The Human Body: An Orientation

An Overview of Anatomy

• **Anatomy**
  • The study of the *structure* of the human body

• **Physiology**
  • The study of body *function*

• **Branches of anatomy**
  • Gross anatomy
  • Microscopic anatomy (histology)
  • Surface anatomy

• Other branches of anatomy
  • Developmental anatomy
  • Embryology
  • Pathological anatomy (pathology)
  • Radiographic anatomy
  • Functional morphology

• **Anatomical terminology**
  • Based on ancient Greek or Latin
  • Provides standard nomenclature worldwide

The Hierarchy of Structural Organization

• **Chemical level**—atoms form molecules

• **Cellular level**—cells and their functional subunits

• **Tissue level**—a group of cells performing a common function

• **Organ level**—a discrete structure made up of more than one tissue

• **Organ system**—organs working together for a common purpose

• **Organism level**—the result of all simpler levels working in unison

Systemic v. Regional Anatomy

• **Systemic**—study of anatomy by system

• **Regional**—study of anatomy by region

• Most students use a combination of regional and systemic study

Integumentary System

• Forms external body covering
• Protects deeper tissues from injury
• Synthesizes vitamin D
• Site of cutaneous receptors
  • (pain, pressure, etc.) and sweat and oil glands

**Skeletal System**
• Protects and supports body organs
• Provides a framework for muscles
• Blood cells formed within bones
• Stores minerals

**Muscular System**
• Allows manipulation of environment
• Locomotion
• Facial expression
• Maintains posture
• Produces heat

**Nervous System**
• Fast-acting control system
• Responds to internal and external changes

**Endocrine System**
• Glands secrete hormones that regulate:
  • Growth
  • Reproduction
  • Nutrient use

**Cardiovascular System**
• Blood vessels transport blood
  • Blood carries oxygen and carbon dioxide
  • It also carries nutrients and wastes
• Heart pumps blood through blood vessels

**Lymphatic System/Immunity**
• Picks up fluid leaked from blood vessels
• Disposes of debris in the lymphatic system
• Houses white blood cells (lymphocytes)
• Mounts attack against foreign substances in the body
Respiratory System
• Keeps blood supplied with oxygen
• Removes carbon dioxide
• Gas exchange occurs through walls of air sacs in the lungs

Digestive System
• Breaks down food into absorbable units
• Indigestible foodstuffs eliminated as feces

Urinary System
• Eliminates nitrogenous wastes
• Regulates water, electrolyte, and acid-base balance

Male & Female Reproductive Systems
• Overall function is to produce offspring
• Testes produce sperm and male sex hormones
• Ovaries produce eggs and female sex hormones
• Mammary glands produce milk

Scale: Length, Volume, and Weight
• Metric system provides a precise system of measurement

Gross Anatomy—An Introduction
• Anatomical position—a common visual reference point
  • Person stands erect with feet together and eyes forward
  • Palms face anteriorly with the thumbs pointed away from the body
• Directional terminology—refers to the body in anatomical position
  • Standardized terms of directions are paired terms

Gross Anatomy—An Introduction
• Directional terms
• Regional terms—names of specific body areas
  • Axial region—the main axis of the body
  • Appendicular region—the limbs

Body Planes and Sections
• Coronal (frontal) plane
  • Lies vertically and divides body into anterior and posterior parts
• Median (midsagittal) plane
  • Specific sagittal plane that lies vertically in the midline
Transverse plane
- Runs horizontally and divides body into superior and inferior parts

Characteristics Common to All Vertebrates
- Tube-within-a-tube
- Bilateral symmetry
- Dorsal hollow nerve cord
- Notochord and vertebrae
- Segmentation
- Pharyngeal pouches

Basic Human Body Plan and Structures
Shared with all Vertebrates

Body Cavities and Membranes
- Dorsal body cavity
  - Cranial cavity
  - Vertebral cavity
- Ventral body cavity
  - Thoracic cavity—divided into three parts
    - Two lateral parts each containing a lung surrounded by a pleural cavity
    - Mediastinum—contains the heart surrounded by the pericardial sac

Body Cavities and Membranes
- Ventral body cavity (continued)
  - Abdominopelvic cavity—divided into two parts
    - Abdominal cavity—contains the liver, stomach, kidneys, and other organs
    - Pelvic cavity—contains the bladder, some reproductive organs, and rectum

- Serous cavities—a slit-like space lined by a serous membrane
  - Pleura, pericardium, and peritoneum
    - Parietal serosa—outer wall of the cavity
    - Visceral serosa covers the visceral organs

Abdominal Regions and Quadrants
- Abdominal regions divide the abdomen into nine regions
- Abdominal quadrants divide the abdomen into four quadrants
  - Right upper and left upper quadrants
  - Right lower and left lower quadrants
Microscopic Anatomy

- **Microscopy**—examining small structures through a microscope
  - **Light microscopy** illuminates tissue with a beam of light (lower magnification)
  - **Electron microscopy** uses beams of electrons (higher magnification)

- Preparing human tissue for microscopy
  - Specimen is fixed (preserved) and sectioned
  - Specimen is stained to distinguish anatomical structures
    - *Acidic stain*—negatively charged dye molecules
    - *Basic stain*—positively charged dye molecules

- **Scanning electron microscopy**
  - Heavy metal salt stain—deflects electrons in the beam to different extents

- **Artifacts**
  - Minor distortions of preserved tissues
  - Not exactly like living tissues and organs

