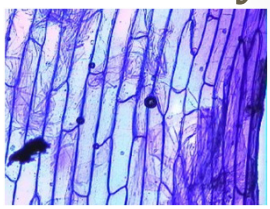
Unit 2
Cell Structure and Function

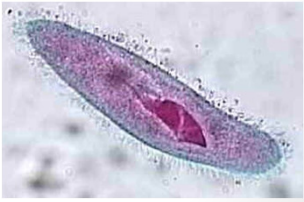
Biology 30
Mr. Oosterom

Development of the Cell Theory

- People have known about the existence of cells for approximately 300 yrs
- Early microscopes allowed scientists to discover what we now take for granted:
  - All living things are made up of cells
  - Cells are fundamental units of life



Onion skin cells



Paramecium

The cell Theory States That…

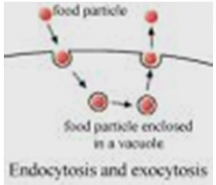
- All living organisms are made up of one or more cells
- Cells are the basic unit of structure and function in all organisms
- All cells are derived from pre-existing cells
  (This means that ALL cells had to come from other cells)
- In a multicellular organism (like a plant or a animal) the activity of the entire organism depends on the total activity of individual cells that make up the organism

Structures in Cells

- **ALL** cells start out as fully functional living things
- They must be able to create and maintain substances (compounds, ATP, ADP) and structures (membranes, organelles) that perform all the essential tasks necessary for the cell to function
- My question for you…
  - What are these essential tasks?

Essential Tasks for Cells

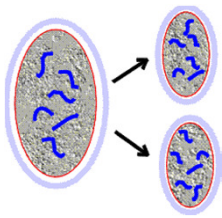
- Obtain food and energy

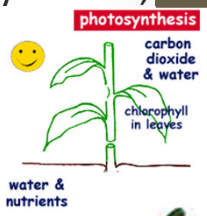


- Convert energy from an external source (sun or food) into a form that the cell can use (ATP)
- Construct and maintain molecules that make up cell structures (proteins)

More Essential Tasks

- Carry out chemical reactions (photosynthesis, respiration)
- Eliminate wastes (CO_2, alcohol, urea)
- Reproduce
- Keep records of how to build structures (DNA)

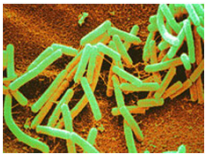


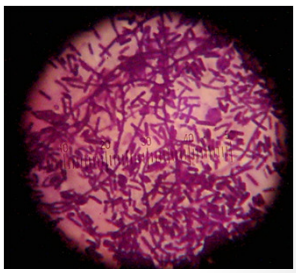


Prokaryotic Cells

- **Smallest** living cells
- **Simple** internal structure
- Lack membrane-bound organelles
- Pro = Before
  Karyon = nucleus
  They have **NO nucleus**
  - DNA in a Nucleoid

ALL BACTERIA ARE PROKARYOTIC





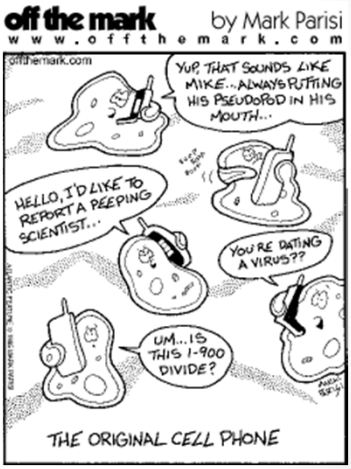
Prokaryotic Cells

- Since they do not have a nucleus, all the genetic information is concentrated in an area called the **nucleoid**. Some prokaryotic cells also have a small ring of DNA called a **plasmid**
- The only living things with prokaryotic cells are Kingdom Bacteria and Kingdom Archaea
- Prokaryotic cells move using **flagella**
  - **Flagella** – long, hair-like projections extending from the cell membrane that propel the cell using a whip-like motion
- prokaryotic cells have cell walls made of a chemical called peptidoglycan
- See Fig. 1.22 on page 33

Eukaryotic Cells

- Eu = True
  Karyon = Nucleus
  The **DO** have a nucleus
- Have membrane-bound organelles
  - Nucleus, vesicles, mitochondria, Golgi body
- Organelles function as a "team" to carry out the essential functions

