The Working Cell

BIO100
Page Baluch

- A handful of peanuts contains enough energy to boil a quart of water
- It takes about 10 million ATP molecules per second to power an active muscle cell

- About 75% of the energy generated by a car's engine is lost as heat
- You'd have to run about 14 miles to burn the calories from a pepperoni pizza

BIOLOGY AND SOCIETY:

STONEWASHING WITHOUT THE STONES

- The sturdy cotton fabric denim has been worn because of its toughness and appeal
- Stonewashing jeans with pumice stone can damage the fabric
- Recently the enzyme cellulase has been used to achieve better results

Figure 5.1

SOME BASIC ENERGY CONCEPTS

- Energy makes the world go around
  - What is energy?

Conservation of Energy

- Energy is defined as the capacity to perform work
- Energy can be changed from one form to another
  - However, it cannot be created or destroyed
  - This is the **conservation of energy principle**

- Potential energy is stored energy
- Kinetic energy is the energy of motion

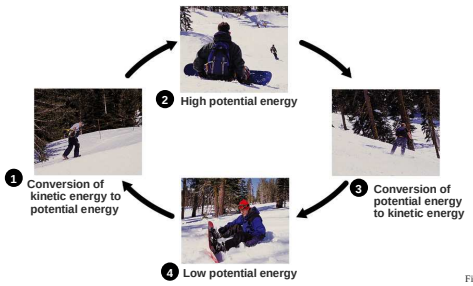


Figure 5.2

Heat

- Heat is
  - A type of kinetic energy
  - A product of all energy conversions
  - Randomized molecular motion

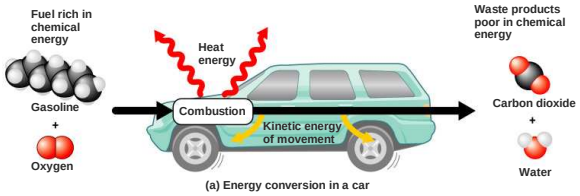
Entropy

- Scientists use the term *entropy* as a measure of disorder, or randomness
  - All energy conversions increase the entropy of the universe

Chemical Energy

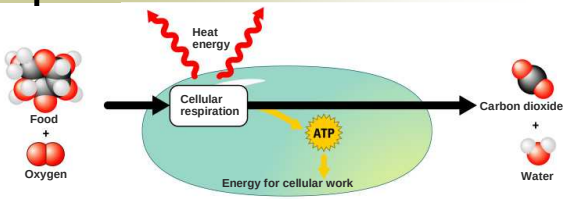
- Chemical energy
  - Is a form of potential energy
  - Is found in food, gasoline, and other fuels

- Living cells and automobile engines use the same basic process to make chemical energy do work



(a) Energy conversion in a car

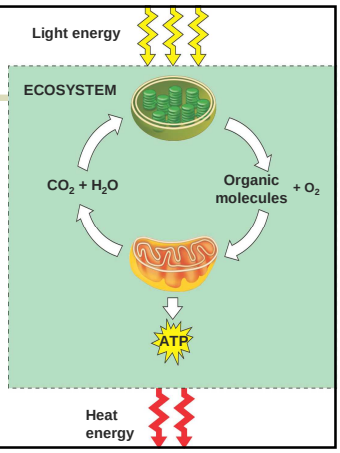
Energy Production in Cells



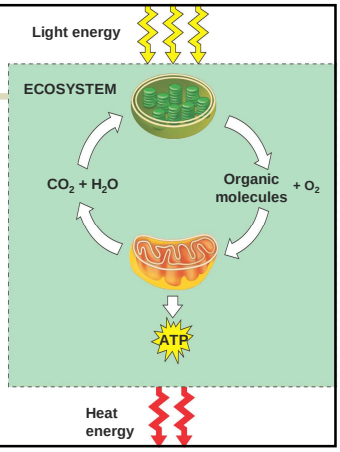
(b) Energy conversion in a cell

Figure 5.3b

- Cells require transfusions of energy from outside sources to perform their many tasks
- **ENERGY**
  - Flows into an ecosystem as **SUNLIGHT** and leaves as **HEAT**



- ATP is the *immediate* energy source for almost all organism function… life's currency!



