BIOL 230: Cell & Molecular Biology

Fall 2019 17-205 W, Sept. 25

http://accounts.smccd.edu/staplesn/biol230/

1. Pre-Lab writeups due each Mon. (for both M&W!!) at the start of lab. (*briefly*, **What**? **Why**? **How**? for each expt.). Question & **Hypothesis**?!
2. **LAB this week: nPAGE and Respiration/Fermentation!**
3. ***Research Topic paragraph!! ☺ ***Due Wed., Oct. 2 with a Professional, Primary Reference!!***
   - ***What is your topic? Why does it interest you?***
   - ***How does it directly apply to BIOL 230?***
4. **Midterm #1 will be returned next week!! M/C Answer key will be under "Additional Materials."**
5. **Native PAGE data** posted under **"Add'l Materials."**
6. **Extra Credit: STEM SPEAKER SERIES, Weds. @ 5pm-6pm, Sept. 11-Nov. 6. (NOT Oct. 9) in 6-102. *Write 1 page summary by the following week, and upload to CANVAS.***
7. **Lab NEXT week: PHOTOSYNTHESIS!!! ☺**

REVIEW

1. Describe & diagram the **3 different cell connections** found in animal cells. What is the function of each, and in what tissues?
2. Diagram and explain the factors determining the **direction of movement of a solute** across a membrane. Discuss why sometimes a protein is needed or not, and why sometimes ATP is needed or not.
3. State the term use to describe the **diffusion of water** across a membrane. Predict the direction of movement of water for a cell placed into solutions of various different solute concentrations (***molarity*** or ***osmolality***).

TODAY's Objectives: Students should be able to....

1. Define **energetic coupling** and provide an example. What types of molecules can couple chemical reactions?
2. Explain how the **change in free energy** affects the equilibrium of a reaction.
3. Diagram and describe **three ways that an enzyme can speed up a chemical reaction**. How does the enzyme affect the energy and equilibrium of a catalyzed reaction?
4. List and describe the effects of 5 factors that can **regulate** enzyme activity.
5. Diagram and describe the **forms in which energy** may be transferred between molecules and reactions in cells.

- ***Objectives and Study Guide Questions are your HOMEWORK between classes!!! DUE NEXT WED. at the end of Lecture!!***

CHAPTER 8
Energy, Enzymes, & Metabolism

8 Opener 1

1. Energy and Energy Conversions
2. ATP: Transferring Energy in Cells
3. Enzymes: Biological Catalysts
4. Molecular Structure Determines Enzyme Function
5. Metabolism and the Regulation of Enzymes

8.1) Energy and Energy Conversions

1. ***Energy = capacity to do work.***

2. **Potential energy** = energy of state or position
   - includes ***energy stored*** in chemical bonds.
   - *Potential energy can be converted to kinetic energy, which does work.*

3. **Kinetic energy** is the energy of motion.
   - *** The KINETIC ENERGY which drives life processes is stored as POTENTIAL energy of the chemical bonds in food substances, sugars and fat stores.

8.1

A. Laws of Thermodynamics

1. **FIRST**: energy cannot be created or destroyed.
   - But it can be transformed!

2. **SECOND**: in a closed system, the
   - quantity of energy available to do work ***decreases*** and
   - unusable energy ***increases***. ("wasted")

