

## Thermodynamics

- **First Law**—total amount of energy within a system remains constant, energy cannot be created or destroyed
- **Second Law**—degree of disorder in a system increases

## Energy in a Cell

- Total amount of energy within a system is conserved (Law #1) [energy released from glucose (**energy rich**) is converted to carbon dioxide (**energy poor**), water and heat]
- $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{heat}$

**Light energy --> Chemical energy (glucose)**

**Chemical energy --> Chemical energy (ATP, NADH)**

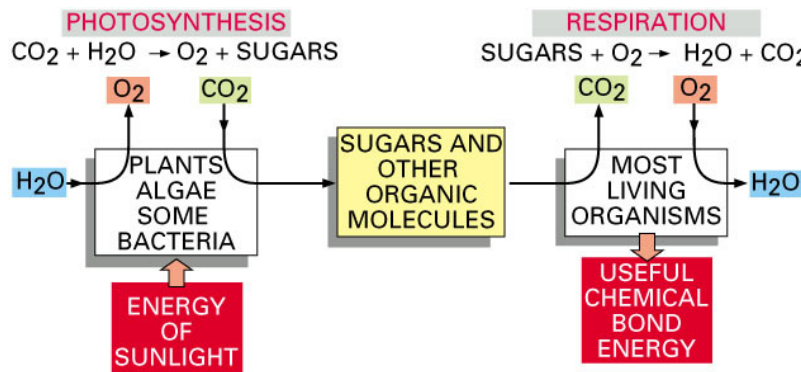


Figure 2-41. Molecular Biology of the Cell, 4th Edition.

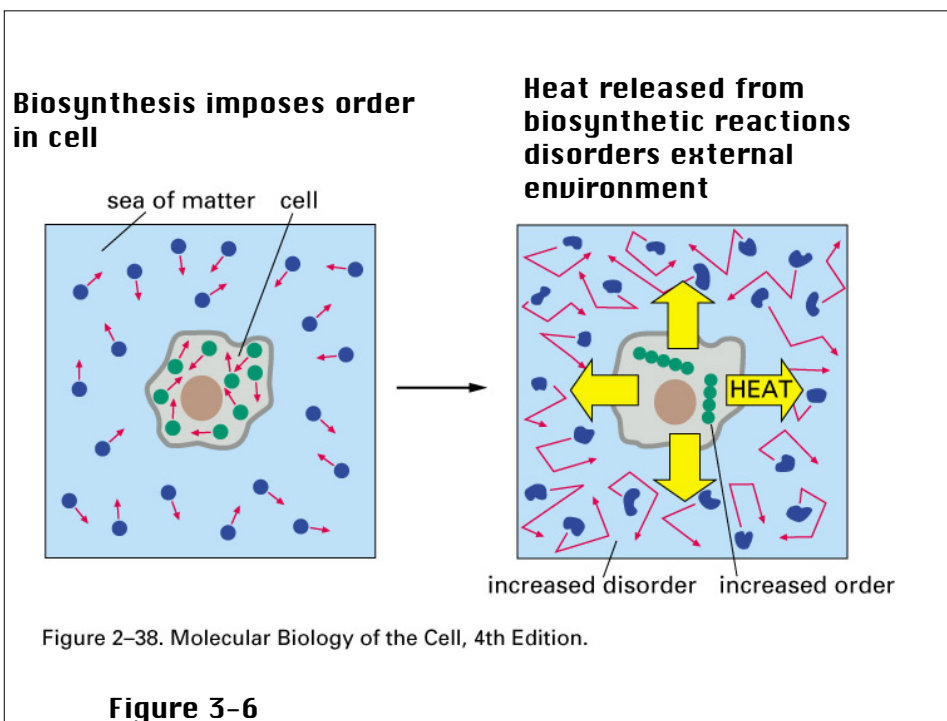
**Figure 3.10**

## **Second Law of Thermodynamics**

**Degree of disorder in a system increases**

## How Cells follow 2nd Law of Thermodynamics

- Synthesis of proteins, carbohydrates, lipids, nucleic acids imposes order
- Cells release heat during these processes which disorders their environment
- Entropy increases around cell, 2nd Law of Thermodynamics is satisfied

