# CHAPTER 3: CELLS

**OBJECTIVES:**

1. Sketch a typical cell membrane layer, label the components, name a term that describes the permeability of this membrane, and describe the factors that determine whether a substance/ particle will pass through the cell membrane.

2. Distinguish between integral and peripheral membrane proteins and list the functions of each.

3. Distinguish between passive and active transport processes and make a quick le comparing the seven processes we studied in terms of energy requirement, direction of concentration gradient, give an example in humans, and if applicable, the significance of each.

4. Define the terms *diffusion, osmosis, filtration* and *facilitated diffusion,* and give an example of each.

5. Describe how gases (oxygen and carbon dioxide) enter and leave human cells.

6. Distinguish between a hypertonic, isotonic, and hypotonic solution and compare the consequences of a human cell being placed in each.

7. Explain how blood passes through the capillaries of our kidneys.

8. Describe how glucose enters and leaves most human cells.

9. Define the terms *active transport, endocytosis,* and *exocytosis*.

10. Distinguish between pinocytosis and phagocytosis.

11. Describe the typical fate of a vesicle brought into a human cell by phagocytosis.

12. Identify each of a "generalized" human cell’s components on a diagram or model.

13. List a function(s) for each cellular component and/or organelle.

14. Describe the structure of each cellular organelle.

## CHAPTER 3: CELLS

### OBJECTIVES:

15. Describe what a nuclear pore is and explain its function.
16. Distinguish between chromatin and chromosomes.
17. Define the term *nucleosome*.
18. Name the cellular organelle that contains cisternae, and the one that contains cristae.
19. Explain what a vesicle is, and name the organelle that is always surrounded by them.
20. Describe the process of autolysis, and name the organelle that accomplishes this process.
21. Name the human organ that is rich in peroxisomes.
22. Name the organelle where cellular respiration occurs.
23. Distinguish between microvilli, cilia, and flagella.
24. Name the human cell type(s) that possess a flagellum or cilia.

## 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 arrangements (See Fig 3.1 & Fig 3.2, page 61), but all cells have similar components, each with a particular function.

A **"COMPOSITE"** or typical animal **cell** contains four major cell parts: See Fig 3.3, page 62.

1. The **CELL** (or plasma) **MEMBRANE**, which is the outer boundary of the cell.
2. The **CYTOPLASM**, which holds the cellular organelles.
3. The **CELLULAR ORGANELLES** which perform specific functions of the cell.
4. The **NUCLEUS**, or control center of the cell.

## II. THE CELL (PLASMA) MEMBRANE

The cell membrane is a thin, **dynamic** membrane that encloses the cell and controls what enters and leaves the cell.

A. **Cell Membrane Structure = Fluid Mosaic Model**
See Fig 3.6 & 3.7, page 64 and 65.

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 and outer surface of the cell membrane.
        1. They serve as enzymes or cytoskeletal anchors.

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

III. **CYTOPLASMIC ORGANELLES**:

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

See Fig 3.20, page 78.

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

a. **Nuclear Membrane** (or nuclear envelope) is a double membrane that separates the contents of the nucleus from the cytoplasm;

- At various point, 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. **Nucleoli** (pl); Nucleolus (s) = a spherical body 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 tightly coiled as **chromosomes** if the cell were preparing to divide.

**CHAPTER 3: CELLS**

III. Cytoplasmic Organelles (continued)

B. **Ribosomes**:

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

**C. Endoplasmic Reticulum (ER):** See Fig 3.10, page 70.

1. 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. **Golgi Apparatus (Complex):** See Fig 3.10, page 70.

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". See Fig 3.12, page 71.

E. **Lysosomes:** See Fig 3.14, page 73.

1. spherical membranous sacs containing digestive enzymes;
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 (see CA, page 75).

*Fig 3.12, page 71 summarizes the role of RER and GA and lysosomes in protein transport.

**CHAPTER 3: CELLS**

III. Cytoplasmic Organelles (continued)

F. **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.

G. **Mitochondria** (pl); Mitochondrion (s): See Fig 3.13, p 72.
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.

H. **Cytoskeletal Elements:** See Fig 3.18 and Fig 3.19, pages 76 & 77..
1. protein structures called microfilaments, microtubules, and intermediate filaments;
2. form "muscles and bones" of the cell.

I. **Cell Membrane Surface Modifications**

1. **Cilia (pl)/ Cilium (s)**: See Fig 3.16, page 76.
   a. short, hair-like cellular extensions (eyelashes);
   b. help move substances through passageways;
   c. located in lining of respiratory tract & fallopian tube.

2. **Flagella (pl)/ Flagellum (s)**: See Fig 3.17, p 76.
   a. tail-like projection;
   b. only one per cell in humans;
   c. aids in cell **locomotion**;
   d. sperm cell.

3. **Microvilli**: See Fig 3.3, page 62.
   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 digestive tract.

L. **Centrosome and Centrioles**: See Fig 3.15, page 75.
1. pair of microtubules located near the nucleus;
2. aid in movement of chromosomes during mitosis.