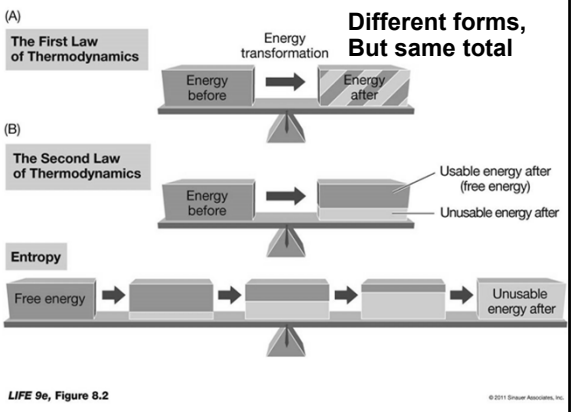
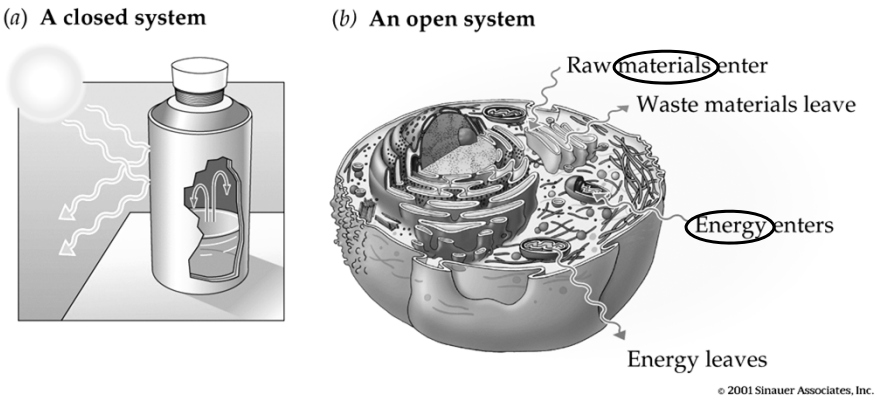


Figure 8.2

- *Living things obey the laws of **thermodynamics**.*
- Organisms are ***open systems*** that are part of a larger ***'closed system'*** (Earth's solar system).
- **Metabolism** = total chemical activity in a living system ***(1000s of rxns/sec/cell!!)***.



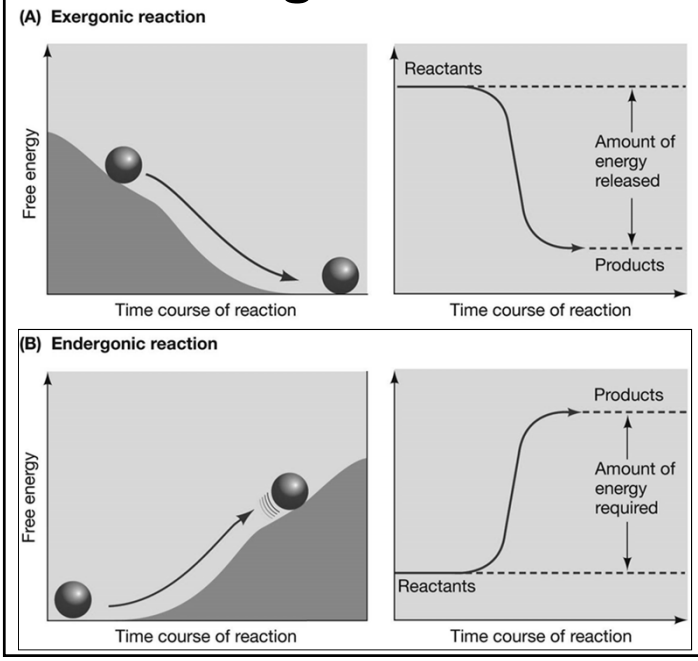
B. 2nd Law: Not all energy can be used; disorder tends to increase

- Changes in ***free energy*** (**G, usable energy**!), total energy (**H, enthalpy**), **temperature (T)**, and entropy (**S**, disorder) are related by the equation

$$\Delta G = \Delta H - T\Delta S$$
$$= G_{products} - G_{reactants}$$

1. ***Spontaneous, exergonic*** reactions release free energy and have a negative ΔG.
2. ***Non-spontaneous, endergonic*** reactions take up free energy, have a positive ΔG, and proceed only if free energy is provided.

