Biology 2201 Chapter 4 Notes **NAME:**_____

Chapter 4 – Cells Up Close: Processes that Sustain Life

4.1 – Developing the Cell Theory

Cell Theory

- People have only known about the existence of cells for only the _____ or so.
- Essential scientific developments such as the invention of the _____ and fundamental breakthroughs regarding the theory of _____ allowed scientists to formulate the _____.

Abiogenesis

- Before people knew about the existence of cells, the leading belief was _____, the idea that _____ _____.
- These beliefs came from _____and experiments_____.

- **Some (Not So Factual) Observations**

- ***There were many "supporting" ideas for abiogenesis:***

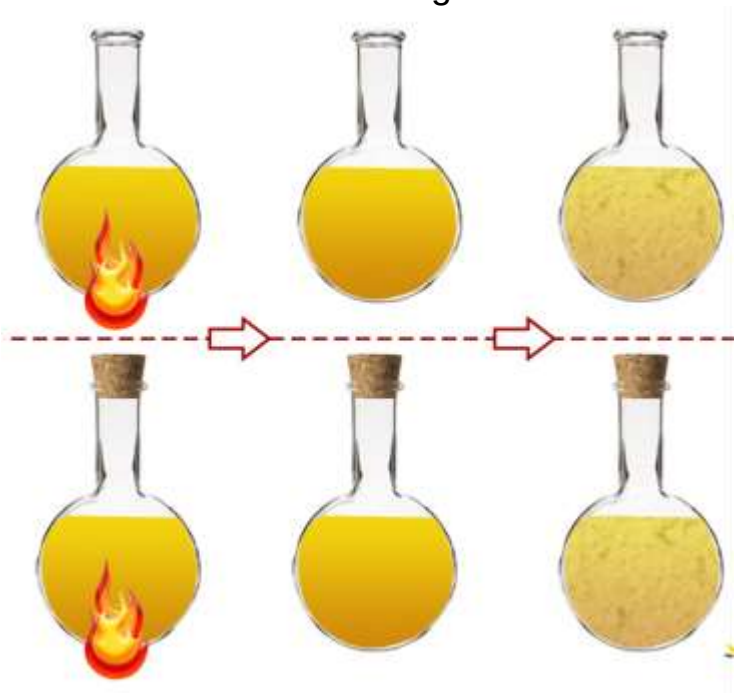
1) Maggots suddenly appeared on uncovered meat after several days.

2) Frogs and salamanders suddenly appearing on or in mud.

3) ***Jan Baptista van Helmont***

4) ***John Needham***

- HIs experiment with meat broth teeming with microbes after being boiled.

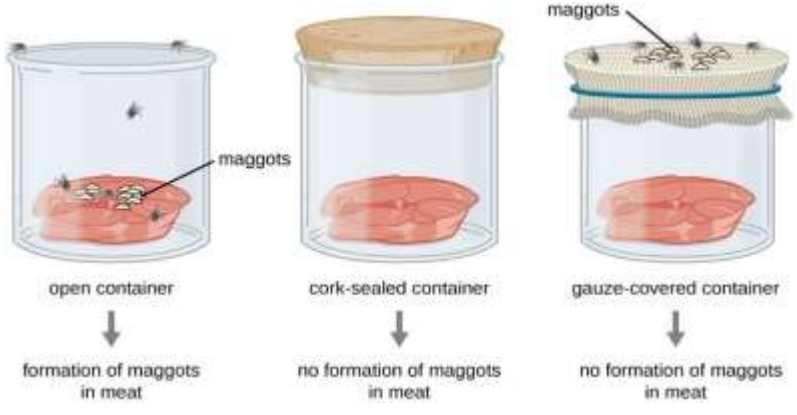


BIOGENESIS

- It is now accepted that the theory of _____ is correct whereby _____ _____.
- Over time, through the conduction of _____using the scientific method, biogenesis was proven.
- This was an example of a major scientific _____.

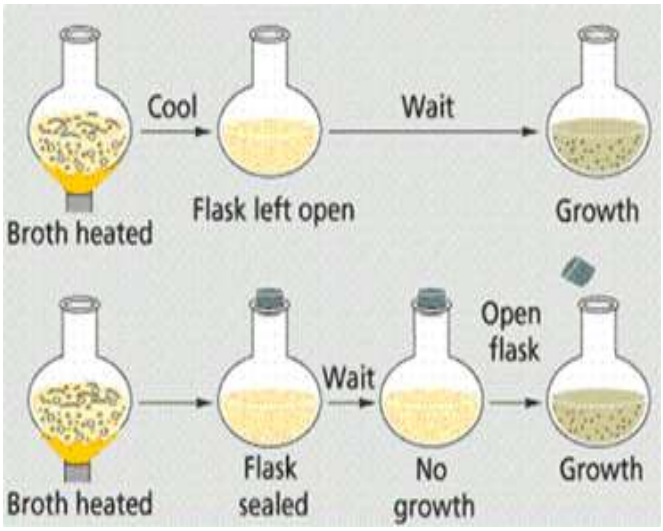
Redi (1626–1697)

- In the 1600's , Francesco Redi conducted one of _____.
- He used meat in jars, half covered with mesh and half open (_____ _____).
- After several days he found that the mesh-covered meat had _____, while the open jar _____.



Spallanzani (1729–1799)

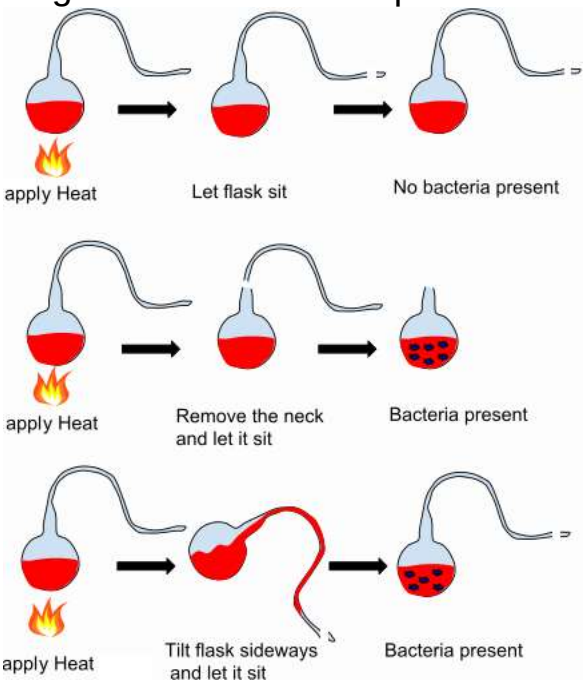
- Lazzaro Spallanzani repeated Needham's experiment
- This time the broth was _____.
- No life appeared in the sealed flask, while the open flask had _____.
- Naysayers said that boiling the broth "_____" that made life arise from non-living matter like water.



Louis Pasteur (1822-1895)

- He conducted experiments that finally _____, concluding that _____.

The infamous _____ showed that microorganisms come from other microorganisms in air and liquids



Cell Theory – 4 Key Ideas

1) All organisms are _____.

2) Cells are the _____ of _____in all organisms.

3) All cells come from other _____.

4) The activities of a multicellular organism depend on the _____.

Microscopes

- Most cells are TOO SMALL to be seen ***macroscopically*** (_____ _____), but can be seen very effectively with _____.
- Microscopes were key to the development of _____ and the study of cells. They remain an important tool for anyone studying cells.
- With the ability to magnify objects as much as 2000 times their actual size, biologists were able to observe _____.

Robert Hooke

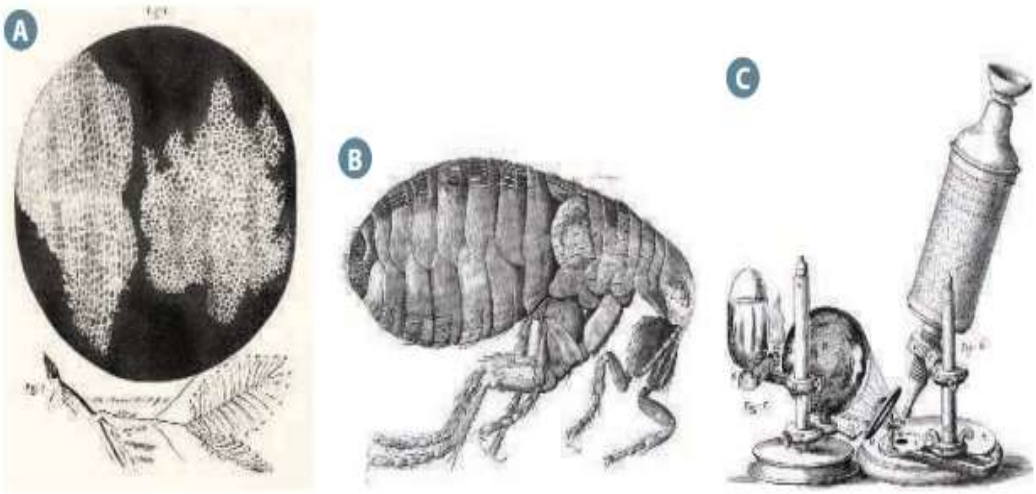
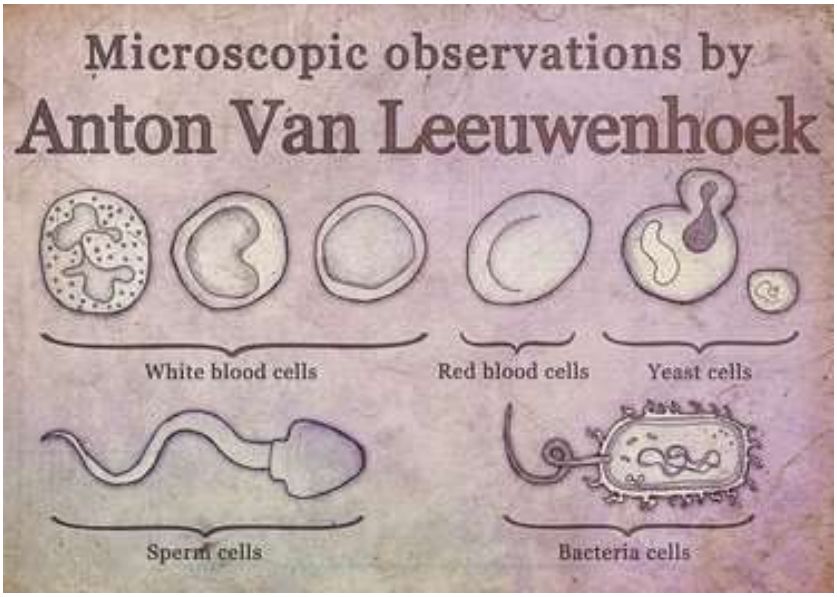


