

# Chapter 04

## APR Enhanced Lecture Slides

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes and animations.

# Chapter 4

# Histology: The Study of Tissues

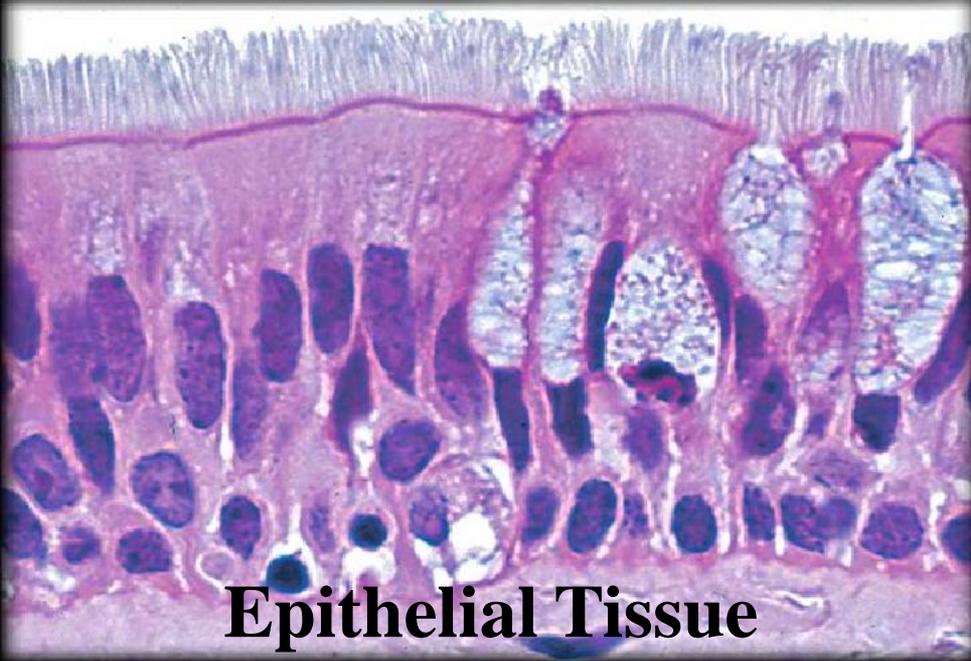
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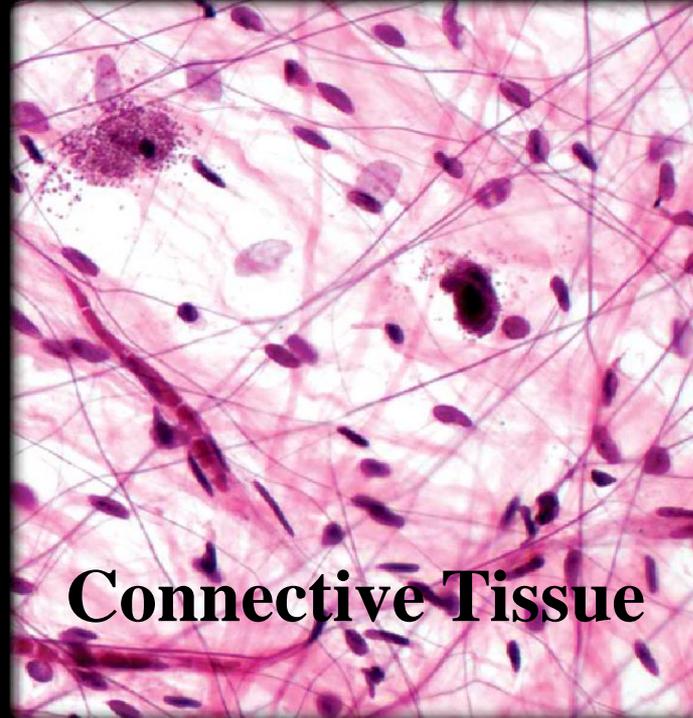
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# 4.1 Tissues and Histology

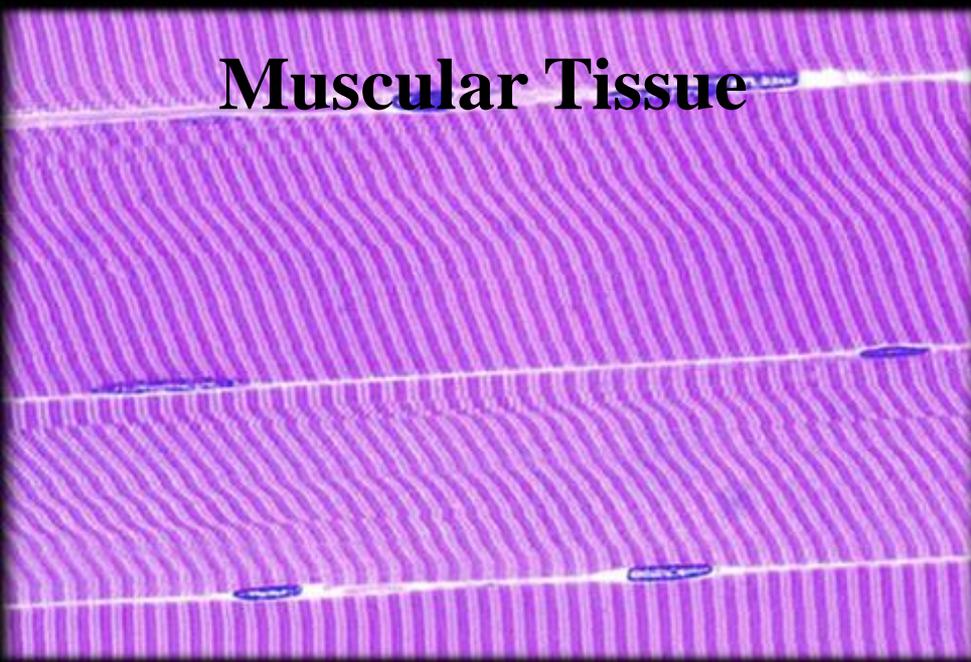
- Tissue classification based on structure of cells, composition of noncellular **extracellular matrix**, and cell function
  - Epithelial
  - Connective
  - Muscle
  - Nervous
- **Histology**: Microscopic Study of Tissues
  - **Biopsy**: removal of tissues for diagnostic purposes
  - **Autopsy**: examination of organs of a dead body to determine cause of death



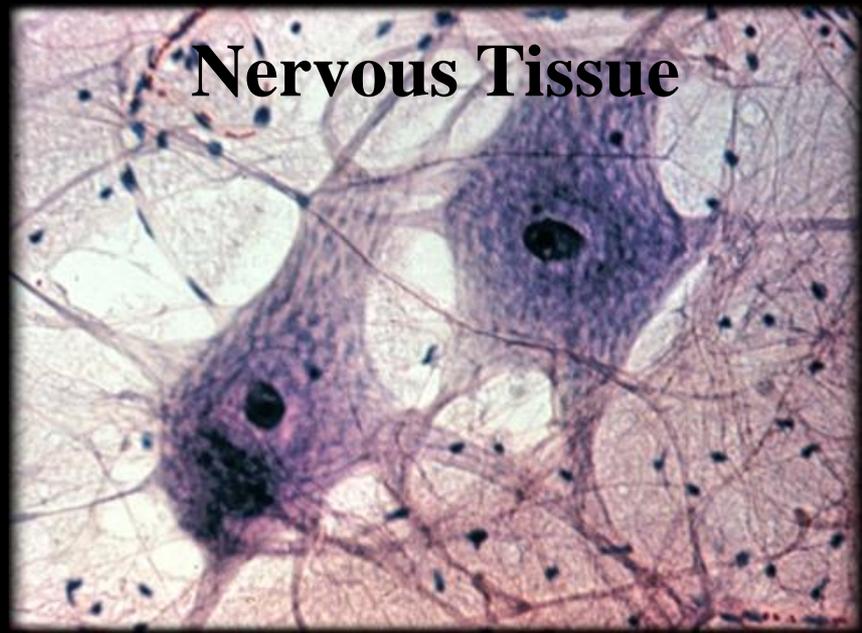
**Epithelial Tissue**



**Connective Tissue**



**Muscular Tissue**



**Nervous Tissue**

# 4.2 Embryonic Tissue

- **Germ layers**

- **Endoderm**

- Inner layer
    - Forms lining of digestive tract and derivatives

- **Mesoderm**

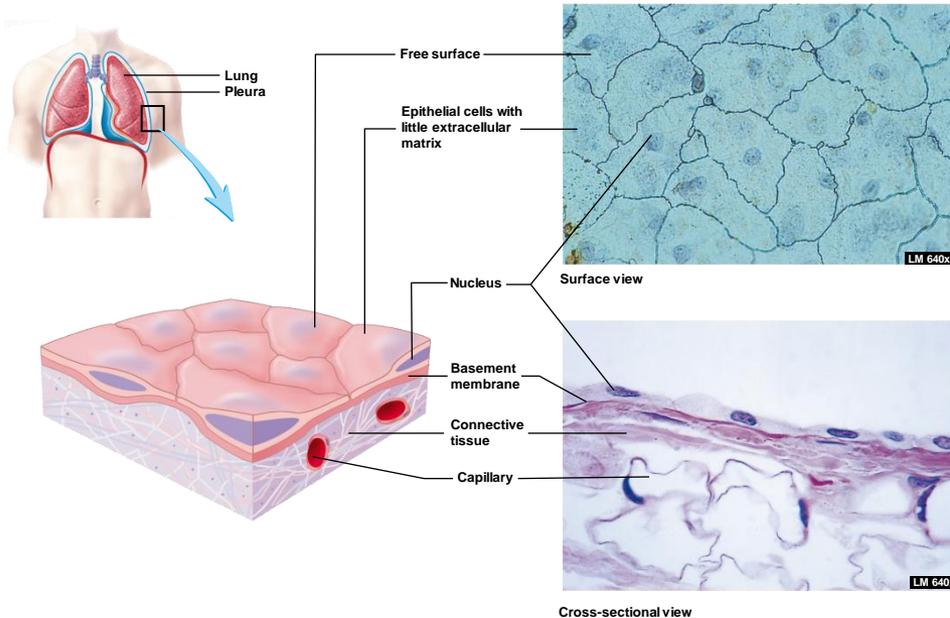
- Middle layer
    - Forms tissues as such muscle, bone, blood vessels

- **Ectoderm**

- Outer layer
    - Forms skin and neuroectoderm

# 4.3 Epithelial Tissue

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- Consists almost entirely of cells
- Covers body surfaces and forms glands
  - Outside surface of the body
  - Lining of digestive, respiratory and urogenital systems
  - Heart and blood vessels
  - Linings of many body cavities
- Has free, basal, and lateral surfaces
- Basement membrane
- Specialized cell contacts
- Avascular
- Regenerate

# Basement Membrane

- Extracellular: formed by secretions of both epithelium and connective tissue. Acellular “glue”
  - Attachment to C.T.
  - Guides cell migration during tissue repair
  - Acts as a filter in the nephron of the kidney
  - Not every epithelium has a basement membrane associated with it

# Functions of Epithelial Tissue

- Protecting underlying structures; e.g., epithelium lining the mouth
- Acting as barriers; e.g., skin
- Permitting the passage of substances; e.g., nephrons in kidney
- Secreting substances; e.g., pancreas
- Absorbing substances; e.g., lining of small intestine

# Classification of Epithelium

- Number of layers of cells
  - **Simple**- one layer of cells. Each extends from basement membrane to the free surface
  - **Stratified**- more than one layer. Shape of cells of the apical layer used to name the tissue. Includes transitional epithelium where the apical cell layers change shape depending upon distention of the organ which the tissue lines
  - **Pseudostratified**- tissue appears to be stratified, but all cells contact basement membrane so it is in fact simple
- Shape of cells
  - **Squamous**- flat, scale-like
  - **Cuboidal**- about equal in height and width
  - **Columnar**- taller than wide

**TABLE 4.1**

**Classification of Epithelium**

Number of Layers or Category	Shape of Cells
<b>Simple (single layer of cells)</b>	<b>Squamous</b> <b>Cuboidal</b> <b>Columnar</b>
<b>Stratified (more than one layer of cells)</b>	<b>Squamous</b> <b>Nonkeratinized (moist)</b> <b>Keratinized</b> <b>Cuboidal (very rare)</b> <b>Columnar (very rare)</b>
<b>Pseudostratified (modification of simple epithelium)</b>	<b>Columnar</b>
<b>Transitional (modification of stratified epithelium)</b>	<b>Roughly cuboidal to columnar when not stretched and squamouslike when stretched</b>

# Functional Characteristics

- Simple: allows diffusion of gases, filtration of blood, secretion, absorption
- Stratified: protection, particularly against abrasion
- Squamous: allows diffusion or acts as filter
- Cuboidal and columnar: secretion or absorption. May include **goblet cells** that produce and secrete mucus.

# Free Surfaces

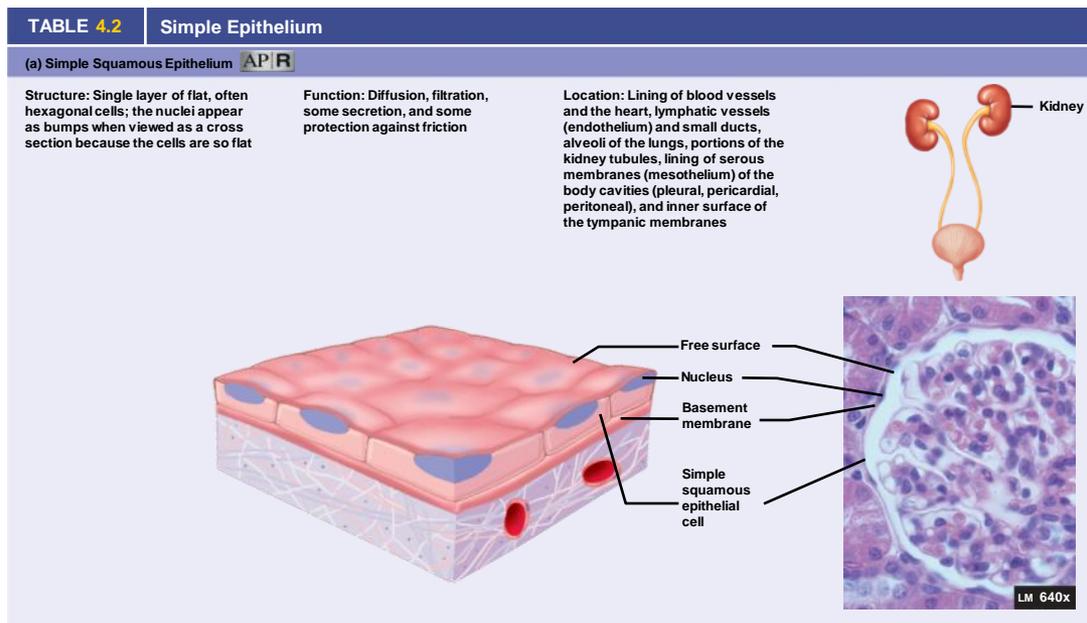
## Free surfaces of epithelium

- Smooth: reduce friction
- Microvilli: increase surface area for absorption or secretion
  - **Stereocilia**: elongated microvilli for sensation and absorption
- Cilia: move materials across the surface
- Folds: in transitional epithelium where organ must be able to change shape. Urinary system.

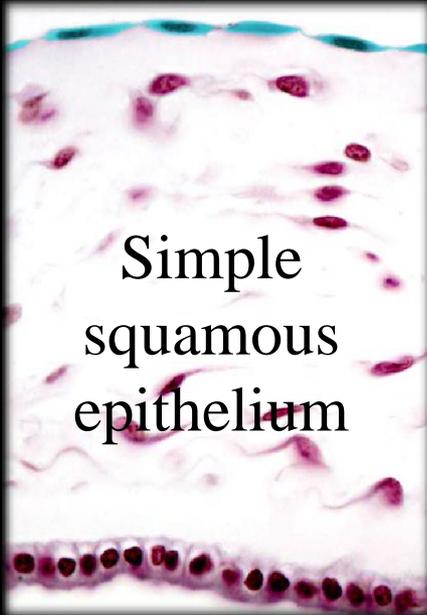
# Simple Squamous Epithelium

- Structure: single layer of flat cells
- Location: simple squamous- lining of blood and lymphatic vessels (endothelium) and small ducts, alveoli of the lungs, loop of Henle in kidney tubules, lining of serous membranes (mesothelium) and inner surface of the eardrum.
- Functions: diffusion, filtration, some protection against friction, secretion, absorption.

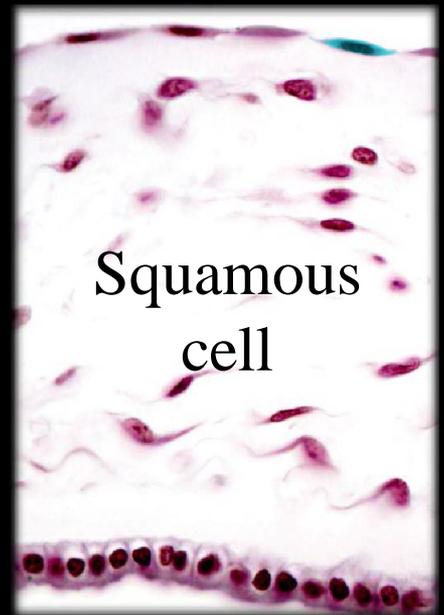
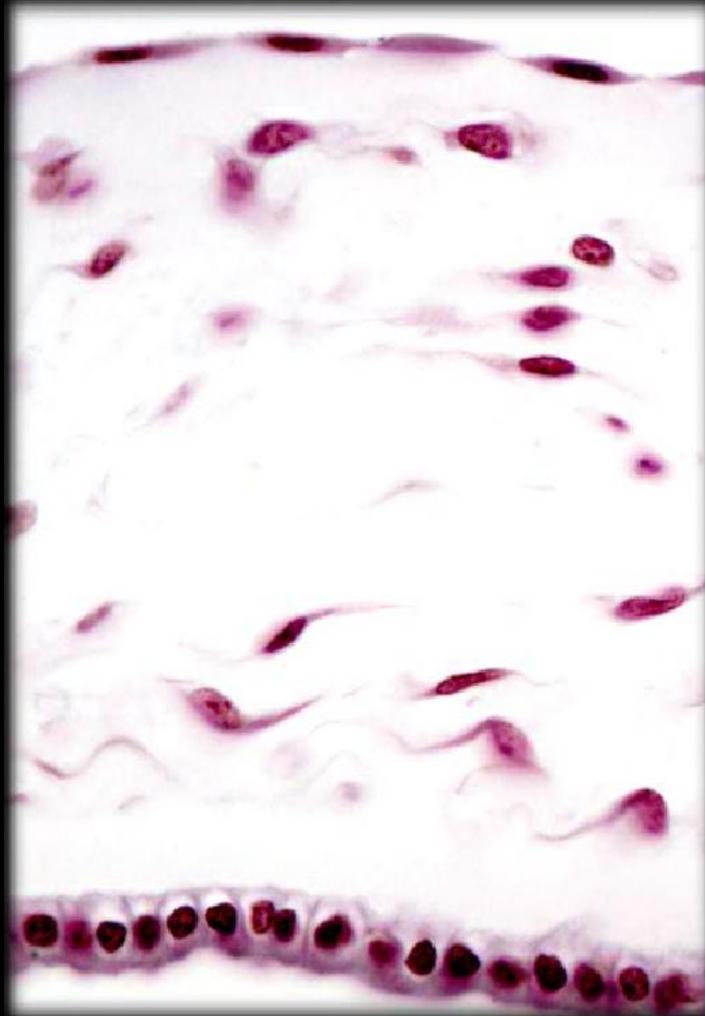
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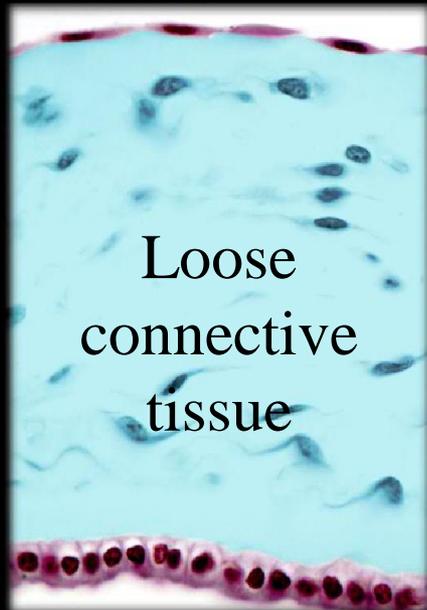
# Simple Squamous Epithelium



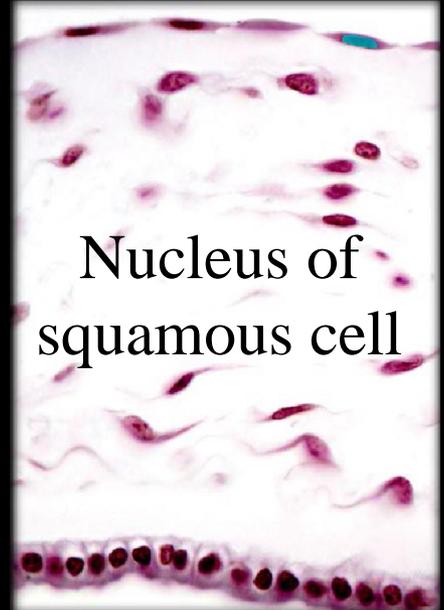
Simple  
squamous  
epithelium



Squamous  
cell



Loose  
connective  
tissue

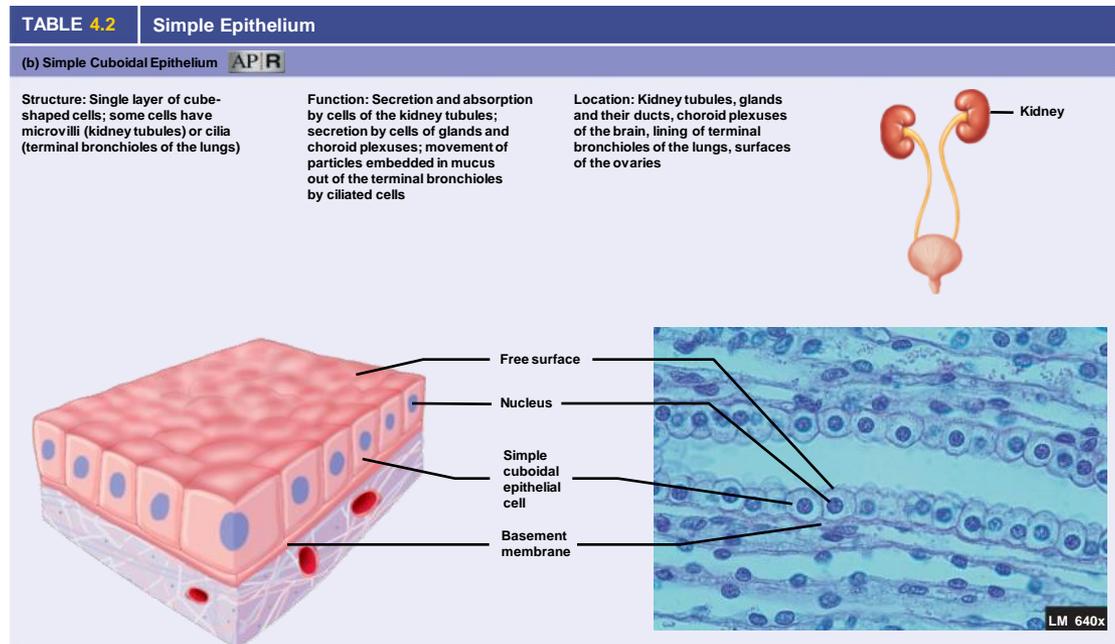


Nucleus of  
squamous cell

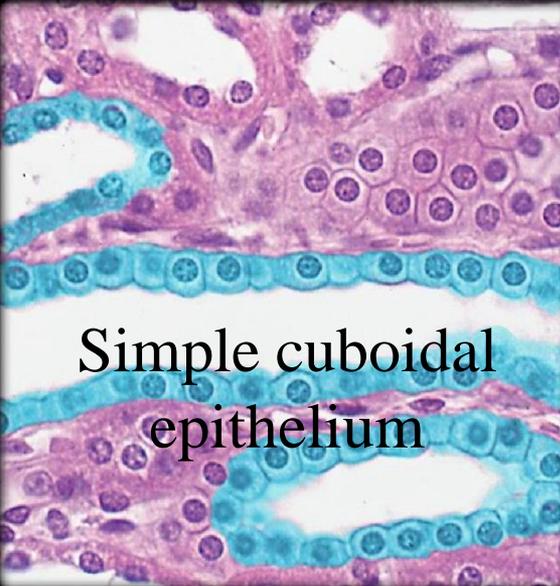
# Simple Cuboidal Epithelium

- Locations: Kidney tubules, glands and their ducts, choroid plexus of the brain, lining of terminal bronchioles of the lungs, and surface of the ovaries.
- Structure: single layer of cube-shaped cells; some types have microvilli (kidney tubules) or cilia (terminal bronchioles of the lungs)
- Functions:
  - Secretion and absorption in the kidney
  - Secretion in glands and choroid plexus
  - Movement of mucus out of the terminal bronchioles by ciliated cells.

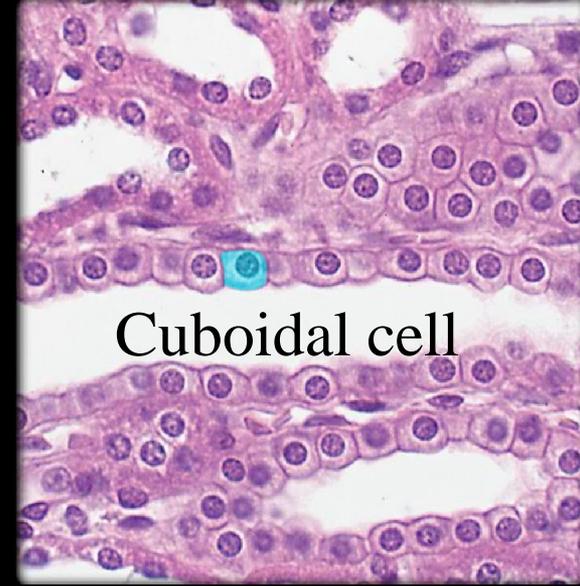
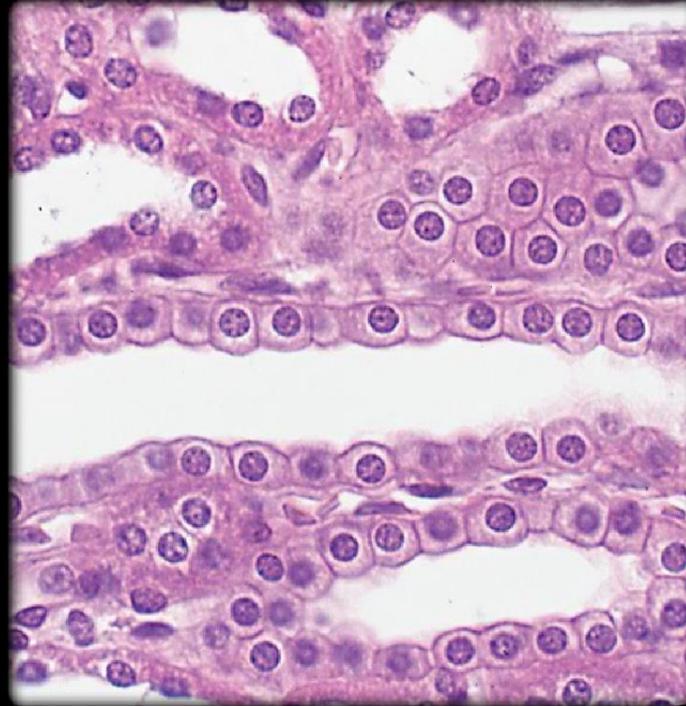
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# Simple Cuboidal Epithelium



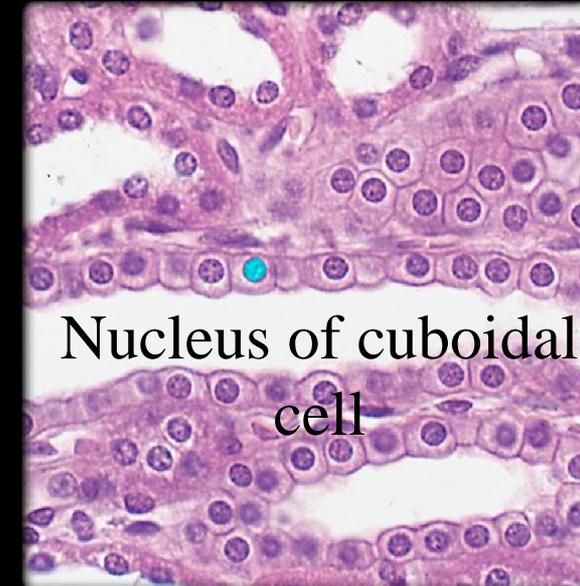
Simple cuboidal epithelium



Cuboidal cell



Lumen of tubule

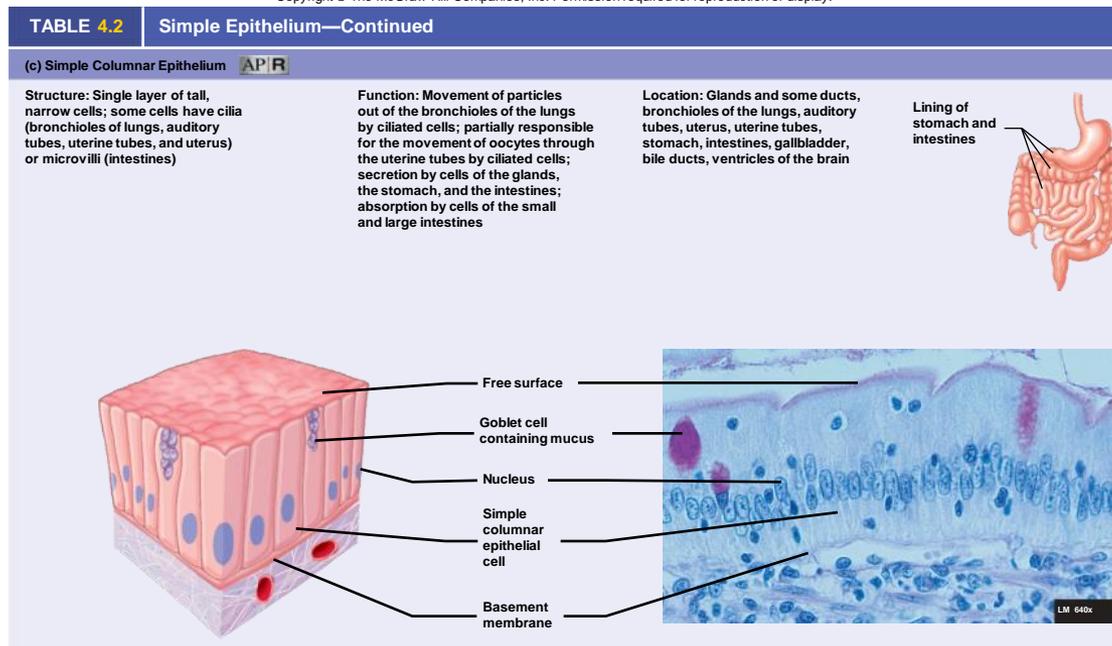


Nucleus of cuboidal cell

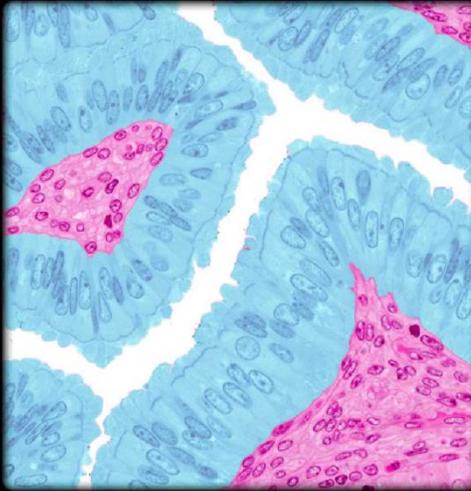
# Simple Columnar Epithelium

- Location. Glands and some ducts, bronchioles of lungs, auditory tubes, uterus, uterine tubes, stomach, intestines, gallbladder, bile ducts and ventricles of the brain.
- Structure: single layer of tall, narrow cells. Some have cilia (bronchioles of lungs, auditory tubes, uterine tubes, and uterus) or microvilli (intestine).
- Functions:
  - Movement of particles out of the bronchioles by ciliated cells
  - Aids in the movement of oocytes through the uterine tubes by ciliated cells
  - Secretion by glands of the stomach and the intestine
  - Absorption by cells of the intestine.

