

**Cells! Cells! Cells!**  
**Cells: The Working Units**  
**of Life**

**Cell Theory**

- Cell theory was the first unifying theory of biology.
- Schleiden and Schwann developed the first two statements of the cell theory.
  - All organisms are composed of one or more cells and the processes of life occur in these cells.
  - Cells are the smallest living things.
- In 1839, Schwann published a book on plant and animal cells, stating all three statements of the cell theory. He stated...
  - All cells are form by free-cell formation (spontaneous generation)

**Omnis cellula e cellula**

- Rudolf Virchow (1855) is the one who finished the cell theory off by saying...
  - All cells only arise from pre-existing cells.
- These statements still hold true today.

**Implications of Cell Theory**

- Functions of all cells are similar
- Life is continuous
- Origin of life was the origin of cells
  
- Cells are small (mostly).
- Exceptions: bird eggs, neurons, some algae and bacterial cells
  
- Cells are small because they need a high surface area-to-volume ratio.
- Volume determines the amount of chemical activity in the cell per unit time.
- Surface area determines the amount of substances that can pass the cell boundary per unit time.
  
- Most cells are  $< 200 \mu\text{m}$  in size.
- Minimum resolution of human eye is  $200 \mu\text{m}$ .
- Microscopes improve resolution.
  
- Two basic types of microscope:
  - Light microscope—uses glass lenses and light. Resolution =  $0.2 \mu\text{m}$
  - Electron microscope—electromagnets focus an electron beam. Resolution =  $0.2 \text{nm}$

## **The cell**

- The smallest entity that retains the properties of life.
- Cells differ in size, shape, and activities.
- For the most part, they have three things in common: a plasma membrane, a DNA-containing region, and a cytoplasm.

### **Plasma Membrane**

- The plasma membrane is the thin outermost component of the cell that maintains its shape.
- It maintains the homeostasis of the cell but does not isolate it.
- The cell membrane consists mainly of phospholipids.
- Phospholipids have a hydrophilic head and a hydrophobic tail.
- These phospholipids arrange themselves in such a way that it forms a lipid bilayer.

### **Fluid Mosaic Model**

- It is fluid because of the motions of the lipids and how they interact.
- It is called a mosaic because of the mixed components found in the membrane.
- The model depicts the membrane not as one that solely consists of a lipid bilayer, but instead one that consists of lipids and proteins.
- A variety of phospholipids, glycolipids, and sterols are incorporated in the membrane and embedded in the membrane are proteins.
- There are different types of proteins found in the plasma membrane.
- Transport proteins allow water-soluble proteins to go in and out of the cell.
- Receptor proteins can bind hormones and other substances that can trigger changes in the cell's activities.
- There are also recognition proteins on the cell surface that act like a "signature", identifying the cell as being a specific type.

### **DNA-containing region**

- Cells have a region in them that is occupied by DNA.
- In some cells, the DNA is membrane bound, while in others, they may not be.
- There are molecules in the cell that can read and copy the hereditary instructions that DNA carries.

### **Cytoplasm**

- The cytoplasm of the cell is everything that the plasma membrane encloses, except for the organelles.
- It is a semi-fluid substance in which particles, filaments, and organelles are organized.

### **Eukaryotes vs. Prokaryotes**

- Two types of cells: prokaryotic and eukaryotic
- Bacteria and Archaea are prokaryotic.
- The first cells were probably prokaryotic.

- Eukarya are eukaryotic—DNA is in a membrane-enclosed compartment called the nucleus.

### **Prokaryotic cells**

- Prokaryotic cells are very small.
- Individuals are single cells, but often found in chains or clusters.
- Prokaryotes are very successful—they can live on a diversity of energy sources and inhabit every environment including extreme environments.

Prokaryotic cells:

- Are enclosed by a plasma membrane
- The DNA is contained in the **nucleoid**
- **Cytoplasm** consists of **cytosol** (water and dissolved material) and suspended particles
- Ribosomes—site of protein synthesis

- Most prokaryotes have a rigid cell wall outside the plasma membrane.
- Bacterial cell walls contain peptidoglycan.
- Some bacteria have an additional outer membrane.
- Some bacteria have a slimy capsule of polysaccharides.
- Some prokaryotes swim by means of flagella, made of the protein flagellin.
- Some bacteria have pili—hair-like structures projecting from the surface. They help bacteria adhere to other cells.
- Some rod-shaped bacteria have a cytoskeleton made of the protein actin.

### **Eukaryotic cells**

- Eukaryotic cells can be up to 10 times larger than prokaryotes.
- Eukaryotic cells have membrane-enclosed compartments called organelles.
- Organelles have specific functions.
- Cell processes occur in these organelles.
- An example of some common ones include the nucleus, ribosomes, endoplasmic reticulum, golgi body, vesicles, mitochondria, and cytoskeleton.

### **Animals vs. plants**

- One very distinct difference between the two is the presence of a cell wall in plants.
- Plants also have chloroplasts, a central vacuole, and plasmodesmata.
- These structures obviously do something for the plant that the plant needs.

