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- Chemical properties are due to electrons
  - How many there are
  - How they are distributed
- All chemical interactions involve the movement of electrons
- Important Interactions
  - Covalent bonds: electrons shared
    - Very strong
  - Ionic bonds: electrons transferred
  - Intermolecular forces
- What are some types of Intermolecular forces
  - Dispersion forces
    - Very weak
  - Van der Waals Forces
  - Electromagnetic attractions
  - Hydrogen bonds… a special case of
    - Gives water its special properties
  - Dipole-Dipole forces

Special properties of water are:

High heat capacity
The high heat of vaporization
The high heat of Fusion
Cohesion/adhesion

8/28

- Intro to macromolecules
  - The most common elements in biological systems are CHONPS
    - Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, and sulfur
  - Organic Chemistry
    - A subset of chemistry that deals with organic compounds
      - Organic: containing carbon **and** hydrogen
  - Macromolecules
    - Most compounds fall into one of four groups of macromolecules
    - **Macromolecule:** very large molecule, often with complex properties
    - Most macromolecules are polymers
    - Polymer: long series of repeated units (monomer)
    - Monomers are the basic building block of a polymer
  - Making and Breaking Polymers
    - Forming and breaking down polymers involves the removal or addition of a water molecule
    - Make polymers via dehydration synthesis or condensation reaction
    - Break down polymers via hydrolysis
    - Hydrolysis breaks polymers, Dehydration makes polymers

- Classes of Macromolecules
  - Four main types of macromolecule
    - Carbohydrates
    - Nucleic Acids
    - Lipids
    - Proteins
  - Each has its own building blocks/distinctive properties
- CarbohydrateBasic unit: monosaccharide (glucose)
  -
  - Polymer form: polysaccharide (complex sugars/carb)
  - Contain C,H,O … usually in 1:2:1 ratio
    - C_6 H_12 O_6
- Carb Function
  - Energy
    - Glucose main substrate of cellular respiration
    - Short term storage of energy
      - Glycogen in animals
      - Starch in plants
  - Structure
    - Cellulose in plants(cell wall)
    - Chitin in animals
  - Signaling/communication
- Nucleic Acids
  - Basic building block: nucleotide
  - Polymer: no special term
  - Contain C,H,N,O,P
    - Have all but sulfur
  - Two main types
    - RNA
    - DNA
- Nucleotide
  - Basic Structure
    - 5 carbon sugar
    - Phosphate group
    - Nitrogenous base (5 of them)
      - Thymine(DNA)
      - Adenine(DNA&RNA)
      - Cytosine(DNA&RNA)
      - Uracil(RNA)