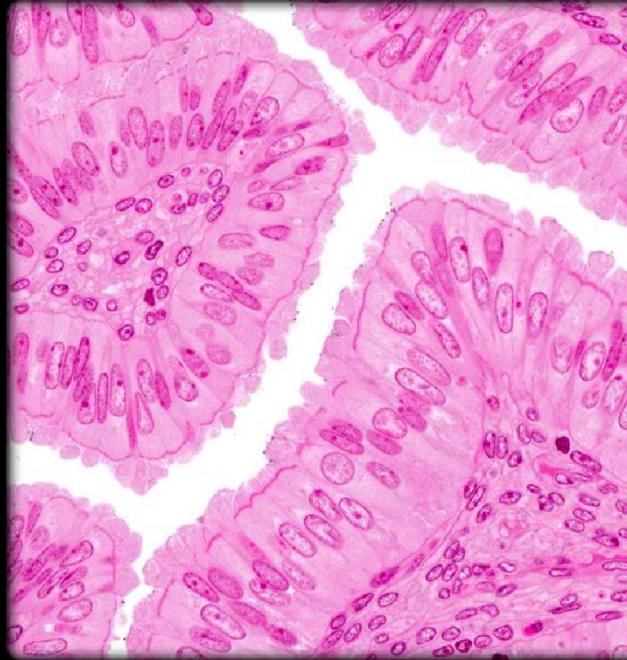
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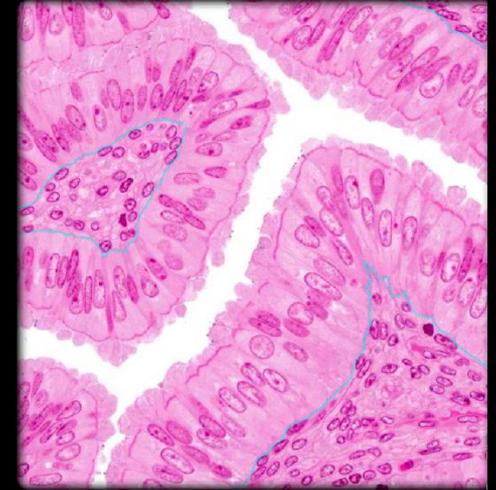
# Simple Columnar Epithelium (Ciliated)



Simple columnar epithelium (ciliated)



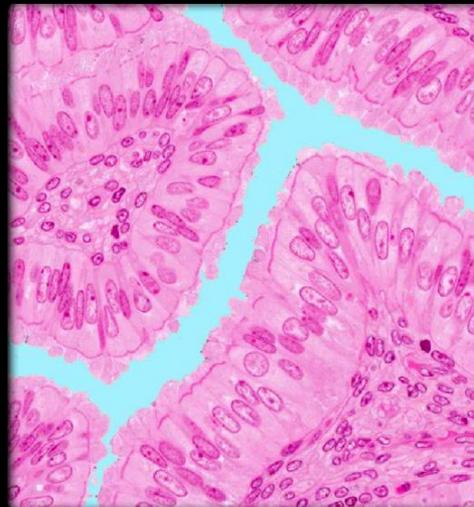
Lumen of uterine tube



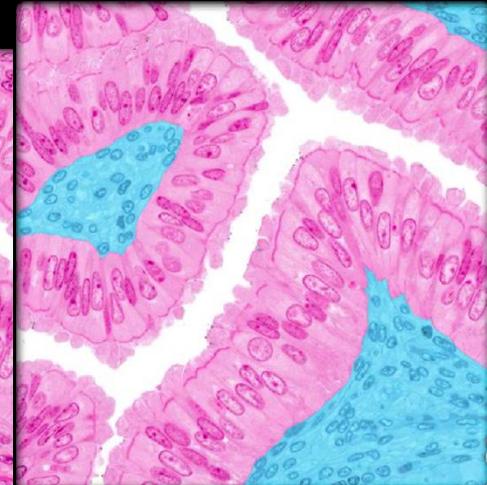
Basement membrane



Simple columnar cell (ciliated)

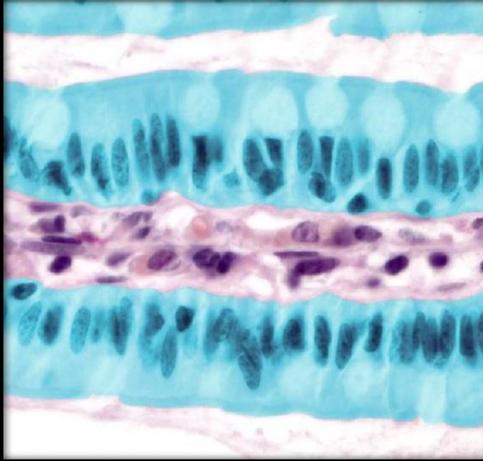


Cilia

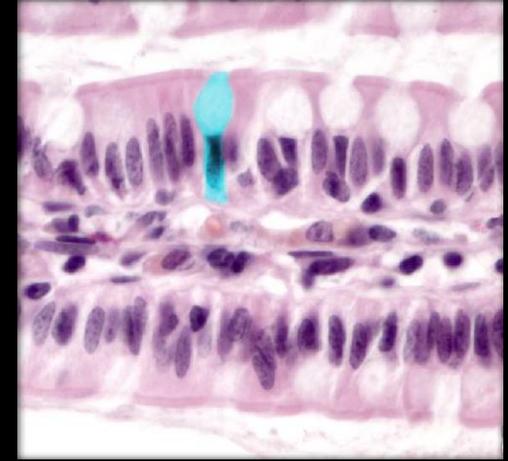
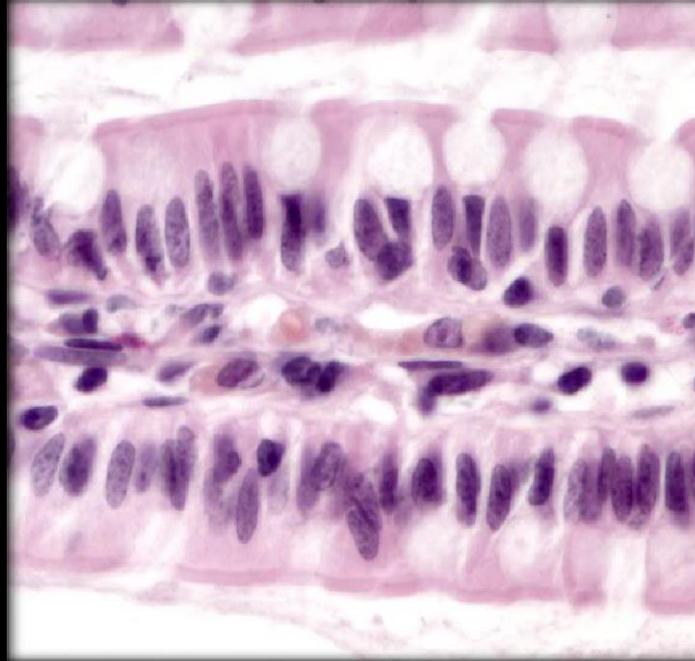


Lamina propria

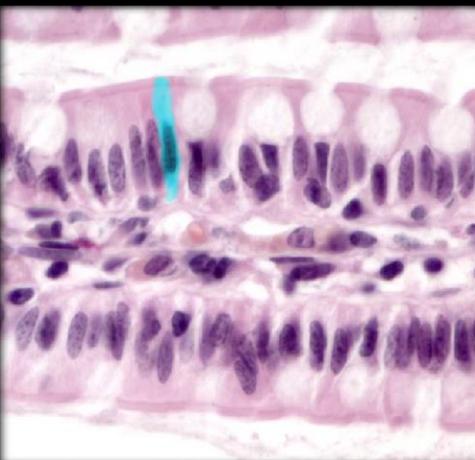
# Simple Columnar Epithelium (nonciliated)



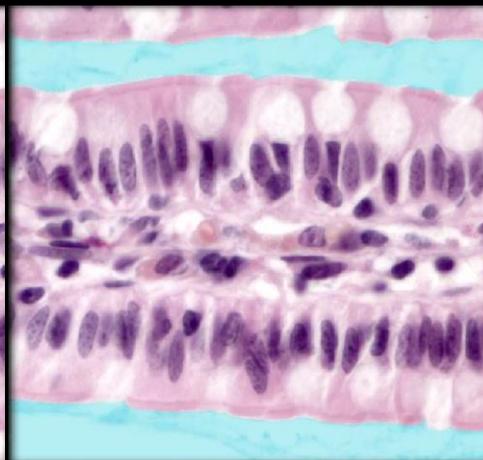
Simple columnar epithelium



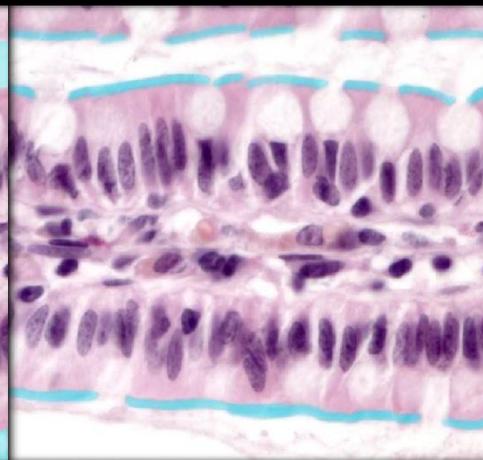
Goblet cell



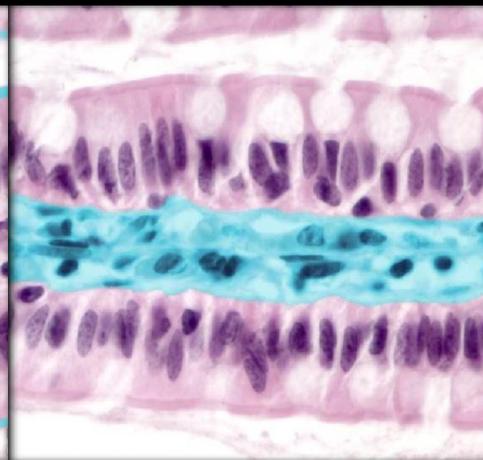
Simple columnar cell



Lumen of jejunum



Microvilli (brush border)

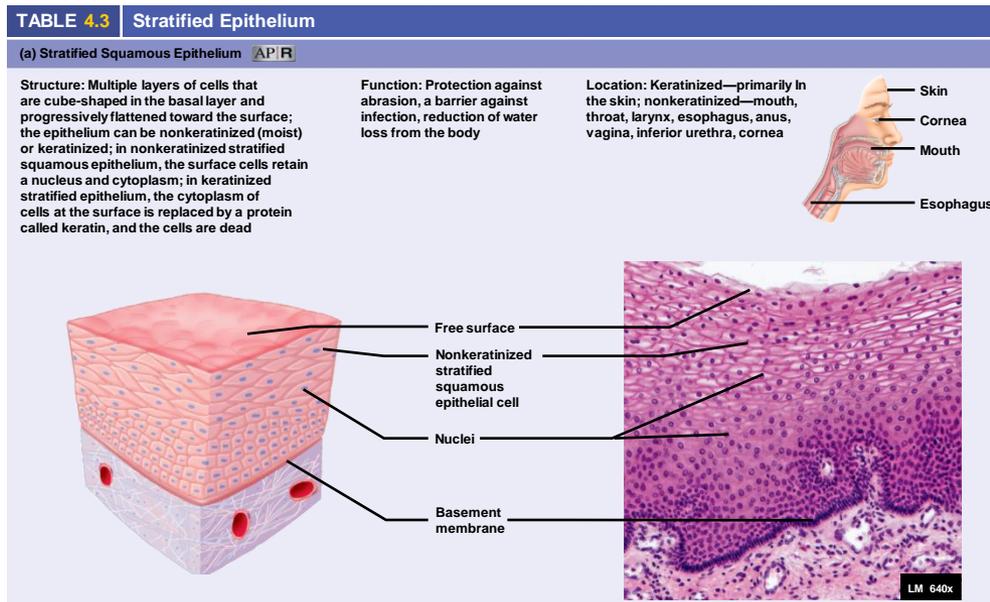


Lamina propria

# Stratified Squamous Epithelium

- Locations:
  - Moist- mouth, throat, larynx, esophagus, anus, vagina, inferior urethra, and cornea
  - Keratinized- skin
- Structure: multiple layers of cells that are cuboidal in the basal layer and progressively flatten toward the surface. In moist, surface cells retain a nucleus and cytoplasm. In keratinized, surface cells are dead.
- Functions: protection against abrasion, caustic chemicals, water loss, and infection.

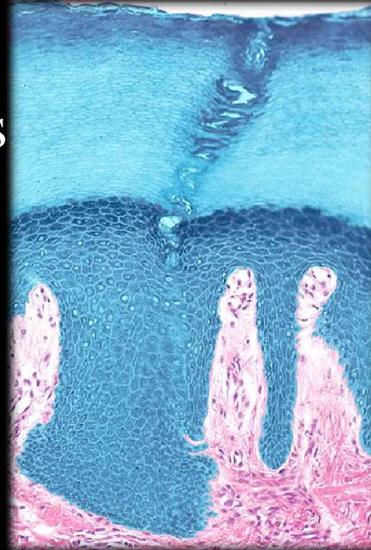
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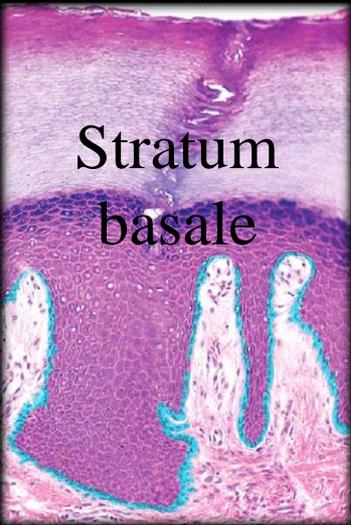
# Stratified Squamous Epithelium (Keratinized)



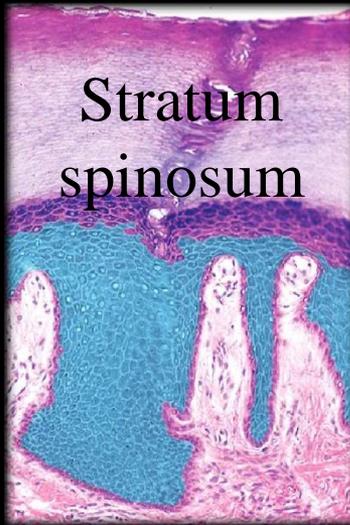
**Epidermis**  
(Stratified squamous epithelium)



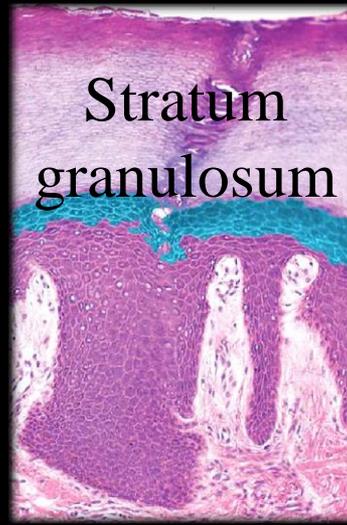
**Dermis**



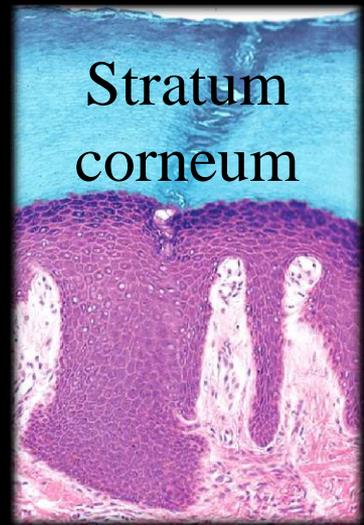
**Stratum basale**



**Stratum spinosum**

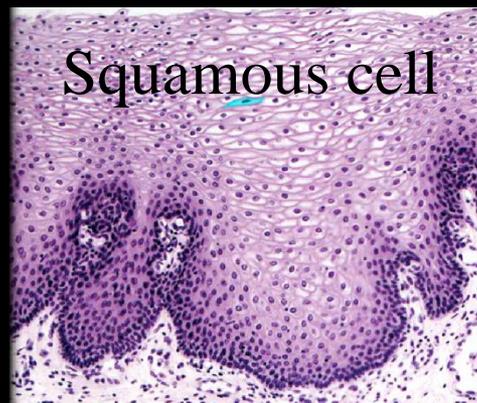
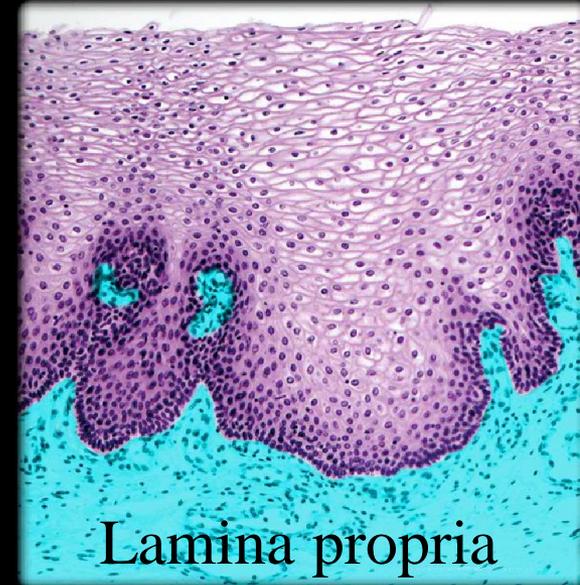
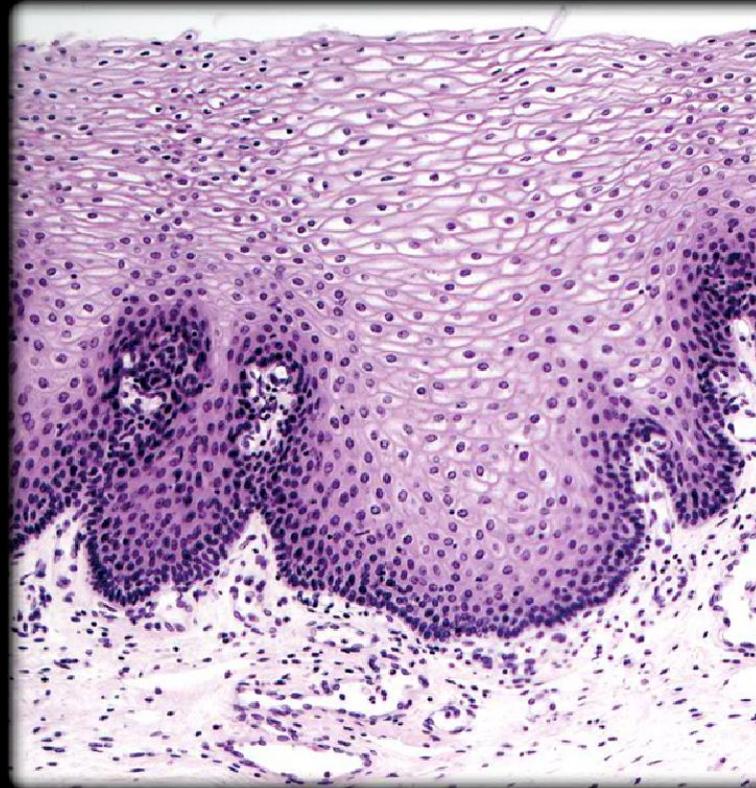
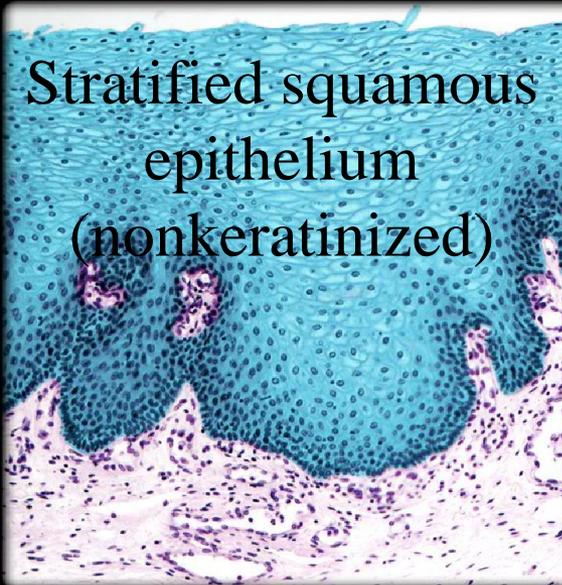


**Stratum granulosum**



**Stratum corneum**

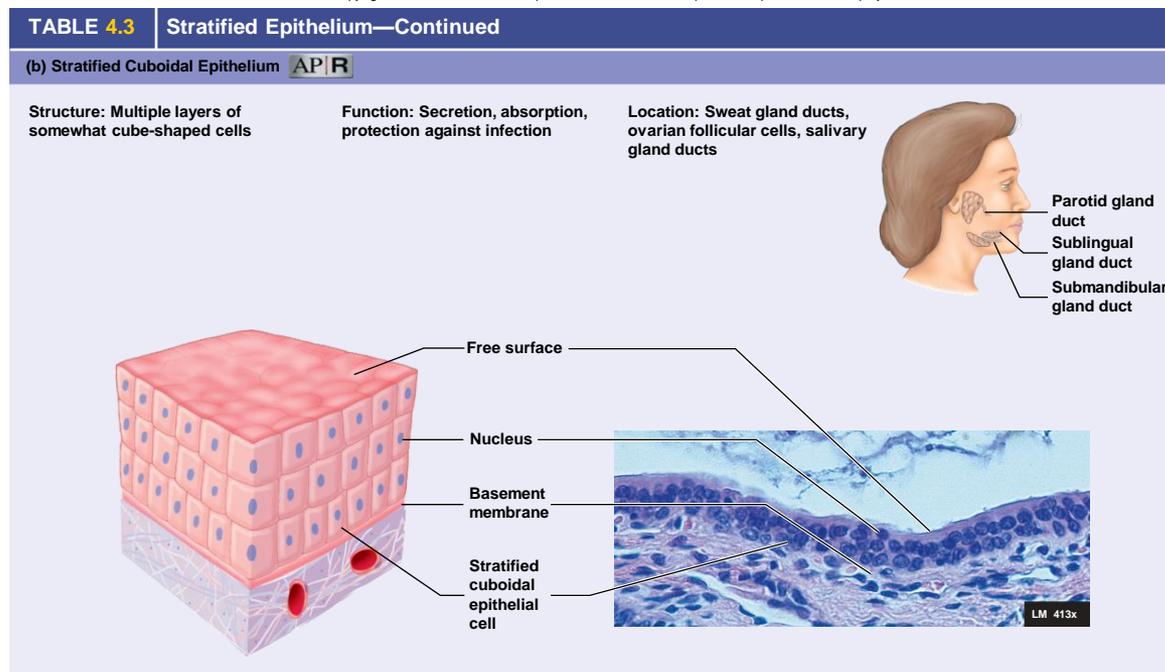
# Stratified Squamous Epithelium (Nonkeratinized)



# Stratified Cuboidal Epithelium

- Locations: sweat gland ducts, ovarian follicular cells, and salivary gland ducts
- Structure: multiple layers of somewhat cube-shaped cells.
- Functions: secretion, absorption and protection against infections.

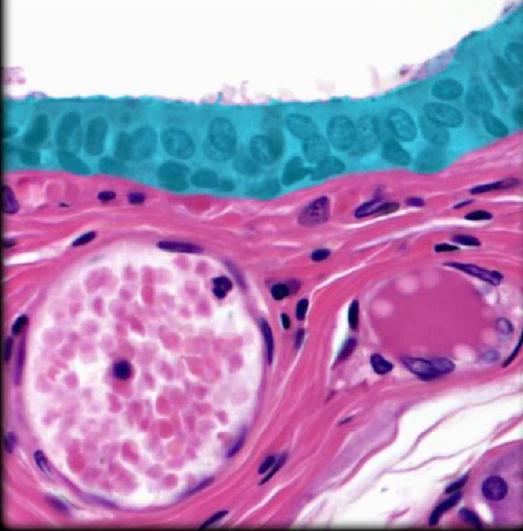
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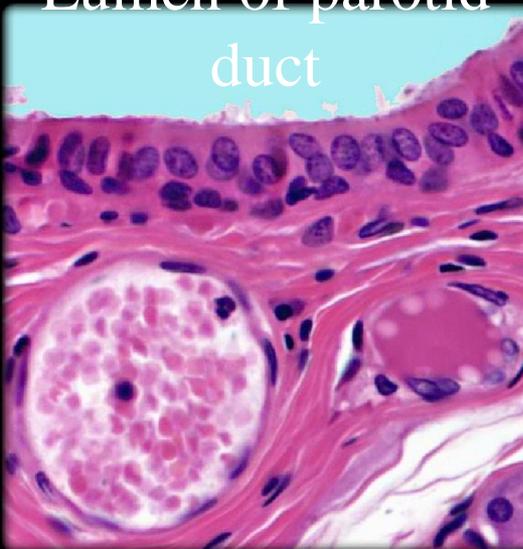
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# Stratified Cuboidal Epithelium

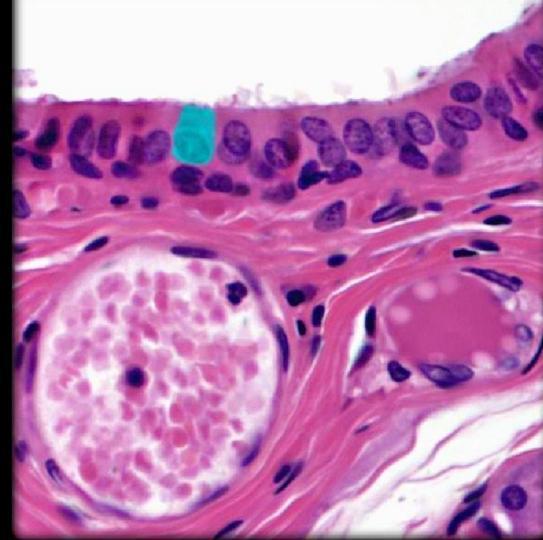
Stratified cuboidal



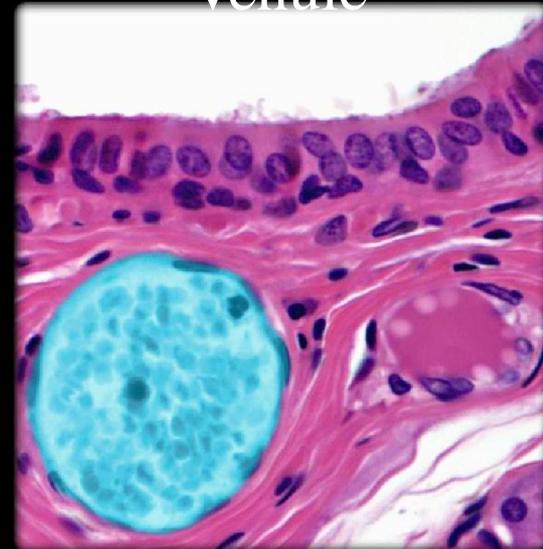
Lumen of parotid duct



Cuboidal cell



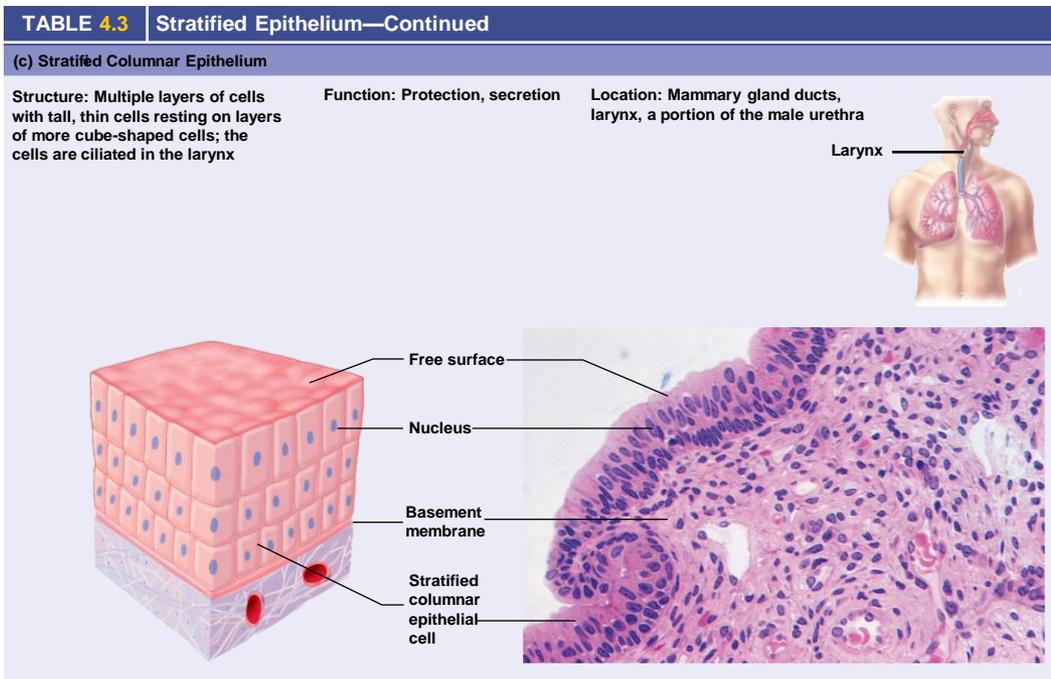
Venule



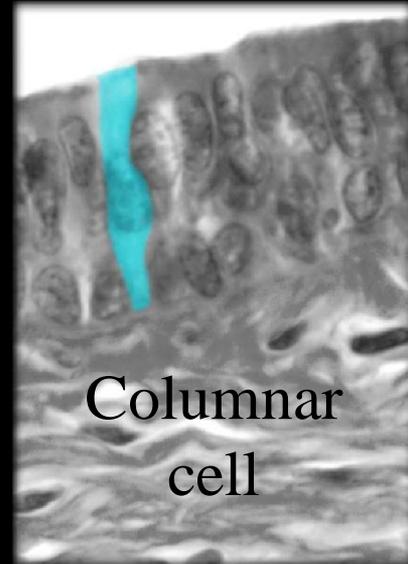
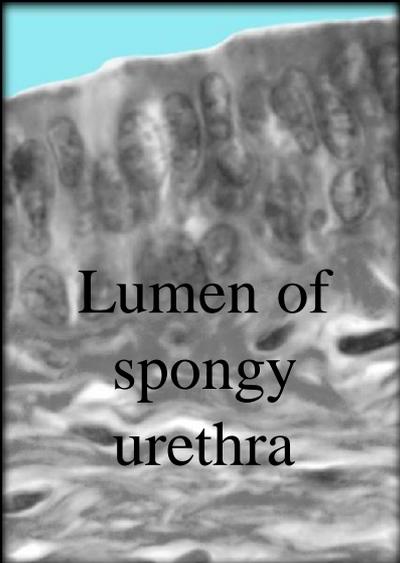
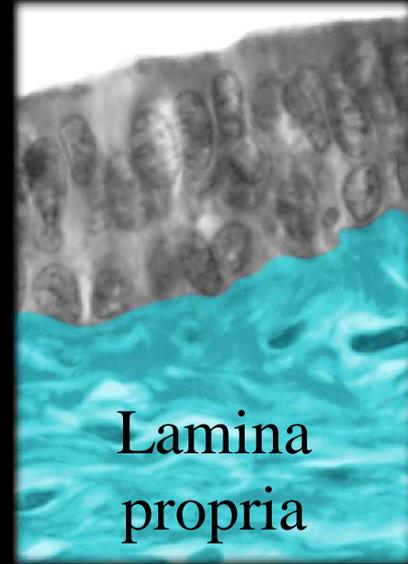
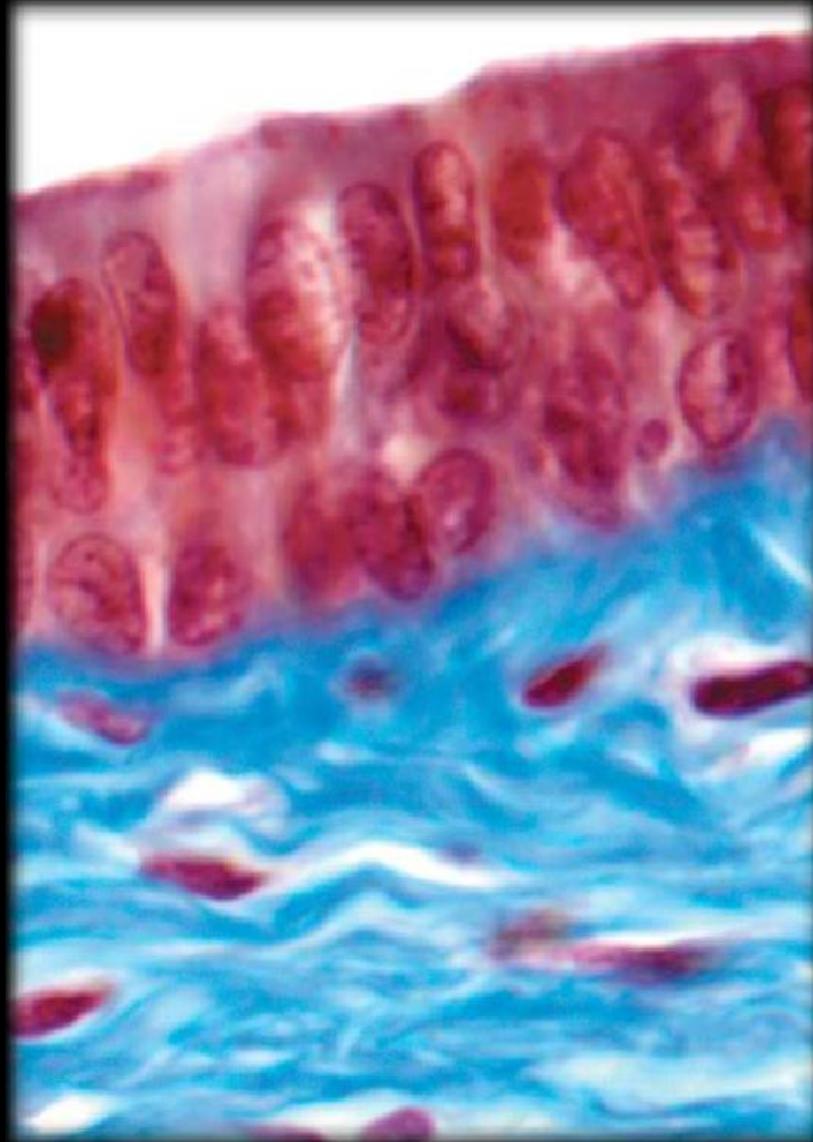
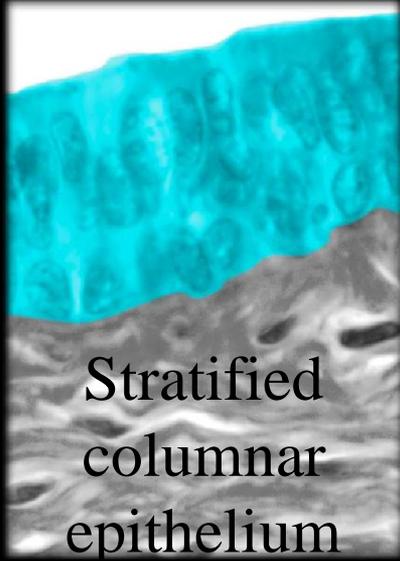
# Stratified Columnar Epithelium

- Locations: mammary gland duct, larynx, portion of male urethra.
- Structure: multiple layers of cells with tall thin cells resting on layers of more cuboidal cells. Cells ciliated in the larynx.
- Function: protection and secretion.