ALL PLANTS, ANIMALS, FUNGI



Cell Organelles

- Organelles (small organs)
  - Specialized structures within cells that each have a specialized function, like nuclei and chloroplasts
- Cytoplasm
  - Fluidic gel made up mostly of water and dissolved nutrients and waste
  - Provides a fluidic environment organelles to carry out chemical reactions
- Cell membrane
  - structure that separates the cell interior from the outside world and controls the movement of materials into and out of the cell

Organelles

- Nucleus
  - Command centre of the cell that contains the DNA blueprints for making proteins and is surrounded by a double-membrane to protect the DNA from potentially damaging by-products of biochemical reactions
- Nuclear pores
  - Pores in the nuclear membrane large enough to allow macromolecules to enter and ribosomes to leave the nucleus
- Chromatin
  - uncoiled chromosomes (DNA)
- Nucleolus
  - a specialized area of chromatin inside the nucleus responsible for producing ribosome

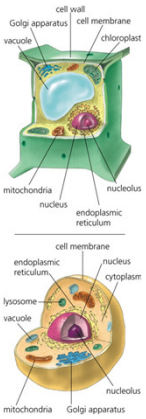
- Ribosome
  - Tiny two-part structure found throughout the cytoplasm that help put together proteins
- Endoplasmic reticulum (ER)
  - System of flattened membrane-bound sacs and tubes continuous with the outer membrane of the nuclear envelope that has two types of membrane
    - **Rough ER** – has ribosomes and synthesizes proteins
    - **Smooth ER** – synthesizes phospholipids and packages macromolecules in vesicles for transport to other parts of the cell

- Vesicle
  - Small membrane bound transport sac. Some special types of vesicles have different jobs in the cell
    - **lysosome** – contains digestive enzymes that break down old cell parts or material brought into cells
    - **peroxisome** – breaks down lipids and toxic waste products
- Golgi apparatus
  - Stack of flattened membrane-bound sacs that receive vesicles from the ER, contain enzymes for modifying proteins and lipids, package finished products into vesicles for transport to the cell membrane (for secretion out of the cell) and within the cell as lysosomes

- Mitochondrion
  - Powerhouse of the cell where organic molecules (usually carbohydrates) are broken down inside a double membrane to release and transfer energy
- Centrosome
  - Organelle located near the nucleus that organizes the cell's microtubules, containing a pair of centrioles (made of microtubules) and helps organize the even distribution of cell components when cells divide
- Vacuole
  - Large, membrane bound fluid filled sac for the temporary storage of food, water or waste products
- Cytoskeleton
  - Network of three kinds of interconnected fibres that maintain cell shape and allow for movement of cell parts

Plant Cells vs. Animal Cell

- Plant cells contain many of the same structures as animal cells, but there are some differences:
- plant cells have an outer cell wall made of cellulose; animal cells do not
  - Provides rigidity and protection
- Plant cells have one large central vacuole; animal cells have several vacuoles
  - Provides rigidity and stores wastes, nutrients and is filled with water
- Animal cells have a centrosome; plant cells do not
  - Involved in animal cell division
- Plant cells have chloroplasts; animal cells do not
  - chloroplast – plastid that gives green plants their colour and transfers energy in sunlight into stored energy in carbohydrates during photosynthesis

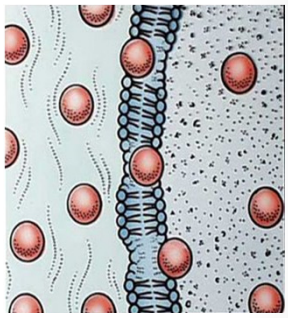


Maintaining Homeostasis

- The cell membrane is **selectively permeable**, allowing some molecules to pass through, while preventing others
- Water is the solvent both inside and outside the cell, allowing materials to be easily dissolved
- In multicellular organisms, every cell is covered in **extracellular fluid** made up of mostly water and dissolved materials
  - Wastes eliminated by cells (CO_2 or urea)
  - Substances needed by the cells (O_2 or water)

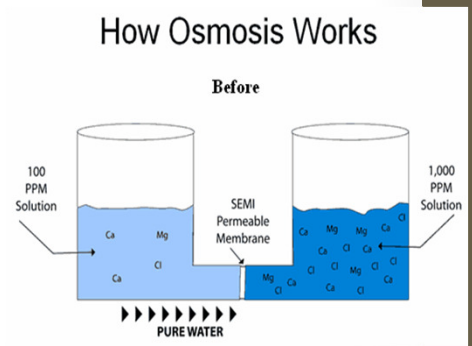
Diffusion and the Cell Membrane

- Passive Transport – Require no cellular energy
- The movement of molecules from a region of higher concentration to a region of lower concentration is called diffusion.
- Occurs along a concentration gradient – high to low
- Reaches a point of equilibrium – no net change in the concentration of a molecule
- Rate of diffusion increases with temperature – increasing Brownian motion (vibrating molecules)

