2016 CELL BIOLOGY – TRAINING HANDOUT
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National Rules Committee Chair-Life Science

DISCLAIMER - This presentation was prepared using draft rules. There may be some changes in the final copy of the rules. The rules which will be in your Coaches Manual and Student Manuals will be the official rules. ***BE SURE TO CHECK THE 2016 EVENT RULES*** for EVENT PARAMETERS and TOPICS FOR EACH COMPETITION LEVEL

TRAINING MATERIALS:

- **Training Power Point** presents an overview of material in the training handout
- **Training Handout** has a Review of Cell Biology Concepts and Possible Test Topics
- **Practice Activities -** A variety of sample stations and their answers
- **2 Sample Tournaments** has sample problems with key
- **Event Supervisor Guide** has event preparation tips, setup needs and scoring tips
- **Internet Resource & Training Materials** are available on the Science Olympiad website at www.soinc.org under Event Information.
- **A Biology-Earth Science CD (updated for 2016)** , a **Cell Biology CD (updated for 2015)** as well as the **Division B and Division C Test Packets** are available from SO store at www.soinc.org

Event Format :

- This is a lab-orientated competition to answer questions, solve problems, and analyze data pertaining to various kinds of microbes.
- Content topics are listed in the rules and the level of reasoning and math skills should be consistent with the grade level. – FROM DRAFT RULES – CHECK FINAL PRINTED RULES 2016

At the regional and state level:	At the national level:
1) Biological monomers and polymers 2) Cellular homeostasis (pH, osmolarity etc.) 3) Enzymes and inhibition 4) Cell organelles/structures and their functions 5) Differences between eukaryotic and prokaryotic cells 6) Bioenergetics 7) Membrane structure and function **including lipid rafts, transport** **8) Vesicle formation, fusion** **9) Nucleotide triphosphates in energetics and signaling** **10)** Cell cycle and mitosis, **role of cyclins and kinases** 11) Chromosome structure 12) Fermentation products and uses	All topics from state and regional plus: 1) Cell communication, membrane receptors**, and signal transduction** 2) Apoptosis **and cancer** **3) Cell cytoskeleton and intracellular trafficking** **4) Induced pluripotent stem cells** **5) Host/virus interactions** 6) C_3 vs. C_4 vs. CAM plants **7) Protein folding and related diseases** 8) Cancerous vs. healthy cells 9) Genomics **and medicine/human health** 10) Bioethics relating to above topics

- **Be sure to check to rules for 2016 for Event Parameters for this event.**

Review of Cell Biology Concepts

Definition of a cell: fundamental structural and functional unit of all living organisms
Characteristics of cells:

- Contain highly organized molecular and biochemical systems and are used to store information
- Use energy
- Capable of movement
- Sense environmental changes
- Can duplicate (transfer genetic information to offspring)
- Capable of self-regulation

Most cells are microscopic (invisible to the naked eye) and thus, a microscope is needed to view most cells.
Cell Theory states: (Note – viruses are not living because they require a host cell to replicate)

- All living organisms are composed of cells
- Cells are the functional units of living organisms
- Cells arise from preexisting cells via division

Cell Structure:

- Most cells are microscopic and cannot be seen by the naked eye.
- Microscopes were developed to visualize cells.
- Resolution is the minimum distance where 2 objects can be visually separated

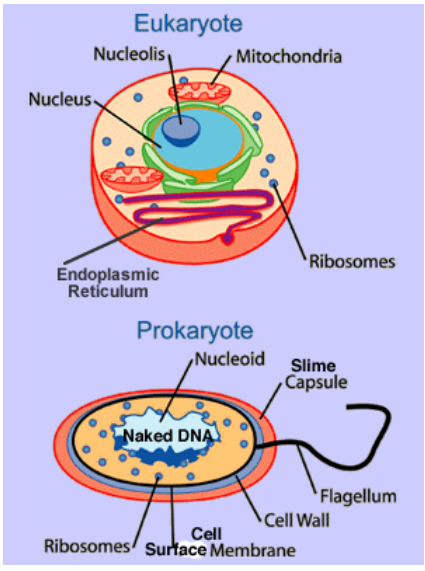
Depends on:-Wavelength of light & Refractive index of the medium of the light
The naked eye can resolve two separate objects separated by 200 um

Differences between Prokaryotic vs Eukaryotic Cells

- **Prokaryotic cell** – single celled microorganism (Archaebacterium or Eubacterium), most often with a cell wall but lacks membrane bound organelles observed in Eukaryotic Cells.
- **Eukaryotic cell** – cell has nucleus with a membrane around the genetic material and other membrane organelles.

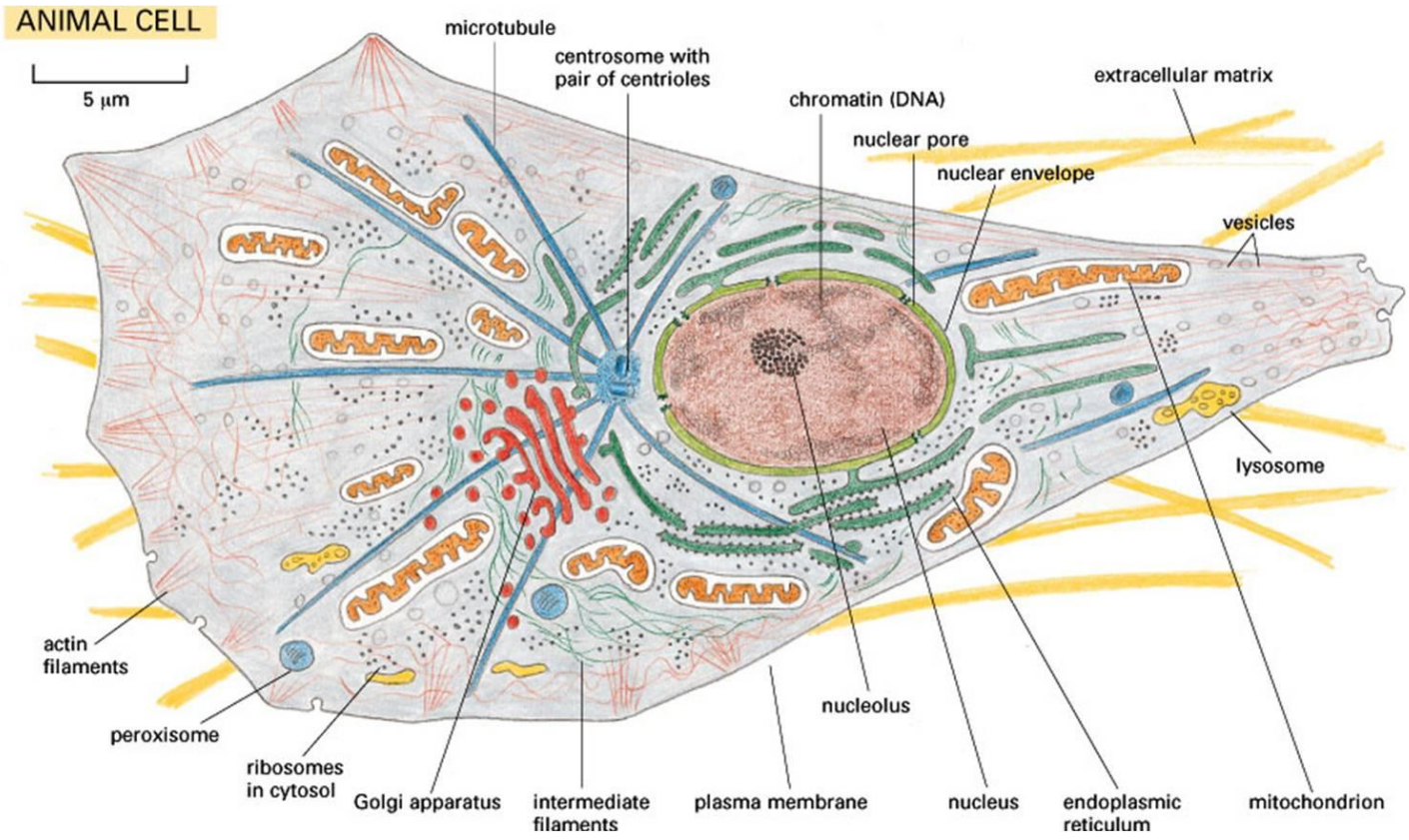
Prokaryotic Cells- small and primitive bacteria and blue-green algae (cyanobacteria)
Greek: Pro=before karyon=nucleus

- Lacks specialized internal membrane-bound compartments known as organelles
- **Cell membrane**- functions in transport, the movement of substances in and out of the cell, and in energy production (breakdown of large molecules, photosynthesis)
- **Cell wall**- gives structural strength (rigidity) to the cell
- **Capsule**- jelly-like substance which protects the cell wall from environmental damage
- **Nucleiod**- contains a single circular molecule of DNA (stores genetic information)
- **Cytoplasm**- region surrounding the nucleiod and within the cell membrane - Contains ribosomes and RNA (site of protein synthesis)
- **Vacuole** (**vesicles**)(blue-green algae)-site of photosynthesis (storage)
- **Flagellum**- protein fiber the functions in movement



Eukaryotic Cell- (eu=true karyon=nucleus)

- Possesses a complex membrane system
- Has a true nucleus
- Distinct membrane-bound intracellular compartments called organelles



Surface of Cell:

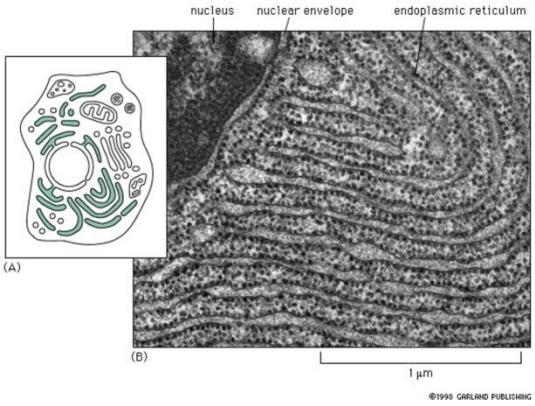
- **Cell Wall** – commonly found in plants cells – protection & support
- **Plasma Membrane** – control of substances coming in and out
- **Cilia** - sweep materials across the cell surface
- **Flagellum** - enables a cell to propel and move in different directions

Cytoplasm – major portion of the protoplasmic substance within the cell membrane - between plasma membrane and nucleus – many organelles

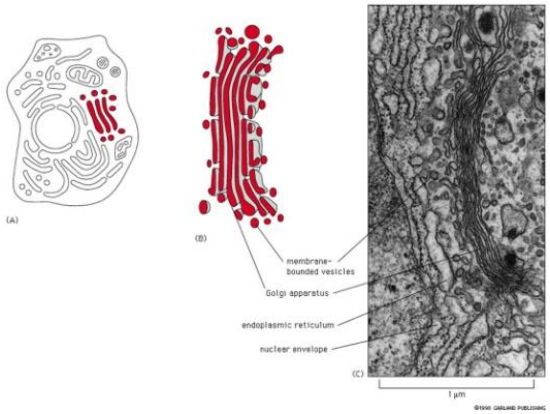
- **Cytosol –** the fluid portion of a cell's cytoplasm, which lies outside the organelles and other insoluble components of the cytoplasm. It contains water, free proteins, and a variety of other substances and is where a major part of cellular metabolism takes place. The proteins within cytosol play an important role in glycolysis, serve as intracellular receptors, and form part of ribosomes, enabling protein synthesis. Cytosol also contains the cytoskeleton.
- **Endomembrane System** which consists of the nuclear envelope, endoplasmic reticulum (ER), Golgi apparatus, vesicles and other organelles derived from them (for example, lysosomes,

peroxisomes), and the plasma membrane. Many materials, including some proteins, are sorted by the functionally cellular membranes of the endomembrane system

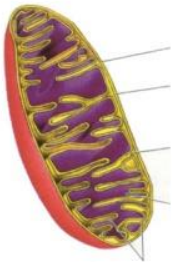
- **Endoplasmic reticulum (ER)** is (***internal transport system***) the passageway for transport of materials within the cell- a network of intracellular membranes where secreting proteins are synthesized
- **Rough ER**- the ER + ribosomes – supply raw materials for protein synthesis
- **Smooth ER**- the ER without ribosomes
    - Functions in the breakdown of fats attached to the rough ER in the Golgi complex
    - Synthesis of lipids – modification of newly formed polypeptide chains

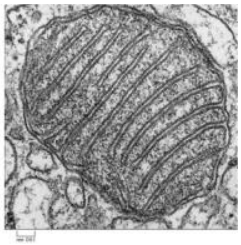


- **Ribosomes** the ***site of protein synthesis*** - a cytoplasmic particle that contains RNA and protein and is involved in the process of protein synthesis.
    - Translocation-process which takes place in the cytoplasm and converts genetic information in RNA into proteins.
    - Ribosomes can either be freely suspended in the cytoplasm or attached to intracellular membranes
    - Many proteins are made on ribosomes that are free in the cytoplasm and remain in the cytoplasm, other proteins are made on ribosomes bound to the rough endoplasmic reticulum (RER).
    - The latter proteins are inserted into the lumen of the RER, carbohydrates are added to them to produce glycoproteins, and they are then moved to cis face of the Golgi apparatus in transport vesicles that bud from the ER membrane
- **Golgi apparatus**-***packing center*** - a membranous organelle that packages and sorts newly synthesized secretory proteins- Final modification of proteins & lipids Packing of materials for secretion of the cell



- Mitochondria Consists of an outer membrane and a convoluted inner membrane- Site of aerobic cellular respiration and site of ATP production within the cell