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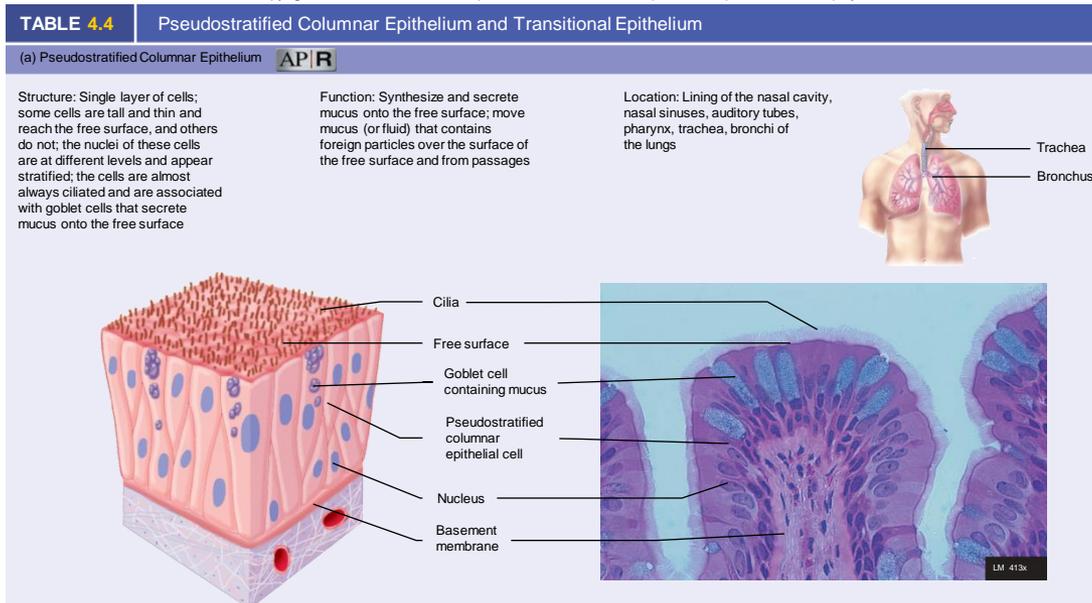
# Stratified Columnar Epithelium



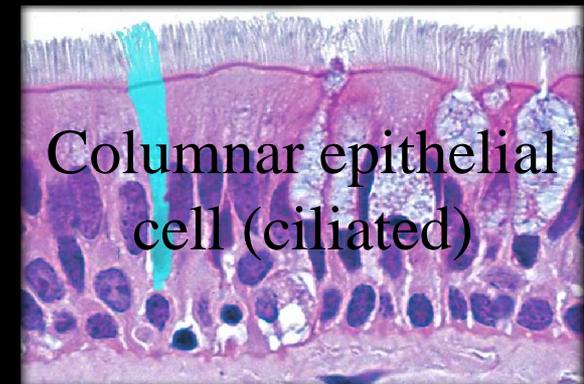
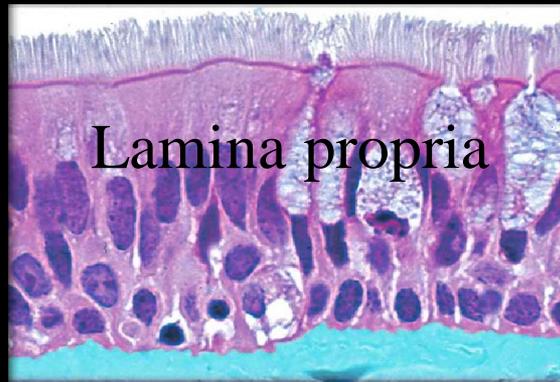
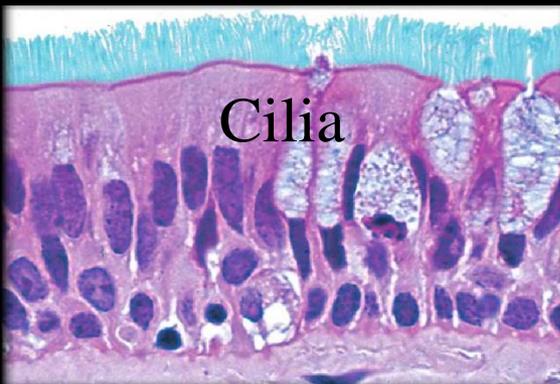
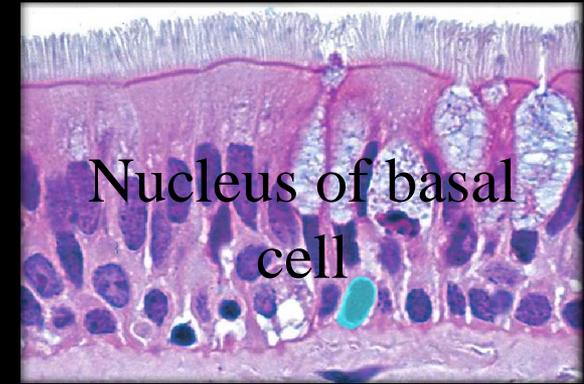
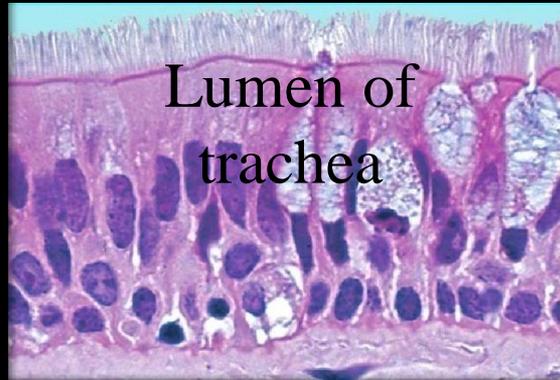
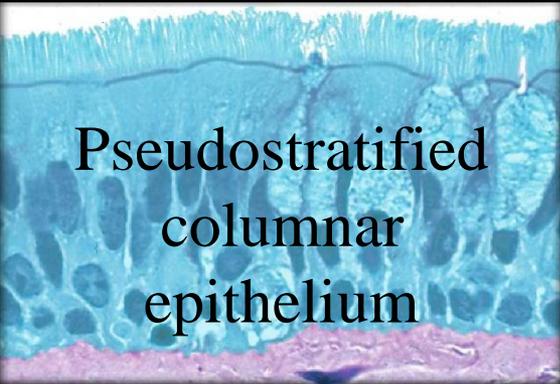
# Pseudostratified Columnar Epithelium

- Locations: lining of nasal cavity, nasal sinuses, auditory tubes, pharynx, trachea, and bronchi of lungs.
- Structure: all cells reach basement membrane. Appears stratified because nuclei are at various levels. Almost always ciliated and associated with goblet (mucus-producing) cells.
- Functions:
  - Synthesize and secrete mucus onto the free surface
  - Move mucus (or fluid) that contains foreign particles over the free surface and from passages

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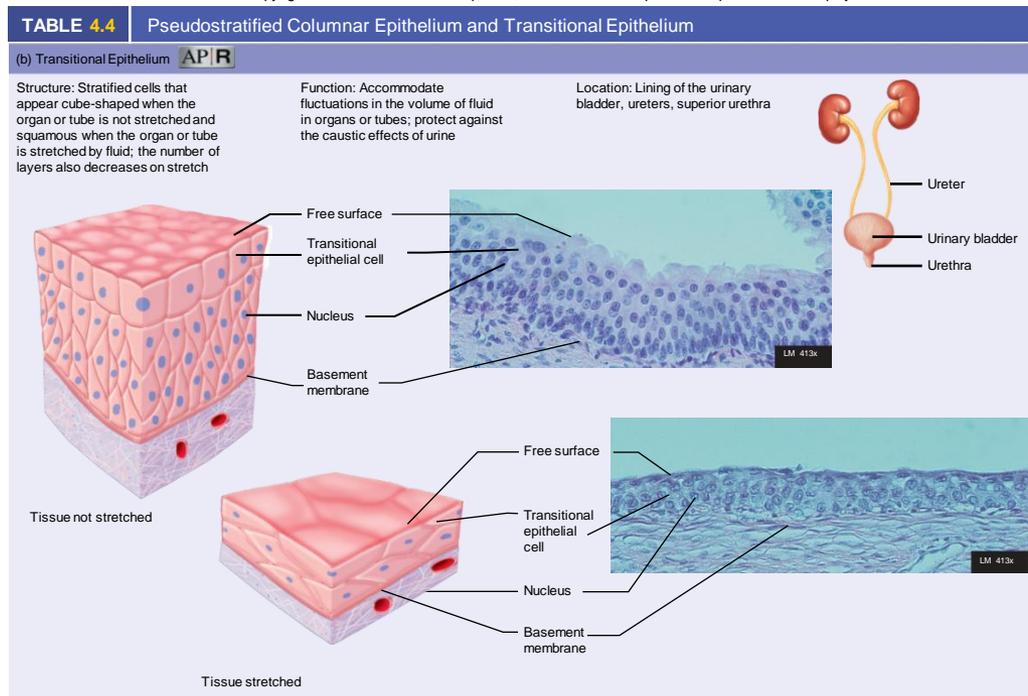
# Pseudostratified Columnar Epithelium



# Transitional Epithelium

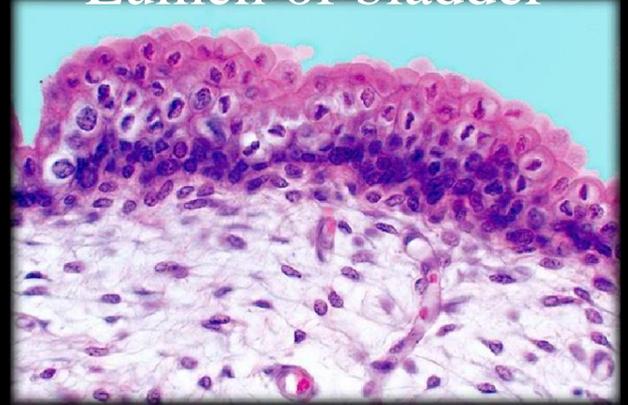
- Location: lining of urinary bladder, ureters and superior urethra.
- Structure: stratified; cells change shape depending upon amount of distention of the organ.
- Functions: accommodates fluctuations in the volume of fluid in an organ or tube; protection against the caustic effects of urine.

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# Transitional Epithelium

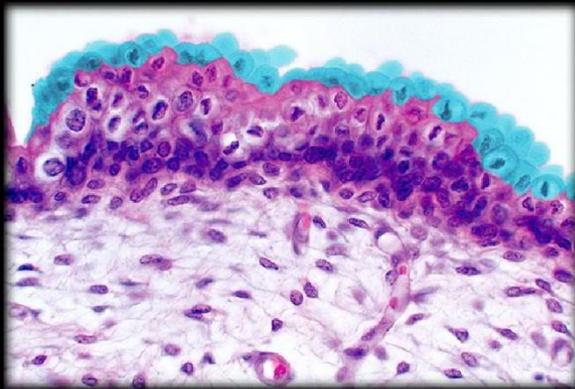
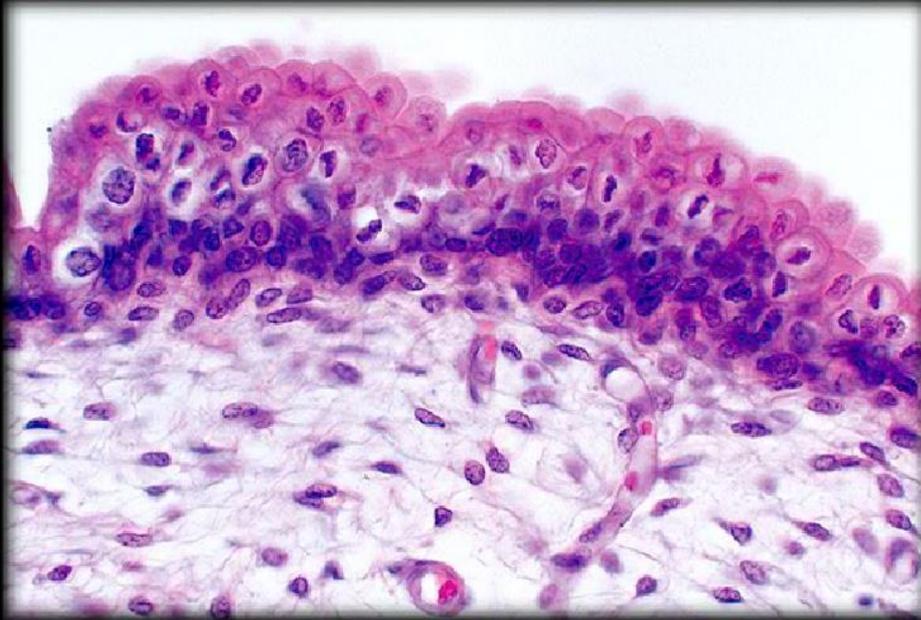
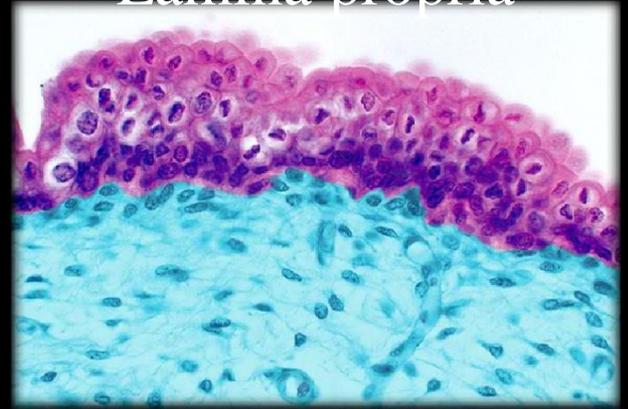
Lumen of bladder



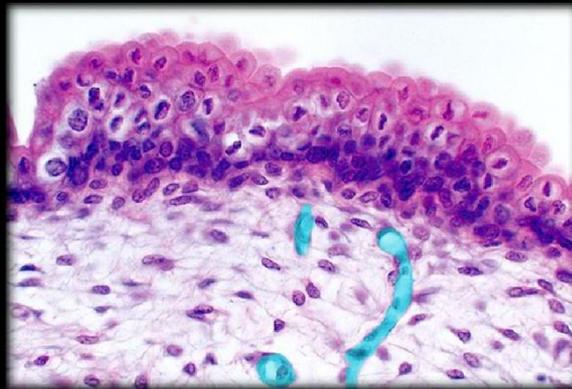
Transitional epithelium



Lamina propria



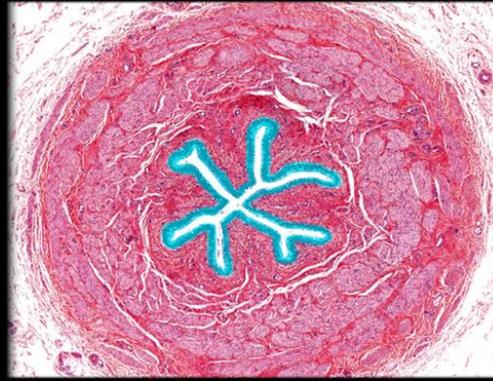
Luminal cells



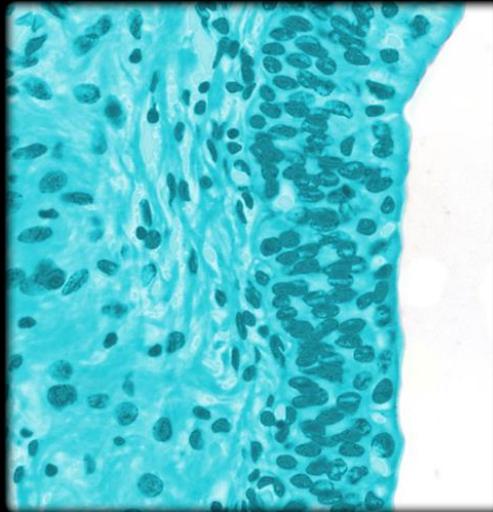
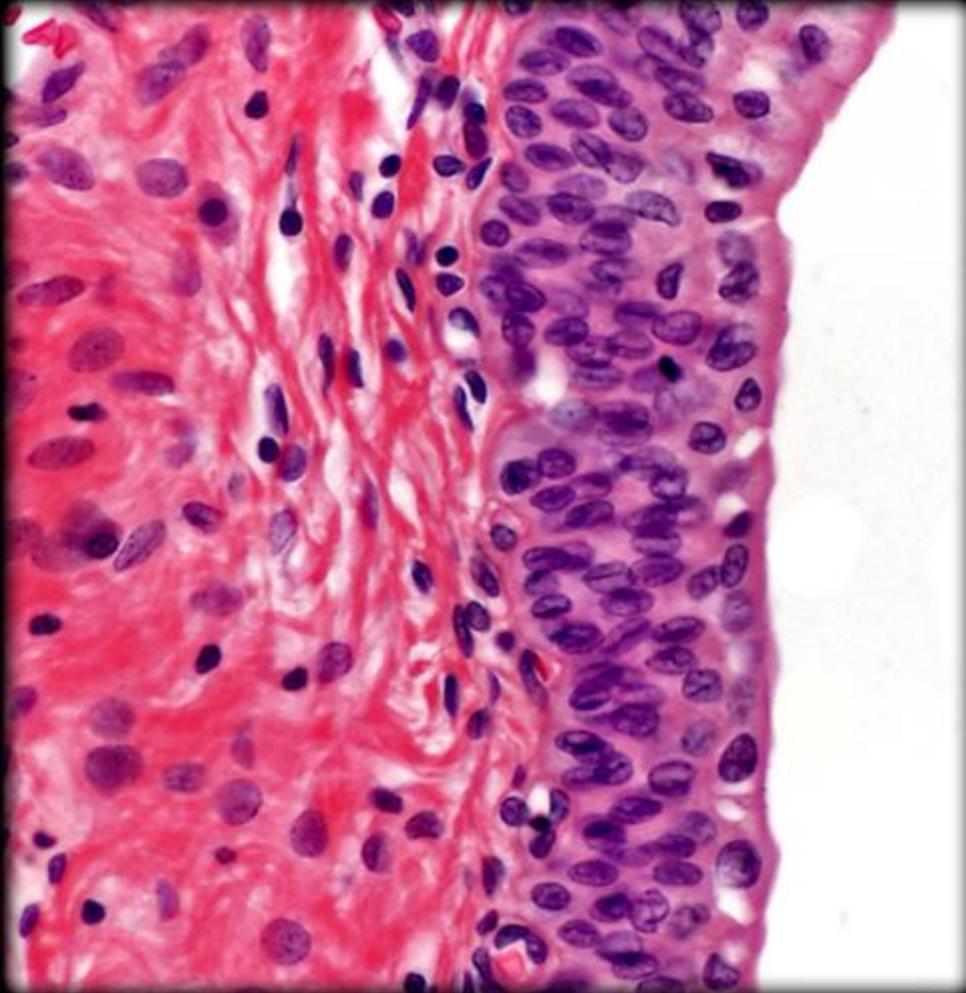
Blood capillary

# Transitional Epithelium

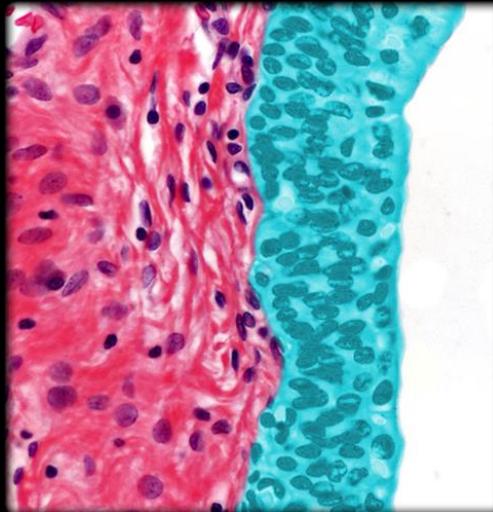
## LM: High Magnification



Cross-section of ureter



Mucosa of ureter

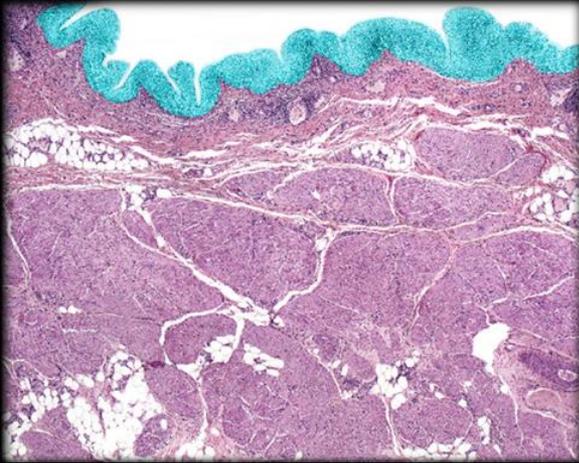


Transitional epithelium of ureter

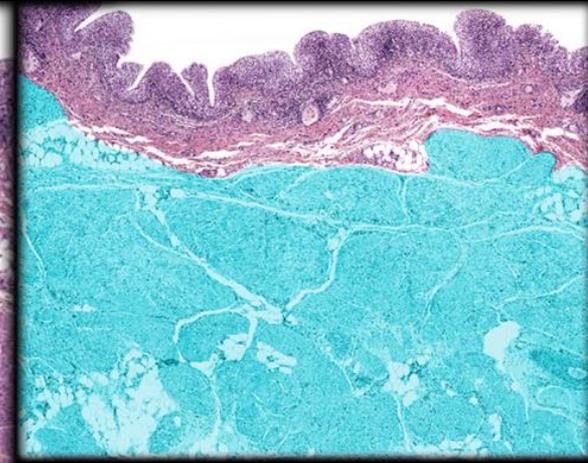
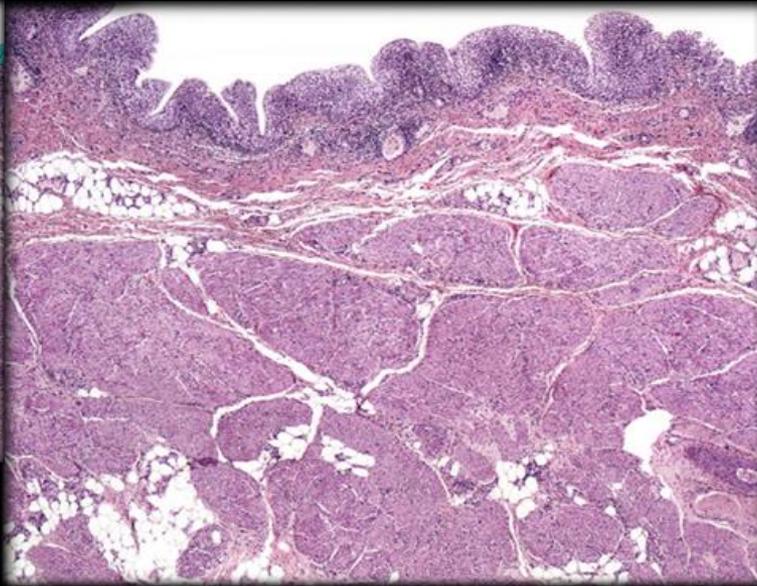
# Transitional Epithelium of Urinary Bladder

## LM: High Magnification

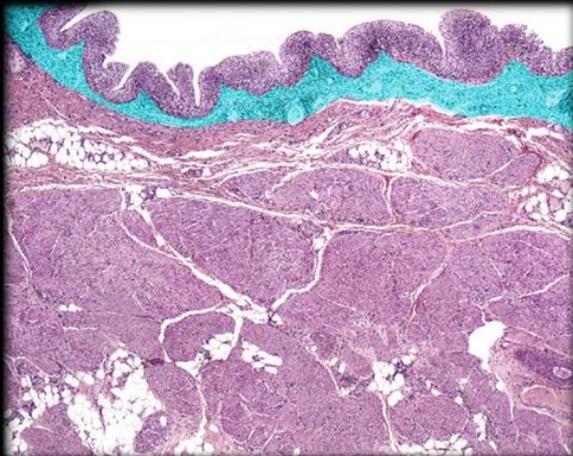
Transitional epithelium of bladder



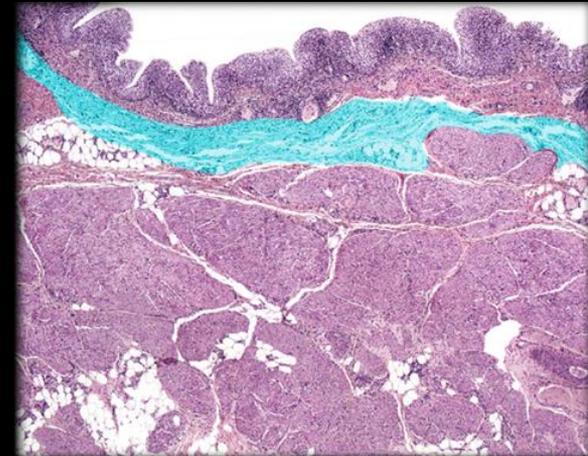
Detrusor muscle



Lamina propria of bladder



Submucosa of bladder

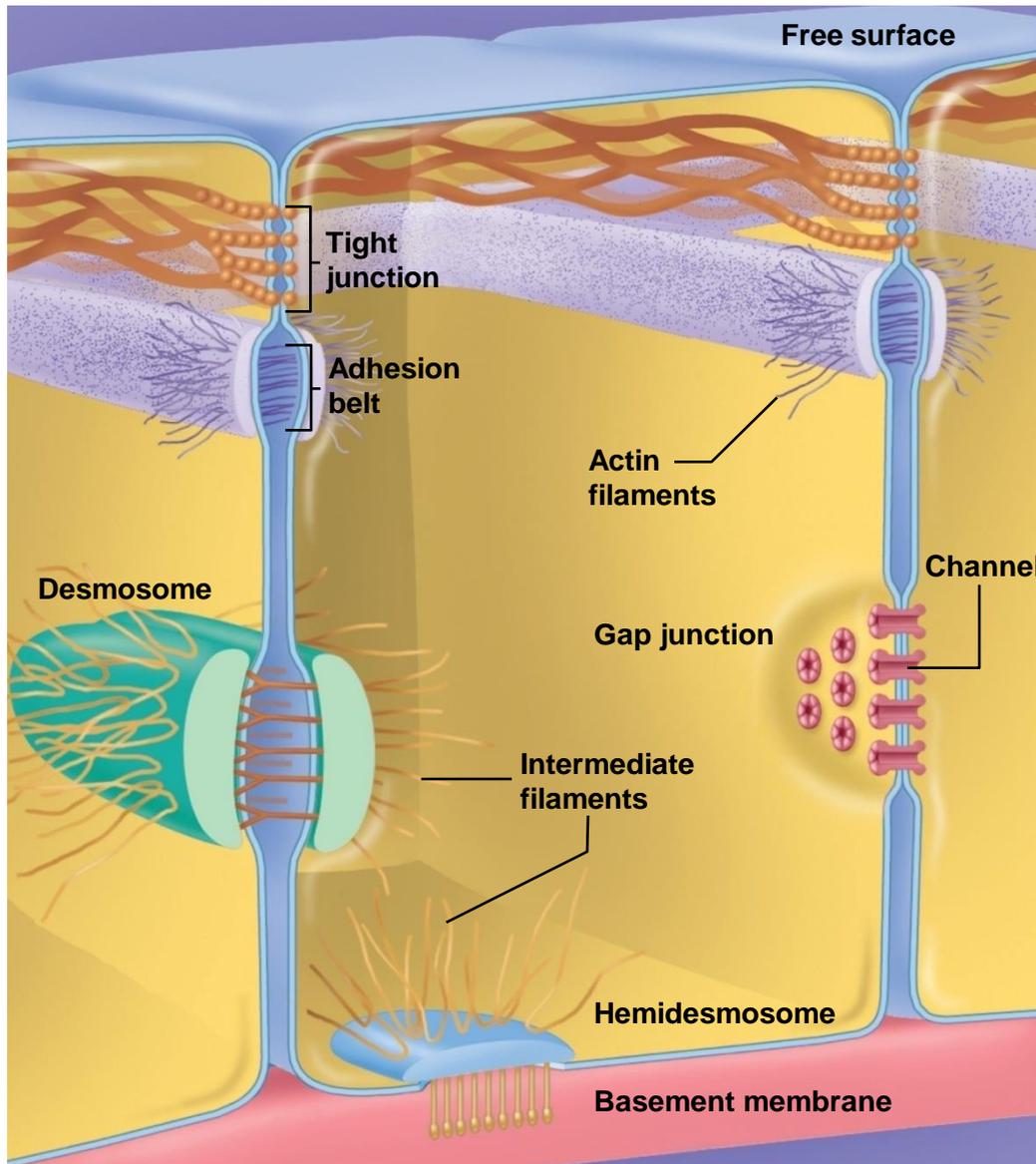


**TABLE 4.5** Function and Location of Epithelial Tissue

LOCATION								
Function	Simple Squamous Epithelium	Simple Cuboidal Epithelium	Simple Columnar Epithelium	Stratified Squamous Epithelium	Stratified Cuboidal Epithelium	Stratified Columnar Epithelium	Pseudostratified Columnar Epithelium	Transitional Epithelium
Diffusion	Blood and lymphatic capillaries, alveoli of lungs, thin segments of loops of Henle							
Filtration	Bowman capsules of kidneys							
Secretion or absorption	Mesothelium (serous fluid)	Choroid plexus (produces cerebrospinal fluid), part of kidney tubules, many glands and their ducts	Stomach, small intestine, large intestine, uterus, many glands					
Protection (against friction and abrasion)	Endothelium (e.g., epithelium of blood vessels) Mesothelium (e.g., epithelium of body cavities)			Skin (epidermis), corneas, mouth and throat, epiglottis, larynx, esophagus, anus, vagina				
Movement of mucus (ciliated)		Terminal bronchioles of lungs	Bronchioles of lungs, auditory tubes, uterine tubes, uterus				larynx, nasal cavity, paranasal sinuses, nasopharynx, auditory tubes, trachea, bronchi of lungs	
Capable of great stretching								Urinary bladder, ureter, superior part of urethra
Miscellaneous	Inner part of tympanic membranes, smallest ducts of glands	Surface of ovaries, inside lining of eyes (pigmented epithelium of retina), ducts of glands	Bile duct, gallbladder, ependyma (lining of brain ventricles and central canal of spinal cord), ducts of glands	Lower part of urethra, sebaceous gland ducts	Sweat gland ducts	Part of male urethra, epididymides, ductus deferens, mammary gland ducts	Part of male urethra, salivary gland ducts	

# Cell Connections

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- Found on lateral and basal surfaces of cells
- Functions
  - Form permeability layer
  - Bind cells together
  - Provide mechanism for intercellular communication
- Types
  - Desmosomes
  - Tight junctions
  - Gap junctions

# Cell Connections

- **Desmosomes**: disk-shaped regions of cell membrane; often found in areas that are subjected to stress.
  - Contain especially adhesive glycoproteins.
  - Intermediate protein filaments extend into cytoplasm of cells.
  - Striated squamous epithelium of the skin.
- **Hemidesmosomes**: half of a desmosome; attach epithelial cells to basement membrane.
- **Tight Junctions**: hold cells together, form permeability barrier.
  - **zonula adherens**: between adjacent cells, weak glue, hold cells together. Simple epithelium.
  - **zonula occludens**: permeability barrier, e.g., stomach and urinary bladder, chemicals cannot pass between cells.
- **Gap Junctions**: protein channels aid intercellular communication.
  - Allows ions and small molecules to pass through.
  - Coordinate function of cardiac and smooth muscle.
  - May help coordinate movement of cilia in ciliated types of epithelium.

