Unit 1: Cell Structure and Function
Content Outline: Types of Cells and Cell Structures (1.1) – Part 1

I. Cells and The Cell Theory
- A. Cells are considered to be the basic unit of life. (Part 1 of the Cell Theory.)
  - a. Proposed by Henri Dutrochet in 1837.
- B. All living organisms are composed of cells. (Part 2 of the Cell Theory.)
  - a. Proposed by Theodor Schwann and Matthias Schleiden in 1839.
  - b. Theodor Schwann worked with animal tissues.
  - c. Matthias Schleidenworked with plant tissues.
- C. All cells come from pre-existing cells. (Part 3 of the Cell Theory.)
  - a. Proposed by Rudolf Virchow in 1858
- D. The cell is an example of Emergent Properties. If you only have organelles, nothing can happen; but if you have all the organelles together and inside a membrane "life" can emerge.
- E. All cells are considered Open Systems in their natural settings because there are materials coming into the cell from the surrounding environment; as well as, materials leaving the cell and going into the surrounding environment. The cell is open to interaction with the environment.

II. Microscope Development
- A. Robert Hooke develops a simple lens microscope, in 1665. (It was basically like a magnifying glass.)
- B. Anton von Leeuwenhoek develops a compound (means "more than one lens") microscope in 1674.
- C. Two Principal Types of microscopes used today for studying cells are:
  1. Light Microscopes
     - a. These use lenses to magnify and direct light in relation to a specimen.
     - b. **Resolution** of light microscopes
       - i. This term refers to the *distance* that two points appear as *separate* points. When they are so close together that they appear as one, we have lost resolution.
       - ii. 2 micrometers (μm) is about the best light microscopes can offer in resolution.
     - c. The magnification capabilities of most light microscopes is up to 1000X.
     - d. Benefits vs. Drawbacks. The benefits of the light microscope are: we can look at living things, they are "fairly" cheap, and they are "fairly small". The drawback is they have limited resolution and limited magnification.
  2. Electron Microscopes
     - a. These use an electron beam pathway to produce an image of a specimen on a computer screen.
     - b. Two main types are in use today:
       - i. **T**ransmission **E**lectron **M**icroscopes (TEM) – used to look inside of a specimen.
       - ii. **S**canning **E**lectron **M**icroscope (SEM) – used to view the surface of a specimen.
     - c. Benefits vs. Drawbacks The benefits of these are that they provide much greater resolution and magnification. The drawbacks are they are very expensive, very large, and can only look at things that are dead.

III. **Cytology** is the study of cells; **Cytologist** – a person who works with cells.

IV. Cell Types that exist
- A. **Prokaryotic cells** ("pro" means "before" , "kary" means "nucleus", "ote" means "organism")
  These organisms (bacteria) would have evolved before a nucleus had evolved into existence. Most abundant cell type.
- B. **Eukaryotic cells** ("Eu" means "true")
  These organisms would have evolved after a nucleus had evolved into existence because they possess a nucleus.

V. Surface- to- Volume Ratio Importance
- A. Cells can only be so small. (There has to be *enough* room (volume) to hold things and to perform work inside a cell.)
- B. Cells can only be so large. (Larger means more traffic going in both directions across the cell membrane)
- C. A cell must be large enough to contain DNA, Ribosomes, and some cytoplasm. They can only be so big because we have to be able to move enough "Food" into and "waste" out of a cell efficiently. If it is too large the cell becomes inefficient at moving these things so it divides to get back to a smaller state.

Cell Structures - Part 2

I. There are three main parts to Eukaryotic Cells
   A. Plasma "cell" membrane (This holds the cell together.)
   B. Nucleus (This controls the activities of a cell by holding the DNA. The DNA is the "instructions".)
   C. Cytoplasm or cytosol (This creates room for work and space for holding organelles and ribosomes.)

II. Nucleus
   A. This acts as a control center for all activities performed by the cell. (Like the principal's office for a school.)
   B. It is the source of genetic information (DNA). It "acts as the vault for the million dollar blueprint of a cell".
   C. **Nuclear Envelope** (This acts as the actual "vault" to protect the DNA that is inside.)
      1. It is made mainly of a *double* membrane layer of Phospholipids.
      2. It also contains pores (tunnels) composed from proteins for molecules to travel through, such as nucleotides (from our food) to make messenger RNA. The messenger RNA leaves to help make proteins in the cytoplasmic "construction site".
   D. DNA (This is the "Million Dollar Blueprint".)
      1. **Chromatin phase** "The DNA is *loose*" (It would look like a bowl of plain spaghetti noodles.)
         a. A cell can move the DNA around to find the gene of importance.
      2. **Chromosome phase** "The DNA is *tightly wrapped up*." (This phase is used for separating the DNA *equally* during cell division. This way we hopefully get two equal sets. One set for each cell.)
   D. **Nucleolus** (This structure acts like a photocopier in your school.)
      1. This is the site of RNA synthesis. ("Synthe" means "to make"; "sis" means "the process of")(This is the making a *cheap, disposable copy* of DNA.)(We can make "messenger" RNA, mRNA, and send it to the cytoplasmic "construction site".)
         a. Lots of these structures are present during *repair*.
         b. It is also responsible for helping to make Ribosomes, which are mostly RNA structures.
         c. It also makes mRNA and other types of RNA molecules.

