Chapter 3

Bioenergetics

Objectives

1. Discuss the function of cell membrane, nucleus, and mitochondria.
2. Define the following terms: *endergonic reactions*, *exergonic reactions*, *coupled reactions*, and *bioenergetics*.
3. Describe the role of enzymes as catalysts in cellular chemical reactions.
4. List and discuss the nutrients that are used as fuels during exercise.
5. Identify the high-energy phosphates.

Objectives

6. Discuss the biochemical pathways involved in anaerobic ATP production.
7. Discuss the aerobic production of ATP.
8. Describe the general scheme used to regulate metabolic pathways involved in bioenergetics.
9. Discuss the interaction between aerobic and anaerobic ATP production during exercise.
10. Identify the enzymes that are considered rate limiting in glycolysis and the Krebs cycle.

Introduction

- Metabolism
- Bioenergetics

Cell Structure

- Cell membrane
- Nucleus
- Cytoplasm

A Typical Cell and Its Major Organelles

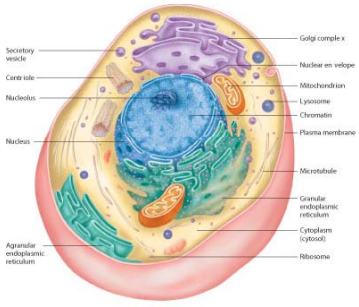

Figure 3.1

Steps Leading to Protein Synthesis

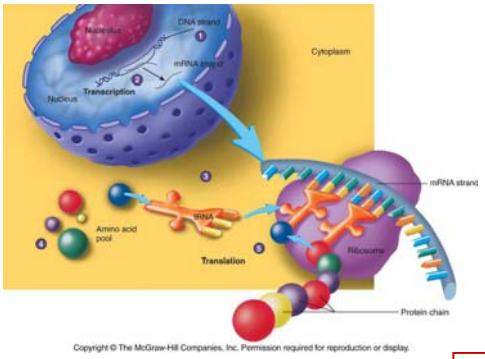

Figure 3.2

Cellular Chemical Reactions

- Endergonic reactions
- Exergonic reactions
- Coupled reactions

The Breakdown of Glucose: An Exergonic Reaction

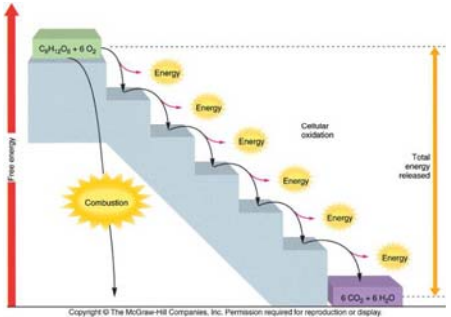

Figure 3.3

Coupled Reactions

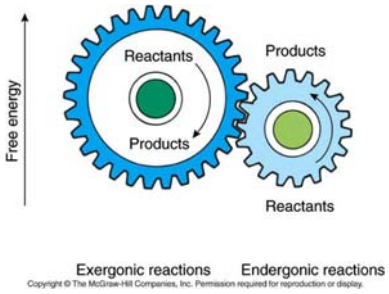

Figure 3.4

Oxidation-Reduction Reactions

- Oxidation
- Reduction

Oxidation-Reduction Reaction involving NAD and NADH

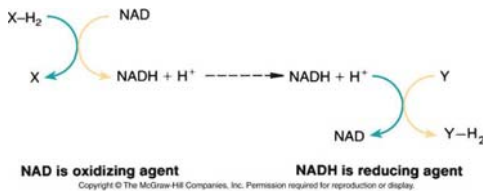

Figure 3.5

