytes and plasma cells; eosinophils; neutrophils and basophils. 1000x

click to identify:

- > Fibroblasts
- Macrophage
- Lymphocyte
- Elastic fibers
- Collagen fibers
- Capillaries

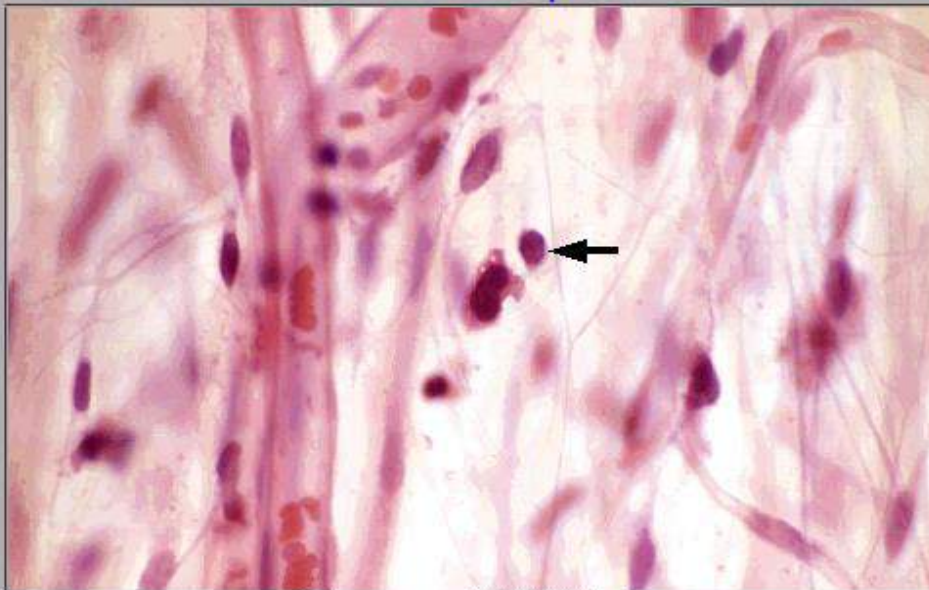


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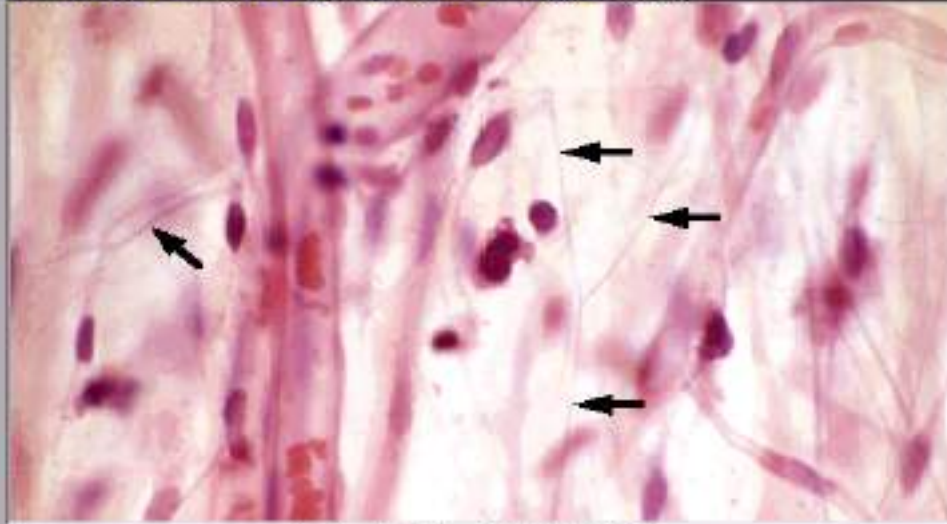


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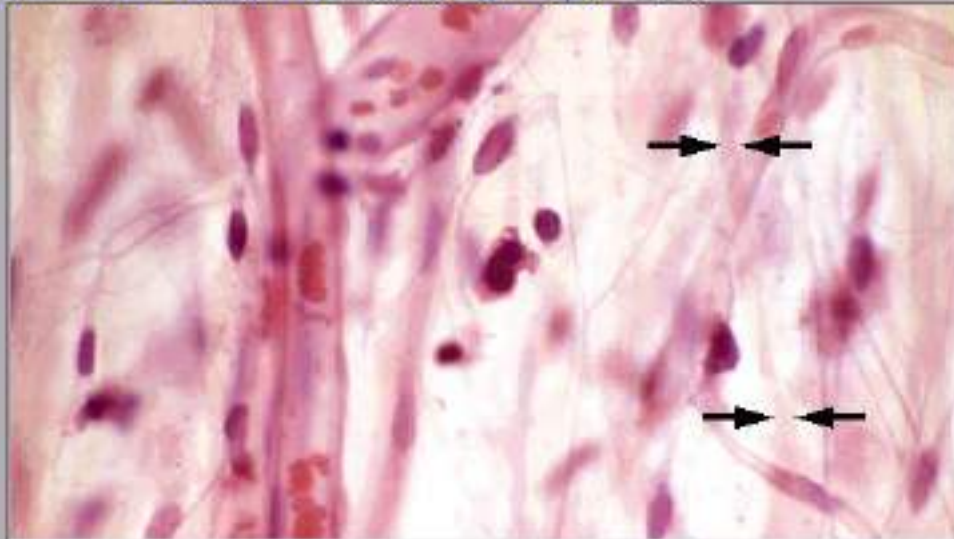


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Fibroblasts
Macrophage
Lymphocyte
Elastic fibers
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Capillaries

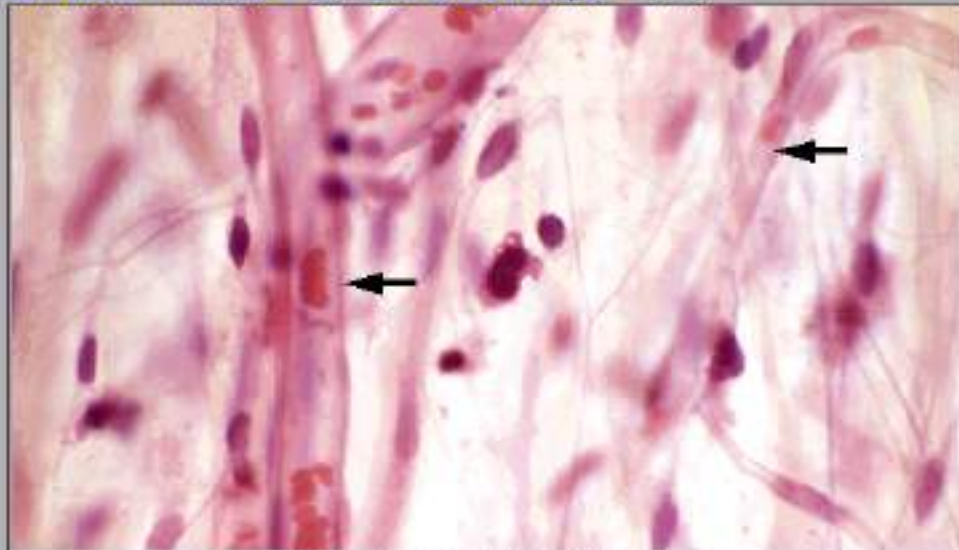


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Fibroblasts
Macrophage
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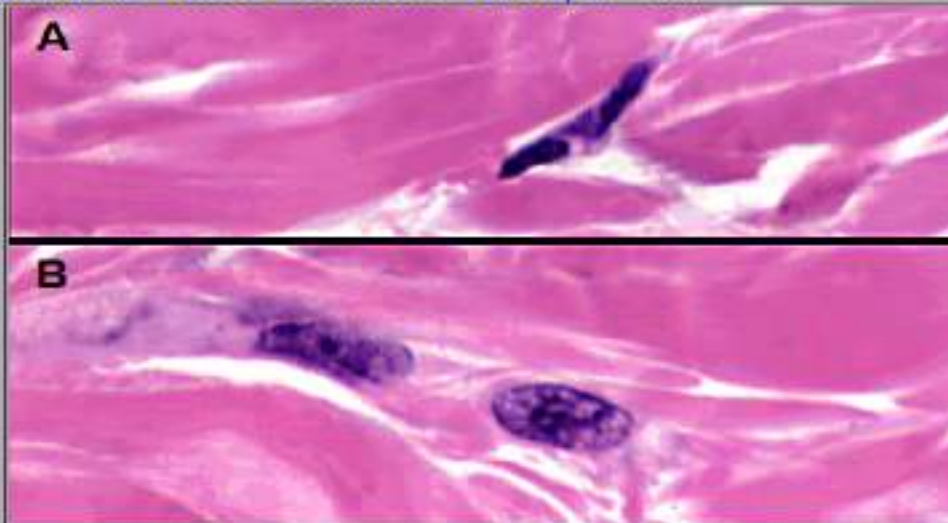


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- Lymphocyte
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- Collagen fibers
- Capillaries

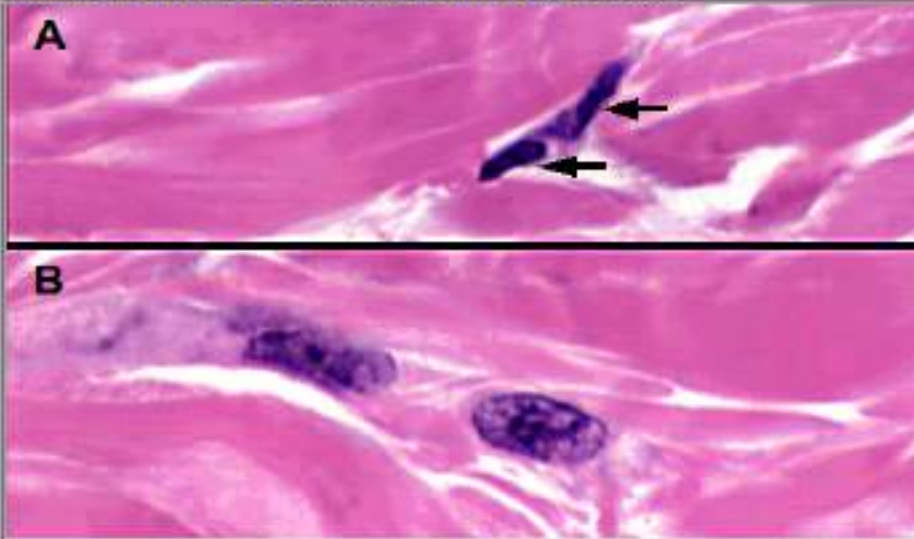


2 of 31

Fibroblast – Fibroblasts produce fibers and ground substance and are the most common cells in connective tissue proper. Nuclei of the two inactive fibroblasts are heterochromatic and flattened (A). Active fibroblast nuclei are euchromatic and more rounded (B). The cytoplasm of fibroblasts is not always visible by LM and, thus, cells must be identified primarily by their nuclei. 1000x, 1000x

click to identify:

- Inactive fibroblast nuclei
- Active fibroblast nuclei
- Collagen bundles

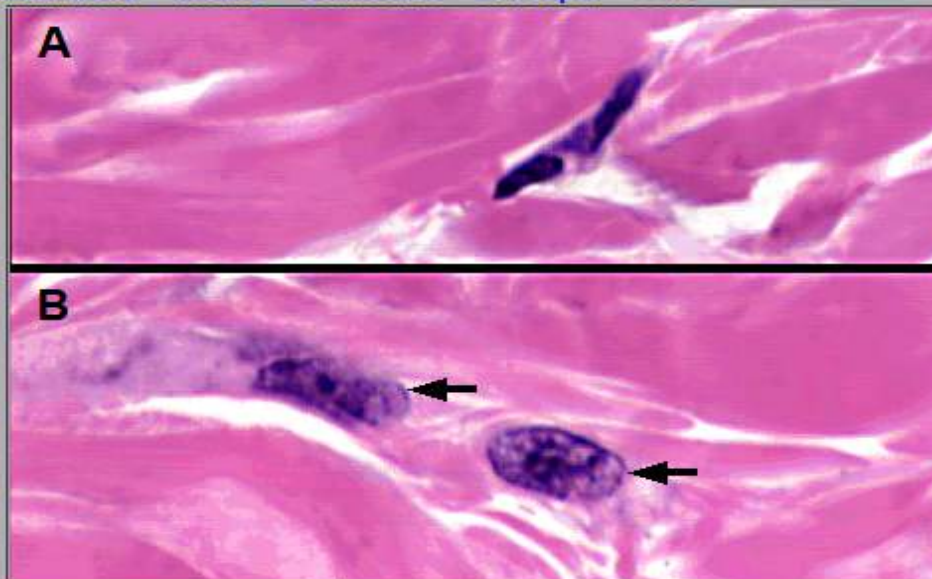


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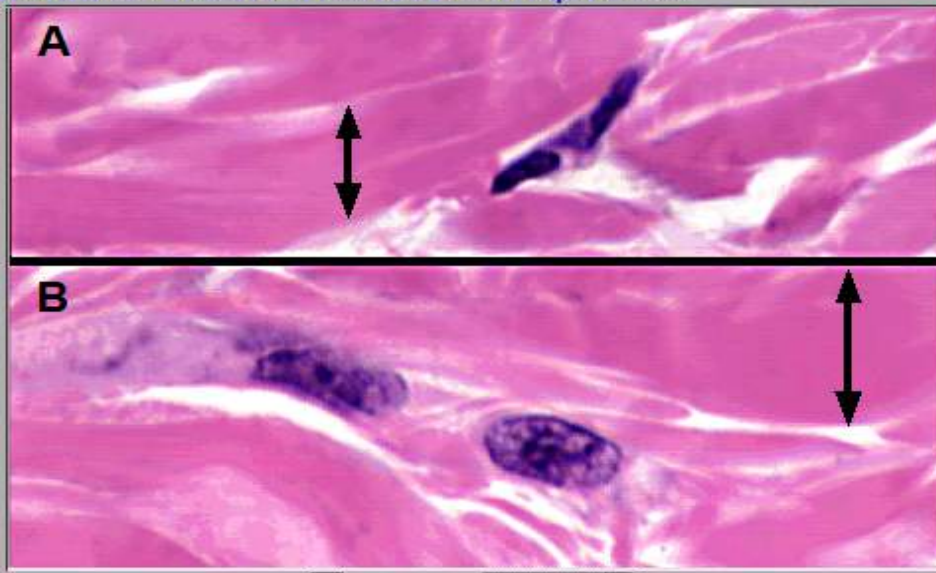


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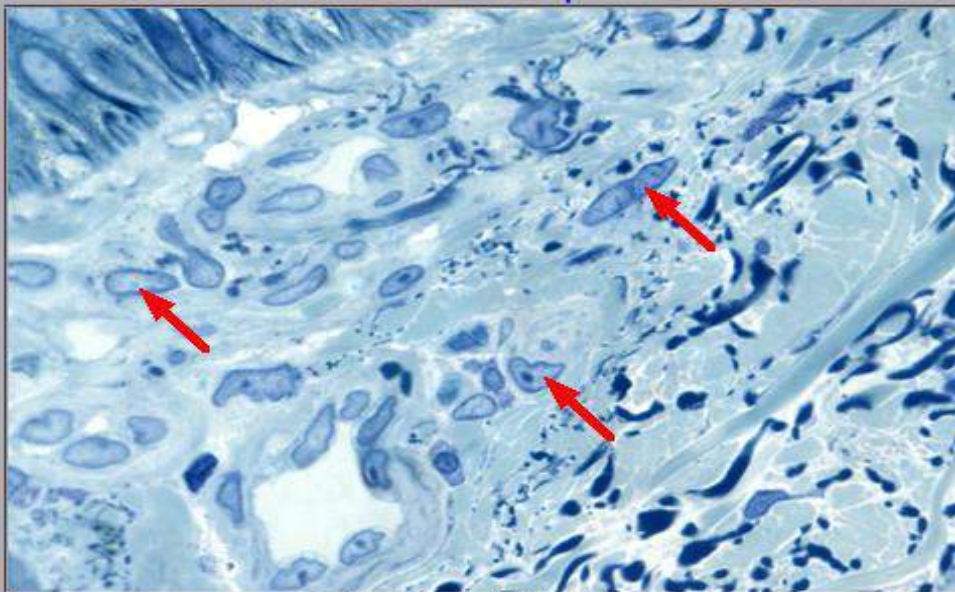


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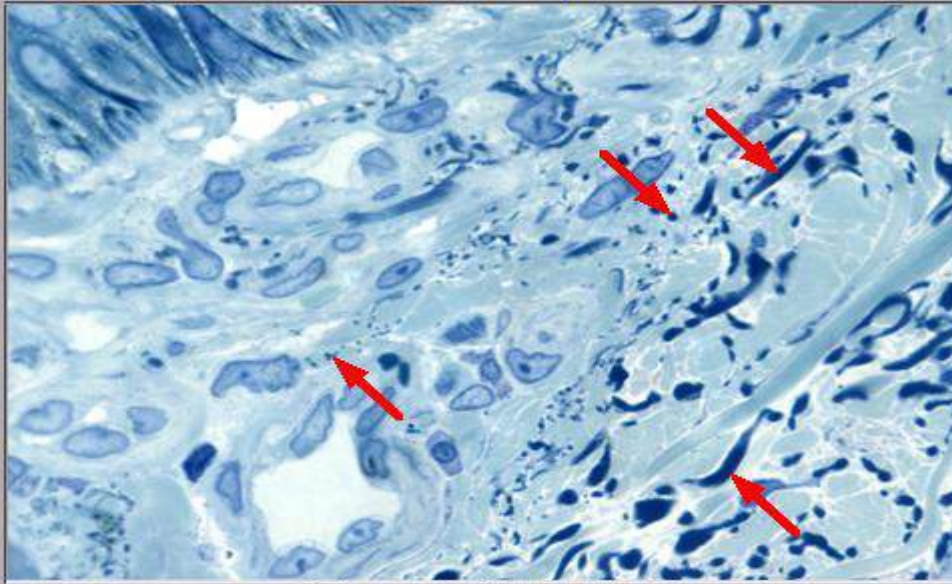


3 of 31

Active fibroblast -- Active fibroblasts are resident cells found in the connective tissues. Their nuclei are euchromatic and elongated. This toluidine blue stain of loose connective tissue beneath an epithelium demonstrates the surrounding collagen and heavily stained elastic fibers. Blood vessels are visible here. 1000x

click to identify:

- > Fibroblast nuclei
- Elastic fibers
- Collagen fibers
- Epithelium
- Plasma cell
- Blood vessels

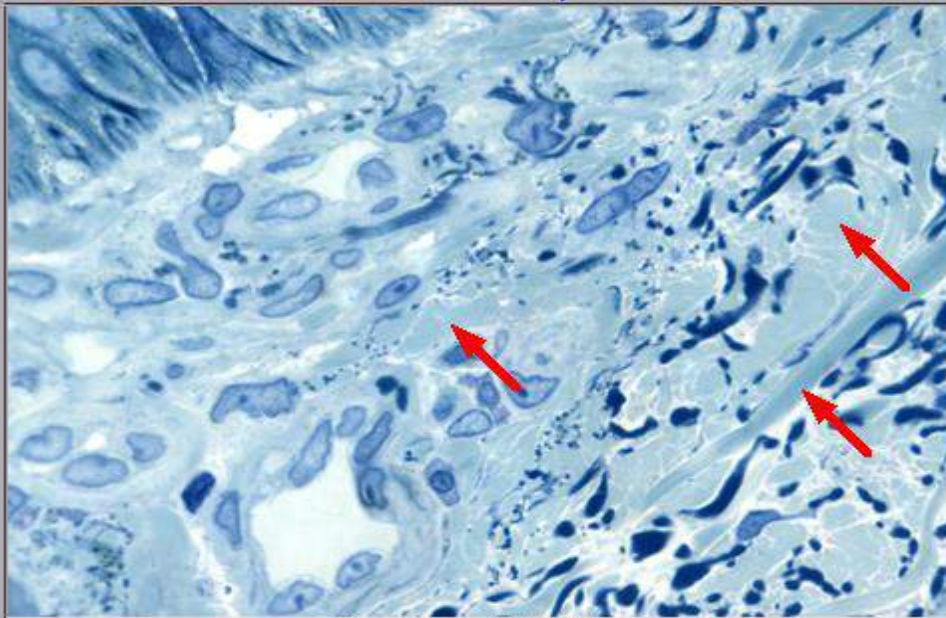


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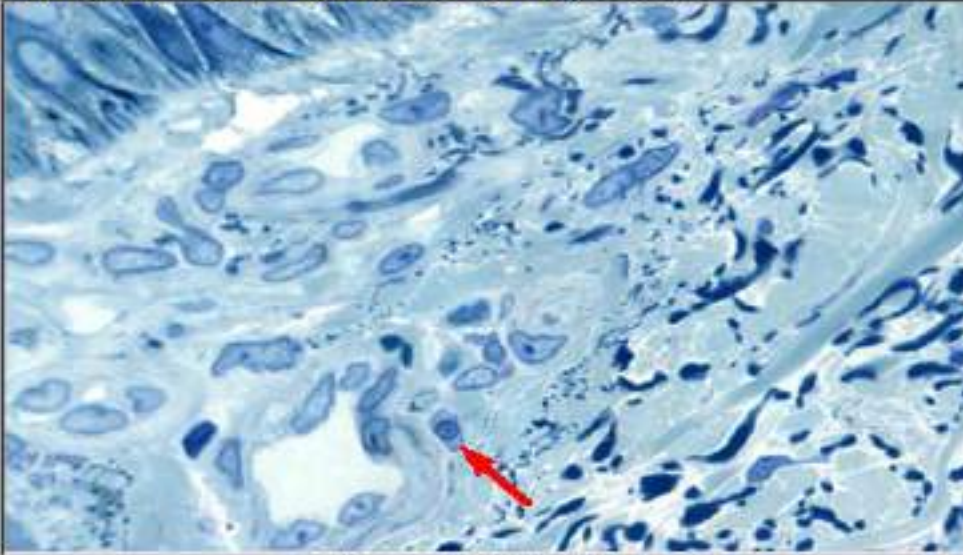


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- Elastic fibers
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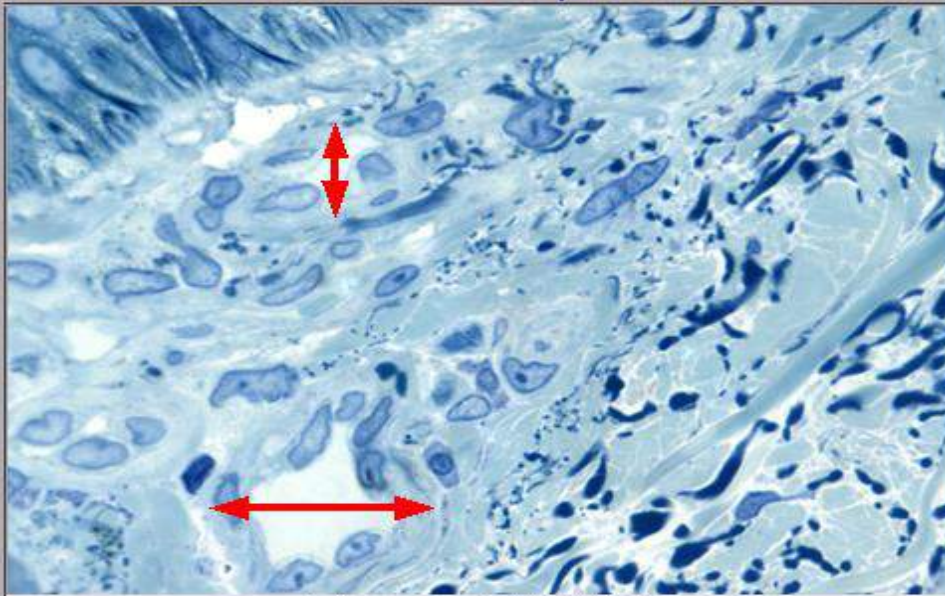


click to identify:

- Fibroblast nuclei
- Elastic fibers
- Collagen fibers
- Epithelium
- ▶ Plasma cell
- Blood vessels

◀ 3 of 31 ▶

Active fibroblast -- Active fibroblasts are resident cells found in the connective tissues. Their nuclei are euchromatic and elongated. This toluidine blue stain of loose connective tissue beneath an epithelium demonstrates the surrounding collagen and heavily stained elastic fibers. Blood vessels are visible here. 1000x

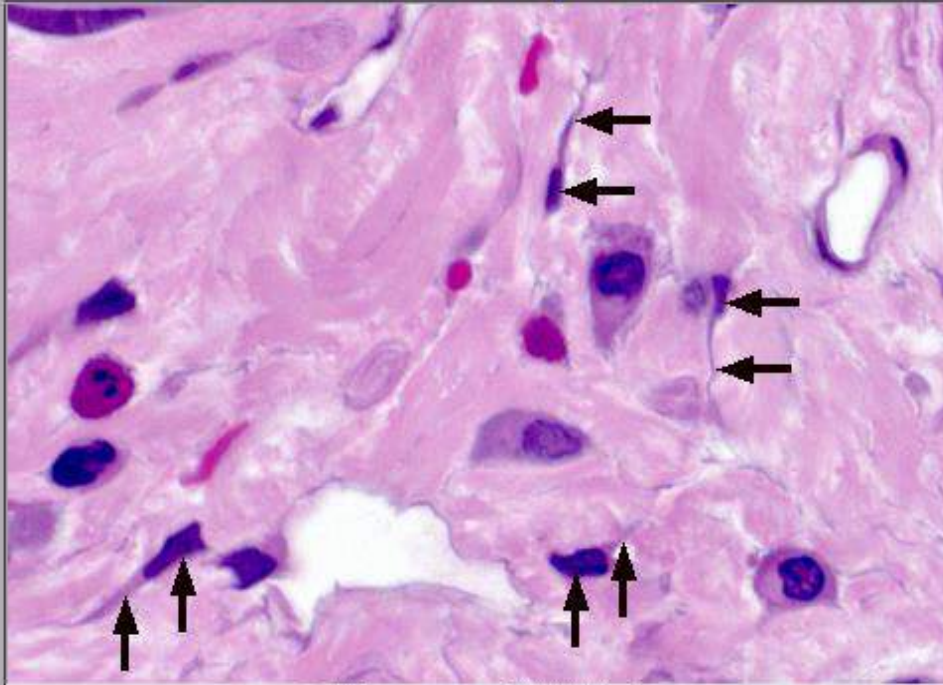


click to identify:

- Fibroblast nuclei
- Elastic fibers
- Collagen fibers
- Epithelium
- Plasma cell
- ▶ Blood vessels

◀ 3 of 31 ▶

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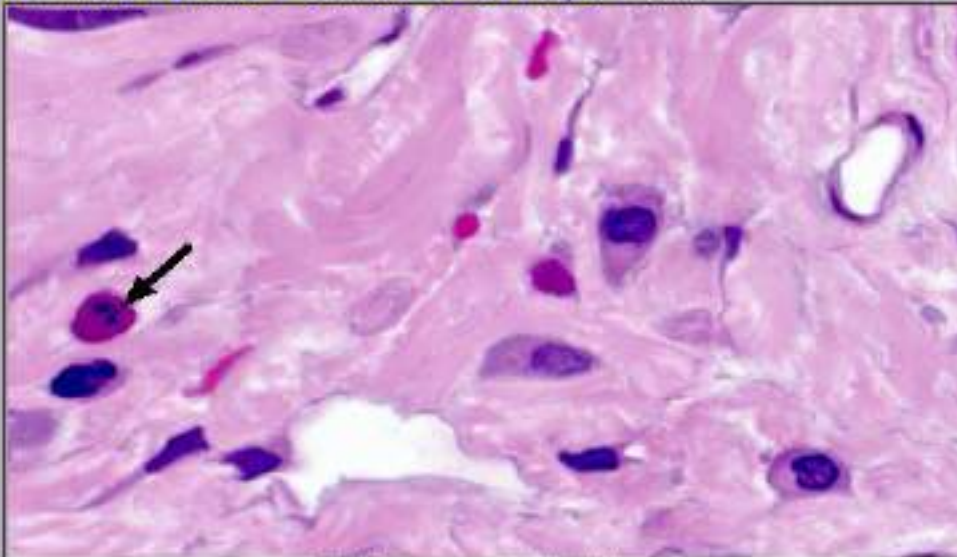


click to identify:

- > Inactive fibroblasts
- Mast cell
- Plasma cell
- Collagen fibers
- Venule

8 of 31

Inactive fibroblast – Loose connective tissue possesses a number of cell types, including inactive fibroblasts. These cells possess heterochromatic, elongated to stellate nuclei and highly attenuated cytoplasm. 1000x

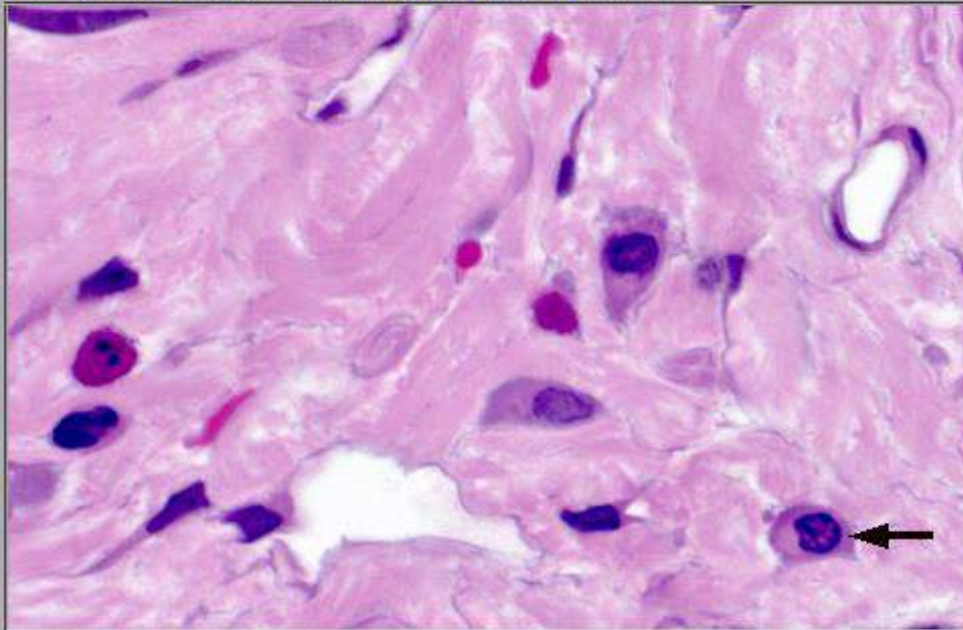


click to identify:

- Inactive fibroblasts
- > Mast cell
- Plasma cell
- Collagen fibers
- Venule

8 of 31

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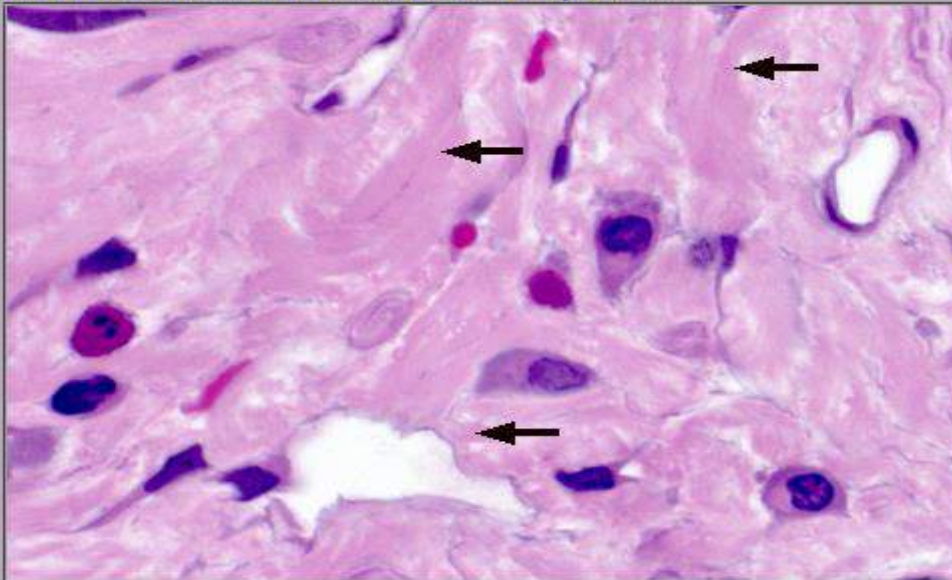


8 of 31

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click to identify:

- Inactive fibroblasts
- Mast cell
- > Plasma cell
- Collagen fibers
- Venule

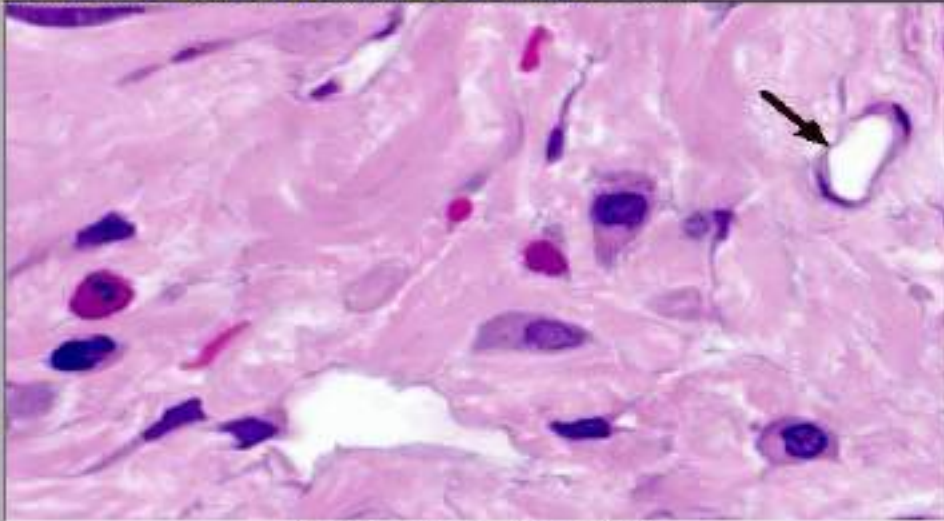


8 of 31

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click to identify:

- Inactive fibroblasts
- Mast cell
- Plasma cell
- > Collagen fibers
- Venule

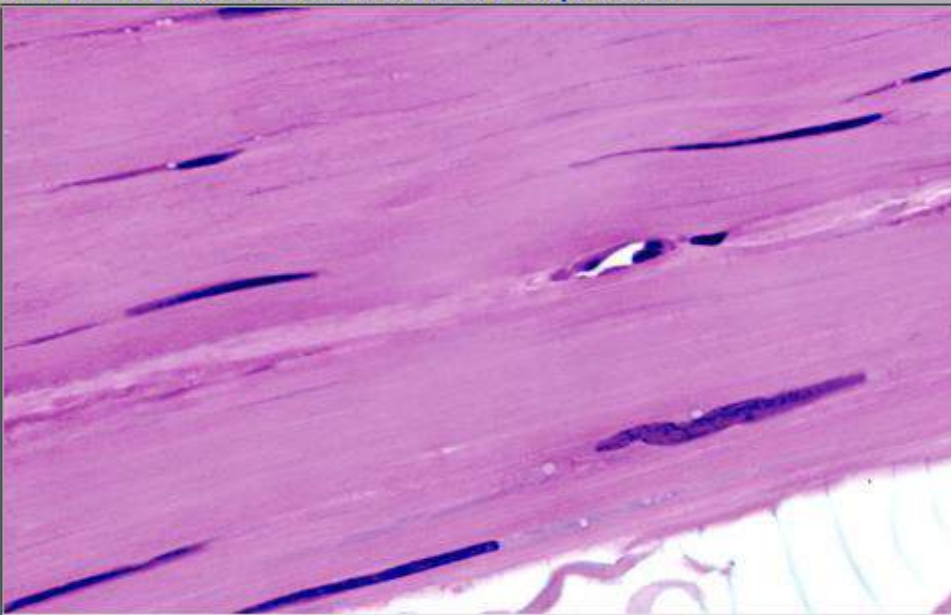


click to identify:

- Inactive fibroblasts
- Mast cell
- Plasma cell
- Collagen fibers
- > Venule

8 of 31

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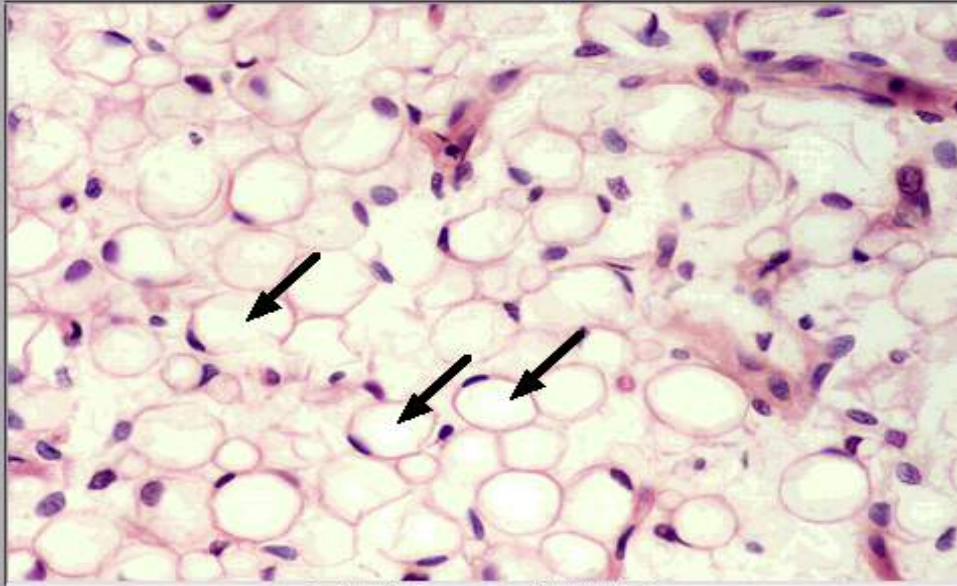
click to identify:

- Fibroblast nuclei
- Fibroblast cytoplasm
- Collagen fibers
- Capillary

9 of 31

Inactive fibroblast – Inactive fibroblasts are the predominate cell type in an adult tendon, which is classified as dense regular connective tissue. Highly flattened and heterochromatic fibroblast nuclei are interspersed with collagen bundles oriented in parallel. A sparse cytoplasm is visible extending from the tips of the nuclei. 1000x.

التأشير جدا واضحة لهذا هي عليكم في هذا السلايد

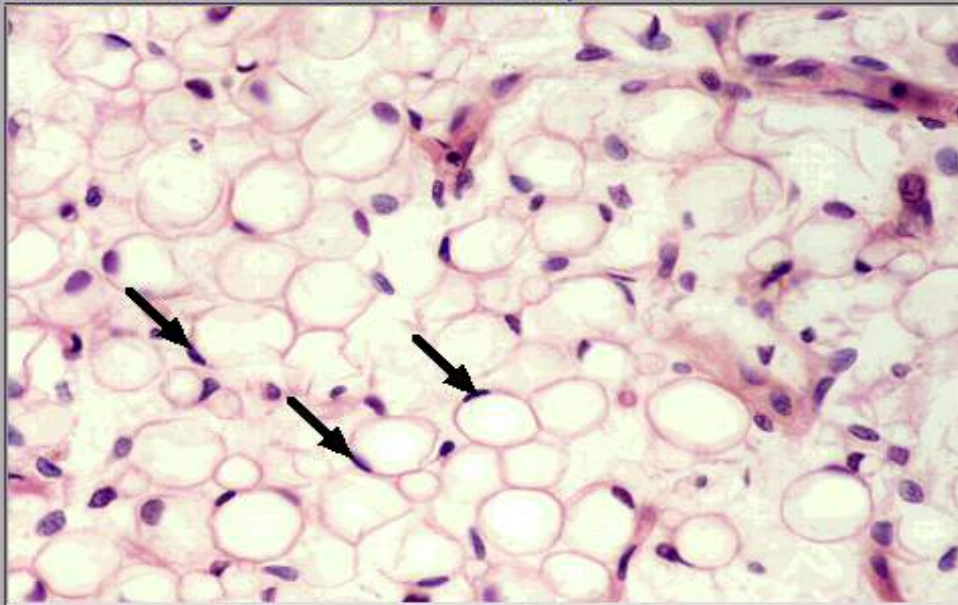


click to identify:

- > Adipocytes
- Adipocyte nuclei
- Active fibroblasts
- Blood vessels

12 of 31

Adipocyte -- Adipocytes are found individually or in small clusters in loose connective tissue. They are also found in larger clusters forming adipose connective tissue, shown here. Adipocytes contain a single large lipid droplet that compresses the nucleus and cytoplasm to the periphery. The lipid is extracted during tissue processing and, therefore, the cell appears empty. 400x

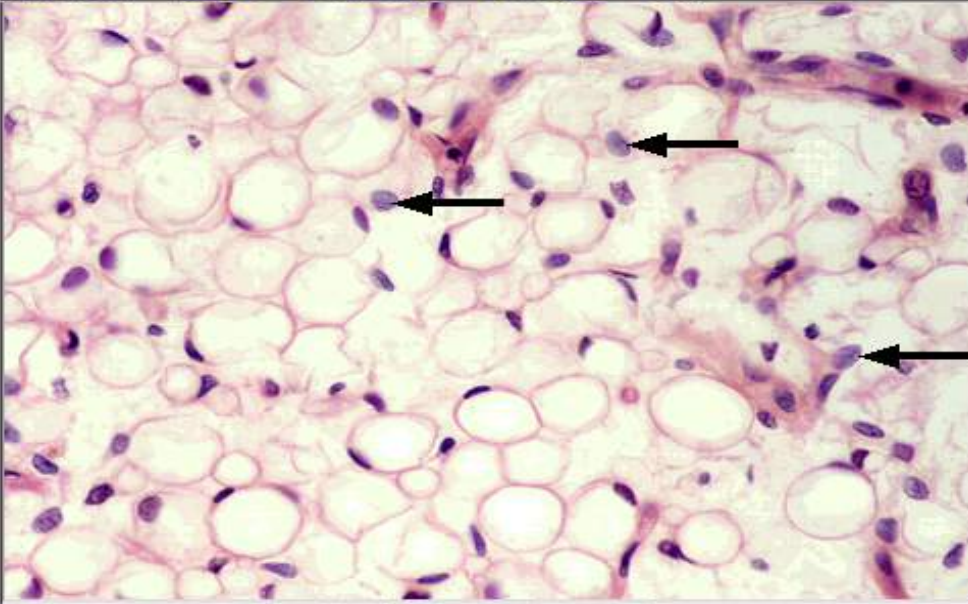


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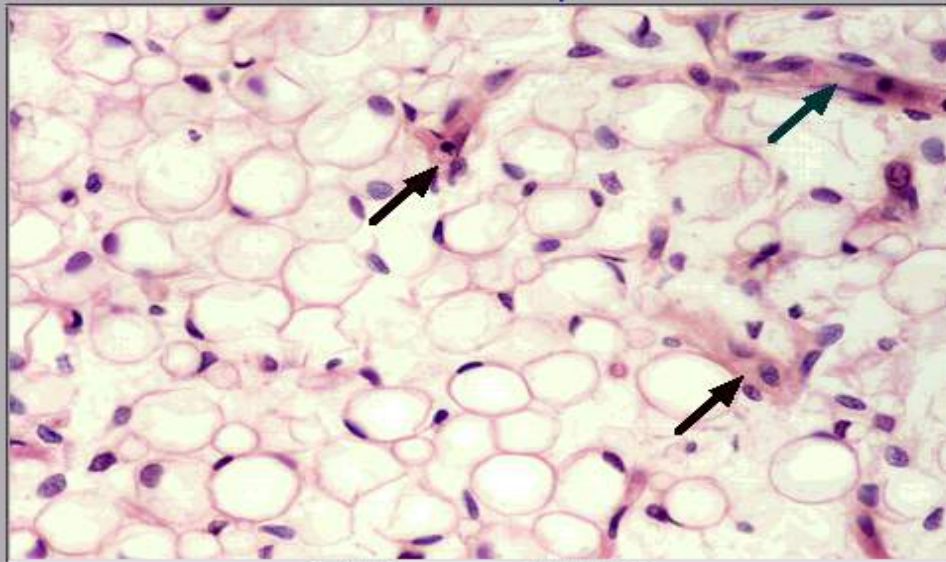


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- Adipocytes
- Adipocyte nuclei
- > Active fibroblasts
- Blood vessels

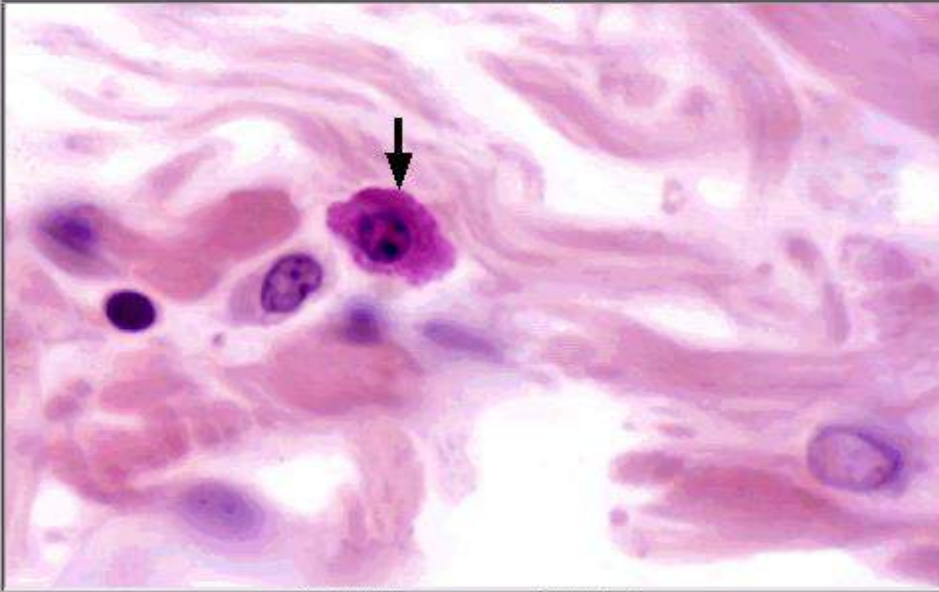


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- Adipocytes
- Adipocyte nuclei
- Active fibroblasts
- > Blood vessels

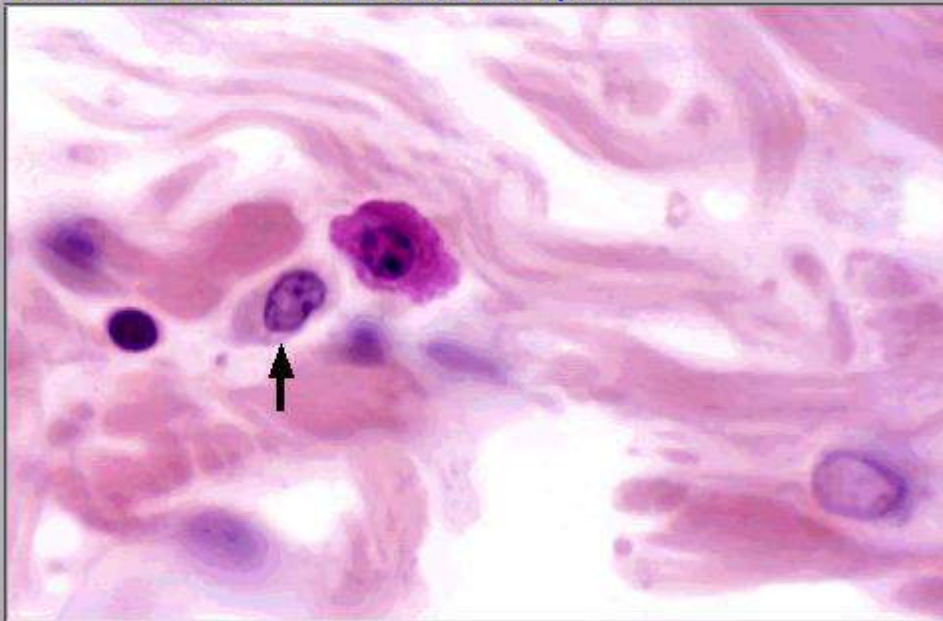


17 of 31

Macrophage and mast cell -- A mast cell is a motile cell that is easily identified by its centrally located, heterochromatic, spherical nucleus and its coarse red granules containing histamine and heparin. A macrophage, with its indented nucleus, has readily visible cytoplasm. A lymphocyte and an active fibroblast can also be seen. 1000x

click to identify:

- > Mast cell
- Macrophage
- Lymphocyte
- Fibroblast nucleus

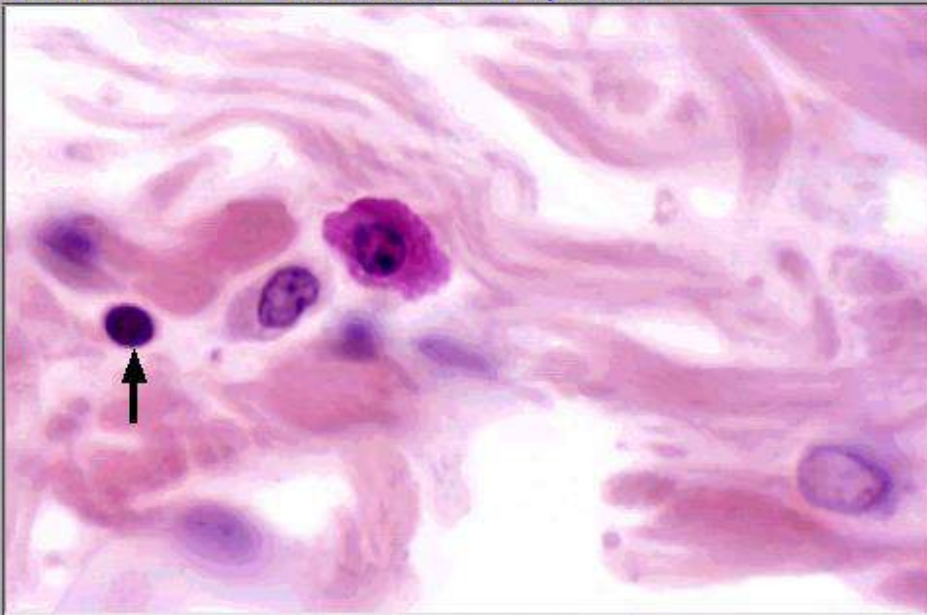


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- Mast cell
- > Macrophage
- Lymphocyte
- Fibroblast nucleus

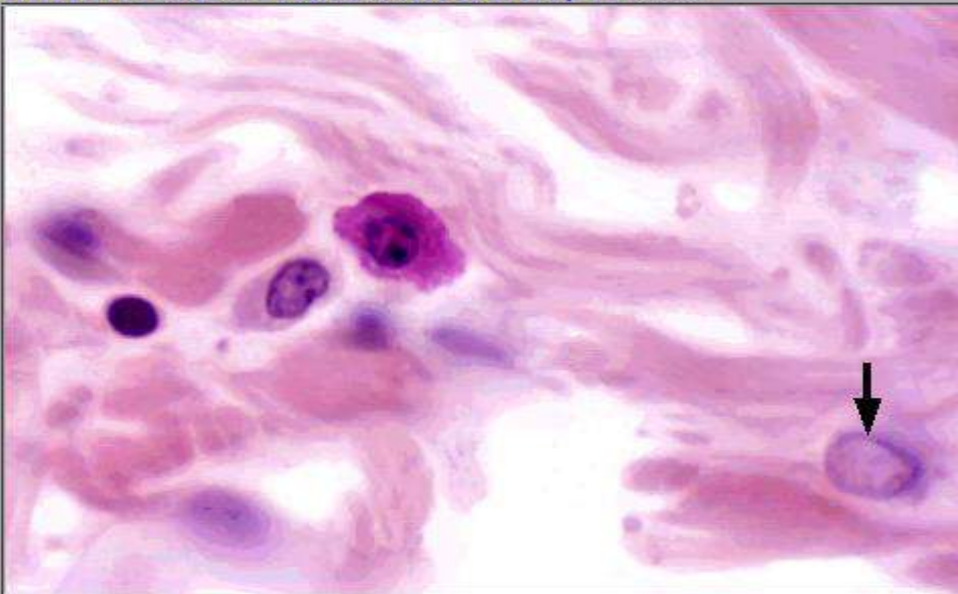


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click to identify:

- Mast cell
- Macrophage
- > Lymphocyte
- Fibroblast nucleus

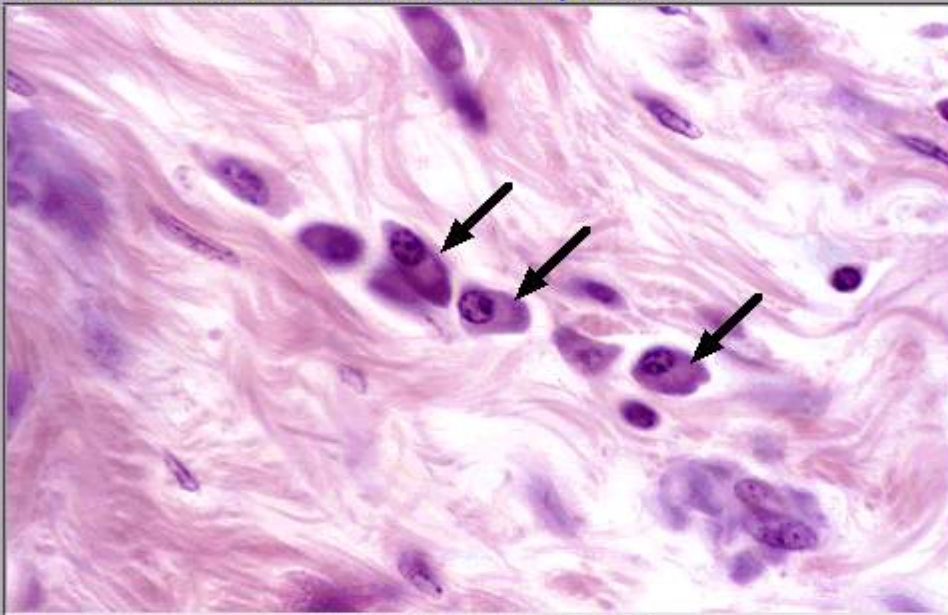


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- Mast cell
- Macrophage
- Lymphocyte
- > Fibroblast nucleus

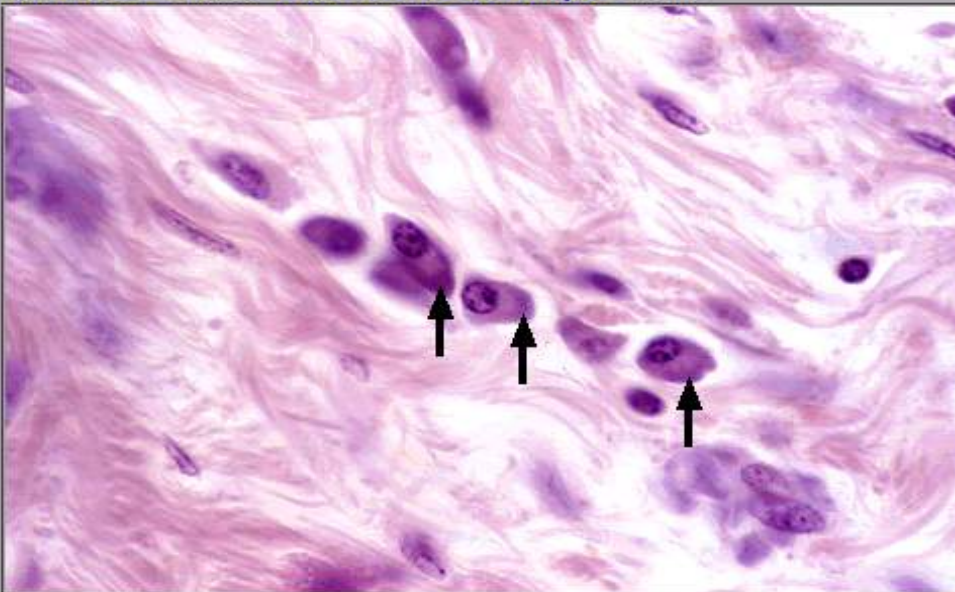


click to identify:

- > Plasma cells
- Peripheral RER
- Negative Golgi
- Lymphocytes
- Fibroblast nuclei
- Collagen fibers

22 of 31

Plasma cell -- A typical plasma cell has an eccentric nucleus; heterochromatin is frequently arranged to form a clock face. A peripheral rim of cytoplasm stains purple with hematoxylin, due to the presence of RER. A "negative" Golgi image lies adjacent to the nucleus. These organelles indicate production of protein for export by these cells, specifically humoral (circulating) antibodies. 1000x.

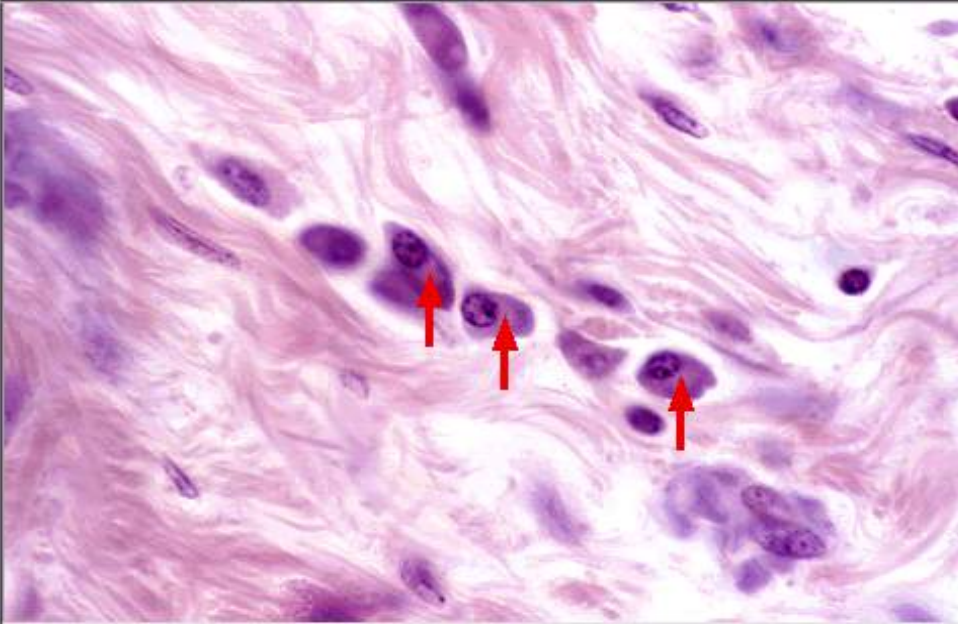


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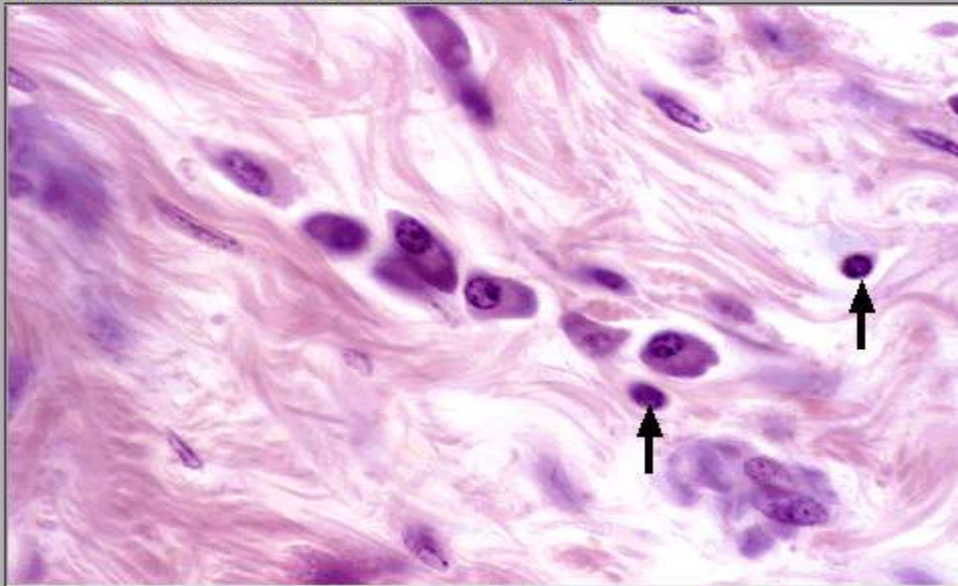


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- Lymphocytes
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- Collagen fibers

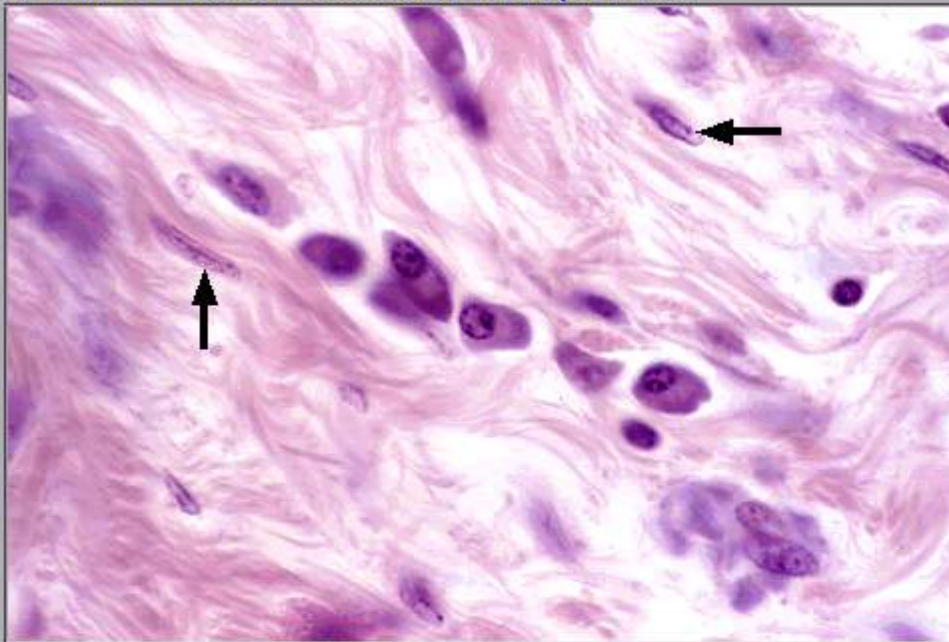


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- Plasma cells
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- Negative Golgi
- > Lymphocytes
- Fibroblast nuclei
- Collagen fibers

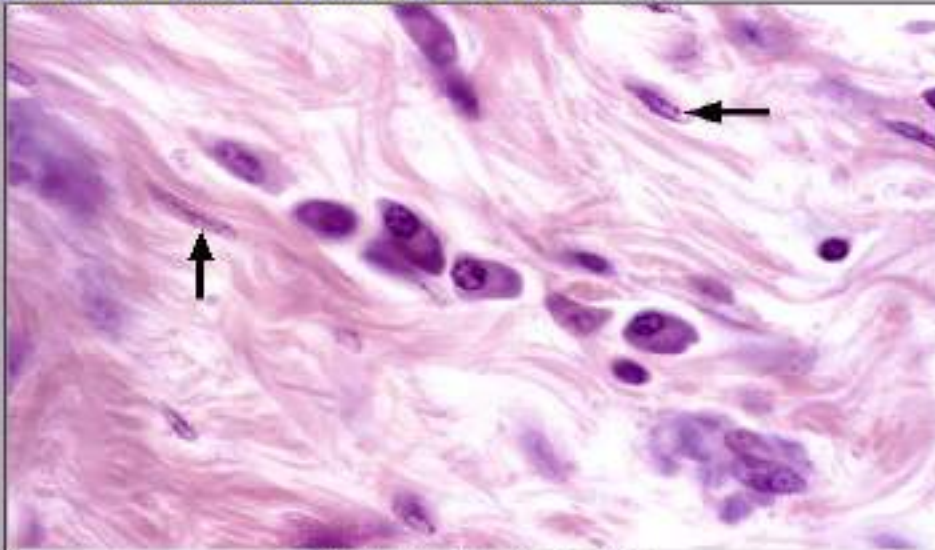


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- Negative Golgi
- Lymphocytes
- > Fibroblast nuclei
- Collagen fibers

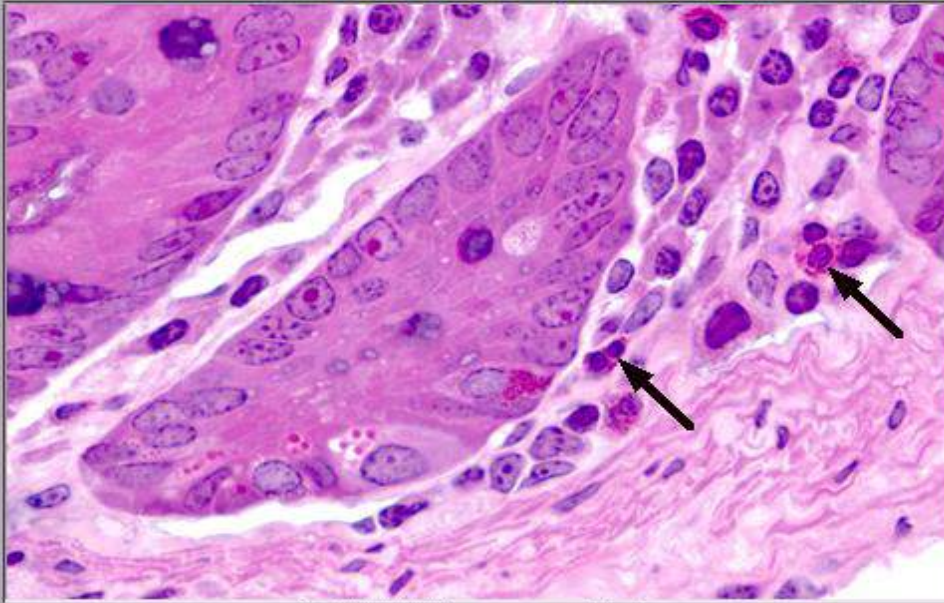


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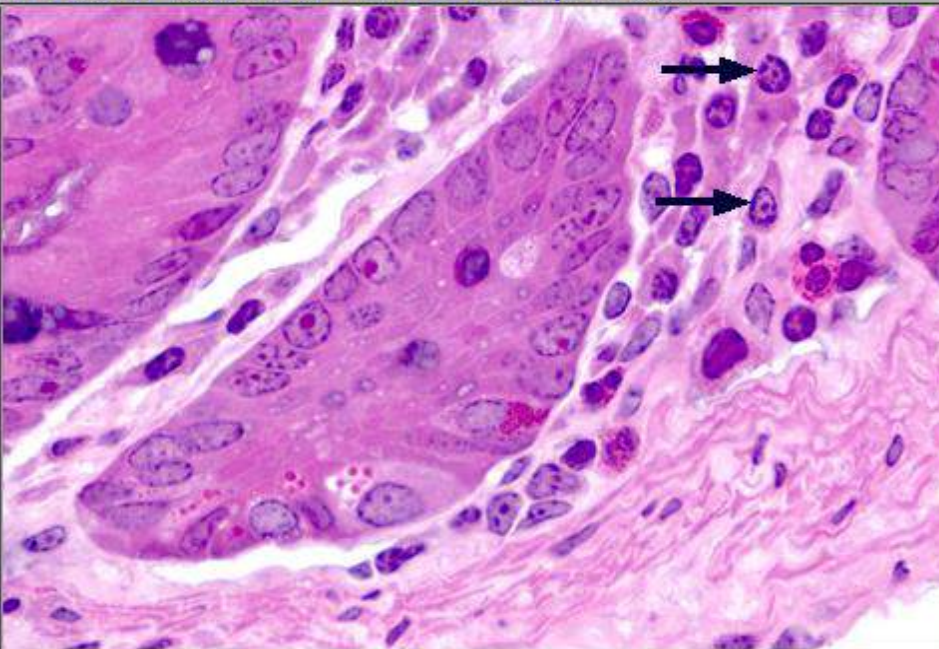


27 of 31

Eosinophil -- An eosinophil has a bi-lobed nucleus and large, eosinophilic granules in its cytoplasm. Eosinophils are frequently encountered in loose connective tissue, as seen here in the small intestine. Mast cells and plasma cells are also present. 1000x.

click to identify:

- > Eosinophils
- Plasma cells
- Mast cell

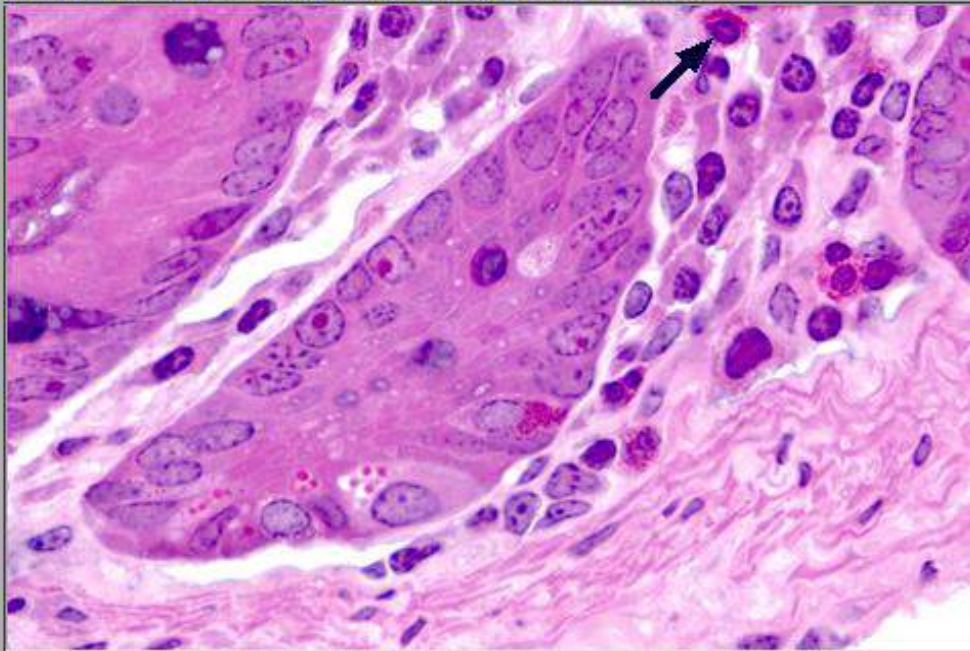


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click to identify:

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- > Plasma cells
- Mast cell

