

# Energy & Metabolism

## Chapter 6

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## Flow of Energy

**Energy:** capacity to do work

-**kinetic energy:** energy of motion

-**potential energy:** stored energy

Energy can take many forms:

mechanical

electric current

heat

light

## Flow of Energy

Most forms of energy can be converted to **heat energy**

Heat energy measured in **kilocalories**

**1 calorie** = amount of heat required to raise temp of water by 1°C

1 kilocalorie (kcal) = 1000 calories

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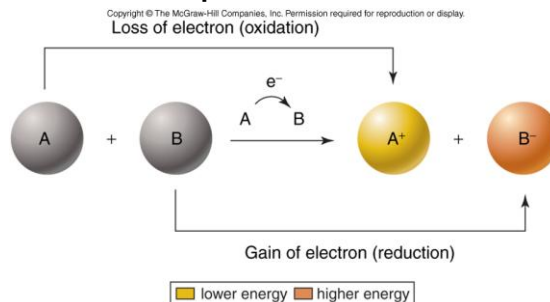
## Flow of Energy

Potential energy stored in **chemical bonds** can be transferred from one molecule to another by way of electrons

**oxidation**: loss of electrons

**reduction**: gain of electrons

**redox reactions** coupled to each other



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## Laws of Thermodynamics

**First Law of Thermodynamics** – energy cannot be created or destroyed  
-energy can only be converted from one form to another

e.g.

sunlight energy  $\longrightarrow$  chemical energy  
photosynthesis

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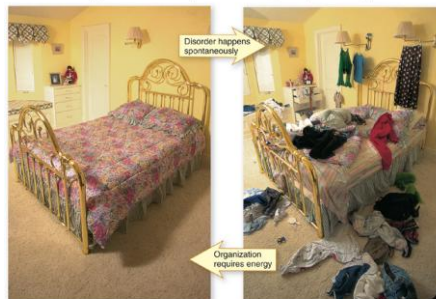
## Laws of Thermodynamics

**Second Law of Thermodynamics:**  
disorder more likely than order

**entropy:** disorder in universe

2<sup>nd</sup> Law of Thermodynamics

entropy always increasing



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## Laws of Thermodynamics

**Free energy:** energy available to do work  
-denoted by symbol **G** (Gibb's free energy)

**enthalpy:** energy contained in a molecule's  
chemical bonds

free energy = enthalpy – (entropy x temp)

$$G = H - TS$$

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## Laws of Thermodynamics

free energy = enthalpy – (entropy x temp)

$$G = H - TS$$

- Chemical reactions can create changes in free energy:

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

- When products contain more free energy than reactants  $\rightarrow \Delta G$  positive
- When reactants contain more free energy than products  $\rightarrow \Delta G$  negative

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# Laws of Thermodynamics

Chemical reactions can be described by transfer of energy that occurs:

**endergonic reaction:** reaction requiring an input of energy

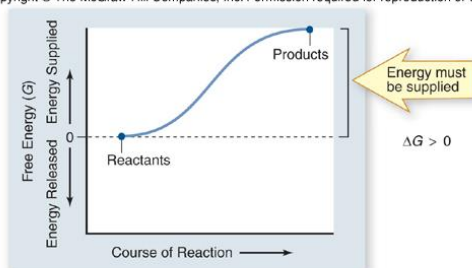
$\Delta G$  positive

**exergonic reaction:** reaction that releases free energy

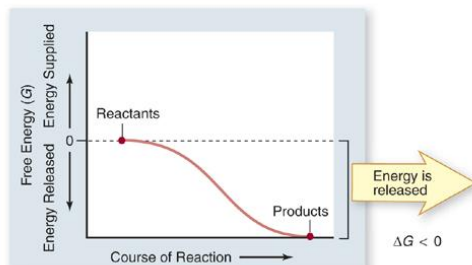
$\Delta G$  negative

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a.



b.