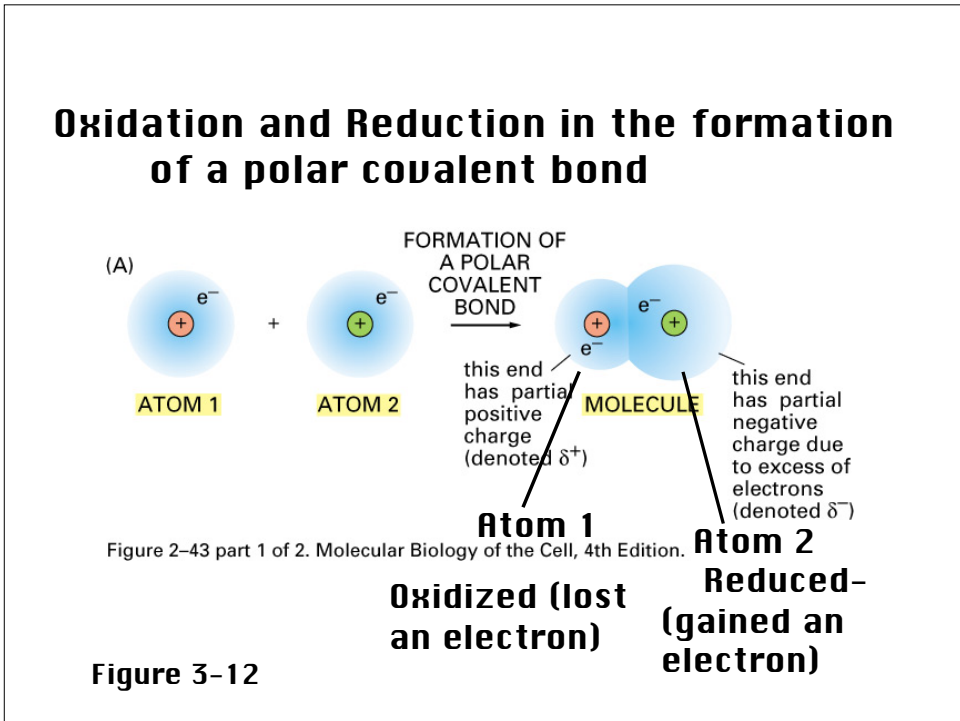
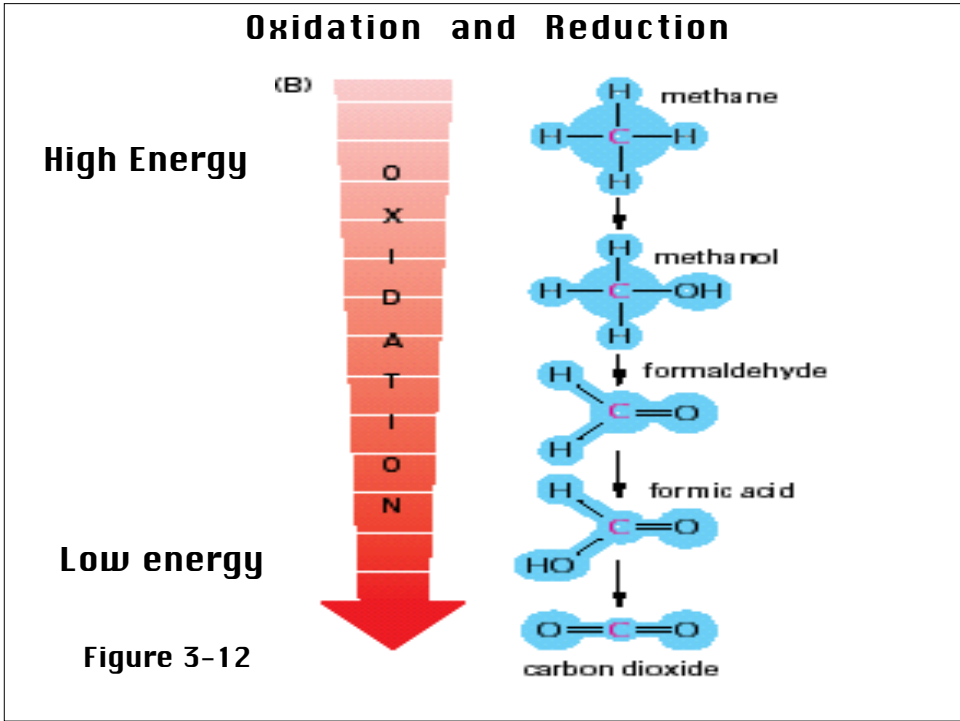


## **Chemical reactions**

- **1. (Chemical) reaction will proceed spontaneously to a state of minimal energy**
- **2. (Chemical) reaction will proceed spontaneously so that there is more disorder(increase in entropy) in the system**