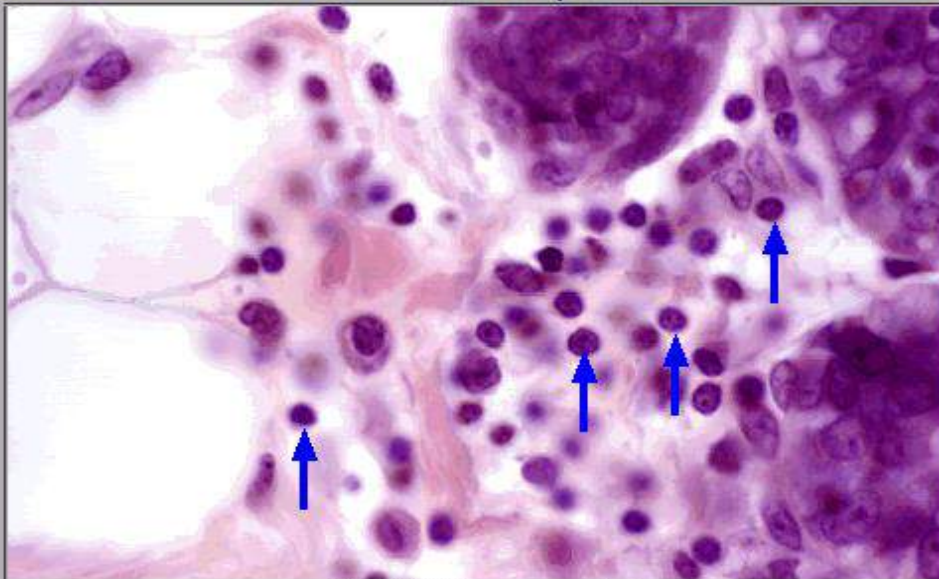


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click to identify:

- Eosinophils
- Plasma cells
- > Mast cell

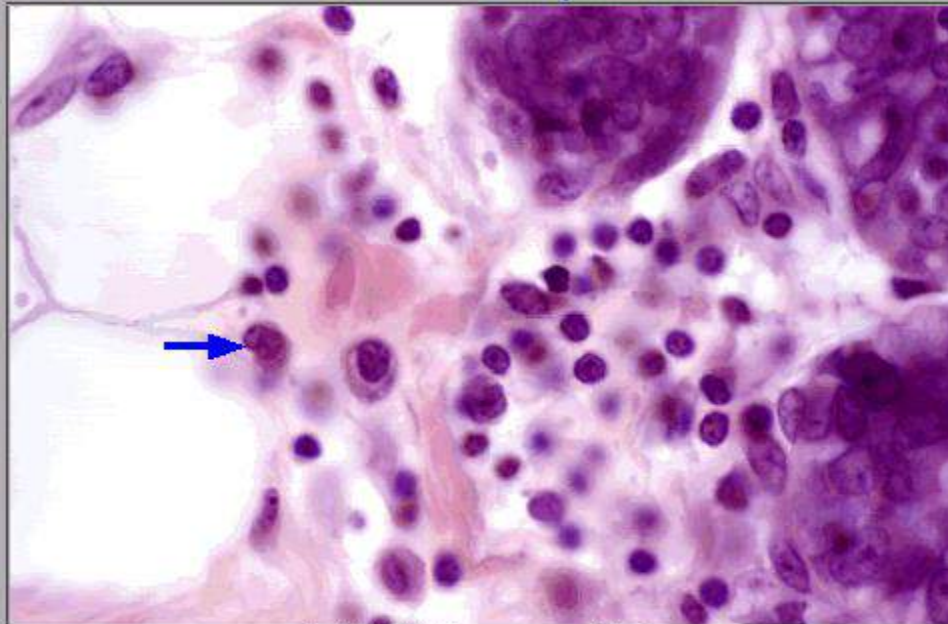


28 of 31

Lymphocyte -- Lymphocytes, small, spherical cells with minimal cytoplasm, have rounded, very heterochromatic nuclei that frequently display an indentation. Lymphocytes are white blood cells transported via the blood, but are active only after entering connective tissue. Lymphocytes function in the immune response; some differentiate into plasma cells and produce antibodies. 1000x

click to identify:

- > Lymphocytes
- Macrophage
- Fibroblasts
- Adipocytes
- Plasma cell
- Collagen

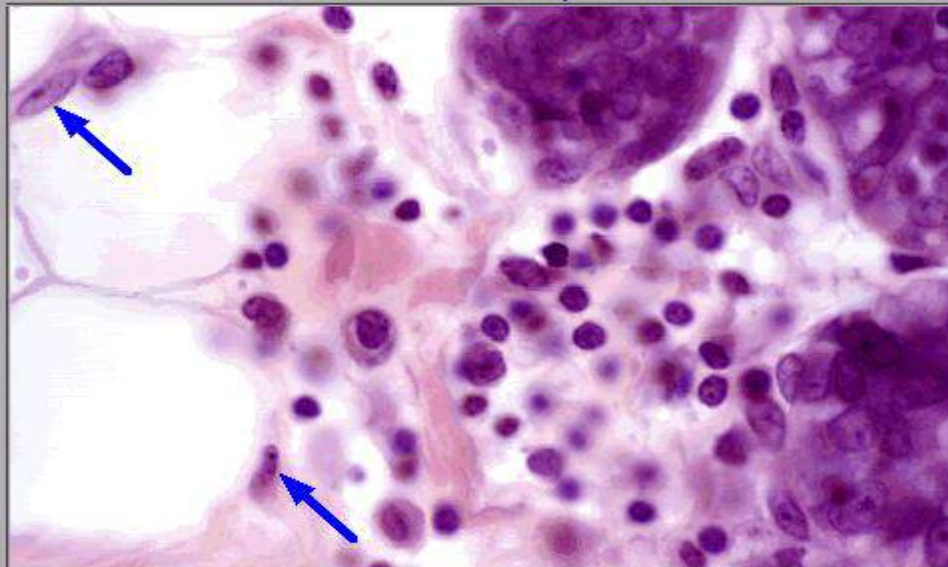


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- Fibroblasts
- Adipocytes
- Plasma cell
- Collagen

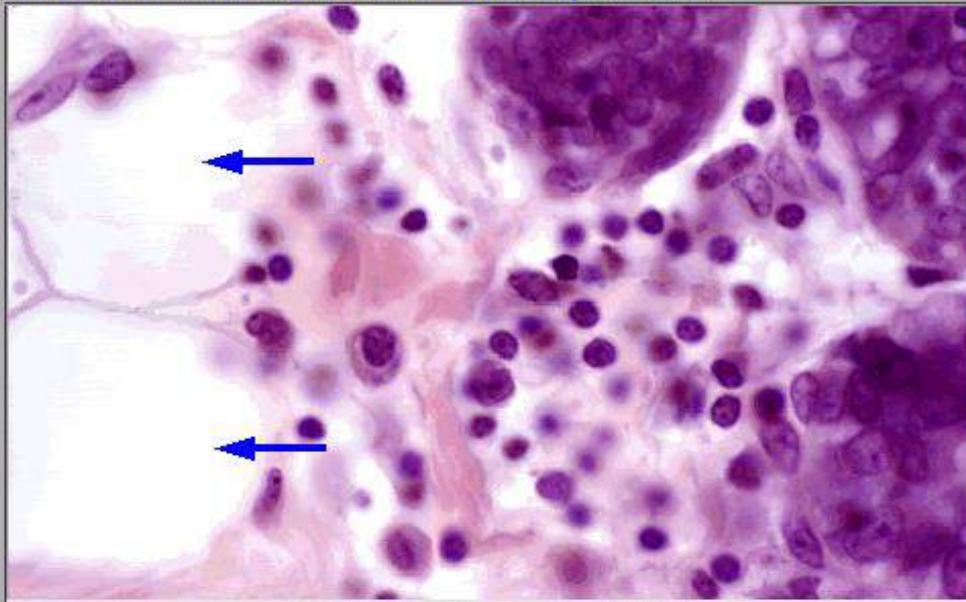


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- Lymphocytes
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- Adipocytes
- Plasma cell
- Collagen

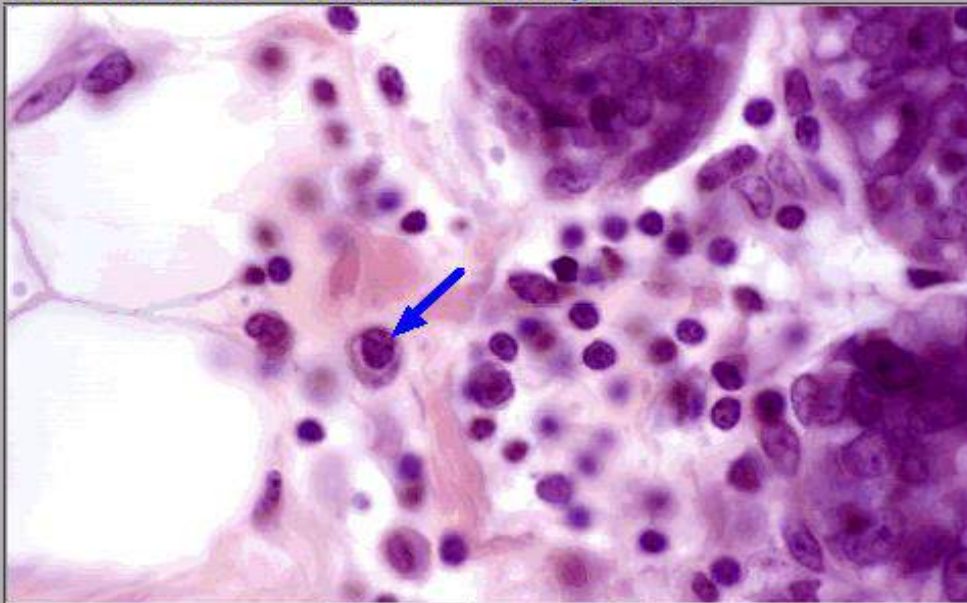


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Lymphocytes
Macrophage
Fibroblasts
> Adipocytes
Plasma cell
Collagen

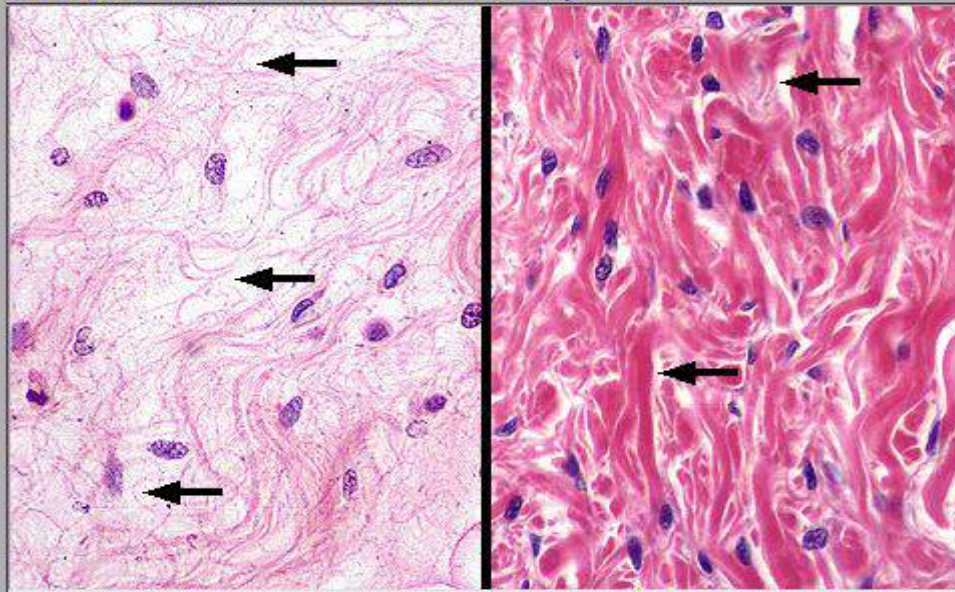


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Lymphocytes
Macrophage
Fibroblasts
Adipocytes
> Plasma cell
Collagen

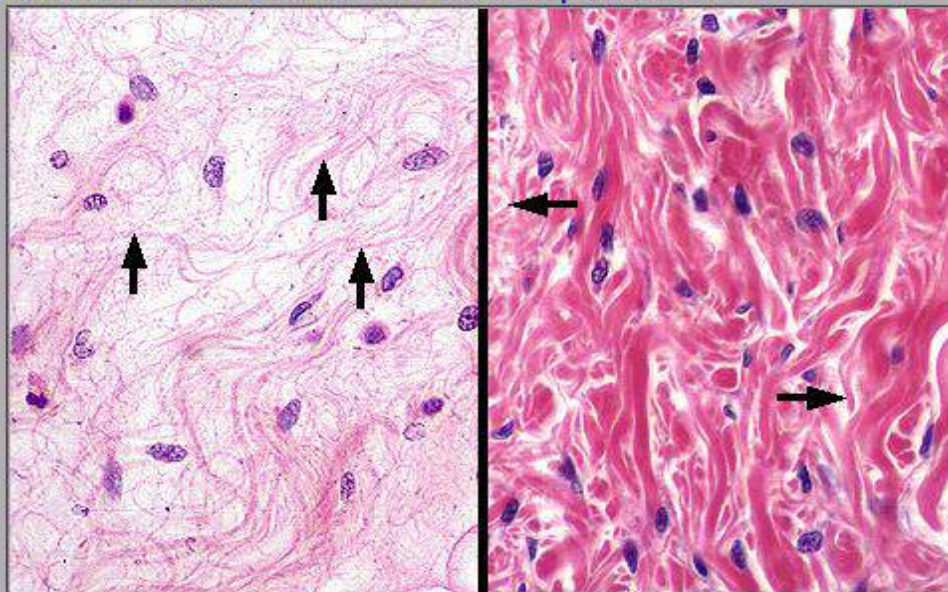


1 of 13

Extracellular matrix – Connective tissue consists of cells and an extracellular matrix composed of fibers (collagen, reticular and elastic), ground substance and tissue fluid. Ground substance, primarily proteoglycans, is present as a gel in connective tissue proper, where it surrounds cells and fibers, and serves as padding between other tissues and organs of the body. 100x

click to identify:

- > Ground substance
- > Collagen fibers
- > Collagen bundles
- Fibroblasts

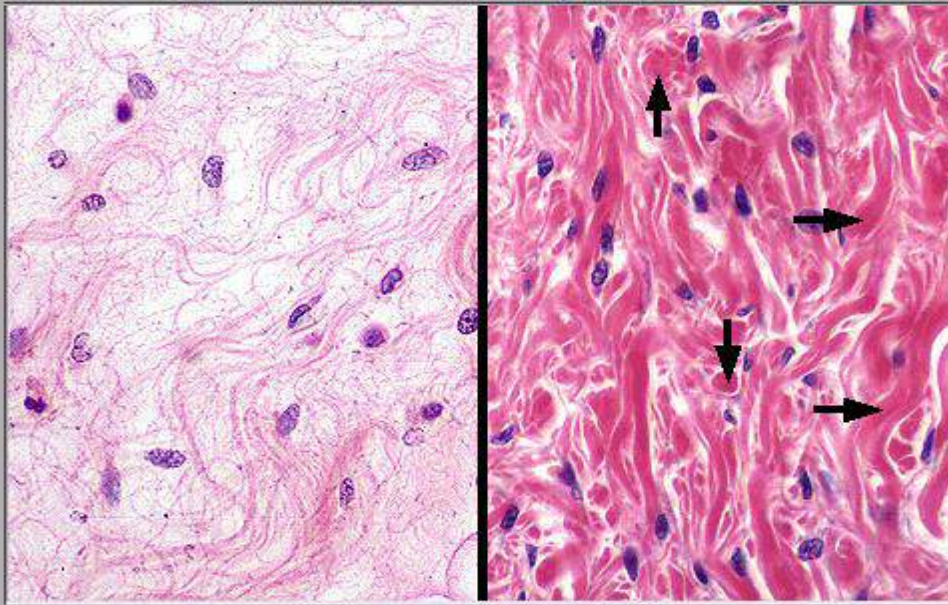


1 of 13

Collagen fibers, the most abundant of the connective tissue fibers, are produced by fibroblasts and stain pink with eosin. These fibers are flexible, but do not stretch and, thus, provide great tensile strength to the tissue. Smaller fibers may aggregate to form larger collagen bundles, and fiber size and orientation are used for classifying connective tissue proper.

click to identify:

- > Ground substance
- > Collagen fibers
- > Collagen bundles
- Fibroblasts

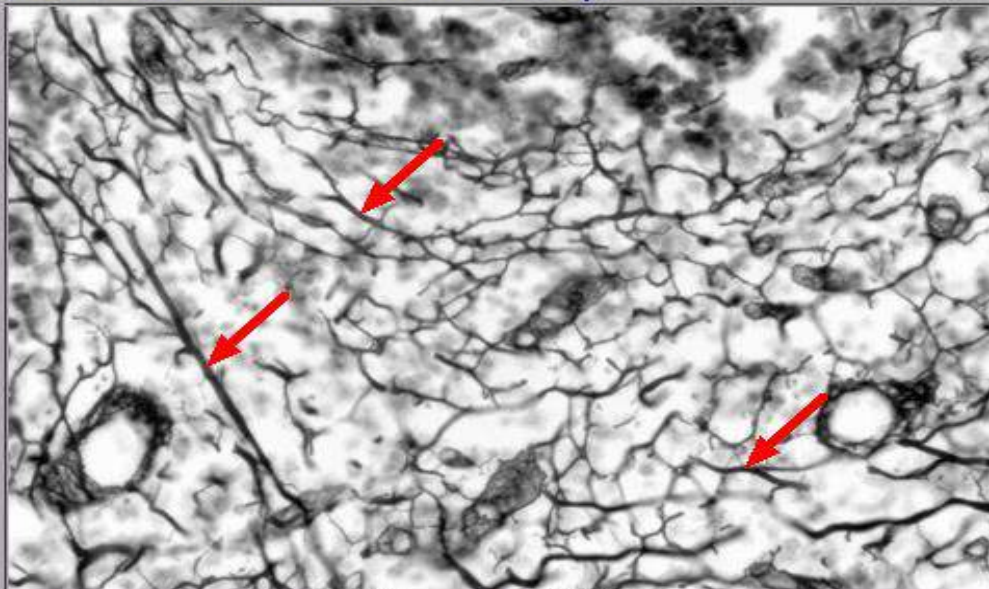


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click to identify:

- Ground substance
- Collagen fibers >
- > Collagen bundles
- Fibroblasts

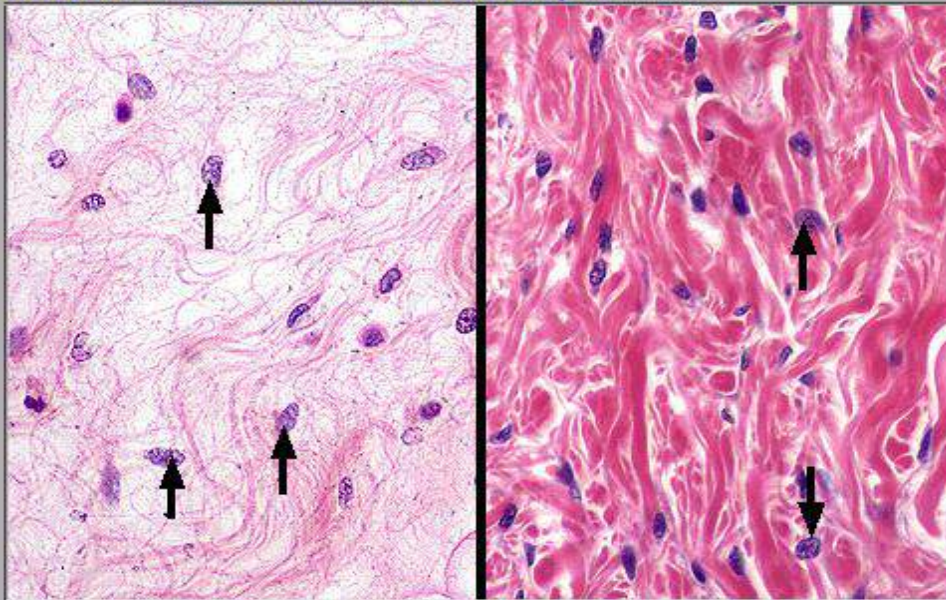


5 of 13

Reticular fibers -- Reticular fibers are a component of all connective tissues proper and provide the sole stroma for lymphatic organs (except thymus), hemopoietic tissue, endocrine organs and liver. Reticular fibers also surround adipocytes and muscle fibers. This high magnification image illustrates the characteristic branching meshwork of reticular fibers. Lymph node 1000x

click to identify:

- > Reticular fibers
- Branch points

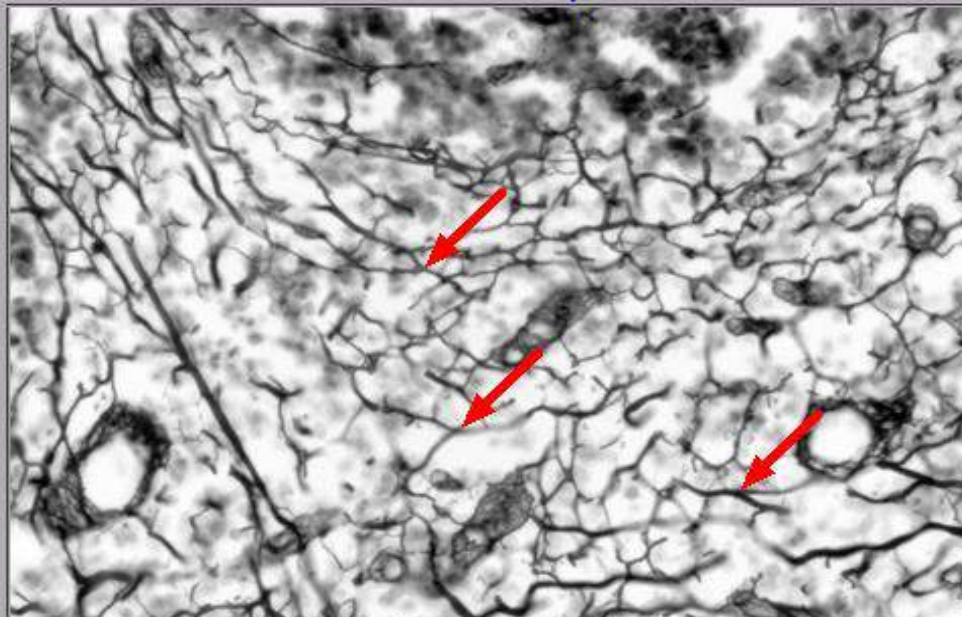


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click to identify:

- Ground substance
- Collagen fibers >
- Collagen bundles
- > Fibroblasts

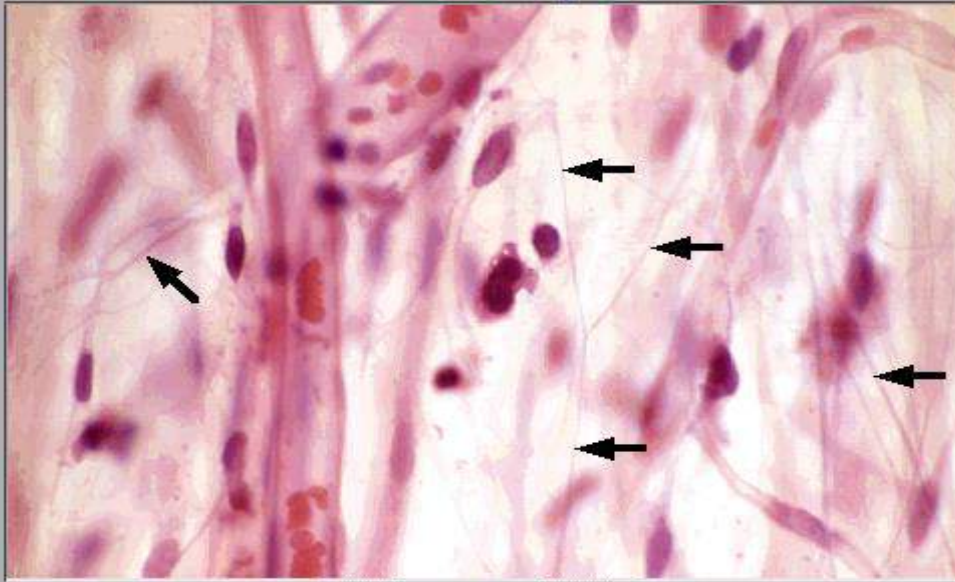


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- Reticular fibers
- > Branch points

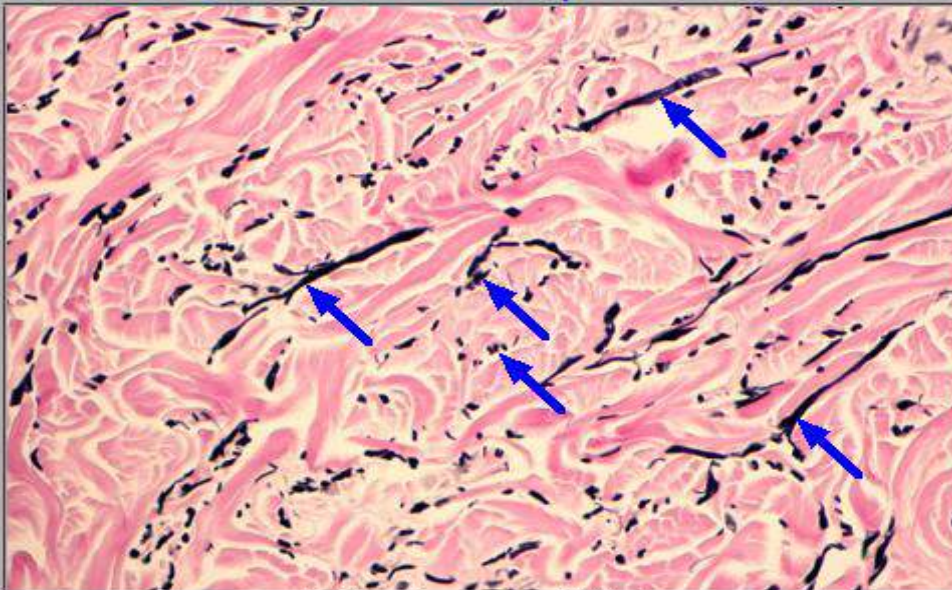


6 of 13

Elastic fibers -- Elastic fibers are thin, straight, branching, and eosinophilic. Elastic fibers are present in most connective tissues; however, they are usually difficult to differentiate from collagen. Elastic fibers are produced by fibroblasts in connective tissues and smooth muscle cells in blood vessels. Ground substance and tissue fluid fills the spaces between fibers and cells. 1000x

click to identify:

- Capillaries
- Fibroblasts
- Macrophage
- Lymphocyte
- > Elastic fibers
- Collagen fibers
- Ground substance

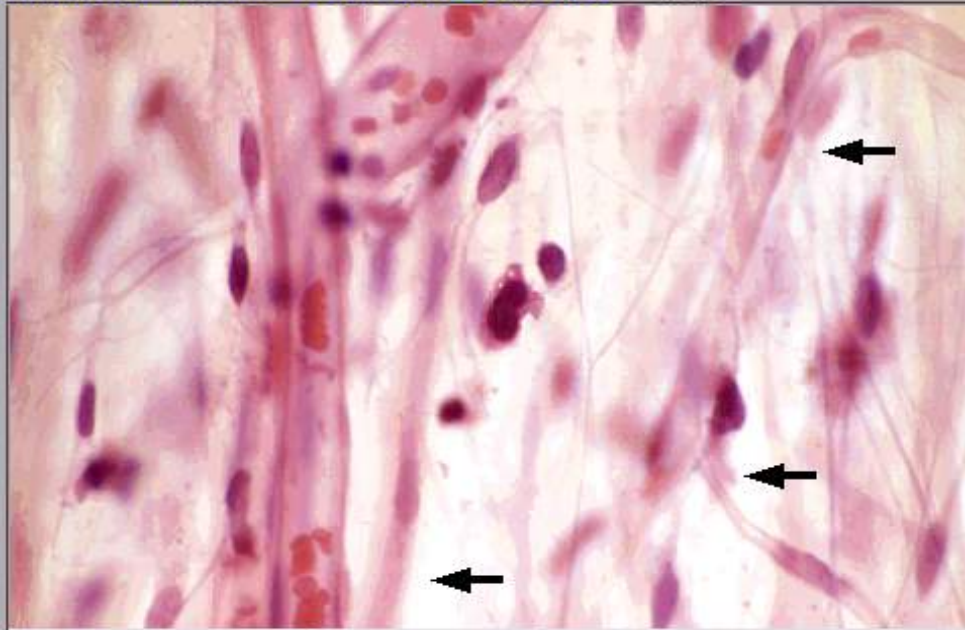


8 of 13

Elastic and collagen fibers -- This dense irregular CT in the dermis of the skin has been stained with a special elastin stain, to show elastic fibers, and eosin for collagen fibers. Branching elastic fibers appear as black or dark magenta structures intermixed with the pink-staining collagen fibers. Elastic fibers are seen in both cross-sectional and longitudinal views. 400x

click to identify:

- > Elastic fibers
- Collagen fibers
- Ground substance

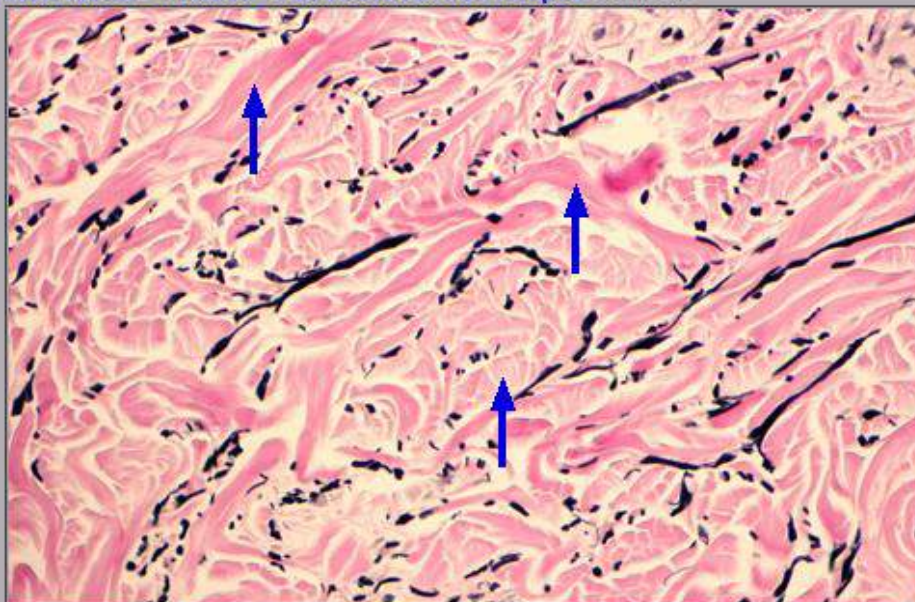


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click to identify:

- Capillaries
- Fibroblasts
- Macrophage
- Lymphocyte
- Elastic fibers
- Collagen fibers
- > Ground substance

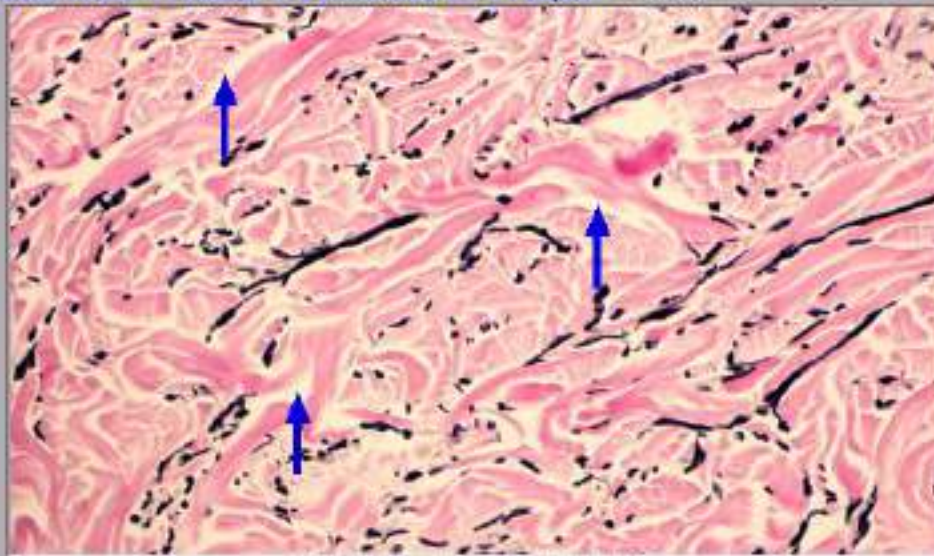


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click to identify:

- Elastic fibers
- > Collagen fibers
- Ground substance

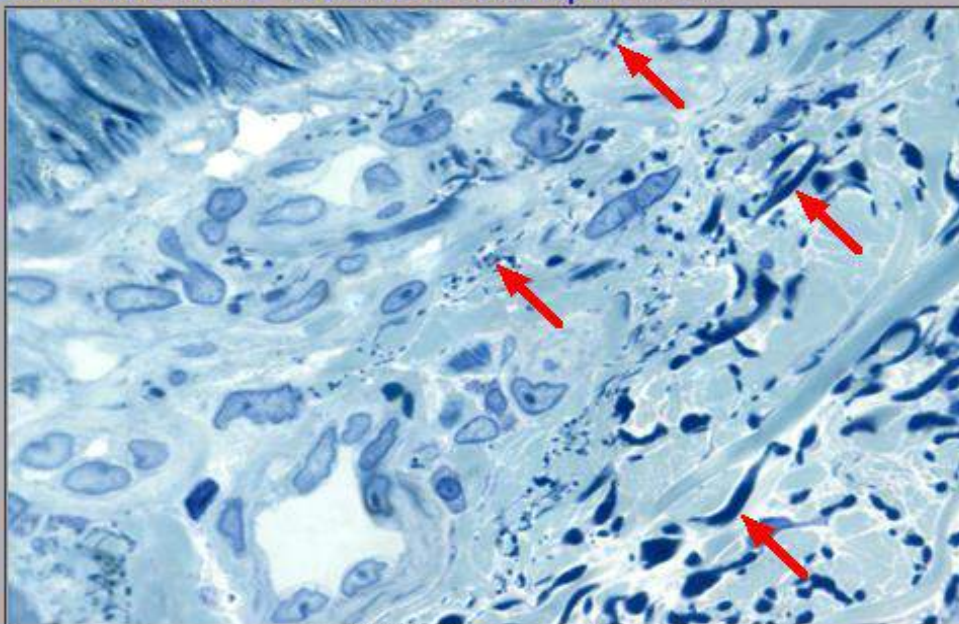


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click to identify:

- Elastic fibers
- Collagen fibers
- > Ground substance

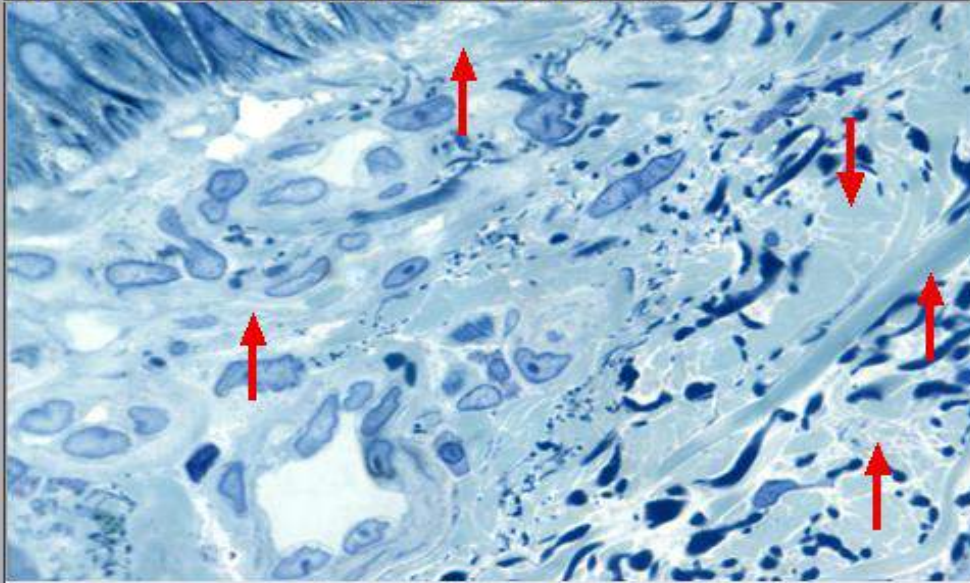


10 of 13

Elastic and collagen fibers -- Toluidine blue-differentiates elastic and collagen fibers at the interface of dense irregular and loose connective tissues. Elastic fibers stain dark blue, with thicker fibers predominating in the dense connective tissue. The elastic fibers present in both regions gives skin its distensibility while the collagen fibers, stained light blue, provide tensile strength. 1000x

click to identify:

- > Elastic fibers
- Collagen fibers
- Loose CT
- Dense irregular CT

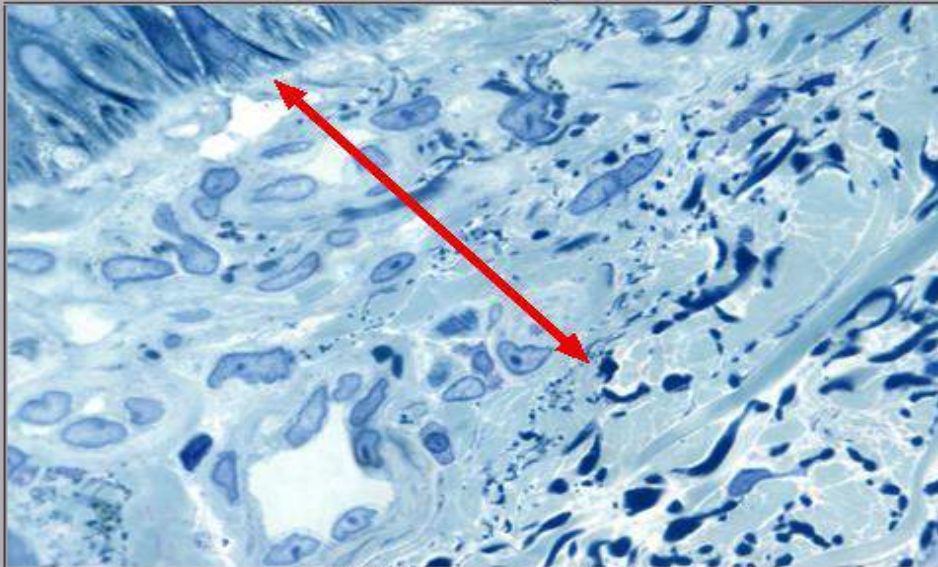


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click to identify:

- Elastic fibers
- > Collagen fibers
- Loose CT
- Dense irregular CT

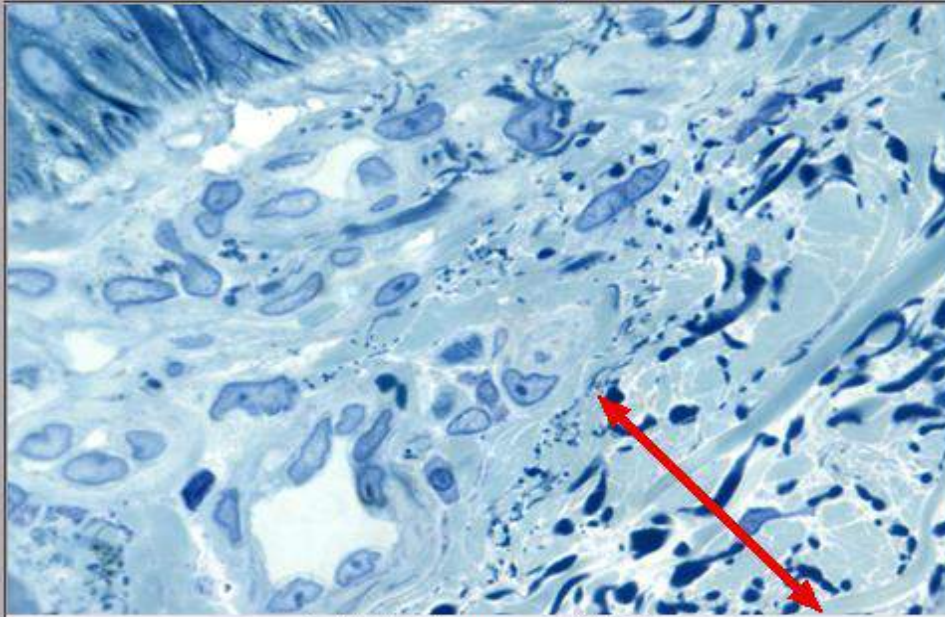


10 of 13

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click to identify:

- Elastic fibers
- Collagen fibers
- > Loose CT
- Dense irregular CT

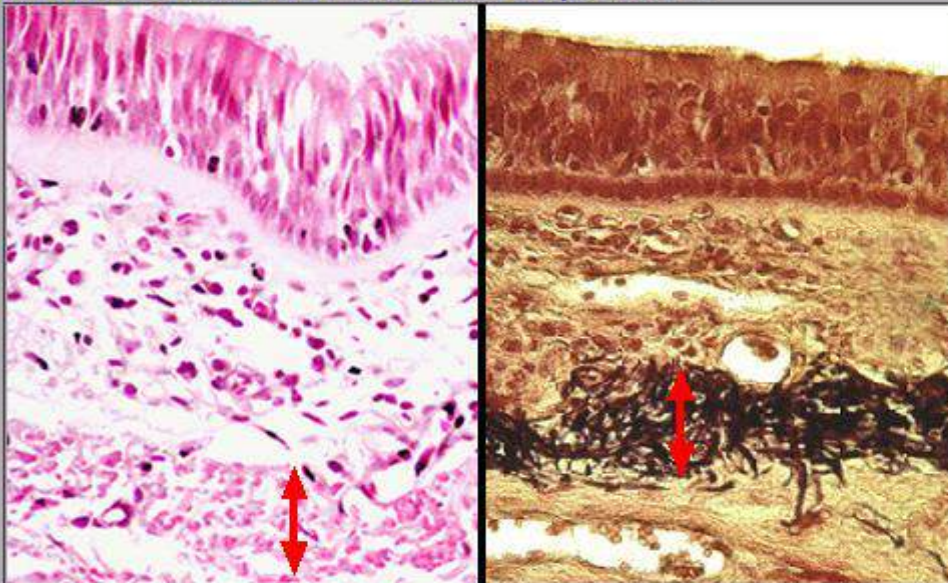


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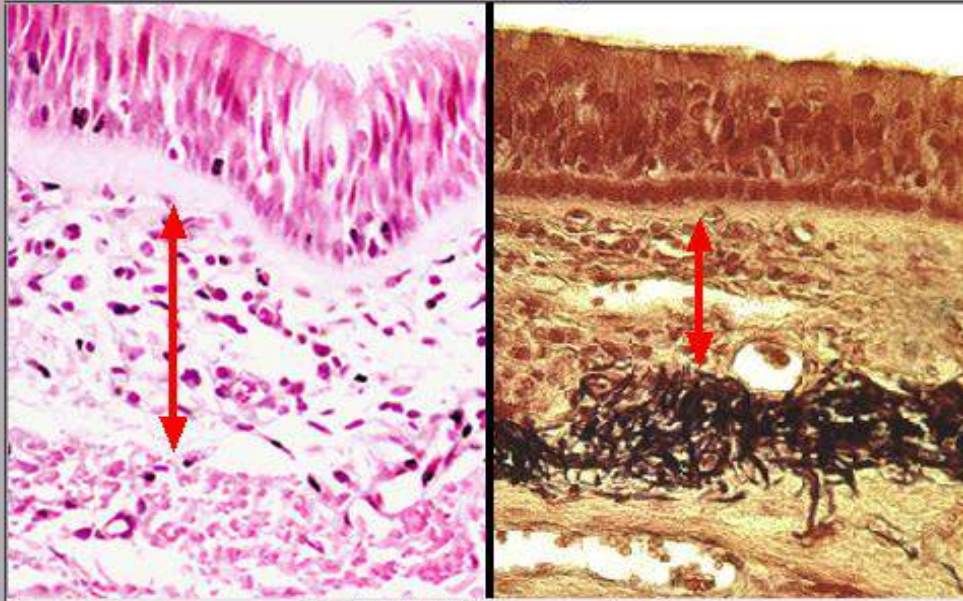


12 of 13

Elastic membrane – A large accumulation of elastic fibers forms an elastic membrane in the mucosa of the trachea. The image on the left is stained with H&E, the one on the right is stained for elastin, the major protein component of elastic fibers. While elastic fibers can be seen with eosin staining, the elastin stain is optimal. 400x, 400x

click to identify:

- > Elastic membrane
- Loose CT
- Epithelium

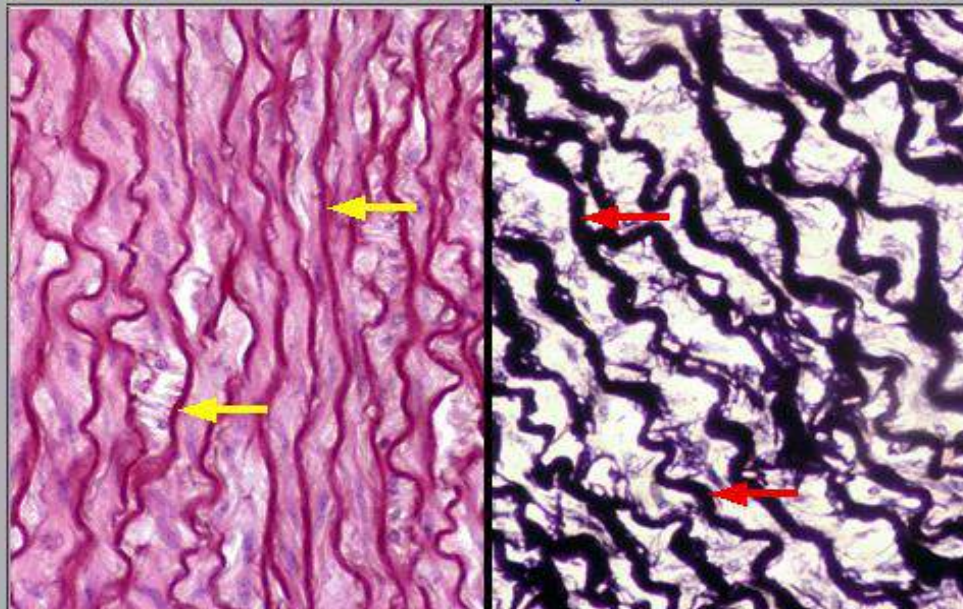


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- Elastic membrane
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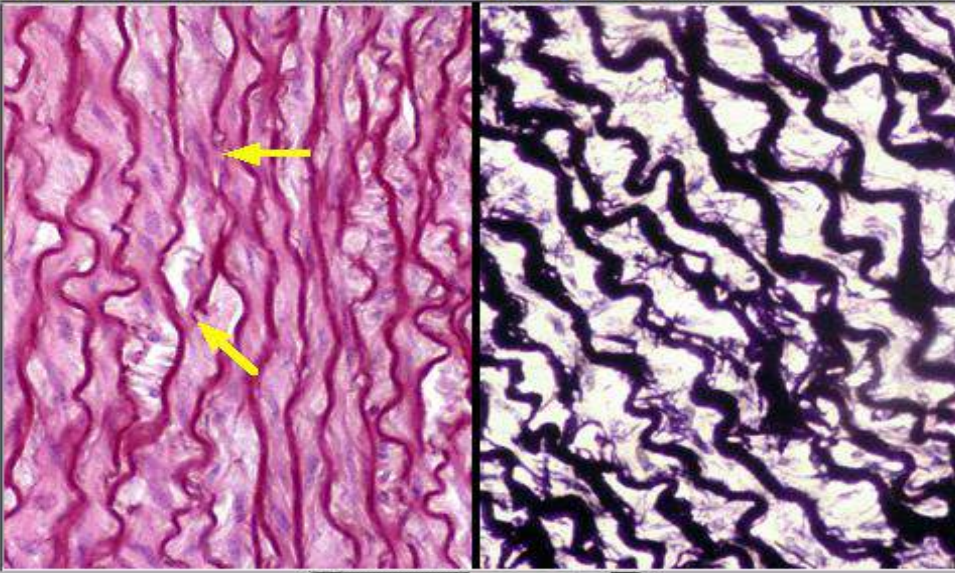


click to identify:

- > Elastic laminae
- Fenestrations
- Smooth muscle

13 of 13

Elastic laminae -- In some cases, elastin, the major component of elastic fibers, forms sheets rather than fibers, such as in these cross sections of elastic arteries. These sheets, termed elastic laminae, are fenestrated, that is, they have holes in them, like slices of Swiss cheese. Between the laminae are smooth muscle cells that produce the elastin sheets. 400x, 400x

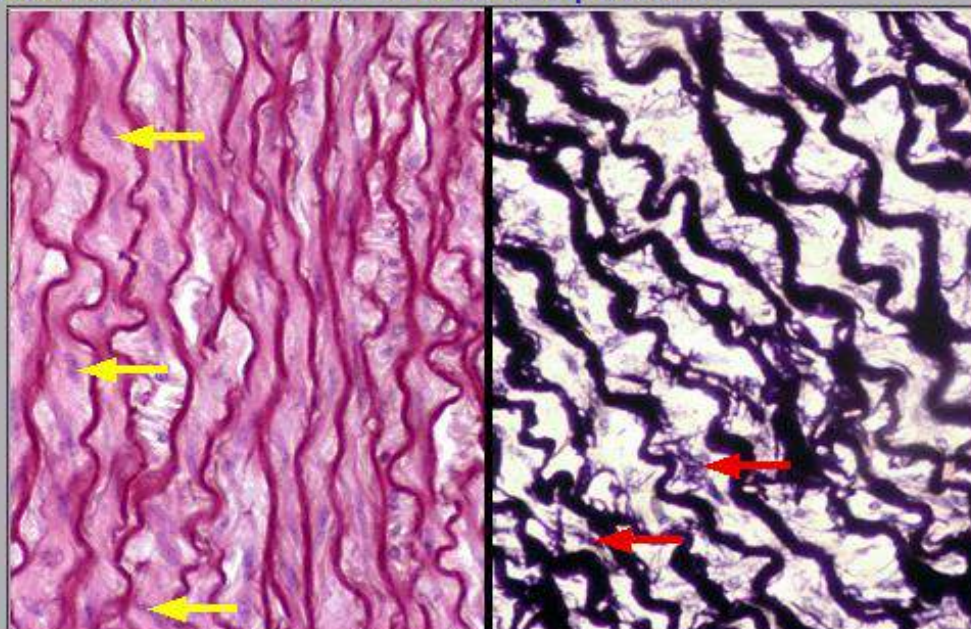


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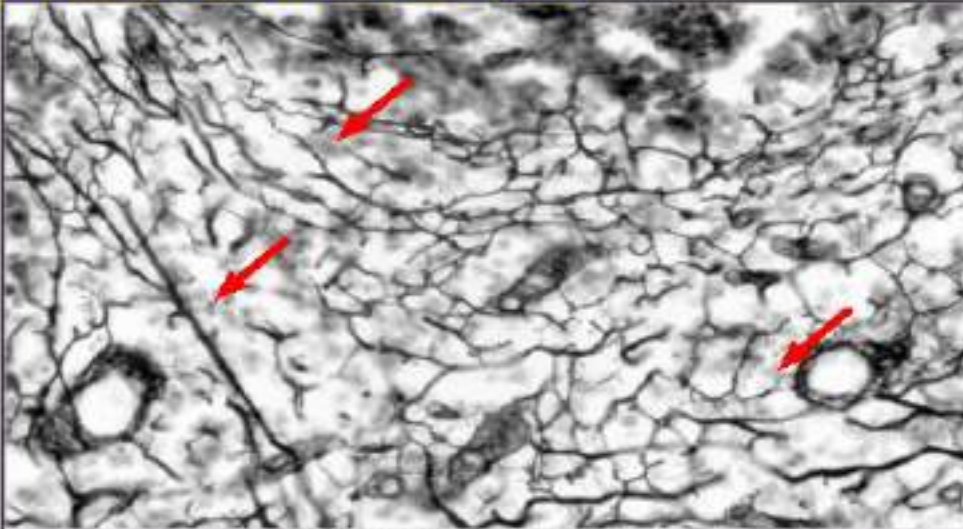


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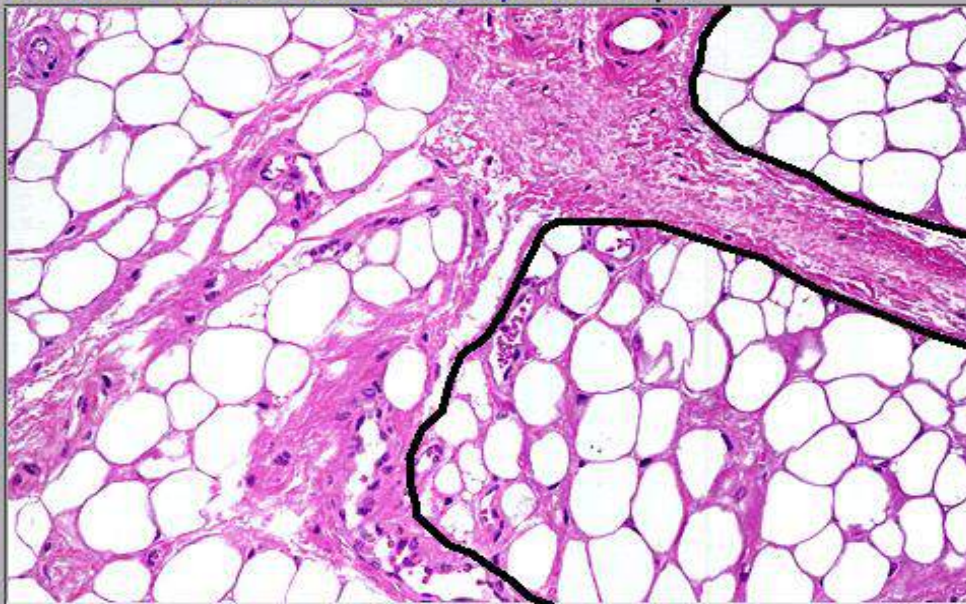


2 of 2

Reticular connective tissue -- Reticular fibers, collagen type III, are branching fibers which require a special stain to be identified, appearing black with this silver stain. Reticular fibers are frequently arranged in a wide-meshed framework through which fluids can readily percolate. Reticular CT provides the stroma for hemopoietic tissue and lymphoid organs, except thymus. Lymph node 1000x

click to identify:

- Reticular fibers
- Branching points
- > Lymphoid tissue

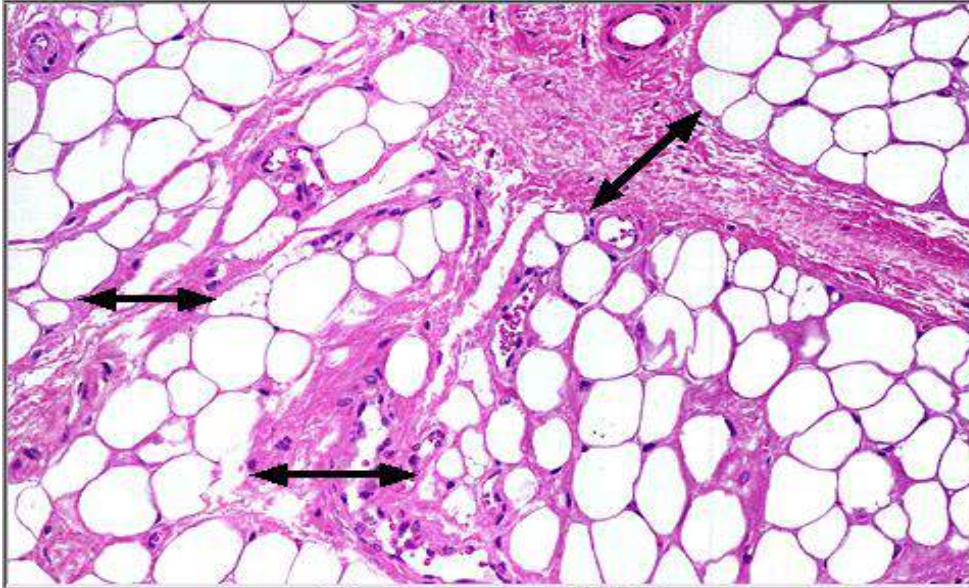


1 of 3

Adipose connective tissue -- Adipose connective tissue is composed of lobules of adipocytes separated by septa of connective tissue proper containing blood and lymphatic vessels. Individual adipocytes contain a single, large lipid droplet; crescent-shaped nuclei and cytoplasm are flattened to the periphery of the droplet. Hypodermis 100x

click to identify:

- > Adipocytes
- Adipocyte nuclei
- CT septa
- Fibroblast nuclei
- Vessels

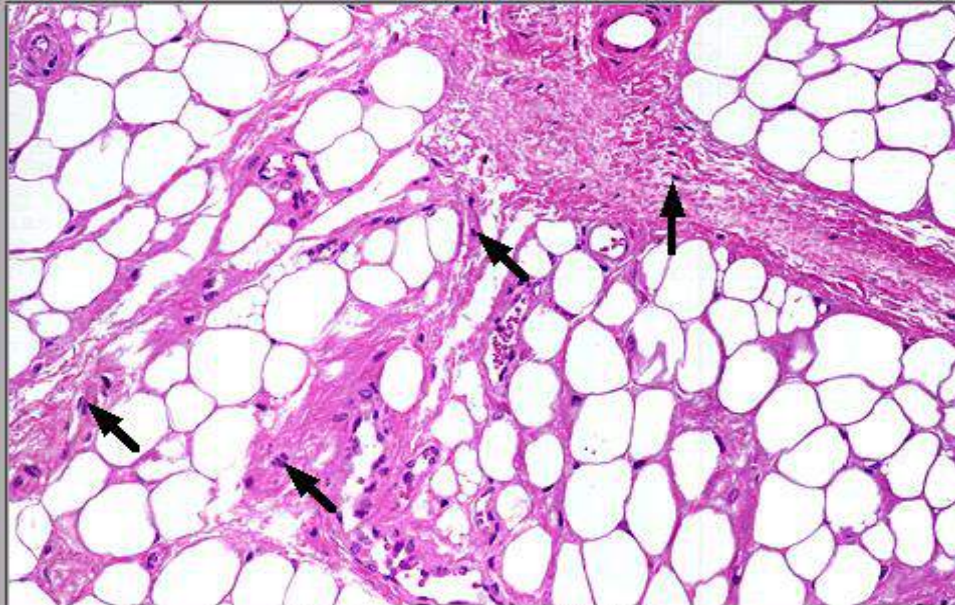


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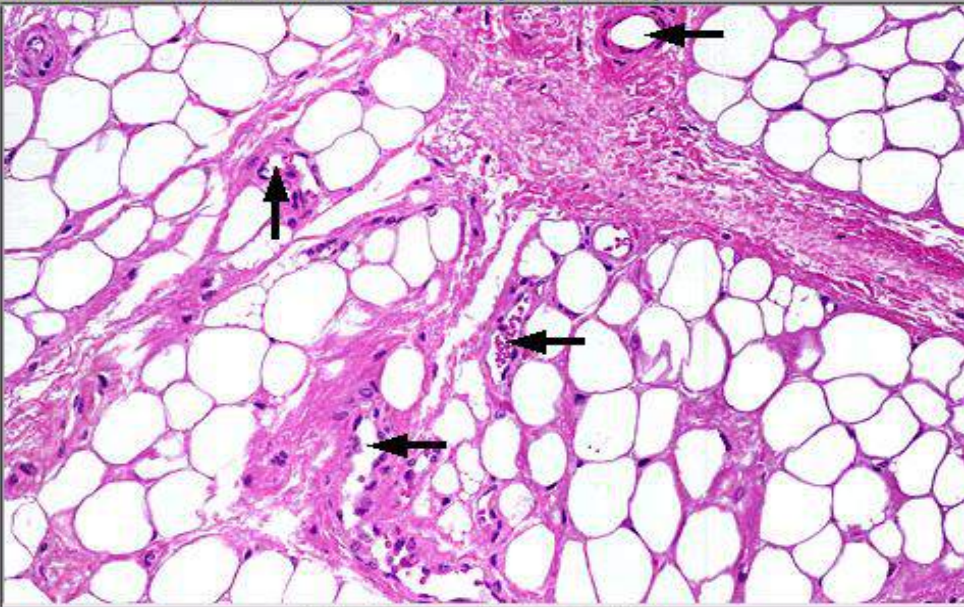


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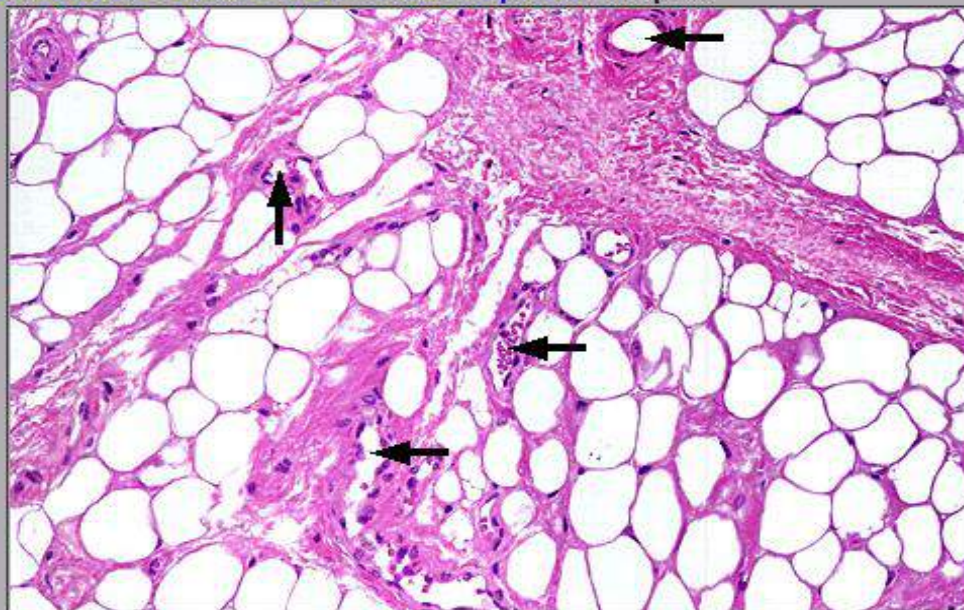


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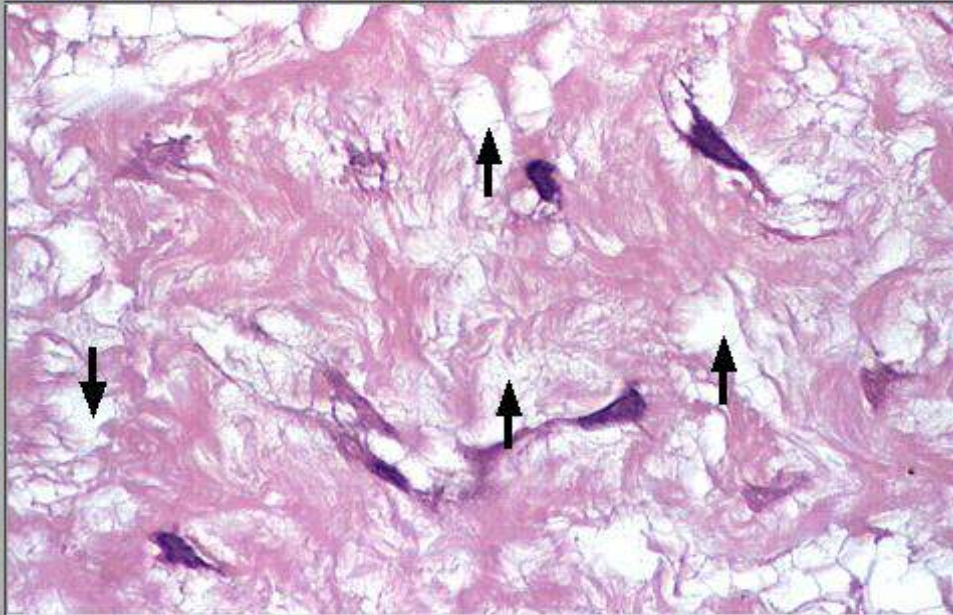


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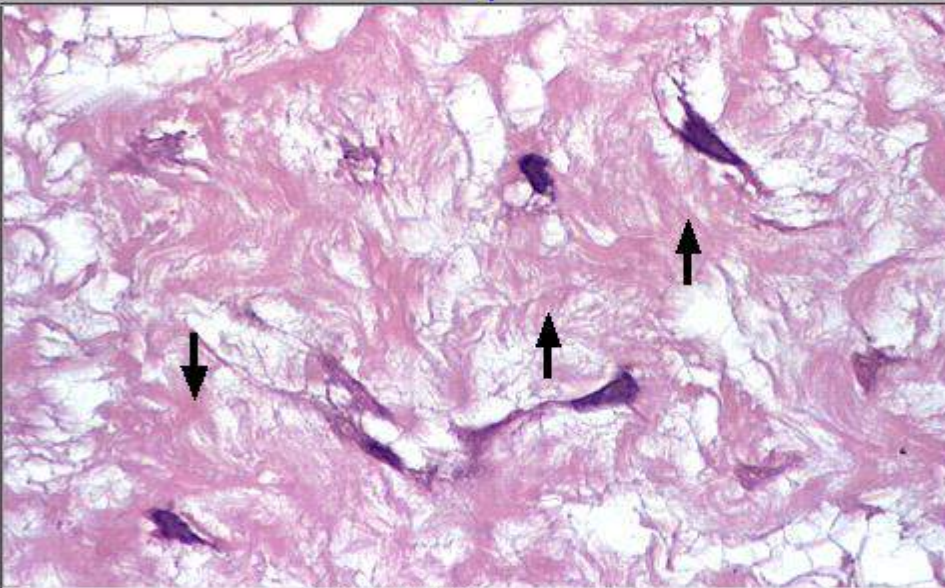


1 of 1

Mucous connective tissue -- Mucous connective tissue is a primitive (embryonic) connective tissue that persists in the umbilical cord. Mucous connective tissue is composed of fibroblast-like cells, which can be spindle or stellate shaped, that produce the surrounding, abundant, gelatinous ground substance (Wharton's jelly) and delicate collagen and reticular fibers. Umbilical cord 1000x

click to identify:

- Fibroblasts
- Fibers
- > Ground substance



1 of 1

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click to identify:

- Fibroblasts
- > Fibers
- Ground substance

CHAPTER 14

LYMPHOID SYSTEM

GENERAL CONCEPTS

I. Functions

- A. Provides immune surveillance and defense against foreign substances and microorganisms
- B. Provides immune tolerance, distinguishing between "self" and "non-self"
- C. Absorbs lipids into small lymphoid vessels (lacteals) in intestinal villi for distribution to the blood stream and liver
- D. Helps to maintain fluid balance by accumulating tissue fluid and white blood cells in lymph vessels and returning them to the blood

II. Overview of lymphoid components

A. **Primary lymphoid organs and structures**

- 1. **Bone marrow.** Site of origin of T and B lymphocytes. B lymphocytes directly seed secondary lymphoid structures and organs.
- 2. **Thymus.** T lymphocytes from bone marrow undergo further maturation in the thymus before seeding secondary lymphoid structures and organs.

B. **Secondary lymphoid organs and structures** (from least to most complex)

- 1. **Diffuse lymphoid tissue**
- 2. **Lymphoid nodules.** Both solitary and in aggregates.
- 3. **Tonsils**
- 4. **Lymph nodes**
- 5. **Spleen**

C. Major lymphoid cell types

- 1. **B lymphocytes** originate and mature in the bone marrow, then seed secondary lymphoid structures and organs. B cells differentiate into B memory cells and plasma cells, providing humoral immunity.

2. **T lymphocytes** originate in bone marrow, mature in the thymus, and subsequently seed secondary lymphoid tissue. T cells differentiate into helper, memory, and cytotoxic cells. T lymphocytes provide cell-mediated immunity and assist B lymphocytes in their humoral response.
3. **Plasma cells** differentiate from B lymphocytes and produce humoral antibodies.
4. **Macrophages** and **dendritic cells** phagocytose foreign matter, enhance the body's response to antigen by "presenting" antigen to lymphocytes, and secrete immunomodulatory factors.

D. **Lymph vessels** (***images***)

1. Are thin-walled vessels lined with endothelium
2. Begin as blind-ended lymphatic capillaries in tissues. These capillaries accumulate tissue fluid, which is called lymph once it is enclosed by the capillary.
3. Gradually increase in diameter and have valves located within their walls. Lymph nodes are positioned along these vessels.
4. Unite to form two **lymph ducts** (thoracic and lymphatic ducts) that return lymph to the venous side of the blood vasculature system

E. **High endothelial venules (HEVs)** (***images***)

1. Located in appendix, tonsils, Peyer's patches, and especially in lymph nodes, but not in spleen
2. Endothelium lining these venules is simple cuboidal rather than simple squamous epithelium
3. Allow transport of lymphocytes through the endothelium, thus permitting diapedesis of these cells and the dissemination of immunological information between different regions of the body

F. Stroma of lymphoid structures and organs

1. **Reticular cells** produce reticular fibers and act as fixed macrophages as they ensheath these fibers. Reticular cells and reticular fibers together constitute reticular connective tissue.
2. **Reticular fibers** are composed of collagen type III and form a meshwork that allows fluid to percolate through it while providing delicate, nondistensible support for cells suspended within it.

