Chapter on
Chemistry and Food/Nucleic Acids
Chapter Learning Objectives

By the end of the chapter, you will recognize that

a. The *macronutrients* are carbohydrates (sugars and starches), lipids (fats and oils), and proteins.

b. The *micronutrients* are vitamins and minerals.

c. Dietary carbohydrates are broken down to glucose or its derivatives and oxidized for energy.
d. “Good” carbohydrates, such as complex carbohydrates, tend to raise the blood sugar slowly.

e. Proteins are broken down into their component amino acids, which are generally used to assemble new proteins rather than being oxidized.

f. Lipids are oxidized for energy.

g. “Good” lipids are polyunsaturated fats (double bonds) such as omega-3 and omega-6 fatty acids.
Chapter Learning Objectives (cont)

h. “Bad” lipids are cholesterol, saturated fats (all single bonds), and trans fats.

i. Phytochemicals are disease-fighting molecules found in plant products.

j. Processed food contains food additives.

k. Dieting alone is not effective for weight control because the body responds by decreasing the amount of energy expended to maintain essential life processes.
# The Five Basic Food Groups

<table>
<thead>
<tr>
<th>Food Group</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>Oranges, apples, bananas, all fruit juices</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Broccoli, peas, corn</td>
</tr>
<tr>
<td>Grains</td>
<td>Bread, rice, cereal, pasta</td>
</tr>
<tr>
<td>Protein</td>
<td>Meat, poultry, fish, dry beans, eggs, nuts, seeds</td>
</tr>
<tr>
<td>Dairy</td>
<td>Milk, yogurt, cheese</td>
</tr>
</tbody>
</table>
Chapter Outline

- Food Guide Pyramids
  a. USDA’s Original Pyramid
    1. Grains form the base of the pyramid; fats, oils, and sweets form the tip; fruit, vegetable, dairy, and protein groups are in the middle.
  b. MyPyramid
    1. Importance of exercise is stressed.
  c. Healthy Eating Pyramid
    1. Distinguishes between “good” and “bad” carbs and fats.
USDA’s Original Pyramid

The US Department of Agriculture in 1992 illustrates the daily recommended amounts of each of the five basic food groups with the foods that should compose of bulk of a good diet at the base and the foods that should be minimum at the top.
MyPyramid

An association website helps an individual choose the foods in appropriate amounts for one’s age, sex, and activity level.
The healthy eating pyramid is a nutrition guide developed by the Harvard School of Public Health, suggesting how much of each food category one should eat each day. The healthy eating pyramid is intended to provide a better eating guide than the widespread food guide pyramid created by the USDA.
Chapter Outline

• Dietary Carbohydrates
  a. Simple Sugars (Monosaccharides)
  b. Complex Carbohydrates (Polysaccharides)
  c. Glycemic Index
    1. A measure of how fast dietary carbohydrates are broken down to raise blood sugar
    2. Diets rich in foods with high GI values have been linked to increased risk of certain chronic diseases such as diabetes.
Overview of Carbohydrates can be simple sugars or complex carbohydrates.
Three important monosaccharides, shown in linear forms

Glucose ("Blood sugar")

Galactose

Fructose
# Key Disaccharides and Their Components

<table>
<thead>
<tr>
<th>Name</th>
<th>Structure</th>
<th>Components</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose</td>
<td><img src="image" alt="Sucrose Structure" /></td>
<td>Glucose, fructose</td>
<td>Table sugar</td>
</tr>
<tr>
<td>Lactose</td>
<td><img src="image" alt="Lactose Structure" /></td>
<td>Glucose, galactose</td>
<td>Milk sugar</td>
</tr>
<tr>
<td>Maltose</td>
<td><img src="image" alt="Maltose Structure" /></td>
<td>Glucose, glucose</td>
<td>Malt</td>
</tr>
</tbody>
</table>
Complex Carbohydrates (Polysaccharides)

Starch and glycogen are both polymers of glucose that contain "branches".

Starch is a complex carbohydrate within plants used for storing energy. Glycogen is a similar molecule within animals.
Cellulose is a straight-chain polymer of glucose arranged in parallel fibers. Extensive hydrogen bonding (as represented by green dots here between the fibers leads to an insoluble matrix that forms the structural basis for plants.