Clinical Anatomy—An Introduction to Medical Imaging Techniques

- **X ray**—electromagnetic waves of very short length
  - Best for visualizing bones and abnormal dense structures

Advanced X-Ray Techniques

- **Computed (axial) tomography** (CT or CAT)—takes successive X rays around a person's full circumference
  - Translates recorded information into a detailed picture of the body section

- **Digital subtraction angiography** (DSA) imaging provides an unobstructed view of small arteries
  - DSA is often used to identify blockages of arteries that supply the heart or brain

- **Positron emission tomography** (PET)—forms images by detecting radioactive isotopes injected into the body

- **Sonography** (ultrasound imaging)—body is probed with pulses of
high-frequency sound waves that echo off the body's tissues
- Imaging technique used to determine the age of a developing fetus

- **Magnetic resonance imaging** (MRI)—produces high-quality images of soft tissues
  - Distinguishes body tissues based on relative water content

# 2

**Cells: The Living Units**

**Introduction to Cells**
- Several important scientists made discoveries about cells
  - Robert Hooke
  - Matthias Schleiden and Theodor Schwann
  - Rudolf Virchow
- **Cells**—the smallest living units in our bodies
  - **Organelles**—“little organs”—carry on essential functions of cells
- Cells have three main components
  - **Plasma membrane**—the outer boundary
  - **Cytoplasm**—contains most organelles
  - **Nucleus**—controls cellular activities

**Structure of a Generalized Cell**

**The Plasma Membrane**
- Plasma membrane defines the extent of the cell
- Structure of membrane
  - Fluid mosaic model (lipid bilayer)
  - Types of membrane proteins
    - **Integral proteins**—firmly imbedded in, or attached to lipid bilayer
    - **Short chains of carbohydrates attach to integral proteins**
      - Form the glycocalyx
    - **Peripheral proteins**—attach to membrane surface
      - Support plasma membrane from the cytoplasmic side

**The Plasma Membrane**
- **Functions**—relate to location at the interface of cell’s exterior and interior
  - Provides barrier against substances outside cell
- Some plasma membranes act as receptors
- Determines which substances enter or leave the cell
  - *Membrane is selectively permeable*

- Membrane is *selectively permeable*

**Membrane Transport**
- Simple diffusion—tendency of molecules to move down their concentration gradient
- Osmosis—diffusion of water molecules across a membrane

**Membrane Transport Mechanisms**
- **Facilitated diffusion**—movement of molecules down their concentration gradient through an integral protein
- **Active transport**—integral proteins move molecules across the plasma membrane against their concentration gradient

**Endocytosis**
- **Endocytosis**
  - Mechanism by which particles enter cells
    - *Phagocytosis*—"cell eating"
    - *Pinocytosis*—"cell drinking"

**Receptor-mediated Endocytosis**
- **Receptor-mediated endocytosis**
  - Plasma proteins bind to certain molecules
    - *Invaginates and forms a coated pit*
      - Pinches off to become a *coated vesicle*
    - *NOTE: This is the method by which insulin and cholesterol enter cells!*

**Three Types of Endocytosis**

**Exocytosis**
- **Exocytosis**—a mechanism that moves substances out of the cell
  - Substance is enclosed in a vesicle
  - The vesicle migrates to the plasma membrane
  - Proteins from the vesicles (v-SNAREs) bind with membrane proteins (t-SNAREs)
  - The lipid layers from both membranes bind, and the vesicle releases
The Cytoplasm

• **Cytoplasm**—lies internal to plasma membrane
  • Consists of cytosol, organelles, and inclusions

• **Cytosol**
  • Jelly-like fluid in which other cellular elements are suspended
  • Consists of water, ions, and enzymes

Cytoplasmic Organelles

• **Ribosomes**—constructed of proteins and ribosomal RNA; not surrounded by a membrane
  • Site of protein synthesis
    • *Assembly of proteins is called translation*
    • Are the “assembly line” of the manufacturing plant

• **Endoplasmic reticulum**—“network within the cytoplasm”
  • **Rough ER**—ribosomes stud the external surfaces
  • **Smooth ER**—consists of tubules in a branching network
    • *No ribosomes are attached; therefore no protein synthesis*

• **Golgi apparatus**—a stack of three to 10 disk-shaped envelopes
  • Sorts products of rough ER and sends them to proper destination
  • Products of rough ER move through the Golgi from the convex (*cis*) to the concave (*trans*) side
  • Is the “packaging and shipping” division of the manufacturing plant

• **Lysosomes**—membrane-walled sacs containing digestive enzymes
  • Digest unwanted substances

• **Mitochondria**—generate most of the cell’s energy; most complex organelle
  • More abundant in energy-requiring cells, like muscle cells and sperm
  • “Power plant” of the cell

• **Peroxisomes**—membrane-walled sacs of oxidase enzymes
  • Enzymes neutralize free radicals and break down poisons
  • Break down long chains of fatty acids
• Are numerous in the liver and kidneys
• Are the toxic waste removal system

• **Cytoskeleton**—“cell skeleton”—an elaborate network of rods
  • Contains three types of rods:
    * **Microtubules**—cylindrical structures made of proteins
    * **Microfilaments**—filaments of contractile protein actin
    * **Intermediate filaments**—protein fibers

• **Centrosomes and centrioles**
  • **Centrosome**—a spherical structure in the cytoplasm
    * Composed of centrosome matrix and centrioles
  • **Centrioles**—paired cylindrical bodies
    * Consists of 27 short microtubules
    * Act in forming cilia
    * Necessary for karyokinesis (nuclear division)

