CHAPTER 14

[redacted] METABOLISM

<u>Metabolism</u>- The sum of all the chemical transformations taking place in a cell or organism

Metabolism occurs through a series of enzyme-catalyzed reactions that constitute <u>metabolic pathways</u>

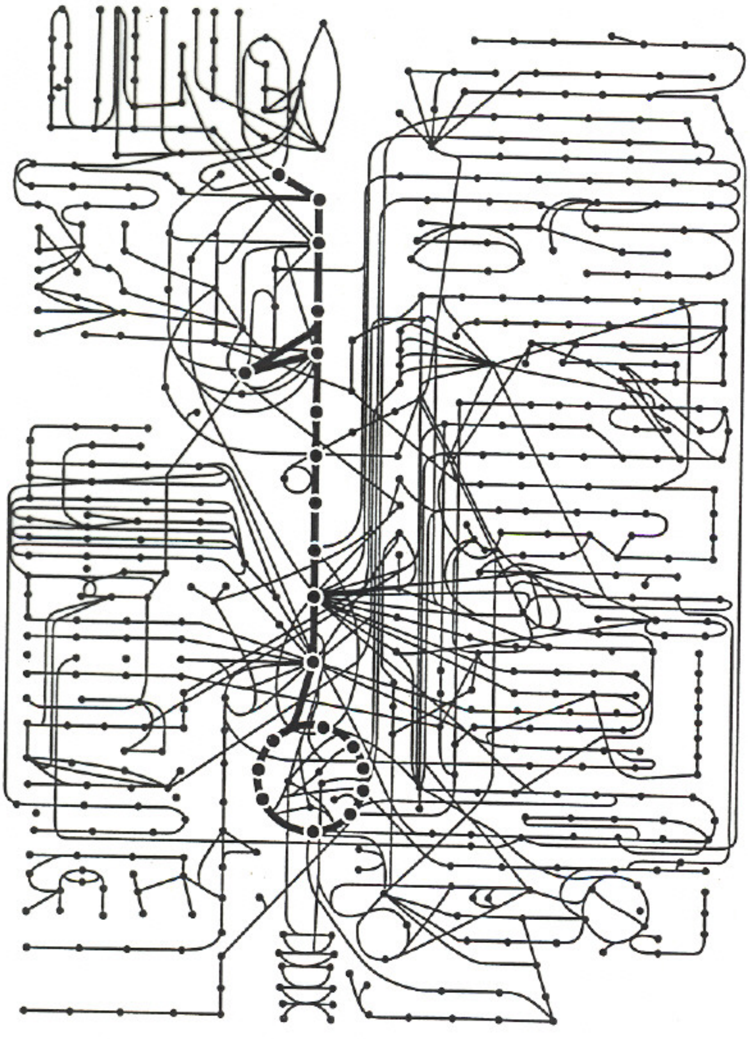


Figure 14.1 The metabolic map as a set of dots and lines. The heavy dots and lines trace the central energy-releasing pathways known as glycolysis and the citric acid cycle. *(Adapted from Alberts, B., et al., 1989.* Molecular Biology of the Cell, *2nd ed. New York: Garland Publishing Co.)*

Metabolism is a highly coordinated activity in which many metabolic pathways cooperate to accomplish four functions:

1) **Obtain chemical energy by capturing solar energy or degrading energy- rich nutrients from the environment**

2) **Convert nutrient molecules into the cell's own characteristic molecules, including precursors of macromolecules**

3) **Polymerize monomeric precursors into macromolecules: proteins, nucleic acids, and polysaccharides**

4) **Synthesize and degrade biomolecules required in specialized cellular functions, such as membrane lipids, intracellular messengers, and pigments**