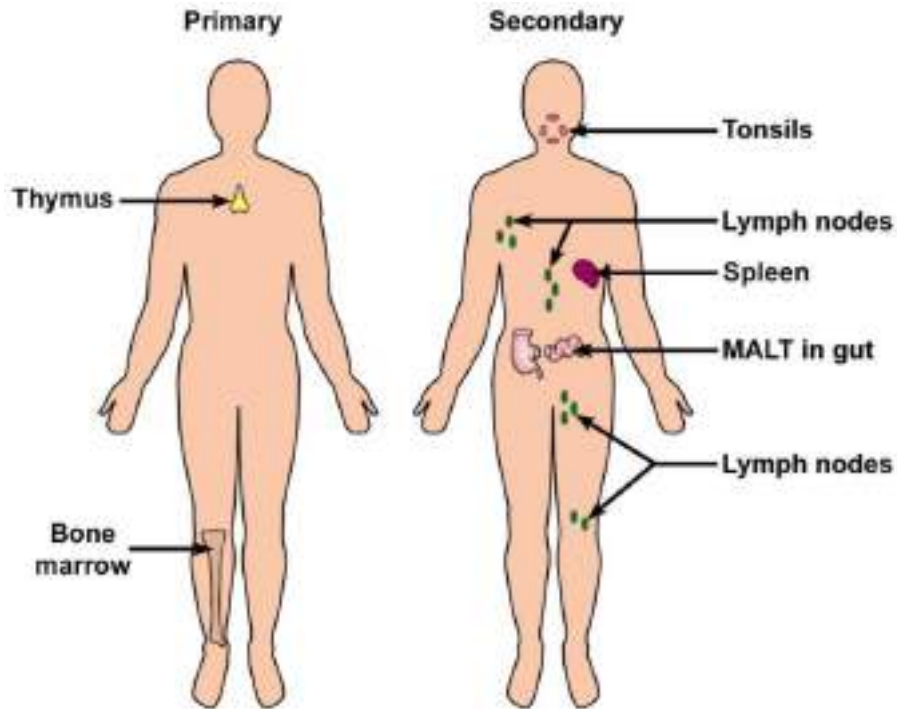


FIGURE 14.1. The primary and secondary lymphoid structures and organs. MALT, mucosal-associated lymphoid tissue.

COMPONENTS OF THE LYMPHOID SYSTEM

I. Diffuse lymphatic tissue (*images*)

- A. Located in lamina propria of any organ system opening to the exterior of the body, such as respiratory and digestive systems, where an antigen could penetrate the epithelium and enter the lamina propria. Diffuse lymphoid tissue in the lamina propria is part of the **mucosal-associated lymphoid tissue (MALT)**. Diffuse lymphatic tissue is also located in tonsils, lymph nodes, and spleen.
- B. Composed of an unorganized cluster of lymphocytes and other cells capable of responding to an antigen that reaches it.
- C. Filters and provides immune surveillance for tissue fluid of the lamina propria in which it is located

II. Lymphoid nodules (*images*)

- A. Distribution
 - 1. Lamina propria of any organ opening to the exterior of the body. May occur singly (solitary) or in clusters (aggregates) such as in tonsils and

Peyer's patches in the small intestine. Lymphoid nodules in the lamina propria are part of MALT.

2. Lymph node and spleen

B. Structure

1. **Primary nodule.** The nodule present before antigen stimulation. The spherical nodule consists primarily of densely packed B lymphocytes.
2. **Secondary nodule.** After antigen stimulation, a central pale core, the **germinal center**, appears. This center is composed of immunoblasts that divide to form lymphocytes that accumulate in the densely packed, peripheral zone of the nodule.

C. Function

1. Filter and provide immune surveillance for the fluid of the layer/organ in which it is located: tissue fluid in the lamina propria, lymph in lymph nodes, and blood in the spleen.
2. Detect specific antigens and causes proliferation of antigen-specific B lymphocytes

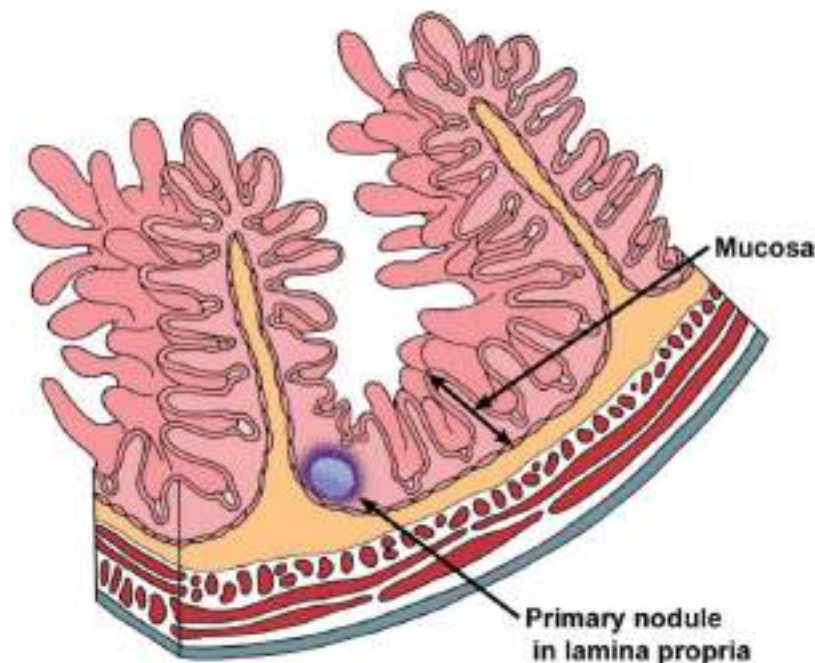


FIGURE 14.2. Nodular lymphoid tissue in the mucosa is part of MALT, mucosal associated lymphoid tissue. Longitudinal section of the small intestine.

III. **Tonsils** *(images)*

- A. **Pharyngeal**, **lingual**, and **palatine tonsils** are located at the junction of the oral cavity with the oral pharynx and in the nasopharynx.
- B. Located in the lamina propria of the mucosa
- C. Structure
 - 1. Aggregations of lymphoid nodules and diffuse lymphoid tissue
 - 2. **Crypts** or folds of surface epithelium invade the tonsils.
 - 3. Partially encapsulated by connective tissue separating it from underlying tissues
- D. Filter and provide immune surveillance for the tissue fluid of the lamina propria in which they are located

IV. **Lymph nodes** *(images)*

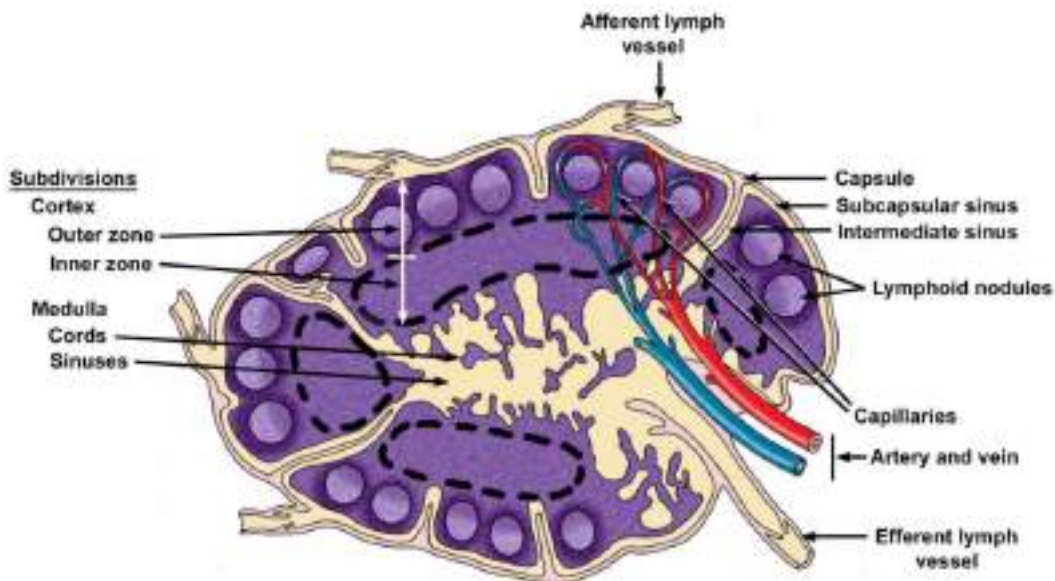


FIGURE 14.3. Lymph node.

- A. Small, encapsulated, kidney-shaped organs occurring in chains or groups along lymph vessels
- B. Structure
 - 1. **Cortex**

- a. **Capsule** of dense connective tissue surrounds the node and sends short trabeculae into the node. Reticular connective tissue forms the stroma for the remainder (interior) of the node.
 - b. **Outer zone**. Filled primarily with lymphoid nodules composed of B lymphocytes
 - c. **Inner zone (paracortex or deep cortex)**. Filled with diffuse lymphoid tissue composed of T lymphocytes
 - d. **Sinuses** in cortex. Loose network of macrophages and reticular fibers through which lymph percolates
 - i. **Subcapsular sinus** lies immediately beneath the capsule and receives incoming lymph fluid from afferent lymphatic vessels that enter through the capsule.
 - ii. **Intermediate sinuses**. Lie adjacent to the trabeculae. Receive lymph from the subcapsular sinus and continue as medullary sinuses
2. **Medulla**. Composed of:
- a. **Medullary cords** of B lymphocytes that extend from the inner cortex into the medulla
 - b. **Medullary sinuses**. Continuations of the intermediate sinuses in the cortex. Lymph flows from medullary sinuses into the efferent lymph vessels that exit at the hilum of the node.
- C. Blood supply. Small arteries enter at the hilum to supply a capillary plexus in the outer cortex. The capillaries anastomose to form HEVs in the paracortex and small veins that exit at the hilum.
- D. Filter and provide immune surveillance for lymph

V. **Spleen** (*images*)

- A. Encapsulated, intraperitoneal organ located in upper left quadrant of the abdominal cavity
- B. Structure
 - 1. **Capsule** surrounds organ, sending trabeculae into the spleen. Larger blood vessels traverse the trabeculae.
 - 2. Subdivisions

- a. **White pulp** appears white in fresh specimens and is composed of:
 - i. **Periarterial lymphoid sheath (PALS)**. A sleeve of T lymphocytes that surrounds a central arteriole as soon as it exits from a trabecula
 - ii. **Lymphoid nodules**, composed of B lymphocytes, are randomly located along and embedded in the PALS.
- b. **Red pulp** appears red in fresh specimens because of the abundant venous sinuses it possesses.
 - i. **Splenic cords (of Billroth)**. Cords of lymphocytes (T and B), macrophages, plasma cells, and other lymphoid cells suspended in a reticular connective tissue stroma. Surrounded by:
 - ii. **Splenic sinuses**. Venous sinuses separating splenic cords. These sinuses are lined by endothelial cells and surrounded by reticular fibers.
- 3. The spleen filters and provides immune surveillance for the blood percolating through it. The spleen also phagocytoses aged and abnormal erythrocytes and stores blood.

C. Blood flow through the spleen

- 1. **Splenic artery** enters at the hilum of the spleen and branches into arteries that lie in the trabeculae.
- 2. Arteries exit from the trabeculae as **central arterioles** and are immediately surrounded by the PALS. The central arteriole becomes eccentrically located when it is displaced by a lymphoid nodule. Branches from the central arterioles supply the PALS, including forming marginal sinuses at the perimeter of the white pulp.
- 3. Central arterioles lose their PALS ensheathment and form a series of smaller arterioles in the red pulp. These arterioles either:
 - a. Open directly into a splenic sinus (**closed circulation**)
 - b. Open into a splenic cord where the blood percolates through the cells of the cord before entering a splenic sinus (**open circulation**)
- 4. **Trabecular veins** are formed by splenic sinuses anastomosing and then entering a trabecula. Trabecular veins anastomose to form the splenic vein.
- 5. The **splenic vein** exits at the hilum of the spleen.

VI. Thymus (*images*)

- A. The thymus is a primary lymphoid organ that receives immature lymphocytes (thymocytes) from the bone marrow. These cells mature in the thymus and are carried to secondary lymphoid structures/organs via the blood vascular system.
- B. The thymus is located in the superior mediastinum under the sternum. The thymus involutes with age.
- C. Structure
 - 1. A connective tissue **capsule** surrounds the thymus and extends into the thymus, dividing it into lobules.
 - 2. The **stroma** is formed by a network of reticular cells of endodermal, rather than the usual mesodermal, origin and are called, therefore, **epithelial reticular cells**. These cells do not form fibers.
 - 3. Each lobule contains an:
 - a. Outer **cortex** that is densely packed with thymocytes, the developing T lymphocytes. These cells mature in the cortex, then migrate into the medulla where they enter the blood stream for transport to secondary lymphoid structures and organs.
 - b. Inner **medulla** has fewer thymocytes and, therefore, stains more palely than does the cortex. **Hassall's corpuscles** are the degenerating remains of the epithelial reticular cells with their keratin granules and are diagnostic for the thymus.
- D. A blood-thymic barrier is formed around capillaries in the cortex, so that the developing lymphocytes are not exposed to circulating antigens.

CHAPTER 17

MALE REPRODUCTIVE SYSTEM

GENERAL CONCEPTS

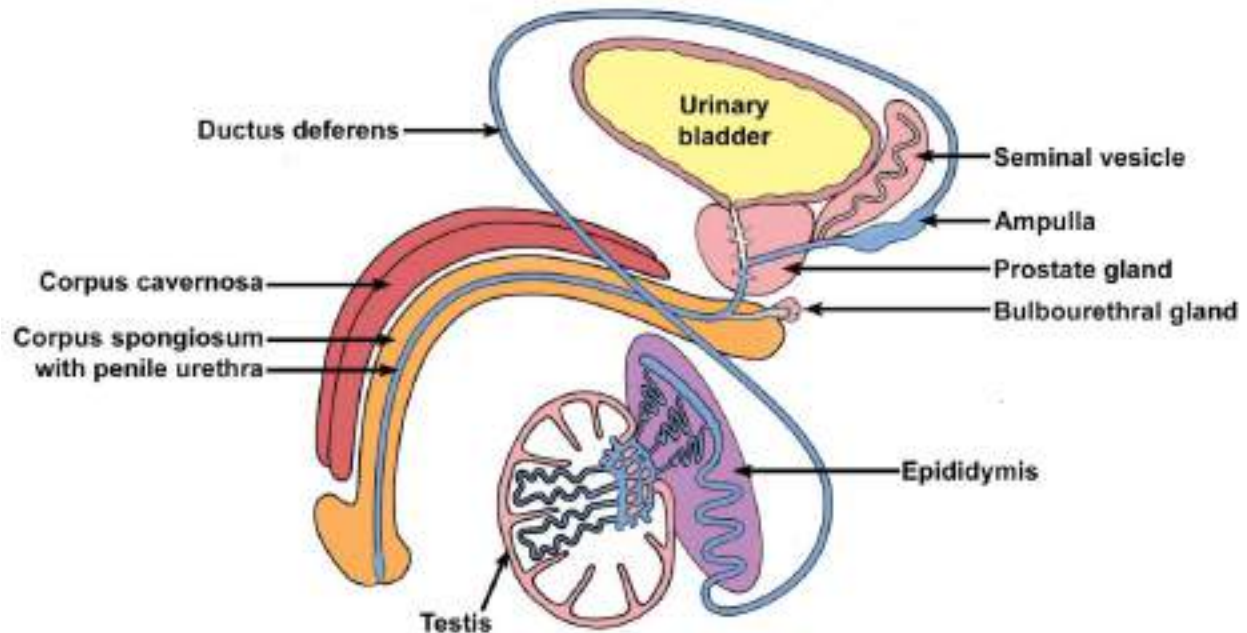


FIGURE 17.1. Components of the male reproductive system

I. Components

A. Testis. Paired organs

1. Seminiferous tubules
2. Rete testis (intratesticular ducts)

B. Genital ducts

1. Epididymis. Paired organs, each containing the duct of the epididymis
2. Ductus deferens. Paired ducts
3. Ejaculatory duct. Paired ducts
4. Urethra

C. Major genital glands

1. Seminal vesicles. Paired glands
2. Prostate. Single gland
3. Bulbourethral glands. Paired glands

II. Functions

- A. Produce sperm
- B. Produce male sex hormones
- C. Produce seminal fluid
- D. Propel sperm and seminal fluid (semen) to exterior

TESTIS

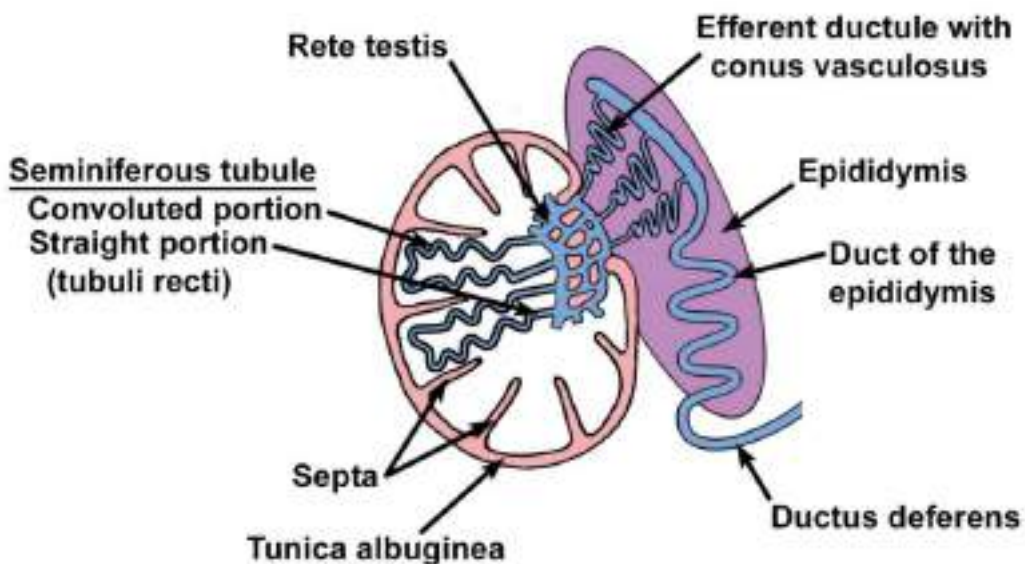


FIGURE 17.2. Components of the testis

GENERAL ORGANIZATION

- I. Paired, ovoid organs; serve both exocrine (sperm production) and endocrine (testosterone production) functions; suspended in the scrotum
- II. Coverings and connective tissue framework (external to internal): ***(images)***
 - A. **Tunica vaginalis**. A serosa (peritoneum) that accompanied the testis

embryologically in its retroperitoneal descent from the abdomen to the scrotum. Covers the anterior and lateral surfaces of the testes but not their posterior surfaces.

- B. **Tunica albuginea**. A layer of dense connective tissue beneath the tunica vaginalis, encapsulating the testis.
- C. **Mediastinum** of the testis
 - 1. Thickening of tunica albuginea, projecting into the testis from its posterior surface
 - 2. Seminiferous tubules converge at the mediastinum where they join the rete testis.
 - 3. **Rete testis**. Interconnecting channels in the mediastinum that receive the contents of the seminiferous tubules
- D. **Septa**, connective tissue partitions extending from the mediastinum toward the tunica albuginea, separate each testis into about 250 lobules. (Note: For clarity, Figure 17.2 shows the septa originating from the tunica albuginea rather than from mediastinum)

III. Internal structure of testis (*images*)

- A. Consists of lobules that are pyramidal in shape with their apices directed toward the mediastinum and their bases adjacent to the tunica albuginea
- B. Composition of lobules
 - 1. **Stroma**. Loose connective tissue, many blood vessels and lymphatics
 - 2. Parenchyma
 - a. **Seminiferous tubules, convoluted portions**
 - i. One to four loop-shaped, tortuous tubules per lobule with both ends opening at the mediastinum
 - ii. Composed of seminiferous epithelium where spermatozoa production occurs
 - iii. Surrounded by a **tunica propria**, a connective tissue layer located beneath the basal lamina of the seminiferous epithelium. Myoid cells, possessing contractile properties, are located in this layer.
 - b. **Seminiferous tubules, straight portions (tubuli recti)** are

located at the periphery of the mediastinum. Interconnect the convoluted portions of the seminiferous tubule with the rete testis in the mediastinum

- c. **Interstitial cells (of Leydig)**. Clusters of endocrine-secreting cells lie outside the seminiferous tubules within the CT stroma; produce testosterone

MICROSCOPIC APPEARANCE OF THE PARENCHYMA OF THE TESTIS

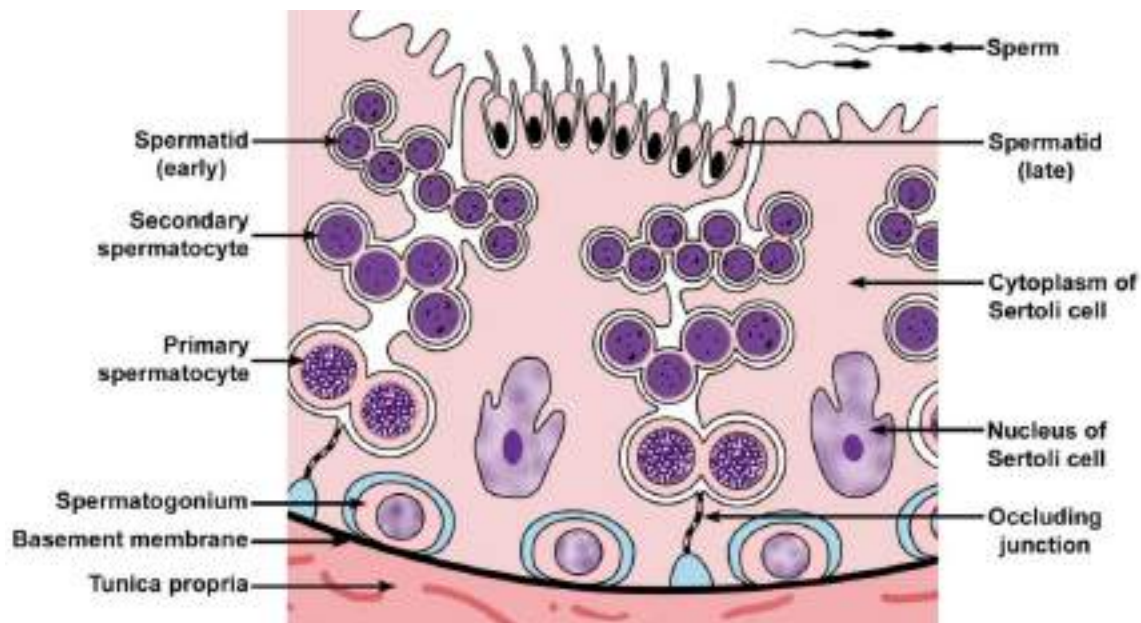


FIGURE 17.3. Seminiferous epithelium in the convoluted portion of seminiferous tubule.

- I. **Interstitial cells (of Leydig)**. (endocrine portion).
 - A. Arranged as clusters of cells in the stroma between seminiferous tubules
 - B. Cytology
 - 1. Euchromatic nucleus
 - 2. Eosinophilic cytoplasm possesses cytological features of steroid-producing cells, such as extensive SER, large numbers of lipid droplets and mitochondria with tubular cristae.
 - C. Function. Secrete testosterone under the influence of luteinizing hormone (LH).
- II. Exocrine portion. **Seminiferous epithelium** lining the convoluted portions of

the seminiferous tubules (exocrine function).

A. **Supporting cells of Sertoli**

1. Tall, columnar cells that rest on the basal lamina and extend to the lumen
2. Nucleus is euchromatic, ovoid, and infolded; its long axis usually lies perpendicular to, but not immediately adjacent to, the basal lamina.
3. Numerous lateral processes surround and invest the maturing germ cells. The most basal of these processes forms a series of tight (occluding) junctions with similar processes of adjacent Sertoli cells.
4. **Blood-testis barrier** is formed by tight (occluding) junctions that unite the basal processes of adjacent Sertoli cells forming a:
 - a. **Basal compartment** with access to blood-borne materials and which contains spermatogonia and earliest primary spermatocytes
 - b. **Luminal compartment**
 - i. Provides a unique microenvironment for developing germ cells that protects these cells from immunologic attack and concentrates hormones needed for sperm production
 - ii. Contains later primary spermatocytes, secondary spermatocytes, and spermatids
5. Functions
 - a. Mediate exchange of nutrients to germ cells
 - b. Form blood-testis barrier to protect developing germ cells from immunologic attack
 - c. Break down excess spermatid cytoplasm
 - d. Produce testicular fluid
 - e. Secrete **androgen-binding protein** that binds to and concentrates testosterone in the seminiferous epithelium
 - f. Produce **inhibin**, which inhibits the secretion of follicle stimulating hormone (FSH) from the adenohypophysis
 - g. Orchestrate movement of germ cells through seminiferous epithelium and facilitate cytodifferentiation and subsequent release of spermatozoa into the lumen of the seminiferous tubule

B. Germ cells (spermatogenic cells)

1. Form a stratified seminiferous epithelium

2. Cell types

a. **Spermatogonia**

- i. Are diploid cells resting on the basal lamina
- ii. Are of two varieties. **Type A spermatogonia** divide mitotically to perpetuate self and to form type B cells. **Type B spermatogonia** divide mitotically to form primary spermatocytes.
- iii. Undergo incomplete cytokinesis so resulting cells remain attached to each other during spermatogenesis
- iv. Divide mitotically to produce primary spermatocytes

b. **Primary spermatocytes**

- i. Are the largest germ cells; each nucleus is 1.5 times larger than that of a spermatogonium
- ii. Form in the basal compartment, then probably migrate through the tight junctions between Sertoli cell processes forming the blood-testis barrier to the luminal compartment
- iii. Remain in prophase about one-third of the spermatogenic cycle, so many are seen. Nuclei contain highly condensed chromosomes.
- iv. Are diploid cells that complete meiosis I (reductional division) to form secondary spermatocytes

c. **Secondary spermatocytes**

- i. Are haploid cells whose pale staining nuclei are similar in size to those of the spermatogonia nuclei
- ii. Are present for only eight hours of the entire 64-day spermatogenic cycle; therefore, very few are seen.
- iii. Divide by meiosis II (equational division) to form spermatids

d. **Spermatids**

- i. Are haploid cells whose nuclei are initially about two-thirds the size

of spermatogonia nuclei

- ii. Are located near the lumen of the seminiferous tubules
- iii. Do not divide but undergo cytodifferentiation (**spermiogenesis**) to form spermatozoa
 - (a) Intercellular bridges break down.
 - (b) Nucleus condenses and elongates.
 - (c) Acrosome forms. An acrosome is a modified lysosome containing enzymes to aid the sperm in penetrating the zona pellucida surrounding the secondary oocyte.
 - (d) Flagellum forms.
 - (e) Excess cytoplasm is shed.

e. **Spermatozoa**

- i. Are haploid cells
- ii. Are anatomically mature, but incapable of fertilization at this time
- iii. Are released from Sertoli cells into the lumen of the seminiferous tubules (**spermiation**)

SPERMATOGENESIS

I. **Spermatogenesis** is a multi-staged process by which diploid somatic cells (spermatogonia) in the basal compartment become haploid spermatozoa lying free in the lumen of the seminiferous tubules.

II. Stages

- A. **Spermatocytogenesis**. At puberty, spermatotogonia (2N cells) differentiate in the testis and divide by mitosis either to perpetuate their own cell line or produce primary spermatocytes that begin meiosis; cytokinesis is incomplete
- B. Meiosis. Two cell divisions convert diploid primary spermatocytes to haploid (i.e., reduction of chromosomes and DNA by half); cytokinesis is incomplete.
 - 1. **Meiosis I**. Primary spermatocytes (diploid) form secondary spermatocytes (haploid).
 - 2. **Meiosis II**. Secondary spermatocytes form spermatids (haploid).

C. **Spermiogenesis**. Cytodifferentiation of spermatids (haploid) into spermatozoa (haploid); no cell division occurs during this stage.

D. **Spermiation**. Release of mature sperm into lumen of seminiferous tubule

III. Under control of follicle stimulating hormone (FSH) from the anterior pituitary

IV. One cycle lasts about 64 days, with a new cycle beginning in any given location about every 16 days.

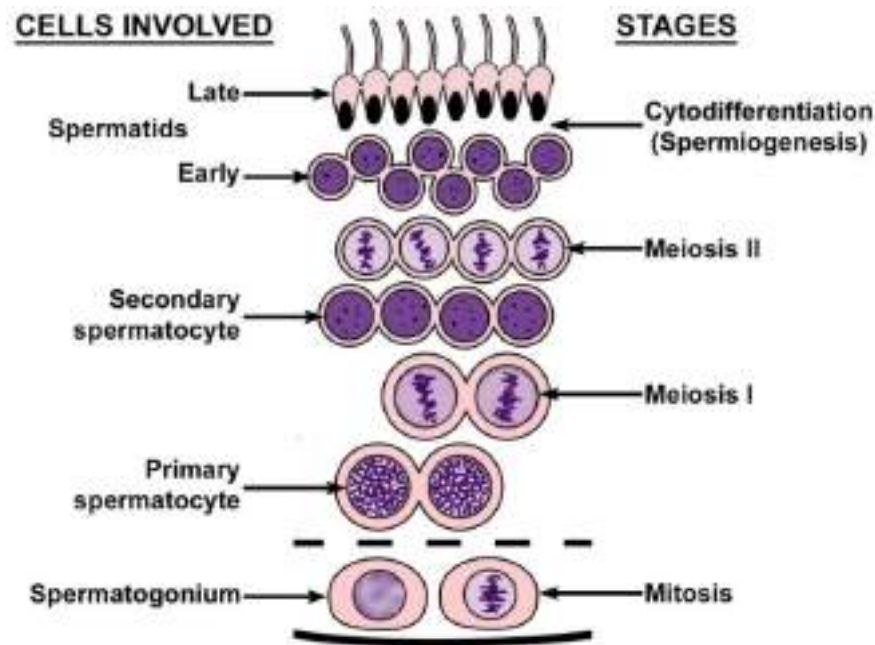


FIGURE 17.4. The stages and cells of spermatogenesis

COMPARISON OF OOGENESIS WITH SPERMATOGENESIS (*image*)

I. Gametogenesis, the formation of haploid ($1N$) ova and sperm, is a multistaged process that includes both mitosis and meiosis. While chromosomal events producing sperm (spermatogenesis) and ova (oogenesis) are similar, cytoplasmic stages, the timing of divisions and the number of gametes formed is different between the male and the female.

II. Stages

A. Mitosis

1. Beginning at puberty in males, diploid precursor spermatogonial cells divide to form diploid spermatogonia. Spermatogonia, in turn, divide by mitosis, renewing their own cell line, as well as producing cells that enter

meiosis. In contrast in the female, before birth diploid precursor oogonial cells divide to form diploid oogonia. Oogonia divide mitotically, again before birth, forming only cells that enter meiosis, thus depleting their own cell line. Oogonia are not self-renewing and, at birth, no oogonia remain in the ovary.

2. In males, cytokinesis of spermatogonia and primary and secondary spermatocytes is incomplete, and thus, cells remain attached to each other. In females, cytokinesis is complete.

B. Meiosis. In the male, primary and secondary spermatocytes complete both meiotic stages, producing four functional, haploid spermatozoa of equal size from each diploid spermatogonia. In contrast, in the female, when primary and secondary oocytes complete meiosis, only a single, functional, haploid ovum is formed, along with two or three small, nonfunctional satellite cells (polar bodies).

C. Maturation

1. In males, after the completion of meiosis, spermatids undergo morphological changes, transforming themselves from spherical cells to tadpole-shaped spermatozoa, and breaking their cytoplasmic connections. No such maturation process occurs in the female.
2. In females, the completion of meiosis II, with the formation of an ovum, occurs only after fertilization. If fertilization does not occur, the secondary oocyte is destroyed or degenerates.
3. Fusion of the haploid male and female nuclei produces a diploid zygote, reconstituting the full complement of chromosomes.

III. Spermatogenesis occurs throughout the reproductive life of a male, producing millions of sperm during this span. Oogenesis lasts for only 30-40 years in the female and produces only a minimal number of ova, because completion of oogenesis is dependent on fertilization.

COURSE OF SPERM WITHIN THE TESTIS (images)

I. **Seminiferous tubules, convoluted portion.** Seminiferous epithelium where sperm production occurs; sperm are released into the lumen of this portion of the tubule from Sertoli cells.

II. **Seminiferous tubules, straight portion (tubuli recti)**

A. Lined by simple columnar epithelium whose cells resemble Sertoli cells

B. Connects convoluted portion of seminiferous tubules with rete testis

III. Rete testis (intratesticular ducts)

- A. Is a meshwork of channels within mediastinum of testis
- B. Lined by simple cuboidal cells, many of which possess a single flagellum
- C. Connects the straight portion of the seminiferous tubules with efferent ducts in the epididymis

GENITAL DUCTS EXTERNAL TO THE TESTIS

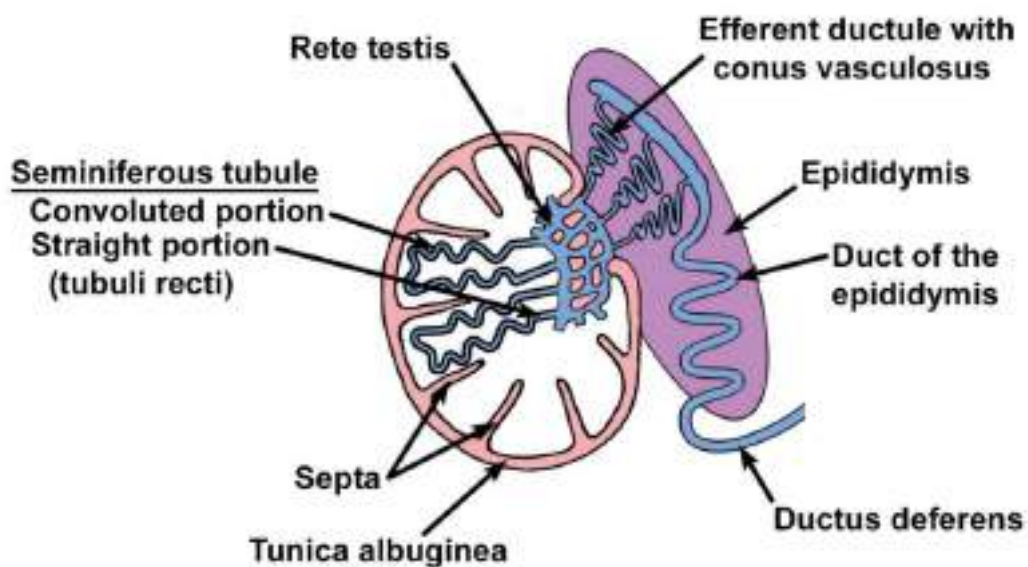


FIGURE 17.3. Components of the testis and epididymis

EPIDIDYMIS (*images*)

- I. The epididymis is a comma-shaped organ lying posterior to the testis that is divided into head, body, and tail subdivisions.
- II. **Head** region composition
 - A. **Efferent ducts**
 - 1. Connect rete testis with duct of epididymis
 - 2. Are about 12 in number, each of which is coiled into a cone shape. Each coiled efferent duct, with its surrounding connective tissue and abundant blood vessels, forms a **conus vasculosus (plural coni vasculosi)**.

3. Each duct connects with the rete testis at the apex of the cone adjacent to the testis. All ducts anastomose to form the single duct of the epididymis at the bases of the cones.
4. Are lined with a simple epithelium composed of alternating taller, ciliated cells and shorter cuboidal cells with lysosomes. Therefore, efferent ducts present a characteristic, scalloped border adjacent to the lumen. A thin muscularis layer surrounds the epithelium.
5. Function. Ciliated cells propel spermatozoa toward duct of epididymis while cuboidal cells absorb testicular fluid.

B. **Duct of epididymis.** A single duct formed by fusion of efferent ducts

III. **Body and tail regions**

A. Contains the remainder of the duct of the epididymis

1. Highly coiled, single tube (6 m long) formed by union of efferent ducts in the head region
2. Lined by tall **pseudostratified columnar epithelium with stereocilia**, which decreases in height from head to tail regions; creates a smooth lumen when compared with efferent ducts
3. Smooth muscle layer surrounds epithelium and increases in thickness and number of layers from head to tail

B. Function

1. Storage and maturation site for sperm
2. Absorption of excess testicular fluid
3. Movement of sperm toward ductus deferens

DUCTUS (VAS) DEFERENS *(images)*

I. The **ductus deferens** is a direct continuation of the duct of the epididymis carrying sperm to the ejaculatory duct.

II. Structure

A. Mucosa

1. Pseudostratified columnar epithelium with stereocilia surrounds a narrow

lumen.

2. Thin lamina propria
3. Longitudinal folds produce an irregular lumen.

B. Thick muscularis. Inner and outer longitudinal, middle circular layers of smooth muscle

III.Course

A. Located in **spermatic cord** in the inguinal canal along with:

1. **Spermatic artery**. Carries oxygenated and nutrient-rich blood to the tests.
2. **Pampiniform plexus**. Plexus of veins returning blood from the testis. Surrounds the spermatic artery forming a counter-current cooling mechanism to reduce the temperature of the blood entering the testis. Spermatogenesis requires temperatures less than normal body temperature.
3. **Cremaster muscle**. Skeletal muscle that elevates and lowers the testis relative to the body surface, aiding in maintaining lower intra-testicular temperature.
4. Nerve plexus.

B. Enters abdominal cavity, crosses above entrance of ureter into bladder, and enlarges to form the **ampulla**, which lies posterior to urinary bladder

C. Is joined by duct of the seminal vesicle just before it enters the prostate

IV. Function. Transports and propels sperm from the epididymis to the ejaculatory duct which travels through the prostate gland.

EJACULATORY DUCT

I. Each ejaculatory duct is formed by the union of a ductus deferens with the **duct of a seminal vesicle**.

II. No muscle layer is retained from the ductus deferens.

III.Each ejaculatory duct traverses the prostate gland to join the prostatic urethra.

URETHRA

- I. **Prostatic urethra**. Within prostate; lined with transitional epithelium
- II. **Membranous urethra**. Pierces skeletal muscle of the urogenital diaphragm; lined with stratified or pseudostratified columnar epithelium
- II. **Penile urethra** (discussed with penis)

GENITAL GLANDS

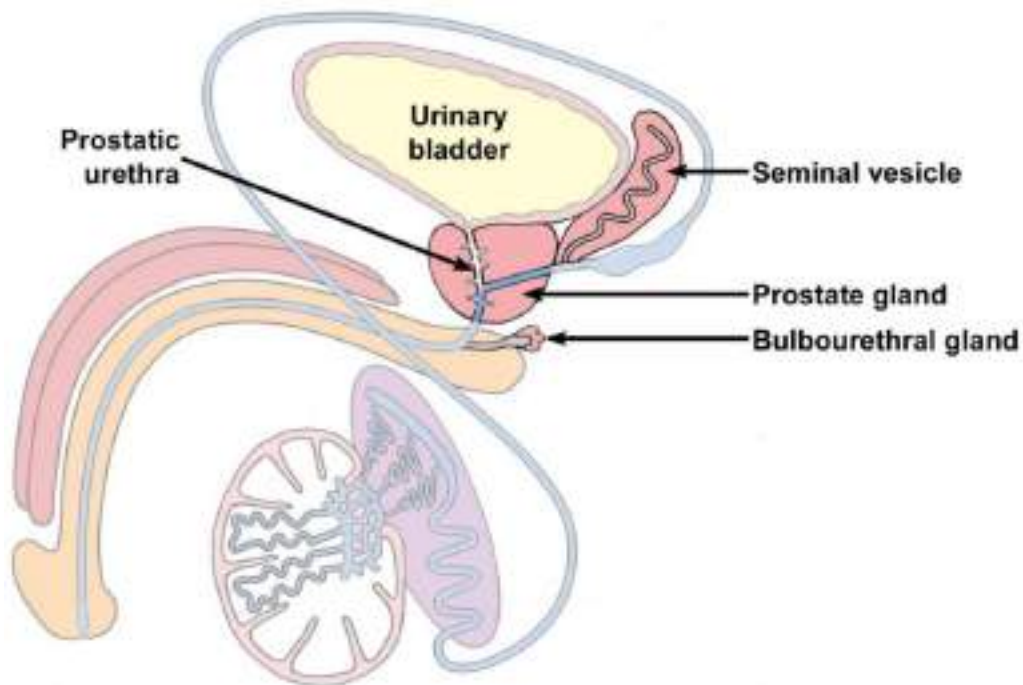


FIGURE 17.6. Major glands and their associated passageways.

SEMINAL VESICLE *(images)*

- I. **Seminal vesicles** are paired glands lying posterior to the urinary bladder.
- II. Each is composed of a single, highly tortuous tube.
- III. Secretions.
 - 1. Produces viscous, alkaline yellowish secretion that forms 70% of the total ejaculate.
 - 2. Components of the secretion.

- a. Fructose. Major energy source for sperm.
- b. Prostaglandins, ascorbic acid and other simple sugars.
- c. Seminogelin. Semen coagulation factor.

IV. Structure

- A. Pseudostratified columnar epithelium with many secretory granules overlies a thin layer of connective tissue. These tissues are thrown into an intricate system of primary, secondary, and tertiary folds that produce a pattern of arcades, dividing the central lumen into fragments.
- B. A thin layer of smooth muscle surrounds the tube.

PROSTATE GLAND (*images*)

- I. The **prostate**, a single, midline gland, is the largest of the genital glands and surrounds the prostatic urethra.
- II. 30-50 tubuloalveolar glands, opening onto the prostatic urethra, can be divided into groups depending on their location.
 - A. **Periurethral glands**. Immediately surround the prostatic urethra (5%). Excessive growth causes benign prostatic hyperplasia (BPH)
 - B. **Submucosal glands**. 25%
 - C. **Main glands**. Located toward the periphery of the gland (70%). Source of prostate cancers.
- III. Capsule. Dense connective tissue with abundant smooth muscle; septa from the capsule also possesses smooth muscle fibers and partition the gland into indistinct lobes.
- IV. Usually lined by a pseudostratified columnar epithelium whose height will vary with its activity
- V. **Prostatic concretions**. Lamellated, spherical bodies that are the condensation of secretory products. The number of concretions increases with age.
- VI. Secretions.
 - A. Contributes a thin, clear, slightly alkaline secretion.
 - B. Components of the secretion.

1. Citric acid, acid phosphatase and zinc.
2. Prostate specific antigen (PSA)
3. Fibrinolysin. Proteases that liquefies the congealed semen resulting from the coagulation produced by semenogelin in seminal vesicle secretion. This liquefaction of the seminal coagulum liberates the sperm, thus allowing them to enter the endocervical canal of the uterus.

BULBOURETHRAL GLAND (COWPER'S GLAND)

- I. Paired, pea-sized glands.
- II. Duct enters the initial portion of the penile urethra.
- III. Mucous secretion (pre-seminal fluid)

PENIS (*images*)

COMPOSITION

- I. Three cylindrical masses of erectile tissue
 - A. **Corpora cavernosa**. Paired dorsal cylinders
 - B. **Corpus spongiosum** (corpus cavernosum urethrae)
 1. Single, ventral cylinder that houses the penile urethra
 2. Expands to terminate in glans penis that caps the two corpora cavernosa
- II. Structure
 - A. Outer covering of skin (epidermis and dermis)
 - B. **Tunica albuginea**
 1. Capsule of dense, nonelastic connective tissue surrounding the three cylinders
 2. Thicker around corpora cavernosa than around corpus spongiosum
 3. Forms an incomplete septum between the corpora cavernosa
 - C. Structure of erectile tissue

1. Sponge-like **cavernous spaces** (venous spaces) separated by connective tissue trabecula with smooth muscle fibers
2. Deep artery in each corpus cavernosum supplies blood to:
 - a. Nutritive arteries that supply trabecula
 - b. **Helicine arteries** that supply cavernous spaces

PROCESS OF ERECTION

- I. Flaccid state is effected by a minimal blood flow to the penis. This blood flow is regulated by the continuous input of the sympathetic division of the autonomic nervous system on the tone of the smooth muscle in the penile vasculature.
- II. Erection
 - A. Parasympathetic division of autonomic nervous system effects relaxation of smooth muscle (vasodilation) of the deep and helicine arteries.
 - B. The subsequent filling of the cavernous spaces expands these vessels against the tunica albuginea, causing the penis to become erect and turgid.
 - C. Corpus spongiosum does not become as erect as the other cavernous bodies because its tunica albuginea is thinner. Therefore, sperm can be transported during ejaculation.
- III. Return to flaccid state occurs with decline of parasympathetic activity and increased sympathetic activity to constrict the helicine arteries.

PENILE URETHRA

- I. The **penile urethra** is located within corpus spongiosum (corpus cavernosum urethrae).
- II. Microscopic anatomy
 - A. Lined by pseudostratified columnar epithelium that becomes stratified squamous moist in fossa navicularis, the terminal enlargement in the glans penis
 - B. **Glands of Littre**
 1. Mucus-secreting glands
 2. Originate in mucus-secreting recesses of the urethra and extend obliquely

toward the base of the penis

3. Secrete a mucous fluid that is the initial ejaculate; provides lubrication

CHAPTER 8

NERVOUS TISSUE

GENERAL CONCEPTS

- I. Nervous tissue is highly specialized to employ modifications in membrane electrical potentials to relay signals throughout the body. Neurons form intricate circuits that:
 - A. Relay sensory information from the internal and external environments.
 - B. Integrate information among millions of neurons
 - C. Transmit effector signals to muscles and glands.
- II. Anatomical subdivisions of nervous tissue
 - A. **Central nervous system (CNS)**
 - 1. **Brain**
 - 2. **Spinal cord**
 - B. **Peripheral nervous system (PNS)**
 - 1. **Nerves**
 - 2. **Ganglia (singular, ganglion)**

CELLS OF NERVOUS TISSUE

- I. **Neurons**
 - A. Functional units of the nervous system; receive, process, store, and transmit information to and from other neurons, muscle cells, or glands
 - B. Composed of a cell body, dendrites, axon and synapses
 - C. Form complex and highly integrated circuits
- II. **Supportive cells**
 - A. Provide metabolic and structural support for neurons, insulate neurons via a

myelin sheath, maintain homeostasis, and perform phagocytic functions

- B. Comprised of astrocytes, oligodendrocytes, microglia, and ependymal cells in the CNS; comprised of Schwann cells in the PNS

STRUCTURE OF A "TYPICAL" NEURON

I. Cell body (soma, perikaryon)

A. Nucleus

1. Large, spherical, usually centrally located in the soma
2. Highly euchromatic with a large, prominent nucleolus

B. Cytoplasm

1. Well-developed cytoskeleton
 - a. Intermediate filaments (*neurofilaments*)
 - b. Microtubules
2. Abundant rough endoplasmic reticulum and polysomes (**Nissl substance**)
3. Well-developed Golgi apparatus
4. Numerous mitochondria

II. Dendrite(s)

- A. Usually multiple and highly branched at acute angles
- B. May possess **spines** small membranous elevations which form excitatory synapses
- C. Collectively, form the majority of the receptive field of a neuron; conduct impulses toward the cell body
- D. Cytoplasmic components
 1. Microtubules and neurofilaments
 2. Rough endoplasmic reticulum and polysomes
 3. Smooth endoplasmic reticulum

4. Mitochondria

III. **Axon**

- A. Usually only one per neuron
- B. Generally of smaller caliber and longer than dendrites
- C. Branches at right angles, fewer branches than dendrites
- D. Cytoplasmic components
 - 1. Microtubules and neurofilaments
 - 2. Lacks rough endoplasmic reticulum and polysomes
 - 3. Smooth endoplasmic reticulum
 - 4. Mitochondria
- E. **Axon hillock**. Region of the cell body where axon originates
 - 1. Devoid of rough endoplasmic reticulum and so stains pale
 - 2. Continuous with **initial segment** of the axon that is a highly electrically excitable zone for initiation of nervous impulse
- F. Usually ensheathed by supporting cells
- G. Transmits impulses away from the cell body to
 - 1. Neurons
 - 2. Effector structures such as muscle and glands
- H. Branches extensively near its target, each branch ends in a swelling, the terminal bouton, which is the presynaptic element of a synapse

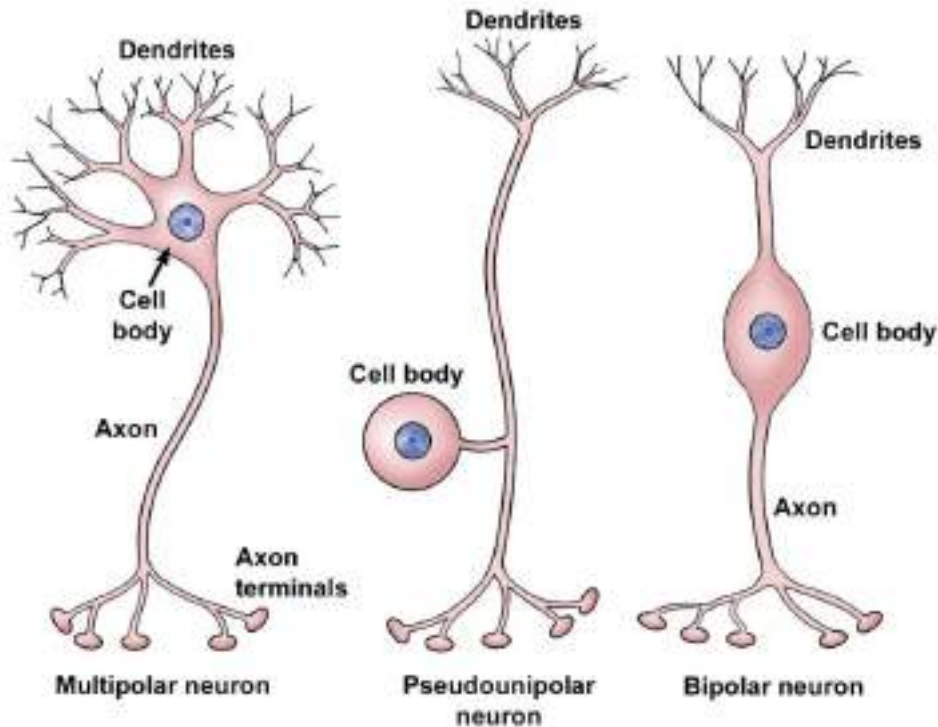


FIGURE 8.1. Types of neurons based on shape.

TYPES OF NEURONS BY SHAPE AND FUNCTION *(images)*

- I. **Multipolar neuron**. Most numerous and structurally diverse type
 - A. Efferent. Motor, carrying impulses out of the CNS or innervating smooth muscle from autonomic ganglia
 - B. Integrative function, axons remain in the CNS
 - C. Found throughout the CNS and in autonomic ganglia in the PNS
- II. **Pseudounipolar neuron**
 - A. Afferent. Sensory function, carrying impulses from peripheral receptors into the CNS
 - B. Found in selected areas of the CNS and in sensory ganglia of cranial nerves and spinal nerves (dorsal root ganglia)
- III. **Bipolar neuron**
 - A. Afferent. Sensory function

- B. Found associated with organs of special sense (retina of the eye, olfactory epithelium, vestibular and cochlear ganglia of the inner ear)
- C. Developmental stage for all neurons

ARRANGEMENT OF NEURONAL CELL BODIES AND THEIR PROCESSES

- I. In both CNS and PNS, cell bodies are found in clusters or layers and axons travel in bundles. These groupings are based on common functions and/or common connections.

| | Group of cell bodies | Bundle of processes |
|---------------------------|---------------------------------|----------------------------|
| Central nervous system | Nucleus or cortex (gray matter) | Tract (white matter) |
| Peripheral nervous system | Ganglion | Nerve |

SYNAPSE

- I. The function of the synapse is to alter the membrane potential of the postsynaptic target cell to either facilitate or inhibit the likelihood of the stimulus to be propagated by the postsynaptic cell. Most neurons receive thousands of synaptic contacts, both stimulatory and inhibitory, and the algebraic sum of these inputs determines whether the postsynaptic cell will depolarize.
- II. Classified according to postsynaptic target
 - A. **Axodendritic**. Most common
 - B. **Axosomatic**
 - C. **Axoaxonic**. Occur mostly at presynaptic terminals
 - D. **Neuromuscular junction**
- III. Structure of the synapse (*images*)
 - A. **Presynaptic component**
 - 1. Distal end of the axon branches, each branch terminating in a swelling or button called the **terminal bouton**.

2. Boutons with neurotransmitter-containing *synaptic vesicles* and numerous mitochondria.
- B. **Synaptic gap/cleft.** Separation (20-30 nm) between pre- and postsynaptic cells.
- C. **Postsynaptic component**
1. Formed by the membrane of the postsynaptic neuron or muscle cell and contains receptors for neurotransmitters
 2. Membrane shows a **postsynaptic density** or thickening on its cytoplasmic side.
- D. **Bouton en passant.** "Bouton-like" swellings along the length of an axon, allow a single axon to contact many distant cells. Common in smooth muscle innervation.

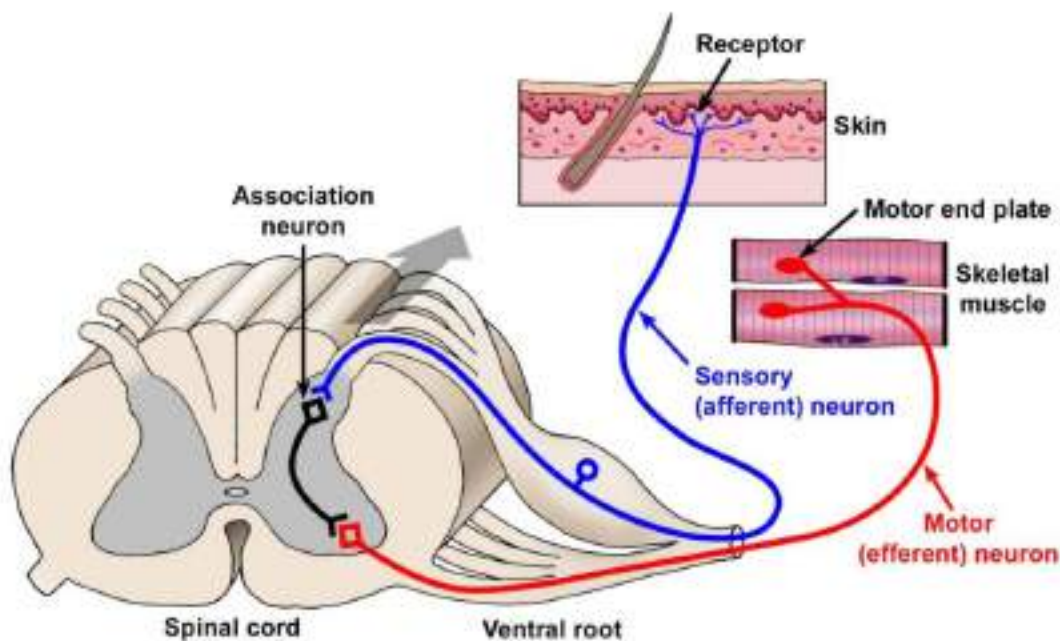


FIGURE 8.2. The reflex arc.

THE REFLEX ARC

- I. The reflex arc is the simplest neuronal circuit and includes each of the elements discussed above. These circuits provide rapid, stereotyped reactions to help maintain homeostasis. To begin the reflex, a pseudounipolar, sensory neuron is activated by a receptor. The axon carries an afferent signal from the skin into the spinal cord where it synapses on a multipolar association neuron or interneuron. The interneuron signals a multipolar, motor neuron whose axon then carries an efferent signal to skeletal muscle to initiate contraction.

SUPPORTIVE CELLS

I. Supporting cells of the CNS (neuroglial cells) (images)

A. **Astrocytes**

1. Stellate morphology
2. Types
 - a. **Fibrous astrocytes** in white matter
 - b. **Protoplasmic astrocytes** in gray matter
3. Functions
 - a. Physical support
 - b. Transport nutrients
 - c. Maintain ionic homeostasis
 - d. Take up neurotransmitters
 - e. Form glial scars (gliosis)

B. **Oligodendrocytes**

1. Present in white and gray matter
2. **Interfascicular oligodendrocytes** are located in the white matter of the CNS, where they produce the myelin sheath.
3. **Perineuronal (satellite) oligodendrocytes** are located in regions of grey matter near neuronal cell bodies

C. **Ependymal cells**. Line ventricles, ciliated.

D. **Microglia**

1. Not a true neuroglial cell; derived from the yolk sac, whereas neuroglial cells, as well as neurons, are derived from ectoderm
2. Highly phagocytic cells
3. Provide immune surveillance and produce immunomodulatory compounds

II. Supporting cells of the PNS. **Schwann cells** (*images*)

- A. **Satellite Schwann cells** surround cell bodies in ganglia
- B. **Ensheathing Schwann cells**
 - 1. Surround unmyelinated axons. Numerous axons indent the Schwann cell cytoplasm and, therefore, are surrounded by a single plasma membrane.
 - 2. Produce the myelin sheath around axons

MYELIN SHEATH (*images*)

- I. The **myelin sheath** is formed by the plasma membrane of supporting cells wrapping around the axon. The sheath consists of multilamellar, lipid-rich segments produced by Schwann cells in the PNS and oligodendrocytes in the CNS.

II. Functions

- A. Increases speed of conduction (**saltatory conduction**)
- B. Insulates the axon

III. Similar structure in CNS and PNS with some differences in protein composition

IV. Organization

- A. **Internode**. Single myelin segment
 - B. **Paranode**. Ends of each internode where they attach to the axon
 - C. **Node of Ranvier**. Specialized region of the axon between myelin internodes where depolarization occurs
- V. In the PNS, each Schwann cell associates with only one axon and forms a single internode of myelin.
 - VI. In the CNS, each oligodendrocyte associates with many axons (i.e. each oligodendrocyte forms multiple internodes on different axons).

CONNECTIVE TISSUE INVESTMENTS OF NERVOUS TISSUE

I. Peripheral nervous system (*images*)

- A. **Endoneurium**. Delicate connective tissue surrounding Schwann cells;

includes the basal lamina secreted by Schwann cells as well as reticular fibers

- B. **Perineurium**. Dense tissue surrounding groups of axons and their surrounding Schwann cells, forming fascicles; forms the blood-nerve barrier
- C. **Epineurium**. Dense connective tissue surrounding fascicles and the entire nerve

II. Central nervous system (**meninges**)

A. **Pia mater**

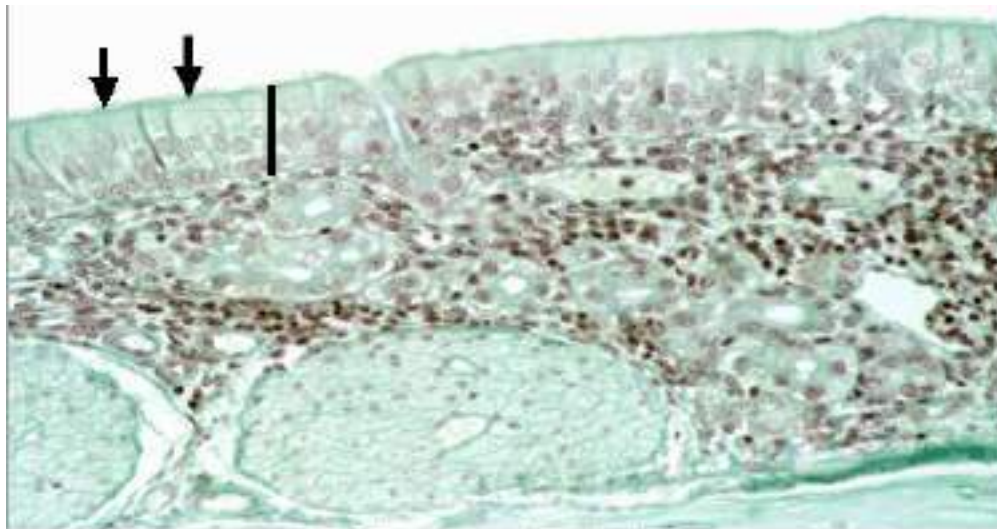
- 1. Thin membrane lying directly on the surface of the brain and spinal cord
- 2. Accompanies larger blood vessels into the brain and spinal cord

B. **Arachnoid membrane**

- 1. Separated from pia mater by connective tissue trabeculae
- 2. Encloses the **subarachnoid space**, which contains blood vessels and the **cerebrospinal fluid (CSF)** produced by the cells of the choroid plexus
- 3. Together with pia mater, constitute the **leptomeninges**; inflammation of these membranes produces meningitis

C. **Dura mater**

- 1. Outermost of the meninges
- 2. Dense connective tissue that includes the periosteum of the skull

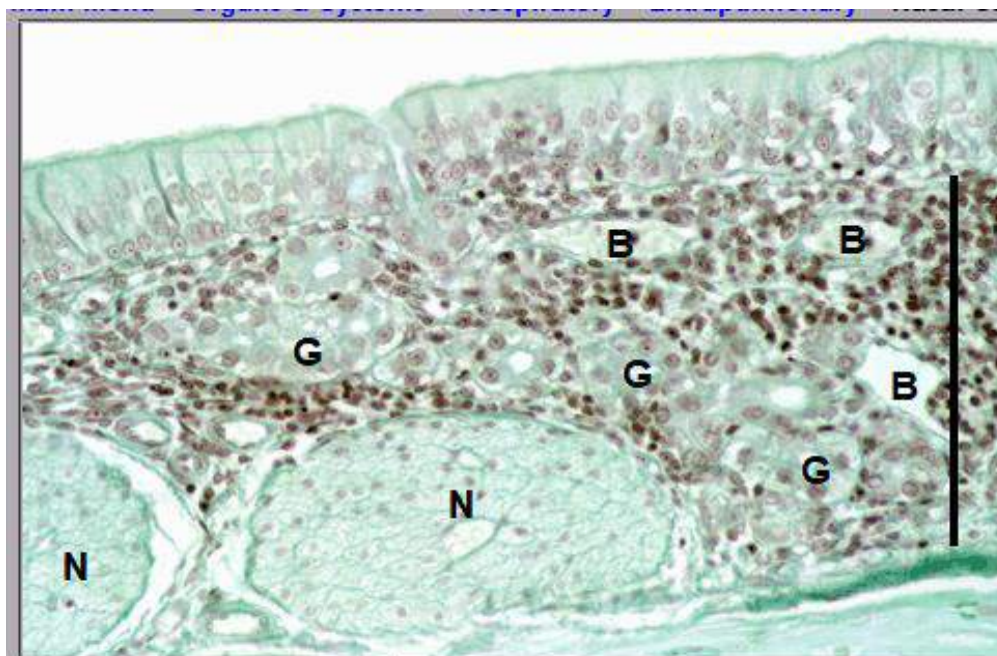


click to identify:

- > Pseudostratified > columnar epithelium
- CT >
- Bone >

2 of 6

The epithelium lining most of the nasal cavities is a thin, respiratory epithelium: pseudostratified columnar epithelium (bar) with cilia (arrows) and goblet cells (which are not readily visible here, probably because this is fetal tissue and these cells are not functional yet).



click to identify:

- Pseudostratified > columnar epithelium
- > CT >
- Bone >

2 of 6

Because the nasal cavity lacks a muscularis mucosae, the connective tissue (bar) beneath the epithelium is a combination of lamina propria in continuity with submucosa. Numerous glands (G) (mixed glands, when functional after birth) are seen, as are numerous blood vessels (B) to moderate air temperature. Sensory, peripheral nerves (N) also traverse this layer.