Photosynthesis

- **Photosynthesis : Transformation of solar light energy trapped by chloroplasts into chemical bond energy stored in sugar and other organic molecules.**
- **Uses CO_2 as the carbon source and light as the energy source**

$$CO_2 + H_2O + \text{Energy (light)} \longrightarrow \text{Glucose} + O_2$$

- **Directly or Indirectly supplies energy for almost all living things**

$$6CO_2 + 6H_2O + \text{Energy (light)} \longrightarrow C_6H_{12}O_6 + 6O_2$$

(glucose)

Balanced Equation

The breakdown of organic molecules is catabolism… and is exergonic

- Catabolic pathways yield energy due to the transfer of electrons down energy gradients
- Specifically… Catabolic pathways yield energy by oxidizing organic fuels

Cellular respiration

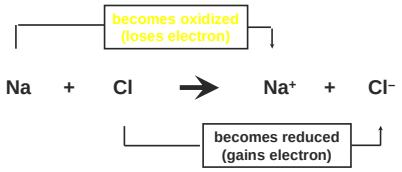
- To keep working
  - Cells must regenerate ATP
- Cellular respiration
  - The most prevalent and energetically efficient catabolic pathway
  - Consumes oxygen and organic molecules such as glucose
  - Yields ATP

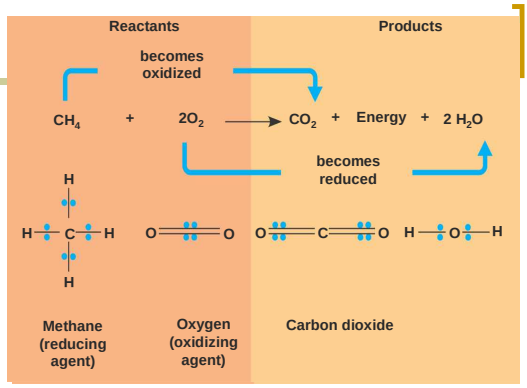
REDOX REACTIONS

- Transfer electrons from one reactant to another by oxidation and reduction

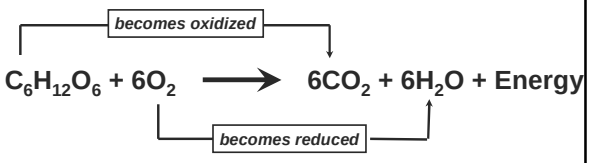
- In oxidation
  - A substance loses electrons, or is oxidized
- In reduction
  - A substance gains electrons, or is reduced

- Example of a redox reaction

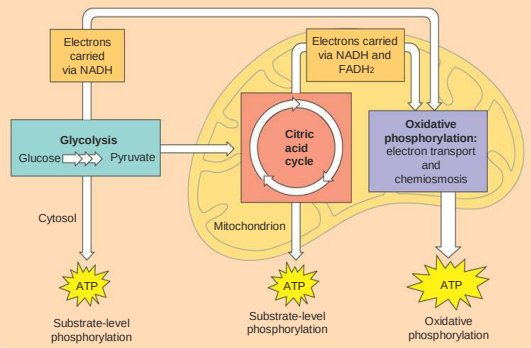




Oxidation of Organic Fuel Molecules During Cellular Respiration



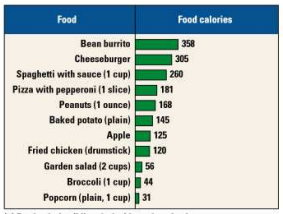
An overview of CELLULAR RESPIRATION



Food Calories

- A calorie is the amount of energy that raises the temperature of 1 gram of water by 1 degree Celsius

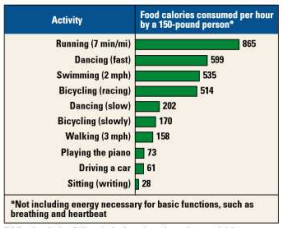
- The kilocalorie is
  - 1,000 calories
  - The unit used to measure the energy in food



(a) Food calories (kilocalories) in various foods

Figure 5.4a

- The energy of calories in food is burned off by many activities



(b) Food calories (kilocalories) we burn in various activities

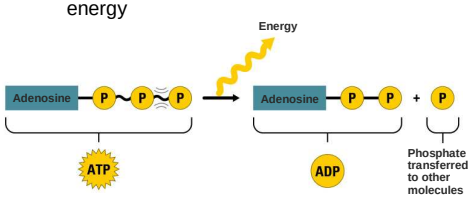
Figure 5.4b

ATP AND CELLULAR WORK

- The chemical energy of organic molecules is released in cellular respiration to make ATP in the mitochondria