Changes in Free Energy:



(lower E products)
= more stable
- ΔG

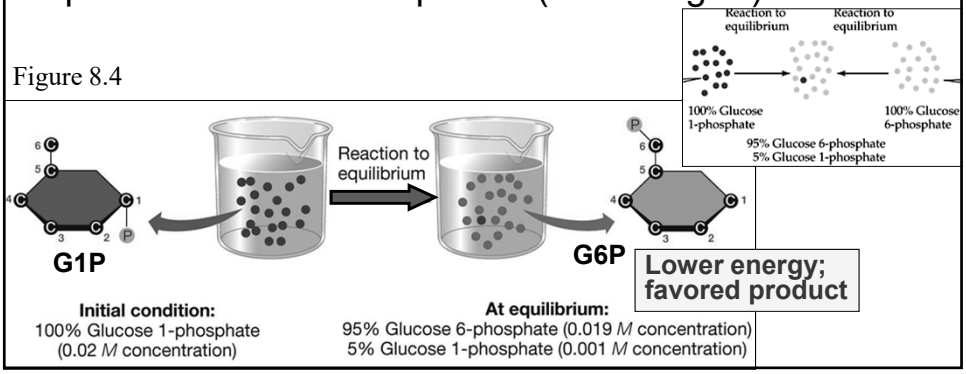
= less stable
+ ΔG
(higher E products)

Figure 8.3

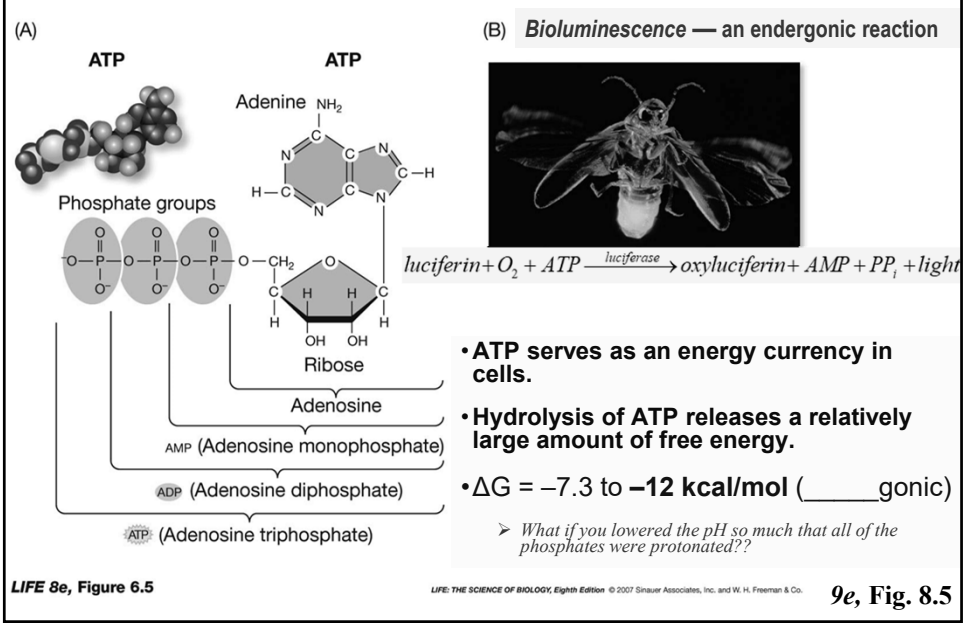
C. Concentration at Equilibrium

- ***The ΔG of a reaction determines its point of chemical equilibrium***
- ***Chemical equilibrium*** = forward and reverse reactions proceed at the same rate.
- For spontaneous/exergonic reactions, the equilibrium point lies toward completion (to the "right").

Figure 8.4



8.2) ATP: Transferring Energy in Cells

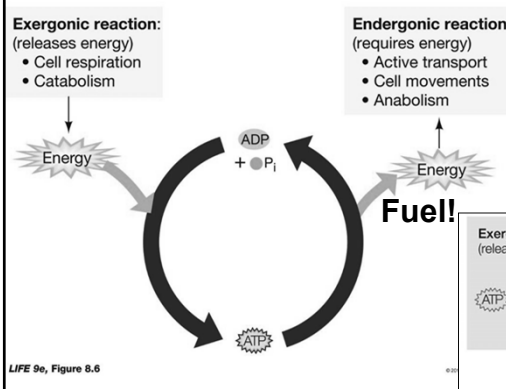


- **ATP serves as an energy currency in cells.**
- **Hydrolysis of ATP releases a relatively large amount of free energy.**
- ΔG = –7.3 to **–12 kcal/mol** (_____gonic)
  - *What if you lowered the pH so much that all of the phosphates were protonated??*