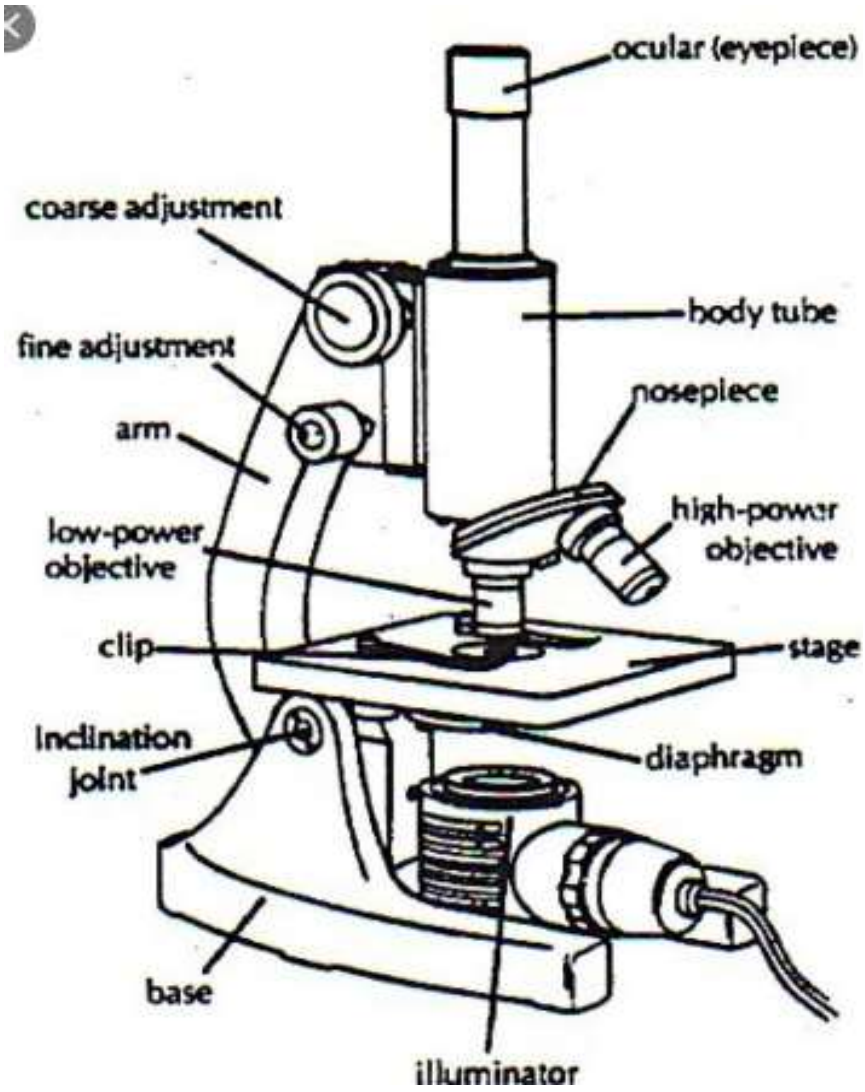
Figure 4.3 Robert Hooke examined cork **(A)** and other objects such as insects **(B)** using microscopes of his own design **(C)**. Hooke chose the name *cells* for the little units he saw in cork because they looked to him like the cubicles in which monks studied and prayed, which were called *cellae* in Latin.

Antoni van Leeuwenhoek (1660s)

- He read Hooke's Book and designed his own _____microscope – much more powerful and clearer than any existing microscopes at the time.
- He reported observing little "_____", what we now know is _____.



- Recall from junior high science the parts of a compound light microscope and how to use a microscope →



- We will also discuss ***magnification, resolution, depth of field, field of view, estimated size of objects viewed, wet mount slides, and proper biological drawings***.

Magnification

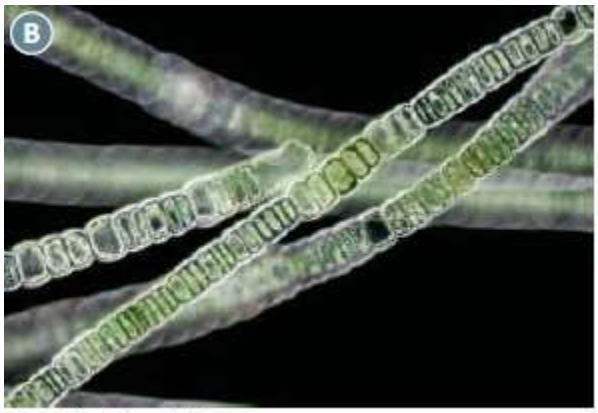
- Magnification describes _____.
- The total magnification of a compound light microscope is determined by the following formula
  - _____
    - Example = 10 x 40 (highpower)
      = 400 x magnification

Resolution

- AKA _____
- Resolution is the ability to distinguish _____, and thus _____.

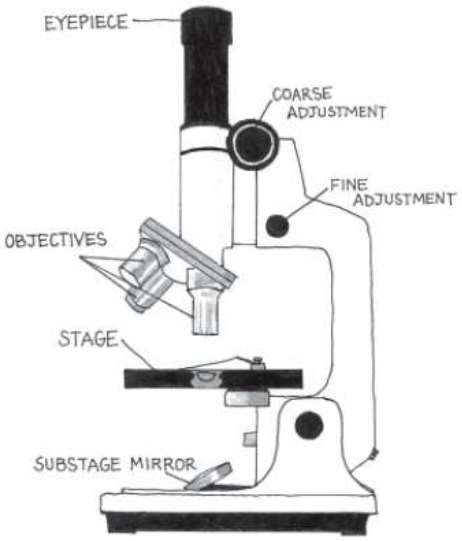
Depth of Field

- Depth of field is the _____ from the _____.
- Microscopes have a _____depth of field, usually measured in micrometres (µm). If a specimen is too thick, only a portion of it will be in focus at one time.
- Note: _____



Magnification: 200 ×

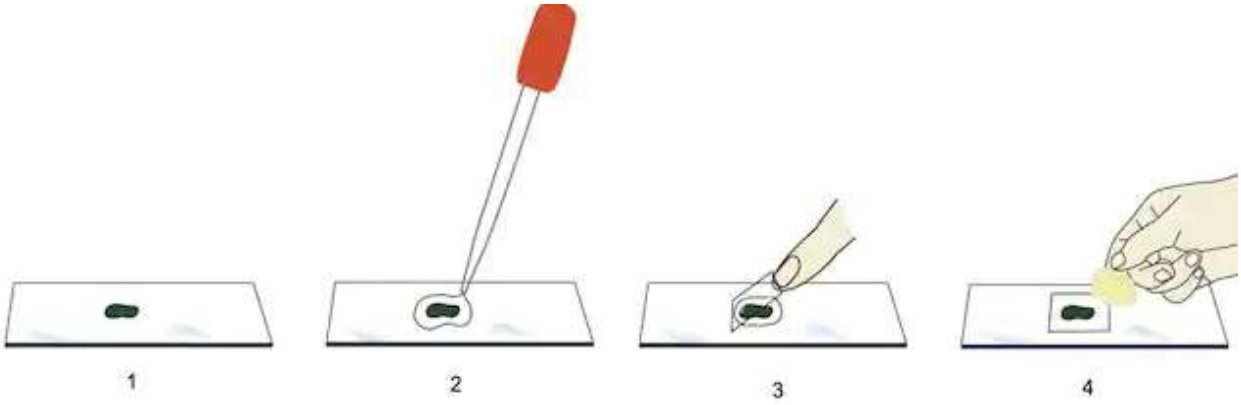
How to Use a Compound Light Microscope



1. When moving the microscope, **ALWAYS** grasp the arm with one hand and place the other hand under the base for support. Place the microscope on a level and stable surface.
2. Turning the revolving nosepiece so that the lowest power objective lens is "clicked" into position. The lowest power objective is the shortest one.
    - This objective lens is the easiest to focus and center the image in the field of view.
3. Microscope slides should always be prepared with a cover slip or cover glass over the specimen. Hold the slide on the stage by fastening it with the stage clips.
4. Turn the coarse focus knob so that the stage moves upward toward the objectives. Move it as far as it will go without touching the slide.
5. Look through the eyepiece and adjust the illuminator and diaphragm until you attain the maximum, comfortable level of light.
6. Turn the fine adjustment knob, as necessary, for perfect focus.
7. Move the microscope slide around until the sample is in the centre of the field of view.
8. Once you have attained a clear image, you should be able to change to a higher power objective lens.
    - **BE CAREFUL TO NOT LET THE LENS TOUCH THE SLIDE.**
    - You may have to move the stage down with the coarse adjustment knob.
    - **NEVER** use the coarse adjustment knob with the highest power lens in place.
9. If you lose your specimen, start from the beginning and the lowest power lens.

How to Prepare a Wet Mount Slide

1. Used for aquatic samples, living organisms and natural observations, wet mounts suspend specimens in fluids such as water, brine, glycerin and immersion oil.
2. Place a sample in the center of the slide.
3. Using a pipette/eye-dropped, place a drop of water on the specimen.
4. Place an edge of the cover slip over the sample and carefully lower the cover slip into place using a toothpick/your fingers. This method will help prevent air bubbles from being trapped under the cover slip.



How to Calculate Magnification

- The value of the objective lens traditionally go 4x, 10x, 40x, and 100x.
    - It should state the magnification on the objective lens.
- However, there is also the eyepiece to consider, which is usually 10x.
- So, we can use the following formula:

$$Total\ Magnification\ =\ (magnification\ of\ eyepiece)\ \cdot\ (magnification\ of\ objective\ lens)$$

❖ Example 1: You are looking at a cell with a 10x eyepiece and a 4x objective lens. What is your total magnification?

How to Calculate Diameter of the Field of View

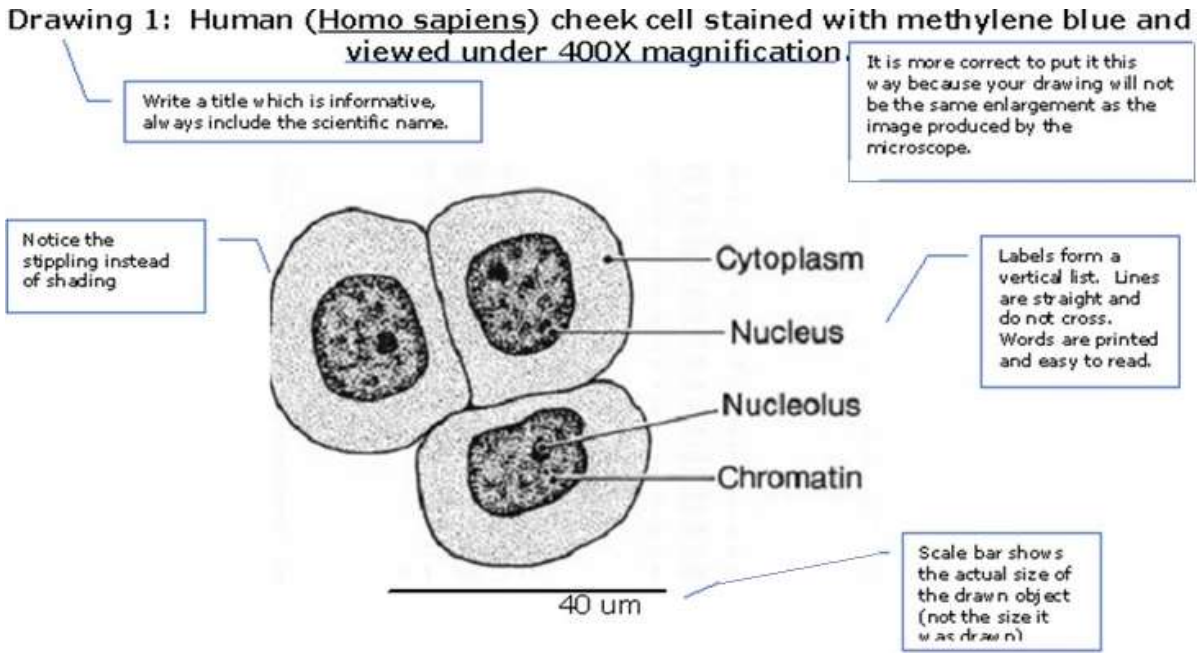
1. Place a transparent ruler under the low power objective lens of a microscope.
2. Focus the microscope on the scale of the ruler, and measure the diameter of the field of vision in millimeters.
3. This will work for the low power objective lens, but not necessarily for the higher power ones… so we can use this formula!

$$field\ of\ view\ =\ diameter\ of\ low\ power\ objective\ \cdot \frac{magnification\ of\ low\ power\ objective}{magnification\ of\ high\ power\ objective}$$

❖ Example 2: You measure your field of view diameter to be 4.0mm on the low power objective lens (4x). What would your field of view diameter be for a high power objective lens (40x)?

