Slide 1

Chapter 8

An Introduction to Metabolism

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Slide 2

- Metabolism in an organism is about energy and enzymes.
- It is the sum of all of the chemical reactions performed by the cells of the organism.

Slide 3

1. **Free Energy**
2. **Kinetic energy**
3. **Heat (thermal energy)**
4. **Potential energy**
5. **Chemical energy**

Energy cannot be converted from one form to another.
True or False?

a) E that matter possesses because of its location or structure
b) Kinetic E associated with random movement of atoms or molecules
c) Potential E available for release in a chemical reaction
d) E associated with motion
e) The capacity to cause change (can be used to do work)

Slide 4

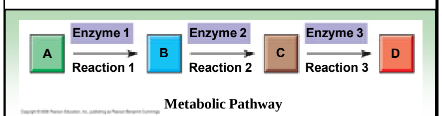
Metabolism

- Thermodynamics says that the flow of chemical energy into an organism is equal to the energy used as work, the energy lost as heat and the chemical potential energy stored by the organism.
  - true for organisms
  - true for the tissues in an organism
  - true for the individual cells in a tissue

Slide 5

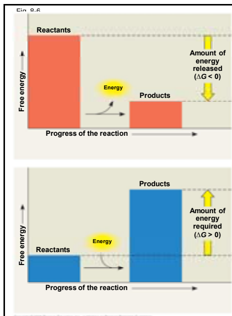
Fig. 8-UN1

Enzymes make it ALL happen!



Starting molecules	Products
proteins	work energy
carbohydrates	heat energy
lipids	chemical energy
polymers v. monomers	storage = potential

Slide 6



- An **exergonic reaction** proceeds with a net release of energy
- An **endergonic reaction** absorbs energy from its surroundings

Slide 7

Metabolic pathways

- **Catabolic pathways** release energy (exergonic) by breaking down complex molecules into simpler compounds
  - Examples?
- **Anabolic pathways** consume energy (endergonic) to build complex molecules from simpler ones
  - Examples?
- **Work pathways** couple the energy derived from exergonic reactions to perform an endergonic activity – together the whole is always exergonic
  - Do we harness all of the exergonic energy?

Slide 8

Fill in the Chart

	Reaction 1: $ATP + H_2O \rightarrow ADP + P_i$	Reaction 2: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
Exergonic/Endergonic		
Anabolic/Catabolic		
Energy Requirements		

Slide 9

Fill in the Chart

	Reaction 1: $ATP + H_2O \rightarrow ADP + P_i$	Reaction 2: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
Exergonic/Endergonic	Exergonic	Endergonic
Anabolic/Catabolic	Catabolic – break down	Anabolic – synthesis reaction
Energy Requirements	E is released	requires the input of E

Slide 10

ATP powers cellular work

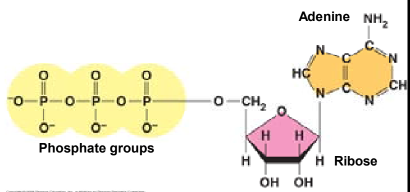
- A cell does three main kinds of work:
  - Chemical:
  - Transport:
  - Mechanical:
- To do work, cells manage energy resources by **energy coupling**, the use of an exergonic process to drive an endergonic one
- Most energy coupling in cells is mediated by ATP

Slide 11

Fig. 8-8

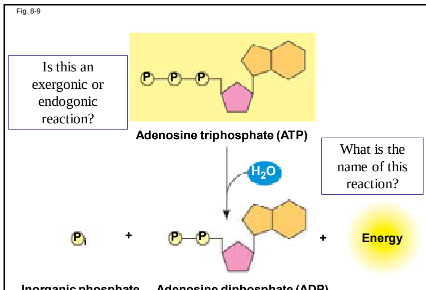
ATP is composed of ribose (a sugar), adenine (a nitrogenous base), and three phosphate groups

What are the two cellular roles of ATP?

