Biology: Unit 1

Cells

Cell Theory

- All living organisms are composed of cells
- All cells come from pre-existing cells
- Cells are the basic structural and functioning units of a living organism
- Cells are the smallest living things

Size

- 1 um – 50 um in diameter
- Compared to viruses: 2-20 um
- Compared to molecules: 10A

Types (in order of increasing size)

- Bacteria (Prokaryotic, simplest)
- Yeast (Eukaryotic, but simple)
- Animal cells (Large, complex, eukaryotic)
- Plant cells (Large complex eukaryotic)

Organization (Cells are NOT simple)

- **Spacing**
  - They are usually around other cells and are sometimes packed close together. Plant cells are almost always packed like this. Other times, they'll be floating around (ex. red blood cells). Bacteria colonies can start with one cell
- **Shape**
  - Plant cells have a defined shape, usually rectangular shape (hence they can pack closely)
  - Animal less have a less defined shape, somewhat spherical (hence they are less tightly packed)
  - Bacteria cells come in 3 main varieities: Spherical (cocci), rod-shaped (bacilli), and helices (spirali).
- **Interior**
  - Prokaryotes: No special compartments. The circular DNA floats around the cell. The cytoplasm in prokaryotes contains water and dissolved nutrients.
  - Eukaryotes: They have a nucleus that is spherical and contains the DNA and many types of organelles. There are other compartments that exist too, which are called organelles. Those will be covered in greater detail later.
- **Exterior**
  - Animal cells have nothing outside their cell membrane
  - Plant cells have a cell wall outside of their membrane. It gives the cell its rigid shape
  - Bacteria cells from a rigid plasma outside of the membrane when "scared".

Membrane

- **General info**
  - The cell membrane is described as a fluid mosaic. In a fluid, things move around. A mosaic is built of several components. The cell membrane is composed of "phospholipids".
- **Components**
  - Phospholipids: Molecules that constitute the inner bi-layer of biological membranes, having a polar hydrophilic head, and a non-polar hydrophobic tail. The hydrophobic and hydrophilic parts of each phospholipids molecule make up the "phospholipid bi-layer". The phospholipids keep the things that are on the inside of a cell inside, and keep what things are outside the cell on the outside.
  - Integral (membrane) protein: Protein that is firmly anchored in a membrane. They recept/intercept hormones and they transmit messages from outside the cell to inside (and vice-versa). They have a binding site on the cell's outside (hormone receptors) and the inside.
  - Peripheral (membrane) protein: Protein that loosely adheres to a biological membrane. They take messages from the integral proteins further into the cell.
  - Cholesterol: A waxy, fatty substance found in tissues throughout the body. It acts as a "grease" in order to help maintain membrane fluidity. That way, the cell membrane doesn't fall apart.

- Protein channel: An aqueous pathway through a protein molecule in a cell membrane. They allow certain molecules in and out of a cell, but they are very specific for a certain kind of molecule.
- Glycoprotein: Proteins with covalently attached carbohydrates. They are important for white blood cell recognition
- Glycolipid: Membrane lipid molecule with a short carbohydrate chain attached to a hydrophobic tail. They provide energy and also serve as markers for cellular recognition.