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# Laws of Thermodynamics

Most reactions require some energy to get started

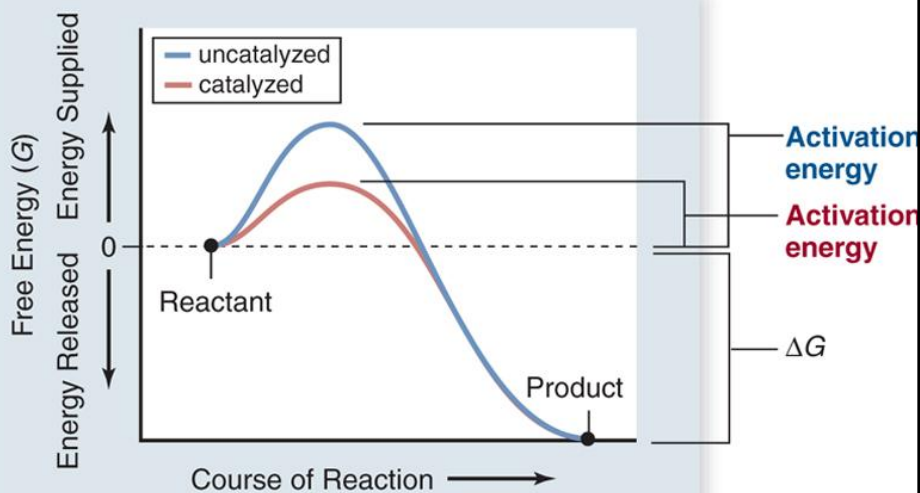
**activation energy**: extra energy needed to get a reaction started

- destabilizes existing chemical bonds
- required even for exergonic reactions

**catalysts**: substances that lower activation energy of a reaction

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# Energy Currency of Cells

**ATP = adenosine triphosphate**

-energy “currency” of cells

ATP structure:

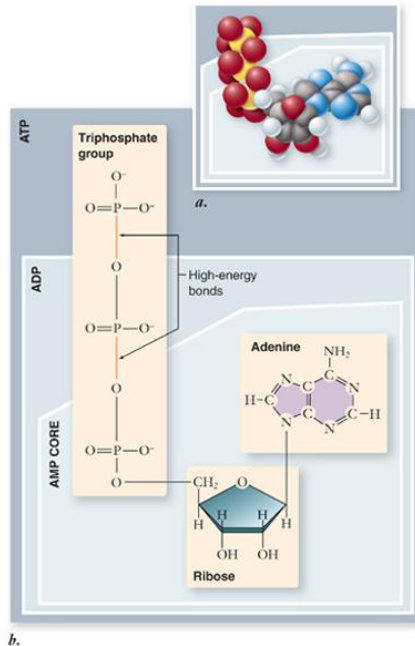
-ribose, a 5-carbon sugar

-adenine

-three phosphates

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## Energy Currency of Cells

ATP stores energy in bonds between phosphates

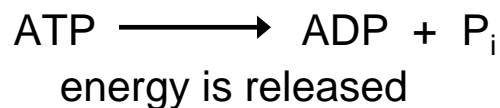
Phosphates highly negative, therefore:

- phosphates repel each other
- much energy required to keep phosphates bound to each other
- much energy released when bond between two phosphates broken

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## Energy Currency of Cells

When bond between phosphates is broken:



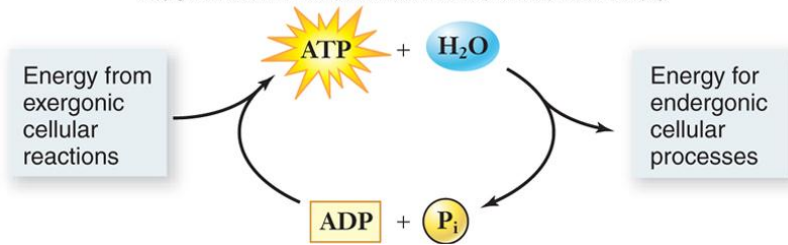
**ADP** = adenosine diphosphate

**P<sub>i</sub>** = inorganic phosphate

This reaction reversible

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## Energy Currency of Cells

Energy released when ATP broken down to ADP can be used to fuel endergonic reactions

Energy released from an exergonic reaction can be used to fuel ATP production from ADP + P<sub>i</sub>.