## **What cells do with energy rich compounds**

- **Break down glucose in little steps**
- **Lose electrons (loss of Hydrogen H<sup>+</sup> plus one electron) OXIDATION**
- **H-C-H---> H-C-OH--->H-C=O**
- **Take high energy compound (glucose) and convert to low energy compounds (carbon dioxide and water) in series of steps**
- **Compounds in the cell that receive or gain electrons are REDUCED.**



## **Oxidation and Reduction in the formation of covalent bonds**

**(For organic molecules, follow the hydrogens,  
Reduction increases the number of C-H bonds  
Oxidation decreases the number of C-H bonds)**



**Glucose is oxidized (loses H's) when it is converted to carbon dioxide**

**Oxygen is reduced (gains H's) when it is converted to water**

## **Energetically favorable and unfavorable reactions**

- Favored; free energy of products is lower than the free energy of reactants**

$$\Delta G = G_p - G_r, \text{ is negative}$$

- Unfavorable- free energy of products is higher than the free energy of reactants**

$$\Delta G = G_p - G_r, \text{ is positive}$$

## How does the cell run energetically unfavorable reactions?

- Couples energetically unfavorable reaction to an energetically favorable reaction
- Glutamic acid  $\rightarrow$  glutamine  $\Delta G$  is +
- ATP  $\rightarrow$  ADP + Pi  $\Delta G$  is -
- Coupling of these two reactions occurs on active site of enzyme

Activated carriers (such as ATP) are used by the cell to couple chemical reactions

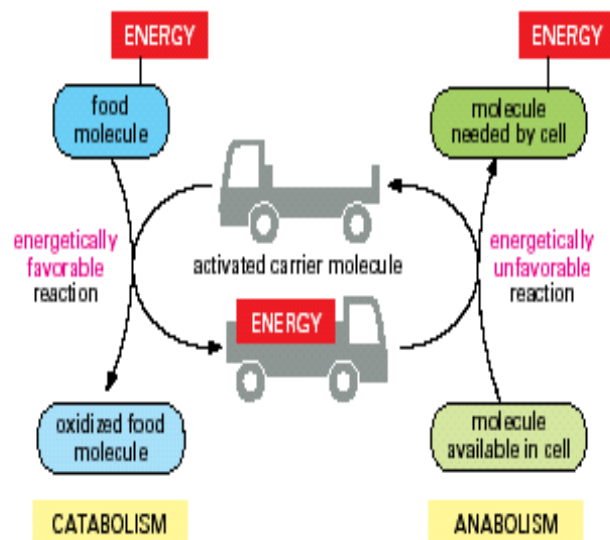
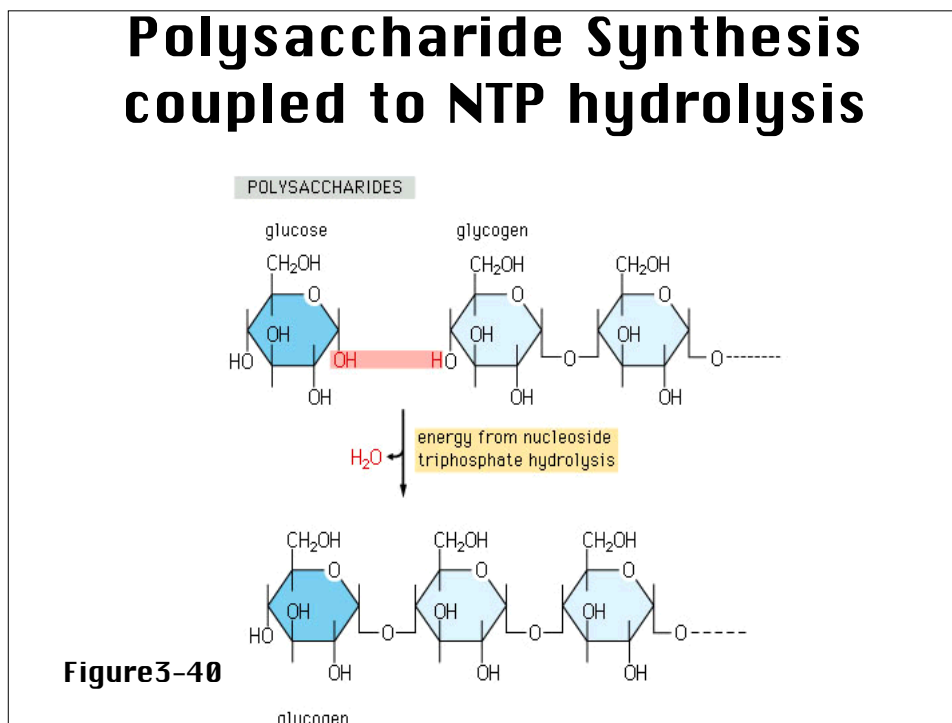
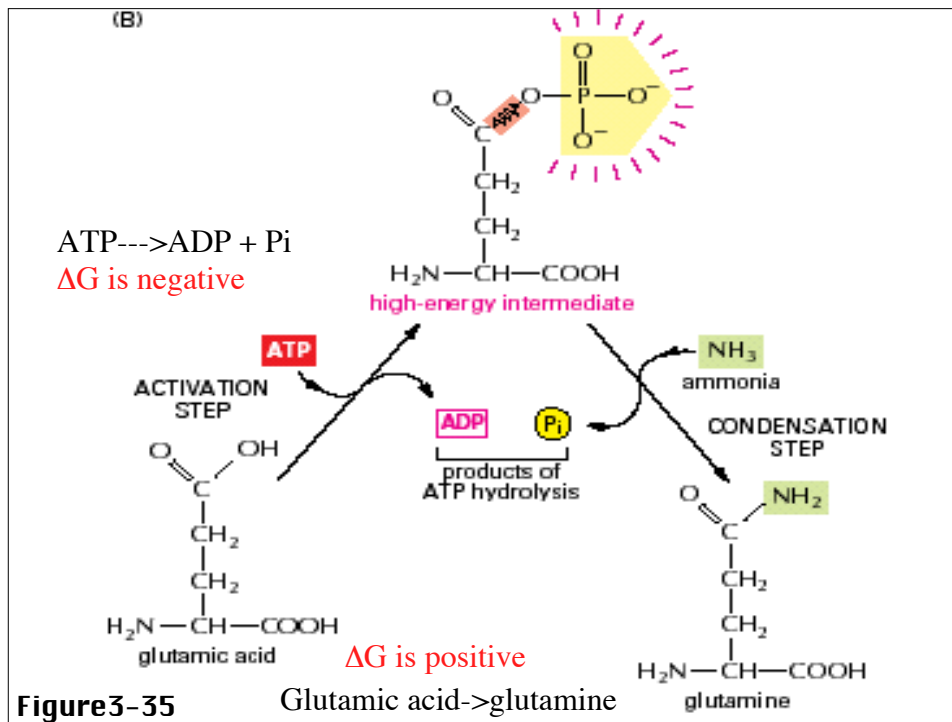


