AP biology
Notes: Metabolism

Metabolism = totality of an organism's chemical process concerned with managing cellular resources.

- Metabolic reactions are organized into pathways that are orderly series of enzymatically controlled reactions. Metabolic pathways are generally of two types:

  - Catabolic pathways = metabolic pathways that release energy by breaking down complex molecules to simpler compounds (e.g. cellular respiration which degrades glucose to carbon dioxide and water; provides energy for cellular work).
  - Anabolic pathways = metabolic pathways that consume energy to build complicated molecules from simpler ones (e.g. photosynthesis which synthesizes glucose from CO_2 and H_2O and synthesis of a macromolecule from its monomers.)
- Metabolic reactions may be coupled so that energy released from a catabolic reaction ca be used to drive an anabolic one.

The energy transformations of life

- **First Law of Thermodynamics** = energy can be transferred and transformed, but it cannot be created or destroyed
- **Second Law of Thermodynamics** = Ever energy transfer or transformation makes the universe more disordered (every process increases the entropy of the universe)
- **Entropy** = Quantitative measure of disorder that is proportional to randomness
- **Closed system** = collection of matter under study which is isolated from its surroundings
- **Open system** = system in which energy can be transferred between the system and its surroundings

  *The entropy of a system may decrease, but the entropy of the system plus its surroundings must always increase

  *Take in complex high energy molecules as food and extract chemical energy to

create
and maintain order

*Return to the surroundings simpler low energy molecules (CO_2 and H_2O) and heat

*the quantity of energy in the universe is constant, but its quality is not

Organisms and free energy

Free energy:
Not all of a system's energy is available to do work. The amount of energy that is available to do work is described by the concept of free energy Free energy (G) is related to the system's total energy (H) and its entropy (S) in the following ways:

$$G = H - TS$$

where:
G = Gibbs free energy (energy available to do work)
H = enthalpy or total energy
T = temperature in ^oK
S = entropy

The maximum amount of usable energy that can be harvested for a particular reaction is the system's free energy change from the initial to the final state.

$$\triangle G = \triangle H - T \triangle S$$

where:
$\triangle$**G** = change in free energy
$\triangle$**H** = change in total energy (enthalpy)
$\triangle$**S** = change in entropy
T = absolute temperature in ^oK

Significance of free energy:

- Indicates the maximum amount of system's energy which is available to do work
- Indicates whether a reaction will occur spontaneously or not
  A spontaneous reaction is one that will occur without additional energy
  In a spontaneous process $\triangle$G or free energy of a system decreases ($\triangle G<0$).
- A decrease in enthalpy ($-\triangle H$) and an increase in entropy ($+\triangle S$) reduce the free energy of a system and contribute to the spontaneity of a process
- A higher temperature enhances the effect of an entropy change. Greater kinetic energy of molecules tends to disrupt order as the chances for random collision increase.
- Temperature may determine if the reaction will be spontaneous or not (e.g. protein denaturation by increased temperature)

- High energy systems, including high energy chemical systems, are unstable and tend to change to a more stable state with a lower free energy.

Free energy and equilibrium

- As a reaction approaches equilibrium, the free energy of the system decreases (spontaneous and exergonic reaction)
- When a reaction is pushed away from equilibrium the free energy of a system increase
- When a reaction reaches equilibrium $\triangle G = 0$(which equals death for a cell), because there is no net change in the system

Reactions can be classified based upon their free energy changes:
Exergonic reaction = a reaction that proceeds with a net loss of free energy.

Endergonic reaction = an energy=requiring reaction that proceeds with a net gain of free energy; a reaction that absorbs free energy from its surroundings.

Exergonic Reaction	Endergonic Reaction
Chemical products have less free energy than the reactant molecules Reaction is energetically downhill Spontaneous reaction $\triangle G$ is negative $-\triangle G$ is the maximum amount of work the reaction can perform	Products store more free energy than reactants Reaction is energetically uphill Non-spontaneous reaction (requires energy input) $\triangle G$ is positive $+\triangle G$ is the minimum amount of work required to drive the reaction

- In cellular metabolism energonic reactions are driven by coupling them to reactions with a greater negative free energy (exergonic). ATP plays a critical role in this energy coupling

Metabolic disequilibrium

- At equilibrium $\triangle G = 0$, so the system can do no work
- Metabolic disequilibrium is necessity of life' a cell at equilibrium is dead

- In the cell, these potentially reversible reactions are pulled forward away from equilibrium, because the products of some reactions become reactants for the next reaction in the metabolic pathway.

ATP powers cellular work by coupling exergonic to endergonic reactions

- The structer and hydrolysis of ATP

Adenine, a ntirogenous base.
Ribose, a five-carbon sugar
Chain of three phosphate groups.

Unstable bonds between the phosphate groups can be hydrolyzed in an exergonic reaction that releases energy.

- When the terminal phosphate bond is hydrolyzed, a phosphate group is removed production ADP
- reaction releases - 31 kJ/mol (-7,3 kcal/mol).
- In a living cell, this reaction releases-55 kJ/mol (-13 kcal/mol) about 77% more than under standard conditions
- products of the hydrolysis of the phosphate bonds is thus exergonic as the system shifts to a more stable state.

How ATP performs work

- Exergonic hydrolysis of ATP is coupled with endergonic process by transferring a phosphate group to another molecule.
- Phosphate transfer is enzymatically controlled
- The molecule acquiring the phosphate (phosphorylated or activated intermediate) becomes more reactive.

- overall $\triangle$G

Regeneration of ATP

- ATP is continually regenerated by the cell
- Process is rapid (10^7 molecules used and regenerated/sec/cell)
  Reaction is endergonic

- Energy to drive the endergonic regeneration of ATP comes from the exergonic process
of cellular respiration.