Chapter 3

Foundations

Tissues and Early Embryology

Lecture Presentation by
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Introduction

• **Atoms** make up molecules
• **Molecules** make up cells
• **Cells** make up tissues
• **Tissues** make up organs
• **Organs** make up organ systems
• **Organ systems** make up organisms
Figure 3.1 An Orientation to the Tissues of the Body.

**Chemical or Molecular Levels**
- Atoms combine to form Molecules (Organic/inorganic)

**Cellular Level**
- Molecules interact to form Cells
  - Secrete and regulate Extracellular material and fluids

**Tissue Level**
- Cells combine to form Tissues with specialized functions

**Epithelial tissue**
- Covers exposed surfaces
- Lines internal passageways and chambers
- Produces glandular secretions
  - See Figures 3.2 to 3.10

**Connective tissue**
- Fills internal spaces
- Provides structural support
- Stores energy
  - See Figures 3.11 to 3.21

**Muscle tissue**
- Contracts to produce active movement
  - See Figure 3.22

**Neural tissue**
- Conducts electrical impulses
- Carries information
  - See Figure 3.23

**Organ Level**
- Composed of Organs

**Organ System Level**
- Organ systems interact in Chapters 4–27

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Introduction

• This chapter concentrates on cells and tissues
  • There are over 75 trillion cells in the body
  • There are approximately 200 types of cells
  • All cells can be placed into one of the four tissue categories
    • Epithelial tissue
    • Connective tissue
    • Muscular tissue
    • Neural tissue
Epithelial Tissue

• Epithelial Tissue Characteristics
  • Cellularity
    • Cells are bound close together
    • No intercellular space
  • Polarity
    • Have an exposed apical surface
    • Have an attached basal surface
    • Surfaces are structurally and functionally different
    • Polarity is the term that is in reference to this structural and functional difference
Many epithelial cells differ in internal organization along an axis between the apical surface and the basal lamina. The apical surface frequently bears microvilli; less often, it may have cilia or (very rarely) stereocilia. A single cell typically has only one type of process; cilia and microvilli are shown together to highlight their relative proportions. Tight junctions prevent movement of pathogens or diffusion of dissolved materials between the cells. Folds of plasmalemma near the base of the cell increase the surface area exposed to the basal lamina. Mitochondria are typically concentrated at the basolateral region, probably to provide energy for the cell’s transport activities.
Epithelial Tissue

• Epithelial Tissue Characteristics (continued)
  • Attachment
    • Basal layer is attached to the basal lamina
  • Avascularity
    • Do not contain blood vessels
Epithelial Tissue

- Epithelial Tissue Characteristics (continued)
  - **Arranged in sheets**
    - Composed of one or more layers of cells
  - **Regeneration**
    - Cells are continuously replaced via cell reproduction
Epithelial Tissue

• Functions of Epithelial Tissue
  • Provides physical protection
    • Protection from abrasion, dehydration, and destruction
  • Controls permeability
  • Provides sensation
  • Produces secretions
Epithelial Tissue

• Specialization of Epithelial Cells
  • **Microvilli**
    • For absorption and secretion
    • Found on apical surface of cells of the urinary and digestive tracts
    • Increases surface area
  • **Stereocilia**
    • Long microvilli, commonly found in the inner ear and male reproductive tract
  • **Ciliated epithelium**
    • Moves substances over the apical surface
    • Found lining the respiratory tract
Many epithelial cells differ in internal organization along an axis between the apical surface and the basal lamina. The apical surface frequently bears microvilli; less often, it may have cilia or (very rarely) stereocilia. A single cell typically has only one type of process; cilia and microvilli are shown together to highlight their relative proportions. Tight junctions prevent movement of pathogens or diffusion of dissolved materials between the cells. Folds of plasmalemma near the base of the cell increase the surface area exposed to the basal lamina. Mitochondria are typically concentrated at the basolateral region, probably to provide energy for the cell’s transport activities.

An SEM showing the surface of the epithelium that lines most of the respiratory tract. The small, bristly areas are microvilli found on the exposed surfaces of mucus-producing cells that are scattered among the ciliated epithelial cells.
Epithelial Tissue

• Maintaining the Integrity of the Epithelium
  • Three factors involved in maintenance
    • Intercellular connections
    • Attachment to the basal lamina
    • Epithelial maintenance and renewal is self-perpetuated
Epithelial Tissue

- Intercellular Connections
  - Extensive connection between the cells
    - Holds the cells together
    - Prevents the passage of chemicals and pathogens
  - Cell junctions, CAMs, intercellular cement gives the epithelium strength and stability
Epithelial cells are usually packed together and interconnected by intercellular attachments. (See Figure 2.14)

Adjacent epithelial plasmalemmata are often interlocked. The TEM, magnified 2600 times, shows the degree of interlocking between columnar epithelial cells.
Epithelial Tissue

