LECTURE 2

Cells: The Living Units

THE CELL

- The cell is the smallest structural and functional living unit
- Organismal functions depend on individual and collective cell functions
- Biochemical activities of cells are dictated by their specific subcellular structures
- Continuity of life has a cellular basis

Cell Diversity

- Over 200 different types of human cells
- Types differ in size, shape, subcellular components, and functions

Generalized Cell

- All cells have some common structures and functions
- Human cells have three basic parts:
  - Plasma membrane—flexible outer boundary
  - Cytoplasm—intracellular fluid containing organelles
  - Nucleus—control center

Plasma Membrane

- Bimolecular layer of lipids and proteins in a constantly changing fluid mosaic
- Plays a dynamic role in cellular activity
- Separates intracellular fluid (ICF) from extracellular fluid (ECF)
  - Interstitial fluid (IF) = ECF that surrounds cells

Membrane Lipids

- 75% phospholipids (lipid bilayer)
  - Phosphate heads: polar and hydrophilic
  - Fatty acid tails: nonpolar and hydrophobic (Review Fig. 2.16b)
- 5% glycolipids
  - Lipids with polar sugar groups on outer membrane surface

- 20% cholesterol
  - Increases membrane stability and fluidity

Lipid Rafts
- ~ 20% of the outer membrane surface
- Contain phospholipids, sphingolipids, and cholesterol
- May function as stable platforms for cell-signaling molecules

Membrane Proteins
- Integral proteins
  - Firmly inserted into the membrane (most are transmembrane)
  - Functions:
    - Transport proteins (channels and carriers), enzymes, or receptors

Membrane Proteins
- Peripheral proteins
  - Loosely attached to integral proteins
  - Include filaments on intracellular surface and glycoproteins on extracellular surface
  - Functions:
    - Enzymes, motor proteins, cell-to-cell links, provide support on intracellular surface, and form part of glycocalyx

Functions of Membrane Proteins
1. Transport
2. Receptors for signal transduction
3. Attachment to cytoskeleton and extracellular matrix

Functions of Membrane Proteins
4. Enzymatic activity
5. Intercellular joining
6. Cell-cell recognition

Membrane Junctions
- Three types:
  - Tight junction
  - Desmosome
  - Gap junction

Membrane Junctions: Tight Junctions
- Prevent fluids and most molecules from moving between cells
- Where might these be useful in the body?

Membrane Junctions: Desmosomes
- "Rivets" or "spot-welds" that anchor cells together
- Where might these be useful in the body?

Membrane Junctions: Gap Junctions
- Transmembrane proteins form pores that allow small molecules to pass from cell to cell
  - For spread of ions between cardiac or smooth muscle cells

Membrane Transport
- Plasma membranes are selectively permeable
- Some molecules easily pass through the membrane; others do not

Cytoplasm
- Located between plasma membrane and nucleus
- Cytosol
  - Water with solutes (protein, salts, sugars, etc.)
- Cytoplasmic organelles
  - Metabolic machinery of cell
- Inclusions
  - Granules of glycogen or pigments, lipid droplets, vacuoles, and crystals

Cytoplasmic Organelles
- Membranous
  - Mitochondria
  - Peroxisomes
  - Lysosomes
  - Endoplasmic reticulum
  - Golgi apparatus
- Nonmembranous
  - Cytoskeleton
  - Centrioles

- Ribosomes

Mitochondria
- Double-membrane structure with shelflike cristae
- Provide most of cell's ATP via aerobic cellular respiration
- Contain their own DNA and RNA

Ribosomes
- Granules containing protein and rRNA
- Site of protein synthesis
- Free ribosomes synthesize soluble proteins
- Membrane-bound ribosomes (on rough ER) synthesize proteins to be incorporated into membranes or exported from the cell

Endoplasmic Reticulum (ER)
- Interconnected tubes and parallel membranes enclosing cisternae
- Continuous with nuclear membrane
- Two varieties:
  - Rough ER
  - Smooth ER

Rough ER
- External surface studded with ribosomes
- Manufactures all secreted proteins
- Synthesizes membrane integral proteins and phospholipids

Smooth ER
- Tubules arranged in a looping network
- Enzyme (integral protein) functions:
  - In the liver—lipid and cholesterol metabolism, breakdown of glycogen, and, along with kidneys, detoxification of drugs, pesticides, and carcinogens
  - Synthesis of steroid-based hormones
  - In intestinal cells—absorption, synthesis, and transport of fats
  - In skeletal and cardiac muscle—storage and release of calcium

Golgi Apparatus

- Stacked and flattened membranous sacs
- Modifies, concentrates, and packages proteins and lipids
- Transport vessels from ER fuse with convex cis face of Golgi apparatus
- Proteins then pass through Golgi apparatus to trans face
- Secretory vesicles leave trans face of Golgi stack and move to designated parts of cell