How to Make a Biological Lab Drawing

- Use a pencil and unlined paper when drawing a biological diagram. Draw only what you actually observe, as opposed to what you think you should be seeing.
- Represent darker areas of an object with stippling or dots. Do not shade any areas of the diagram.
- Use sharp single lines to represent an object. Do not use soft lines characteristic of sketches. Make the illustration large so that various parts of the specimen are easily distinguishable.
- Draw scale bars indicating the length and width of a specimen. A scale bar is a straight line that represents the relationship between space on your page and the actual space occupied by the specimen.
- Use a ruler to draw straight, horizontal lines in order to label different parts of the specimen. The labels should form a vertical list. All labels should be printed.
- The title should state what has been drawn and what lens power it was drawn under.

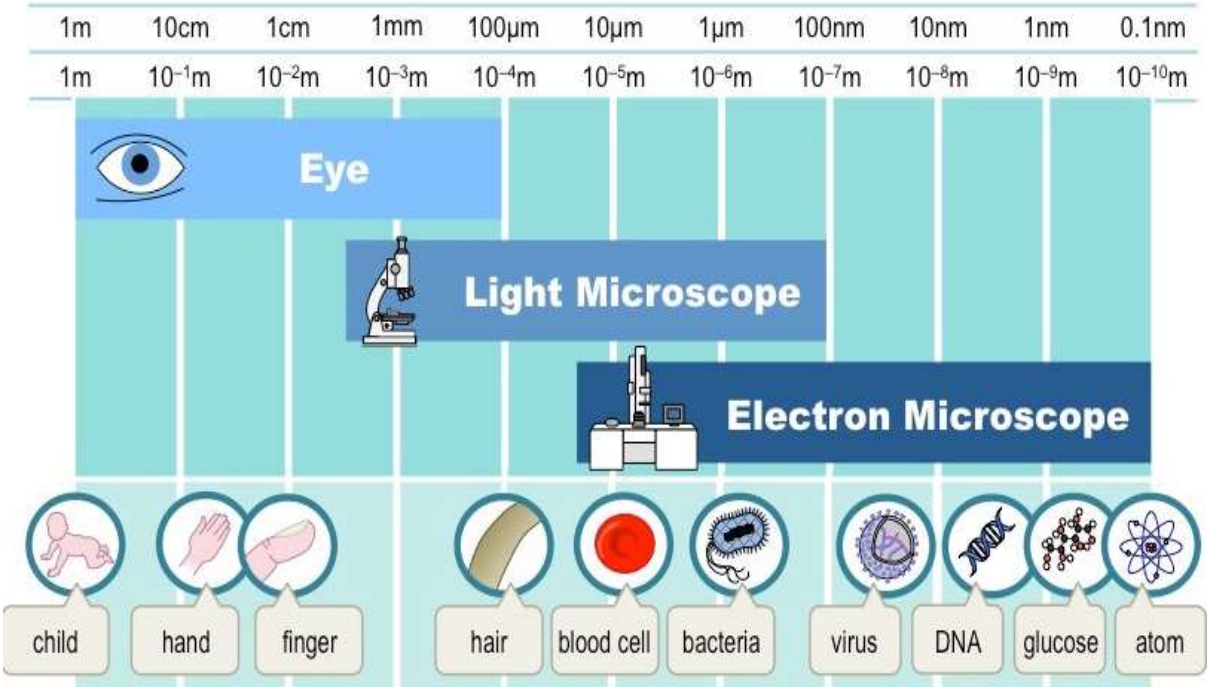


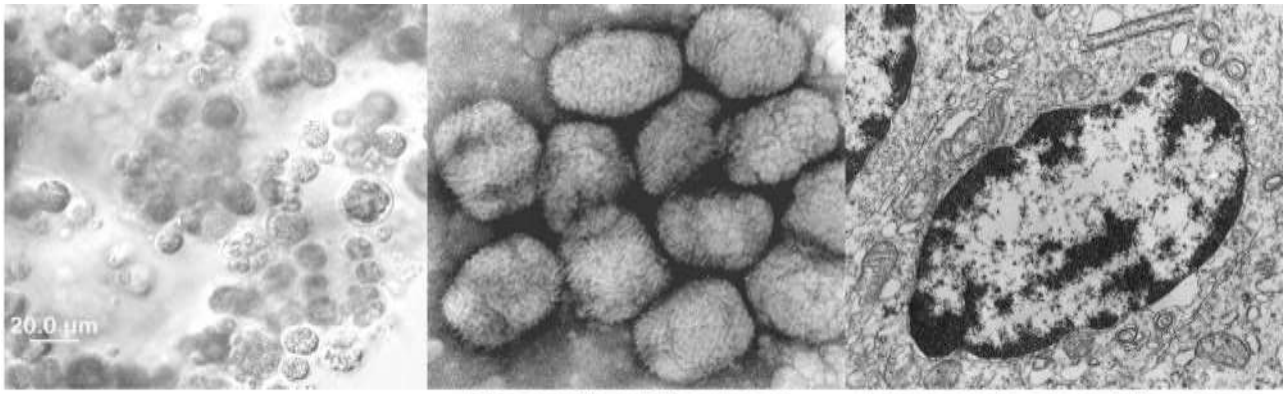
How to Estimate the Size of a Specimen

1. Objects observed with microscopes are often too small to be measured conveniently in millimeters
2. Estimate what fraction of the diameter of the field of vision that the object occupies.
    - In other words, estimate how many times your specimen can fit into the field of view.
3. Divide your field of view diameter by how many times your specimen will fit into the diameter.

❖ Example 3: You observe a cell under a medium power lens. You've measured the diameter of the field of view to be 2.0 mm. You estimate that the cell will fit into the diameter of the field of view about 5 times. What is the size of the cell?

TYPES OF MICROSCOPES





Light Microscope | Scanning Electron Microscope (SEM) | Transmission Electron Microscope (TEM)

Compound Light Microscope

- Compound light microscopes _____and use multiple lenses to produce a magnified image (_____**).**
- Can see _____, and few cell structures.
- Resolution limited to about _____.

Fluorescence Microscope

- Fluorescence microscopes _____given off by _____specimens or specimens stained with _____.
- Magnification range: _____
- _____ on specimens to make them fluoresce

Transmission Electron Microscope (TEM)

- Electron microscopes use electromagnets to focus a narrow beam of electrons on a specimen to produce a magnified image (up to 1 000 000×).
- Specimens are embedded in plastic, _____, and stained with a heavy metal or salt of a heavy metal.
- Produces a _____.
- _____.

Scanning Electron Microscope (SEM)

- ¨Magnification is over _____.
- ¨Resolutions _____.
- Specimen is sprayed with _____with a narrow beam of electrons.
- ¨An electron detector produces _____of the specimen on a TV screen.

Atomic Force Microscopy

- Magnification range: _____
- _____of the specimen is needed.
- Metal-and-diamond probe scans surface of specimen; responding movements of probe are used to produce three-dimensional image in near-atomic detail

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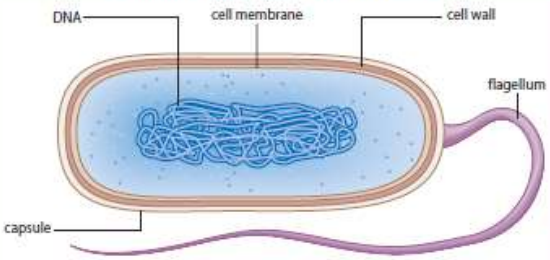
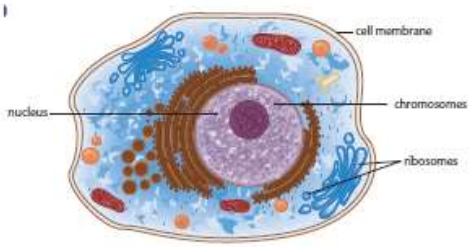
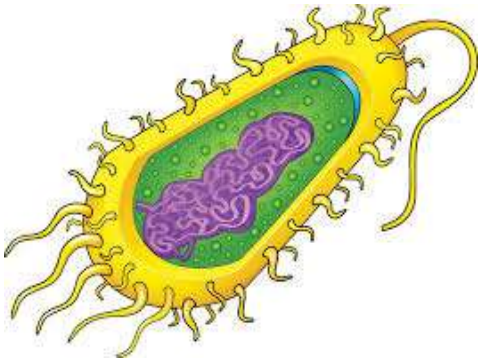
❖ 4.2 – Cell Types and Structures

Characteristic	Prokaryotes: Bacteria, Archaea	Eukaryotes: Protists, Plants, Fungi, Animals
Typical size	 2–100 µm	 100–1000 µm
Genetic material	• no nucleus; DNA not bound by a membrane • one circular chromosome	• DNA in nucleus, bounded by a membrane
Division of genetic material	• not by mitosis or meiosis	• mitosis and meiosis
Reproduction	• asexual	• asexual or sexual
Number of cells	• unicellular	• unicellular or multicellular
Organelles	• has ribosomes but membrane-bound organelles are absent	• has both ribosomes and membrane-bound organelles
Metabolism	• varies; includes cells that require oxygen to make ATP and cells that do not • some are photosynthetic	• most require oxygen to make ATP • some are photosynthetic

TYPES OF CELLS

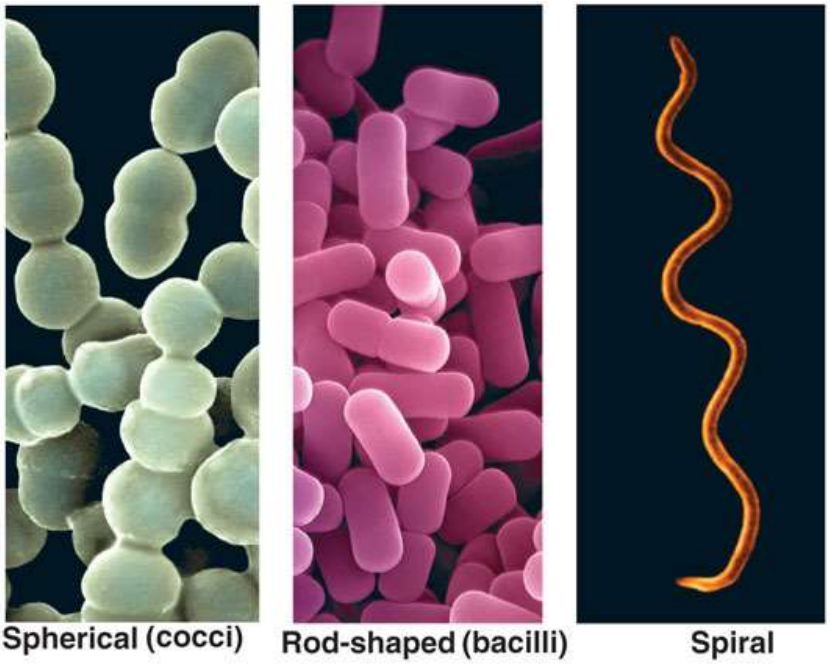
- We will explore the two main types of cells**:** _____ _____.
- We will also look at similarities and differences between two types of eukaryotic cells – _____.