• Attachment to the Basal Lamina
  • The plasmalemma attaches to the basal lamina
    • Consists of typically two layers
      • Clear layer
      • Dense layer
  • Basal lamina in turn attaches to underlying connective tissue
Epithelial cells are usually packed together and interconnected by intercellular attachments. (See Figure 2.14)

At their basal surfaces, epithelia are attached to a basal lamina that forms the boundary between the epithelial cells and the underlying connective tissue.
Epithelial Tissue

- Epithelial Maintenance and Renewal
  - Must be replaced frequently
    - Due to exposure to:
      - Disruptive enzymes
      - Toxic chemicals
      - Pathogens
      - Mechanical abrasion
  - Replaced through time via continual division of stem cells
Epithelial Tissue

• Classification of Epithelia
  • **Simple**
    • Epithelium has only one layer of cells
    • Nuclei are approximately at the same level within each cell
    • Found in protected areas such as the internal compartments of the body
  • **Stratified**
    • Epithelium has two or more layers of cells
    • Found in areas where there are mechanical or chemical stresses
Epithelial Tissue

- Epithelial Tissue Cells
  - **Squamous cells**
    - Thin, flat cells / “squished” nuclei
  - **Cuboidal cells**
    - Cube-shaped cells / centered, round nucleus
  - **Columnar cells**
    - Longer than they are wide / nucleus near the base
  - **Transitional cells**
    - Mixture of cells / nuclei appear to be scattered
Epithelial Tissue

• **Simple Squamous Epithelium**
  • Consists of very delicate cells
  • Location
    • Lining body cavities, the heart, the blood vessels
  • Function
    • Reduces friction
    • Absorbs and secretes material
Figure 3.4a Histology of Squamous Epithelia

**Simple Squamous Epithelium**

**Locations:** Mesothelia lining ventral body cavities; endothelia lining heart and blood vessels; portions of kidney tubules (thin sections of nephron loops); inner lining of cornea; alveoli of lungs

**Functions:** Reduces friction; controls vessel permeability; perform absorption and secretion

A superficial view of the simple squamous epithelium (mesothelium) that lines the peritoneal cavity

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Epithelial Tissue

• Stratified Squamous Epithelium
  • Location
    • Surface of skin
    • Lines mouth, esophagus, anus, vagina
  • Function
    • Protection against abrasion, pathogens, and chemicals
Stratified Squamous Epithelium

**LOCATIONS:** Surface of skin; lining of oral cavity, throat, esophagus, rectum, anus, and vagina

**FUNCTIONS:** Provides physical protection against abrasion, pathogens, and chemical attack

**Sectional views of the stratified squamous epithelium that covers the tongue**

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Epithelial Tissue

- **Simple Cuboidal Epithelium**
  - **Location**
    - Thyroid gland, ducts, kidney tubules
  - **Function**
    - Secretion, absorption
    - Very limited protection
Simple Cuboidal Epithelium

LOCATIONS: Glands; ducts; portions of kidney tubules; thyroid gland

FUNCTIONS: Limited protection; secretion; absorption

A section through the simple cuboidal epithelium lining a kidney tubule. The diagrammatic view emphasizes structural details that permit the classification of an epithelium as cuboidal.
Epithelial Tissue

• **Stratified Cuboidal Epithelium**
  • This type of cells is rare
  • Location
    • Ducts of sweat glands
  • Function
    • Secretion, absorption
Figure 3.5b Histology of Cuboidal Epithelia

Stratified Cuboidal Epithelium

**LOCATIONS:** Lining of some ducts (rare)

**FUNCTIONS:** Protection; secretion; absorption

A sectional view of the stratified cuboidal epithelium lining a sweat gland duct in the skin.

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Epithelial Tissue

• Simple Columnar Epithelium
  • Location
    • Lining stomach, intestines, gallbladder, uterine tubes, and collecting ducts of the kidneys
  • Function
    • Secretion, absorption, protection
Simple Columnar Epithelium

**LOCATIONS:** Lining of stomach, intestine, gallbladder, uterine tubes, and collecting ducts of kidneys

**FUNCTIONS:** Protection; secretion; absorption

A light micrograph showing the characteristics of simple columnar epithelium. In the diagrammatic sketch, note the relationship between the height and width of each cell; the relative size, shape, and location of nuclei; and the distance between adjacent nuclei. Contrast these observations with the corresponding characteristics of simple cuboidal epithelium.
Epithelial Tissue

• Stratified Columnar Epithelium
  • Location
    • Pharynx, epiglottis, anus, mammary glands, salivary glands, and urethra
  • Function
    • Protection
A stratified columnar epithelium is sometimes found along large ducts, such as this salivary gland duct. Note the overall height of the epithelium and the location and orientation of the nuclei.
Epithelial Tissue

- **Pseudostratified Ciliated Columnar Epithelium**
  - Nuclei situated at different levels
  - Location
    - Nasal cavity, trachea, bronchi
  - Function
    - Protection, secretion
Pseudostratified ciliated columnar epithelium. The pseudostratified, ciliated, columnar epithelium of the respiratory tract. Note the uneven layering of the nuclei.
Epithelial Tissue

