Slide 1

Energy

Dr. Michelle Palmisano

Slide 2

Energy is Central to Life

- All living things require energy.
- The sun is a source of energy.
- Photosynthesizing agents (plants) capture the sun's energy.
- Transform light energy into food.
  - An energy source animals can use.

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Slide 3

The Nature of Energy

- Energy
  - the capacity to bring about movement against an opposing force
- Types of Energy
  - **Potential energy**
  - **Kinetic energy**
  - **Chemical energy**
  - **Thermal energy**

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Thermodynamics

- Thermodynamics
  - The study of energy
  - (Really saying the study of temperature and pressure in a system)
- The laws of thermodynamics are fundamental principles of energy.

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Thermodynamics

- The First Principle of Thermodynamics
  - Energy can neither be created nor destroyed
- The Second Principle of Thermodynamics
  - Systems tend to move from a higher energy state to a lower energy state

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Transformations of Energy

- Since energy cannot be created nor destroyed
  - First principle
- And, systems tend toward lower energy states
  - Second principle
- Then, where did the 'excess' energy go when a reaction proceeds from higher energy to lower energy?

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Transformations of Energy

- Typically the energy is transformed into heat
- We say, the energy is '*lost'* as heat
- Heat can be used to warm up something, but cannot spontaneously reform into potential, chemical or kinetic energy (more ordered energy states)…so it is lost
- Example: car engine, only part of the energy released by the combustion of gasoline actually helps propel the car; the rest of the energy released in the combustion is lost to heat. Cars are only 25% efficient.

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Transformations of Energy

- Entropy
- Measure of disorder in a system
- Second Principle means energy is:
- Tending toward *disorder*
  - Things having higher energy are more ordered than those having lower energy

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Transformations of Energy

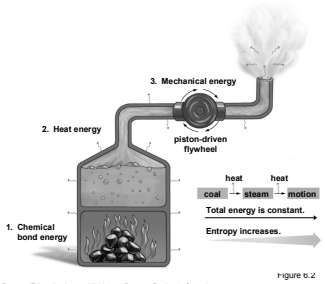

Figure 6.2

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Slide 10

How is Energy Used by Living Things?

- Living things can bring about local increases in order (in themselves) through their metabolic processes.
- If things increase in order, does it require energy?
- Yes, if things are *increasing* in order, then energy must be put into the system (second principle of thermodynamics).
- Metabolic processes require energy.

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Macromolecular Synthesis

- Living things build up more-ordered molecules (starches, proteins) from less ordered molecules (simple sugars, amino acids).
- However, it takes energy to do this.

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Endergonic and Exergonic Reactions

- Endergonic reactions (uphill reactions)
  - the products of the reaction contain more energy than the starting substances (or reactants).
- **Exergonic** reactions (downhill reactions)
  - the reactants contain more energy than the products.
  - Spontaneous reactions are exergonic reactions

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Endergonic and Exergonic Reactions

- From simple sugars to a complex carbohydrate
  - is an endergonic reaction.
- Such a reaction will not occur without an **input of energy**.

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Endergonic and Exergonic Reactions

- Breakdown of a complex carbohydrate into simple sugars
  - is an exergonic reaction.
- Such a reaction **releases energy**.

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Energy Stored and Released

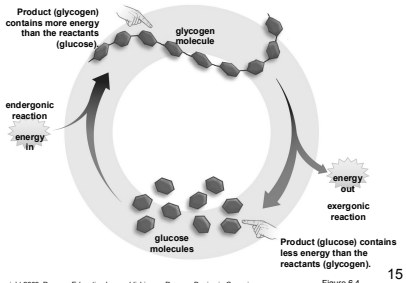

Figure 6.4

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Endergonic and Exergonic Reactions

- **Coupled reactions**
- Reactions in which an energy yielding exergonic reaction powers an energy-requiring endergonic reaction.
- This is how metabolic processes are able to proceed.

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ATP

- The molecule most often used in living things to power coupled reactions is ATP.
- Adenosine triphosphate (ATP) is the most important energy transfer molecule in living things.

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Slide 18

ATP

- Coupled reaction:
- Food transferred to ATP
- Energy (ATP) is used to power cellular processes
  - Examples:
  - pump molecules across plasma membrane against their concentration gradient,
  - cause muscle cells to contract,
  - cause nerve cells to transmit electrical signals

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ATP

- ATP's structure
- Nucleotide: adenine(base),sugar, phosphate
- And, 2 more phosphates
- = **A**denosine **T**ri**p**hosphate (ATP)
- Phosphate groups are negatively charged
  - They repel each other
- Energy is stored in the binding of phosphates with one another

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The ATP/ADP Cycle

- ATP drives chemical reactions by donating its third phosphate group to them.
- In the process, it becomes the two-phosphate molecule adenosine diphosphate (ADP).

