**Tissues**  
*(Chapter 4)*  
Lecture Materials  
for  
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Primary Sources for figures and content:  

**Tissue** = collection of specialized cells that perform limited number of functions  

**Histology** = the study of tissues  

**Four Main Types of Tissue:**  
1. Epithelial tissue → “covering” surfaces, linings, glands  
2. Connective tissue → “support” fill space, structure, strength, transport, storage  
3. Muscle tissue → “movement”  
4. Nervous tissue → “control” transmit info  

**Primary Germ Layers** =embryonic layers, give rise to all four tissue types in adult  

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**Epithelial Tissue**  
*2 categories:*  
1. Epithelia - covering  
2. Glands -produce fluid secretions  
3. Provide sensation:  
4. Provide physical protection:  
5. Contacts: cells linked by strong  
6. Polarity: apical + basal surfaces, separate functions  
7. Attachment: attached to CT via basal lamina  
8. Avascularity: diffusion from CT  
9. Regeneration: high turnover, stem cells at basal surface  

**Functions:**  
1. Provide physical protection: abrasion, dehydration, infection  
2. Control permeability: semi-permeable, covers all surfaces  
3. Provide sensation: sensory neurons  
4. Produce specialized secretions: (glandular) protection, chemical messengers
Structure
1. Apical surface: exposed to environment may have:
   - microvilli: absorption or secretion
   - cilia: fluid movement
2. Basolateral surface: attachment to neighboring cells via intercellular connections

Basal lamina (a.k.a. basement membrane)
1. Lamina lucida: from epithelia
   - glycoproteins + fine filaments
   - restrict large molecule movement
2. Lamina densa: from CT
   - coarse protein fibers
   - provide strength

Epithelial stem cells anchored to lamina lucida:
   - divide and migrate toward apical region

Classification (based on shape and layers)
Shape: (all are hexagonal from the top)
1. Squamous: flat, disc shaped nucleus
2. Cuboidal: cube, center round nucleus
3. Columnar: tall, basal oval nucleus

Layers:
1. Simple: one cell layer
   - absorption, secretion, filtration
2. Stratified: 2 or more
   - protection
In stratified, name for apical cell shape
1. Simple Squamous Epithelium
- Thin, delicate
- In protected regions
- Locations:
  - Mesothelium (serosa)
  - Endothelium (blood vessels, heart)
  - Kidney tubules
  - Conjunctiva
  - Alveoli of lungs
- Functions:
  - Absorption, diffusion, filtration or secretion

2. Stratified Squamous Epithelium
- Basal cells look cuboidal, apical cells squamous
- On exposed surfaces
- Two types:
  A. Nonkeratinized = mucosa
    - Kept moist
    - All cells nucleated
  B. Keratinized = epidermis
    - Dry, apical cells dead
    - Cells contain keratin protein to resist dehydration
- Functions:
  - Provide protection from abrasion, pathogens, chemicals

3. Simple Cuboidal Epithelium
- Locations:
  - Kidney tubules
  - Pancreas
  - Salivary glands
  - Thyroid
- Functions:
  - Secretion or absorption

4. Stratified Cuboidal Epithelium
- Rare
- Typically 2 layers
- Locations:
  - Some sweat glands
  - Some mammary glands
- Functions:
  - Secretion or absorption

5. Transitional Epithelium
- Relaxed: looks like stratified cuboidal
- Stretched: looks squamous
- Locations:
  - Urinary bladder
  - Ureters
- Function:
  - Tolerate excessive stretching
6. Simple Columnar Epithelium

- Nuclei line up near basal lamina
- Apical surface of cells often has microvilli = “brush border” (in intestine)
- Goblet cells often present: secrete mucus
- Locations:
  - Stomach
  - Intestine
  - Gallbladder
  - Uterine tubes
  - Collecting ducts of kidney
- Functions:
  - Absorption or secretion

7. Pseudostratified Columnar Epithelium

- Several cell types:
  - Varying shapes and functions
- All cells contact basal lamina
- Some too short to reach apical surface
- Nuclei scattered so it appears stratified
- Tall cells have cilia on apical surface
- Goblet cells (mucus) often present
- Locations:
  - Nasal cavity, trachea, bronchi
  - Male reproductive tract
  - Female uterine tubes
- Functions:
  - Move material across surface