- **Transitional Epithelium**
  - Consists of many layers
  - Consists of a combination of cuboidal and “oddly” shaped cells
  - Location
    - Urinary bladder, renal pelvis, and ureters
  - Function
    - Ability to stretch extensively
Transitional epithelium. A sectional view of the transitional epithelium lining the urinary bladder. The cells from an empty bladder are in the relaxed state, while those lining a full urinary bladder show the effects of stretching on the arrangement of cells in the epithelium.
Epithelial Tissue

- Glandular Epithelia
  - Many epithelia contain gland cells
  - Glands are classified based on:
    - Type of secretion released
    - Structure of the gland
    - Mode of secretion
- Types of glands
  - Exocrine
  - Endocrine
Epithelial Tissue

- Types of Secretion
  - **Exocrine glands**
    - Secretions travel through ducts to the epithelial surface
  - **Endocrine glands**
    - Secretions enter into the blood or lymph
Epithelial Tissue

• Types of Secretion (continued)
  • Exocrine gland categories
    • **Serous glands**: secrete watery fluids rich in enzymes
    • **Mucous glands**: secrete glycoproteins (mucins) that absorb water to produce mucus
    • **Mixed exocrine glands**: contain both serous and mucous secretions
Epithelial Tissue

• Types of Secretion (continued)
  • Endocrine gland categories
    • Release their secretions by exocytosis
    • Secretions are called hormones
Epithelial Tissue

• Gland Structure
  • Unicellular
    • Secrete mucins
      • Two types: goblet cells and mucous cells
  • Multicellular
    • Secrete mucins
      • Produces secretory sheets
Epithelial Tissue

• Gland Structure
  • Unicellular
    • Goblet
      • Found among columnar epithelium of small and large intestines
  • Mucous
    • Found among pseudostratified ciliated columnar epithelium of the trachea
Epithelial Tissue

• Gland Structure
  • Multicellular
    • Producers exocrine secretions
      • Consists of a portion that produces the secretion
      • Consists of a portion that carries the secretion to the epithelial surface
    • Producers endocrine secretions
Epithelial Tissue

• Gland Structure
  • Characteristics of a multicellular gland organization
    • Tubular
      • Cells form tubes
    • Alveolar or acinar
      • Cells form blind pockets
    • Tubuloalveolar or tubuloacinanar
      • Cells form both tubes and blind pockets
Epithelial Tissue

• Gland Structure
  • Simple and compound
    • Simple: do not have branching ducts
      • Simple tubular: found in intestines
      • Simple coiled tubular: found in merocrine sweat glands
      • Simple branched tubular: found in gastric glands and mucous glands of esophagus, tongue, and duodenum
    • Simple alveolar: found only during the developmental stages of glands
    • Simple branched alveolar: found in sebaceous glands
### Simple Glands

<table>
<thead>
<tr>
<th>Type</th>
<th>Examples</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMPLE TUBULAR</td>
<td>Examples: • Intestinal glands</td>
<td>• Not found in adult; a stage in development of simple branched glands</td>
</tr>
<tr>
<td>SIMPLE COILED TUBULAR</td>
<td>Examples: • Merocrine sweat glands</td>
<td>• Sebaceous (oil) glands</td>
</tr>
<tr>
<td>SIMPLE BRANCED TUBULAR</td>
<td>Examples: • Gastric glands</td>
<td></td>
</tr>
<tr>
<td>SIMPLE ALVEOLAR (ACINAR)</td>
<td>Examples: • Mucous glands of esophagus, tongue, duodenum</td>
<td></td>
</tr>
<tr>
<td>SIMPLE BRANCED ALVEOLAR</td>
<td>Examples: • Sebaceous (oil) glands</td>
<td></td>
</tr>
</tbody>
</table>

Glands whose glandular cells form tubes are **tubular**; those tubes may be straight or coiled. Those that form blind pockets are **alveolar** or **acinar**.
Epithelial Tissue

• Gland Structure
  • Simple and Compound
    • Compound: have various branching ducts
      • Compound tubular: found in mucous glands, bulbo-urethral glands, and testes
      • Compound alveolar: found in mammary glands
      • Compound tubuloalveolar: found in salivary glands, respiratory tubes, and pancreas
### Compound Glands

<table>
<thead>
<tr>
<th>COMPOUND TUBULAR</th>
<th>COMPOUND ALVEOLAR (ACINAR)</th>
<th>COMPOUND TUBULOALVEOLAR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Examples:</strong></td>
<td><strong>Examples:</strong></td>
<td><strong>Examples:</strong></td>
</tr>
<tr>
<td>• Mucous glands (in oral cavity)</td>
<td>• Mammary glands</td>
<td>• Salivary glands</td>
</tr>
<tr>
<td>• Bulbo-urethral glands (in male reproductive system)</td>
<td></td>
<td>• Glands of respiratory passages</td>
</tr>
<tr>
<td>• Testes (seminiferous tubules)</td>
<td></td>
<td>• Pancreas</td>
</tr>
</tbody>
</table>