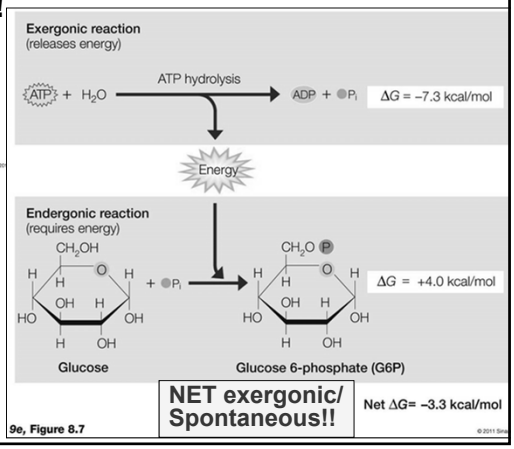
LIFE 8e, Figure 6.5

9e, Fig. 8.5

ATP: ***Energetic Coupling***



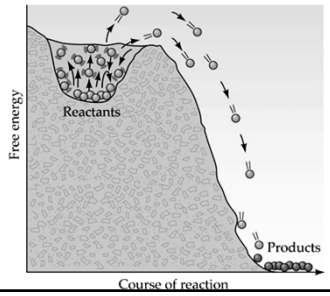
- The ATP cycle ***couples*** exergonic & endergonic reactions.

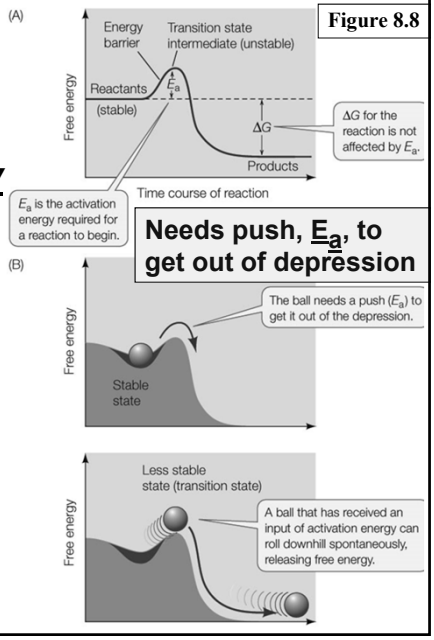


- ATP transfers free energy from the exergonic to the endergonic reaction

8.3) Enzymes: Biological Catalysts

- The ***rate*** of a chemical reaction is independent of ΔG
- Rate is determined by the size of the ***Activation Energy*** barrier.
- *Catalysts speed reactions by lowering the barrier.*

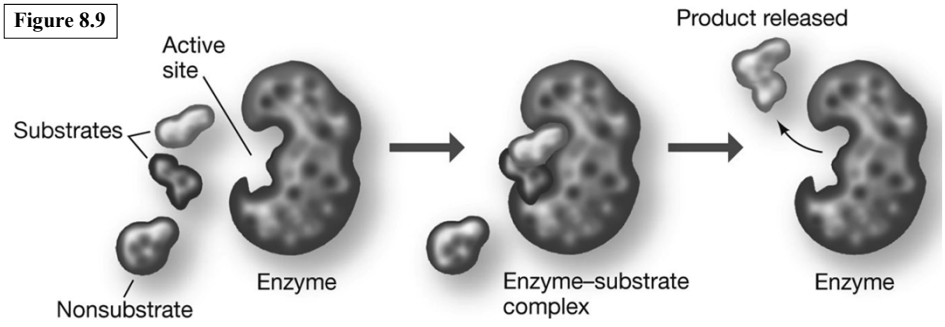




A. Enzymes: Substrate Binding

- Enzymes are biological catalysts, & are highly specific for their substrates.
- ***Substrates*** bind to the ***active site***,
  a) where catalysis takes place
  b) form enzyme–substrate complex

Figure 8.9



B. Enzymes: Mechanisms of Catalysis

1. At the active site, a substrate can be:
   a) oriented correctly,
   b) strained, or
   c) chemically modified.
   - Temporary charges.
2. Result: substrate readily forms its ***transition state***, and the reaction proceeds.