III. **Ribosomes**
   A. These are *cellular particles* made of ribosomal RNA, rRNA, and proteins. (These are *not* organelles… as <u>all</u> cell *types* have them so that <u>all</u> cells can make proteins and enzymes.)
   B. These are the sites of Protein Synthesis. (These are like an actual *construction site* for a building, except they make proteins and not buildings.)
      1. Normal proteins and enzymes are <u>all</u> made here.
   C. They are composed of two sub-units:
      1. Small sub-unit– Acts as a table or support structure for the actual protein "building process".
      2. Large sub-unit – Acts as the "factory" to make the actual proteins.
      3. *Both* must come together to work making proteins.
   D. Two types of ribosomes exist based on location:
      1. **Free Ribosomes**– These float "freely" in the cytoplasm of a cell. (They are found in <u>all</u> types of cells.)
         a. These ribosomes make proteins that will stay *inside* the cell for use by the cell.
      2. **Bound Ribosomes** – These are attached to the endoplasmic reticulum organelle (RER). (These are <u>only</u> found in Eukaryotes because *only* they have the organelle.)
         a. These make proteins that will *leave* the cell to be used elsewhere. (Most are for communication between cells or cell protection.)

Cell Structures – Part 3

I. Endoplasmic Reticulum (ER)

A. It is composed of a *network* of small tubes called **cisternae**. ("cisternae" means "tubes")
B. They are <u>always</u> found just outside and around the nucleus.
C. *Two types* of ER can exist inside Eukaryotic cells:
    1. **S**mooth **E**ndoplasmic **R**eticulum (SER)
        a. This structure helps with the *synthesis of lipids, phospholipids, and steroids*.
        b. Helps with carbohydrate breakdown. (Glycogen "stored sugar" to glucose "usable sugar".)
        c. Helps to detoxify the blood. (Liver cells are loaded with SER.
        d. Liver cells and muscle cells have lots of SER.
    2. **R**ough **E**ndoplasmic **R**eticulum (RER)
        a. This structure helps with *protein synthesis*. (Provides a water free environment for protein folding.)
        b. Ribosomes are bound to the outside of the organelle and depositing the protein inside as it is made by the ribosome. Inside the structure, the protein can fold up into the specific 3-D structure needed to function.

II. Golgi Apparatus

A. This structure *modifies proteins* by attaching sugars to them (What are called **Glycoproteins**)
    1. It is like "Gift Wrapping" to *disguise* the protein for export through the cell membrane.
B. They are also composed of flattened tubes also called **cisternae** (These look like a stack of pancakes.)
C. Please have students demonstrate the "pathway" for exo-protein synthesis - Nucleus, nucleolus, ribosome, RER, Golgi, cell membrane. Also for endo-protein synthesis – Nucleus, nucleolus, ribosome

III. **Lysosomes** (These act like a "stomach" for the cell.)

A. They are involved in *digestion and recycling* (autophagy) of molecules. Discuss intracellular and extracellular digestion. Give examples of each.
B. They are full of digestive enzymes. (**Lysozyme** is the name of the enzyme.)
C. The organelle is composed of a phospholipid *bilayer***.**

IV. **Vacuoles** and **Vesicles** (These act as "closets" for storage of materials.)

A. *Storage structures* for various products needed by the cell.
B. Various types can exist (Food, Contractile, Central)

V. **Endocytosis** – This is the process of bringing something *into* the cell. ("cyto" means "cell"; "sis" means "process of")

A. **Phagocytosis** – This is the process of cell "eating". ("phag" means "to eat")
B. **Pinocytosis** – This is the process of cell "drinking". ("pino" means "to drink")

VI. **Mitochondria** (Nicknamed the "Power House")

A. This organelle is involved in *making energy* by performing the process of *cellular respiration* inside it.
B. This organelle has it's own DNA, ribosomes, and enzymes inside it.
C. It has a "Room within a Room" Appearance.
    1. Cristae – the folded inner membrane (The folding *increases surface area* for making energy. This creates the inner most "room" called the Mitochondrial Matrix – inner skeleton with ribosomes present. The matrix is the site for the Kreb's Cycle of cellular respiration.)
D. The space between the membranes is important in cellular respiration.
E. Evolutionary Significance? (They were believed to have been purple bacteria. Remember bacteria are prokaryotes. They entered into a symbiotic relationship with a larger prokaryote that could provide protection in return for extra energy. Together they would have an evolutionary *advantage* over other bacteria. The advantage allowed them to survive and reproduce and eventually lead to Eukaryotic cells.)

