Section 3.1 Metabolism and Energy

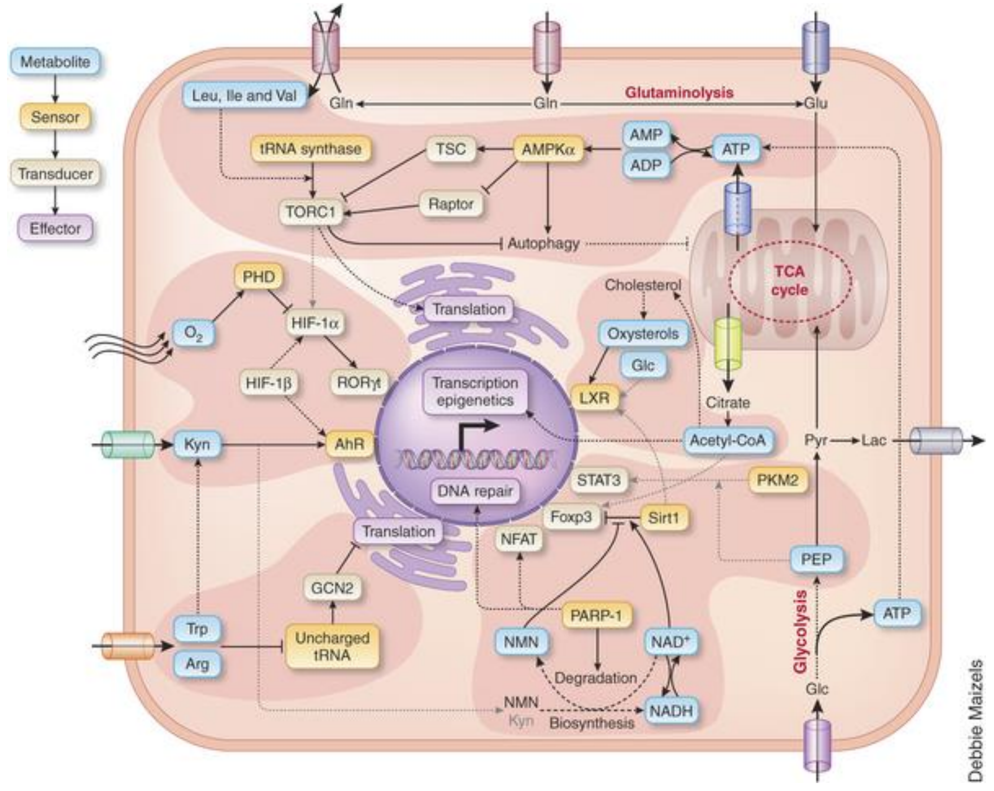
SBI4UP

MRS. FRANKLIN

Energy

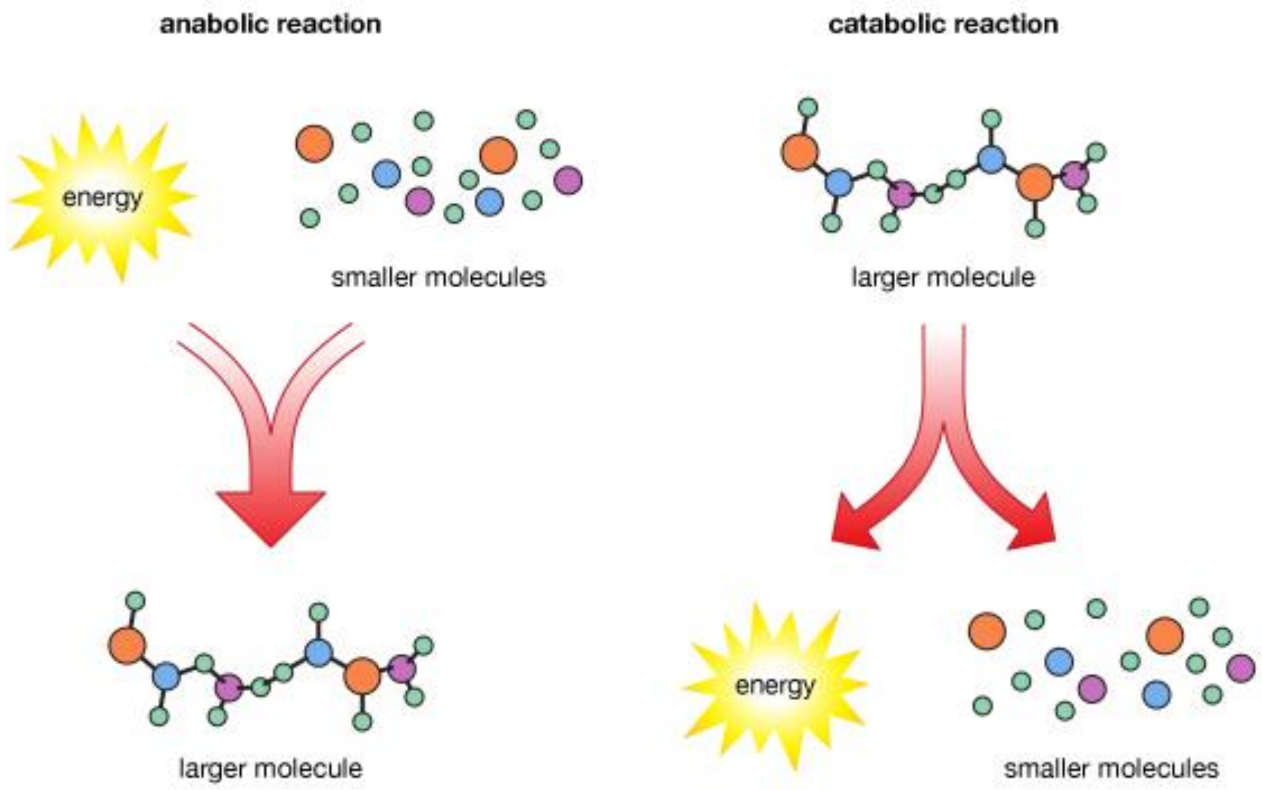
Energy is the ability to do work and organisms must continually capture, store and use energy.

Organisms tend to do all of their work at a molecular level through a series of chemical reactions.



Energy

Organisms must manage the amount of energy that is being used and produced in a living cell.



Metabolism is the sum of all anabolic and catabolic processes in a cell or organism.

Energy

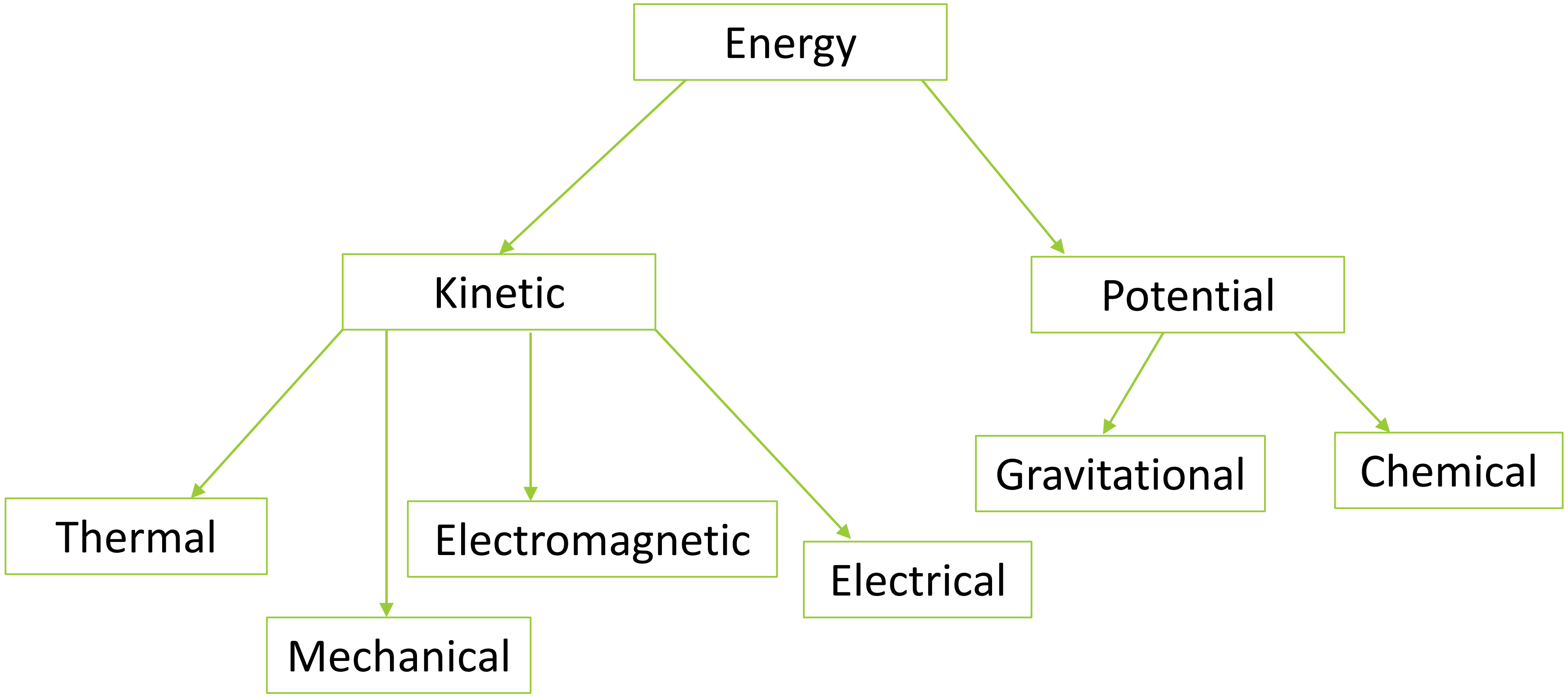
Work occurs when one object applies a force on another object and changes its position or state of motion.

