Chapter 6: Ground Rules of Metabolism

What Is Energy?

- Capacity to do work

- Forms of energy
  - Potential energy
  - Kinetic energy
  - Chemical energy

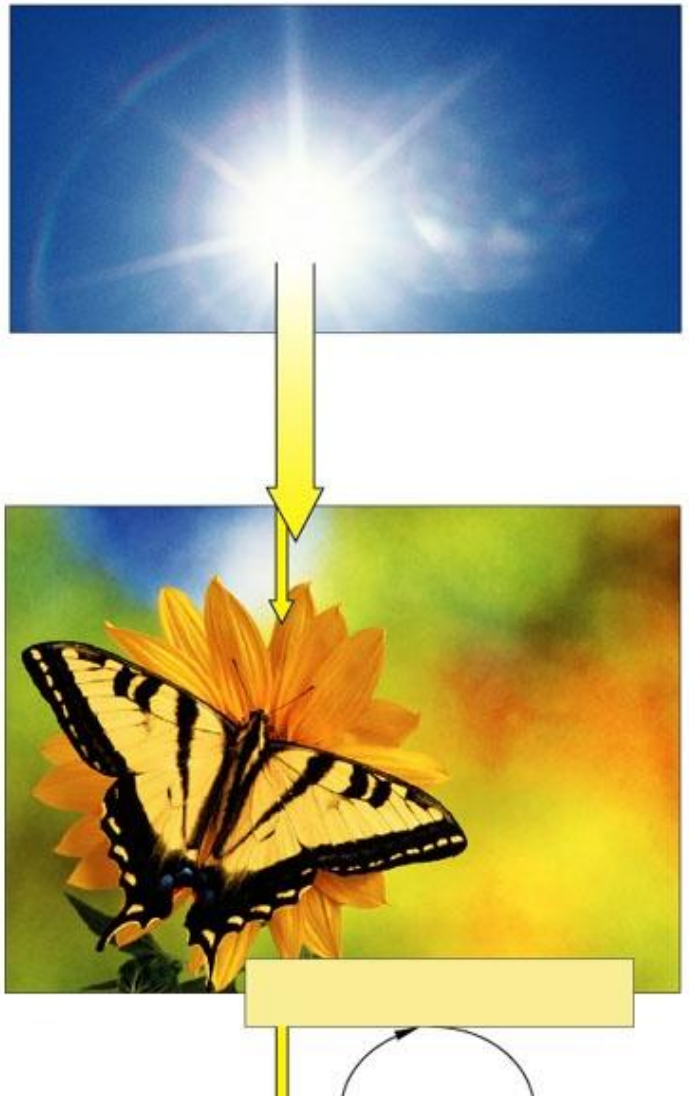
First Law of Thermodynamics

- Energy can undergo conversions from one form to another, but it cannot be created or destroyed

- Total amount of energy in the universe stays constant.

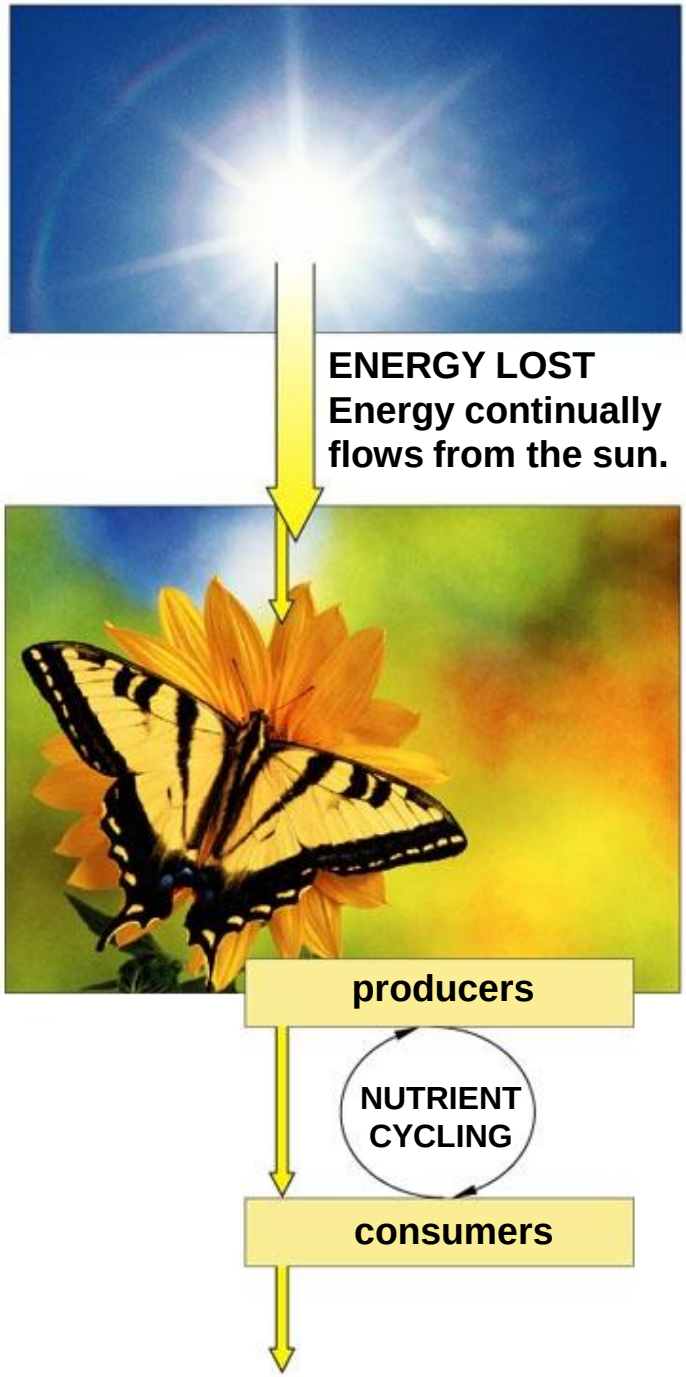
One-Way Flow of Energy

- The sun is life's primary energy source
- Producers trap energy from the sun and convert it into chemical bond energy
- All organisms use the energy stored in the bonds of organic compounds to do work



What Can Cells Do with Energy?

- Energy inputs become coupled to energy-requiring processes
- Cells use energy for:
  - Chemical work
  - Mechanical work
  - Electrochemical work



ENERGY GAINED

Sunlight energy reaches environments on Earth. Producers of nearly all ecosystems secure some and convert it to stored forms of energy. They and all other organisms convert stored energy to forms that can drive cellular work.

ENERGY LOST

With each conversion, there is a one-way flow of a bit of energy back to the environment. Nutrients cycle between producers and consumers.

Fig. 6-4, p.74

Second Law of Thermodynamics

- **No energy conversion is ever 100 percent efficient**

- The total amount of energy is flowing from high-energy forms to forms lower in energy

Entropy

- Measure of degree of disorder in a system

- The world of life can resist the flow toward maximum entropy only because it is resupplied with energy from the sun

Entropy

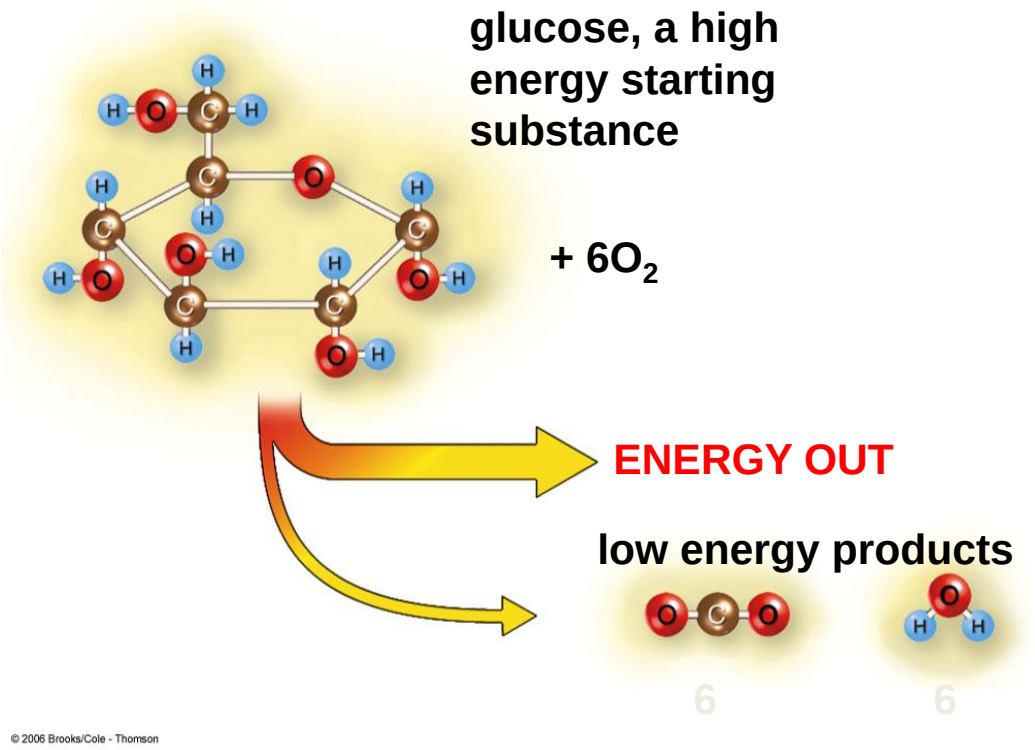
Fig. 6-3a, p.93

Entropy

Fig. 6-3b, p.93

Exergonic Reactions

- **Energy is released**
- **Products have less energy than starting substance**



The Role of ATP

- Cells “earn” ATP in exergonic reactions
- Cells “spend” ATP in endergonic reactions