Enzymes

Enzymes Catalyze Reactions

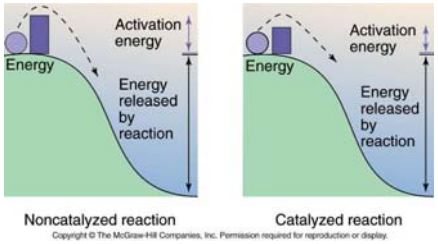

Figure 3.6

The Lock-and-Key Model of Enzyme Action

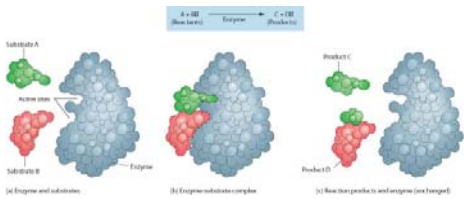

Figure 3.7

Diagnostic Value of Measuring Enzyme Activity in the Blood

Enzyme	Diseases Associated w/ High Blood Levels of Enzyme
Lactate dehydrogenase (Cardiac-specific isoform)	Myocardial infarction
Creatin kinase	Myocardial infarction, muscular dystrophy
Alkaline phosphatase	Carcinoma of bone, Paget's disease, obstructive jaundice
Amylase	Pancreatitis, perforated peptic ulcer
Aldolase	Muscular dystrophy

Table 3.1

Classification of Enzymes

- Oxidoreductases
  - Catalyze oxidation-reduction reactions
- Transferases
  - Transfer elements of one molecule to another
- Hydrolases
  - Cleave bonds by adding water
- Lyases
  - Groups of elements are removed to form a double bond or added to a double bond
- Isomerases
  - Rearrangement of the structure of molecules
- Ligases
  - Catalyze bond formation between substrate molecules

Example of the Major Classes of Enzymes

Enzyme Class	Example of Enzyme w/n this Class	Reaction Catalyzed
Oxidoreducatases	Lactate dehydrogenase	Lactate + NAD <-> Pyruvate + NADH + H
Transferases	Hexokinase	Glucose + ATP -> Glucose 6-phosphate + ADP
Hydrolases	Lipase	Triglyceride + 3 H_20 -> Glycerol + Fatty acids
Lyases	Carbonic anhydrase	Carbon dioxide + H_20 -> Carbonic acid
Isomerases	Phosphoglycerate mutase	3-Phosphoglycerate -> 2-Phosphoglycerate
Ligases	Pyruvate carboxylase	Pyruvate + $HC0_3$ + ATP -> Oxaloacetate + ADP