Vesicles

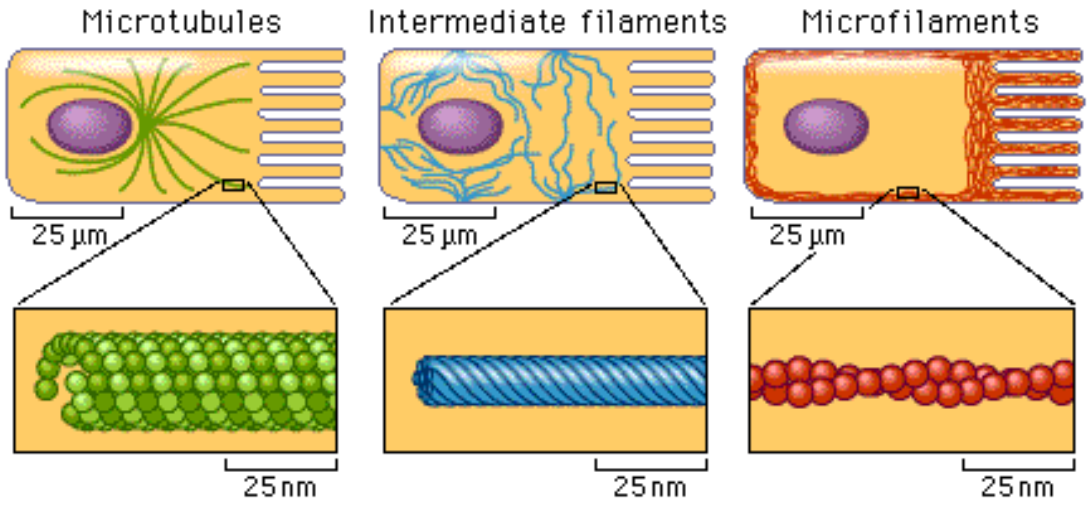
- Small cell organelles that are present in cells.
- Small, membrane enclosed sacs which store and transport substances to and from one cell to another and from one part of a cell to another.
- Separated from the rest of the cytoplasm by at least one phospholipid bilayer. The membrane that encloses the vesicle is similar to the plasma membrane.
- Can fuse with the plasma membrane when they want to release their contents outside the boundaries of the cell.
- Can also fuse with other organelles that are present inside the cell to release or engulf substances.
- Function in cell, thus, varies depending on the **type of vesicle** that is present:

- **Lysosomes**- ***recycling center*** - contain enzymes to digest ingested material or damaged tissues contain digestive enzymes that are used to break down substances in the cell into smaller molecules. - present only in animal cell, - consists of small sacs that are bound by a single layered membrane. involved with cellular digestion to eliminate harmful substances from the cell with the help of endocytosis. through a phagocytosis process.
- **Vacuoles** - an organelle that is predominantly present in plant and fungal cells. It is also seen in certain animal and bacterial cells, though it is one of the prominent plant cell parts. These organelles are filled with fluid and basically contain enzymes in solution. The vacuoles are responsible for isolating materials from the cell which may be harmful to it and also, containing waste products within themselves. As an autophagic vesicle, function of this cell organelle is to ingest and destruct any invading bacteria. It is also responsible for ***storage*** of liquids to increase cell surface area for maintaining the turgor pressure in the cell and the pH of the cell.
- **Transport Vesicles** - membrane bound vesicles which are nothing but secreted proteins and are made on ribosomes which are found in the rough endoplasmic reticulum. Most of these proteins mature in the Golgi apparatus before going to their final location, which may be lysosomes, peroxisomes or some place outside the cell. These proteins are carried from one location to another inside the transport vesicles. Hence, as the name suggests, transport vesicle function is to move molecules between different locations inside the cell.
- **Secretory Vesicles** - Secretory vesicles are those vesicles that contain material that is to be excreted from the cell. Thus, these vesicles may contain material that is harmful for the cell, and hence, there is need to get rid of it. So, it may contain waste products or end products of reactions in the cell. These in fact, may even contain many useful secretions that are needed in different parts of the body. There are different types of secretory vesicles, like synaptic vesicles, which are located at pre-synaptic terminals in the neurons. In this type of secretory vesicle, function of the organelle consists of storing neurotransmitters. The hormones that are secreted from the endocrine glands are also stored in secretory vesicles, from where they are released into the bloodstream.
- **Microbody-(peroxisome)-** organelle within a cell containing specialized enzymes whose functions involve hydrogen peroxide

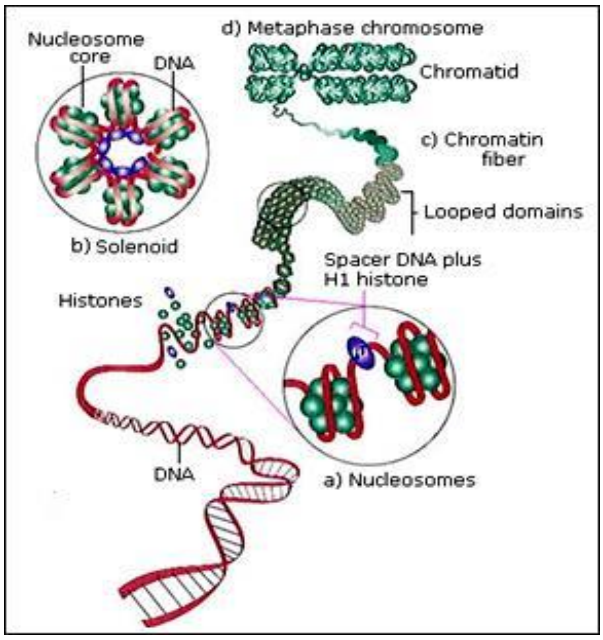
- **Chloroplasts – *store chlorophyll*** – photosynthesis light reaction
- **Centrioles** - organize the spindle fibers during cell division

Cytoskeleton – cell shape, internal organization, cell movement & locomotion

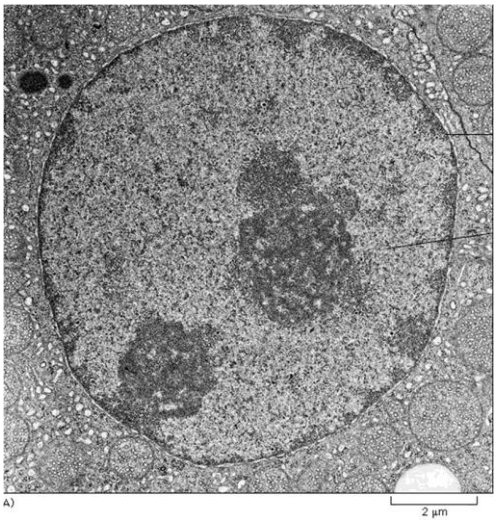
- Consists of microtubules, intermediate fibers, and microfilaments, which together maintain cell shape, anchor organelles, and cause cell movement.
- Microtubules and microfilaments are frequently assembled and disassembled according to cellular needs for movement and maintaining cell shape.
  - **Intermediate filaments** are more permanent than microtubules and microfilaments- they provide tensile strength for the cell
  - **Microtubules**-composed of tubulin - act as a scaffold to determine cell shape, and provide a set of "tracks" for cell organelles and vesicles to move on. Microtubules also form the spindle fibers for separating chromosomes during mitosis. When arranged in geometric patterns inside flagella and cilia, they are used for locomotion.
  - **Microfilaments**-composed of actin - Microfilaments' association with the protein myosin is responsible for muscle contraction. Microfilaments can also carry out cellular movements including gliding, contraction, and cytokinesis.
- The location and appearance of cytoskeletal fibers in different cell types will vary.
- Both microtubules and microfilaments are involved in cellular movement
- Intercellular-includes flagella and cilia
- Intracellular- cytoplasmic streaming
- The cell diagrams shown here represent intestinal epithelial cells with fingerlike projections, the microvilli.

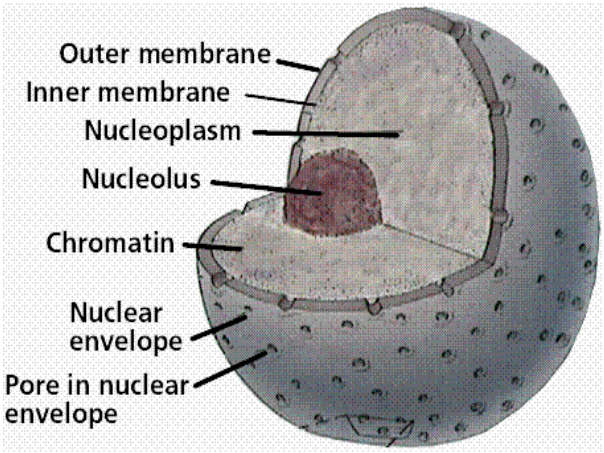


Nucleus: - control center of the cell dark-staining body within the cell by enclosed an intracellular membrane called the nuclear envelope

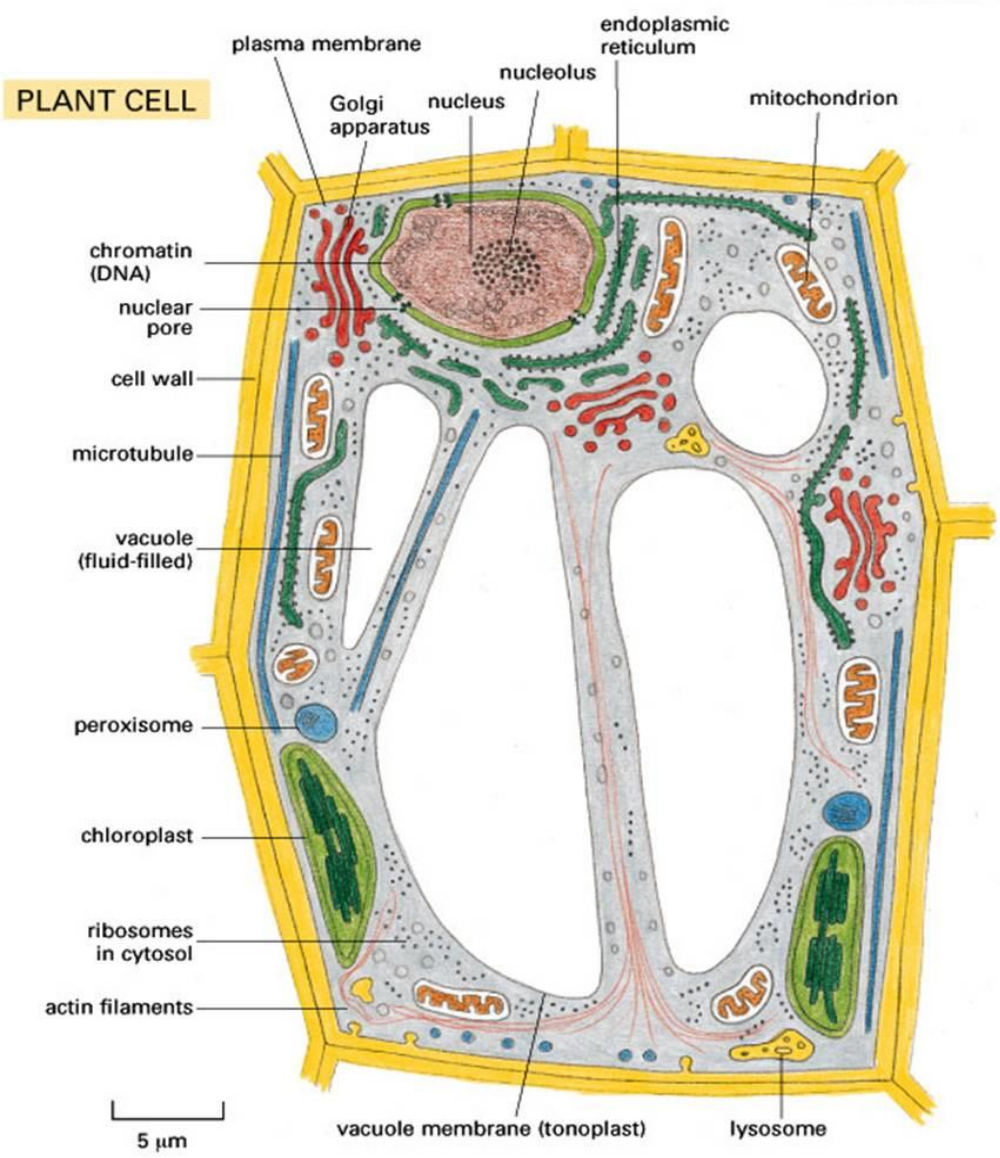


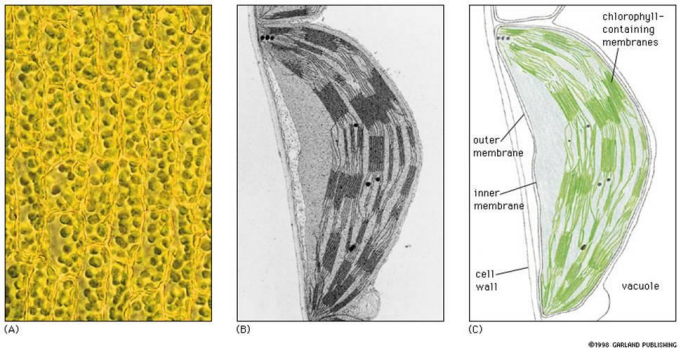
- DNA replication-duplication of genetic material
- Contains DNA in the form of chromatin fibers
- DNA is linear (linear DNA + proteins = chromosome)
  a. **Nucleosomes** – fundamental repeating units of DNA wrapped around 8 histone proteins plus stretches of linker DNA
  b. **Solenoid** – coiling of nucleosomes like a phone cord
  c. **Chromatin fiber** – fiber of repeating nucleosomes
  d. **Metaphase chromosomes** – coiled chromosomes during metaphase of mitosis
- Nucleus also contains RNA (mRNA, rRNA, and tRNA)
- Transcription- conversion of genetic information from DNA to RNA occurs in the nucleus
- **Nuclear membrane or Nuclear envelope** contains pores, which are filled with a ring of proteins called annulus– membrane around nucleus – controls movement in an out
- **Nucleolus** – assembly of subunits of ribosomes.
- **DNA** - a cell organelle in the nucleus that disappears during part of cell division. Contains rRNA genes encoding of heredity information
- **RNA** – transcription and translation of DNA coding into proteins