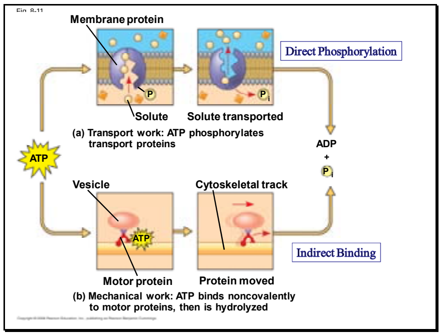


Slide 12

Fig. 8-9



Slide 13

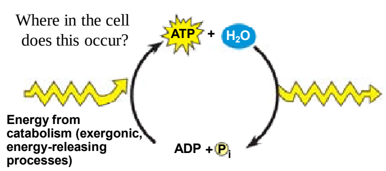


Slide 14

Fig. 8-12

ATP is a renewable resource that is regenerated by addition of a phosphate group to adenosine diphosphate (ADP)

The energy to phosphorylate ADP comes from catabolic reactions in the cell

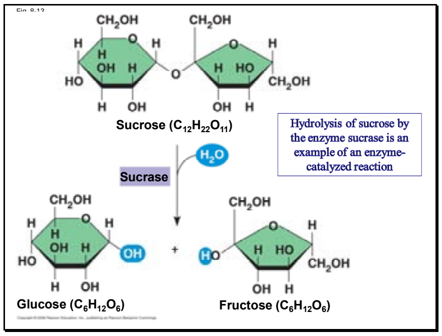


Slide 15

Concept 8.4: Enzymes speed up metabolic reactions by lowering energy barriers

- A **catalyst** is a chemical agent that speeds up a reaction without being consumed by the reaction
- An **enzyme** is a catalytic protein

Slide 16



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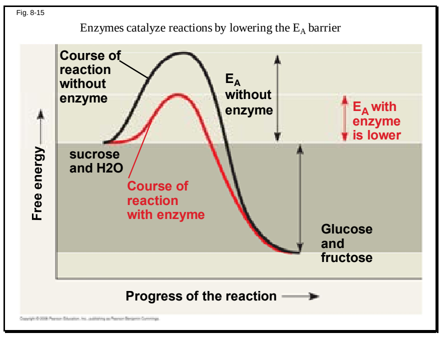


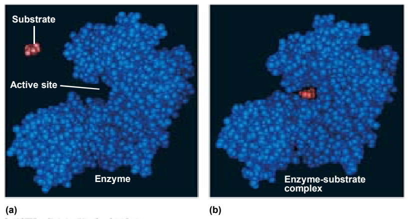
Slide 18

Substrate Specificity of Enzymes

- The reactant that an enzyme acts on is called the enzyme's ___________.
- The ________is the region on the enzyme where it binds
- This binding is extremely specific (sucrase – recognizes sucrose, not maltose). Why?

Slide 19

Fig. 8-16



Hexokinase - first enzyme in the breakdown of glucose (glycolysis)

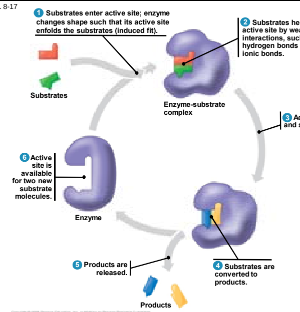
Slide 20

Catalysis in the Enzyme's Active Site

- In an enzymatic reaction, the substrate binds to the active site of the enzyme
- The active site can lower an E_A barrier by:
  - Orienting substrates correctly
  - Straining substrate bonds
  - Providing a favorable microenvironment
  - Covalently bonding to the substrate

Slide 21

Fig. 8-17



Induced fit of a substrate brings chemical groups of the active site into positions that enhance their ability to catalyze the reaction

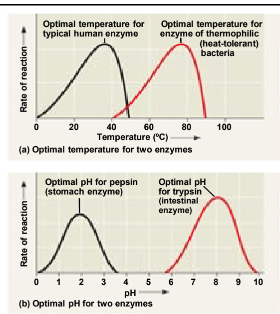
Slide 22

Effects of Local Conditions on Enzyme Activity

- An enzyme's activity can be affected by
  - General environmental factors, such as temperature and pH
  - Chemicals that specifically influence the enzyme

Slide 23

Fig. 8-18



Slide 24

Cofactors

- **Cofactors** are nonprotein enzyme helpers
- Cofactors may be inorganic (such as a metal in ionic form) or organic
- An organic cofactor is called a **coenzyme**
- Coenzymes include vitamins

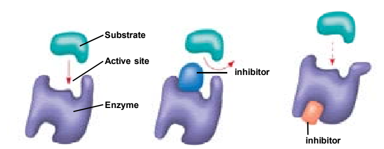
Slide 25

Enzyme Inhibitors

- **Competitive inhibitors** bind to the active site of an enzyme, competing with the substrate
- **Noncompetitive inhibitors** bind to another part of an enzyme, causing the enzyme to change shape and making the active site less effective
- Examples of inhibitors include toxins, poisons, pesticides, and antibiotics