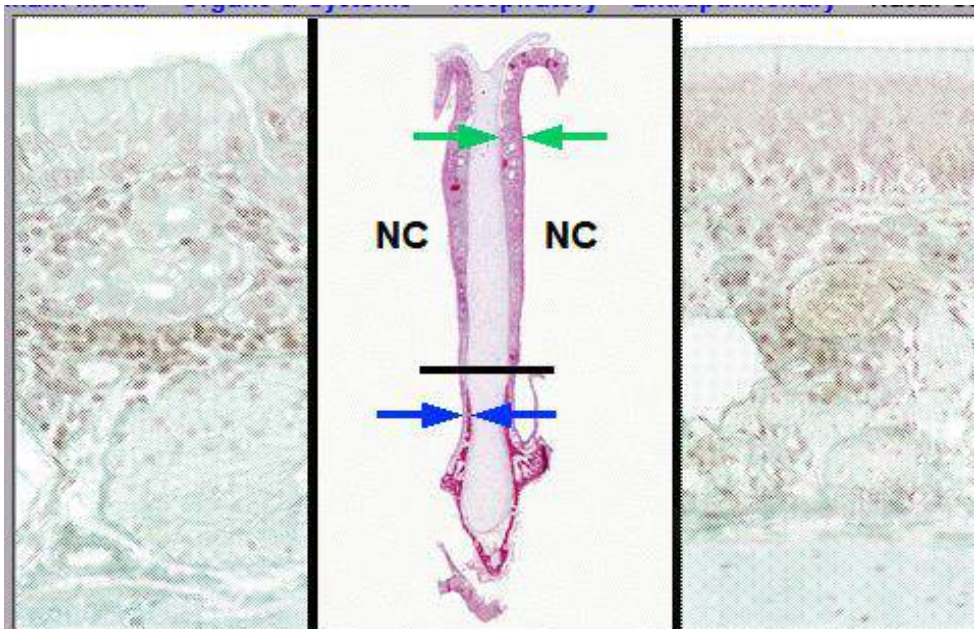


2 of 6

All the extra-pulmonary structures of the respiratory system are supported by either bone or cartilage to maintain patency. In the nasal cavity both cartilage and bone are present in different locations to keep this passageway open.

click to identify:

- Pseudostratified >
- columnar
- epithelium
- CT >
- > Bone >

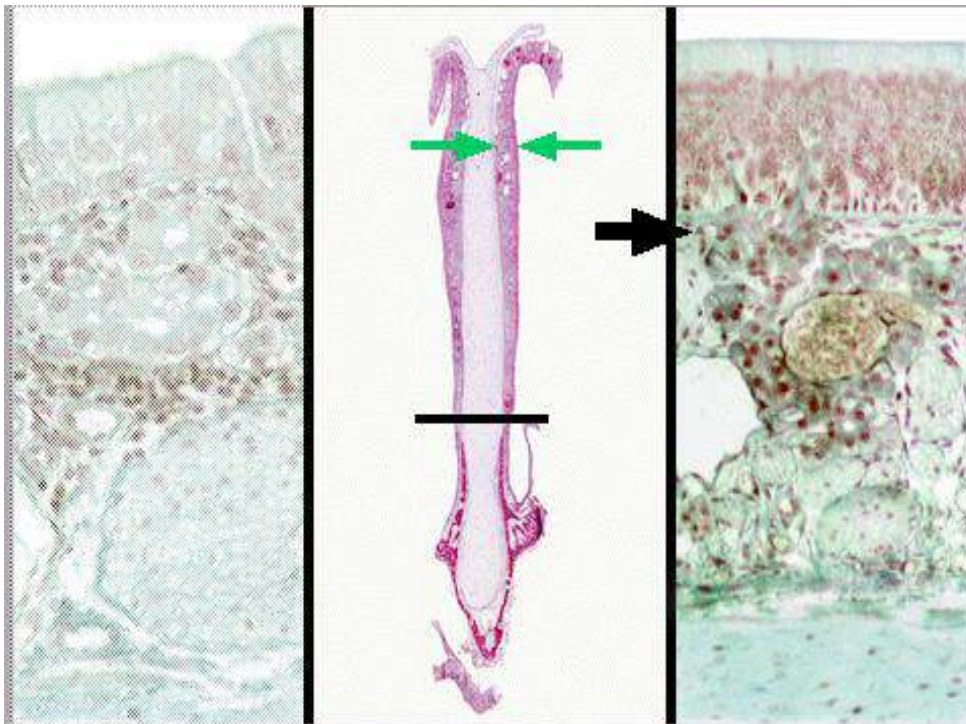


3 of 6

The nasal septum separates the two nasal cavities (nasal fossae, NC). Cartilage forms the central frame of this fetal septum. Note that the olfactory mucosa (green arrows) above the horizontal bar is much thicker than the respiratory mucosa (blue arrows) below the bar.

click to identify:

- > Nasal septum >
- Respiratory >
- mucosa
- Olfactory >
- mucosa
- Cartilage / bone >

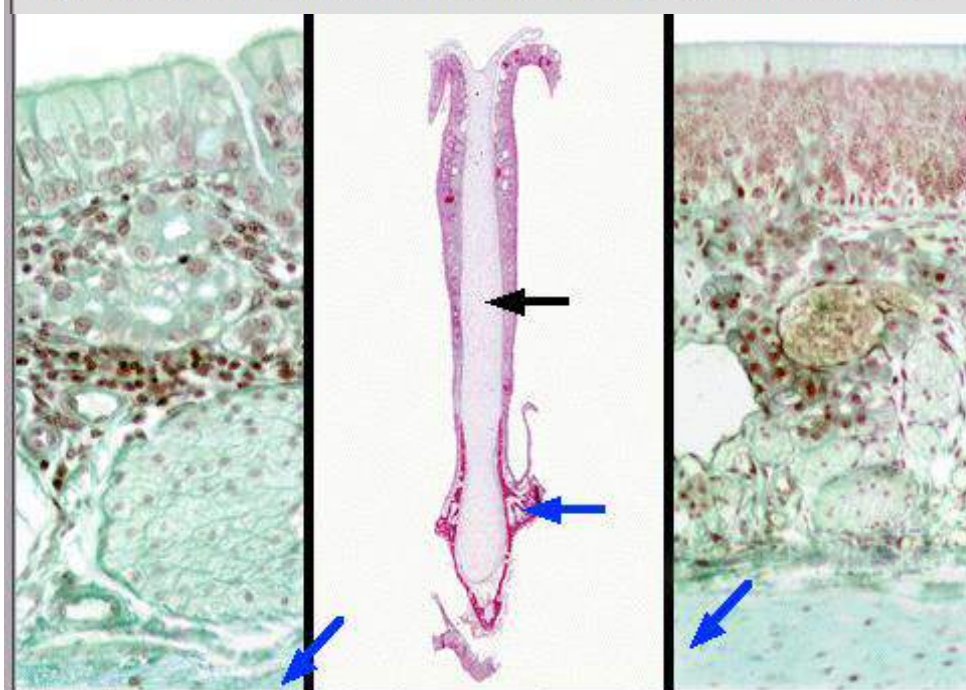


3 of 6

The thicker olfactory mucosa, above the bar, lines the superior portion of the septum and is seen at higher magnification on the right and in the next image.

click to identify:

- Nasal septum >
- Respiratory >
mucosa
- > Olfactory >
mucosa
- Cartilage / bone >

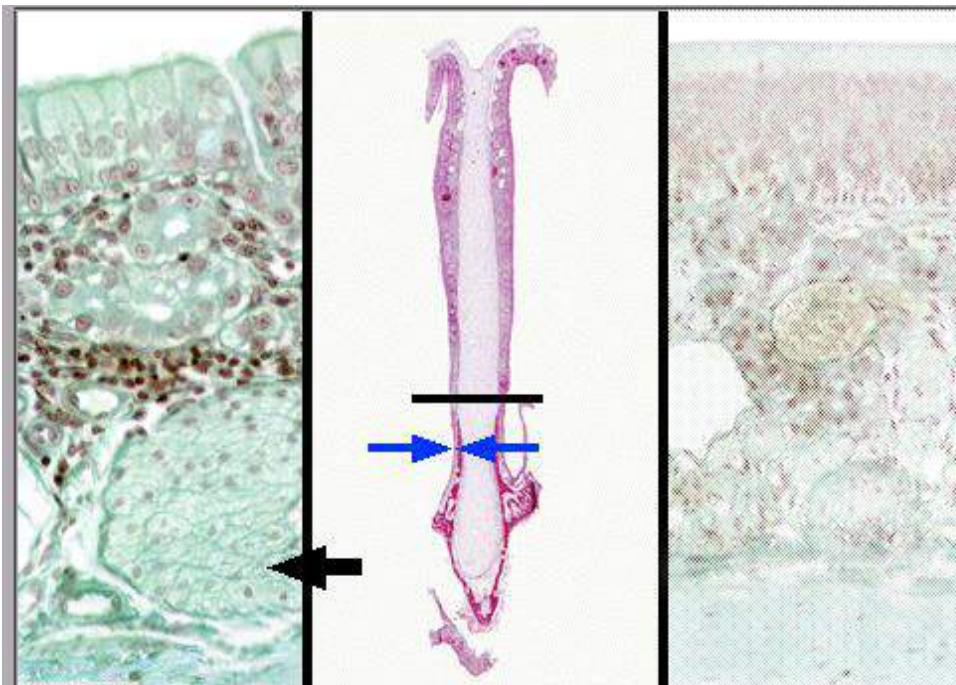


3 of 6

Cartilage (black arrow) forms the framework for the septum at this stage of fetal development. Bone (blue arrows) is already being deposited along the inferior border of the septum and will replace the cartilage over time.

click to identify:

- Nasal septum >
- Respiratory >
mucosa
- Olfactory >
mucosa
- > Cartilage / bone >

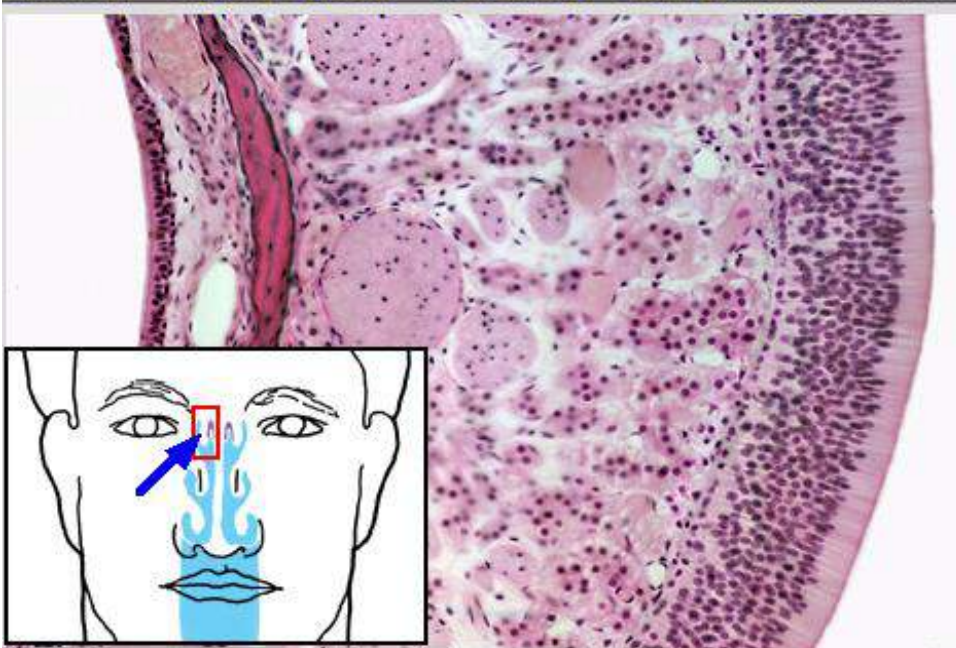


3 of 6

Respiratory mucosa, lining the nasal septum below the bar, is seen at higher magnification on the left and in the previous image.

click to identify:

- Nasal septum >
- > Respiratory >
- mucosa
- Olfactory >
- mucosa
- Cartilage / bone >

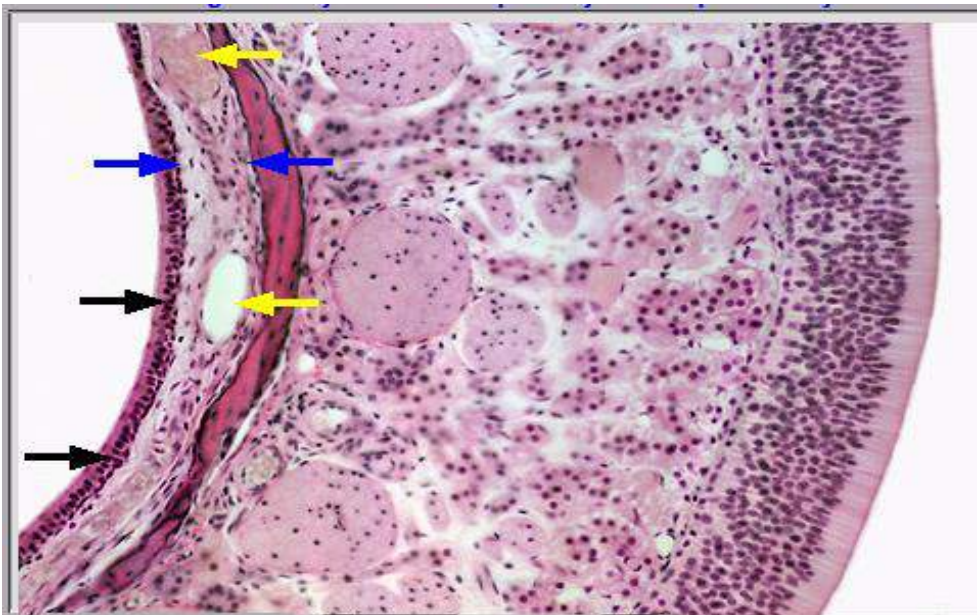


5 of 6

The outline in the inset shows the location from which this section was taken, including the superior concha (arrow) extending into the superior region of the nasal cavity. The location of the olfactory epithelium covering the medial surface of this concha is colored purple; non-olfactory epithelium lines the lateral surface of the concha.

click to identify:

- > Orientation >
- Respiratory >
- mucosa
- Ethmoid bone >
- Olfactory >
- mucosa
- Bowman's glands
- Sensory nerves

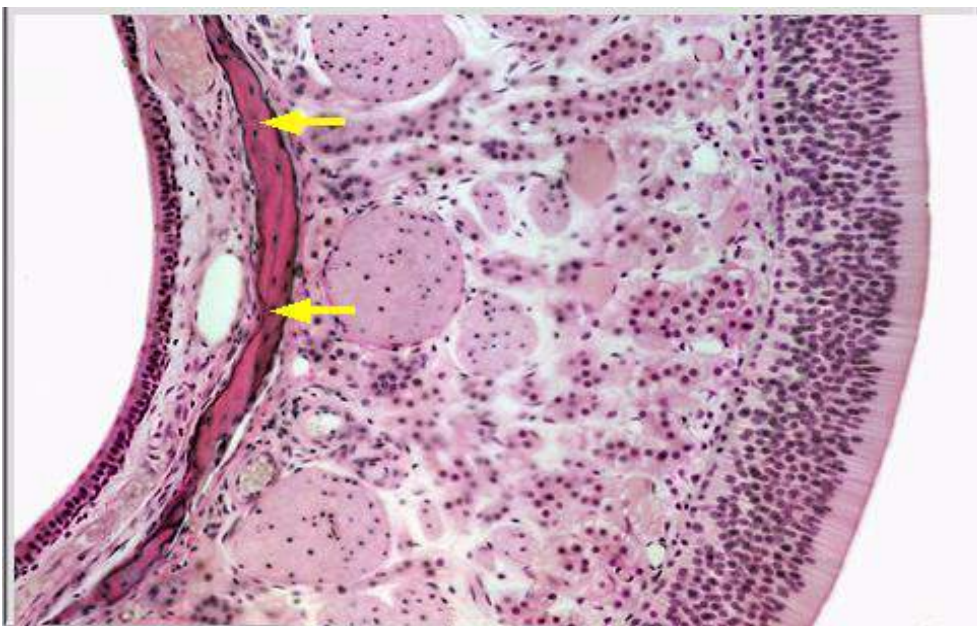


click to identify:

- Orientation >
- > Respiratory >
- mucosa
- Ethmoid bone >
- Olfactory >
- mucosa
- Bowman's glands
- Sensory nerves

5 of 6

Respiratory mucosa lines the non-olfactory region of the nasal fossae, represented here by the lateral surface of a superior concha. This mucosa possesses a pseudostratified columnar epithelium (black arrows) with cilia and goblet cells. The underlying connective tissue (between blue arrows) is rich in blood vessels (yellow arrows) to moderate air temperature.

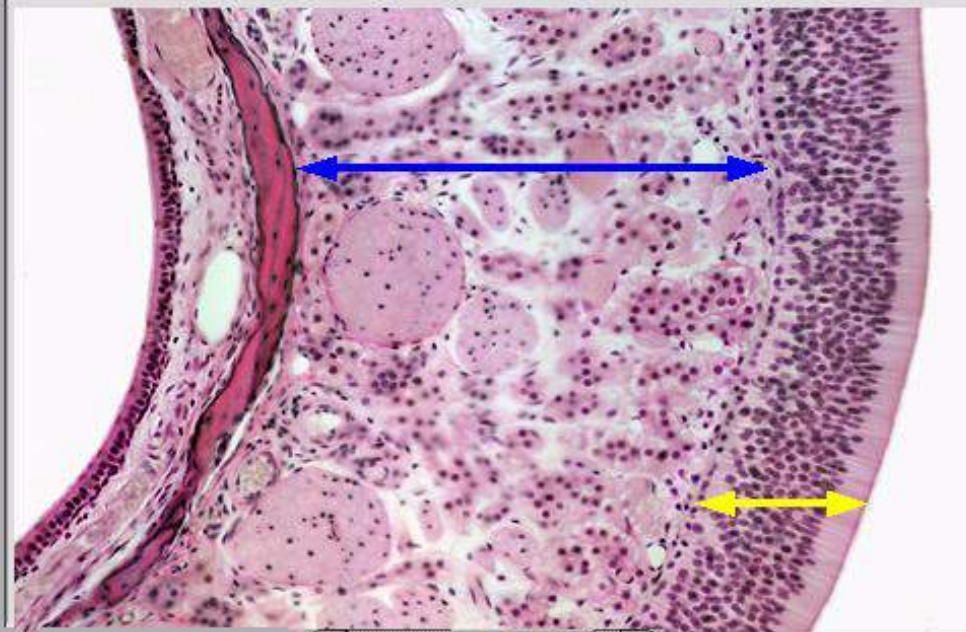


click to identify:

- Orientation >
- Respiratory >
- mucosa
- > Ethmoid bone >
- Olfactory >
- mucosa
- Bowman's glands
- Sensory nerves

5 of 6

An extension of the ethmoid bone, the superior concha, provides internal support.

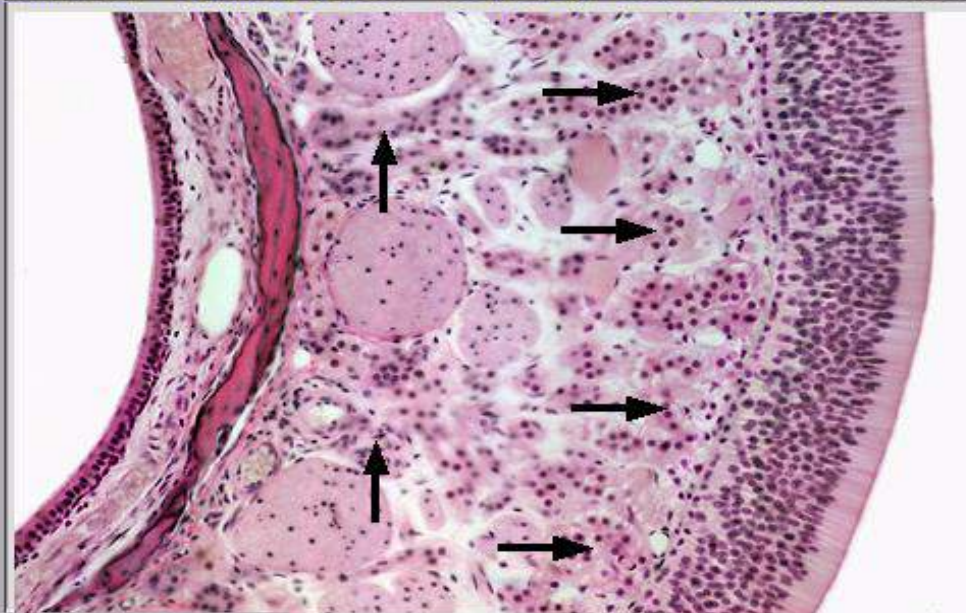


5 of 6

Olfactory mucosa lines the medial surface of the superior concha. Its epithelium, pseudostratified columnar with cilia (yellow arrow), is markedly thicker than that of respiratory mucosa. The underlying connective tissue (blue arrow) is also thicker, filled with serous-secreting Bowman's glands and cranial sensory nerves supplying both general and special sensations.

click to identify:

- Orientation >
- Respiratory >
- mucosa
- Ethmoid bone >
- > Olfactory >
- mucosa
- Bowman's glands
- Sensory nerves

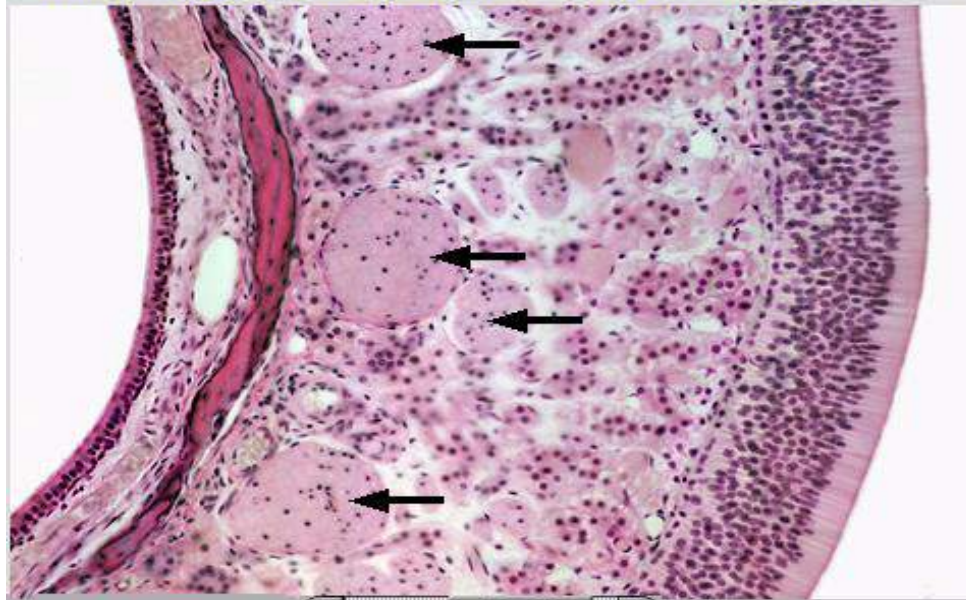


5 of 6

Olfactory mucosa lines the medial surface of the superior concha. Its epithelium, pseudostratified columnar with cilia (yellow arrow), is markedly thicker than that of respiratory mucosa. The underlying connective tissue (blue arrow) is also thicker, filled with serous-secreting Bowman's glands and cranial sensory nerves supplying both general and special sensations.

click to identify:

- Orientation >
- Respiratory >
- mucosa
- Ethmoid bone >
- Olfactory >
- mucosa
- > Bowman's glands
- Sensory nerves



5 of 6

Olfactory mucosa lines the medial surface of the superior concha. Its epithelium, pseudostratified columnar with cilia (yellow arrow), is markedly thicker than that of respiratory mucosa. The underlying connective tissue (blue arrow) is also thicker, filled with serous-secreting Bowman's glands and cranial sensory nerves supplying both general and special sensations.

click to identify:

- Orientation >
- Respiratory >
- mucosa
- Ethmoid bone >
- Olfactory >
- mucosa
- Bowman's glands
- > Sensory nerves

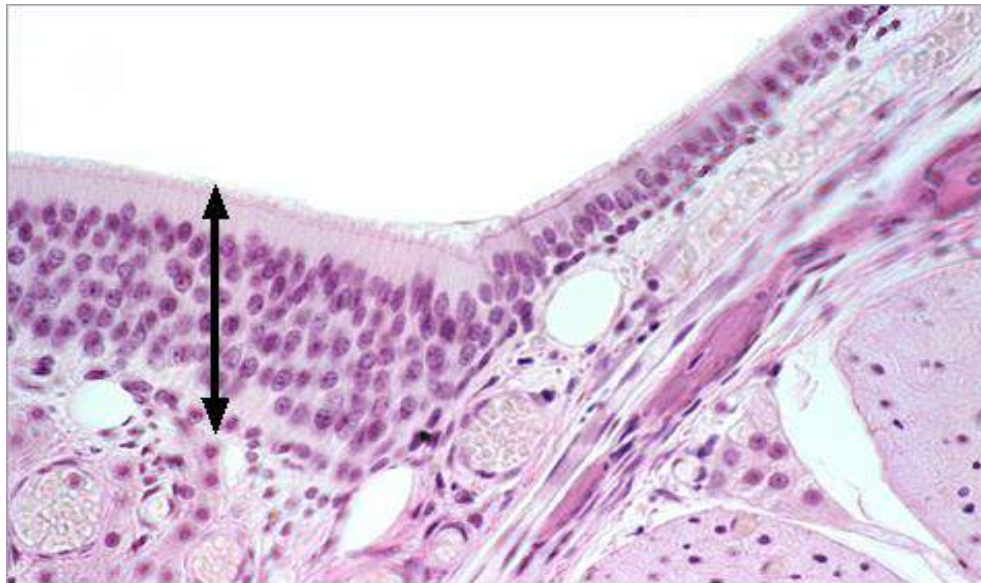


6 of 6

Nasal cavity -- This particular section shows the junction of respiratory with olfactory epithelia, demonstrating the difference in their thicknesses. Numerous blood vessels are present to moderate air temperature. The superior concha of the ethmoid bone provides support. 400x

click to identify:

- > Respiratory
- epithelium
- Olfactory
- epithelium
- Blood vessels
- Bone
- Basal bodies



click to identify:

- Respiratory epithelium
- › Olfactory epithelium
- Blood vessels
- Bone
- Basal bodies

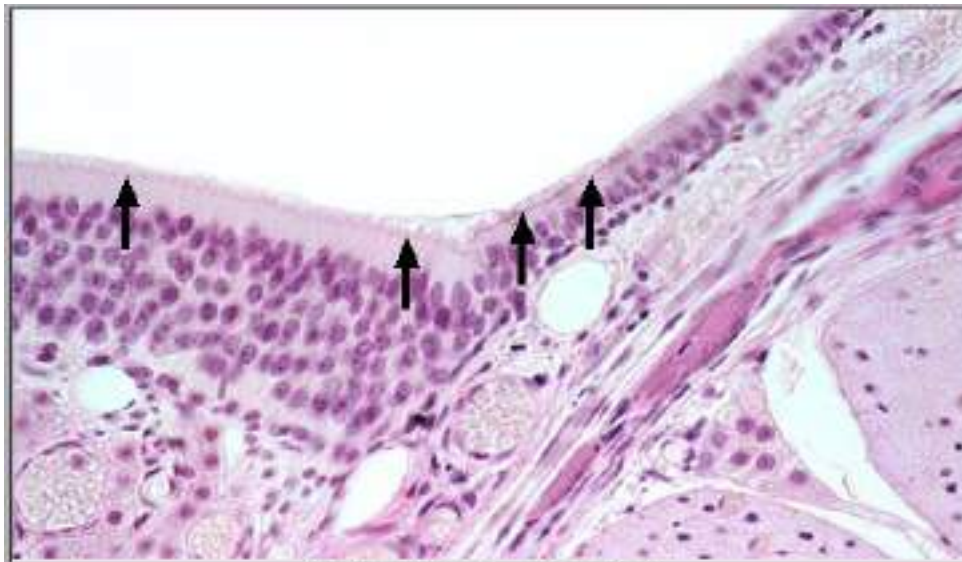
Nasal cavity -- This particular section shows the junction of respiratory with olfactory epithelia, demonstrating the difference in their thicknesses. Numerous blood vessels are present to moderate air temperature. The superior concha of the ethmoid bone provides support. 400x



click to identify:

- Respiratory epithelium
- Olfactory epithelium
- Blood vessels
- › Bone
- Basal bodies

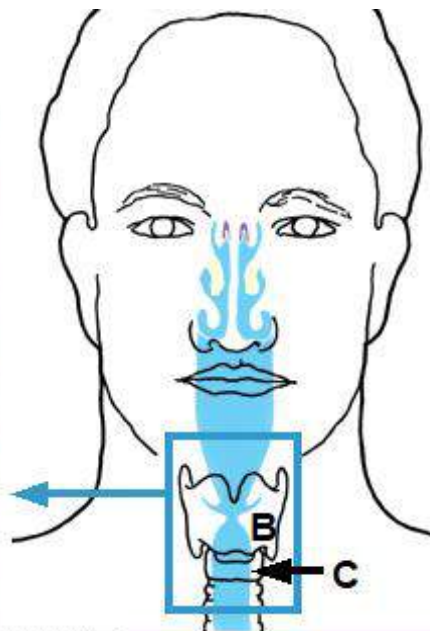
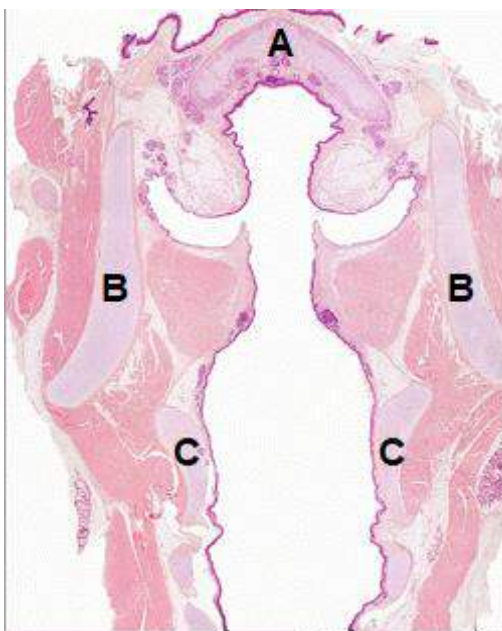
Nasal cavity -- This particular section shows the junction of respiratory with olfactory epithelia, demonstrating the difference in their thicknesses. Numerous blood vessels are present to moderate air temperature. The superior concha of the ethmoid bone provides support. 400x



click to identify:

- Respiratory epithelium
- Olfactory epithelium
- Blood vessels
- Bone
- > Basal bodies

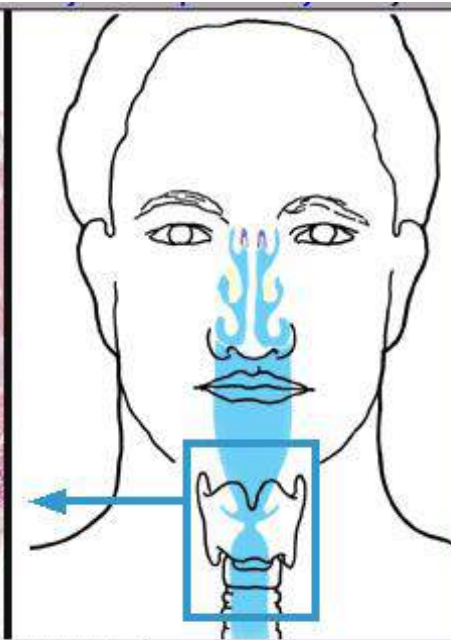
Nasal cavity – This particular section shows the junction of respiratory with olfactory epithelia, demonstrating the difference in their thicknesses. Numerous blood vessels are present to moderate air temperature. The superior concha of the ethmoid bone provides support. 400x



click to identify:

- > Cartilages >
- False vocal fold >
- Ventricle >
- True vocal folds >
- Epithelium >
- Trachea >

Cartilagenous support for the larynx is provided by three large cartilages and multiple smaller ones (not seen here). The epiglottis (A, elastic cartilage) guards the entrance to the larynx. The large thyroid cartilage (B, hyaline) protects the anterior and lateral sides, and the cricoid (C) cartilage (hyaline) encircles the larynx, providing the major posterior support.

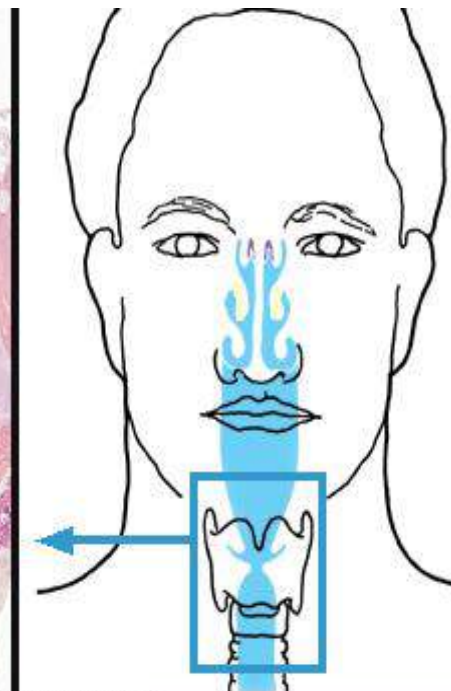
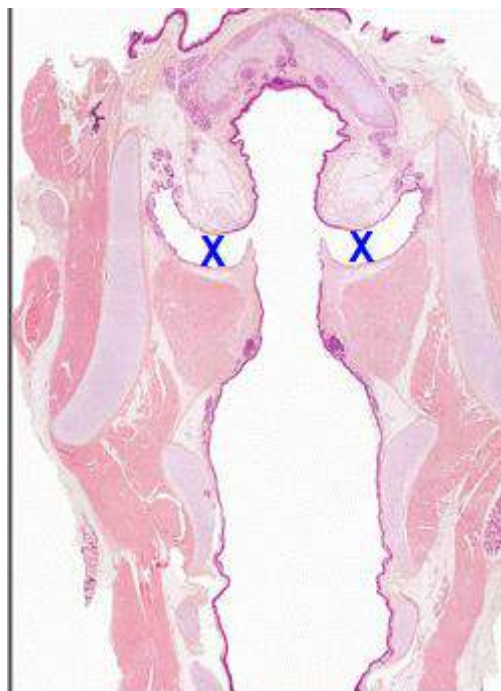


click to identify:

- Cartilages >
- > False vocal fold >
- Ventricle >
- True vocal folds >
- Epithelium >
- Trachea >

1 of 2

The paired false vocal folds lie superior to the true vocal folds. The false folds are covered by pseudostratified columnar epithelium overlying a connective tissue containing adipose tissue and mixed, mucoserous glands. The vestibule (X) separates the two false vocal folds.

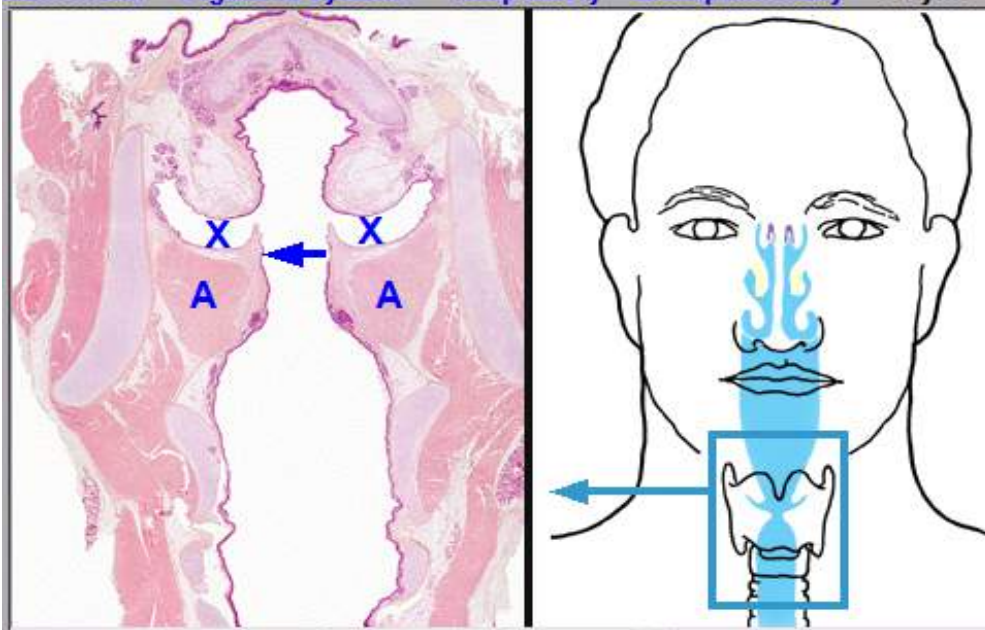


click to identify:

- Cartilages >
- False vocal fold >
- > Ventricle >
- True vocal folds >
- Epithelium >
- Trachea >

1 of 2

The space beneath the false vocal folds is the ventricle, separating the false and true vocal folds.

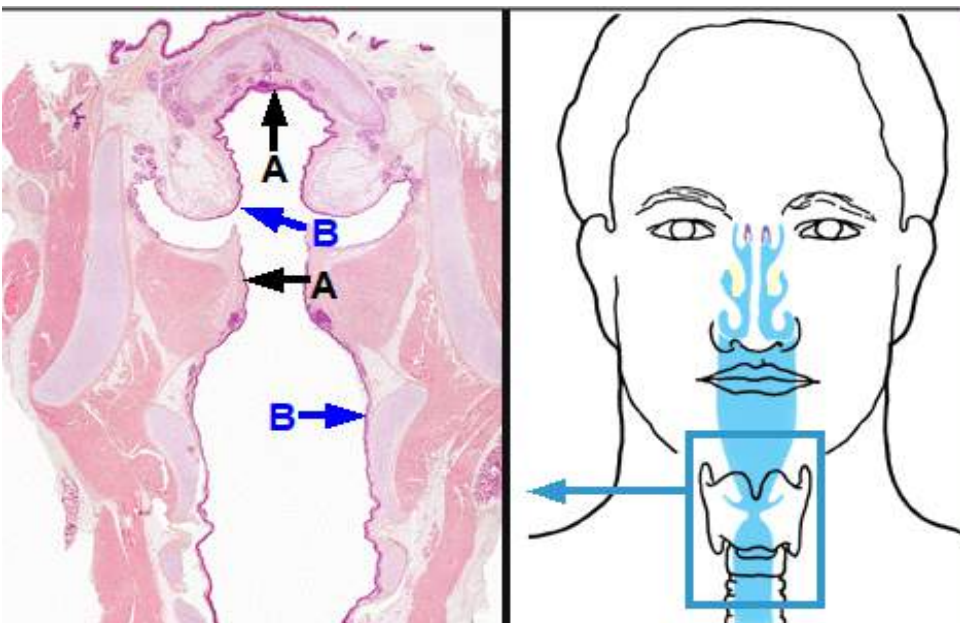


1 of 2

Each true vocal fold houses a vocalis muscle (A, skeletal) that alters the length of the fold. The vocal ligament (dense regular elastic connective tissue) maintains tautness in the edge of the fold but cannot be differentiated from collagen with this H and E stain. Stratified squamous moist epithelium (arrow) covers the fold. The ventricle (X) lies between the two folds.

click to identify:

- [Cartilages >](#)
- [False vocal fold >](#)
- [Ventricle >](#)
- [True vocal folds >](#)
- [Epithelium >](#)
- [Trachea >](#)



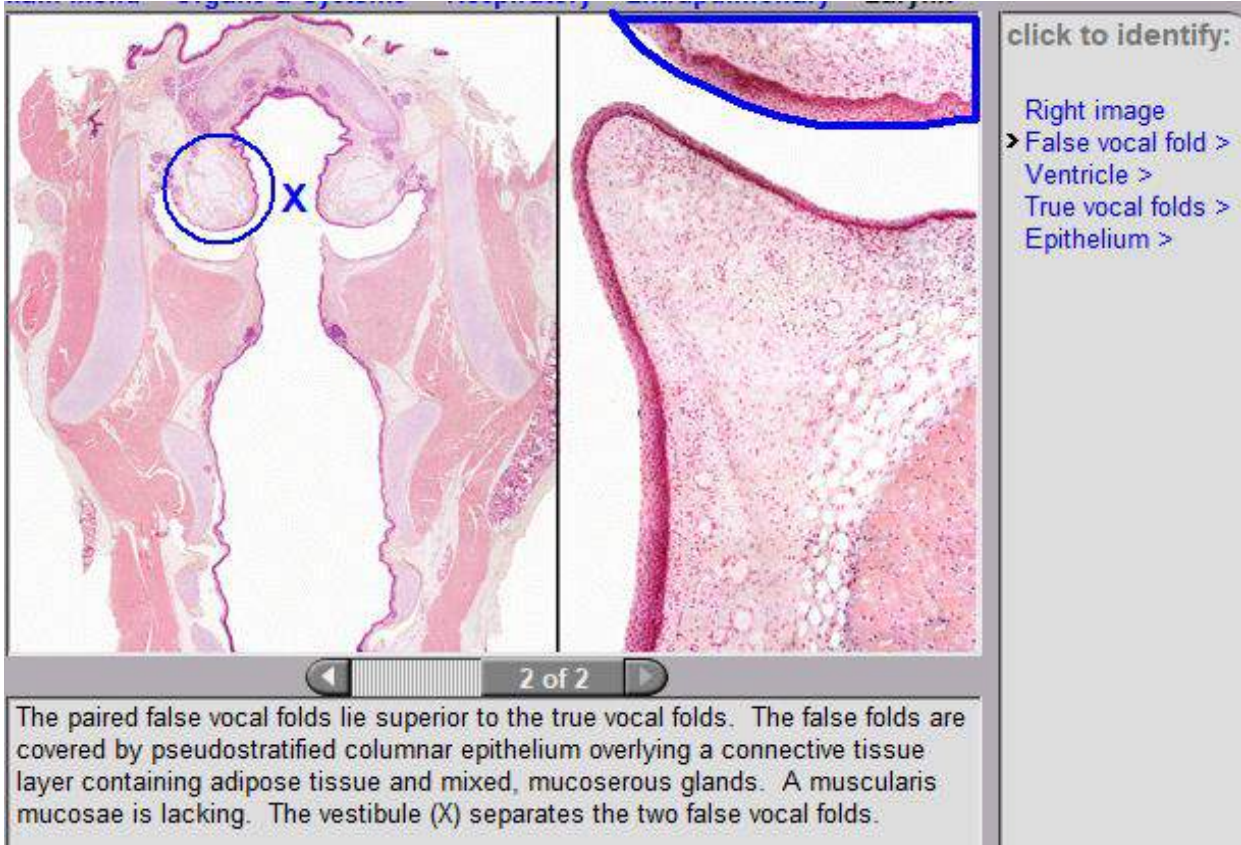
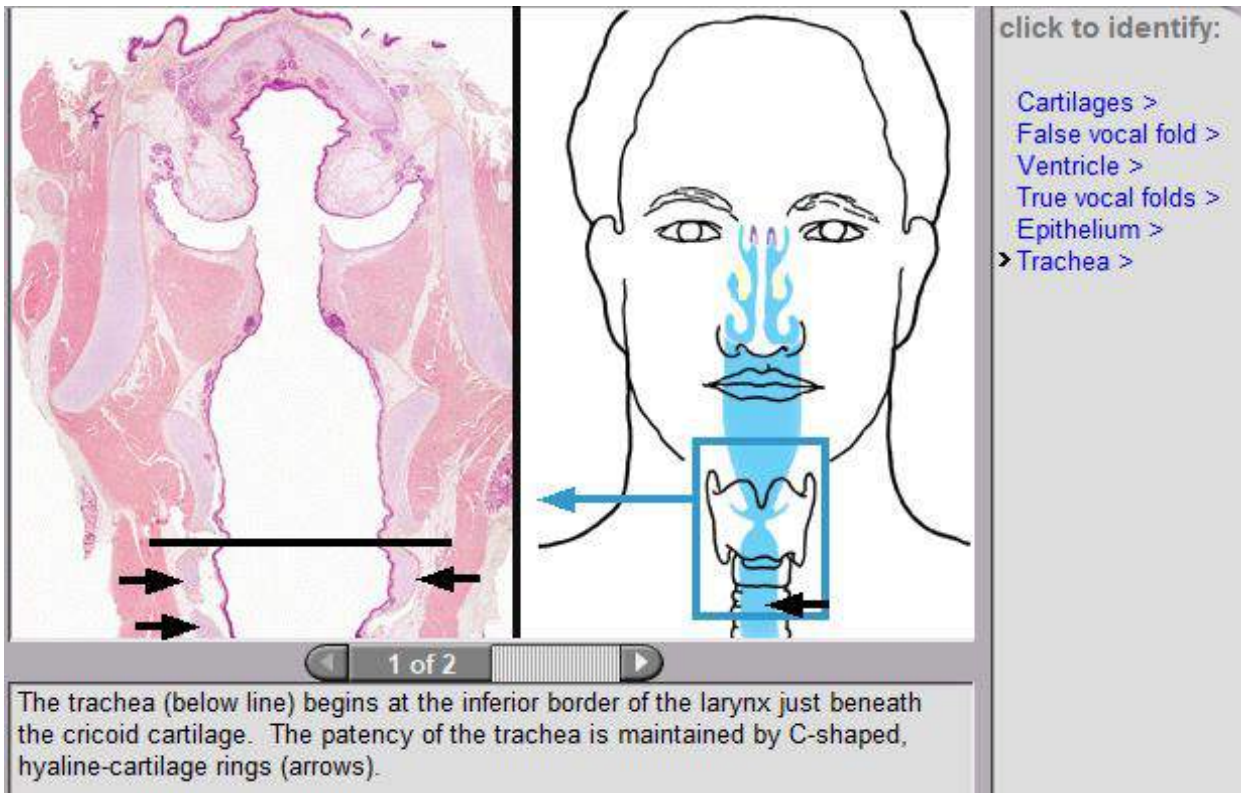
1 of 2

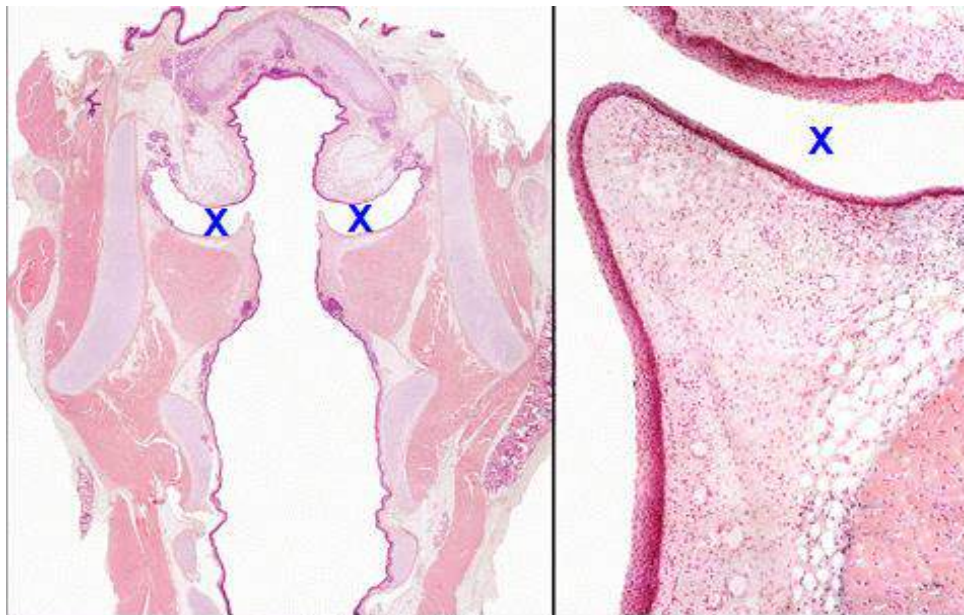
Laryngeal epithelium varies depending on the stress it undergoes. Stratified squamous moist epithelium (A) normally lines the epiglottis and the true vocal folds, areas that undergo continual stress. Respiratory epithelium (B), lining the remainder of the larynx, may be converted to stratified squamous moist in cases of irritation, such as in the larynx of a smoker.

click to identify:

- [Cartilages >](#)
- [False vocal fold >](#)
- [Ventricle >](#)
- [True vocal folds >](#)
- [Epithelium >](#)
- [Trachea >](#)

0

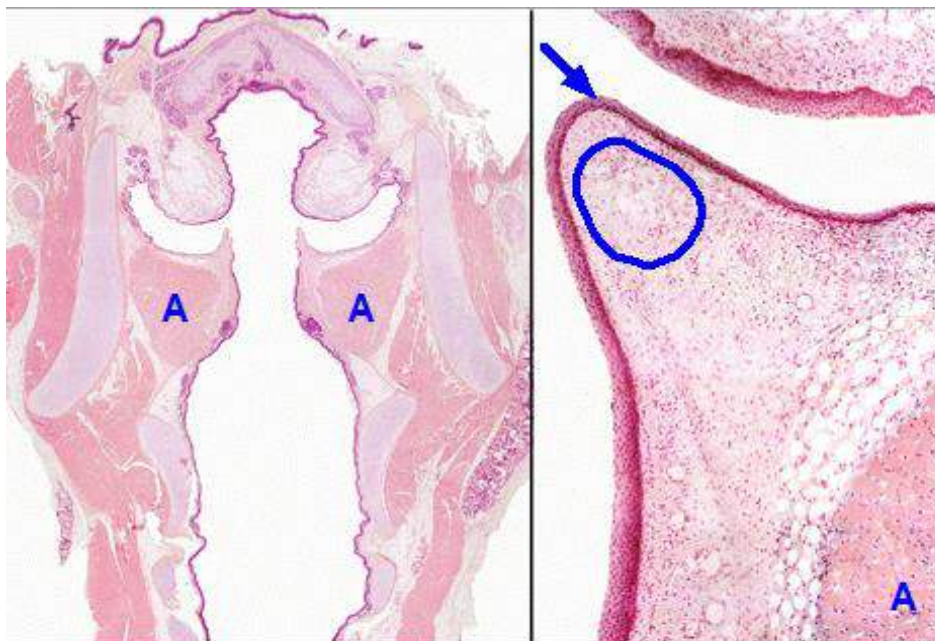




click to identify:

- Right image
- False vocal fold >
- > Ventricle >
- True vocal folds >
- Epithelium >

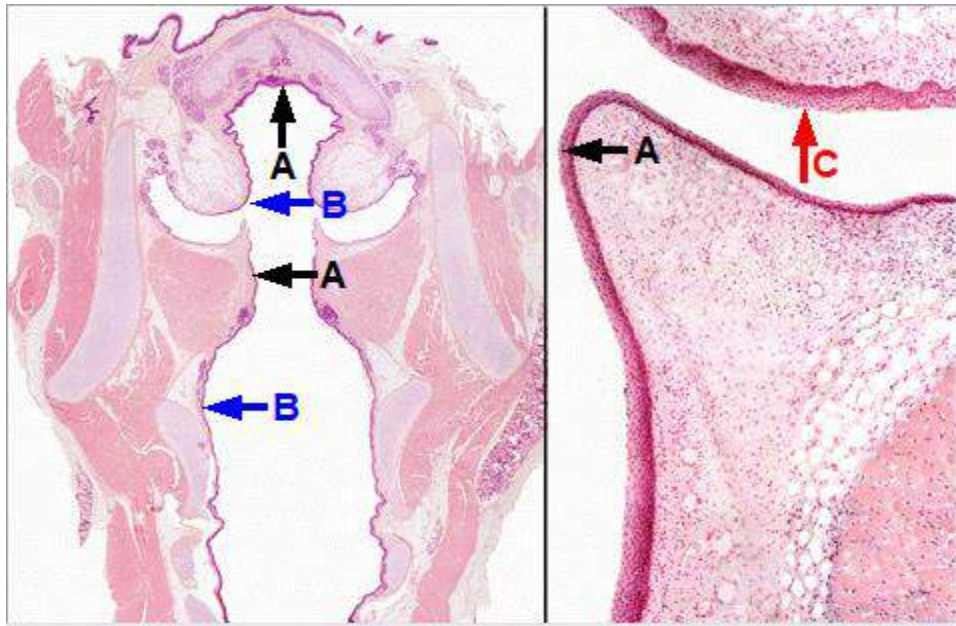
The space beneath the false vocal folds is the ventricle, separating the false and true vocal folds.



click to identify:

- Right image
- False vocal fold >
- Ventricle >
- > True vocal folds >
- Epithelium >

Each true vocal fold houses a vocalis muscle (A, skeletal) that alters the length of the fold. The vocal ligament (circle, dense regular elastic connective tissue) maintains tautness, but is hard to distinguish because elastic fibers stain similarly to collagen with H and E. Stratified squamous moist epithelium (blue arrow) covers the fold; a muscularis mucosae is lacking.

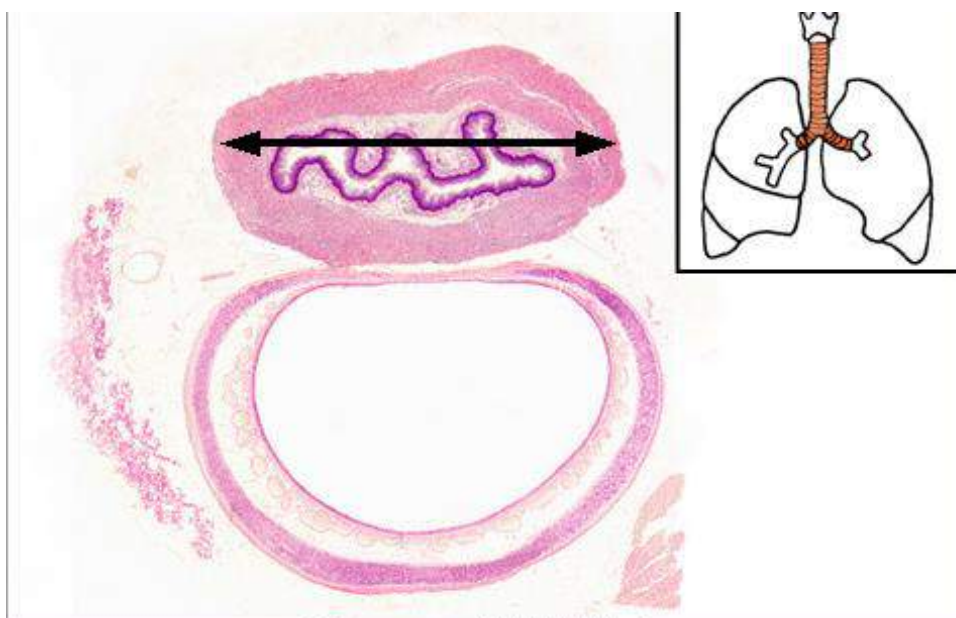


2 of 2

Laryngeal epithelium varies depending on the stress it undergoes. Stratified squamous moist epithelium (A) normally lines the epiglottis and the true vocal folds, areas that undergo continual stress. Respiratory epithelium (B), lining the remainder of the larynx, may be converted to stratified squamous moist epithelium (C) in cases of irritation, such as in the larynx of a smoker.

click to identify:

- Right image
- False vocal fold >
- Ventricle >
- True vocal folds >
- Epithelium >

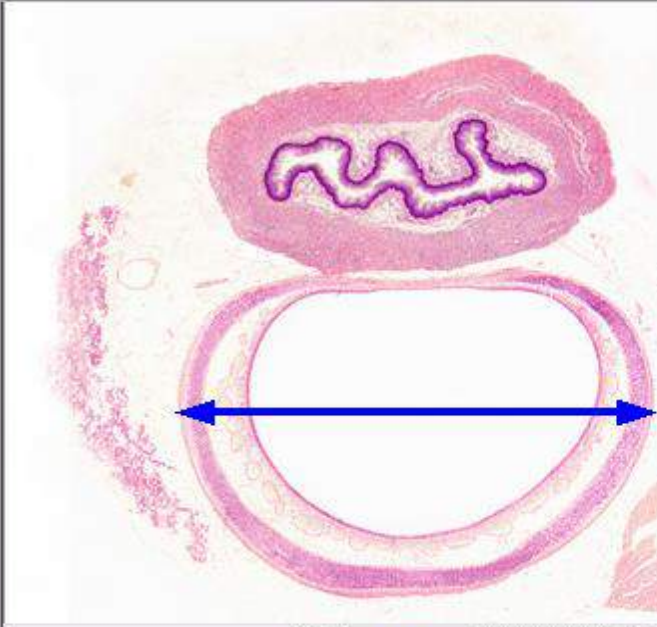
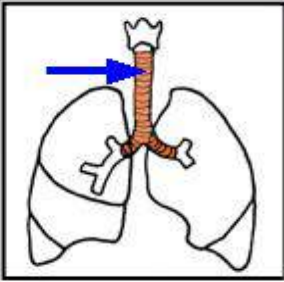


1 of 9

Trachea -- The trachea and primary bronchi are extrapulmonary and part of the conducting portion of the system. The trachea, continuing inferiorly from the larynx, lies anterior to the esophagus. The patency of these respiratory organs is maintained by C-shaped cartilage rings, whose openings face the esophagus. These passageways cannot be distinguished from each other histologically. 10x

click to identify.

- > Esophagus
- Trachea
- Primary bronchi
- Cartilage ring
- Cartilage ring opening
- Next image

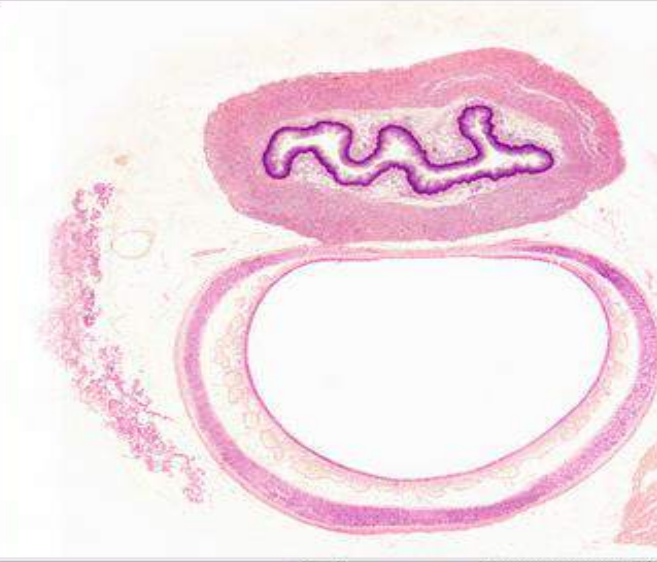
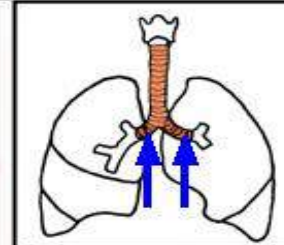



click to identify:

- Esophagus
- ▶ Trachea
- Primary bronchi
- Cartilage ring
- Cartilage ring opening
- Next image

1 of 9

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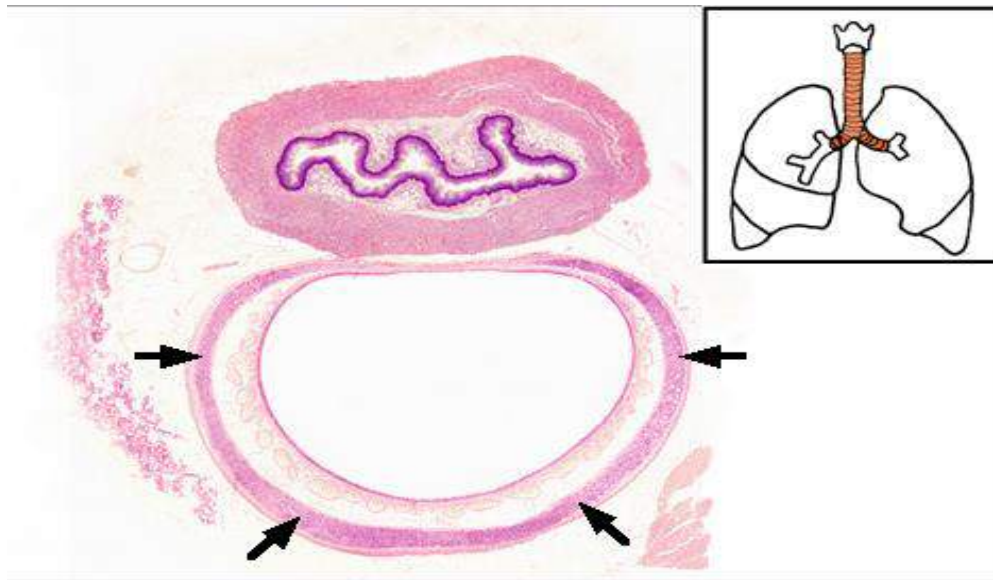



click to identify:

- Esophagus
- Trachea
- ▶ Primary bronchi
- Cartilage ring
- Cartilage ring opening
- Next image

1 of 9

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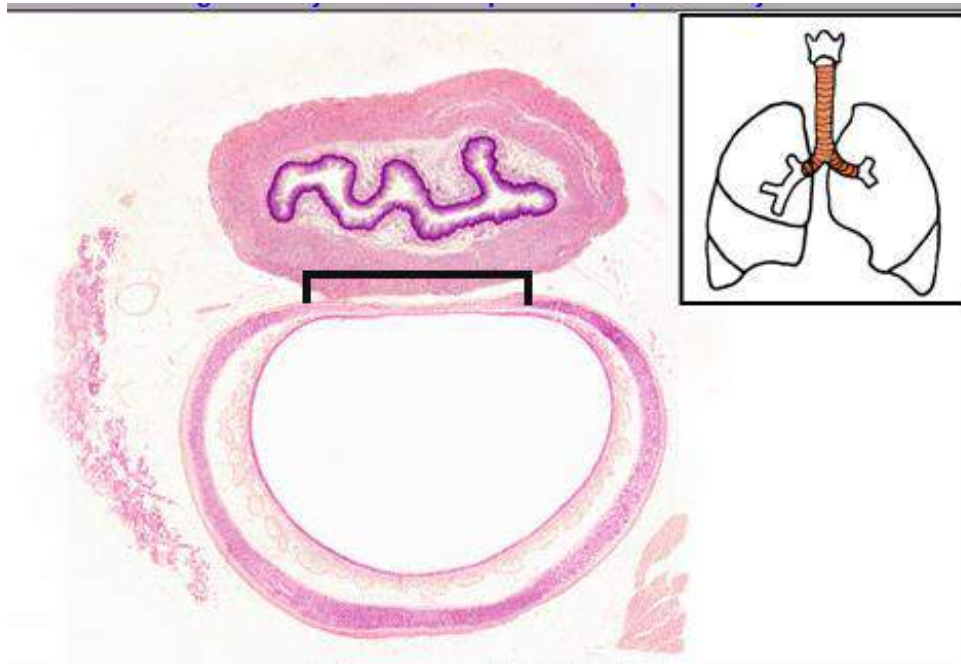


click to identify

- Esophagus
- Trachea
- Primary bronchi
- ▶ Cartilage ring
- Cartilage ring opening
- Next image

1 of 9

Trachea -- The trachea and primary bronchi are extrapulmonary and part of the conducting portion of the system. The trachea, continuing inferiorly from the larynx, lies anterior to the esophagus. The patency of these respiratory organs is maintained by C-shaped cartilage rings, whose openings face the esophagus. These passageways cannot be distinguished from each other histologically. 10x

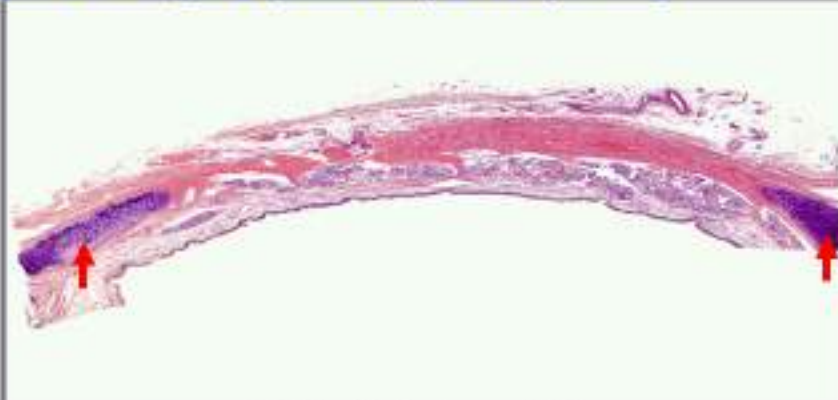


click to identify:

- Esophagus
- Trachea
- Primary bronchi
- Cartilage ring
- ▶ Cartilage ring opening
- Next image

1 of 9

Trachea -- The trachea and primary bronchi are extrapulmonary and part of the conducting portion of the system. The trachea, continuing inferiorly from the larynx, lies anterior to the esophagus. The patency of these respiratory organs is maintained by C-shaped cartilage rings, whose openings face the esophagus. These passageways cannot be distinguished from each other histologically. 10x

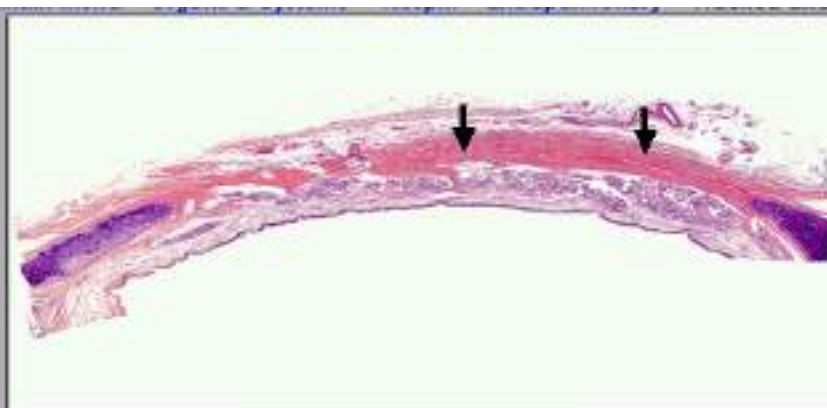


click to identify:

- Lumen
- Cartilage
- Trachealis muscle
- Mixed glands

2 of 9

Trachea – The trachealis muscle is smooth muscle and spans the opening between the ends of each cartilage ring, controlling the diameter of the trachea. Frequently, mixed glands accumulate over this muscle. 40x

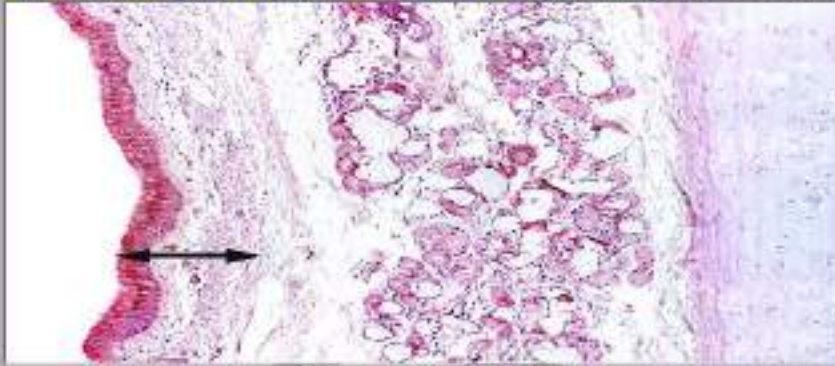


click to identify:

- Lumen
- Cartilage
- Trachealis muscle
- Mixed glands

2 of 9

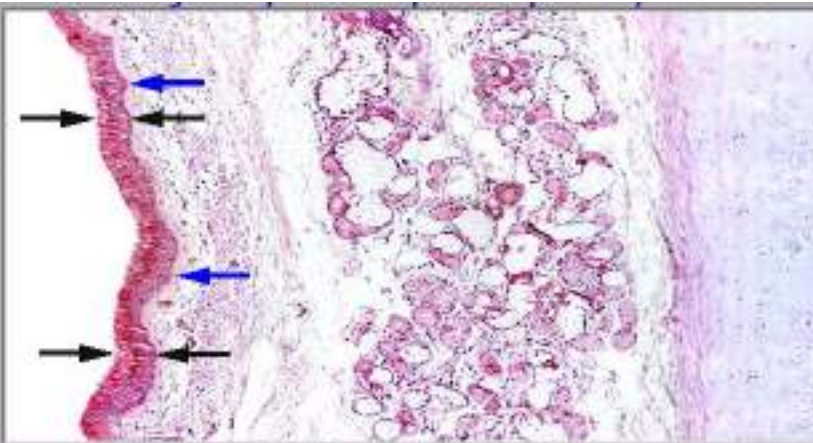
Trachea – The trachealis muscle is smooth muscle and spans the opening between the ends of each cartilage ring, controlling the diameter of the trachea. Frequently, mixed glands accumulate over this muscle. 40x



click to identify:

- > Mucosa
 - > Epithelium >
 - > Lamina propria
 - > Elastic lamina >
 - > Submucosa >
 - > Cartilage >

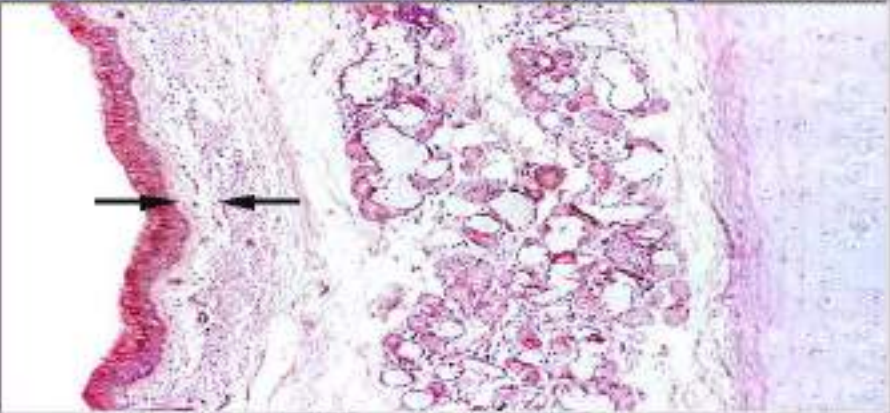
Trachea and primary bronchus -- The walls of the trachea and primary bronchi are identical, resembling the pattern typical for most passageways, except that the muscularis mucosae is replaced by an elastic lamina. The trachea and primary bronchi are extrapulmonary and are part of the conducting portion of the respiratory system. 100x



click to identify:

- Mucosa
 - > Epithelium >
 - > Lamina propria
 - > Elastic lamina >
 - > Submucosa >
 - > Cartilage >

The epithelium lining the trachea and primary bronchi is pseudostratified columnar (between black arrows) with cilia and goblet cells. Note the thickened basement membrane (blue arrows) that is typical in the respiratory system. The lamina propria is composed of loose connective tissue.



click to identify:

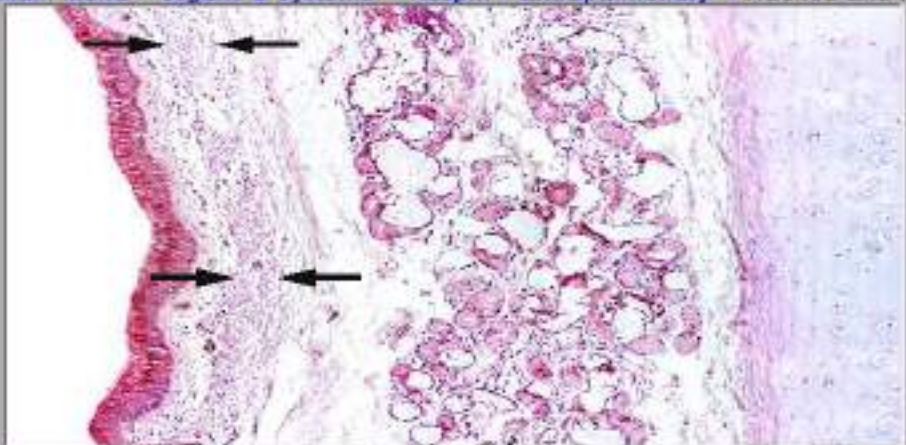
- Mucosa
 - Epithelium >
 - Lamina propria >
 - Elastic lamina >
 - Submucosa >
 - Cartilage >

4 of 9

The epithelium lining the trachea and primary bronchi is pseudostratified columnar (between black arrows) with cilia and goblet cells. Note the thickened basement membrane (blue arrows) that is typical in the respiratory system. The lamina propria is composed of loose connective tissue.

File View Go Quiz Help

Main Menu > Organs & Systems > Resp... > Extrapulmonary > Trachea and Primary Bronchus



click to identify:

- Mucosa
 - Epithelium >
 - Lamina propria >
 - Elastic lamina >
 - Submucosa >
 - Cartilage >

4 of 9

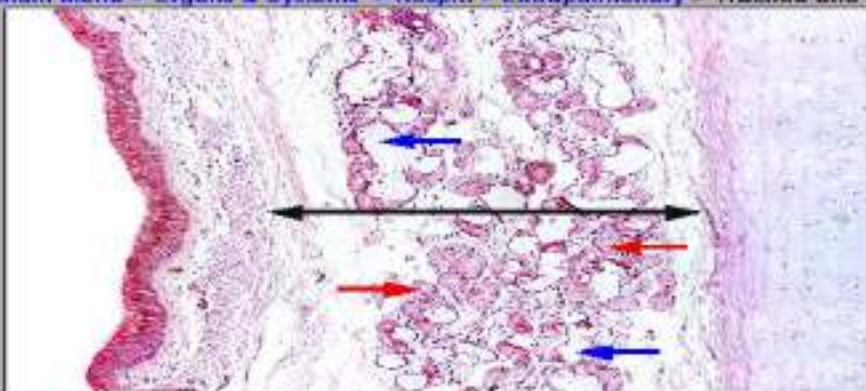
The deepest layer of the mucosa is a band of elastic fibers, the elastic lamina. Elastic fibers run longitudinally throughout the respiratory passageways, but are only organized into a definitive layer, the elastic lamina, in the trachea and primary bronchi. Elastic fibers aid in passive expiration of air from the lungs and respiratory passageways.

2 Organ 1 Organ 3 Organ 4 Organ

Digital Histology

File View Go Quiz Help

Main Menu > Organs & Systems > Resp... > Extrapulmonary > Trachea and Primary Bronchus



click to identify:

- Mucosa
 - Epithelium >
 - Lamina propria
 - Elastic lamina >
- > Submucosa >
- Cartilage >

4 of 9

The submucosa (black arrow) lies beneath the mucosa and is filled with mixed glands. The paler-staining mucous cells (blue arrows) can be readily distinguished from the more intensely staining serous cells (red arrows).