# Glands

- Epithelium with supporting network of C.T.
- Two types of glands formed by infolding of epithelium:
  - **Endocrine**: no open contact with exterior; no ducts; produce hormones
  - **Exocrine**: open contact maintained with exterior; ducts
- Exocrine glands classified either by structure or by the method of secretion
- Classified by structure
  - Unicellular: **goblet cells**
  - Multicellular

# Goblet Cells



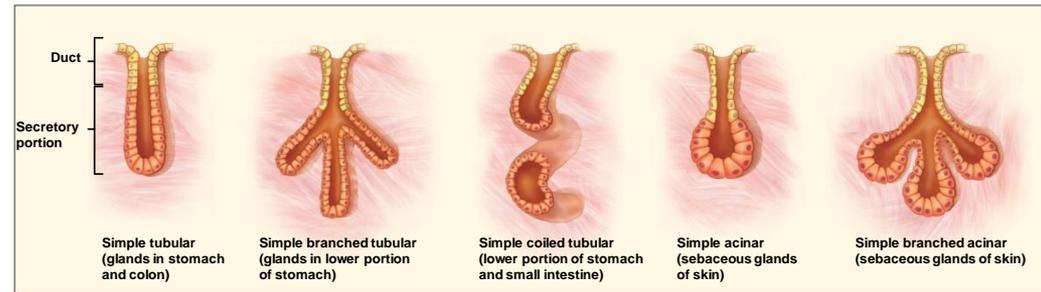
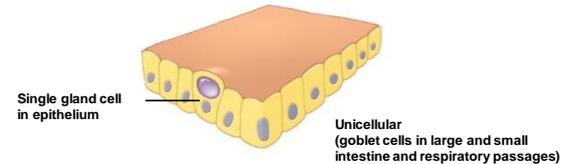
Goblet  
cells

Trachea

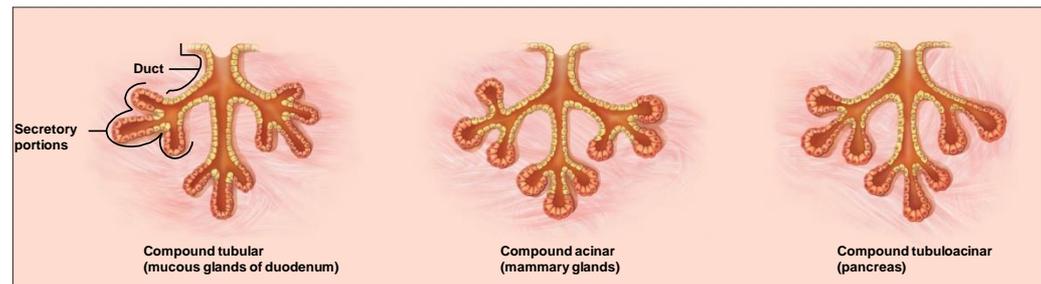
# Multicellular Exocrine Glands

- Classified on the basis of types of ducts or mode of secretion
- Types of ducts
  - **Simple**: ducts with few branches
  - **Compound**: ducts with many branches
    - If ducts end in tubules or sac-like structures: **acini**. Pancreas
    - If ducts end in simple sacs: **alveoli**. Lungs

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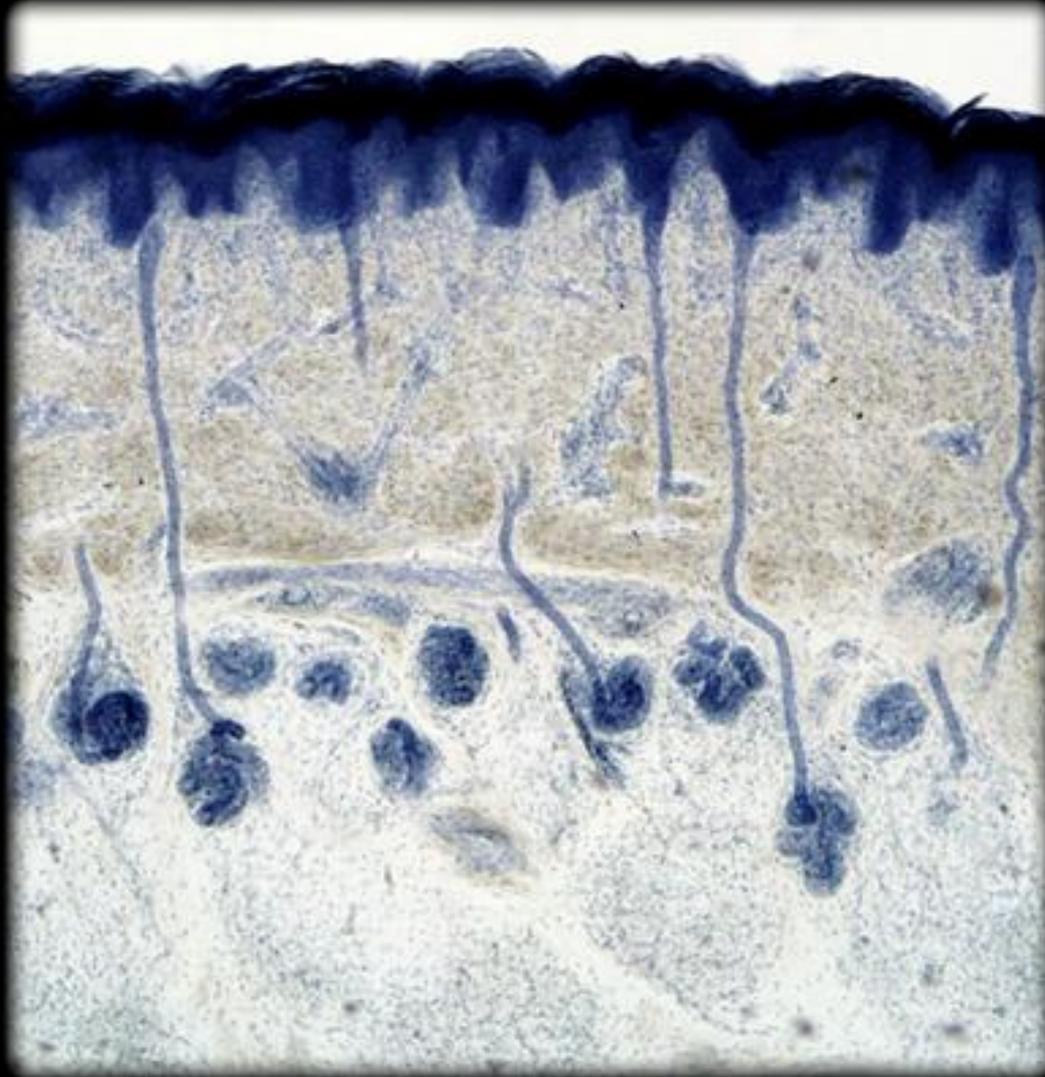


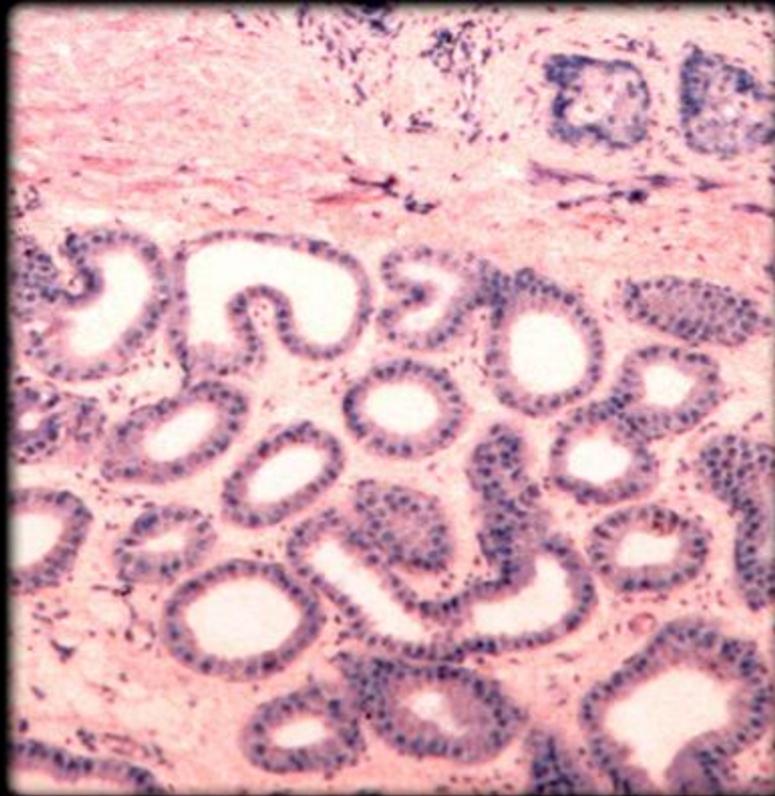
(a) Simple glands



(b) Compound glands

# Merocrine Sweat Gland

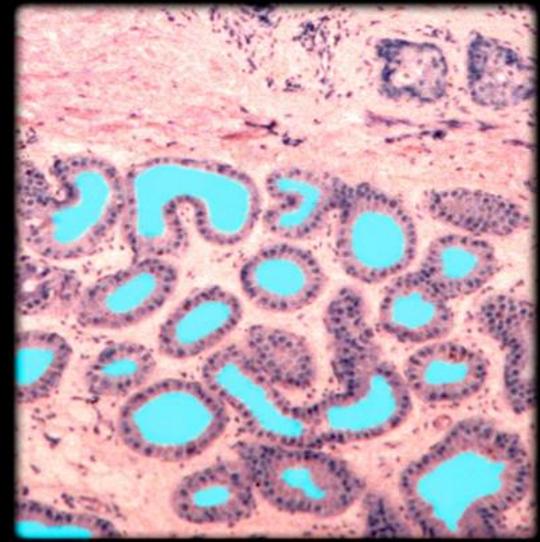
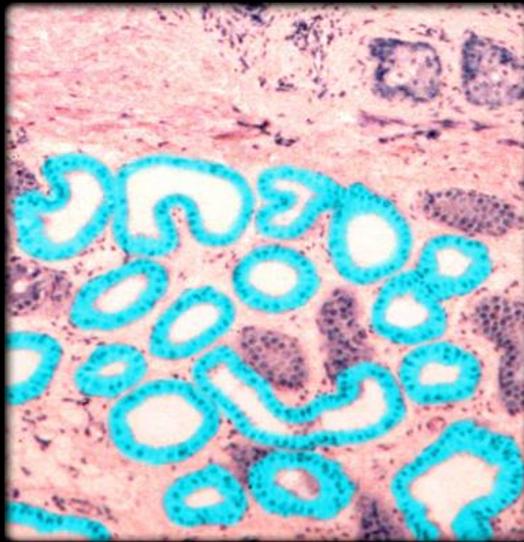
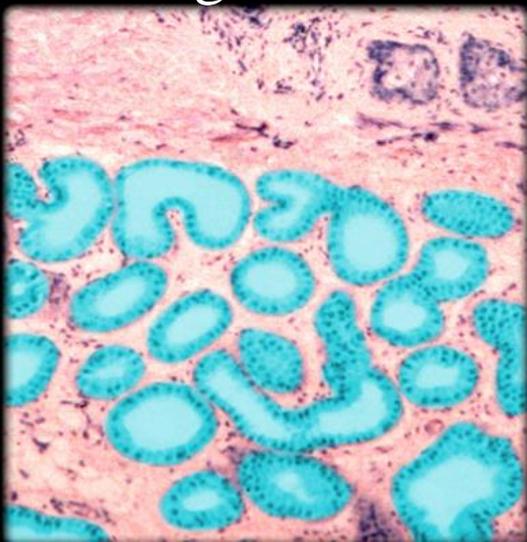




Apocrine sweat  
gland

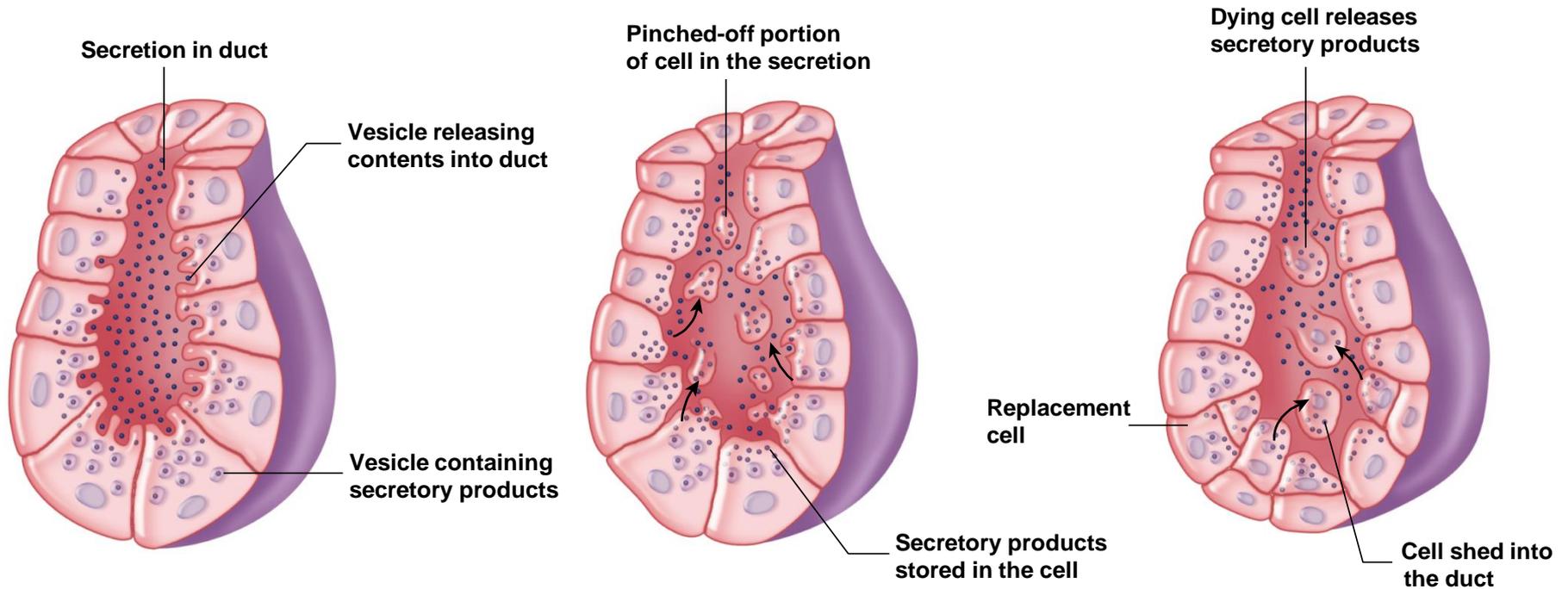
Epithelium of apocrine sweat gland

Lumen



# Method of Secretion Types

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## (a) Merocrine gland

Cells of the gland produce secretions by active transport or produce vesicles that contain secretory products, and the vesicles empty their contents into the duct through exocytosis.

## (b) Apocrine gland

Secretory products are stored in the cell near the lumen of the duct. A portion of the cell near the lumen containing secretory products is pinched off the cell and joins secretions produced by a merocrine process.

## (c) Holocrine gland

Secretory products are stored in the cells of the gland. Entire cells are shed by the gland and become part of the secretion. The lost cells are replaced by other cells deeper in the gland.

# 4.4 Connective Tissue

- Abundant; found in every organ
- Consists of cells separated by extracellular matrix
- Many diverse types
- Performs variety of important functions

**TABLE 4.6**

**Classification of Connective Tissue**

**Embryonic Connective Tissue**

**Mesenchyme**

**Mucous connective tissue**

**Adult Connective Tissue**

**Connective Tissue Proper**

**Loose (fewer fiber, more ground substance)**

**Areolar**

**Adipose**

**Reticular**

**Dense (more fiber, less ground substance)**

**Dense, regular collagenous**

**Dense, regular elastic**

**Dense, irregular collagenous**

**Dense, irregular elastic**

**Supporting Connective Tissue**

**Cartilage (semisolid matrix)**

**Hyaline**

**Fibrocartilage**

**Elastic**

**Bone (solid matrix)**

**Spongy**

**Compact**

**Fluid Connective Tissue**

**Blood**

**Red blood cells**

**White blood cells**

**Platelets**

**Hemopoietic tissue**

**Red marrow**

**Yellow marrow**

# Functions of Connective Tissue

- Enclose organs as a capsule and separate organs into layers
- Connect tissues to one another. Tendons and ligaments.
- Support and movement. Bones.
- Storage. Fat.
- Cushion and insulate. Fat.
- Transport. Blood.
- Protect. Cells of the immune system.

# Cells of Connective Tissue

- Specialized cells produce the extracellular matrix
- Descriptive word stems
  - **Blasts**: create the matrix, example osteoblast
  - **Cytes**: maintain the matrix, example chondrocyte
  - **Clasts**: break the matrix down for remodeling, example osteoclasts

# Cells of Connective Tissue

- **Adipose** or **fat cells (adipocytes)**. Common in some tissues (dermis of skin); rare in some (cartilage)
- **Mast cells**. Common beneath membranes; along small blood vessels. Can release heparin, histamine, and proteolytic enzymes in response to injury.
- **White blood cells (leukocytes)**. Respond to injury or infection
- **Macrophages**. Phagocytize or provide protection
  - **Fixed**: stay in position in connective tissue
  - **Wandering**: move by amoeboid movement through the connective tissue
- **Platelets**. Fragments of hematopoietic cells involved in clotting.
- **Undifferentiated mesenchyme** (stem cells). Have potential to differentiate into adult cell types.

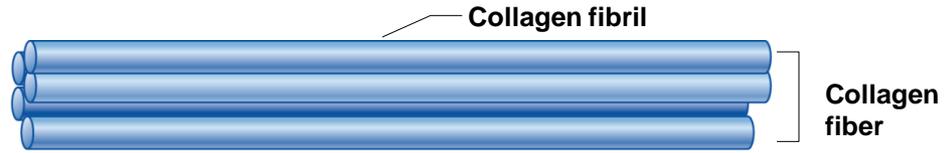
# Extracellular Matrix

- Protein fibers of the matrix
  - **Collagen**. Most common protein in body; strong, flexible, inelastic
  - **Reticular**. Fill spaces between tissues and organs. Fine collagenous, form branching networks
  - **Elastic**. Returns to its original shape after distension or compression. Contains molecules of protein elastin that resemble coiled springs; molecules are cross-linked

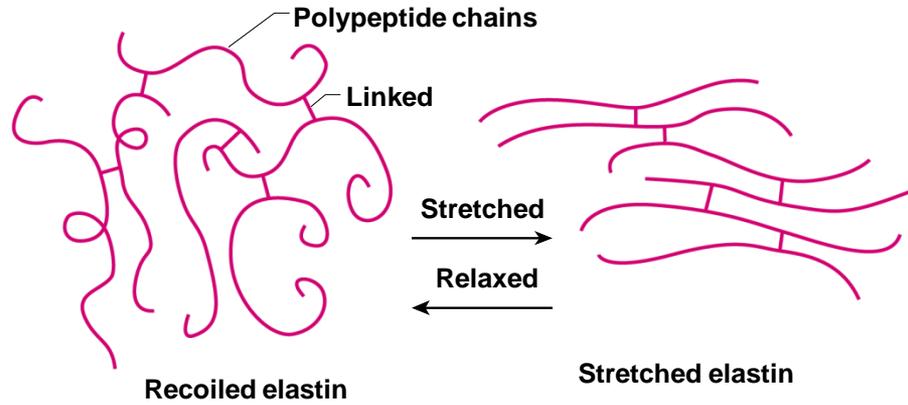
# Other Matrix Molecules

Most common molecules are called the **ground substance** and include:

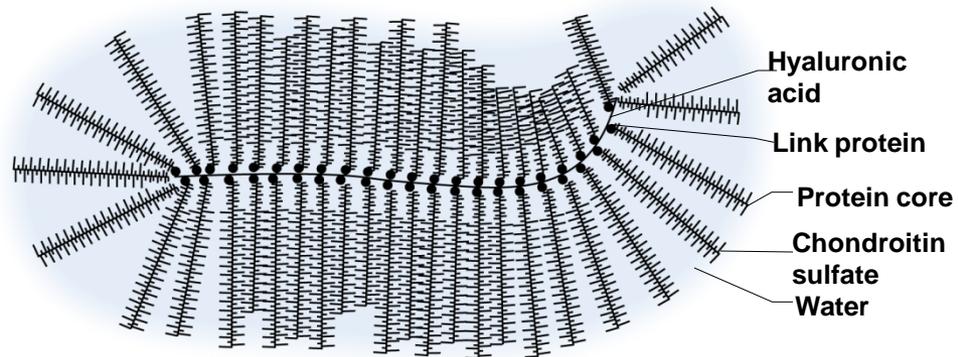
- **Hyaluronic acid**: polysaccharide. Good lubricant. Vitreous humor of eye.
- **Proteoglycans**: protein and polysaccharide. Protein part attaches to hyaluronic acid. Trap large amounts of water.
- **Adhesive molecules**: hold proteoglycan aggregates together. **Chondronectin** in cartilage, **osteonectin** in bone, **fibronectin** in fibrous connective tissue.



(a) Collagen fibers.



(b) Elastic fibers



(c) Proteoglycan aggregates.

# Embryonic Connective Tissue

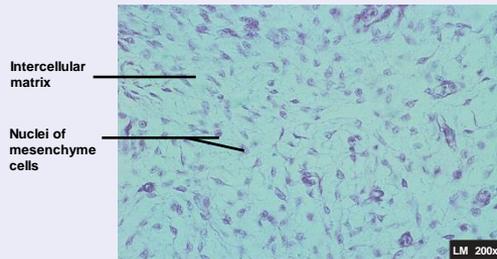
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TABLE 4.7 Embryonic Connective Tissue

(a) Mesenchyme

Structure: The mesenchymal cells are irregularly shaped; the extracellular matrix is abundant and contains scattered reticular fibers

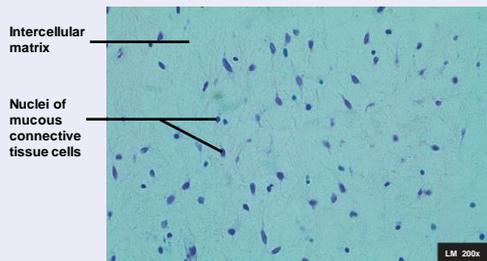
Location: Mesenchyme is the embryonic tissue from which connective tissues, as well as other tissues, arise



(b) Mucous Connective Tissue

Structure: Mucous tissue is mesenchymal tissue that remains unspecialized; the cells are irregularly shaped; the extracellular matrix is abundant and contains scattered reticular fibers

Location: Umbilical cord of newborn



a-b: © Victor Eroschenko

- **Mesenchyme:** source of all adult connective tissue.
  - Forms primarily from mesoderm
  - Delicate collagen fibers embedded in semi-fluid matrix
- **Mucus:** found only in the umbilical cord. Wharton's jelly.

# Adult Connective Tissues

- Connective Tissue Proper
  - Loose (areolar). Collagenous fibers are loosely arranged
  - Dense. Fibers form thick bundles that nearly fill all extracellular space
- Supporting CT
  - Cartilage
  - Bone
- Fluid CT
  - Blood

# Loose (Areolar) Connective Tissue

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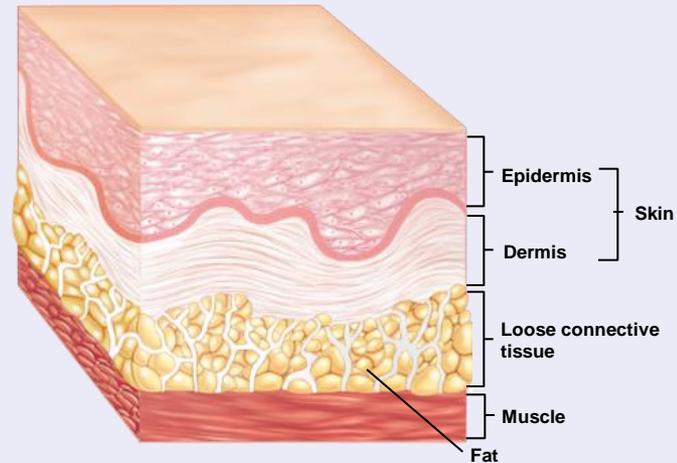
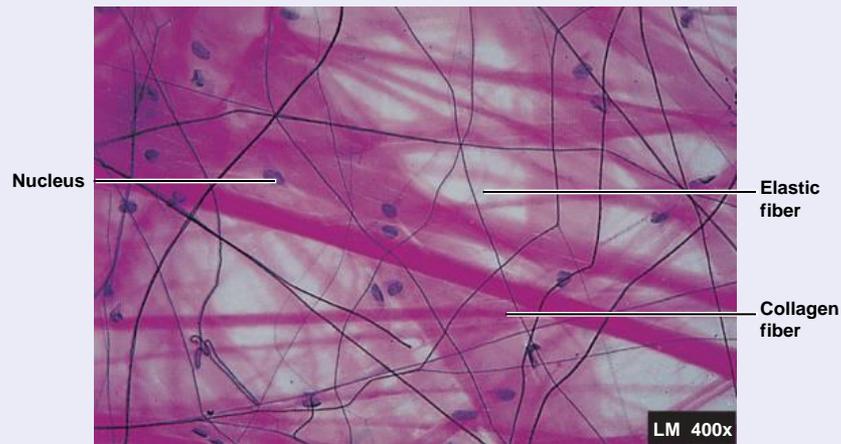
**TABLE 4.8** Connective Tissue Proper: Loose Connective Tissue

(a) Areolar Connective Tissue **AP|R**

**Structure:** Cells (e.g., fibroblasts, macrophages, and lymphocytes) within a fine network of mostly collagen fibers; often merges with denser connective tissue

**Function:** Loose packing, support, and nourishment for the structures with which it is associated

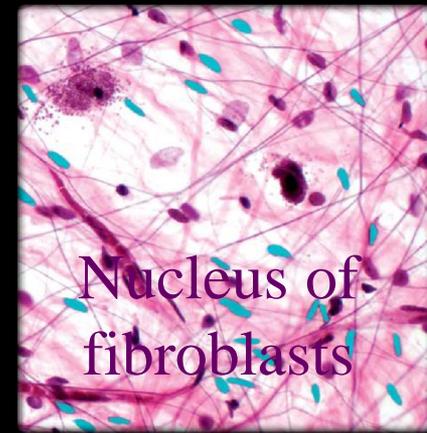
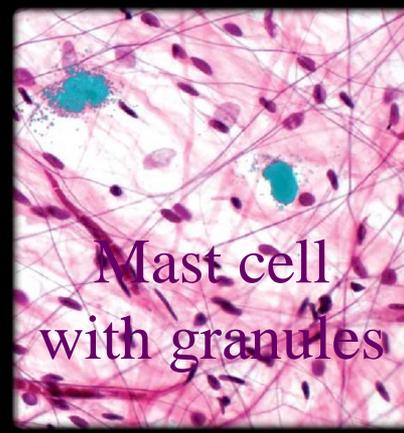
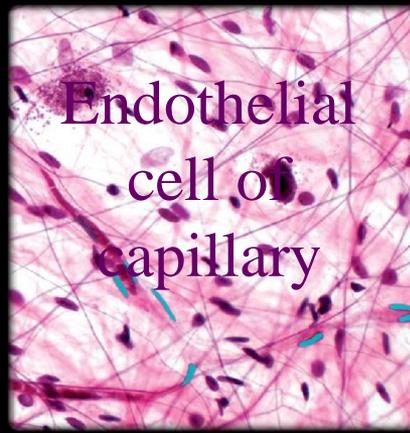
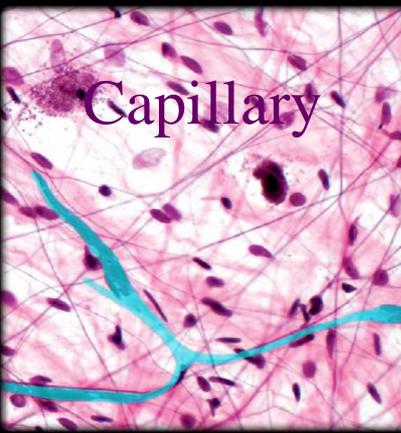
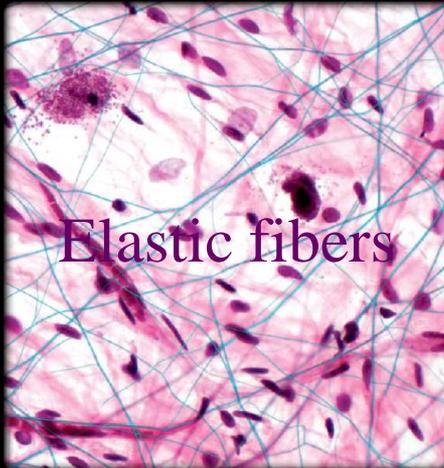
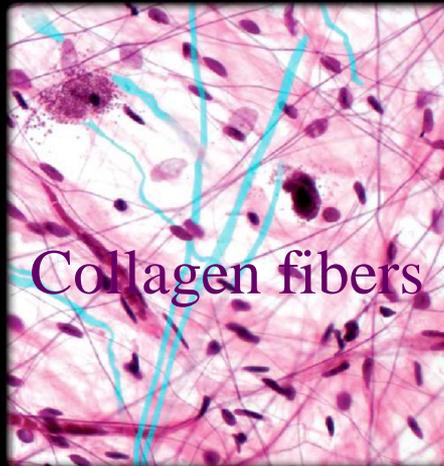
**Location:** Widely distributed throughout the body; substance on which epithelial basement membranes rest; packing between glands, muscles, and nerves; attaches the skin to underlying tissues



a:© Ed Reschke

- Loose packing material of most organs and tissues, also known as stroma
- Attaches skin to underlying tissues. Superficial fascia = subcutaneous layer = hypodermis
- Contains collagen, reticular, elastic fibers and all five types of cells
- Often seen in association with other types of C.T., like reticular tissue and fat
- Cells include fibroblasts, mast cells, lymphocytes, adipose cells, macrophages

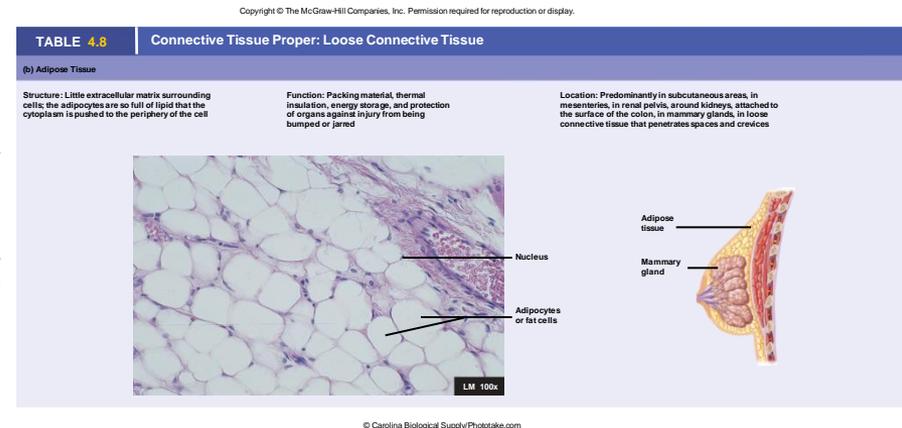
# Areolar Connective Tissue



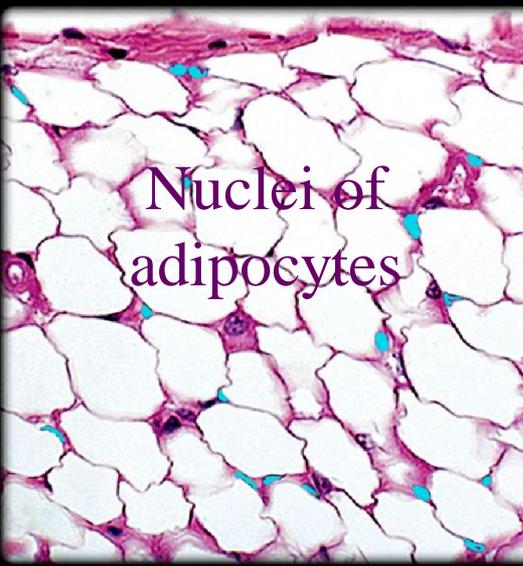
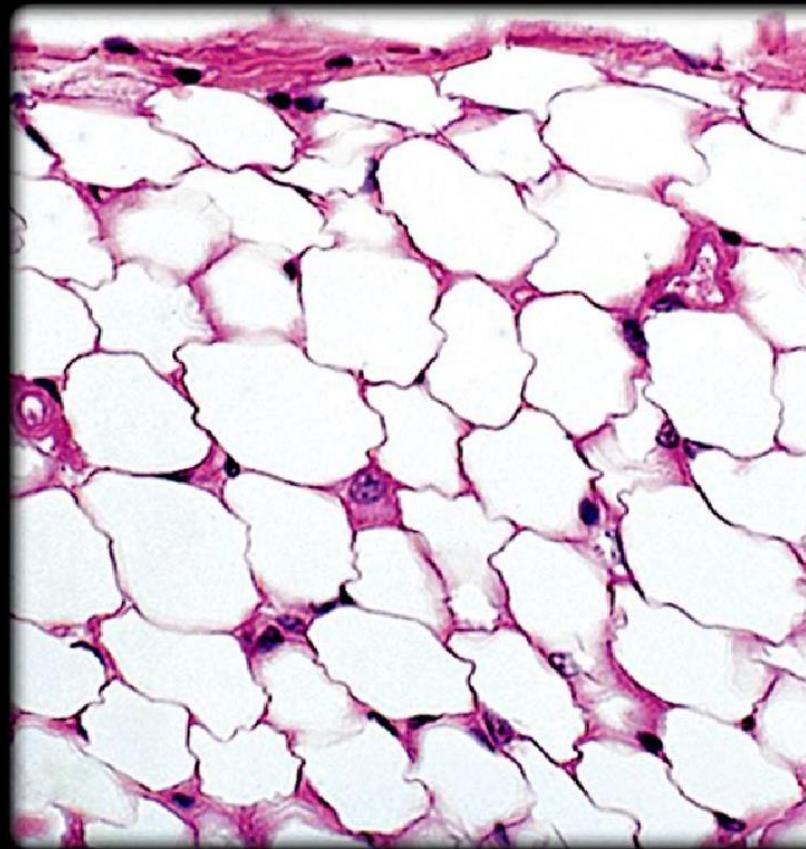
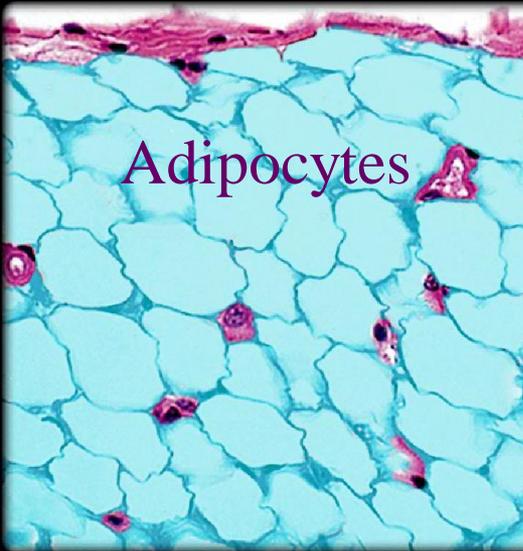
# Connective Tissue with Special Properties: Adipose

Predominant cells are **adipocytes**

- **Yellow (white)**. Most abundant type, has a wide distribution. White at birth and yellows with age.
  - Carotenes come from plants and can be metabolized into vitamin A.
  - Scant ring of cytoplasm surrounding single large lipid droplet. Nuclei flattened and eccentric.
- **Brown**. Found only in specific areas of body: axillae, neck and near kidneys
  - Cells are polygonal in shape, have a considerable volume of cytoplasm and contain multiple lipid droplets of varying size. Nuclei are round and almost centrally located.