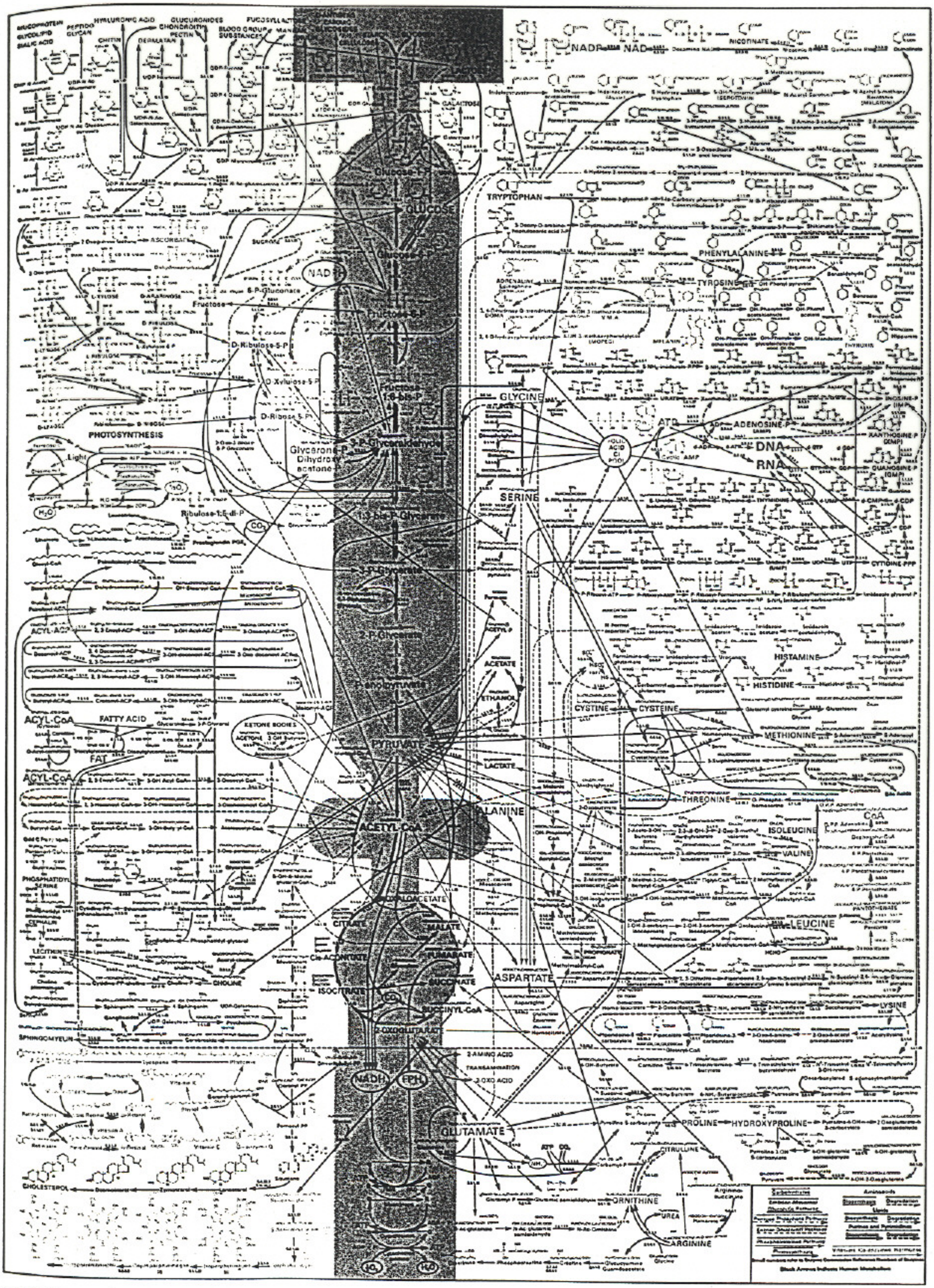


FIGURE 15-1. A map of the major metabolic pathways in a typical cell. The main pathways of glucose metabolism are shaded. [Designed by D. E. Nicholson. Published by BDH Ltd., Poole 2, Dorset, England.]