IV. **SUMMARY TABLE OF CELL COMPONENTS:**
**See Chart 3.2, page 79 in text and key on pages 56-57.**

| CELL COMPONENT | DESCRIPTION/ STRUCTURE | FUNCTION(S) |
|---|---|---|
| **CELL MEMBRANE** | | |
| **CYTOPLASM** | | |
| **NUCLEUS** | | |
| **NUCLEOLUS** | | |
| **RIBOSOMES** | | |
| **ROUGH ER** | | |
| **SMOOTH ER** | | |
| **GOLGI** | | |
| **LYSOSOMES** | | |
| **PEROXISOMES** | | |
| **MITOCHONDRIA** | | |
| **CYTOSKELETON** | | |
| **FLAGELLA** | | |
| **CILIA** | | |
| **MICROVILLI** | | |
| **CENTRIOLES** | | |

## CHAPTER 3: CELLS

V. Movements Into and Out of the Cell (i.e. **Membrane Transport)**

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

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

1. SIMPLE **DIFFUSION**

a. Molecules or ions spread spontaneously from regions where they are in
b. **higher** concentrations **toward** regions where
c. they are in **lower** concentrations (i.e. down a concentration gradient).
d. A state of equilibrium is produced!
e. Examples:

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

See Fig 3.21, page 80.

**CHAPTER 3: CELLS**

V. Movements Into and Out of the Cell (i.e. **Membrane Transport)**

A. Passive (no energy) Membrane Transport (continued)

2. **OSMOSIS: See Fig 3.23, page 81.**

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, **not** the solute!!!
c. Osmosis is significant when solutions are infused into our blood or tissues.

- The solute concentration must be equal to that of our cells and tissues (**isotonic** = 0.9% NaCl), or our cells will either:

1. lose water and shrink, or
2. gain water and swell (perhaps burst).

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

See Fig 3.24, page 82.

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

1. **Hypertonic**

**2. Hypotonic**

3. **Isotonic**

**CHAPTER 3: CELLS**

V. Movements Into and Out of the Cell (i.e. **Membrane Transport)**

A. Passive (no energy) Membrane Transport (continued)

3. **FILTRATION**: See Fig 3.25 & 3.26, page 82.

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.

4. **FACILITATED DIFFUSION: See Fig 3.22, page 80.**

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.

**CHAPTER 3: CELLS**

V. Movements Into and Out of the Cell (i.e. **Membrane Transport)**

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

1. **ACTIVE TRANSPORT: See Fig 3.27, page 83.**

a. Molecules or ions move from an area where they are in **low** concentration **toward** an area where they are in **high**er concentration at the expense of cellular energy (i.e. ATP).

- m low to high;
- m ATP necessary;
- m substances include many ions, amino acids and monosaccharides.
- m 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 diffusion or active transport are brought into the cell within a vesicle formed from a section of the cell membrane.

b. Examples: See Fig 3.28 and 3.29, page 84.

- **m** **PINOCYTOSIS** = cell drinking; the cell brings in liquid droplets which may contain dissolved substances.

- **m** **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, toxins**, etc.,
     a. that then fuse with a **lysosome** in their cytoplasm to digest the foreign particles.

     See Fig 3.30, page 85.

**CHAPTER 3: CELLS**

V. Movements Into and Out of the Cell (i.e. **Membrane Transport)**

B. Active (energy requiring) Membrane Transport

3. **Receptor-Mediated Endocytosis**
See Fig 3.31, page 86.

4. **Exocytosis** : See Fig 3.32, page 86.

a. how cells get rid of something by dumping it to the outside (i.e. into the extracellular fluid).

b. Membrane-enclosed structures called **secretory vesicles** that form inside the cell, fuse with the cell membrane and release their contents into the extracellular fluid.

m Significance?

See Table 3.3 on page 87 for a Summary of Transport Processes and complete the following table.

**CHAPTER 3: CELLS**

V. MEMBRANE TRANSPORT SUMMARY TABLE (Key on page 58 of outline)

| **TRANSPORT PROCESS** | **GENERAL DESCRIP-TION** | **IS ENERGY NEEDED?** | **CONCEN-TRATION GRADIENT** | **EXAMPLE IN HUMANS** | **SIGNIF-ICANCE** |
|---|---|---|---|---|---|
| SIMPLE DIFFUSION | | | | | |
| OSMOSIS | | | | | |
| FACILI-TATED DIFFUSION | | | | | |
| FILTRATION | | | | | |
| ACTIVE TRANSPORT | | | | | |
| ENDOCY-TOSIS | | | | | |
| EXOCYTOSIS | | | | | |

**CHAPTER 3: CELLS**

## VI. THE **LIFE CYCLE OF A CELL (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.

See Fig 3.34, page 88.

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

See Fig 3.35, page 88.

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.** **G1** = rapid growth and replication of centrioles;
   b. **S** = growth and DNA replication; and
   c. **G2** = growth and final preps for cell division.

B. **MITOTIC PHASE (M)**: See Fig 3.36, page 89.

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

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

      m **PROPHASE: See Fig 3.37 & 3.38, page 90.**

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

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

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

      3. The nuclear envelope and nucleolus disappear.

**CHAPTER 3: CELLS**

VI. The Life Cycle of the Cell (continued)

B. Mitotic (M) phase (continued)

a. Mitosis (continued)

2. **METAPHASE**: See Fig 3.39, page 91.