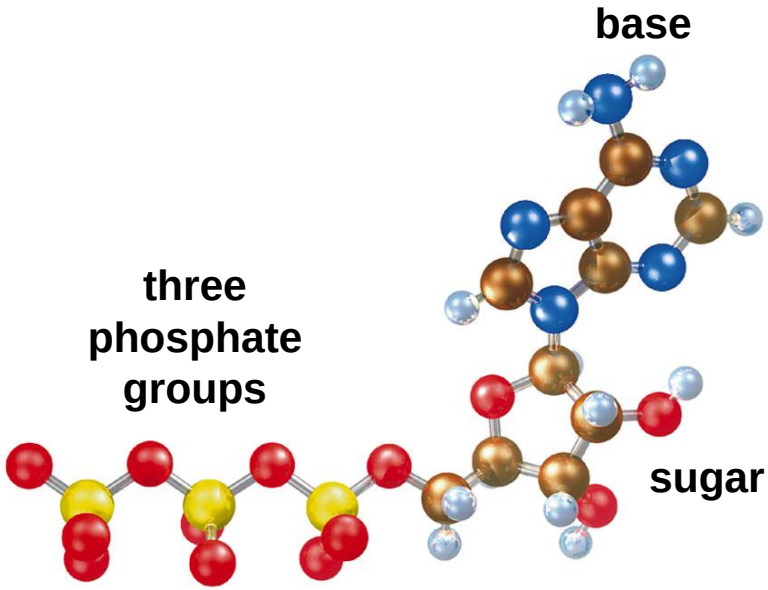
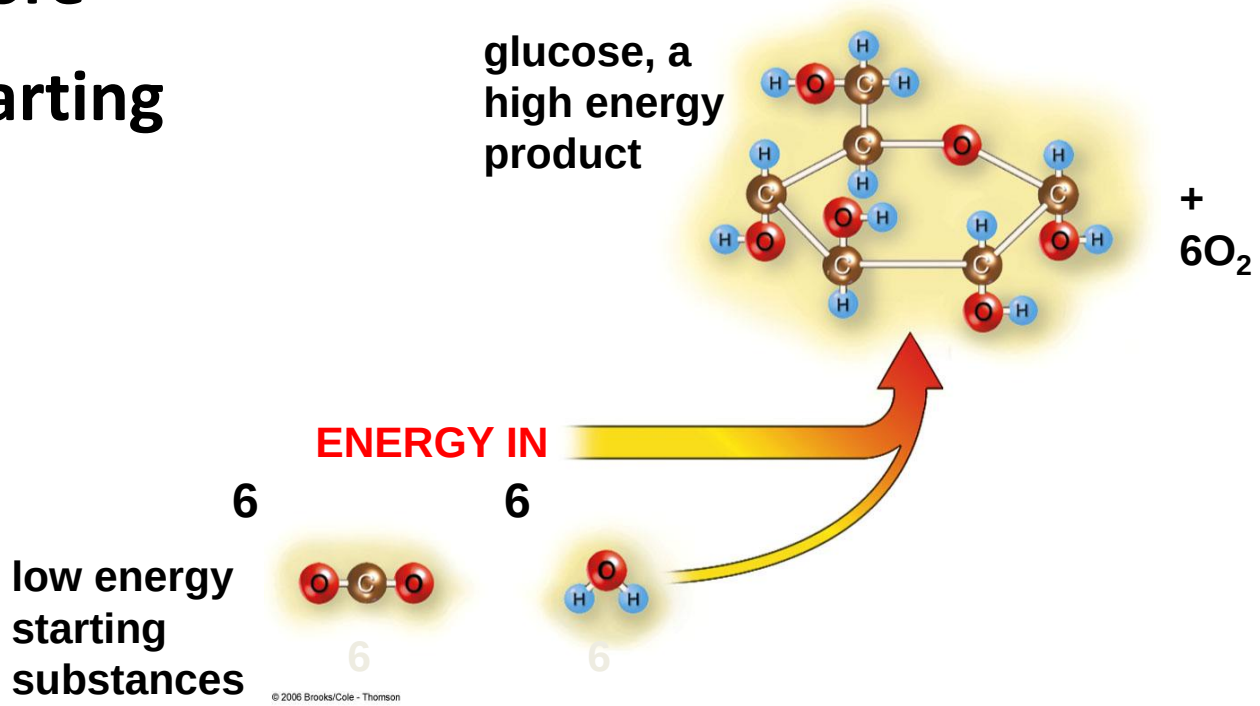


Fig. 6-6a, p.96

Endergonic Reactions

- **Energy input required**
- **Product has more energy than starting substances**



ATP/ADP Cycle

- When adenosine triphosphate (ATP) gives up a phosphate group, adenosine diphosphate (ADP) forms
- ATP can re-form when ADP binds to inorganic phosphate or to a phosphate group that was split from a different molecule
- Regenerating ATP by this ATP/ADP cycle helps drive most metabolic reactions