Cellulose is a component of dietary fiber, complex carbohydrates that pass through our systems undigested. Humans cannot digest cellulose because they lack an enzyme to break the bonds between it sugar groups.
Some Key Polysaccharides

Polysaccharides that contain repeating units of glucose (glucose polymers) are important energy-storage molecules in both plants and animals, as discussed in Ch9.

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>Energy storage in plants</td>
</tr>
<tr>
<td>Glycogen</td>
<td>Energy storage in animals</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Structural material of plants</td>
</tr>
<tr>
<td>Chitin</td>
<td>Tough exoskeleton of insects, spiders, crustaceans</td>
</tr>
<tr>
<td>Peptidoglycan</td>
<td>Comprises part of bacterial cell walls</td>
</tr>
</tbody>
</table>
Starch and cellulose are both polymers of glucose
Carbohydrates for Recognition determine blood types

These different sugars are the basis of rejection of blood of the wrong type. The presence of incompatible blood triggers a massive immune system response, resulting in destruction of the foreign blood cells and serious problems for the patient.
Glycemic Index of Some Common Foods

The rate at which carbohydrate sources are processed to glucose varies widely, with the **glycemic index (GI)** reflecting how fast a food elevates blood sugar levels.

*Insulin* (a protein) is the hormone that signals cells to take up glucose, thereby regulating blood sugar levels.

Not producing enough insulin is why one becomes diabetic.

**Table 9.3**

<table>
<thead>
<tr>
<th>Food</th>
<th>GI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baked potato</td>
<td>85</td>
</tr>
<tr>
<td>Corn flakes</td>
<td>84</td>
</tr>
<tr>
<td>White bread</td>
<td>70</td>
</tr>
<tr>
<td>Table sugar</td>
<td>65</td>
</tr>
<tr>
<td>Popcorn</td>
<td>55</td>
</tr>
<tr>
<td>Maple syrup</td>
<td>54</td>
</tr>
<tr>
<td>Breakfast oatmeal</td>
<td>51</td>
</tr>
<tr>
<td>Apple juice</td>
<td>41</td>
</tr>
<tr>
<td>Apple</td>
<td>36</td>
</tr>
<tr>
<td>Green beans</td>
<td>30</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>25</td>
</tr>
</tbody>
</table>
Dietary carbohydrates can be simple sugars or complex carbohydrates. All are composed of monosaccharide building blocks (often glucose).

“Bad” carbohydrates are those that have a high glycemic index, meaning that they trigger a rapid increase in blood glucose levels. Generally, more highly processed carbohydrate sources have higher glycemic index values.

“Good” carbohydrates tend to be whole foods that contain complex carbohydrates. These are digested fairly slowly, resulting in a gradual increase in blood glucose levels.
Chapter Outline

• Dietary Proteins
  a. Essential Amino Acids
    1. Adult humans cannot make 9 of the 20 amino acids and must obtain these in the diet on a regular basis.
  b. Complete Proteins
    1. Provide all the essential amino acids
  c. Role of Dietary Proteins
    1. Provide the amino acids needed to make new proteins
Dairy products, meats, and legumes are all rich in dietary protein.

Proteins are polymers of amino acids.

Components of an amino acid

Upon digestion, dietary proteins are broken down into the component amino acids, which can be classified as *essential amino acids* and *nonessential amino acids*. 
Components of an amino acid

Proteins are polymers constructed from 20 different building blocks called **amino acids**, much as words are constructed from letters. Amino acids all contain an **amine** and a **carboxylic acid** functional group but vary in the identity of the “side chain”. Side chains range from simply hydrogen to more complex nonpolar groups to polar and charged groups.
The **nonpolar** amino acids

- **Glycine (Gly)**
- **Alanine (Ala)**
- **Valine (Val)**
- **Proline (Pro)**
- **Methionine (Met)**
- **Leucine (Leu)**
- **Isoleucine (Ile)**
- **Phenylalanine (Phe)**
- **Tryptophan (Trp)**
Structures of the polar amino acids