- 9/2
- Dna vs Rna
  - Both nucleic acids
  - Three main differences

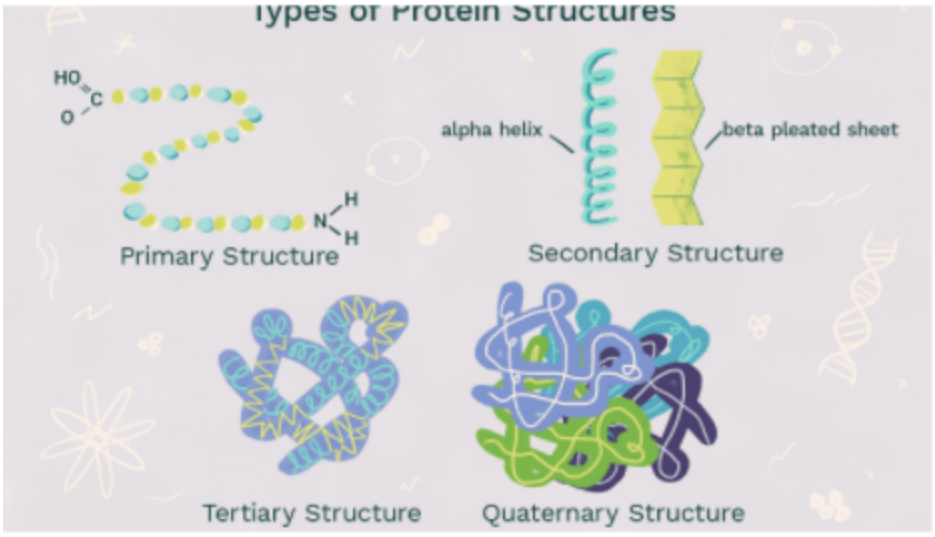
        - DNA is double-stranded, RNA is single-stranded
        - DNA has thymine, RNA has uracil
        - DNA's sugar=deoxyribose, RNA's = ribose
    - Both are present in all living cells
- Nucleic acids Function
    - One Big one
        - INFORMATION
            - Nucleic acids and transmit that controls cell function
            - Also can function as an enzyme
- Lipids
    - Contain C, H, O, sometimes P
    - Largely hydrophobic
    - Hydrophobic:"water-fearing"
    - 3 main types
        - Triglycerides
        - Phospholipids
        - Steroids
    - (another term is hydrophilic = water-loving)
- Triglycerides
    - AKA "fats and oils"
    - The main function is long term energy storage
    - Glycerol+ three fatty acids
    - Saturated vs. unsaturated...
        - **Saturated fats** have no C-C double bonds; tend to be solid at room temp
        - **Unsaturated Fats** have c-c bonds; tend to be liquid, plant fat
- Phospholipids
    - Like triglycerides, but one fatty acid replaced with phosphate
    - Changes nature of lipid
        - Fatty acids are hydrophobic
        - Phosphates are hydrophilic
    - Phospholipids want to be both
    - Will naturally create a bilayer...origin of the cell membrane
    - Function: makeup cell membrane
- Steroids
    - Distinctive structure: 4 fused carbon rings
    - Little functional group additions give properties
    - Primary function: signaling, regulation (think, hormones)
    - Also, play a role in the cell membrane
- Proteins
    - Contain C,H,O,N,S
    - Monomer: amino acid
    - Polymer: Polypeptide
    - HUGE AND IMPORTANT GROUP

- Amino Acids
  - 20 of them
  - 4 basic parts
    - Central Carbon with hydrogen
    - Carboxyl group
    - Amino group
    - R-group

9/4

- R-group
  - The 20 amino acids vary in the R-group or sidechain
  - Gives amino acids its properties
  - Those properties determine the shape/function of the whole protein
- Layers of Structure
  - An analogy: what are the layers of structure of a book
    - 1. A string of letters...thecatjumpsoverthelazydog
    - 2. Recognize subunits: words… cat the jumps lazy the dog
    - 3. Repeated structures: a sentence: the cat jumps over the lazy dog
    - 4. Multiple sentences
- Protein Structure
  - Primary: a sequence of amino acids
  - Secondary: repeated structures… alpha-helix and beta-sheet
  - Tertiary: 3d shape
  - Quaternary: several polypeptides interacting
  - Each level of structure tells us a little bit more about the shape and function of a protein
- Primary Structure
  - Just a sequence of amino acids
  - What we get from reading the genetic code
  - Doesn’t tell us much about the protein
- Secondary Structure
  - H-bind interactions between “backbone” of amino acids
  - Two major structures form
    - Alpha helix
    - Beta sheet
  - Tells us more about shape/function than the primary structure
- Tertiary Structure
  - Determined by interactions between R-groups
  - Gives us the 3D shape/function of the protein
- Quaternary Structure

- Some proteins are made of multiple polypeptides to form a single protein = quaternary structu

