Chapter 1

The Macronutrients
Macronutrients

1. Carbohydrates
2. Lipids
3. Protein

Macronutrients
- Provide energy
- Maintain structure
- Provide functional integrity
Atoms and Molecules

- **Atoms**
  - Total of 103 elements have been identified
  - The human body is made up of elements
    - Nitrogen: 3%
    - Hydrogen: 10%
    - Carbon: 18%
    - Oxygen: 65%

- **Molecules**
  - Created when two or more atoms are united
  - Chemical bonds hold the molecules together
Substances

- Substances are formed when two or more molecules are chemically bonded together.
- Substances display different properties depending upon their atomic arrangement.
  - Solid
  - Liquid
  - Gas
Carbon — A Versatile Element

- Carbon is a component of all nutrients, except for water and minerals.

- Carbon bonds with hydrogen, oxygen, and nitrogen to form carbohydrates, lipids, and proteins.

- Vitamins are also carbon based.
Carbohydrates

- Monosaccharides
  - One sugar molecule
- Disaccharides
  - Two sugar molecules bonded together
- Oligosaccharides
  - Combination of 3–9 monosaccharides
- Polysaccharides
  - Combination of 10 to thousands of sugar molecules in chains
  - Usually glucose
Monosaccharides

- Glucose – $C_6H_{12}O_6$
- Fructose – $C_6H_{12}O_6$
- Galactose – $C_6H_{12}O_6$
  - Each has a unique atomic arrangement, giving them different biochemical characteristics.
Glucose

- Glucose is also called dextrose or blood sugar.
  - Used directly by the cell for energy
  - Stored as glycogen in the muscles and liver for later use
  - Converted to fat and stored for energy
Fructose and Galactose

- Fructose is also called levulose or fruit sugar.
  - The liver converts fructose to glucose.
- Galactose forms milk sugar called lactose.
  - The body converts galactose to glucose for energy metabolism.
Disaccharides

- Combining two monosaccharide molecules forms a disaccharide.

- Each disaccharide includes glucose as a principal component.
  - Sucrose = Glucose + Fructose
  - Lactose = Glucose + Galactose
  - Maltose = Glucose + Glucose
Polysaccharides

- Polysaccharides are classified into plant and animal categories.
- Glycosidic bonds link monosaccharides together to form polysaccharides.
Plant Polysaccharides

- Starch and fiber are two common forms of plant polysaccharides.

- Starch
  - Plant starch accounts for approximately 50% of the total carbohydrate intake of Americans.
  - The term *complex carbohydrate* commonly refers to dietary starch.
Fiber

- Fibrous materials resist hydrolysis by human digestive enzymes.
- Fibers differ widely in physical and chemical characteristics.
  - Water-soluble gums and pectin
  - Water-insoluble cellulose, hemicellulose, and lignin
Dietary fiber delays gastric emptying, interfering with digestive enzymes and micelle formation, inhibiting cholesterol synthesis. Flattened glucose curve leads to lower serum cholesterol.

Dietary soluble fiber forms gel in the stomach, delaying gastric emptying and producing uniform levels of cholesterol in the small intestine. Flattened blood glucose curve results from depressed insulin surge.
Roles of Fiber

- Retains considerable water and thus gives “bulk” to the food residues in the intestines
  - Exerting a scraping action on the cells of the gut wall
  - Binds or dilutes harmful chemicals
  - Shortens transit time for food residues (and possibly carcinogenic materials) to pass through the digestive tract
Animal Polysaccharides

- Glycogen is the storage polysaccharide found in mammalian muscle and liver.
- Glycogen is synthesized from glucose during glucogenesis.
- Glycogenolysis is the reconversion process; it provides a rapid extramuscular glucose supply.
Stage 1
Glucose $\rightarrow$ ATP $\rightarrow$ ADP + P $\rightarrow$ Glucose 6-phosphate

Stage 2
Glucose 1-phosphate $\rightarrow$ Glucose 6-phosphate isomerase

Stage 3
UDP glucos $\rightarrow$ Uridyl transferase (UTP) $\rightarrow$ Prophosphate (PPI)

Stage 4
Glycogen synthase $\rightarrow$ Glycogen
Glycogen Dynamics

- Hormones help to regulate blood sugar levels.
- Insulin enables peripheral tissues to take up glucose.
- Glucagon stimulates liver glycogenolysis and gluconeogenesis to raise blood glucose concentration.
Recommended Intake

- Regular physical activity: 60% of total intake (400–600 grams)
- During intense training: 70% of total intake
- Typical American diet: 40–50% of total intake
High Blood Glucose

- May occur from consuming many foods with a high glycemic load
- May occur due to insulin resistance, insulin deficiency, or both and result in type 2 diabetes
- Metabolic syndrome
**DIABETES**
126 mg · dL\(^{-1}\) or higher

below 126 mg · dL\(^{-1}\)

**PRE-DIABETES**
100 mg · dL\(^{-1}\) or higher

below 100 mg · dL\(^{-1}\)

**NORMAL**

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**DIABETES**
200 mg · dL\(^{-1}\) or higher

below 200 mg · dL\(^{-1}\)

**PRE-DIABETES**
140 mg · dL\(^{-1}\) or higher

below 140 mg · dL\(^{-1}\)

**NORMAL**

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**Fasting Blood Glucose**

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**Oral Glucose Tolerance Test**
Roles of Carbohydrate

- Energy source
- Adequate carbohydrate intake preserves tissue proteins.
- Metabolic primer/prevents ketosis
- Fuel for the central nervous system (CNS) and red blood cells
Hypoglycemia

