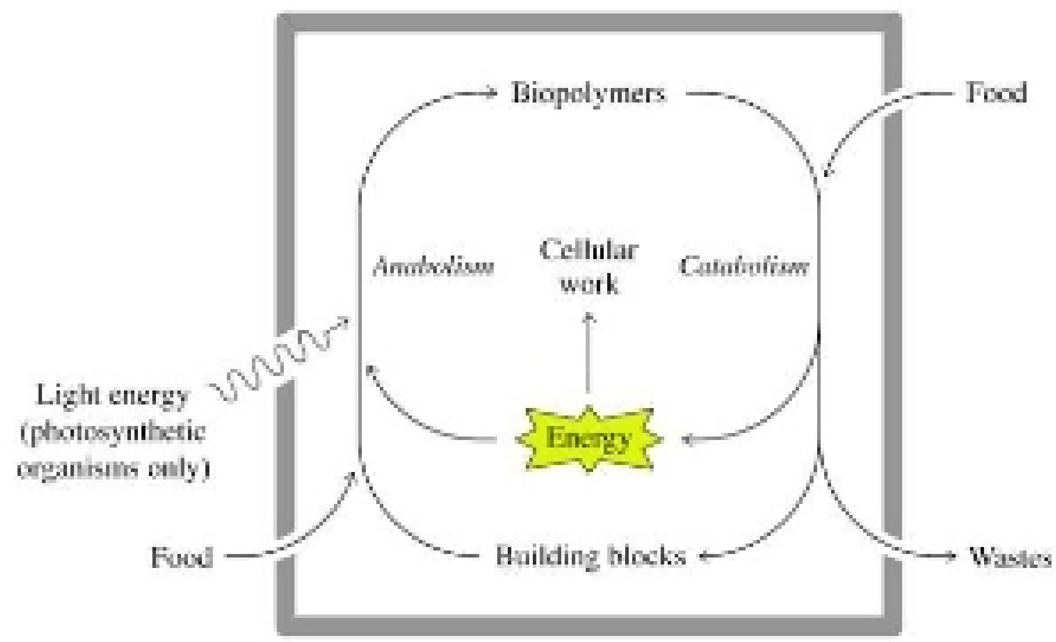
Lecture 4 September 2nd

Energy, Catalysis, and Biosynthesis

1. Cells are highly organized systems
    a. Food is used as the building blocks (chemical energy)
    b. Recycle needed molecule and release the waste ones
    c. Release waste energy as heat
2. Spontaneous drive to entropy
    a. Spontaneous 'reaction' – room gets more disorganized as time passes
    b. Requires an organized effort of energy input to clean the room
    c. If cell keeps going towards spontaneous reaction then the cell will die, so it works using the energy from food to restore the proteins
3. Cellular metabolism
    a.



4. The degree of disorder can only increase. However cells can grow and divide, so are they defying the second Law of Thermodynamics?
    a. No because when they form macromolecules they release heat into the environment around them, leaving order inside them
5. 1st law of thermodynamics
    a. No energy can be created or destroyed, only converted
    b. Ex. Sunlight → high energy electrons (chlorophyll) → chemical bond energy (sugar synthesis)
    c. In each step energy is lost through heat
6. Photosynthesis and respiration

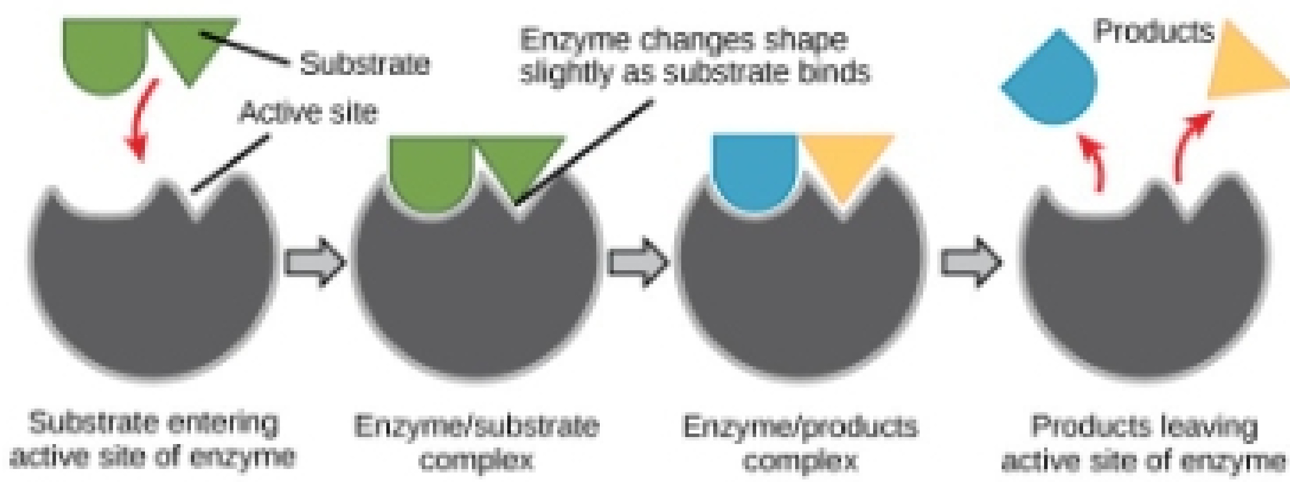
photosynthesis

$$6CO_2 + 6H_2O + \underbrace{\text{energy}}_{\text{energy in}} \longrightarrow C_6H_{12}O_6 + 6O_2$$

aerobic respiration

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \underbrace{\text{energy}}_{\text{energy out}}$$