Digital Histology

File View Go Quiz Help

Main Menu > Organs & Systems > Resp... > Extrapulmonary > Trachea and Primary Bronchus

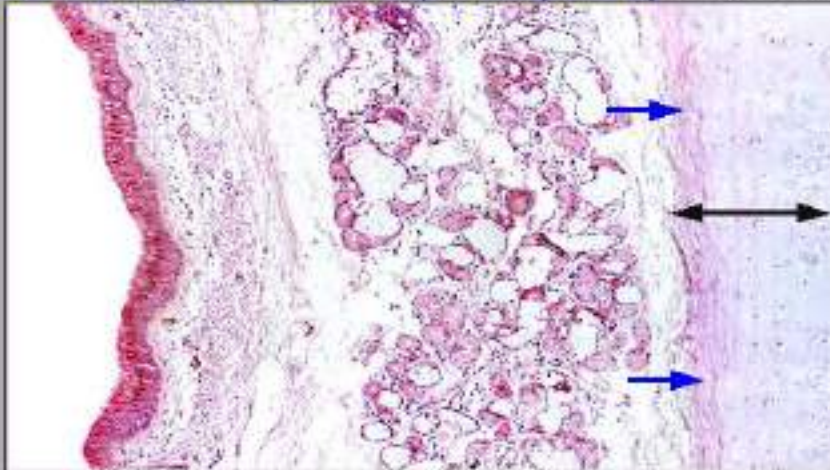


click to identify:

- > Mucosa
 - Epithelium
 - Basement membrane
 - Lamina propria
 - Elastic lamina
- Submucosa
- Mixed glands
- Perichondrium
- Cartilage

5 of 9

Trachea and primary bronchus – Another image of the trachea or primary bronchus demonstrates the components forming the wall of this passageway. 100x

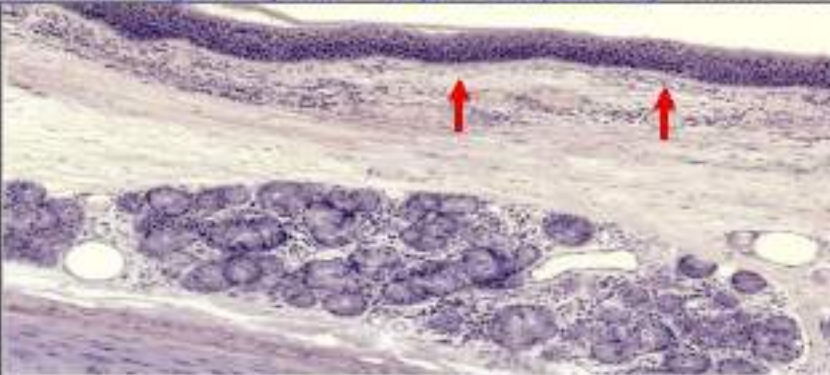


click to identify:

- Mucosa
- Epithelium >
- Lamina propria
- Elastic lamina >
- Submucosa >
- > Cartilage >

4 of 5

Patency of the trachea and primary bronchi is maintained by a series of hyaline cartilage rings (black arrow). A perichondrium (blue arrows) surrounds this tissue.



click to identify:

- Mucosa
- Epithelium
- Basement membrane
- > Lamina propria
- Elastic lamina
- Submucosa
- Mixed glands
- Perichondrium
- Cartilage

5 of 9

Trachea and primary bronchus — Another image of the trachea or primary bronchus demonstrates the components forming the wall of this passageway. 100x

File View Go Quiz Help
Main Menu > Organs & Systems > Resp... > Extrapulmonary > Trachea and Primary Bronchus



click to identify:

- Mucosa
 - Epithelium
 - Basement membrane
 - Lamina propria
 - Elastic lamina
- Submucosa
- Mixed glands
- Perichondrium
- Cartilage

5 of 9

Trachea and primary bronchus – Another image of the trachea or primary bronchus demonstrates the components forming the wall of this passageway. 100x

File View Go Quiz Help
Main Menu > Organs & Systems > Resp... > Extrapulmonary > Trachea and Primary Bronchus

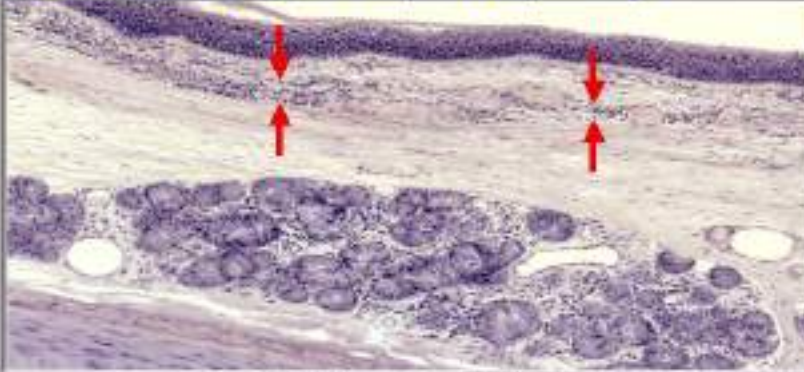


click to identify:

- Mucosa
 - Epithelium
 - Basement membrane
 - Lamina propria
 - Elastic lamina
- Submucosa
- Mixed glands
- Perichondrium
- Cartilage

5 of 9

Trachea and primary bronchus – Another image of the trachea or primary bronchus demonstrates the components forming the wall of this passageway. 100x

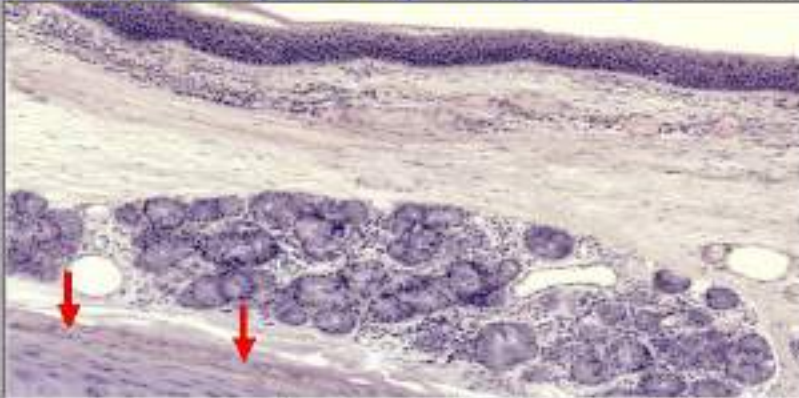


click to identify:

- Mucosa
- Epithelium
- Basement membrane
- Lamina propria
- Elastic lamina
- Submucosa
- Mixed glands
- Perichondrium
- Cartilage

5 of 9

Trachea and primary bronchus — Another image of the trachea or primary bronchus demonstrates the components forming the wall of this passageway. 100x

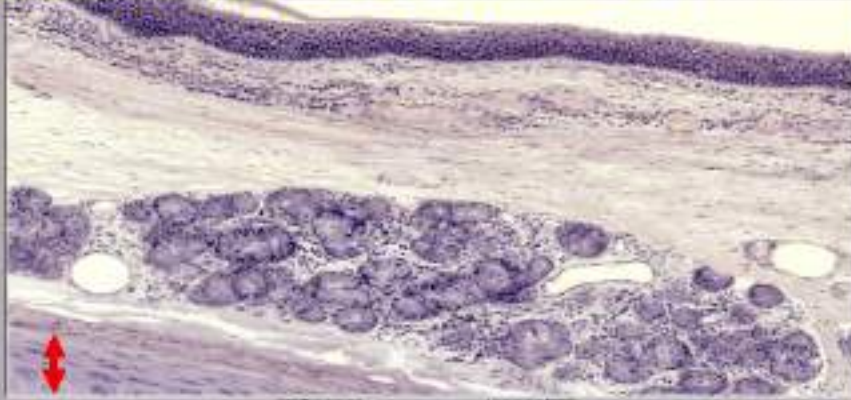


click to identify:

- Mucosa
- Epithelium
- Basement membrane
- Lamina propria
- Elastic lamina
- Submucosa
- Mixed glands
- Perichondrium
- Cartilage

5 of 9

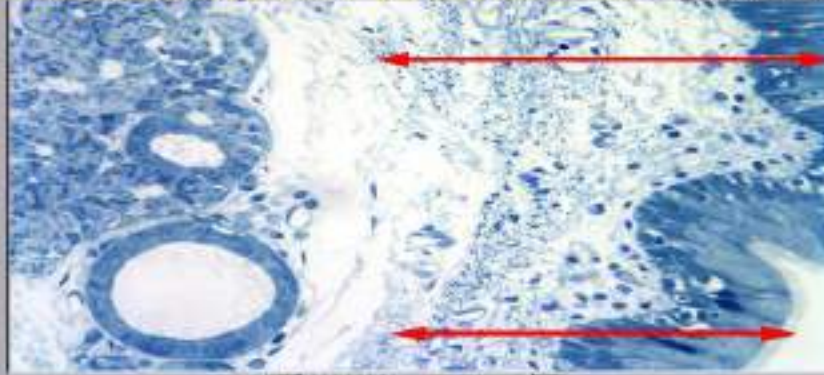
Trachea and primary bronchus — Another image of the trachea or primary bronchus demonstrates the components forming the wall of this passageway. 100x



click to identify:

- Mucosa
- Epithelium
- Basement membrane
- Lamina propria
- Elastic lamina
- Submucosa
- Mixed glands
- Perichondrium
- > Cartilage

Trachea and primary bronchus – Another image of the trachea or primary bronchus demonstrates the components forming the wall of this passageway. 100x.

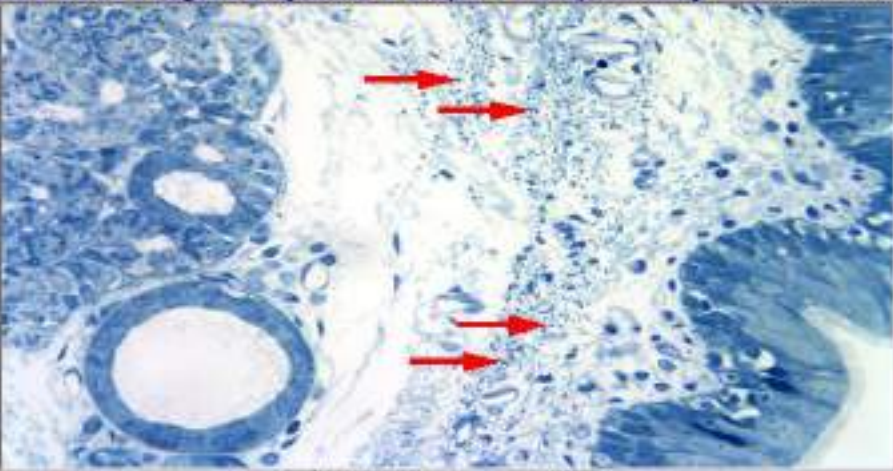


click to identify:

- > Mucosa
- Epithelium
- Lamina propria
- Elastic lamina
- Elastic fibers (xs)
- Submucosa
- Mixed glands
- Ducts

Trachea and primary bronchus – A higher magnification of the trachea or primary bronchus demonstrates the layers adjacent to the lumen. The longitudinally oriented elastic fibers in the elastic lamina are seen cut in cross section. 400x

main menu > Organs & Systems > Resp... > Extrapulmonary > Trachea and Primary Bronchus



click to identify:

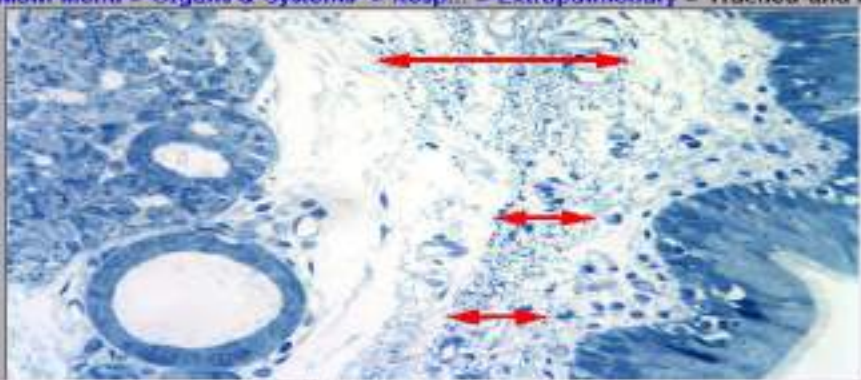
- Mucosa
- Epithelium
- Lamina propria
- Elastic lamina
- > Elastic fibers (xs)
- Submucosa
- Mixed glands
- Ducts

8 of 9

Trachea and primary bronchus -- A higher magnification of the trachea or primary bronchus demonstrates the layers adjacent to the lumen. The longitudinally oriented elastic fibers in the elastic lamina are seen cut in cross section. 400x

File View Go Quiz Help

main menu > Organs & Systems > Resp... > Extrapulmonary > Trachea and Primary Bronchus

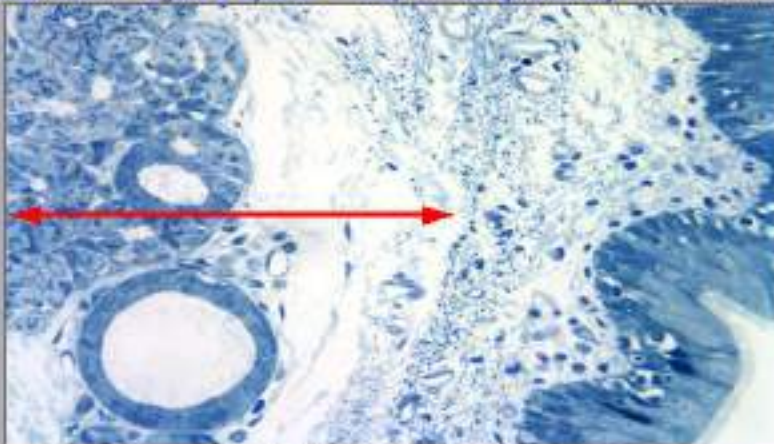


click to identify:

- Mucosa
- Epithelium
- Lamina propria
- > Elastic lamina
- Elastic fibers (xs)
- Submucosa
- Mixed glands
- Ducts

8 of 9

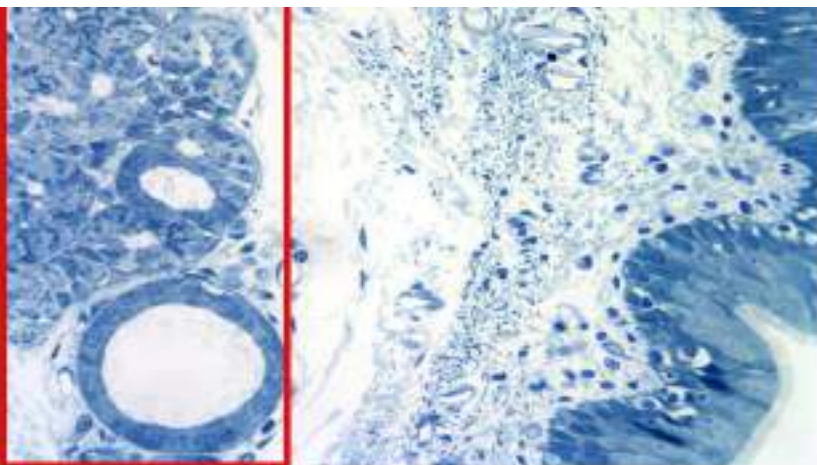
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click to identify:

- Mucosa
- Epithelium
- Lamina propria
- Elastic lamina
- Elastic fibers (xs)
- Submucosa
- Mixed glands
- Ducts

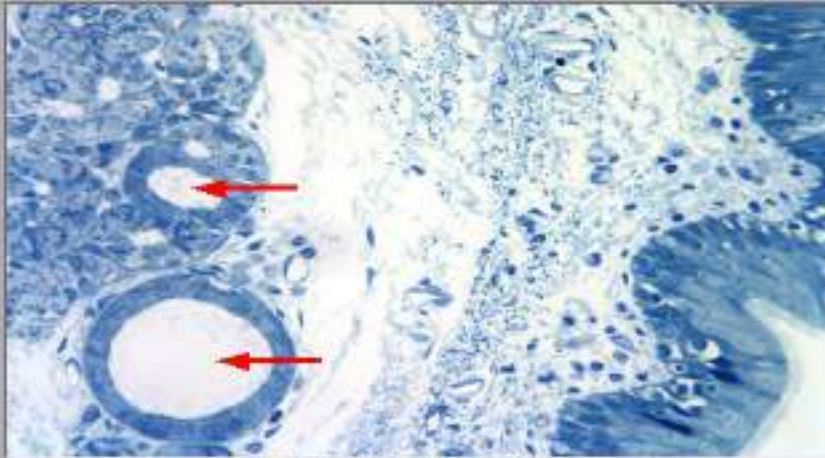
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click to identify:

- Mucosa
- Epithelium
- Lamina propria
- Elastic lamina
- Elastic fibers (xs)
- Submucosa
- Mixed glands
- Ducts

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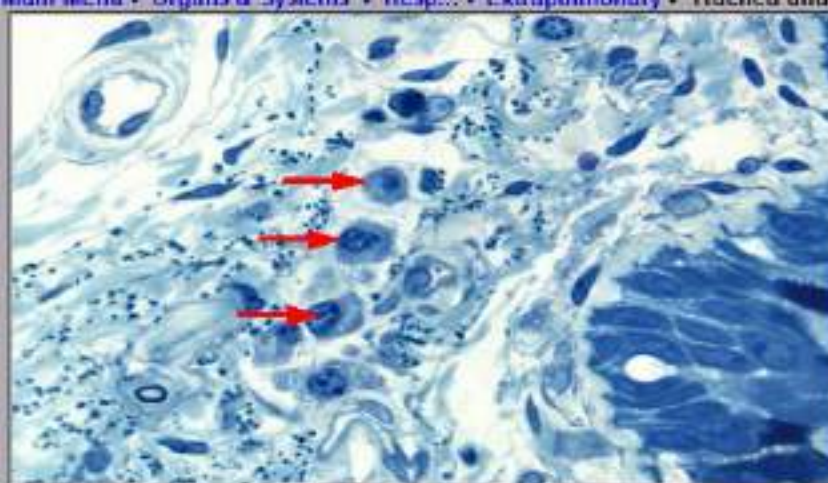


8 of 9

Trachea and primary bronchus -- A higher magnification of the trachea or primary bronchus demonstrates the layers adjacent to the lumen. The longitudinally oriented elastic fibers in the elastic lamina are seen cut in cross section. 400x

click to identify:

Mucosa
Epithelium
Lamina propria
Elastic lamina
Elastic fibers (xs)
Submucosa
Mixed glands
Ducts

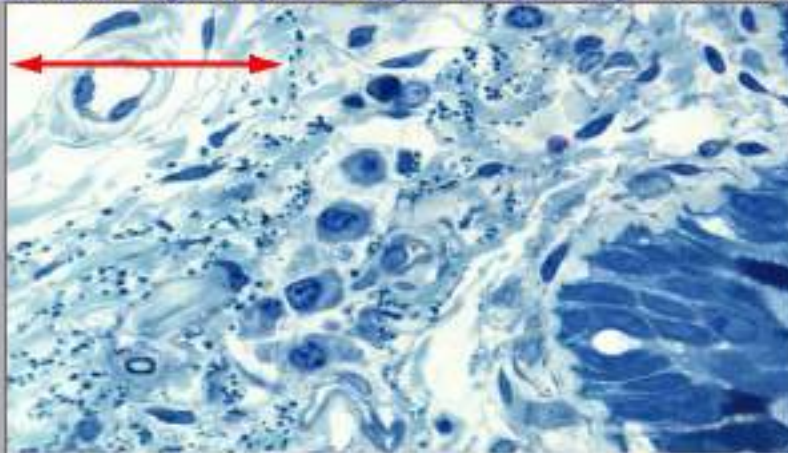


9 of 9

Trachea and primary bronchus -- The elastic lamina that forms the deepest layer of the mucosa of the trachea and primary bronchi is composed of longitudinally oriented elastic fibers that are organized into a discrete band, the elastic lamina. Cells of the immune system, such as the plasma cells seen here, are prevalent in the connective tissue of the respiratory system. 1000x

click to identify:

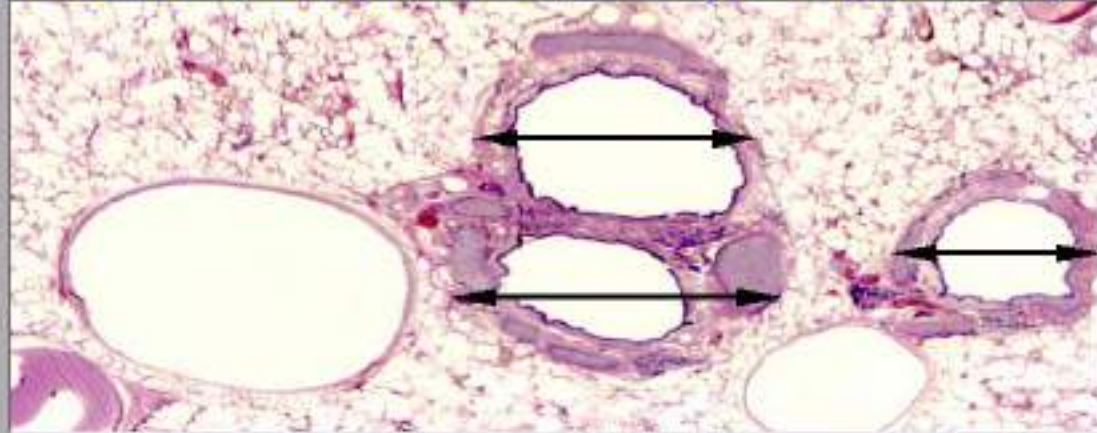
Respiratory
epithelium
Lamina propria
Elastic lamina
Elastic fibers
Plasma cells
Submucosa



click to identify:

- Respiratory epithelium
- Lamina propria
- Elastic lamina
- Elastic fibers
- Plasma cells
- Submucosa

Trachea and primary bronchus – The elastic lamina that forms the deepest layer of the mucosa of the trachea and primary bronchi is composed of longitudinally oriented elastic fibers that are organized into a discrete band, the elastic lamina. Cells of the immune system, such as the plasma cells seen here, are prevalent in the connective tissue of the respiratory system. 1000x

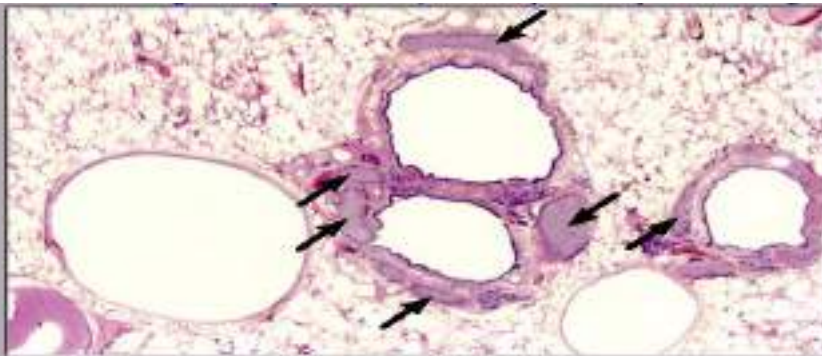


click to identify:

- > Secondary bronchi
- Cartilage plates
- Mixed glands
- Alveoli
- Pulmonary arteries

2 of 7

Secondary bronchus -- Secondary bronchi are intrapulmonary passages that are part of the conducting portion of the system. As a secondary bronchus branches from a primary, it becomes smaller in diameter and its wall thins. Cartilage plates and mixed glands remain, distinguishing these passages from bronchioles. Pulmonary arteries accompany secondary bronchi. 40x



click to identify:

- Secondary bronchi
- > Cartilage plates
- Mixed glands
- Alveoli
- Pulmonary arteries

2 of 7

Secondary bronchus -- Secondary bronchi are intrapulmonary passages that are part of the conducting portion of the system. As a secondary bronchus branches from a primary, it becomes smaller in diameter and its wall thins. Cartilage plates and mixed glands remain, distinguishing these passages from bronchioles. Pulmonary arteries accompany secondary bronchi. 40x

Main Menu > Organs & Systems > Resp... > Intrapulmonary > Conducting > Secondary Bronchus

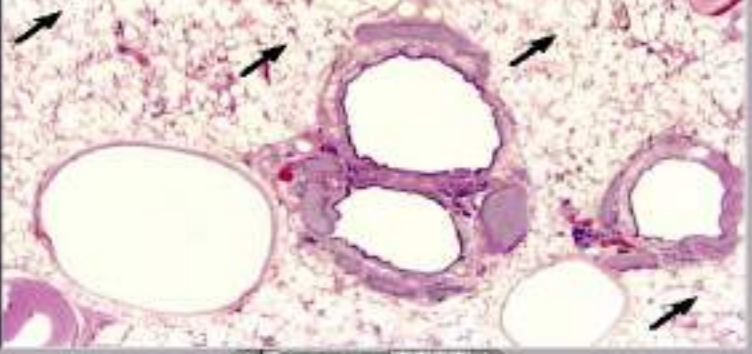


click to identify:

- Secondary bronchi
- Cartilage plates
- Mixed glands
- Alveoli
- Pulmonary arteries

2 of 7

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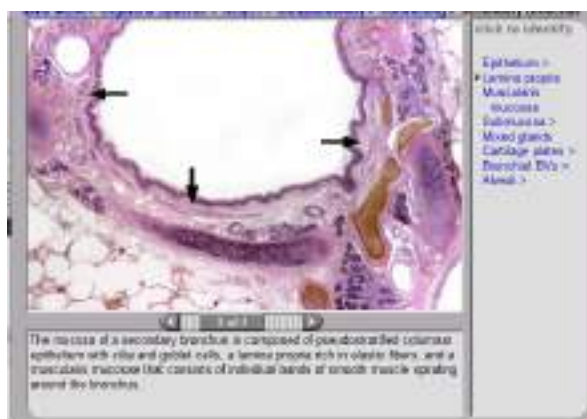
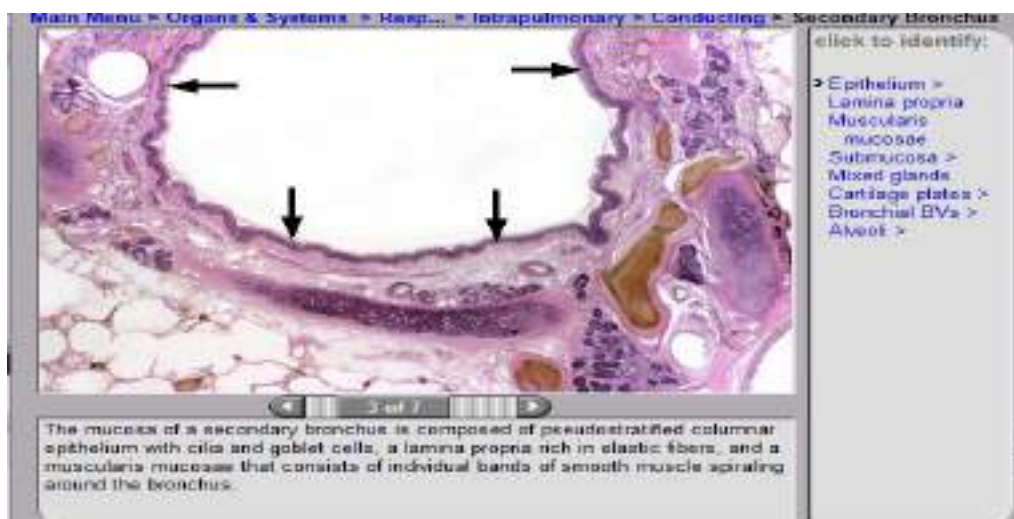


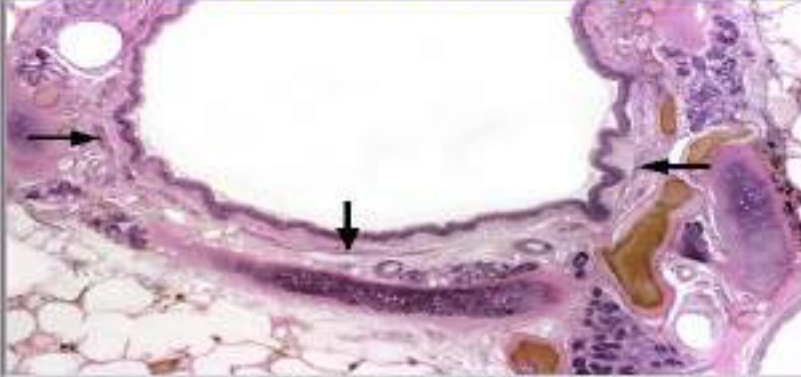
click to identify:

- Secondary bronchi
- Cartilage plates
- Mixed glands
- Alveoli
- Pulmonary arteries

2 of 7

Secondary bronchus — Secondary bronchi are intrapulmonary passages that are part of the conducting portion of the system. As a secondary bronchus branches from a primary, it becomes smaller in diameter and its wall thins. Cartilage plates and mixed glands remain, distinguishing these passages from bronchioles. Pulmonary arteries accompany secondary bronchi. 40x





click to identify:

- Epithelium >
- Lamina propria
- Muscularis mucosae
- Submucosa >
- Mixed glands
- Cartilage plates >
- Bronchial BVs >
- Alveoli >

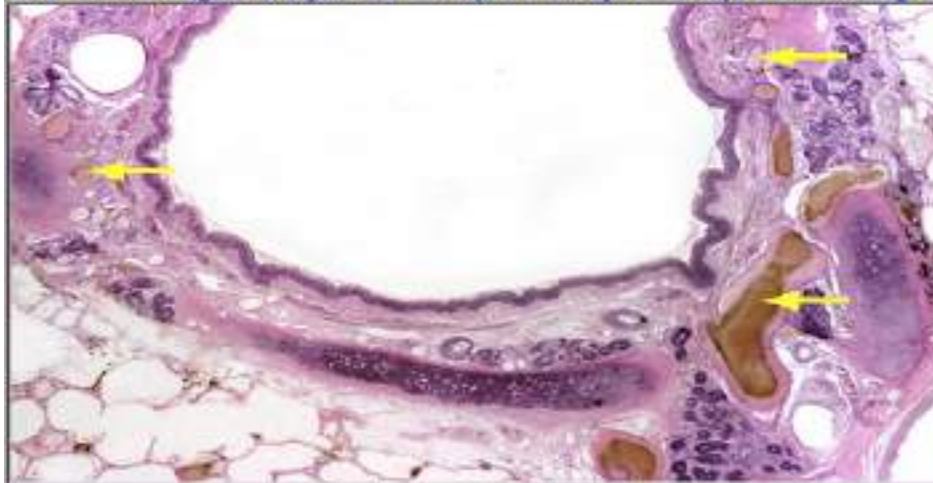
The mucosa of a secondary bronchus is composed of pseudostratified columnar epithelium with cilia and goblet cells, a lamina propria rich in elastic fibers, and a muscularis mucosae that consists of individual bands of smooth muscle spiraling around the bronchus.



click to identify:

- Epithelium >
- Lamina propria
- Muscularis mucosae
- Submucosa >
- Mixed glands
- Cartilage plates >
- Bronchial BVs >
- Alveoli >

The submucosa of the secondary bronchus possesses mixed glands.

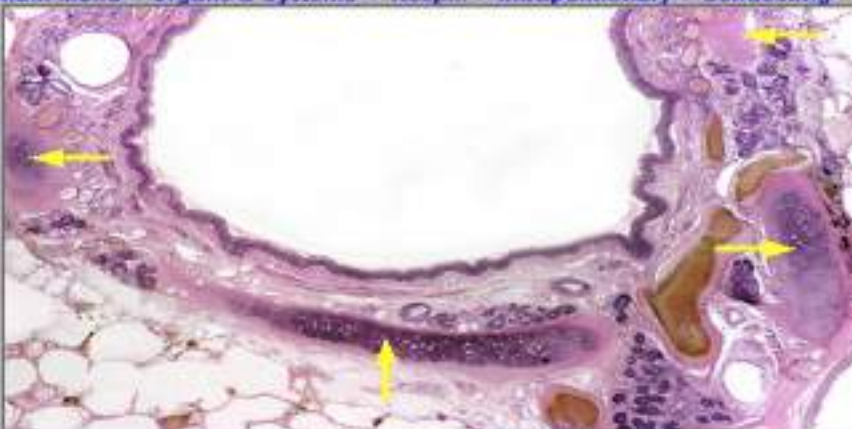


3 of 7

Bronchial blood vessels lie within the wall of the secondary bronchus, supplying the tissues of the wall.

click to identify:

- Epithelium >
- Lamina propria
- Muscularis mucosae
- Submucosa >
- Mixed glands
- Cartilage plates >
- Bronchial BVs >
- Alveoli >



3 of 7

Cartilage plates, rather than cartilage rings, maintain patency in a secondary bronchus.

click to identify:

- Epithelium >
- Lamina propria
- Muscularis mucosae
- Submucosa >
- Mixed glands
- Cartilage plates >
- Bronchial BVs >
- Alveoli >

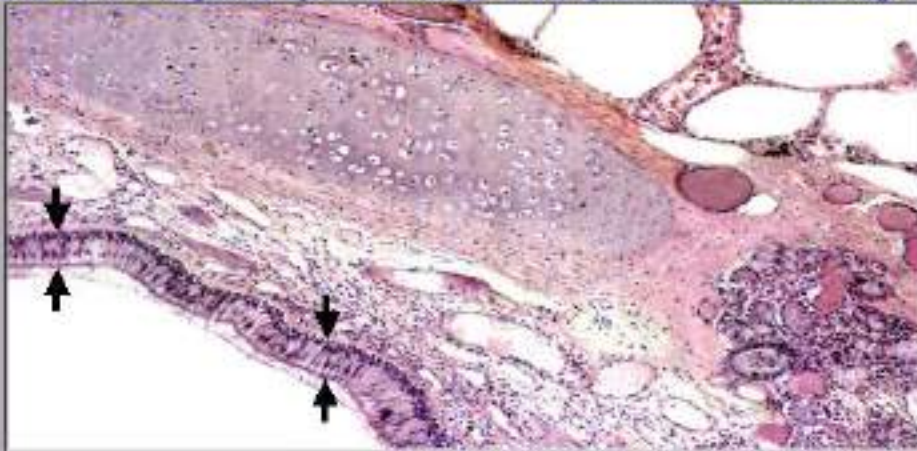


click to identify:

- Epithelium >
- Lamina propria
- Muscularis
- mucosae
- Submucosa >
- Mixed glands
- Cartilage plates >
- Bronchial BVs >
- > Alveoli >

3 of 7

Alveoli surrounding this secondary bronchus indicate that this passageway is intrapulmonary.

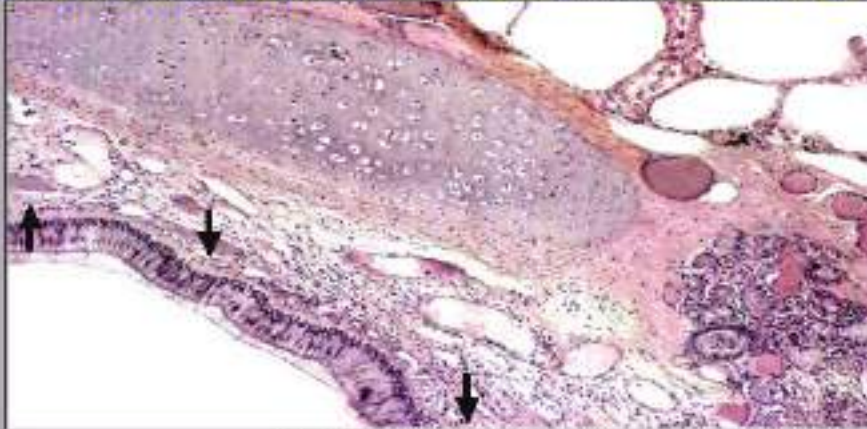


click to identify:

- > Epithelium
- Lamina propria
- Muscularis
- mucosae
- Submucosa
- Mixed glands
- Cartilage plate
- Bronchial BVs
- Alveoli

4 of 7

Secondary bronchus – Secondary bronchi decrease in diameter as they progress into the lungs, with all layers continuing but becoming thinner. 100x

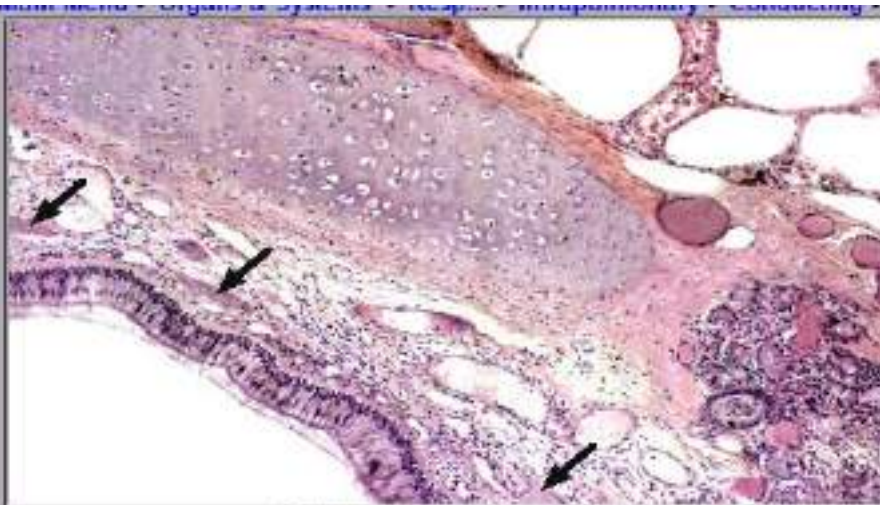


click to identify:

- Epithelium
- > Lamina propria
- Muscularis mucosae
- Submucosa
- Mixed glands
- Cartilage plate
- Bronchial BVs
- Alveoli

4 of 7

Secondary bronchus – Secondary bronchi decrease in diameter as they progress into the lungs, with all layers continuing but becoming thinner. 100x



click to identify:

- Epithelium
- Lamina propria
- > Muscularis mucosae
- Submucosa
- Mixed glands
- Cartilage plate
- Bronchial BVs
- Alveoli

4 of 7

Secondary bronchus – Secondary bronchi decrease in diameter as they progress into the lungs, with all layers continuing but becoming thinner. 100x

Main Menu > Organs & Systems > Resp... > Intrapulmonary > Conducting > Secondary Bronchus



click to identify:

- Epithelium
- Lamina propria
- Muscularis mucosae
- Submucosa
- Mixed glands
- Cartilage plate
- Bronchial BVs
- Alveoli

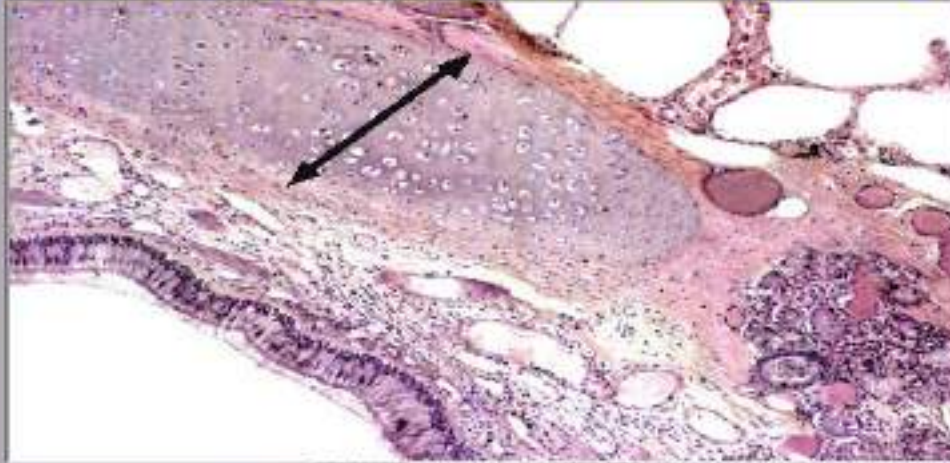
Secondary bronchus – Secondary bronchi decrease in diameter as they progress into the lungs, with all layers continuing but becoming thinner. 100x



click to identify:

- Epithelium
- Lamina propria
- Muscularis mucosae
- Submucosa
- Mixed glands
- Cartilage plate
- Bronchial BVs
- Alveoli

Secondary bronchus – Secondary bronchi decrease in diameter as they progress into the lungs, with all layers continuing but becoming thinner. 100x

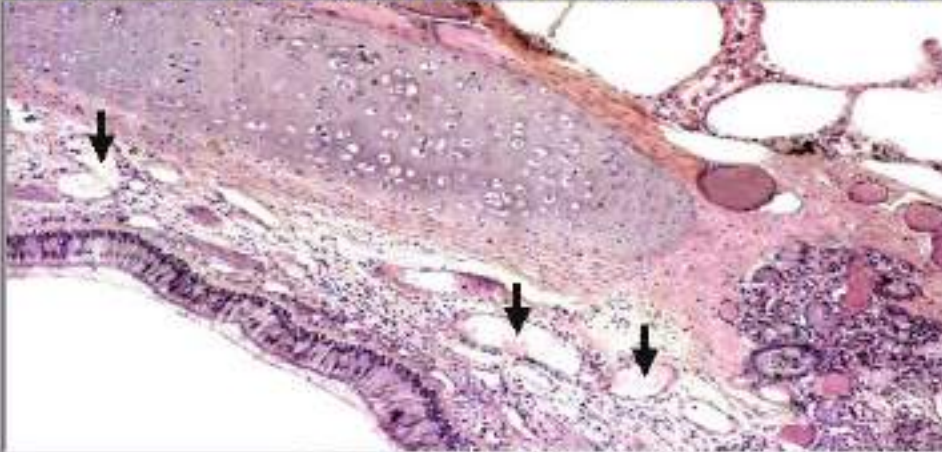


click to identify:

- Epithelium
- Lamina propria
- Muscularis
- mucosae
- Submucosa
- Mixed glands
- Cartilage plate
- Bronchial BVs
- Alveoli

4 of 7

Secondary bronchus -- Secondary bronchi decrease in diameter as they progress into the lungs, with all layers continuing but becoming thinner. 100x

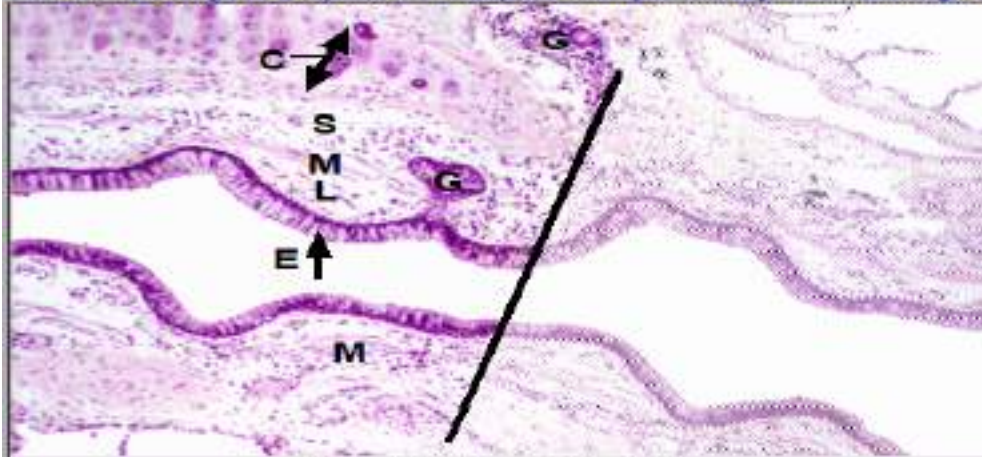


click to identify:

- Epithelium
- Lamina propria
- Muscularis
- mucosae
- Submucosa
- Mixed glands
- Cartilage plate
- Bronchial BVs
- Alveoli

4 of 7

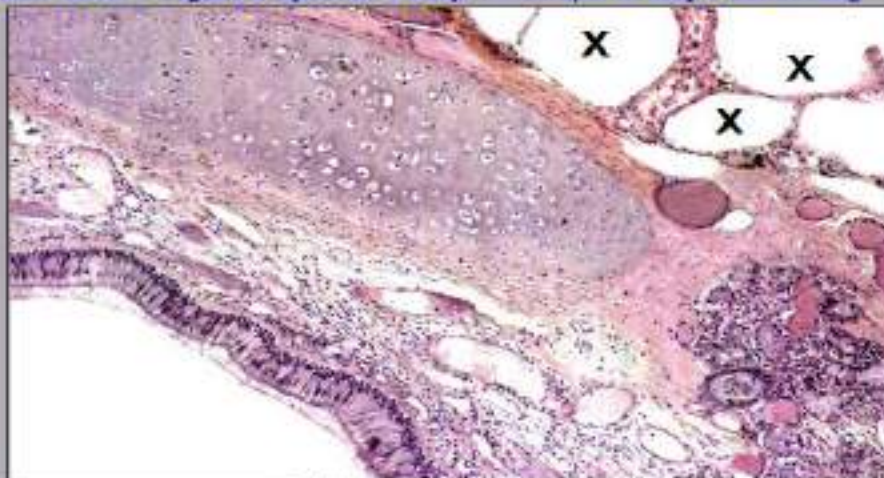
Secondary bronchus -- Secondary bronchi decrease in diameter as they progress into the lungs, with all layers continuing but becoming thinner. 100x



click to identify:

- > Secondary >
- bronchus
- Bronchiole >
- Alveoli >
- Macrophages >

A secondary bronchus is identified by a mucosa of pseudostratified columnar epithelium with cilia and goblet cells (E), lamina propria (L), and a muscularis mucosae (M). Beneath the mucosa are two layers: a submucosa (S) with mixed glands (G) and cartilagenous plates (C). (Some of the glands are atypical in that they are located beneath the cartilage rather than in the submucosa.)

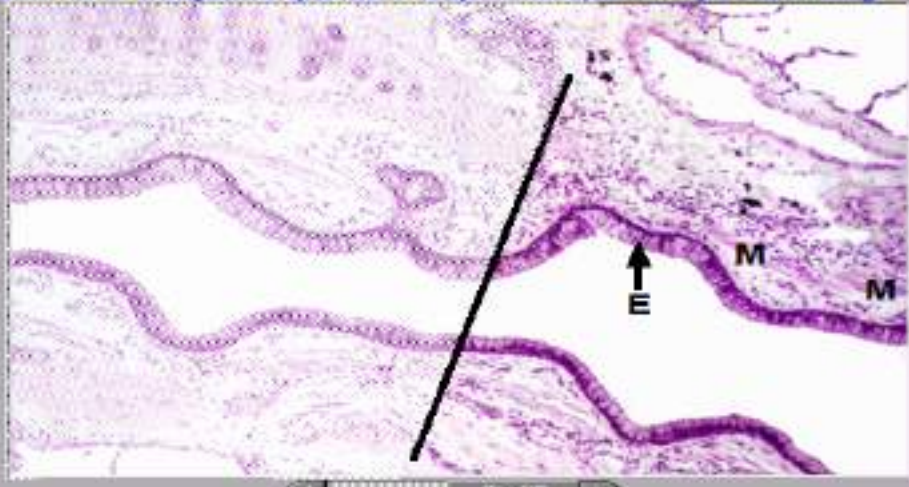


click to identify:

- Epithelium
- Lamina propria
- Muscularis mucosae
- Submucosa
- Mixed glands
- Cartilage plate
- Bronchial BVs
- > Alveoli

Secondary bronchus → Secondary bronchi decrease in diameter as they progress into the lungs, with all layers continuing but becoming thinner. 100x

[Main Menu](#) > [Organs & Systems](#) > [Respiratory](#) > [Intrapulmonary](#) > [Conducting](#) > [Secondary Bronchus](#)




click to identify:

- [Secondary >](#)
- [bronchus](#)
- [> Bronchiole >](#)
- [Alveoli >](#)
- [Macrophages >](#)

7 of 7

A bronchiole is lined with a lower pseudostratified columnar epithelium with cilia and goblet cells (E). A muscularis mucosae (M) continues but neither cartilage nor mixed glands persist.

[Main Menu](#) > [Organs & Systems](#) > [Respiratory](#) > [Intrapulmonary](#) > [Conducting](#) > [Secondary Bronchus](#)

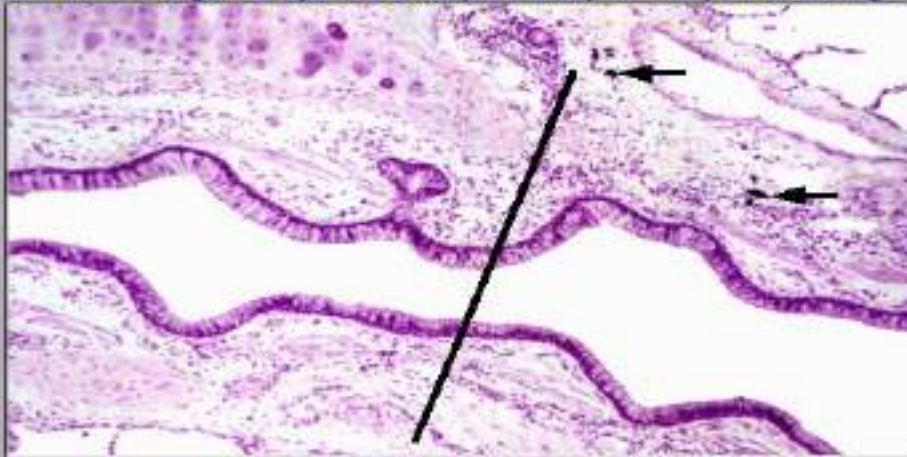


click to identify:

- [Secondary >](#)
- [bronchus](#)
- [> Bronchiole >](#)
- [Alveoli >](#)
- [Macrophages >](#)

7 of 7

Alveoli are visible in this field and, therefore, these larger passageways are intrapulmonary. The lumens of the alveoli, however, are not continuous with those of the secondary bronchi and bronchioles and, therefore, these larger passageways are not capable of gas exchange.

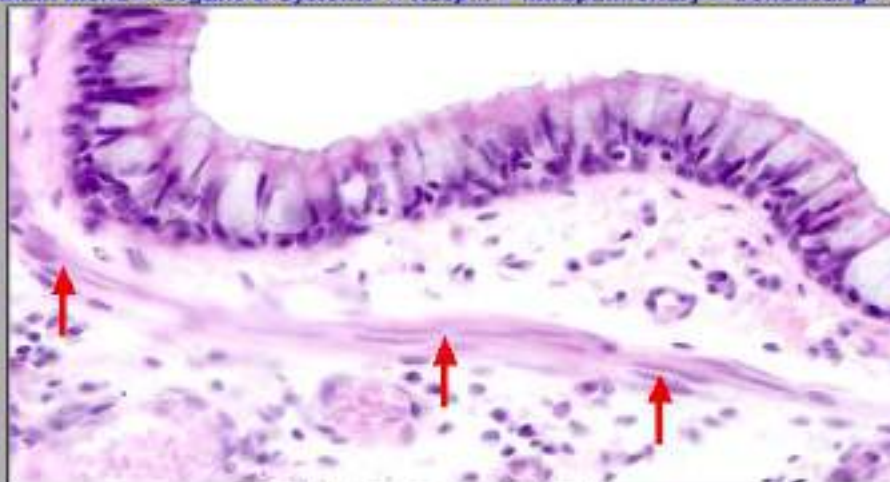


click to identify:

- Secondary >
- bronchus
- Bronchiola >
- Alveoli >
- > Macrophages >

1 of 7

Macrophages with engulfed carbon particles, called dust cells, lie in the connective tissue adjacent to the passageways.



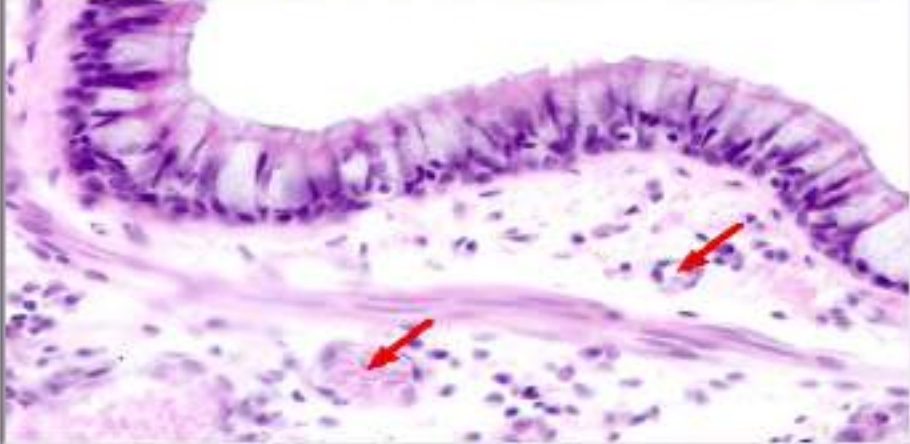
click to identify:

- Respiratory
- epithelium
- Lamina propria
- Elastic fibers
- > Muscularis
- mucosae
- Bronchial vessels

5 of 10

Bronchiole -- At higher magnification the components of the wall of a bronchiole are apparent. This is a larger bronchiole because it is lined by pseudostratified columnar epithelium with cilia and goblet cells. Abundant, longitudinally arranged elastic fibers are located in lamina propria. Muscularis mucosae is composed of spiraling bands of smooth muscle. 200x

File View Go Quiz Help
Main Menu > Organs & Systems > Resp... > Intrapulmonary > Conducting > Bronchiole



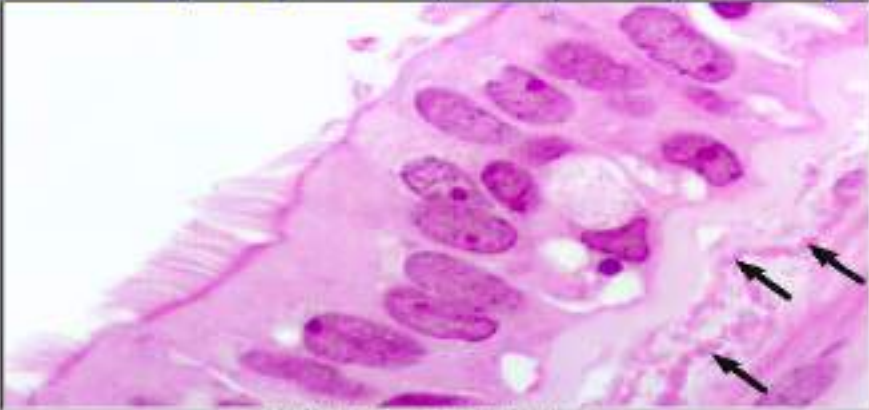
click to identify:

- Respiratory epithelium
- Lamina propria
- Elastic fibers
- Muscularis mucosae
- Bronchial vessels

5 of 10

Bronchiole -- At higher magnification the components of the wall of a bronchiole are apparent. This is a larger bronchiole because it is lined by pseudostratified columnar epithelium with cilia and goblet cells. Abundant, longitudinally arranged elastic fibers are located in lamina propria. Muscularis mucosae is composed of spiraling bands of smooth muscle. 200x

Main Menu > Organs & Systems > Resp... > Intrapulmonary > Conducting > Bronchiole



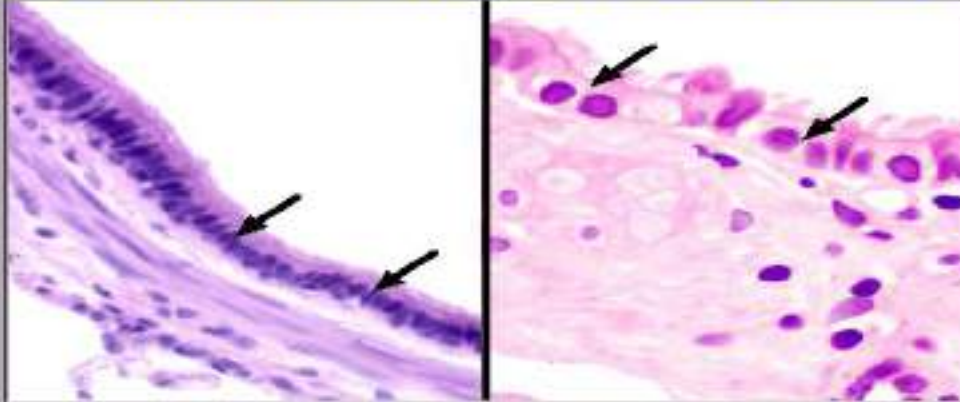
click to identify:

- Simple columnar epithelium
- Goblet cell
- Basement membrane
- Lamina propria
- Elastic fibers

7 of 10

Bronchiole -- The pseudostratified columnar epithelium of the larger bronchioles decreases in height as bronchioles decrease in diameter. This bronchiole is lined by a simple columnar epithelium with cilia and goblet cells. 1500x

اي صورة بيها تاشيرات لم تذكر هي مطلوبة

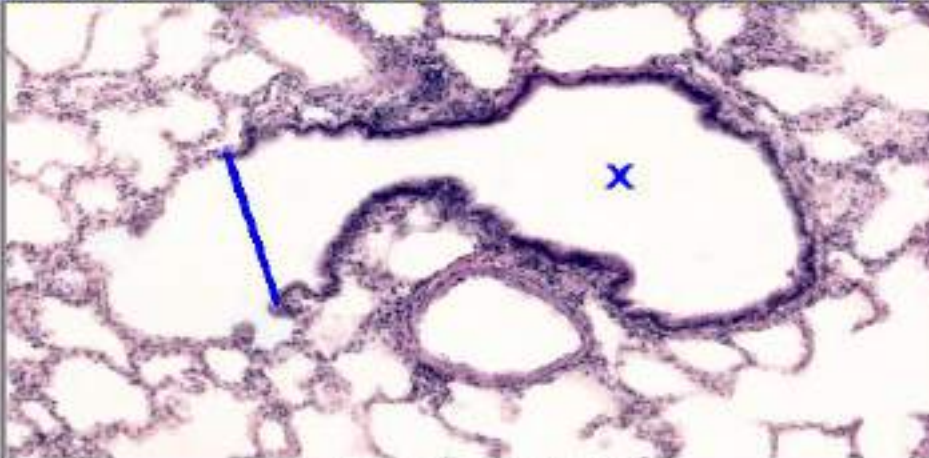


click to identify:

- Pseudostratified epithelium
- > Simple columnar epithelium
- Cilia
- Clara cells >
- Lamina propria
- Muscularis mucosae

8 of 10

Bronchiole – Bronchioles continue to decrease in diameter, their pseudostratified epithelium decreases in thickness until it becomes simple columnar epithelium with cilia in the smallest, or terminal, bronchioles. Goblet cells are not present in terminal bronchioles, but another secretory cell type, the Clara cell, appears. 400x, 1000x



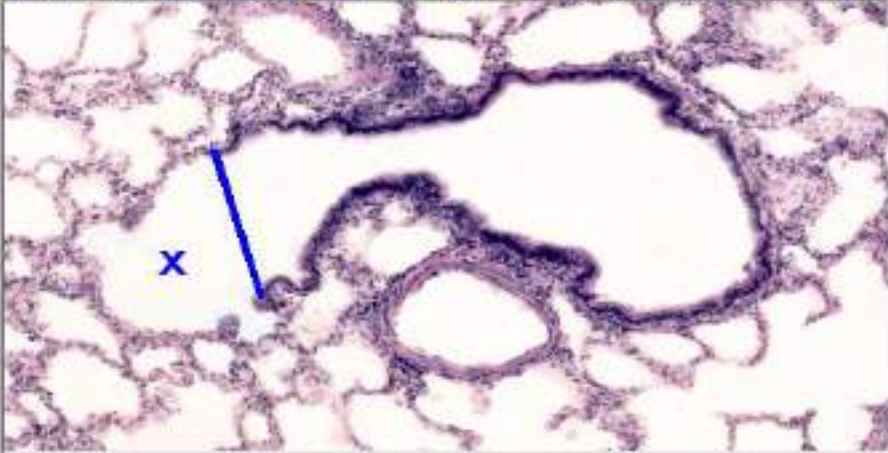
click to identify:

- > Terminal bronchiole
- Respiratory bronchiole
- Alveoli >
- Pulmonary artery >

2 of 5

Transition of terminal to respiratory bronchiole – The transition of a terminal bronchiole (conducting portion) to a respiratory bronchiole (respiratory portion) is indicated by the appearance of alveoli associated with the wall of the respiratory bronchiole. The decrease in epithelial height at this transition is demonstrated well here. 100x?

File View Help
Main Menu > Organs & Systems > Resp... > Intrapulmonary > Respiratory > Resp... Bronchiole



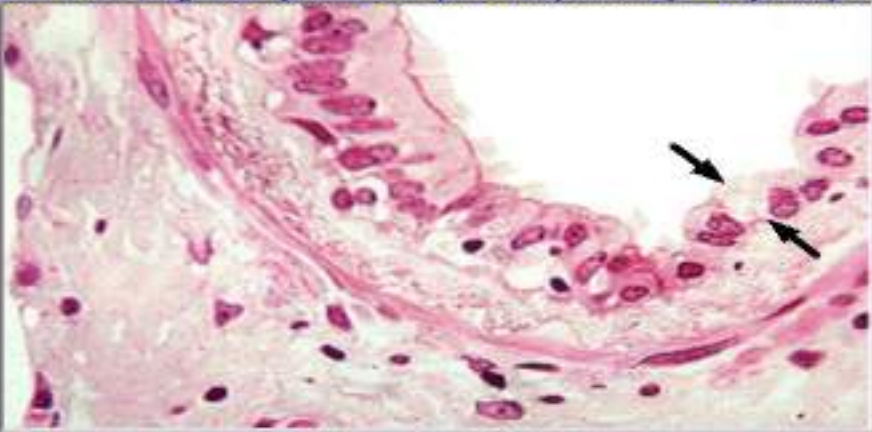
click to identify:

- Terminal bronchiole
- > Respiratory bronchiole
- Alveoli >
- Pulmonary artery >

2 of 8

Transition of terminal to respiratory bronchiole – The transition of a terminal bronchiole (conducting portion) to a respiratory bronchiole (respiratory portion) is indicated by the appearance of alveoli associated with the wall of the respiratory bronchiole. The decrease in epithelial height at this transition is demonstrated well here. 100x?

File View Help
Main Menu > Organs & Systems > Resp... > Intrapulmonary > Respiratory > Resp... Bronchiole

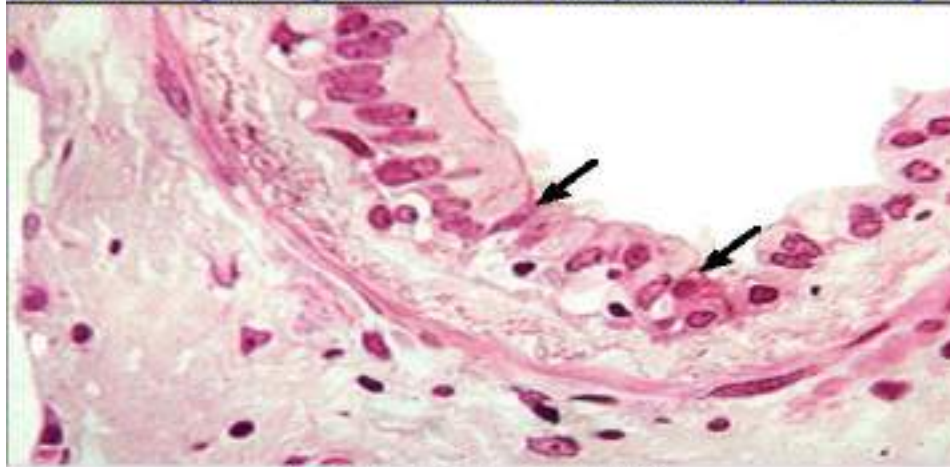


click to identify:

- Terminal bronchiole
- Respiratory bronchiole
- Simple columnar epithelium
- > Simple cuboidal epithelium
- Cilia
- Clara cells
- Elastic fibers
- Smooth muscle

3 of 8

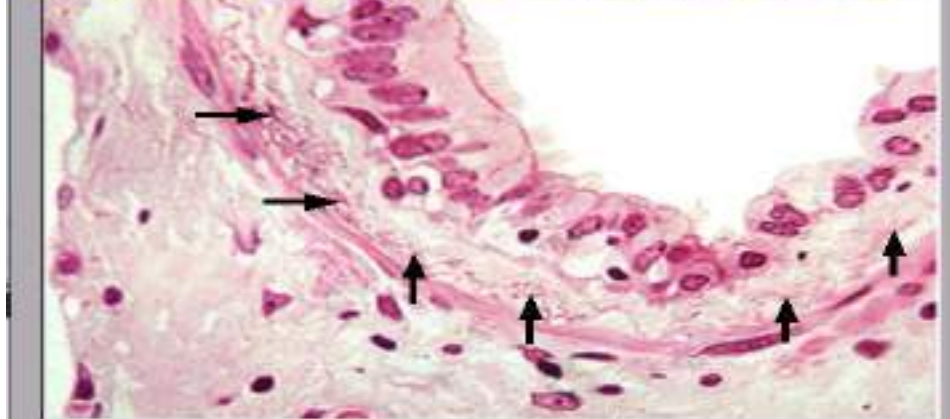
Transition of terminal to respiratory bronchiole – This transition shows the simple columnar ciliated epithelium of the terminal bronchiole continuing into simple cuboidal epithelium with scattered cilia of the respiratory bronchiole. Clara cells are present in both passages, as are longitudinally arranged elastic fibers in lamina propria and a thin muscle layer. 400x



click to identify:

- Terminal bronchiole
- Respiratory bronchiole
- Simple columnar epithelium
- Simple cuboidal epithelium
- Cilia
- > Clara cells
- Elastic fibers
- Smooth muscle

Transition of terminal to respiratory bronchiole -- This transition shows the simple columnar ciliated epithelium of the terminal bronchiole continuing into simple cuboidal epithelium with scattered cilia of the respiratory bronchiole. Clara cells are present in both passages, as are longitudinally arranged elastic fibers in lamina propria and a thin muscle layer. 400x



click to identify:

- Terminal bronchiole
- Respiratory bronchiole
- Simple columnar epithelium
- Simple cuboidal epithelium
- Cilia
- Clara cells
- > Elastic fibers
- Smooth muscle

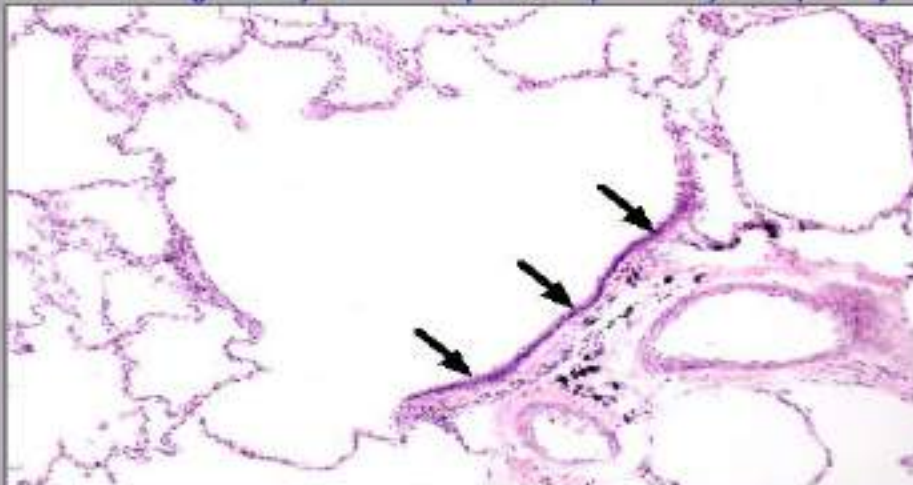
Transition of terminal to respiratory bronchiole -- This transition shows the simple columnar ciliated epithelium of the terminal bronchiole continuing into simple cuboidal epithelium with scattered cilia of the respiratory bronchiole. Clara cells are present in both passages, as are longitudinally arranged elastic fibers in lamina propria and a thin muscle layer. 400x



click to identify:

Terminal bronchiole
Respiratory
bronchiolar wall
Associated alveoli
Pulmonary artery
Macrophages >

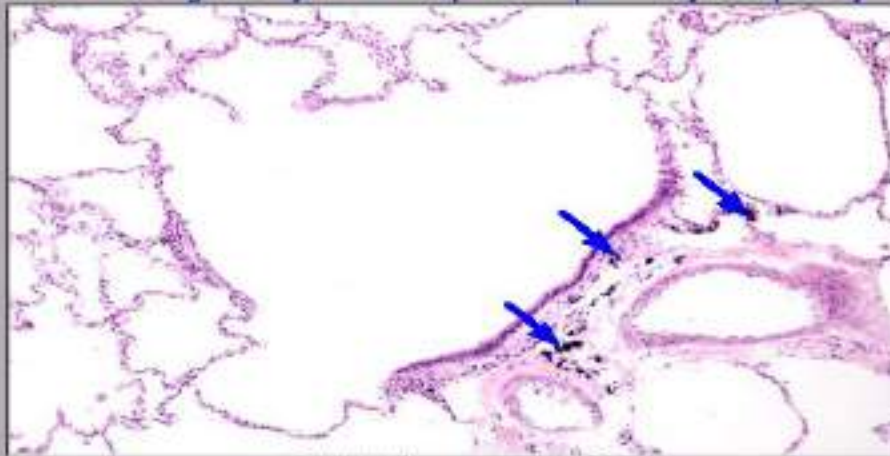
Respiratory bronchiole -- An edge of a terminal bronchiole is seen transitioning into a respiratory bronchiole. 100x



click to identify:

> Terminal bronchiole
Respiratory
bronchiolar wall
Associated alveoli
Pulmonary artery
Macrophages >

Respiratory bronchiole -- An edge of a terminal bronchiole is seen transitioning into a respiratory bronchiole. 100x



click to identify:

- Terminal bronchiole
- Respiratory
bronchiolar wall
- Associated alveoli
- Pulmonary artery
- Macrophages ➤

Macrophages, filled with black carbon particles, are seen scattered in the connective tissue surrounding the bronchioles. Such macrophages are called "dust cells."

CHAPTER 13

RESPIRATORY SYSTEM

OVERVIEW

COMPONENTS OF THE RESPIRATORY SYSTEM

- I. In relationship to lungs (listed in order from exterior to interior, i.e., the path of inspired air)
 - A. Extrapulmonary
 1. Nasal cavity
 2. Pharynx
 3. Larynx
 4. Trachea
 5. Primary bronchi
 - B. Intrapulmonary
 1. Secondary bronchi
 2. Bronchioles
 3. Terminal bronchioles
 4. Respiratory bronchioles
 5. Alveolar ducts
 6. Alveoli
- II. According to function (listed in order from exterior to interior)
 - A. Conducting Portion (Transports air from exterior)
 1. Nasal cavity
 2. Pharynx

3. Larynx
 4. Trachea
 5. Primary bronchi
 6. Secondary bronchi
 7. Bronchioles
 8. Terminal bronchioles
- B. Respiratory Portion (Involved with gas exchange)
1. Respiratory bronchioles
 2. Alveolar ducts
 3. Alveoli

STRUCTURAL ORGANIZATION OF RESPIRATORY PASSAGEWAYS

- I. Conducting portion (nasal cavities through secondary bronchi)
- A. Mucosa (mucous membrane). Faces the lumen
1. **Respiratory epithelium. Pseudostratified with cilia and goblet cells.**
 2. Lamina propria of loose connective tissue with blood vessels and nerves
 3. Deepest layer of mucosa may consist of:
 - a. An **elastic lamina** or
 - b. A **muscularis mucosae** or
 - c. This layer may be absent.
- B. **Submucosa.** Dense irregular connective tissue with mucous and serous (mixed) glands
- C. **Cartilage** or **bone**
- D. **Adventitia.** Loose connective tissue forming the outer layer of the passageway

II. Structural transitions in walls and layers of the passageways from extrapulmonary passageways to alveoli

A. Transitions

1. Layers become thinner as passageways decrease in diameter.
2. Epithelium decreases in height from pseudostratified to simple columnar to simple cuboidal to simple squamous.
3. Goblet cells and mixed glands stop relatively abruptly at the junction of a secondary bronchus with a bronchiole.
4. Cartilage decreases in size, breaks up into plates, and stops relatively abruptly at the junction of a secondary bronchus with a bronchiole.
5. Cilia are gradually eliminated.

