Chapter 3

Cells and Tissues

Slides 3.1 – 3.89

Lecture Slides in PowerPoint by Jerry L. Cook

Copyright © 2003 Pearson Education, Inc. publishing as Benjamin Cummings
Cells and Tissues

- Carry out all chemical activities needed to sustain life
- Cells are the building blocks of all living things
- Cells are bathed in a dilute saltwater solution called interstitial fluid derived from the blood
- Tissues are groups of cells that are similar in structure and function → organs → organ systems → organism
Anatomy of the Cell

- Cells are not all the same
  - Size, shape, and function very different
- All cells share general structures
- Cells are organized into three main regions
  - Nucleus
  - Cytoplasm
  - Plasma membrane
The Nucleus

- Control center of the cell
- Contains genetic material (DNA)
- Three regions
  - Nuclear membrane
  - Nucleolus
  - Chromatin
**Nuclear Membrane**

- Barrier of the nucleus
- Consists of a selectively permeable, double phospholipid membrane
- Contains nuclear pores that allow for exchange of material with the rest of the cell
- Inside is the nucleoplasm containing the nucleoli and chromatin – fluid similar to cytoplasm
Nucleoli

- Nucleus contains one or more nucleoli (nucleolus - singular)
- Sites of ribosome production and partial assembly
  - Ribosomes then migrate to the cytoplasm through nuclear pores
Chromatin

- Composed of unwound DNA and protein – used for making proteins
- Scattered throughout the nucleus
- Chromatin condenses to form chromosomes when the cell divides
Plasma Membrane

- Barrier for cell contents
- Semi-permeable, Double phospholipid layer
  - Hydrophilic heads – water loving
  - Hydrophobic tails – water fearing
- Other materials in plasma membrane
  - Protein – receptors, cell recognition and communication, channels for transport
  - Cholesterol – keep membrane fluid and stable
  - Glycoproteins – receptors, cell-to-cell interactions
Plasma Membrane

Figure 3.2
Plasma Membrane Specializations

- Microvilli
  - Finger-like projections that increase surface area for absorption
Plasma Membrane Specializations

Membrane junctions

- **Tight junctions** – impermeable, leakproof sheets
- **Desmosomes** – anchorings that prevent cells from being separated
- **Gap junctions** – allow communication between cells through connexons that span the two cell membranes
Cytoplasm

- Material outside the nucleus and inside the plasma membrane
  - Cytosol
    - Fluid containing nutrients dissolved in water that suspends other elements
  - Organelles
    - Metabolic machinery of the cell
  - Inclusions
    - Non-functioning units – stored nutrients such as fat droplets, glycogen granules, pigments, and mucus
Cytoplasmic Organelles

- Chromatin
- Nucleoli
- Nucleus
- Plasma membrane
- Nuclear envelope
- Smooth endoplasmic reticulum
- Cytosol
- Lysosome
- Mitochondrion
- Centrioles
- Microvilli
- Microfilament
- Microtubule
- Intermediate filaments
- Golgi apparatus
- Rough endoplasmic reticulum
- Ribosomes
- Peroxisome

Figure 3.4

Secretion being released from cell by exocytosis
Cytoplasmic Organelles

- Mitochondria
  - “Powerhouses” of the cell
  - Change shape continuously
  - Has a double membrane and had its own DNA
  - Carry out reactions where oxygen is used to break down food – cell respiration
    - Provides ATP for cellular energy
Cytoplasmic Organelles

- Ribosomes
  - Made of protein and RNA
  - Sites of protein synthesis
  - Found at two locations
    - Free in the cytoplasm
    - Attached to rough endoplasmic reticulum
Cytoplasmic Organelles

- Endoplasmic reticulum (ER)
  - Fluid-filled tubules for carrying substances
  - Two types of ER
    - Rough Endoplasmic Reticulum
      - Studded with ribosomes
      - Site where building materials of cellular membrane are formed
    - Smooth Endoplasmic Reticulum
      - Functions in cholesterol synthesis and breakdown, fat metabolism, and detoxification of drugs
Cytoplasmic Organelles

- Golgi apparatus
  - Modifies and packages proteins
  - Produces different types of packages
    - Secretory vesicles – contain proteins for export
    - Cell membrane components to be added to the plasma membrane
    - Lysosomes – contain hydrolytic enzymes
Cytoplasmic Organelles