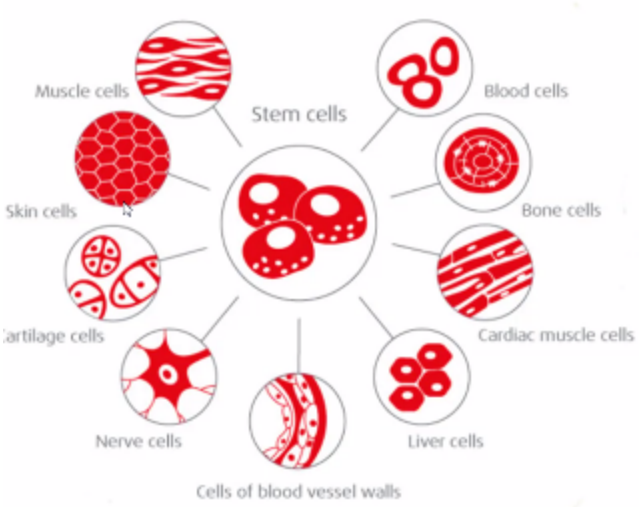


- R-group interactions
  - Hydrophobic/hydrophilic interactions
  - Ionic attractions
  - H-bonding
  - Disulfide bridges
  - **All of these give a protein its shape and the shape of a protein determines its function**
  - Denature: alter interactions/shape of proteins… loss/change in function
- Protein Function
  - Tons of functions
    - Structure
    - Transport
    - Movement
    - Signaling/communication
    - **Enzymes**
- Enzymes
  - Enzyme
    - Class of protein that catalyzes the reaction
  - Catalyst:
    - a molecule that lowers the activation energy of reaction… not consumed in a reaction
  - Typically named by adding “-ase” to what the enzyme acts on
- Enzyme function
  - Enzymes ac on a **substrate**
  - The reaction takes place at the **active site**
  - Enzymes are specific...tend to catalyze one and only one reaction

- ➢ **Lock and key model**: idea that only one type of molecule is shaped correctly to bind with active site

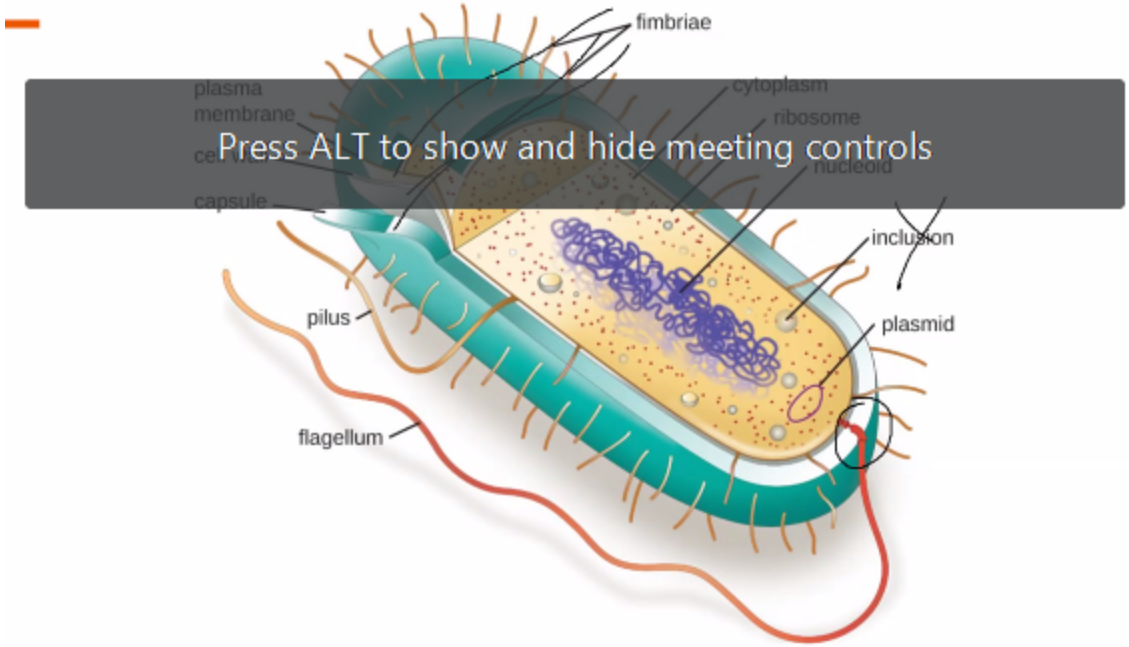
9/9

- ❖ Cell Theory and Structure
  - ➢ Cell Theory
    - ■ All organisms are made of one or more cells
    - ■ The cell is basic unit of living things
    - ■ All cells come from existing cells
  - ➢ What is a cell
    - ■ Membrane-bound structure
    - ■ Contains all material necessary for life
    - ■ All cells
      - ● Have DNA
      - ● Have cell membrane
      - ● Have sub-cellular structures



