CHAPTER 3: CELLS

I. INTRODUCTION

The cell is the basic unit of structure and function in living things. Cells vary in their shape, size, and arrangement, but all cells have similar components, each with a particular function.

II. **A COMPOSITE CELL** or typical animal **cell** contains four major cell parts:

A. The **CELL** (or plasma) **MEMBRANE**, which is the outer boundary of the cell.
B. The **CYTOPLASM**, which holds the cellular organelles.
C. The **CELLULAR ORGANELLES**, which perform specific functions of the cell.
D. The **NUCLEUS**, or control center of the cell.

A. **Membrane Structure = Fluid Mosaic Model**

1. composed of a double layer (**bilayer) of phospholipid molecules** with many protein molecules dispersed within it;

   a. The **surfaces** of the membrane **are "hydrophilic"** due to the polar phosphate heads;
   b. The **internal portion** of the membrane **is "hydrophobic"** due to the non-polar fatty acid tails;
   c. The membrane proteins also have both hydrophilic and hydrophobic properties. There are two types:

      - **Integral proteins** are firmly inserted into and extend across the lipid bilayer.
        1. Most are glycoproteins;
        2. They serve as either channels (pores), transporters (carriers), receptors (recognition sites) or enzymes.
      - **Peripheral proteins** lie loosely on the inner surface of the cell membrane.
        1. They serve as cytoskeletal anchors.

2. Intercellular Junctions
   a. Connect adjacent cell membranes
   b. Three types
      - **Tight Junctions** prevent movement of substances in between cells, like caulking between tiles
      - **Desmosomes** are structural reinforcement, like superglue
      - **Gap Junctions** allow ions to pass from cell to cell for communication, they are true cell phones

II. A COMPOSITE CELL

A. Membrane Structure

3. Cell Adhesion Molecules – guide cellular movements

B. Cytoplasm (cytosol) = the jelly-like fluid (70%) that holds the cellular **organelles** and occupies the space between the nucleus and cell membrane.

C. Endoplasmic Reticulum (ER):

1. A network of interconnected parallel membranes (maze), that is continuous with the nuclear membrane;
2. Two types:
   a. **Rough Endoplasmic Reticulum (RER)**
      - ER studded with ribosomes;
      - Function = **protein synthesis**;
   b. **Smooth Endoplasmic Reticulum (SER)**
      - lacks ribosomes;
      - Function = **lipid & cholesterol synthesis**.

D. Ribosomes:

1. small granules dispersed throughout the cytoplasm and on the membranes of some endoplasmic reticulum (as rough endoplasmic reticulum);
2. composed of RNA and protein;
3. Function = **protein synthesis**.

E. Golgi Apparatus (Complex):

1. flattened membranous sacs ("cisternae") arranged in stacks ("stack of pancakes") associated with many vesicles (membrane bound sacs containing proteins);
2. Function = **modification, packaging, and transport of proteins**;
3. Vesicles pinch off as "secretory vesicles", which are transported out of the cell.

F. Mitochondria (pl); Mitochondrion (s):

1. kidney-shaped organelle whose inner membrane is folded into shelf-like partitions called **cristae**;
2. "**Powerhouse**" of the cell = site of cellular respiration, where energy is released from glucose.

II. A COMPOSITE CELL

G. Lysosomes:

1. spherical membranous sacs containing digestive enzymes (proteins);
2. "suicide sacs" which destroy anything the cell no longer wants or needs.
3. **Autolysis** is the process by which worn cell parts are digested by autophagy.

H. Peroxisomes:

1. membranous sacs containing oxidase enzymes;
2. Function = **detoxification of harmful or toxic substances** (i.e. alcohol, formaldehyde, oxygen free radicals);
3. H_2O_2 (peroxide) ----> water.

I. Centrosome:

1. pair of microtubules located near the nucleus;
2. aid in movement of chromosomes during mitosis.