Figure 3.5

Copyright © 2003 Pearson Education, Inc. publishing as Benjamin Cummings
Cytoplasmic Organelles

- **Lysosomes**
  - Contain enzymes that digest non-usable materials within the cell such as old organelles as well as bacteria and viruses

- **Peroxisomes**
  - Membranous sacs of oxidase enzymes
  - Detoxify harmful substances using O$_2$
  - Break down free radicals (highly reactive chemicals with free electrons)
  - Replicate by pinching in half
Cytoplasmic Organelles

- Cytoskeleton
  - Network of protein structures that extend throughout the cytoplasm
  - Provides the cell with an internal framework
  - Determines cell shape, supports organelles, provides path for intracellular transport, involved in cell movement
Cytoplasmic Organelles

Cytoskeleton

- Three different types

  - Microfilaments – cell motility and changed in cell shape – actin and myosin
  - Intermediate filaments – help form desmosomes and internal guy wires
  - Microtubules – determine overall shape of a cell and location of organelles
Cytoplasmic Organelles

- **Centrioles**
  - Rod-shaped bodies made of microtubules that lie at right angles to each other and near the nucleus
  - Direct formation of mitotic spindle during cell division
Cellular Projections

- Cilia and Flagella
  - Not found in all cells
  - Used for movement
    - Cilia moves materials across the cell surface – usually short and many
    - Flagellum propels the cell – usually long and few in number
Cell Diversity

1. **Cells that connect body parts**
   - Googi apparatus
   - Nucleus
   - Rough ER
   - Fiber outside the cell
   - No organelles

   Fibroblast

   Erythrocyte (red blood cell)

2. **Cells that cover and line body organs**
   - Intermediate filaments
   - Nucleus

   Epithelial cell

Figure 3.7; 1, 2
Cell Diversity

3 Cells that move organs and body parts

Skeletal muscle cell

Smooth muscle cell

Figure 3.7; 3
Cell Diversity

4. Cell that stores nutrients
   - Lipid droplet
   - Nucleus
   - Fat cell

5. Cell that fights disease
   - Pseudopods
   - Lysosomes
   - Macrophage cell

Figure 3.7; 4, 5
Cell Diversity

6. **Cell that gathers information and controls body functions**

- Rough ER
- Processes
- Nucleus

Nerve cell

7. **Cells of reproduction**

- Rough endoplasmic reticulum
- Golgi apparatus
- Mitochondria
- Cytoskeleton
- Nucleus
- Lysosome

Ovum (egg)

- Nucleus
- Flagellum

Sperm

Figure 3.7; 6, 7

Copyright © 2003 Pearson Education, Inc. publishing as Benjamin Cummings

Slide 3.27
Solutions and Transport

- Solution – homogeneous mixture of two or more components
  - Solvent – dissolving medium
  - Solutes – components in smaller quantities within a solution
- Intracellular fluid – nucleoplasm and cytosol
- Interstitial fluid – fluid on the exterior of the cell
Cellular Physiology: Membrane Transport

- Membranes are selectively permeable –
- Membrane Transport – movement of substance into and out of the cell
- Transport is by two basic methods
  - Passive transport
    - No energy is required
  - Active transport
    - The cell must provide metabolic energy
Selective Permeability

- The plasma membrane allows some materials to pass while excluding others.
- This permeability includes movement into and out of the cell.
Passive Transport Processes

Diffusion

- Particles tend to distribute themselves evenly within a solution
- Movement is from high concentration to low concentration, or down a concentration gradient
- Movement is due to kinetic energy in the molecules and affected by size and temperature
Passive Transport Processes

- Types of diffusion
  - Simple diffusion – Passive diffusion
    - Unassisted process
    - Solutes are lipid-soluble materials or small enough to pass through membrane pores
Passive Transport Processes

Types of diffusion

- Osmosis – simple diffusion of water
  - Highly polar water easily crosses the plasma membrane
  - Occurs all the time
- Facilitated diffusion
  - Substances require a protein carrier for passive transport
  - Still moving down concentration gradient and so no energy is needed
Diffusion through the Plasma Membrane