- **Functions**
  - The cell membrane's main function is transporting nutrients into cell and waste out
  - Animal cells want: O2, H20, C6H12O6 (glucose), ions (Na+, K+, Cl-), and amino acids (protein building blocks)
  - Animals cells don't want CO2 and molecules they can't turn into energy
  - How does transport happen?
  - Active Transport (needs energy)
    - *Pinocytosis*
      - The cell will take in the dissolved nutrients by pinching off a small portion of the membrane. The pinched off membrane with the dissolved nutrients inside is now a vesicle
      - The vesicle will enter the cell and transfer its contents to the cytosol (the semifluid portion of the cytoplasm)
      - Shortly, a new vesicle forms inside the cell containing the waste, moves to the cell membrane and then fuses with it, releasing the waste outside of the cell
    - *Phagocytosis*
      - The process for phagocytosis is the same as pinocytosis, except that it involves undissolved nutrients rather than dissolved ones
    - *Protein pump*
      - This is a transport protein responsible for maintaining a specific molecule in a specific concentration across a cell membrane.
      - A protein pump will store energy by concentrating an ion/molecule on one side of the membrane. As the substance moves back across the membrane through transport proteins, it escorts other substances into the cell
      - The protein pump process is different from simple diffusion because energy is actually involved when concentrating the ion/molecule on one side. Also, the protein pump has a closed end, whereas in diffusion, both ends of the protein are open.
  - Passive Transport (does not need energy)
    - *Diffusion*
      - The spontaneous tendency of a substance to move down its concentration gradient from a more concentrated to a less concentrated area
    - *Osmosis*
      - The diffusion of water across a selectively permeable membrane
    - *Facilitated Diffusion*
      - The spontaneous passage of molecules and ions, bound to specific carrier proteins, across a biological membrane down their concentration gradients

Eukaryotic cells vs. Prokaryotic Cells (Credits go to Dr. Cheeseman)

Aspect	Prokaryotic cells	Eukaryotic cells
DNA	free floating, circular	organized into chromosomes (shorter pieces) in a contained organelle (nucleus)
Ribosomes	50 S + 30 S = 70 S	60 S + 40 S = 80 S
Mitochondria	none	lots
Organization	no organelles	many organelles

Organelles

Cell Membrane ("Gate Keeper")
- Responsible for the controlled entry and exit of molecules
- Thin and nearly invisible structure that surrounds the cytoplasm of the cell

Cell Wall
- Provides and maintains the shape of cells and serves as a protective barrier
- Only found in plant cells

Chloroplast (“Food Factory”)
- Contains the plant cell’s chlorophyll. Produces food, turns sunlight into food for the cell (photosynthesis). Helps give plant its green colour
- Only found in plant cells

Cytoplasm (“Cell Jello”)
- Allows the cell to take up 3-dimensional space and the cell's many organelles to "float" freely throughout
- Gel-like substance in which all cellular components outside of the nucleus are immersed.

Cytoskeleton (“Framework”)
- Helps maintain the cell shape, motility and internal movement

Endoplasmic Reticulum (Rough)
- Ribosomes are attached to the cytosolic side of the membrane
- Transports synthesized proteins to the regions in the cell where it is needed

Endoplasmic Reticulum (Smooth)
- Important in synthesis of lipid and membrane proteins
- lacks attached ribosomes and often appears more tubular than rough ER

Golgi Bodies (“Packagers”)
- Composed of a stack of about half a dozen sacuoles
- “Prepare and store chemical products produced in the cell, and then to secrete these outside the cell

Lysosome (“Suicide Sacs”)
- Responsible for digestion of products/“nutrients”
- Responsible for cell suicide

Mitochondria (“Powerhouse”)
- Provides the energy a cell needs
- Powerhouse of the cell and contains the molecular machinery for the conversion of energy

Nucleus (“Brain”)
- Where DNA, which is responsible for providing the cell with its unique characteristics, is located
- Where the chromosomes are separated from the cytoplasm by the nuclear membrane.
- It is a spherical, sometimes elongated structure

Nuclear Membrane
- A structure that binds the nucleus within the cell
- Surrounds the nucleus
- Composed of two layers and has numerous openings for nuclear traffic

Nucleolus
- Produces ribosomes, moves the rough ER and is critical in protein synthesis
- Composed of DNA, RNA and protein
- Disappears during cell division but reappears in the final stage of mitosis.