ATP/ADP Cycle

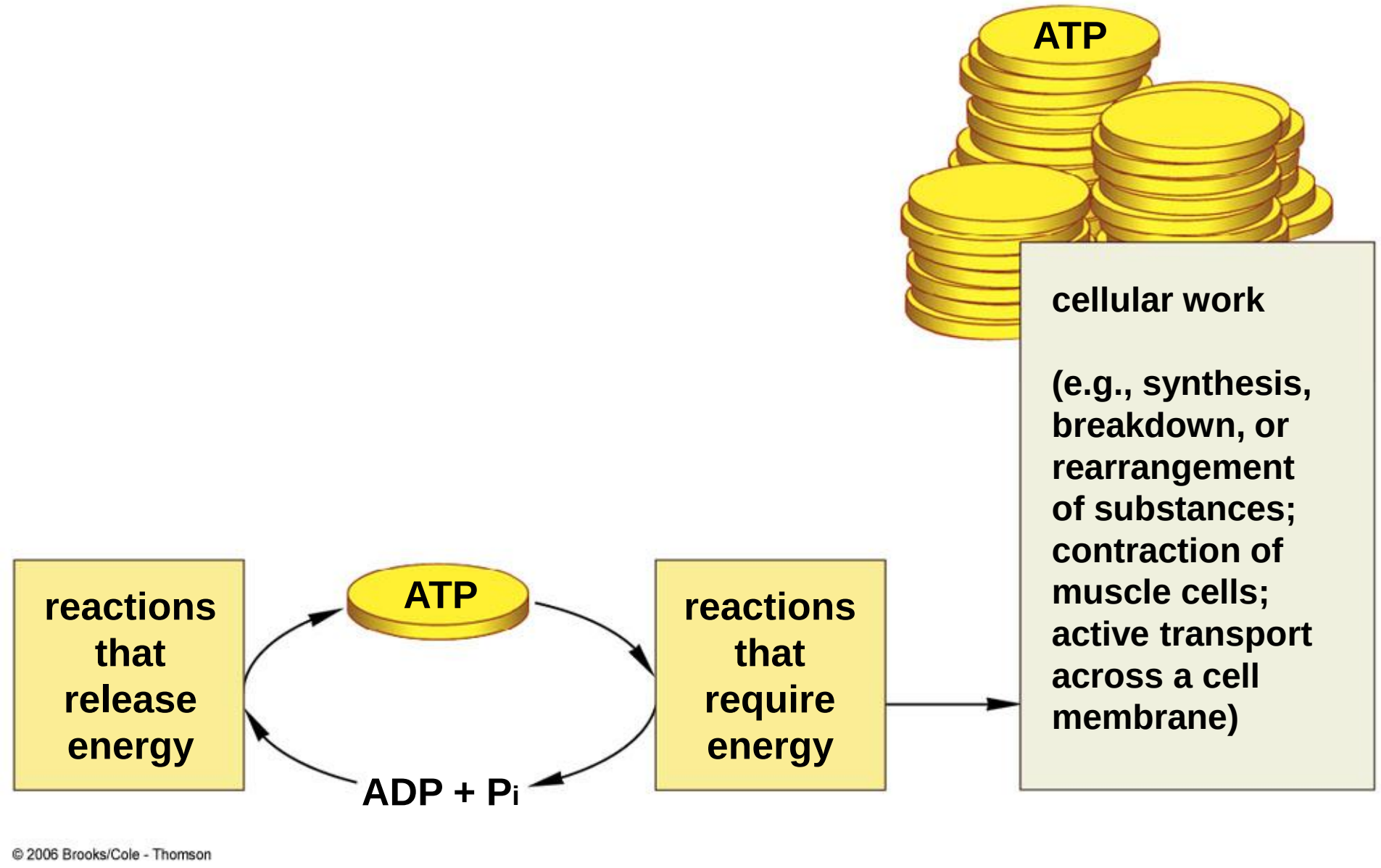


Fig. 6-7a, p.75

ATP/ADP Cycle

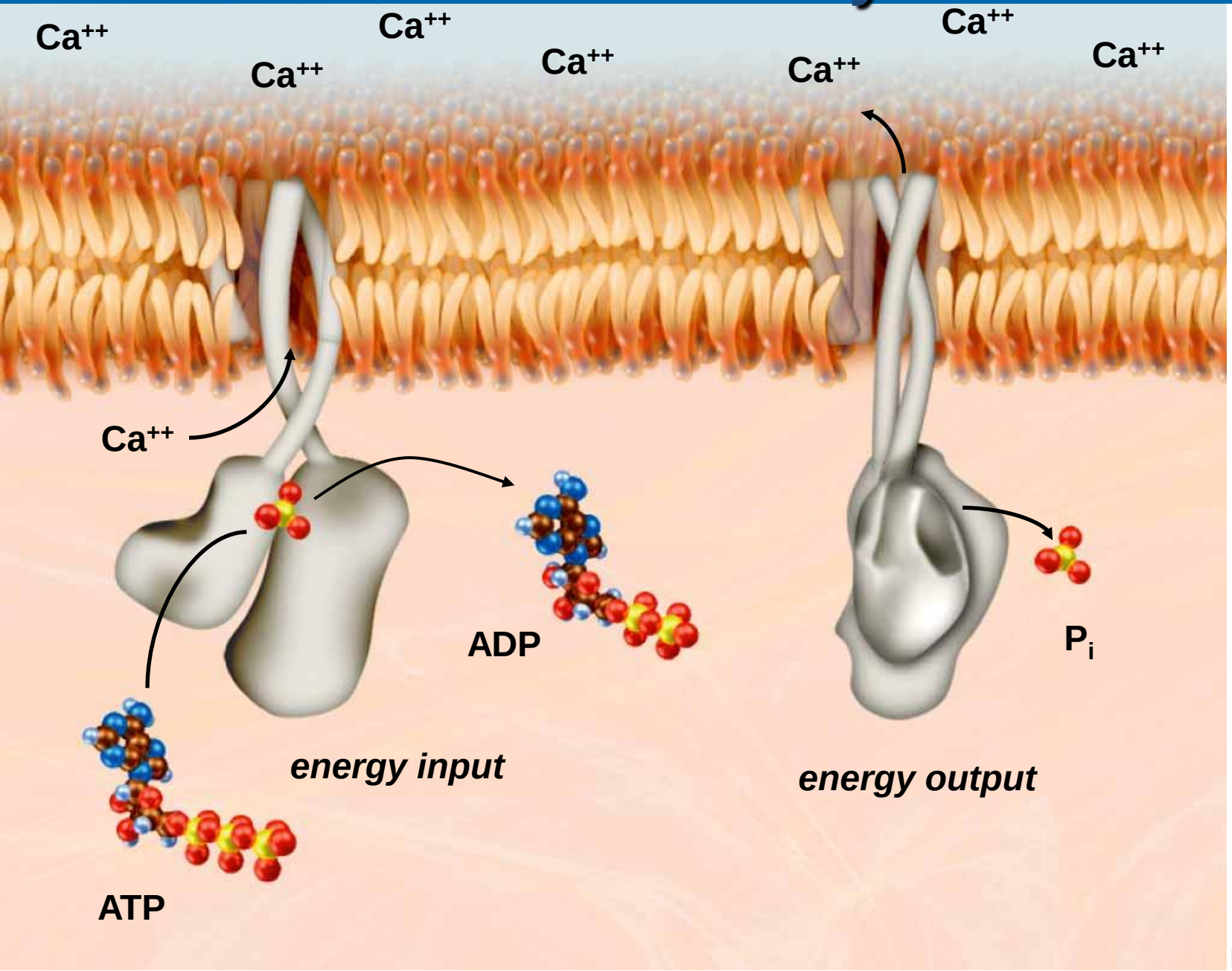


Fig. 6-7b, p.95

Enzyme Structure and Function

- **They speed the rate at which reactions approach equilibrium**
- **Most are proteins**
- **Enzymes are catalytic molecules**

Four Features of Enzymes

1) **Enzymes do not make anything happen that could not happen on its own. They just make it happen much faster.**

2) Reactions do not alter or use up enzyme molecules.

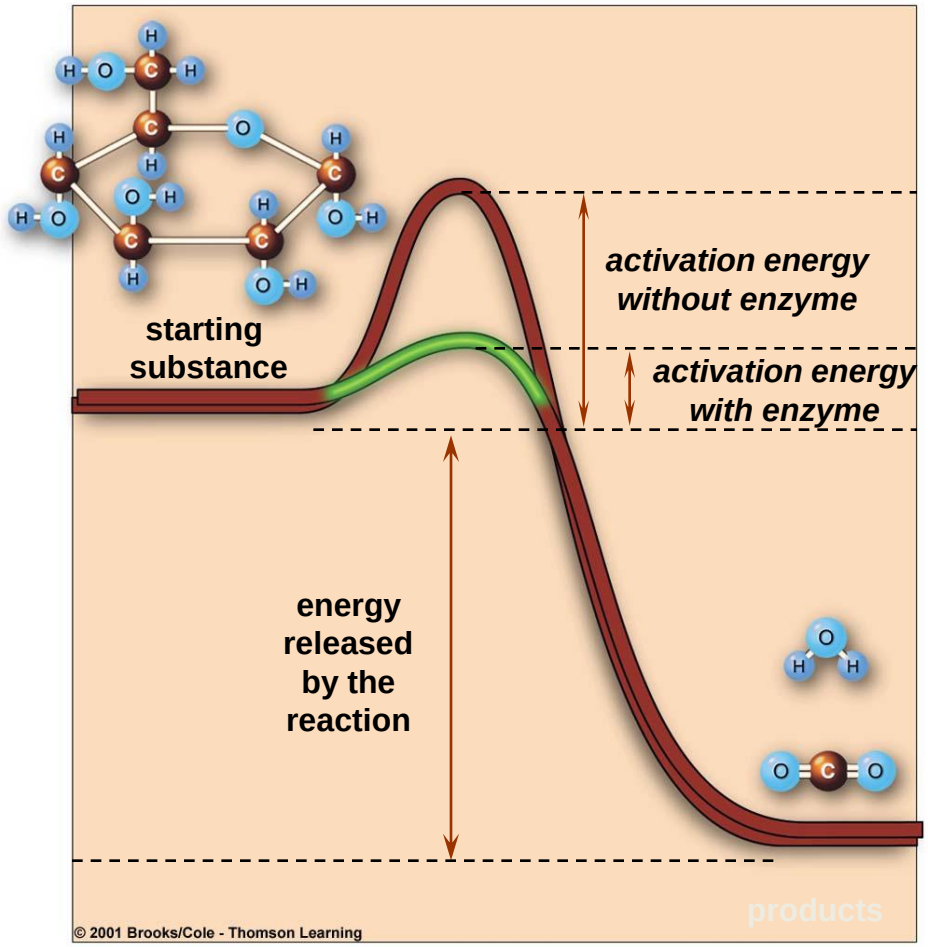
Four Features of Enzymes

3) The same enzyme usually works for both the forward and reverse reactions.

4) Each type of enzyme recognizes and binds to only certain substrates. (Lock and key)

Activation Energy

- For a reaction to occur, an energy barrier must be surmounted
- Enzymes make the energy barrier smaller