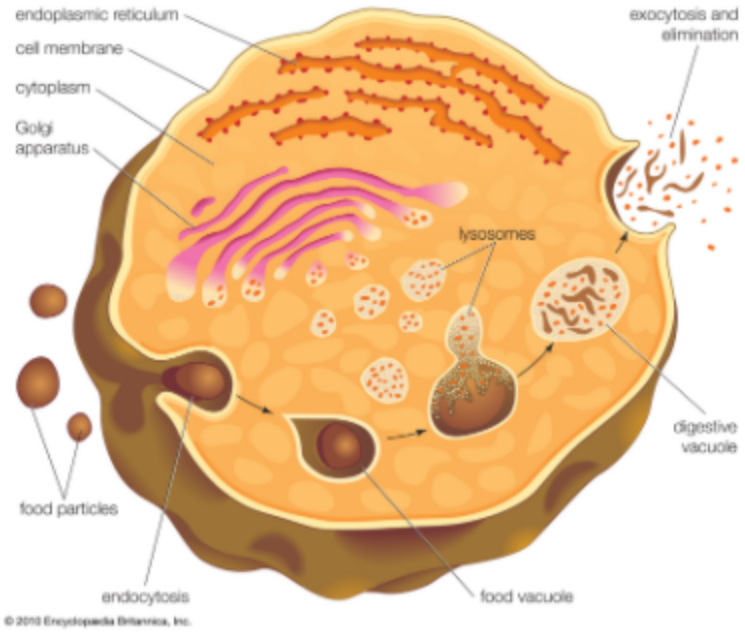
    - ■
  - ➢ Why are cells small
    - ■ Pretend a cell is a cube (not a bad approximation)
    - ■ Surface area...sqare
    - ■ Volume...cube
    - ■ Cells absorb nutrients across their surface area but use them in their entire volume
    - ■ **Surface Area: Volume Ratio**
  - ➢ Two main types of cells
    - ■ Prokaryotic: archaea and bacteria
      - ● No membrane-bound organelles, incl. Nucleus
      - ● Always single-celled
      - ● Most diverse and numerous group
    - ■ Eukaryotic: animals, plants, fungi, etc.

        - Membrane-bound organelles incl. Nucleus
        - Single Cellular, or multi-cellular
        - Complex cells, moderately diverse
- ➢ Prokaryotic Cell Structure
    - Cell membrane (all cells have one)
    - The Nucleoid region where DNA is found
    - Many ribosomes that produce proteins
    - Cell wall outside the cell membrane; provides protection
    - Capsule outside cell wall; provides protection and helps cell stick to things
    - Plasmid: a small circular bit of DNA carrying 1 to a few accessory games… not part of the main chromosome
    - Flagellum: whip-like extension for movement
    - Fimbriae: extensions that help cell attach to things
    - Pilus: for exchanging genetic information



- ➢ Eukaryotic Cells
    - Similarities with Pro
        - Cell Membrane
        - DNA
        - Ribosomes
        - Cytoskeleton
        - Cell WAll
        - Flagella
    - Differences
        - Eukaryotes much larger

        - Membrane-bound organelles
- Eukaryotic Cell Function
    - Energy production
    - Photosynthesis
    - Membrane construction
    - Most of them are membrane bound structures
- Eukaryotic Cell Structure



-
    - Has plasma
    - Membrane
    - Cytoplasm
    - membrane-bound nucleus
    - Many membrane bound organelles
    - Cell Membrane
        - Provides the inside of a cell with a protective layer
        - Phospholipid bilayer
        - No nucleic acids
        - Also contains
            - Proteins
            - Carbohydrates
            - Steroids e.g. cholesterol
        - Fluid-mosaic model
            - Membrane is fluid, elements move around
            - Membrane is composed of many different parts
        - Roles

- Defines the cell
- Selectively permeable(controls entry/exit)
- Communication with other cells
- Receiving/responding to signals
- Holding cell in place