Figure 3.9
Passive Transport Processes

- Filtration
  - Water and solutes are forced through a membrane by fluid, or hydrostatic pressure
  - A pressure gradient must exist
    - Solute-containing fluid is pushed from a high pressure area to a lower pressure area
  - Not very selective on what is filtered out – size
Active Transport Processes

- Transport substances that are unable to pass by diffusion
  - They may be too large
  - They may not be able to dissolve in the fat core of the membrane
  - They may have to move against a concentration gradient
- Two common forms of active transport
  - Solute pumping
  - Bulk transport
Active Transport Processes

- Solute pumping
  - Amino acids, some sugars and ions are transported by solute pumps
  - ATP energizes protein carriers, and in most cases, moves substances against concentration gradients
  - Can transport different molecules different directions such as the sodium-potassium pump
Active Transport Processes

Figure 3.10

1. Binding of cytoplasmic Na\(^+\) to the pump protein stimulates phosphorylation by ATP, which causes the pump protein to change its shape.

2. The shape change expels Na\(^+\) to the outside. Extracellular K\(^+\) binds, causing release of the phosphate group.

3. Loss of phosphate restores the original conformation of the pump protein. K\(^+\) is released and Na\(^+\) sites are ready to bind Na\(^+\) again; the cycle repeats.
Active Transport Processes

- Bulk transport
  - Exocytosis
    - Moves materials out of the cell
    - Material is carried in a membranous vesicle
    - Vesicle migrates to plasma membrane
    - Vesicle combines with plasma membrane
    - Material is emptied to the outside
Active Transport Processes

Figure 3.11

Copyright © 2003 Pearson Education, Inc. publishing as Benjamin Cummings
Active Transport Processes

- Bulk transport
  - Endocytosis
    - Extracellular substances are engulfed by being enclosed in a membranous vesicle
  - Types of endocytosis
    - Phagocytosis – cell eating
    - Pinocytosis – cell drinking
Active Transport Processes

(a) Phagocytosis

(b) Bulk-phase endocytosis

Copyright © 2003 Pearson Education, Inc. publishing as Benjamin Cummings
Cell Life Cycle

- Series of changes a cell goes through from the time it is formed until it divides

- Cells have two major periods
  - Interphase – metabolic phase
    - Longest phase where the cell grows
    - Cell carries on metabolic processes
  - Cell division
    - Cell replicates itself
    - Function is to produce more cells for growth and repair processes
DNA Replication

- Genetic material duplicated and readies a cell for division into two cells
- Occurs toward the end of interphase
- DNA uncoils and each side serves as a template
Events of Cell Division

- **Mitosis**
  - Division of the nucleus
  - Results in the formation of two daughter nuclei

- **Cytokinesis**
  - Division of the cytoplasm
  - Begins when mitosis is near completion
  - Results in the formation of two daughter cells
Stages of Mitosis

- Interphase
  - No cell division occurs
  - The cell carries out normal metabolic activity and growth

- Prophase
  - First part of cell division
  - Centromeres migrate to the poles and direct the assembly of the mitotic spindle
  - Chromosomes form
Stages of Mitosis

- Metaphase
  - Spindle from centromeres are attached to chromosomes that are aligned in the center of the cell
Stages of Mitosis

- **Anaphase**
  - Daughter chromosomes are pulled toward the poles
  - The cell begins to elongate

- **Telophase**
  - Daughter nuclei begin forming
  - A cleavage furrow (for cell division) begins to form and finished dividing the cell into two by the end of cytokinesis
  - Everything from prophase is reversed
Stages of Mitosis

Figure 3.14; 1
Stages of Mitosis

Figure 3.14; 2
Protein Synthesis

- Gene – DNA segment that carries a blueprint for building one protein
- Proteins have many functions
  - Building materials for cells
  - Act as enzymes (biological catalysts)
- RNA is essential for protein synthesis
Role of RNA

- **Transfer RNA (tRNA)**
  - Transfers appropriate amino acids to the ribosome for building the protein

- **Ribosomal RNA (rRNA)**
  - Helps form the ribosomes along with proteins where proteins are built

- **Messenger (mRNA)**
  - Carries the instructions for building a protein from the nucleus to the ribosome
Transcription and Translation