# Adipose Connective Tissue



# Connective Tissue with Special Properties: Reticular Tissue

- Forms superstructure of lymphatic and hemopoietic tissues
- Network of fine reticular fibers and reticular cells.
- Spaces between cells contain white cells and dendritic cells

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**TABLE 4.8**

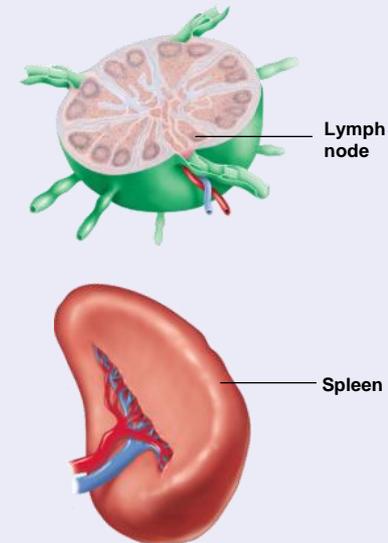
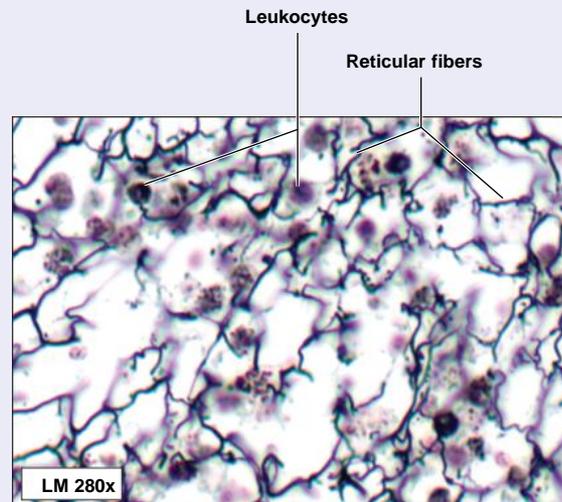
## Connective Tissue Proper: Loose Connective Tissue

### (c) Reticular Tissue

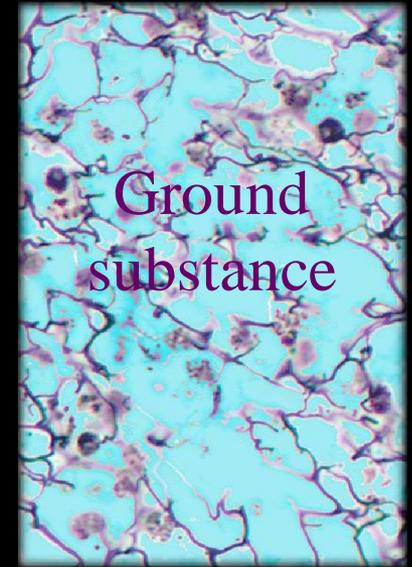
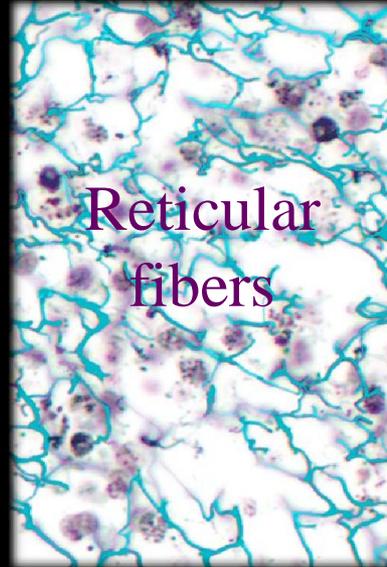
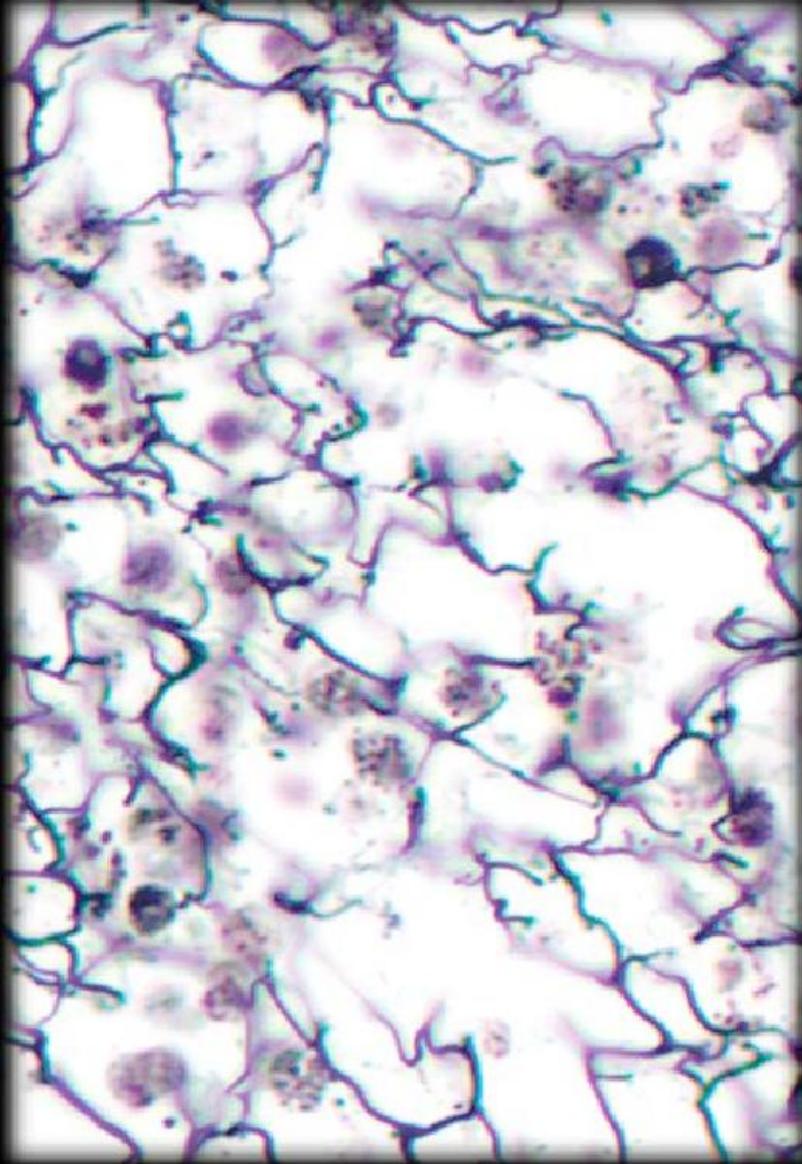
**Structure:** Fine network of reticular fibers irregularly arranged

**Function:** Provides a superstructure for lymphatic and hemopoietic tissues

**Location:** Within the lymph nodes, spleen, bone marrow



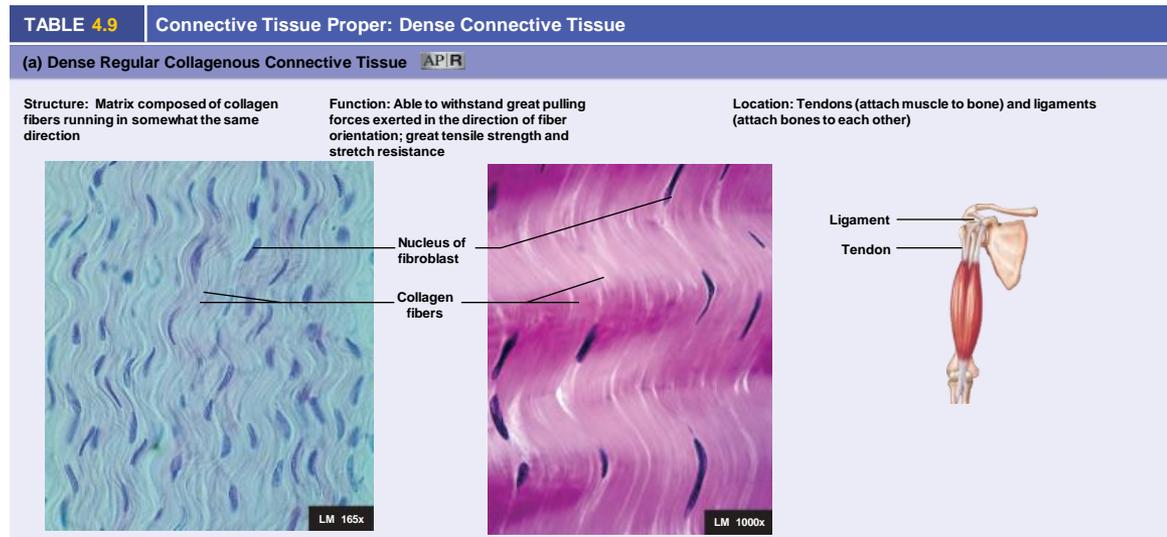
# Reticular Connective Tissue



# Dense Regular Collagenous Connective Tissue

- Has abundant collagen fibers that resist stretching
  - **Tendons:** Connect muscles to bones; fibers are not necessarily parallel
  - **Ligaments:** Connect bones to bones. Collagen often less compact, usually flattened, form sheets or bands

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a1: © Victor Eroschenko; a2: © Ed Reschke/Peter Arnold, Inc.

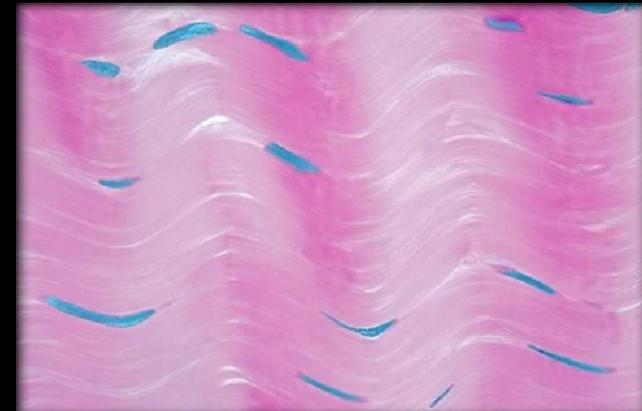
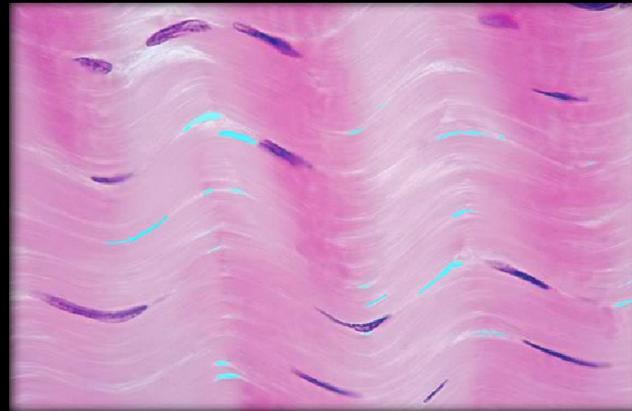
# Dense Regular Connective Tissue



Collagen fibers

Ground substance

Nuclei of fibroblasts



# Dense Regular Elastic Connective Tissue

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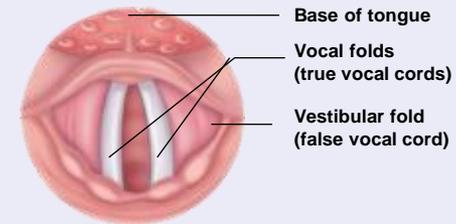
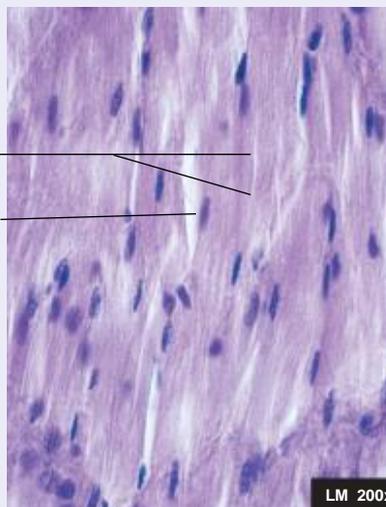
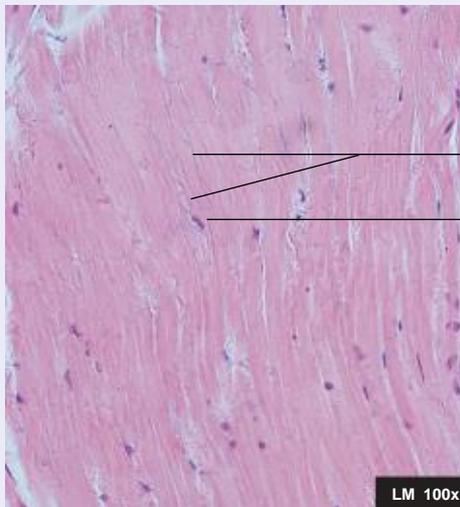
TABLE 4.9 Connective Tissue Proper: Dense Connective Tissue

(b) Dense Regular Elastic Connective Tissue **AP|R**

Structure: Matrix composed of regularly arranged collagen fibers and elastic fibers

Function: Able to stretch and recoil like a rubber band, with strength in the direction of fiber orientation

Location: Vocal folds and elastic ligaments between the vertebrae and along the dorsal aspect of the neck



© Victor Eroschenko

- Ligaments in vocal folds; **nuchal ligament**
- Collagen fibers give strength (for when you shout), but elastic fibers are more prevalent

# Dense Irregular Collagenous Connective Tissue

- Protein fibers arranged in a randomly oriented network
- Forms innermost layer of the dermis of the skin, scars, capsules of kidney and spleen

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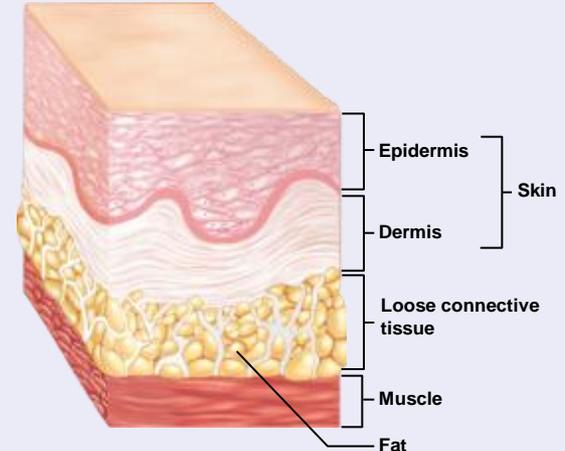
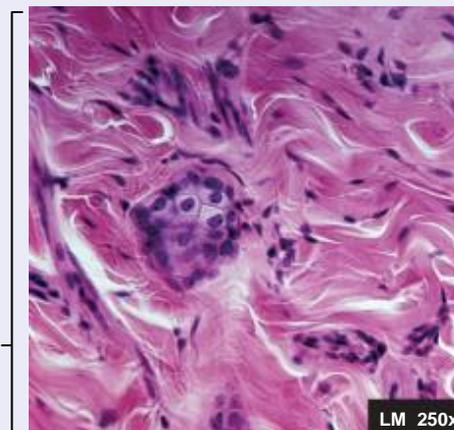
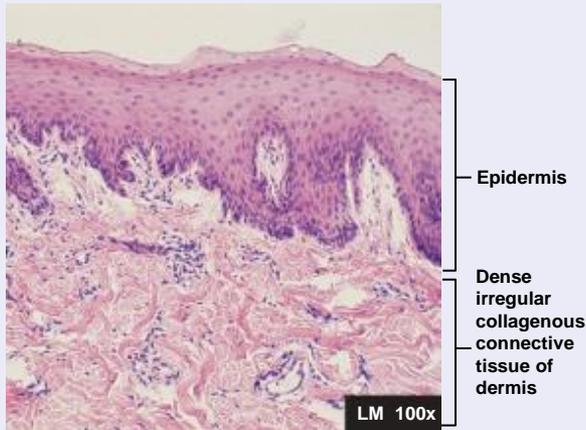
**TABLE 4.9** Connective Tissue Proper: Dense Connective Tissue—Continued

**(c) Dense Irregular Collagenous Connective Tissue**

**Structure:** Matrix composed of collagen fibers that run in all directions or in alternating planes of fibers oriented in a somewhat single direction

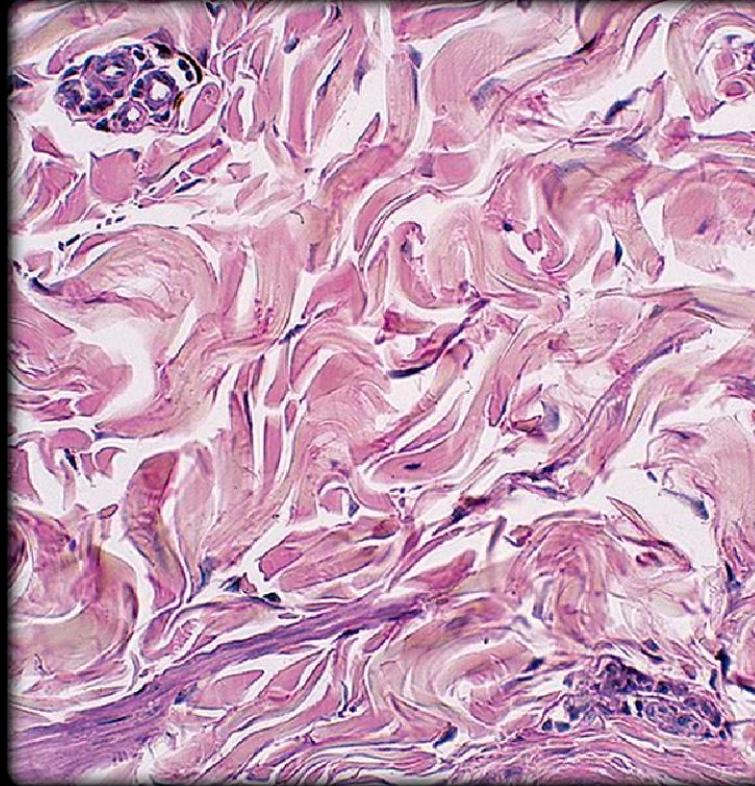
**Function:** Tensile strength capable of withstanding stretching in all directions

**Location:** Sheaths; most of the dermis of the skin; organ capsules and septa; outer covering of body tubes

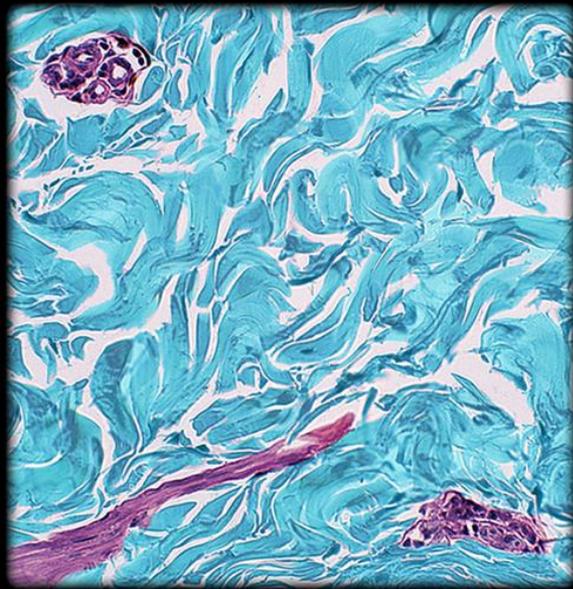


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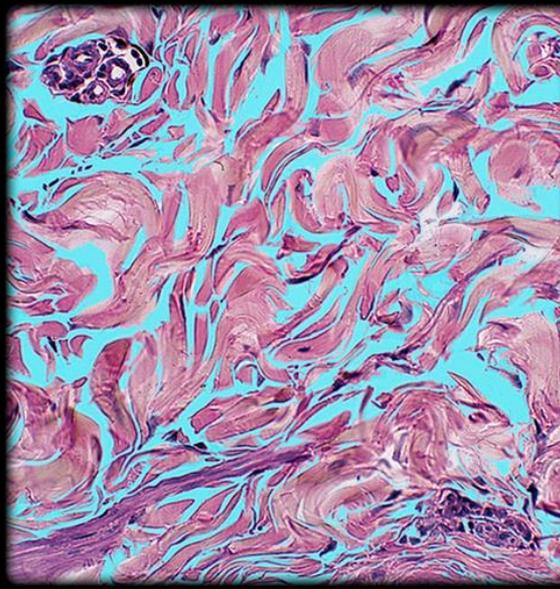
# Dense Irregular Connective Tissue



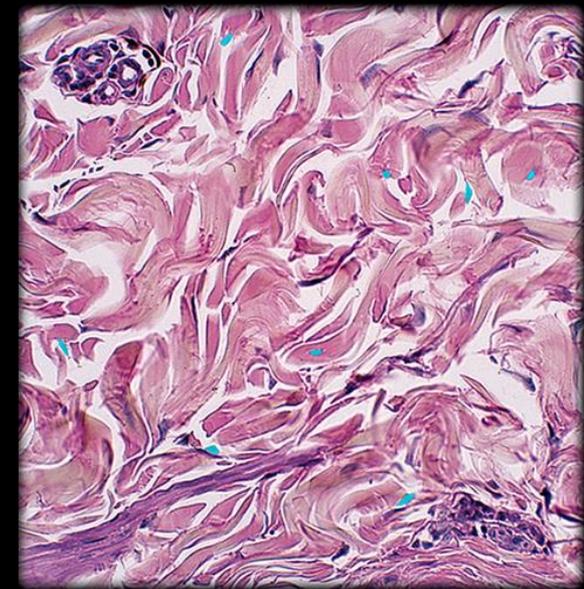
Collagen fibers



Ground substance



Nuclei of fibroblasts



# Dense Irregular Elastic Connective Tissue

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TABLE 4.9

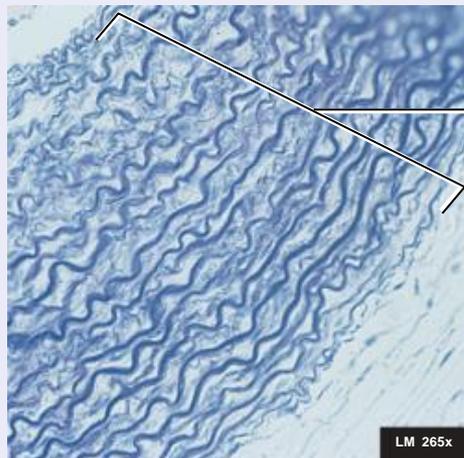
## Connective Tissue Proper: Dense Connective Tissue

### (d) Dense Irregular Elastic Connective Tissue

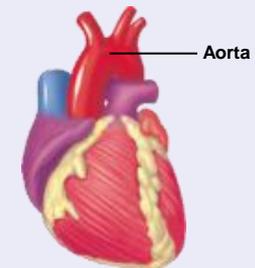
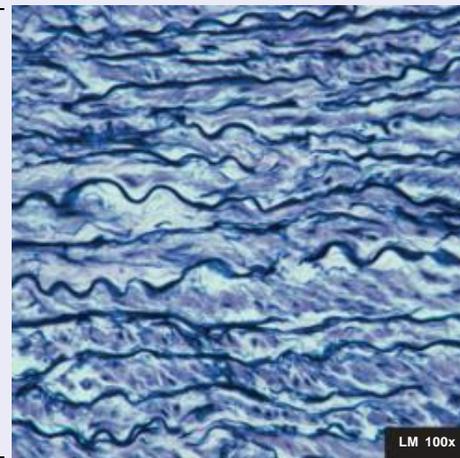
**Structure:** Matrix composed of bundles and sheets of collagenous and elastic fibers oriented in multiple directions

**Function:** Capable of strength, with stretching and recoil in several directions

**Location:** Elastic arteries



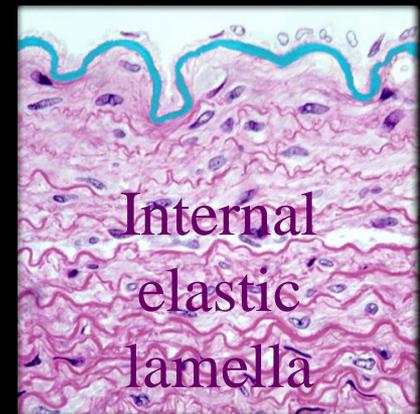
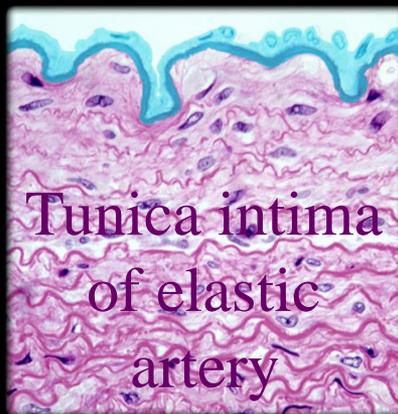
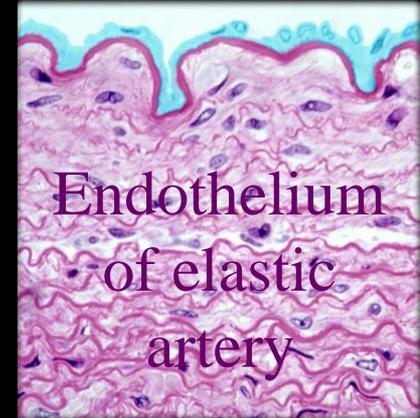
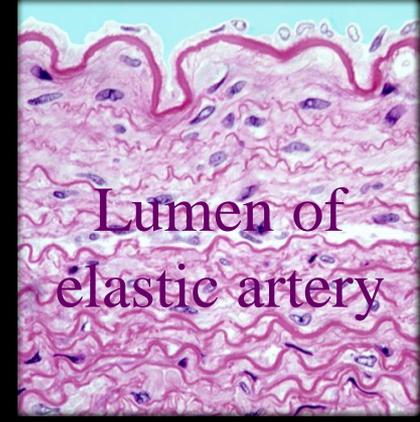
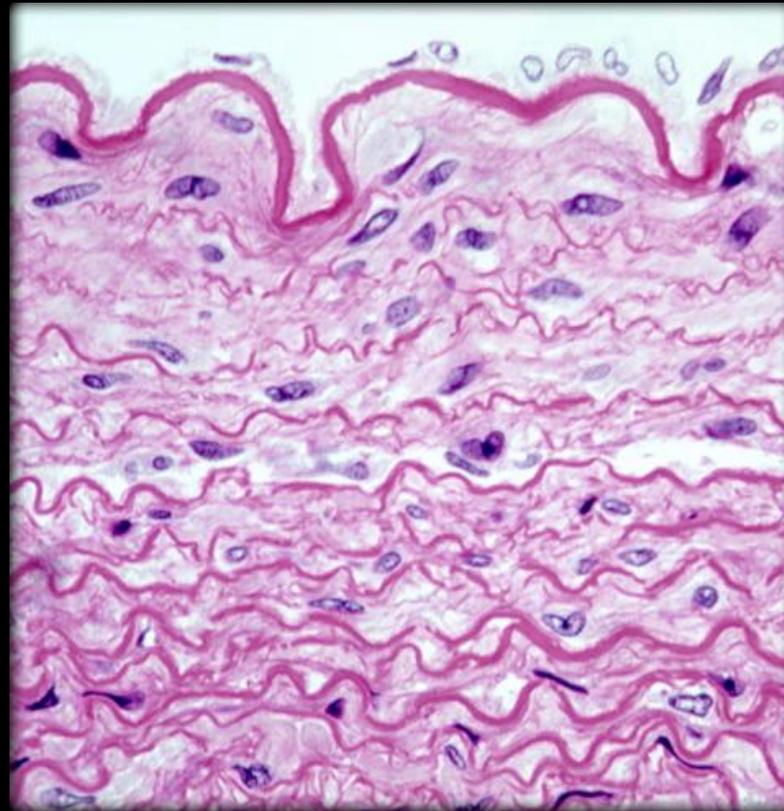
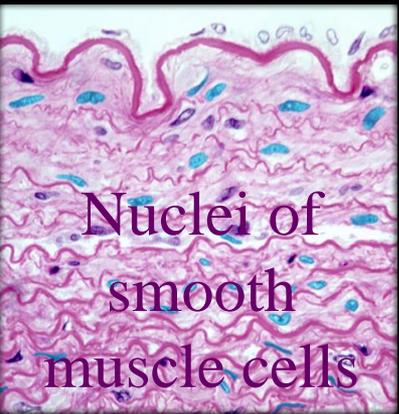
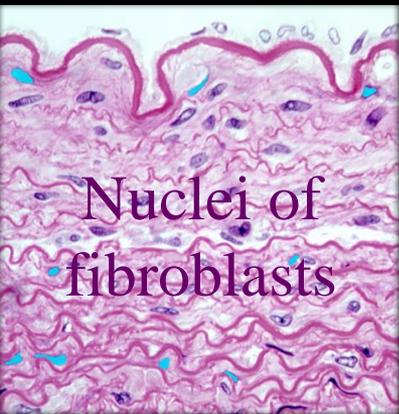
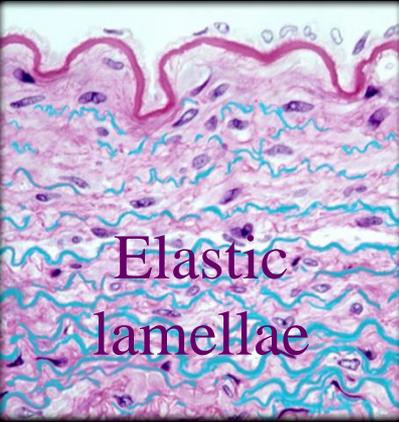
Dense irregular elastic connective tissue



© Ed Reschke

- Bundles and sheets of collagenous and elastic fibers oriented in multiple directions
- In walls of elastic arteries
- Strong, yet elastic

# Elastic Connective Tissue



# Supporting Connective Tissue: Cartilage

- Composed of chondrocytes located in matrix-surrounded spaces called lacunae.
- Type of cartilage determined by components of the matrix.
- Firm consistency.
- Ground substance: Proteoglycans and hyaluronic acid complexed together trap large amounts of water. Tissue can spring back after being compressed.
- Avascular and no nerve supply. Heals slowly.
- **Perichondrium**. Dense irregular connective tissue that surrounds cartilage. Fibroblasts of perichondrium can differentiate into chondroblasts.
- Types of cartilage
  - Hyaline
  - Fibrocartilage
  - Elastic

# Hyaline Cartilage

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TABLE 4.10

## Supporting Connective Tissue: Cartilage

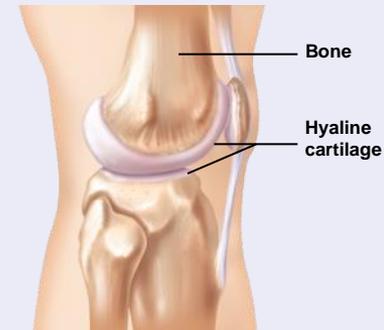
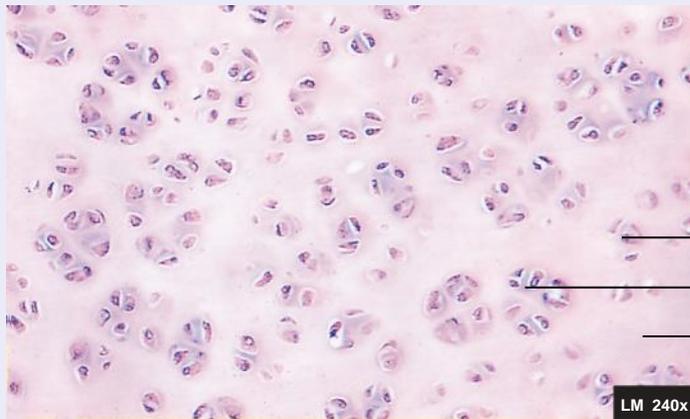
(a) Hyaline Cartilage