Figure 8.11

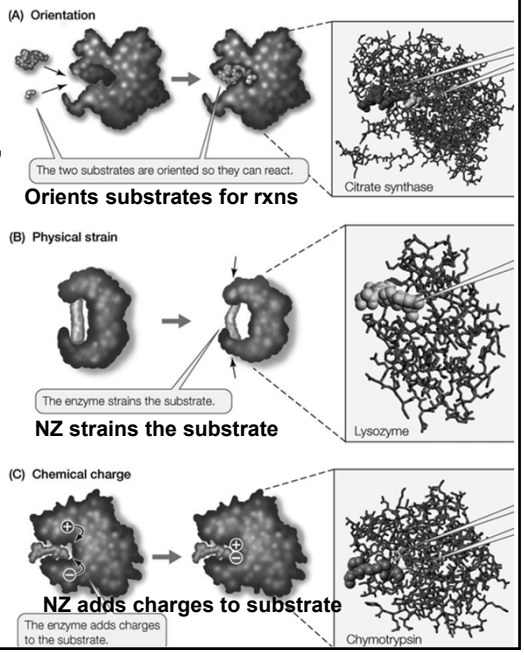
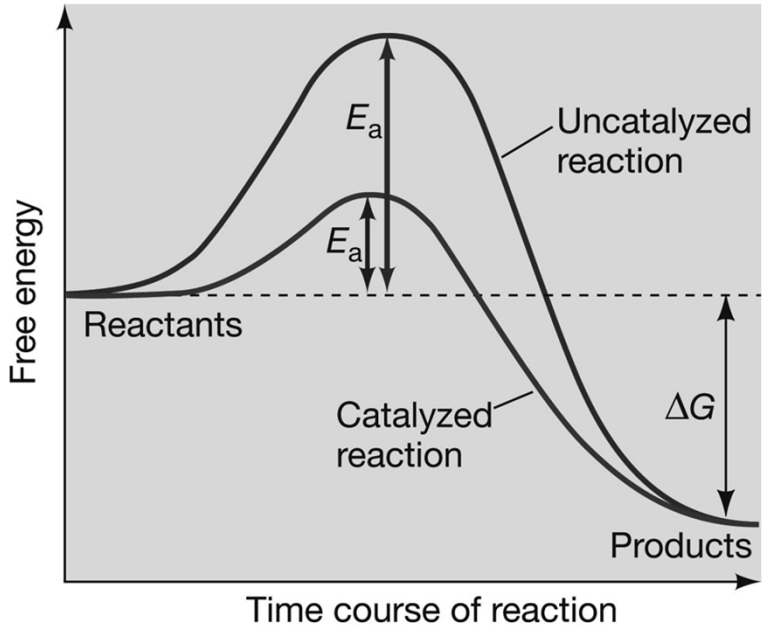


Fig 8.10 Enzymes Lower the Energy Barrier



9e, Figure 8.10

C. Molecular Structure Determines Enzyme Function *(Imagine that!! ☺)*

- The ***active site*** where substrate binds
  - determines the **specificity** of an enzyme.
  - Upon binding, some enzymes **change shape**, facilitating catalysis.

Lock & Key

vs.

Induced Fit:

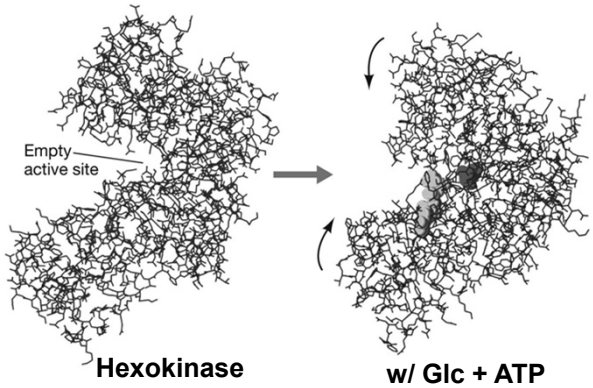
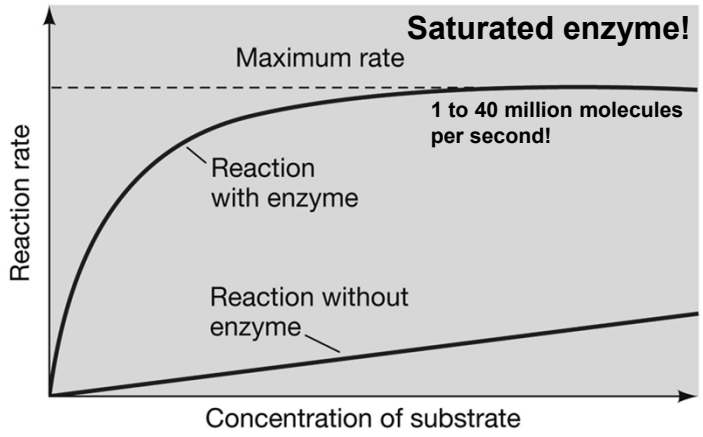


Fig. 6.12

LIFE 9e, Figure 8.12

8.3) Enzymes Regulation: A. Environmental Factors

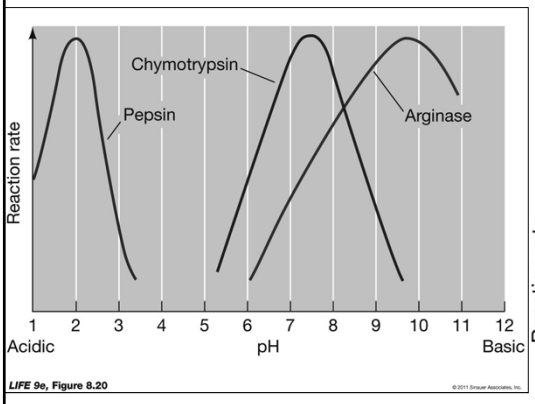
1. **Substrate concentration** affects the rate of an enzyme-catalyzed reaction.



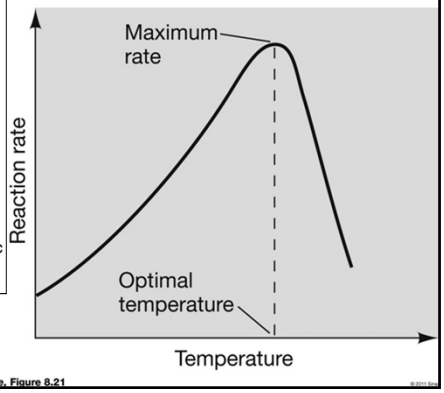
LIFE 9e, Figure 8.13

Metabolism and the Regulation of Enzymes

- Enzymes are sensitive to their environment.
  - Both (2.) **pH** and
  - (3.) **temperature** affect enzyme activity.



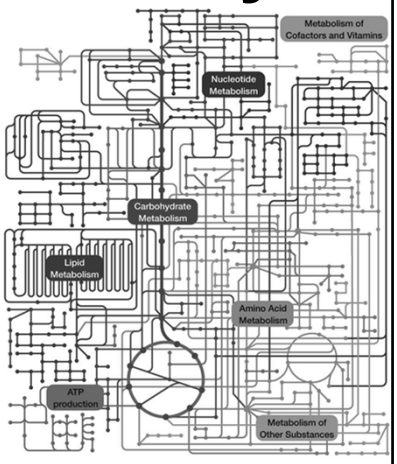
LIFE 9e, Figure 8.20



LIFE 9e, Figure 8.21

B. Metabolic Pathways

- Metabolism is organized into <u>pathways</u>:
  - the product of one reaction is a reactant for the next.
  - *Each reaction is catalyzed by a separate and specific enzyme.*



A → B → C → <u>D</u> → E → F
↘ G → H → I

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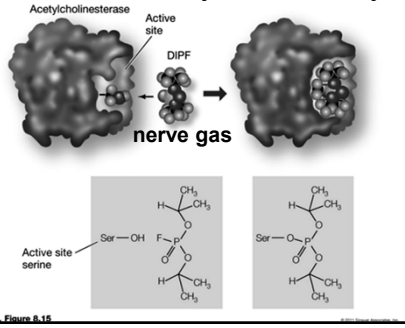
C. Enzyme Inhibitors: Chemical Regulators

- **<u>Irreversible Inhibitors</u>:** permanently reduce their catalytic activity. Covalent binding.
- **<u>Reversible Inhibitors</u>:** inhibit enzyme action temporarily. (***Competitive*** or ***Noncompetitive***)
  - A compound structurally similar to an enzyme's normal substrate may inhibit enzyme action.