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Epithelial Tissue

• Mechanisms of Secretion
  • Merocrine secretion
    • Exocytosis
    • Found in salivary glands
  • Apocrine secretion
    • Shedding of the apical portion of the cell
    • Found in mammary glands
  • Holocrine secretion
    • Cell bursts apart
    • Found in sebaceous glands
Merocrine secretion

Example: Serous cells of the salivary glands

In merocrine secretion, the secretory product, packaged into secretory vesicles, is released through exocytosis onto the surface of the cell. This is the most common mode of secretion. An example of this type of secretion is the release of saliva from serous cells in the salivary gland, or mucins from goblet cells in the intestine.
Apocrine secretion

**Example:** Lactiferous cells of the mammary glands

In **apocrine secretion**, the secretory product is released during the shedding of the apical portion of the cell's cytoplasm, which has become packed with secretory vesicles. The gland cells then undergo regrowth and produce additional secretory vesicles.

1. Secretory vesicle
2. Shed cytoplasm breaks down, releasing secretory product
3. Golgi apparatus

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Holocrine secretion

**Example: Sebaceous gland cells**

*Holocrine secretion* destroys the gland cell. During holocrine secretion, the entire cell becomes packed with secretory products and then bursts apart. The secretion is released and the cell dies. Further secretion depends on gland cells being replaced by the division of stem cells found deeper within the epithelium.
Connective Tissues

• All connective tissues have three main components
  • Specialized cells
  • Extracellular protein fibers
  • Matrix
    • The matrix is the collective term for the extracellular component of any connective tissue that is made of protein fibers and the ground substance

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Connective Tissues

- Functions of Connective Tissue
  - Establishing the structural framework of the body
  - Transporting fluid and dissolved materials
  - Protecting organs
  - Supporting, surrounding, and connecting other tissues
  - Storing energy
  - Defending the body from microorganisms
Connective Tissues

• Classification of Connective Tissue
  • **Connective tissue proper**
    • Has a matrix of fibers (loose fibers and dense fibers)
  • **Fluid connective tissue**
    • Has a matrix of liquid (blood and lymph)
  • **Supporting connective tissue**
    • Has a matrix consisting of a gel or a solid (cartilage and bone)
Connective Tissues

can be divided into three types

Connective Tissue Proper

Loose
- Fibers create loose, open framework
  - areolar tissue
  - adipose tissue
  - reticular tissue

Dense
- Fibers densely packed
  - dense regular
  - dense irregular
  - elastic

Fluid Connective Tissue

Blood
- Contained in cardiovascular system

Lymph
- Contained in lymphatic system

Supporting Connective Tissue

Cartilage
- Solid, rubbery matrix
  - hyaline cartilage
  - elastic cartilage
  - fibrous cartilage

Bone
- Solid, crystalline matrix
Connective Tissue Proper

- Connective Tissue Proper
  - Two classes of connective tissue proper cells
    - Fixed cells
      - Mesenchymal cells
      - Fibroblasts
      - Fibrocytes
      - Fixed macrophages
      - Adipocytes
      - Melanocytes
    - Wandering cells
<table>
<thead>
<tr>
<th>Cell Types</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIXED CELLS</td>
<td></td>
</tr>
<tr>
<td>Fibroblasts</td>
<td>Produce connective tissue fibers</td>
</tr>
<tr>
<td>Fibrocytes</td>
<td>Maintain connective tissue fibers and matrix</td>
</tr>
<tr>
<td>Fixed macrophages</td>
<td>Phagocytize pathogens and damaged cells</td>
</tr>
<tr>
<td>Adipocytes</td>
<td>Store lipid reserves</td>
</tr>
<tr>
<td>Mesenchymal cells</td>
<td>Connective tissue stem cells that can differentiate into other cell types</td>
</tr>
<tr>
<td>Melanocytes</td>
<td>Synthesize melanin</td>
</tr>
</tbody>
</table>
Connective Tissue Proper

- Two classes of connective tissue proper cells
  - Fixed cells
  - Wandering cells
    - Free macrophages (monocytes)
    - Mast cells
    - Lymphocytes
    - Neutrophils
    - Eosinophils
<table>
<thead>
<tr>
<th>Cell Types</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WANDERING CELLS</strong></td>
<td></td>
</tr>
<tr>
<td>Free macrophages</td>
<td>Mobile/traveling phagocytic cells (derived from monocytes of the blood)</td>
</tr>
<tr>
<td>Mast cells</td>
<td>Stimulate local inflammation</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>Participate in immune response</td>
</tr>
<tr>
<td>Neutrophils and eosinophils</td>
<td>Small, phagocytic blood cells that mobilize during infection or tissue injury</td>
</tr>
</tbody>
</table>
Connective Tissue Proper

• Connective Tissue Fibers
  • Three types of fibers associated with connective tissue
    • Collagen fibers
    • Reticular fibers
    • Elastic fibers
Figure 3.12 Histology of the Cells and Fibers of Connective Tissue Proper