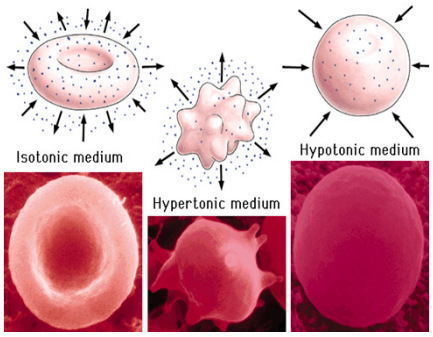


Osmosis: The Diffusion of Water

- The diffusion of water across a semi-permeable membrane
- When the membrane does not allow the diffusion of materials, water is still able to cross the membrane from high concentration to low concentration



Cellular Tonicity



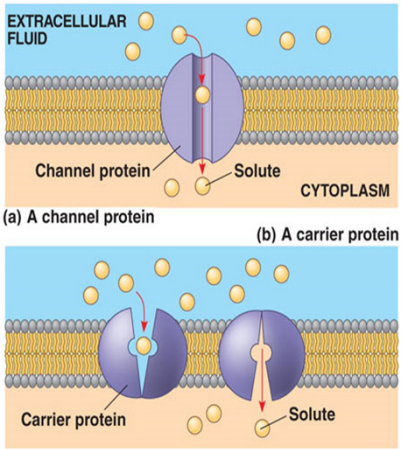
Note: Water moves in or out of the cell down the concentration gradient in an attempt to reach equilibrium

- Isotonic Solution
  - Water Concentration outside the cell is **equal** to the concentration inside the cell
  - **Equal** amounts of solute inside and outside
- Hypotonic Solution
  - Water concentration inside the cell is **Less** than the water concentration outside the cell
  - **More** solute inside the cell
- Hypertonic Solution
  - Water concentration outside the cell is **less** than the water concentration inside the cell
  - **More** solute outside the cell

Facilitated Diffusion

- Sometimes materials are too large to diffuse across the membrane without assistance, or they may not be soluble in lipids, so they cannot dissolve in the lipid bilayer
- These material need **help** from a protein
- **Passive transport**
  - **No cellular energy is required for the carrier protein to function**
- These **carrier proteins** are specific to the materials that they are transporting (moving) across the membrane by size, shape and electrical charge
- Movement of molecules is still going down the concentration gradient, but now the carrier protein is helping to move them

Carrier Protein vs. Channel Protein



- Carrier protein
  - Changes shape to move specific molecules in or out of the cell
  - Ex. Glucose
- Channel proteins
  - Have a tunnel that allows ions of a specific charge to move in or out of the cell
  - Ex. Na^+ or Cl^-

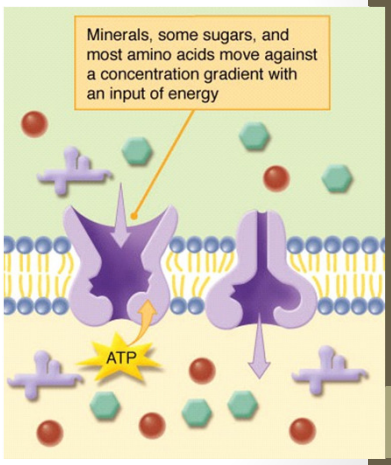
Rate of Diffusion

- A number of different factors affect the rate or speed at which solutes diffuse

Temperature	• Higher temperature → Diffuse Faster
Surface Area	• Larger surface → Diffuse Faster
Concentration Gradient	• Higher Gradient → Diffuse faster
Size of Particles	• Smaller particles → Diffuse faster
Diffusion Medium	• Solid → Slowest • Liquid → Faster • Gas → Fastest

Active Transport

- **The process of moving materials backwards up their concentration gradient**
  - **FROM LOW CONCENTRATION TO HIGH CONCENTRATION**
- ATP is used to activate the transport protein and pump the material out of the cell.
- Often a specific shape is required to be set into the protein before the ATP will release energy to open the pump.
- Similar to pushing an object up a hill