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# Enzymes

**Enzymes:** molecules that catalyze reactions in living cells

- most are proteins
- lower activation energy required for a reaction
- are not changed or consumed by the reaction

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# Enzymes

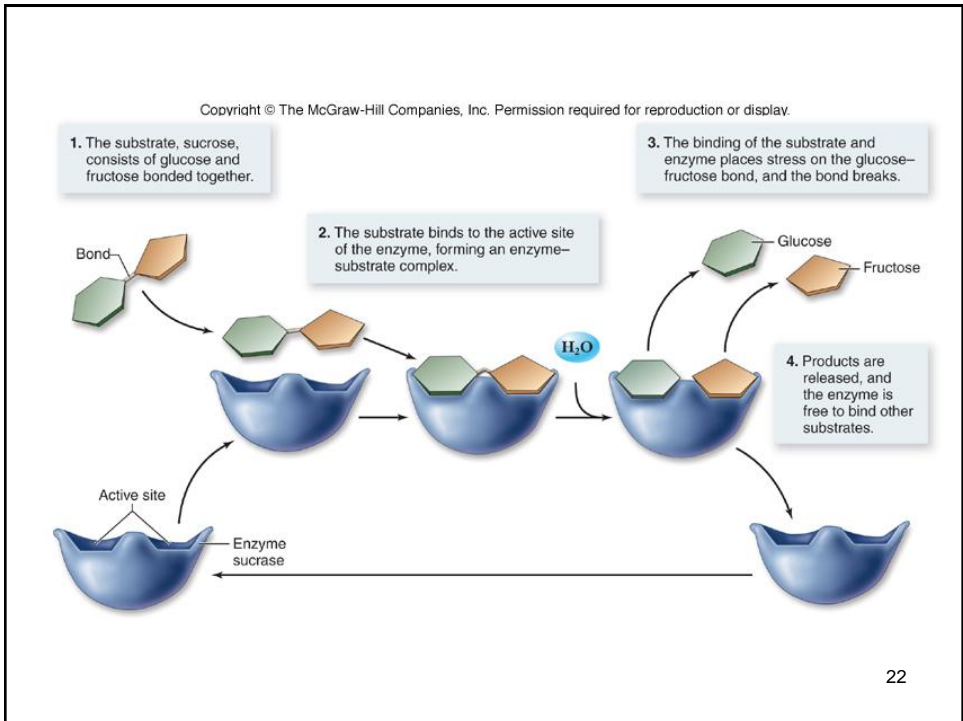
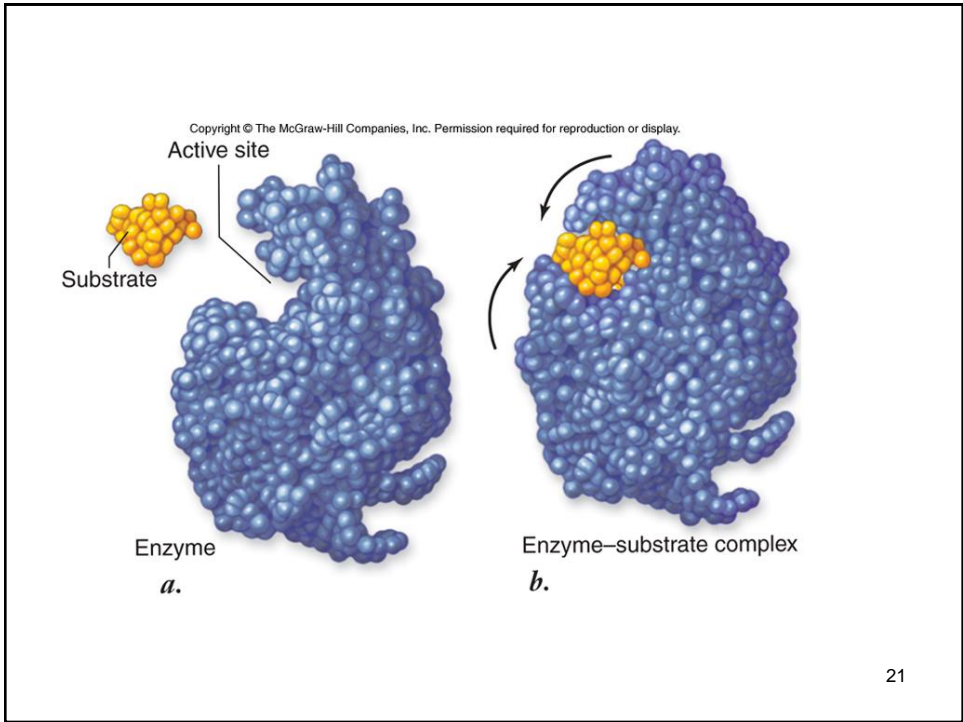
Enzymes interact with substrates