Diagrammatic view of the cells and fibers in areolar tissue, the most common type of connective tissue proper

A light micrograph showing the areolar tissue that supports the mesothelium lining the peritoneum
Connective Tissue Proper

• Connective Tissue Proper
  • Loose fibers
    • Areolar tissue
    • Adipose tissue
    • Reticular tissue
  • Dense fibers
    • Dense regular
    • Dense irregular
    • Elastic
Connective Tissue Proper

• Areolar Tissue (details)
  • Location
    • Deep dermis
    • Between muscles, around blood vessels, around nerves
  • Function
    • Connects skin to muscle
    • Provides minimal support but independent movement
  • Matrix
    • Fibers
**Areolar Connective Tissue**

**LOCATIONS:** Within and deep to the dermis of skin, and covered by the epithelial lining of the digestive, respiratory, and urinary tracts; between muscles; around blood vessels, nerves, and around joints

**FUNCTIONS:** Cushions organs; provides support but permits independent movement; phagocytic cells provide defense against pathogens

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**Areolar tissue.** Note the open framework; all the cells of connective tissue proper are found in areolar tissue.
Connective Tissue Proper

• Adipose Tissue (details)
  • Location
    • Hypodermis
    • Buttocks, surrounds organs
  • Function
    • Cushion
    • Insulation
  • Matrix
    • Fibers
Adipose tissue. Adipose tissue is a loose connective tissue dominated by adipocytes. In standard histological views, the cells look empty because their lipid inclusions dissolve during slide preparation.
Connective Tissue Proper

• Reticular Tissue (details)
  • Location
    • Liver, spleen, kidney, lymph nodes, tonsils, appendix, bone marrow
  • Function
    • Supporting framework
  • Matrix
    • Fibers
Reticular tissue. Reticular tissue consists of an open framework of reticular fibers. These fibers are usually very difficult to see because of the large numbers of cells organized around them.
Connective Tissue Proper

- Dense Regular Connective Tissue (details)
  - Location
    - Tendons, aponeuroses, ligaments, elastic tissue
  - Function
    - **Tendons**: connect muscle to bone
    - **Aponeuroses**: connect muscle to muscle or covers entire muscle
    - **Ligaments**: connect bone to bone
    - **Elastic**: stabilizes the vertebrae

- Matrix
  - Fibers

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**Dense Regular Connective Tissue**

**LOCATIONS:** Between skeletal muscles and skeleton (tendons and aponeuroses); between bones or stabilizing positions of internal organs (ligaments); covering skeletal muscles; deep fasciae

**FUNCTIONS:** Provides firm attachment; conducts pull of muscles; reduces friction between muscles; stabilizes relative positions of bone

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**Figure 3.15a Histology of Dense Connective Tissues**

- **Tendon.** The dense regular connective tissue in a tendon consists of densely packed, parallel bundles of collagen fibers. The fibrocyte nuclei can be seen flattened between the bundles. Most ligaments resemble tendons in their histological organization.
**Elastic Ligament.** Elastic ligaments extend between the vertebrae of the spinal column. The bundles of elastic fibers are fatter than the collagen fiber bundles of a tendon or typical ligament.
Connective Tissue Proper

• Dense Irregular Connective Tissue (details)
  • Location
    • Nerve and muscle sheaths
  • Function
    • Provides strength
  • Matrix
    • Fibers
**Dense Irregular Connective Tissue**

**LOCATIONS:** Capsules of visceral organs; periostea and perichondria; nerve and muscle sheaths; dermis

**FUNCTIONS:** Provides strength to resist forces applied from many directions; helps prevent overexpansion of organs such as the urinary bladder

**Deep Dermis.** The deep portion of the dermis of the skin consists of a thick layer of interwoven collagen fibers oriented in various directions.
Fluid Connective Tissue

- Fluid Connective Tissue
  - Blood
    - Erythrocytes
    - Leukocytes
    - Platelets
    - Plasma
Fluid Connective Tissue

• Blood (details)
  • Location: circulatory system
  • **Erythrocytes**
    • Transport oxygen and carbon dioxide
  • **Leukocytes**
    • Fight infections
  • **Platelets**
    • Blood clotting
• **Matrix**
  • Liquid (plasma)
Red Blood Cells

Red blood cells, or erythrocytes, are responsible for the transport of oxygen (and, to a lesser degree, of carbon dioxide) in the blood.

Red blood cells account for roughly half the volume of whole blood, and give blood its color.

White Blood Cells

White blood cells, or leukocytes, help defend the body from infection and disease.

Monocytes are related to the free macrophages in other tissues.

Lymphocytes are relatively rare in the blood, but they are the dominant cell type in lymph.

Eosinophils and neutrophils are phagocytes. Basophils promote inflammation much like mast cells in other connective tissues.

Platelets

The third type of formed element consists of membrane-enclosed packets of cytoplasm called platelets, or thrombocytes.