8. Stratified Columnar Epithelium

- Rare
- Two layers or multiple layers with only apical layer columnar
- Locations (tiny parts of):
  - Pharynx, epiglottis
  - Anus
  - Mammary glands
  - Salivary glands
  - Urethra
- Functions:
  - Minor protection

Glandular Epithelium

For secretion, makes up glands

1. Endocrine glands: “Internally secreting” secrete into interstitial fluid → blood secretions = hormones regulate and coordinate activities e.g. pancreas, thyroid, thymus, pituitary

2. Exocrine glands: “externally secreting” secrete into duct → epithelial surface e.g. digestive enzymes, perspiration, tears, milk, mucus
Classified three ways:
  a. Mode of secretion
  b. Type of secretion
  c. Structure
A. Mode of secretion
1. Merocrine secretion
   - product released from secretory vesicles by exocytosis
   e.g. mucus, sweat
2. Apocrine secretion
   - product accumulates in vesicles
   - apical region of cell with vesicles is shed to release product
   e.g. milk
3. Holocrine secretion
   - product accumulates in vesicles
   - whole cell is lysed to release product
   - cell dies, must be replaced by stem cells
   e.g. sebum

B. Type of secretion
1. Serous glands: water + enzymes
   e.g. parotid salivary gland
2. Mucus glands: mucin (+water = mucus)
   e.g. goblet cell
3. Mixed exocrine glands:
   serous + mucus secretion
   e.g. submandibular salivary gland

C. Gland structure
1. Unicellular gland: 1 cell
   e.g. goblet cell
2. Multicellular gland: group of cells
   named for shape and structure

Connective Tissue
Features:
- never exposed to environment
- usually vascularized
- consists of cells in a matrix

Components:
1. Specialized cells:
   produce matrix, provide protection
2. Extracellular protein fibers:
   support, strength
3. Ground substance:
   gel fluid, consists of:
   - interstitial fluid,
   - CAMs,
   - GAGs (glycosaminoglycans)
   - proteoglycans that gel

   Fibers + Ground substance = Matrix

Functions
1. Establish structural framework
2. Transport fluid and dissolved materials
3. Protect organs
4. Support, surround, interconnect tissues
5. Store energy reserves
6. Insulate body
7. Defend against pathogens

Classification: based on physical properties
1. Connective Tissue Proper:
   - many cell types and fiber types in thick ground substance
   A. Loose: open fiber framework
   B. Dense: tightly packed fibers
2. Fluid Connective Tissue:
   - many cell types in watery matrix with soluble fibers
3. Supporting Connective Tissue:
   - limited cell population in tightly packed matrix
All CT derived from Mesenchyme:

embryonic CT: mesenchymal cells in gelatinous matrix with fine fibers

1. Connective Tissue Proper
   - viscous ground substance
   - varied extracellular fibers
   - varied cell population

   Ground substance: rich in GAGs
   - viscous, prevents microbe penetration

Fiber types:
1. Collagen fibers: collagen protein
   - rope-like, long, straight
   - resists force
   - most common
2. Reticular fibers: collagen protein
   - branchy, forms framework
   framework of an organ = stroma
   (functional cells of an organ = parenchyma)

3. Elastic fibers: elastin protein
   - wavy, flexible
   - designed to stretch

Cell Types:
1. Fibroblasts
   - most common, most abundant
   - secrete ground substance:
     hyaluronan + proteins = GAGs
   - secrete fiber proteins (collagen, elastin)
   - some specialized types:
     chondrocytes (cartilage)
     osteocytes (bone)
2. Mesenchymal cells
   - stem cells
   - differentiate to replace CT cells after injury (e.g. fibroblasts, adipocytes)

3. Adipocytes (fat cells)
   - store triglycerides
   - organelles pushed to periphery
   - number, size and location of cells varies

4. Macrophages
   - phagocytic for defense
   - some fixed in tissues
   - others migrate from blood to tissues after injury

5. Microphages
   - neutrophils and eosinophils
   - phagocytic
   - migrate from blood to site of injury
6. Lymphocytes: B and T cells
   -involved in immune response
   -make antibodies, attack foreign cells
   -increase in number during infection
   -constantly migrate between blood and tissues and lymph