Energy can be defined in two ways:

1) **Kinetic Energy:**

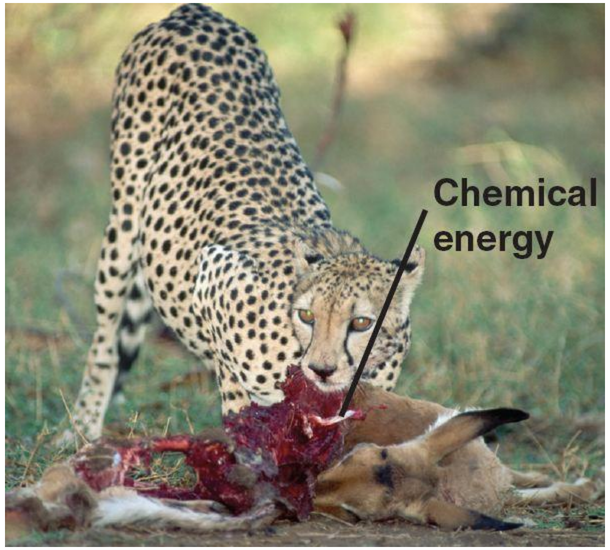
2) **Potential Energy:**

Energy


Energy
Kinetic
Potential
Thermal
Mechanical
Electromagnetic
Electrical
Gravitational
Chemical

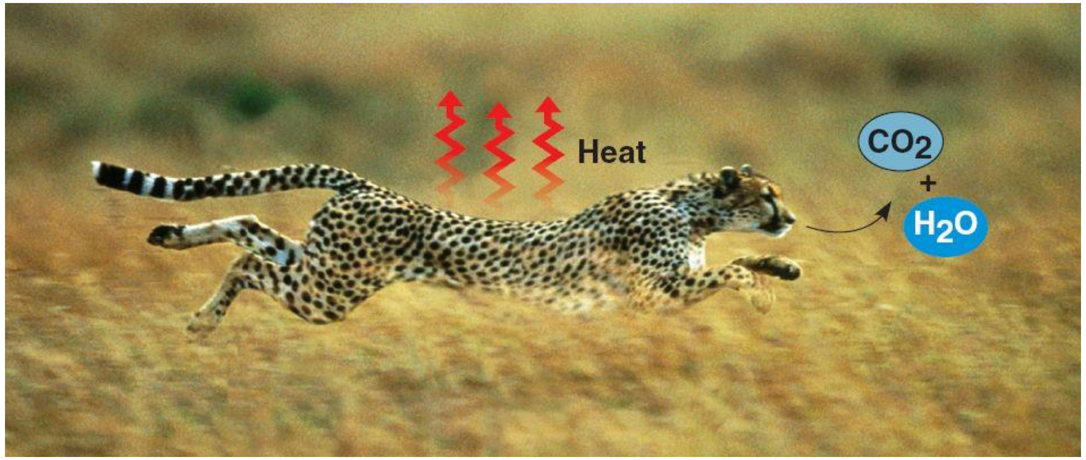
First Law of Thermodynamics

The total amount of energy in the universe is constant. Energy cannot be created or destroyed but only converted from one form into another.



Potential Energy stored in macromolecules

Energy Conversion



Kinetic Energy used for motion and energy lost as heat

Bond Energy – 1st law of thermodynamics

Bond Energy is the measure of the stability of a covalent bond, it is measured in kJ. It is equal to the amount of energy required to break one mole of bond between two atoms.

Enthalpy: the heat absorbed or released from a system under constant pressure.

In a series of chemical reactions bond will break and reform which will change the potential energy in a system.

Average Bond Enthalpies (kJ/mol)

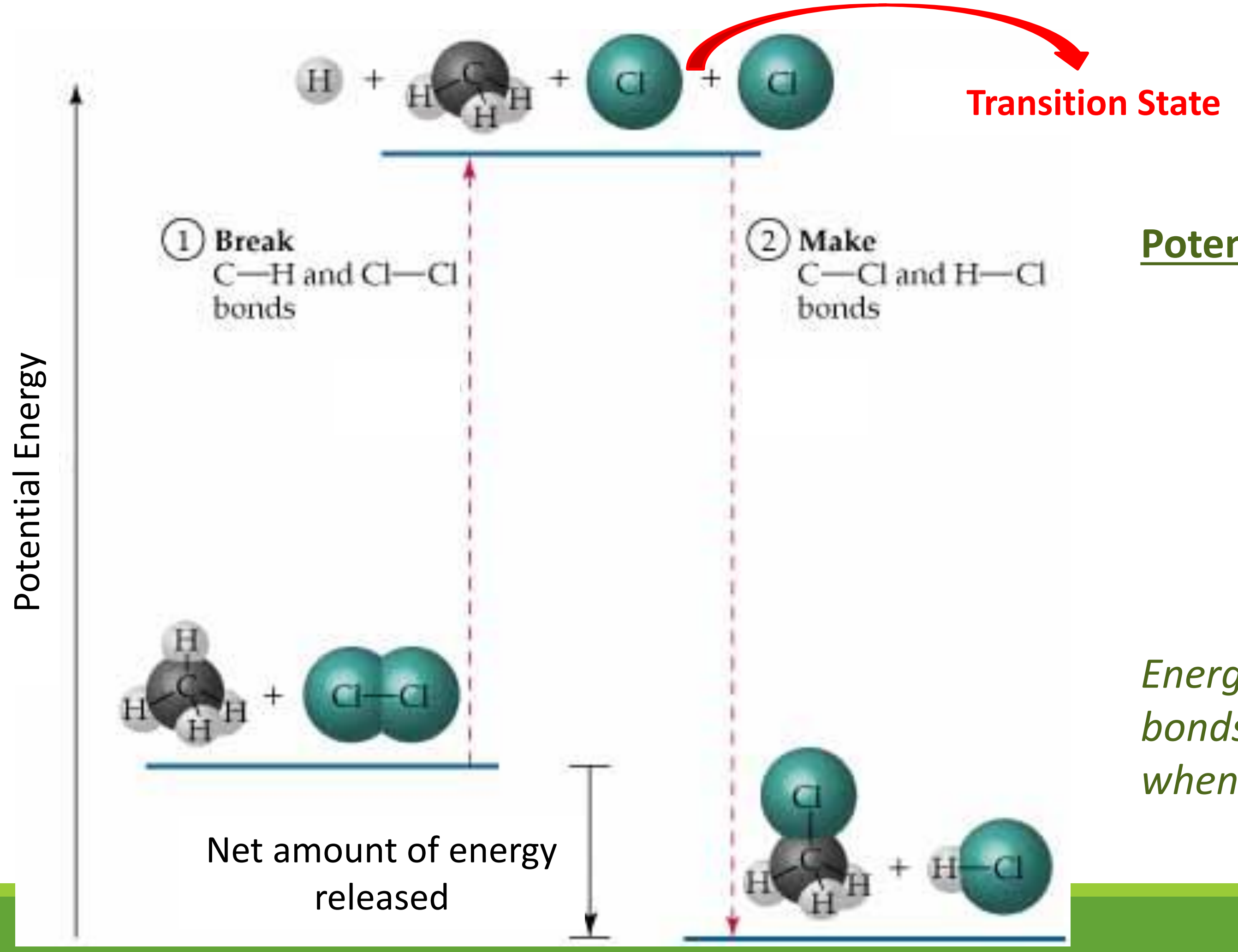
Single Bonds

C—H	413	N—H	391	O—H	463	F—F	155
C—C	348	N—N	163	O—O	146		
C—N	293	N—O	201	O—F	190	Cl—F	253
C—O	358	N—F	272	O—Cl	203	Cl—Cl	242
C—F	485	N—Cl	200	O—I	234		
C—Cl	328	N—Br	243			Br—F	237
C—Br	276			S—H	339	Br—Cl	218
C—I	240	H—H	436	S—F	327	Br—Br	193
C—S	259	H—F	567	S—Cl	253		
		H—Cl	431	S—Br	218	I—Cl	208
Si—H	323	H—Br	366	S—S	266	I—Br	175
Si—Si	226	H—I	299			I—I	151
Si—C	301						
Si—O	368						

Multiple Bonds

C=C	614	N=N	418	O_2	495
C≡C	839	N≡N	941		
C=N	615			S=O	523
C≡N	891			S=S	418
C=O	799				
C≡O	1072				

Enthalpy

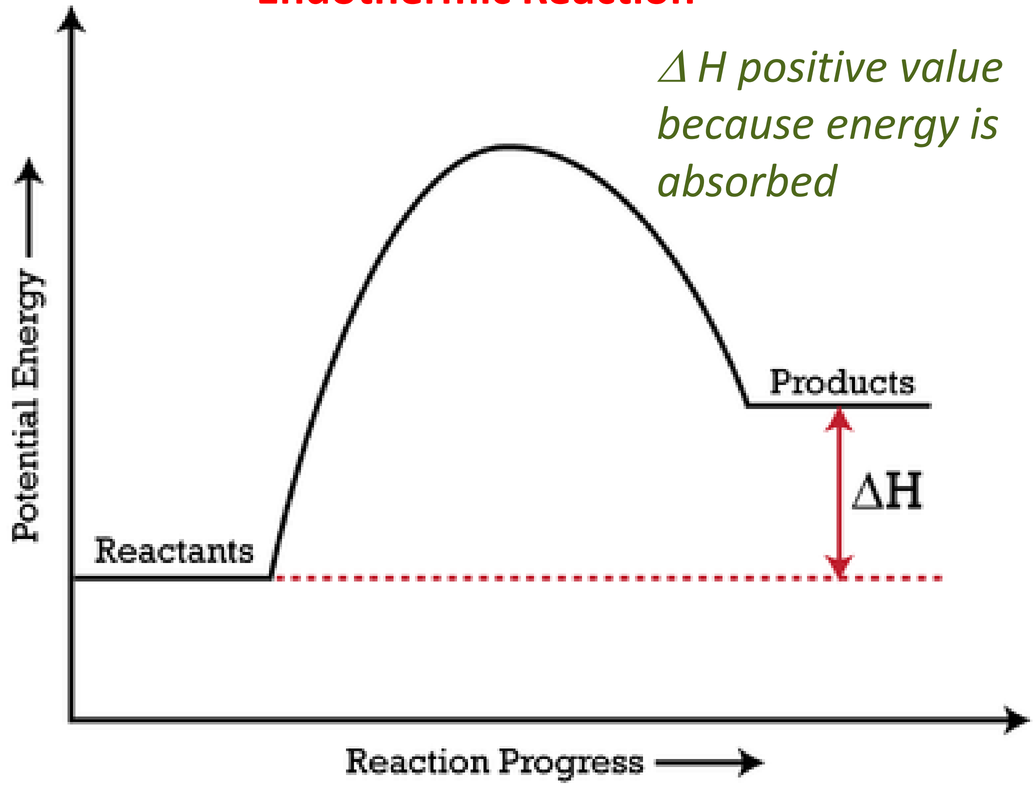


Potential Energy Diagram:

Energy is absorbed when reactant bonds break and energy is released when product bonds form.