J. Cilia and Flagella and Microvilli

1. **Cilia (pl)/ Cilium (s)**:
   a. short, hair-like cellular extensions (eyelashes);
   b. help move substances through passageways;
   c. located in lining of trachea and fallopian tube.
2. **Flagella (pl)/ Flagellum (s)**:
   a. tail-like projection;
   b. only one per cell in humans;
   c. aids in cell **locomotion**;
   d. sperm cell.
3. **Microvilli**:
   a. small finger-like extensions of the external surface of the cell membrane;
   b. Function = to **increase surface area**.
   c. located in the lining of the small intestine

K. Vesicles

1. membrane transport sacs
2. made by Golgi and ER

II. A COMPOSITE CELL

L. **Microfilaments and Microtubules:**

1. protein structures called microfilaments, microtubules, and intermediate filaments;
2. form "muscles and bones" of the cell.
3. allow for intracellular transport/movements.

M. **Other structures**

1. inclusions
2. temporary storage
3. pigments, lipids, and glycogen

N.. **CELL NUCLEUS** = the central core, control center or "brain" of the cell.

1. the largest organelle of the cell;
2. filled with nucleoplasm;
3. contains three distinct regions:

a. **Nuclear envelope** is a double membrane that separates the contents of the nucleus from the cytoplasm;

- At various points, these two membranes fuse = **nuclear pore**.
- The nuclear membrane is "selectively permeable"; pores serve as sites where mRNA can pass out of the nucleus during protein synthesis, and how ribosomes exit the nucleus.

b. **Nucleolus** = dense spherical body(ies) within the nucleus;

- composed of RNA and proteins;
- Function = synthesis of ribosomes.

c. **CHROMATIN** = loosely coiled fibers of DNA and histone proteins present in the nucleus;

- **Nucleosome** = fundamental unit of chromatin; spherical clusters of eight histone proteins connected like beads on DNA string.
- These fibers of chromatin would be condensed into tightly coiled **chromosomes** if the cell were preparing to divide.

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SUMMARY TABLE OF CELL COMPONENTS:
Keyed at the end of the outline.

CELL COMPONENT	DESCRIPTION/ STRUCTURE	FUNCTION(S)
CELL MEMBRANE		
CYTOPLASM		
ROUGH ER		
SMOOTH ER		
RIBOSOMES		
GOLGI		
MITOCHONDRIA		
LYSOSOMES		
PEROXISOMES		
CENTROSOMES		
CILIA		
FLAGELLA		
MICROVILLI		
VESICLES		
CYTOSKELETON		
OTHER STRUCTURES		
NUCLEUS		
NUCLEOLUS		
CHROMATIN		

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III. Movement Into and Out of the Cell (Membrane Transport)

The passage of a substance through the cell membrane may be physical (passive, requires no energy expenditure) or physiologic (active process, requires energy expenditure).

In physical (passive) transport processes, substances move from where they are in high concentration to where they are in low concentration. Passive transport processes include simple diffusion, facilitated diffusion, osmosis, and filtration.

In physiologic (active) transport mechanisms, substances move from where they are in low concentration to where they are in high concentration at the expense of cellular energy (ATP). Active processes include active transport, endocytosis, exocytosis and transcytosis.

A. **Physical (Passive) Transport Processes** (require no energy expenditure):

1. **Simple Diffusion**

a. Molecules or ions spread spontaneously down a concentration gradient.
b. A state of equilibrium is produced!
c. Examples:

- A sugar cube dissolving in water;
- A drop of dye diffusing in water;
- An odor diffusing throughout the air in a room;
- The diffusion of oxygen and carbon dioxide through the cell membrane.

d. Significance in human metabolism: Cellular respiration.

2. **Facilitated Diffusion:**

a. a special case of diffusion.
b. Concentration gradient is high to low
c. Special carrier protein molecules within the cell membrane act as shuttle buses to transport a molecule into/out of a cell;
d. Significant because this is the process by which **glucose** enters and leaves most human cells (i.e. cellular respiration)

III. Movement Into and Out of the Cell (Membrane Transport)

A. Physical (Passive) Transport Processes (require no energy expenditure):

3. Osmosis:

a. Diffusion of **WATER** molecules through a **SELECTIVELY PERMEABLE MEMBRANE** (i.e. cell membrane), in an attempt to dilute a particular solute.

b. Remember that only water can pass through the membrane, but the solute **cannot**!!!

c. Osmosis is significant in maintaining the osmotic pressure of our cells at 0.9%.