AP|R

**Structure:** Collagen fibers are small and evenly dispersed in the matrix, making the matrix appear transparent; the cartilage cells, or chondrocytes, are found in spaces, or lacunae, within the firm but flexible matrix

**Function:** Allows the growth of long bones; provides rigidity with some flexibility in the trachea, bronchi, ribs, and nose; forms rugged, smooth, yet somewhat flexible articulating surfaces; forms the embryonic skeleton

**Location:** Growing long bones, cartilage rings of the respiratory system, costal cartilage of ribs, nasal cartilages, articulating surface of bones, embryonic skeleton

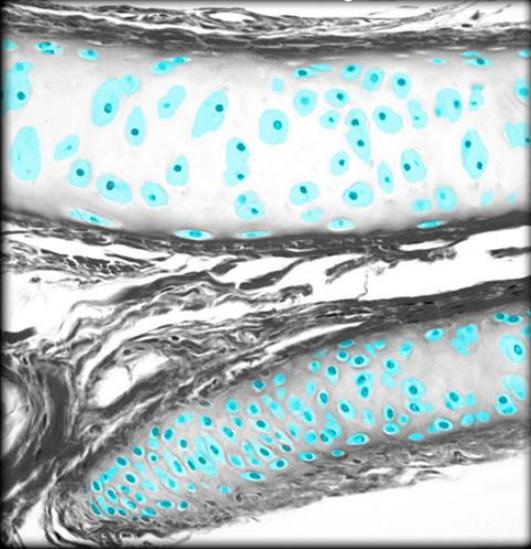


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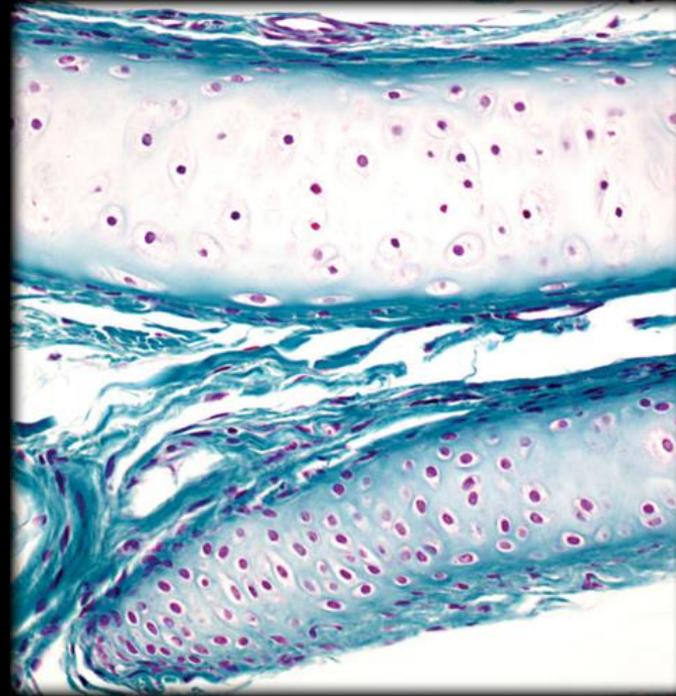
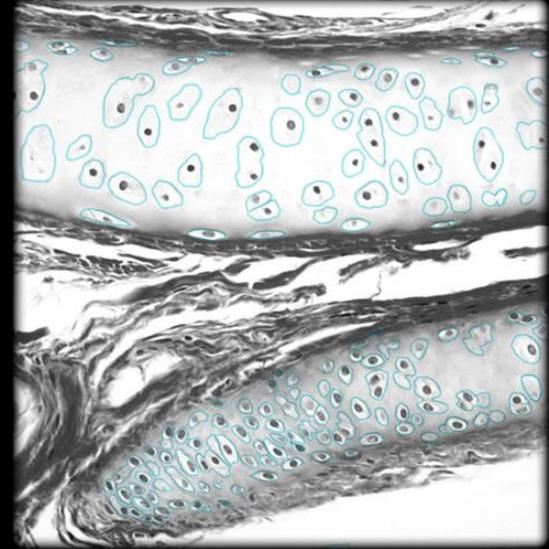
- **Structure:** large amount of collagen fibers evenly distributed in proteoglycan matrix. Smooth surface in articulations
- **Locations:**
  - Found in areas for strong support and some flexibility: rib cage, trachea, and bronchi
  - In embryo forms most of skeleton
  - Involved in growth that increases bone length

# Hyaline Cartilage

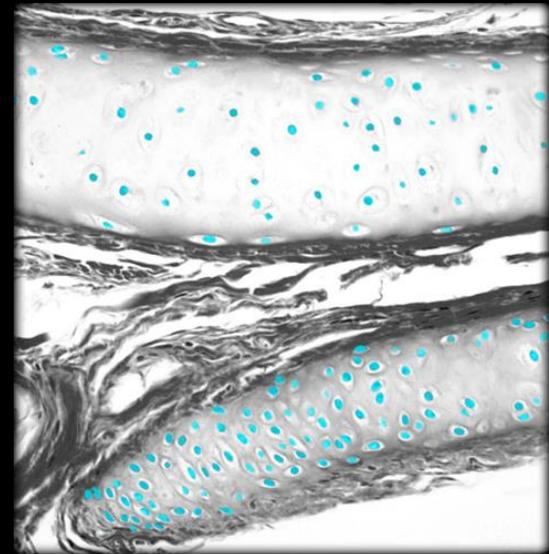
Chondrocytes



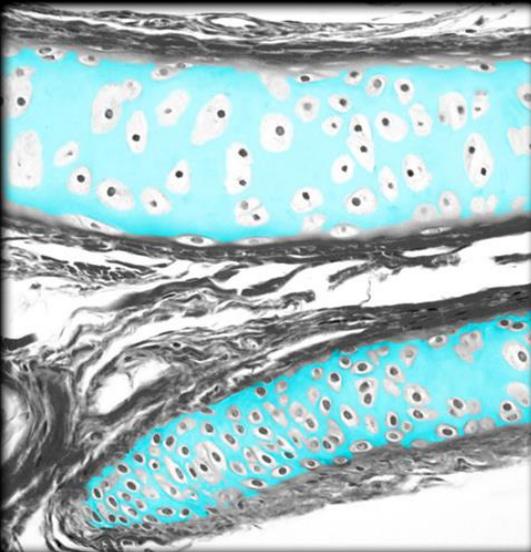
Lacunae



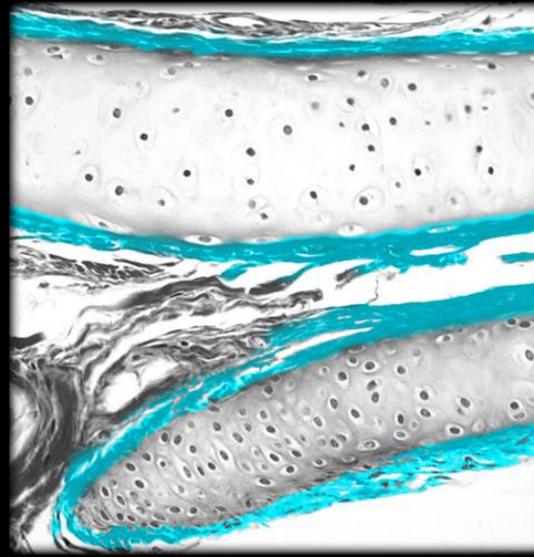
Nuclei of chondrocytes



Extracellular matrix



Perichondrium



# Fibrocartilage

- Structure: thick collagen fibers distributed in proteoglycan matrix; slightly compressible and very tough
- Locations: found in areas of body where a great deal of pressure is applied to joints
  - Knee, jaw, between vertebrae

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TABLE 4.10

## Supporting Connective Tissue: Cartilage

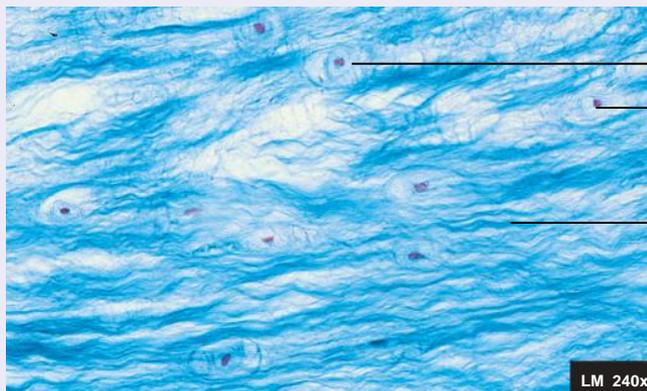
(b) Fibrocartilage

AP|R

**Structure:** Collagen fibers similar to those in hyaline cartilage; the fibers are more numerous than in other cartilages and are arranged in thick bundles

**Function:** Somewhat flexible and capable of withstanding considerable pressure; connects structures subjected to great pressure

**Location:** Intervertebral disks, symphysis pubis articular disks (e.g., knee and temporomandibular [jaw] joints)



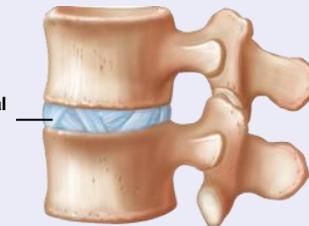
Chondrocyte in lacuna

Nucleus

Collagen fibers in matrix

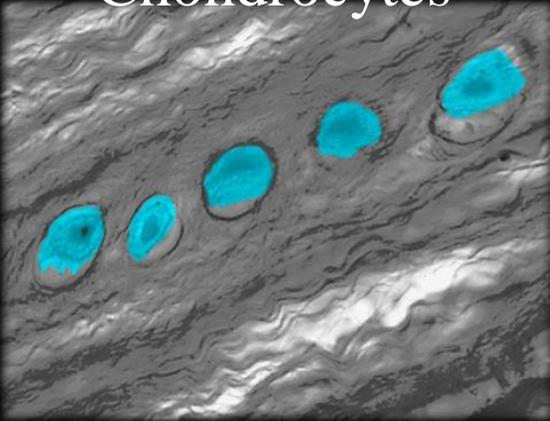
LM 240x

Inter vertebral disk

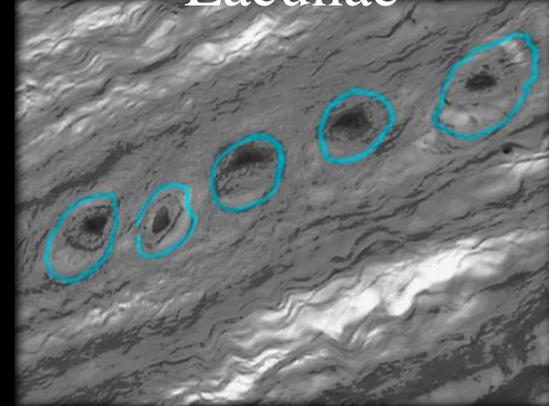


# Fibrocartilage

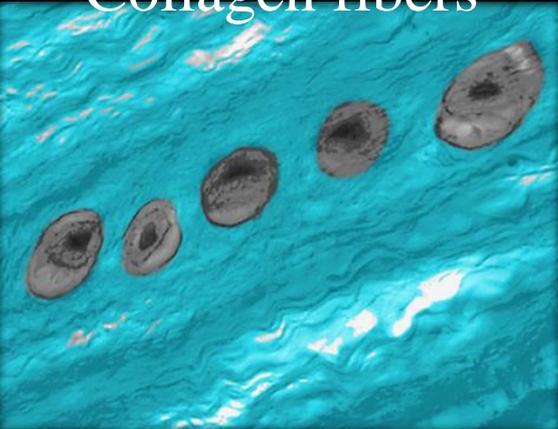
Chondrocytes



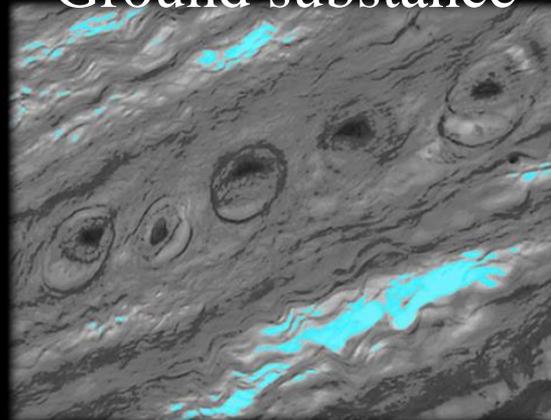
Lacunae



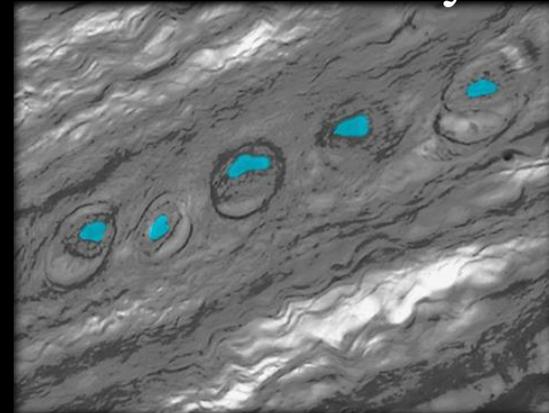
Collagen fibers



Ground substance



Nuclei of chondrocytes



# Elastic Cartilage

- Structure: elastic and collagen fibers embedded in proteoglycans. Rigid but elastic properties
- Locations: external ears and epiglottis

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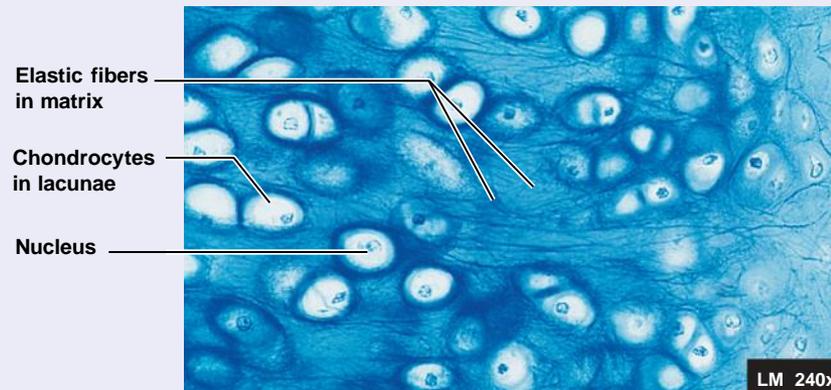
**TABLE 4.10** Supporting Connective Tissue: Cartilage

**(c) Elastic Cartilage**

**Structure:** Similar to hyaline cartilage, but matrix also contains elastic fibers

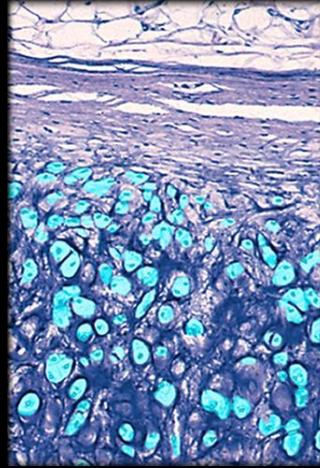
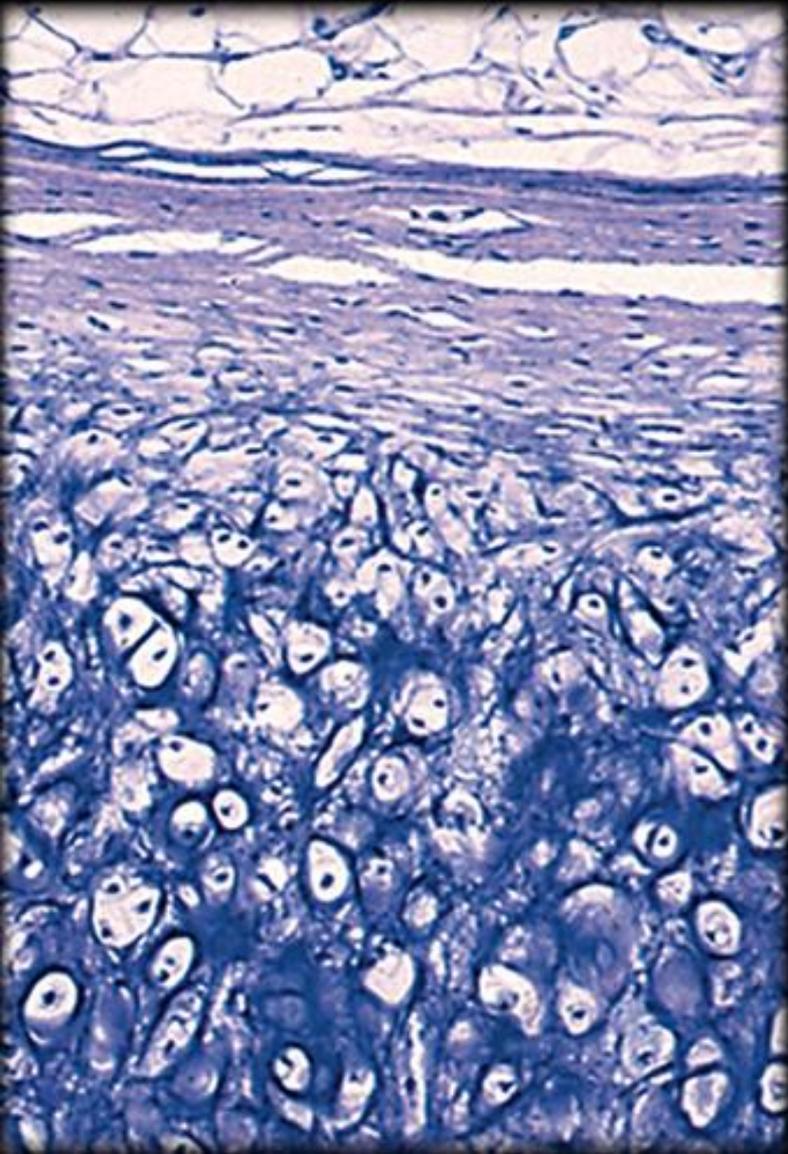
**Function:** Provides rigidity with even more flexibility than hyaline cartilage because elastic fibers return to their original shape after being stretched

**Location:** External ears, epiglottis, auditory tubes



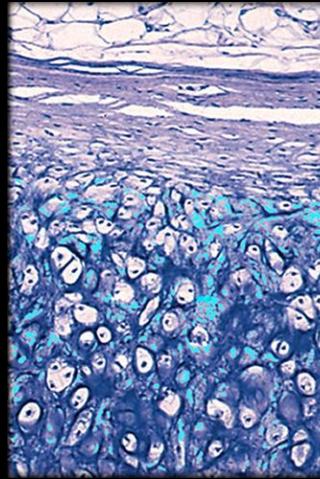
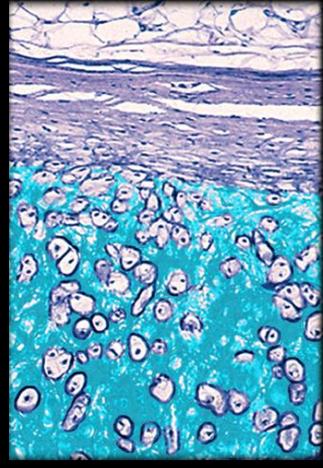
© Victor Eroschenko

# Elastic Cartilage



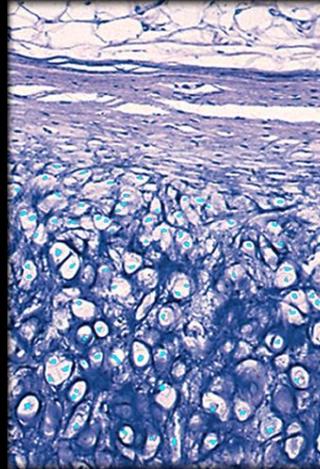
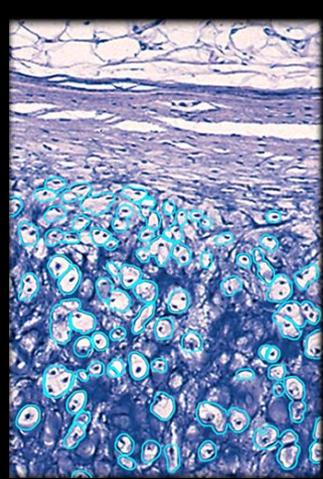
Chondrocytes

Elastic fibers



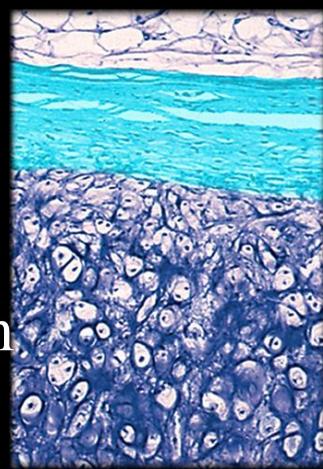
Ground  
substance

Lacunae



Nuclei of  
chondrocytes

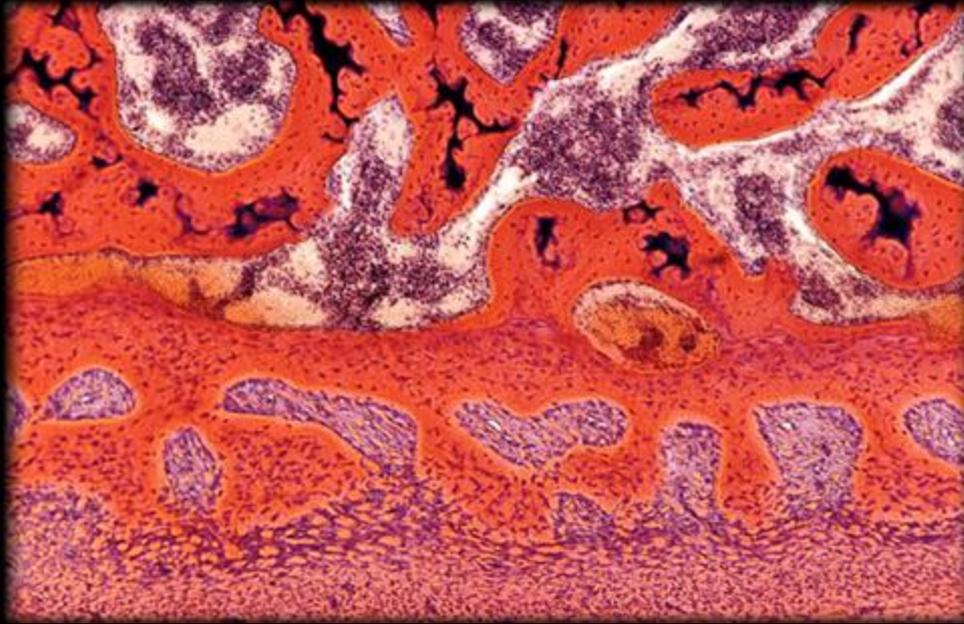
Perichondrium



# Supporting Connective Tissue: Bone

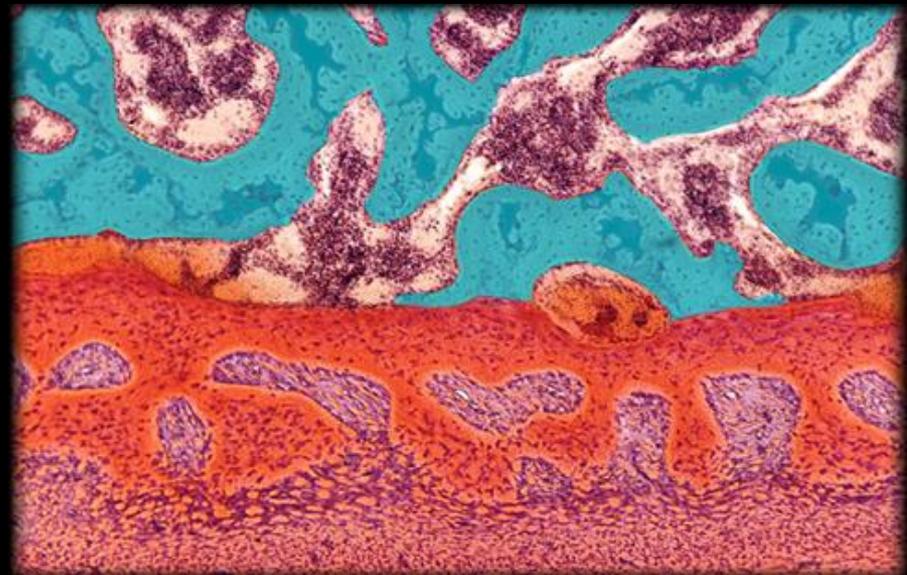
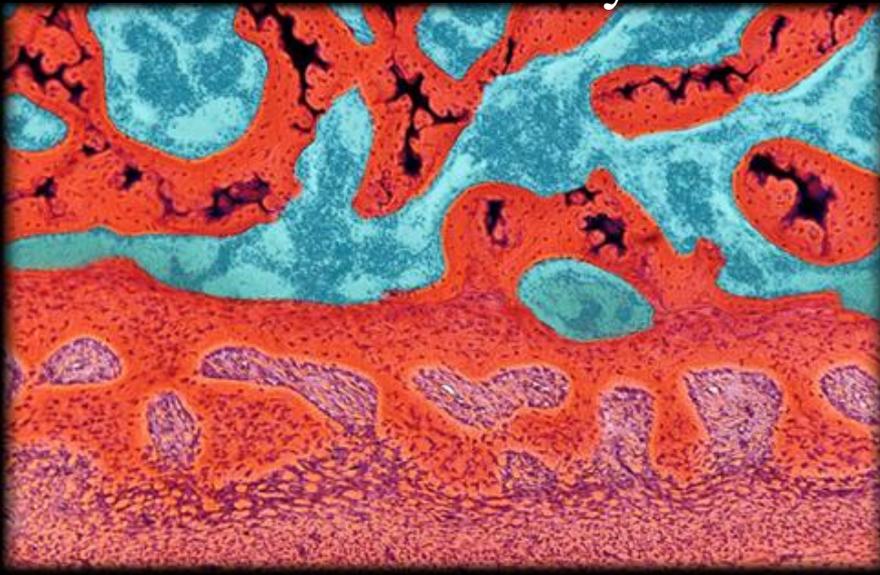
- Hard connective tissue composed of living cells (**osteocytes**) and mineralized matrix
- Matrix: gives strength and rigidity; allows bone to support and protect other tissues and organs
  - Organic: collagen fibers
  - Inorganic: hydroxyapatite (Ca plus  $\text{PO}_4$ )
- Osteocytes located in lacunae
- Types
  - Spongy bone
  - Compact bone

# Spongy Bone



Marrow cavity

Trabeculae



# Bone

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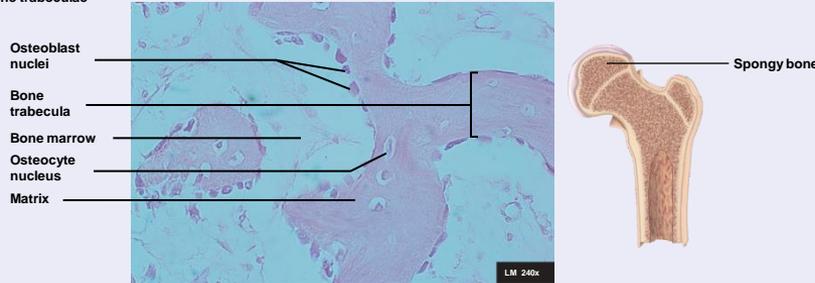
**TABLE 4.11** Supporting Connective Tissue: Bones

**(a) Spongy Bone**

**Structure:** Lattice-like network of scaffolding characterized by trabeculae with large spaces between them filled with hemopoietic tissue; the osteocytes, or bone cells, are located within lacunae in the trabeculae

**Function:** Acts as scaffolding to provide strength and support without the greater weight of compact bone

**Location:** In the interior of the bones of the skull, vertebrae, sternum, and pelvis; in the ends of the long bones

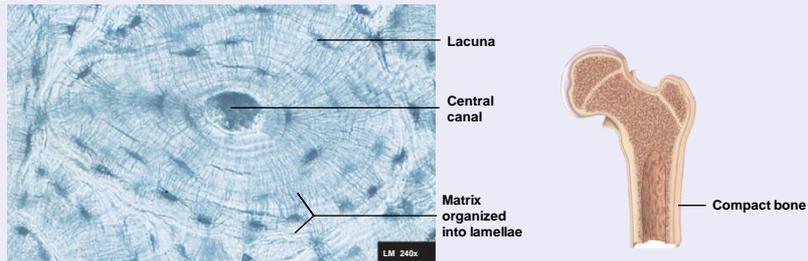


**(b) Compact Bone**

**Structure:** Hard, bony matrix predominates; many osteocytes (not seen in this bone preparation) are located within lacunae that are distributed in a circular fashion around the central canals; small passageways connect adjacent lacunae

**Function:** Provides great strength and support; forms a solid outer shell on bones that keeps them from being easily broken or punctured

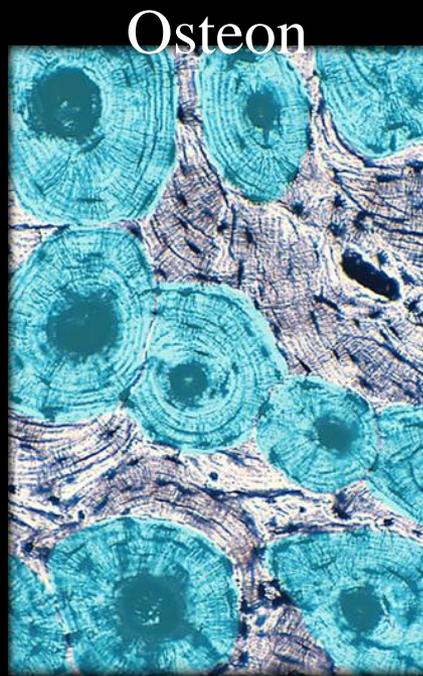
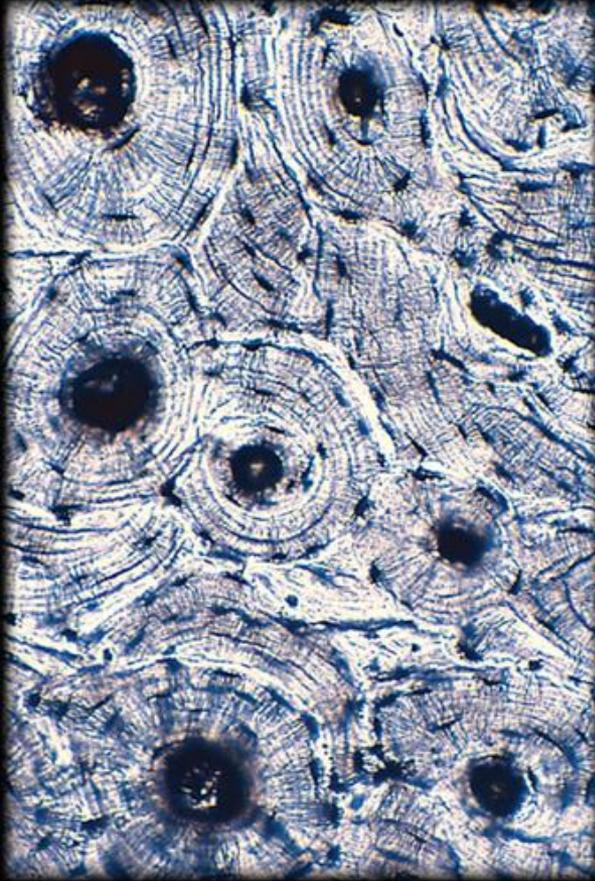
**Location:** Outer portions of all bones, the shafts of long bones



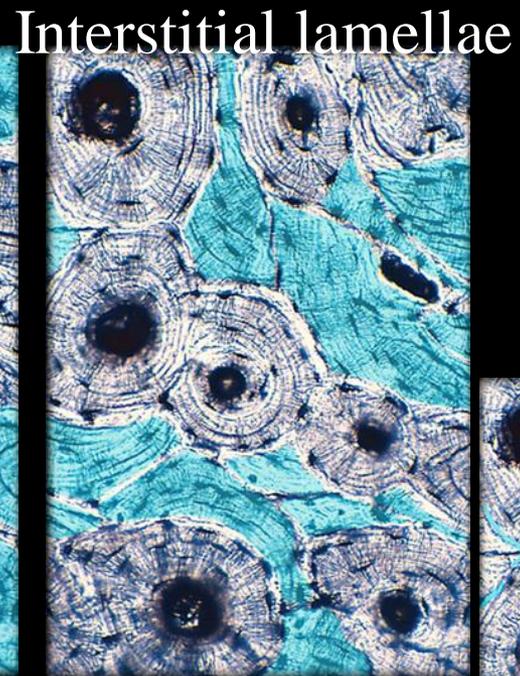
a: © Victor Eroschenko; b: © Trent Stephens

- **Spongy** bone: trabeculae of bone with spaces between. Looks like a sponge. Found inside bones.
- **Compact** bone: arranged in concentric circle layers around a central canal that contains a blood vessel. Found on periphery of bones.