B. Results in the formation of the wall of an **alveolus**, where gas exchange occurs

1. Epithelium is simple squamous
2. Connective tissue core with numerous capillaries

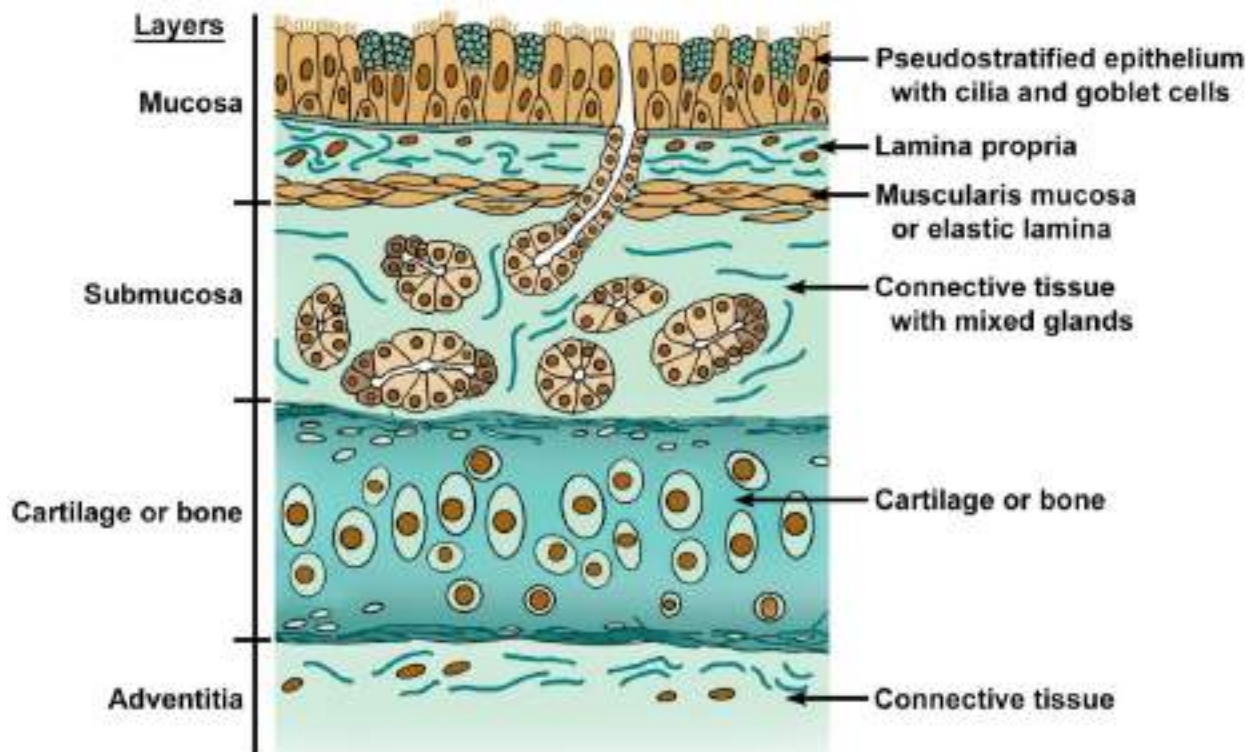


FIGURE 13.1. Layers and components of respiratory passageways.

CONDUCTING PORTION

NASAL CAVITIES (EXTRAPULMONARY) *(images)*

I. The nasal cavities can be subdivided into two regions, the olfactory and the non-olfactory regions.

II. **Non-olfactory region**

A. **Vestibules**. The epithelium undergoes a transition from epidermis of skin with hairs to pseudostratified, respiratory epithelium, with cilia.

B. **Nasal fosse**

1. Typical mucosa but deepest layer is lacking (i.e., neither a muscularis mucosae nor an elastic lamina is present)
2. Patency maintained by bones or cartilage.

C. **Olfactory region**

1. Upside-down, U-shaped area in posterior, superior region of each nasal fossa, extending over a superior concha and about 1 cm down nasal septum
2. Composition of wall
 - a. Mucosa
 - i. Epithelium is tall, thick, **pseudostratified columnar** with nonmotile cilia. The epithelium is composed of:
 - (a). **Olfactory cells** (neurons). Bipolar neurons that respond to odors. A single dendrite extends to the surface to form a swelling, the **olfactory vesicle**, from which nonmotile cilia extend over the surface. These cilia increase surface area and respond to odors.
 - (b). **Support cells** span the epithelium and support the olfactory cells.
 - (c). **Basal cells** are located on the basal lamina and serve as reserve cells for the epithelium.
 - ii. Deepest layer of mucosa is not present, so the lamina propria blends with the submucosa. This connective tissue layer contains

Bowman's glands, serous glands whose watery secretions flush odorants from the epithelial surface.

- b. Patency maintained by bone.

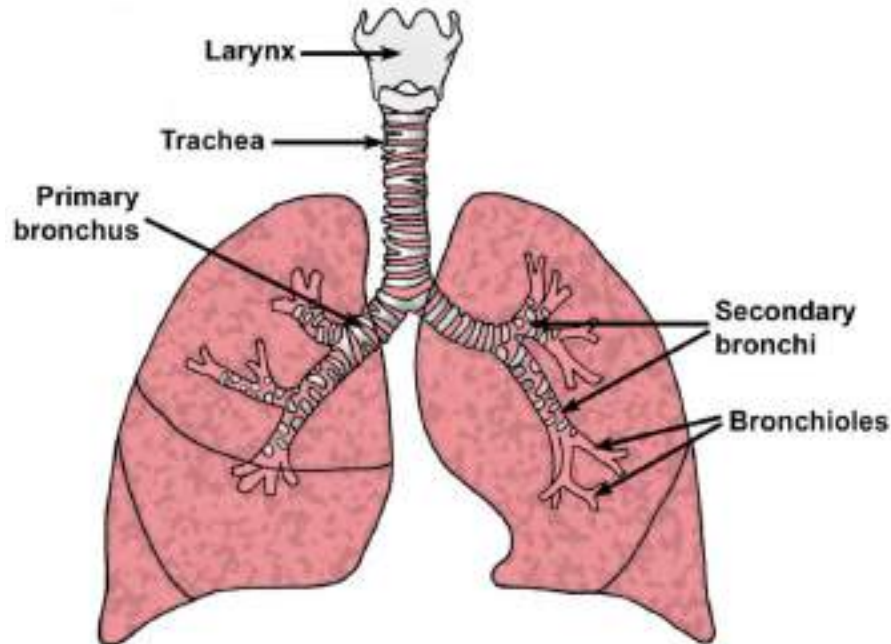


FIGURE 13.2. Conducting portion of the respiratory system.

LARYNX (EXTRAPULMONARY) (*images*)

I. Composition of the wall of the larynx

A. Mucosa

1. Epithelium

- a. Pseudostratified with cilia and goblet cells in most areas
- b. Stratified squamous moist over true vocal folds and much of epiglottis because of friction incurred in these areas

- 2. No muscularis mucosae or elastic lamina, so lamina propria is continuous with submucosa.

B. Submucosa with mixed glands (except in true vocal fold)

- C. Cartilages maintaining patency are numerous, uniquely shaped and are either hyaline or elastic. The larger cartilages are the **epiglottis**, **thyroid**,

and **cricoid**.

D. An adventitia is present.

II. Vocal apparatus. Modification in the larynx composed of two pairs of horizontally positioned mucosal folds located on the lateral walls of the larynx.

A. **False vocal folds**. More superior in location. Resemble the wall of a typical respiratory passageway except the deepest layer of the mucosa is absent (no muscularis mucosae nor elastic lamina).

B. The **ventricle**, a space, separates the false from the true vocal folds.

C. **True vocal folds**

1. Are lined by a stratified squamous moist epithelium and its lamina propria

2. A **vocal ligament** of dense regular elastic connective tissue is located at the edge of the fold, keeping the rim of the fold taut.

3. **Vocalis muscle**, skeletal muscle, lies within each true vocal fold. This muscle alters the shape of the vocal fold and aids in phonation.

TRACHEA AND PRIMARY BRONCHI (EXTRAPULMONARY) (images)

I. The **trachea** and **primary bronchi** are identical in structure and will be considered together.

II. Mucosa

A. Epithelium is pseudostratified with cilia and goblet cells with a very prominent basement membrane

B. Lamina propria of loose connective tissue

C. Elastic lamina of longitudinally arranged elastic fibers

III. Submucosa with mixed glands

IV. **C-shaped cartilage** rings maintain patency; **trachealis muscle** (smooth) interconnects the open ends of the tracheal rings.

V. Adventitia is present.

SECONDARY BRONCHI (INTRAPULMONARY) (images)

I. **Secondary bronchi**

- A. The first intrapulmonary structures; a secondary bronchus supplies each of the three lobes of the right lung and the two lobes of the left lung.
- B. Similar to, but diminished in size from, the primary bronchi

II. Mucosa

- A. Epithelium, pseudostratified with cilia and goblet cells
- B. Lamina propria contains numerous, longitudinally arranged elastic fibers.
- C. Muscularis mucosae of smooth muscle fibers arranged in crisscrossing bands

III. Submucosa with mixed glands

IV. Patency maintained by **plates of hyaline cartilage**.

V. Adventitia is present.

BRONCHIOLES (INTRAPULMONARY) *(images)*

- I. Walls of **bronchioles** continue to decrease in size. The greatest changes in histology occur in the walls of the bronchioles as glands and cartilage are eliminated.

II. Mucosa

A. Epithelium

- 1. Pseudostratified with cilia and goblet cells in largest bronchioles that decreases to:
- 2. Simple columnar with cilia in smallest bronchioles (**terminal bronchioles**), but no goblet cells persist.
- 3. **Clara cells** are present in terminal bronchioles.
 - a. Tall, dome-shaped, nonciliated cells
 - b. Possess numerous secretory granules whose contents aid in lowering surface tension of the terminal bronchioles, thus aiding in inspiration

B. Lamina propria contains numerous, longitudinally arranged elastic fibers.

C. Muscularis mucosae. Greatest development of smooth muscle (crisscrossing

bands) in relationship to thickness of wall of all respiratory passageways

III. Submucosa contains no glands.

IV. No cartilages or bones support bronchioles; therefore, submucosa and adventitia form a single connective tissue layer.

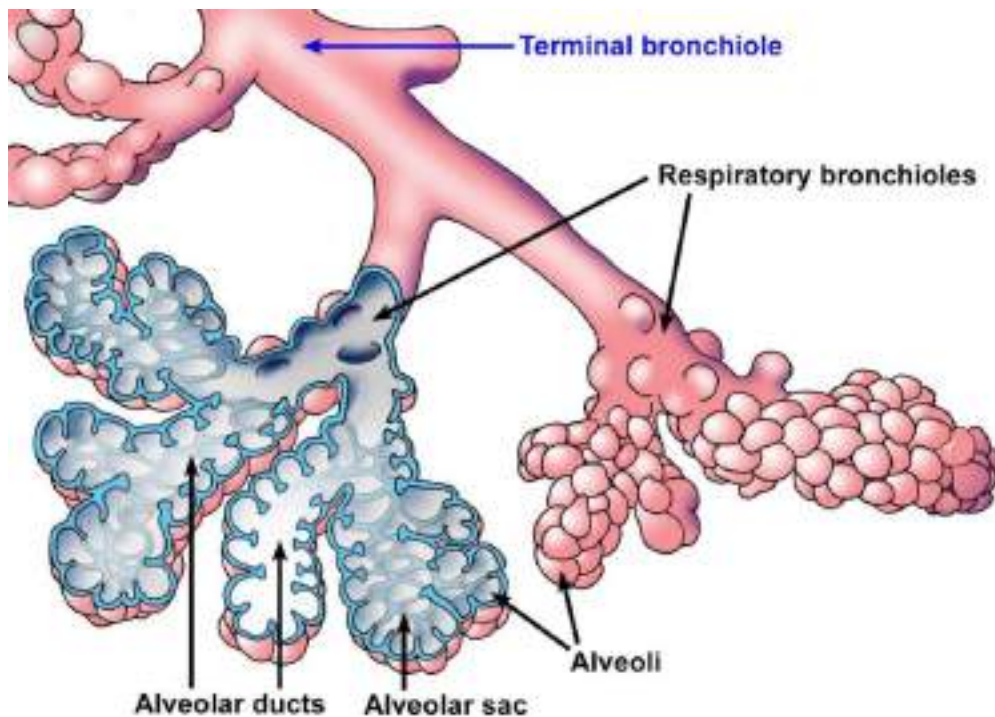


FIGURE 13.3. Components of the respiratory portion of the respiratory system.

RESPIRATORY PORTION

PRIMARY FUNCTION

I. Gas exchange occurs in the alveolus. Therefore, an alveolus must be an integral part of all the passageways of the respiratory part of the respiratory system.

RESPIRATORY BRONCHIOLES (*images*)

I. **Respiratory bronchioles** continue to decrease in diameter and in thickness of their walls.

II. Mucosa.

- A. Simple cuboidal epithelium with Clara cells and a few sparsely scattered cilia
- B. Longitudinal arranged elastic fibers in lamina propria
- C. Muscularis mucosae of smooth muscle

III. Alveoli bulge from wall (i.e., lumen of alveolus is continuous with lumen of respiratory bronchiole).

ALVEOLAR DUCTS *(images)*

- I. An **alveolar duct** is formed as the alveoli in a respiratory bronchiole increase in number, thereby decreasing the amount of wall that is present.
 - A. At the level of the alveolar duct, the "wall" is reduced to a series of rings framing the entrance to an alveolus or a group of alveoli (alveolar sac).
 - B. When sectioned, these rings resemble knobs to which the alveoli are attached.
- II. Wall
 - A. Simple cuboidal epithelium
 - B. Elastic fibers and smooth muscle in "knobs"
 - C. Alveoli bulge from the framework formed by the knobs.

ALVEOLAR SACS

- I. **Alveolar sacs** are two or more alveoli arising from a single ring of knobs.

ALVEOLI *(images)*

- I. **Alveoli** are thin-walled, hollow polyhedrons forming the bulk of the lungs; where gas exchange occurs.
- II. Individual alveoli are components of respiratory bronchioles and alveolar ducts, or multiple alveoli may be grouped together to form alveolar sacs.
- III. **Interalveolar septum**. Structure between two adjacent alveoli is composed of:
 - A. The epithelium lining each alveolus.

1. **Squamous alveolar or type I cells** form a simple squamous epithelium lining 95% of the alveolar surface area and forming a portion of the blood-air barrier.
 2. **Septal or type II cells**
 - a. Spherical cells with microvilli and abundant, vacuolated cytoplasm; bulge into alveolar space
 - b. **Lamellar bodies** in the cytoplasm of septal cells are responsible for the vacuolated appearance of these cells. Lamellar bodies give rise to surfactant, a secretory product consisting of phospholipids, glycosaminoglycans, and proteins.
 - c. Serve as progenitors for both type I and type II cells
- B. Connective tissue core contains a vast capillary bed that bulges into the alveolar space, elastic fibers, alveolar macrophages, and other connective tissue components.

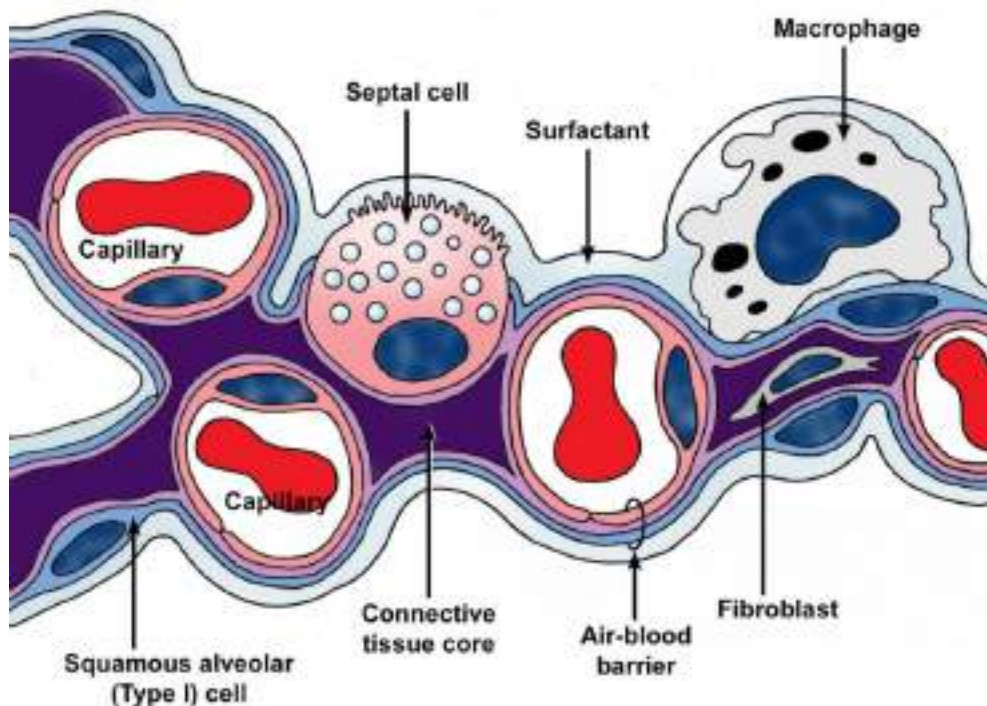


FIGURE 13.4. Components of the interalveolar septum, including the air-blood barrier.

- C. Additional components
1. **Pulmonary surfactant**

- a. Is an extracellular fluid coating alveolar surfaces
- b. Lowers alveolar surface tension, aiding in inflation of alveoli during inspiration, and preventing collapse of alveoli during expiration
- c. Is composed of a monomolecular, phospholipid surface film that covers an underlying aqueous hypophase
- d. Appears during the last weeks of gestation. Absence or insufficiency of surfactant may result in respiratory distress syndrome or hyaline membrane disease in infants born prematurely.

2. **Alveolar macrophages**

- a. Lie free in the alveolar space within the surfactant layer. With congestive heart failure, RBCs pass into alveolar spaces and are phagocytized by these macrophages, which are then called "heart failure" cells.
- b. Are located within the connective tissues of all respiratory passageways. Macrophages that engulf dust and carbon particles are called dust cells.

3. **Alveolar or Kohn's pores.** Small openings in the interalveolar septa between neighboring alveoli that aid in equalizing interalveolar pressure. These pores can contribute to the spread of bacteria in the lung.

AIR-BLOOD BARRIER

I. The **air-blood barrier** separates air from blood. Oxygen and carbon dioxide must cross this barrier during gas exchange.

II. Composition

- A. Squamous alveolar (type I) cell with its basal lamina
- B. Capillary endothelial cell with its basal lamina
- C. In most cases the basal laminae are fused.

PLEURA (*images*)

I. The **pleura** is a serous membrane (serosa) that lines each thoracic cavity and is reflected over the exterior surface of each lung.

II. Composition

- A. Simple squamous epithelium (**mesothelium**)
- B. Underlying connective tissue layer with elastic fibers

III. Produces a fluid film that lubricates the surface of the lungs and provides surface tension for lung expansion

IV. Components

- A. **Visceral pleura**. Pleura reflected over the surface of the lung
- B. **Parietal pleura**. Pleura reflected onto the inner body wall

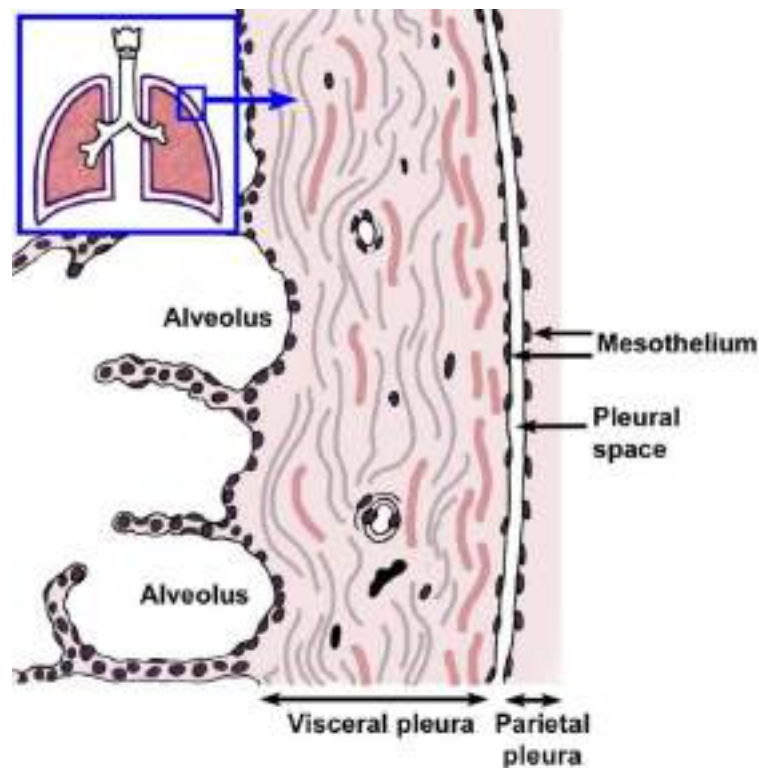


Figure 13.5 Pleura

VASCULAR SUPPLY TO LUNG (**images**)

- I. Pulmonary circulation supplies deoxygenated blood for gas exchange
 - A. The **pulmonary artery** and its branches travel adjacent to the bronchial passageways, supplying deoxygenated blood to the pulmonary capillaries. Pulmonary arteries are comparable in diameter to their neighboring

respiratory passageways.

- B. **Alveolar (pulmonary) capillaries** lie in the interalveolar septa, forming part of the air-blood barrier. These abundant capillaries anastomose to form pulmonary veins.
 - C. **Pulmonary veins** carry oxygenated blood, and travel alone in the parenchyma away from respiratory passageways. After leaving a lung lobule, pulmonary veins, the bronchial passageways, and pulmonary arteries collect near the hilum of the lung.
- II. **Bronchial circulation** supplies oxygenated blood and nutrients to the tissue layers forming the walls of the bronchial passageways. These vessels, therefore, lie within and are much smaller than the wall of the passageways they supply.

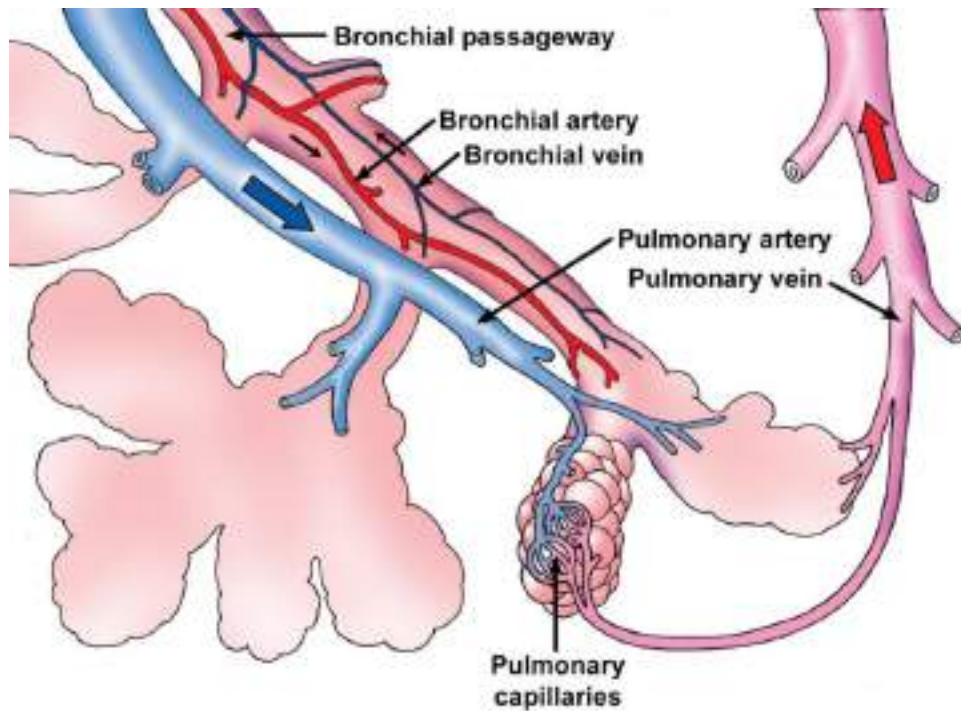


FIGURE 13.6. Vascular supply to the lungs. Arrows indicate direction of blood flow.

CHAPTER 11

SKIN (INTEGUMENTARY SYSTEM)

FUNCTIONS OF SKIN

- I. Protection against physical abrasion, chemical irritants, pathogens, UV radiation, and desiccation
- II. Thermoregulation
- III. Reception of pressure and touch sensations
- IV. Production of vitamin D
- V. Excretion

COMPONENTS OF SKIN

- I. **Epidermis**. Stratified squamous keratinized epithelium
- II. **Dermis**. Composed of two layers of connective tissue containing blood vessels, nerves, sensory receptors, and sweat and sebaceous glands. Beneath the dermis is a layer of loose connective and adipose tissues that forms the superficial fascia of gross anatomy termed the **hypodermis (subcutis)**. This layer is considered along with the skin, though technically it is not part of the integument.

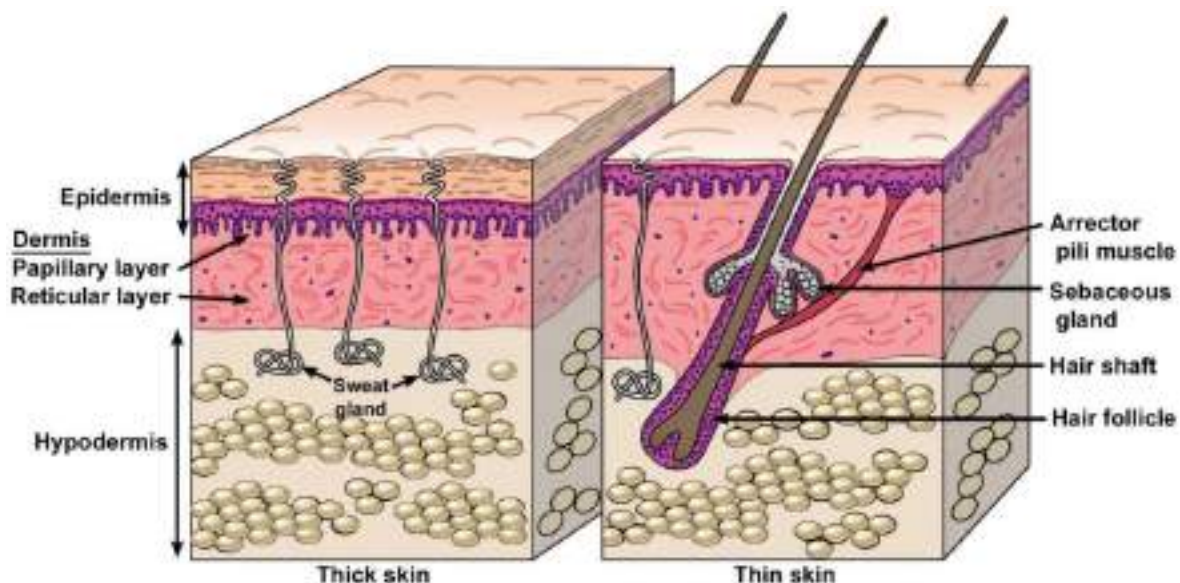


FIGURE 11.1. Structure of thin and thick skin.

CLASSIFICATION OF SKIN (Based on the thickness of the epidermis)

I. Thin skin

- A. Covers entire body except palms and soles; 0.5 mm thick on the eyelid, 5 mm thick on the back and shoulders
- B. Epidermis is thin, 0.075-0.15 mm thick, but the dermis varies from thin to very thick, depending on location.
- C. Possesses hair with sebaceous glands
- D. Sweat glands are present.

II. Thick (glabrous) skin

- A. Located on palms of the hands and soles of the feet; 0.8-1.5 mm thick
- B. Epidermis is 0.4-0.6 mm thick.
- C. Hairless and, thus, possesses no sebaceous glands
- D. Sweat glands are present.

EPIDERMIS (*images*)

I. Cell types

- A. **Keratinocytes**. Keratinizing epidermal cells, major cell type in the epidermis
- B. **Melanocytes**. Melanin pigment-producing cells
 - 1. Present in stratum germinativum and stratum spinosum
 - 2. Rounded cell bodies with clear cytoplasm. Numerous "dendrite-like" processes insinuate themselves between the keratinocytes
 - 3. Synthesize **melanin**, a dark brown pigment that is packaged into **melanosomes** and injected into keratinocytes
 - 4. Melanin caps the keratinocyte nucleus, reducing damage from solar radiation.
- C. **Langerhans cells**. Macrophages that function in immunological skin reactions.

D. Merkel's cells. Touch receptors.

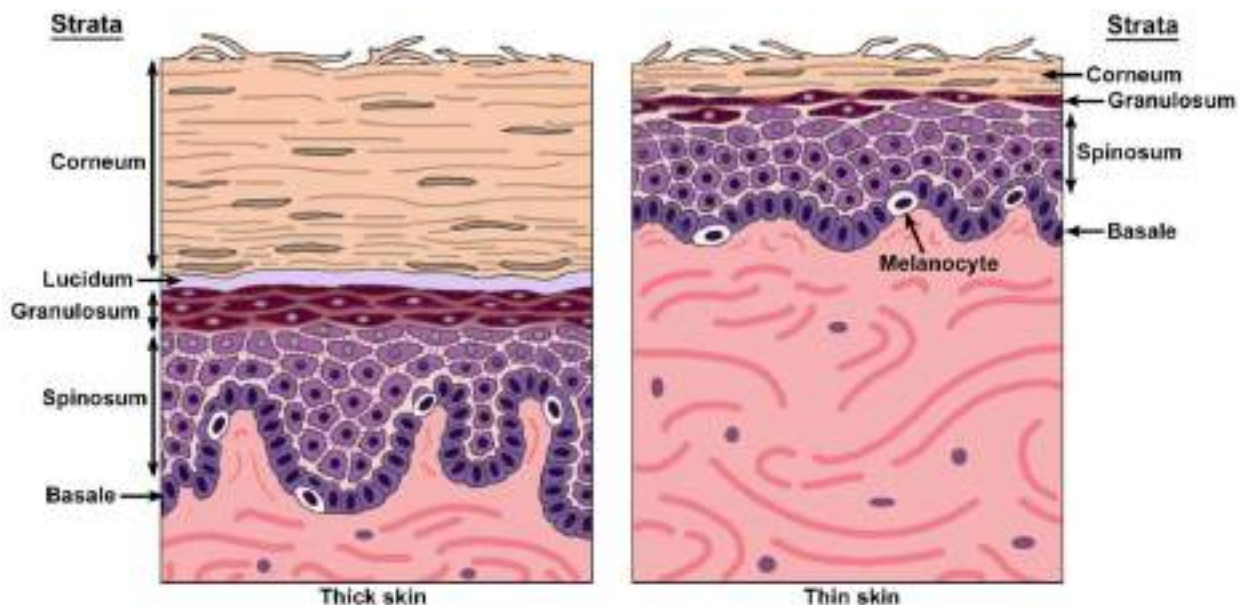


FIGURE 11.2. Comparison of epidermal layers in thick and thin skin.

II. Layers of the epidermis and keratinization

A. The epidermis is a stratified squamous, keratinized (dry) epithelium. It is continually renewed every 15-30 days. Rapid cell proliferation occurs primarily in the deepest layer (stratum germinativum) and daughter cells differentiate as they migrate toward the surface. This differentiation involves a process called keratinization, which results in a variably thick layer of nonliving cellular husks at the surface of the epidermis. All cells in the epidermis that undergo the keratinization process are called keratinocytes.

B. Layers of the epidermis

1. **Stratum basale (germinativum)**. A single layer of cuboidal to columnar shaped cells that rest on the basement membrane and undergo rapid cell proliferation. These cells contain intermediate filaments composed of keratin (tonofilaments).
2. **Stratum spinosum**. "Prickle-cell" or spiny cell layer; 3-10 cells thick. This layer is so-called because the cells are attached to one another by desmosomes, and the cellular shrinkage resulting from fixation produces the spine-like structures. These cells accumulate bundles of tonofilaments called tonofibrils.
3. **Stratum granulosum**: two to four cells thick; cells synthesize basophilic, **keratohyalin granules**, which associate with the tonofibrils. Cells also accumulate **lamellar bodies**, which contain a lipid material that is

secreted and serves as a sealant and penetration barrier between cells. Cells also begin to lose other organelles.

4. **Stratum lucidum.** A clear layer of non-nucleated, flattened cells that is only visible as a distinct layer in thick skin. In this region, the proteins contained in the keratohyalin granules mediate the aggregation of tonofibrils. This process occurs whether or not a distinct stratum lucidum is visible.
5. **Stratum corneum.** Variably thick layer of extremely flattened, cornified scales containing aggregated tonofibrils surrounded by a thickened plasma membrane. These cell remnants are sloughed off without damage to the underlying, living epidermal cells.

III. Epidermal-dermal junction

- A. Scalloped margin at the interface of the epidermis and dermis, formed by interdigitations of:
 1. **Epidermal pegs.** Downward projections of the epidermis
 2. **Dermal papillae.** Upward, finger-like protrusion of connective tissue from the dermis
- B. This junction strengthens the attachment of the epidermis to the underlying dermis.

DERMIS (images)

I. Composition

A. **Papillary layer**

1. Located immediately beneath the basement membrane of the epidermis, forming the dermal papillae
2. Thin layer composed of loose connective tissue
3. Contains small blood vessels, nerves, lymphatics, and the sensory receptors, Meissner's corpuscles

B. **Reticular layer**

1. Located between the papillary layer and the hypodermis
2. Thick layer composed of dense, irregular connective tissue
3. Contains larger nerves and blood vessels, glands, hair follicles, and the

sensory receptors, Pacinian corpuscles and Ruffini end organs

II. Vasculature of the dermis

- A. **Papillary plexus** located in the dermal papillae
- B. **Cutaneous plexus** located in the reticular layer of the dermis
- C. **Arteriovenous anastomoses** allow shunting of blood between papillary and cutaneous plexuses for temperature regulation.

HYPODERMIS (SUBCUTIS)

- I. Not technically part of the integument
- II. Composed of loose connective tissue and adipose tissue, which can accumulate in large fatty deposits
- III. Provides anchorage for skin to the underlying tissues
- IV. May contain the bases of sweat glands and hair follicles
- V. Many sensory receptors, especially Pacinian corpuscles, are present.

STRUCTURES ASSOCIATED WITH THE SKIN

I. Glands (*images*)

A. **Sweat glands**

- 1. Simple, coiled tubular glands
- 2. Contain **myoepithelial cells**, which are specialized cells that contract to aid in the expulsion of the sweat
- 3. Types of sweat glands
 - a. **Merocrine or eccrine**. Located in all regions of the body except the axillary and anal regions; produce a watery secretion that empties onto the surface of the epidermis
 - b. **Apocrine**. Restricted to the axillary, areolar, and anal regions; much larger than eccrine sweat glands with a broader lumen. Produce a viscous secretion that empties into the hair follicle. Do not secrete by the apocrine mode, as once thought.

B. **Sebaceous glands**

1. Simple, branched acinar glands
2. Usually secrete into a hair follicle
3. Produce sebum, an oily secretory product, released by the holocrine mode of secretion
4. Absent from thick skin

II. **Hair follicles**

- A. Invaginations of the epidermis
- B. Consist of a **bulb** at the base of the follicle that is located in the hypodermis or in the deep layers of the dermis. **Internal and external sheaths** surround the growing **hair shaft** as it passes through the dermis and epidermis.
- C. An **arrector pili** muscle attaches a hair follicle to the papillary layer of the dermis. Contraction provides elevation of the hair, forming "goose-bumps."

III. **Nails** *(images)*

- A. Keratinized epithelial cells on the dorsal surface of the fingers and toes
- B. Consist of a **nail plate** that corresponds to the stratum corneum of the epidermis. This plate rests on the **nail bed**, consisting of cells corresponding to the stratum spinosum and stratum germinativum.
- C. **Nail root** lies in an epidermal fold, whose stratum corneum forms the **eponychium (cuticle)**
- D. **Nail matrix** lies beneath the nail root and is the germinative portion of the nail.
- E. The **hyponychium**, a thickened epidermis, secures the nail at the fingertip

IV. Sensory structures *(images)*

- A. Nonencapsulated. **Free nerve endings** in the epidermis, responsive to touch, pressure, heat, cold, and pain
- B. Encapsulated pressure receptors
 1. **Meissner's corpuscle**

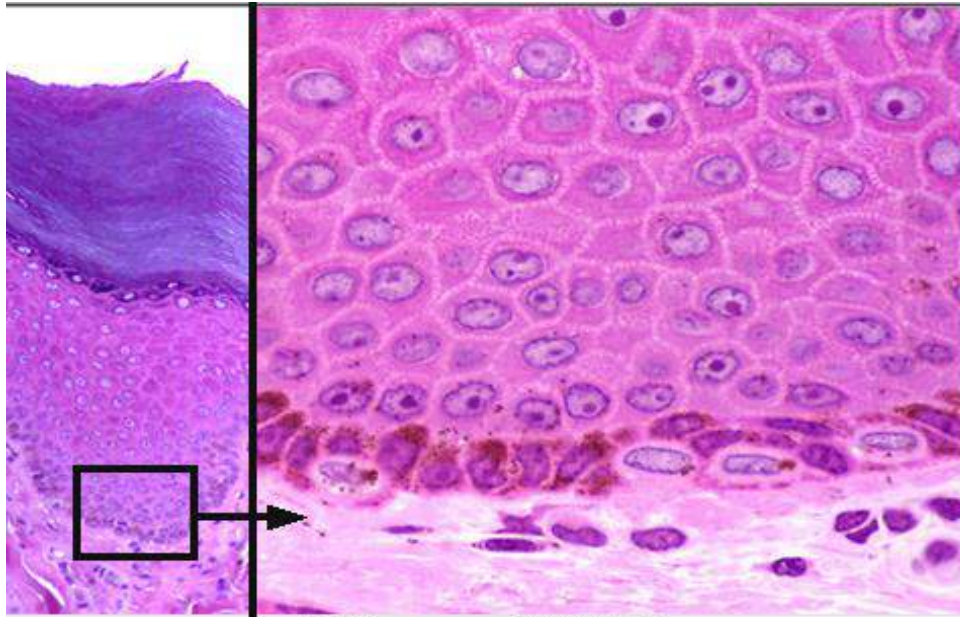
- a. Located at the apex of a dermal papilla
- b. Consists of a coil of **Schwann cells** around a nerve terminal
- c. Responds to light touch

2. **Pacinian corpuscle**

- a. Located in the dermis and hypodermis
- b. Consists of concentric layers of **endoneurial cells** around a nerve terminal
- c. Responds to vibration and deep pressure

3. **Ruffini ending**

- a. Located in the dermis
- b. Consists of groups of nerve terminals surrounded by a thin connective tissue capsule
- c. Responds to touch and pressure

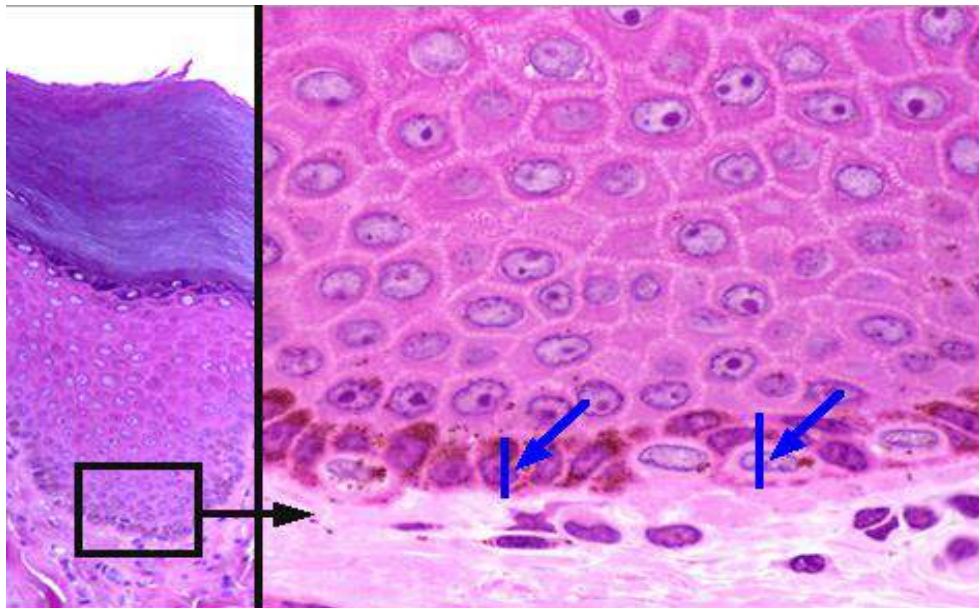


click to identify:

Stratum basale >
Melanocytes >
Melanin granules
Stratum >
spinosum

4 of 19

Stratum basale -- Stratum basale (germinativum) is the deepest layer of the epidermis and rests directly on the basal lamina. Cell division occurs primarily in the stratum basale, forming daughter cells which undergo keratinization while moving up to form the more superficial layers. Stratum basale is composed primarily of keratinocytes. 200x, 1000x

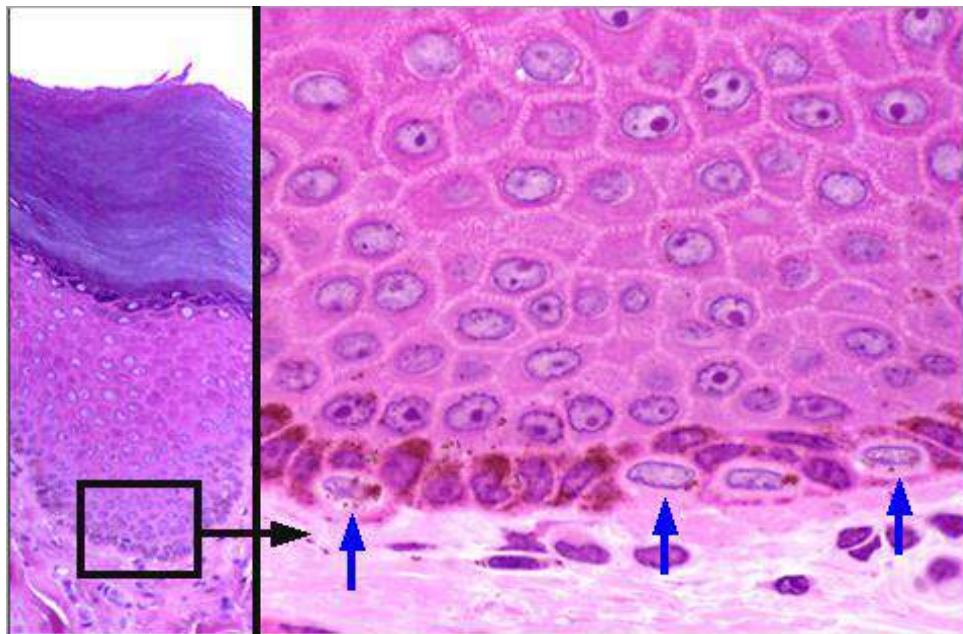


click to identify:

> Stratum basale >
Melanocytes >
Melanin granules
Stratum >
spinosum

4 of 19

The stratum basale consists of a single layer of cuboidal to columnar shaped cells and rests on the basement of the epidermis. These cells accumulate melanin granules which are synthesized by neighboring melanocytes. The majority of keratinocyte proliferation occurs in stratum basale.

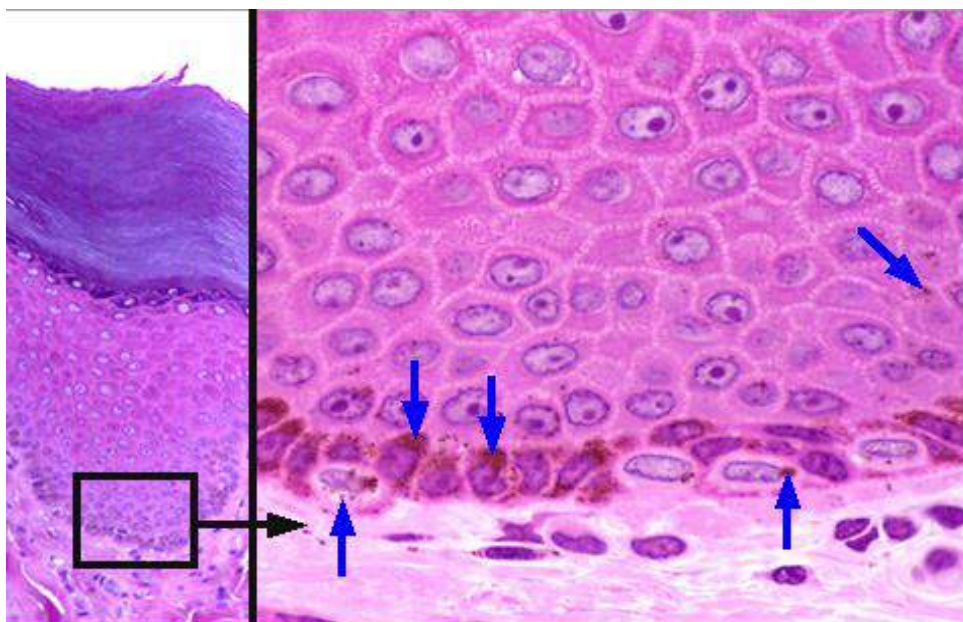


click to identify:

- Stratum basale >
- > Melanocytes >
- Melanin granules
- Stratum >
- spinosum

4 of 19

Melanocytes are located primarily in the stratum germinativum, although they can also be found in the stratum spinosum. Melanocytes synthesize melanin pigment, which they package into melanosomes (melanin granules) that are transferred to neighboring keratinocytes. Melanin protects nuclear DNA in keratinocytes against ultraviolet light.

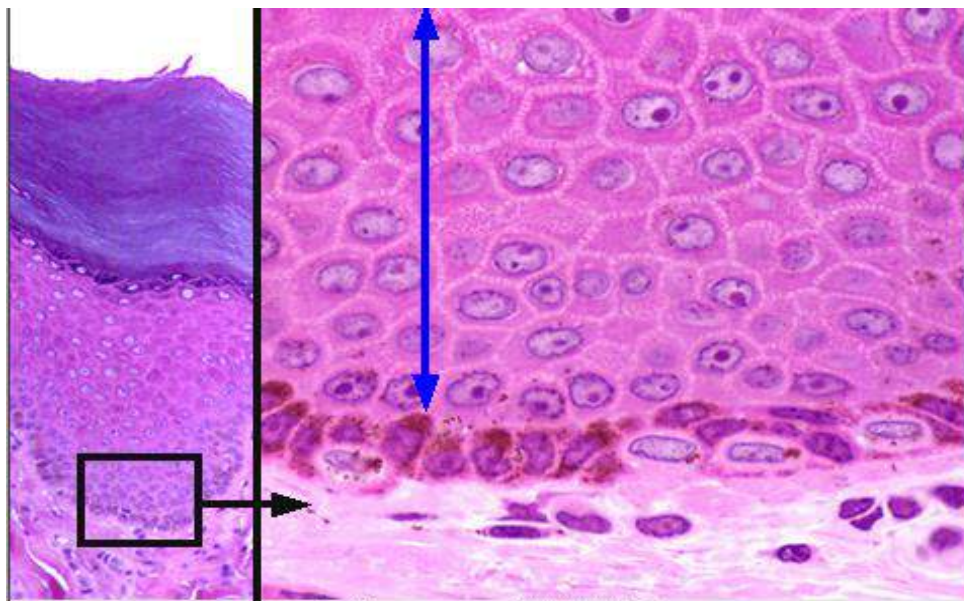


click to identify:

- Stratum basale >
- Melanocytes >
- > Melanin granules
- Stratum >
- spinosum

4 of 19

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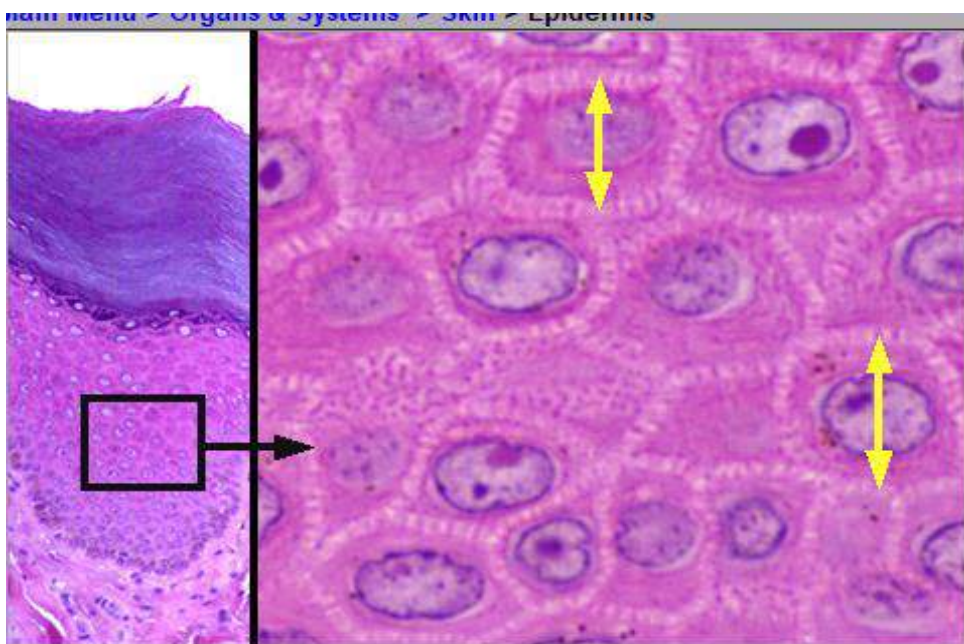


click to identify:

- Stratum basale >
- Melanocytes >
- Melanin granules
- > Stratum >
- spinosum

4 of 19

Stratum spinosum, the layer immediately above stratum basale, consists of 3-10 layers of cells and is the major site of keratin filament synthesis in the epidermis. Cells of the stratum spinosum are securely bound to each other by desmosomes, which aid the epidermis in resisting frictional trauma and account for the spiny appearance of these cells.

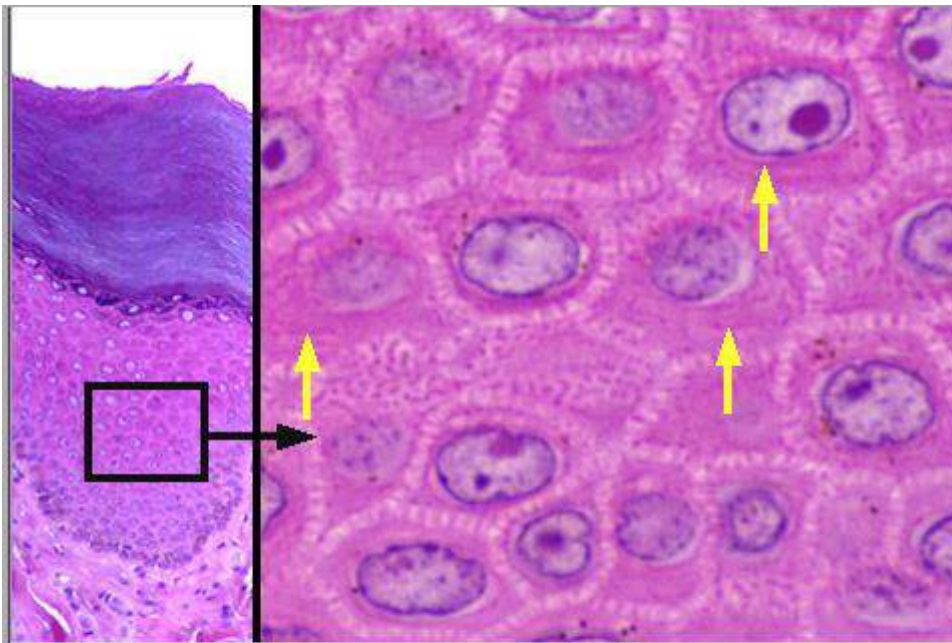


click to identify:

- > Stratum spinosum
- cells
- Tonofibrils

10 of 19

Stratum spinosum -- The stratum spinosum contains 3-10 layers of polygonal keratinocytes with euchromatic nuclei. These cells contain prominent bundles of intermediate filaments (tonofibrils) containing keratin tonofilaments. These keratinocytes are attached to one another by numerous desmosomes, which account for the spiny appearance around their periphery. 200x, 2000x



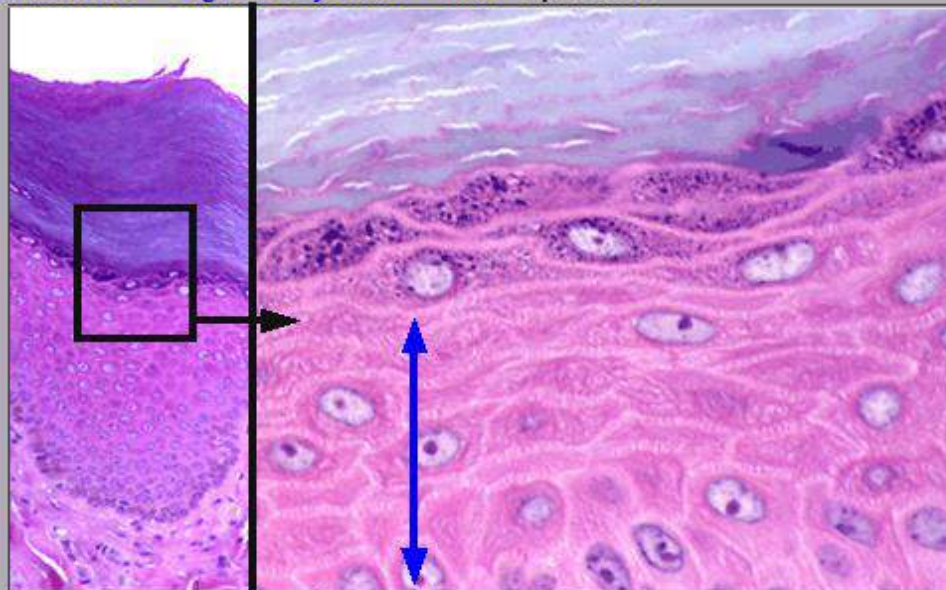
10 of 19

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click to identify:

- Stratum spinosum cells
- > Tonofibrils

Main Menu > Organs & Systems > Skin > Epidermis

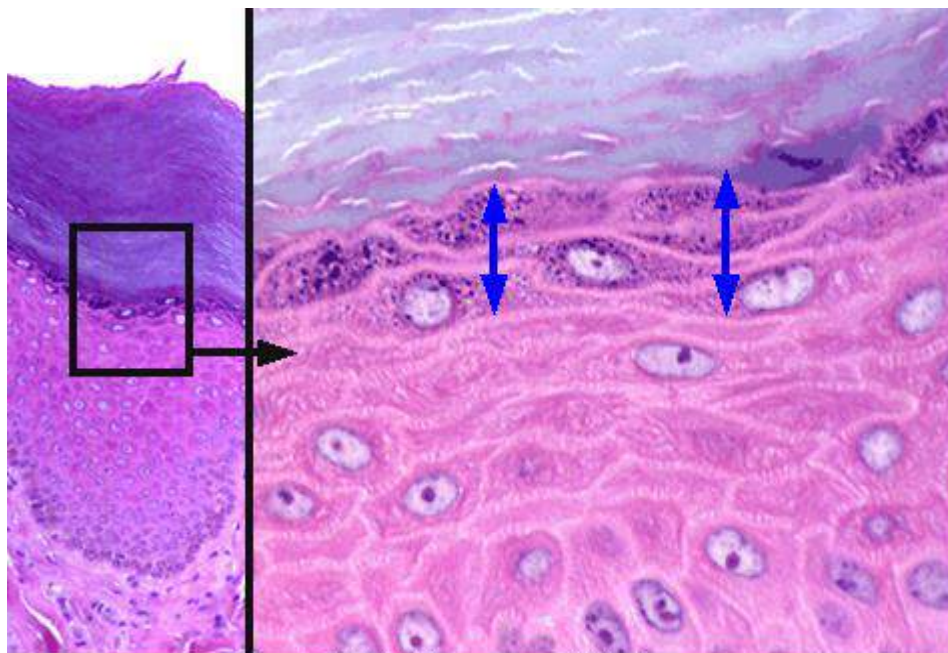


14 of 19

Stratum granulosum -- The stratum granulosum is three to five cell layers thick with prominent, basophilic, keratohyalin granules. These granules combine with the tonofilaments (keratin intermediate filaments) to produce keratin. At the same time, the organelles in these cells degenerate, resulting in keratinized scales which form the stratum corneum. 200x, 1000x

click to identify:

- > Stratum spinosum
- Stratum granulosum
- Keratohyalin granules
- Stratum lucidum >
- Stratum corneum >

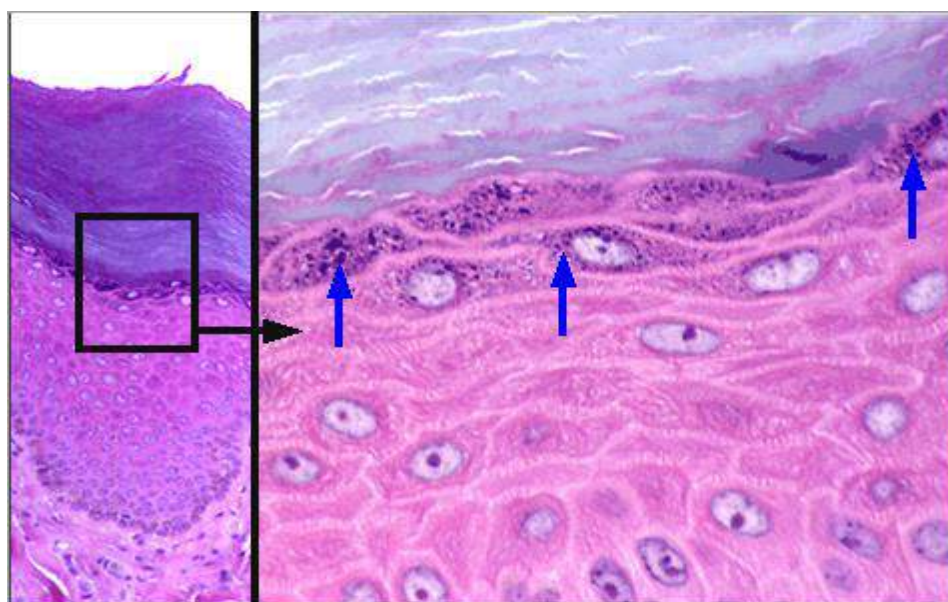


14 of 19

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- Stratum spinosum
- > Stratum granulosum
- Keratohyalin granules
- Stratum lucidum >
- Stratum corneum >

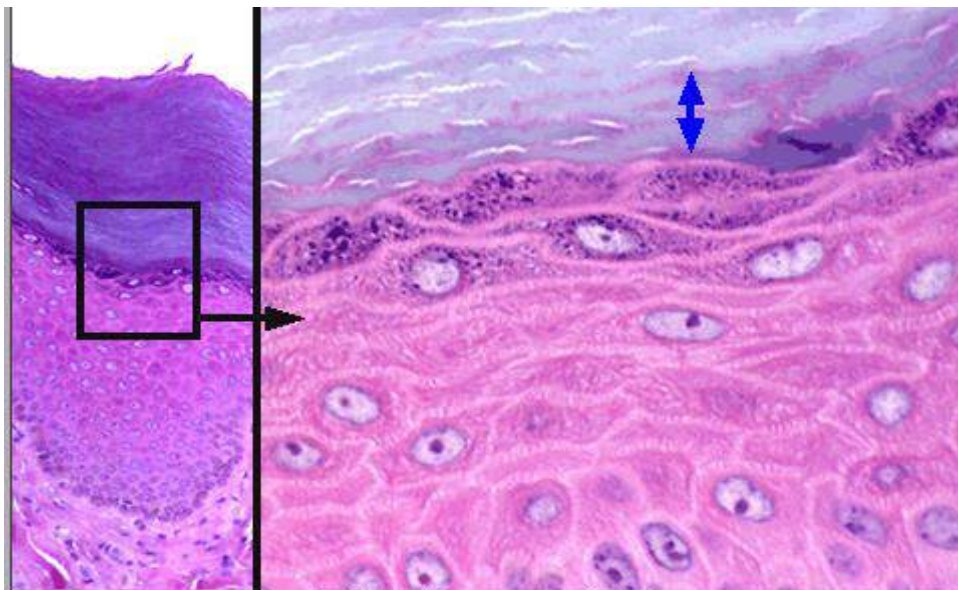


14 of 19

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click to identify:

- Stratum spinosum
- Stratum granulosum
- > Keratohyalin granules
- Stratum lucidum >
- Stratum corneum >

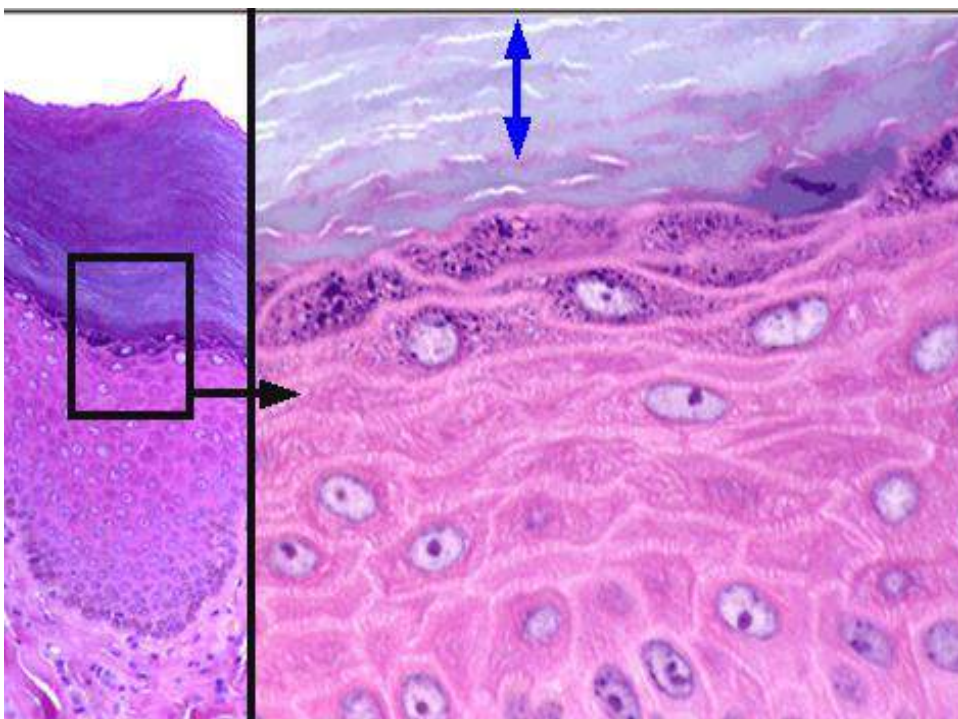


click to identify:

- Stratum spinosum
- Stratum granulosum
- Keratohyalin granules
- > Stratum lucidum >
- Stratum corneum >

14 of 19

The stratum lucidum is a clear layer of non-nucleated, flattened cells where the proteins contained in the keratohyalin granules mediate the aggregation of bundles of tonofilaments.

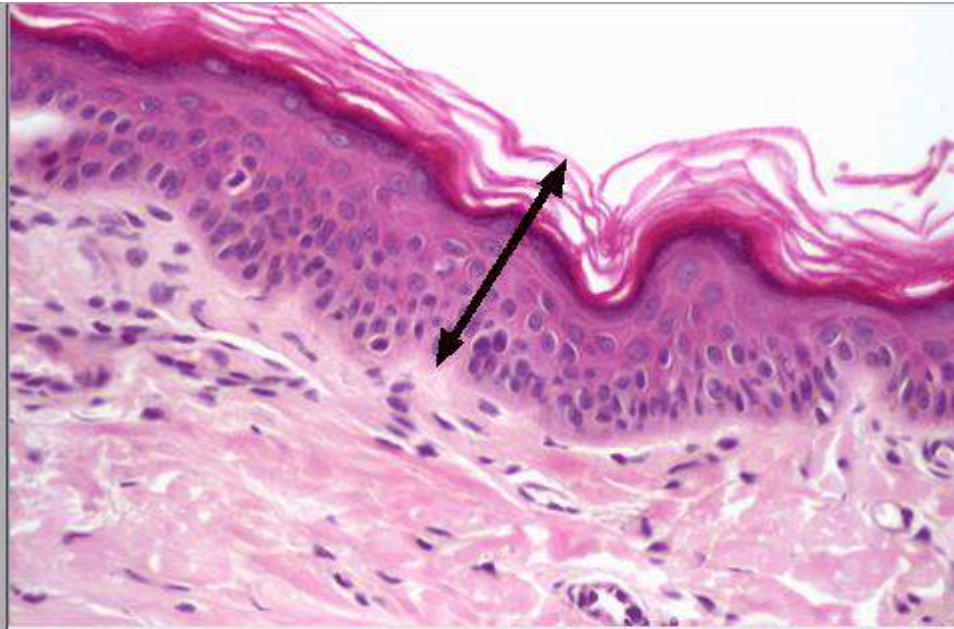


click to identify:

- Stratum spinosum
- Stratum granulosum
- Keratohyalin granules
- Stratum lucidum >
- > Stratum corneum >

14 of 19

As the keratohyalin granules combine with the tonofilaments, the nuclei and organelles in the cells degenerate, resulting in keratinized scales which form the stratum corneum.