- The solutes dissolved in the water of our cells, tissue fluid, and blood measure 0.9% (saline).
- When solutions are infused into our blood or tissues, the solute concentration of the solution must be equal to that of our cells and tissues (**isotonic** = 0.9%), or our cells will either:
  1. lose water and shrink, or
  2. gain water and swell and perhaps burst or lyse.

d. Osmosis is demonstrated nicely with red blood cells (rbc's) being placed in solutions of varying tonicity.

- **Three (3) conditions may exist**:

1. **Isotonic**

2. **Hypertonic**

3. **Hypotonic**

III. **Movement Into and Out of the Cell (Membrane Transport)**

A. **Physical (Passive) Transport Processes** (require no energy expenditure):

4. **Filtration**:
   a. Water and solutes are forced through a body membrane by the **hydrostatic pressure** of blood (i.e. blood pressure).

   b. Concentration gradient is high to low;

   c. Solutes include glucose, gases, ions, hormones, and vitamins;

   d. Example is blood being filtered through the capillaries (glomerulus) of the kidney to remove wastes.

B. **Physiologic (Active) Transport Processes (require energy expenditure)**

1. **ACTIVE TRANSPORT:**

   a. Molecules or ions move from an area where they are in **low** concentration **toward** an area where they are in **higher** concentration at the expense of cellular energy (i.e. ATP).
      - substances include many ions, amino acids and monosaccharides.
      - The Na^+- K^+- ATPase pump (which maintains the Resting Membrane Potential in many cells) is an example.

2. **ENDOCYTOSIS**

   a. Molecules or particles that are **too large** to enter the cell by passive transport or active transport (above) are brought into the cell within a vesicle formed from a section of the cell membrane.

   b. Examples:
      - **Pinocytosis** = cell drinking; the cell brings in liquid droplets which may contain dissolved substances.
      - **Phagocytosis** = cell eating; the cell engulfs and brings in a solid particle.
        1. Phagocytes (or macrophages) are very important scavenger white blood cells in humans.
        2. They will bring in **foreign particles, bacteria**, etc.,
           a. that then fuse with a **lysosome** in their cytoplasm to digest the foreign particles.
      - **Receptor-Mediated Endocytosis**

III. **Movement Into and Out of the Cell (Membrane Transport)**

B. **Physiologic (Active) Transport Processes (require energy expenditure)**

3. **EXOCYTOSIS** :

a. is the process by which cells transport secretory proteins out.
b. allows cells to get rid of debris by dumping it to the outside (i.e. into the extracellular fluid).

4. **TRANSCYTOSIS:**
a. combines endocytosis with exocytosis
b. particles travel across cell from apical to basal surfaces

MEMBRANE TRANSPORT SUMMARY TABLE (Keyed at the end of the outline)

TRANSPORT PROCESS	IS ENERGY REQUIRED?	[ ] Gradient	GENERAL DESCRIPTION	EXAMPLE IN HUMANS	SIGNIFICANCE
SIMPLE DIFFUSION					
FACILITATED DIFFUSION					
OSMOSIS					
FILTRATION					
ACTIVE TRANSPORT					
ENDOCYTOSIS					
EXOCYTOSIS					
TRANSCYTOSIS					

IV. THE CELL CYCLE (NORMAL CELL DIVISION)

The life cycle of a cell is divided into two major portions that include interphase and a mitotic phase. Remember that the process of **cell division is continuous**. It is only divided into stages for convenience and to help you learn.

A. **INTERPHASE** = cell growth and DNA replication;

1. **not considered part of mitosis**.
2. represents the majority of a cell's life and includes:
   a. cell growth and
   b. duplication of DNA prior to prophase;

3. Interphase is divided into 3 parts:
   a. **G_1** = rapid growth and replication of centrioles;
   b. **S** = growth and DNA replication; and
   c. **G_2** = growth and final preps for cell division.

B. **MITOTIC PHASE (M)**:

1. The mitotic phase (M) is divided into 2 parts that include mitosis and cytokinesis.

   a. **MITOSIS** = division of nuclear parts; includes four parts:

      - **PROPHASE:**

        1. Distinct pairs of chromosomes become apparent (tightly coiled DNA and protein).

           a. Each pair of chromosomes is made up of identical sister chromatids, held together by a centromere.

