

## Cell Organelles

### Chapter 3

#### **Cell Theory**

- The cell is the smallest unit of life
- All living things are composed of cells
- Cells arise only from pre-existing cells

#### **Components of cells**

Cells are composed of the cell membrane, cytoplasm and the nucleus. Within the cytoplasm are the cytosol and the organelles (membraneous and non-membranous).

#### **The Cytosol**

The cytosol is the broth of the soup. The CYTOSOL is a viscous, semitransparent fluid that contains proteins, salts, sugars and nutrient monomers. The main salts in the cell are potassium and electrolytes.

Also in the cytosol are INCLUSIONS, which are non-encapsulated collections of material...kind of like an amphitheater...not an enclosure, but there's a general area. Inclusions include glycogen granules (liver and muscle cells), lipid droplets (adipose cells), and melanin (skin cells...protects nucleus from UV).

#### **The Organelles**

The organelles are "little organs" that are suspended in the cytosol. There are two types of organelles...membraneous organelles and non-membraneous organelles.

MEMBRANEOUS ORGANELLES are internal bodies surrounded by membrane. They maintain internal environments separate from cytosol.

NON-MEMBRANEOUS ORGANELLES are internal structures composed of protein or nucleic acid.

#### **Mitochondria (Membraneous)**

The Mitochondria are considered the "powerhouse" of the cell. This is where ATP production occurs in the cell (via cellular respiration). Mitochondria are capsule shaped, with a smooth outer layer and convoluted inner membrane that provides a lot of inner surface area. Mitochondria are unique in that they contain their own DNA! The quantity of mitochondria in a cell indicate its level of activity.

Mitochondria = plural

Mitochondrion = singular

### **Endoplasmic Reticulum (Membraneous)**

The ER is a network of flattened, fluid-filled sacs that is continuous with the membrane around the nucleus (it's part of the endomembrane system). There are two types of ER...the ROUGH ENDOPLASMIC RETICULUM (RER), which has ribosomes imbedded into the membrane. This is the site of protein synthesis in the cell (just the basic protein product...not the end product). The SMOOTH ENDOPLASMIC RETICULUM (SER) is involved in lipid metabolism and the detoxification of drugs and carcinogens.

### **Golgi Apparatus (Membraneous)**

Material from the ER goes to the GOLGI APPARATUS for modification, packaging and distribution. The Golgi apparatus is the "Pack-N-Ship" of the cell. It is a series of stacked, flattened and slightly concave discs

### **Vesicles (Membraneous)**

Vesicles are "bubbles" of membrane containing some material. They are produced by the Golgi apparatus. There are three types of vesicles

1. Secretory vesicles
2. Lysosomes
3. Peroxisomes

SECRETORY VESICLES contain material to be released from the cell, such as hormones, enzymes and mucus. The membrane of the vesicles fuses with the cell membrane and replenishes it. LYSOSOMES contain digestive enzymes for degrading biological molecules. PEROXISOMES detoxify substances and neutralizes free radicals. Vesicles are the only organelles that go in and out of the cell.

### **Endomembrane System (Membraneous)**

The endomembrane system is a continual flow of membrane through the cell. It does not include the mitochondria.

Material flows through...

- Nuclear envelope
- Endoplasmic reticulum
- Golgi apparatus
- Vesicles
- Plasma membrane

### **Ribosomes (Non-membraneous)**

Ribosomes are the protein factories of the cell. They are made of ribosomal RNA (rRNA) and associated proteins in two unequal subunits that are only together when they are making protein. Ribosomes are located in the cytosol (free floating) where they create intracellular proteins, and in the RER where they create membrane-bound or exported proteins.

### **Cytoskeleton (Non-membraneous)**

There are three types of cytoskeleton organelles. The first are the MICROTUBULES. These are the largest of the three and they are composed of tubulin. The microtubules radiate from the centrosome and function in internal cell movement.

MICROFILAMENTS are the smallest of the three. They are composed of actin (a globular protein) and function in cell motility.

INTERMEDIATE FILAMENTS are intertwined filamentous proteins whose composition varies among cell types. The static strands provide strength and support.