Where To Find 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

The Sodium – Potassium Pump

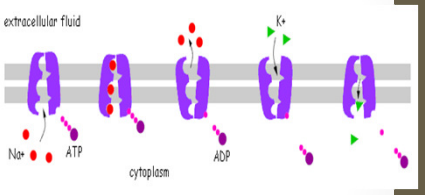
A. Carrier protein has the shape to allow 3 Na^+ (sodium) ions

B. ATP molecule splits, releasing its energy into ADP + phosphate

C. Energy causes the carrier protein to change shape, releasing sodium out of the cell

D. Phosphate is release

E. Shape change causes 2 K^+ ions to be moved out of the cell



Bulk Membrane Transport

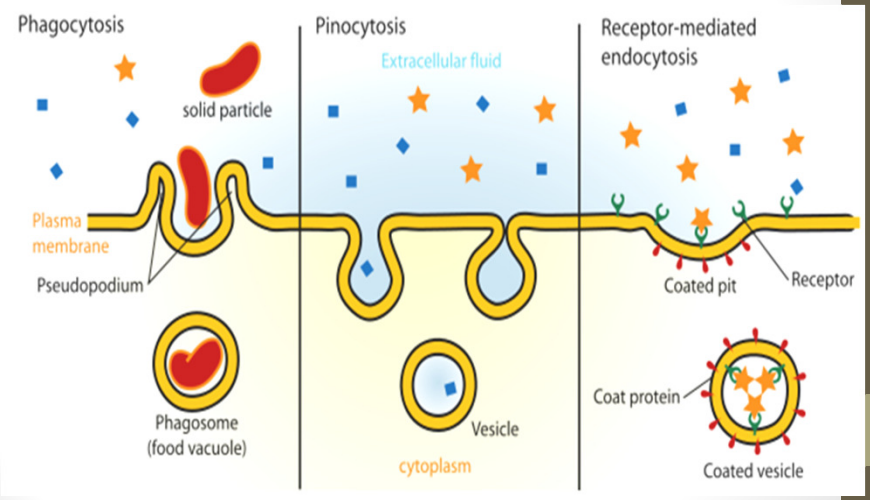
- Sometimes molecules are too large or too polar to cross through the cell membrane
- The cell uses a specialized method of getting these materials in or out of the cell.
- The cell membrane is able to fold in on itself and engulf material into a membrane bubble called a **vesicle**
- Vesicles may be newly formed and separate into or out of the cell, or they may simple fuse with the membrane releasing its contents out of the cell

Endocytosis

- The membrane folds in on itself trapping matter from the extra cellular fluid within it.
- There are three types of endocytosis used by cells depending on what it is engulfing

1. Pinocytosis
   - Cell "drinking"
   - Engulfs extracellular fluid containing dissolved nutrients
2. Phagocytosis
   - Cell "eating"
   - Engulfs extracellular fluid containing bits of matter or bacteria
   - Process used by macrophages in the immune system when they encounter bacteria
3. Receptor-assisted endocytosis
   - Involves intake of specific molecules that attach to special proteins on the cell membrane
   - This **membrane receptors** are specific to molecules that bind to them like a key into a lock

Endocytosis

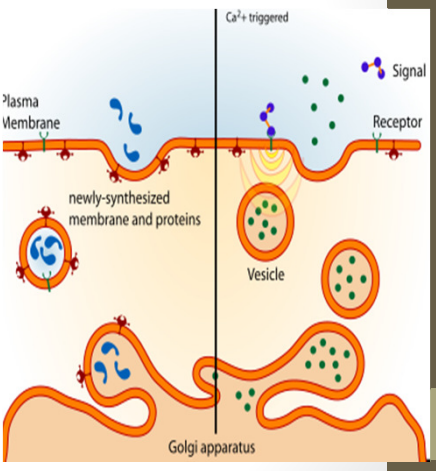


Receptor-Assisted Endocytosis & Cholesterol

- Animal cells bring in cholesterol using this method of endocytosis
- The liver produces cholesterol when levels are low
- Cholesterol is a lipid and cannot dissolve in the extracellular fluid (which is mostly water)
- Each molecule is surrounded in a single layer of phospholipids, each with a protein tag
- This protein tag binds to the receptor side on the cell surface triggering endocytosis to begin
  - See page 63 in your textbook – Figure 2.34

Exocytosis

- Reverse of endocytosis
- A vesicle from the inside of the cell fuses with the cell membrane
- The contents of the vesicle are excreted (expelled) into the extracellular fluid
- Very important to the cells of organs that secrete hormones
  - Ex. The pancreas secretes insulin