Lysosomes

- Spherical membranous bags containing digestive enzymes (acid hydrolases)
- Digest ingested bacteria, viruses, and toxins
- Degrade nonfunctional organelles
- Break down and release glycogen
- Break down bone to release $Ca2^{+}$
- Destroy cells in injured or nonuseful tissue (autolysis)

Endomembrane System

- Overall function
  - Produce, store, and export biological molecules
  - Degrade potentially harmful substances

Endomembrane System

Peroxisomes

- Membranous sacs containing powerful oxidases and catalases
- Detoxify harmful or toxic substances
- Neutralize dangerous free radicals (highly reactive chemicals with unpaired electrons)

Cytoskeleton

- Elaborate series of rods throughout cytosol
  - Microtubules
  - Microfilaments
  - Intermediate filaments

Microfilaments

- Dynamic actin strands attached to cytoplasmic side of plasma

membrane
- Involved in cell motility, change in shape, endocytosis and exocytosis

Intermediate Filaments
- Tough, insoluble ropelike protein fibers
- Resist pulling forces on the cell and attach to desmosomes

Microtubules
- Dynamic hollow tubes
- Most radiate from centrosome
- Determine overall shape of cell and distribution of organelles

Motor Molecules
- Protein complexes that function in motility (e.g., movement of organelles and contraction)
- Powered by ATP

Centrosome
- "Cell center" near nucleus
- Generates microtubules; organizes mitotic spindle
- Contains centrioles: Small tube formed by microtubules

Cellular Extensions
- Cilia and flagella
  - Whiplike, motile extensions on surfaces of certain cells
  - Contain microtubules and motor molecules
  - Cilia move substances across cell surfaces
  - Longer flagella propel whole cells (tail of sperm)

Cellular Extensions
- Microvilli
  - Fingerlike extensions of plasma membrane
  - Increase surface area for absorption
  - Core of actin filaments for stiffening

Nucleus
- Genetic library with blueprints for nearly all cellular proteins
- Responds to signals and dictates kinds and amounts of proteins to be synthesized

- Most cells are uninucleate
- Red blood cells are anucleate
- Skeletal muscle cells, bone destruction cells, and some liver cells are multinucleate

Nuclear Envelope
- Double-membrane barrier containing pores
- Outer layer is continuous with rough ER and bears ribosomes
- Inner lining (nuclear lamina) maintains shape of nucleus
- Pore complex regulates transport of large molecules into and out of nucleus

Nucleoli
- Dark-staining spherical bodies within nucleus
- Involved in rRNA synthesis and ribosome subunit assembly

Chromatin
- Threadlike strands of DNA (30%), histone proteins (60%), and RNA (10%)
- Arranged in fundamental units called nucleosomes
- Condense into barlike bodies called chromosomes when the cell starts to divide

Cell Cycle
- Defines changes from formation of the cell until it reproduces
- Includes:
  - Interphase
  - Cell division (mitotic phase)

Interphase
- Period from cell formation to cell division
- Nuclear material called chromatin
- Four subphases:
  - G_1 (gap 1)—vigorous growth and metabolism
  - G_0—gap phase in cells that permanently cease dividing
  - S (synthetic)—DNA replication
  - G_2 (gap 2)—preparation for division

Cell Division

- Mitotic (M) phase of the cell cycle
- Essential for body growth and tissue repair
  - Does not occur in most mature cells of nervous tissue, skeletal muscle, and cardiac muscle

Cell Division

- Includes two distinct events:
  1. Mitosis—four stages of nuclear division:
     - Prophase
     - Metaphase
     - Anaphase
     - Telophase
  2. Cytokinesis—division of cytoplasm by cleavage furrow

Cell Division

Prophase

- Chromosomes become visible, each with two chromatids joined at a centromere
- Centrosomes separate and migrate toward opposite poles
- Mitotic spindles and asters form

Prophase

- Nuclear envelope fragments
- Kinetochore microtubules attach to kinetochore of centromeres and draw them toward the equator of the cell
- Polar microtubules assist in forcing the poles apart

Metaphase

- Centromeres of chromosomes are aligned at the equator
- This plane midway between the poles is called the metaphase plate

Anaphase

- Shortest phase
- Centromeres of chromosomes split simultaneously—each chromatid now becomes a chromosome
- Chromosomes (V shaped) are pulled toward poles by motor

proteins of kinetochores
• Polar microtubules continue forcing the poles apart

Telophase
• Begins when chromosome movement stops
• The two sets of chromosomes uncoil to form chromatin
• New nuclear membrane forms around each chromatin mass
• Nucleoli reappear
• Spindle disappears

Cytokinesis
• Begins during late anaphase
• Ring of actin microfilaments contracts to form a cleavage furrow
• Two daughter cells are pinched apart, each containing a nucleus identical to the original