Special Plant cell organelles:
Chloroplast- involved in photosynthesis
Central vacuole- provides support to the plant via osmotic pressure
Cell wall- composed of cellulose, which provides extra strength and rigidity

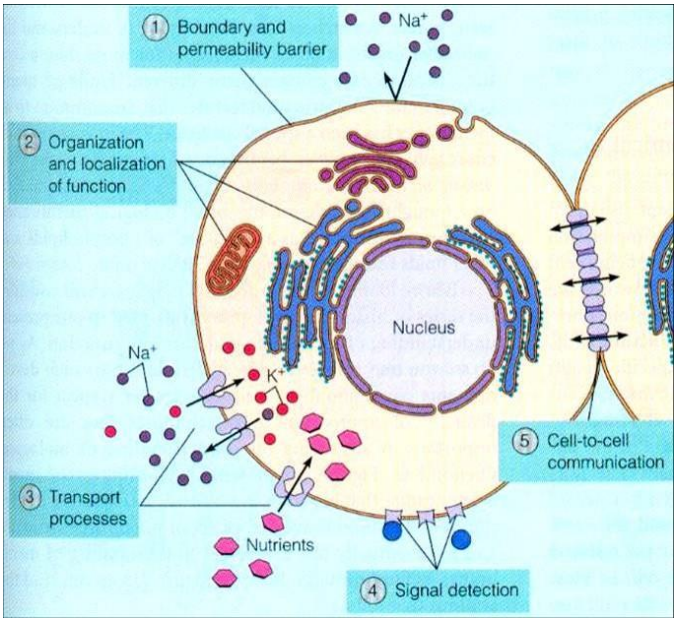




Cell Membrane Structure and Function

Cell membranes

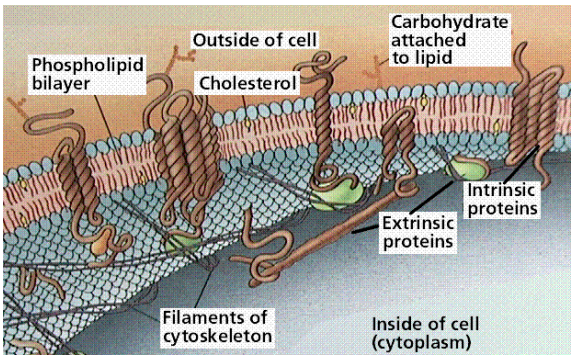
- ***Boundary*** - provide adjustable barriers between the cell and the extracellular environment or adjacent cells
- ***Transport*** - regulate the transport of materials into and out of the cell
- ***Cell to cell communication*** - respond to external and internal stimuli – communicate with other cells
- ***Cell-to-cell recognition***
- The cell itself is surrounded by the **plasma membrane,** and membranes form intracellular organelles or isolate the contents of cellular organelles from the cytoplasm

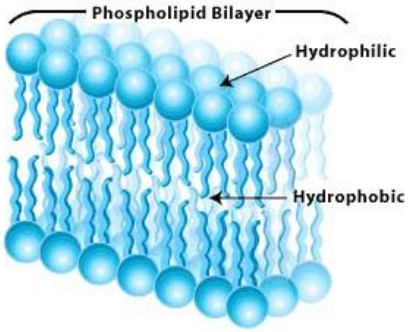


Composition: mainly protein and phospholipid; some proteins extend thru membrane-Cholesterol is also a constituent of the lipid bilayer. It stiffens and strengthens the plasma membrane

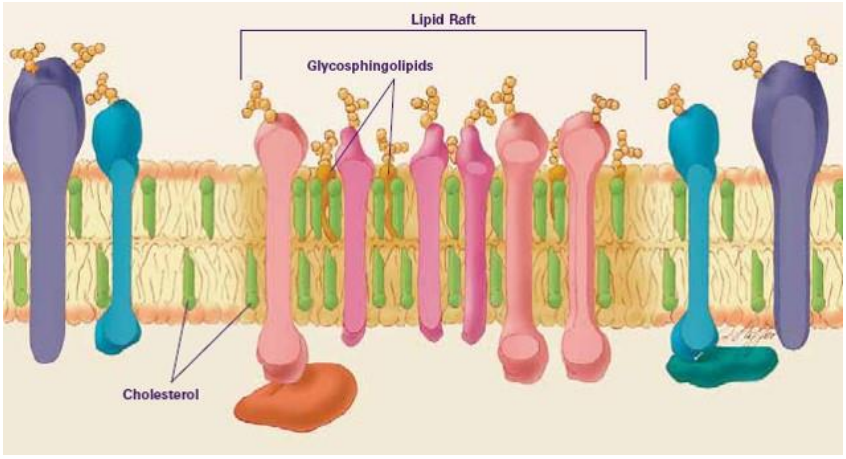
Fluid Mosaic Model

- For 30 years, the **fluid mosaic model** of Singer and Nicolson has provided the foundation for our understanding of the structure of cellular membranes. In this model, membrane proteins are viewed as icebergs floating in a sea of phospholipids.





Lipid Rafts



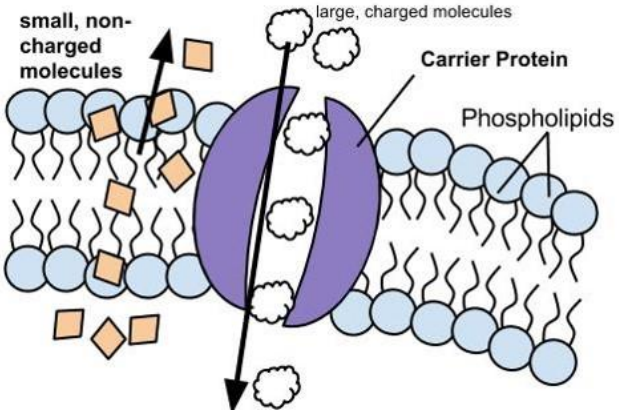
- Work over the last decade has provided evidence that the plasma membrane is not a random ocean of lipids.
- There is structure within this sea of lipids that in turn imposes organization on the distribution of proteins in the bilayer. The lipid "structures" within the membrane ocean are called **lipid rafts**
- The plasma membranes of cells contain combinations of glycosphingolipid**s** and protein receptors organized in glycolipoprotein microdomains termed **lipid rafts**.
    - These specialized membrane microdomains compartmentalize cellular processes by serving as organizing centers for the ***assembly of signaling molecules,*** influencing membrane fluidity and membrane protein trafficking, and regulating neurotransmission and receptor trafficking.
    - Lipid rafts are more ordered and tightly packed than the surrounding bilayer, but float freely in the membrane bilayer.
    - Although more common in plasma membrane, lipid rafts have also been reported in other parts of the cell, such as Golgi and lysosomes.

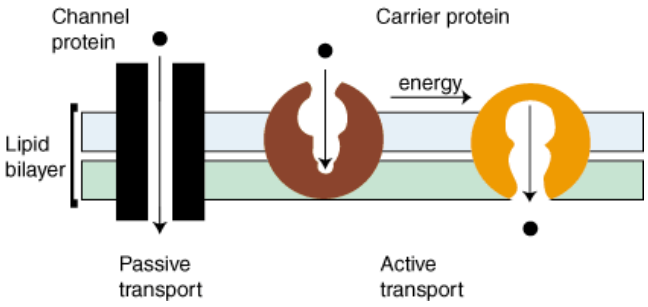
Cell membrane with lipid rafts

- Functions of the lipid rafts
    - Lipid rafts appear to exert both positive and negative control on signal transduction.
    - In their positive role, rafts containing different signaling proteins may cluster or fuse upon agonist stimulation, leading to the mixing of components and resulting in the activation of signaling pathways.
    - In their negative role, rafts may spatially segregate interacting components to block nonspecific pathway activation, or may directly suppress the activity of signaling proteins present in rafts.

Proteins serve different functions

- **Transport Proteins** – that move chemicals into and out of the cell
    - **Channel Proteins** that form small openings for molecules (electrolytes) to diffuse through by means of passive transport
    - **Carrier Proteins**- binding site on protein surface "grabs" certain molecules and pulls them into the cell (gated channels) – it involves active transport so energy is required

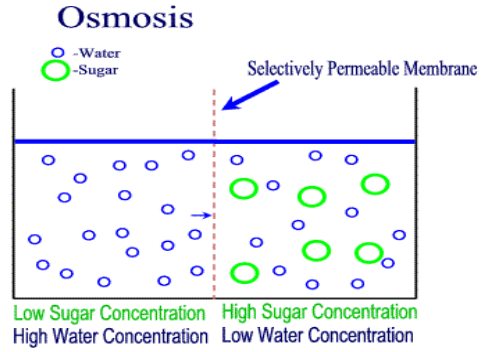


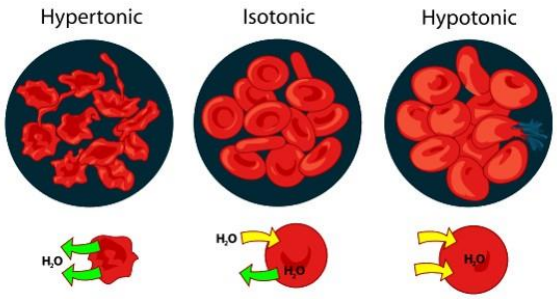


- **Receptor Proteins** - molecular triggers that set off cell responses (such as release of hormones or opening of channel proteins)
- **Adhesion Proteins** – attach cells to other cells or fibrous extracellular material
- **Cell Recognition Proteins** - ID tags, to identify cells to the body's immune system
- **Enzymatic Proteins** - carry out metabolic reactions
- **Structural Proteins** – stabilize the cell

Movement across Membranes

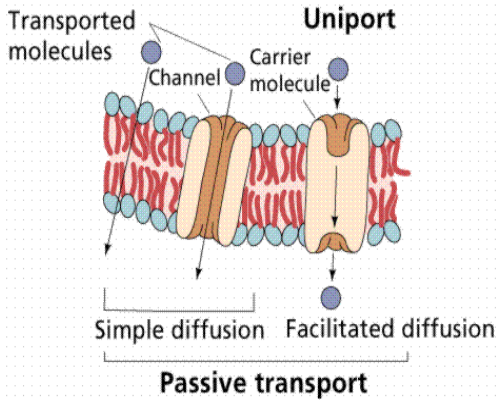
- **Diffusion**: molecules moving from high to low concentration; concentration = #molecules/volume
- **Osmosis**: diffusion of water across a selective membrane; amount of water is opposite of number molecules-if water is high, solute (molecules) is low.
- **Facilitative diffusion**: just like diffusion (high to low) but a protein carrier is involved **Note**: diffusion will continue but rate of transport with carrier will level off because carrier becomes saturated
- **Hypotonic** - low solute concentration relative to another solution.
- **Hypertonic** - high solute concentration relative to another solution.
- **Isotonic** - solute concentration is the same as that of another solution.

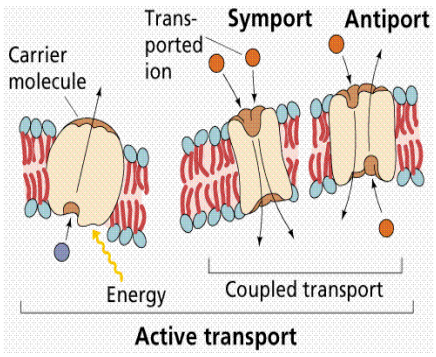




Turgor Pressure: In plant cells, water moving into the cell pushes the cell membrane up against the cell wall. The large central vacuole stores liquids and aids in maintaining turgor pressure. Loss of water from the vacuole or cytoplasm causes shrinkage of cellular contents or **Plasmolysis.** In plants cells it results in wilted tissue – in animal cells it may cause cell to collapse as with RBC's.