- Nucleus
  - Controls center of cell
  - Contains all cell's DNA
  - Structure
    - **Nuclear Envelope:** double membrane
    - **Nuclear pores**: allow/control entry and exit via **pore complex**.
    - Dna contained in **Chromosomes**, combined with protein to make **chromatin**
- Nucleolus
  - Sub-section of nucleus (not separate by membrane)
  - Dense region of DNA where ribosomes are made
  - Combines rRNA with protein
- Ribosomes
  - Made of rRNA and protein… no membrane
  - Make Proteins
  - Two subunits: large and small
  - Two types
    - Free...float in cytoplasm; make proteins for use in cell
    - Bound...attached to rough ER, make proteins for export
- Cytoplasm
  - Broad: everything outside the nucleus, including organelles
  - Often used in place of **cytosol**, the fluid that makes up most of the cell
  - Most cellular activities occurs hereE

- Endomembrane System
  - Large complex of inter-related organelles that share an evolutionary origin.
  - Carries out
    - Protein synthesis/modification/transport
    - Metabolism of lipids
    - Detoxification
  - Includes
    - Nuclear envelope
    - ER
      - Two types
    - Golgi
    - Lysosomes
    - Transport vesicles

- Endoplasmic reticulum (ER)
  - Large network of membranes and compartments
  - Two types with distinct function
    - Rough (RER)
    - Smooth(SER)
- Rough ER
  - Associated with ribosomes
  - Ribosomes make proteins, release them into ER
  - RER folds/modifies proteins
  - Proteins “tagged” for specific destinations
  - All secreted and most membrane-bound proteins travel through RER
- Smooth ER
  - Series of membrane-bound tubes
  - Production of lipids
  - Polysaccharide metabolism
  - Detoxification
  - Storage of calcium in some cells
- Golgi Apparatus
  - “Warehouse” or “shipping center”
  - Receives proteins from ER, prepares for export; adds sugar”tags”
  - Directionally
    - *Cis* side toward ER, recieves transport vesicles
    - *Trans* side towards membrane, sends vesicles again
- Lysosomes
  - Small organelle filled with digestive enzymes
  - Roles
    - Breaks down polymers to harvest monomers
    - Break down old organelles for recycling
    - Digestion in unicellular organisms
    - Destruction of pathogens
    - Apoptosis
- Energy Conversion
  - Cells work with two main types of energy
    - Light
    - Chemical
  - Two main “currencies”:
    - ATP
    - Sugars
  - Cells have to be able to convert between energy forms
- Mitochondria
  - Conversion of sugar energy to ATP energy
  - Two membranes...inner membrane folded into numerous cristae
  - Site of Krebs cycle and electron transport chain

- Contains DNA
- Chloroplasts
  - Found in plant and in algal cells
  - Conversion of light energy to chemical energy
  - 3 membranes, innermost contains **chlorophyll**
  - Contains DNA
- Endosymbiosis
  - Chloroplasts and mitochondria originated as individual cells
  - Ancestral eukaryote engulfed prokaryotic, but developed symbiotic relationship
  - Evidence
    - Presence of DNA
    - Presence of prokaryotic ribosomes
    - Prokaryotic double membrane
- Structural Organelles
  - Cytoskeleton
  - Centrosomes
  - Cell Wall
- Cytoskeleton
  - Network of protein fibers throughout cell
  - Gives cell shape, organizes contents
  - Three components
    - Microfilaments, smallest
    - Intermediate filaments, medium
    - Microtubules, largest, similar in structure to flagella/cilia.
- Centrosomes
  - Animal cells only
  - Contain two centrioles
  - Organizes cell division
- Cell Wall
  - Plant, algae, fungi cells
  - Rigid structure outside cell membrane
  - Provides structural support and protection
  - Contains openings; **plasmodesmata**
- Diffusion
  - Particles are always in motion
  - Movement from high to low concentration
- Osmosis
  - If something Cant diffuse
  - Water can move through aquaporins
  - Movement of water from low solute concentration to high solute concentration
- Cell Membrane Structure
  - Nearly all cell membranes are flexible. double -layer sheets called lipid **bilayers.**
  - In addition to phospholipids, most cell membranes contain protein molecules.