- Transcription
  - Transfer of information from DNA’s base sequence to the complimentary base sequence of mRNA – switching T for U

- Translation
  - Base sequence of mRNA is translated to an amino acid sequence based on codon/anticodon complements
    - Amino acids are the building blocks of proteins
Protein Synthesis

Figure 3.15
Copyright © 2003 Pearson Education, Inc. publishing as Benjamin Cummings
Body Tissues

- Cells are specialized for particular functions

- Tissues
  - Groups of cells with similar structure and function
  - Four primary types
    - Epithelium - covering
    - Connective tissue - support
    - Nervous tissue - control
    - Muscle - movement
Epithelial Tissues

- Found in different areas
  - Body coverings
  - Body linings
  - Glandular tissue

- Functions
  - Protection
  - Absorption
  - Filtration
  - Secretion
Epithelium Characteristics

- Cells fit closely together
- Tissue layer always has one free surface – unattached, the apical surface
- The lower surface is bound by a basement membrane – structureless material secreted by the cells
- Avascular (have no blood supply) – depend on diffusion
- Regenerate easily if well nourished
Classification of Epithelium

- Number of cell layers
  - Simple – one layer
  - Stratified – more than one layer

Figure 3.16a
Classification of Epithelium

- **Shape of cells**
  - Squamous – flattened
  - Cuboidal – cube-shaped
  - Columnar – column-like

![Figure 3.16b](image)
Simple Epithelium

Simple squamous

- Single layer of flat cells
- Usually forms membranes where filtration or exchange occurs
  - Lines body cavities – serous membranes
  - Lines lungs and capillaries

Figure 3.17a
Simple Epithelium

- Simple cuboidal
  - Single layer of cube-like cells
  - Common in glands and their ducts
  - Forms walls of kidney tubules
  - Covers the ovaries

Figure 3.17b
Simple Epithelium

- **Simple columnar**
  - Single layer of tall cells that fit closely together
  - Often includes goblet cells, which produce mucus
  - Lines digestive tract
  - Mucosae – mucous membranes line body cavities open to the body exterior

Figure 3.17c
Simple Epithelium

- Pseudostratified columnar
  - Single layer, but some cells are shorter than others
  - Often looks like a double cell layer
  - Sometimes ciliated, such as in the respiratory tract
  - May function in absorption or secretion

Figure 3.17d
Stratified Epithelium – 2+ layers

Stratified squamous

- Cells at the free edge are flattened while cells close to the basement membrane are cuboidal or columnar
- Found as a protective covering where friction is common
- Locations
  - Skin
  - Mouth
  - Esophagus

Figure 3.17e

Copyright © 2003 Pearson Education, Inc. publishing as Benjamin Cummings
Stratified Epithelium

- Stratified cuboidal
  - Two layers of cuboidal cells
- Stratified columnar
  - Surface cells are columnar, cells underneath vary in size and shape
- Stratified cuboidal and columnar
  - Rare in human body
  - Found mainly in ducts of large glands
Stratified Epithelium

- Transitional epithelium
  - Shape of cells depends upon the amount of stretching
  - Cells of the basal layer are cuboidal or columnar while those at the free surface vary
  - Lines organs of the urinary system

Figure 3.17f

Copyright © 2003 Pearson Education, Inc. publishing as Benjamin Cummings
Glandular Epithelium

- Gland – one or more cells that secretes a particular product – a secretion, which contains protein molecules in an aqueous fluid

- Two major gland types
  - Endocrine gland
    - Ductless
    - Secretions are hormones – diffuse into blood
  - Exocrine gland
    - Empty through ducts to the epithelial surface
    - Include sweat and oil glands
Connective Tissue

- Found everywhere in the body
- Includes the most abundant and widely distributed tissues

Functions
- Binds body tissues together
- Supports the body
- Provides protection
Connective Tissue Characteristics

- Variations in blood supply
  - Some tissue types are well vascularized
  - Some have poor blood supply or are avascular such as tendons, ligaments, and cartilage

- Extracellular matrix
  - Non-living material that surrounds living cells
Extracellular Matrix

- Two main elements
  - Ground substance – mostly water along with adhesion proteins and polysaccharide molecules
  - Fibers
    - Produced by the cells
    - Three types
      - Collagen fibers
      - Elastic fibers
      - Reticular fibers
Connective Tissue Types