Prokaryotic vs Eukaryotic



Prokaryotic:

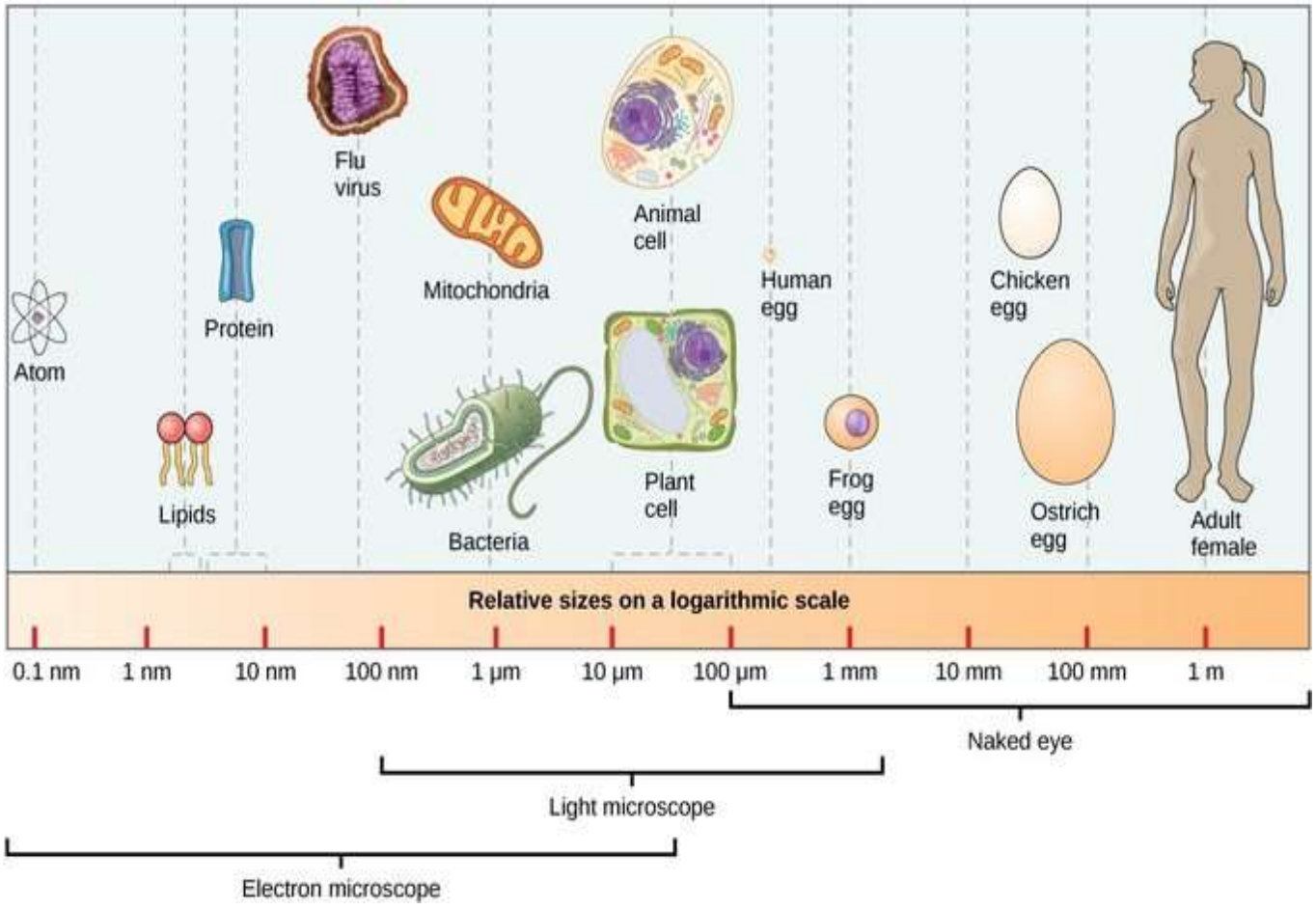
- Have _____
  - *Pro* = _____
  - *Karyon* = _____
  - DNA in _____ **or** small ring called a _____
- _____ living cells.
- _____ internal structure.
- Lack _____
- **All** _____ **cells are prokaryotic.**
- The only living things with prokaryotic cells are _____ _____.
- Prokaryotic cells move using _____**.**
- **Flagella** – _____ extending from the cell membrane that propel the cell using _____.
- Prokaryotic cells have _____ made of a chemical called _____.



Spherical (cocci) Rod-shaped (bacilli) Spiral

Eukaryotic:

- These cells _____
- *Eu* = _____
- *Karyon* = _____
- Have _____.
- i.e. **Nucleus, vesicles, mitochondria, Golgi body**
- Organelles function _____to carry out the essential functions.
- _____other than bacteria are eukaryotic (including _____ _____).
- The presence of membrane –bound organelles is a major reason why eukaryotic cells _____than prokaryotic cells.



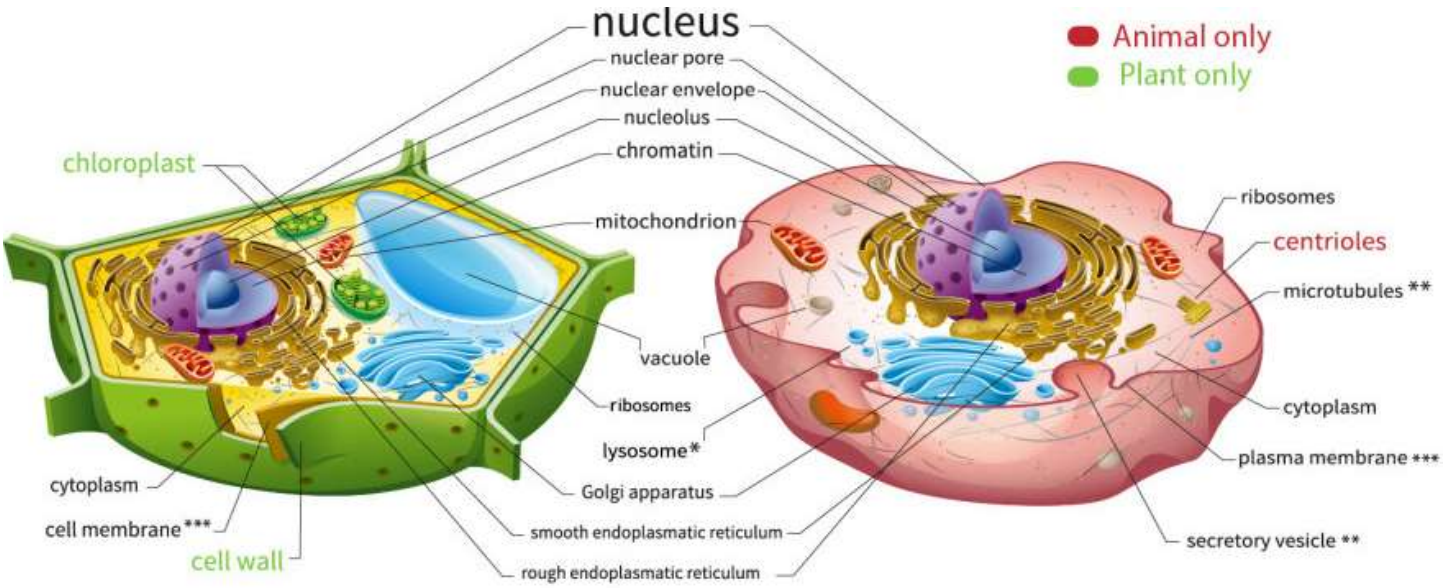
Plant Cells vs Animal Cells

Plant cells contain many of the same structures as animal cells, but there are some differences:

1) Plant cells have _____; animal cells do not. This _____provides _____.

2) Plant cells have _____; animal cells have _____ _____.Vacuoles provide_____ _____ and is filled with water.

3) Plant cells have _____ whereas animals do not and have _____**.**



* Plants may have lytic vacuoles, which act like lysosomes in animal cells.
** Although they're not labelled here, plant cells have microtubules and secretory vesicles, too.
*** Cell membrane and plasma membrane are just different names for the same structure.

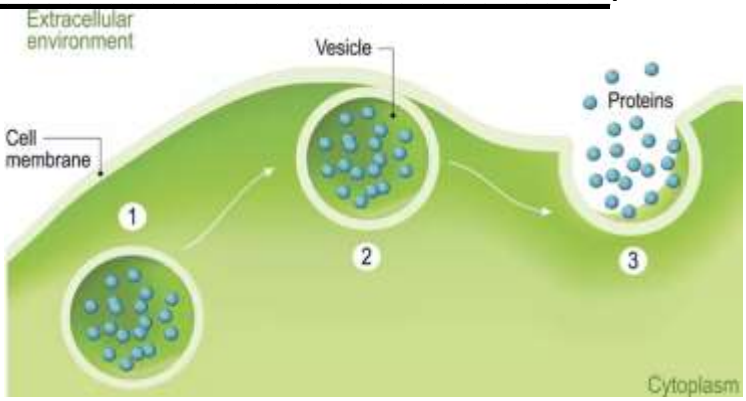
Cell Organelles

What are organelles?

- "_____"
- _____are carried out by organelles.
- The structure of each organelle matches its _____**.**
- Organelles work together in a cell to carry out functions such as _____ _____.

Cell Membrane

- Structure that _____ the cell interior from the outside world and _____ into and out of the cell.
- Helps the cell _____.
- It has a _____.



Cell Wall

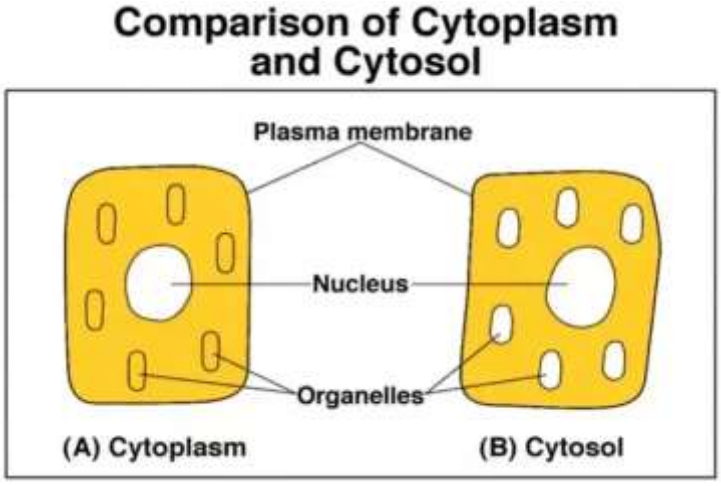
- Surrounds the cell membrane and is _____.
- It helps to give a plant _____.
- Made up of a network of tough fibres, made mainly of _____.

Cytoplasm

- Everything _____ including the _____ (except the nucleus).

Cytosol

- The _____ in which the organelles are suspended.



Nucleus

- Command centre of the cell that _____ _____.
- Surrounded by a _____ to protect the DNA.

Nucleolus

- A specialized area of chromatin inside the nucleus _____ _____.

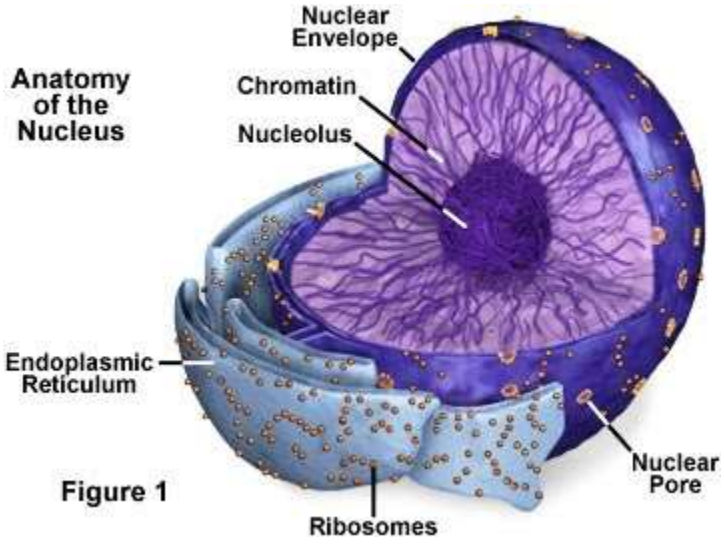


Figure 1

Ribosome

- Tiny two-part structure found throughout the cytoplasm that _____ _____.

Endoplasmic Reticulum (ER)

- System of _____ continuous with the outer membrane of the nuclear envelope.
  1. **Rough ER** – _____.
  2. **Smooth ER** – _____ throughout the cell.

Vesicles

- Small membrane bound _____. Some special types of vesicles have different jobs in the cell.

Lysosome

- Contains _____ that break down _____ _____.