- ➢ Some of these membrane bound proteins have carbohydrate molecules attached: **glycoproteins**
- ➢ Functions of cell membrane proteins
  - ■ Selective Transport channel
  - ■ Enzyme
  - ■ Cell surface receptor
  - ■ Cell surface identity marker
  - ■ Cell adhesion
  - ■ Attachment to the cytoskeleton
- ➢ Membranes also contain other molecules such as glycolipids and cholesterols
- ➢ Phospholipids float freely
- ➢ Proteins also float but they move slowly cuz they big
- ➢ Fluidity of the cell membrane depends on composition
  - ■ Unsaturated bonds five more fluidity
  - ■ Other molecules matter too

❖ Transmembrane Proteins
- ➢ Problem: If everything is moving why do they stay in the bilayer
  - ■ Hydrophobic Interactions

❖ Moving Across a membrane
- ➢ Passive transport- no energy required
  - ■ Facilitated diffusion
  - ■ No diffusion or osmosis
- ➢ Active transport - need energy
  - ■ Molecular
  - ■ Endocytosis/Exocytosis
- ➢ Main difference if whether or not energy source is required

❖ Diffusion through Cell boundaries
- ➢ Some small molecules diffuse through the cell membrane down the **concentration gradient**
- ➢ No protein channels are needed
- ➢ No energy needed - spontaneous process
- ➢ Oxygen will move through a cell membrane

❖ Diffusion
- ➢ Non polar particles pass through cell membrane
- ➢ Large polar molecules cannot pass through the cell membrane
- ➢ In the case of O2 as long as the mitochondria are using the oxygen for cellular respiration it will continue to diffuse
- ➢ If it is not doing cellular respiration then oxygen will eventually stop which will lead to cell death.

❖ Osmosis
- ➢ **Hypertonic** - The more concentrated solution in comparing 2 solutions
- ➢ **Hypotonic** - The more dilute solution when comparing 2
- ➢ **Isotonic** - When they are both the same concentration in both solutions

- ➢ Osmotic pressure
- ➢ Cells have
  - Salts
  - Sugar
  - Proteins
- ➢ That is why cells are almost always hypertonic to fresh water

❖ Facilitated Diffusion
- ➢ The movement of specific molecules across cell membranes through membrane proteins
- ➢ When diffusion would take too long
- ➢ What type of molecules would benefit from FD
  - Sugars

❖ Active transport
- ➢ Moves materials against concentration gradient
- ➢ Goes only ONE direction
- ➢ Needs energy
- ➢ ATP
- ➢ 2 different types
  - Molecular Active Transport
    - Small molecules and ions
    - Allows dor concentration of substances in a particular location
  - Endo and Exocytosis
    - Active transport
    - Large molecules and even solid clumps of material
    - **Endocytosis** - Material is engulfed by the cell through pockets of the cell membrane
    - Pocket eventually forms a vesicle
- ➢ Phagocytosis
  - Large Particles
  - Extensions of cytoplasm surrounds a particle
  - Needs a lot of energy
- ➢ Exocytosis
  - Vesicle membrane fuses with the cell membrane, forcing its contents out of the cell
  - Many cells also release large amounts of materials from the cells

❖ Metabolism
- ➢ Sum of all reactions occurring within a cell
  - Catabolic reactions which break things down
  - Anabolic reaction builds things up(when u are making polymers)