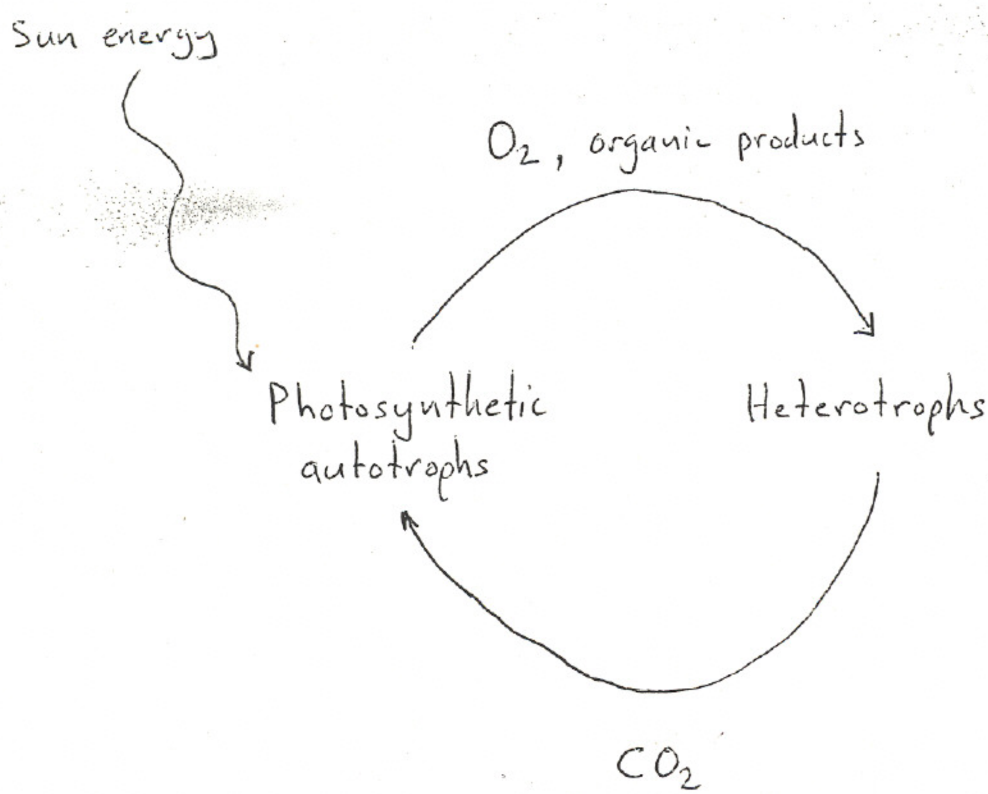
Living organisms can be divided into two large groups according to the chemical form in which they obtain carbon from the environment:

1) **<u>Autotrophs [redacted]:</u> Use CO_2 from the atmosphere as their sole source of carbon.**

   (Ex. Plants, Photosynthetic bacteria)

2) **<u>Heterotrophs [redacted]:</u> Obtain carbon from their environment in the form of relative complex organic molecules, such as glucose**

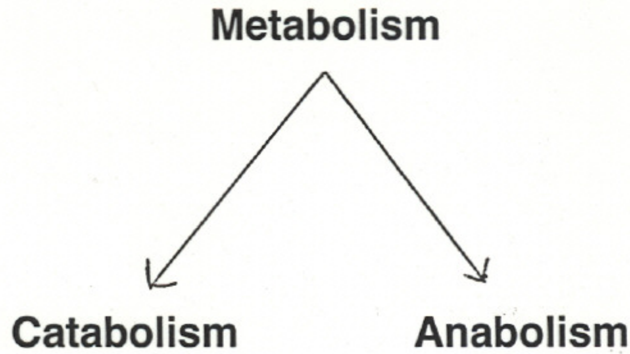
   (Ex. Animals, Most microorganisms)



Phototrophs - Chemotrophs

Table 14.2 Metabolic Classification of Organisms According to Their Carbon and Energy Requirements

Classification	Carbon Source	Energy Source	Electron Donors	Examples
Photoautotrophs	CO_2	Light	H_2O, H_2S, S, other inorganic compounds	Green plants, algae, cyanobacteria, photosynthetic bacteria
Photoheterotrophs	Organic compounds	Light	Organic compounds	Nonsulfur purple bacteria
Chemoautotrophs	CO_2	Oxidation-reduction reactions	Inorganic compounds: H_2, H_2S, NH_4^+, NO_2^-, Fe^{2+}, Mn^{2+}	Nitrifying bacteria; hydrogen, sulfur, and iron bacteria
Chemoheterotrophs	Organic compounds	Oxidation-reduction reactions	Organic compounds, e.g., glucose	All animals, most microorganisms, nonphotosynthetic plant tissue such as roots, photosynthetic cells in the dark



Catabolism: The degradation phase of metabolism in which organic nutrient molecules are converted into smaller and simpler end products

- It releases energy and heat

Anabolism (biosynthesis): Small, simple precursors are built up into large and more complex molecules, including lipids, polysaccharides, proteins, nucleic acids.