### **Centrioles (Non-membraneous)**

Centrioles are paired barrel-shaped organelles that reside in the centrosome (the main microtubule organizing center). Their structure is a circular array of nine microtubule triplets. The centrioles aid in cell division and form the base of cilia and flagella.

### **Cilia (Non-membraneous)**

Cilia are numerous projections of the cell membrane. They contain a core of microtubules arranged in nine doublets around a central pair. They create a wavelike fluid motion over the cell surface. The action moves stuff (like mucus) across the cell surface.

### **Flagellum (Non-membraneous)**

Flagella are structurally similar to cilia, but they are significantly longer and exist singly (only one per cell). Their movement propels the cell through medium...sperm cells are the only flagellated cells.

## Cell Membrane Chapter 3 cont'd

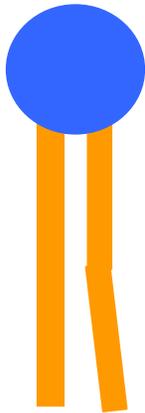
### **Fluid Mosaic Model**

The Fluid Mosaic Model describes the structure of the cell membrane. It is made up of three components:

- 1) phospholipid bilayer
- 2) cholesterol
- 3) proteins

### **The Plasma Membrane**

The basic material of the plasma membrane is the PHOSPHOLIPID BILAYER. It is composed of two layers of phospholipids that line up tail to tail.



Phosphate group is hydrophilic and polar. Faces water on inside and outside of cell

The tails are hydrophobic. They are slightly kinked and UNSATURATED, so the membrane is fluid. The tails are on the inside of the membrane and never come into contact with water.

The bilayer spontaneously forms in aqueous solutions. The ends close together to make a bubble!

CHOLESTEROL is another material of the membrane. It makes up about 20% of the membrane lipids. Cholesterol is a flat molecule that wedges between the tails of the fatty acids. This keeps the tails from packing too closely so it works to ensure the fluidity of the plasma membrane.

PROTEINS perform the most membrane functions, and there are a lot of proteins involved (which is the “mosaic” part of the Fluid Mosaic Model). INTEGRAL PROTEINS are imbedded in the bilayer. Most span the entire width of the membrane, and others protrude from one side only. The ones that span the entire width act as transport proteins, regulating the passage of materials into and out of the cell.

CHANNEL PROTEINS create a passive “pore”, contributing to the “leakiness” of the cell.

With CARRIER PROTEINS, a substance binds to the protein and it actively moves the substance across the membrane.

PERIPHERAL PROTEINS are attached to integral proteins or lipids, on one side of the membrane only (one or the other). The functions include acting as enzymes, receptors (when on outer surface) and mechanical support (when on inner surface).

### **The Glycocalyx**

The glycocalyx is a carbohydrate rich layer surrounding the cell surface. It is made up of GLYCOPROTEINS and GLYCOLIPIDS. A glycoprotein is a protein with a small polysaccharide, and a glycolipid is a phospholipid attached to a carbohydrate. The function of the glycocalyx is to aid in cell-to-cell recognition. Cells have different patterns of sugars that make them recognizable.

### **Microvilli**

Microvilli are tiny projections of membrane. They have a cytoskeleton core made of actin and microfilaments and a smaller than cilia. They don't actually move the way cilia do...their purpose is to increase the surface area of the cell membrane. It is most important in absorbant cells, such as the intestine.

### **Membrane Junctions**

There are three types of membrane junctions.

1. Tight Junctions are a series of integral proteins interlocking with adjacent cells. This type of junction restricts movement between cells, and serves to keep things in and out. (EX: epithelial cells)
2. Desmosomes are rivet-like integral proteins between adjacent cells. They are STRONGER than tight junctions. Intermediate filaments join desmosomes across cells to provide strength, structure and resistance to pulls and stress. Desmosomes are found in tissues that stretch such as the heart and bladder. Desmosomes keep the integrity of the tissue.
3. Gap Junctions are transmembrane proteins that connect adjacent cells. This creates a cytoplasmic connection between cells, like a hallway between houses. This allows cells to communicate with neighbors and is especially important in electrically excitable cells, such as the heart muscle. Gap Junctions allow synchronicity of functioning.