Golgi Apparatus

- Stack of flattened membrane-bound sacs that _____.
- Package finished products into vesicles for _____ (for secretion out of the cell) and within the cell as lysosomes.

Vacuole

- Large, membrane bound fluid filled sac for the _____, _____.

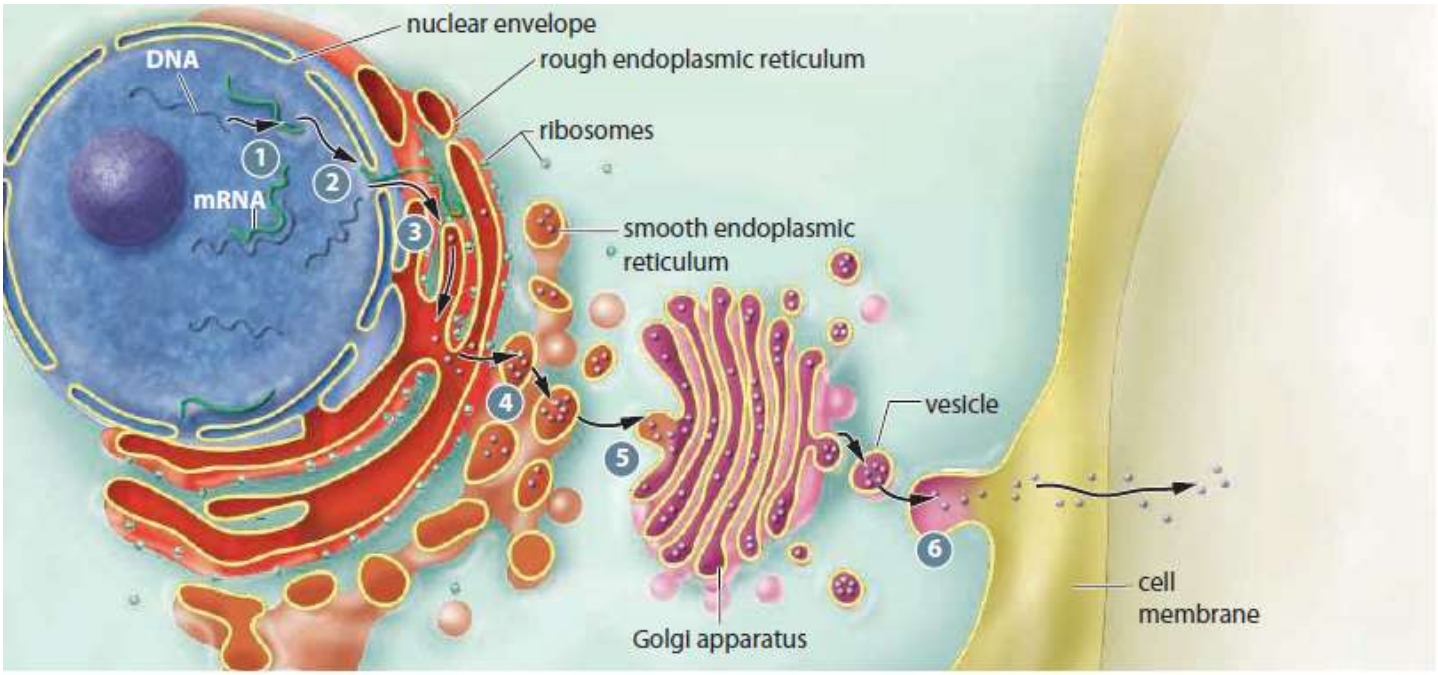
Mitochondrion

- _____ where organic molecules (usually carbohydrates) are broken down inside a double membrane to _____.

Chloroplast

- Site of _____
- Gives_____ and transfers energy from sunlight into stored energy in carbohydrates during photosynthesis.
- Contains stacks of structures called _____.
- The thylakoids sit in a fluid called _____.

Cell organelles _____.



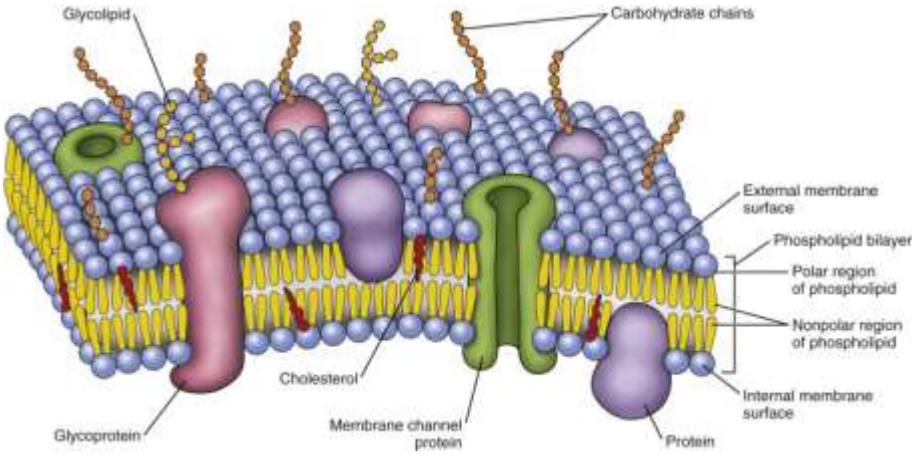
1. Insulin protein information from DNA is copied to RNA.
2. RNA exits the nucleus.
3. At ribosomes on surface of rough ER, information from RNA is used to make a protein that will become insulin.
4. Vesicles from smooth ER package the protein for transport to Golgi apparatus.
5. In Golgi apparatus, the proteins are processed to form insulin protein and packaged for export out of the cell.
6. Insulin is released from the cell when vesicles fuse with the cell membrane.

4.3 – Cell Membrane Structure & Support

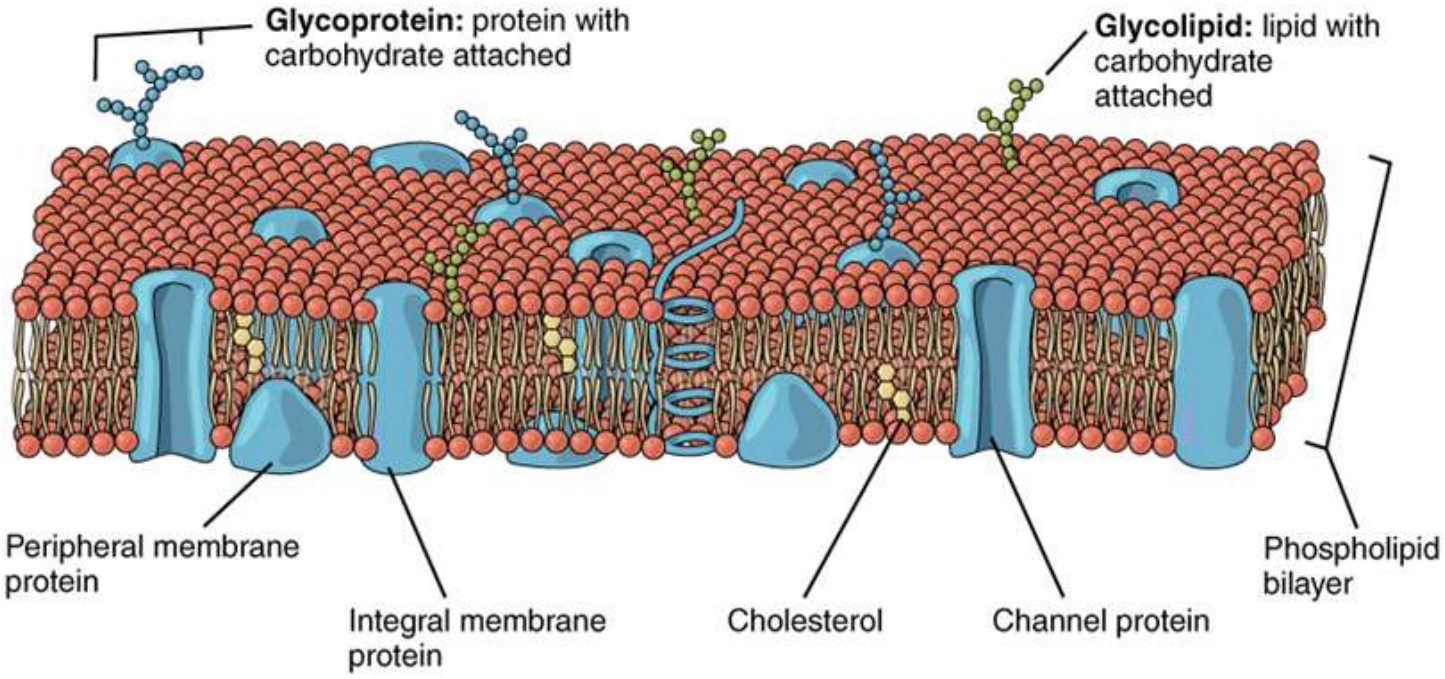
Cell Membranes

1. _____the cell.
2. _____of the cell.
3. _____the cell.
4. _____

Phospholipid Bilayer - Fluid Mosaic Model

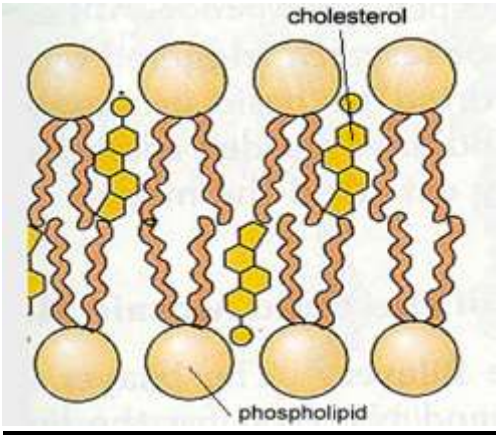


Cell Membrane Part	Structure	Functions
Phospholipids 	• Provide the overall structure for the cell membrane • Arranged in two layers	• Act as a barrier between the cell and its surroundings • Hold the other components of the cell membrane
Proteins 	• Most are embedded in the phospholipid bilayer • Some are attached to the inside or outside surface of the phospholipid bilayer	• Some proteins transport specific substances across the membrane • Some proteins are enzymes, and they control chemical reactions • Some proteins transmit signals from other cells or elsewhere in the body
Cholesterol 	• Embedded in the phospholipid bilayer	• Helps keep fluidity of membrane consistent • Reduces fluidity of membrane at high temperatures • Increases fluidity of membrane at low temperatures
Carbohydrates 	• Attach to proteins or phospholipids and protrude outside the cell	• Allow other cells to "recognize" the cell as belonging to the organism and not an intruder



Phospholipid Bilayer

- Phospholipids are composed of **a hydrophilic head and two hydrophobic tails**



Cholesterol

- A lipid that regulates the _____ over different _____.

Proteins

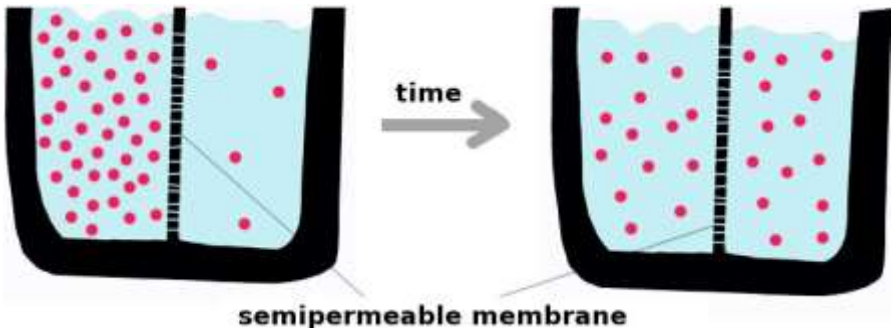
- **Channel or Carrier proteins**– Serve to allow materials in and out of the cell.
- These proteins are often _____.

Carbohydrates

- Attach to proteins or phospholipids and protrude outside the cell.
- Often involved in _____.