- **Serine (Ser)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C} - \text{O}^- \)  
- **Threonine (Thr)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C} - \text{OH} \)  
- **Cysteine (Cys)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C} - \text{SH} \)  
- **Asparagine (Asn)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C} - \text{C}=\text{O} \)  

- **Lysine (Lys)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C} - \text{NH}_2 \)  
- **Glutamine (Gln)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C} - \text{NH}_2 \)  
- **Tyrosine (Tyr)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C}=\text{O} \)  
- **Arginine (Arg)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C}=\text{NH}_2 \)  

- **Histidine (His)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C} - \text{HN} - \text{C}=\text{N} \)  
- **Aspartate (Asp)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C} = \text{O} \)  
- **Glutamate (Glu)**: \( \text{H}_3\text{N}^+ \text{C} - \text{C} - \text{C} = \text{O} \)
Two amino acids form a covalent peptide bond

Amino acids react with other amino acids to form amide bonds, also called peptide bonds when bonding amino acids. Covalently linking two or more amino acids together with amide bonds results in a peptide.
An Example of 5 amino acids covalently bonding to form a peptide

<table>
<thead>
<tr>
<th>Tyrosine</th>
<th>Glycine</th>
<th>Glycine</th>
<th>Phenyl alanine</th>
<th>Leucine</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Tyrosine" /></td>
<td><img src="image" alt="Glycine" /></td>
<td><img src="image" alt="Glycine" /></td>
<td><img src="image" alt="Phenyl alanine" /></td>
<td><img src="image" alt="Leucine" /></td>
</tr>
</tbody>
</table>

Leucine enkephalin
Essential Amino Acids in Humans

Essential Amino Acids are those that the body cannot make itself from simpler molecules and must therefore be obtained in the diet.

### TABLE 9.4 Essential Amino Acids in Humans

<table>
<thead>
<tr>
<th>Histidine</th>
<th>Isoleucine</th>
<th>Leucine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lysine</td>
<td>Methionine</td>
<td>Phenylalanine</td>
</tr>
<tr>
<td>Threonine</td>
<td>Tryptophan</td>
<td>Valine</td>
</tr>
<tr>
<td>Arginine (only in children undergoing rapid growth)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Proteins primarily provide amino acid building blocks to make new proteins.
Complete Proteins

A food that contains all the essential amino acids is considered to be a complete protein.

There are 20 common amino acids but in recent years 3 new amino acids have been discovered.

Combining different foods will let you obtain a complete protein. Ex. Together, beans and rice provide all the essential amino acids in sufficient amounts for good health. Another classic favorite is the peanut butter sandwich, which combines a cereal grain with a legume to achieve a complete set of the essential amino acids.
Role of Dietary Protein

The Primary function of dietary proteins is to provide the nitrogen-containing amino acid building blocks needed to make new proteins in the body.

The carbon skeletons of excess dietary proteins can also be burned for energy, releasing 4 kcal/gram. The liver then converts the amino groups to urea for excretion.

A complex series of reaction in the liver converts the –NH\textsubscript{3} groups from amino acids into urea, which is then excreted in the urine. This transformation is necessary if amino acids are oxidized for energy rather than used to make new proteins.
Sources of Dietary Protein

Protein Recommendations is that most adults need ~0.8 g of protein for every kilogram of body mass per day, which can be meet in a variety of ways.

<table>
<thead>
<tr>
<th>Food</th>
<th>Portion</th>
<th>Protein (g)</th>
<th>Approximate % of Daily Requirementa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean hamburger</td>
<td>6 oz</td>
<td>49</td>
<td>88</td>
</tr>
<tr>
<td>Roasted chicken</td>
<td>6 oz</td>
<td>43</td>
<td>77</td>
</tr>
<tr>
<td>Fish</td>
<td>6 oz</td>
<td>41</td>
<td>73</td>
</tr>
<tr>
<td>Cottage cheese</td>
<td>1 cup</td>
<td>28</td>
<td>50</td>
</tr>
<tr>
<td>Low-fat yogurt</td>
<td>8 oz</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>Tofu</td>
<td>1/2 cup</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Whole milk</td>
<td>1 cup</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Kidney beans</td>
<td>1/2 cup</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Peanut butter</td>
<td>2 Tbsp</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Whole-wheat bread</td>
<td>2 slices</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