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The ATP/ADP Cycle

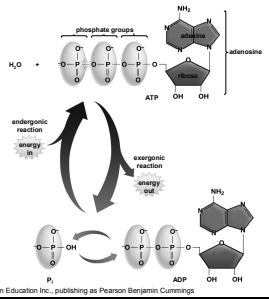

Figure 6.6

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The ATP/ADP Cycle

- To again become ATP, it must have a third phosphate group attached to it.
- This shuttling back and forth between ATP and ADP takes place constantly in living things.

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Slide 23

Efficient Energy Use in Living Things: Enzymes

- Complex carbohydrates to simple carbohydrates: releases energy
- Spontaneous reaction (according to second principle of thermodynamics)
- And, it will proceed, but this reaction takes too much time for living things
- Need Enzymes
- Protein
- Speeds up reaction times

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Enzymes

- Nearly every chemical process that takes place in living things is facilitated by an **enzyme**.
- For example, the enzyme lactase facilitates the splitting of the sugar lactose into its component sugars, glucose and galactose.

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Enzymes

- The substance that an enzyme helps transform through chemical reaction is called its **substrate**.
- Lactose is the substrate of the enzyme lactase.
- Enzymes generally end with –ase
- There are thousands of enzymes specialized for thousands of different reactions

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Enzymes

- Can develop into complex metabolic pathways
  - Series of reactions in sequence
- The product of one reaction becomes the substrate for the next

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Enzyme Action

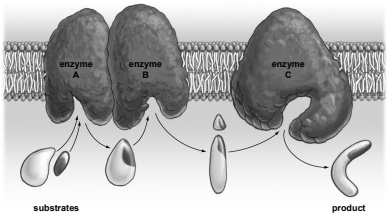

Figure 6.8 27

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Metabolism and Enzymes

- Metabolism
  - Sum of all chemical reactions that a cell or larger living thing carries out
- Enzymes are a major part of metabolism in all living things
- Enzymes speed up reactions in metabolic pathways, but how?

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Lowering the Activation Barrier through Enzymes

- Enzymes work by lowering **activation energy**
  - The energy required to initiate a chemical reaction.

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Enzymes Accelerate Chemical Reactions

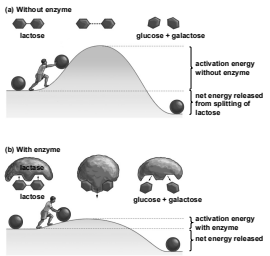

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Figure 6.9

Slide 31

Enzymes Accelerate Chemical Reactions

- Enzymes are catalysts.
- They bring about a change in their substrates without being chemically altered themselves.

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Enzymes Accelerate Chemical Reactions

- Enzyme shape
  - Generally, globular or ball-like proteins whose shape includes a pocket into which the enzyme's substrate fits.
- This pocket is the **active site**
- Portion of an enzyme that binds with a substrate, thus helping transform it.

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Substrate Binding

Glucose molecule binding to active site of hexokinase enzyme.

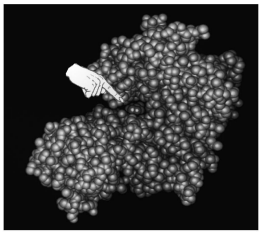

Figure 6.10 33

Slide 34

Substrate Binding

- Enzymes made up of hundreds of amino acids
- Only a few amino acids are the active site
- To help enzymes: **coenzymes**
- Molecules other than amino acids that facilitate the work of enzymes by binding with them
- Examples are vitamins we get in our dietary intake

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Regulating Enzymatic Activity

- **How are enzymes controlled?**
- **Controlling Enzymes:**
- **Competitive inhibition**
- Reduction in the activity of an enzyme
- Some compound binds at active site, thus 'blocking' active site from substrate

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Regulating Enzymatic Activity

- **Controlling Enzymes:**
- **Allosteric regulation**
- a molecule binds with the enzyme at a site other than its active site
- Such binding changes the enzyme's shape, thereby decreasing or increasing the enzyme's ability to bind with its substrate.

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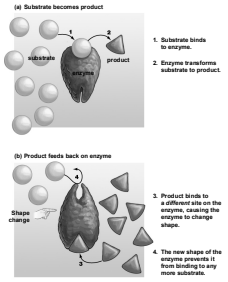
Allosteric Regulation



1. Substrate binds to enzyme.
2. Enzyme transforms substrate to product.
3. Product binds to a *different* site on the enzyme, causing the enzyme to change shape.
4. The new shape of the enzyme prevents it from binding to any more substrate.

Figure 6.12 37

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Regulating Enzymatic Activity

- **Controlling Enzymes**:
- Without regulation, enzymes would continue to turn out products as long as substrate is present.
- Could produce buildup of metabolic material that is unnecessary or harmful.
- With regulation, cells can finely tune enzymatic activity in accordance with cellular needs.

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