The Structure of ATP

- ATP (adenosine triphosphate)
  - Consists of adenosine plus a tail of three phosphate groups
  - Is broken down to ADP, accompanied by the release of energy



Phosphate Transfer

- ATP can energize other molecules by transferring phosphate groups
  - This energy can be used to drive cellular work

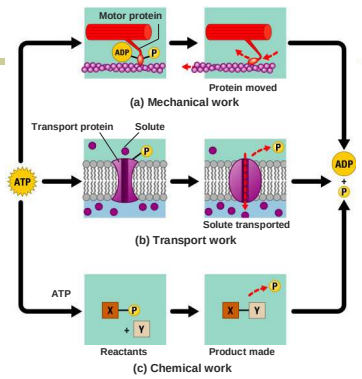


Figure 5.6

The ATP Cycle

- Cellular work spends ATP
- ATP is recycled from ADP and phosphate through cellular respiration

- ATP functions in what is called **energy coupling**, or the **ATP cycle**

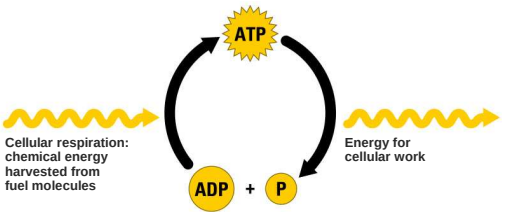


Figure 5.7

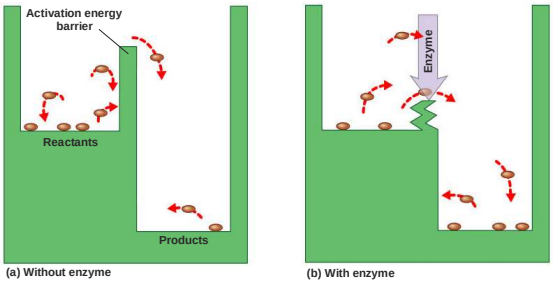
ENZYMES

- Metabolism is defined as the many chemical reactions that occur in organisms
- Few metabolic reactions occur without the assistance of enzymes

Activation Energy

- Activation energy
  - Is the energy that activates the reactants
  - Triggers a chemical reaction

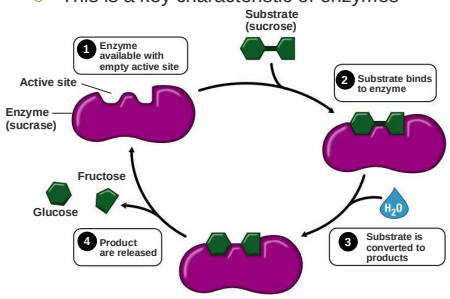
- Lower the activation energy for chemical reactions



Induced Fit

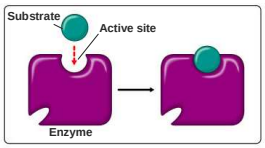
- Each enzyme is very selective
  - It catalyzes specific reactions
- Each enzyme recognizes a specific substrate
  - The active site fits to the substrate, and the enzyme changes shape slightly
  - This interaction is called induced fit

- Enzymes can function over and over again
  - This is a key characteristic of enzymes

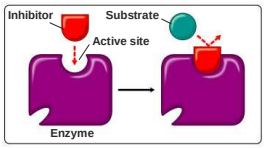


Enzyme Inhibitors

- Enzyme inhibitors
  - Can inhibit a metabolic reaction
  - Bind to the active site, as substrate impostors

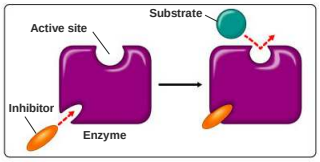


(a) Normal enzyme action



(b) Enzyme inhibition by a substrate imposter

- Other inhibitors
  - Bind at a remote site, changing the enzyme's shape
  - In some cases, this is called feedback regulation



(c) Enzyme inhibition by a molecule that causes the active site to change shape

MEMBRANE TRANSPORT

- Working cells must control the flow of materials
  - This is the primary function of the plasma membrane
  - Transport proteins also help with this task

Passive Transport: Diffusion Across Membranes

- Molecules contain heat energy
  - They vibrate and wander randomly
- Diffusion is one result of the movement of molecules
  - Molecules tend to spread into the available space
  - Diffusion is passive transport; no energy is needed