aFor an average 70-kg male.  154 lbs male
Chapter Outline

• Two major classes of dietary lipids are Cholesterol and Triglycerides (commonly known as fats and oils).
  a. Cholesterol
    1. Cholesterol is carried through the bloodstream in lipoprotein complexes that act as emulsifying agents, (dissolving the nonpolar compound cholesterol in an aqueous environment in the bloodstream).
    2. LDL is the “bad” form of cholesterol, while HDL is the “good” form.
    3. Diets rich in saturated fats and cholesterol are linked to increased risk of heart disease.
    4. Although the French have diets rich in animal fats, they have a lower incidence of heart disease. This “French paradox” is attributed to protective compounds in red wine due to a molecule called resveratrol.
Lipoprotein Complexes

- Lipoprotein
- Triglycerides
- Cholesterol
- Chemically modified cholesterol
- Phospholipids
Cholesterol can clog up arteries, a condition known as **atherosclerosis** (cause of heart attacks).

There are actually different types of lipoprotein complexes that carry cholesterol in different directions.

**Low-density lipoprotein complexes (LDL)**, the ones that can clog up arteries, transport cholesterol from the liver to the tissues.

**High-density lipoprotein complexes (HDL)**, act as “cholesterol scavengers”, scouring artery walls and transporting cholesterol to the liver for excretion.

High levels of LDL, often called “bad” cholesterol, increase the risk of atherosclerosis, whereas high levels of HDL, the “good” cholesterol, decreases the risk.
Red grapes (red wine) are good sources of resveratrol.

Decreasing the amount of dietary animal fats is a way to lower cholesterol.

“The French Paradox” reported in 1992
Dietary Lipids (cont)

b. Triglycerides

1. Dietary triglycerides from animal sources tend to contain saturated fatty acids and are generally solids at room temperature.

2. Dietary triglycerides from plant sources tend to contain unsaturated fatty acids and are generally liquids at room temperature.

Triglycerides are efficient energy stores, releasing ~9 kcal/g upon oxidation (more than twice the energy of carbohydrates and proteins).
Fats and Oils of triglycerides, lipids that contain glycerol bonded to 3 fatty acids. A fatty acid contains a hydrocarbon chain (red) and a carboxylic acid group (purple). Fatty acids with 12 to 24 carbons are most common in nature and may be either saturated or unsaturated.
Triglycerides

FIGURE 8.5 The camel's hump contains a large reservoir of fat molecules in the form of triglycerides. A triglyceride consists of glycerol (blue) linked to three fatty acids (red). Like any compound containing carbon, hydrogen, and oxygen, burning a triglyceride releases CO₂, H₂O, and energy.
Chapter Outline

• Lipids (cont)
  
c. Membrane Lipids: Phospholipids
    1. Amphiphilic molecules composed of glycerol linked to two fatty acids and a charged phosphorus-containing group
    2. Phospholipids form a membrane bilayer in water with the nonpolar fatty acids on the interior and the polar phosphate groups on the exterior facing water.
Saturated fatty acid chains resemble firewood
Unsaturated fatty acid chains resemble a brush pile

destabilizing "kink"
Phospholipids

Looks like a triglyceride molecule except for the polar phosphate head group

Membranes are made up of phospholipids, which are composed of glycerol (green), two fatty acids (red), and a variable phosphorus-containing head group (purple). The lengths of the fatty acid chains vary, as does the chemical makeup of the head group (as indicated by the X). Different membranes contain different phospholipids. A cartoon such as the one shown here is often used to represent phospholipids.
How phospholipids assemble to form a membrane

Inside of cell (aqueous solution)

Outside of cell (aqueous solution)

Polar heads

Central nonpolar tails

Plasma membrane (lipid bilayer)
Dietary Fatty Acids

Fatty acids contain long hydrocarbon chains than can be either unsaturated (containing 1 or more double bonds) or saturated (containing no double bonds). Unsaturated fats are nutritionally more superior than saturated ones.
Chapter Outline

• Dietary Lipids (cont)
  c. The “Bad” Fats
    1. Saturated fats (those with no double bonds)
    2. Trans fats are isomers of natural fats produced during the partial hydrogenation of plant oils.
      Both increase LDL and trans fats lower HDL
  d. The “Good” Fats
    1. Polyunsaturated fats (with more than 1 double bond) such as the essential fats the omega-6 and omega-3 fatty acids
Double bonds that occur naturally in fats have the \textit{cis} configuration.