- It requires an input of energy

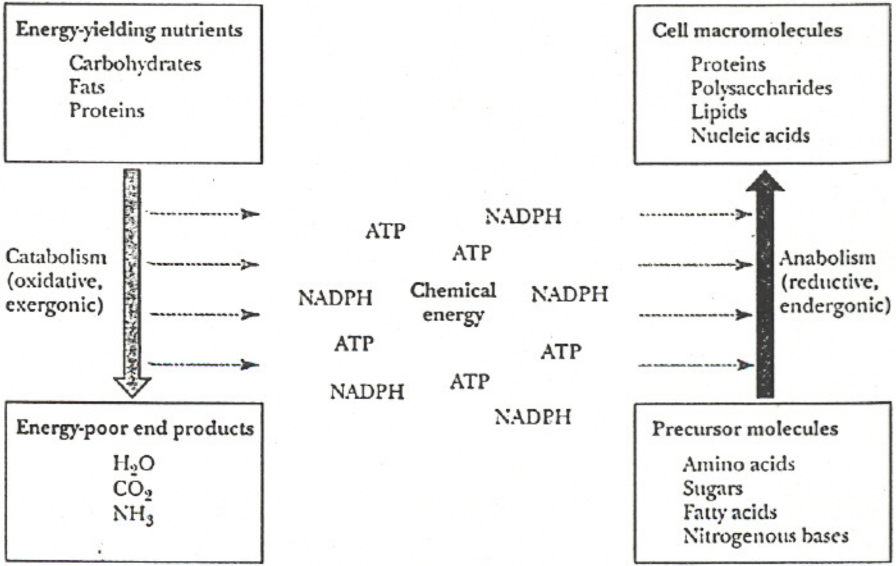


Figure 14.3 Energy relationships between the pathways of catabolism and anabolism. Oxidative, exergonic pathways of catabolism release free energy and reducing power that are captured in the form of ATP and NADPH, respectively. Anabolic processes are endergonic, consuming chemical energy in the form of ATP and using NADPH as a source of high-energy electrons for reductive purposes.