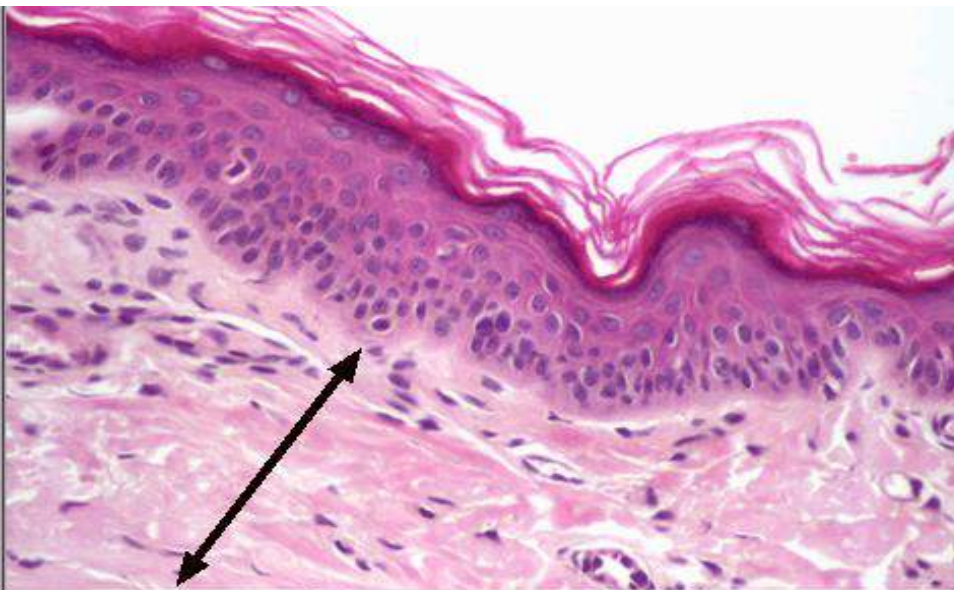


18 of 19

Stratum corneum -- Stratum corneum consists of squamous cells containing keratin protein surrounded by a thickened plasma membrane. These cells are continuously shed from the surface of the epidermis and are replenished through the upward migration and ongoing keratinization of epidermal keratinocytes. Stratum lucidum does not form a discrete layer in thin skin, as seen here. 400x

click to identify:

- > Epidermis
- Dermis
- Stratum basale
- Stratum spinosum
- Stratum
- granulosum
- Stratum corneum

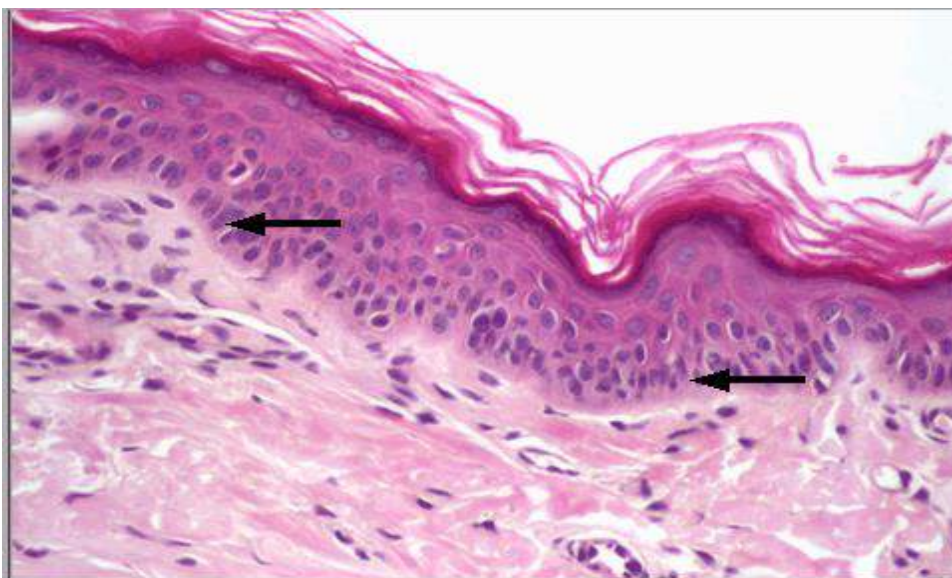


18 of 19

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- Epidermis
- > Dermis
- Stratum basale
- Stratum spinosum
- Stratum
- granulosum
- Stratum corneum

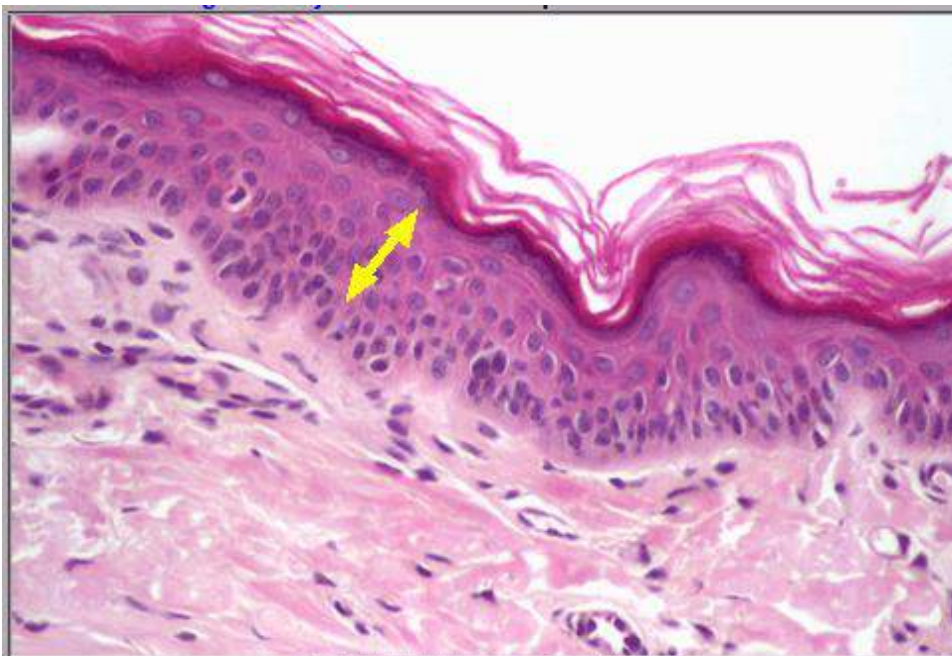


18 of 19

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click to identify:

- Epidermis
- Dermis
- ▶ Stratum basale
- Stratum spinosum
- Stratum granulosum
- Stratum corneum

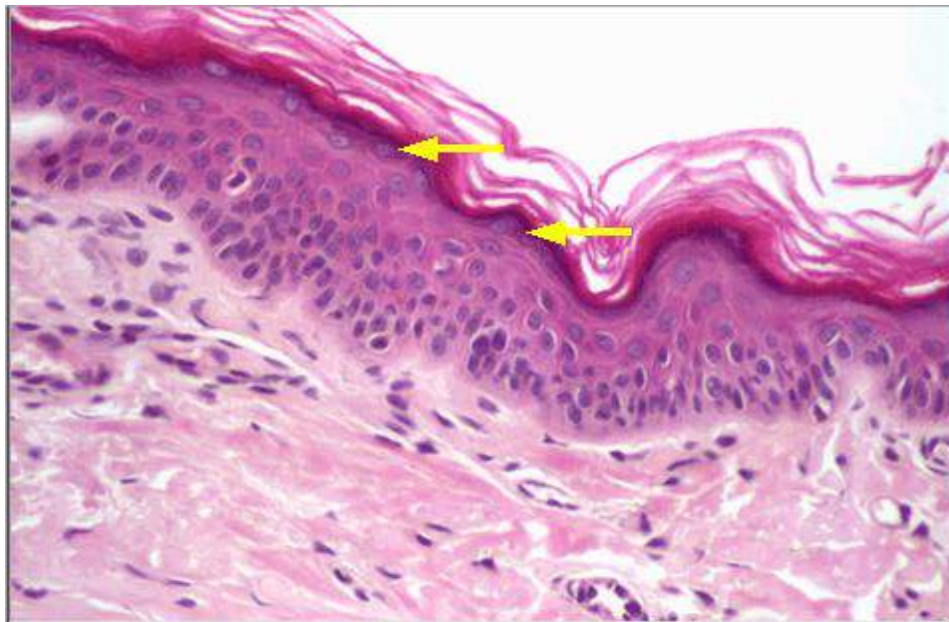


18 of 19

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- Dermis
- Stratum basale
- ▶ Stratum spinosum
- Stratum granulosum
- Stratum corneum

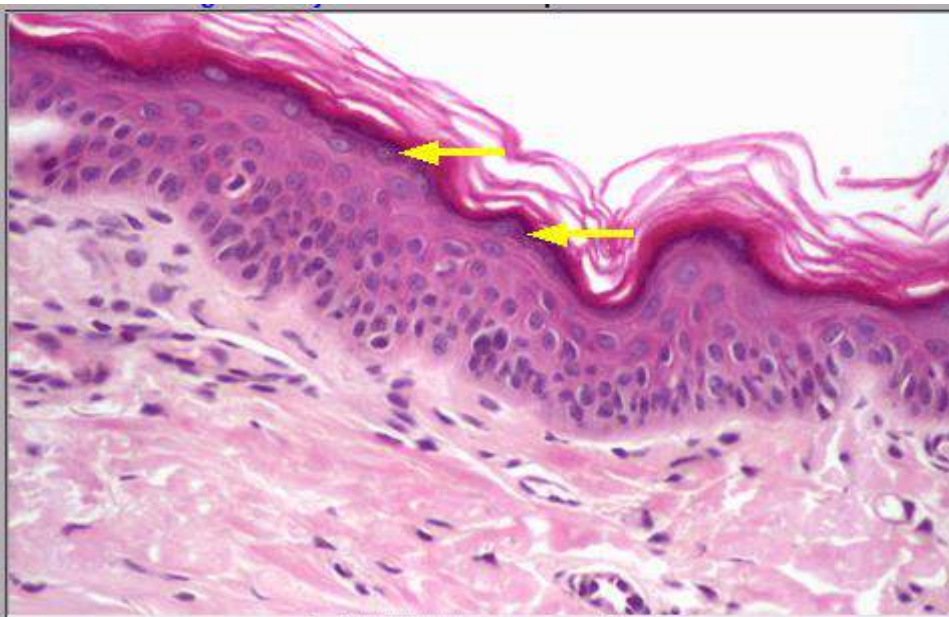


18 of 19

Stratum corneum -- Stratum corneum consists of squamous cells containing keratin protein surrounded by a thickened plasma membrane. These cells are continuously shed from the surface of the epidermis and are replenished through the upward migration and ongoing keratinization of epidermal keratinocytes. Stratum lucidum does not form a discrete layer in thin skin, as seen here. 400x

click to identify:

- Epidermis
- Dermis
- Stratum basale
- Stratum spinosum
- Stratum
- granulosum
- Stratum corneum



18 of 19

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- Epidermis
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- Stratum basale
- Stratum spinosum
- Stratum
- granulosum
- Stratum corneum

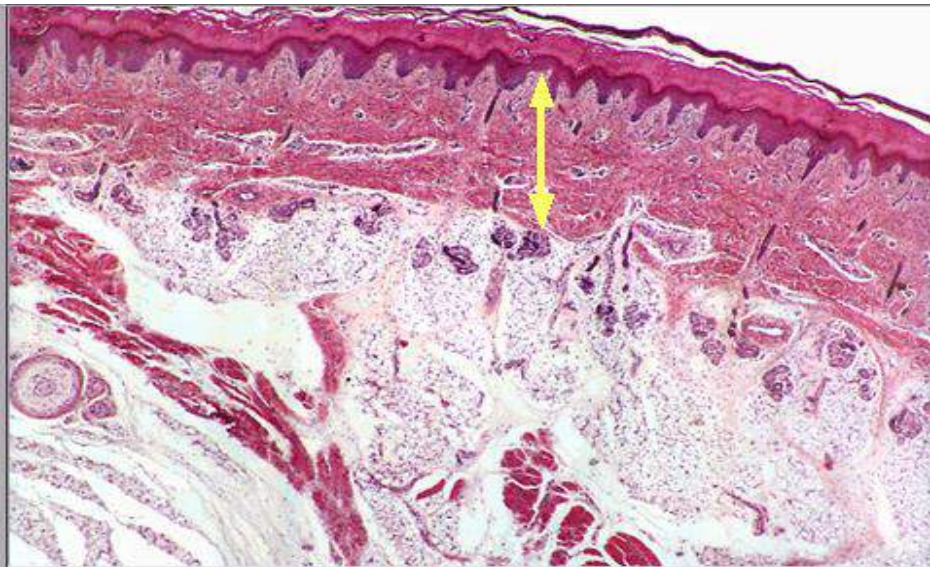


1 of 10

Dermis -- The dermis of skin consists of two layers, a thin papillary layer immediately beneath the epidermis and a thick reticular layer. The hypodermis lies beneath the skin but is not part of it. Sweat glands, their ducts, blood vessels and sensory receptors, Pacinian corpuscles, are located deep in the dermis or in the adjacent hypodermis. Thick skin 40x

click to identify:

- › Epidermis
- Dermis
- Hypodermis
- Sweat glands
- Ducts of sweat glands
- Blood vessels
- Pacinian corpuscle
- Next image

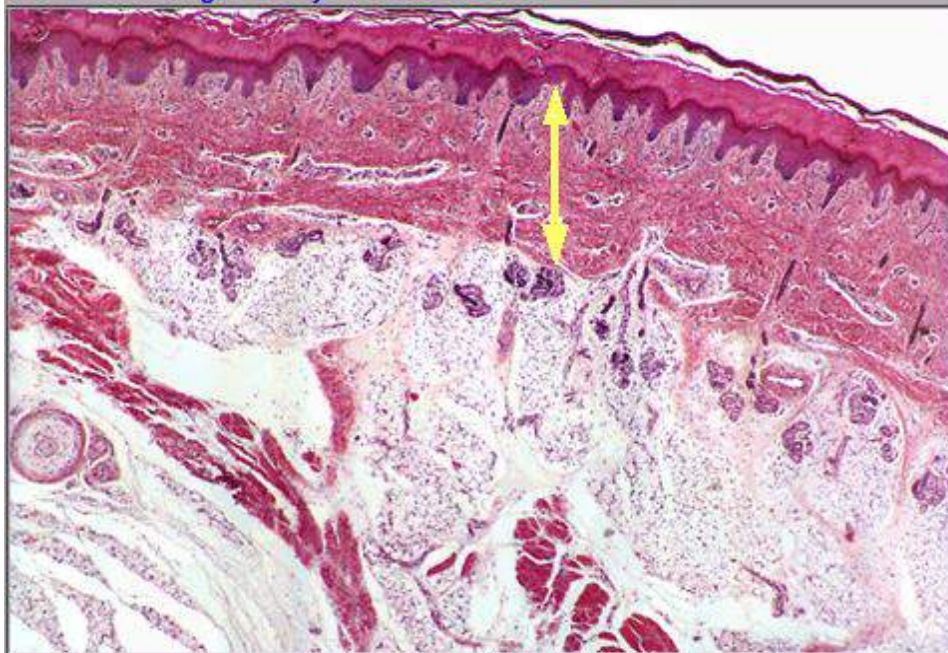


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- Epidermis
- › Dermis
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- Sweat glands
- Ducts of sweat glands
- Blood vessels
- Pacinian corpuscle
- Next image

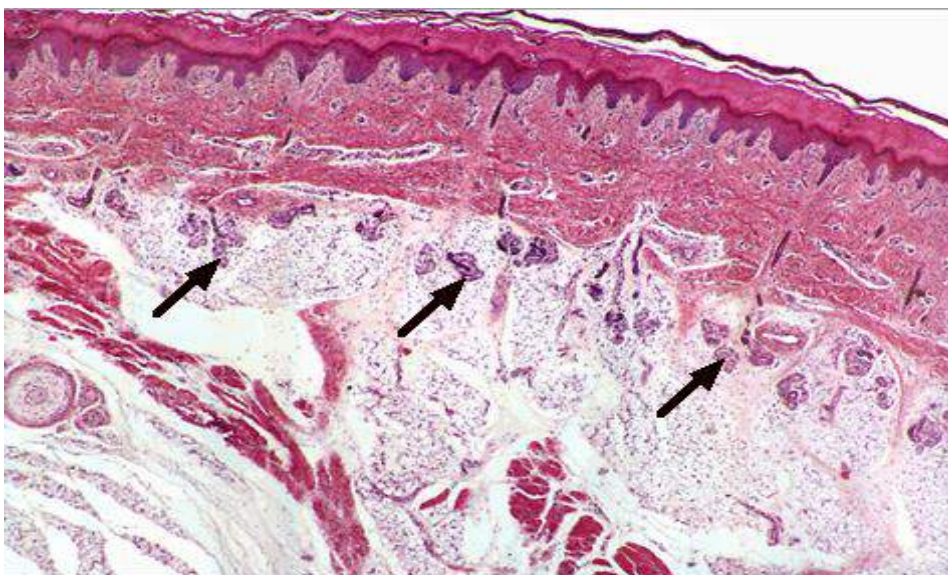


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- Sweat glands
- Ducts of sweat glands
- Blood vessels
- Pacinian corpuscle
- Next image

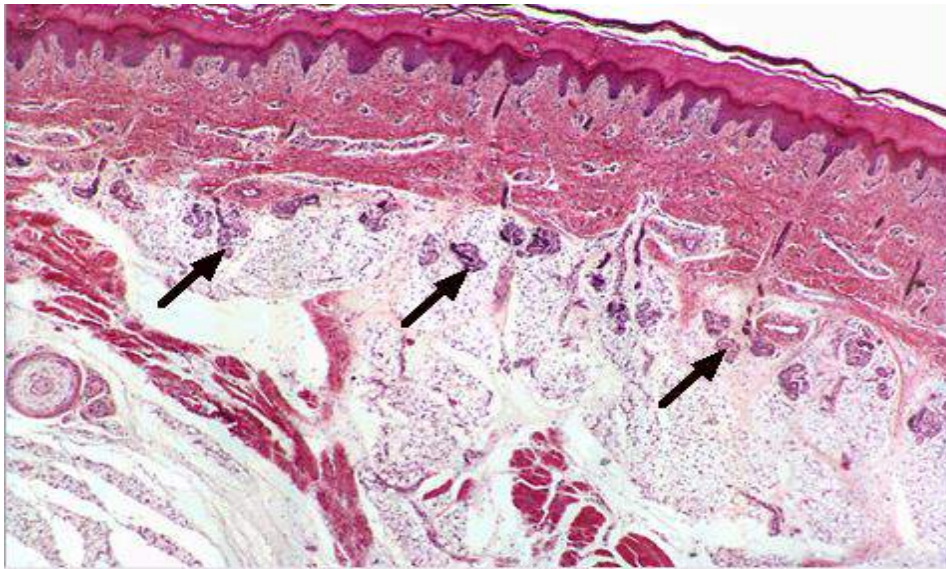


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click to identify:

- Epidermis
- Dermis
- Hypodermis
- › Sweat glands
- Ducts of sweat glands
- Blood vessels
- Pacinian corpuscle
- Next image

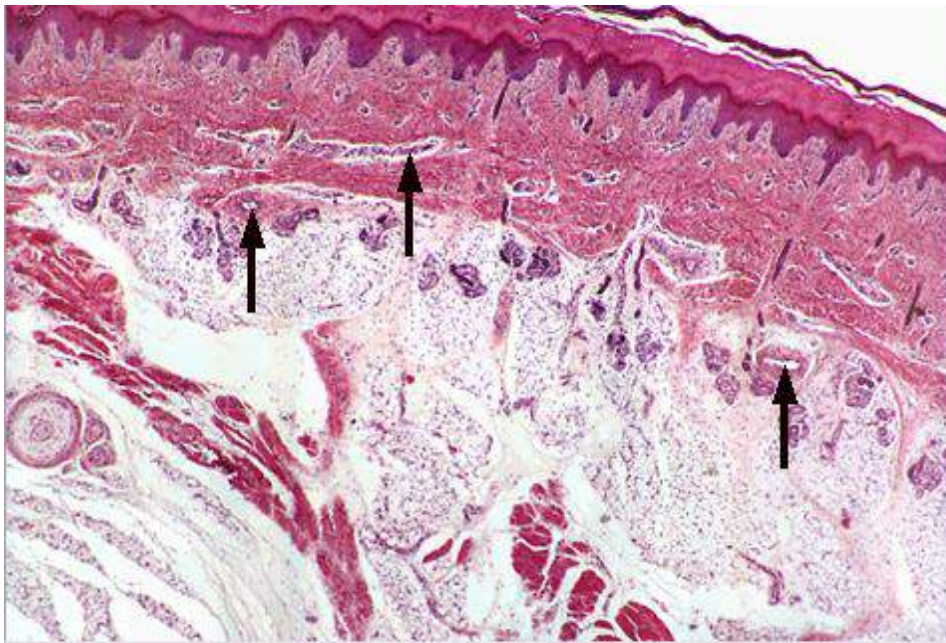


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click to identify:

- Epidermis
- Dermis
- Hypodermis
- > Sweat glands
- Ducts of sweat glands
- Blood vessels
- Pacinian corpuscle
- Next image

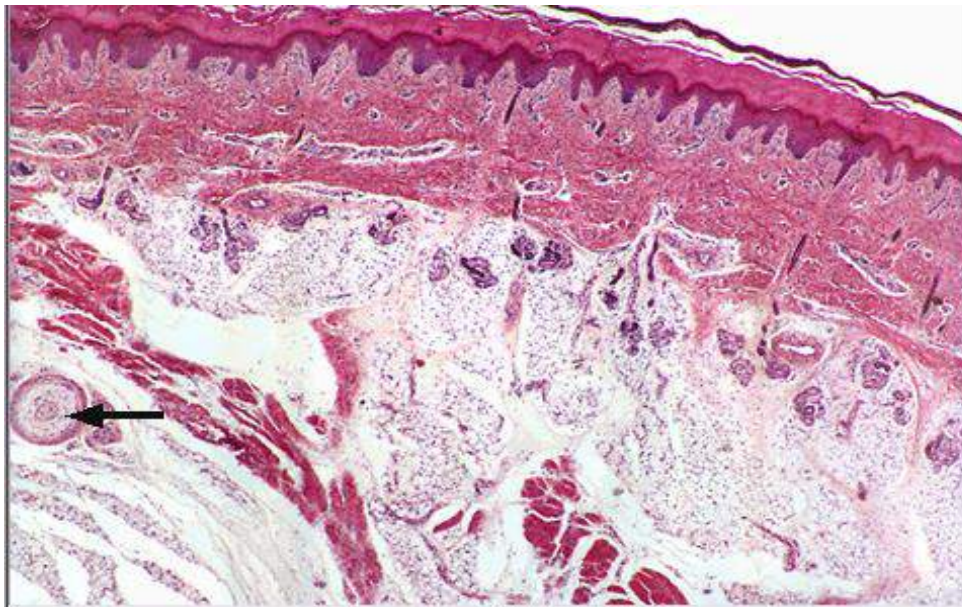


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click to identify:

- Epidermis
- Dermis
- Hypodermis
- Sweat glands
- Ducts of sweat glands
- > Blood vessels
- Pacinian corpuscle
- Next image

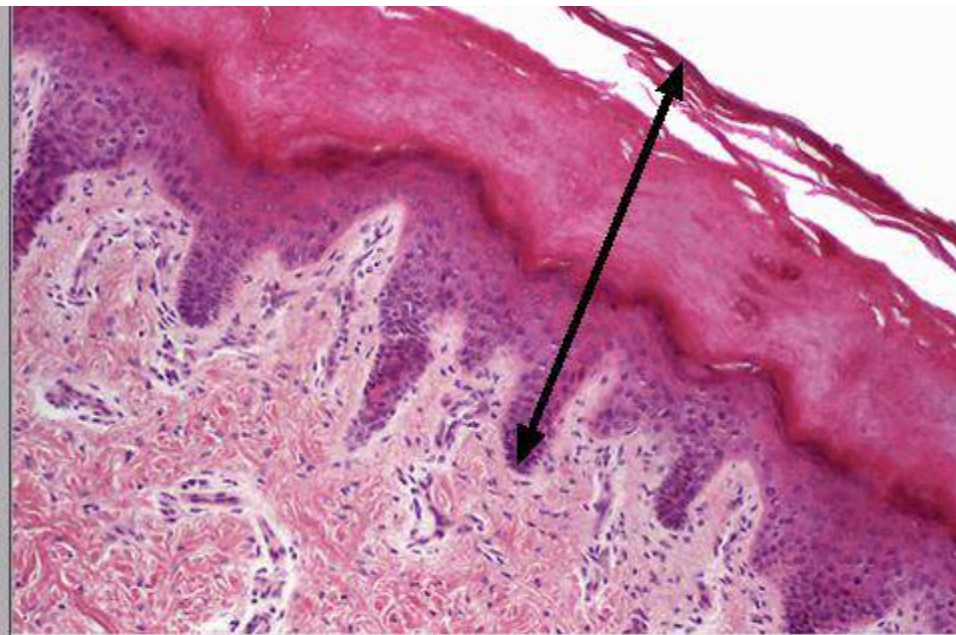


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- Epidermis
- Dermis
- Hypodermis
- Sweat glands
- Ducts of sweat glands
- Blood vessels
- Pacinian corpuscle
- Next image

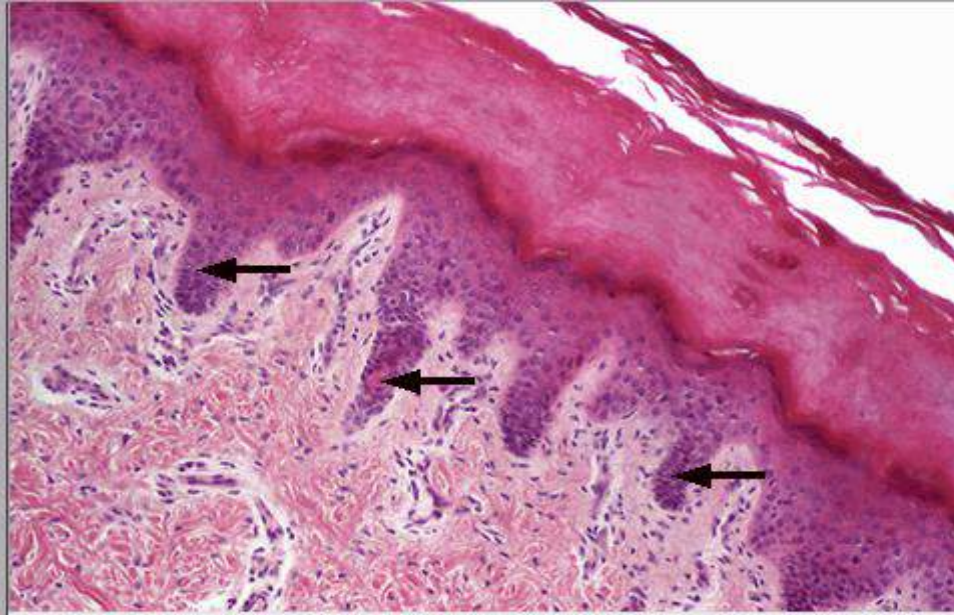


3 of 10

Dermis -- The papillary layer of the dermis, composed of loose connective tissue, forms an undulating interface with the overlying epidermis. At this junction, dermal papillae alternate with epidermal pegs projecting downward from the epidermis. The thicker reticular layer of dermis is composed of dense irregular connective tissue. 200x

click to identify:

- Epidermis
- Epidermal pegs
- Dermis
- Papillary layer
- Dermal papillae
- Reticular layer

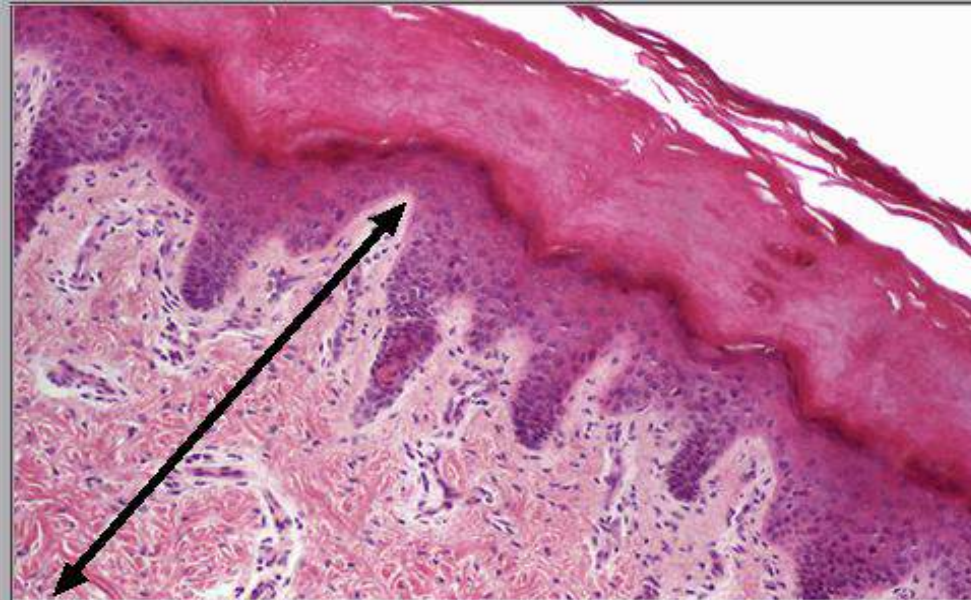


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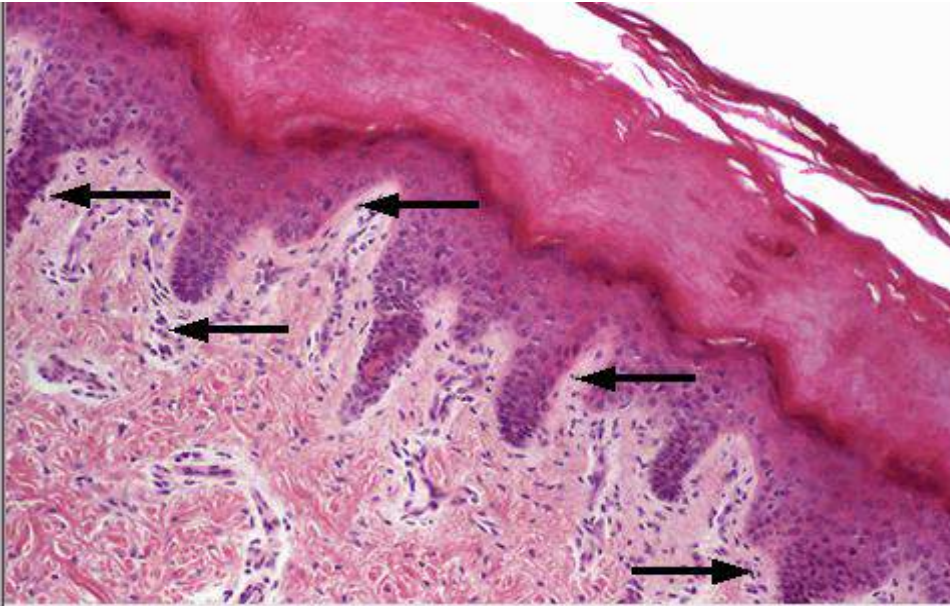


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- › Dermis
- Papillary layer
- Dermal papillae
- Reticular layer

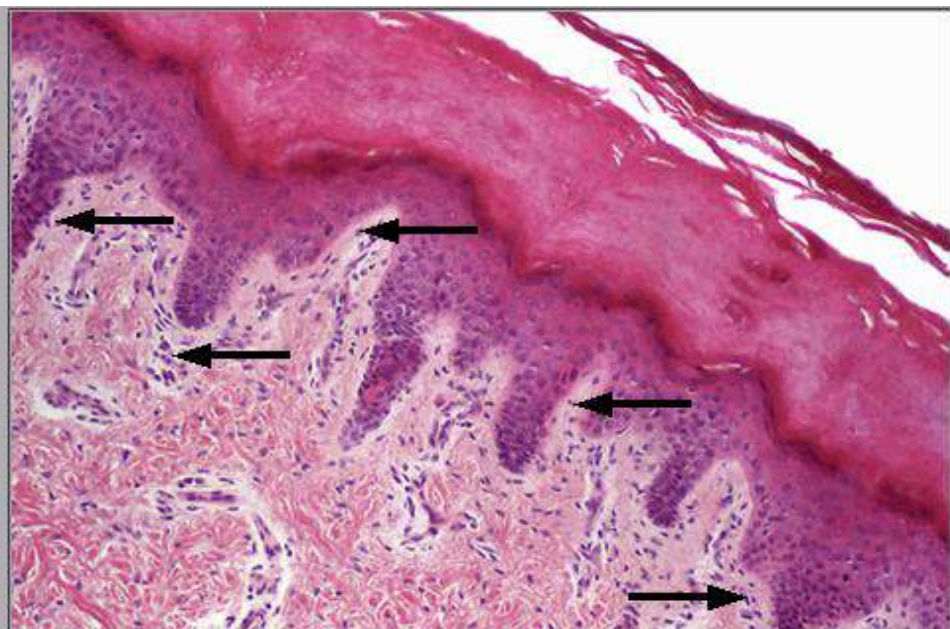


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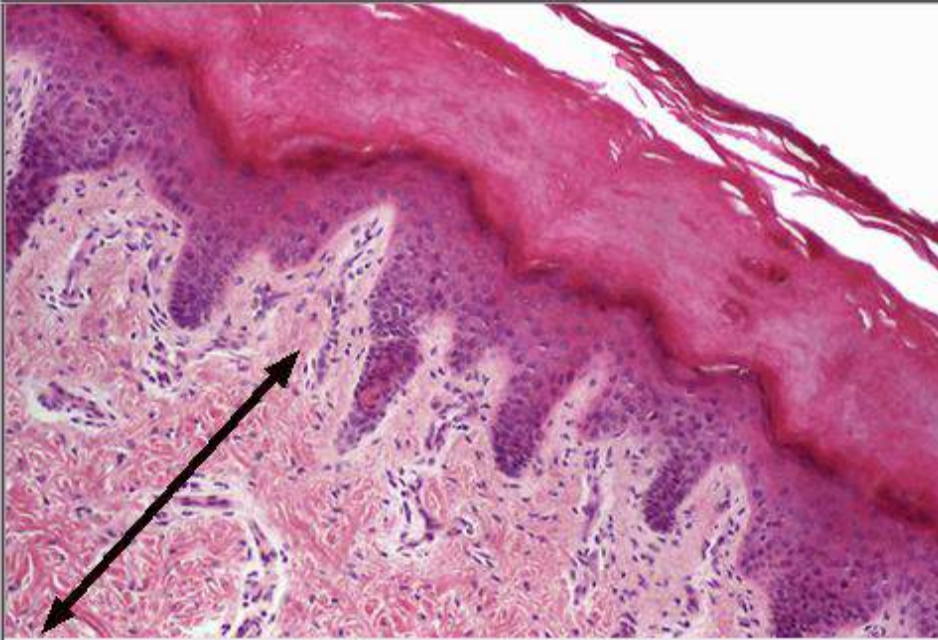


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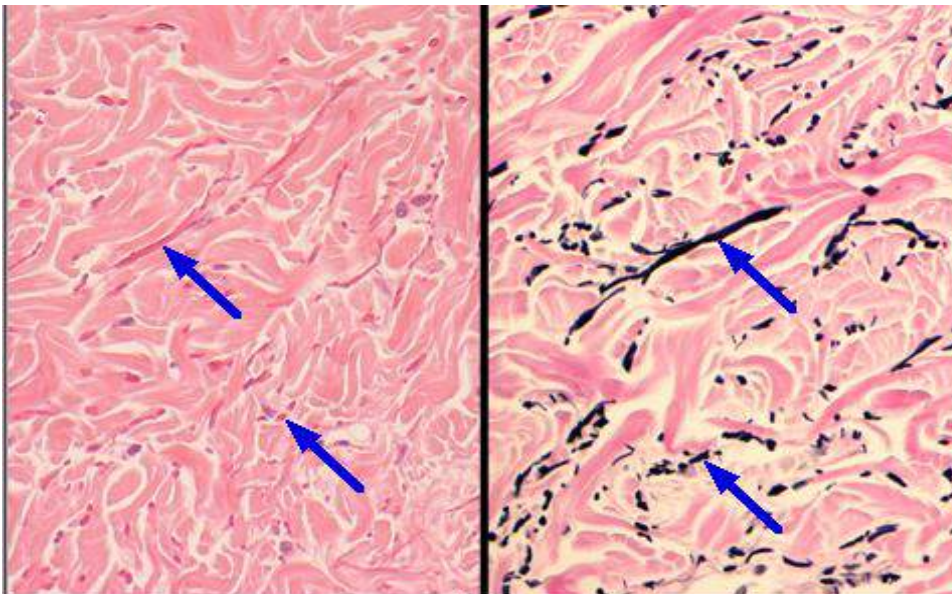


3 of 10

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- Papillary layer
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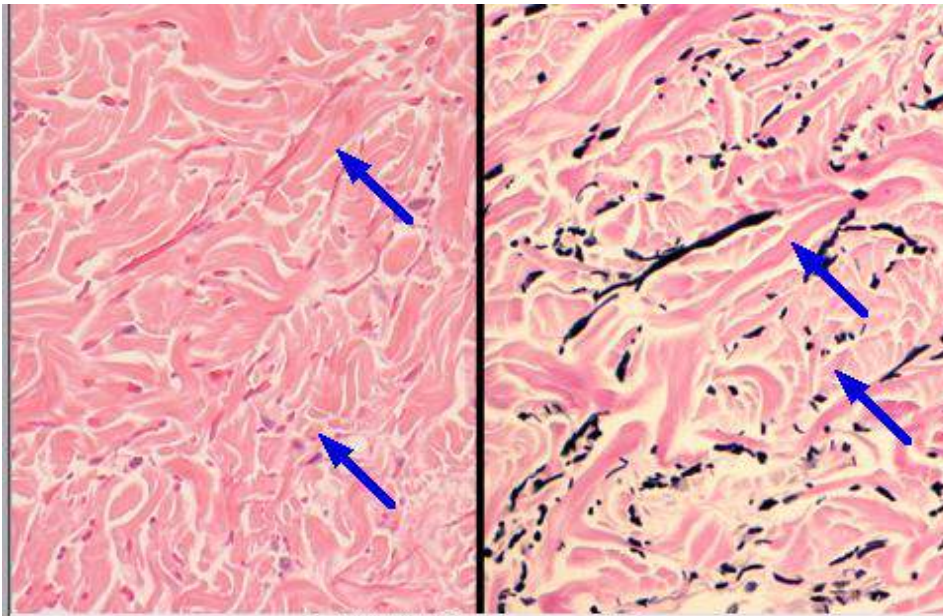


9 of 10

Dermis -- These images of dense irregular connective tissue in the reticular layer compare the appearance of elastic fibers stained with eosin and with a special elastin stain. In some preparations elastic fibers can be demonstrated with eosin, as shown here. In most cases however, a special elastin stain is required. 200x, 200x

click to identify:

- Elastic fibers
- Collagen fibers
- Ground substance
- Hematoxylin and eosin stain
- Elastin stain

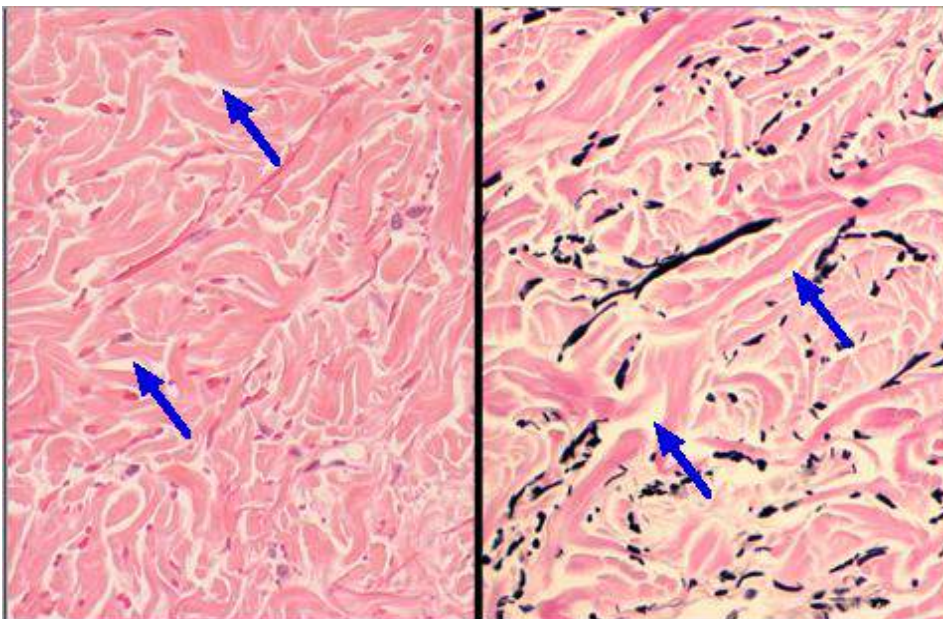


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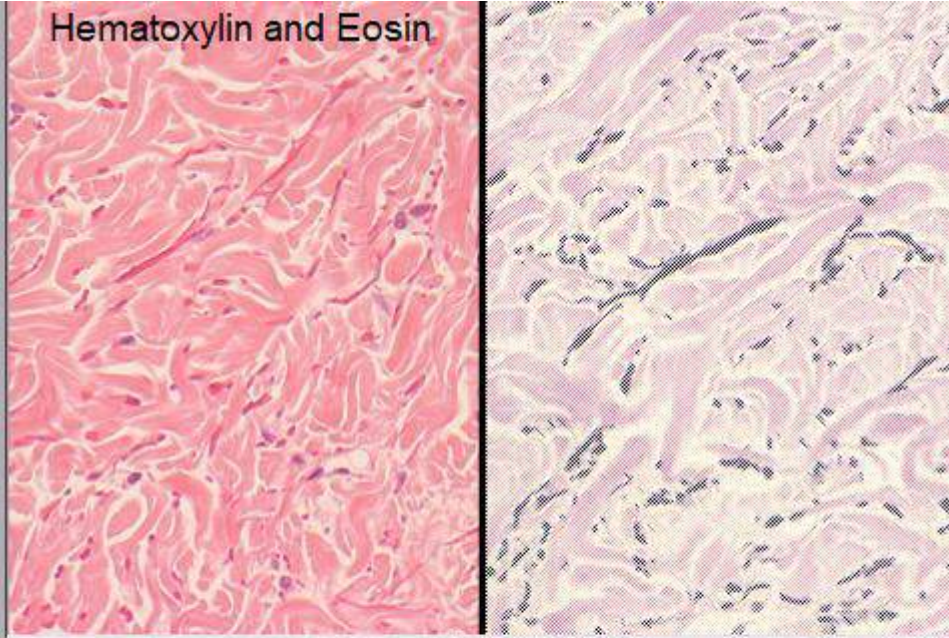
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Hematoxylin and Eosin



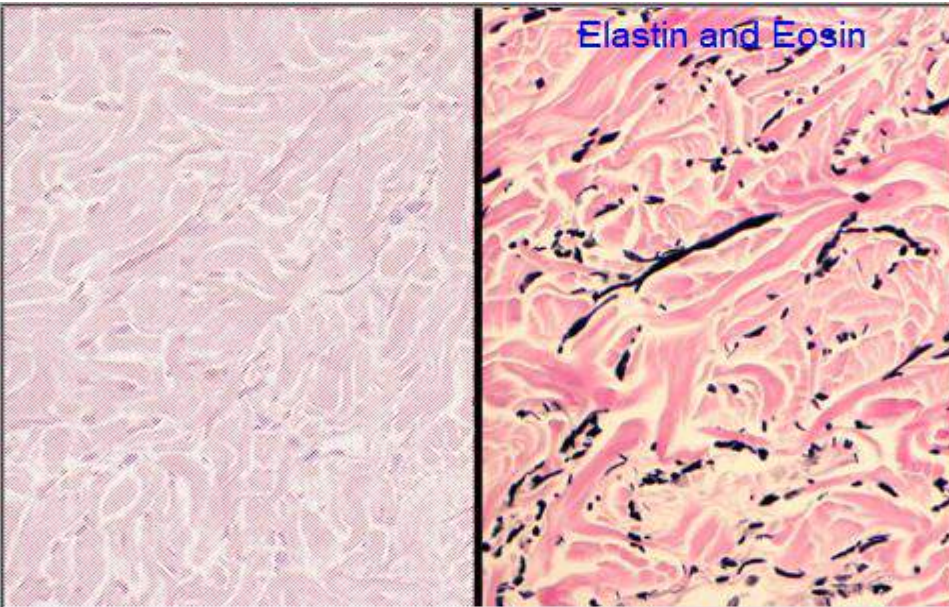
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- Ground substance
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- Elastin stain

Elastin and Eosin

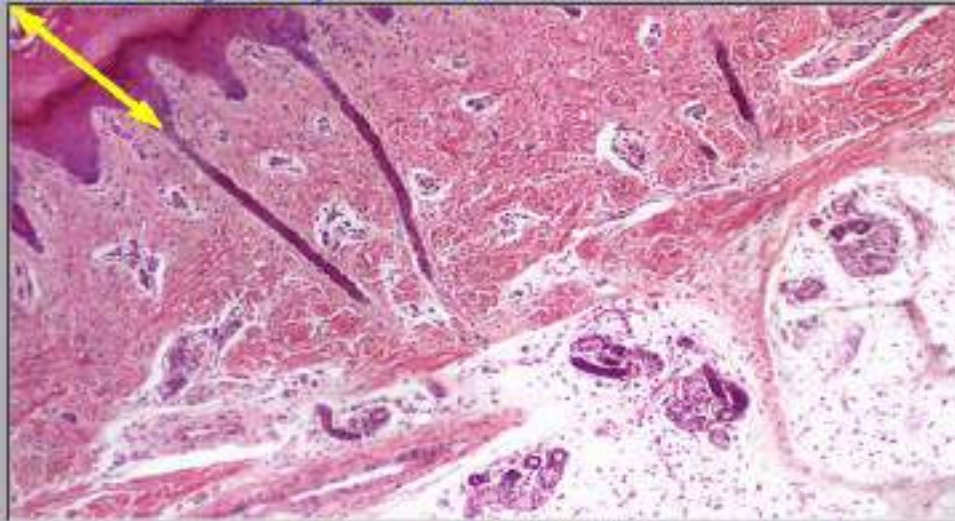


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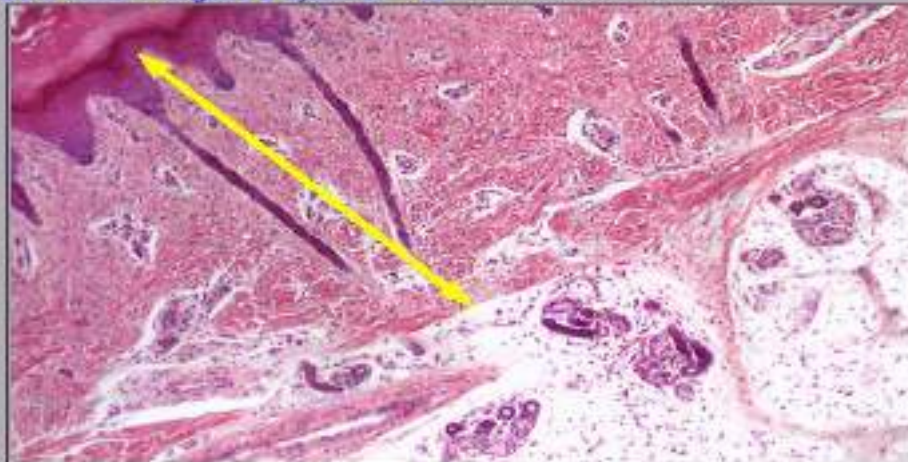


1 of 11

Eccrine sweat gland -- There are two types of sweat glands, eccrine and apocrine. These eccrine sweat glands, present in thick and thin skin throughout the body, produce a watery secretion. They secrete by the merocrine mode and are located deep in the dermis and in the hypodermis. Both types of sweat glands are classified as simple, coiled tubular glands. 100x

click to identify:

- > Epidermis
- Dermis
- Hypodermis
- Ducts >
- Eccrine sweat >
- glands

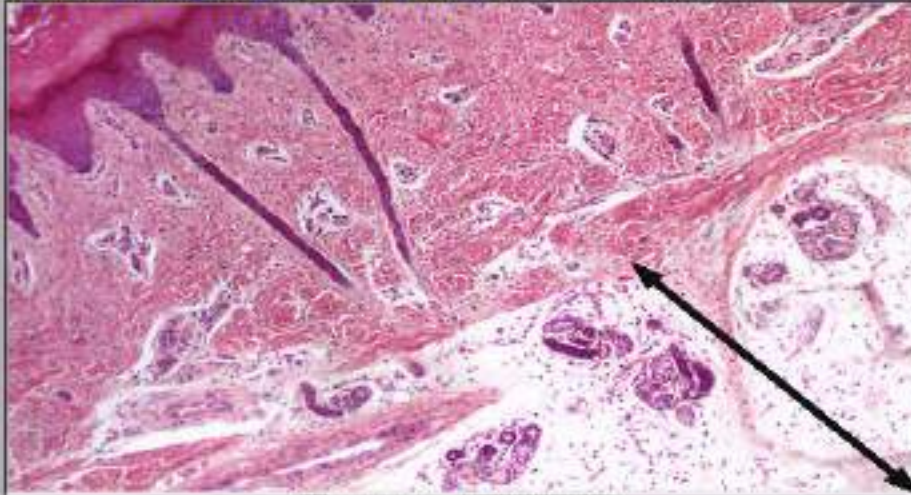


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- Epidermis
- > Dermis
- Hypodermis
- Ducts >
- Eccrine sweat >
- glands

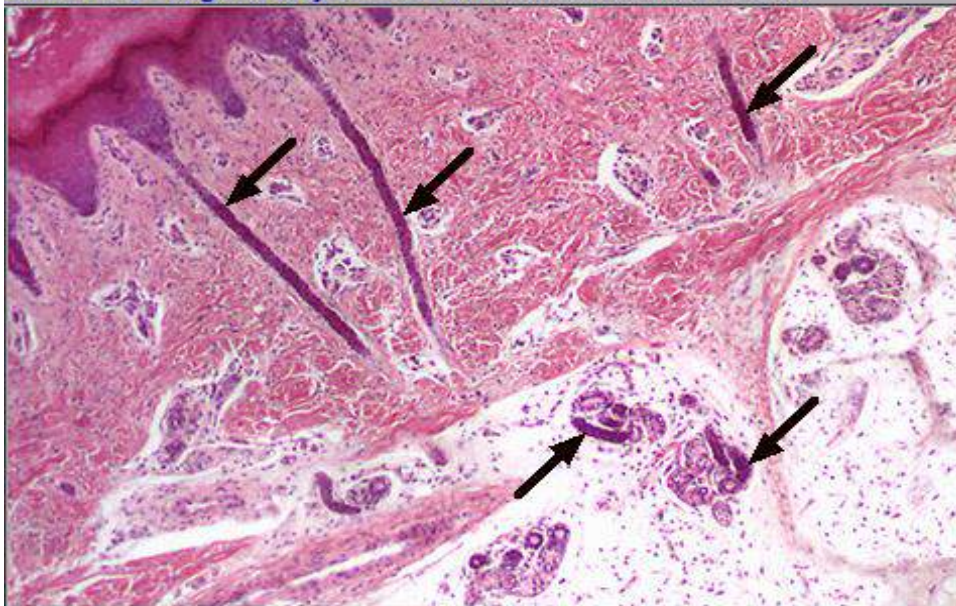


click to identify:

- Epidermis
- Dermis
- > Hypodermis
- Ducts >
- Eccrine sweat >
- glands

1 of 11

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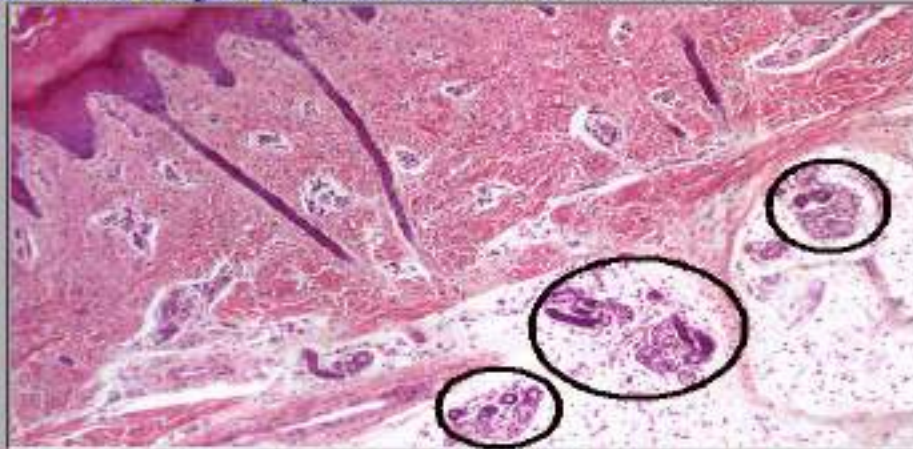


click to identify:

- Epidermis
- Dermis
- Hypodermis
- > Ducts >
- Eccrine sweat >
- glands

1 of 11

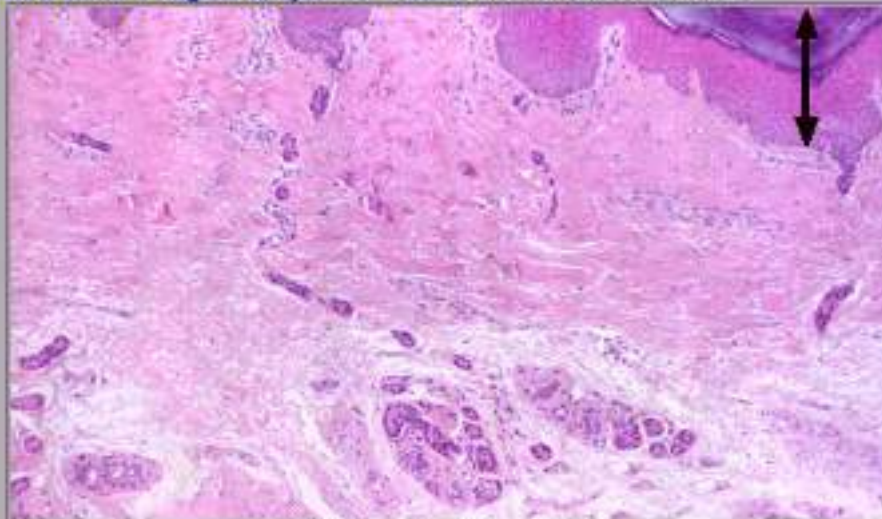
Each sweat gland possesses a long, unbranched duct which passes through the dermis, interconnecting the secretory tubules with the surface of the skin. The portion of the duct adjacent to the secretory unit of the gland coils with the secretory part similar to winding yarn into a ball.



click to identify:

- Epidermis
- Dermis
- Hypodermis
- Ducts >
- > Eccrine sweat >
- glands

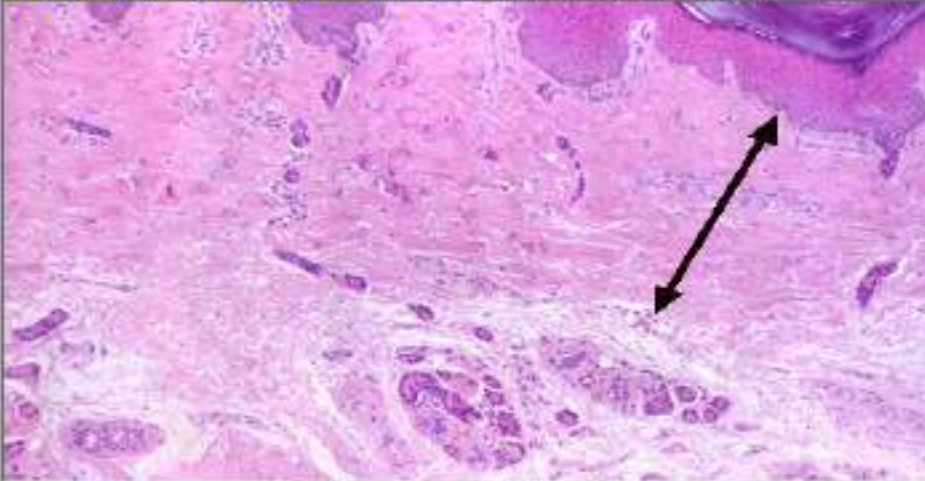
The secretory part of the tubule and a portion of the duct coil on themselves like a ball of yarn; the secretory portion in the coil stains paler than does the duct portion.



click to identify:

- > Epidermis
- Dermis
- Hypodermis
- Eccrine sweat
- glands
- Ducts of
- sweat glands

Eccrine sweat gland – The secretory portions of each sweat gland lie deep in the dermis or in the hypodermis. Extending from the secretory portion, the duct travels through the dermis and epidermis to open on the surface of the skin. 100x

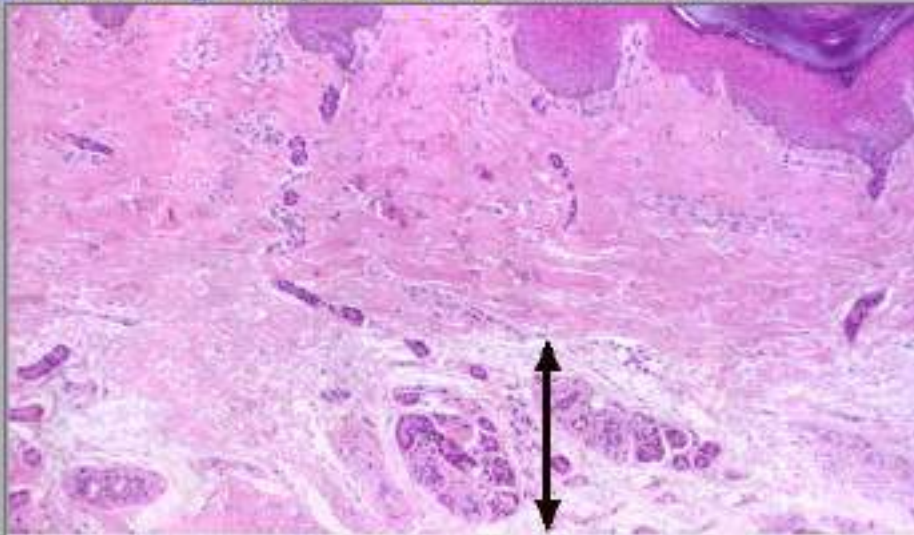


click to identify:

- Epidermis
- > Dermis
- Hypodermis
- Eccrine sweat glands
- Ducts of sweat glands

2 of 11

Eccrine sweat gland -- The secretory portions of each sweat gland lie deep in the dermis or in the hypodermis. Extending from the secretory portion, the duct travels through the dermis and epidermis to open on the surface of the skin.
100x

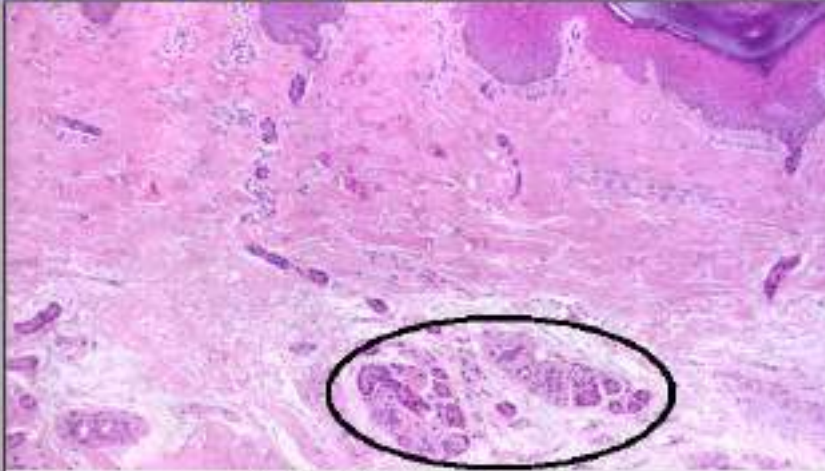


click to identify:

- Epidermis
- Dermis
- > Hypodermis
- Eccrine sweat glands
- Ducts of sweat glands

2 of 11

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100x

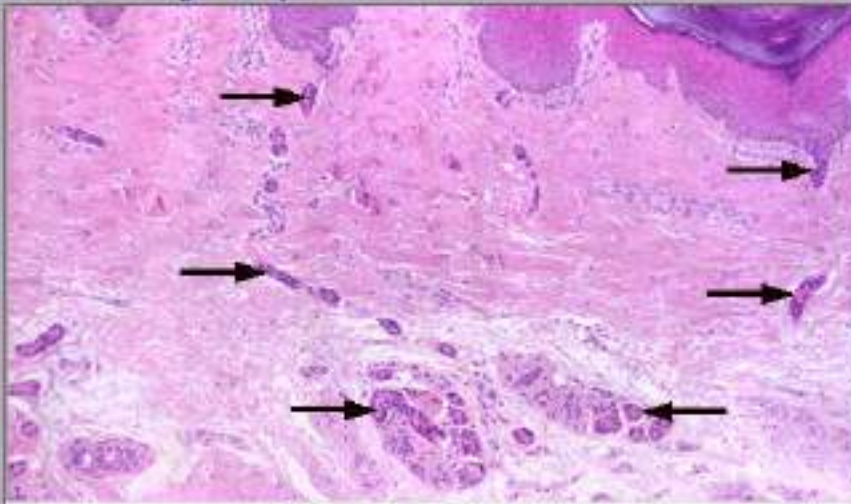


click to identify:

- Epidermis
- Dermis
- Hypodermis
- > Eccrine sweat glands
- Ducts of sweat glands

2 of 11

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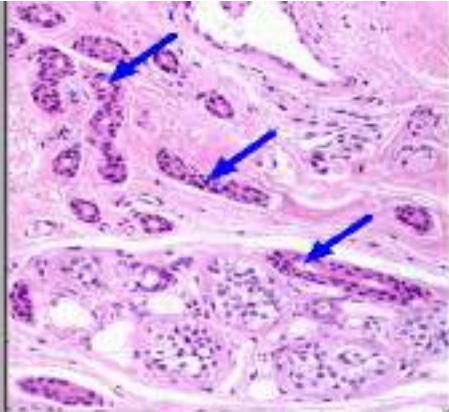
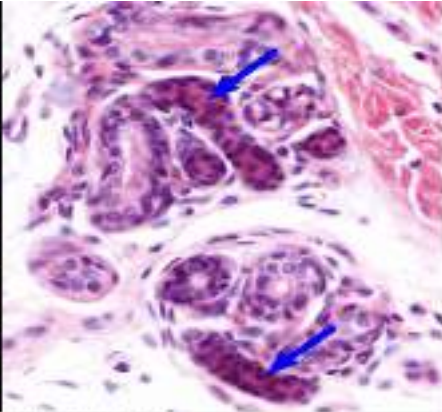



click to identify:

- Epidermis
- Dermis
- Hypodermis
- Eccrine sweat glands
- > Ducts of sweat glands

2 of 11

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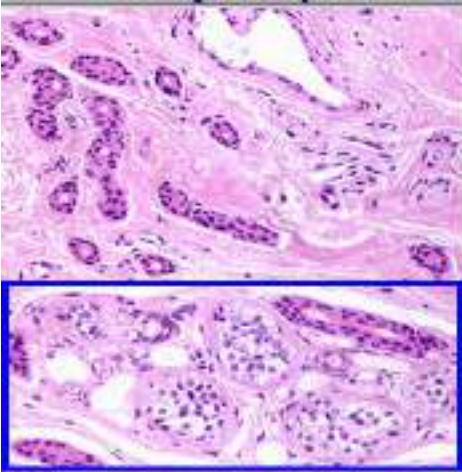
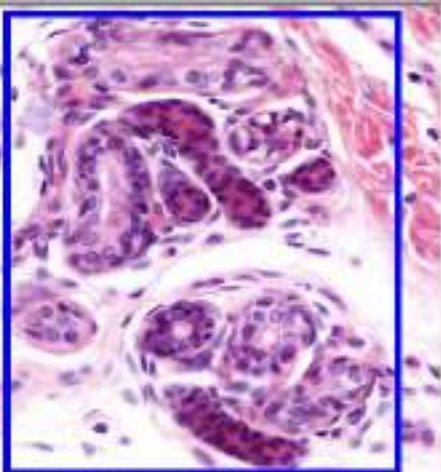





3 of 11

The upper portion of the left image contains two or three ducts which meander through the dermis, thus producing isolated profiles in section. Other portions of the darkly staining ducts can be seen coiled within the secretory units.

click to identify:

- > Ducts >
- > Secretory units >
- > Blood vessels >
- > Nerve
- Next image

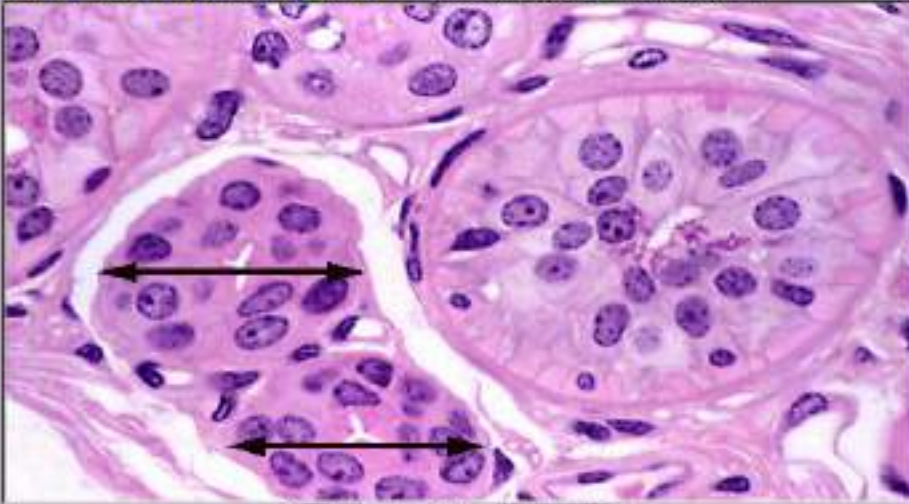




3 of 11

The secretory portions of glands are also visible; coiled with the beginnings of the ducts. The secretory tubules stain paler than do the ducts.

click to identify:

- > Ducts >
- > Secretory units >
- > Blood vessels >
- > Nerve
- Next image

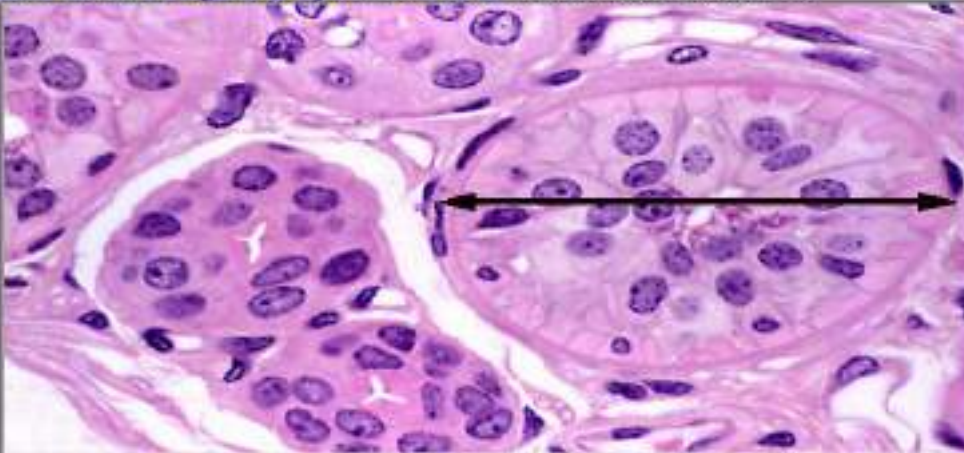


4 of 11

Eccrine sweat gland – The secretory portion of the gland is composed of three cell types, two of which are secretory: clear cells, which contain abundant glycogen, and dark cells, which contain secretory granules. Both secretory cell types lie on the basement membrane. 1000x

click to identify:

- > Duct
- Secretory portion
- Secretory granules
- Myoepithelial > cells

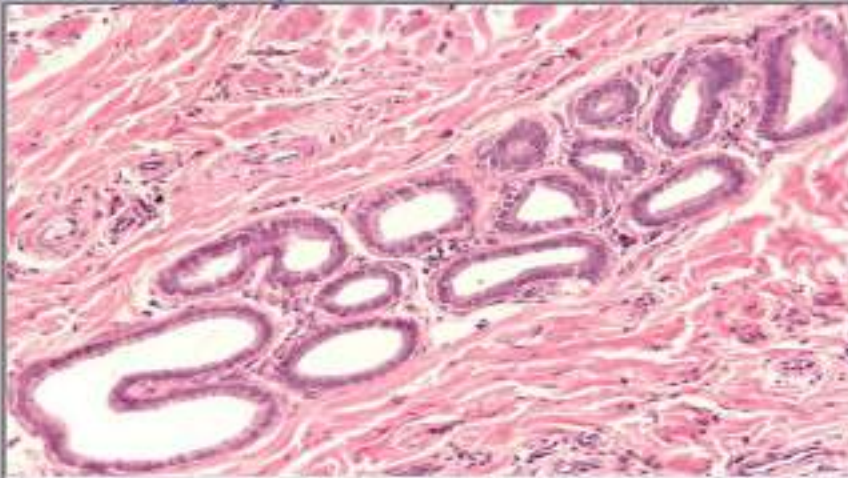


4 of 11

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click to identify:

- Duct
- > Secretory portion
- Secretory granules
- Myoepithelial > cells

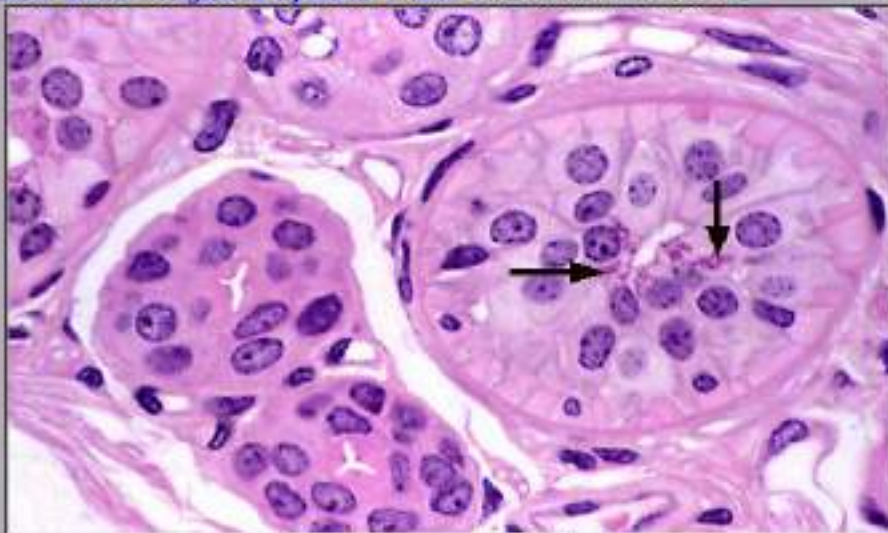


6 of 11

Apocrine sweat gland -- Apocrine sweat glands are located in the axillary, areolar and anal regions. Contrary to their name, they secrete a thick, protein-rich secretion by the merocrine mode. These secretions acquire a distinctive odor by the action of bacteria on the skin surface. The duct of an apocrine sweat gland empties into the hair follicle. 400x

click to identify:

Apocrine sweat gland

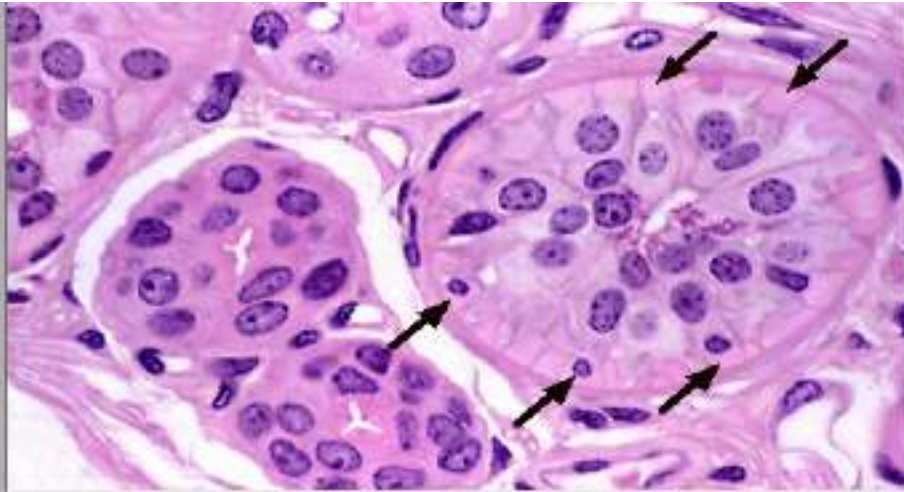


4 of 11

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click to identify:

Duct
Secretory portion
Secretory granules
Myoepithelial cells

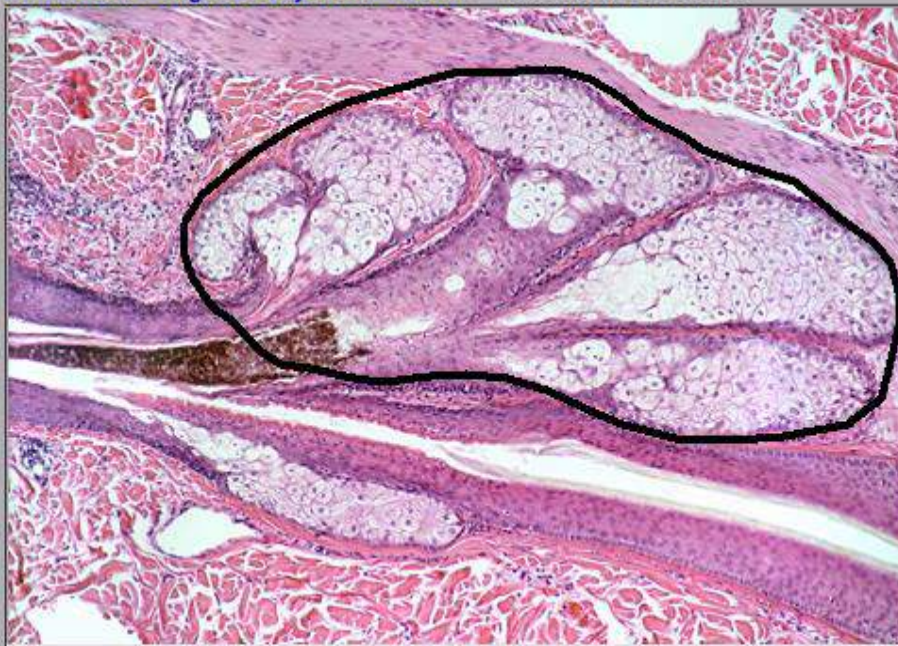


Duct
 Secretory portion
 Secretory granules
 > Myoepithelial >
 cells

4 of 11

The third cell type is the contractile myoepithelial cell, whose long extensions wrap around the tubule. These epithelial cells possess contractile filaments and are located at the periphery of the tubule within the basement membrane. Their contractions assist in expulsion of the gland contents. Myoepithelial cells are also present in mammary glands, which are modified sweat glands.