Types of Energy

- Energy
  - The capacity to do work
  - Light, heat, electrical, etc
- Potential Energy
  - Stored energy
  - Sugar, ATP
- Kinetic Energy
  - Energy of Motion
- Chemical Energy
  - Energy stored in bond in the atoms between molecules
  - Once bonds are broken the energy is released
- Metabolism
  - Total of all the chemical reactions that take place within a cell
  - Includes all of the building up and breaking down of substances in a cell
  - Relies on chemical energy within the cell

Photosynthesis

- The process by which an organism captures the energy of the sun to convert CO_2 and water into glucose.
- Light energy is converted into chemical energy.
- The process looks as follows:
- carbon dioxide + water $\xrightarrow{\text{Light , chlorophyll}}$ glucose + oxygen

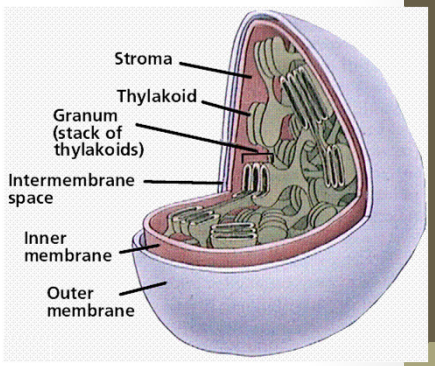
$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Importance of Photosynthesis

1. It is the chief source of energy on earth.
2. It supplies most of the oxygen found in the atmosphere.
3. It is the first step in food chains.

Chloroplast

- Energy is put into this system during a 'Light reaction' in the Thylakoid.
- Sugars are created during a 'synthesis reaction' that can take place in the dark. Also called 'dark reaction' or 'Calvin Cycle'



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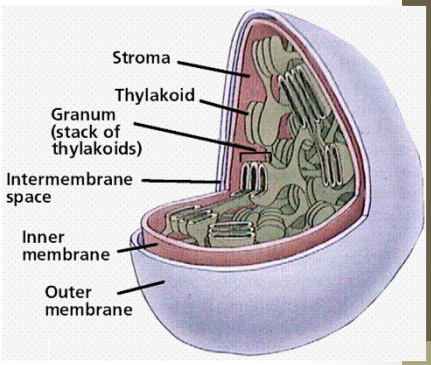
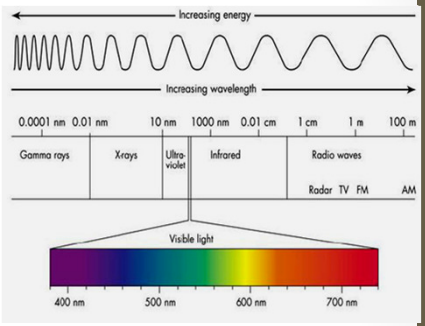


What is Light?

- Visible light makes up a very small portion of the range of radiations known as the **electromagnetic spectrum**.
  - All light travels as a wave that behaves as a particle
  - Composed of small packets of energy called **photons**



Photosynthetic Pigments

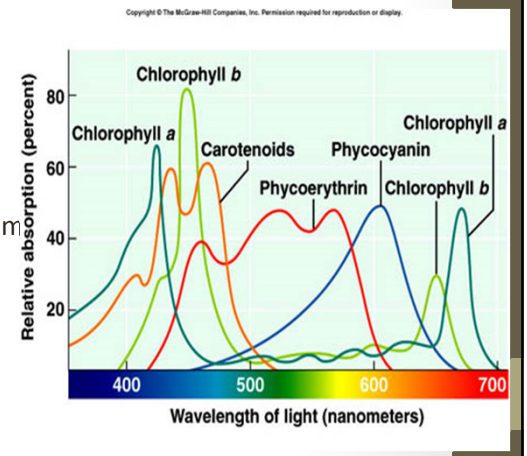
- In order to capture sunlight, plants require special pigments.
- A pigment is any substance that can absorb light.
- Several types of pigments are necessary to trap the full light spectrum.
- These pigments consist of
  - red, orange, yellow, green, blue, and violet

Pigments - Chlorophyll

- Most important pigment
- Present in the largest numbers compared to other pigments
- Capture red and blue light while reflecting green
- Green in color
- There are two types
- Chlorophyll A
  - This is the primary photosynthesis pigment. It directly converts light energy to chemical energy.
- Chlorophyll B
  - Absorbs light energy and transfers it to chlorophyll A.