        2. Pairs of centrioles migrate to opposite ends of the cell, g spindle fibers form between them.

        3. The nuclear envelope and nucleolus disappear.

IV. THE CELL CYCLE (NORMAL CELL DIVISION)

B. Mitotic (M) phase (continued)

a. Mitosis (continued)

2. **METAPHASE**:

- Chromosomes line up in an orderly fashion midway between the centrioles (i.e. along equatorial plate);
- Centromere holding each pair of chromosomes together attaches to a spindle fiber between the centrioles.

3. **ANAPHASE**:

- Centromere holding the chromosome pair together separates;
- Individual chromosomes migrate in opposite directions on the spindle fibers toward the polar centrioles;
- cytokinesis begins.

4. **TELOPHASE:**

- Chromosomes complete migration toward centrioles;
- Nuclear envelope develops around each set of chromosomes;
- Nucleoli develop;
- Spindle fibers disappear;
- cleavage furrow nearly complete.

b. **CYTOPLASMIC DIVISION** -Cytokinesis =forming 2 daughter cells.

1. begins during anaphase, when the cell membrane begins to constrict (pinch) around the daughter cells.

2. is completed at the end of telophase when the nuclei and cytoplasm of the two newly formed daughter cells (in interphase) are completely separated by cleavage furrow.

IV. THE CELL CYCLE (NORMAL CELL DIVISION):

NAME OF PHASE	DESCRIPTION OF EVENTS	TYPICAL SKETCH
INTERPHASE		
PROPHASE		
METAPHASE		
ANAPHASE		
TELOPHASE		

V. CONTROL OF CELL DIVISION

A. **Significance**:

1. to form a multi-celled organism from one original cell.
2. growth of organism
3. tissue repair.

B. **Length of the Cell Cycle**

1. varies with cell type, location and temperature;
2. Average times are 19-26 hrs;
3. Neurons, skeletal muscle, and red blood cells do not reproduce!

C. **Details of Cell Signaling**

1. Maturation promoting factor (MPF) induces cell division when it becomes activated;

2. cdc2 proteins are a group of enzymes that participate in the cell division cycle.
   a. They transfer a phosphate group from ATP to proteins to help regulate cell activities.

3. Cyclin is a protein whose level rises and falls during the cell cycle;
   a. It builds up during interphase and activates the cdc2 proteins of MPF above.

D. **Abnormal Cell Division (CANCER):**

1. When cell division occurs with no control (goes awry), **a tumor, growth, or neoplasm** results.

2. A **malignant** tumor is a cancerous growth, a non-cancerous tumor is a **benign** tumor;
   a. Malignant tumors may spread by metastasis to other tissues by direct invasion, or through the bloodstream or lymph system.

3. **Oncology** is the study of tumors, an **oncologist** is a physician who treats patients with tumors.

VI. STEM AND PROGENITOR CELLS

Allow for continued growth and renewal of cells

A. **Stem cell**
   1. divide by mitosis
   2. may partially specialize producing a

B. **Progenitor cell**
   1. committed to a specific cell line
      - epithelial
      - connective
      - muscle
      - nervous

C. **Totipotent** – can become every cell type

D. **Pluripotent** – can become many cell types, but not all

E. **Differentiation** – process of specializing cell types; occurs due to gene activation

CELL COMPONENT	DESCRIPTION/ STRUCTURE	FUNCTION(S)
CELL MEMBRANE	Bilayer of phospholipids with proteins dispersed throughout	cell boundary; selectively permeable (i.e. controls what enters and leaves the cell; membrane transport)
CYTOPLASM	jelly-like fluid (70% water)	suspends organelles in cell
ROUGH ER	Membranous network studded with ribosomes	protein synthesis
SMOOTH ER	Membranous network lacking ribosomes	lipid & cholesterol synthesis
RIBOSOMES	RNA & protein; dispersed throughout cytoplasm or studded on ER	protein synthesis
GOLGI	"Stack of Pancakes"; cisternae	modification, transport, and packaging of proteins
MITOCHONDRIA	Kidney shaped organelles whose inner membrane is folded into "cristae".	Site of Cellular Respiration; "Powerhouse"
LYSOSOMES	Membranous sac of digestive enzymes	destruction of worn cell parts (autolysis) and foreign particles
PEROXISOMES	Membranous sacs filled with oxidase enzymes (catalase)	detoxification of harmful substances (i.e. ethanol, drugs, etc.)
CENTROSOMES	paired cylinders of microtubules at right angles near nucleus	aid in chromosome movement during mitosis
CILIA	short, eyelash extensions; human trachea & fallopian tube	to allow for passage of substances through passageways
FLAGELLA	long, tail-like extension; human sperm	locomotion