## **Nucleus**

- A cell's structure and function begin with proteins, and instructions for building them are contained in DNA.
- The nucleus houses the DNA of a eukaryotic organism.
- The nucleus has a distinct structure and serves two very key functions.
- First, the nucleus localizes the DNA. This localization makes it easier to sort it out when it comes time for it to divide.
- Second, the nuclear membrane controls the exchange of signals and substances between the nucleus and the cytoplasm.

## **Components of the nucleus**

- Inside the nucleus are several components that have specific functions.
- One such component is the nucleolus.
- The nucleolus is a dense cluster of RNA and proteins which is used in the assembly of ribosomal subunits.
- These subunits are later shipped from the nucleus into the cytoplasm. Here, proteins are synthesized.
- The outermost component of the nucleus has two lipid bilayers, one wrapped around the other.
- This bilayer completely surrounds the fluid portion of the nucleus called the nucleoplasm.
- This double-membrane is called the nuclear envelope.
- Just like in all cell membranes, the nuclear envelope serves as a barrier to water-soluble substances.
- In the envelope are proteins that allow the free exchange of ions and control the passage of ribosomal subunits, and other large molecules.
- On the inside of the envelope are protein filaments which anchor the DNA molecules to the membrane and help keep them organized.
- Between cell divisions, DNA is thread-like, with proteins attached to it.
- Before a cell divides, it duplicates DNA molecules.
- These molecules are folded and twisted into condensed structures, including everything associate with it (proteins).
- Early on, scientists called the grainy substance chromatin, and called the condensed structures chromosomes.
- Now, chromatin is defined as a cell's total collection of DNA, together with all of the proteins that are associated with it.
- Each chromosome is an individual DNA molecule and its associated proteins, whether

it is in its threadlike or condensed form.

- The chromosome does not always look the same during its life in the cell.

### **Ribosomes**

- Ribosomes—sites of protein synthesis.
- Occur in both prokaryotic and eukaryotic cells.
- In eukaryotes, ribosomes are free in the cytoplasm, attached to the endoplasmic reticulum, and inside mitochondria and chloroplasts.
- There are sufficient differences between bacterial ribosomes and eukaryotic ribosomes that some antibiotics will inhibit the functioning of bacterial ribosomes, but not a eukaryote's, thus killing bacteria but not the eukaryotic organisms they are infecting.
- Ribosomes are composed of two subunits, each one consists of a protein and ribosomal RNA.
- The prokaryotic ribosome consists of a 30s subunit and a 50s subunit. Together, they make a 70s subunit.
- The “s” refers to Svedberg units, which indicate the relative rate of sedimentation during ultra-high-speed centrifugation.

### **The Endomembrane System**

- The endomembrane system includes the endoplasmic reticulum and the Golgi apparatus.
- The outer membrane of the nuclear envelope is continuous with the endomembrane system.
- Endoplasmic reticulum (ER): a network of interconnected membranes—large surface area
- Rough endoplasmic reticulum (RER): ribosomes are attached
- RER segregates newly made proteins—they enter an inner cavity called the lumen and can be modified and transported.

Smooth endoplasmic reticulum (SER): more tubular, no ribosomes

- Chemically modifies small molecules such as drugs and pesticides
- Hydrolysis of glycogen in animal cells
- Synthesis of lipids and steroids

### **The Golgi Apparatus**

- Receives proteins from the ER—can further modify them
- Concentrates, packages, sorts proteins
- In plant cells, polysaccharides for cell walls are synthesized

- The *cis* region receives vesicles (a piece of the ER that “buds” off) from the ER.
- At the *trans* region, vesicles bud off from the Golgi apparatus and are moved to the plasma membrane.

### **A plethora of vesicles**

- Many types of vesicles move through the cytoplasm or find a place and reside in them.
- An example is the lysosome, which is a vesicle that pinches off the Golgi complex of animal and some fungal cells.
- They are organelles of intracellular digestion.
- They contain an enzyme-rich fluid which aids in lipid, protein, carbohydrate, and nucleic acid breakdown.
- Lysosomes will also help digest the cell’s own parts acting in a sense as a recycler, of sorts.
- In plants, there are vesicles that contain enzymes that perform two different functions.
- The first is found in plant seeds. They contain enzymes that convert fats to carbohydrates for growth. These are called glyoxysomes.
- Peroxisomes, found in all eukaryotic cells, function to rid the body of toxic substances like hydrogen peroxide or other metabolites.
- They are a major site of toxic utilization and are numerous in the liver where toxic byproducts are going to accumulate.
- Food molecules enter the cell by phagocytosis—a phagosome is formed, which fuses with a primary lysosome, forming a secondary lysosome.
- Enzymes in the secondary lysosome hydrolyze the food molecules.
- Lysosomes also digest cell materials—autophagy

### **Powerhouse of the cell**

- All cell activities are driven by energy that ATP molecules carry from one reaction site to another.
- In mitochondria, energy that is released when organic molecules are broken apart is used to form many ATP molecules.
- These oxygen-requiring reactions are energy rich.
- The oxygen you breathe primarily goes to your mitochondria.
- Mitochondria have two membranes.
- The outer membrane “faces” the cytoplasm.
- The inner membrane continually folds in on itself creating cristae.
- Two distinct compartments are made by these membranes - an inner and an outer.