Carotene & Xanthophylls

- Carotenes
  - Orange in colour
- Xanthophylls
  - Yellow in colour
- Both absorb light in the regions of the colour spectrum no covered by chlorophyll



Light Reaction vs. Dark Reaction

Light Reaction

- Requires light and takes place on the thylakoid membrane of the chloroplast.
- Chlorophyll captures the sun's energy and uses it to produce oxygen and high energy compounds which are used in the dark reaction.

Dark Reaction

- Does not require light, but does depend upon the high energy chemical products made in the light reaction.
- This reaction occurs in the stroma.
- The reaction produces glucose and is often called carbon fixation

Rate of Photosynthesis – 4 Factors

1. Light Intensity
   - The greater the amount of light, the more photosynthesis occurs
2. Temperature
   - below 0°C and above 35°C there is little photosynthesis
3. Water
   - when in short supply, photosynthesis slows down
4. Minerals
   - When in short supply, photosynthesis slows down

Cellular Respiration

- This is the process of releasing energy, within a cell, through a complex series of chemical reactions.
- It occurs at the mitochondria, and consists of the step-by-step breakdown of a nutrient, most commonly glucose, in order to release energy.
- This energy is then stored in the cell in the form of ATP.

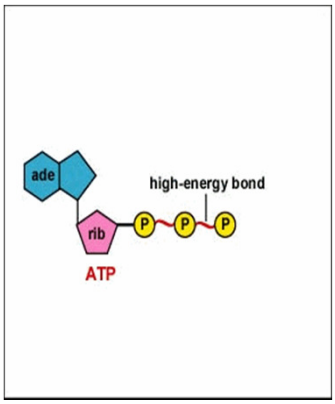
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$$

glucose + oxygen → carbon dioxide + water + ATP

Importance of ATP formation

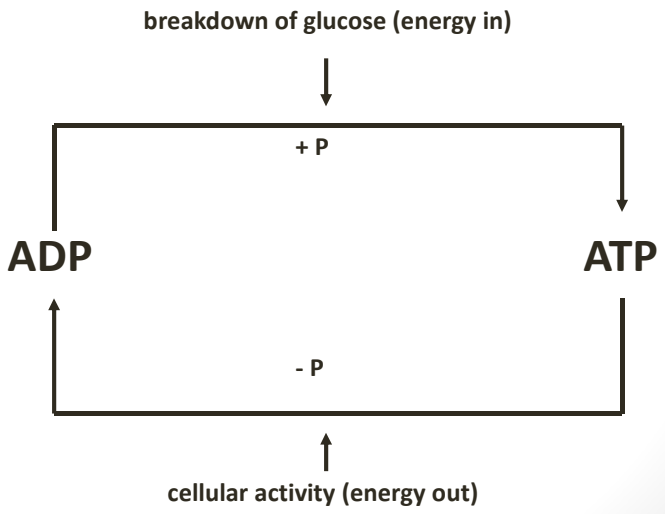
- The energy stored in glucose is not readily available to all cell parts, whereas ATP is.
- Releases energy in the cell with greater control than if the energy came directly from glucose.
- The ATP acts as the intermediary between energy-releasing (exergonic) and energy-requiring (endergonic) reactions in the cell

What is ATP?



- Adenosine Triphosphate
- A high-energy compound found within cells
- Composed of a molecule of adenosine and three molecules of phosphate. The phosphates are held to the adenosine by high energy bonds
- The bonds break, releasing energy along with ADP (adenosine diphosphate) and a phosphate

ATP –ADP Cycle



Aerobic vs. Anaerobic Respiration

Aerobic Respiration

- Glucose is completely oxidized into CO_2 and H_2O in the presence of O_2 to release energy.
- It is the most common form of glucose breakdown, and allows for the maximum amount of energy to be released from the glucose
- Ongoing in all cells most of the time to produce energy

Anaerobic Respiration

- Glucose is broken down in the absence of oxygen to release energy.
- It creates little energy for the cell. It occurs in smaller organisms and in larger organisms when oxygen is not present.
- Location
  - It occurs in the cytoplasm of plant and animal cells.
- Muscles get sore during exercise because of the lactic acid build-up in the tissues resulting from A.R

Two Aerobic Respiration

Alcohol Fermentation:

$$C_6H_{12}O_6 \text{ (glucose)} \longrightarrow 2\ C_2H_5OH \text{ (ethyl alcohol)} + 2\ CO_2 \text{ (carbon dioxide)}$$

Lactic Acid Fermentation:

$$C_6H_{12}O_6 \text{ (glucose)} \longrightarrow 2\ C_3H_6O_3 \text{ (lactic acid)}$$