MICROVILLI	**microscopic ruffling of cell membrane**	**increase surface area**
VESICLES	**Cylindrical membrane sacs**	**Storage and transport**
CYTOSKELETON	**Protein strands that makeup cellular frame**	**Provide shape of cell, locomotion**
OTHER STRUCTURES	**Accumulations of substances**	**storage**
NUCLEUS	**Central control center of cell; bound by lipid bilayer membrane; contains chromatin (loosely coiled DNA and proteins)**	**controls all cellular activity by directing protein synthesis (i.e. instructing the cell what proteins/enzymes to make).**
NUCLEOLUS	**dense spherical body(ies) within nucleus; RNA & protein**	**Ribosome synthesis**
CHROMATIN	**DNA wrapped in protein forming nucleosomes**	**Protection of genetic material**

CHAPTER 3: CELLS

MEMBRANE TRANSPORT SUMMARY TABLE

TRANSPORT PROCESS	IS ENERGY REQUIRED?	[ ] Gradient	GENERAL DESCRIPTION	EXAMPLE IN HUMANS	SIGNIFICANCE
SIMPLE DIFFUSION	NO	[HIGH] TO [LOW]	spreading out of molecules to equilibrium	O_2 into cells; CO_2 out of cells.	Cellular Respiration
FACILITATED DIFFUSION	NO	[HIGH] TO [LOW]	Using a special cm carrier protein to move something through the cell membrane (cm)	Process by which glucose enters cells	Gaining necessary material
OSMOSIS	NO	[HIGH] TO [LOW]	water moving through the cm to dilute a solute	maintenance of osmotic pressure of 0.9%.	Regulation of cell size
FILTRATION	NO	[HIGH] TO [LOW]	using pressure to push something through a cm	manner in which the kidney filters things from blood	removal of metabolic wastes
ACTIVE TRANSPORT	YES	[LOW] TO [HIGH]	opposite of diffusion at the expense of energy	K^+-Na^+-ATPase pump	maintenance of the resting membrane potential
ENDOCYTOSIS	YES	[LOW] TO [HIGH]	bringing a substance into the cell that is too large to enter by any of the above ways; Phagocytosis: cell eating; Pinocytosis: cell drinking.	Phagocytosed (foreign) particles fuse with lysosomes to be destroyed	help fight infection
EXOCYTOSIS	YES	[LOW] TO [HIGH]	expelling a substance from the cell into ECF	Exporting proteins; dumping waste	Excretion of waste
TRANSCYTOSIS	YES	[LOW] TO [HIGH]	Endocytosis followed by exocytosis	Absorption of substances	Obtaining nutrients

Cell Cycle Summary

NAME OF PHASE	DESCRIPTION OF EVENTS	
INTERPHASE	Cell is growing and duplicates (replicates) centrioles during G_1, replicates DNA during S phase; DNA appears as chromatin in nucleus.	
PROPHASE	Distinct chromosomes become apparent (i.e. sister chromatids held together by a centromere); Centrioles migrate to opposite poles of cell and spindle fibers form between them; nucleolus disintegrates; nuclear envelope disintegrates.	
METAPHASE	Chromosomes line up in an orderly fashion in the middle of the cell (on metaphase plate); Each centromere holding chromatids of the chromosome together attaches to a spindle fiber.	
ANAPHASE	The centromere holding the chromosome together splits; Resulting chromosomes migrate toward opposite poles of the cell being pulled by spindle fibers; Cytokinesis begins.	
TELOPHASE	Cleavage furrow between daughter cells is apparent (i.e. dumb-bell shaped); Chromosomes complete migration to poles; Nuclear envelope & nucleolus reappear; Cytokinesis is completed	