These cell fragments function in the clotting response that seals leaks in damaged or broken blood vessels.
Fluid Connective Tissue

• Lymph (details)
  • Location
    • Lymphatic system
  • Lymphocytes
    • Develop into T cells and B cells (for example)
• Function
  • Involved with the immune system
Supporting Connective Tissue

• Supporting Connective Tissue
  • Provide a strong framework that supports rest of body
• Cartilage
  • Gel matrix made of chondroitin sulfate
  • Cells reside in lacunae
• Bone
  • Solid matrix made of calcium phosphate
  • Cells reside in lacunae
Supporting Connective Tissue

• Cartilage
  • Types of Cartilage:
    • Hyaline cartilage
    • Elastic cartilage
    • Fibrous cartilage
Supporting Connective Tissue

• Hyaline Cartilage Tissue (details)
  • Location
    • Connection between ribs and sternum
    • Connection within the joints of the elbow and knee
    • Tracheal cartilage rings
  • Function
    • Flexible support
    • Reduces friction
  • Matrix
    • Gel
Hyaline Cartilage

**LOCATIONS:** Between tips of ribs and bones of sternum; covering bone surfaces at synovial joints; supporting larynx (voice box), trachea, and bronchi; forming part of nasal septum

**FUNCTIONS:** Provides stiff but somewhat flexible support; reduces friction between bony surfaces

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**Hyaline Cartilage**

- **Chondrocytes in lacunae**
- **Matrix**

---

**Hyaline cartilage.** Note the translucent matrix and the absence of prominent fibers.
Supporting Connective Tissue

• Elastic Cartilage Tissue (details)
  • Location
    • Auricle of the ear
    • Epiglottis
    • Auditory tube
  • Function
    • Flexible support
  • Matrix
    • Gel
**Elastic cartilage.** The closely packed elastic fibers are visible between the chondrocytes.

**FUNCTIONS:** Provides support, but tolerates distortion without damage and returns to original shape.

**LOCATIONS:** Auricle of external ear; epiglottis; auditory canal; cuneiform cartilages of larynx.

**Elastic Cartilage**

- **Chondrocyte in lacunae**
- **Elastic fibers in matrix**
Supporting Connective Tissue

• Fibrous Cartilage Tissue (details)
  • Location
    • Pads within the knee joints
    • Pads between the spinal vertebrae
    • Pubic symphysis
  • Function
    • Resists compression
    • Absorbs shock
  • Matrix
    • Gel
Fibrous cartilage. The collagen fibers are extremely dense, and the chondrocytes are relatively far apart.
Supporting Connective Tissue

• Bone
  • Location
    • Skeletal system
  • Function
    • Support and strength
  • Matrix
    • Solid (lamellae)
Supporting Connective Tissue

• Bone (details)
  • Made of osteons
  • Osteons consist of:
    • Central canal
    • Osteocytes
    • Lacunae
    • Canaliculi
    • Matrix of lamellae
Figure 3.19 Anatomy and Histological Organization of Bone.

- **Osteon**
  - Central canal
  - Blood vessels
  - Matrix
  - Osteocytes in lacunae
  - Canaliculi
  - Small vein (contained in central canal)
- **Compact bone**
- **Spongy bone**
- **Capillary**
- **Concentric lamellae**
- **Fibrous layer**
- **Cellular layer**
- **Periosteum**

LM × 375
### Table 3.2  A Comparison of Cartilage and Bone

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Cartilage</th>
<th>Bone</th>
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<tbody>
<tr>
<td><strong>STRUCTURAL FEATURES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cells</td>
<td>Chondrocytes in lacunae</td>
<td>Osteocytes in lacunae</td>
</tr>
<tr>
<td>Matrix</td>
<td>Chondroitin sulfates with proteins, forming hydrated proteoglycans</td>
<td>Insoluble crystals of calcium phosphate and calcium carbonate</td>
</tr>
<tr>
<td>Fibers</td>
<td>Collagen, elastic, reticular fibers (proportions vary)</td>
<td>Collagen fibers predominate</td>
</tr>
<tr>
<td>Vascularity</td>
<td>None</td>
<td>Extensive</td>
</tr>
<tr>
<td>Covering</td>
<td>Perichondrium, two layers</td>
<td>Periosteum, two layers</td>
</tr>
<tr>
<td>Strength</td>
<td>Limited: bends easily but hard to break</td>
<td>Strong: resists distortion until breaking point is reached</td>
</tr>
<tr>
<td>Growth</td>
<td>Interstitial and appositional</td>
<td>Appositional only</td>
</tr>
<tr>
<td>Repair capabilities</td>
<td>Limited ability</td>
<td>Extensive ability</td>
</tr>
<tr>
<td>Oxygen demands</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Nutrient delivery</td>
<td>By diffusion through matrix</td>
<td>By diffusion through cytoplasm and fluid in canaliculi</td>
</tr>
</tbody>
</table>
Membranes

• Membranes
  • Epithelia and connective tissue combine to form membranes
  • Each membrane consists of:
    • Sheet of epithelial cells
    • An underlying connective tissue
  • Four types of membranes
    • Mucous
    • Serous
    • Cutaneous
    • Synovial

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Membranes

• Mucous Membranes
  • Line digestive, respiratory, reproductive, and urinary tracts
    • Form a barrier that resists pathogen entry
    • Keep the epithelial surfaces moist
    • The connection of the epithelium with underlying tissue is called lamina propria
    • Provide support for blood vessels and nerves
Figure 3.20a Membranes.