7. Mast cells
   -contain histamine and heparin
   -stimulate inflammation in response to injury

A. Loose Connective Tissue
   -highly vascularized
   -varied cell types
   -functions:
     -fill space
     -cushion & support tissues
     -store fat
     -feed epithelial layers

1. Areolar CT
   -most common
   -least specialized
   -open framework:
     -matrix mostly ground substance
     -all fiber types
   Location:
     -deep to epithelium
   Functions:
     -reservoir for water & salts
     -absorbs shock & distortion
     -fills space
     -feeds epithelium

2. Adipose Tissue
   -90% adipocytes
   Locations:
     -deep to skin
     -surrounding eyeballs, kidneys, heart
   Functions:
     -padding & insulation
     -energy storage
     -two types:
       a. white fat: adults, triglyceride storage
       b. brown fat: infants, high mitochondria content for heat generation

3. Reticular Tissue
   -stroma of organs
   -consists of reticular fibers
   Locations: some organs:
     e.g. lymph nodes, bone marrow, liver
   Function:
     support parenchyma cells

B. Dense Connective Tissue
   -poorly vascularized
   -mostly fibers, little ground substance
   -only fibroblasts

1. Dense Regular CT
   -bundles of parallel collagen fibers, aligned with direction of force

Locations:
   -tendons (muscle to bone)
   -ligaments (bone to bone)
   -muscle coverings
   -fascia
Function:
   -high strength attachment
   -stabilize positions
### 2. Dense Irregular CT
- mesh of collagen fibers

**Locations:**
- capsules of organs & fascia
- periosteum (sheath around bone)
- perichondrium (around cartilage)
- dermis (deep skin)

**Function:**
- resist tension from many directions
- attachment

### 3. Elastic CT
- mostly elastic fibers, some collagen

**Locations:**
- vertebral ligaments
- artery walls

**Function:**
- strength with stretch and flex

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### 2. Fluid Connective Tissue

**A. Blood**

- **Matrix** = plasma: serum (fluid) + plasma proteins (produced by liver)
- fibers are soluble until clot forms

- **Cells** = formed elements
- originate from hemocytoblast (stem cell) in bone marrow

1. Erythrocytes (RBCs): carry O₂
2. Leukocytes (WBCs): defense
   - Neutrophils, Eosinophils, Basophils,
   - Lymphocytes (B and T cells),
   - Monocytes (Macrophages)
3. Platelets: carry clotting factors

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### 3. Supporting Connective Tissue
- strong framework, few cells, fibrous matrix
- function: support and shape
- mature cells in lacunae

#### A. Cartilage

**Composition:**
- Matrix: 80% water, firm gel of GAGs made of chondroitin sulfate and hyaluronic acid, + fibers
- Cells: chondrocytes (in lacunae) (cells formed the matrix)

**Structure:**
- no innervation
- avascular (antiangiogenesis factor)
- surrounded by perichondrium:
  - outer layer = dense irregular CT protection, attachment
  - inner layer = cellular (fibroblasts) growth and repair
**Growth of cartilage:** (not common in adults)
1. Interstitial growth (embryos)
   - chondroblasts in matrix divide
   - daughters produce more matrix
     (mature cells = chondrocytes)
2. Appositional growth (children, minor repair in adult)
   - new layers added by cells of inner perichondrium

Serious injury = scar: cartilage replaced by fibrous collagen

**Types of cartilage:**
1. Hyaline Cartilage
   - matrix contains fine, closely packed collagen fibers
   - tough, springy
   Locations:
   - ribs
   - nose
   - respiratory tract
   - articular surfaces (no perichondrium)
   Function:
   - provide stiff flexible support
   - reduce friction between bones
2. Elastic Cartilage
   - matrix contains elastic fibers
   - flexible
   Locations:
   - auricle of ear
   - epiglottis
   Function:
   - resilient, flexible, shape holding support

3. Fibrocartilage
   - matrix contains dense interwoven collagen fibers with little ground substance
   - tough, durable

Locations:
- knee (meniscus)
- pubic symphysis
- intervertebral discs

Functions:
- resist compression
- absorb shock

**B. Bone / Osseous Tissue**
- highly vascularized
- little ground substance

- matrix = 2/3 calcium salts for strength
  (calcium phosphate + calcium carbonate)
- 1/3 collagen for flexibility to resist shatter
- cells = osteocytes
  (cells formed the matrix)
- located in lacunae
- connected by cytoplasmic extensions
  that extend through canaliculi
- canaliculi necessary for nutrient & waste exchange, no diffusion through calcium
- surrounded by periosteum:
  - outer fibrous layer for attachment
  - inner cellular layer for growth and repair