**Cytoplasmic Inclusions**
• Temporary structures
  • Not present in all cell types
• May consist of pigments, crystals of protein, and food stores
  • **Lipid droplets**—found in liver cell and fat cells
  • **Glycosomes**—store sugar in the form of glycogen

**The Nucleus**
• The nucleus—“little nut” or “kernel”—control center of cell
  • DNA directs the cell’s activities
  • Nucleus is approximate 5µm in diameter

**The Nucleus**
• **Nuclear envelope**—two parallel membranes separated by fluid-filled space
• Nuclear pores penetrate the nuclear envelope
  • Pores allow large molecules to pass in and out of the nucleus

**The Nucleus**
• Nucleolus—“little nucleus”—in the center of the nucleus
  • Contains parts of several chromosomes
  • Site of **ribosome subunit** assembly
**Chromatin and Chromosomes**
- DNA double helix is composed of four subunits:
  - Thymine (T), adenine (A), cytosine (C), and guanine (G)
- DNA is packed with proteins
  - DNA plus the proteins form **chromatin**
- Each cluster of DNA and histone proteins is a **nucleosome**

**Extended chromatin**
- Is the active region of DNA where DNA’s genetic code is copied onto mRNA (transcription)

**Condensed chromatin**
- Tightly coiled nucleosomes
- Inactive form of chromatin

**Chromosomes**—highest level of organization of chromatin
- Contains a long molecule of DNA
  - *46 chromosomes are in a typical human cell*

**The Cell Life Cycle**
- The cell life cycle is the series of changes a cell goes through
  - **Interphase**
    - *G1* phase—growth 1 or Gap 1 phase
      - The first part of **interphase**
      - Cell metabolically active—growth—make proteins
      - Variable in length from hours to **YEARS**
        (egg cell)
      - **Centrioles** begin to replicate near the end of G1

  - **S** (synthetic) phase—DNA replicates itself
    - Ensures that daughter cells receive identical copies of the genetic material (chromatin extended)

  - **G2** phase—growth 2 or Gap 2
    - **Centrioles** finish copying themselves
    - Enzymes needed for cell division are synthesized in G2
    - During S (synthetic) and G2 phases, cell carries on normal activities

  - **Cell division**
    - **M** (mitotic) phase—cells divide during this stage
      - *Follows interphase (G1, S, and G2)*
Cell division involves:

- **Mitosis**—division of the nucleus during cell division
  - *Chromosomes are distributed to the two daughter nuclei*
- **Cytokinesis**—division of the cytoplasm
  - *Occurs after the nucleus divides*

### The Stages of Mitosis

- **Prophase**—the first and longest stage of mitosis
  - Early prophase—chromatin threads condense into chromosomes
    - *Chromosomes are made up of two threads called chromatids (sister chromatids)*
    - *Chromatids are held together by the centromere*
    - *Centriole pairs separate from one another*
    - *The mitotic spindle forms*
  - Prophase (continued)
    - Late prophase—centrioles continue moving away from each other
      - *Nuclear membrane fragments*

- **Metaphase**—the second stage of mitosis
  - Chromosomes cluster at the middle of the cell
    - *Centromeres are aligned along the equator*

- **Anaphase**—the third and shortest stage of mitosis
  - **Centromeres** of chromosomes split

- **Telophase** begins as chromosomal movement stops
  - Chromosomes at opposite poles of the cell uncoil
  - Resume threadlike extended-chromatin form
  - A new nuclear membrane forms

- **Cytokinesis** completes the division of the cell into two daughter cells

### Cellular Diversity

- Specialized functions of cells relates to:
  - Shape of cell
  - Arrangement of organelles
- Cells that *connect body parts or cover organs*
  - **Fibroblast**—makes and secretes protein component of fibers
  - **Erythrocyte**—concave shape provides surface area for uptake of the respiratory gases
• **Epithelial cell**—hexagonal shape allows maximum number of epithelial cells to pack together

• Cells that move organs and body parts
  • **Skeletal** and **smooth muscle cells**
    • Elongated and filled with actin and myosin
    • Contract forcefully

• Cells that store nutrients
  • **Fat cell**—shape is produced by large fat droplet in its cytoplasm

• Cells that fight disease
  • **Macrophage**—moves through tissue to reach infection sites

• Cells that gather information
  • **Neuron**—has long processes for receiving and transmitting messages

• Cells of reproduction
  • **Sperm** (male) – possesses long tail for swimming to the egg for fertilization

**Developmental Aspects of Cells**
• **Aging**—a complex process caused by a variety of factors
  • **Free radical theory**
    • Damage from byproducts of cellular metabolism
    • Radicals build up and damage essential molecules of cells
  • **Mitochondrial theory**
    • A decrease in production of energy by mitochondria weakens and ages our cells

• Aging (continued)
  • **Genetic theory** proposes that aging is programmed by genes
    • Telomeres—“end caps” on chromosomes
    • Telomerase—prevents telomeres from degrading

4 Tissues
Tissues
• **Cells** work together in functionally related groups called tissues
• **Tissue**
  • A group of closely associated cells that perform related functions and are similar in structure

Four Basic Tissue Types and Basic Functions
• **Epithelial tissue**—covering (Chapters 4 and 5)
• **Connective tissue**—support (Chapters 4, 5, 6, and 9)
• **Muscle tissue**—movement (Chapters 10 and 11)
• **Nervous tissue**—control (Chapters 12–16 and 25)