Activation Energy

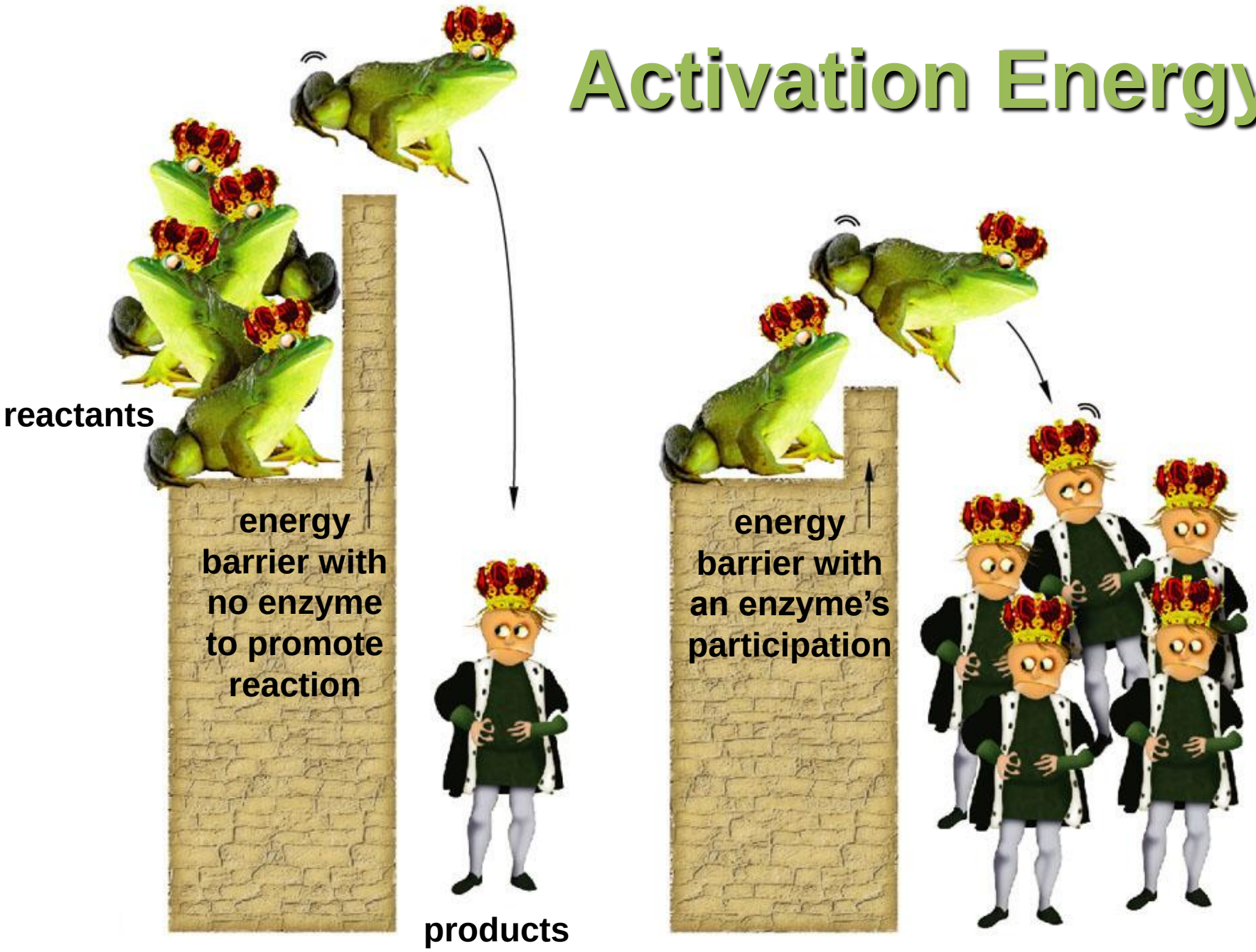


Fig. 6-9, p.96

one of four heme groups cradled in one of four polypeptide chains

How Catalase Works

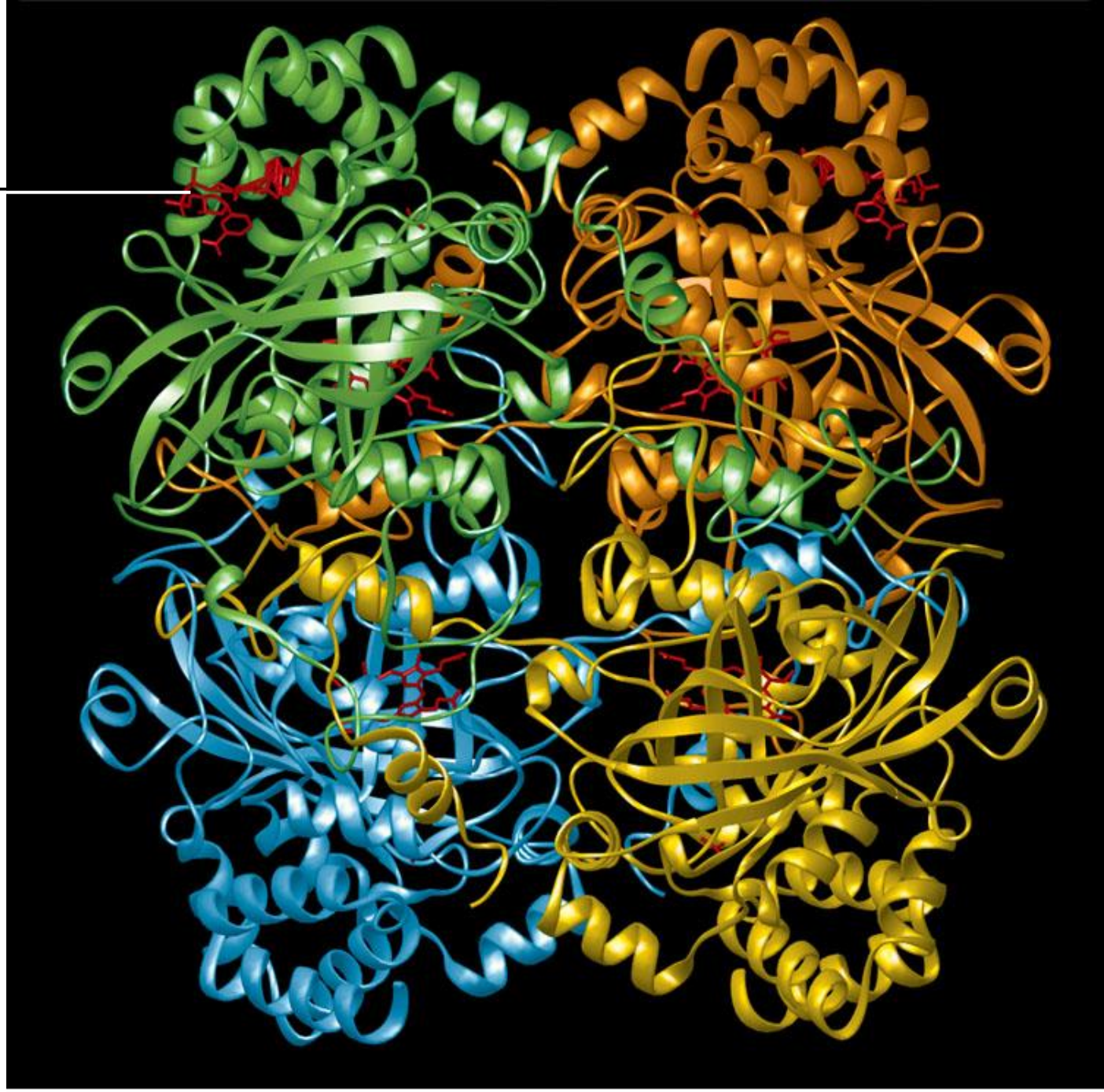
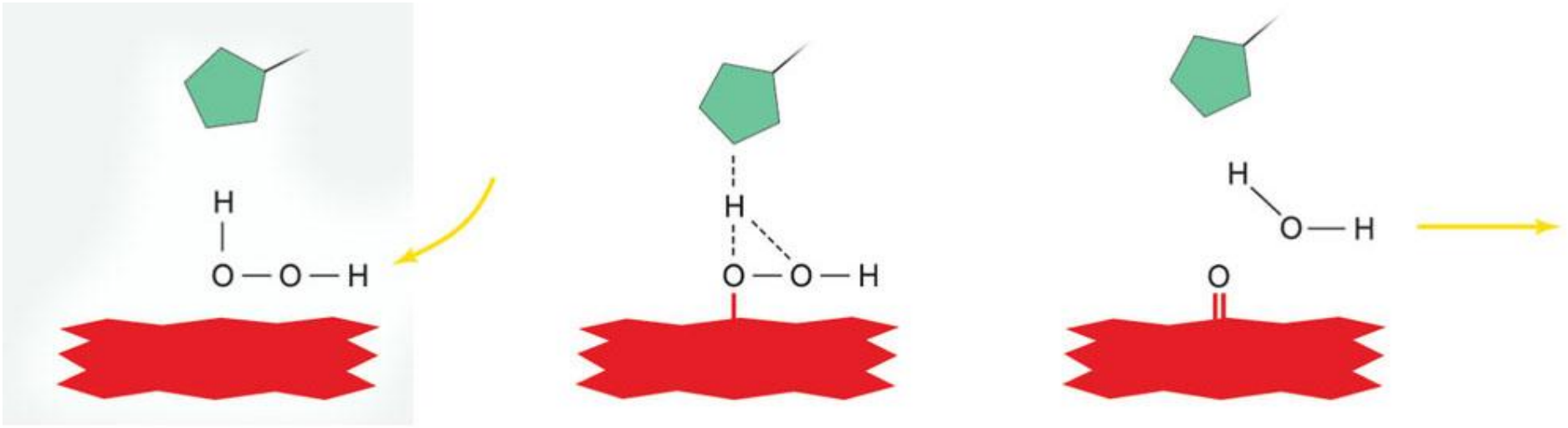


Fig. 6-10a, p.97

How Catalase Works



Hydrogen peroxide (H_2O_2) enters a catalase. It is the substrate for a reaction aided by an iron molecule in a heme group (red).

A hydrogen of the peroxide is attracted to histidine, an amino acid projecting into the cavity. One oxygen binds the iron.

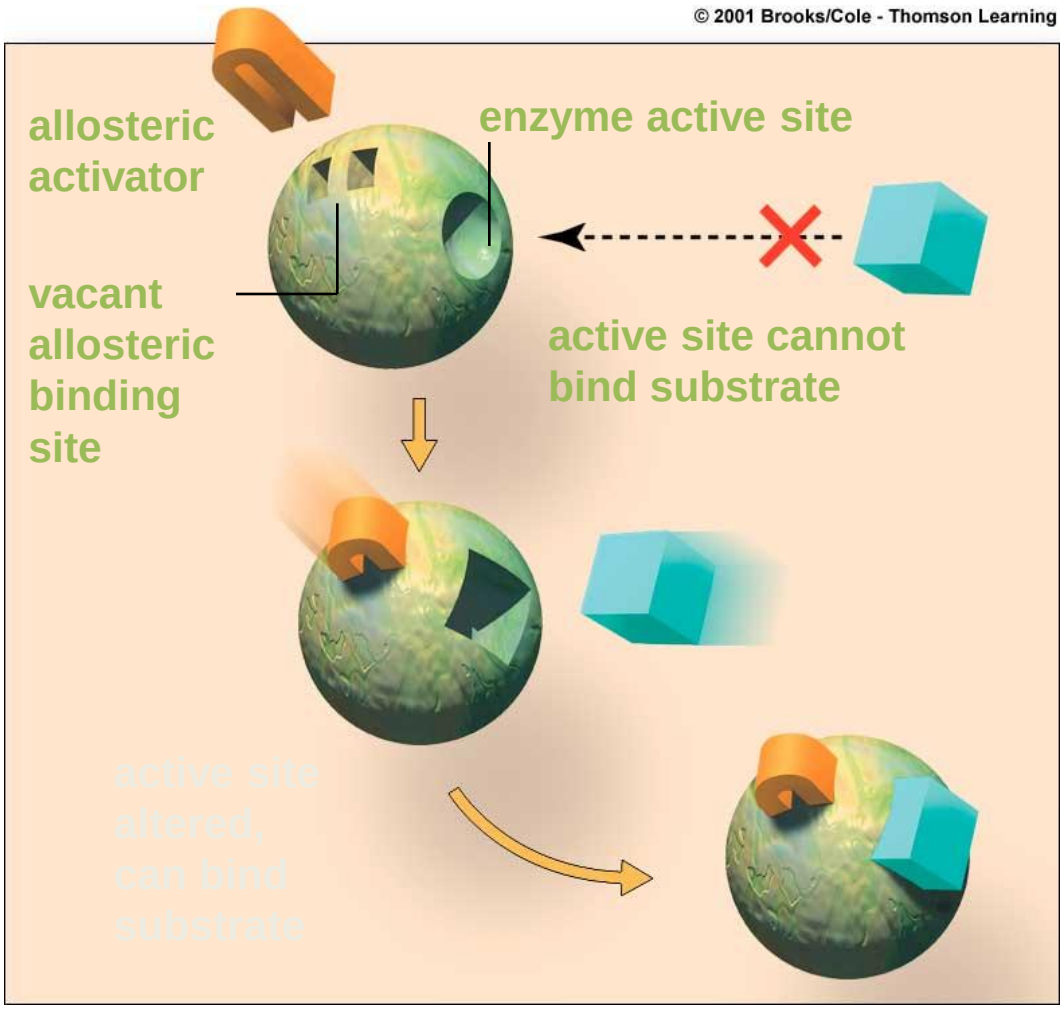
This binding destabilizes the peroxide bond which breaks. Water (H_2O) forms. In a later reaction, another H_2O_2 will pull the oxygen from iron, which will then be free to act again.