Location:
- bones
Functions:
- support & protection
- levers for movement
- storage of minerals

Special Connective Tissue Structures
1. Fascia
- connective tissue that provides a framework to connect organs to the body
- Functions:
  - provide strength and stability
  - maintain the position of the organs
  - anchor blood vessels, lymphatic vessels and nerves

Three layers:
A. Superficial fascia
- located between cutaneous membrane and organs
- composed of areolar CT and adipose
- a.k.a. subcutaneous layer/hypodermis
- functions to provide insulation and padding

B. Deep fascia
- forms strong framework of dense CT
- creates capsules around organs, binds capsules, tendons, ligaments to hold tissues together
- functions to resist force and anchor positions of organs

C. Subserous fascia
- between serous membranes and deep fascia
- composed of areolar CT
- functions to prevent distortion of organs by muscles

2. Membranes
- typically epithelium plus supporting CT

A. Mucous Membranes / Mucosa
- epithelium + areolar connective tissue called lamina propria
- line passageways that connect to external environment
- epithelium kept moist with mucus secretions

B. Serous Membranes / Serosa
- mesothelium + areolar connective tissue
- lines body cavities to reduce friction (pleura, peritoneum, pericardium)
- parietal layer lines cavity, visceral layer around organ
- epithelium kept moist by serous fluid / transudate
C. Cutaneous Membrane
(epidermis + dermis = “skin”)
- keratinized stratified squamous epithelium
  + areolar and dense irregular connective tissue
- only dry membrane

D. Synovial Membranes
- areolar connective tissue with woven collagen, proteoglycans and glycoproteins
  in matrix
- lines joint capsules
- produces synovial fluid to reduce friction of articular cartilage
- only membrane with no epithelium

Muscle Tissue
Function:
- produce movement
Features:
  - highly vascularized
  - contains actin and myosin for contraction
Types:
1. Skeletal Muscle (Striated Voluntary Muscle)
  - cells = fibers
    - up to 1 ft long
    - multinuclear
    - no cell division
    - appear striated: actin and myosin organized into myofibrils
  - some satellite cells (stem cells) present for minor repair after injury
Location: skeletal muscles (“meat”)
Functions:
  - move skeleton
  - guard entrances/exits
  - generate heat

2. Cardiac Muscle
   (Striated Involuntary Muscle)
   - cells = cardiocytes
     - long, branched
     - usually single nucleus but up to 5
     - no cell division
     - striated
     - neighboring cells connected by intercalated discs: desmosomes + intercellular cement + gap junctions
       * desmosomes & cement provide tight linkage of neighboring cells
       * gap junctions allow exchange of ions to coordinate contraction
Location: majority of heart
Function: move blood through body

3. Smooth Muscle
   (Nonstriated Involuntary Muscle)
   - cells small, spindle shaped
     - uninuclear
     - capable of cell division
     - no striations: no myofibril organization
Location:
  - walls of blood vessels
  - walls of hollow organs:
    digestive, respiratory, urinary and reproductive tracts
Function:
  - move materials through the organ
Nervous Tissue
Function:
- conduct nervous impulses to relay information
Location:
- most in brain and spinal cord: CNS
- 2% in PNS
Cells:
1. Neuroglia cells
   - support, repair, and supply nutrients to nervous tissue
2. Neurons
   - transmit information
   - up to 3 ft long
   - large soma (cell body)
   - large nucleus, visible nucleoli
   - many dendrites: receive info
   - one axon: transmits info
   - no cell division

Tissue Injuries
- maintain homeostasis:
  inflammation and repair

Inflammation:
- prevent spread of injury or infection
- characterized by: swelling, redness, warmth, and pain
- process to remove necrotic cells and infectious agents
  (inflammation process on handout)

Injury and Cancer:
- repeat or chronic inflammation causes damage

Dysplasia: change in normal shape, size, organization of tissue cells (reversible)

Metaplasia: more serious changes, abnormal division of stem cells (reversible)

Anaplasia: breakdown of tissue organization, genetic abnormalities of stem cells (irreversible)

Cancer = uncontrolled growth