**substrate:** molecule that will undergo a reaction

**active site:** region of enzyme that binds to substrate

Binding of an enzyme to a substrate causes enzyme to change shape, producing a better induced fit between molecules

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# Enzymes

Multienzyme complexes offer certain advantages:

1. Product of one reaction can be directly delivered to next enzyme
2. Possibility of unwanted side reactions is eliminated
3. All of reactions can be controlled as a unit

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# Enzymes

Not all enzymes are proteins

Certain reactions involving RNA molecules are catalyzed by RNA itself

**ribozymes**: RNA with enzymatic abilities

e.g.: ribosome is ribozyme

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# Enzymes

Enzyme function affected by its environment

Factors that can change an enzyme's 3-dimensional shape can change its function

-e.g. pH, temperature, regulatory molecules

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# Enzymes

Temperature

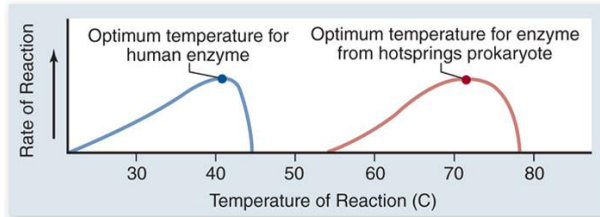
-enzyme activity may be increased with increasing temp, up to temp optimum

-temperatures too far above temp optimum can **denature** enzyme, destroying its function

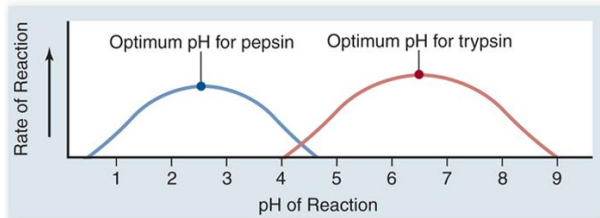
pH: most enzymes prefer pH from 6 to 8

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a.



b.