- Enzymes and other proteins that are associated with the inner membrane are machinery for ATP formation, using oxygen as the fuel for the machinery.
- All eukaryotic cells have one or more mitochondria. Cells which require a high energy demand will more than likely contain many mitochondria.
- In size and biochemistry, mitochondria look like bacteria.
- They have their own DNA, ribosomes, and even divide on their own.
- An organelle that could tie in to the endosymbiotic theory.

### **Chloroplasts**

- Plant cells contain plastids which are organelles that function in photosynthesis or storage.
- One plastid, the chloroplast, basically, is the organelle responsible for photosynthesis.
- Here sunlight is captured, ATP is formed, and organic molecules are synthesized from water and carbon dioxide.
- They are often oval-shaped and structurally are very similar to the mitochondrion.
- It contains a permeable outer membrane, a less permeable inner membrane, an intermembrane space, and an inner section called the stroma.
- However, the chloroplast is larger than the mitochondria. It needs to have the larger size because its membrane is not folded into cristae.
- Also the inner membrane contains the light-absorbing system and ATP synthase in a third membrane that forms a series of flattened discs, called the thylakoids.
- Thylakoids are the location of the light-powered reactions that go on in a plant.
- Thylakoids are found stacked in structures called grana.

Other plastids:

- Chromoplasts contain red, orange, and yellow pigments—gives color to flowers.
- Leucoplasts store starches and fats.

### **Vacuoles**

Plant and protist cells have vacuoles:

- Store waste products and toxic compounds—may deter herbivores
- Provide structure for plant cells—turgor
- Store anthocyanins (pink and blue pigments) in flowers and fruits
- Digestion in seeds—vacuoles have enzymes to hydrolyze stored food for early growth
- Many protists have food vacuoles—formed by phagocytosis.
- Freshwater protists may have contractile vacuoles to expel excess water.

### **Cytoskeleton**

- Supports and maintains shape

- Allows some types of movement
- Positions organelles
- Some fibers act as support for motor proteins
- Interacts with extracellular structures to hold cell in place

The cytoskeleton has three components:

- Microfilaments
- Intermediate filaments
- Microtubules

### **Microfilaments (Actin Filaments)**

- Help a cell or parts of a cell to move
- Determine cell shape
- Made from the protein actin
- Actin has + and – ends and polymerizes to form long helical chains (reversible).

### **Intermediate Filaments**

- Many different kinds
- Made of fibrous proteins of the keratin family
- Stabilize cell structure and resist tension

### **Microtubules**

- Form rigid internal skeleton in some cells
- Act as tracks along which motor proteins move
- Made from the protein tubulin—a dimer
- Have + and – ends
- Can change length rapidly by adding or losing dimers

### **Cilia and Eukaryotic Flagella**

- Made of microtubules in “9 + 2” array
- Each cilium or flagellum is made of a cylindrical array of 9 evenly-spaced microtubules, each with a partial microtubule attached to it.
- 2 single microtubules run up through the center of the bundle completing the so-called “9+2” arrangement.
- Cilia—short, usually many present, move with stiff power stroke and flexible recovery stroke
- Flagella—longer, usually one or two present, movement is snake-like

- Centrioles are identical to basal bodies.
- Involved in formation of the mitotic spindle.
- Motor proteins: undergo reversible shape changes powered by ATP
- Dynein binds to microtubule doublets and allows them to slide past each other.
- Kinesin binds to a vesicle and “walks” it along by changing shape.

### **Extracellular Structures**

Extracellular structures are outside the plasma membrane

- Peptidoglycan cell wall of bacteria
- Plant cell wall

### **Plant cell wall**

- Plant cell walls: cellulose fibers embedded in other complex polysaccharides and proteins
- Adjacent plant cells are connected by plasma membrane-lined channels called plasmodesmata.
- Many animal cells are surrounded by an extracellular matrix, composed of fibrous proteins such as collagen, gel- like proteoglycans (glycoproteins), and other proteins.

### **Extracellular matrix**

- Holds cells together in tissues
- Contributes to properties of bone, cartilage, skin, etc.
- Orient cell movements in development and tissue repair
- Plays a role in chemical signaling

### **The Endosymbiotic Theory**

- Eukaryotic cells appeared about 1.5 billion years ago.
- Endosymbiotic theory explains how eukaryotes could evolve from prokaryotes. Cells engulfed other cells that became mitochondria and chloroplasts.

Shared chemistry suggests that eukaryotes evolved from prokaryotes:

- Both use nucleic acids as hereditary material
- Both use the same 20 amino acids
- Both use D sugars and L amino acids