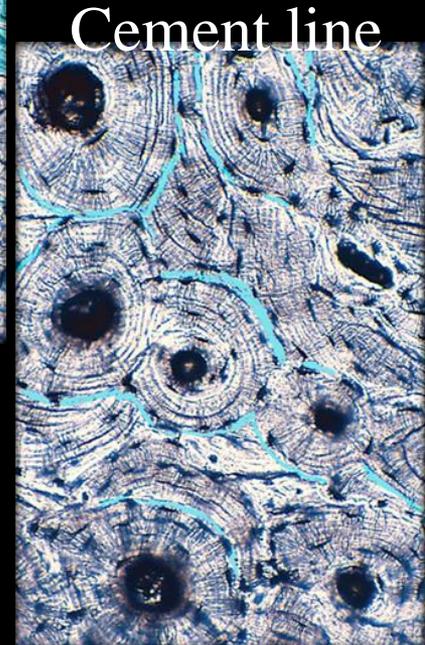
# Compact Bone



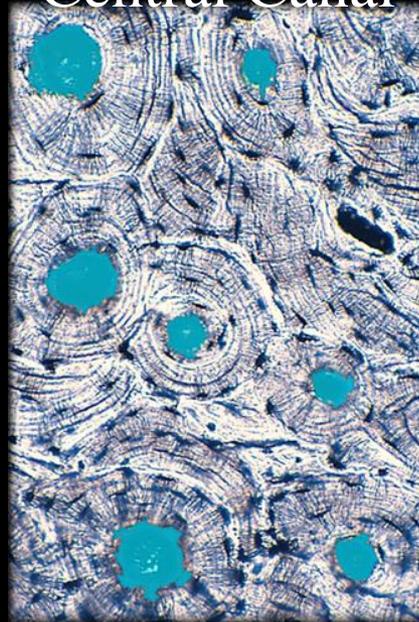
Osteon



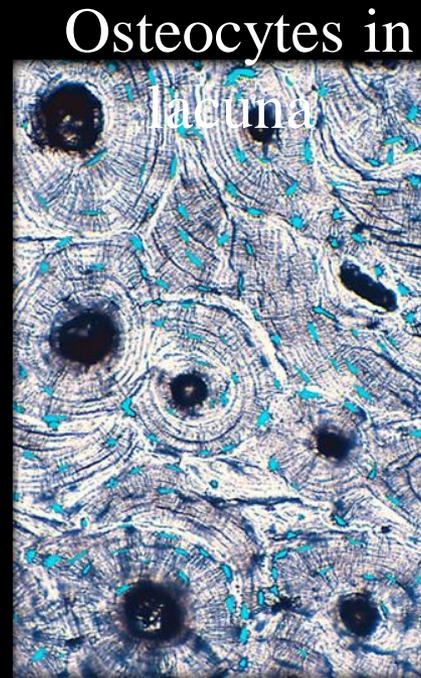
Interstitial lamellae



Cement line



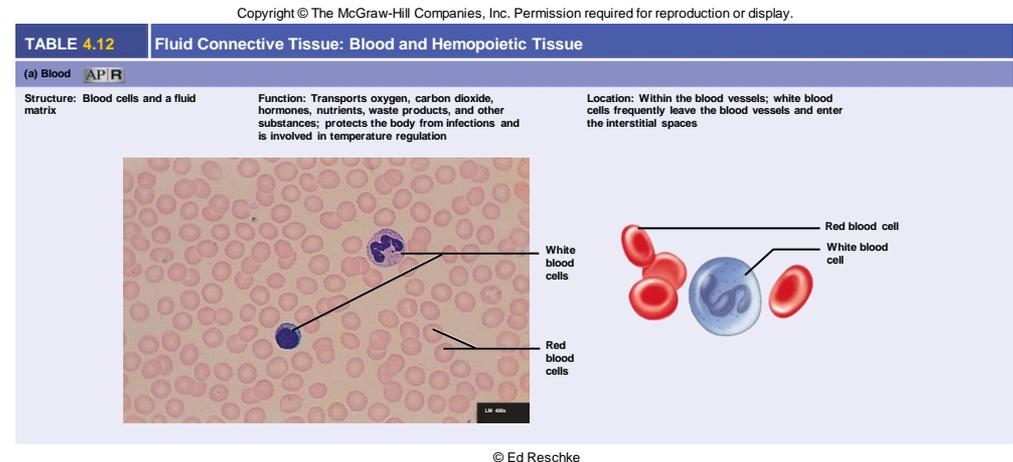
Central Canal



Osteocytes in lacuna

# Fluid Connective Tissue: Blood

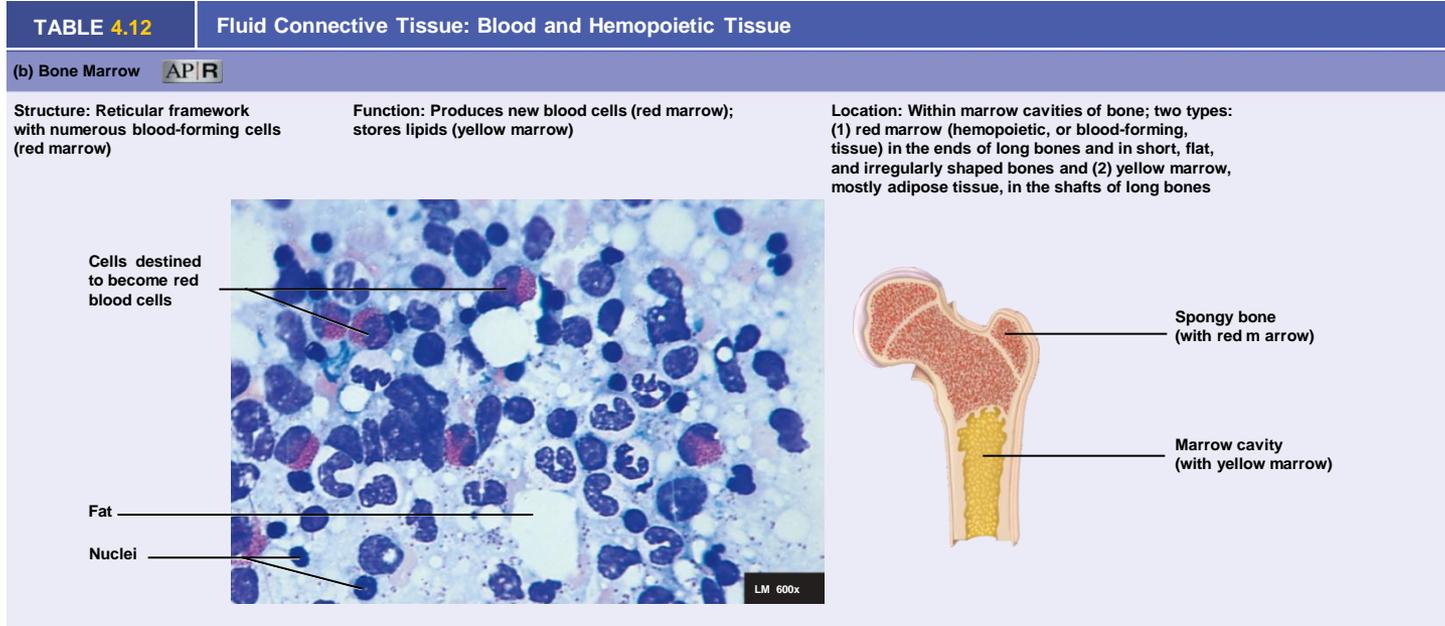
- Matrix: **plasma**
  - Liquid and lacks fibers.
  - Matrix formed by other tissues, unlike other types of connective tissue.
  - Moves through vessels, but both fluid and cells can move in/out of the vessels.
- Formed elements: red cells, white cells, and platelets
- Hemopoietic tissue
  - Forms blood cells
  - Two types of bone marrow
    - Yellow
    - Red



# Fluid Connective Tissue: Hemopoietic Tissue

- Forms blood cells
- Found in bone marrow
- Types of bone marrow
  - Red: hemopoietic tissue surrounded by a framework of reticular fibers. Produces red and white cells
  - Yellow: yellow adipose tissue
- As children grow, yellow marrow replaces much of red marrow.

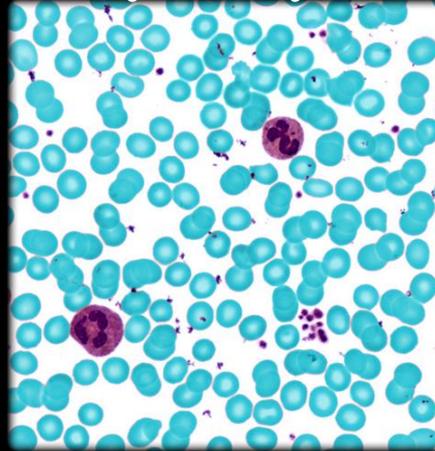
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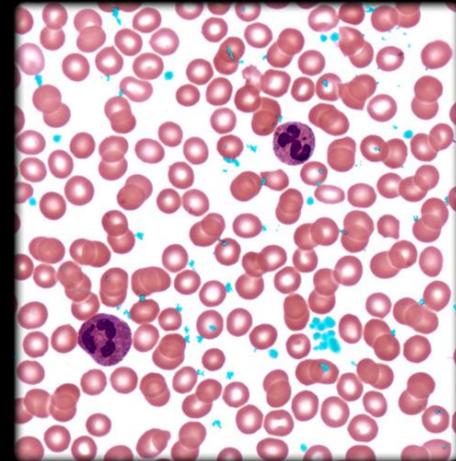
# Fluid Connective Tissue

## Blood

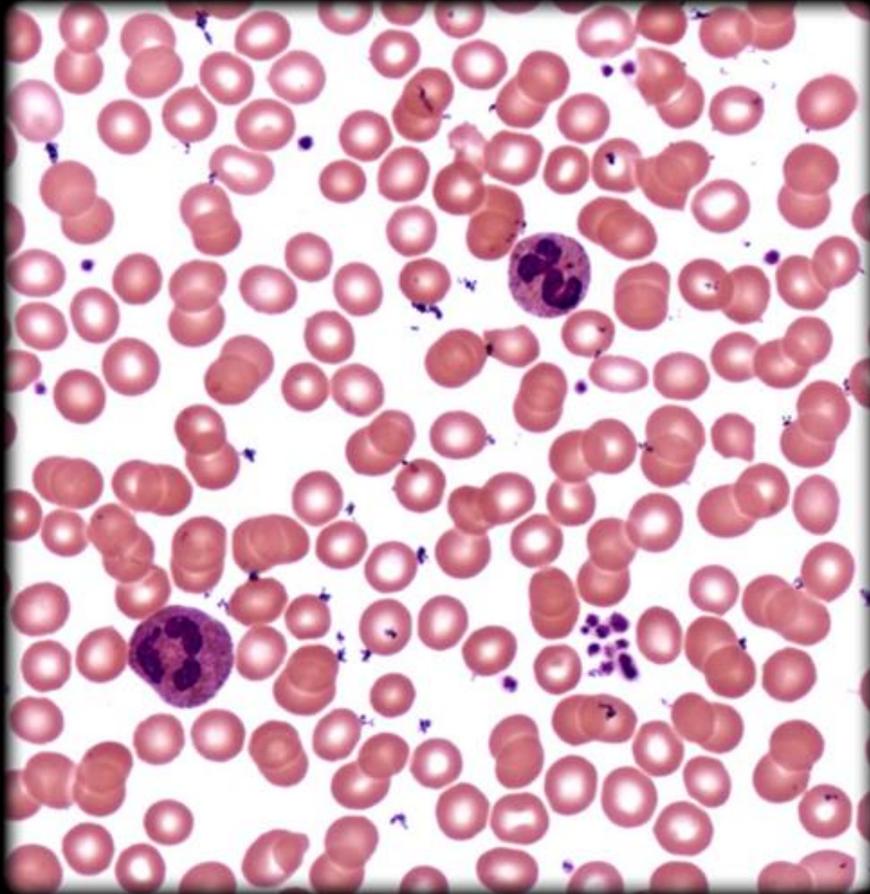
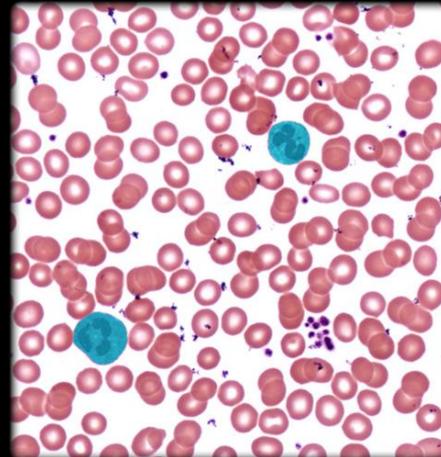
Erythrocytes



Platelets



Neutrophils



# 4.5 Muscle Tissue

- Characteristics
  - Contracts or shortens with force
  - Moves entire body and pumps blood
- Types
  - **Skeletal**: most attached to skeleton, but some attached to other types of connective tissue. Striated and voluntary.
  - **Cardiac**: muscle of the heart. Striated and involuntary.
  - **Smooth**: muscle associated with tubular structures and with the skin. Nonstriated and involuntary.

**TABLE 4.13**

**Comparison of Muscle Types**

	<b>Skeletal Muscle</b>	<b>Cardiac Muscle</b>	<b>Smooth Muscle</b>
<b>Location</b>	Attached to bones	In the heart	In the walls of hollow organs, blood vessels, eyes, glands, skin
<b>Cell Shape</b>	Very long, cylindrical cells (1–4 cm and may extend the entire length of the muscle, 10–100 $\mu\text{m}$ in diameter)	Cylindrical cells that branch (100–500 $\mu\text{m}$ in length, 12–20 $\mu\text{m}$ in diameter)	Spindle-shaped cells (15–200 $\mu\text{m}$ in length, 5–8 $\mu\text{m}$ in diameter)
<b>Nucleus</b>	Multinucleated, peripherally located	Single, centrally located	Single, centrally located
<b>Striations</b>	Yes	Yes	No
<b>Control</b>	Voluntary(conscious)	Involuntary(unconscious)	Involuntary (unconscious)
<b>Ability to Contract Spontaneously</b>	No	Yes	Yes
<b>Function</b>	Moves the body	Provides the major force for moving blood through the blood vessels	Moves food through the digestive tract, empties the urinary bladder, regulates blood vessel diameter, changes pupil size, contracts many gland ducts, moves hair, performs many other functions
<b>Special Features</b>	None	Branching fibers, intercalated disks containing gap junctions joining the cells to each other	Gap junctions

# Skeletal Muscle

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TABLE 4.14

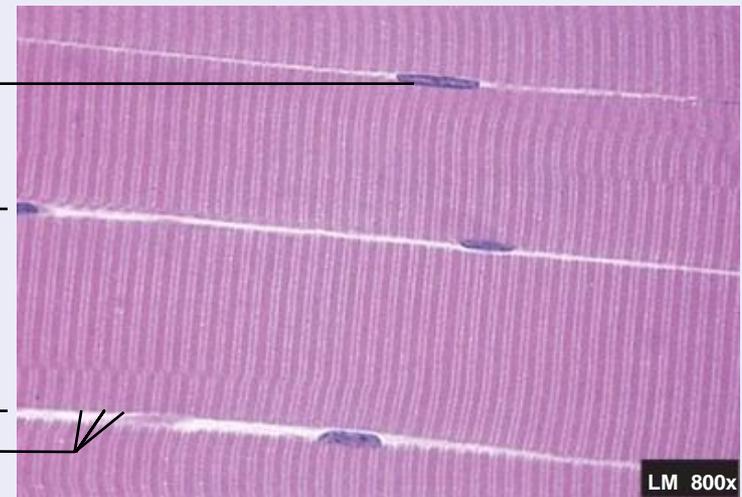
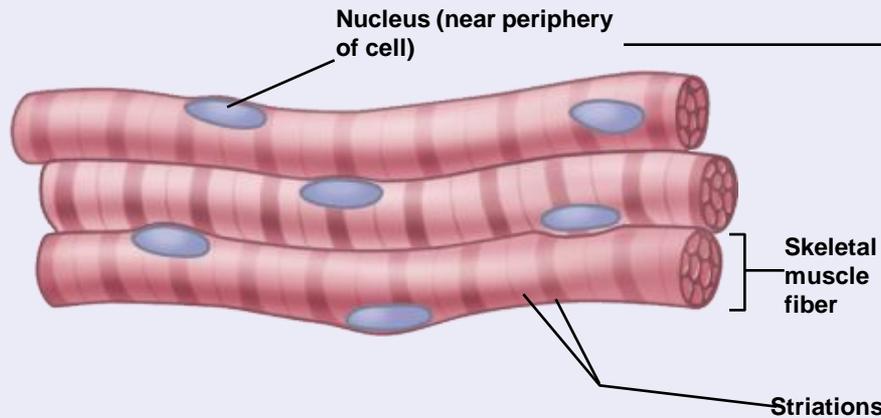
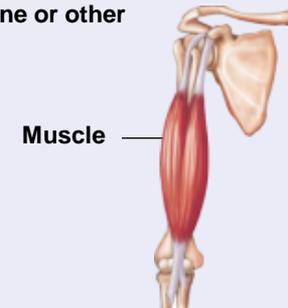
## Muscle Tissue

### (a) Skeletal Muscle **AP|R**

**Structure:** Skeletal muscle cells or fibers appear striated (banded); cells are large, long, and cylindrical, with many nuclei located at the periphery

**Function:** Moves the body; is under voluntary (conscious) control

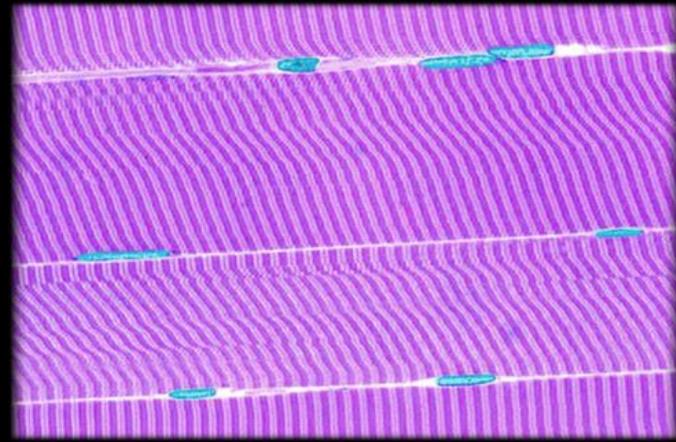
**Location:** Attached to bone or other connective tissue



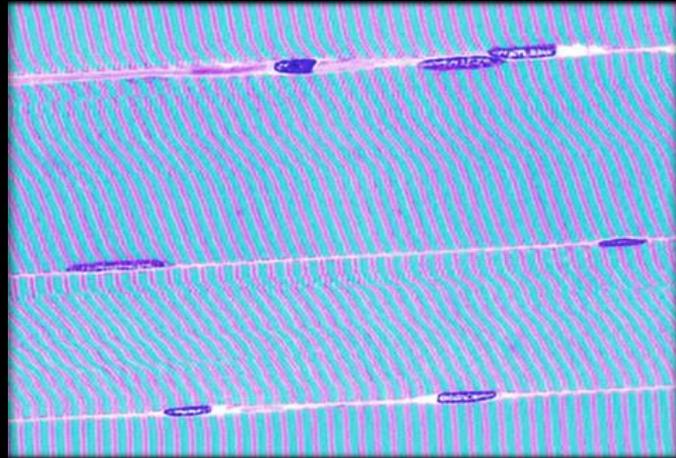
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# Skeletal Muscle

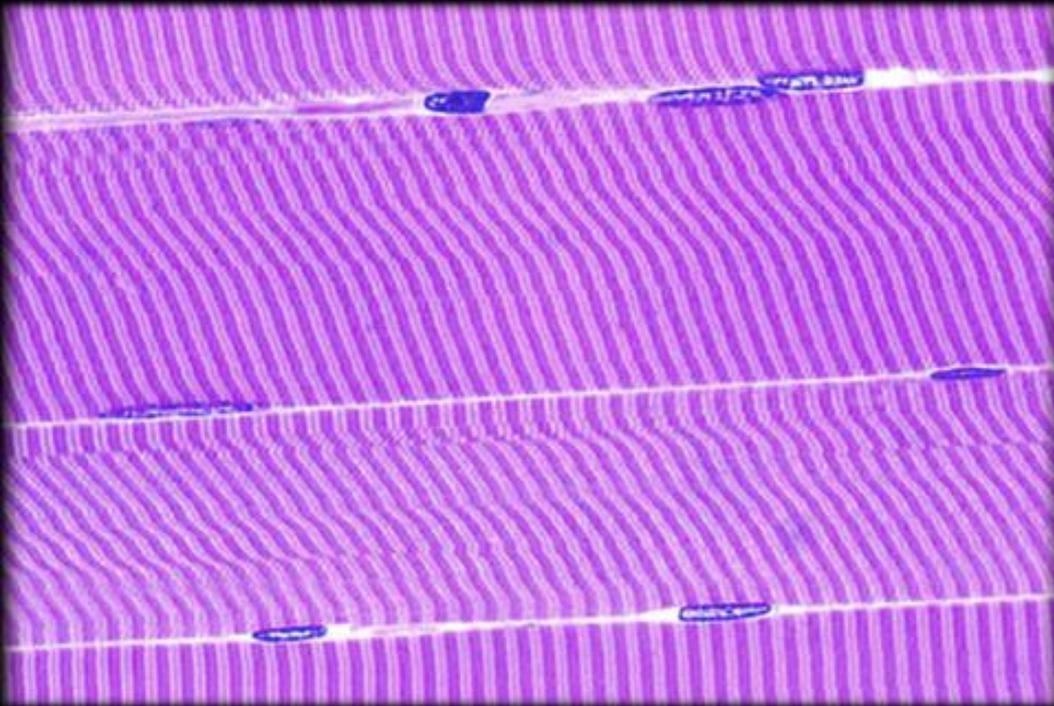
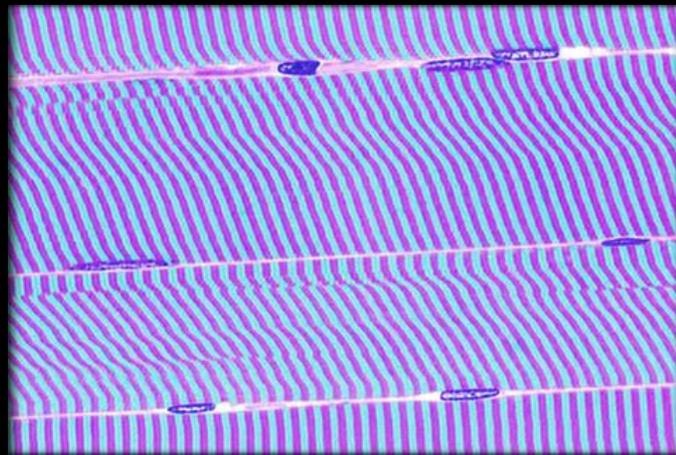
Nuclei



A band



I band



# Cardiac Muscle

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TABLE 4.14

## Muscle Tissue—Continued

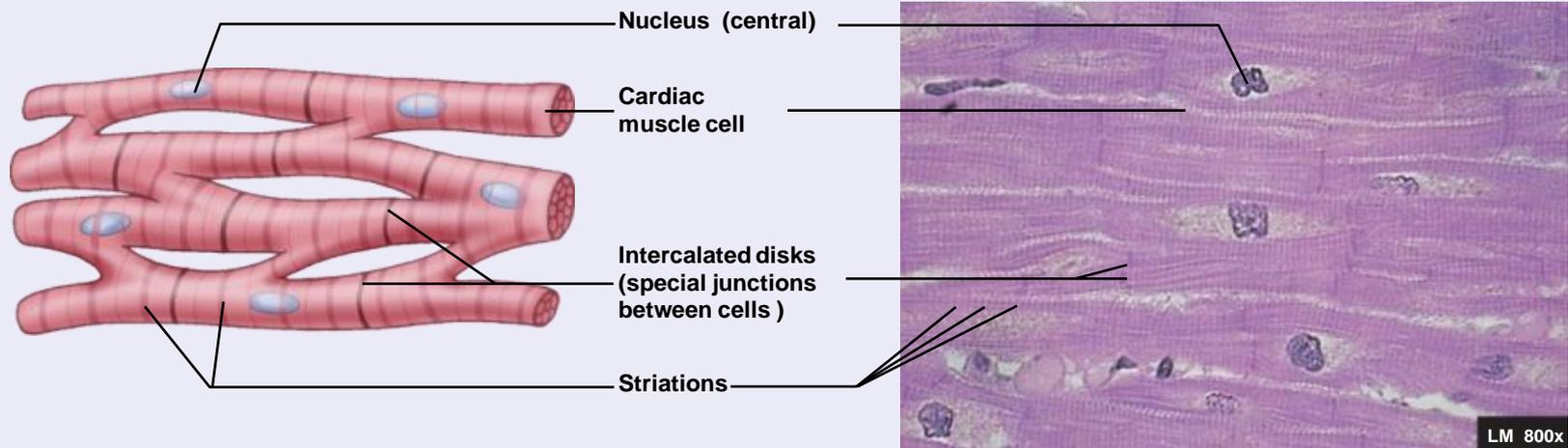
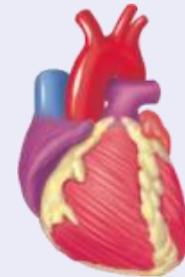
(b) Cardiac Muscle



**Structure:** Cardiac muscle cells are cylindrical and striated and have a single, centrally located nucleus; they are branched and connected to one another by intercalated disks, which contain gap junctions

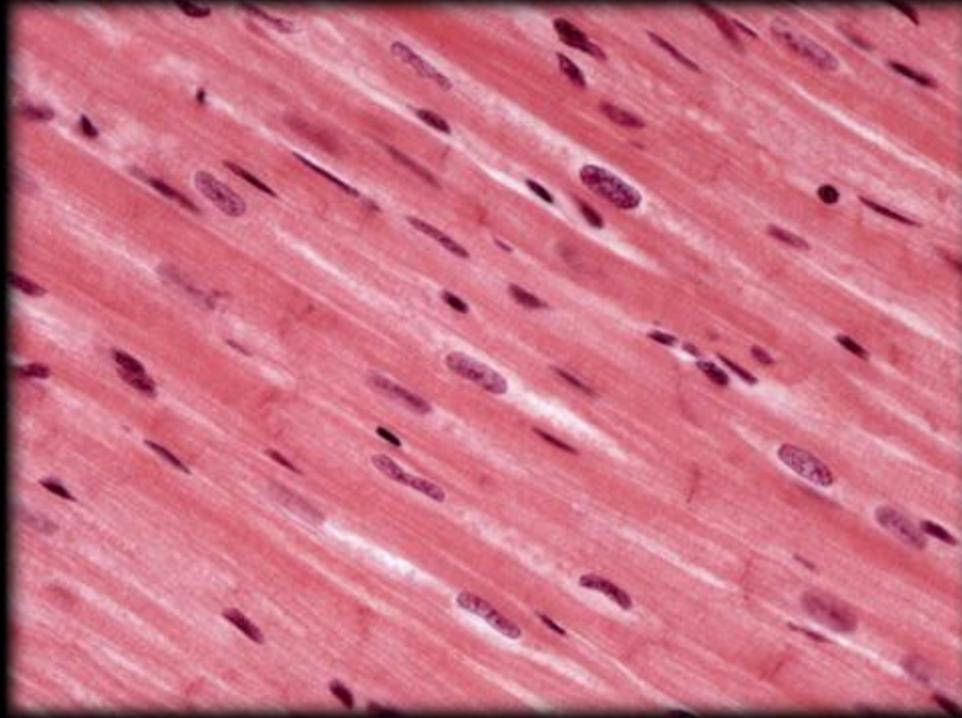
**Function:** Pumps the blood; is under involuntary (unconscious) control

**Location:** In the heart

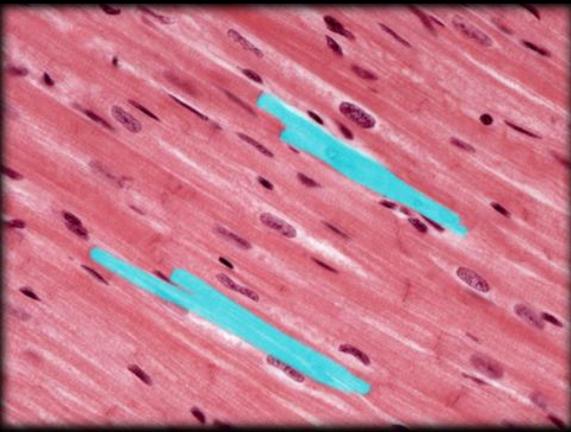


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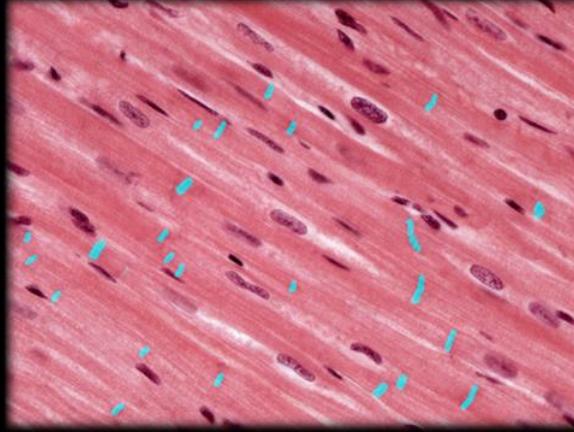
# Cardiac Muscle



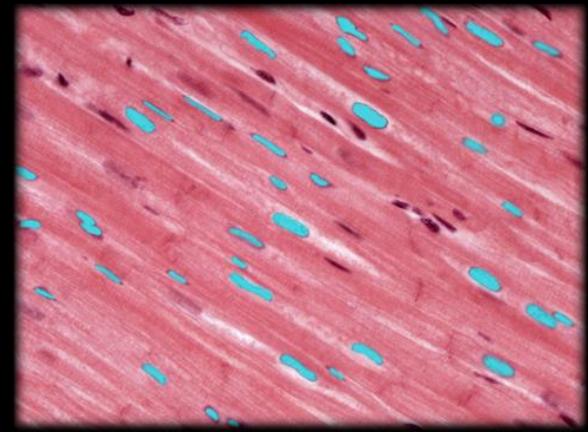
Branched cardiac cell



Intercalated disc



Nuclei of cardiac cell



# Smooth Muscle

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TABLE 4.14

## Muscle Tissue—Continued

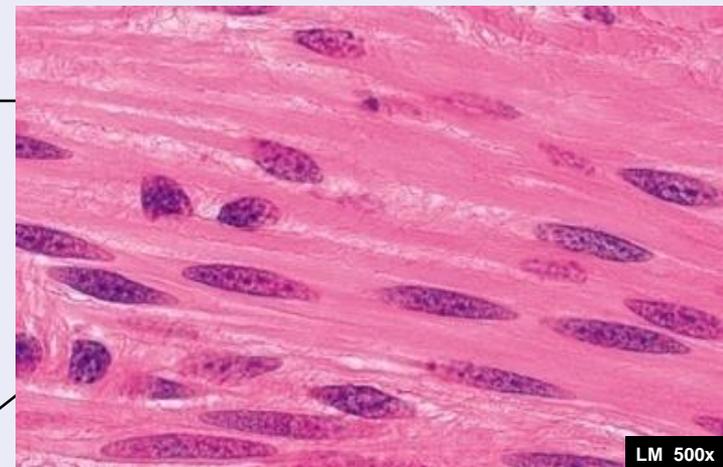
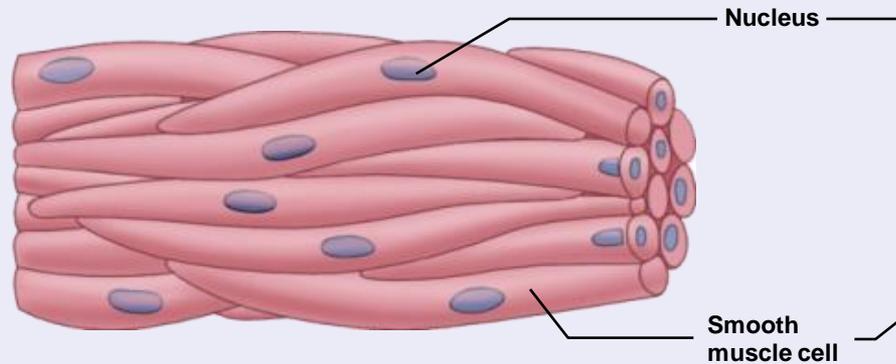
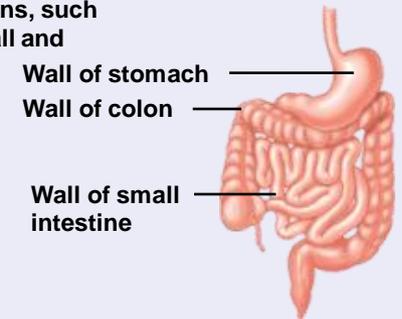
### (c) Smooth Muscle