Epithelial Tissue
• Covers a body surface or lines a body cavity
• Forms parts of *most glands*
• **Functions** of epithelia
  • Protection
  • Diffusion
  • Absorption, secretion, and ion transport
  • Filtration
  • Forms slippery surfaces

Special Characteristics of Epithelia
• **Cellularity**
  • Cells separated by minimal extracellular material
• **Specialized contacts**
  • Cells joined by special junctions
• **Polarity**
  • Cell regions of the apical surface differ from the basal surface
• **Support by connective tissue**
• **Avascular but innervated**
  • Epithelia receive nutrients from underlying connective tissue
• **Regeneration**
  • Lost cells are quickly replaced by cell division

Classifications of Epithelia
• First name of tissue indicates *number of cell layers*
  • **Simple**—one layer of cells
  • **Stratified**—more than one layer of cells
• Last name of tissue describes shape of cells
  • Squamous—cells are wider than tall (plate-like)
  • Cuboidal—cells are as wide as tall, like cubes
  • Columnar—cells are taller than they are wide, like columns

Classifications of Epithelia

Simple Squamous Epithelium
• Description—single layer; flat cells with disc-shaped nuclei

Simple Squamous Epithelium
• Function
  • Passage of materials by passive diffusion and filtration
  • Secretes lubricating substances in serosae
• Location
  • Renal corpuscles
  • Alveoli of lungs
  • Lining of heart, blood, and lymphatic vessels
  • Lining of ventral body cavity (serosae)

Simple Squamous Epithelium

Simple Cuboidal Epithelium
• Description
  • Single layer of cubelike cells with large, spherical central nuclei
• Function
  • Secretion and absorption
• Location
  • Kidney tubules, secretory portions of small glands, ovary surface

Simple Cuboidal Epithelium

Simple Columnar Epithelium
• Description—single layer of column-shaped (rectangular) cells with oval nuclei
  • Some bear cilia at their apical surface
  • May contain goblet cells
• Function
  • Absorption; secretion of mucus, enzymes, and other substances
  • Ciliated type propels mucus or reproductive cells by ciliary action
Simple Columnar Epithelium

- **Location**
  - **Nonciliated form**
    - *Lines digestive tract, gallbladder, ducts of some glands*
  - **Ciliated form**
    - *Lines small bronchi, uterine tubes, and uterus*

Simple Columnar Epithelium

**Pseudostratified Columnar Epithelium**

- **Description**
  - All cells originate at basement membrane
  - Only tall cells reach the apical surface
  - May contain goblet cells and bear cilia
  - Nuclei lie at varying heights within cells
    - *Gives false impression of stratification*

Pseudostratified Columnar Epithelium

- **Function**—secretion of mucus; propulsion of mucus by cilia
- **Locations**
  - Nonciliated type
    - *Ducts of male reproductive tubes*
    - *Ducts of large glands*
  - Ciliated variety
    - *Lines trachea and most of upper respiratory tract*

Pseudostratified Ciliated Columnar Epithelium

**Stratified Epithelia**

- **Properties**
  - Contain *two or more* layers of cells
  - Regenerate from below (basal layer)
  - Major role is protection
  - Named according to shape of cells at *apical layer*

Stratified Squamous Epithelium

- **Description**
  - Many layers of cells are squamous in shape
  - Deeper layers of cells appear cuboidal or columnar
  - Thickest epithelial tissue
    - *Adapted for protection from abrasion*
Stratified Squamous Epithelium
• Two types—keratinized and non-keratinized
  • Keratinized
    • Location—epidermis
    • Contains the protective protein keratin
    • Waterproof
    • Surface cells are dead and full of keratin
  • Non-keratinized
    • Forms moist lining of body openings

Stratified Squamous Epithelium
• Function—Protects underlying tissues in areas subject to abrasion
• Location
  • Keratinized—forms epidermis
  • Nonkeratinized—forms lining of mucous membranes
    • Esophagus
    • Mouth
    • Anus
    • Vagina
    • Urethra

Stratified Squamous Epithelium

Stratified Cuboidal Epithelium
• Description—generally two layers of cube-shaped cells
• Function—protection
• Location
  • Forms ducts of
    • Mammary glands
    • Salivary glands
    • Largest sweat glands

Stratified Cuboidal Epithelium

Stratified Columnar Epithelium
• Description—several layers; basal cells usually cuboidal; superficial cells elongated
• Function—protection and secretion
• Location
  • Rare tissue type
- Found in male urethra and large ducts of some glands

**Stratified Columnar Epithelium**

**Transitional Epithelium**
- **Description**
  - Has characteristics of stratified cuboidal and stratified squamous
  - Superficial cells dome-shaped when bladder is relaxed, squamous when full
- **Function**—permits distension of urinary organs by contained urine
- **Location**—epithelium of urinary bladder, ureters, proximal urethra

**Glands**
- **Endocrine glands**
  - Ductless glands that secrete directly into surrounding tissue fluid
    - *Produce messenger molecules called hormones*
  - Covered in detail in chapter 17

**Glands**
- *Ducts* carry products of **exocrine glands** to epithelial surface
- Include the following diverse glands
  - Mucus-secreting glands
  - Sweat and oil glands
  - Salivary glands
  - Liver and pancreas

**Unicellular Exocrine Glands (The Goblet Cell)**
- Goblet cells produce **mucin**
  - Mucin + water → mucus
  - Protects and lubricates many internal body surfaces
  - Goblet cells are a unicellular exocrine gland