### **Membrane Transport**

The cell membrane regulates the flow of material between the internal cytosol and the external interstitial fluid.

Cell membranes are selectively permeable...it allows some things through, but not others.

There are two methods for crossing the membrane:

1. Passive processes
  - a. Diffusion
    - i. Simple Diffusion
    - ii. Facilitated Diffusion

- b. Osmosis
- c. Filtration
- 2. Active processes
  - a. Primary Active Transport
  - b. Secondary Active Transport
  - c. Vesicular Transport
    - i. Exocytosis
    - ii. Endocytosis

**Passive Processes**

**DIFFUSION** involves the molecules of a solute distributing evenly throughout the solution...the way a sugar cube will dissolve in tea. The solutes move due to KINETIC ENERGY of the molecules...and they move DOWN THE CONCENTRATION GRADIENT. This movement occurs until equilibrium is reached and the gradient no longer exists. The speed with which this occurs depends on:

- o The steepness of the gradient (steeper = faster)
- o The size of the molecules (smaller = faster)
- o The temperature (hotter = faster)

There are two types of diffusion...simple diffusion and facilitated diffusion. In SIMPLE DIFFUSION, the solute moves directly across the phospholipids membrane. The solute must be non-polar and lipid-soluble. This includes oxygen, CO<sub>2</sub>, fat-soluble vitamins and alcohol.

In FACILITATED DIFFUSION, the solute moves through a carrier or channel protein. This process is for polar and or larger molecules (glucose, amino acids, ions). There is a maximum amount that can get across at any given time b/c there are only so many proteins available.

**OSMOSIS** involves the solution (generally H<sub>2</sub>O) moving DOWN its own concentration gradient. This process comes into play when the membrane itself is impermeable to the solute. Because the solute molecule is too big to cross the membrane, the water itself moves across.

TONICITY refers to the ability of a solution to change the H<sub>2</sub>O volume of a cell through osmosis.

ISOTONIC SOLUTIONS = the same concentration of solutes.  
No net movement

HYPERTONIC SOLUTION = has a higher concentration than the other solution.  
Will draw water TOWARD IT TO DILUTE ITSELF  
The compartment will EXPAND

HYPOTONIC SOLUTION = has a lower concentration than the other solution  
Water will be DRAWN FROM IT  
The compartment will SHRINK

In FILTRATION, the driving force is hydrostatic pressure gradient. The membrane selectively depends on the solute size. This occurs in capillaries and kidney tubules.

### Active Processes

ACTIVE TRANSPORT is similar to facilitated diffusion in that it requires a carrier integral protein. The difference is that it moves the solute UP THE CONCENTRATION GRADIENT by way of a “pump.” Active transport uses ATP for energy. There are two types: primary active transport and secondary active transport.

PRIMARY ACTIVE TRANSPORT = involves the direct usage of ATP to move solute  
= solute binds to protein and waits for ATP to hydrolyze  
= the energy release transforms the shape of the protein

SECONDARY ACTIVE TRANSPORT = does not use ATP directly  
= the ACTIVE transport of one solute CREATES A GRADIENT that may be used to move a second solute

If it moves in the same direction it's SYMPORT  
If moving in both directions, it's ANTI-PORT

VESICULAR TRANSPORT involves the moving of large particles across the membrane (bacteria and macromolecules such as proteins). This is used for the bulk intake of fluid. There are two types of vesicular transport...exocytosis and endocytosis. EXOCYTOSIS is the outward movement of particles. Vesicles are formed internally by the Golgi apparatus. Exocytosis is used for secretions such as mucus, signal molecules (hormones and neurotransmitters), and cellular waste...and for adding fresh membrane molecules to replenish the cellular membrane. ENDOCYTOSIS is the inward movement of particles...vesicle forms at the cell surface.