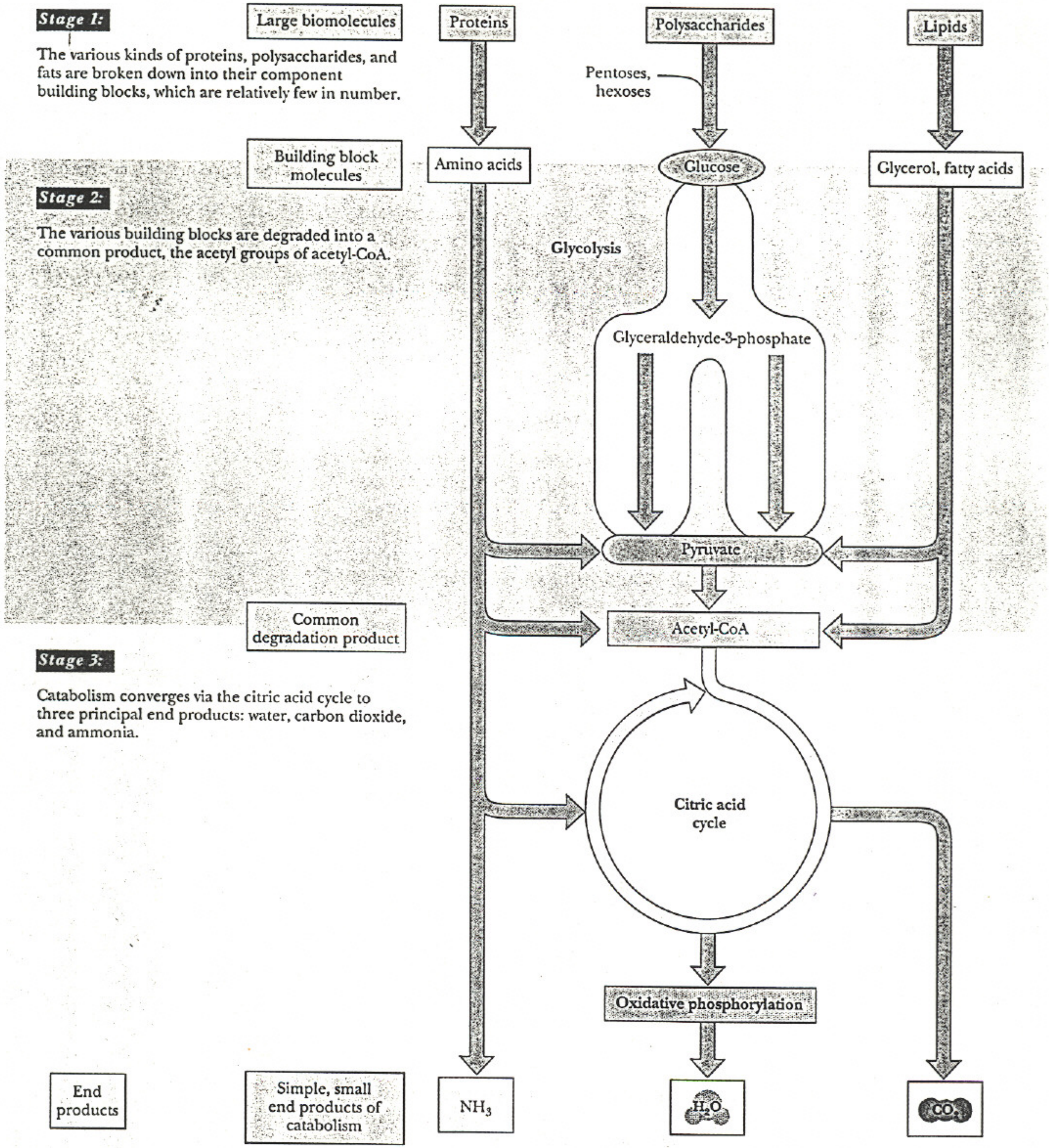


Figure 14.5 The three stages of catabolism. **Stage 1:** Proteins, polysaccharides, and lipids are broken down into their component building blocks, which are relatively few in number. **Stage 2:** The various building blocks are degraded into the common product, the acetyl groups of acetyl-CoA. **Stage 3:** Catabolism converges to three principal end products: water, carbon dioxide, and ammonia.

Table 13-1. **Metabolic Functions of Eukaryotic Organelles**

Organelle	*Function*
Mitochondrion	Citric acid cycle, oxidative phosphorylation, fatty acid oxidation, amino acid breakdown
Cytosol	Glycolysis, pentose phosphate pathway, fatty acid biosynthesis, many reactions of gluconeogenesis
Lysosomes	Enzymatic digestion of cell components and ingested matter
Nucleus	DNA replication and transcription, RNA processing
Golgi apparatus	Posttranslational processing of membrane and secretory proteins; formation of plasma membrane and secretory vesicles
Rough endoplasmic reticulum	Synthesis of membrane-bound and secretory proteins
Smooth endoplasmic reticulum	Lipid and steroid biosynthesis
Peroxisomes (glyoxysomes in plants)	Oxidative reactions catalyzed by amino acid oxidases and catalase; glyoxylate cycle reactions in plants

REGULATION OF METABOLISM

In general, metabolism is regulated by controlling

1. The amounts of enzymes

2. Their catalytic activities

3. The accessibility of substrates

ATP: Adenosine Triphosphate

ATP is the free- energy donor in most energy requiring reactions

ATP consists of

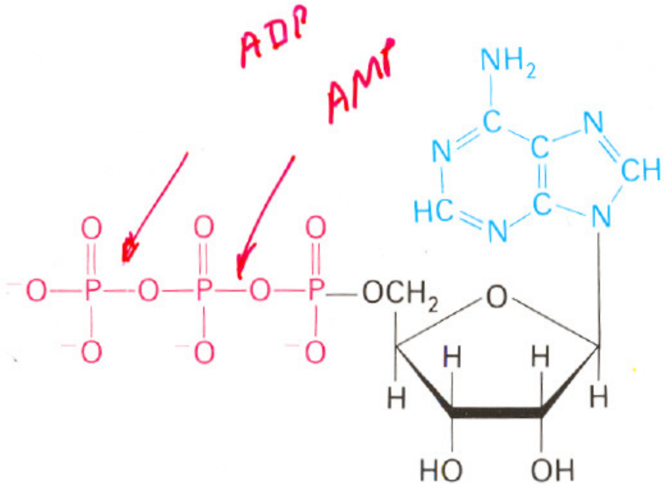
- **An Adenine (Nucleotide)**
- **A Ribose (Sugar)**
- **A Triphosphate Unit**

ATP is an energy- rich molecule because its triphosphate unit contains two phospoanhydride bonds