**Goblet Cells**

**Multicellular Exocrine Glands**
- Have two basic parts
  - Epithelium-walled duct
  - Secretory unit
Multicellular Exocrine Glands
• Classified by structure of duct
  • Simple
  • Compound
• Categorized by secretory unit
  • Tubular
  • Alveolar
  • Tubuloalveolar

Types of Multicellular Exocrine Glands

Lateral Surface Features—Cell Junctions
• Factors binding epithelial cells together
  • Adhesion proteins link plasma membranes of adjacent cells
  • Contours of adjacent cell membranes
  • Special cell junctions

Lateral Surface Features—Cell Junctions
• Tight junctions (zona occludens)—close off intercellular space
  • Found at apical region of most epithelial tissues types
  • Some proteins in plasma membrane of adjacent cells are fused
  • Prevent certain molecules from passing between cells of epithelial tissue

Tight Junction

Lateral Surface Features—Cell Junctions
• Adhesive belt junctions (zonula adherens)—anchoring junction
  • Transmembrane linker proteins attach to actin microfilaments of the cytoskeleton and bind adjacent cells
  • With tight junctions, these linker proteins form the tight junctional complex around apical lateral borders of epithelial tissues

Lateral Surface Features
• Desmosomes—main junctions for binding cells together
  • Scattered along abutting sides of adjacent cells
  • Cytoplasmic side of each plasma membrane has a plaque
  • Plaques are joined by linker proteins

Lateral Surface Features
• Desmosomes (continued)
• Intermediate filaments extend across the cytoplasm and anchor at desmosomes on opposite side of the cell
  • Are common in cardiac muscle and epithelial tissue

**Desmosome**

**Lateral Surface Features—Cell Junctions**
• **Gap junctions**—passageway between two adjacent cells
  • *These let small molecules move directly between neighboring cells*
  • Cells are connected by hollow cylinders of protein
  • Function in intercellular communication

**Gap Junction**

**Basal Feature: The Basal Lamina**
• Noncellular supporting sheet between the ET and the CT deep to it
  • Consists of proteins secreted by ET cells

**Basal Feature: The Basal Lamina**
• Functions
  • Acts as a *selective filter*, determining which molecules from capillaries enter the epithelium
  • Acts as *scaffolding* along which regenerating ET cells can migrate
  • **Basal lamina** and **reticular layers** of the underlying CT deep to it form *the basement membrane*

**Epithelial Surface Features**
• **Apical surface features**
  • **Microvilli**—fingerlike extensions of plasma membrane
    • *Abundant in ET of small intestine and kidney*
    • *Maximize surface area across which small molecules enter or leave*
    • *Act as stiff knobs that resist abrasion*

**Epithelial Surface Features**
• **Apical surface features**
  • **Cilia**—whiplike, highly motile extensions of apical surface membranes
    • *The apical surface contains a core of nine pairs of microtubules encircling one middle pair*
• **Axoneme**—a set of microtubules
  • Each pair of microtubules are arranged in a doublet
    • **Microtubules in cilia**—*arranged similarly to cytoplasmic organelles called* centrioles
    • **Movement of cilia**—*in coordinated waves*

**A Cilium**

**Classes of Connective Tissue**
• *Most diverse and abundant tissue*
• Main classes
  • **Connective tissue proper**
  • **Cartilage**
  • **Bone tissue**
  • **Blood**
• Cells separated by a *large amount of extracellular matrix*
• Extracellular matrix is composed of ground substance and fibers
• Common embryonic origin—**mesenchyme**

**Classes of Connective Tissue**

**Structural Elements of Connective Tissue**
• Connective tissues differ in structural properties
  • Differences in types of cells
  • Differences in composition of extracellular matrix
• However, connective tissues all share structural elements
• **Loose areolar connective tissue**
  • Will illustrate connective tissue features

**Structural Elements of Connective Tissue**
• Cells—primary cell type of connective tissue produces matrix
  • **Fibroblasts**
    • *Make protein subunits*
    • *Secrete molecules that form the ground substance*
  • **Chondroblasts**—secrete matrix in cartilage
  • **Osteoblasts**—secrete matrix in bone

**Structural Elements of Connective Tissue**
• Cells (continued)
  • Blood cells—an exception
    • *Do not produce matrix*
  • Areolar connective tissue contains
• Fat cells
• White blood cells
• Mast cells

Structural Elements of Connective Tissue

Structural Elements of Connective Tissue
• Fibers—function in support
  • Collagen fibers—strongest; resist tension
  • Reticular fibers—bundles of special type of collagen
    • Cover and support structures
  • Elastic fibers—contain elastin
    • Recoil after stretching

Structural Elements of Connective Tissue
• Ground substance
  • Is produced by primary cell type of the tissue
  • Is usually gel-like
  • Cushions and protects body structures
  • Holds tissue fluid
  • Blood is an exception
    • Plasma is not produced by blood cells

Connective Tissue Proper
• Has two subclasses
  • Loose connective tissue
    • Areolar, adipose, and reticular
  • Dense connective tissue
    • Dense irregular, dense regular, and elastic

Classes of Connective Tissue

Areolar Connective Tissue—A Model Connective Tissue
• Areolar connective tissue
  • Underlies epithelial tissue
  • Surrounds small nerves and blood vessels
  • Has structures and functions shared by other CT
  • Borders all other tissues in the body

Major Functions of Connective Tissue
• Structure of areolar connective tissue reflects its functions
• Support and binding of other tissues
• Holding body fluids (interstitial fluid → lymph)
• Defending body against infection
• Storing nutrients as fat