- 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**: See Fig 3.40, page 91.

- 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:** See Fig 3.41, page 92.

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

b. **CYTOKINESIS** = division of cytoplasm, 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.

**See Figure 3.42, page 93 to observe some spectacular scanning electron micrographs of cell division!!!**

**CHAPTER 3: CELLS**

VI. Cell Cycle Summary: See Chart 3.4, page 92 and key on page 59 in outline.

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

**CHAPTER 3: CELLS**

VI. The Life cycle of the Cell (continued)

C. **Significance**:

1. cell growth,
2. tissue repair.

D. **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!

E. **Control of Cell Division**

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.

F. **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.

4. Types:

**CHAPTER 3: CELLS**
**SUMMARY TABLE OF CELL COMPONENTS (outline page 45)**

| CELL COMPONENT | DESCRIPTION/ STRUCTURE | FUNCTION(S) |
|---|---|---|
| CELL MEMBRANE | Bilayer of phospholipids with proteins dispersed throughout | cell boundary; controls what enters and leaves the cell (Transport) |
| CYTOPLASM | jelly-like fluid (70% water) | suspends organelles in cell |
| NUCLEUS | Central control center of cell; bound by lipid bilayer membrane; contains DNA | controls all cellular activity by instructing the cell what proteins to make (i.e. enzymes) |
| NUCLEOLUS | dense spherical body within nucleus; RNA & protein | synthesis of ribosomes |
| RIBOSOMES | RNA & protein; dispersed throughout cytoplasm or studded on ER | protein synthesis |
| ROUGH ER | Membranous network studded with ribosomes | protein synthesis |
| SMOOTH ER | Membranous network lacking ribosomes | lipid & cholesterol synthesis |
| GOLGI | "Stack of Pancakes"; cisternae | modification, transport, and packaging of proteins |
| LYSOSOMES | Membranous sac of digestive enzymes | destruction of worn cell parts ("autolysis) and foreign particles |
| PEROXISOMES | Membranous sacs filled with catalase enzymes (catalase) | detoxification of harmful substances (i.e. ethanol, drugs, etc.) |
| MITOCHONDRIA | Kidney shaped organelles whose inner membrane is folded into "cristae". | Site of Cellular Respiration; "Powerhouse" |
| CYTOSKELETON | Protein filaments: microtubules, microfilaments, etc | provide scaffolding for cell; allows for intracellular transport |

| CELL COMPONENT | DESCRIPTION/ STRUCTURE | FUNCTION(S) |
|---|---|---|
| **FLAGELLA** | **long, tail-like extension; human = sperm** | **locomotion** |
| **CILIA** | **short, eyelash extensions; human = respiratory tract & fallopian tube** | **to push substances through passageways** |
| **MICROVILLI** | **microscopic ruffling of cell membrane** | **increase surface area** |
| **CENTRIOLES** | **paired cylinders of microtubules at right angles near nucleus** | **aid in chromosome movement during mitosis** |

**CHAPTER 3: CELLS**

MEMBRANE TRANSPORT SUMMARY TABLE (outline page 51)

| **TRANSPORT PROCESS** | **GENERAL DESCRIP-TION** | **IS ENERGY NEEDED?** | **CONCEN-TRATION GRADIENT** | **EXAMPLE IN HUMANS** | **SIGNIF-ICANCE** |
|---|---|---|---|---|---|
| **SIMPLE DIFFUSION** | spreading out of molecules to equilibrium | NO | [HIGH] TO [LOW] | $O_2$ into cells; $CO_2$ out of cells. | Cellular respiration |
| **OSMOSIS** | water moving through the cell membrane (c.m.) to dilute a solute | NO | [HIGH] TO [LOW] | maintenance of osmotic balance of 0.9% saline | maintenance of osmotic balance of 0.9% saline |
| **FACILI-TATED DIFFUSION** | using a special c.m. carrier protein to move something thru the c.m. | NO | [HIGH] TO [LOW] | manner in which glucose enters and leaves cell | Cellular respiration |
| **FILTRATION** | using pressure to push something through a cell membrane | NO | [HIGH] TO [LOW] | manner in which the kidney filters things from blood | removal of metabolic wastes |
| **ACTIVE TRANSPORT** | opposite of diffusion at the expense of energy | YES | [LOW] TO [HIGH] | $K^+$-$Na^+$-ATPase pump | maintenance of the resting membrane potential |
| **ENDOCY-TOSIS** | bringing a substance into the cell that is too large to enter by any of the above; Phagocytosis= cell eating; Pinocytosis = cell drinking. | YES | [LOW] TO [HIGH] | Phago-cytosed (foreign) particles fuse with lysosomes to be destroyed | help fight infection |
| **EXOCYTOSIS** | expelling a substance from the cell into ECF | YES | [LOW] TO [HIGH] | Exporting proteins; dumping waste | Exporting proteins; dumping waste |

## CHAPTER 3: CELLS

Cell Cycle Summary (outline page 54)

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