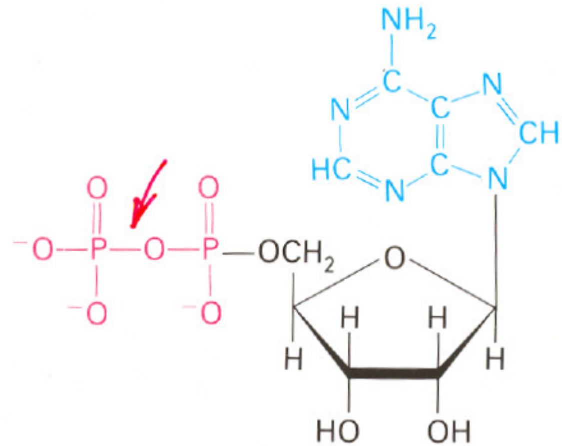
$ATP + H_2O \Leftrightarrow ADP + Pi + H^+$ $\Delta G^{\circ\prime} = -7.3$ kcal/ mol

$ATP + H_2O \Leftrightarrow AMP + Pi + H^+$ $\Delta G^{\circ\prime} = -7.3$ kcal/ mol

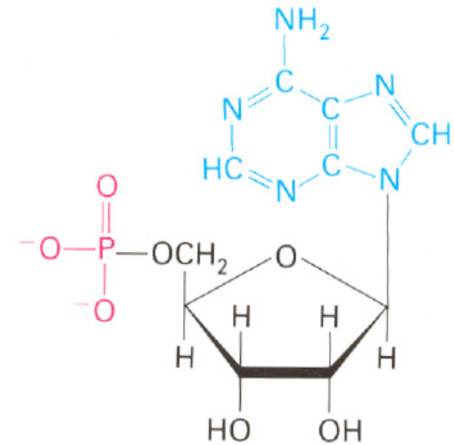
or (– 30.5 kj/ mol)



Adenosine triphosphate
(ATP)



Adenosine diphosphate
(ADP)



Adenosine monophosphate
(AMP)

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Stryer: *Biochemistry*, Fourth Edition

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Free energy (G): The component of the total energy of a system that can do work at constant temperature and pressure.

Free- energy change (ΔG): The amount of free energy released (negative ΔG) or absorbed (positive ΔG) in a reaction at constant temperature and pressure.

The ΔG of a reaction depends on:

1. The nature of the reactants

2. The concentration of the reactants

$\Delta G°'$: The standard free- energy change at pH 7

$$A+B \Leftrightarrow C+D$$

$$\Delta G = \Delta G° + RT \log_e \frac{[C]\,[D]}{[A]\,[B]}$$

R: the gas constant

T: the absolute temperature

$\Delta G°$: The standard free- energy change = the free energy change for a reaction under standard conditions (all reactants present at concentrations of 1.0 M)

The overall free- energy change for a chemically coupled series of reactions is equal to the sum of the free- energy changes of the individual steps

$A \Leftrightarrow B + D$	$\Delta G°' = +5$ kcal/ mol
$B \Leftrightarrow D$	$\Delta G°' = -8$ kcal/ mol
$A \Leftrightarrow C + D$	$\Delta G°' = -3$ kcal/ mol

A thermodynamically unfavorable reaction can be driven by a thermodynamically favorable reaction that is coupled to it.

(a)

				$\Delta G^{\circ\prime}$ (kJ • mol^{-1})
Endergonic half-reaction 1	P_i + glucose	$\rightleftharpoons$	glucose-6-P + H_2O	+13.8
Exergonic half-reaction 2	ATP + H_2O	$\rightleftharpoons$	ADP + P_i	–30.5
Overall coupled reaction	ATP + glucose	$\rightleftharpoons$	ADP + glucose-6-P	–16.7