Table 3.2

Factors That Alter Enzyme Activity

Effect of Body Temperature on Enzyme Activity

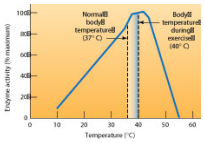

Figure 3.8

Effect of pH on Enzyme Activity

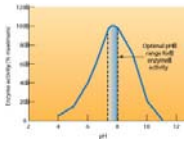

Figure 3.9

Fuels for Exercise

High-Energy Phosphates

Structure of ATP

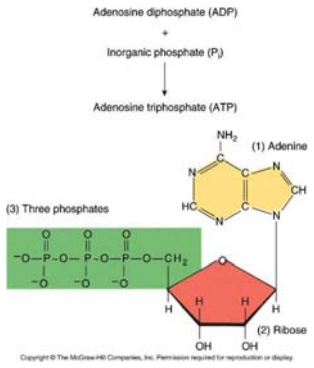

Figure 3.10

Model of ATP as the Universal Energy Donor

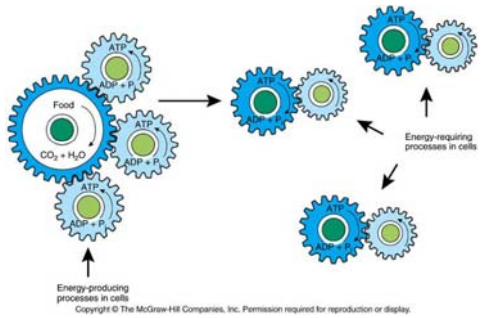

Figure 3.11

Bioenergetics

- Formation of ATP
- Anaerobic pathways
- Aerobic pathways

Anaerobic ATP Production

The 2 Phases of Glycolysis

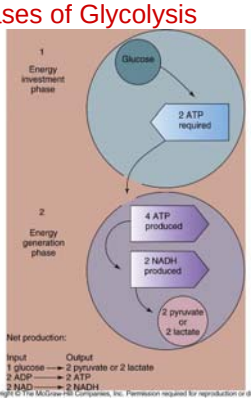

Figure 3.12

Interaction b/n Bld Glucose & Muscle Glycogen in Glycolysis

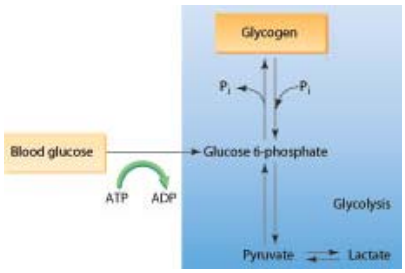

Figure 3.14

Glycolysis: Energy Investment Phase

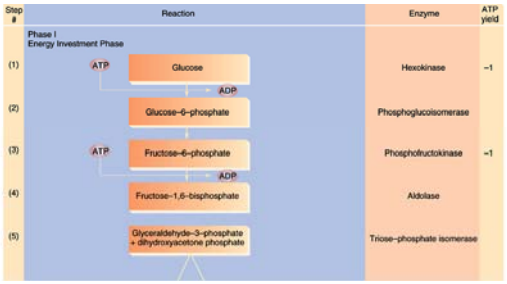

Figure 3.15

Glycolysis: Energy Generation Phase

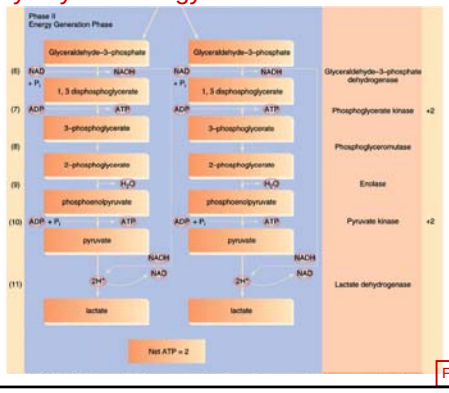

Figure 3.15

H^+ & Electron Carrier Molecules

Conversion of Pyruvic Acid to Lactic Acid

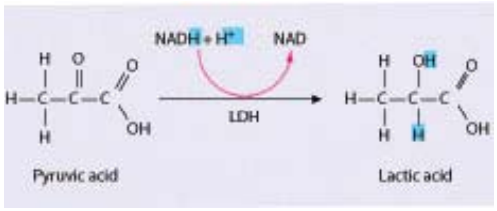

Figure 3.16

Aerobic ATP Production

- Krebs cycle (citric acid cycle)
- Electron transport chain (ETC)