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## Enzymes

- Inhibitors** are molecules that bind to an enzyme to decrease enzyme activity
- competitive inhibitors** compete with substrate for binding to the same active site
  - noncompetitive inhibitors** bind to sites other than enzyme's active site

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# Enzymes

**Allosteric enzymes** exist in either an active or inactive state

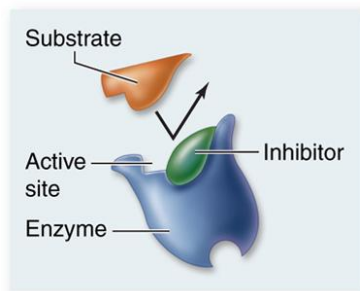
-possess an **allosteric site** where molecules other than substrate bind

-**allosteric inhibitors** bind to allosteric site to inactivate enzyme

**allosteric activators** bind to allosteric site to activate enzyme

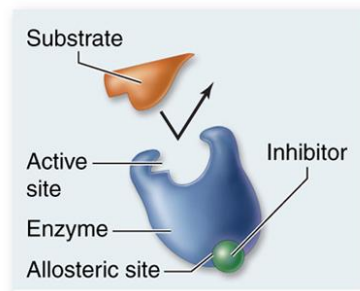
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Competitive inhibitor interferes with active site of enzyme so substrate cannot bind

*a.* Competitive inhibition



Allosteric inhibitor changes shape of enzyme so it cannot bind to substrate

*b.* Noncompetitive inhibition

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## Metabolism

**Metabolism:** all chemical reactions occurring in an organism

**Anabolism:** chemical reactions that expend energy to make new chemical bonds

**Catabolism:** chemical reactions that harvest energy when bonds are broken

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## Metabolism

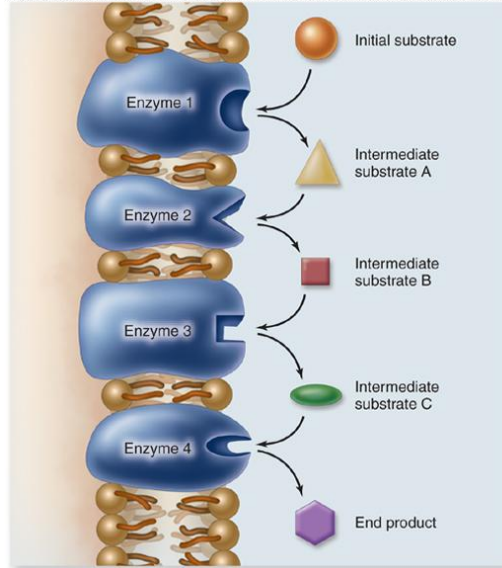
Some enzymes require additional molecules for proper enzymatic activity

Molecules could be:

-**cofactors:** usually metal ions, found in active site participating in catalysis

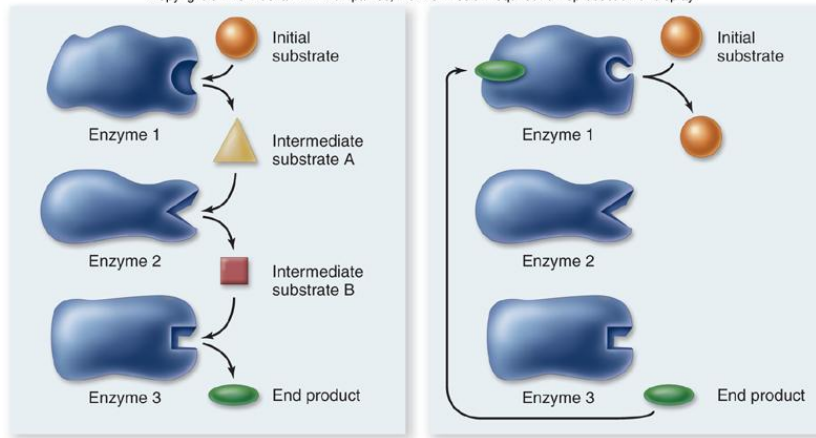
-**coenzymes:** nonprotein organic molecules, often used as electron donor/acceptor in redox reactions

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## Metabolism

**Biochemical pathways:** series of reactions in which product of one reaction becomes substrate for next reaction 33



## Metabolism

Biochemical pathways: often regulated by **feedback inhibition** in which end product of pathway is allosteric inhibitor of earlier enzyme in pathway