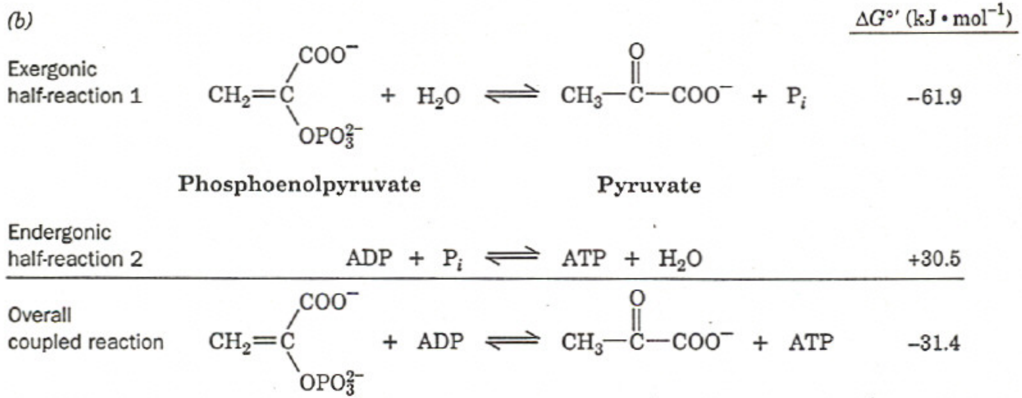
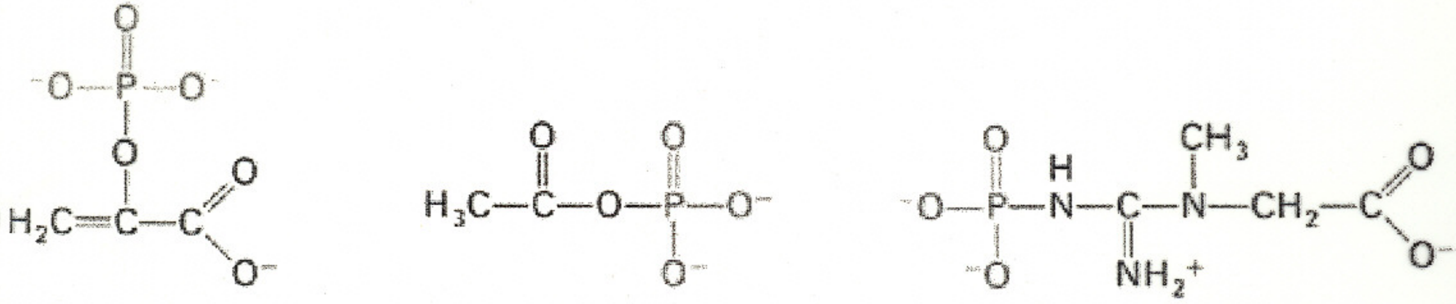


Figure 13-5. **Some coupled reactions involving ATP.** (*a*) The phosphorylation of glucose to form glucose-6-phosphate and ADP. (*b*) The phosphorylation of ADP by phosphoenolpyruvate to form ATP and pyruvate. Each reaction has been conceptually decomposed into a direct phosphorylation step (half-reaction 1) and a step in which ATP is hydrolyzed (half-reaction 2). Both half-reactions proceed in the direction that makes the overall reaction exergonic ($\Delta G < 0$).

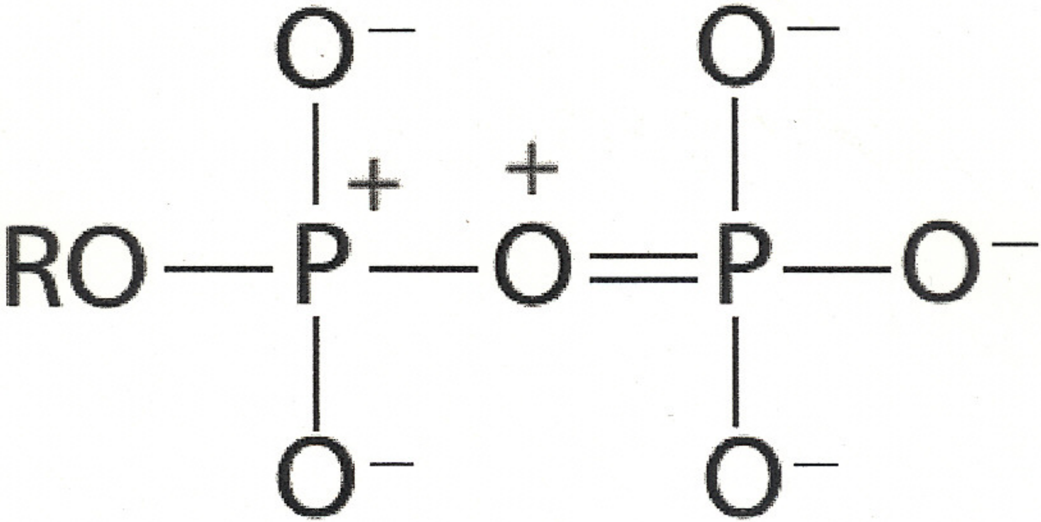
Structural basis of the high phosphoryl transfer potential of ATP:

- Electrostatic repulsion
- Resonance stabilization



Phosphoenolpyruvate **Acetyl phosphate** **Creatine phosphate**

Fig 17- 6



An improbable resonance form of the terminal portion of ATP

Fig 17- 5

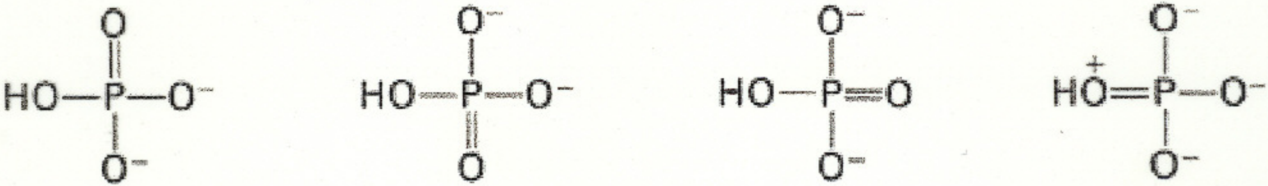
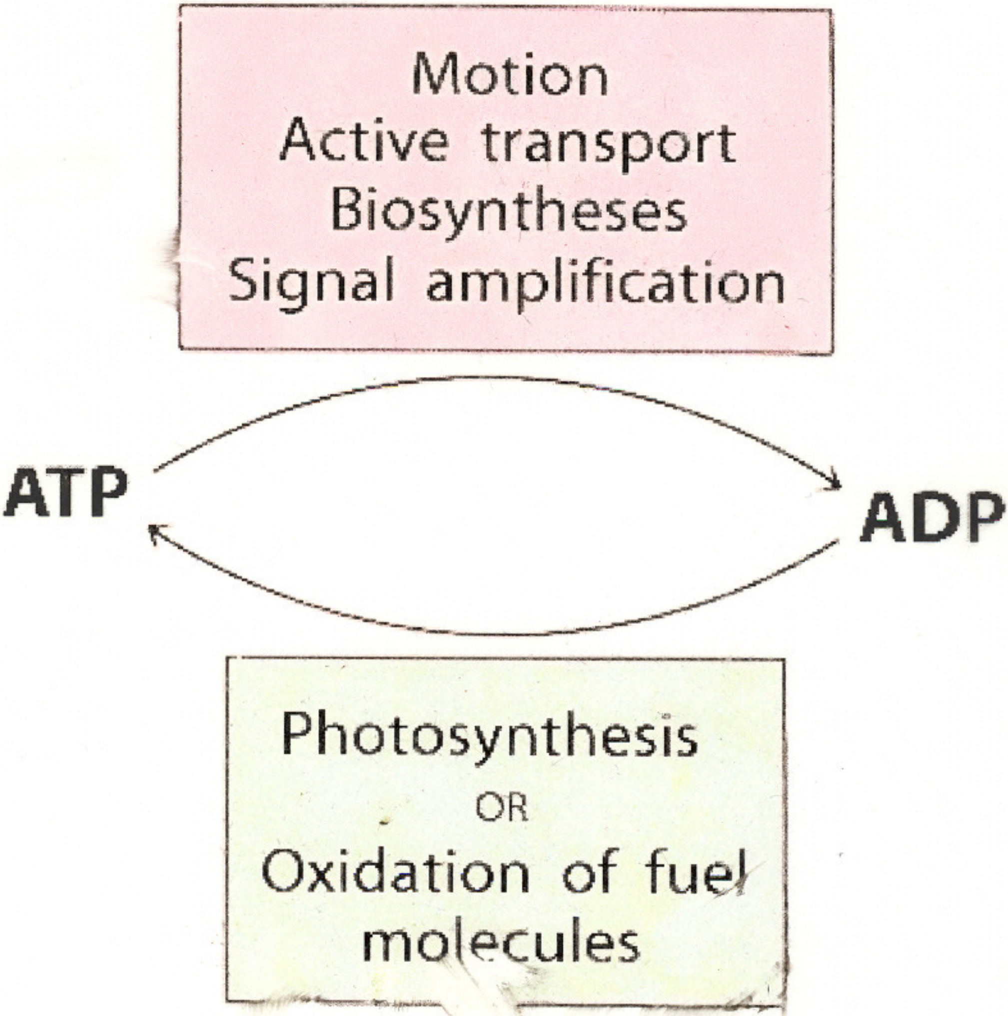


Fig 17- 4



The ATP-ADP cycle

Fig 17-3