Figure 8.15



Reversible Inhibitors

1. Competitive:

http://highered.mheducation.com/olcweb/cgi/pluginpop.cgi?it=swf::535::535::/sites/dl/free/0072437316/120070/bio10.swf

2. Non-Competitive:

- ***Allosteric*** = "different" + "shape"

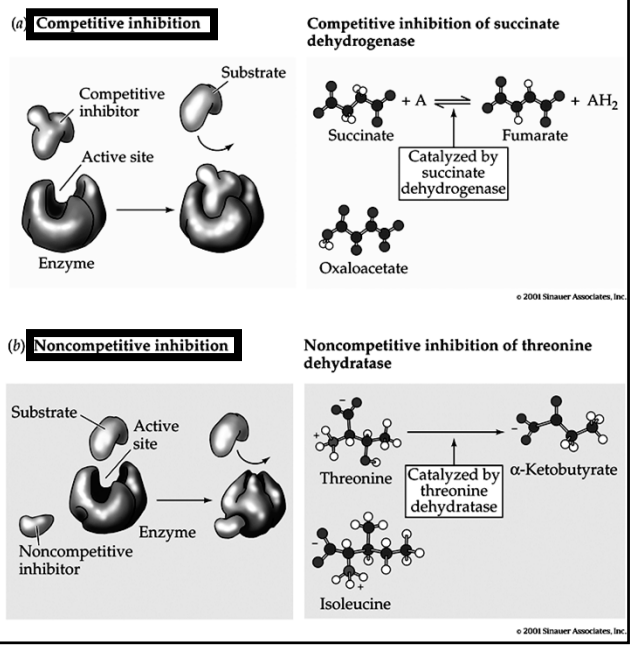


Figure *8e:* 6.17, *9e:* 8.16

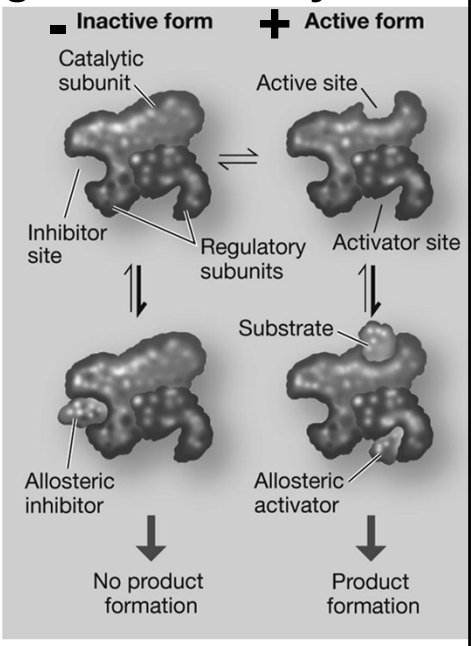
Allosteric enzymes

1. ***Allosteric*** inhibitors bind to a site different from the active site (***Noncompetitive***)
   - *stabilize the inactive form of the enzyme.*
   - Most allosteric enzymes have quaternary structure.