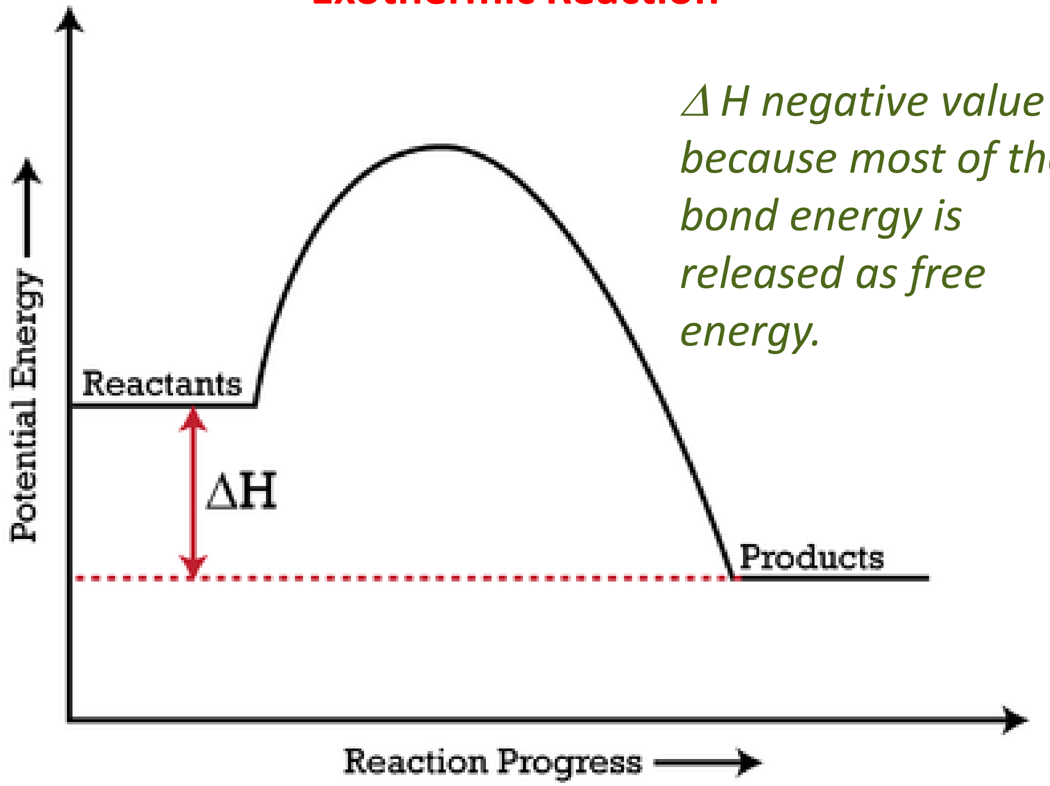
Enthalpy

Endothermic Reaction



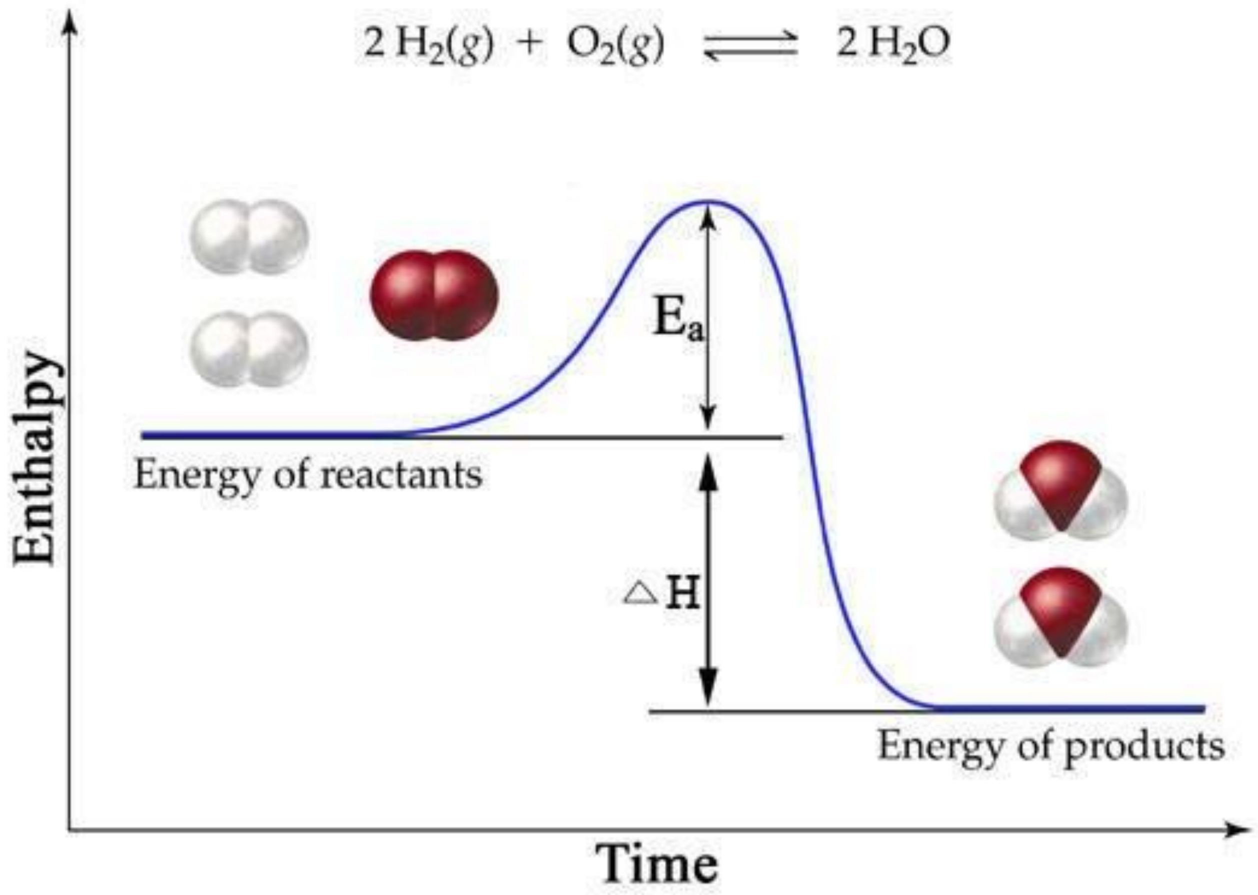
Δ H positive value because energy is absorbed

Exothermic Reaction



Δ H negative value because most of the bond energy is released as free energy.

Enthalpy Example



If the reverse reaction were to occur, it would be an endothermic reaction, because more energy would be absorbed in the bond.

Bond Energy in Reactions

Although molecules are attracted to one another, extra energy is still required to help keep these atoms together. The energy used to create a bond is stored and active within the covalent bond.

Energy is required to form a bond between the green and blue molecule.

The free energy is now stored/active as chemical potential energy.

Bond Energy

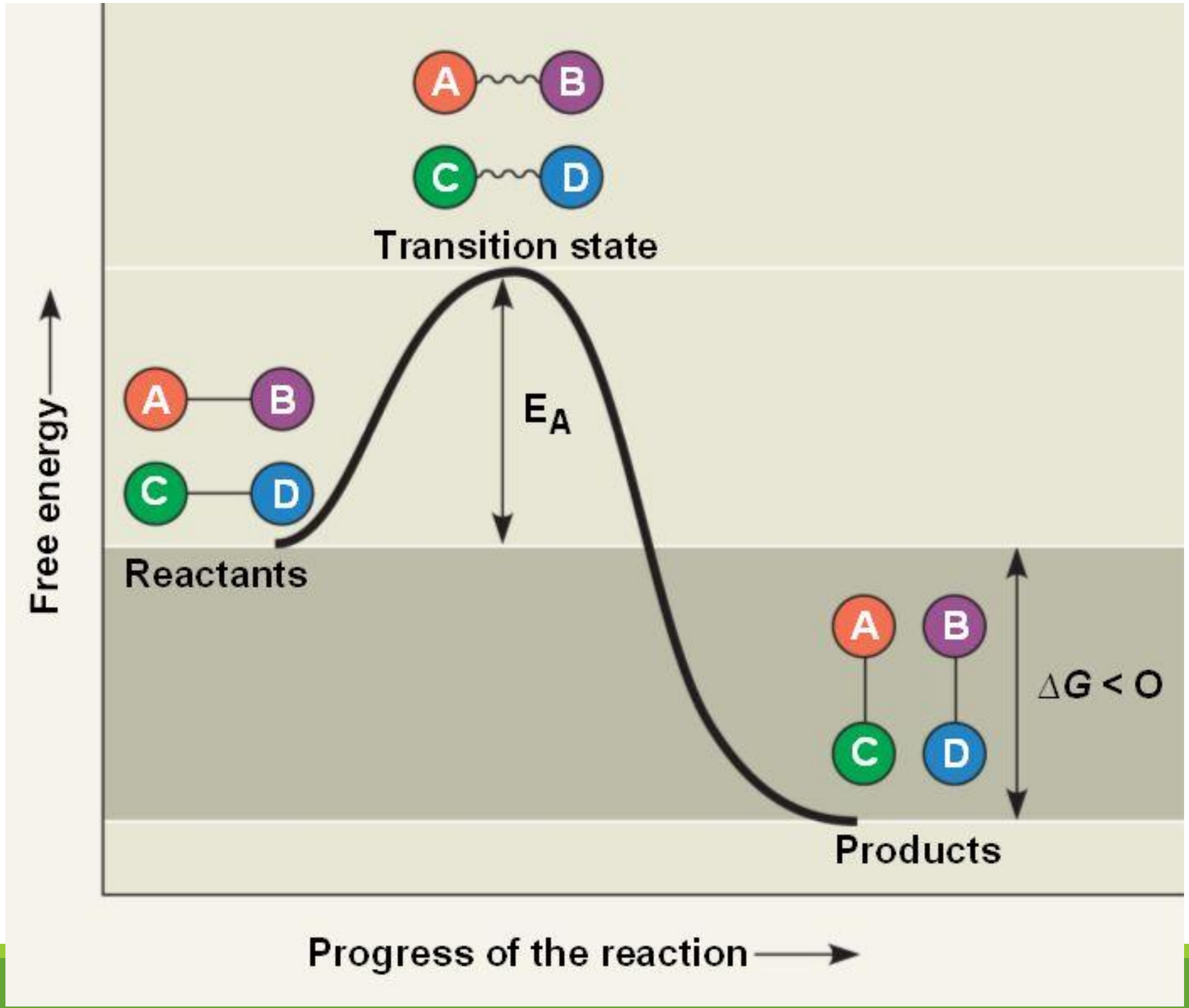
Energy is needed to break the bond

Additional energy is known as ***'Activation energy'***

Although a chemical bond contains energy, additional energy is required to break the bond. This energy could come from heat, not always as free energy.

