5.1 What Is Energy?

- Energy is the capacity to do work.
- Where does our biosphere get its energy from?
- 2 basic forms of energy
  - Potential energy – stored energy
  - Kinetic energy – energy of motion
- 2 forms are converted back and forth

Stonewashing Without the Stones!!

- Stonewashing jeans with pumice stone can damage the fabric.
- The enzyme *cellulase* is used to achieve better results.
- What does *cellulase* digest?

Figure 5.1 Potential energy versus kinetic energy

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

2nd Law: The universe increases in Entropy

- Energy cannot be changed from one form to another without a loss of usable energy
  - Heat is the least usable form of energy
- Heat is due to the motion of molecules
  - Is a type of kinetic energy.
  - Is a product of all energy conversions.
- As usable energy decreases and unusable energy increases, "entropy" increases

Entropy

- Entropy is a measure of disorder or randomness.
- All energy conversions increase the entropy of the universe.
- Only way to maintain or bring about order is to add energy

Figure 5.2a Entropy

Figure 5.2b Cells and Entropy

Chemical Energy

- Chemical energy
  - Form of potential energy.
  - Found in food, gasoline, and other fuels.
- Living cells and automobile engines use the same basic process to make chemical energy do work.
Chemical Energy

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

Cellular Respiration

• Cellular respiration
  – Energy-releasing chemical breakdown of fuel molecules.
  – Provides energy for the cell to do work.

• Measuring Energy…
  – What’s a calorie?

Measuring Energy in Food Calories (kcal)

• Food energy measured in calories
• calorie – amount of heat required to raise temperature of 1 gram of water by 1°C
• Kilocalorie (kcal) or Calorie = 1,000 calories
  – Value listed on food packages

<table>
<thead>
<tr>
<th>Food</th>
<th>Food Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheeseburger</td>
<td>295</td>
</tr>
<tr>
<td>Spaghetti with sauce (1 cup)</td>
<td>241</td>
</tr>
<tr>
<td>Baked potato (plain, with skin)</td>
<td>220</td>
</tr>
<tr>
<td>Fried chicken (drumstick)</td>
<td>193</td>
</tr>
<tr>
<td>Bean burrito</td>
<td>189</td>
</tr>
<tr>
<td>Pizza with pepperoni (1 slice)</td>
<td>181</td>
</tr>
<tr>
<td>Peanuts (1 ounce)</td>
<td>166</td>
</tr>
<tr>
<td>Apple</td>
<td>81</td>
</tr>
<tr>
<td>Garden salad (2 cups)</td>
<td>56</td>
</tr>
<tr>
<td>Popcorn (plain, 1 cup)</td>
<td>31</td>
</tr>
<tr>
<td>Broccoli (1 cup)</td>
<td>25</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Activity</th>
<th>Food Calories consumed per hour by a 150-pound person*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running (7 min/mi)</td>
<td>979</td>
</tr>
<tr>
<td>Dancing (fast)</td>
<td>510</td>
</tr>
<tr>
<td>Bicycling (10 mph)</td>
<td>490</td>
</tr>
<tr>
<td>Swimming (2 mph)</td>
<td>408</td>
</tr>
<tr>
<td>Walking (3 mph)</td>
<td>245</td>
</tr>
<tr>
<td>Dancing (slow)</td>
<td>204</td>
</tr>
<tr>
<td>Playing the piano</td>
<td>73</td>
</tr>
<tr>
<td>Driving a car</td>
<td>51</td>
</tr>
<tr>
<td>Sitting (writing)</td>
<td>28</td>
</tr>
</tbody>
</table>

*Not including energy necessary for basic functions, such as breathing and heartbeat

5.2 ATP—Energy for Cells!

Adenosine triphosphate

• Energy currency for cells
• Cells use ATP to carry out nearly all activities
• 3 phosphate groups makes it unstable
• Easily loses a phosphate group to become ADP (adenosine diphosphate)
• Continual cycle of breakdown and regeneration

Figure 5.3 ATP

• ATP releases energy quickly
  – One active muscle cell needs about 10 million ATP per second!
• Amount of energy released is usually just enough for a biological purpose
• Breakdown can be easily coupled to an energy-requiring reaction

Figure 5.4 The ATP cycle
**Coupled Reactions**

- Energy-releasing reaction can drive an energy-requiring reaction
- Usually energy-releasing reaction is ATP breakdown

**Flow of Energy**

- Chloroplasts and mitochondria enable energy to flow from the sun through all living things

**Flow of Energy**

- Photosynthesis – solar energy used to convert water and carbon dioxide into carbohydrates
  - Food for plants and other organisms
- Cellular respiration – carbohydrates broken down and energy used to build ATP
  - Useful energy is lost with each transformation
- Living things dependent on constant in/out of solar energy