Fig. 6-10b, p.97

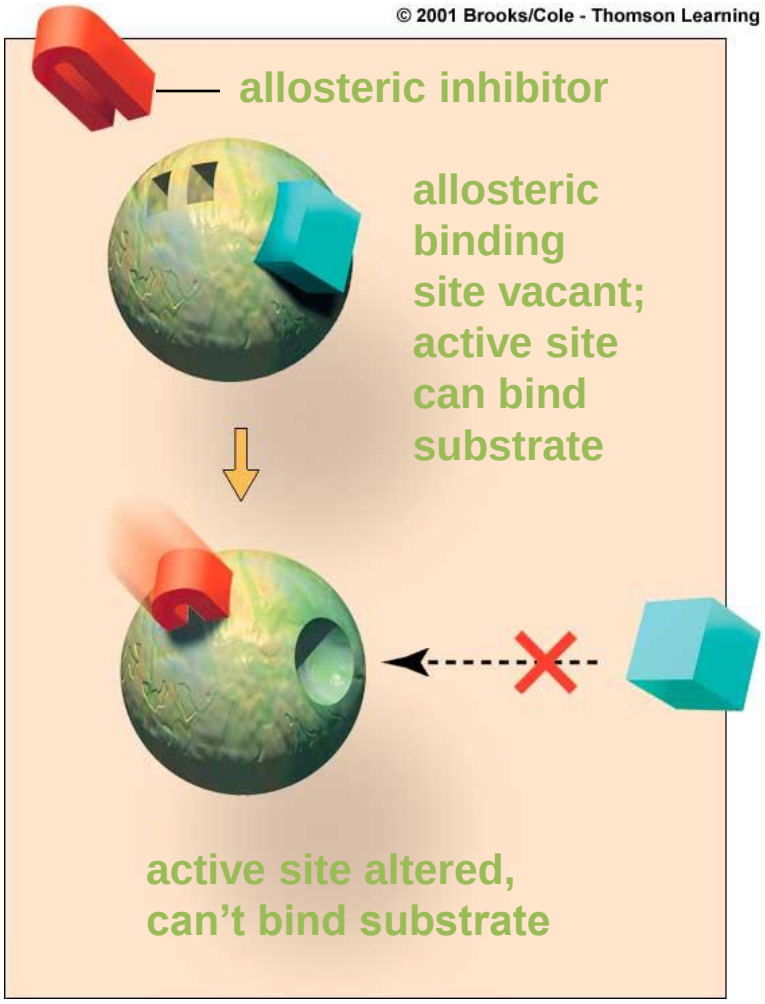
Induced-Fit Model

- Substrate molecules are brought together
- Substrates are oriented in ways that favor reaction