- Low levels of sugar in the blood
- Can result in weakness, hunger, and dizziness
- Impairs exercise performance
- Prolonged and profound hypoglycemia can result in the loss of consciousness and irreversible brain damage.
The Nature of Lipids

- Lipid is a general term for a heterogeneous group of compounds.
  - Oils, fats, waxes, and related compounds
- Lipid molecules contain the same structural elements as carbohydrate.
Three Main Groups of Lipids

- **Simple lipids**
  - Neutral fats – consist primarily of triacylglycerols
  - Major storage form of fat in adipose cells

- **Compound lipids**
  - Consist of a triacylglycerol molecule combined with other chemicals

- **Derived lipids**
  - Formed from simple and compound lipids
  - Contain hydrocarbon rings (i.e., cholesterol)
Triglycerides

- Glycerol: a 3-carbon alcohol molecule
- Three clusters of carbon-chained atoms, termed fatty acids, attach to the glycerol molecule to form a triglyceride.
- Most dietary and storage fat is in this form.
Fatty Acids

- Saturated fatty acids contain only single covalent bonds between carbon atoms; all of the remaining bonds attach to hydrogen.

- Unsaturated fatty acids contain one or more double bonds along the main carbon chain.
  - Monounsaturated fatty acid contains one double bond.
  - Polyunsaturated fatty acid contains two or more double bonds.
**Saturated Fatty Acid**

Carbon atoms linked by single bonds enable close packing of these fatty acid chains.

A. No double bonds; fatty acid chains fit close together.

**Unsaturated Fatty Acid**

Carbon atoms linked by double bonds increase distance between fatty acid chains.

B. Double bonds present; fatty acid chains do not fit close together.
Oils

- Oils exist as liquid and contain unsaturated fatty acids.
- Omega-3 family of fatty acids
  - These oils are characterized by the presence of a double bond three carbons from the “n” end of the molecule.
Lipids in the Diet

- Typical daily lipid intake: 66% animal lipids, 34% vegetable lipids
- Average saturated fat consumption: 15% of total calories
- Saturated fat increases the risk for coronary heart disease.
Essential Fatty Acids

- Fatty acids that the body cannot synthesize
  - Linoleic acid: omega-6 polyunsaturated fatty acid
  - Alpha-linolenic acid and related omega-3 fatty acids
  - Oleic acid: major omega-9 fatty acid
- Fish oils have an antiarrhythmic effect on myocardial tissue.
- All fats contain a mix of each fatty acid type, although different fatty acids predominate in certain lipid sources.
**Compound Lipids**

- Triacylglycerol molecules combined with other chemicals
  - Phospholipids: one or more fatty acids, a phosphorus-containing group, and a nitrogenous base
- Glycolipids: fatty acid bound with carbohydrate and nitrogen
- Lipoproteins: proteins joined with triacylglycerols or phospholipids
Cholesterol and Lipoproteins

- High-density lipoprotein (HDL) contains more protein and less lipid and cholesterol than the other lipoproteins.
- Very-low-density lipoprotein (VLDL) contains the greatest percentage of lipid, primarily triacylglycerol.
- Low-density lipoprotein (LDL) contains the highest percentage of cholesterol.
Bile, produced in the liver, is stored in the gallbladder and secreted into the common bile duct that empties into the duodenum of the GI tract. Bile contains cholesterol, which is eliminated in the feces or reabsorbed in the GI tract.
Low-density lipoprotein (LDL) delivers cholesterol to the cells.

Plaque formed from LDL deposition on the inside walls of artery.
Derived Lipids

- Form simple and compound lipids
- Contain hydrocarbon rings
- Cholesterol
  - Allows for the production of steroid compounds
  - Found only in animal tissues
- LDL carries the most cholesterol and has the greatest affinity for cells of the arterial wall.
Roles of Lipids

- Energy reserve
- Protect vital organs
- Provide insulation from the cold
- Transport the fat-soluble vitamins A, D, E, and K
The Nature of Proteins

- Formed from amino acids
  - Each of the amino acids has an amine group (NH$_2$) and an acid group (COOH). The remainder of the molecule is called the side chain.
  - The side chain’s unique structure dictates the amino acid’s particular characteristics.
  - Peptide bonds link amino acids in chains that take on diverse forms and chemical combinations.
Amino Acids

- The body requires 20 different amino acids.
- The potential for combining the 20 amino acids creates an almost infinite number of possible proteins.
- The building blocks of proteins
- The body cannot synthesize eight amino acids (nine in children and some older adults), so they must be ingested in foods; these are known as essential amino acids.
  - The essential amino acids are isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.
Complete vs. Incomplete

- Complete proteins contain the essential amino acids in the quantity and correct ratio to maintain nitrogen balance and allow for tissue growth and repair.
- An incomplete protein lacks one or more essential amino acid.
Roles of Protein

- Proteins in nervous and connective tissue generally do not participate in energy metabolism.
- The amino acid alanine plays a key role in providing carbohydrate fuel via gluconeogenesis during prolonged exercise.
- During strenuous exercise of long duration, the alanine-glucose cycle accounts for up to 40–50% of the liver’s glucose release.
Protein Metabolism

- Protein catabolism accelerates during exercise as carbohydrate reserves deplete.

- Athletes who train vigorously must maintain optimal levels of muscle and liver glycogen to minimize lean tissue loss and deterioration in performance.

- Regular exercise training enhances the liver’s capacity to synthesize glucose from the carbon skeletons of noncarbohydrate compounds.