The free energy that had been stored in the bonds, once broken is released as free energy and can now be used in the cell to create new bonds.

Exergonic Reaction



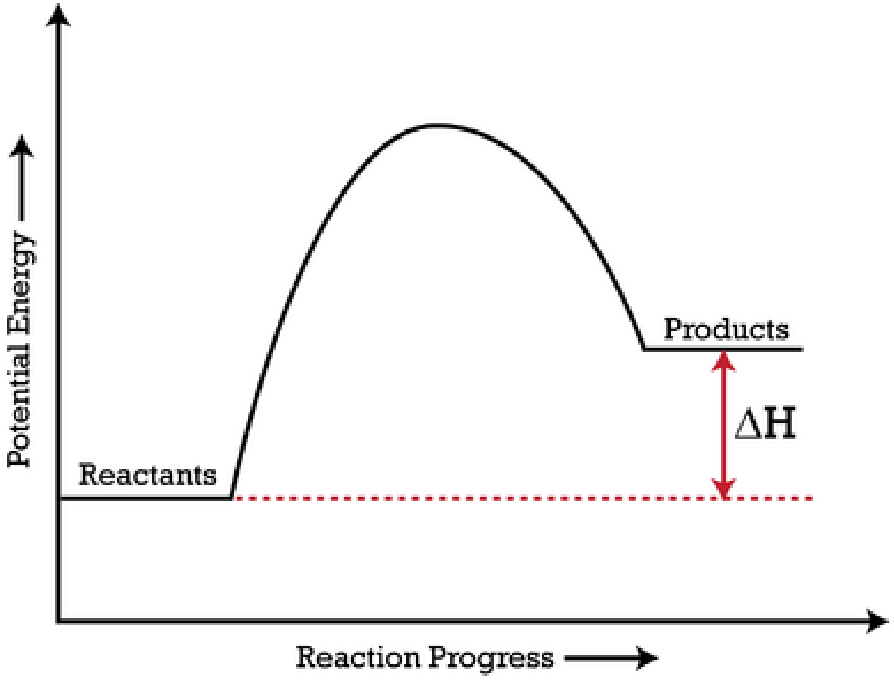
Activation Energy:

Transition State:

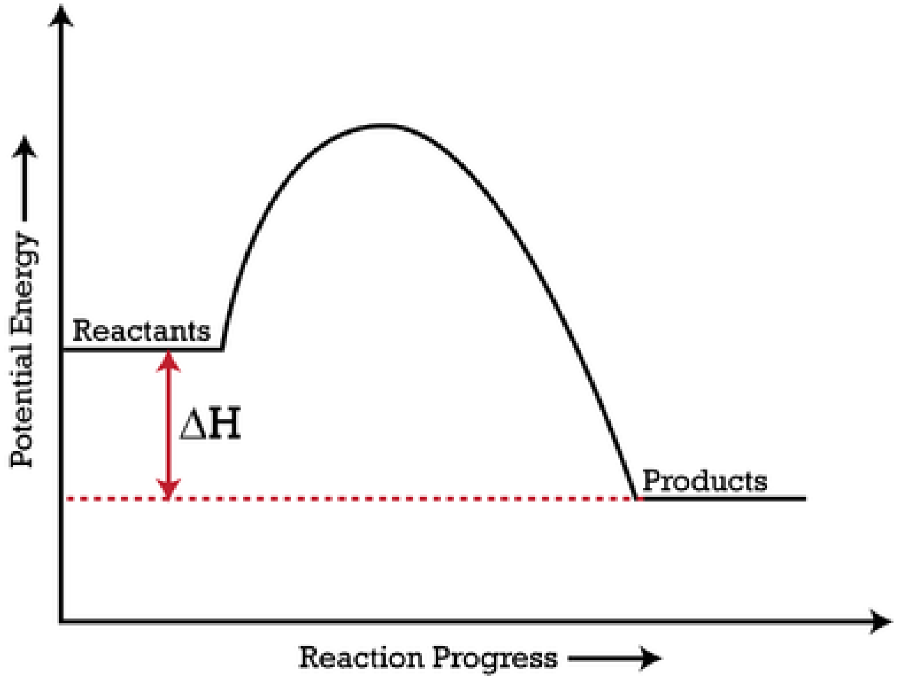
The more stable the molecule the less potential energy is required in order to hold the bond. If the product is more stable more energy is released during the reaction.

Spontaneity of a Reaction

Endothermic Reaction



Exothermic Reaction



Entropy (S)

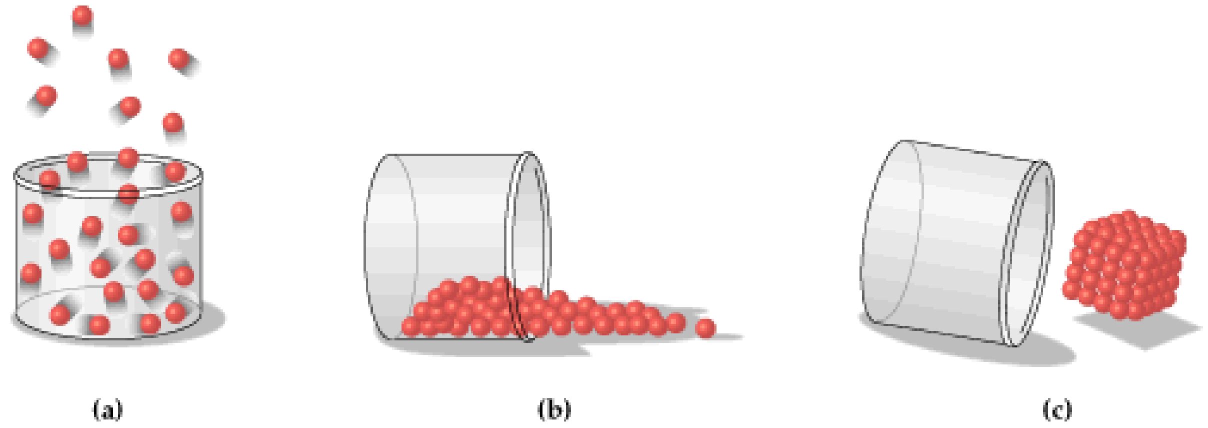
Entropy is a measure of the randomness or disorder energy and it tends to increase when disorder increases.

Increasing disorder
(i.e entropy)

Entropy (S)

In chemical reactions entropy will increase in the following circumstances:

1) Solid reactant become liquid



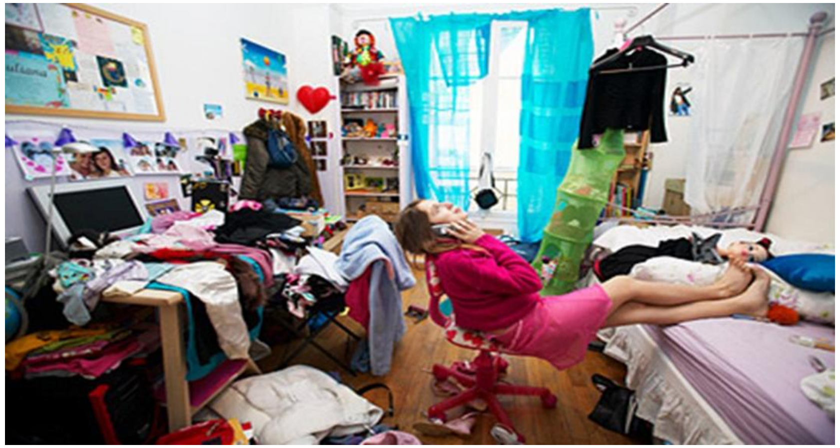
2) Liquid reactants become gaseous

3) Complex molecules react to form simpler molecules

4) Solutes move with their concentration gradients

Second Law of Thermodynamics

The entropy of the universe increases with any change that occurs.



Naturally our universe will go from an ordered stated to a disordered state.

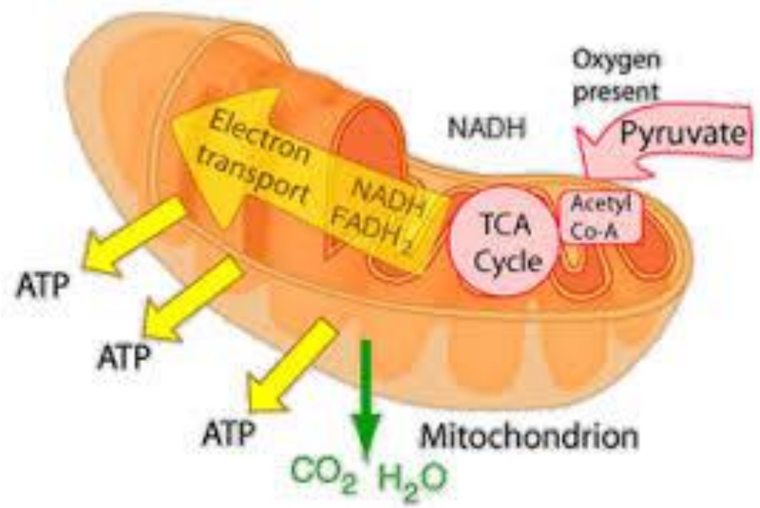
Second Law of Thermodynamics

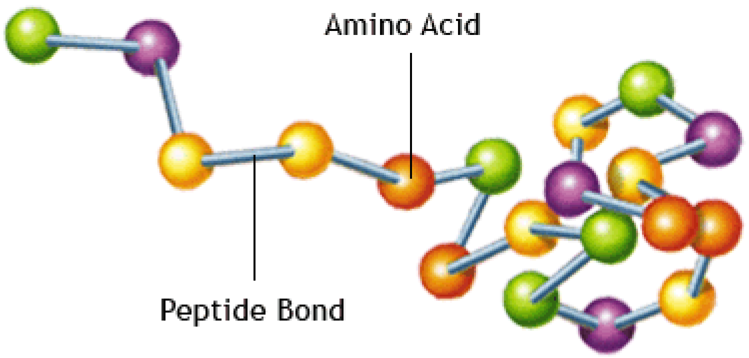
Remember…

- when a molecule is broken down in a catabolic reaction, energy is released (ΔH is negative) and entropy increases (ΔS increases). This is an exothermic reaction and a spontaneous process.