- Bone (osseous tissue)
  - Composed of:
    - Bone cells in lacunae (cavities)
    - Hard matrix of calcium salts
    - Large numbers of collagen fibers
  - Used to protect and support the body

Figure 3.18a
Connective Tissue Types

- Hyaline cartilage
  - Most common cartilage
  - Composed of:
    - Abundant collagen fibers
    - Rubbery matrix
  - Entire fetal skeleton is hyaline cartilage

Figure 3.18b
Connective Tissue Types

- Fibrocartilage
  - Highly compressible
  - Example: forms cushion-like discs between vertebrae

Figure 3.18c
Connective Tissue Types

- Elastic cartilage
  - Provides elasticity
  - Example: supports the external ear
Connective Tissue Types

Dense connective tissue

- Main matrix element is collagen fibers
- Crowded between the collagen fibers are rows of cells called fibroblasts
- Examples
  - Tendon – attach muscle to bone
  - Ligaments – attach bone to bone

Figure 3.18d
Loose Connective Tissue Types

- Areolar connective tissue
  - Most widely distributed connective tissue
  - Soft, pliable tissue
  - Functions as universal packing tissue and connective tissue glue
  - Contains all fiber types
  - Can soak up excess fluid

Figure 3.18e
Connective Tissue Types

- Adipose tissue
  - Matrix is an areolar tissue in which fat globules predominate
  - Many cells contain large lipid deposits
  - Functions
    - Insulates the body
    - Protects some organs
    - Serves as a site of fuel storage
Connective Tissue Types

- Reticular connective tissue
  - Delicate network of interwoven fibers
  - Forms stroma (internal supporting network) of lymphoid organs
    - Lymph nodes
    - Spleen
    - Bone marrow

Figure 3.18g
Connective Tissue Types

- Blood
  - Blood cells surrounded by fluid matrix
  - Fibers are visible during clotting
  - Functions as the transport vehicle for materials
Muscle Tissue

- Function is to produce movement by contracting or shortening
- Three types
  - Skeletal muscle
  - Cardiac muscle
  - Smooth muscle
Muscle Tissue Types

- **Skeletal muscle**
  - Can be controlled voluntarily
  - Cells attach to connective tissue
  - Cells are striated
  - Cells have more than one nucleus

Figure 3.19b
Muscle Tissue Types

- Cardiac muscle
  - Found only in the heart
  - Function is to pump blood (involuntary)
  - Cells attached to other cardiac muscle cells at intercalated disks
  - Cells are striated
  - One nucleus per cell

Figure 3.19c
Muscle Tissue Types

- Smooth muscle – visceral muscle
  - Involuntary muscle
  - Surrounds hollow organs
  - Attached to other smooth muscle cells
  - No visible striations
  - One nucleus per cell
  - Spindle shaped

Figure 3.19a
Nervous Tissue

- Neurons and nerve supporting cells (those that insulate, support, and protect neurons)
- Function is to receive and send impulses to other areas of the body
  - Irritability
  - Conductivity
Tissue Repair (wound Healing)

- Regeneration
  - Replacement of destroyed tissue by the same kind of cells

- Fibrosis
  - Repair by dense fibrous connective tissue (scar tissue)

- Determination of method
  - Type of tissue damaged
  - Severity of the injury
Events in Tissue Repair

- Capillaries become very permeable
  - Introduce clotting proteins to make clot
  - Wall off injured area to prevent blood loss and infection
- Formation of granulation tissue
  - Contains capillaries and phagocytes
- Regeneration of surface epithelium just below the scab
Regeneration of Tissues

- Tissues that regenerate easily
  - Epithelial tissue
  - Fibrous connective tissue and bone
- Tissues that regenerate poorly
  - Skeletal muscle
- Tissues that are replaced largely with scar tissue
  - Cardiac muscle
  - Nervous tissue within the brain and spinal cord
Developmental Aspects of Tissue

- Epithelial tissue arises from all three primary germ layers
- Muscle and connective tissue arise from the mesoderm
- Nervous tissue arises from the ectoderm
- With old age there is a decrease in mass and viability in most tissues