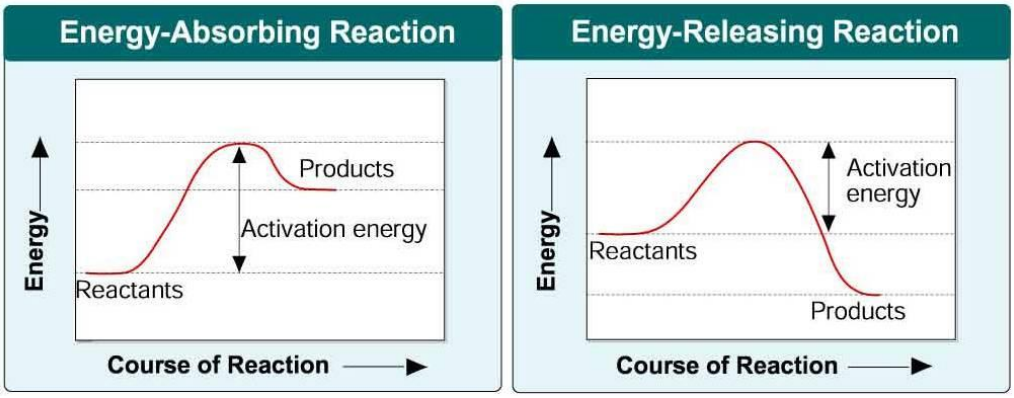
- **Passive Transport:** No energy is required
- **Active transport**: movement from low to high; requires protein carrier; requires ATP



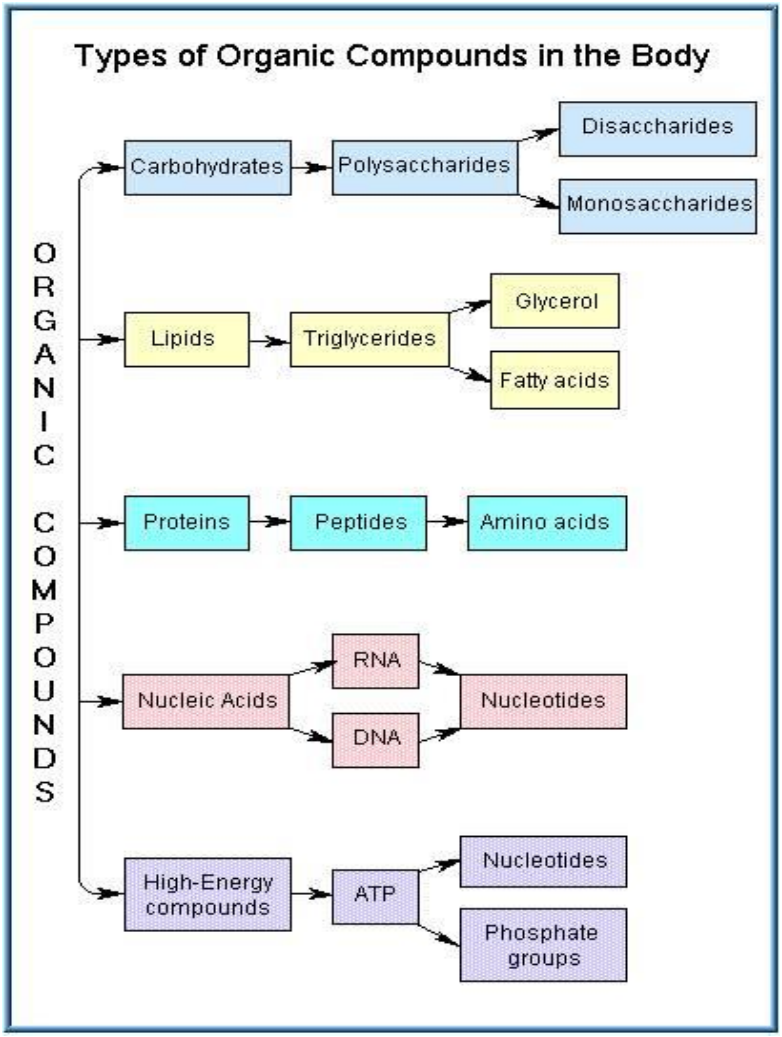


Introduction - Types of chemical reactions

- **Endergonic**: require energy
- **Exergoinc**: give off energy



- **Catabolism**: reactions breakdown large molecules and produce small molecules; Ex. Digestion of protein into amino acids
- **Anabolism**: reactions requiring energy to make large molecules from small molecules; Ex: the synthesis of a protein from amino acids



Types of Biological Molecules – Monomers and Polymers

- Building blocks are monomers
- Macromolecules are polymers
- **Monomers** are simple sugars, amino acids, nucleotides, glycerol and fatty acids
- They are the building blocks for the **Polymers** - polysaccharides, proteins, nucleic acid (DNA & RNA), and triglyceride or fats.
- Polymers are made by dehydration synthesis or the removal of the equivalent of water.

Chemical Bonds:

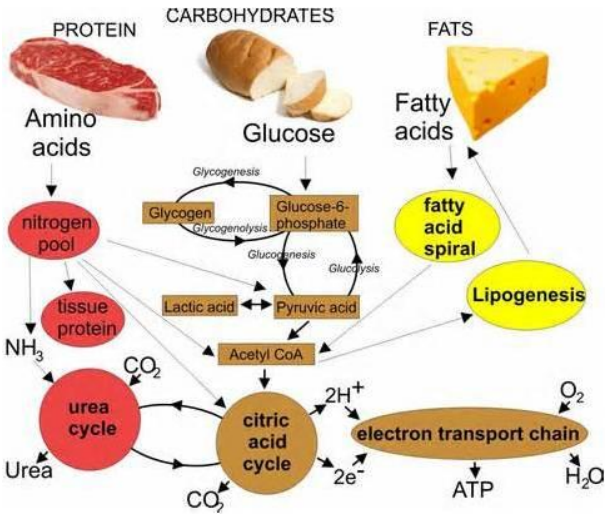
4 types of molecules make up cells:

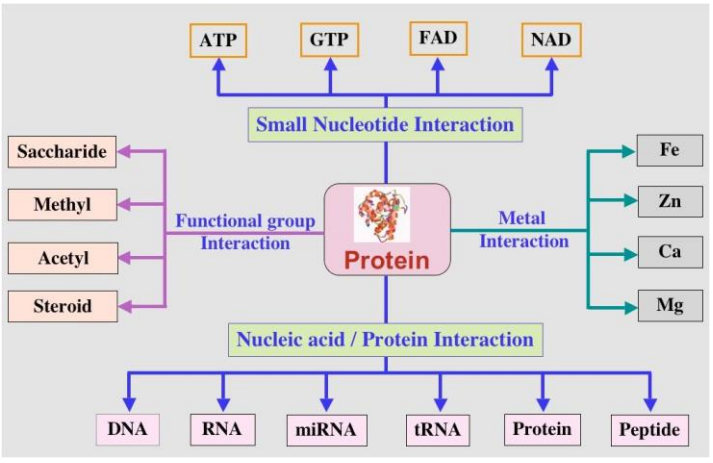
- Carbohydrates
- Lipids
- Proteins
- Nucleic acids

Biological macromolecules are held together by several different types of bonds:

- Ionic bond-a transfer of electrons
- Covalent bond-the sharing of electrons
- H-bonds-weak attraction when H^+ serves as a bridge between 2 electronegative atoms by a covalent bond and electrostatic attraction
- Nonpolar associations-hydrophobic vs. Hydrophilic
- Van der Waals-a momentary dipole that will affect the electron distribution of neighboring molecules

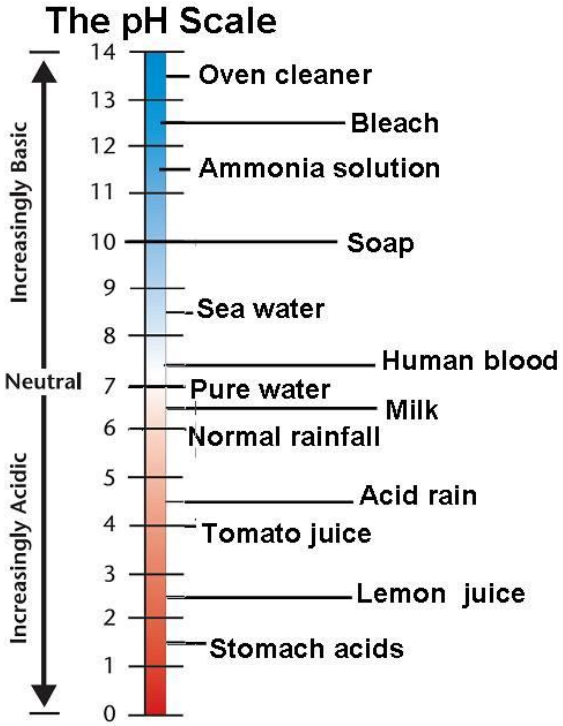
monomer	polymer	example	Reagents
simple sugar (monosaccharide)	polysaccharide	starch, cellulose, glycogen (animal)	Benedicts-glucose Iodine-starch
amino acid	protein, polypeptide	hair, enzyme, hemoglobin, insulin	Ninhydrin, Biuret
nucleotide	nucleic acid	DNA, RNA	methyl green
fatty acid/glycerol	fat or tri -glyceride **LDL and HDL**	cooking oil, butter	grease test with brown paper





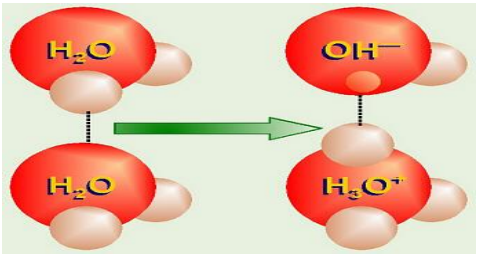
pH **–** Hydrogen ion concentration

- A liquid may be an acid, base, or neutral.
- The degree of acidity or basicity can be measured by using the pH scale.
- The scale is divided into three areas: Acid (readings below 7), neutral (reading of 7), and basic (readings above 7).
- Each division either increase or decreases the pH of a substance 10 times.
- The pH of 5 is ten times more acidic than a pH of 6.
- Water has a pH of 7 but when it mixes with air the suspended materials will either raise or lower its pH.
- Acid Rain is an example of this type of reaction.



Acids and Bases: Lewis definition:

- **Acid**-a substance that can take up an electron pair to form a covalent bond
- **Base**-a substance that can donate an electron pair to form a covalent bond

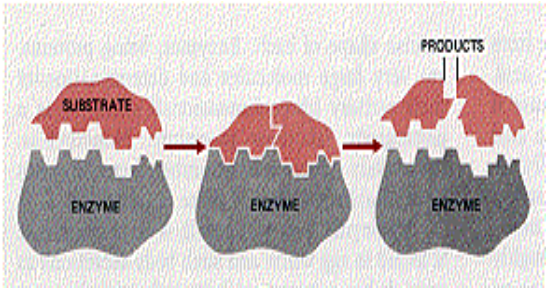


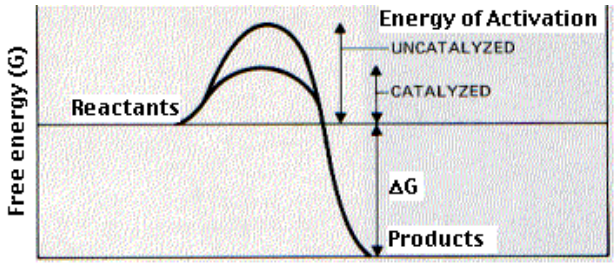
- H_2O dissociates into H^+ ions and OH^-
- $[H^+] + [OH^-] = 1x10^{-14}$ moles/liter (M)
- $pH = -\log_{10} [H+]$
- Acid pH is from 0 to 7
- Base pH is from 7 to 14
- **Condensation reaction**-when two molecules are combined into one molecule with the release of one water molecule A + B == C + H_2O Ex: 2 amino acids are joined together to form a dipeptide molecule
- **Hydrolysis reaction**-when one molecule is broken into two molecules with the addition of water molecule C + H_2O == A + B Ex: disaccharide maltose + water == 2 glucose molecules
- **Reactive Organic Molecules**
  - *Hydroxyl group* - strongly polar and highly reactive
  - *Carbonyl group* - weakly polar and highly reactive
  - *Aldehyde*
  - *Ketone*
  - *Carboxyl group* - strongly polar and acts as an acid
  - *Amino group* - polar and acts as a base
  - *Phosphate group* - acidic and polar
  - *Sulfhydral group* - readily oxidized-Two sulfhydral groups can bond together to form a disulfide bond

Enzymes

Characteristics of enzymatic proteins:

- **Activation energy**: the energy that must be added to a molecular system to allow a chemical reaction to start
  - One way to supply energy is to heat the reactants
  - Second way is to add a catalyst
- Catalyst forms a complex with the reactant, thus bringing the reactants closer together so they can react
- Enzymes are catalysts.
- Enzyme vs. other catalysts: enzymes are very specific and only work on one or a few molecules substrate: molecule(s) upon which enzyme works active site: part of enzyme that interacts with substrate
- Three enzymatic mechanisms which can contribute to the formation of a transition state is a catalyzed biological reaction
  - Enzyme brings reacting molecules into close proximity
  - Enzyme orients reactants into positions to induce favorable interactions
  - Enzymes alter the chemical environment of the reactants to promote interaction



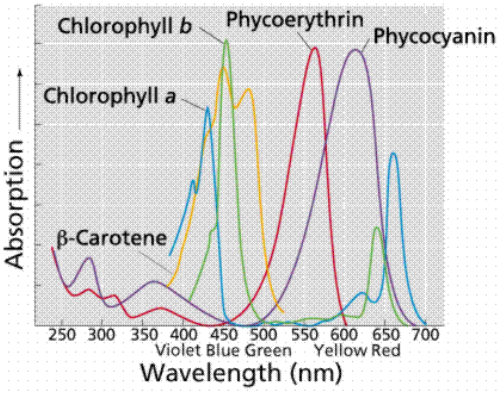


- They lower activation energy and remain unchanged by the reaction
- Enzymes combine briefly with reactants during an enzyme-catalyzed reaction **(enzyme-substrate complex**)
- Enzymes are specific in their activity; each enzyme catalyzes the reaction of a single type of molecule or a group of closely related molecules
- Enzymes are saturated by high substrate concentrations
- Enzymes are released unchanged after catalyzing the conversion of reactants to products because they do take part in the reaction.
- Enzymes are proteins (usually, some RNA molecules can act as enzymes); proteins are sensitive to changes in temperature and pH. They will change shape and become inactive. some enzymes are larger inactive molecule; activation involves enzymatic removal of some amino acids
- Many enzymes contain non-protein groups called **cofactors**
- Co-factors, usually metal or vitamin; others activated by addition/removal of phosphate
  - Inorganic cofactors = metal ions
  - Organic cofactors = coenzymes (ex: vitamins)
- **Competitive Inhibition** has the molecule binding at active site; it resembles the substrate and is overcome by increase in substrate concentration while **Non-competitive Inhibition** has binding at a site other than the active site; its molecule is different than the substrate and it is not reversed by increased substrate but it may be irreversible if it covalently alters the enzyme. It binds only to enzyme substrate complex