Peroxisome
- Responsible for protecting the cell from its own production of toxic peroxide
- Contains oxidative enzymes

Pinocytic Vesicle
- Stores water for the cell

Vacuole (“Storage”)
- Membrane-bound sac responsible for cell storage, cell digestion, and waste removal
- Found in plant cells only

Ribosome (“Protein Factory”)
- Serves as the site of protein synthesis in the cytoplasm
- Small organelles composed of ribosomal RNA and 80 some different proteins

Plastids
- The synthesis and storage of food
- Found in plant cells only

Phagocytic Vesicle
- The mouth of the cell that stores food
- Found in animal cells only

Cilia (“Hairs”)
- Projections from the cell, designed to move the cell or substances around the cell
- Found in animal cells only

Centrioles
- forms spindle fibres to separate chromosomes during cell division
- Found in animal cells only

Nuclear Pore
- Allows the transport of water-soluble molecules across the nuclear envelope

Mitosis (Credits go to Dr. Cheeseman)

Stage	# of chromosomes	description
Interphase	2	-Cell functions normal -DNA remains uncondensed
Early Prophase	4	-DNA replication and condensation into chromosomes
Late Prophase	4	-chromosomes form homologous pairs -centrioles begin forming spindle complex
Metaphase	4	-chromosomes line up at cell equator on the spindle complex
Anaphase	4	-chromosomes move to one pole or other
Telophase	2 (per daughter cell)	-cell divides cytoplasm and other cell components -membrane pinches off in middle to form two identical daughter cells

Lab Results (Credits go to Natasha for the following summaries)

Lab 1.1 Cells: Microscope Mini-Lab

In this lab, we observed various pre-prepared slides under the microscope. Nothing too complex going on here.

Allium root: Plant cell (onion family)

Note the various stages of mitosis. The meristemic (part that divides the most) nature of the root cells makes it great for the study of mitosis.

Fish Blastula: Animal cell (fish embryo)

Clostridium botulinum: Bacteria responsible for producing the neurotoxin *botulin*→ Botulism and Botox.

Stuff you should retain:

1- How to use a microscope.
2- How to distinguish between animal, plant and bacterial (prokaryotic) cells.
3- General size of various cell types. (Eukaryotic: 1µm to 50, Prokaryotic: 0.2µm and 700µm(or so tells me the internet, the number seems a bit odd))
4- How to make proper biological drawings to scale (Dr. Cheeseman has a file concerning this on his website). This includes calculating the field of vision as well as magnification.

Lab 1.2- Cell Size: Is Bigger Better?

Various sized cubes of agar jelly (with phenolphthalein) are cut. They are all placed in a 0.1 Mol Sodium Hydroxide (NaOH) solution for a set period of time. Cut the cubes in half. You then measure the width of the pink band around the side of the cubes, which you then use to determine the volume of the area affected by osmosis.

Why the pink area? : This is the area in which the phenolphthalein from the cube has reacted with the NaOH from outside the cube, giving you an accurate view of which parts were affected by osmosis.

Verdict: ~~Busted~~ ... A larger surface area does mean that more of the "cell" will be affected by osmosis by *volume*, but it means that a smaller *percentage* of it will be affected.

Stuff you should retain:

1- Cells are small because once they reach a certain size, large portions of it would not be able to get nutrients and whatnot in sufficient quantities. This is why a large internal vacuole is important (and why in plant cells, the vacuole grows, the amount of cytoplasm does not).
2- Phenolphthalein turns pink in acid.

Lab 1.3- Planning Lab

Find a variable that might affect diffusion and find a way to reliably vary it. People tended to use heat, surface area, and concentration as variables.
Three factors that affect the rate of diffusion are temperature, the concentration difference between the two compartments, and the surface area of the membrane. Temperature affects diffusion because it makes the molecules move faster, therefore increasing the rate of diffusion. When there is a greater concentration difference between the two compartments, the rate of diffusion increases. If a membrane's surface area is increased, the probability of a molecule going through is also increased. Therefore, an increase in surface area means an increase in the rate of diffusion.

Lab 1.4 Cell Membrane: Diffusion & Osmosis

More slides under the microscope. This time, you'll be making your own wet mount.