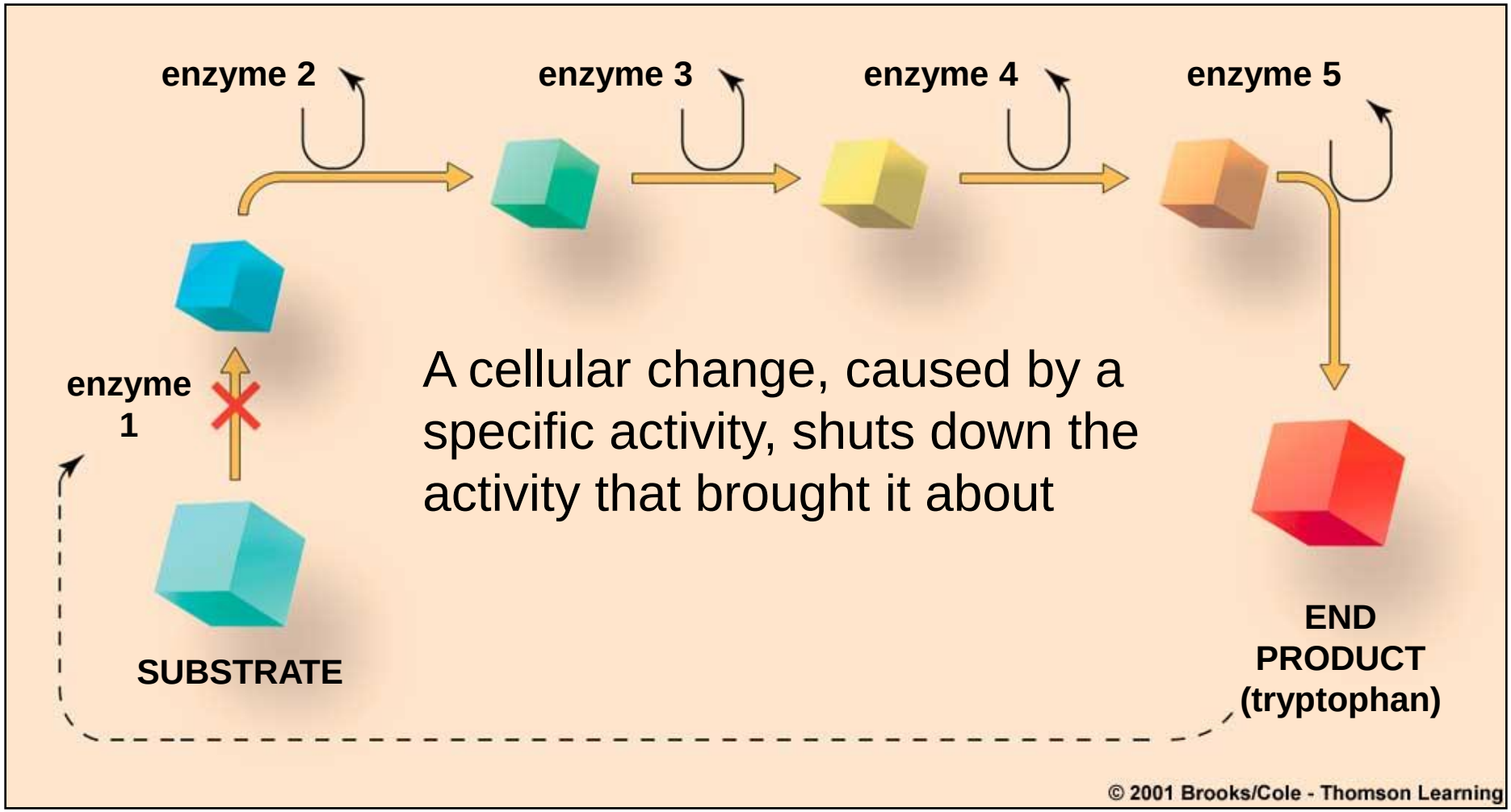
Allosteric Activation



Allosteric Inhibition



Feedback Inhibition



Factors Influencing Enzyme Activity

Temperature

pH

Salt concentration

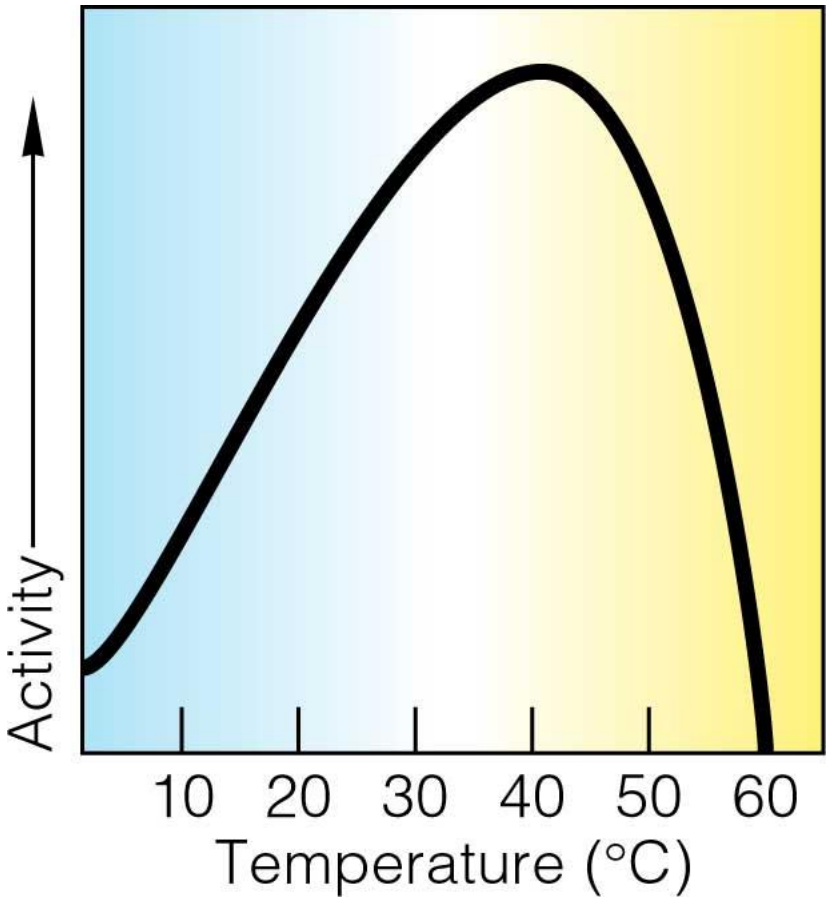
Allosteric regulators

Coenzymes and cofactors

Effect of Temperature

- Small increase in temperature increases molecular collisions, reaction rates

- High temperatures disrupt bonds and destroy the shape of active site



Effect of Temperature

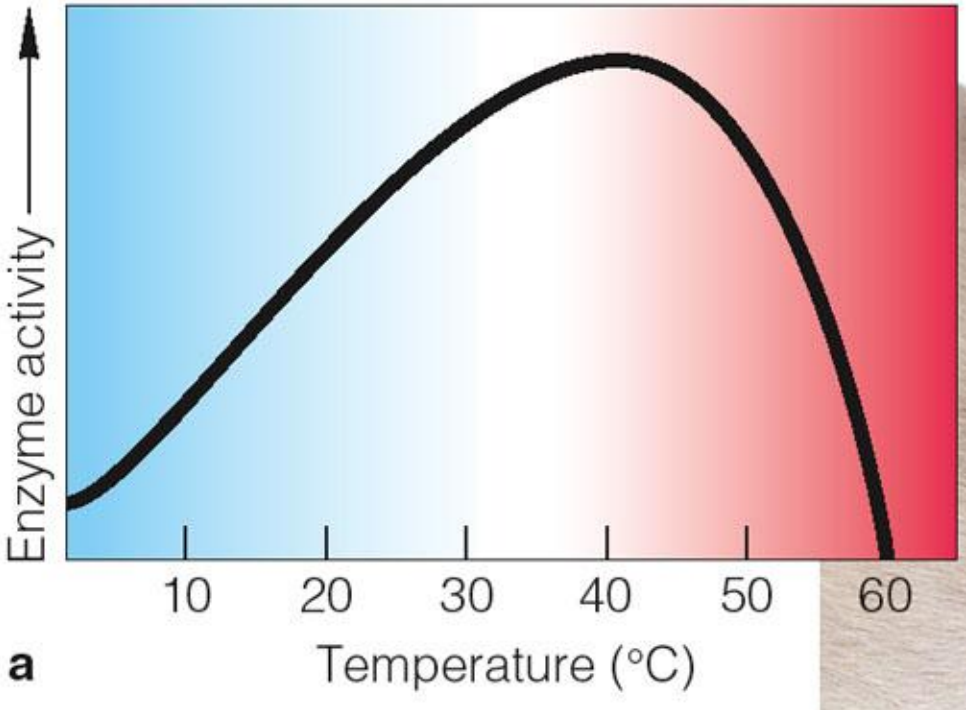


Fig. 6-13, p.81

Effect of pH

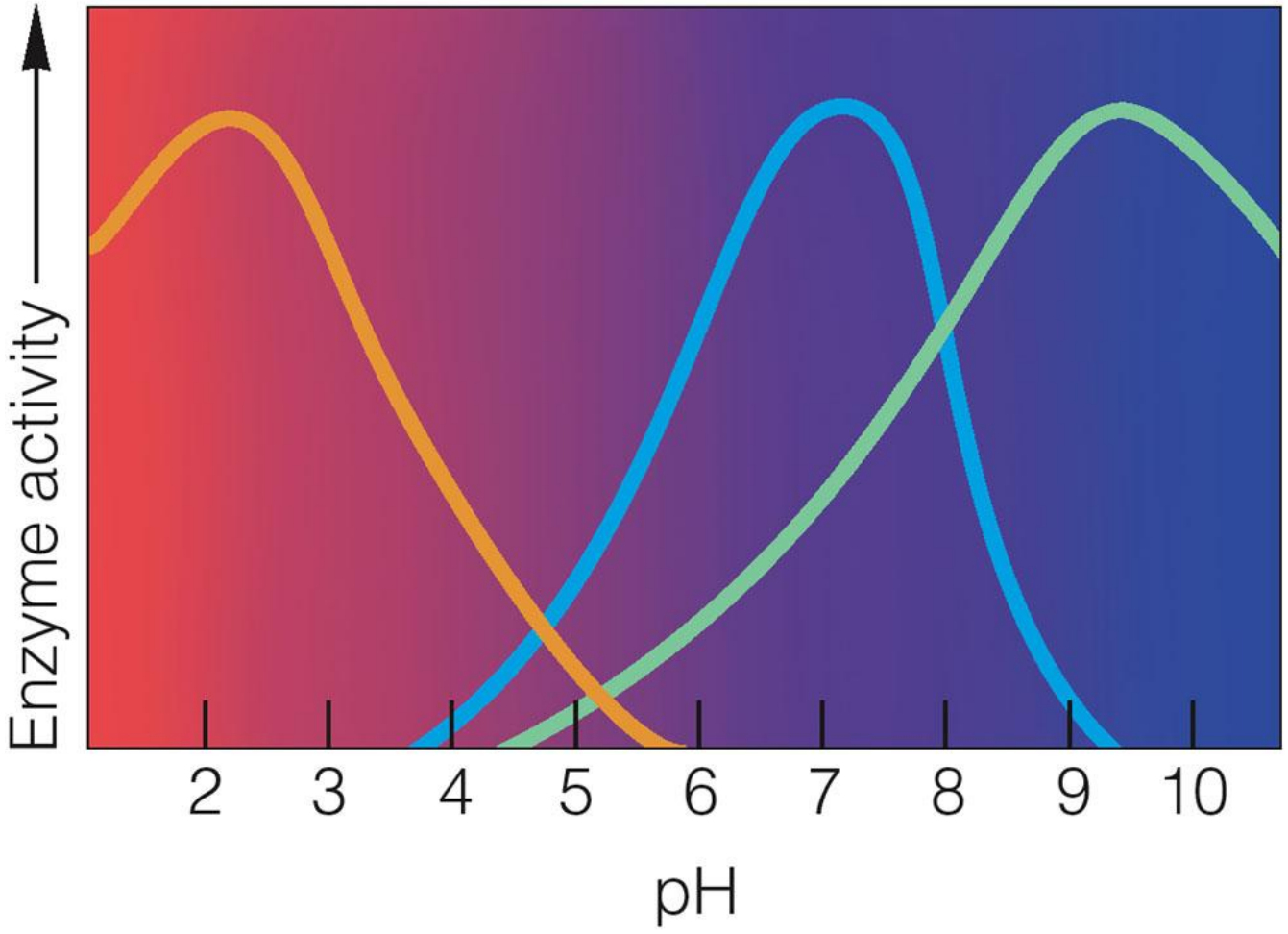


Fig. 6-14a, p.81

Effect of pH

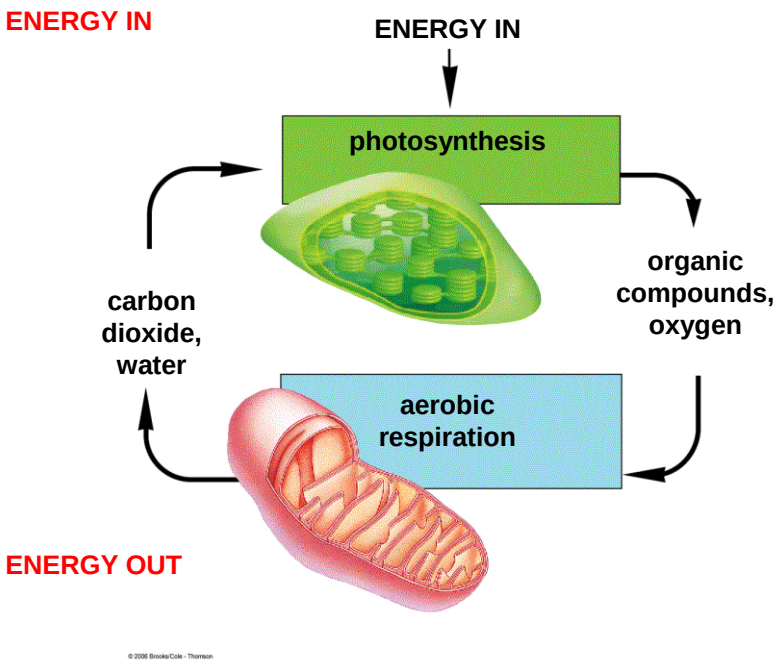
Fig. 6-14b, p.81

Enzyme Helpers

- Cofactors
  - Coenzymes
    - NAD^+, $NADP^+$, FAD
    - Accept electrons and hydrogen ions; transfer them within cell
    - Derived from vitamins
  - Metal ions
    - Ferrous iron in cytochromes