VII. Chloroplasts

A. These organelles are the site of *photosynthesis* in plants and algae.
B. They are a type of plastid. (Plastid is a pigment containing molecule. These contain the pigments chlorophyll.)("phyll" means "pigment")
C. Has it's own DNA, ribosomes, and enzymes (ATP Synthase) too!
D. "Room within a Room" Appearance too!

1. **Thylakoid** – looks like a "green cookie rooms". (Site of the *light reaction of photosynthesis*. This is where sunlight energy is converted into "batteries". The "batteries" are ATP and NADPH. These "batteries" will be used to power the making of sugar in the Calvin Cycle.)
2. **Grana**- is a stack of "green cookies" or thylakoids.
3. **Stroma**- This is mostly *watery space* in between the thylakoids and outer membrane (This is the site of the *Calvin cycle* of photosynthesis. This is where the sugar is made.)

E. Evolutionary Significance? (They too were believed to have been blue-green bacteria that entered into a symbiotic relationship for protection in return for energy.)

VIII. **Endosymbiont** Hypothesis

A. This hypothesis was proposed by Lynn Margulis in the 1960's.
B. Define symbiosis and introduce common types of symbiotic relationships.
C. It basically hypothesized that Prokaryotes came to live together in a symbiotic relationship, the smaller living *inside* the larger, to gain a survival *advantage* over other prokaryotes and eventually they evolved into Eukaryotic cells over many generations that spanned hundreds of thousands of years.
    1. Smaller organism gained protection.
    2. Larger organism gained energy production or faster motility.

Cell Structures – Part 4

I. Cytoskeleton

A. This structure helps *support and protect* the cell. (Much like your skeleton does for you.)
B. It also helps to keep inner organelles *organized*. (Much like your skeleton does for you.)
C. It also helps in cell *motility* or cell organelle *movement* (Much like your skeleton helps you move.)
D. The cytoskeleton is composed of various sized protein fibers (Your skeleton has different sized structures too. (Largest – bones, middle – Ligament and tendons, smallest- muscle fibers)

1. **Microtubules** (largest)
   - These are *large, hollow tubes*.
   - They are composed of *Tubulin protein*.
   - There main function is support or movement.
   - They also function as guide supports for organelle movement within the cell.
   - Important structures made of microtubules within a cell:
     i. Centrosomes/Centrioles (These act as anchors during cell division.)
     ii. Spindle Fibers (Act as guides or "tow ropes" for the chromosomes during cell division.)
       - Used to move chromosomes during the processes of Mitosis or Meiosis.
     iii. Cilia
       - These help with cell movement. Cells usually have *a lot* and they are *small in length*.
       - They create a *wavelike* movement.
     iv. Flagella
       - These are also for movement. Cells usually have *few* and they are *very long* in length.
       - These create an *undulating (whipping*) movement.
2. **Microfilaments** (These are the *smallest* structures in the cytoskeleton.)
   - These are *solid rods*.
   - Composed of *Actin or Myosin protein.*
   - They provide a *pulling force*.
     i. They are abundant in muscle tissue.
3. **Intermediate Filaments** (These are *medium* sized structures.)("inter" means "between")
   - These are permanent, *solid rods*.
   - They are mostly composed of *keratin protein*.
   - They help to *reinforce* and brace the large microtubules.

II. **Cell Wall** of Plant Cells

A. Plant cells create this structure for *protection and durability*.(Basically, weight bearing.)
B. Composition of most plant cell wall:

1. **Primary Cell Wall** (Cellulose Sugar) (Found in all plant cells. It is not very strong by itself.)
2. **Middle Lamella** (Composed of Pectin Sugar.)
   a. The Pectin acts as super glue between cells to hold them firmly together. This helps them grow tall.
3. **Secondary Cell Wall** (Composed of Lignin sugar)
   a. The Lignin is found inside the primary cell wall allowing it to reinforce the primary wall. Thickest on the corners. This also helps them grow really tall.)

III. Extracellular Matrix (ECM)

A. This is the *outer protective "skeleton"* of the cell plasma membrane in *animal* cells. ("extra" means "outside of"; "matrix" means "skeleton")
B. It also functions in *communication* with other cells. (By using the glycoprotein like a blind man's hands.)
C. The ECM is composed mainly of Glycoproteins and Glycolipids ("glyco" means "sugar")

IV. Cellular Junctions (These act as stitching to "sew" cells together to make tissues.)

A. These help to hold cells together so that they may work together. ("junction" means "connection")
B. Some are tunnels for cell to cell communication.

V. A cell is the <u>sum</u> of its parts. (It is the basic unit of life only when all the parts work together to make "*life*" possible.) (This is an example of the *theme* of *Emergent Properties*.)

A. *Characteristics* of living things:

1. Composed of cells.
2. Responds and adapts to the environment.
3. Uses energy.
4. Grows and reproduces.