Maintaining Homeostasis

- The cell membrane is **selectively permeable**, _____ _____.



- Two Main Methods:
  1. _____
  2. _____

Passive Transport

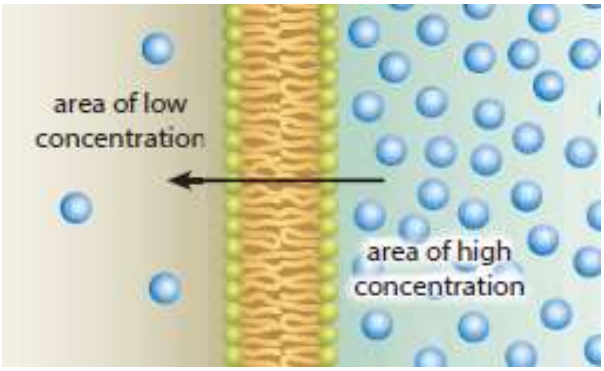
- The movement of any substance across a cell membrane _____ _____.

Three types*:*

1. _____
2. _____
3. _____

1. Simple Diffusion

- The movement of molecules from a region of _____ to a region of _____.
- Occurs _____ – _____.



2. Osmosis

- The diffusion of _____.
- When the membrane does not allow the diffusion of materials, water is still able to cross the membrane from _____.
- *A discussion about osmosis requires us to learn about cell tonicity.*

TONICITY AND CELLS

❖ Cells react differently to immersion in 3 different extracellular solutions:

1. _____
2. _____
3. _____

1. Isotonic Solution

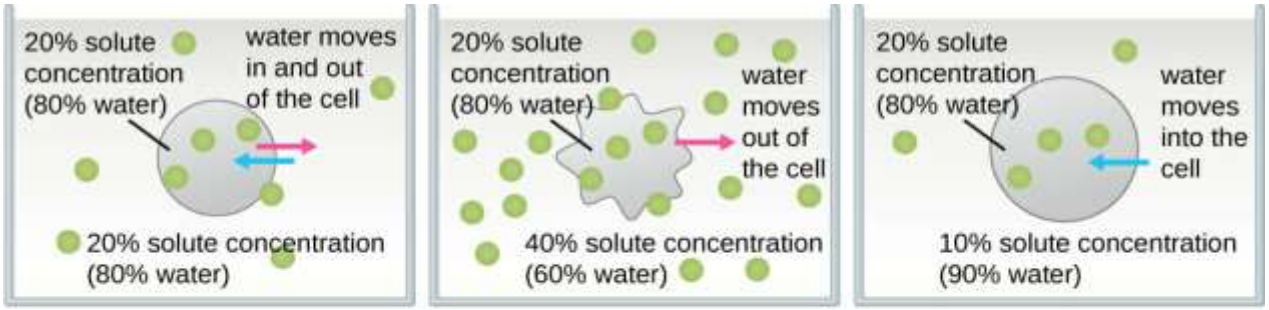
- Water Concentration _____ the cell is _____the concentration _____ the cell.
- **Equal** amounts of _____.
- Water _____.

2. Hypotonic Solution

- Water concentration _____the cell is _____ than the water concentration _____ the cell.
- _____ the cell.
- Water moves _____.

3.Hypertonic Solution

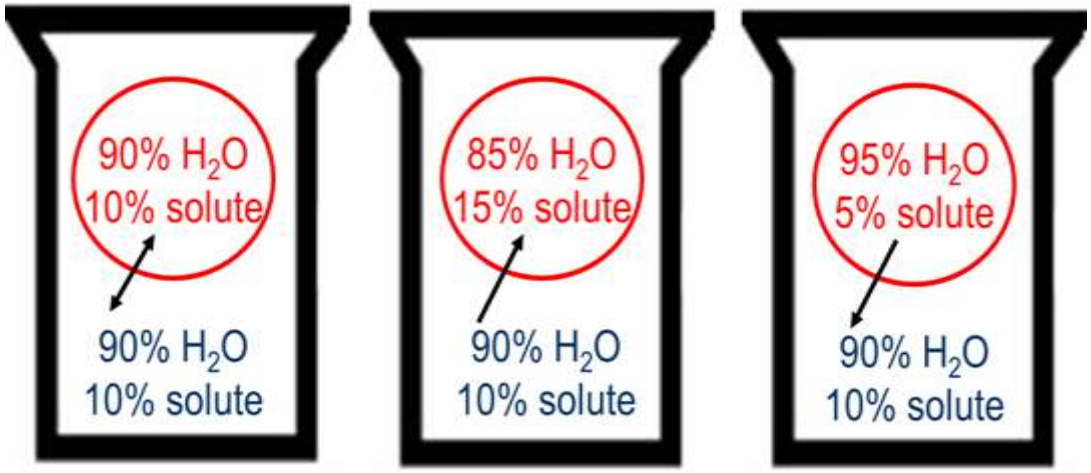
- Water concentration _____the cell is _____ than the water concentration _____ the cell.
- _____ the cell .
- Water moves _____.



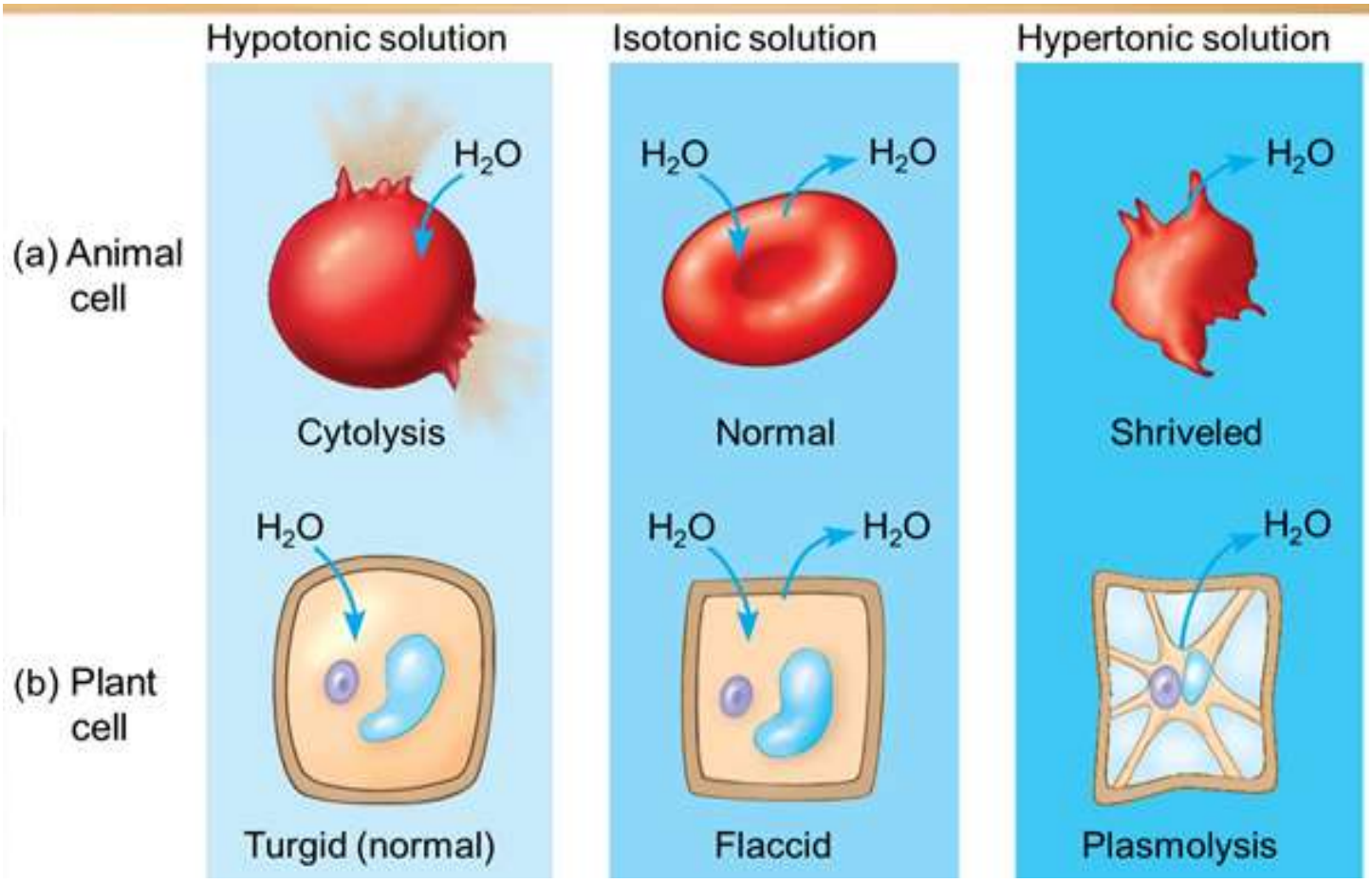
a Isotonic solution
A solution that has the *same* solute concentration as another solution. There is no net movement of water particles, and the overall concentration on both sides of the cell membrane remains constant.

b Hypertonic solution
A solution that has a *higher* solute concentration than another solution. Water particles will move out of the cell, causing crenation.

c Hypotonic solution
A solution that has a *lower* solute concentration than another solution. Water particles will move into the cell, causing the cell to expand and eventually lyse.

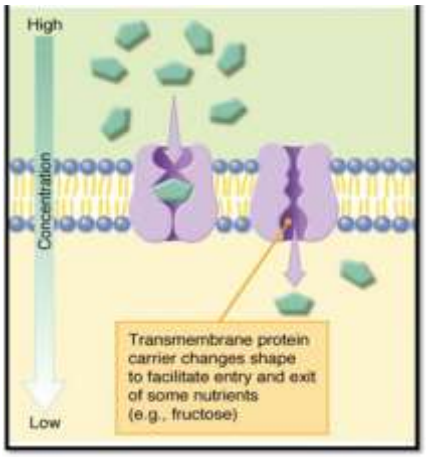


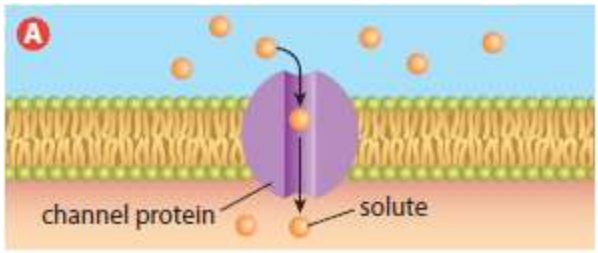
Osmosis in Animal vs Plant Cells

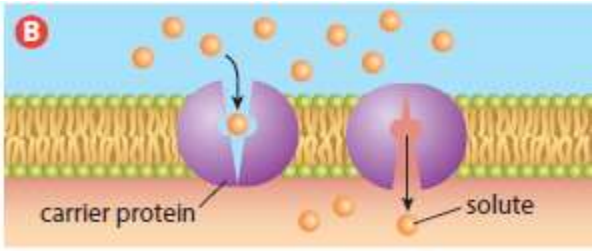


3.Facilitated Diffusion

- Sometimes materials are _____to diffuse across the membrane without assistance, or _____, so they cannot dissolve in the lipid bilayer.
- These materials _____**(*channel or carrier*)**.
- Movement of molecules is still _____**,** but now the carrier or channel protein is helping to move them**.**
- These _____are specific to the materials that they are transporting (moving) across the membrane by _____ _____.