Figure 3-30



# Protein Synthesis coupled to NTP hydrolysis ( $\text{NTP} \rightarrow \text{NDP} + \text{Pi}$ ) (N=A/G)

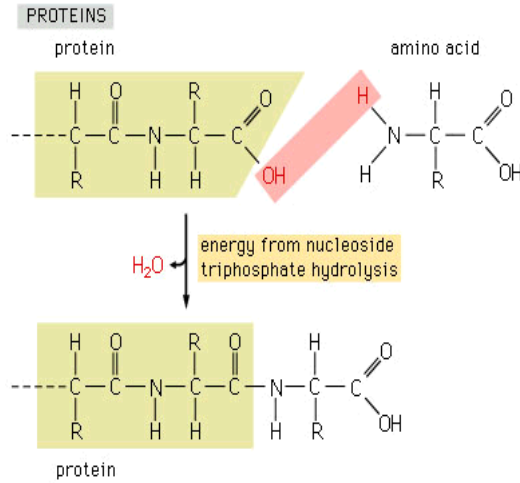


Figure3-40

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# Nucleic Acid Synthesis coupled to NTP hydrolysis ( $\text{NTP} \rightarrow \text{NMP} + \text{PPi}$ )

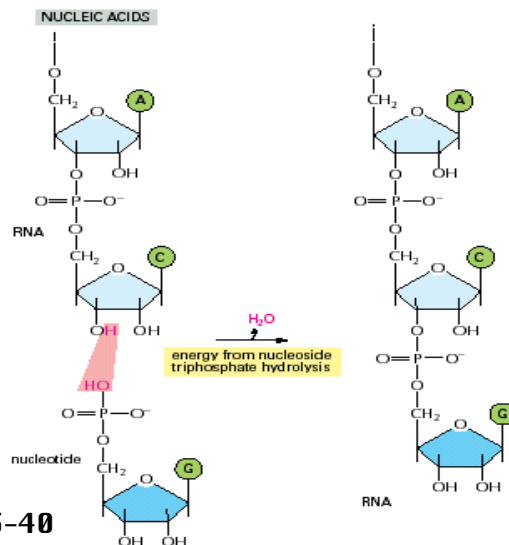


Figure3-40