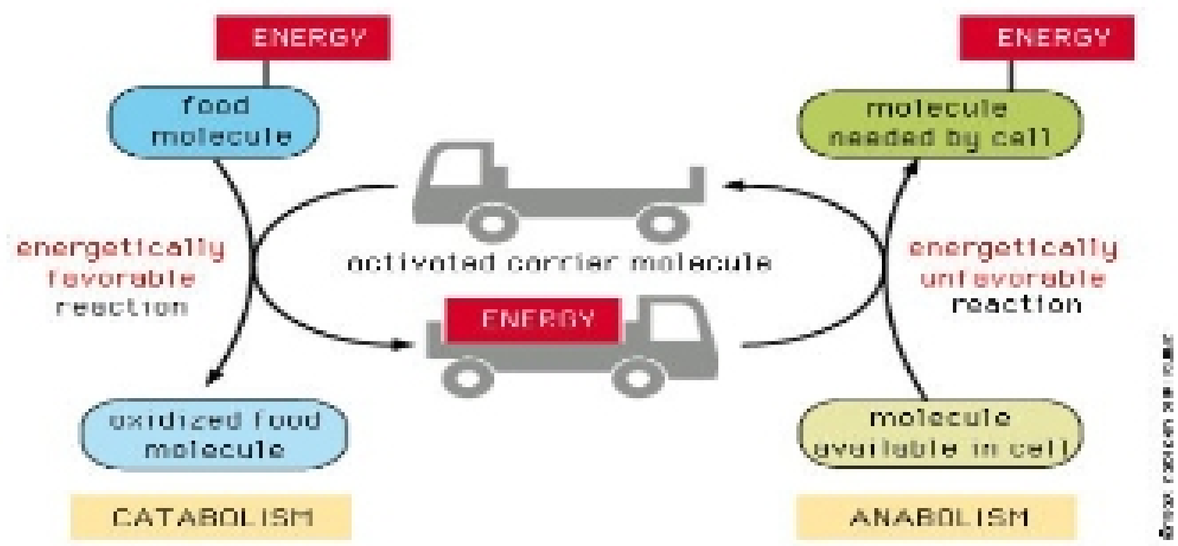
7. Oxidation and reduction
    a. Reduction is the addition of electrons Ex. CO_2 → COO^-
    b. Oxidation is the removal of an electron. Ex. NaCl → Na^+ (oxidized) Cl^- (reduced)
    c. In water the H are oxidized and the O is reduced
    d. The more bounds there are with oxygen the more oxidized the bond is
8. Enzymes
    a. Speed up energetically favorable reactions = catalysts
    b. Cannot force energetically unfavorable reactions, so they form favorable paths around the unfavorable reactions



    c. All an enzyme does is lower the activation energy, therefore reducing the ΔG. ΔG must be negative for a reaction to occur because the negative value means that the total energy is decreasing and entropy is increasing
9. If the ΔG is positive from X → Y then the cell will form a path from X → Y → Z . It is a longer path, but it requires less energy.
10. Standard free energy (ΔG °) allows the comparison of different reactions
    a. For a reversible reaction (X ⇆ Y) ΔG will depend on
        i. The energy stored in each molecule
        ii. Concentration of each molecule
    b. Therefore, the direction of a reaction depends on X and Y concentrations
    c. Standard free energy ΔG °considers ideal conditions, concentrations of all reactants = 1 mile/liter
    d. Formula is $\Delta G = \Delta G° + RT \ln(X/Y)$
    e. (X/Y) = constant Kat equilibrium ΔG
    f. R = the gas constant T = absolute temperature 37K RT = -0.616
11. For example Glucose + Fructose → Sucrose
    a. Requires a +ΔG = +5.5 kcal/mole
    b. And the cell needs a –ΔG, so it couples the reaction with ATP → ADP + Pi. ΔG is -7.3 kcal/mole
    c. The combination of these two reactions is an overall –ΔG so the reaction can proceed
12. Reactions tend to equilibrium. For example:
    a. Y converts to X faster than X converts to Y
    b. Over time the concentration of X will increase and the concentration of Y will decrease

c. Eventually there will be so much X that the rate of conversion to X will equal the fast conversion to Y

13. Dissociation and Association
    a. Dissociation: AB $\rightarrow$ A + B
        i. Dissociation rate = dissociation rat constant x concentration of AB [AB]
        ii. Dissociation = Koff [AB]
    b. Association: A + B $\rightarrow$ AB
        i. Association rate = association rate constant x concentration of a [A] x [B]
        ii. Association = Kon [A][B]
    c. At equilibrium association = dissociation
        i. Kon [A][B] = Koff [AB]
        ii. K (equilibrium constant) = Kon/Koff = [AB]/[A][B]
14. Activated carriers
    a. Store and transfer energy needed for metabolism
    b.



    c. Chart of carriers

ACTIVATED CARRIERS	GROUP CARRIED IN LINKAGE
ATP	Phosphate group
NADH	Electrons and Hydrogen
Acetyl CoA	Acetyl group
Carboxylate biotin	Carboxyl group
Uri dine Diphosphate	Glucose

15. Synthesis requires energy input whereas degradation does not
    a. A-H + OH-B $\rightarrow$ releases H_2O (condensation) $\rightarrow$ A-B
    b. A-B $\rightarrow$ requires H_2O (Hydrolysis) $\rightarrow$ A-H + OH-B
16. Chemical bond energy is converted to other forms of energy
    a. Heat
    b. Cell motility
    c. Concentration gradients
    d. Electric potential
    e. Molecule transport