This \textit{cis} configuration leads to a kink in the structure, poor packing of the chains, and a more liquid consistency. During the hydrogenation process to solidify liquid oils, some unhealthy trans unsaturated fats are created.
Some good fats are called **essential fats** because the body cannot synthesize them, necessitating their intake in the diet. Two of these are Linoleic acid and Linolenic acid. These essential fats (have beneficial health effects are parent compounds from which **omega-6 fatty acid** (as in Borage) and **omega-3 fatty acids** are derived.
# Percentage of Different Fats in Common Foods

<table>
<thead>
<tr>
<th>Food</th>
<th>% Saturated</th>
<th>% Monounsaturated</th>
<th>% Polyunsaturated</th>
<th>% Trans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola oil</td>
<td>7</td>
<td>58</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>Corn oil</td>
<td>13</td>
<td>24</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>Olive oil</td>
<td>13</td>
<td>72</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Coconut oil</td>
<td>87</td>
<td>6</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Shortening</td>
<td>22</td>
<td>29</td>
<td>29</td>
<td>18</td>
</tr>
<tr>
<td>Butter</td>
<td>62</td>
<td>27</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Stick margarine</td>
<td>18</td>
<td>2</td>
<td>29</td>
<td>23</td>
</tr>
<tr>
<td>Tub margarine</td>
<td>17</td>
<td>24</td>
<td>49</td>
<td>8</td>
</tr>
</tbody>
</table>

Source: [www.hsph.harvard.edu/nutritionsource/fats.html](http://www.hsph.harvard.edu/nutritionsource/fats.html)
Chapter Outline

• Water
  a. Water comprises about 60% of the body mass of an average human.
  b. We cannot survive for more than a few days without water.
  c. The average individual should consume 8-12 glasses of water daily.

Metabolic Water is actually produced when there is complete oxidation of glucose as written in the following reaction.

\[
C_6H_{12}O_6 \text{ (sugar)} + 6O_2 \rightarrow 6CO_2 + 6H_2O
\]
Chapter Outline

- Micronutrients
  a. Vitamins
    1. There are 4 fat soluble Vitamins (A, D, E, K) and are relatively nonpolar and are stored in fat tissue
    2. There are 9 water soluble vitamins (vitamin C and 8 B-complex vitamins)
  b. Minerals are essential inorganic substances required by living organism.
    1. Macrominerals (e.g., calcium)
    2. Trace minerals (e.g., iron)
  c. Phytochemicals
    1. Disease-preventing molecules found in plant products
# Fat-Soluble Vitamins

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Sources</th>
<th>Adult RDA&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Fish, liver, eggs, dark green leafy vegetables, yellow-orange fruits and vegetables</td>
<td>800 μg&lt;sup&gt;b&lt;/sup&gt; (women) &lt;br&gt;1000 μg (men)</td>
<td>Vision</td>
</tr>
<tr>
<td>D</td>
<td>Eggs, fish, liver, fortified milk</td>
<td>5 μg &lt;br&gt;10 μg (50 years old+) &lt;br&gt;15 μg (70 years old+)</td>
<td>Calcium absorption (for strong bones and teeth)</td>
</tr>
<tr>
<td>E</td>
<td>Almonds, green leafy vegetables, wheat germ, whole grains</td>
<td>15 mg&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Antioxidant</td>
</tr>
<tr>
<td>K</td>
<td>Green leafy vegetables, cabbage</td>
<td>65 μg (women) &lt;br&gt;80 μg (men)</td>
<td>Blood clotting</td>
</tr>
</tbody>
</table>

<sup>a</sup>Recommended Daily Allowance; <sup>b</sup>Micrograms; <sup>c</sup>Milligrams
# Water-Soluble Vitamins