**Areolar Connective Tissue**
• Fibers provide support
  • Three types of protein fibers in extracellular matrix
    • Collagen fibers
    • Reticular fibers
    • Elastic fibers
  • Fibroblasts produce these fibers

**Areolar Connective Tissue**
• Description
  • Gel-like matrix with *all three fiber types*
  • Cells of areolar CT
    • Fibroblasts, macrophages, mast cells, and white blood cells
• Function
  • Wraps and cushions organs
  • Holds and conveys tissue fluid (interstitial fluid)
  • Important role in inflammation

**Areolar Connective Tissue**
• Locations
  • Widely distributed under epithelia
  • Packages organs
  • Surrounds capillaries

**Areolar Connective Tissue**

**Areolar Connective Tissue**
• **Tissue fluid** (interstitial fluid)
  • Watery fluid occupying extracellular matrix
  • Tissue fluid derives from blood
• **Ground substance**
  • Viscous, spongy part of extracellular matrix
  • Consists of sugar and protein molecules
  • *Made and secreted by fibroblasts*
Areolar Connective Tissue
• *Main battlefield in fight against infection*
• Defenders gather at infection sites
  • Macrophages
  • Plasma cells
  • Mast cells
  • White blood cells
    * Neutrophils, lymphocytes, and eosinophils

Adipose Tissue
• Description
  • Closely packed adipocytes
  • Have nucleus pushed to one side by fat droplet
  • Richly vascularized

Adipose Tissue
• Function
  • Provides reserve food fuel
  • Insulates against heat loss
  • Supports and protects organs
• Location
  • Under skin
  • Around kidneys
  • Behind eyeballs, within abdomen, and in breasts
  • Hypodermis

Adipose Tissue

Reticular Connective Tissue
• Description—network of reticular fibers in loose ground substance
• Function—forms a soft, internal skeleton
  • (stroma); supports other cell types
• Location—lymphoid organs
  • Lymph nodes, bone marrow, and spleen

Reticular Connective Tissue

Dense Connective Tissue
• Dense irregular connective tissue
• Dense regular connective tissue
• Elastic connective tissue

Dense Irregular Connective Tissue
• Description
  • Primarily *irregularly* arranged collagen fibers
  • Some elastic fibers and fibroblasts

Dense Irregular Connective Tissue
• Function
  • Withstands tension
  • Provides structural strength
• Location
  • Dermis of skin
  • Submucosa of digestive tract
  • Fibrous capsules of joints and organs

Dense Irregular Connective Tissue

Dense Regular Connective Tissue
• Description
  • Primarily *parallel* collagen fibers
  • Fibroblasts and some elastic fibers
  • Poorly vascularized
  • Forms *fascia*

Dense Regular Connective Tissue
• Function
  • Attaches muscle to bone
  • Attaches bone to bone
  • Withstands great stress in one direction
• Location
  • Tendons and ligaments
  • Aponeuroses
  • Fascia around muscles

Dense Regular Connective Tissue

Elastic Connective Tissue
• Description
  • Elastic fibers predominate
• Function—allows recoil after stretching
• Location
  • Within walls of arteries, in certain ligaments, and surrounding bronchial tubes

Elastic Connective Tissue

Cartilage
• Firm, flexible tissue
• Contains no blood vessels or nerves
• Matrix contains up to 80% water
• Cell type—chondrocyte

Types of Cartilage
• Hyaline cartilage
• Elastic cartilage
• Fibrocartilage

Hyaline Cartilage
• Description
  • Imperceptible collagen fibers (hyaline = glassy)
  • Chondroblasts produce matrix
  • Chondrocytes lie in lacunae

Hyaline Cartilage
• Function
  • Supports and reinforces
  • Resilient cushion
  • Resists repetitive stress

Hyaline Cartilage
• Location
  • Fetal skeleton
  • Ends of long bones
  • Costal cartilage of ribs
  • Cartilages of nose, trachea, and larynx

Elastic Cartilage
• Description
  • Similar to hyaline cartilage
  • More elastic fibers in matrix

Elastic Cartilage
• Function
  • Maintains shape of structure
  • Allows great flexibility
• Location
  • Supports external ear
  • Epiglottis

Elastic Cartilage

Fibrocartilage
• Description
  • Matrix similar but less firm than hyaline cartilage
  • Thick collagen fibers predominate
• Function
  • Tensile strength and ability to absorb compressive shock

Fibrocartilage
• Location
  • Intervertebral discs
  • Pubic symphysis
  • Discs of knee joint

Fibrocartilage

Bone Tissue
• Description
  • Calcified matrix containing many collagen fibers
  • Osteoblasts—secrete collagen fibers and matrix
  • Osteocytes—mature bone cells in lacunae
  • Well vascularized

Bone Tissue
• Function
  • Supports and protects organs
  • Provides levers and attachment site for muscles
• Stores calcium and other minerals
• Stores fat
• Marrow is site for blood cell formation
• Location
  • Bones

Bone Tissue

Blood Tissue
• An atypical connective tissue
• Develops from mesenchyme
• Consists of cells surrounded by nonliving matrix

Blood Tissue
• Description
  • Red and white blood cells in a fluid matrix
• Function
  • Transport of respiratory gases, nutrients, and wastes
• Location
  • Within blood vessels

Blood Tissue

Covering and Lining Membranes
• Combine epithelial tissues and connective tissues
• Cover broad areas within body
• Consist of epithelial sheet plus underlying connective tissue