Carrier Protein vs Channel Protein

Channel protein

- _____that allows _____to move in or out of the cell.
- Ex. _____

Carrier proteins

- _____in or out of the cell.
- Ex. _____

Active Transport

- The movement of any substance _____ _____.
- In active transport, proteins move substances from areas of _____ _____. This is important in the process of digestion and the removal of waste.
- Example: _____

- **Examples of Active Transport**
  - *Kidney cells pump glucose and amino acids out of the urine and back into the blood.*
  - *Intestinal cells pump nutrients from the gut.*
  - *Plant root cells pump nutrients from the soil.*
  - *Fish gill cells pump sodium ions out of the body.*

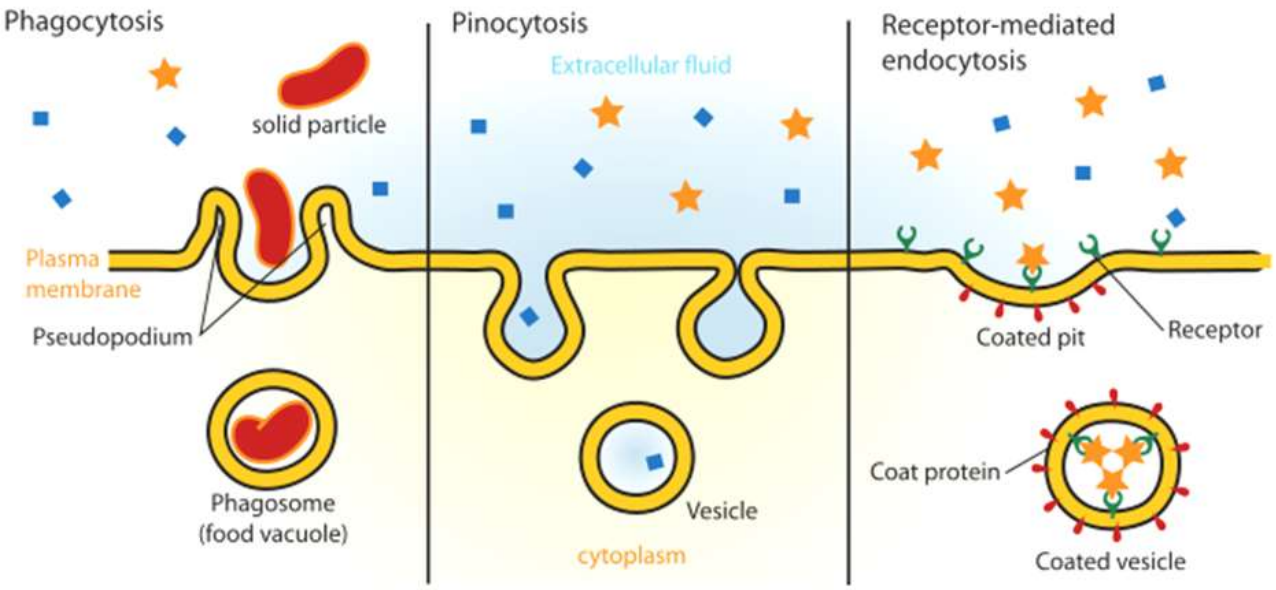
Bulk Membrane Transport - Active Transport Example

- Sometimes molecules are _____ to cross through the cell membrane.

- The cell uses a specialized method of getting materials in or out of the cell using the _____ itself:
  - **Endocytosis**
  - **Exocytosis**

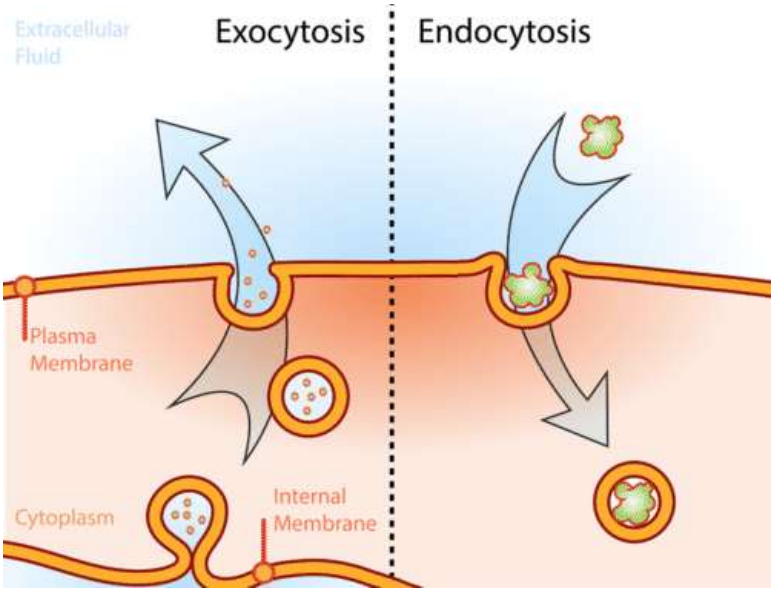
Endocytosis

- The process by which a **cell** _____.
- The membrane _____ trapping matter from the extracellular fluid within it forming a _____.

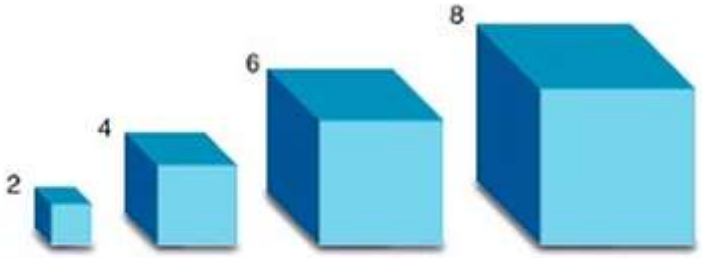


Exocytosis

- _____.
- A vesicle _____fuses with the cell membrane.
- The contents of the vesicle are _____.
- Very important to the _____.
- Ex. The pancreas secretes insulin.
- Exocytosis is also the process by which_____ _____.



Limits on CELL SIZE



Surface area (cm^2)	24	96	216	384
Volume (cm^3)	8	64	216	512
Surface area / Volume	3.0	1.5	1.0	0.75

- Although there are many types of cells, there is one feature that most cells share in common – _____.
- Cells are typically _____in diameter.
- They need to be small because nutrients, water, oxygen, carbon dioxide and waste products _____, ***the cell membrane***.
- If a cell gets too large, it would be _____ for interior substances to travel to and from the cell membrane.

- The key relationship is – _____ _____.

- **LARGE CELLS**
  - _____
  - Less surface exposed for cell membrane transport
- **SMALL CELLS**
  - _____
    - More _____ at allowing transport across the CELL MEMBRANE

4.4 – Energy Transformation in Cells

The Need for Energy

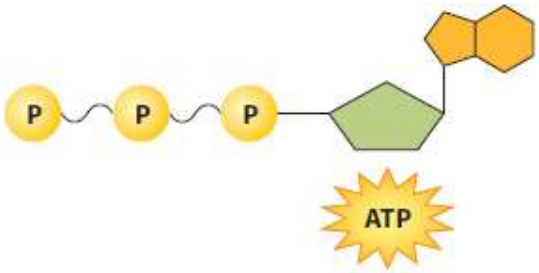
- Cells need _____ to function and carbon to build biological molecules.
  _____ that cells use for readily available energy.
- ATP breaks down to form another molecule _____, releasing a small "packet" of energy that the cell can use.

- Examples of processes in the body that requires ATP:
  - *Active transport of materials into the cell*
  - *Moving chromosomes during cell division*
  - *The contraction of muscles*
  - *Synthesizing macromolecules*

- There are two types of cellular respiration:
  1. **Aerobic Respiration** is the cellular process that uses oxygen to release energy, as ATP, from glucose.

  2. Cellular respiration that proceeds without oxygen is called **anaerobic respiration**.

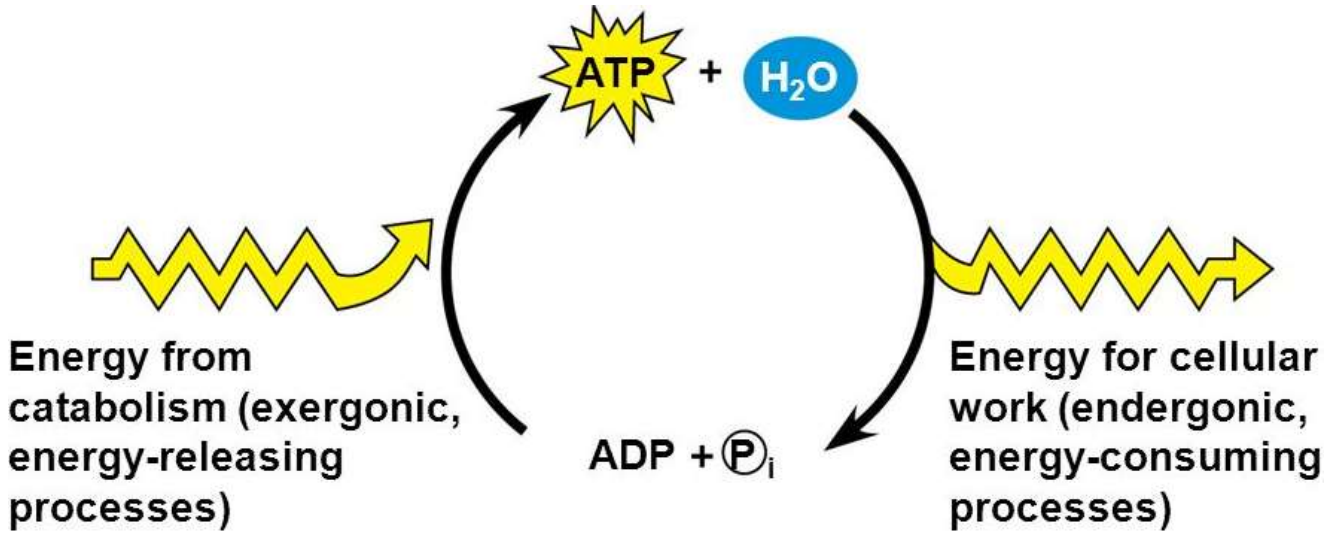
Aerobic Respiration



- ATP, short for adenosine triphosphate, is a nucleotide consisting of a group called adenosine and three phosphate groups.
- ATP undergoes a chemical reaction that results in the release of energy. This reaction produces three things:
    - a molecule called ADP (short for adenosine diphosphate)
    - a free phosphate group
    - a burst of energy that cells can use right away.
- Recall: an appreciable amount of energy is released when one of the bonds is broken in a hydrolysis (water-mediated breakdown) reaction. ATP is hydrolyzed to ADP in the following reaction:

$$\mathrm{ATP} + \mathrm{H_2O} \leftrightharpoons \mathrm{ADP} + \mathrm{P}_i + \text{energy}$$

    - Note: P_i stands for an inorganic phosphate group (PO_4^{3-})

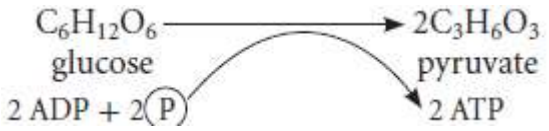


- Aerobic respiration actually consists of many, many chemical reactions
- Each reaction is catalyzed by a particular enzyme.
- These reactions take place in four stages.
    - The first stage, glycolysis, takes place in the cytosol.
    - The remaining stages take place in mitochondria.

The Stages of Aerobic Respiration

A. Glycolysis

- Through two distinct phases, the six-carbon ring of glucose is cleaved into two three-carbon sugars of pyruvate through a series of enzymatic reactions.
- The net result of the process, in addition to the splitting of glucose, is that two molecules of ATP are formed.



- Glycolysis is also the first stage anaerobic respiration that makes ATP without using oxygen.