Metabolic Pathways

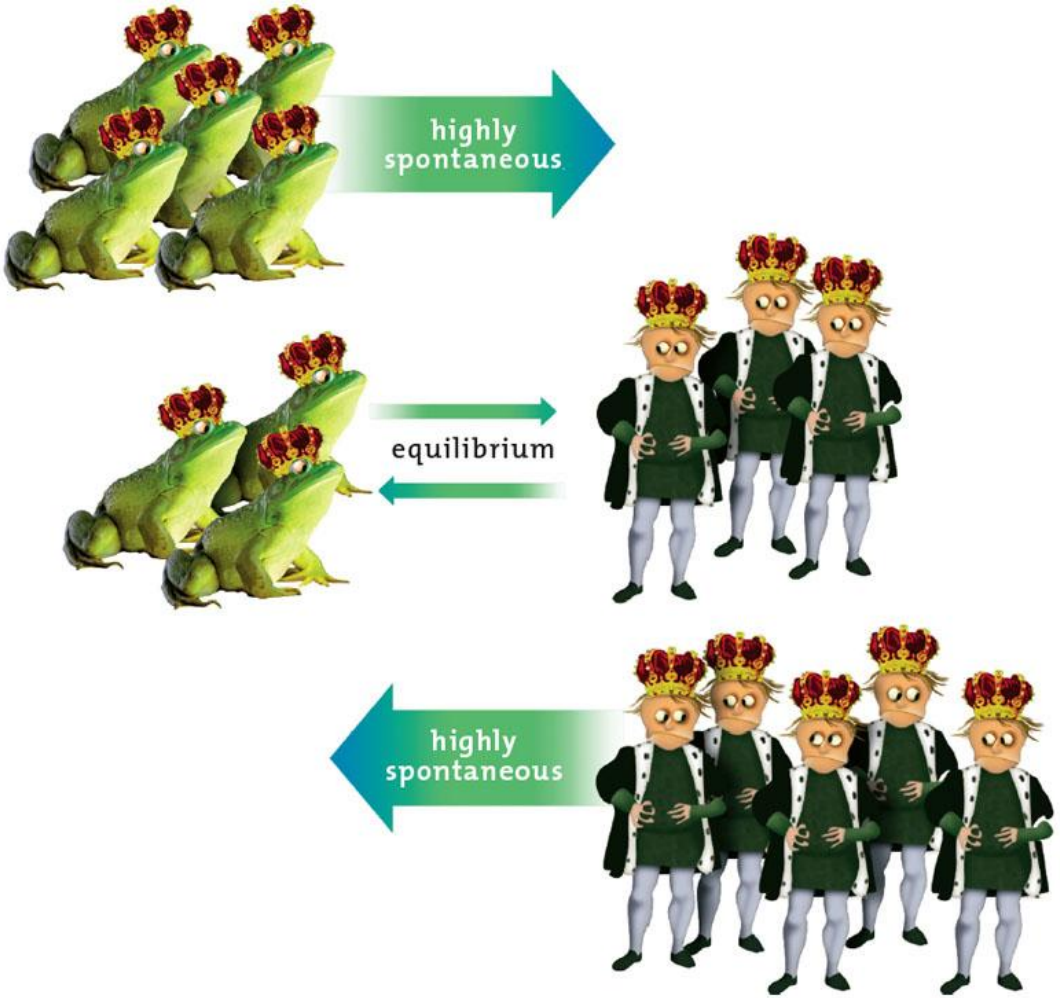
- Defined as enzyme-mediated sequences of reactions in cells
  - Biosynthetic (anabolic) – ex: photosynthesis
  - Degradative (catabolic) – ex: aerobic respiration



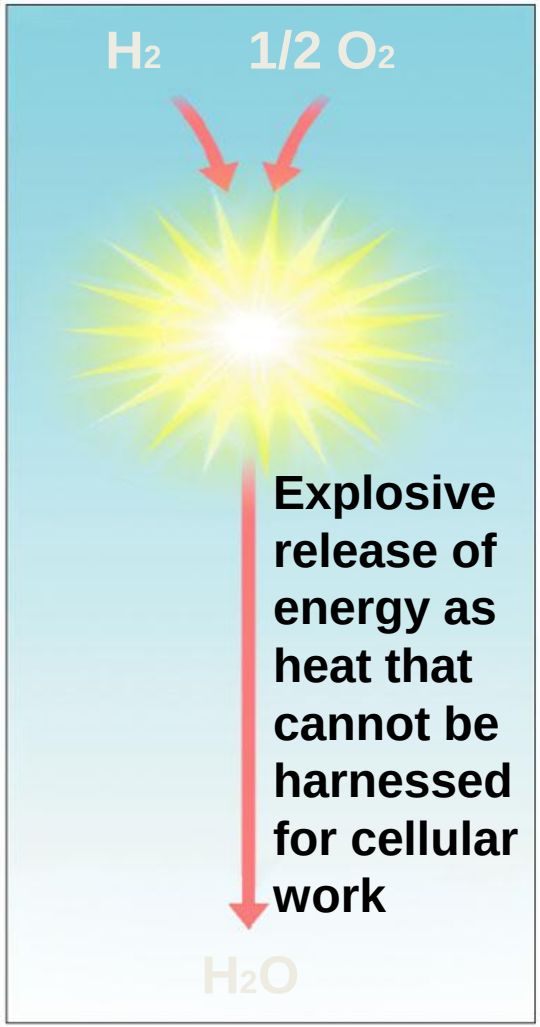
Chemical Equilibrium

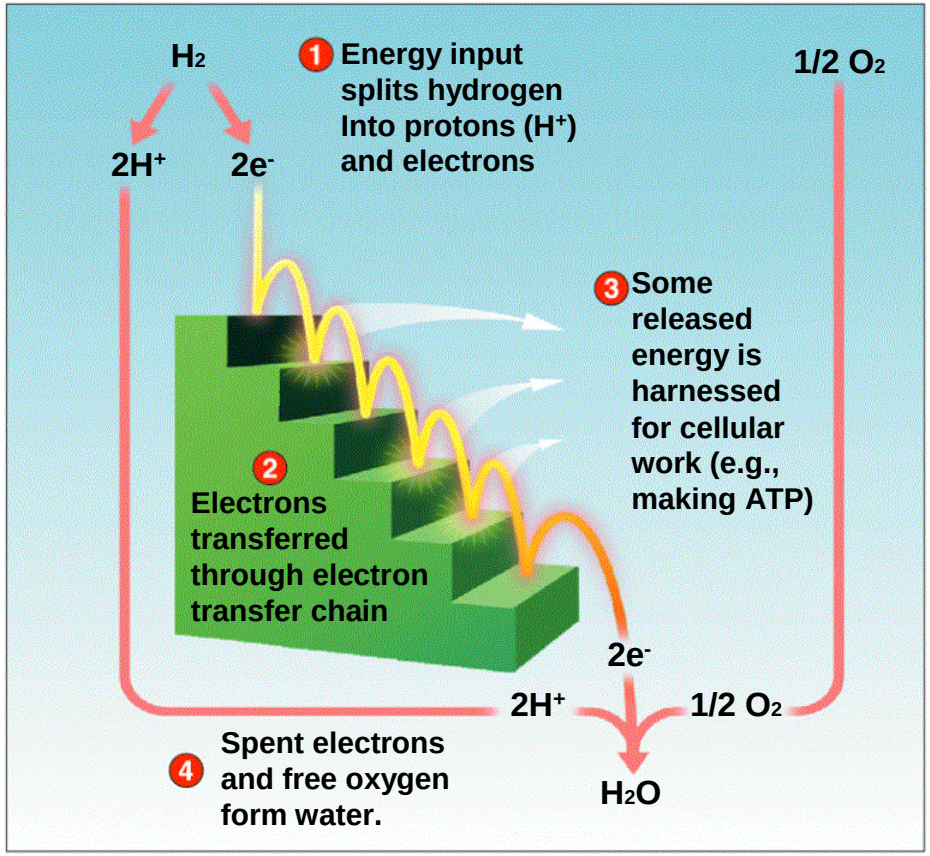
- At equilibrium, the energy in the reactants equals that in the products
- Product and reactant molecules usually differ in energy content
- Therefore, at equilibrium, the amount of reactant almost never equals the amount of product

Chemical Equilibrium



Uncontrolled vs. Controlled Energy Release





Bioluminescence

- An outcome of enzyme-mediated reactions that release energy as fluorescent light