Three Types of Membranes
• Cutaneous membrane—skin
• Mucous membrane
  • Lines hollow organs that open to surface of body
  • An epithelial sheet underlain with layer of *lamina propria*

Three Types of Membranes
• Serous membrane
  • Simple squamous epithelium lying on areolar connective tissue
  • Lines closed cavities
    • *Pleural, peritoneal, and pericardial cavities*
Covering and Lining Membranes

Muscle Tissue
• Skeletal muscle tissue
• Cardiac muscle tissue
• Smooth muscle tissue

Skeletal Muscle Tissue
• Description
  • Long, cylindrical cells
  • Multinucleate
  • Obvious striations

Skeletal Muscle Tissue
• Function
  • Voluntary movement
  • Manipulation of environment
  • Facial expression
• Location
  • Skeletal muscles attached to bones (occasionally to skin)

Cardiac Muscle Tissue
• Description
  • Branching cells, striated
  • Generally uninucleate
  • Cells interdigitate at intercalated discs

Cardiac Muscle Tissue
• Function
  • Contracts to propel blood into circulatory system
• Location
  • Occurs in walls of heart

Smooth Muscle Tissue
• Description
• Spindle-shaped cells with central nuclei
• Arranged closely to form sheets
• No striations

**Smooth Muscle Tissue**
• Function
  • Propels substances along internal passageways
  • Involuntary control
• Location
  • Mostly walls of hollow organs

**Smooth Muscle Tissue**

**Nervous Tissue**
• Description
  • Main components are brain, spinal cord, and nerves
  • Contains two types of cells
    • *Neurons—excitatory cells*
    • *Supporting cells (neuroglial cells)*

**Nervous Tissue**
• Function
  • Transmit electrical signals from sensory receptors to effectors
• Location
  • Brain, spinal cord, and nerves

**Nervous Tissue**

**Tissue Response to Injury**
• **Inflammatory response**
  • Nonspecific, local response
  • Limits damage to injury site
• **Immune response**
  • Takes longer to develop and very specific
  • Destroys particular microorganisms at site of infection

**Inflammation**
• Acute inflammation
  • Heat
  • Redness
  • Swelling
• Pain
  • Chemicals signal nearby blood vessels to dilate
• **Histamine** increases permeability of capillaries

**Inflammation**
• **Edema**—accumulation of fluid
  • Helps dilute toxins secreted by bacteria
  • Brings oxygen and nutrients from blood
  • Brings antibodies from blood to fight infection

**Repair**
• **Regeneration**
  • Replacement of destroyed tissue with same type of tissue
• **Fibrosis**
  • Proliferation of scar tissue
• **Organization**
  • Clot is replaced by granulation tissue

**The Tissues Throughout Life**
• At the end of second month of development:
  • Primary tissue types have appeared
  • Major organs are in place
• Adulthood
  • Only a few tissues regenerate
  • Many tissues still retain populations of stem cells

**Capacity for Regeneration**
• **Good to excellent:**
  • *ET, bone CT, areolar CT, dense irregular CT, and blood forming CT*
• **Moderate:**
  • *Smooth muscle, dense regular CT*

**Capacity for Regeneration**
• **Weak:**
  • *Skeletal MT, cartilage*
• **None or almost none:**
  • *Cardiac MT, Nervous Tissue*

**The Tissues Throughout Life**
• With increasing age:
• Epithelia thin
• Collagen decreases
• Bones, muscles, and nervous tissue begin to atrophy
• Poor nutrition and poor circulation lead to poor health of tissues

5
The Integumentary System

The Skin and the Hypodermis
• Skin—our largest organ
  • Accounts for 7% of body weight
  • Varies in thickness from 1.5–4.4mm
  • Divided into two distinct layers
    • Epidermis
    • Dermis
  • Hypodermis—lies deep to the dermis

Skin Structure

The Skin and Hypodermis
• Functions
  1. Protection—cushions organs and protects from bumps, chemicals, water loss, UV radiation
  2. Regulation of body temperature
  3. Excretion—urea, salts, and water lost through sweat

The Skin and Hypodermis
• Functions (continued)
  4. Production of vitamin D
  5. Sensory reception—keeps us aware of conditions at the body’s surface

Epidermis
• Contains four main cell types
  • Keratinocytes
    • Location—stratum spinosum; produce keratin a fibrous protein
• **Melanocytes**
  - *Location*—basal layer; manufacture and secrete pigment

**Epidermis**
• Contains four main cell types (continued)
  • **Tactile epithelial cells**
    - *Location*—basal layer; attached to sensory nerve endings
  • **Dendritic cells**
    - *Location*—stratum spinosum; part of immune system; macrophage-like

**Epidermis**
• **Keratinocytes**—most abundant cell type in epidermis
  • Arise from *deepest layer of epidermis*
  • Produce **keratin**, a tough fibrous protein
  • Produce **antibodies** and **enzymes**
  • Keratinocytes are *dead at skin's surface*

**Layers of the Epidermis**
• Stratum basale (stratum geminatum)
• Stratum spinosum
• Stratum granulosum
• Stratum lucidum (only in thick skin)
• Stratum corneum

**Epidermal Cells and Layers of the Epidermis**
• **Stratum spinosum** (spiny layer)
  - “Spiny” appearance caused by:
    - *Artifacts of histological preparation*
  - Contains thick bundles of **intermediate filaments** (tonofilaments)
    - *Resist tension*
    - *Contain protein prekeratin*
  - Contains star-shaped dendritic cells
    - *A type of macrophage*
    - *Function in immune system*