Distilled water # 1: Basically: too much water around the cell, not enough inside (concentration-wise). The water will start to enter the cell in order to reach some sort of equilibrium, making the cells **hypotonic**. You might notice that the cells seem a bit swelled, depending on how long you keep the water in there.

Saline (salt) solution: This time, it's the opposite. The salt is too large to enter the cell itself in any sort of noticeable quantity, so something else has to happen to regain the equilibrium of concentrations. To do this, the water from inside the cell "migrates" to the outside of the cell. The cells become **hypertonic.** You'll notice that the cell seems to shrink, except for the cell wall which is too rigid to do much.

Distilled water # 2: A lot of the cell's water has left it, so the cell will take on water much more quickly than before. The cells will become hypertonic yet again, and the gap between the cell membrane and wall will cease to be.

Stuff you should retain:

1- The terms hypertonic, hypotonic, osmosis and diffusion (Hypertonic describes water leaving a cell, and hypotonic describes water entering a cell)
2- Nature "likes" a balance. Concentrations will use whatever ways possible to have the same concentrations as their environment.

Check out this diagram on turgor if you're more of a visual learner.

Lab 1.5a - **Selectivity of Membranes**

One dialysis tube is filled with a starch suspension, another with a glucose solution.

Starch: When placed in a water and Lugol iodine solution, the starch inside the dialysis tube turns navy blue.

What does this tell us? : The starch is too large to leave the dialysis tube, so the reaction must happen in the tube itself.

Glucose: When placed in a solution of water and Benedict's solution and heated, the water/Benedicts solution turns an opaque orangy-red colour. The inside of the tube remains mainly unchanged though.

What does this tell us? : The Benedict's solution is too large to enter the tube, so the reaction must happen outside the dialysis tube (heat must be added).

Stuff you should retain :

1- Not everything can pass through everything : humans can't pass through screen doors, but atoms can.
2- Benedict's solution detects glucose and Lugol's iodine solution detects starch.
3- Concentrations try to reach equilibrium.

Lab 1.5b- Molasses

A dialysis tube filled with molasses is placed in a water bath.
The water will try to reach some sort of balance on either sides of the tube, so water will go in. More water will mean that the more matter is inside the tube, this will make it weigh more.

Lab 1.6 Cell Membrane: Osmosis and Turgor in Living Cells

Potato cylinders are placed in glucose solutions of various concentrations.
The water from inside the potatoes will migrate to the outside of the cell to equalize the concentrations. This will make the potatoes lose mass (and become really bendy!).

Note: Depending on how long you left the potatoes in there, the 0.1 Mol and 0.2 Mol solutions may have made the potatoes gain some weight. That may be because the potatoes themselves have a concentration of natural sugars higher than 0.2 Mol, making the water from the glucose solution go inside the potato. This will make it weigh a bit more.

Lab 1.7 Cell Membrane: Effects of Temperature on Membrane Permability

This lab is very similar to the potato lab. Small cylinders of beet are placed in the same amount of distilled H_20. The variable that is changed in this one is temperature.
Basically what you're trying to do is break the cell wall so as to release the red pigment found inside the beet cell. The concentration of pigment is measured using the spectrophotometer.

Freezer tube: When water freezes, it forms large crystals that would in turn break the cell wall. This is why it released so much pigment.

Fridge tube: The stress the cell underwent here is not all that extreme, so not all that much pigment was released.

20° tube: Same as the tube in the fridge.

40° tube: The heat managed to expand the cell a bit and fracture the cell wall, a bit more pigment was released.

55° tube: The heat was more extreme, so more pigment was released.

70° tube: The heat was even more extreme, so even more pigment was released.

Things you should remember:

1- Temperature changes stress the cell, sometimes damaging the cell wall.
2- Know what a spectrophotometer is (a device for measuring light intensity that can measure intensity as a function of the color, or more specifically, the wavelength of light). It is set at 460 nm because the pigment molecules escaping the beet roots absorb that particular wavelength. The spectrophotometer can show us the concentration of that pigment and thus tell us how much of it was released.