- In living systems, cells seem to create a more ordered state through anabolic reactions by building molecules. Although it seems to violate the second law of thermodynamics, scientists believe that these reactions are always coupled to catabolic reactions that is favoured in the universe.

Second Law of Thermodynamics



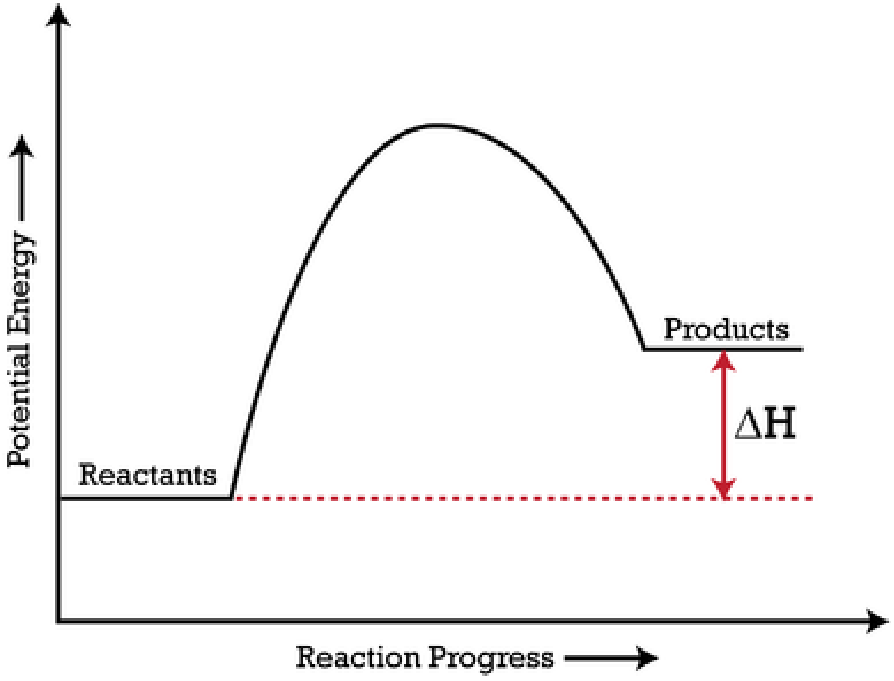


In order to produce the free energy that the cell will use for anabolic reactions, a catabolic reaction must occur much more often ***(increasing entropy)***

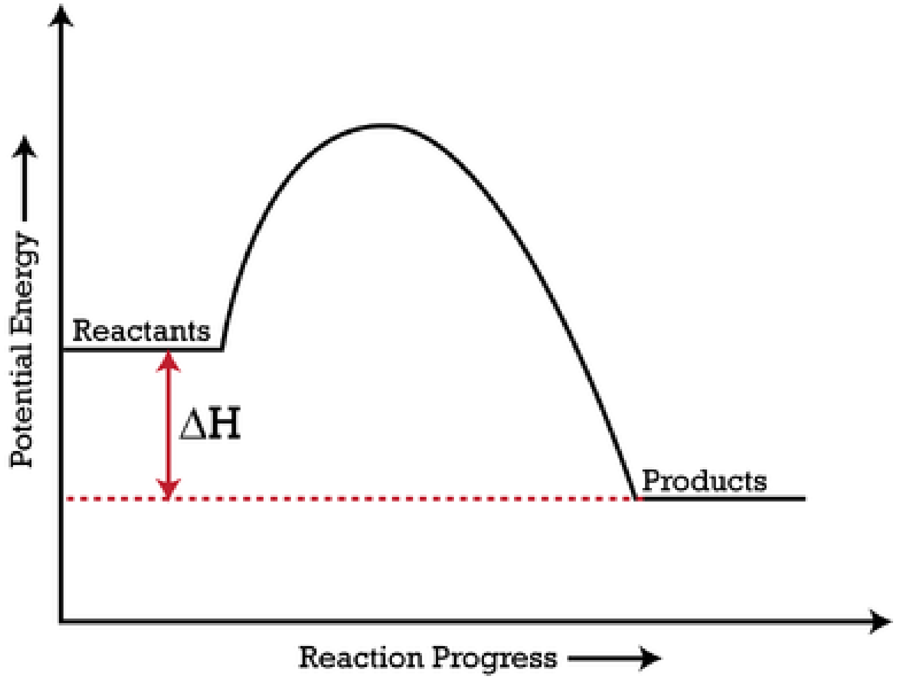
Building the macromolecules that our body requires decreases entropy. However, A LOT of free energy had to be created (increase in entropy) in order to build these ordered molecules. Thus the universe still became more disordered.

Spontaneity of a Reaction

Endothermic Reaction



Exothermic Reaction



Gibb's Free Energy

- Josiah Willard Gibbs, discovered a relationship between the energy change and the temperature of a reaction and how this relationship could determine whether or not the reaction would occur spontaneously.
- In chemical reactions, some bonds are broken in the reactants and new ones are formed in the products. Thus, the free energy changes depending on the reaction.
- In biological systems, the chemical reactions occur under a constant temperature, pressure and volume.