**Structure:** Smooth muscle cells are tapered at each end, are not striated, and have a single nucleus

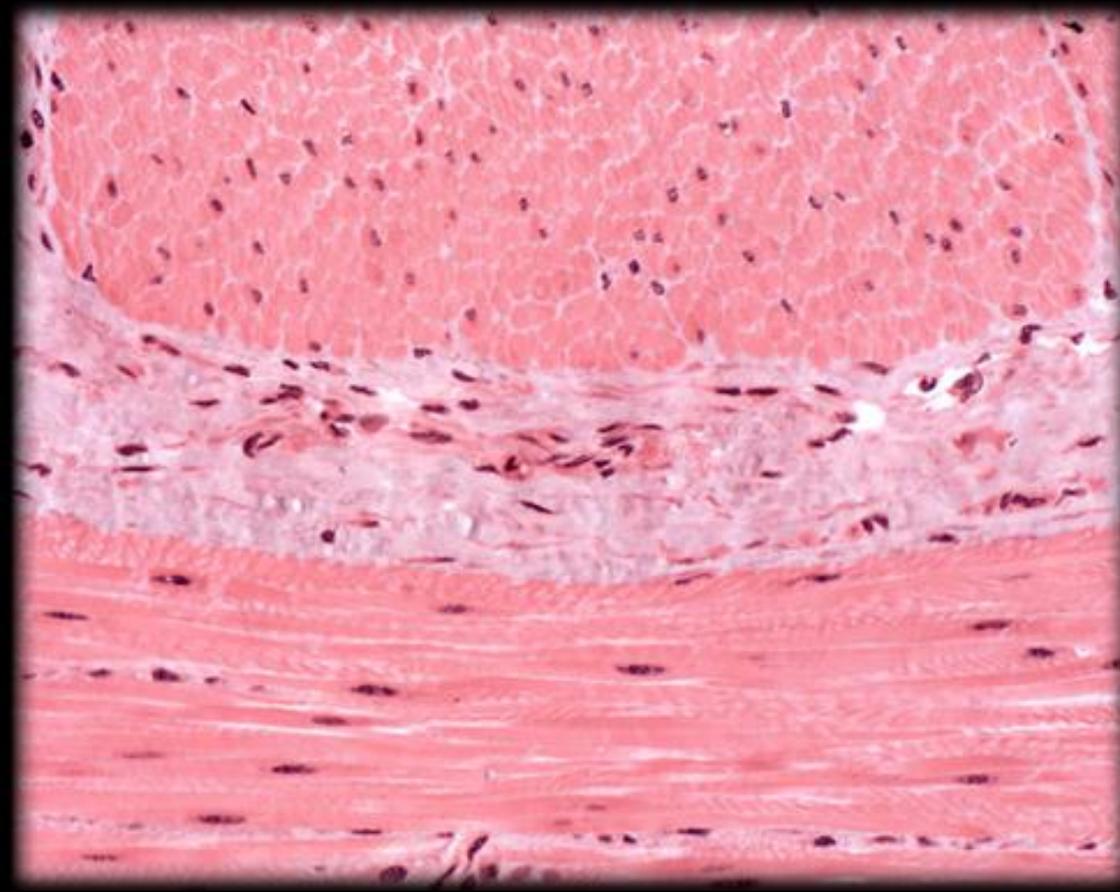
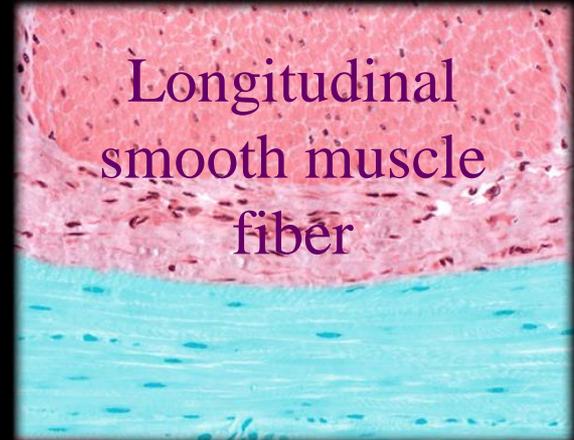
**Function:** Regulates the size of organs, forces fluid through tubes, controls the amount of light entering the eye, and produces “goose flesh” in the skin; is under involuntary (unconscious) control

**Location:** In hollow organs, such as the stomach and small and large intestines

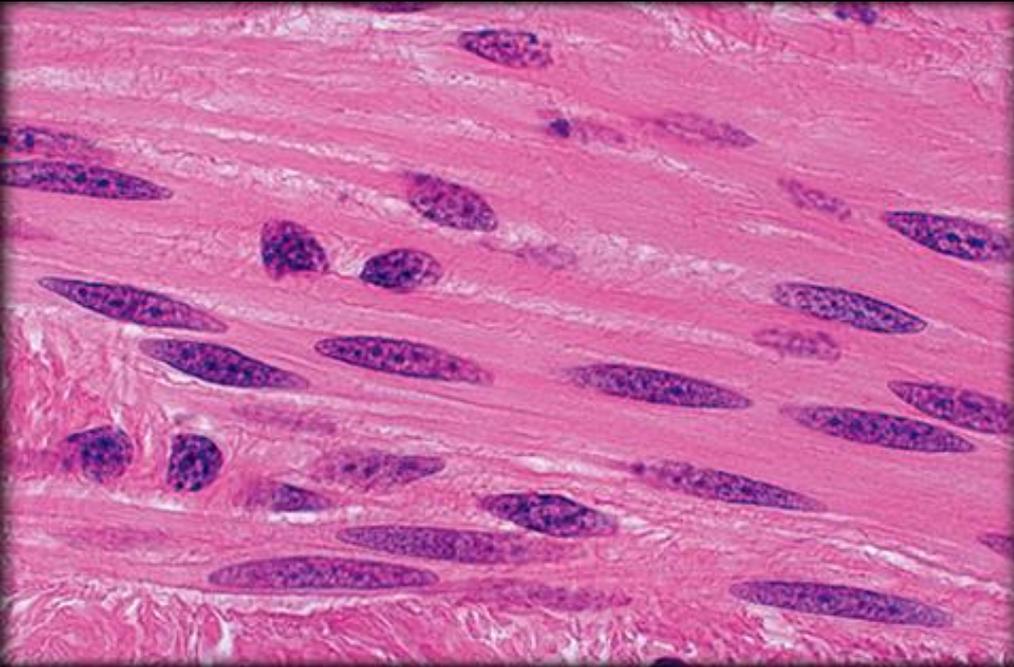


# Smooth Muscle

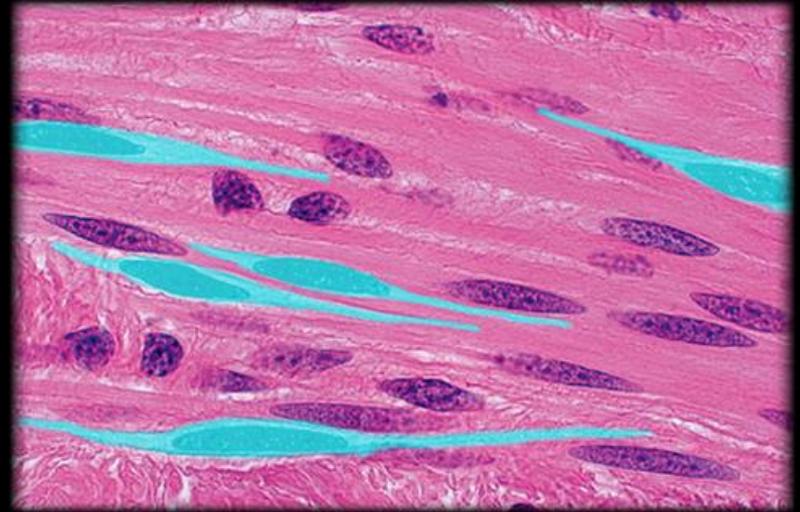
## Low Magnification



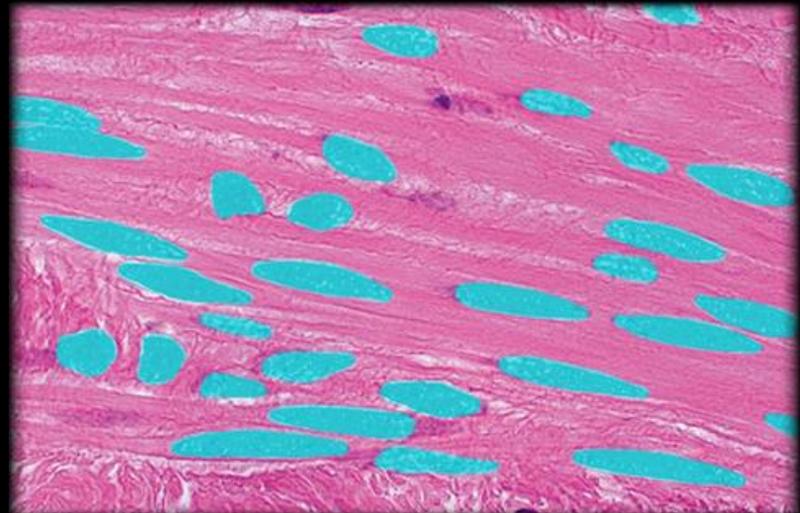
# Smooth Muscle High Magnification



Smooth muscle fiber



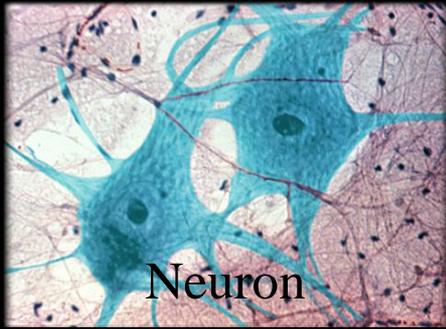
Nuclei of smooth muscle fiber



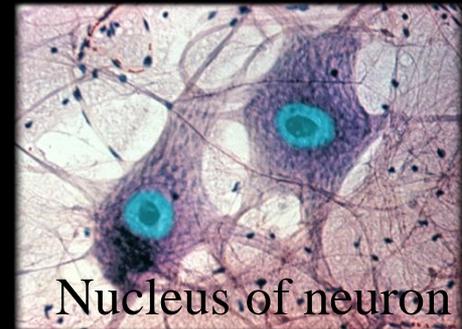
# 4.6 Nervous Tissue: Neurons

- **Neurons** or **nerve cells** have the ability to produce action potentials
  - Parts:
    - **Cell body**: contains nucleus
    - **Axon**: cell process; conducts impulses away from cell body; usually only one per neuron
    - **Dendrite**: cell process; receive impulses from other neurons; can be many per neuron
  - Types:
    - **Multipolar**, **bipolar**, and **unipolar**

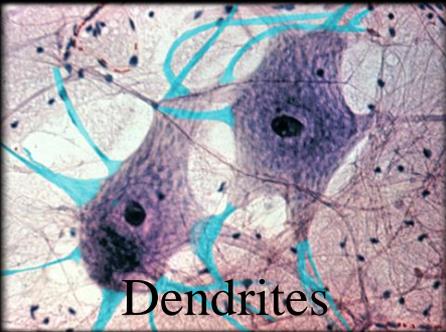
# Nervous Tissue



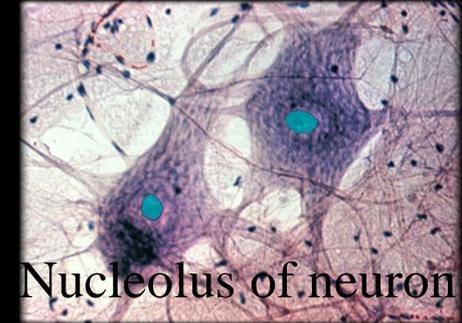
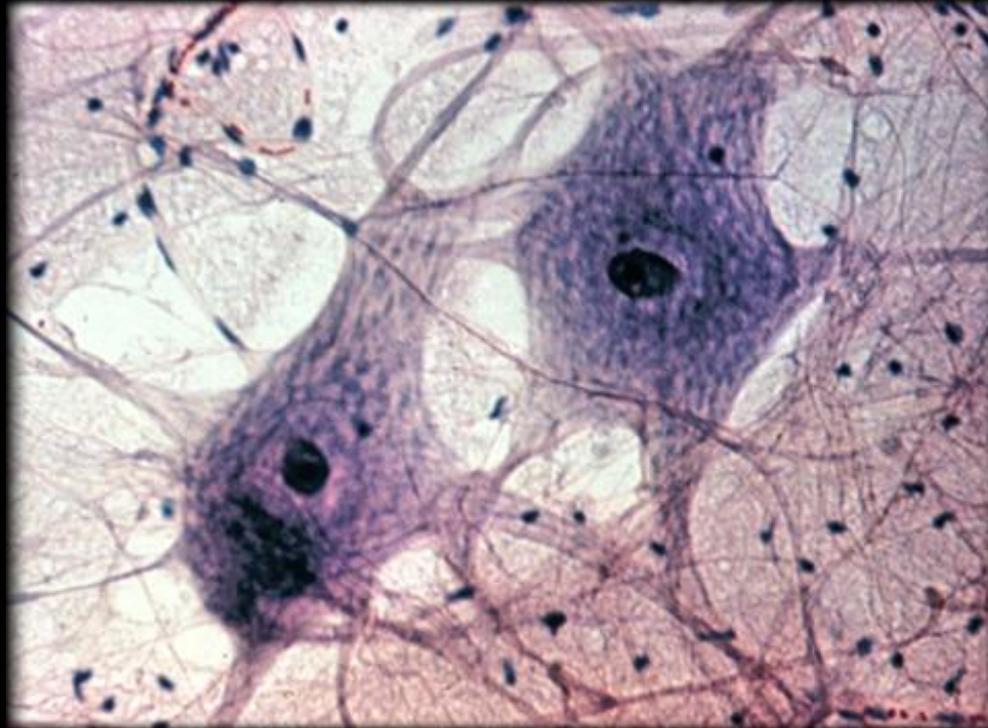
Neuron



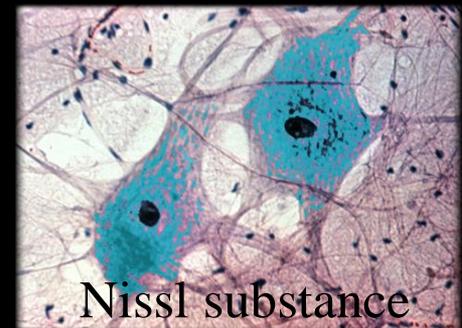
Nucleus of neuron



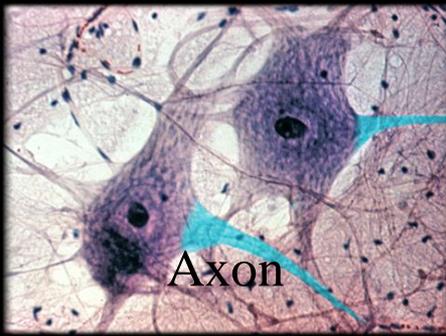
Dendrites



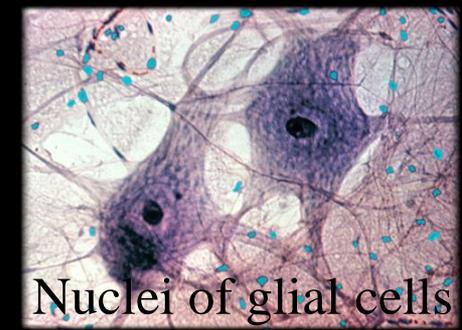
Nucleolus of neuron



Nissl substance



Axon



Nuclei of glial cells

# Neurons

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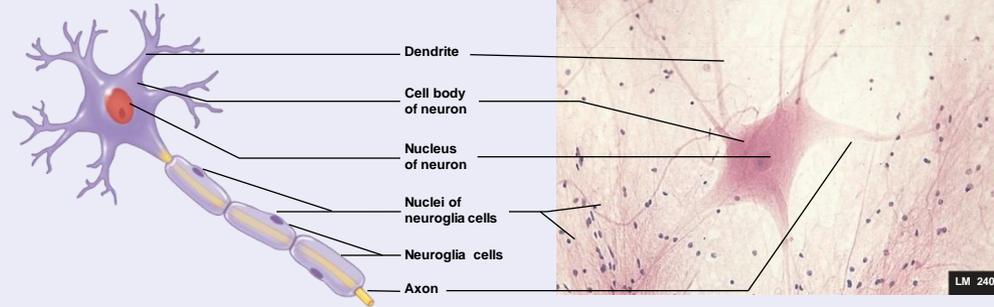
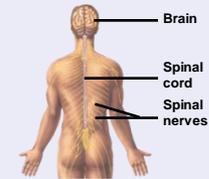
**TABLE 4.15** Types of Neurons

**(a) Multipolar Neuron** **APR**

**Structure:** The neuron consists of dendrites, a cell body, and a long axon; neuroglia, or support cells, surround the neurons

**Function:** Neurons transmit information in the form of action potentials, store "information," and integrate and evaluate data; neuroglia support, protect, and form specialized sheaths around axons

**Location:** In the brain, spinal cord, ganglia

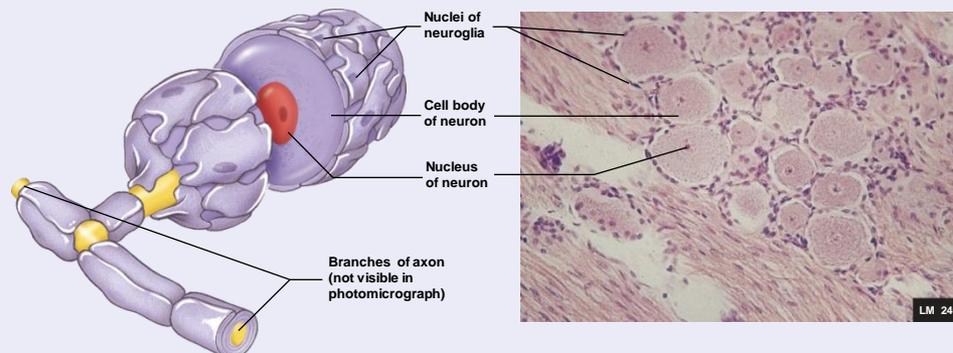


**(b) Pseudo-Unipolar Neuron**

**Structure:** The neuron consists of a cell body with one axon

**Function:** Conducts action potentials from the periphery to the brain or spinal cord

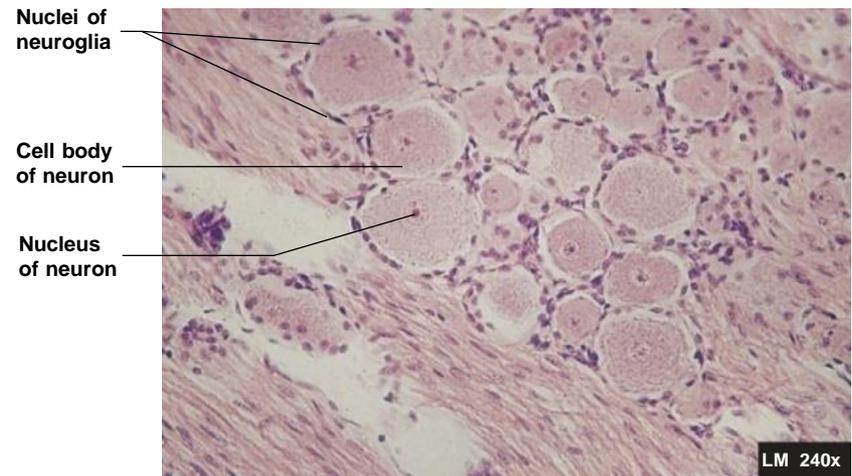
**Location:** In ganglia outside the brain and spinal cord



# Nervous Tissue: Neuroglia

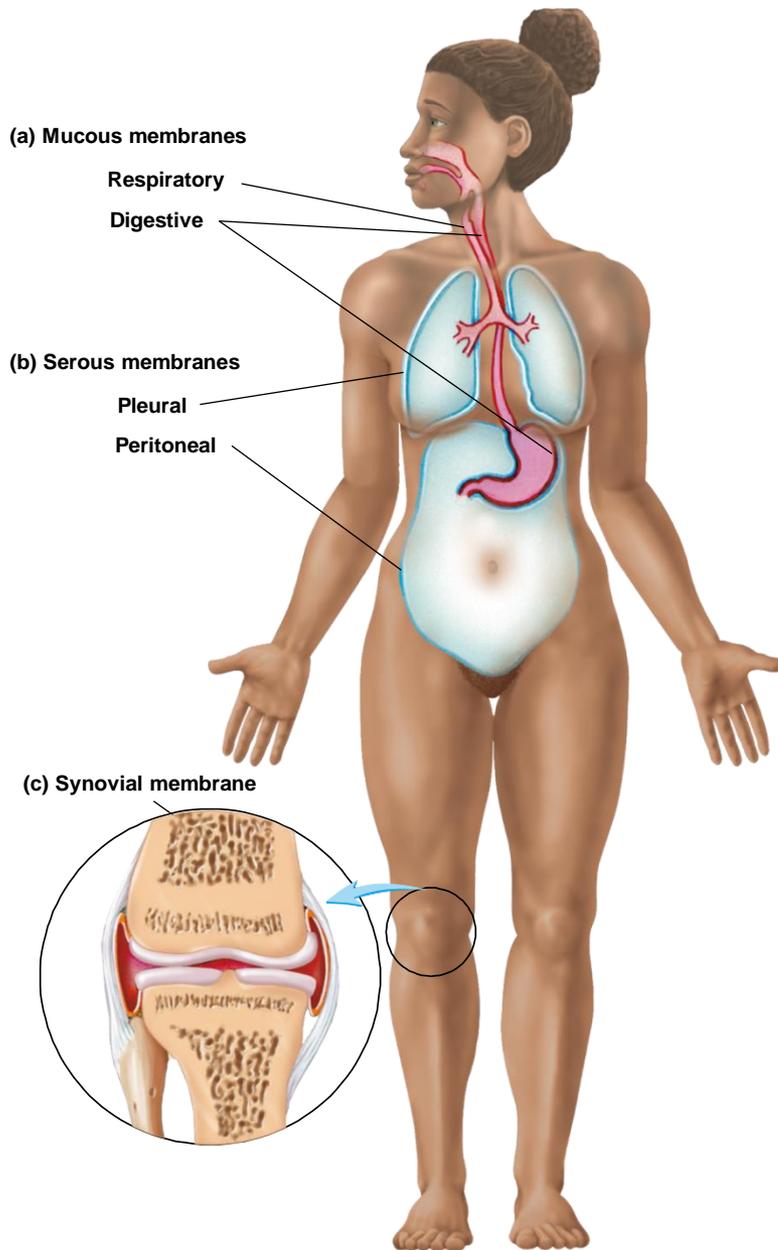
- Support cells of the brain, spinal cord and nerves
- Nourish, protect, and insulate neurons

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# 4.7 Tissue Membranes

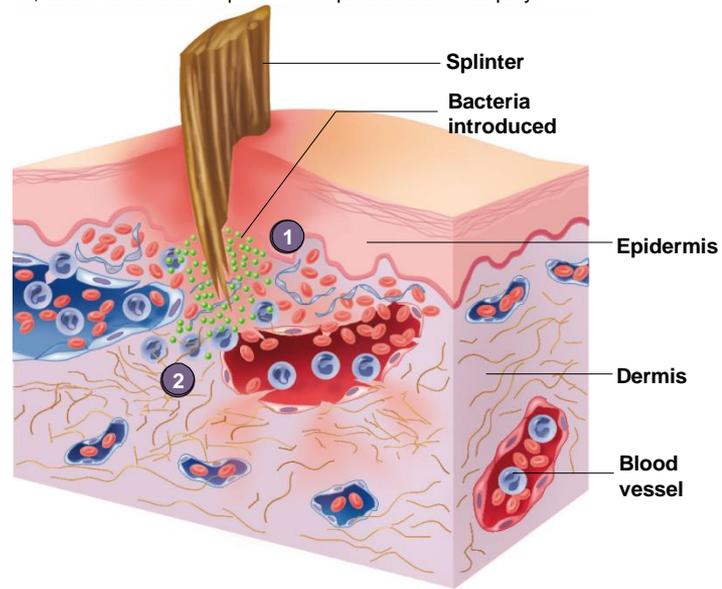


- **Mucous**
  - Line cavities that open to the outside of body
  - Secrete mucus
  - Contains epithelium with goblet cells, basement membrane, lamina propria (sometimes with smooth muscle)
  - Found in respiratory, digestive, urinary and reproductive systems.
- **Serous**. simple squamous epithelium called **mesothelium**, basement membrane, thin layer of loose C.T.
  - Line cavities not open to exterior
    - Pericardial, pleural, peritoneal
- **Synovial**
  - Line freely movable joints
  - Produce fluid rich in hyaluronic acid

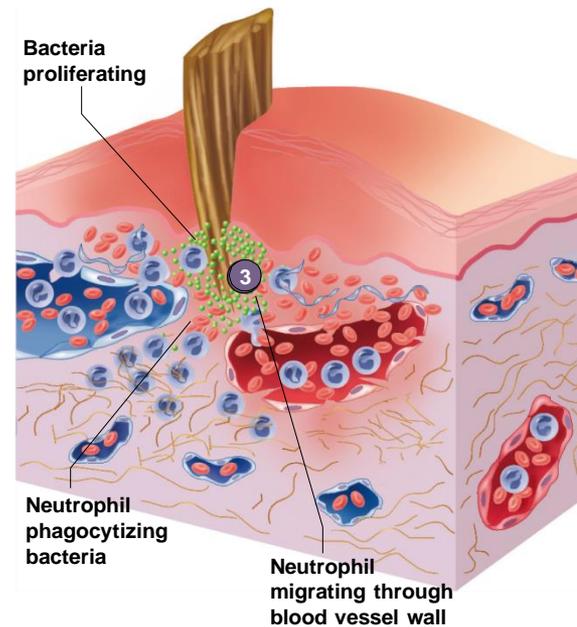
# 4.8 Tissue Damage and Inflammation

- Responds to tissue damage or with an immune response
- Manifestations
  - Redness, heat, swelling, pain, disturbed function
- Chemical Mediators
  - Include histamine, kinins, prostaglandins, leukotrienes
  - Stimulate pain receptor and increase blood vessel permeability as well movement of WBCs to affected area.

- 1 A splinter in the skin causes damage and introduces bacteria. Chemical mediators of inflammation are released or activated in injured tissues and adjacent blood vessels. Some blood vessels rupture, causing bleeding.
- 2 Chemical mediators cause capillaries to dilate and the skin to become red. Chemical mediators also increase capillary permeability, and fluid leaves the capillaries, producing swelling (arrows).



- 3 White blood cells (e.g., neutrophils) leave the dilated blood vessels and move to the site of bacterial infection, where they begin to phagocytize bacteria and other debris.

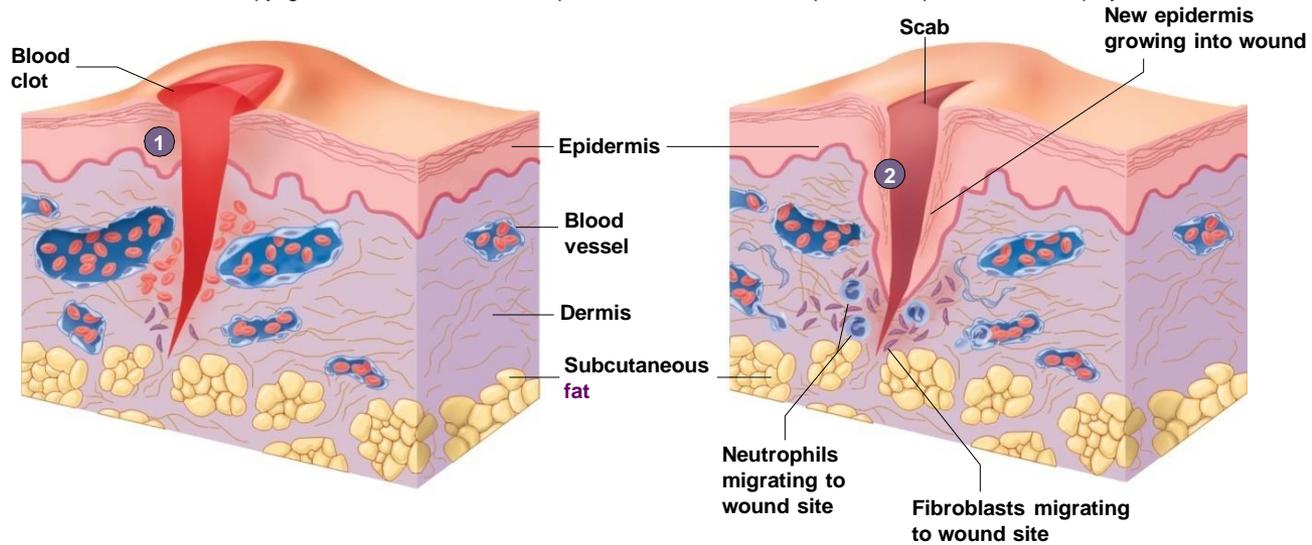


# 4.9 Tissue Repair

- Substitution of dead/damaged cells by viable/functional cells
- Types of cells
  - **Labile**: capable of mitosis through life. skin, mucous membranes, hemopoietic tissue, lymphatic tissue
  - **Stable**: no mitosis after growth ends, but can divide after injury. Liver, pancreas, endocrine cells
  - **Permanent**: if killed, replaced by a different type of cell. Limited regenerative ability. nervous, skeletal and cardiac muscle

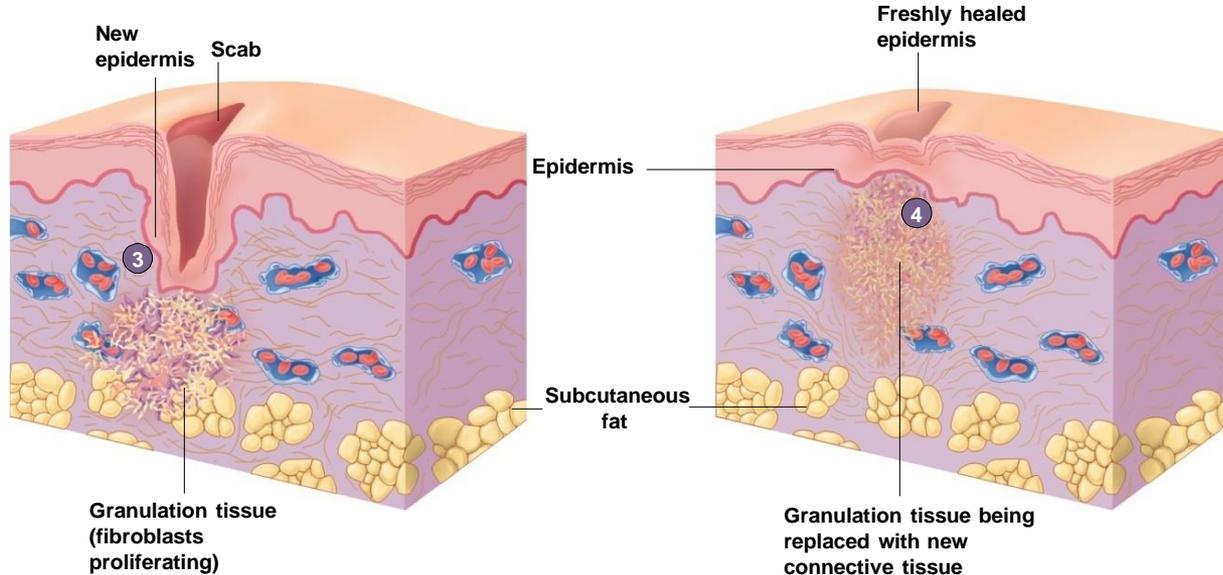
# Skin Repair

- **Primary union:** Edges of wound are close together
  - Wound fills with blood
  - Clot forms: fibrin threads start to contract; pull edges together
  - Scab
  - Inflammatory response; pus forms as white cells die
  - Granulation tissue. Replaces clot, delicate C.T. composed of fibroblasts, collagen fibers, capillaries
  - Scar. Formed from granulation tissue. Tissue turns from red to white as capillaries are forced out.
- **Secondary union:** Edges of wound are not closed; greater chance of infection
  - Clot may not close gap
  - Inflammatory response greater
  - Wound contraction occurs leading to greater scarring



**1** Fresh wound cuts through the epithelium (epidermis) and underlying connective tissue (dermis), and a clot forms.

**2** Approximately 1 week after the injury, a scab is present, and epithelium (new epidermis) is growing into the wound.



**3** Approximately 2 weeks after the injury, the epithelium has grown completely into the wound, and fibroblasts have formed granulation tissue.

**4** Approximately 1 month after the injury, the wound has completely closed, the scab has been sloughed, and the granulation tissue is being replaced by new connective tissue.

# 4.10 Effects of Aging on Tissues

- Cells divide more slowly
- Collagen fibers become more irregular in structure, though they may increase in number
  - Tendons and ligaments become less flexible and more fragile
- Elastic fibers fragment, bind to calcium ions, and become less elastic
  - Arterial walls and elastic ligaments become less elastic
- Changes in collagen and elastin result in
  - Atherosclerosis and reduced blood supply to tissues
  - Wrinkling of the skin
  - Increased tendency for bones to break
- Rate of blood cell synthesis declines in the elderly
- Injuries don't heal as readily