Mucous membranes are coated with the secretions of mucous glands. Mucous membranes line most of the digestive and respiratory tracts and portions of the urinary and reproductive tracts.
Membranes

• Serous Membranes
  • Line the body cavities
  • Consist of a parietal and a visceral layer
  • Three types of serous membranes
    • Pleura: lines the lungs
    • Peritoneum: lines the peritoneal cavity
    • Pericardium: lines the heart
Serous membranes line the ventral body cavities (the peritoneal, pleural, and pericardial cavities).
Membranes

Cutaneous Membrane

• Makes up the skin
• Consists of keratinized stratified squamous epithelium
• Thick and waterproof
The cutaneous membrane, the skin, covers the outer surface of the body.
Membranes

• **Synovial Membrane**
  • Lines the joint cavities
  • Produces synovial fluid that reduces friction within the joints
  • Different than the other membranes
    • No basal lamina or reticular lamina
    • Has gaps between cells
    • Cells are derived from macrophages and fibroblasts
Synovial membranes line joint cavities and produce the fluid within the joint.
The Connective Tissue Framework of the Body

• Connective tissue creates the internal framework of the body

• Layers of connective tissue connect organs with the rest of the body

• Layers of connective tissue are called **fascia**
  • Superficial fascia
  • Deep fascia
  • Subserous fascia
Figure 3.21 The Fasciae.

Connective Tissue Framework of Body

Superficial Fascia
- Between skin and underlying organs
- Areolar tissue and adipose tissue
- Also known as subcutaneous layer or hypodermis

Deep Fascia
- Forms a strong, fibrous internal framework
- Dense connective tissue
- Bound to capsules, tendons, ligaments, etc.

Subserous Fascia
- Between serous membranes and deep fascia
- Areolar tissue

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Muscle Tissue

- Have the ability to contract and relax
- Three types of muscle cells
  - Skeletal muscle
  - Smooth muscle
  - Cardiac muscle
- Cells are different than “typical” cells
  - Cytoplasm is called sarcoplasm
  - Plasmalemma is called a sarcolemma
Muscle Tissue

• Skeletal Muscle
  • Sometimes referred to as skeletal muscle fibers
  • Multinucleated: Nuclei lie just under the sarcolemma
  • Incapable of cell reproduction
    • Myosatellite cells can reproduce and therefore muscle repair is possible
  • Have a striped appearance under the microscope
  • Voluntarily moves the skeleton
Skeletal Muscle Tissue

Cells are long, cylindrical, striated, and multinucleate.

**LOCATIONS:** Combined with connective tissues and neural tissue in skeletal muscles

**FUNCTIONS:** Moves or stabilizes the position of the skeleton; guards entrances and exits to the digestive, respiratory, and urinary tracts; generates heat; protects internal organs

---

**Skeletal Muscle Fibers.** Note the large fiber size, prominent banding pattern, multiple nuclei, and unbranched arrangement.
Muscle Tissue

- Smooth Muscle
  - Found:
    - Base of hair follicles, in the walls of blood vessels, lining the urinary bladder, within respiratory, circulatory, digestive, and reproductive tracts
  - Is capable of cell reproduction
  - Has tapered ends
  - Nonstriated
  - Involuntary contraction
Smooth Muscle Tissue

Cells are short, spindle-shaped, and nonstriated, with a single, central nucleus

LOCATIONS: Found in the walls of blood vessels and in digestive, respiratory, urinary, and reproductive organs

FUNCTIONS: Moves food, urine, and reproductive tract secretions; controls diameter of respiratory passageways; regulates diameter of blood vessels

Smooth Muscle Cells. Smooth muscle cells are small and spindle shaped, with a central nucleus. They do not branch, and there are no striations.
Muscle Tissue

• Cardiac Muscle
  • Found only associated with the heart
  • Each cell has just one nucleus
  • Cells connected by intercalated discs
  • Pulsating contractions
  • Also called striated involuntary muscle
Cardiac Muscle Cells. Cardiac muscle cells differ from skeletal muscle fibers in three major ways: size (cardiac muscle cells are smaller), organization (cardiac muscle cells branch), and number of nuclei (a typical cardiac muscle cell has one centrally placed nucleus). Both contain actin and myosin filaments in an organized array that produces the striations seen in both types of muscle cell.
Neural Tissue

- Neural Tissue
  - Specialized to conduct electrical signals through the body
- Two types of neural cells
  - **Neurons** are the cells that actually transmit the impulse
  - **Neuroglia** are the supporting cells of the neural tissue; these cells protect the neurons
Neural Tissue

• Neural Tissue
  • Longest cells in the body
  • Incapable of cell reproduction
  • Consists of:
    • Soma, axon, dendrite
Figure 3.23a Histology of Neural Tissue.