Slide 26

Fig. 8-19



(a) Normal binding (b) __________ inhibition (c) __________ inhibition

Slide 27

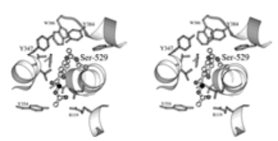
CONNECTION

- Many poisons, pesticides, and drugs are enzyme inhibitors

Cyanide - binds competitively and irreversibly to *cytochrome oxidase*, an enzyme involved in ATP production during cellular respiration

Penicillin - binds competitively and irreversibly to *transpeptidase*, an enzyme needed for the growth of bacterial cell walls - humans lack this enzyme

Ibuprofen and aspirin - bind competitively to *cyclooxygenases*, the enzymes that make prostaglandins, chemicals that promote inflammation (and can lead to pain and fever)



Slide 28

Concept 8.5: Regulation of enzyme activity helps control metabolism

- Metabolic pathways must be tightly regulated
- A cell does this by switching on or off the genes that encode specific enzymes or by regulating the activity of enzymes (once they are made)

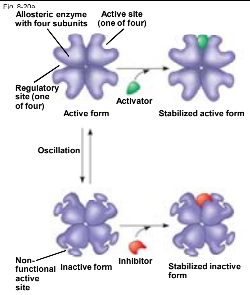
Slide 29

Allosteric Regulation of Enzymes

- **Allosteric regulation** occurs when a regulatory molecule binds to a protein at one site and affects the protein's function at another site
- Allosteric regulation may either inhibit or stimulate an enzyme's activity

Slide 30

Fig. 8-20a



(a) Allosteric activators and inhibitors

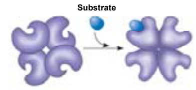
Allosterically regulated enzymes:

- Usually polypeptide subunits
- have active and inactive forms
- binding of either activators or inhibitors stabilize the enzyme

Slide 31

Fig. 8-20b

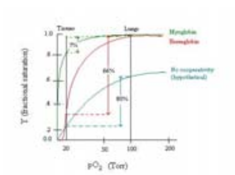
- **Cooperativity** is a form of allosteric regulation that can amplify enzyme activity
- In cooperativity, binding by a substrate to one active site stabilizes favorable conformational changes at all other subunits

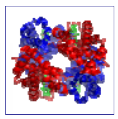


(b) Cooperativity: another type of allosteric activation

Slide 32

Cooperativity and Hemoglobin





When one oxygen binds a heme, the rest bind more easily. When the first oxygen is released, it stimulates the release of the others. This is due to conformational changes in the hemoglobin subunits.

http://en.wikibooks.org/wiki/Structural_Biochemistry/Protein_function/Heme_group/Hemoglobin

Slide 33

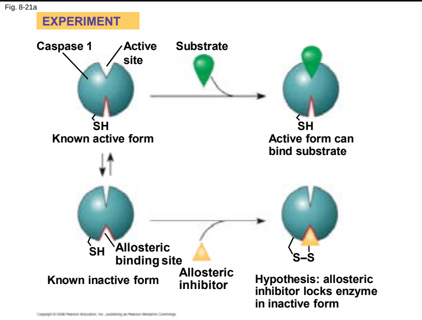
Identification of Allosteric Regulators

- Allosteric regulators are attractive drug candidates for enzyme regulation
- Inhibition of proteolytic enzymes called caspases may help management of inappropriate inflammatory responses

Animation: http://bcs.whfreeman.com/thelifewire/content/chp06/0602002.html

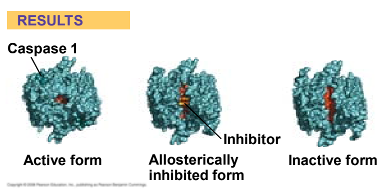
Slide 34

Fig. 8-21a



Slide 35

Fig. 8-21b



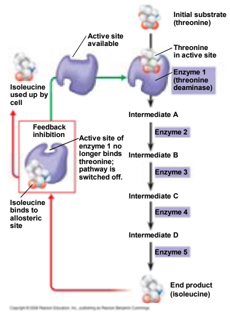
Slide 36

Feedback Inhibition

- In **feedback inhibition**, the end product of a metabolic pathway shuts down the pathway
- Feedback inhibition prevents a cell from wasting chemical resources by synthesizing more product than is needed

Slide 37

Fig. 8-22



Slide 38

Specific Localization of Enzymes Within the Cell

- Cellular structures help bring order to metabolic pathways
- Some enzymes act as structural components of membranes
- In eukaryotic cells, some enzymes reside in specific organelles; for example, enzymes for cellular respiration are located in mitochondria