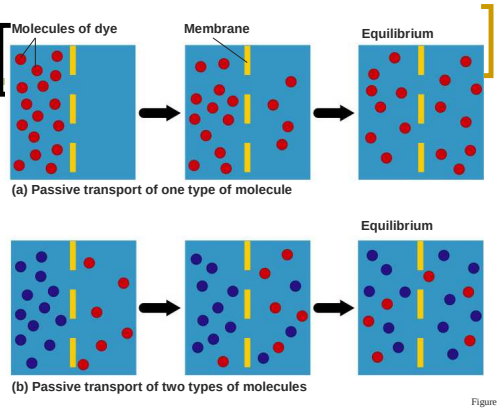


Figure 5.11

Facilitated Diffusion

- Another type of passive transport is facilitated diffusion, the transport of some substances by specific transport proteins that act as selective corridors

Osmosis and Water Balance in Cells

- Osmosis is the passive transport of water across a selectively permeable membrane

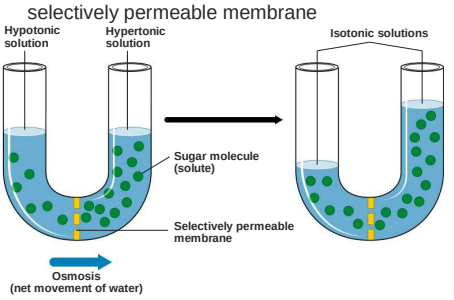
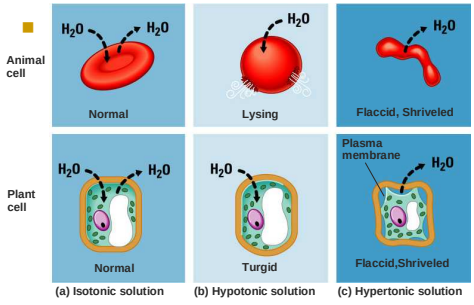


Figure 5.13

Osmoregulation is the control of water balance in animals

- A hypertonic solution
  - Has a higher concentration of solute in the solution surrounding the cell in reference
- A hypotonic solution
  - Has a lower concentration of solute
- An isotonic solution
  - Has an equal concentration of solute

Water Balance in Animal Cells



Water Balance in Plant Cells

- Water balance in plant cells is different
  - They have rigid cell walls
  - They are at the mercy of the environment

Turgid | Flaccid

Figure 5.15

Active Transport: the Pumping of Molecules Across Membranes

- Active transport requires energy to move molecules across a membrane

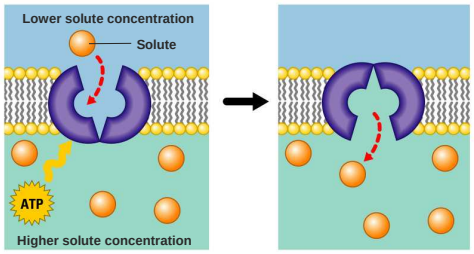
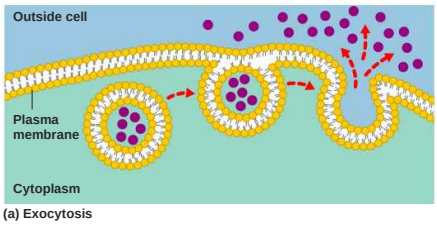


Figure 5.16

Exocytosis and Endocytosis: Traffic of Large Molecules

- Exocytosis
  - Secretes substances outside of the cell

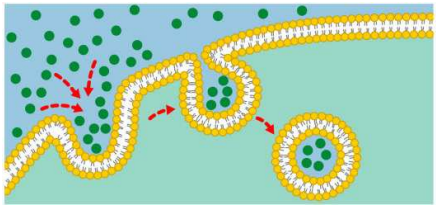


(a) Exocytosis

Figure 5.17a

Endocytosis

- Takes material into the cell



(b) Endocytosis

Figure 5.17b

Types of Endocytosis

- In **pinocytosis** ("cellular drinking") a cell "gulps" droplets of fluid by forming tiny vesicles
- In **phagocytosis** ("cellular eating") a cell engulfs a particle and packages it within a food vacuole