MECHANISMS OF ENERGY TRANSFER

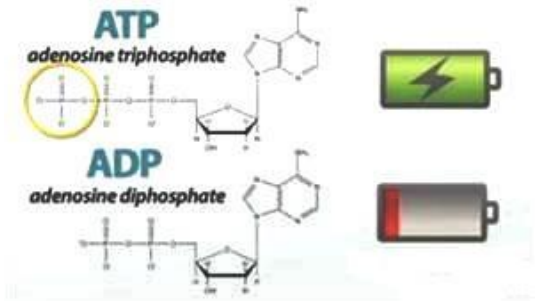
Energy

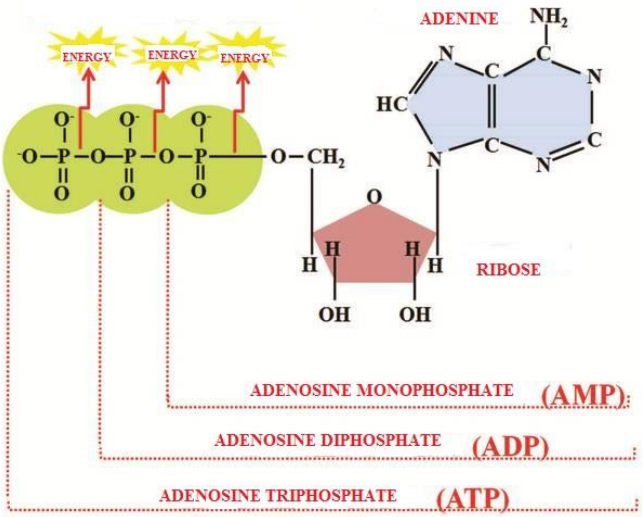
- Sunlight contains energy – under the right conditions it can be converted into other forms of energy as chemical bond energy, electricity, kinetic energy, heat, etc.
- Light has both wave-like and particle-like properties.
    - Packets of energy are called photons
    - Wavelengths of light are measured in units called nanometers (very small units)
    - The shorter the wavelength of light, the more energy it contains photon
- Plants contain the pigment chlorophyll (a & b) in the thylakoids of the chloroplast
- When sunlight hits a leaf, the light is absorbed – some of the light is transmitted through the leaf like a filter and the rest is reflected away
- The green in the photosynthesis causes red and blue to be absorbed while green and yellow are reflected away



Importance of ATP

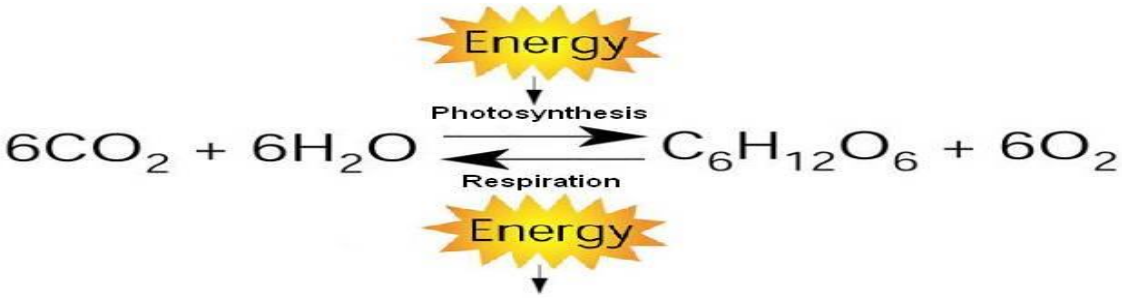
- Chemical storage battery for cells – major energy currency for the cell
- Production of much ATP requires membranes to generate current to make ATP
- ATP has many cell functions
    - Transport work – moving substances across the cell in active transport
    - Mechanical work – supplying energy for muscle contraction, chromosomes, and flagella
    - On-off switch to control chemical reactions and send messages.
- Plants carry out both photosynthesis and cellular respiration
- Almost all of ATP produced in photosynthesis is used in photosynthesis to provide the energy to produce the bonds for the glucose molecules
- Amount of ATP produced in cellular respiration varies from cell to cell; emphasize quantitative aspects; most of ATP is produced via electron transport chain.



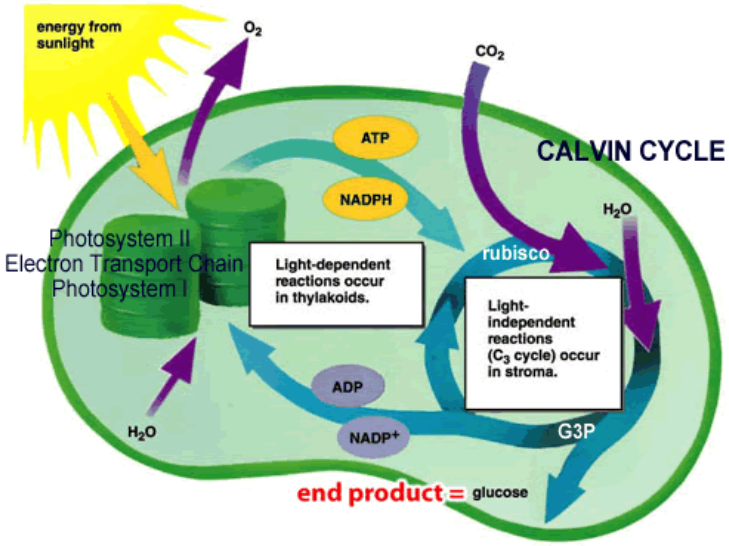


- Main reason that cells need oxygen: to allow them to make lots of ATP. Oxygen cannot be stored, so it must be constantly supplied.

Aspects of Photosynthesis and Respiration

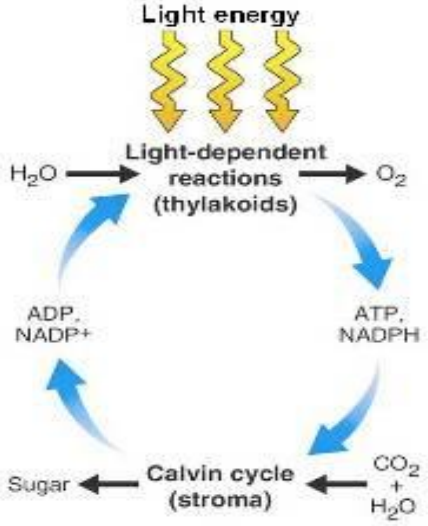


PHOTOSYNTHESIS - The process which occurs in the chloroplasts of green plants in which simple sugars are formed from carbon dioxide and water in the presence of light and chlorophyll - light energy is absorbed by specialized pigments of a cell and is converted to chemical energy – it involves trapping of sunlight energy followed by its conversion to chemical energy (ATP, NADPH, or both) and then synthesis into sugar phosphates which convert into sucrose, cellulose, starch, and other end products. It is the main pathway by which energy and carbon enter the food webs.



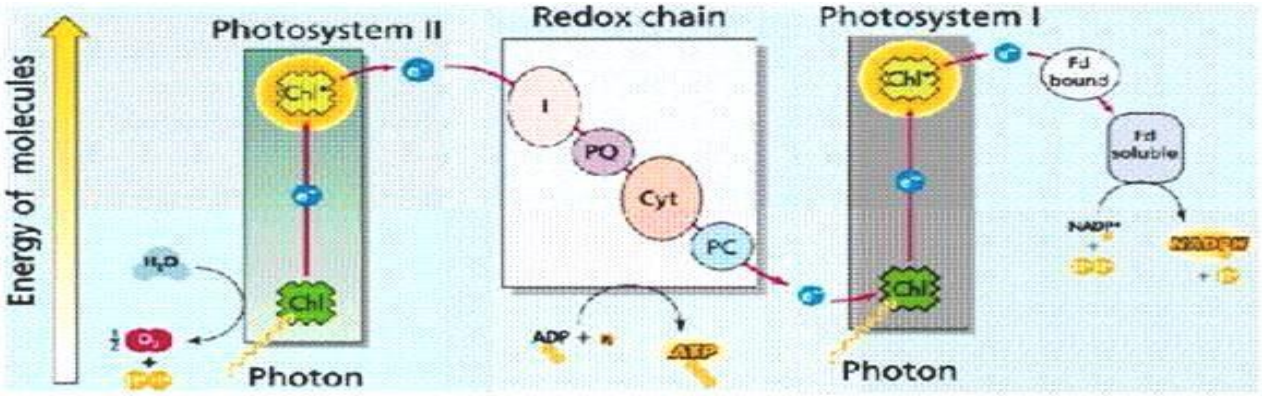
CO^2 + H^2O -------> glucose + oxygen

- Photosynthesis is a reduction process, where hydrogen is reduced by a coenzyme. This is in contrast to respiration where glucose is oxidized.
- Two major parts of photosynthesis
  - **Light reactions**: (Photolysis) conversion of light energy into ATP and NADPH
  - **Dark reactions:** *Calvin Cycle* (the thermochemical stage) use of energy (ATP & NADPH) to form carbohydrates
    - Purpose of photosynthesis
    - Main biosynthetic pathway by which carbon and energy enter the web of life
- Where it occurs – in the Chloroplast
  - **Light reactions** - granum (several thylakoids) and thylakoid membranes
    Dark reactions - stroma

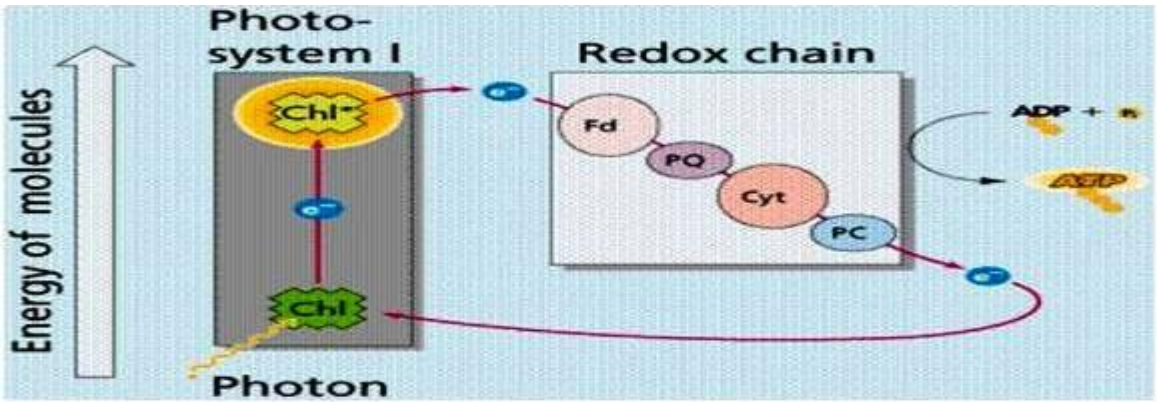


LIGHT REACTIONS (also light-dependent reactions)

- This part of photosynthesis occurs in the *granum* of *a chloroplast* where light is absorbed by *chlorophyll*; a type of photosynthetic pigment that converts the light to chemical energy. This reacts with water (H_2O) and splits the oxygen and hydrogen molecules apart.
- From this dissection of water (**photolysis)**, the **oxygen** is released as a by-product while the **reduced hydrogen acceptor** makes its way to the second stage of photosynthesis, the Calvin cycle. - water is oxidized (hydrogen is removed) and **energy** is gained in photolysis which is required in the Calvin Light-trapping molecule
- Chlorophyll (antenna chlorophyll pick up light)
  - Transmits green and absorbs red and blue
  - Right wavelength of energy excites an electron of chlorophyll
  - Inductive resonance carries excitation energy from molecule to molecule
  - Energy (P700 or P680) is transferred to an acceptor molecule
- Two options for **electron excitation energy** – electrons originate from the breakdown of water which liberates hydrogen ions and oxygen
  - **Non-cyclic photophosphorylation (Photosystem II-P680 and then Photosystem I** – P680) - long pathway - Occurs in eukaryotic plants – algae, mosses, ferns, conifers, & flowering plants Oxygen and NADP are generated