### STEPS OF EXOCYTOSIS:

1. Vesicle migrates to the cell surface
2. It fuses with the membrane
3. Contents are expelled into extracellular space

### STEPS OF ENDOCYTOSIS:

1. Cell creates cytoplasmic extensions
2. They envelop extracellular particles/fluid
3. Vesicle is moved internally

Phagocytosis (cell “eating”) is common among macrophages...and pinocytosis (cell “drinking”) is when the cell takes in fluid droplets containing solutes. Pinocytosis is common among absorptive cells. In RECEPTOR MEDIATED ENDOCYTOSIS, specific membrane-bound proteins bind substances like a lock & key. It allows for selective endocytosis...the cell gets exactly what it wants. This happens with things like enzymes, LDLs, iron and some hormones.

NO NET SOLUTE MOVEMENT IS WHEN THE MEMBRANE IS IMPERMEABLE OR WHEN EQUILIBRIUM IS REACHED.

### **THE CELL NUCLEUS**

The structure of the nucleus:

- Contains information for cell functions
- Most cells are uninucleate
- Some are multinucleate (these were formed by the fusion of multiple cells. EX: skeletal muscle and osteoclasts.
- Some cells are anucleate such as red blood cells (they eject the nucleus!) and platelets (fragments of cells)

The NUCLEAR ENVELOPE (AKA nuclear membrane)

- Has a double phospholipids bilayer...the outer layer is continuous with the ER
- Is punctuated by nuclear pores where the two bilayers meet
- The pores allow large molecules to get out of the nucleus (mRNA and rRNA)

Inside the envelope is the NUCLEOPLASM

- Similar to cytosol (the broth of the nucleus)
- Differences are that it has different components and more nucleotides
- Contains CHROMATIN (collective term for ALL the DNA)
- Also present with the DNA are histones and nucleosomes
- The DNA supercoils/condense into distinct CHROMOSOMES (the compact structure)

Within the nucleus is the NUCLEOLUS

- Dense area of chromatin
- This is where ribosomes are synthesized (RNA, hormones & enzymes)
- Active cells have MANY nucleoli

### **THE CELL LIFE CYCLE**

There are two major phases of the cell life cycle:

1. Interphase: non-dividing growth phase. The cell is performing its function
2. Cell division phase: distribution of chromatin & cytoplasm into 2 daughter cells

INTERPHASE has three stages: G1, S and G2.

- G1: The cell grows some  
Performs its functions  
Most variable in length among different cells

S: DNA replication  
One copy of DNA for each daughter cell  
The first step in preparation for cell division

G2: Cell manufactures organelles  
Slight growth in size

CELL DIVISION has two stages: Mitosis and Cytokinesis

MITOSIS has four stages: Prophase, metaphase, anaphase, telophase.

Early Prophase: -ASTERS EXTEND from centrioles  
(asters are projections of microtubules)  
-Asters form a MITOTIC SPINDLE  
-As MICROTUBULES extend toward each other they push each other toward poles  
-CHROMOSOMES condense  
-Sister chromatids (the two DNA strands) remain attached at the centromere  
-NUCLEOLI disappear

Late Prophase: -NUCLEAR ENVELOPE breaks down  
-KINETOCHORE microtubules form  
-The spindle fibers from the CENTRIOLES attach to the chromatid  
-POLAR MICROTUBULES cross-link...they lengthen and push the centrioles apart

Metaphase: -CHROMOSOMES align on METAPHASE PLATE by the push-pull of the microtubules  
-Equal pull on the kinetochore microtubules aligns pairs of sister chromatids

Anaphase: -SISTER CHROMATIDS separate  
-Centromere splits and kinetochore microtubules continue to shorten while polar microtubules continue to lengthen and push  
-The cell ELONGATES

Telophase: -The nuclear envelope reforms  
-Chromosomes decondense  
-Nucleoli reappear  
-Mitotic spindle breaks down

CYTOKINESIS is the second stage of cell division. It involves the division of the cytoplasm. In cytokinesis:

- Contractile proteins form a ring around the equator
- This creates a CLEAVAGE FURROW which is caused by the shortening microfilaments
- They continue to shorten until they pinch the cell in half
- This process overlaps mitosis...it begins in late anaphase and ends after telophase

### **Protein Synthesis**

Protein synthesis is the decoding of DNA to produce proteins...DNA is used almost exclusively to produce protein!