Bioluminescent Bacteria

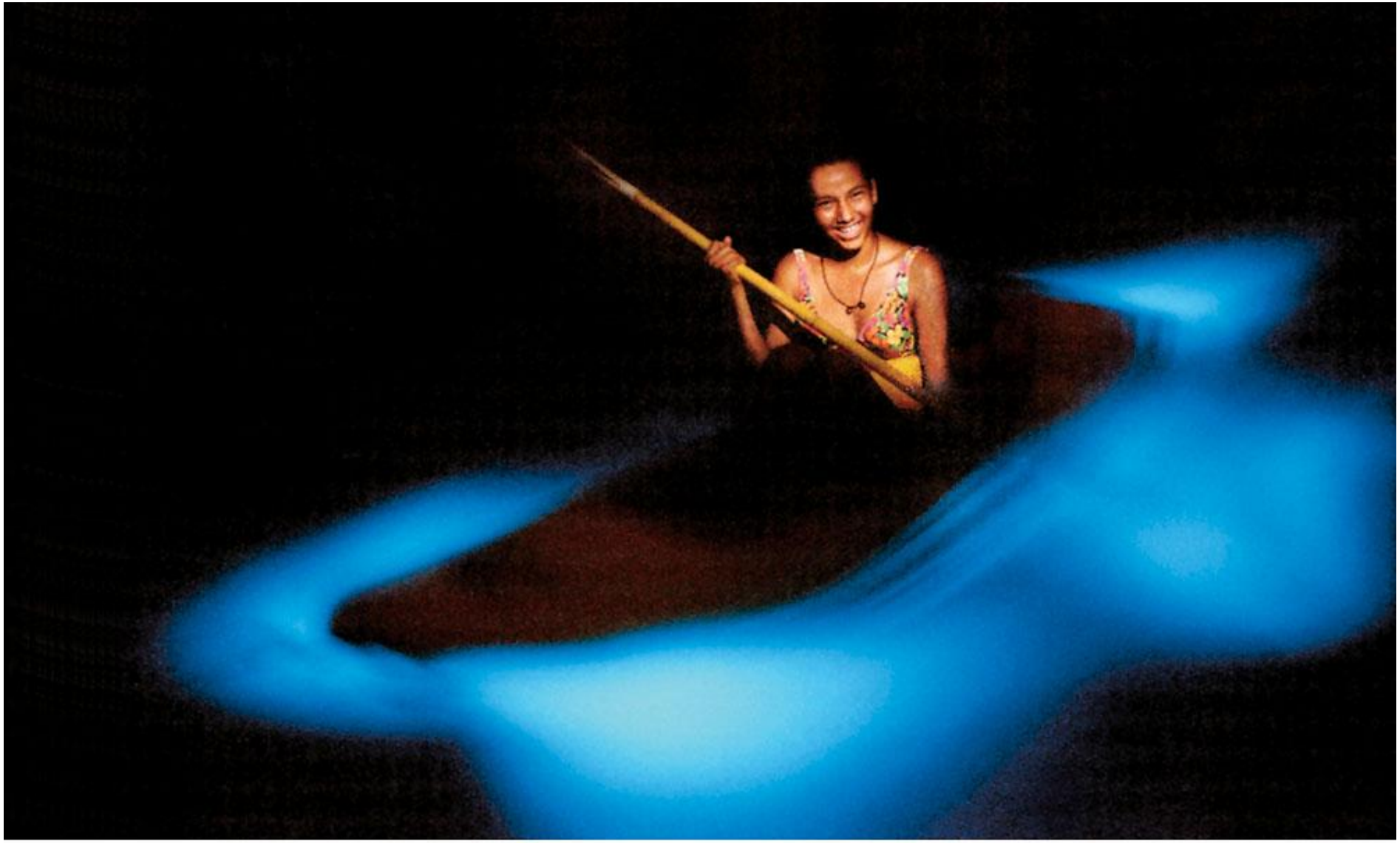
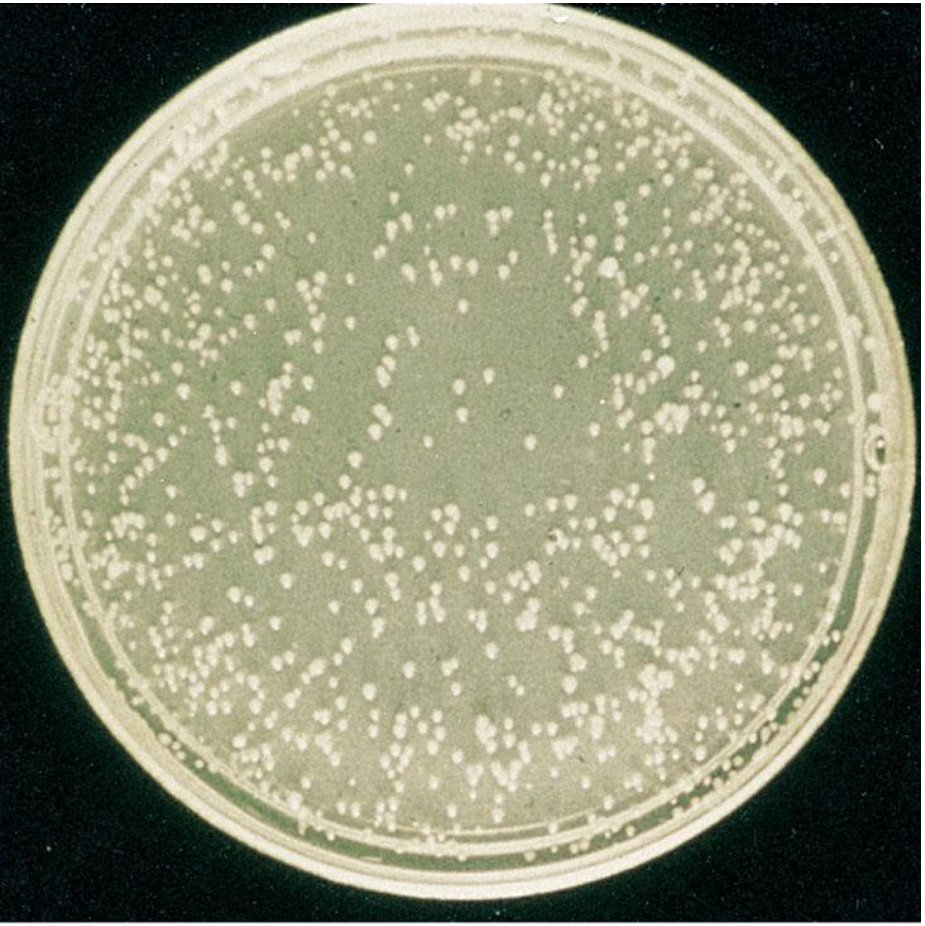


Fig. 6-18a, p.102

Bioluminescent Bacteria

Fig. 6-18b, p.102

Bioluminescent Bacteria



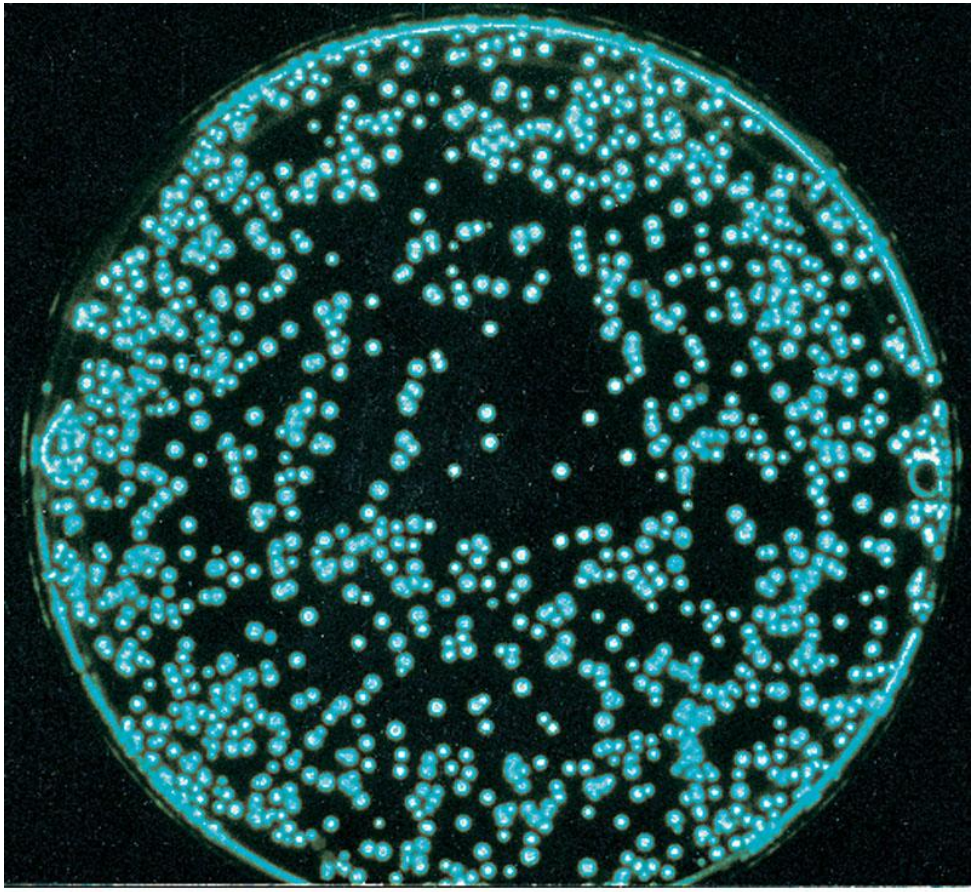


Fig. 6-19, p.103

Table 6.1 Summary of the Main Participants in Metabolic Reactions

Reactant	Substance that enters a metabolic reaction or pathway; also called the substrate of a specific enzyme
Intermediate	Any substance that forms in a reaction or pathway, between the reactants and the end products
Product	Substance at the end of a reaction or pathway
Enzyme	A protein that greatly enhances reaction rates; a few RNAs also do this
Cofactor	Coenzyme (such as NAD^+) or metal ion; assists enzymes or move electrons, hydrogen, or functional groups to other reaction sites
Energy carrier	Mainly ATP; couples energy-releasing reactions with energy-requiring ones
Transport protein	Protein that passively assists or actively pumps specific solutes across a cell membrane