Eukaryotes: The Other Guys
Part I: Structure and Function

Eukaryotic Characteristics

- DNA found in membrane-bound nucleus.
- DNA associated with histone proteins.
- Contains membrane-bound organelles.
- Relatively simple cell walls.
- Cell division occurs by mitosis, producing two identical daughter cells.

Eukaryotic Cells

- These cells have membrane-bound structures called organelles.
- Cell processes occur in these organelles.
- An example of some common ones include the nucleus, ribosomes, endoplasmic reticulum, golgi body, vesicles, mitochondria, and cytoskeleton.
- Within the eukaryotes, however, are differences.

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 plasmodermata.
- 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

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- 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.

Let's take a visit to the ER

- The endoplasmic reticulum (ER) is the first part of the cytomembrane system (endomembrane system) that we will be exploring.
- The term *endoplasmic* means "within the cytoplasm" and *reticulum* means "little net".
- The endoplasmic reticulum of a cell is an extensive network of membranes that extends from the cell membrane through the cytoplasm to the nuclear membrane.

- The membranes of the ER surround an inner cavity called the lumen.
- There are also isolated spaces called vesicles, which turn out to be membrane-enclosed sacs.
- The membranes of the ER enclose a series of tubes and flattened membranous areas. The ER membranes actually attach to the cell membrane and the nuclear membrane as well as the Golgi bodies in the cytoplasm.

- Different regions of these membranes have a smooth or rough appearance.
- Rough ER is arranged as stacked, flattened sacs that have ribosomes attached to them.
- Smooth ER does not have ribosomes on them and curves through the cytoplasm.

ER Function

- The basic function of the ER is transport.
- Proteins produced by the ribosomes (on Rough ER) are transported to regions of the cell where they are needed or are transported to the golgi body for export from the cell.
- Smooth ER is associated with regions of the cytoplasm involved in detoxification of poisons and lipid synthesis.
- In fact, this is the main site of lipid synthesis in the cell.

- Smooth ER in liver cells inactivates certain drugs and harmful by-products of metabolism.
- In skeletal muscle, a type of smooth ER has a key role in muscle contraction.

Golgi Bodies

- Named after the Italian biologist Camillo Golgi.
- They are formed when small sac-like pieces of membrane are pinched away from the cell.
- They are composed of a stack of about half a dozen sacuoles.
- Their purpose is to prepare and store chemical products produced in the cell and then to secrete these outside the cell.

- Proteins (or other molecules) coming from the ER meet up with Golgi bodies (at cisternae) and are packaged in vesicles.
- The membranes of these vesicles then bond to the cell membrane and the contents of these vesicles are exported out of the cell.
- The number and size of Golgi bodies found in a cell depends on the quantity of chemicals produced in the cell.
- More chemicals = larger bodies (and more of them).
- How organelles cooperate in protein synthesis and transport.

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.
- Peroxisomes 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.
- The other type of peroxisome is found in all eukaryotic cells.

- These peroxisomes 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.

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 synthetase 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.

Vacuoles

- The vacuole is used only in plant cells.
- It is responsible for maintaining the shape and structure of the cell. Plant cells don't increase in size by expanding the cytoplasm, rather they increase the size of their vacuoles.
- The vacuole is a large vesicle which is also used to store nutrients, metabolites, and waste products.

- The pressure applied by the vacuole, called turgor, is necessary to maintain the size of the cell. If turgor is lost, the cell becomes flaccid. The vacuole typically is 50% of the volume of the cell, yet it can take up to 95% of the cell!

Cell wall

- It is a non-living secretion of the cell membrane, composed of cellulose.
- Actually, it is composed of cellulose fibrils deposited in alternating layers for strength.
- It contains pits which make it permeable.
- Its primary function is to provide protection from physical injury.
- Together with the vacuole, it provides skeletal support.

Cytoskeleton

- Cells contain elaborate arrays of protein fibers that serve various functions including establishing cell shape, providing mechanical strength, locomotion, chromosome separation in mitosis and meiosis, and intracellular transport of organelles.
- The cytoskeleton is made up of three kinds of protein filaments. They are: actin filaments (microfilaments), intermediate filaments, and microtubules.

Actin Filaments

- Monomers of the protein actin polymerize to form long, thin fibers. These are about 8 nm in diameter and, being the thinnest of the cytoskeletal filaments, are also called microfilaments.
- Actin filaments form a band just beneath the plasma membrane that provides mechanical strength to the cell and links transmembrane proteins to cytoplasmic proteins.
- Also, the band that is formed anchors the centrosomes at opposite poles of the cell during mitosis.

- During cytokinesis, it pinches dividing animal cells apart.
- Another functions of actin filaments include the generation of locomotion in cells and the interaction with myosin to provide the force of muscular contraction.

Intermediate filaments

- These are cytoplasmic fibers that average 10 nm in diameter.
- There are several types of intermediate filament, each having one or more proteins characteristic of it.
- Keratins are found in epithelial cells and also form hair and nails.
- Nuclear lamins form a meshwork that stabilizes the inner membrane of the nuclear envelope.

- Neurofilaments strengthen the long axons of neurons and vimentins provide mechanical strength to muscle cells and others.
- Despite their diversity, intermediate filaments play similar roles in the cell: to provide a supporting framework within the cell.

Microtubules

- Microtubules are straight, hollow cylinders that have a diameter of about 25 nm and are found in both animal and plant cells.
- They are variable in length but can grow 1000 times as long as they are thick.
- They are built by the assembly of dimers of alpha tubulin and beta tubuln

Tiny little motors

- There are two major groups of microtubule motors: kinesins and dyneins.
- The migration of chromosomes in mitosis and meiosis takes place on microtubules that make up the spindle fibers.
- Both kinesins and dyneins are very important in this regard.
- In plant cells, microtubules are created at many sites scattered through the cell. In animal cells, the microtubules originate at the centrosome.

The Centrosome

- The centrosome is located in the cytoplasm attached to the outside of the nucleus.
- Just before mitosis occurs, the centrosome duplicates.
- The two centrosomes move apart until they are on opposite sides of the nucleus and the microtubules grow from them resulting in a spindle fiber.
- In addition to their role in spindle formation, they signal that it is o.k. to proceed to cytokinesis.
- Centrosomes also signal that it is o.k. for the daughter cells to begin another round of the cell cycle.
- Cancer cells often have more than the normal number of centrosomes. They also have an abnormal number of chromosomes. So, might there be a correlation between the two?

Centrioles

- Each centrosome contains a pair of centrioles.
- They are built from a cylindrical array of 9 microtubules, each of which has attached to it 2 partial microtubules.
- Centrioles appear to be needed to organize the centrosome in which they are embedded .
- Sperm cells contain a pair of centrioles, but eggs have none. The sperm’s centrioles are absolutely essential for forming a centrosome (which will form a spindle) enabling the first division to take place.
- Centrioles are also needed to make cilia and flagella.

Cilia and flagella

- Both of these are constructed from microtubules and both provide either locomotion for the cells or move fluid past the cells.
- Both cilia and flagella have the same basic structure.
- 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.
- There is a very big difference between eukaryotic flagella and bacterial flagella.