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

ΔG =

T =

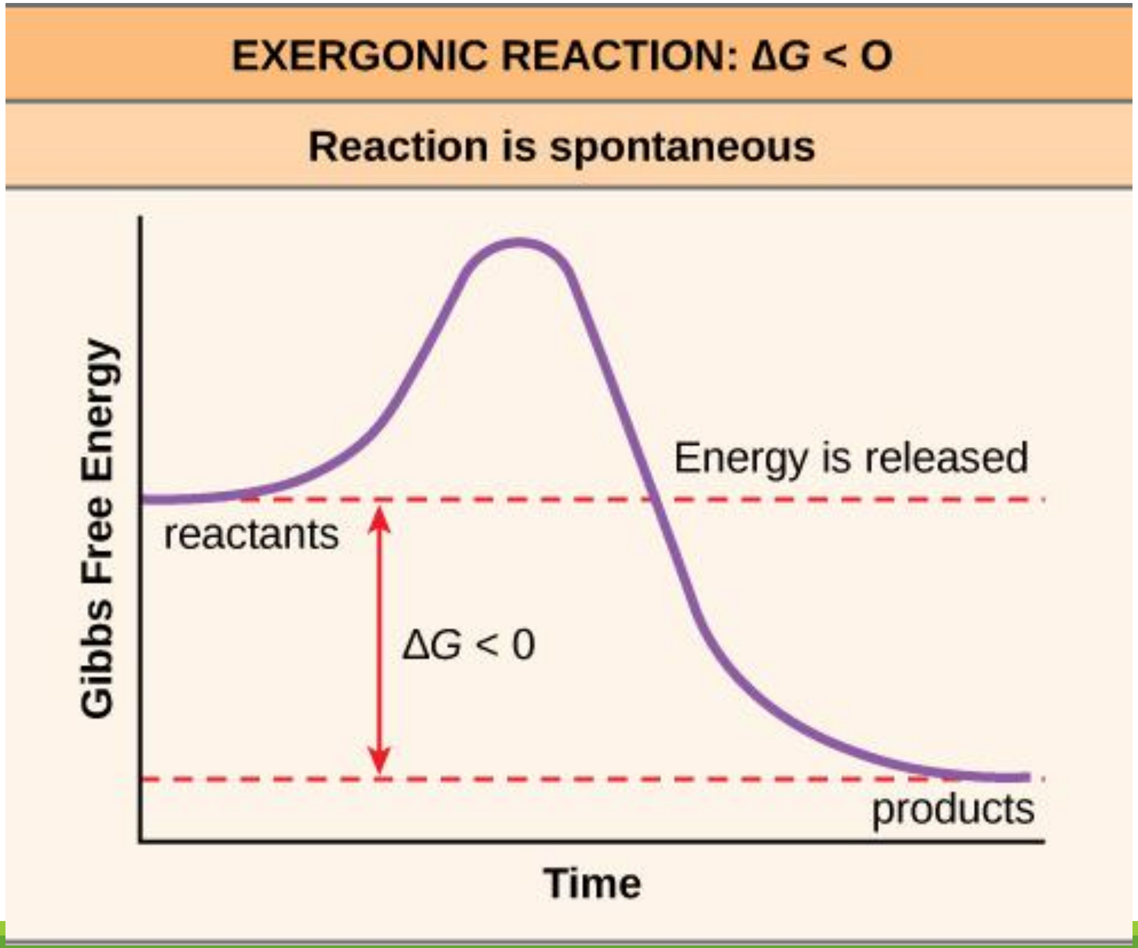
ΔH =

ΔS =

Spontaneity of Reactions

	∆ H < 0	∆ H > 0
∆ S > 0		
∆ S < 0		

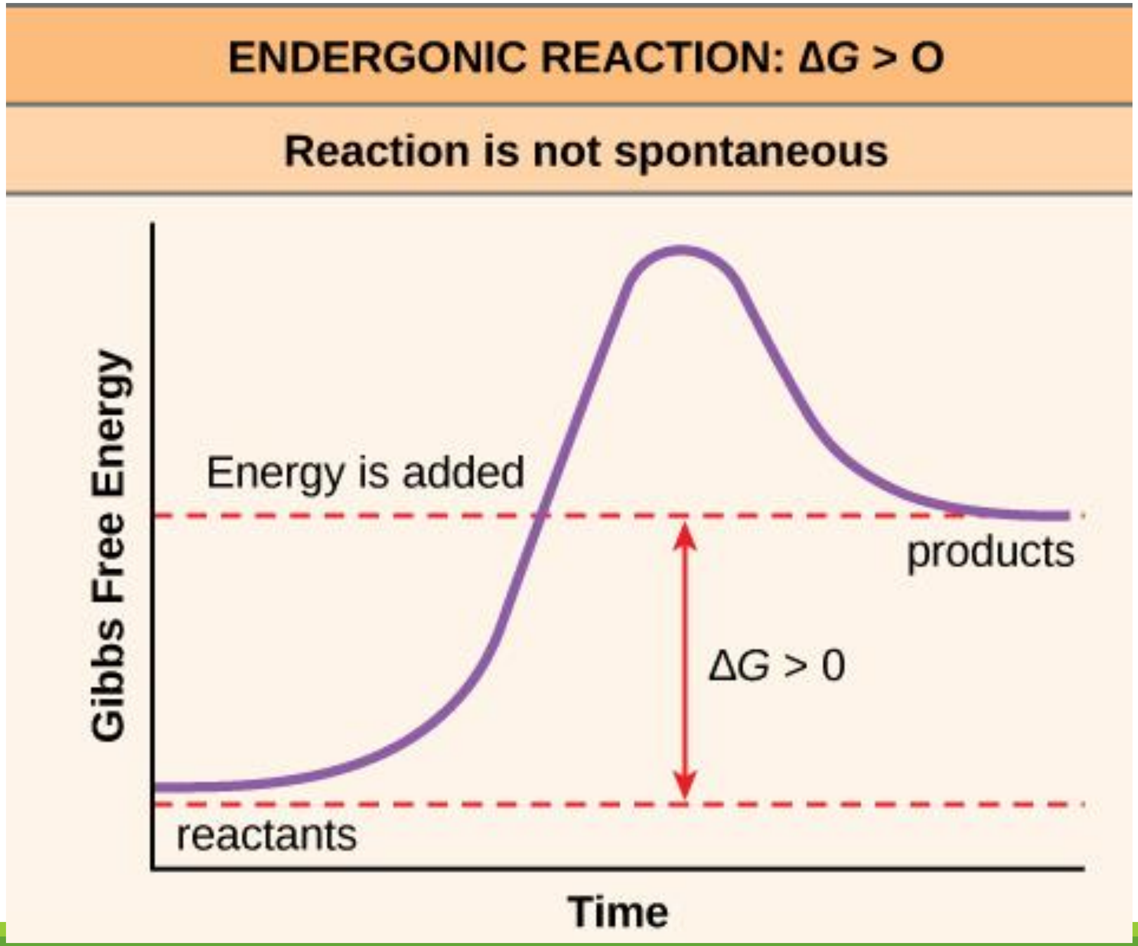
Gibb's Free Energy



NEGATIVE ΔG :

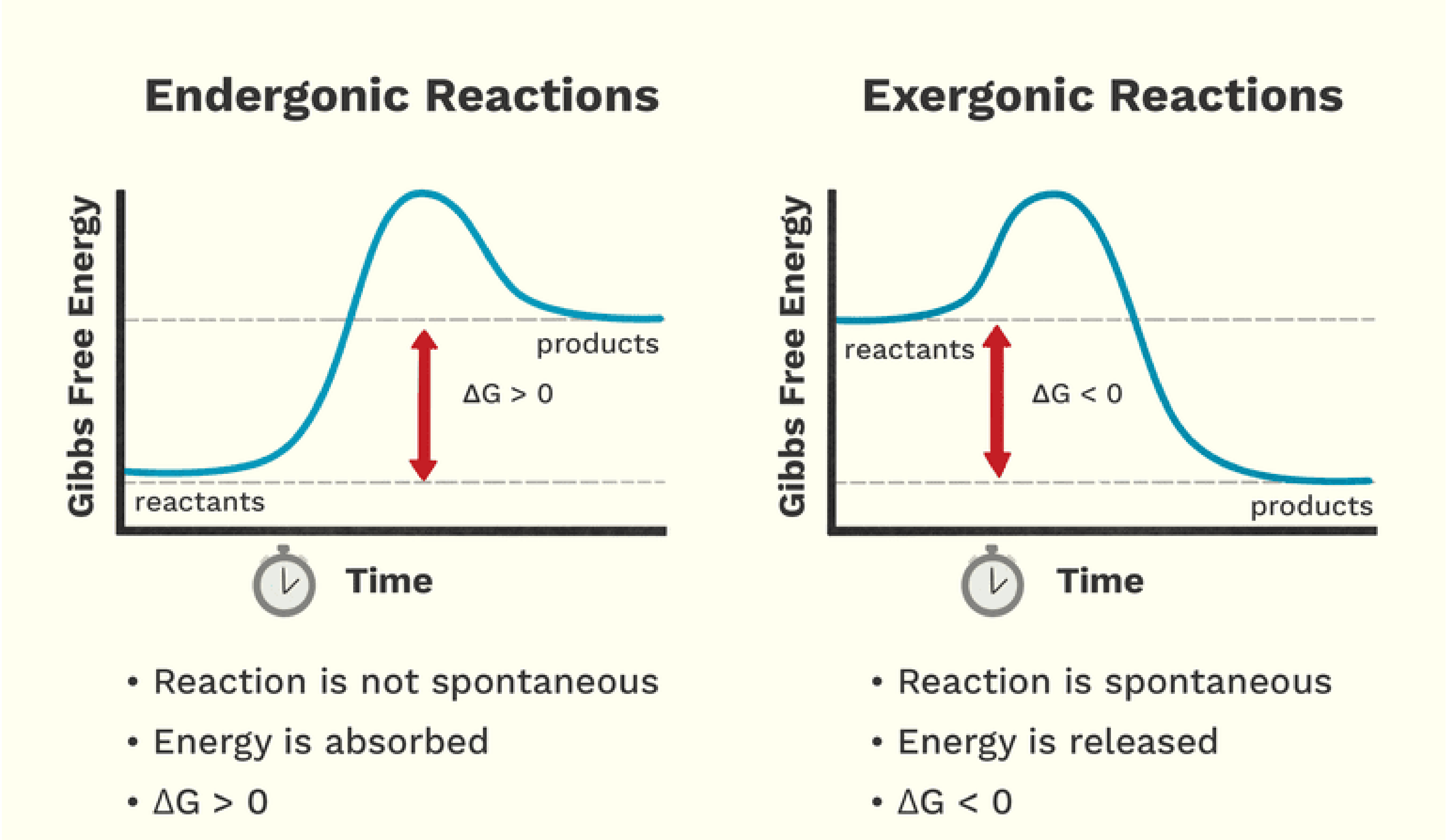
$$\Delta G = \Delta H - T\Delta S$$

Gibb's Free Energy

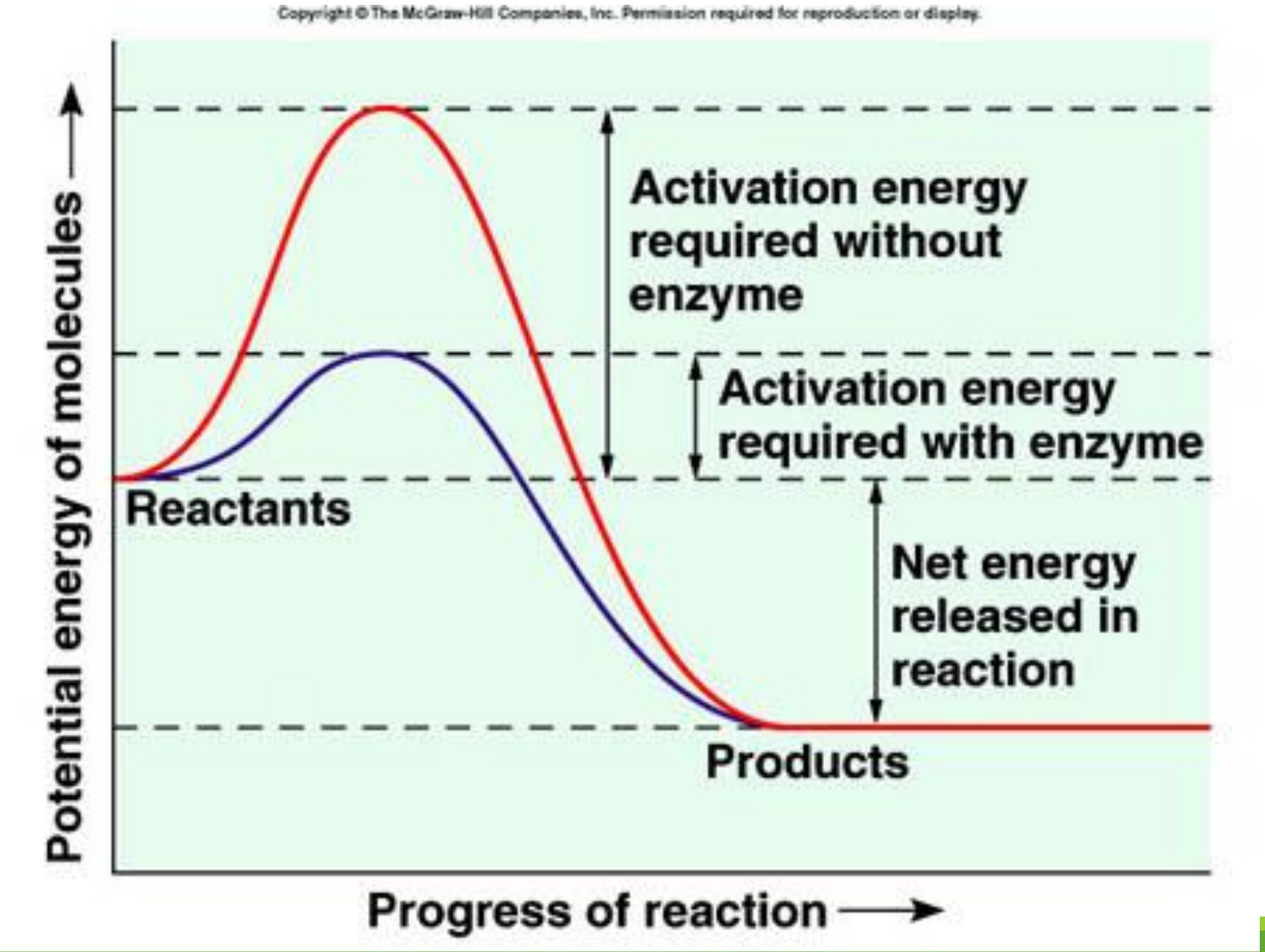


POSITIVE ΔG :