2. The multiple catalytic subunits of many allosteric enzymes interact ***cooperatively***.
   - *Binding to one subunit facilitates binding to others*

Fig 8.17 Allosteric Regulation of Enzymes

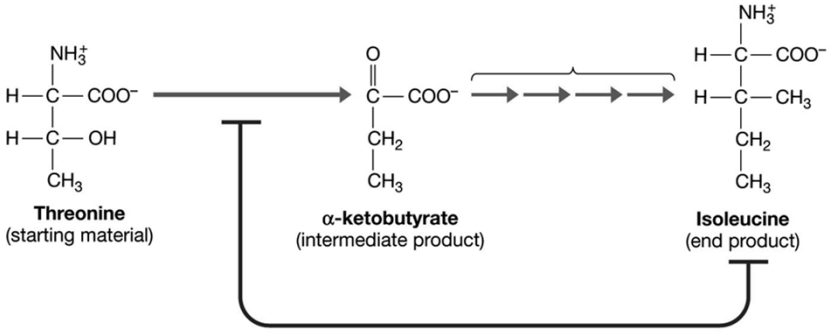
- **Binding at allosteric site <u>changes shape</u> of separate, active site!!**
  - **Conformational Change**
- **<u>Allosteric Regulation</u>: Activate or Inhibit**
- **Binding to one subunit facilitates binding to others**
  - **Activation site**
  - **<u>Cooperative Binding</u>**



8.17

G. Allosteric regulation of metabolism

- The ***end product*** of a metabolic pathway may inhibit the allosteric enzyme that catalyzes the ***commitment step (branch-point)*** of the pathway.



<u>Feedback Inhibition:</u> **accumulation of an end product signals to end its own synthesis. <u>Usually</u> ALLOSTERIC inhibition.**

***LIFE 9e*, Figure 8.19** http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::535::535::/sites/dl/free/0072437316/120070/bio10.swf

H. Some Enzymes Require Non-protein "accessories" to work

Some enzymes require "partners":

- **Cofactors:** inorganic ions (metals).
- **Coenzymes:** not bound permanently to enzymes.
- **Prosthetic groups:** non-amino acid groups bound to enzymes.

TABLE 8.1

Some Examples of Nonprotein "Partners" of Enzymes

TYPE OF MOLECULE	ROLE IN CATALYZED REACTIONS
COFACTORS	
Iron (Fe^{2+} or Fe^{3+})	Oxidation/reduction
Copper (Cu^{+} or Cu^{2+})	Oxidation/reduction
Zinc (Zn^{2+})	Helps bind NAD
COENZYMES	
Biotin	Carries $-COO^{-}$
Coenzyme A	Carries $-CO-CH_3$
NAD	Carries electrons
FAD	Carries electrons
ATP	Provides/extracts energy
PROSTHETIC GROUPS	
Heme	Binds ions, O_2, and electrons; contains iron cofactor
Flavin	Binds electrons
Retinal	Converts light energy

Part I – Major Themes So Far!!

1. **Electronegativity, charge** and **polarity** govern the major chemical and functional properties of water and biomolecules.
2. Molecular shape/**structure** → Molec./Biol. **Function**
   - Lipids, Polysacch., Proteins! (strx. Levels)…., RNA, DNA
3. Biological reactions in eukaryotes are **compartmentalized**.
   - Mitoch., chloroplasts, nucleus, nucleolus, lysosome, RER, SER, vacuole, Golgi…….
4. Membranes are more than just barriers:
   a) Dynamic – cycling contents!
   b) regulate transport – passive, active (1°, 2°) and bulk (endocyt., exocyt.)
   c) transduce signals and energy; enzyme alignment
5. Biochemical energy can be harvested to do cellular work. *COUPLING*!!
   - Endergonic reactions can be powered by exergonic reactions by energetic coupling
     - ***Uses ATP and enzymes/cofactors to transfer the energy between reactions***
6. **Enzyme Regulation:** *Physical factors, Inhibition, Allostery, Cooperativity*

Chapter 9: Cellular Pathways That Harvest Chemical Energy

1. An Overview: Releasing Energy from Glucose
2. Glycolysis: From Glucose to Pyruvate
3. Pyruvate Oxidation
4. The Citric Acid Cycle: Obtaining Energy and Electrons from Glucose
5. The Respiratory Chain: Electrons, Proton Pumping, & ATP
6. Fermentation: ATP from Glucose, without O_2
7. Contrasting Energy Yields
8. Metabolic Pathways & Regulation

Cellular Pathways

- **Metabolic pathways:**
  1. occur in small steps,
  2. each catalyzed by a specific enzyme,
  3. often compartmentalized, and are
  4. highly regulated (allowed by #s 1-3).