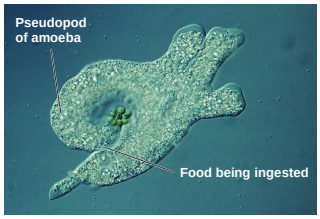
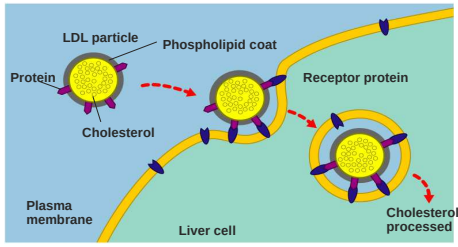


Figure 5.18

Receptor-mediated endocytosis

- Is triggered by the binding of external molecules to membrane proteins



The Role of Membranes in Cell Signaling

- Cellular communication
  - Begins with the reception of an extracellular signal
- The signal transduction pathway
  - Consists of proteins and other molecules that relay the signal

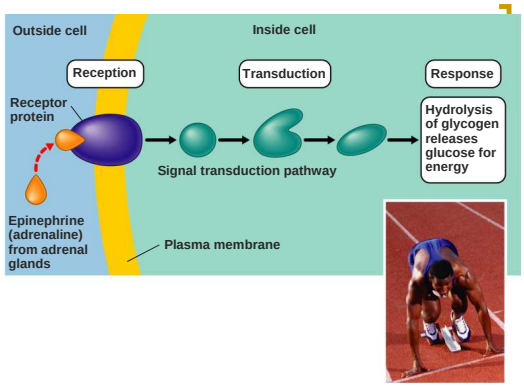


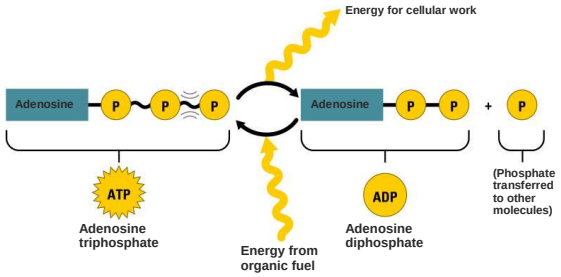
Figure 5.20

Organisms use many distinct enzymes

- Scientists compare enzymes from different organisms
- Comparisons show similarities between organisms

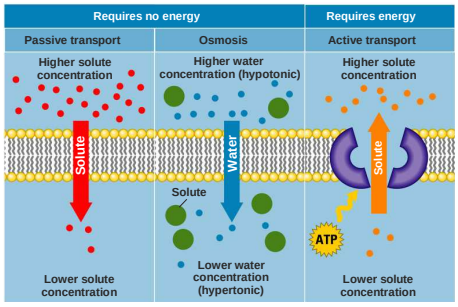
- The processes of natural selection and directed evolution both result in the production of new enzymes with new functions

SUMMARY OF KEY CONCEPTS



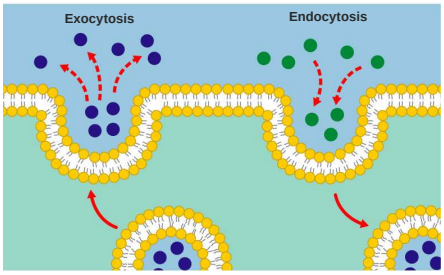
Visual Summary 5.1

- Passive Transport, Osmosis, and Active Transport



Visual Summary 5.2

- Exocytosis and Endocytosis:
- Traffic of Large Molecules



Visual Summary 5.3

Photosynthesis converts the sun's radiant energy into stored (potential) chemical energy.

1000 calories (c) = 1 Kcal = 1 Calorie (C)

so 12 Kcal= 12 C = 12,000 c

Enzymes are proteins that serve as biological catalysts, changing the rate of chemical reactions without being changed themselves in the process. They reduce the amount of activation energy required to break the bonds of reactant molecules.

Diffusion

Diffusion is the spontaneous, random movement of particles of any kind from where they are more concentrated to where they are less concentrated. This is a passive process.

Osmosis

Osmosis is the passive transport of water across a selectively permeable membrane.

The solution with lower solute concentration is said to be hypotonic. This same solution would therefore have the highest water concentration.

The control of water balance is called **osmoregulation.**

Turgor results in cells with cell walls when water enters the cell (osmosis). Cells of all types become flaccid when water escapes and the net cell contents decrease.

When water escapes plant cells they become **flaccid.** Produce in the market place is kept moist so they will not “wilt”.

Phagocytosis is a type of **endocytosis** whereby a cell engulfs macromolecules, other cells, or particles into its cytoplasm.