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


Endergonic Reactions
Gibbs Free Energy
products
ΔG > 0
reactants
Time
• Reaction is not spontaneous
• Energy is absorbed
• ΔG > 0
Exergonic Reactions
Gibbs Free Energy
reactants
ΔG < 0
products
Time
• Reaction is spontaneous
• Energy is released
• ΔG < 0

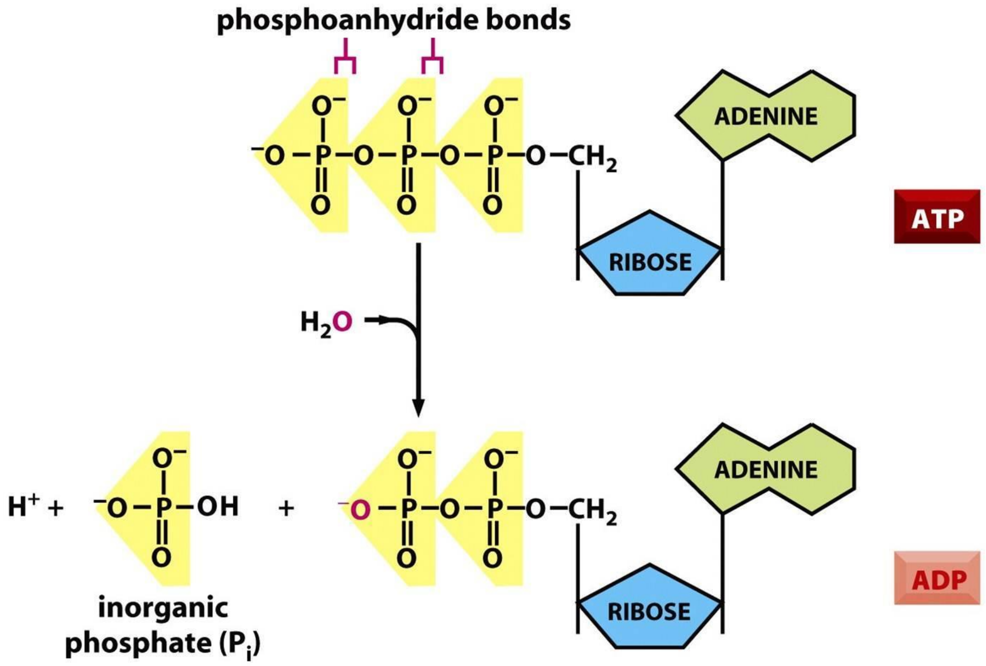
Exergonic vs. Endergonic Reactions

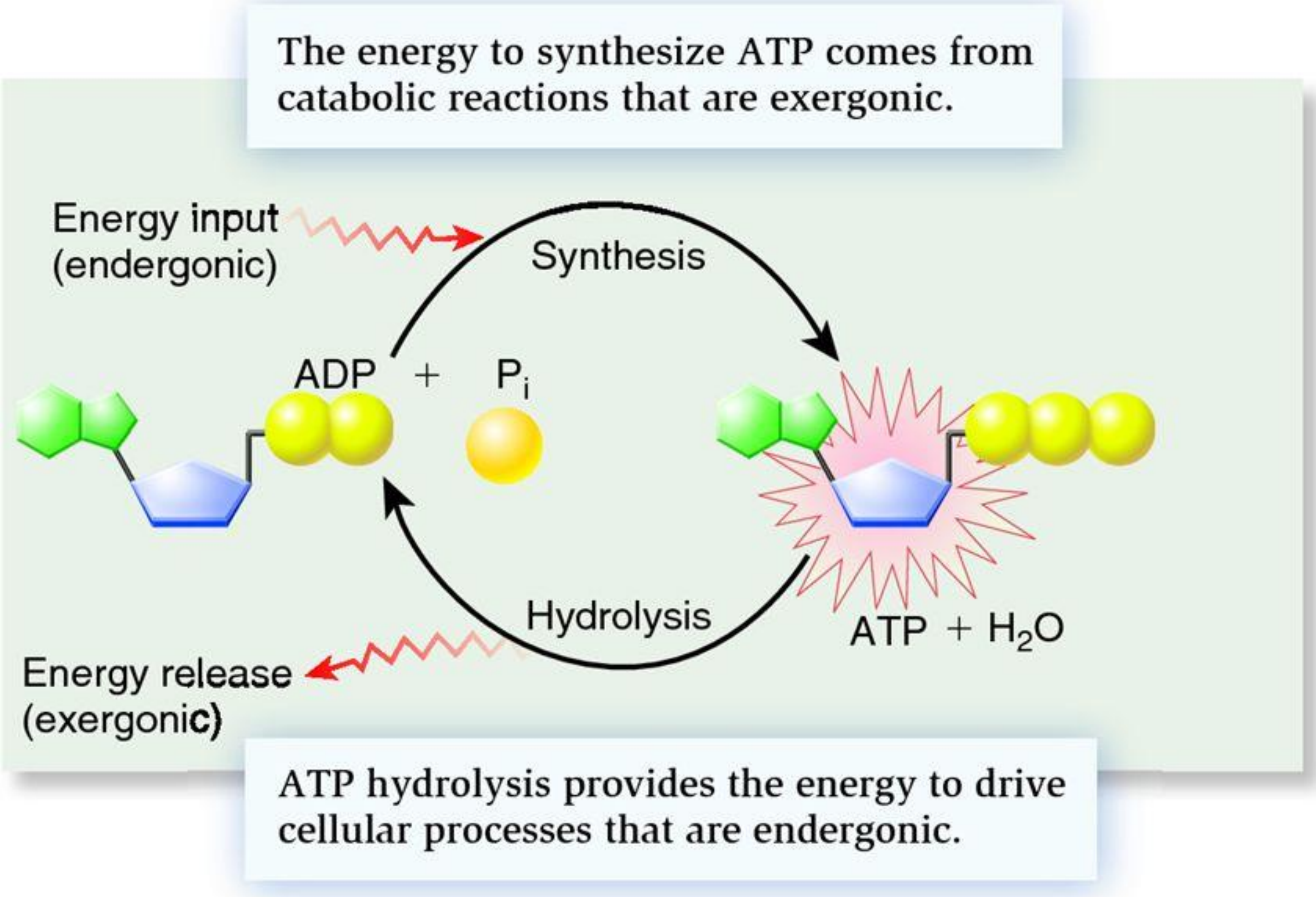


An enzyme can help speed up a chemical reaction by lowering the activation energy. ∆G is never affected by the enzyme.

ATP and ADP Cycle

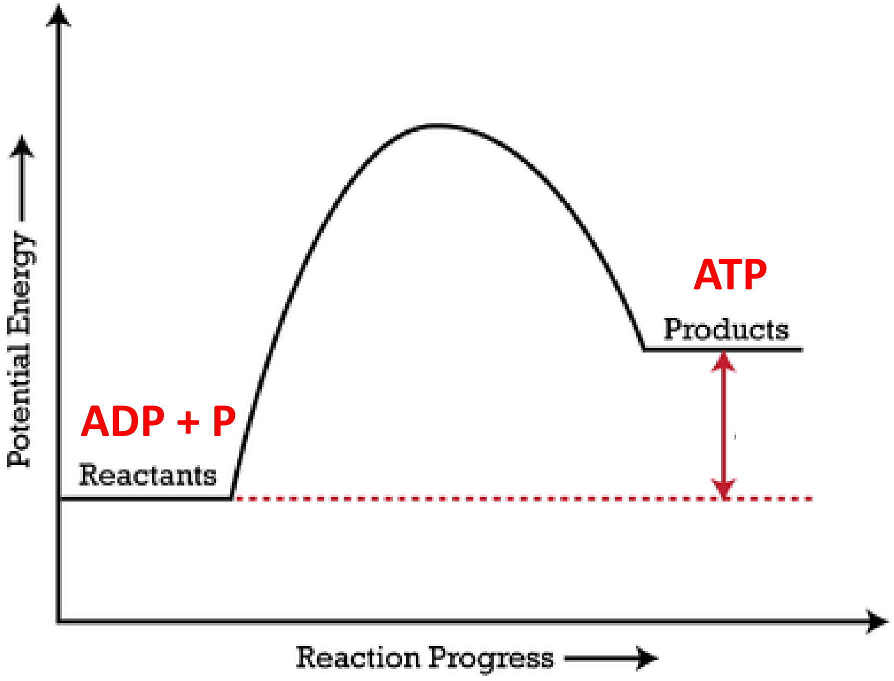
Remember,… a hydrolysis reaction must occur in order to break the phosphate bond to make ADP.

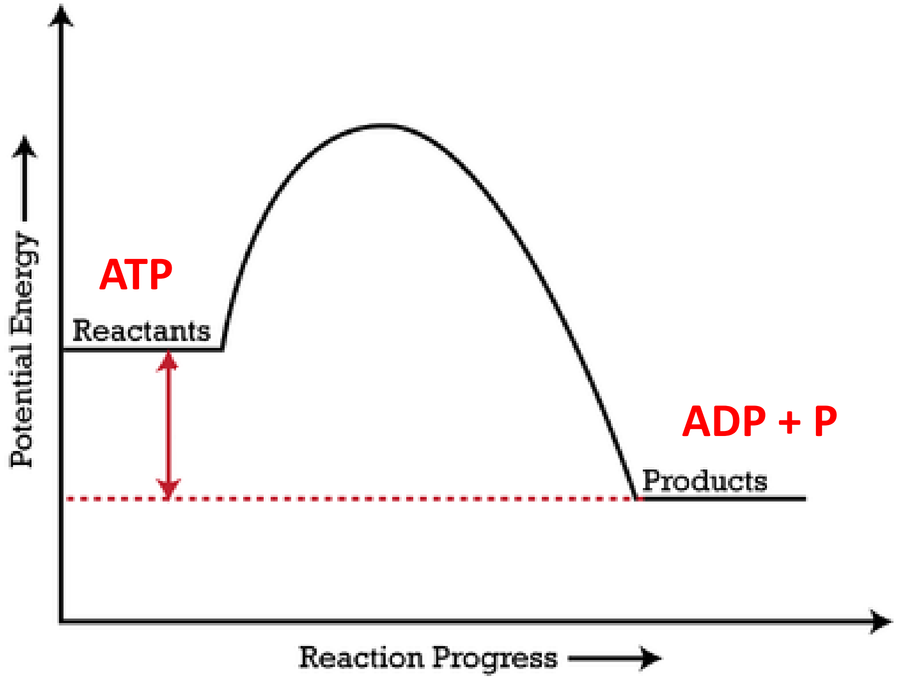




Adenosine triphosphate (ATP) is the primary source of free energy in living cells. It can provide energy for endergonic reactions used in the cell.