**5.3 Metabolic Pathways and Enzymes**

- Metabolism is the sum total of all chemical reactions that occur in an organism.
- Most metabolic reactions need an enzyme
- Metabolic Pathway….

\[ A \rightarrow B \rightarrow C \rightarrow D \rightarrow E \rightarrow F \rightarrow G \]

- Product of a previous reaction becomes the reactant of the next reaction
- **Substrates:** _________
- **Enzymes:** _________
  - Protein catalyst that speeds up a reaction without being used up
  - Enzymes are reaction specific (i.e. Each reaction requires its own enzyme) Why?
Enzymes
• Act on substrates
• Facilitate breakdown or synthesis reactions
  ✓ i.e. catalyze hydrolysis or dehydration synthesis reactions

How Enzymes Work

Enzyme’s Active Site
• Accommodates substrate
• Lock and Key Model – only one key will fit!
  ✓ Lock = ?
  ✓ Key = ?
• Induced fit model – undergoes slight shape change to accommodate substrate
  ✓ Like a hand and glove
  ✓ Active site returns to original shape after releasing product(s)
  ✓ Enzymes are not used up by the reaction

How does an enzyme speed up a reaction?

Activation Energy
• Molecules often do not react with each other unless they have enough kinetic energy.
• Energy of activation ($E_a$)
  – energy needed for molecules to react with one another
  – Triggers a chemical reaction to proceed.
• Enzymes
  – Lower the $E_a$ of chemical reactions
  – Bring substrates into contact to react

$E_a$ Lowering
• A LOWER barrier is easier/faster to get over
• A LOWER $E_a$ makes a reaction easier/faster

Figure 5.10
Energy of activation
Enzymes can function over and over again.

Controlling Metabolism: Feedback inhibition

**Enzyme inhibition**
- Occurs when an active enzyme is prevented from combining with its substrate
  - *Cyanide* binds to and inhibits enzymes (a poison!!)
  - *Penicillin* interferes with a bacterial enzyme which kills the bacteria

**Feedback inhibition**
- An end product of a pathway inhibits the 1st enzyme in the pathway
  - binds to site other than active site
  - Causes enzyme to change shape
    - End result???

![Figure 5.9 Feedback Inhibition (1 of 3)]

- Not enough produced!!
- Consequence?

![Figure 5.9 Feedback Inhibition (2 of 3)]

- Product builds up—cell doesn’t need more
- Product binds to enzyme and changes its shape
- Consequences??

![Figure 5.9 Feedback Inhibition (3 of 3)]

- Now substrate can’t bind to enzyme
  - Consequences??
- When product gets low, enzyme will go back to original shape.
  - Consequences??
5.4 Cell Transport

- Plasma membrane regulates traffic in and out of cell.
- Selectively permeable
  - some substances pass freely, some prohibited
- 3 ways to enter
  - Passive transport
    - Substances move from higher to lower concentration
    - No additional energy required.
  - Active transport
    - Substances move from lower to higher concentration,
    - Requires additional energy (ATP)
  - Bulk transport
    - movement independent of gradient; additional energy required.

Passive Transport

- Molecules move down their concentration gradient until equilibrium is reached
- Cell does not expend additional energy – molecules already in motion
- Some molecules slip between phospholipids
- Facilitated diffusion – others use transport protein specific to molecule
- Water uses aquaporins – explains faster than expected transport rate

Simulation of Random Molecular Motion

BioFlix: Membrane Transport

BioFlix:  Membrane Transport

Another kind of inhibitor

Competitive Inhibitors

- Attach to active site of enzyme
- A molecular “imposter”
- Block access to active site
- Mechanism of many drugs

Enzyme & substrate binding normally

Enzyme inhibition by substrate impostor

Negative Feedback Inhibition: Allosteric Inhibition

- Inhibitor binds to a site away from the active site
Figure 5.11 Simple diffusion demonstration

- Net movement of dye is to the left side of membrane
- At equilibrium, dye equal on both sides of membrane and net movement stops
- Solution – contains solute (dye or other substance) and solvent (water)

Osmosis and Water Balance in Cells

- Osmosis is the passive transport of water across a selectively permeable membrane.
- Water moves from a ....
  a) Hypertonic to a hypotonic solution.
  b) Hypotonic to a hypertonic solution.
  c) Hypotonic to an isotonic solution.
  d) Hypertonic to an isotonic solution.
  e) I really don’t know!

Osmosis: Important terms to remember!