Layers of the Epidermis
- **Stratum granulosum**
  - Consists of keratinocytes and tonofilaments
  - Tonofilaments contain:
    - *Keratohyaline granules—help form keratin*
    - *Lamellated granules—contain a waterproofing glycolipid*

Layers of the Epidermis
- **Stratum lucidum** (clear layer)
  - Occurs only in **thick skin**
    - *Locations of thick skin—palms and soles*
  - Composed of a few rows of flat, dead keratinocytes

Layers of the Epidermis
- **Stratum corneum** (horny layer)
  - Thick layer of dead keratinocytes and thickened plasma membranes
  - Protects skin against abrasion and penetration

Dermis
- Second major layer of the skin
- Strong, flexible connective tissue
- Richly supplied with blood vessels and nerves
- Has two layers
  - **Papillary layer**—includes dermal papillae
  - **Reticular layer**
    - *Deeper layer—80% of thickness of dermis*
- **Flexure lines**
  - Creases on palms
The Two Regions of the Dermis

Dermal Modifications

Hypodermis
- Deep to the skin—also called *superficial fascia*
- Contains *areolar* and *adipose CT*
- Anchors skin to underlying structures
- Helps *insulate* the body

Skin Color
- Three pigments contribute to skin color
  - *Melanin*
    - *Most important pigment—made from tyrosine*
  - *Carotene*
    - *Yellowish pigment from carrots and tomatoes*
  - *Hemoglobin*
    - *Caucasian skin contains little melanin*
    - *Allows crimson color of blood to show through*

Nails
- *Nails*—scalelike modification of epidermis
  - Made of hard keratin
  - Parts of the nail
    - *Free edge*
    - *Body*
    - *Root*
    - *Nail folds*
    - *Eponychium—cuticle*

Structure of a Nail

Appendages of the Skin
- *Hair*
  - Flexible strand of dead, keratinized cells
  - Hard keratin—tough and durable
  - Chief parts of a hair
    - *Root—imbedded in the skin*
    - *Shaft—projects above skin's surface*

Appendages of the Skin
• Hair has three concentric layers of keratinized cells
  • **Medulla**—central core
  • **Cortex**—surrounds medulla
  • **Cuticle**—outermost layer

**Cross Section of a Hair**

**Appendages of the Skin**
• **Hair follicles**
  • Extend from epidermis into dermis
• **Hair bulb**
  • Deep, expanded end of the hair follicle
• **Root plexus**
  • Knot of sensory nerves around hair bulb

**Longitudinal Section of Base of Follicle**

**Appendages of the Skin**
• Wall of hair follicle
  • CT root sheath
  • ET root sheath
• **Arrector pili** muscle
  • Bundle of **smooth muscle**
  • Hair stands erect when *arrector pili* contracts

**Types and Growth of Hair**
• **Vellus hairs**
  • Body hairs of women and children
• **Terminal hairs**
  • Hair of scalp
  • Axillary and pubic area (at puberty)
• Hair thinning and baldness
  • Due to aging
  • Male pattern baldness

**Sebaceous Glands**
• Occur over entire body
  • Except palms and soles
• Secrete **sebum**—an oily substance
  • **Simple alveolar glands**
• **Holocrine secretion**—entire cell breaks up to form secretion
  • Most are associated with a hair follicle
• Functions of **sebum**
  • Collects dirt; softens and lubricates hair and skin

**Sebaceous Glands**

**Sweat Glands**

• **Sweat glands** (sudoriferous glands) widely distributed on body
• **Sweat**—is a blood filtrate
  • 99% water with some salts
  • Contains traces of metabolic wastes
    • *About 2% urea*

**Sweat Glands**

**Sweat Glands**

• Two types of sweat gland
  • **Eccrine gland** (merocrine)
    • Most numerous—these produce true sweat
  • **Apocrine gland**
    • Confined to axillary, anal, and genital areas
    • Produce a special kind of sweat
      • Musky odor—attracts a mate
      • Signal information about a person’s immune system, MHC
    • **Ceruminous glands and mammary glands**
      • Modified apocrine glands

**Burns**

• Classified by **severity**
  • **First-degree burn**—only upper epidermis is damaged
  • **Second-degree burn**—upper part of dermis is also damaged
    • Blisters appear
    • *Skin heals with little scarring*
  • **Third-degree burn**
    • Consumes thickness of skin
    • *Burned area appears white, red, or blackened*

**Estimating Burns Using the Rule of Nines**
Skin Cancer

• **Basal cell carcinoma**
  • Least malignant and most common

• **Squamous cell carcinoma**
  • Arises from keratinocytes of stratum spinosum

• **Melanoma**
  • A cancer of melanocytes
  • The most dangerous type of skin cancer

Skin Cancer

The Skin Throughout Life

• **Epidermis**
  • Develops from embryonic **ectoderm**

• **Dermis and hypodermis**
  • Develop from **mesoderm**

• **Melanocytes**
  • Develop from neural crest cells

The Skin Throughout Life

• **Fetal skin**
  • Well formed after the fourth month
  • At 5–6 months, the fetus is covered with **lanugo** (downy hairs)
  • Fetal sebaceous glands produce **vernix caseosa**

The Skin Throughout Life

• **Middle to old age**
  • Skin thins and becomes less elastic
  • Shows harmful effects of environmental damage
  • Skin inflammations become more common