Diagrammatic view of a representative neuron.
Figure 3.23b Histology of Neural Tissue.

- Nuclei of neuroglia
- Cell body
- Nucleus of neuron
- Nucleolus
- Axon
- Dendrites

Histological view of a representative neuron

LM × 600
Tissues, Nutrition, and Aging

- Repair and maintenance become less efficient as one ages
- Hormonal changes and lifestyle changes also affect the functioning of tissues
- Epithelia become thinner and connective tissues become fragile
- Cardiac muscle cells and neural tissue cannot regenerate; therefore, relatively minor damage adds up over time, sometimes causing severe health issues

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Summary of Early Embryology

• The Formation of Tissues
  • Fertilization
  • Zygote
  • Cellular division
  • Formation of a blastocyst
    • Hollow ball of cells
  • Formation of the two layers of the blastocyst
    • Trophoblast: forms the placenta
    • Inner cell mass: forms the embryo
  • Three germ layers form the four tissues of the body
Fertilization produces a single cell, or **zygote** (ZĪ-gōt), that contains the normal number of chromosomes (46).

**Fertilization** → **Zygote**

During **cleavage**, cell divisions produce a hollow ball of cells called a **blastocyst**. This process takes about a week to complete.

In section, the blastocyst contains two groups of cells with very different fates. The outer layer, or **trophoblast** (TRŌ-fō-blast; *trophos*, food + blast, precursor), will form the placenta, which nourishes the developing embryo. The **inner cell mass** will form the actual embryo.

During the second week of development, different populations of cells can be seen in the inner cell mass. These cells are organized into three primary germ layers: the **ectoderm**, **mesoderm**, and **endoderm**. Further differentiation of the primary germ layers will produce the major tissue types.
Summary of Early Embryology

• The Development of Epithelia
  • Begin as simple epithelia
  • Differentiate into functional epithelial and gland cells
  • Complex glands begin to form
    • Endocrine and exocrine
All epithelia begin as simple epithelia that may later become stratified. These cells differentiate into functional epithelial cells and gland cells that may have endocrine or exocrine functions.

Complex glands begin to form as epithelial cells grow into the underlying connective tissue. In the formation of an exocrine gland, the cells connecting the secretory cells to the surface form the duct that carries the secretions of the gland cells to the epithelial surface. In the formation of an endocrine gland, the connecting cells disappear, and the gland cells secrete into blood vessels or into the surrounding tissue fluids.
Summary of Early Embryology

- Origins of Connective Tissues
  - Endoderm forms **mesenchyme**
  - Mesenchyme differentiates to form:
    - Chondroblasts
    - Osteoblasts
    - Blood
    - Lymph
    - Embryonic connective tissue
      - Loose connective
      - Dense connective
Mesenchyme is the first connective tissue to appear in the developing embryo. Mesenchyme contains star-shaped cells that are separated by a ground substance that contains fine protein filaments. Mesenchyme gives rise to all other forms of connective tissue, and scattered mesenchymal cells in adult connective tissues participate in their repair after injury.

Embryonic connective tissue develops as the density of fibers increases. Embryonic connective tissue may differentiate into any of the connective tissues proper.

Cartilage develops as mesenchymal cells differentiate into chondroblasts that produce cartilage matrix. These cells later become chondrocytes.

Bone formation begins as mesenchymal cells differentiate into osteoblasts that lay down the matrix of bone. These cells later become trapped as osteocytes.

Fluid connective tissues form, as mesenchymal cells create a network of interconnected tubes. Cells trapped in those tubes differentiate into red and white blood cells.

Supporting connective tissue

Fluid connective tissue

Loose connective tissue

Dense connective tissue
Summary of Early Embryology

• The Development of Organ Systems
  • An **ectoderm** layer and **endoderm** layer form
  • Day 14: Cells migrate between those two layers forming a **mesoderm**
  • Day 18: Organs begin to develop
  • Day 28: Beginning of all major organ systems
Many different organ systems show similar patterns of organization. For example, the digestive, respiratory, urinary, and reproductive systems each include passageways lined by epithelia and surrounded by layers of smooth muscle. These patterns are the result of developmental processes under way in the first two months of embryonic life.

After roughly two weeks of development, the inner cell mass is only a millimeter in length. The region of embryonic development is called the embryonic shield. It contains a pair of epithelial layers: an upper ectoderm and an underlying endoderm. At a region called the primitive streak, superficial cells migrate between the two, adding to an intermediate layer of mesoderm.

By day 18, the embryo has begun to lift off the surface of the embryonic shield. The heart and many blood vessels have already formed, well ahead of the other organ systems. Unless otherwise noted, discussions of organ system development in later chapters will begin at this stage.

After one month, you can find the beginnings of all major organ systems. The role of each of the primary germ layers in the formation of organs is summarized in the accompanying table; details are given in later Embryology Summaries.