Main Menu > Organs & Systems > Skin > Associated Structures

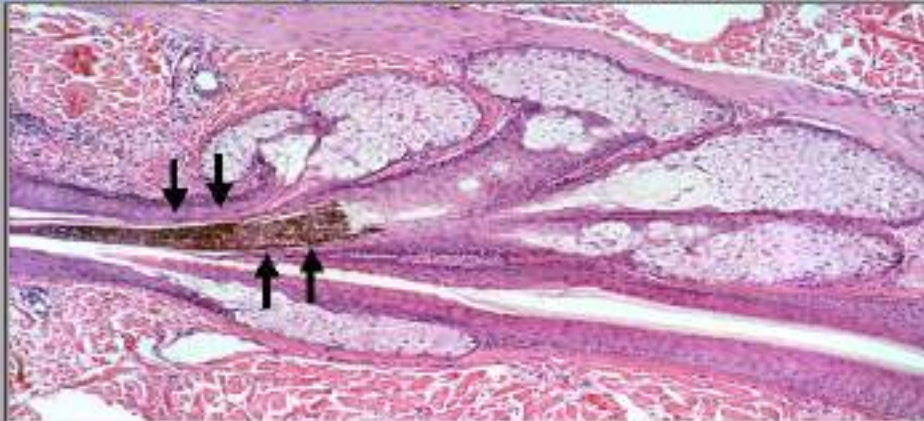


click to identify:

> Sebaceous gland
 Duct
 Acini
 Hair follicle
 Sebum
 Next image

8 of 11

Sebaceous gland -- Sebaceous glands are most often associated with hair follicles and, thus, do not occur in thick skin. These glands are simple branched acinar glands that secrete a thick oily material, sebum, into the upper portion of hair follicles. 100x

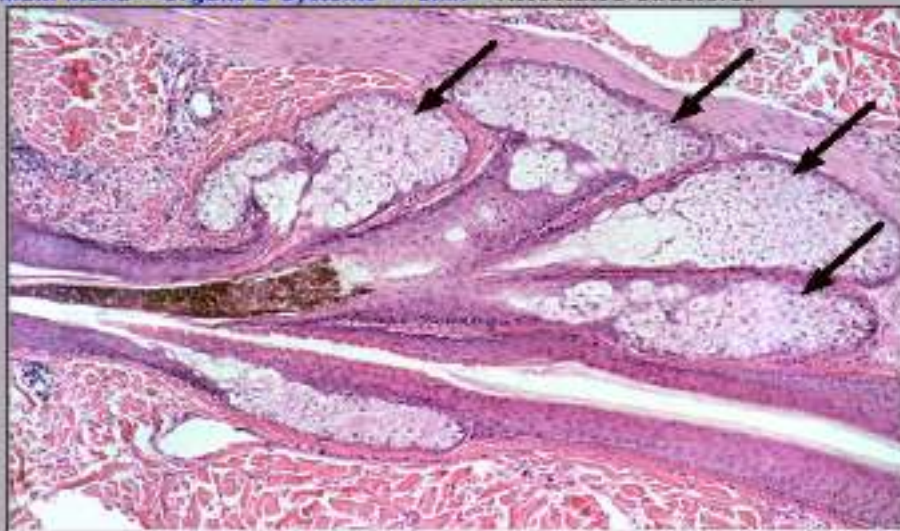


8 of 11

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click to identify:

- Sebaceous gland
- > Duct
- Acini
- Hair follicle
- Sebum
- Next image



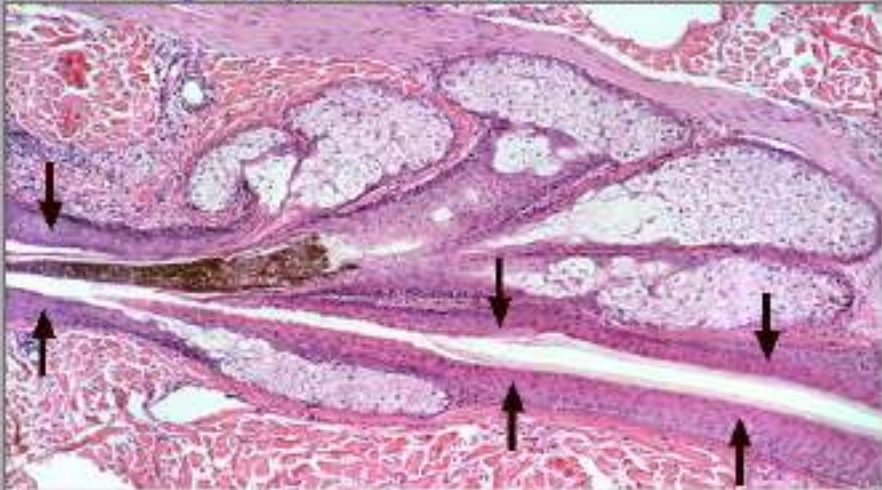
8 of 11

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click to identify:

- Sebaceous gland
- Duct
- > Acini
- Hair follicle
- Sebum
- Next image

Main Menu > Organs & Systems > Skin > Associated Structures



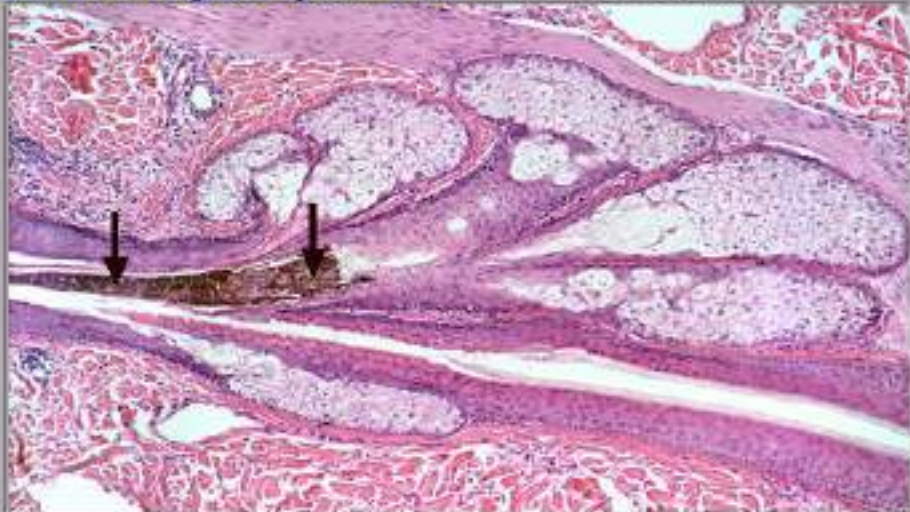
click to identify:

- Sebacous gland
- Duct
- Acini
- > Hair follicle
- Sebum
- Next image

8 of 11

Sebacous gland – Sebaceous glands are most often associated with hair follicles and, thus, do not occur in thick skin. These glands are simple branched acinar glands that secrete a thick oily material, sebum, into the upper portion of hair follicles. 100x

Main Menu > Organs & Systems > Skin > Associated Structures

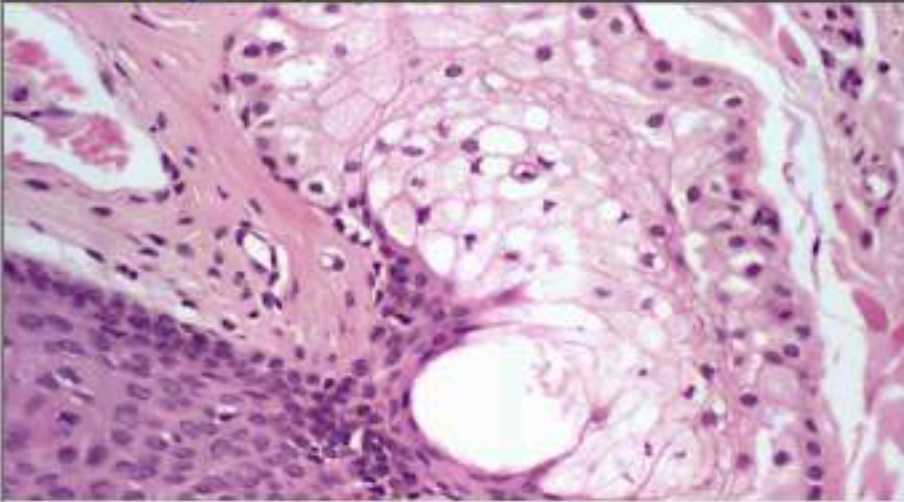


click to identify:

- Sebacous gland
- Duct
- Acini
- Hair follicle
- > Sebum
- Next image

8 of 11

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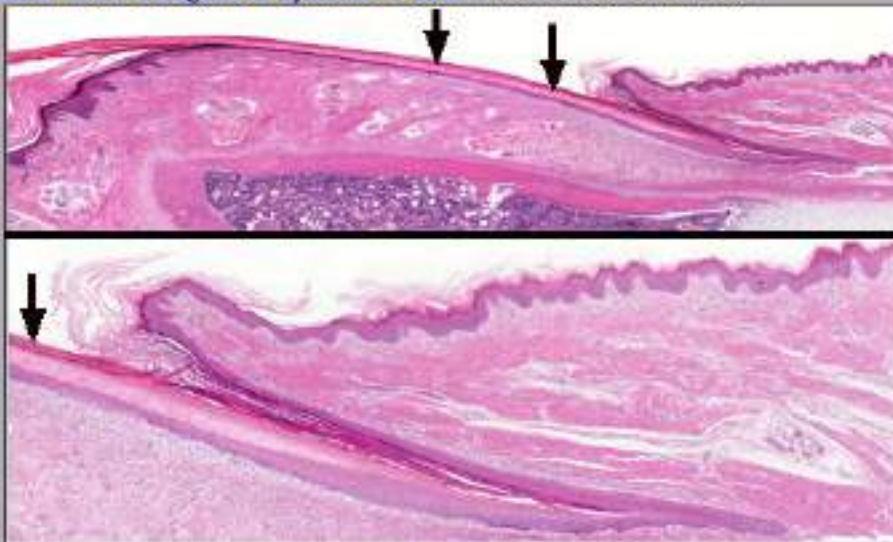


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Sebaceous gland – Sebaceous glands secrete by the holocrine mode. Cells at the periphery proliferate and, as they are pushed toward the center of the acinus, accumulate lipid (sebum) and degenerate, eventually filling the center of the acinus. These dead cells, and the sebum they contain, are released into a short duct opening onto the hair shaft. 400x

click to identify:

Proliferating cells
Lipid accumulation
Dead cells
Duct
Hair follicle

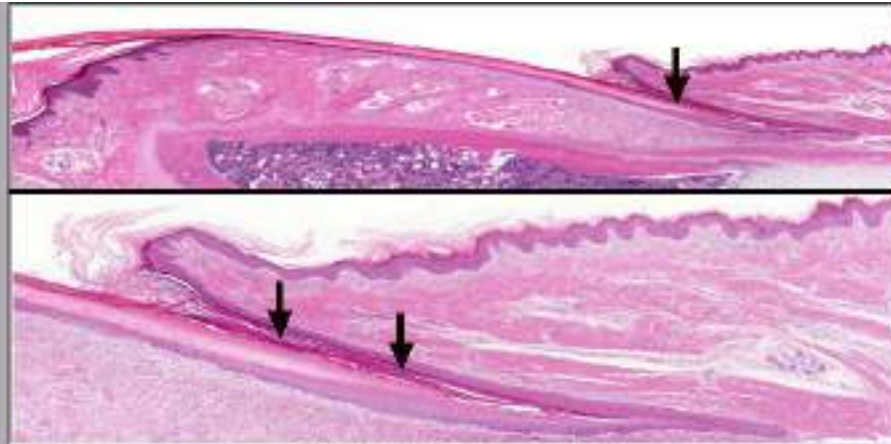


11 of 11

Fingernail – The fingernail (nail plate) corresponds to stratum corneum and rests on a nail bed of strata basale and spinosum. The nail root lies in an epidermal fold, whose stratum corneum forms the eponychium (cuticle). Beneath the root is the nail matrix, the germinative portion of the nail. The hyponychium, a thickened epidermis, secures the nail at the fingertip. Upper: 4x; Lower: 20x

click to identify:

Lower image
Nail plate
Nail root
Nail bed
Nail matrix
Eponychium
Hyponychium
Epidermis
Dermis
Bone

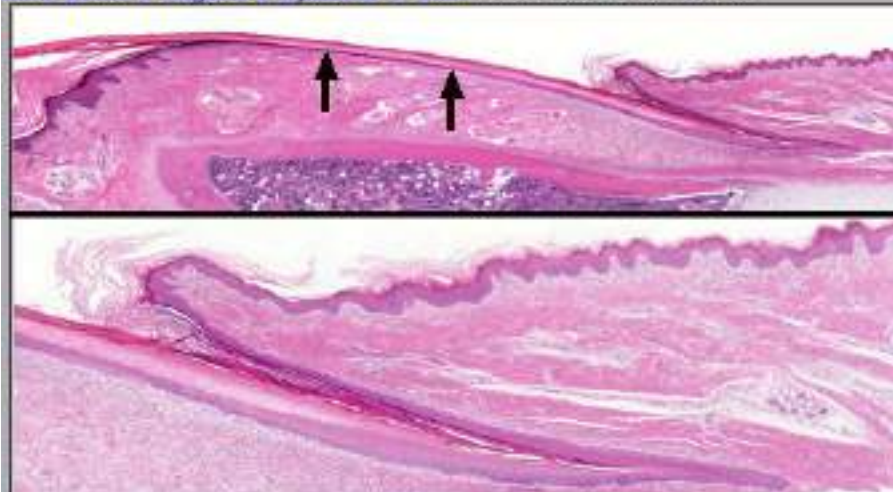


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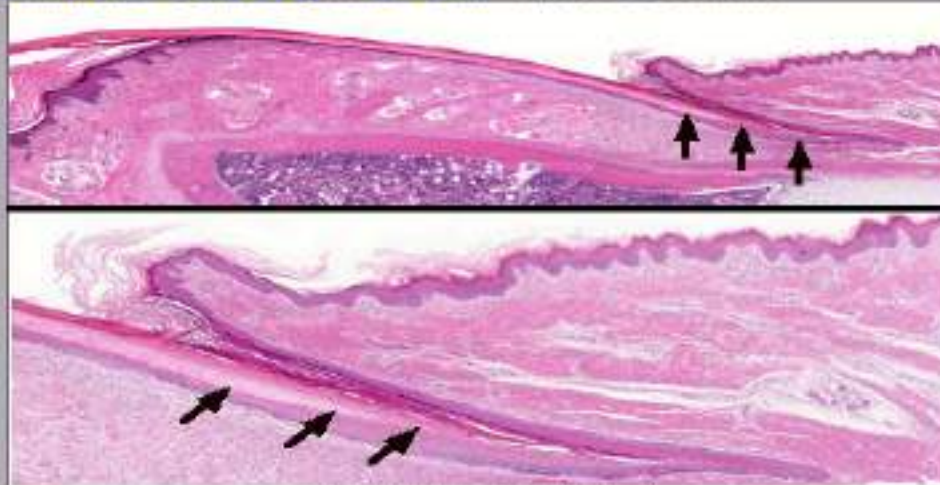
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click to identify:

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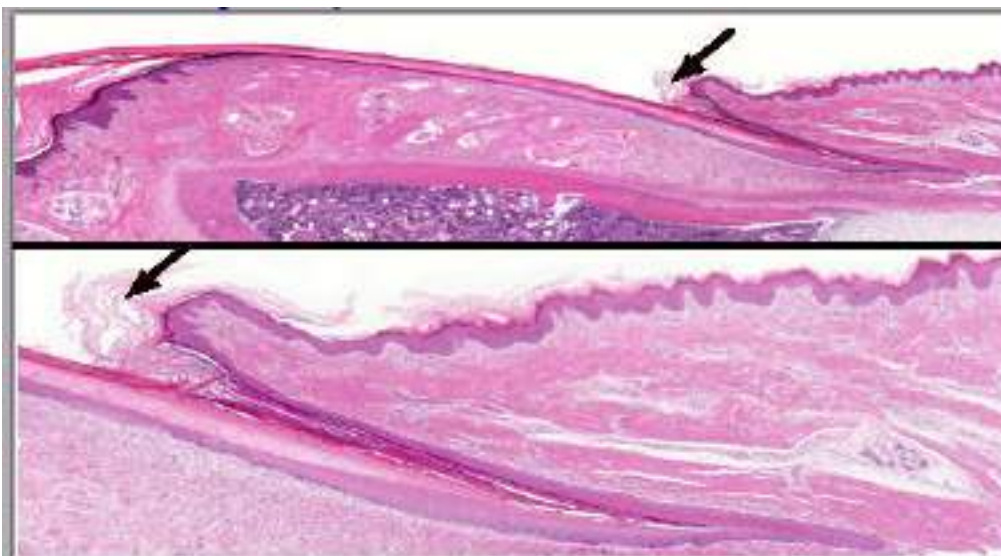


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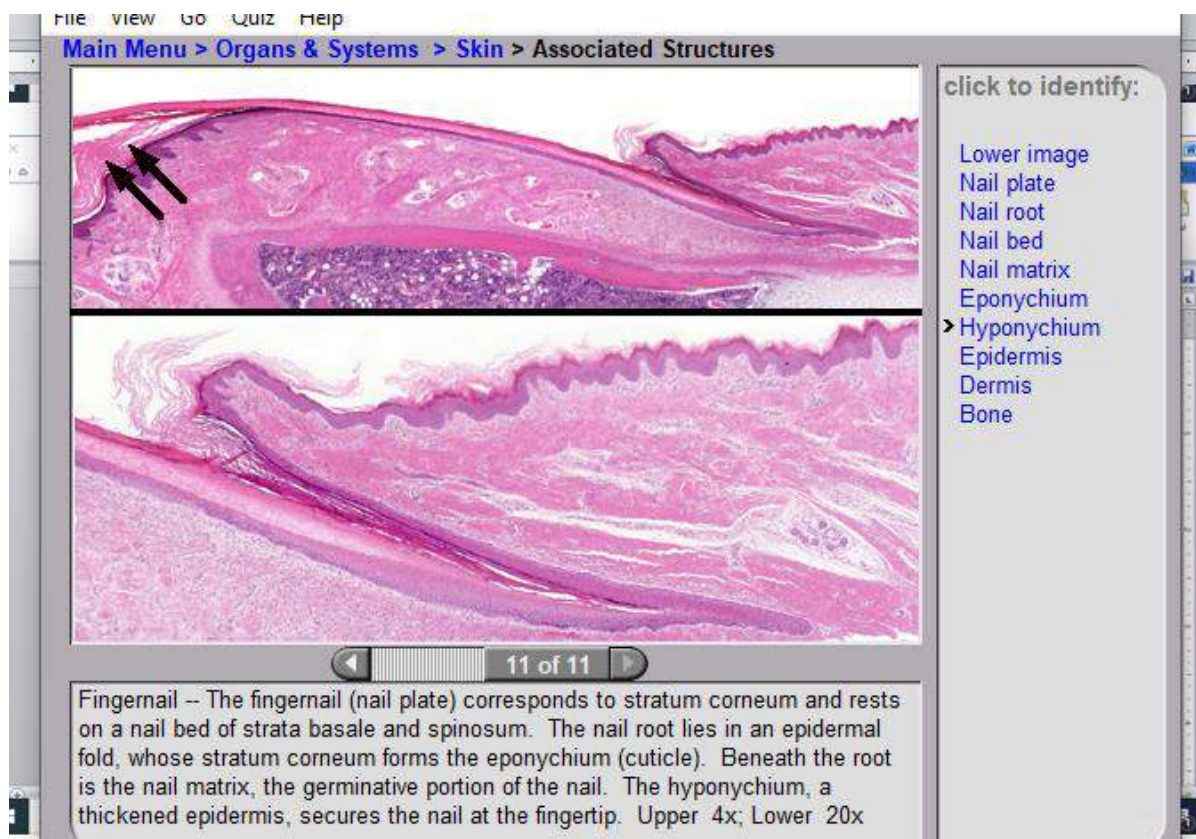
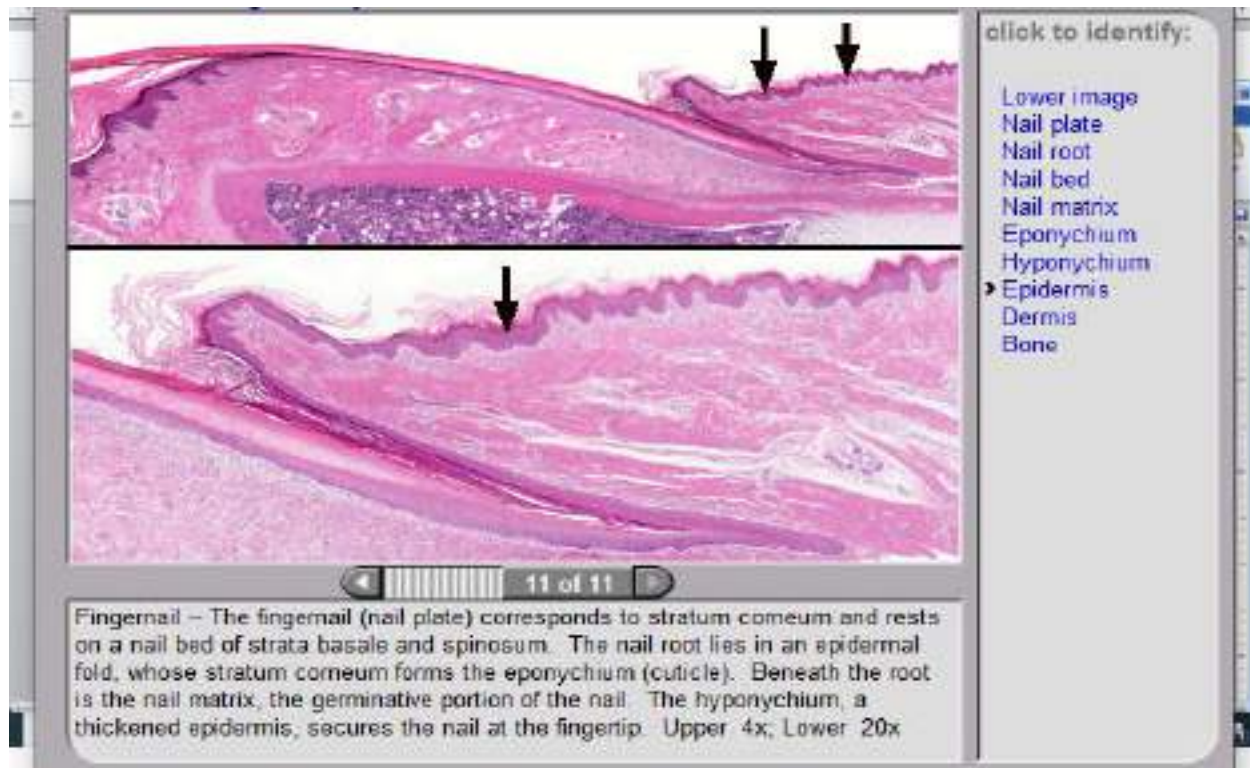


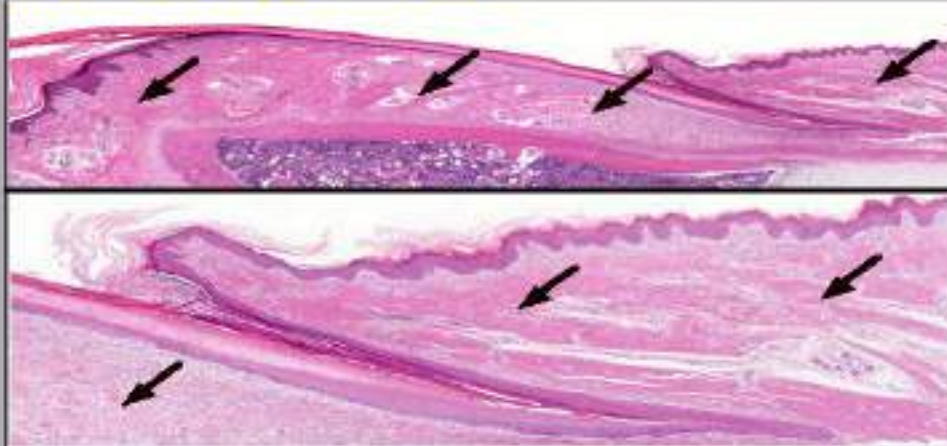
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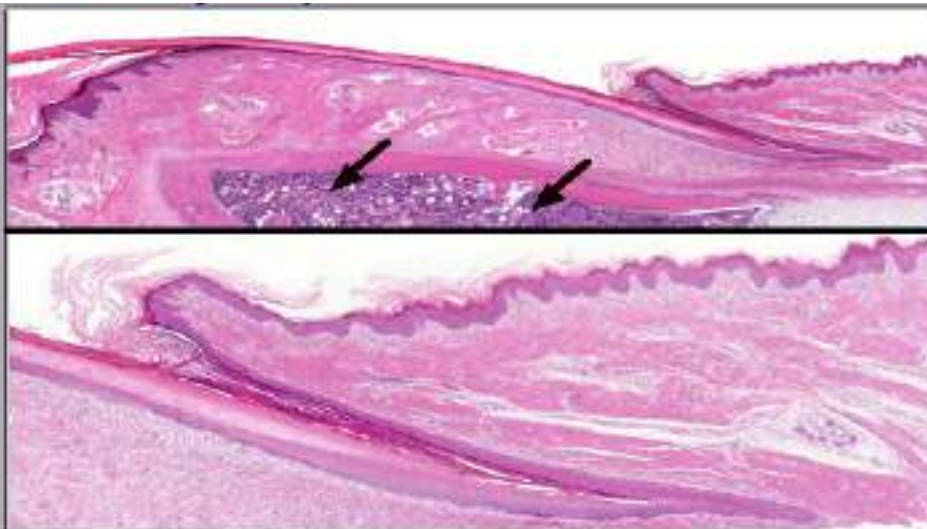




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SUPPORTING CONNECTIVE TISSUES

CARTILAGE

GENERAL CONCEPTS

- I. Composition is similar to that of all connective tissues.
 - A. *Cells*.
 - B. *Extracellular matrix* consisting of fibers and ground substance.
- II. Cartilage is avascular and possesses no lymph vessels or nerves.
- III. Types of cartilage
 - A. Hyaline. Provides nonrigid support.
 - B. Elastic. Provides support with large amount of flexibility.
 - C. Fibrocartilage. Provides strength in areas under stress.

COMPONENTS OF CARTILAGE

- I. *Perichondrium*. Layer of connective tissue proper surrounding cartilage tissue. Layers include
 - A. *Fibrous layer*. Outer portion, composed of dense connective tissue, serves as a source of reserve cells for the chondrogenic layer.
 - B. *Chondrogenic layer*. Inner, more cellular portion contains chondroblasts and blends imperceptibly into cartilage tissue proper.

II. Cells

A. *Chondroblasts*

1. Lie on the surface of cartilage in the chondrogenic layer of perichondrium.
2. Secrete extracellular matrix around themselves, thereby becoming chondrocytes.

B. *Chondrocytes*

1. Are chondroblasts that have surrounded themselves with matrix.
2. Lie within cartilage in potential spaces called lacunae.
3. Secrete and maintain extracellular matrix.
4. Frequently form *isogenous groups*, a cluster of chondrocytes, resulting from the proliferation of a single chondrocyte.

III. *Extracellular matrix*. Both flexible and noncompressible.

A. Composition

1. *Fibers*. Collagen fibrils and fibers predominate in hyaline cartilage and fibrocartilage, respectively; elastic fibers predominate in elastic cartilage.
2. *Ground substance*. Tissue fluid surrounds proteoglycan aggregates bound to collagen fibrils by electrostatic interactions. Collectively, these form a firm gel, which resists compressive forces.

B. Subdivisions

1. *Territorial matrix* immediately surrounds chondrocytes. This matrix stains more intensely with hematoxylin due to the high concentration of proteoglycans.
2. *Interterritorial matrix* is the lighter-staining matrix outside the territorial matrix and between isogenous groups.

GROWTH OF CARTILAGE

- I. *Appositional* growth occurs at the surface of cartilage. New cartilage is added (apposed) to the surface of preexisting cartilage by the activity of chondroblasts lying in the chondrogenic layer of the perichondrium.
- II. *Interstitial* growth occurs from within cartilage tissue. Chondrocytes produce additional matrix and divide, forming isogenous groups.

TYPES OF CARTILAGE

I. *Hyaline cartilage*

- A. Is the most common cartilage type and is hyaline (glassy) in appearance.
- B. Contains type II collagen. Because of the small size of these fibrils and because they have the same refractive index as ground substance, they are not visible with the light microscope by conventional staining methods.
- C. Stains blue with conventional dyes, due to the relative abundance of its ground substance matrix.
- D. Possesses numerous isogenous groups.
- E. Function and distribution. Forms most of the cartilages of the body, comprises the fetal skeleton, attaches ribs to the sternum, forms epiphyseal plates, and lines articular surfaces. (The lack of a perichondrium on the articular cartilages provides a smooth, glassy articular surface.)

II. *Elastic cartilage*

- A. Has a visible network of interlacing elastic fibers in addition to collagen type II.
- B. Possesses fewer isogenous groups than does hyaline cartilage.
- C. Function and distribution. Pinna of ear, epiglottis, smaller laryngeal cartilages (i.e., present where flexibility and support are necessary).

III. *Fibrocartilage*

- A. Is a functional and structural intermediate between hyaline cartilage and dense connective tissue.
- B. Possesses abundant collagen type I fibers, arranged in either a regular or an irregular configuration. These collagen fibers cause this cartilage to stain pink with eosin.
- C. Has minimal ground substance. The ground substance that is present is usually located immediately around the chondrocytes.
- D. Possesses few isogenous groups.
- E. Combines great tensile strength with flexibility.
 - 1. Frequently found where a tendon or a ligament attaches to a bone (regular arrangement of fibers).
 - 2. Located in the pubic symphysis and knee cartilages (irregular fiber arrangement).

REGRESSIVE CHANGES IN CARTILAGE

- I. Occur in cartilage more frequently than in many other tissues.
- II. Regressive changes also occur in the hyaline cartilage of the epiphyseal plate and represent critical steps in endochondral bone formation.
- III. Stages of regression
 - A. Chondrocytes hypertrophy and secrete alkaline phosphatase that provides a calcifiable matrix.
 - B. Calcium phosphate is deposited in the matrix, prohibiting diffusion of nutrients to the chondrocytes.
 - C. Chondrocytes die, leaving behind empty lacunae and the calcified matrix.

STRUCTURES IDENTIFIED IN THIS SECTION

| | |
|----------------------------|-----------------------------------|
| Calcified cartilage matrix | Hypertrophy |
| Chondroblasts | Interterritorial matrix |
| Chondrocytes | Isogenous group |
| Collagen bundles | Lacunae |
| Elastic cartilage | Perichondrium |
| Elastic fibers | Perichondrium, chondrogenic layer |
| Fibrocartilage | Perichondrium, fibrous layer |
| Ground substance | Territorial matrix |
| Hyaline cartilage | |

SUPPORTING CONNECTIVE TISSUES: BONE

GENERAL CONCEPTS

- I. Bone
 - A. Provides structural support, giving shape and form to the body.
 - B. Enables movement through the action of muscles inserting on the bone.
 - C. Serves as a stored source for calcium and phosphate.
 - D. Contains bone marrow (myeloid tissue).

II. Histological preparation of bone

- A. *Ground bone preparation.* Unpreserved bone is ground to a thinness where light can be transmitted through it. Because no preservation has occurred, neither cells nor organic matrix survives. Lamellae, lacunae, canaliculi, and general architecture of inorganic matrix are well displayed.
- B. *Decalcified bone.* Cells are fixed (preserved) and inorganic matrix removed by decalcification. Good detail of organic matrix (cells, periosteum, etc.) is maintained, but lamellae and inorganic matrix are difficult to distinguish.

GROSS APPEARANCE OF BONE, MACROSCOPIC STRUCTURE

- I. *Compact bone.* Appears as a solid mass to the naked eye, covering the exterior of bones and forming the shaft of long bones.
- II. *Spongy or cancellous bone.* Gross appearance is like a sponge, with a labyrinth of bony spicules and intervening spaces that are filled with loose connective tissue or red marrow and blood vessels. Spongy bone is located in the interior of bones.

ARCHITECTURE OF A LONG BONE

- I. The *diaphysis* (shaft), composed of compact bone, is hollow, is usually lined by a thin band of spongy bone, and is filled with yellow marrow in the adult.
- II. An *epiphysis*, the knob at either end of the diaphysis, is composed of a thin rim of compact bone. The spongy bone in its interior houses red marrow.
- III. *Metaphysis.* Flared region between diaphysis and epiphysis.
- IV. *Epiphyseal plate.* Hyaline cartilage separating epiphysis and metaphysis in growing bones. Growth in bone length occurs as hyaline cartilage in the epiphyseal plate goes through various stages of regression, providing a framework on which bone is deposited. When the hyaline cartilage in the epiphyseal plate is exhausted, growth stops. The epiphysis and metaphysis fuse in the adult, leaving an epiphyseal line as a remnant of the epiphyseal plate.

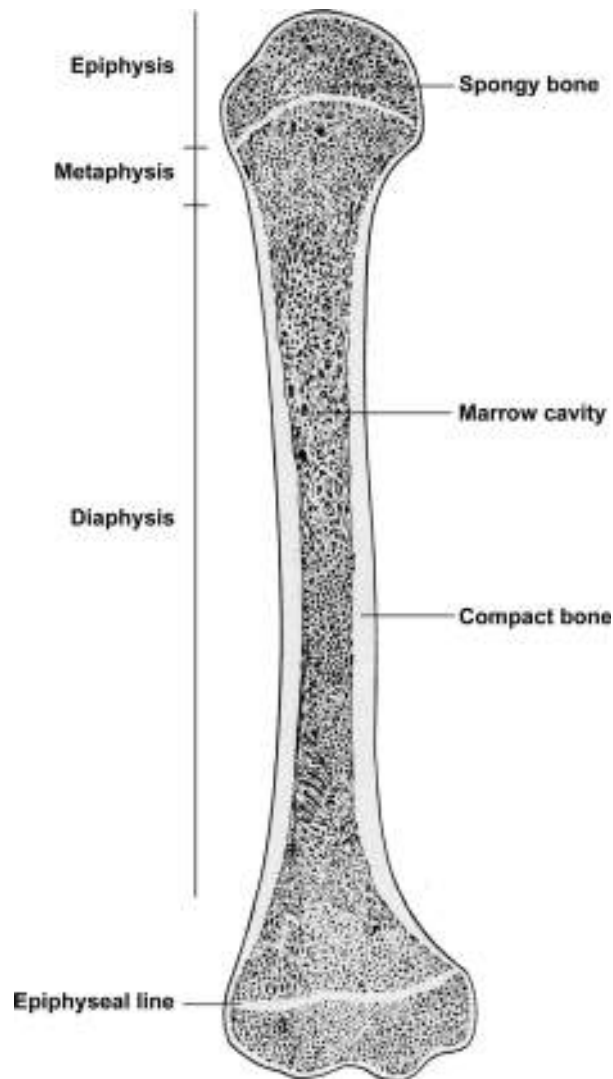


FIGURE 5.1. Longitudinal section of an adult long bone.

V. Marrow

- A. *Red marrow*, found in all bones of the fetus, is restricted to spongy bone areas of selected bones in the adult and contains hemopoietic tissue that forms blood cells.
- B. *Yellow marrow*, found in the shafts of long bones in the adult, consists mainly of adipose connective tissue that retains the potential to become red marrow under hemorrhagic stress.

- VI. *Articular cartilage* is composed of hyaline cartilage and covers articular surfaces of bone. This cartilage does not possess a perichondrium; the glassy, smooth cartilage provides a good articulating surface.

COMPONENTS OF BONE

I. *Extracellular matrix*

A. *Organic portion, osteoid*. Secreted by osteoblasts

1. Collagen type I *fibers* comprise the majority of the organic matrix. Their predominance causes bone to stain pink with eosin.
2. *Ground substance* is minimal, composed of glycosaminoglycans such as chondroitin sulfate, keratan sulfate, and some glycoproteins that avidly bind calcium.

B. *Inorganic portion*. Calcium and phosphate, in the form of hydroxyapatite crystals, are deposited along the collagen fibrils and form 50% of the dry weight of bone. This ossified matrix renders bone impermeable to diffusion of nutrients and requires that bone be well vascularized.

II. Cells

A. *Osteoblasts*

1. Located on all exterior surfaces of bone as the innermost portion of the periosteum or in the endosteum lining all interior bony surfaces.
 - a. Inactive osteoblasts are flattened cells with heterochromatic nuclei.
 - b. Active osteoblasts are stellate and contain organelles necessary for protein, primarily collagen, production. These cells synthesize high levels of alkaline phosphatase.
2. Function to synthesize bone
 - a. Secrete osteoid first.
 - b. In the presence of alkaline phosphatase, osteoblasts facilitate the deposition of calcium phosphate, thus mineralizing the osteoid.

B. *Osteocytes*

1. Are osteoblasts that have completely surrounded themselves by bony matrix and, therefore, must lie within, rather than on, bone tissue. These flattened, inactive cells lie in *lacunae* (spaces) in the bone and extend long processes from the cell body. These processes

lie in narrow bony tunnels called *canaliculi* and connect, via gap junctions, with adjacent osteocytes and/or osteoblasts at the bone surface.

2. Function to transport materials between blood and bone and to maintain surrounding matrix; they do not divide or secrete matrix.

C. *Osteoclasts*

1. Are large cells with 15–20 or more nuclei and vacuolated, frothy cytoplasm. A ruffled border, the highly enfolded cell membrane facing the bone, is the site of bone resorption.
2. Are located on internal surfaces as part of the endosteum or on external surfaces as part of the osteogenic layer of the periosteum. Osteoclasts lie in depressions in the bone, *Howship's lacunae*, which form as osteoclasts resorb bone.
3. Resorb bone via the acid phosphatase and proteolytic enzymes they secrete.

III. Surface coverings

A. *Periosteum*. Double layer of connective tissue surrounding the outer surface of bones, except for articular surfaces.

1. Layers

- a. *Fibrous layer*. Outer layer of dense connective tissue that serves as a reserve cell source for the osteogenic layer.
- b. *Osteogenic layer*. Inner, more cellular layer, contains osteoblasts, osteoclasts, and/or osteoprogenitor cells. Site of bone deposition and resorption.

2. Well vascularized and richly innervated.

B. *Endosteum*

1. Is composed of a single row of osteoblasts, osteoclasts, and/or osteoprogenitor cells that line all interior surfaces of bone except for lacunae and canaliculi.
2. Serves as a means of bone growth and/or resorption.

MICROSCOPIC APPEARANCE OF BONE (RELATED TO THE AGE OF A BONE)

I. *Woven or immature bone* is the first bone deposited.

- A. May be either spongy or compact.

- B. Referred to as woven bone because fibers are deposited in a random array.
 - C. Contains osteocytes that are more numerous and spherical than those of lamellar bone. These osteocytes are not in any orderly arrangement.
 - D. Is less well mineralized than lamellar bone and, therefore, appears bluer than lamellar bone with hematoxylin and eosin stains.
 - E. Is usually resorbed and replaced by lamellar bone.
- II. *Lamellar or mature bone*
- A. Replaces most woven bone or may be deposited *de novo*.
 - B. May be either spongy or compact.
 - C. Is referred to as lamellar bone because the matrix is deposited in layers or lamellae.
 - D. Fibers are deposited in parallel array within a lamella.
 - E. Osteocytes are fewer and flatter than those in woven bone and are organized in rows between the lamellae.
 - F. Better mineralized than woven bone.
 - G. Bone is not a static structure and is constantly being resorbed and reconstructed. Therefore, lamellar bone is also resorbed and reconstructed throughout life.

ARCHITECTURE OF ADULT, COMPACT LAMELLAR BONE

- I. *Outer circumferential lamellae*. Stacks of lamellae extend at least partially around the outer circumference of a long bone. Deposition of these lamellae by the periosteum results in increased thickness in the wall of the diaphysis.
- II. *Inner circumferential lamellae*. Stacks of lamellae extend at least partially around the inner circumference of a long bone facing the marrow cavity. Deposition of these lamellae by the endosteum results in increased thickness of the wall of the diaphysis.
- III. *Haversian systems, osteons*
 - A. Primary structures of compact lamellar bone.
 - B. Cylinders of concentric lamellae, deposited by endosteum, that run parallel to the long axis of a bone.
 - C. Composition

1. Central *Haversian canal*
 - a. Appears round in cross-section with a smooth periphery.
 - b. Contains a blood vessel(s) and loose connective tissue.
 - c. Is lined with an endosteum.
2. Concentric lamellae (4–20) surround the Haversian canal
 - a. Collagen fibers are in parallel alignment within a single lamella, wrapping helically around the Haversian canal.
 - b. Pitch of the helix varies with each lamella in the osteon.
- D. Provides great strength to a long bone.
- E. An osteon is formed by the centripetal deposition of the concentric lamella (i.e., outer lamella is the oldest).
- IV. Additional lamellae/structures associated with adult, compact lamellar bone
 - A. *Interstitial lamellae*. Portions of Haversian systems that remain after resorption of the rest of the osteon. These lamellae are interposed between other, complete Haversian systems.
 - B. *Volkman's canals*. Channels oriented perpendicularly between adjacent Haversian canals, interconnecting these canals with each other and with the surfaces of bone. Volkmann's canals contain blood vessels that transport blood from the surface of bone to blood vessels within Haversian canals.
 - C. *Cement lines*. Thin, refractive lines that are collagen poor and stain, therefore, with hematoxylin. Cement lines are located
 1. Around Haversian systems, demarcating where resorption stopped and the formation of a new osteon began.
 2. Beneath and between circumferential lamellae, denoting where deposition of lamellae halted for a period of time and then began again.

BONE GROWTH, DEPOSITION, AND RESORPTION

BONE GROWTH

- I. New, adult bone is always laid down on preexisting bone or cartilage.
- II. Bone growth is always appositional, with either endosteum or periosteum laying down lamellae of bone. Interstitial growth is impossible in bone

because its rigid, ossified matrix does not allow osteocytes to secrete additional matrix or to divide.

BONE DEPOSITION

- I. Newly deposited bone assumes the shape of the bone or cartilage on which it is deposited.
- II. In spongy, lamellar bone, new lamellae are laid down by osteoblasts in the endosteum located at the periphery of each trabecula, thus increasing its thickness.
- III. In compact lamellar bone, new lamellae are laid down either as outer circumferential lamellae by osteoblasts in the periosteum or as inner circumferential lamellae and Haversian systems (osteons) by the endosteum.

BONE RESORPTION

- I. Definition. Removal of bone by osteoclasts for remodeling during growth and/or to mobilize calcium throughout life.
- II. Resorption process
 - A. Osteoclasts on the periosteal and endosteal surfaces resorb bone from bone surfaces.
 - B. *Resorption canal*
 1. Is a cylindrical, longitudinal tunnel formed as compact bone in the interior of bone is resorbed.
 2. Appears in cross-section as an irregularly shaped, bony surface lined with an endosteum containing osteoclasts.
 3. Usually extends past cement lines, eroding through portions of several osteons. Therefore, remnants of resorbed osteons may surround the resorption canal.
 4. Is not lined by concentric lamellae as are osteons.
 5. When resorption stops, osteoblasts begin filling in a resorption canal by centripetal (from outside to inside) deposition of new lamellae, forming a new osteon. The newest lamella of this secondary osteon is the one adjacent to the Haversian canal.
 6. Remains of partially resorbed Haversian systems around this secondary osteon are called interstitial lamellae.

BONE FORMATION (OSSIFICATION)

INTRAMEMBRANOUS BONE FORMATION

- I. Definition. Bone formation by a connective tissue membrane. No cartilage precedes this bone formation. Bone formed may be woven or lamellar, spongy or compact.
- II. Connective tissue membranes involved in intramembranous ossification include mesenchyme in the fetus and periosteum or endosteum in both the fetus and the adult.
- III. Occurrence of intramembranous bones
 - A. Bone laid down by mesenchyme forming the flat bones of the skull and part of the mandible.
 - B. Bone laid down by the periosteum or endosteum.
- IV. Types of intramembranous ossifications
 - A. Ossification from mesenchyme in the fetus.
 1. Mechanism of ossification
 - a. Mesenchymal cells cluster and differentiate into osteoblasts that secrete organic matrix (osteoid) around themselves. This matrix becomes mineralized, thereby forming bone.
 - b. Bone formed is woven, spongy bone.
 2. Many areas of this spongy, woven bone are converted to compact, lamellar bone by the filling in of the spaces between trabeculae with osteons.
 3. Other areas of this spongy bone are not converted to compact, however, such as the spongy bone forming the diploe of flat bones of the skull.
 - B. Ossification from a connective tissue membrane, such as periosteum or endosteum, both in the fetus and in the adult.
 1. Mechanism of ossification. Osteoblasts in the endosteum or in the osteogenic layer of the periosteum secrete and lay down lamellae of bone.
 2. Lamellae conform to the shape of the bone or cartilage on which they are deposited.
 - a. Lamellae deposited around a cylindrical cavity within bone form an osteon.

- b. Circumferential lamellae form on the inner and outer surfaces of bone from the endosteum or periosteum, respectively.
- c. Endosteum adds lamellae to trabeculae of spongy bone.

ENDOCHONDRAL BONE FORMATION

- I. Definition. Formation of bone by replacement of a preexisting hyaline cartilage template. The cartilage must first undergo regressive changes that produce a framework upon which bone is deposited (ossification).
- II. Bones formed endochondrally include bones at the base of the skull, long bones, vertebrae, pelvis, and ribs.

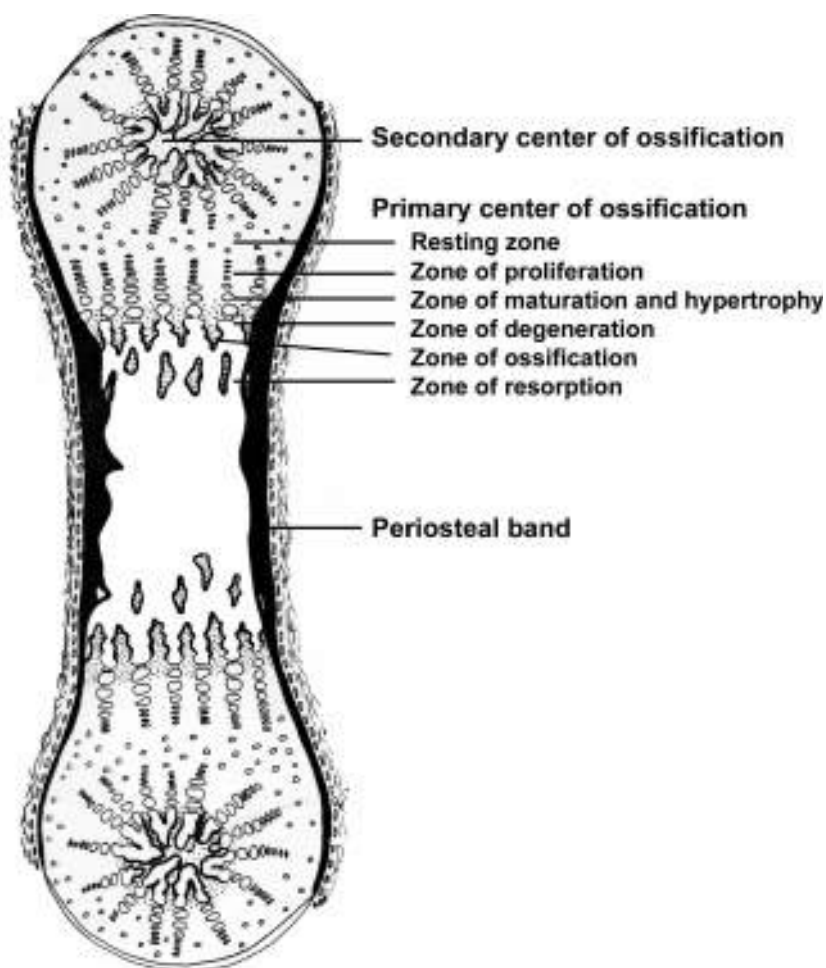


FIGURE 5.2. Zones of endochondral ossification.

III. Events occurring before ossification begins

- A. Hyaline cartilage template of the future bone is formed in the fetus. This cartilage is surrounded by a perichondrium and enlarges by appositional and interstitial growth as the fetus grows.
- B. Regressive changes begin in cartilage cells in the central, diaphyseal region of the template at what will become the primary center of ossification.
 - 1. Chondrocytes mature, greatly hypertrophy at the expense of surrounding matrix, and begin to secrete alkaline phosphatase.
 - 2. The presence of alkaline phosphatase leads to the calcification of the cartilage matrix, making it impermeable to metabolites.
 - 3. Chondrocytes die, leaving behind their lacunae separated by spicules of calcified cartilage matrix.
 - 4. The oxygen supply to the fetus is increasing as the fetal circulatory system becomes functional, supplying blood to the hyaline cartilage template of the future bone.

IV. Stages of ossification

A. Formation of a *periosteal band* or *collar*

- 1. Around the middle of the shaft of the cartilage template, the chondroblasts differentiate into osteoblasts and begin secreting a bony, rather than a cartilaginous, band called the periosteal band or collar. This cylinder of bone is formed by intramembranous ossification because it does not replace cartilage that has gone through regressive changes. The perichondrium surrounding the periosteal collar is now called a periosteum.
- 2. The remainder of the cartilage template is surrounded by a perichondrium.

B. *Primary center of ossification*

- 1. One of the fetal arteries, called the *periosteal bud*, and its surrounding mesenchymal cells penetrate the diaphyseal region of the cartilage template into the area of the degenerating calcified cartilage.
- 2. Mesenchymal cells accompanying the artery differentiate into osteoblasts that deposit bone on the spicules of the calcified cartilage framework. Resulting spicules consist of
 - a. A core of calcified cartilage that stains blue with hematoxylin.
 - b. An outer perimeter of woven bone that stains pink with eosin.

3. Some of the spicules of cartilage and bone are resorbed to form the future marrow cavity.
4. This cartilage degeneration–bone deposition process continues toward either epiphysis, becoming more organized into discrete zones, and forming the epiphyseal plate.
 - a. *Resting zone* of “normal” hyaline cartilage.
 - b. *Zone of proliferation* where isogenous groups of chondrocytes actively divide, forming linear isogenous groups. This zone maintains cartilage thickness.
 - c. *Zone of maturation, hypertrophy, and calcification* where chondrocytes mature, hypertrophy, and produce alkaline phosphatase with the subsequent *calcification* of the cartilage matrix.
 - d. *Zone of degeneration* where chondrocytes die, leaving empty lacunae surrounded by vertically oriented spicules of calcified cartilage.
 - e. *Zone of ossification* where bone is deposited on the calcified cartilage spicules immediately adjacent to the bony diaphysis, thus increasing the length of that diaphysis.
 - f. *Zone of resorption* where calcified cartilage–bone spicules are resorbed to form the marrow space.
- C. *Secondary center of ossification* occurs in each epiphysis; ossification follows a similar pattern as that at the primary center except
 1. No periosteal band is formed.
 2. Ossification occurs in a radial manner from the original center of the secondary center of ossification.
 3. Bone resorption does not occur; thus, spongy bone permanently fills the epiphyses.
 4. Ossification does not replace articular cartilage.
- V. Growth in length continues from epiphyseal plates, which
 - A. Are established by formation of the primary and secondary centers of ossification.
 - B. Are composed of hyaline cartilage showing the zonations described above.
 - C. Are located between each epiphysis and metaphysis.
 - D. Maintain a constant thickness throughout growth due to equivalent activity in the zones of proliferation and resorption.

E. Are depleted at appropriate developmental stages as cartilage proliferation stops and the epiphyseal plate can no longer perpetuate itself. Spongy bone replaces the epiphyseal plate, leaving an epiphyseal line as its remnant. This process is referred to as closure of the epiphyseal plate.

STRUCTURES IDENTIFIED IN THIS SECTION

| | |
|-----------------------|--------------------------------|
| Bone tissue | Epiphyseal plate |
| Blood vessels | Epiphysis |
| Bone marrow | Flat bone, diploe |
| Canaliculi | Flat bone, inner table |
| Compact bone | Flat bone, outer table |
| Decalcified bone | Hyaline cartilage |
| Ground bone | Long bone |
| Howship's lacunae | Metaphysis |
| Intercellular matrix | Periosteum, osteogenic layer |
| Lacunae | Spongy woven bone |
| Lamellae of bone | Suture |
| Lamellar bone | Deposition and resorption |
| Organic matrix | Cement lines |
| Osteoblasts, active | Haversian canal |
| Osteoblasts, inactive | Haversian canal contents |
| Osteoclasts | Inner circumferential lamellae |
| Osteocytes | Interstitial lamellae |
| Osteoid | Osteon (Haversian system) |
| Periosteum | Outer circumferential lamellae |
| Spicules | Resorption canal |
| Spongy bone | Canaliculi |
| Woven bone | Spongy lamellar bone |
| Organ structures | Spongy woven bone |
| Articular cartilage | Formation |
| Diaphysis | Endochondral formation |
| Endosteum | Calcified cartilage |

Chapter 15

URINARY SYSTEM

COMPONENTS

- I. **Kidneys**. Contain the **uriniferous tubules**, which consist of nephrons and a system of collecting ducts; filter blood and produce urine
- II. **Ureters**. Muscular tubes that collect urine output from the kidney and carry it to the urinary bladder
- III. **Urinary bladder**. Hollow muscular organ that stores urine
- IV. **Urethra**. Tube that drains urine from urinary bladder to the exterior

FUNCTIONS OF THE URINARY SYSTEM

- I. Excretion of waste products of metabolism
- II. Regulation and maintenance of the fluid volume of the body Regulation of acid-base balance
- III. Regulation of salt concentrations and other compounds in body fluid
- IV. Production of renin, an enzyme that influences blood pressure

MACROSCOPIC ORGANIZATION OF THE KIDNEY

- I. **Cortex**. Broad outer zone of kidney
 - A. Subdivisions
 - 1. **Cortical labyrinth**. "True" cortical tissue
 - 2. **Medullary rays**. Medullary tissue located in the cortex
 - B. Contains renal corpuscles, portions of renal tubules, and collecting ducts
- II. **Medulla**. Deep to cortex
 - A. Subdivisions
 - 1. **Renal pyramids**. Inverted cones whose bases are adjacent to the cortex;

send "stripes" of medullary tissue into the cortex forming the medullary rays

2. **Renal columns**. Extensions of cortical tissue between renal pyramids

B. Consists of portions of renal tubules and collecting ducts

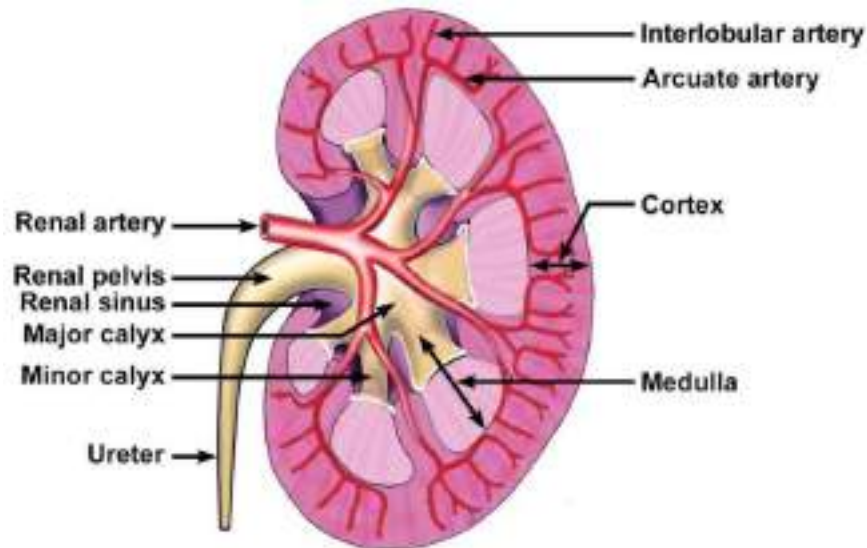


FIGURE 15.1. Extrarenal passageways and vascular supply of the kidney.

III. Renal lobulations

- A. **Renal lobe**. A medullary pyramid, the surrounding renal column extending to the interlobar vessels, and the overlying cortical tissue
- B. **Renal lobule**. A central medullary ray and the adjacent cortical labyrinth extending to the interlobular vessels

IV. Extrarenal passageways

- A. **Minor calyx**. Funnel-shaped structure (one for each pyramid) into which the point (apex) of a pyramid projects; urine flows from the pyramid into a minor calyx and several minor calyces unite to form a major calyx.
- B. **Major calyx**. Four or five per kidney; formed by the confluence of minor calyces
- C. **Renal pelvis**. Structure formed by the uniting of the major calyces; forms the expanded upper portion of the ureter

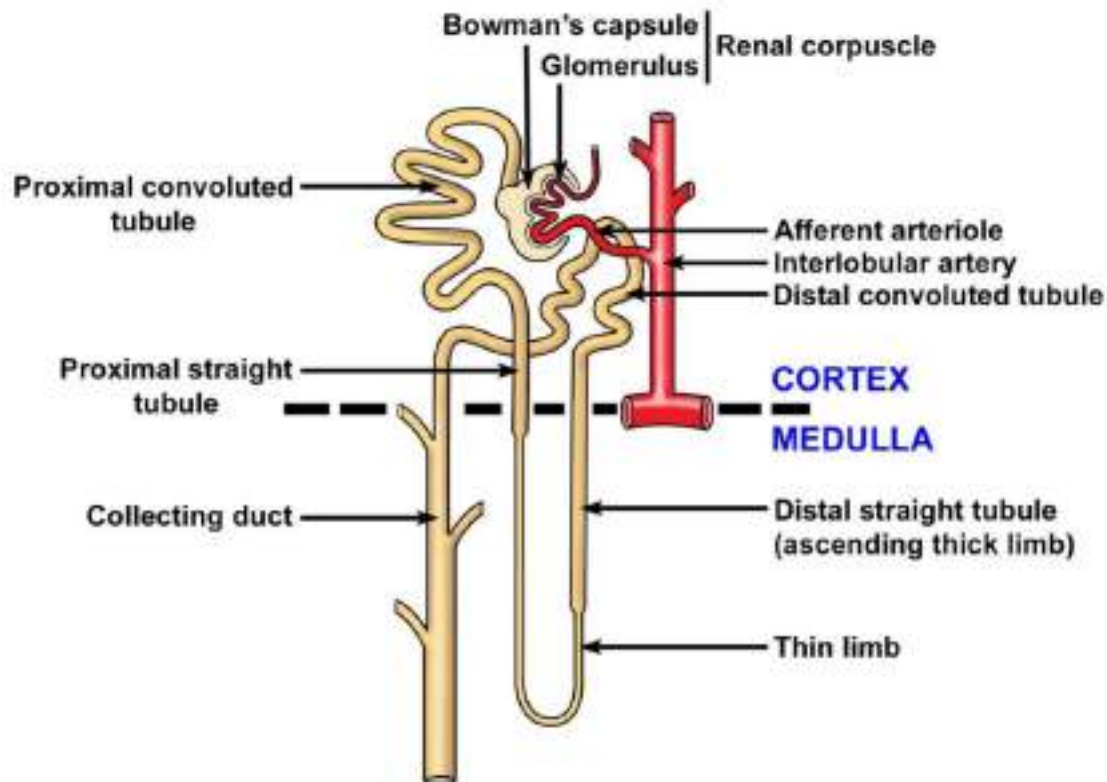


FIGURE 15.2. The nephron, collecting tubule, and associated blood supply.

THE NEPHRON

I. 1.5-2 million per kidney

II. **Renal corpuscle** (*images*)

A. Located in the cortical labyrinth

B. Components

1. **Glomerulus**. A tuft of fenestrated capillaries, whose pores lack diaphragms; filter blood. Formed by an afferent arteriole, the glomerulus indents into Bowman's capsule like a baseball fits into a baseball glove. Blood leaves the glomerulus via the efferent arteriole.
2. **Bowman's capsule**. Double-walled, epithelial capsule with central space called **Bowman's space**; surrounds the glomerulus and receives the fluid filtered from the blood
 - a. **Parietal layer**. Outer layer, simple squamous epithelium which is reflected at the vascular pole of the renal corpuscle to become the visceral layer; continuous with the proximal tubule at the urinary pole

- b. **Visceral layer.** Inner layer surrounding the glomerulus. Consists of a single layer of modified epithelial cells called **podocytes**. The radiating foot processes of these cells give rise to many secondary processes called **pedicels**. Pedicels of adjacent podocytes interdigitate and surround the glomerular capillaries. The slits (**filtration slits**) between the pedicels are bridged by **slit diaphragms**.
3. **Filtration barrier.** Barrier between blood in glomerular capillary and space of Bowman's capsule
 - a. Fenestrated endothelium of glomerular capillary
 - b. Thick, fused basal laminae of the podocytes and the glomerular endothelial cells
 - c. Slit diaphragms between pedicels of visceral layer of epithelium
4. Poles of the glomerulus
 - a. **Vascular pole.** Where afferent and efferent arterioles enter and leave the renal corpuscle, respectively
 - b. **Urinary pole.** Where the parietal layer of Bowman's capsule is continuous with the proximal convoluted tubule

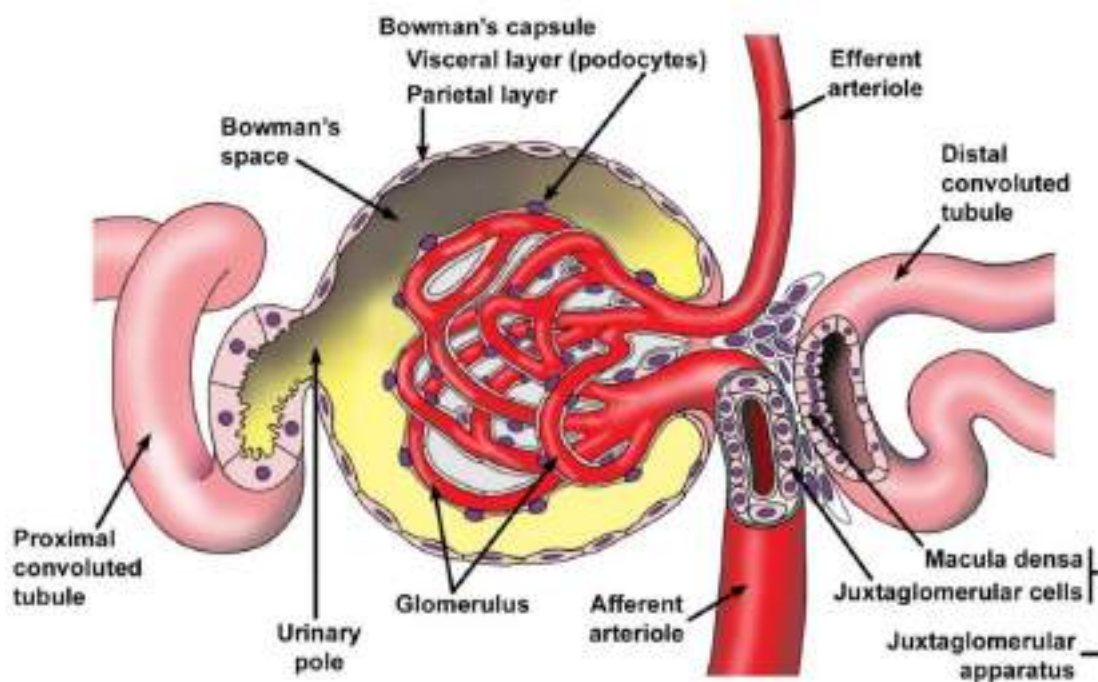


FIGURE 15.3. The renal corpuscle and associated structures.

III. Renal tubule (*images*)

A. The glomerular filtrate of the blood continues from Bowman's space into the renal tubule, which meanders first through the cortex, then the medulla, then back to the cortex, and finally enters the collecting duct.

B. Regions of the renal tubule

1. Listed in order are regions of the renal tubule through which urine passes

- a. **Proximal convoluted tubule**
- b. **Proximal straight tubule**
- c. **Thin limbs**
- d. **Ascending thick tubule (distal straight tubule)**
- e. **Distal convoluted tubule**

2. **Proximal tubule, convoluted portion**

- a. Located in labyrinth of cortex; highly convoluted
- b. Interconnects parietal epithelium of Bowman's capsule with straight portion of proximal tubule
- c. Composed of a simple cuboidal epithelium with microvilli; cells possess numerous infoldings of the basal plasma membrane and many mitochondria
- d. Absorption of glucose, amino acids, and the majority of salt and water occur here.

3. **Loop of Henle.** Located in medullary tissue (i.e., medullary ray and medulla)

- a. **Proximal tubule, straight portion (thick descending limb of the loop of Henle)**
 - i. Located in the medullary ray (in cortex) and continues into the medulla
 - ii. Interconnects proximal convoluted tubule with thin limb of Henle's loop
 - iii. Histology is identical to that of the proximal convoluted tubule

- iv. Absorption of same substances as in proximal convoluted tubule

b. **Thin segment**

- i. Found in medulla
- ii. Interconnects proximal straight tubule with distal straight tubule
- iii. Frequently makes the "loop" in the loop of Henle
- iv. Composed of a simple squamous epithelium
- v. Actively pumps out chloride, with sodium following passively, to produce a hypertonic urine

c. **Distal tubule, thick ascending limb of the loop of Henle.**

- i. Begins in the medulla and continues into the medullary ray (in cortex)
- ii. Interconnects thin segment with distal convoluted tubule
- iii. Composed of a simple cuboidal epithelium with inconsistent microvilli. The cytoplasm is less acidophilic and the lumen is wider than in the proximal tubule. The basal plasma membrane is extensively infolded with numerous mitochondria between the folds.
- iv. Returns to a glomerulus to form part of the juxtaglomerular apparatus.
- v. Major site of salt and water control in the body

4. **Distal tubule, convoluted portion**

- a. Located in the labyrinth portion of cortex; highly convoluted
- b. Interconnects the ascending thick limb with collecting tubule
- c. Histology is identical with the distal straight tubule
- d. Major site of salt and water control in the body

C. **Juxtaglomerular (JG) apparatus**

- 1. Located at the vascular pole of a nephron; helps regulate blood pressure

2. Composition

- a. **Juxtaglomerular cells**. Modified smooth muscle cells in wall of an afferent arteriole
 - b. **Macula densa**. Cluster of modified cells in the wall of the ascending thick limb adjacent to the juxtaglomerular cells. The clustering of cells, and therefore of their nuclei, gives the appearance of a "dense spot" in the wall of the distal convoluted tubule.
3. Monitors the tonicity of the urine in the tubule. The macula densa affects the adjacent JG cells to adjust their production of renin, an enzyme that aids in regulating blood pressure.

EXCRETORY TUBULES AND DUCTS AND EXTRARENAL PASSAGES *(images)*

I. Separate embryological origin from the nephron

II. Components

A. **Collecting tubule**

1. Composed of simple cuboidal to simple columnar cells; usually displays distinct lateral boundaries between cells
2. Drains urine from the distal convoluted tubule of many nephrons in the cortical labyrinth, enters the medullary ray in the cortex and descends into the medulla
3. Joins with other collecting tubules to form the papillary ducts (of Bellini)
4. Aids in concentrating the urine

B. **Papillary ducts (of Bellini)**. Located deep in the medullary pyramid near the minor calyces; composed of a tall, pale, simple columnar epithelium. Empty into the minor calyx at the area cribosa at the apex of each pyramid

C. **Minor** and **major calyces**. Transport urine to the renal pelvis and into the ureter; lined by **transitional epithelium**

D. **Renal pelvis**. Expanded origin of the ureter, lined by transitional epithelium; formed by the union of major calyces

E. **Ureter**. Muscular tube connecting the renal pelvis and the urinary bladder, lined by transitional epithelium; two layers of smooth muscle in the upper two-thirds, inner longitudinal and outer circular, with the addition of a third outer longitudinal layer in the lower one-third

- F. **Urinary bladder.** Lined by a transitional epithelium, a stratified cuboidal epithelium specialized to provide for distension of the organ; a thick muscular wall contains three interlacing layers of smooth muscle.

BLOOD SUPPLY OF THE KIDNEY

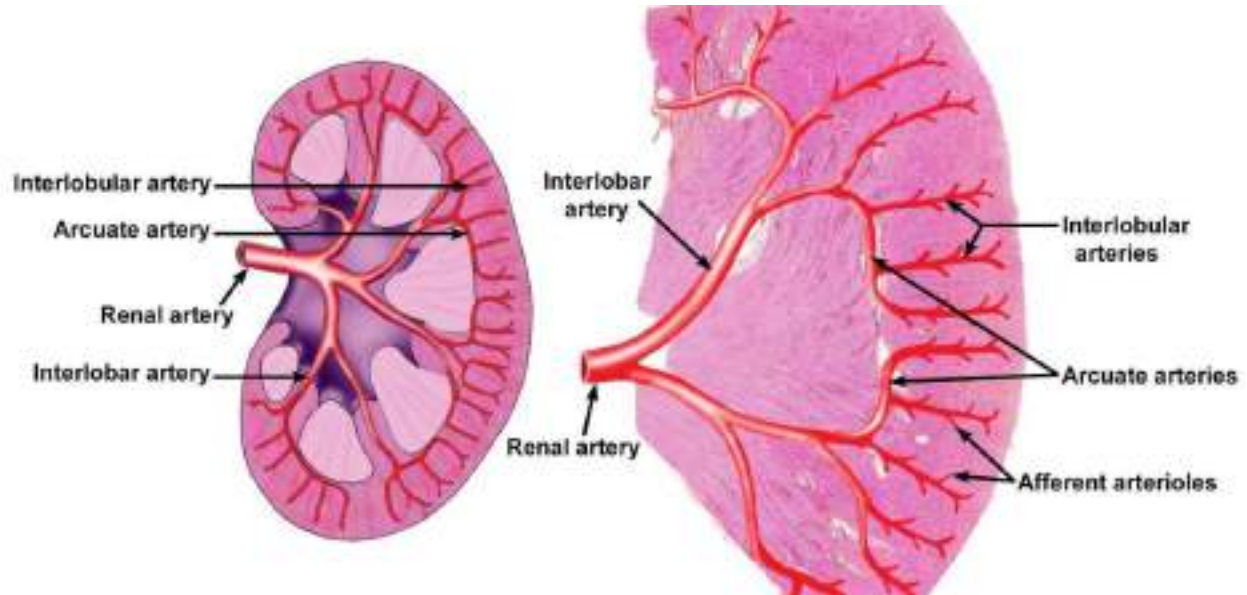


FIGURE 15.4. Blood supply of the kidney

- I. **Renal artery.** A branch of the aorta, enters the kidney at the *hilus*; branches to form the interlobular arteries
- II. **Interlobar arteries.** Lie between adjacent pyramids in renal columns and branch into arcuate arteries
- III. **Arcuate arteries.** Arch between medulla and cortex; give rise to interlobular arteries
- IV. **Interlobular arteries.** Branch perpendicular to the arcuate artery in the cortex and lie between adjacent lobules; supply a number of afferent arterioles
- V. **Afferent arterioles** supply the glomerulus, entering at the vascular pole of the renal corpuscle
- VI. **Glomerulus.** A tuft of capillaries protruding into Bowman's capsule where blood is filtered.
- VII. **Efferent arteriole** exits from the glomerulus and forms either **peritubular capillaries**, which nourish the convoluted tubules, or the **vasa recta**. The vasa

recta parallel the straight portions of the renal tubule into the medulla and play an important role in concentrating the urine.