The 3 Stages of Oxidative Phosphorylation

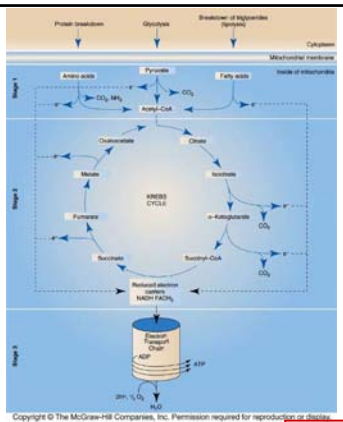

Figure 3.17

The Krebs Cycle

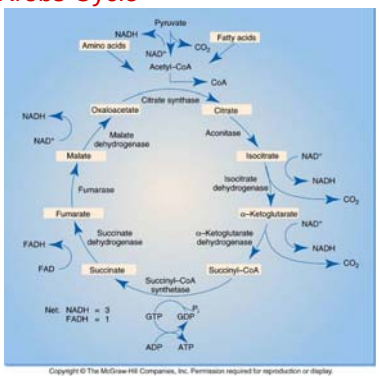

Figure 3.18

Fats & Proteins in Aerobic Metabolism

- Fats
- Protein

Relationship b/n the Metabolism of Proteins, CHO, & Fats

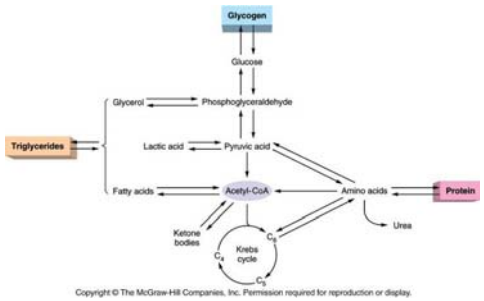

Figure 3.19

Beta-oxidation

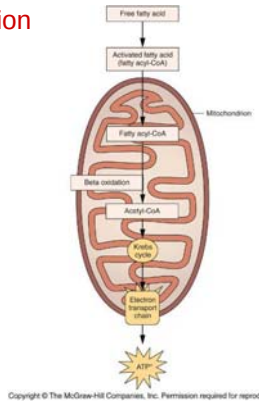

Figure 3.21

The ETC

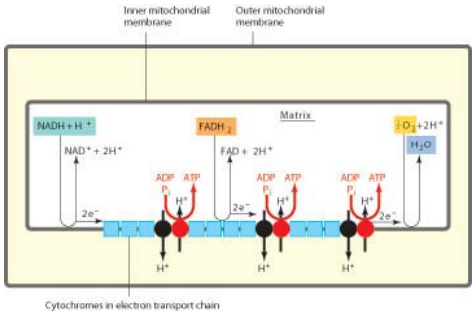

Figure 3.20

The Chemiosmotic Hypothesis of ATP Formation

- ETC results in pumping of H^+ ions across inner mitochondrial mb
- Energy released to form ATP as H^+ diffuse back across the mb

The Chemiosmotic Hypothesis of ATP Formation

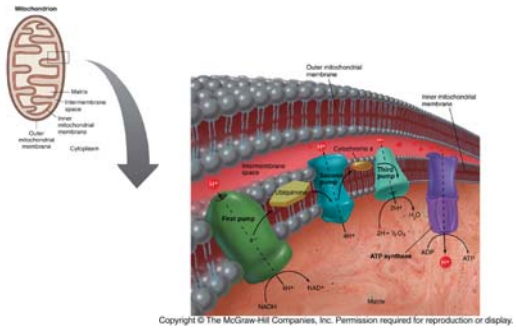

Figure 3.22

Aerobic ATP Tally Per Glucose Molecule

TABLE 3.3 Aerobic ATP Tally from the Breakdown of One Molecule of Glucose

Metabolic Process	High-Energy Products	ATP from Oxidative Phosphorylation	ATP Subtotal
Glycolysis	2 ATP	—	2 (total if anaerobic)
	2 NADH*	5	7 (if aerobic)
Pyruvic acid to acetyl-CoA	2 NADH	5	12
Krebs cycle	2 GTP	—	14
	6 NADH	15	29
	2 FADH**	3	32
			Grand total: 32 ATP

Table 3.3

Efficiency of Oxidative Phosphorylation

- One mole of ATP has energy yield of 7.3 kcal
- 32 moles of ATP are formed from one mole of glucose
- Potential energy released from one mole of glucose is 686 kcal/mole

$$\frac{\text{32 moles ATP/mole glucose x 7.3 kcal/mole ATP}}{\text{686 kcal/mole glucose}} \text{ x 100 = 34\%}$$

- Overall efficiency of aerobic respiration is 34%

Control of Bioenergetics

- Rate-limiting enzymes
- Modulators of rate-limiting enzymes

Action of Rate-Limiting Enzymes

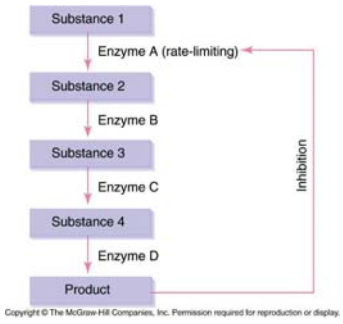

Figure 3.24

Interaction b/n Aerobic & Anaerobic ATP Production

Effect of Event Duration on the Contribution of Aerobic/Anaerobic ATP Production

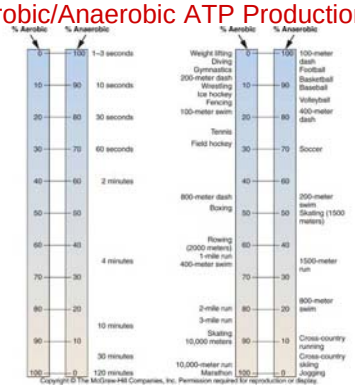

Figure 3.24