A GENE is a DNA segment that provides instructions for the synthesis of one polypeptide chain.

There are three steps to PROTEIN SYNTHESIS:

1. Transcription (making a copy of the DNA strand)
2. Editing (the copy is long...have to edit and delete portions)
3. Translation (have to translate into the correct language)

STEP 1: TRANSCRIPTION is the process of making a copy of the DNA strand...it involves RNA polymerase.

- RNA polymerase binds to and unwinds segments of the DNA strand (helicase is not needed)
- RNA polymerase only replicates one strand of the DNA
- As it moves along, it inserts and polymerases complementary RNA bases (Adenine binds with uracil, instead of thymine)
- This short segment is called mRNA...it is a complementary copy of the segment of DNA

### STEP 2: EDITING

Pre-mRNA contains segments of “nonsense”...these are INTRONS. Spliceosomes excise introns and put the “good” pieces together. The rejoined segments are EXONS.

### STEP 3: TRANSLATION

Nucleic acids are the language of DNA/RNA. This language must be translated into the “amino acid language” of proteins. Nucleic acids are composed of combinations of 4 letters (ACGU). Proteins contain 20 “letters”, which are the 20 common amino acids. Nucleic acids are used in groups of three to code for amino acids...this is called a CODON. There are 64 possible codons ( $4^3$ ).

It is important to note that there is redundancy in the code...several codons will code for the same amino acid. This helps to reduce errors. For example, GUU, GUC, GUA and GUG all code for valine.

There are a few “special codes”... AUG is the universal start signal, and the stop signals are UAA, UAG and UGA.

### **The process of translation**

First, mRNA leaves the nucleus via the nuclear pores and then binds to the large ribosomal subunit at a unique leader sequence of bases. The tRNA is a clover-leaf shaped molecule with a stem region that binds to a specific AA. The anticodon is the codon that is complementary to the code (AGC—UCG).

Protein synthesis is initiated when an mRNA, a ribosome, and the first tRNA molecule (carrying its Methionine amino acid) come together.

Messenger RNA (**mRNA**) provides the template of instructions from the cellular DNA for building a specific protein. Transfer RNA (**tRNA**) brings the protein building blocks, amino acids, to the ribosome. tRNA binds to the large ribosomal subunit.

Once the Ribosome is complete (both subunits together), it starts scanning the mRNA for the START CODON (AUG=methionine). Next, the tRNA binds the correct amino acid in place. The ribosome enzyme forms a peptide bond between the first two amino acids and the protein has begun!

The ribosome then shifts down along the mRNA, bringing the next codon into the ACTIVE SITE. The first tRNA leaves and the process repeats. It stops when it comes across a STOP codon on mRNA (UAA, UAG or UGA). The ribosome then disassembles and our protein is complete ☺ It then goes to the ER then the Golgi body for export, or it hangs out in the cytoplasm to do something for that particular cell.

### **DNA Replication**

There are three stages to DNA replication

1. Uncoiling
2. Polymerization
3. Ligation

In UNCOILING the DNA uncoils from the nucleosomes with the aid of DNA helicase which unzips the strands by breaking the hydrogen bonds that hold them together. As helicase moves along the strand it forms a replication bubble, and the strands meet at a replication fork.

In POLYMERIZATION a group of enzymes converge on a single DNA strand, forming a replisome. One of these enzymes is primase. Primase creates an RNA primer, which is temporary. Next, DNA polymerase III (the molecule which does the actual polymerization) starts pulling in nucleotides and binding them to complementary nucleotides, moving in a 5 to 3 direction only. (A with T, G with C).

In LIGATION, there is a leading strand and a lagging strand. The leading strand is created by polymerase moving in the *same direction as the helicase*. It is formed continuously. The lagging strand is create by polymerase moving in the *opposite direction as the helicase*. It is formed in segments which are spliced together by DNA ligase.

Marieb, E. N. (2006). *Essentials of human anatomy & physiology* (8th ed.). San Francisco: Pearson/Benjamin Cummings.

Martini, F., & Ober, W. C. (2006). *Fundamentals of anatomy & physiology* (7th ed.). San Francisco, CA: Pearson Benjamin Cummings.