ATP Coupled Reaction





ADP and Inorganic Phosphate

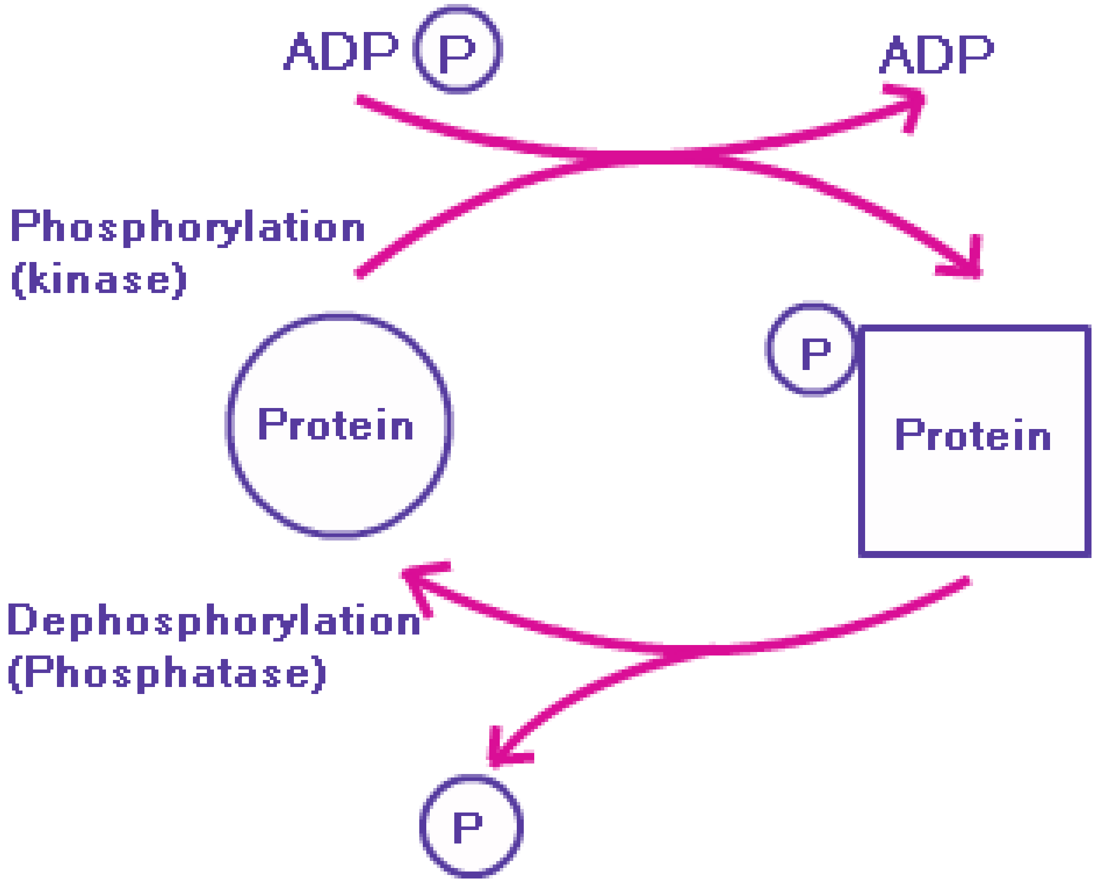
The inorganic phosphate can participate in a wide range of chemical reactions:

1)Phosphorylation

2) Substrate level Phosphorylation

3) Oxidative Phosphorylation

1) Phosphorylation

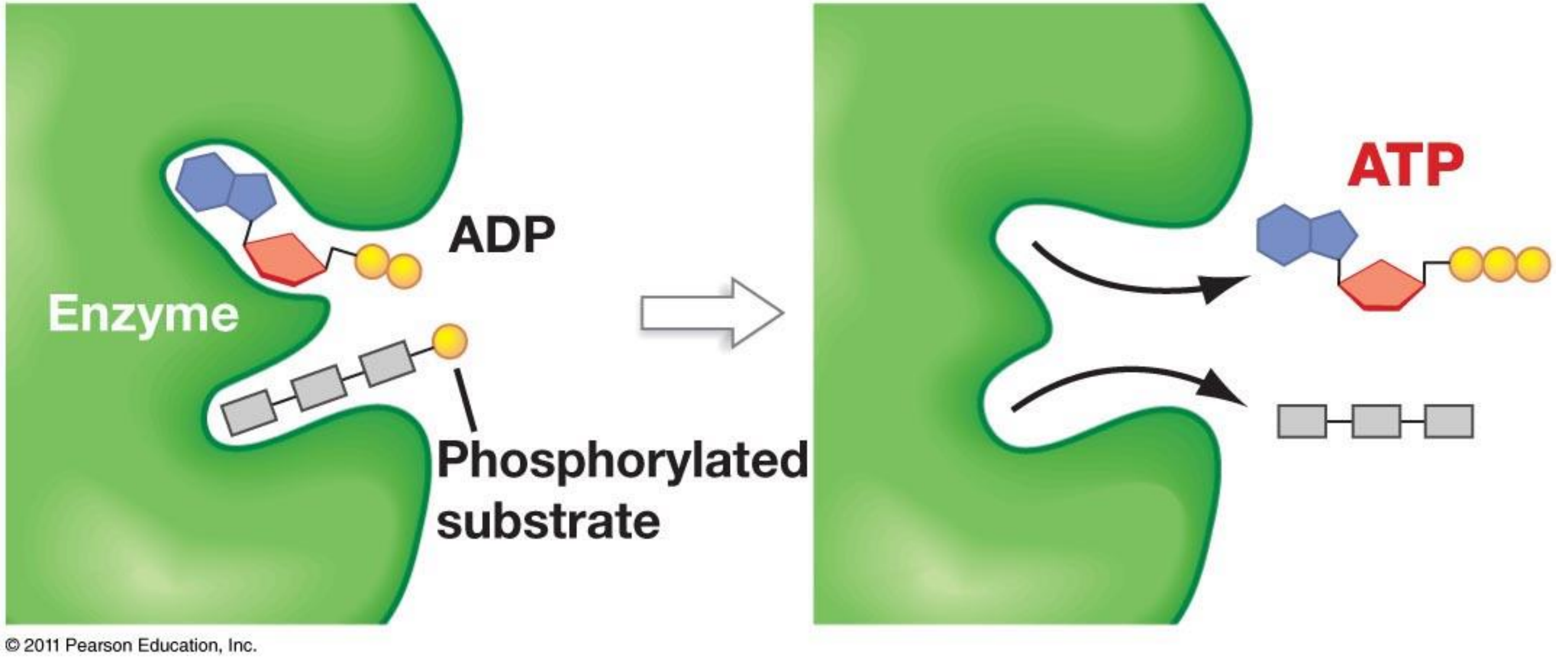


*The inorganic phosphate attaches to a protein. This process is known as **phosphorylation.***

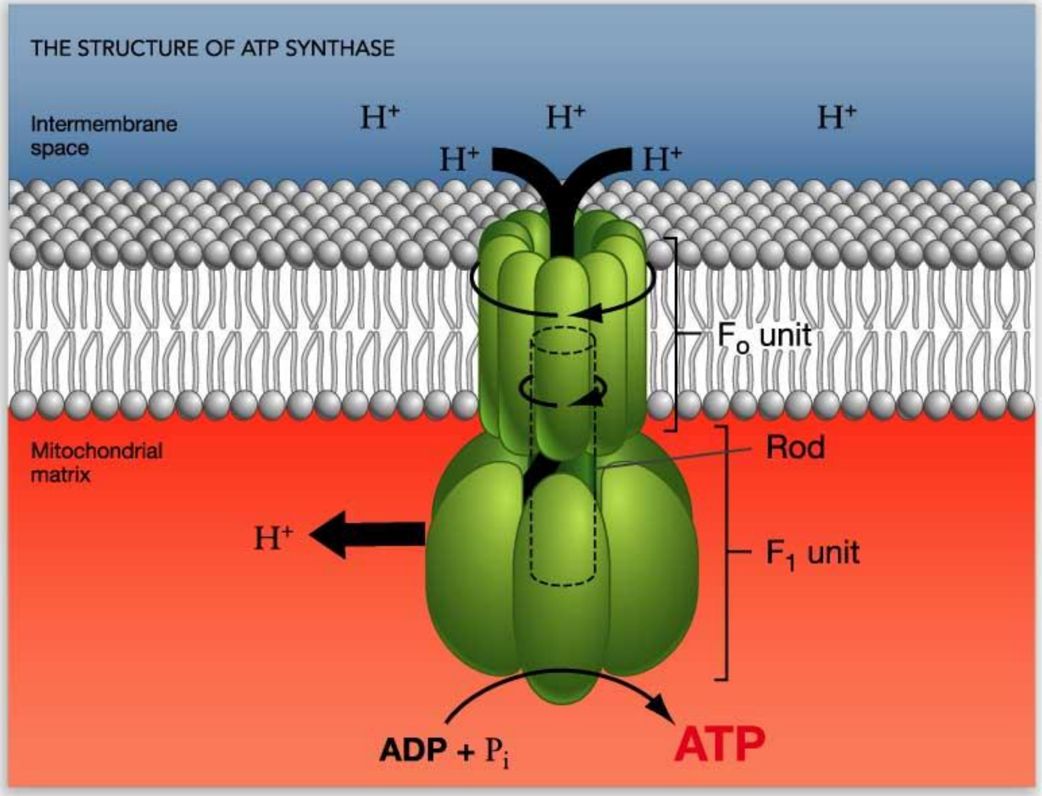
2) Substrate Level Phosphorylation

Substrate-level phosphorylation is the mechanism used to form ATP directly in an enzyme-catalyzed reactions.

The inorganic phosphate is removed from the protein and attached to ADP to make ATP.



3)Oxidative Phosphorylation



This process is used in cellular respiration within the mitochondria to create ATP. The voltage gated channel opens when there is a high concentration of H+ in the intermembrane space. H+ are pumped back in to create ATP.

Homework

Read pg. 114 – 118 of your textbook and complete pg. 118 # 1, 2, 4 & 6