- A hypertonic solution
  - Has a higher concentration of solute.
  - Therefore has a ________ concentration of H₂O

- A hypotonic solution
  - Has a lower concentration of solute.
  - Therefore has a ________ concentration of H₂O

- An isotonic solution
  - Has an equal concentration of solute.
  - Therefore has a ________ concentration of H₂O
Osmosis and Water Balance in Cells

- Osmosis is the passive transport of water across a selectively permeable membrane.
- Water moves from a ....
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  e) I really don’t know!

Osmosis—the diffusion of water!

Key Questions
1. Which solution is hypertonic? Which one is hypotonic?
2. What will happen to the water levels?
3. In which direction will the sugar molecules diffuse?

Water Balance in Animal vs. Plant Cells—why the different?

- The ability to balance water loss and water uptake is vital to life!

Osmoregulation in Plant Cells

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

Plasmolysis

Turgid Elodea

Cells in an Isotonic Solution

- Cell neither gains or loses water
- Concentration of water and solute the same on both sides of the membrane
- 0.9% saline isotonic to red blood cells
  - What’s the % H_2O of the solution?
Cells in a Hypotonic Solution
- Concentration of water outside cell ____?____ than inside cell
- Cell ____?____ water
- Animal cells may lyse or burst
- Plant cells use this to remain turgid

Cells in a Hypertonic Solution
- Concentration of water outside cell is ____?____ than inside cell
- Cell ____?____ water
- Animal cells shrink (crenate)
- Plant cells undergo plasmolysis and may wilt

Active Transport—Pumping Molecules Across Membranes
- Cells expend energy to move molecules against their concentration gradient
- Requires transport protein and ATP
- Sodium-potassium pump important in maintaining gradient of ions used in nerve impulse conduction

Bulk Transport—Movement of Large Molecules
- Macromolecules are too large to be moved by transport proteins
- Vesicles takes them in or out of cell
- Exocytosis
  - Vesicles secrete substances outside of the cell
- Endocytosis
  - Movement of substances into a cell

Endocytosis
- Phagocytosis—“cell eating”
  - cell surrounds, engulfs and digests particle.
  - e.g. ??
- Pinocytosis—“cell drinking”
  - vesicle form around liquid or small particles
- Receptor-mediated endocytosis
  - triggered by the binding of external molecules to membrane proteins
  - selective and more efficient
Endocytosis

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

Phagocytosis in Amoeba

- Triggered by the binding of external molecules to membrane proteins.

Receptor-mediated Endocytosis

- Removal of cholesterol from the blood by Low Density Lipoprotein Particle (LDL).
Concept Check

This diagram represents osmosis of water across a semipermeable membrane. The U-tube on the right shows the results of the osmosis. What could you do to level the solutions in the two sides of the right hand U-tube?

a. Add more water to the left hand side.
b. Add more water to the right hand side.
c. Add more solute to the left hand side.
d. Add more solute to the right hand side.

Membranes organize cell activities. The proteins imbedded in the membranes are essential to their function. These membrane proteins have properties that allow them to “float” in the membrane. Which of the following describe those properties?

a. The surface region of the protein in the interior of the membrane is mostly hydrophobic.
b. The surface region of the protein in the interior of the membrane is mostly hydrophilic.
c. The surface region exposed to the outer environment is hydrophobic.
d. The surface region exposed to the interior environment is hydrophobic.

Enzymes catalyze the many reactions in a cell. There are hundreds of different enzymes in a cell—each with a unique three-dimensional shape. Why do cells have so many different enzymes?

a. Each enzyme molecule can only be used once.
b. The shape of enzyme’s active site generally fits a specific substrate.
c. The substrate molecules react with enzymes to create new enzymes.
d. Enzymes are randomly produced. With thousands of different shapes—one is likely to work.

In order to start a reaction a certain amount of energy must be absorbed by the reactants. This is called the energy of activation. Which of the following is the normal energy of activation?

a. A.  

Which of the following represents the energy of activation that is modified by an enzyme?

a. A.  

Many insecticides operate as permanent enzyme inhibitors. Organo-phosphate insecticides interfere with nerve transmission, affecting not only insects but also humans and other vertebrates. Use of such insecticides is carefully regulated and requires caution. Is an unblemished and low cost food supply worth the risk of the pesticide use?

Strongly  

Agree  

B.  

C.  

D.  

E.  

Strongly  

Disagree
Many insecticides operate as permanent enzyme inhibitors. Organophosphate insecticides interfere with nerve transmission, affecting not only insects but also humans and other vertebrates. Use of such insecticides is carefully regulated and requires caution. Would you be willing to pay a little more for slightly blemished but otherwise healthy food products—especially if pesticides were not used?

Strongly Agree A. B. C. D. E. Strongly Disagree

Do you think that regulation in the insecticide industry is appropriate?

Strongly Agree A. B. C. D. E. Strongly Disagree