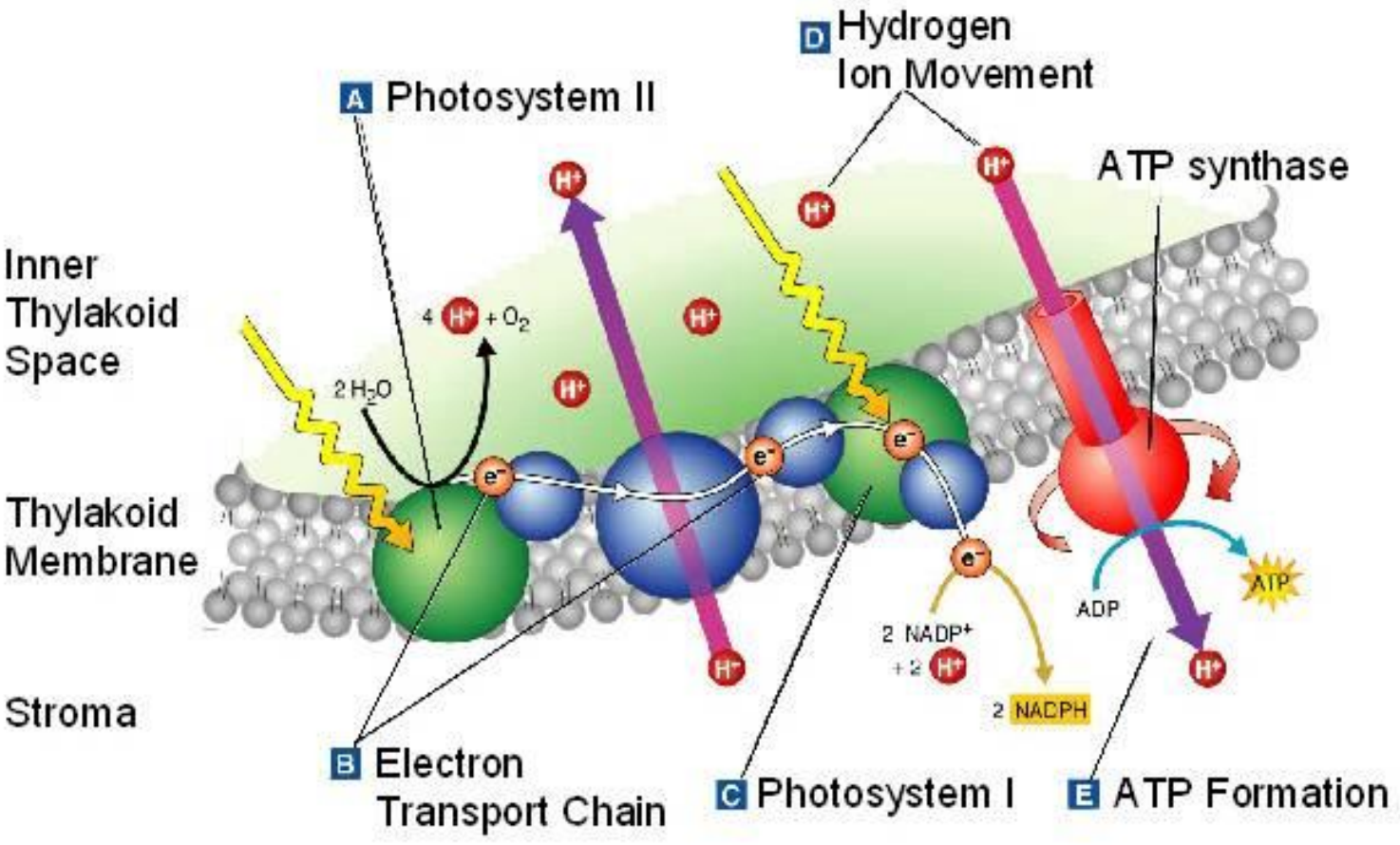


  - **Cyclic photophosphorylation – (Photosystem I –P700) –** short pathway
    Occurs in prokaryotes (Cyanobacteria) with electrons being used over and over again
    No oxygen or NADP are generated

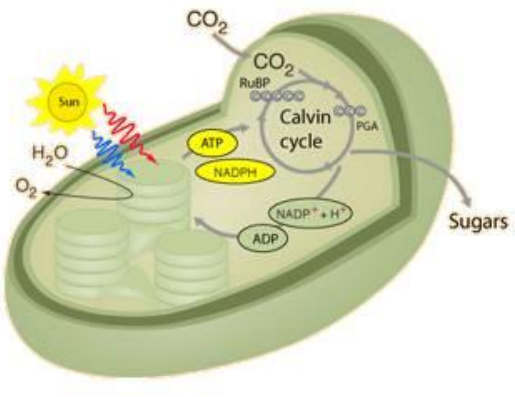


Steps in Non-cyclic Photophosporulation

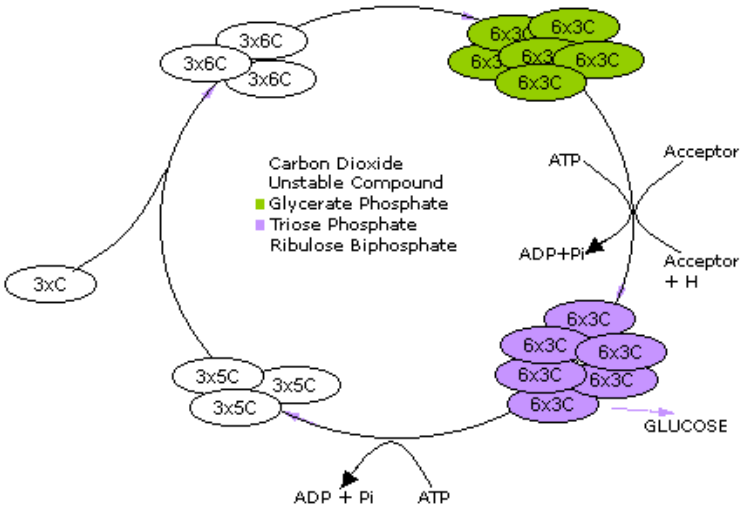
- When light is captured by pigments in chloroplast, water is split to yield hydrogen atoms, electrons, and oxygen (the process is called photolysis)
- When light strikes the electron, the electron gets excited
- Electrons are jumped to a higher energy level and the energy is transferred by fluorescence - by photons of longer wavelengths and less energy - from one pigment molecule to the next in an antennae complex until it is captured at the reaction center
- The energetic electron is funneled to the electron transport system imbedded in the thylakoid membrane of the chloroplast
- The electrons move from one electron acceptor to another in the thylakoid membrane – first with Photosystem II (P680) and then moving through Photosystem I (P700)
- The energetic electrons and hydrogen ions are used to generate ATP by noncyclic photophosporylation and chemiosmosis as hydrogen passes through the channel protein, ATP synthase, and NADPH (from $NADP^{+)}$
- The **energy from the light** is now present in chemical bonds associated with **ATP and NADPH**



DARK REACTIONS (also light-independent reactions)



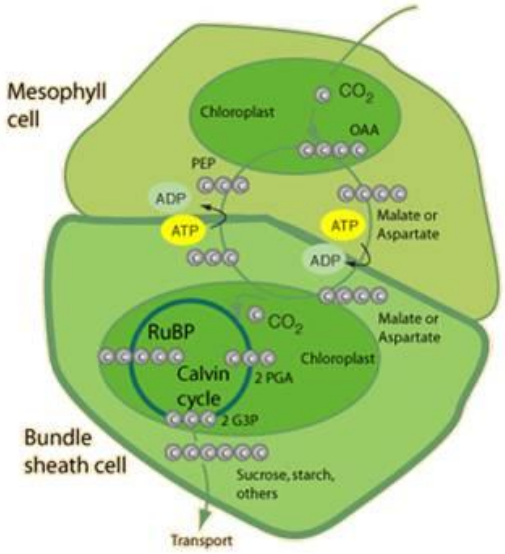
- **C3 cycle - Calvin cycle (Calvin-Benson cycle)**
  - Major metabolic pathway by which CO2 is fixed during photosynthesis – about 95% of plants on earth are C3 plants
  - Also known as the carbon fixation stage, this part of the photosynthetic process occurs in the *stroma* of chloroplasts.
  - Major purpose - use energy from light reactions to fix CO_2 into organic molecules
  - Fixation of CO_2- Store and use chemical energy in the form of organic compounds
  - Uses CO2, ATP, NADPH as reactants
  - Releases ADP, NADP +, and 3 PGAL as products
  - Enzymes (especially RUBISCO - Ribulose bisphosphate carboxylase / oxygenase)
  - 8 step pathway
  - **Steps of CO_2 fixation:**
    - The carbon made available from breathing in carbon dioxide enters this cycle
    - Carbon from CO^2 enters the cycle combining with Ribulose Biphosphate (RuBP)
    - A compound formed is unstable and breaks down from its 6 carbon nature to a 3 carbon compound called glycerate phosphate (GP)
    - Energy is used to break down GP INTO triose phosphate, while a hydrogen acceptor reduces the compound therefore requiring energy
    - Triose Phosphate is the end product of this, a 3 carbon compound which can double up to form glucose, which can be used in respiration.
    - The cycle is completed when the leftover GP molecules are met with a carbon acceptor and then turned INTO RuBP, which is to be joined with the carbon dioxide molecules to re-begin the process.
    - **The energy that is used up in the Calvin cycle is the energy that is made available during photolysis**.
    - The glucose that is made can be used in respiration or a building block in forming more complex organic compounds as polysaccharides, lipids, protein and nucleotides.



NOTE: All photosynthetic plants need carbon to build sugars which comes from CO_2

- Most cells use the C3 pathway where CO_2 reacts with the five-carbon compound called **RuBP** (ribulose 1.5-bisphosphate).
- This products splits immediately to form the 3 carbon compounds giving the pathway its C3
- The enzyme that catalyzes the joining of RuBP and CO_2 is known as RuBP carboxylase or **Rubisco –** it is believed to be the most abundant protein in the world but it is not very efficient at grabbing CO_2 and when CO_2 concentrations in the air inside the leaf fall to low, Rubisco starts grabbing oxygen instead.
- The result is photorespiration where sugar is broken down instead of being created.
- Photorespiration becomes a significant problem for plants during hot, dry days, when they must keep their stomates (leaf pores) closed to prevent water loss
- Some groups of plants have evolved different systems for coping with the problem of photorespiration - C4 plants and CAM plants - initially bind carbon dioxide using a much more efficient enzyme allowing the plant to trap sufficient CO_2 without opening its stomates so often
- **Each then uses the CO_2 for the Calvin-Benson cycle**

- **C4 cycle: - The Hatch and Slack Cycle**
  - Some examples for C4 plants are corn and sugarcane
  - In mesophyll cells, CO_2 is attached to PEP (phosphoenolpyruvate) to form the four-carbon compound OAA (oxaloacetate) using the enzyme PEP carboxylase
  - OAA is then pumped to another set of cells, the bundle sheath cells, which surround the leaf vein where OAA releases the CO_2 for use by Rubisco
  - By concentrating CO_2 in the bundle sheath cells, C4 plants promote the efficient operation of the Calvin-Benson cycle and minimize photorespiration

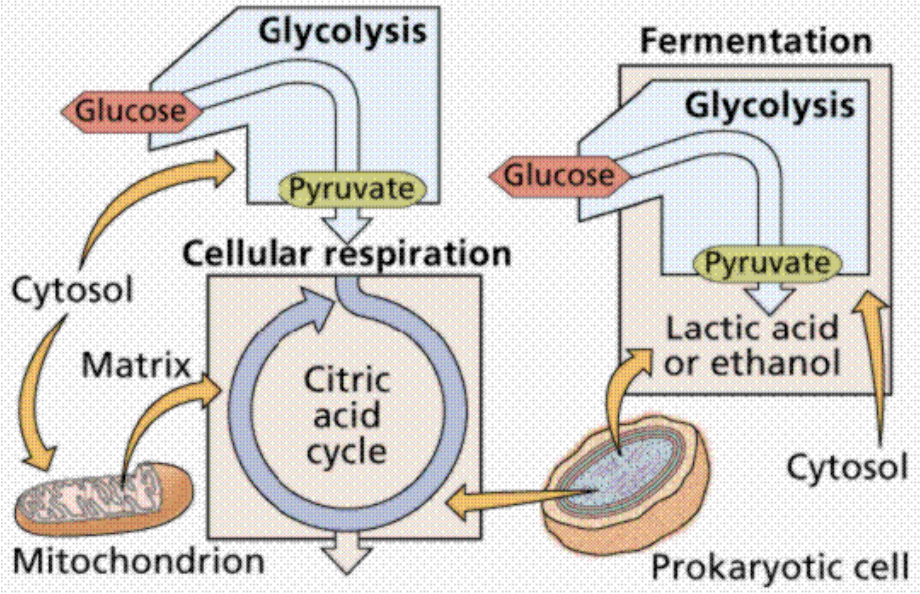


- **CAM photosynthesis** - is an abbreviation of **crassulacean acid metabolism**
  - The cell initially attach CO_2 to PEP and forms OAA
  - Instead of fixing carbon during the day and pumping the OAA to other cells, CAM plants fix carbon at night and store the OAA in large vacuoles within the cell
  - They absorb sunlight energy during the day, then use the energy to fix carbon dioxide molecules during the night.
  - During the day, the organism's stomata close up to resist dehydration, while the carbon dioxide from the night prior undergoes the Calvin cycle.
  - It allows plants to survive in arid climates - it is the type of photosynthesis used by cacti and other desert plants but is also observed in non-desert plants including pineapples and epiphyte plants such as orchids.

Limiting Factors in Photosynthesis

- ***Temperature*** plays a role in affecting the rate of photosynthesis. Enzymes involved in the photosynthetic process are directly affected by the temperature of the organism and its environment,
- ***Light Intensity*** is also a limiting factorif there is no sunlight, then the photolysis of water cannot occur without the light energy required.
- ***Carbon Dioxide*** concentration also plays a factor, due to the supplies of carbon dioxide required in the Calvin cycle stage.