❖ Autotroph
- ➢ Organism capable of undergoing **Carbon Fixation**

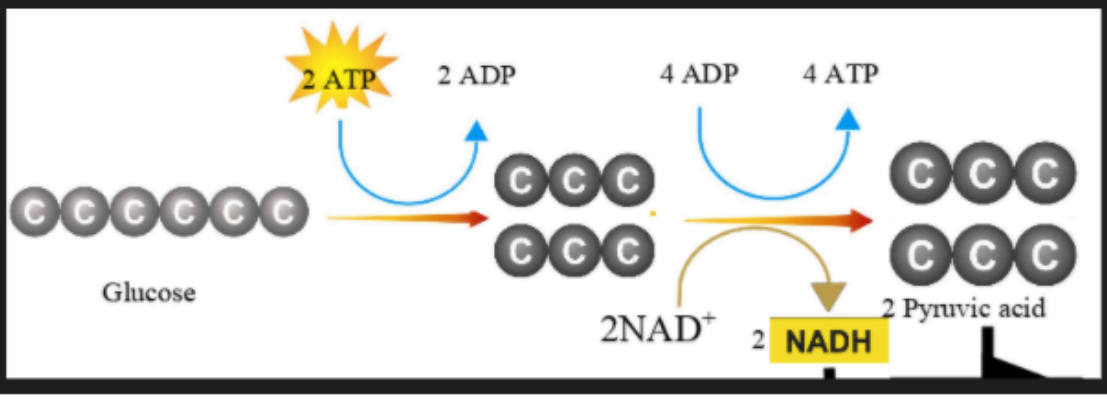
❖ Heterotroph
- ➢ Incapable of carbon fixation

- Carbon fixation: conversion of inorganic carbon to organic carbon
- Energy
  - Comes in many forms
  - 2 main forms
    - Chemical
    - Light
  - Two main “currencies”
    - Glucose: long term
    - ATP: short term
  - Broadly, respiration/photosynthesis are all about energy conversions and transfers between light, glucose, ATP
  - Energy cannot be created nor destroyed
  - Metabolism is all about energy transfer to do work
    - Chemical work
    - Mechanical work
    - Transport work
  - Coupling:endergonic work coupled to exergonic reactions
  - 99% energy comes from sun
  - Overall metabolism: harvest energy from photons, transfer to do work
- ATP
  - 3 parts
    - Adenine
    - Ribose
    - 3 phosphates
  - Energy is stored within the bonds
- ATP and energy
  - ATP use centers around phosphates
  - Hydrolysis… cuts final phosphate stopping ADP and energy
  - Condensation reaction adds phosphate and energy… charges ATP
- Bonds and energy
  - Breaking bonds requires energy
  - ATP hydrolysis releases energy
  - Electrons
    - Phosphates are dense in electrons
    - Electrons repel each other
    - Electrons that are in ATP have a higher energy state
    - After hydrolysis, the electron becomes a lower energy state. Releases energy
- Intermediates
  - Glucose
  - ATP
  - NAD+/NADH… FAD/FADH2
    - Mobile electron carriers

        - Assist in transfer of energy
    - NADP+/NADPH in plants
- Aerobic Cellular Respiration has 3 stages
    - Glycolysis (anaerobic)
    - Krebs cycle/citric acid cycle (aerobic)
    - Electron transport chain (aerobic)
    - Electron transport chain (aerobic)
- Aerobic = requires oxygen; anaerobic = doesn't need oxygen
- Location
    - Glycolysis in cytosol
    - Krebs cycle and Electron transport chain in mitochondria
- Things to know
    - For each stage
        - Where and if oxygen is needed or not
        - What goes in
        - What comes out
    - Ask
        - What happens to carbon
        - What electron carriers are involved
        - Do we use ATP
- Stage 1 - Glycolysis
    - 1 glucose split into 2 pyruvate
    - Inputs: sugar, ATP, and NAD+
    - Outputs: pyruvate, ATP, NADH
- Glucose breakdown
    - Glucose is the overall source of energy, but bonds have to be broken
    - Initial phase requires 2 ATP
    - Adds phosphates destabilizes carbon-carbon bonds
    - Energy dense electrons harvested, breaks bonds to yield 2 pyruvates
    - Additional electrons are gone through a cycle
- ATP production
    - Glucose breakdown lowers free energy… the products have lost energy
    - Has to go somewhere and to it becomes ATP
    - Net gain of 2 ATP

Glycolysis - NADH production

- Some free energy used to make ATP
- Some free energy transferred in form of electrons
- 2 NAD^+ EACH are reduced with 2 electrons, yields 2 NADH
- Electrons hold energy; will be used in electron transport chain



Glycolysis

Inputs

- 1 Glucose
- 2 NAD^+
- 2 ATP
- (and 2 ADP but we usually ignore that)

Outputs

- 2 pyruvate
- 2 NADH
- 4 ATP (for a NET gain of 2)

Net gain: 2 pyruvate, 2 NADH, 2 ATP