B. Breakdown of Pyruvate

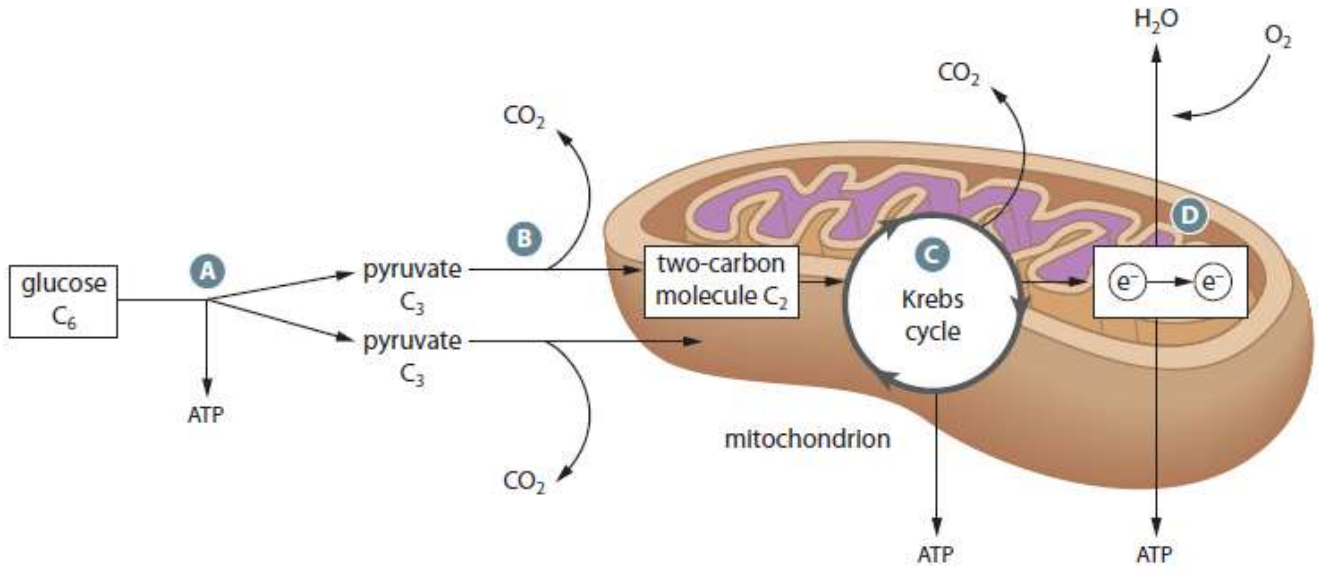
- Although glycolysis produces ATP, the more important thing is those pyruvate molecules.
- The pyruvate molecules enter the mitochondria and are converted into a two-carbon intermediate.

C. Krebs Cycle

- This is the breaking down of the molecules from stage two into CO_2 molecules, H_2O molecules, and generating additional ATP.

D. Oxidative Phosphorylation

- The energy-carrying molecules produced in the previous stages are used to make ATP.



A Glycolysis is the breakdown of one glucose molecule to form two pyruvate molecules and a small amount of ATP.

B The conversion of pyruvate into a 2-carbon molecule connects glycolysis in the cytosol to the Krebs cycle in the mitochondrion. During pyruvate conversion, carbon dioxide is released.

C The Krebs cycle is a circular series of reactions that produce a small amount of ATP along with energy-carrying molecules that move on to the next stage of cellular respiration. Carbon dioxide is also released during the Krebs cycle.

D In oxidative phosphorylation energy-carrying molecules pass electrons to an electron transport chain in the mitochondrial membrane. Oxygen is the last electron acceptor in the chain. As electrons are passed from one carrier in the chain to the next, energy is released. This energy is harnessed to make ATP. More ATP is produced during this stage of cellular respiration than any other.

- For every one molecule of glucose that undergoes aerobic cellular respiration, a maximum of 36 to 38 ATP molecules can form.
- Six oxygen molecules are consumed in the reaction, and six molecules each of carbon dioxide and water are produced.

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \longrightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

$$38\ ADP + 38\ (P) \longrightarrow 38\ ATP$$

The Stages of Photosynthesis

A. Light Dependent Reactions

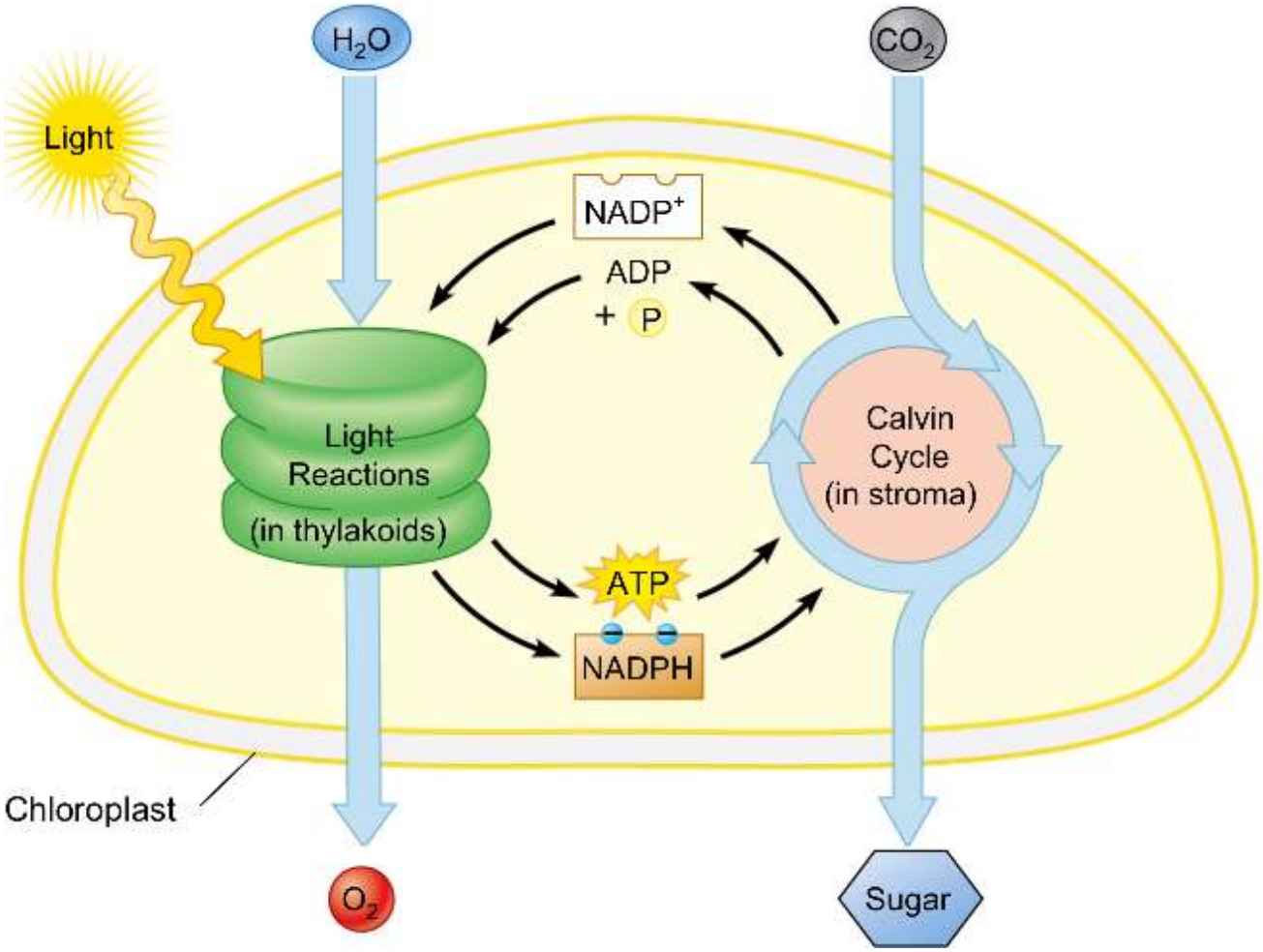
- Chlorophyll pigments absorb light energy.
- Light energy is used to make two molecules needed for the next stage of photosynthesis: the energy storage molecule ATP and the reduced electron carrier NADPH.
- This stage of photosynthesis uses a molecule of water and produces a molecule of oxygen.

B. Calvin Cycle

- Uses the products of the light dependent reactions to convert carbon dioxide into glucose.
- These reactions occur in the stroma of the chloroplast.

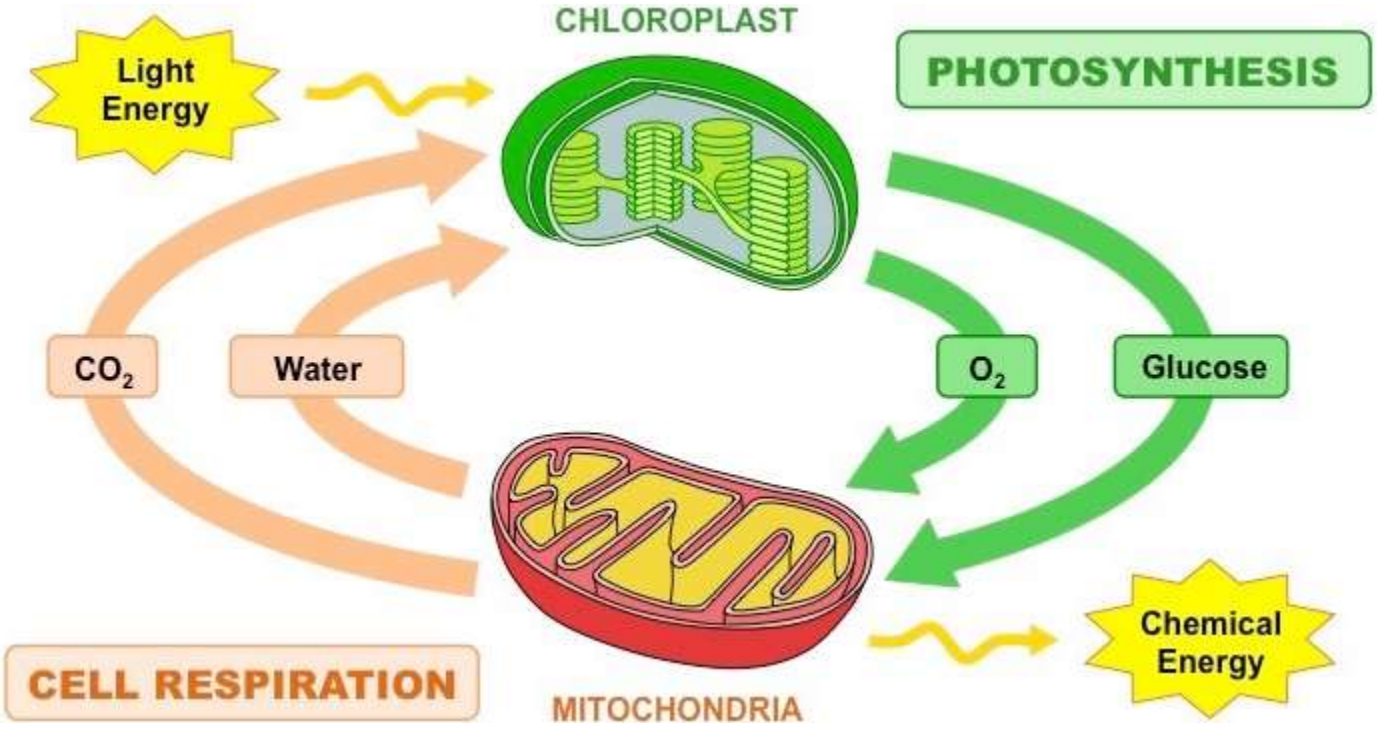
$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

carbon dioxide — water — glucose — oxygen



Complementary Processes

- In photosynthesis, plants use energy from sunlight to convert carbon dioxide and water into glucose and oxygen.
    - This overall reaction is the reverse of the overall reaction for aerobic respiration.
- Photosynthesis not only supplies our atmosphere with oxygen, but also removes carbon dioxide from the atmosphere.



Complementary Reactions

- In fact, photosynthesis and cellular respiration are _____ _____.

Process	Reactants	Products	Energy Involved
Photosynthesis	carbon dioxide, water	glucose, oxygen	input of radiant energy (sunlight)
Cellular Respiration	glucose, oxygen	carbon dioxide, water	release of chemical energy (ATP)