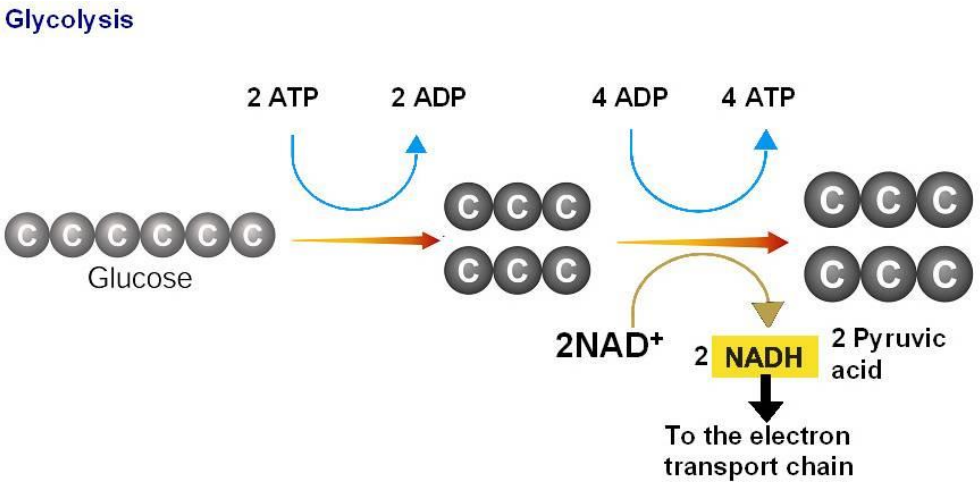
CELLULAR RESPIRATION



- The conversion of chemical energy (found in the chemical bonds of the glucose molecule) into chemical bonds that hold phosphate groups to adenosine triphosphate or ATP.
- Organic substances are broken down to simpler products with the release of energy which is incorporated into special energy-carrying molecules (ATP) and is eventually used for metabolic processes.
- The process is a step by step degradation of sugar mediated at each step by a specific enzyme.
- All cells carry on some form of cellular respiration.
- Occurs in the presence or absence of oxygen.
  Anaerobic respiration (absence of oxygen) = fermentation (alcoholic or lactic acid fermentation)
  Aerobic respiration (presence of oxygen is required) = oxidative phosphorylation
- Most plants and animals require oxygen.
- **NOTE: The amount of NET ATP production varies from cell to cell but is much more efficient (about 18 times more efficient) when oxygen is used.**

GLYCOLYSIS - or Sugar Breaking Reactions

- Both Aerobic and Anaerobic Respiration begin by breaking down a six carbon sugar (glucose) into two molecules of a three carbon compound called pyruvate
- Initial step(s) - energy requiring (2 ATP)
- Subsequent steps
  - Two - substrate-level phosphorylations (4 ATP)
  - One - reduction of NAD to NADH (2 NADH)
- Yield - 2 ATP & 2 NADH
- Final product - 2 pyruvates



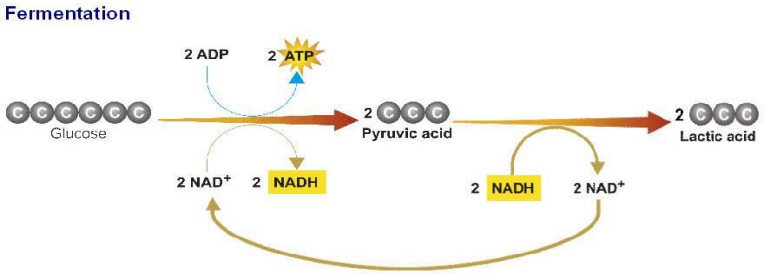
ALTERNATIVES AFTER GLYCOLYSIS

Alcholic Fermentation

- ***Ethanol*** - **2 ATP** (no NADH)
- Certain types of bacteria and yeast
- ***Fermentation Products and Their Uses:***
  - Carbon dioxide – bread making
  - Alcohol – wine making and brewing
  - Lactic Acid – lactic acid bacteria ferment milk into products as yogurt

Lactic Acid Fermentation – certain types of bacteria and overworked muscles

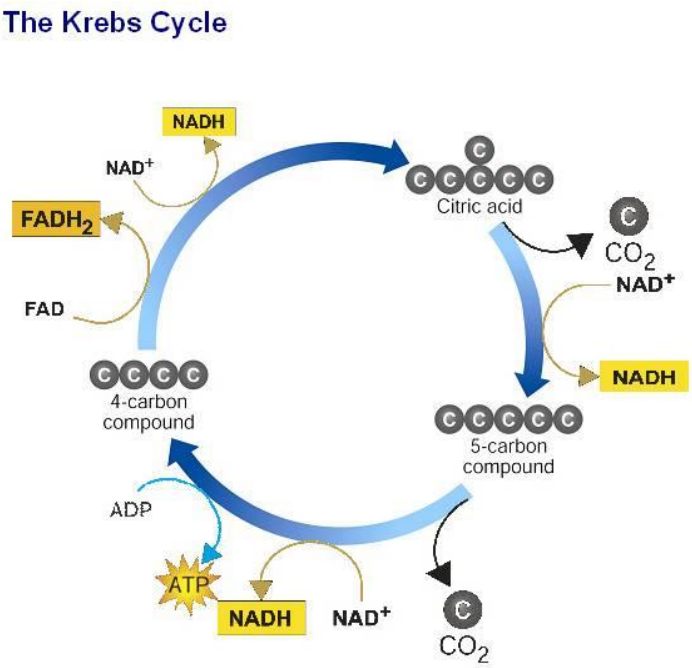
- Lactic acid is found in yogurt, sauerkraut, and overworked muscles
- **2 ATP** (no NADH) ... intense muscle activity (little O_2 available)



Krebs Cycle and Oxidative Phosphorylation **(net ATP varies – about 36 ATP)** - Organisms which contain eukaryotic cells containing mitochondria are capable of respiring in the presence of oxygen.

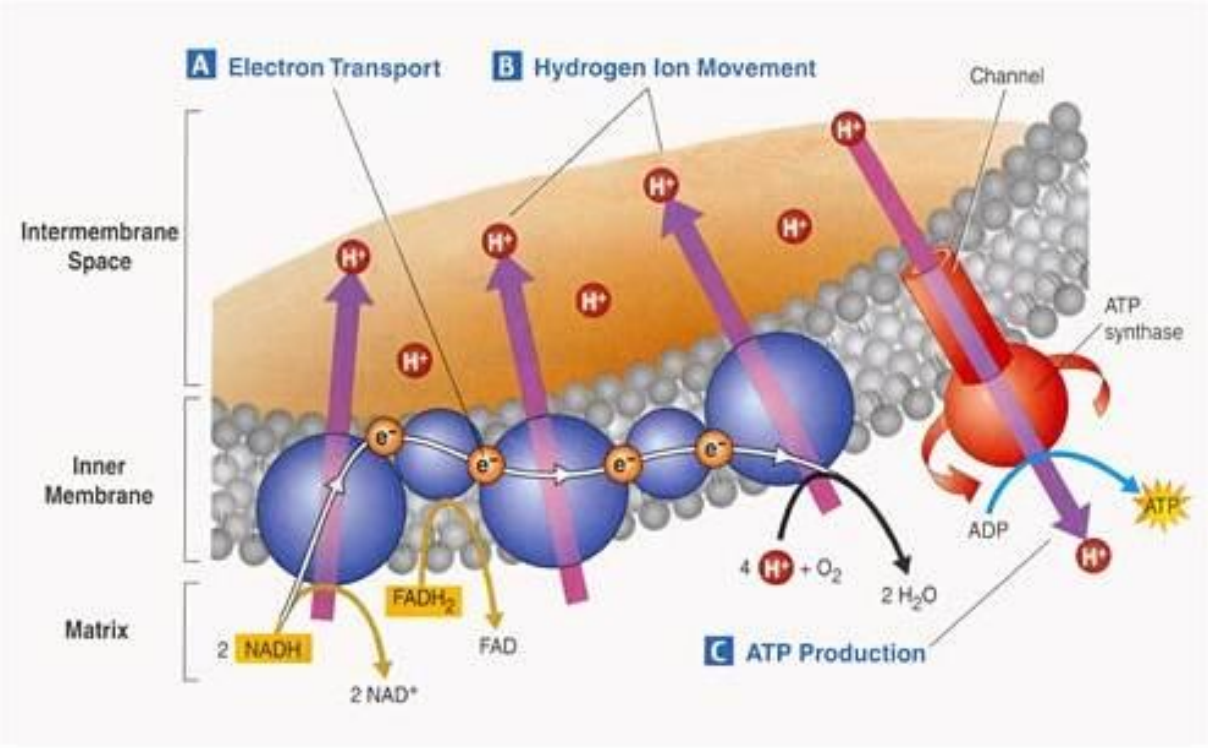
Krebs Cycle – also called TCA cycle – tricarboxylic acid cycle or citric acid cycle

- Occurs in the mitochondrial matrix
- Pyruvate is further broken down by other enzyme-mediated reactions into **carbon dioxide**
- NADH AND $FADH_2$ are formed

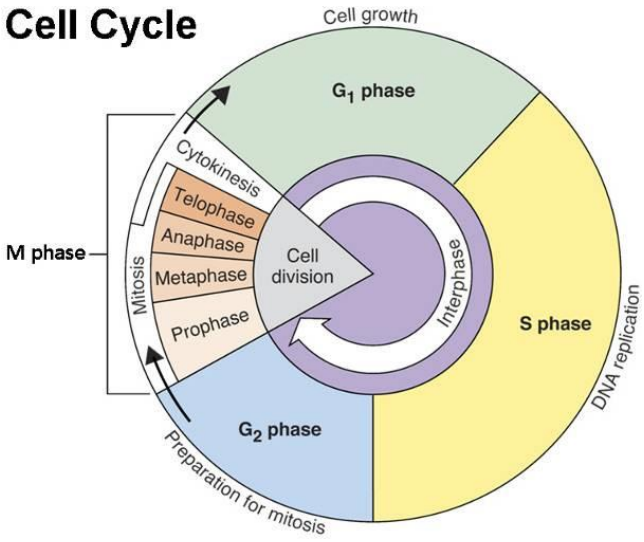


Electron Transport System – Electron Transport Oxidative Phosphorylation

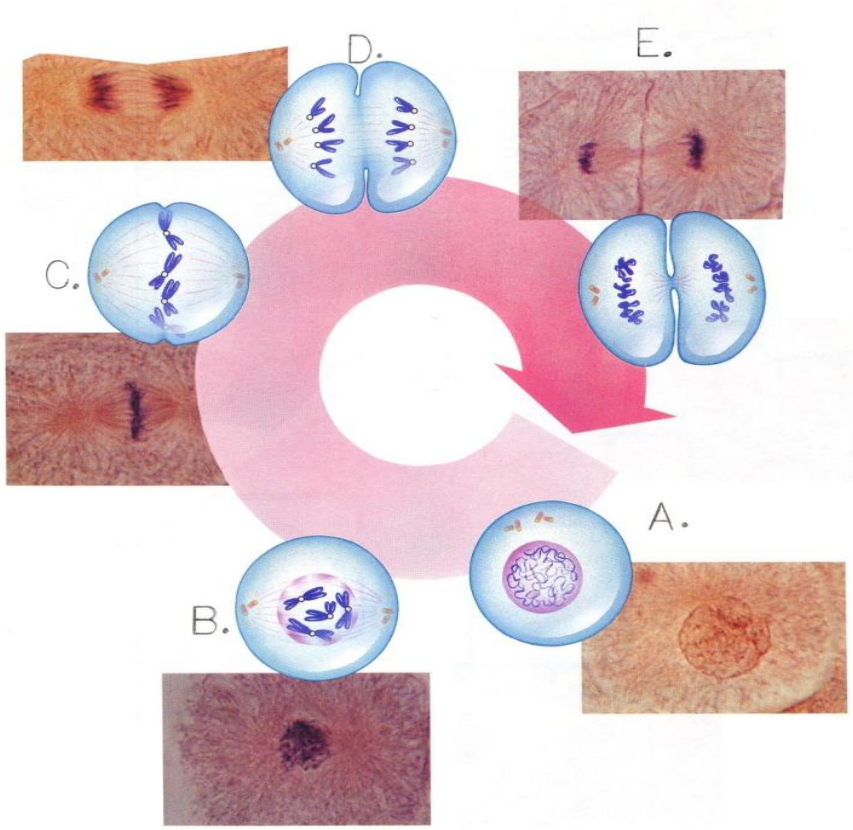
- Occurs on three sites in inner mitochondrial membrane
- NADH AND $FADH_2$ from the Krebs Cycle are used to feed the process
- Electrons and hydrogen ions are liberated – yielding NAD^+ and FAD^+
- The electrons move from one acceptor molecule to another
- The acceptor molecules are imbedded in the inner membrane of the mitochondrion
- As the electrons move back and forth across the membrane, the energy contained in the electrons is used to shuttle additional hydrogen ions across the membrane into the outer compartment
- Hydrogen ions liberated from the NADH AND $FADH_2$ also increase the concentration
- An electrochemical concentration gradient develops between the outer and inner compartments of the mitochondrion.
- Hydrogen ions removed from the inner compartment combine with electrons and oxygen (the final electron acceptor) to yield **water**
- The Hydrogen ions are eventually allowed to diffuse into the inner compartment through the membrane by passing though a channel protein (ATP synthase) in a process called chemiosmosis.
- As the hydrogen ions pass through the channel protein, the couple a chemical reaction between ADP and Pi to produce ATP
- It is estimated that each NADH is responsible for generating 3 APT molecules and each $FADH_2$ generates 2 ATP's



Cell Cycle and Mitosis



- **G_1 *Phase* –** high rate of biosynthesis and growth
- **S *Phase* –** DNA content doubles and chromosomes replicate
- **G_2 *Phase* -** final preparations for Mitosis
- **M *Phase* –** Mitosis and Cytokinesis
    - ***Prophase* –** chromatid pairs coil up, spindle forms, nuclear membrane dissolves, chromatid pairs attach to spindle fibers (microtubules),
    - ***Metaphase* –** chromatid pairs move to the equator, chromatid pairs align at the equator,
    - ***Anaphase* –** chromatids separate into individual chromosomes, chromosomes are pulled apart toward the equator by the spindle fibers (microtubules)
    - ***Telophase* -** chromosomes uncoil, spindle dissolves, nuclear membrane reforms
    - ***Cytokinesis* –** division of the cytoplasm to make two new cells



Regulating the Cell Cycle

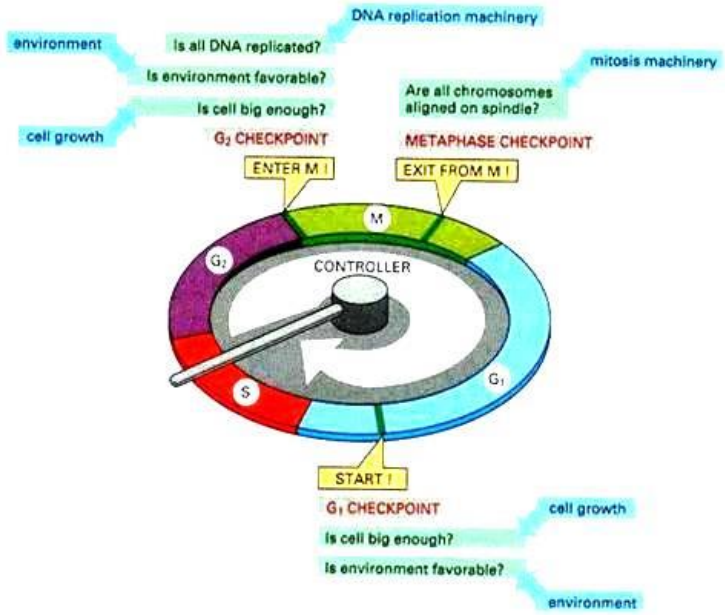
- **Normal cells** divide and reproduce until they come in contact with other cells
  - In a multicellular organism, cell growth and cell division are carefully controlled.
  - Skin and bone cells grow and divide rapidly throughout life while nerve and muscle cells usually stop dividing once developed
  - For example, when an injury such as a cut in the skin occurs, cells at the edge of the cut divide rapidly
  - When the healing process is nearly complete, the rate of cell division slows and then returns to normal
  - The main components of cell cycle regulation are **CDKs (cyclin dependant kinases)** and **cyclins**
  - CKDs remain at a constant number throughout the cycle whereas cyclins fluxuate.
  - **Cyclins** – a group of proteins – regulate the timing of the cell cycle
  - Controls on cell growth can be turned on and off by the body
    - The two main checkpoints are G1-S and G2-M.
    - If there is no DNA damage in G1, then there will be enough cyclins produced to bind to the CDKs which allows the cell to enter S phase (DNA replication).
    - The G2-M checkpoint ensures there is no DNA damage, and also that the chromosomes have successfully replicated.
    - If everything is in order, then the M phase cyclins will be abundant enough to bind to the CDKs. This allows the cell to enter into mitosis.
    - There are also other mechanisms, such as p53 and Rb that are activated when damage is detected. They will either hold the cell in G1 phase until the damage is repaired or induce apoptosis (cell suicide) if the damage is too overwhelming.
    - The condition caused by irregular cell growth is cancer.

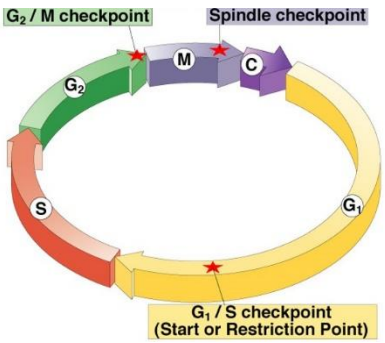
3 major checkpoints:

G_1/S can DNA synthesis begin?

G_2/M has DNA synthesis been completed correctly? commitment to mitosis

spindle checkpoint
are all chromosomes attached to spindle?
can sister chromatids separate correctly?





- **Cancer** is a disorder in which some of the body's cells lose the ability to control growth
  - Cancer cells do not respond to the signals that control the growth of most cells
  - Cancer cells divide uncontrollably
  - They form masses of cells called tumors, which can damage surrounding tissues
  - Cancer cells do not stop growing when they touch other cells
  - Rather, they continue to grow and divide until their supply of nutrients is used up
  - These cells may break loose from tumors and spread throughout the body

- **Stem Cells** are unspecialized that have the potential to differentiate into any type of cell
  - They are found in human embryos, umbilical cord blood and some adult cells
  - They are used to repair injuries as brain and spinal cord, cure some diseases as diabetes, and replace organs as liver tissue and heart valves

Death of Cells – by injurious agents or by being induced to commit suicide

Apoptosis - A form of cell death in which a programmed sequence of events leads to the elimination of cells without releasing harmful substances into the surrounding area

Necrosis - The uncontrolled cell death that occurs as a response to lethal injury leading to a severe physical damage in the cell as well as the tissue containing it.

Structure of Viruses

- Non-cellular infectious agent
- Composed of DNA or RNA and a protein coat
- Replicates only after its genetic material enters a host cell
- Subverts the host's metabolic machinery

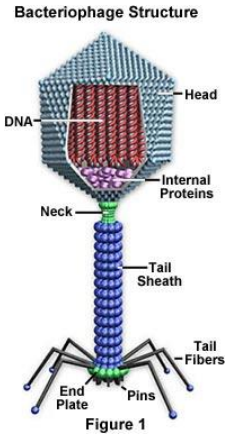
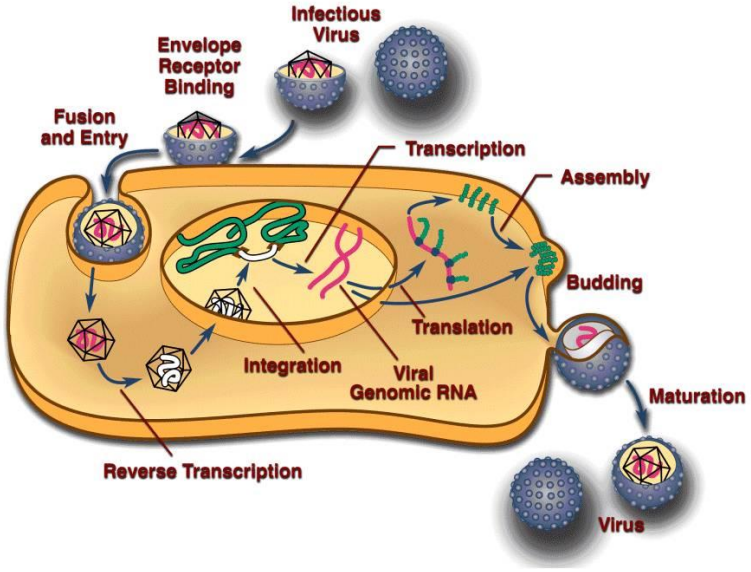


Figure 1

Viral Replication

- The process by which a virus reproduces itself within a living organism.
- Involves turning infected cells into virus factories, which manufacture copies of the virus's genetic code and expel them to spread into the host body.
- Turns the infected body against itself, using its own cells as tools of mass production and infection.



TYPES OF TEST QUESTIONS

EUKARYOTIC & PROCARYOTIC CELL STRUCTURES

* Using models, photographs, or illustrations of structures such as organic molecules and cell organelles, identify the structure and describe its function or role in life processes.
* Identifying differences between prokaryotic & eukaryotic cells.
* Analyzing studies used to determine key pieces of current knowledge.
* Identifying types of microscopes -light vs. electron - uses, capacities, limits
* Identifying cell types and their functions
* Identifying electron micrographs of organelles - function, identification of parts, and chemical mechanisms.
* Understanding and interpreting the role of cell membranes structures and surface specialization.

CELL FUNCTION AND CELL CLASSIFICATION

* Comparing surface area to volume ratio of various cells.
* Using a light microscope, estimate cell size and determine the 3-dimensional shape of cells. Relate the size and shape of a cell to its function.
* Making measurements to calculate surface area to volume relationships. Relate SA/VOL relationships to cell structure and function.
* Analyzing or making predictions concerning osmosis, diffusion and cell transport.
* Using mechanisms that control of cell size to explain shapes modifications in cells
* Analyzing cell cultures
* Using photographs or microscope slides, identify various types of cells such as muscle, nerve, epithelial, and leaf epidermis and relate the structure of the cell to its function.
* Identifying tissue types - structure, function, chemical mechanisms

CHEMICAL REACTIONS AND BONDING

* Using the protocol and data derived from an experiment such as one on the effect of pH on enzyme activity, determine (1) the independent and dependent variables, (2) variables that must be kept constant, (3) a control, (4) the most appropriate measure of central tendency to use in analyzing the data, (5) if the data are quantitative or qualitative, (6) the type of graph to use and how to label the X and Y axes, and (7) an appropriate conclusion.

ORGANIC MOLECULES

* Determining the most appropriate reagent test for identifying substances such as gelatin, vitamin C, glucose, butter, and cornstarch.
* Identifying key organic chemicals and their role in cell operation.

PHOTOSYNTHESIS AND CELLULAR RESPIRATION

* Calculating the energy content of food from data obtained from calorimeters. Relating the energy content of food molecules to the flow of energy and the cycling of matter that occur during photosynthesis and cellular respiration in ecosystems.
* Drawing conclusions about the relationship between photosynthesis and cellular respiration from data collected on the production/uptake of oxygen and carbon dioxide by green plants and animals. Predict how changing the environment of a plant or animal might affect the rate of photosynthesis or respiration.
* Interpreting photosynthesis & cellular respiration experiments or their data.
* Understanding and interpreting data concerning enzymes and their role in cell activities
* Analyzing and comparing the ATP production in aerobic and anaerobic respiration

CELL REPRODUCTION

* Using photographs or illustrations of mitosis and meiosis, identify major events that occur in these processes and relate these events to cell and organism continuity.
* Comparing & analyzing data - stages of mitosis & meiosis their similarities and differences
* Analyzing cell cycle data–timing for normal vs. abnormal cells

* Understanding and interpreting information on prokaryotic cell reproduction and DNA operation

CELL DIFFERENTIATION
* Interpreting and analyzing cell differentiation processes and data relative to their study.

IMMUNOLOGY
* Analyzing immunology mechanisms and studies related to their operation.

VIRUSES
* Understanding and interpreting mechanisms of viruses – their structure, reproduction, genetics, and retroviruses
* Analyzing the effects of viruses on other cells

PROTEIN PROFILES AND EVOLUTIONARY RELATIONSHIPS
* Using the results of gel electrophoresis, compare the protein profiles of different species to infer evolutionary relationships

Process Skills and Tasks Which Might Be Tested

Methods
* Understanding techniques used in studying cells as electrophoresis, DNA probes cell fractionation, radioactive tracers, spectrophotometry, centrifugation, computer imaging, photography of cells.

Lab Safety
* Distinguishing "safe" behaviors vs. "unsafe" behaviors, identifying safety symbols related to experiments , evaluating situations -- what to do "if" or what's wrong.

Microscopy
* Understanding of parts of microscope & their function, magnification, appearance of images, resolution, changes in field with magnification, types of microscopes and their uses.
* Understanding the different types of microscopes, their uses, and their differences.
* Using types of light microscopes to perform a requested task.
* Determining the three dimensions of a cell
* Determining length, width, depth, area, and volume of cells.
* Interpreting electron micrographs

Lab Equipment
* Identifying pieces of lab equipment and their functions.
* Identifying appropriate pieces of equipment to perform a specific task.

Measurement
* Identifying the capacity, range, and increments of measuring devices used to study cells .
* Converting units within the metric system.

Calculations
* Using measurements to determine area, volume, percentages, probabilities.
* Using area and sample number to determine density of a sample.
* Understanding and using statistics to analyze data.

Chemical Analysis
* Using reagents for chemical analysis.

Observations
* Using senses to notice specific features.
* Identifying similarities and differences in features.
* Identifying qualitative and quantitative changes in conditions.

	* Using observable properties to classify objects, organisms or events.
Inferences	* Formulating assumptions based upon observations. * Distinguishing between observations and inferences.
Problem	* Using observations to propose a testable question.
Hypothesis	* Proposing a hypothesis for a given problem. * Identifying statements presented along with a set of data as. 1. logical hypothesis 2. illogical hypothesis of contrary to data 3. not a hypothesis, but a restatement of data 4. reasonable hypothesis, but not based on data
Predictions	* Predicting the results for a proposed lab test or setup. * Selecting predictions based upon previously observed patterns.
Design Analysis	***** Analyzing designs for experiments relative to problem, identifying variables & constants, procedure analysis , proper control of variables, types of data collected, basic assumptions used, time period for the test.
Procedures	* Analyzing procedures for flaws in design. * Arranging steps of procedures in the appropriate order. * Determining the repeatability of a procedure. * Identifying an appropriate procedure to test a problem.
Graphing	* Interpreting line, bar, and pie graphs. * Identifying the title, source, independent variable & dependent variables, and the legend. * Predicting data points not included in a given graph. * Preparing a line, bar or pie graph to represent a set of data. * Scaling each axis for a line graph. * Making predictions or inferences based upon the data on a graph.
Analysis of Data	* Identifying data which supports or rejects a hypothesis. * Identifying discrepancies between stated hypothesis and actual data. * Identifying types of error in the data as experimental and random. * Determining the validity of experimental data. * Interpreting charts and diagrams.
Conclusions	* Selecting the most logical conclusion for given experimental data. * Accepting or rejecting hypotheses based upon data analysis. * Proposing a new hypothesis for rejected hypotheses