## Table 9.8 Water-Soluble Vitamins

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Sources</th>
<th>Adult RDA</th>
<th>Normal Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamine (B₁)</td>
<td>Pork, liver, whole grains, beans, nuts</td>
<td>1.1 mg (women)</td>
<td>Carbohydrate metabolism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2 mg (men)</td>
<td></td>
</tr>
<tr>
<td>Riboflavin (B₂)</td>
<td>Dairy products, whole grains</td>
<td>1.1 mg (women)</td>
<td>Nutrient oxidation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.3 mg (men)</td>
<td></td>
</tr>
<tr>
<td>Niacin (B₃)</td>
<td>Meat, milk, eggs, nuts, poultry, whole grains</td>
<td>14 mg (women)</td>
<td>Nutrient oxidation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 mg (men)</td>
<td></td>
</tr>
<tr>
<td>Pantothenic acid (B₅)</td>
<td>Whole grains, meat, vegetables</td>
<td>5 mg</td>
<td>Nutrient oxidation</td>
</tr>
<tr>
<td>Pyroxidine (B₆)</td>
<td>Meat, fish, poultry, beans, grains, oranges</td>
<td>1.5 mg (women)</td>
<td>Protein metabolism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.7 mg (men)</td>
<td></td>
</tr>
<tr>
<td>Biotin (H)</td>
<td>Eggs, milk, cereal</td>
<td>30 mg</td>
<td>Nutrient oxidation</td>
</tr>
<tr>
<td>Folic Acid (B₉)</td>
<td>Green leafy vegetables</td>
<td>400 μg</td>
<td>Red blood cell formation, prevention of spina bifida</td>
</tr>
<tr>
<td>Vitamin B₁₂</td>
<td>Animal products</td>
<td>2.4 mg</td>
<td>Red blood cell formation, nerve cell maintenance</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Citrus fruits</td>
<td>75 mg (women)</td>
<td>Antioxidant, collagen formation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90 mg (men)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+35 mg for smokers</td>
<td></td>
</tr>
</tbody>
</table>
The B-complex vitamins are grouped together because they all act in energy-producing pathways of metabolism and are found in similar types of foods.

Depletion of the water-soluble vitamins may result in as little as 2 weeks if they are not regularly supplied.

Macrominerals are found in the human body in fairly large amounts (more than 5 g). An example is calcium.

Trace minerals are found in the human body in amounts of less than 5 g.
# Macrominerals and Their Functions in Humans

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Sources</th>
<th>Adult RDA</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Dairy products</td>
<td>1200 mg (19-24 yrs)</td>
<td>Component of bones and teeth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>800 mg (25 yrs+)</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Meat, dairy, beans</td>
<td>1200 mg (19-24 yrs)</td>
<td>Component of nucleic acids, bones, and teeth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>800 mg (25 yrs+)</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>Fruit, milk</td>
<td>2 g (estimated)</td>
<td>Nerve signaling</td>
</tr>
<tr>
<td>Sulfur</td>
<td>All proteins</td>
<td>None</td>
<td>Component of proteins</td>
</tr>
<tr>
<td>Sodium</td>
<td>Table salt</td>
<td>500 mg (estimated)</td>
<td>Nerve signaling</td>
</tr>
<tr>
<td>Chloride</td>
<td>Table salt</td>
<td>750 mg (estimated)</td>
<td>Charge balance</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Vegetables, grains</td>
<td>350 mg (men)</td>
<td>Component of bones, vital to many enzymes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>280 mg (women)</td>
<td></td>
</tr>
</tbody>
</table>
About 99% of the body's calcium is in bones and teeth.

Credit: Corbis
## Trace Minerals with Established RDAs

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Sources</th>
<th>Adult RDA</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Meat, whole grains, legumes, green leafy vegetables</td>
<td>15 mg (women)</td>
<td>Oxygen transport</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 mg (men)</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>Seafood, meat, nuts, legumes</td>
<td>12 mg (women)</td>
<td>Nutrient metabolism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 mg (men)</td>
<td></td>
</tr>
<tr>
<td>Iodine</td>
<td>Iodized salt</td>
<td>150 mg</td>
<td>Thyroid gland function (metabolism)</td>
</tr>
<tr>
<td>Selenium</td>
<td>Grains, Brazil nuts, meat</td>
<td>55 mg (women)</td>
<td>Antioxidant activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70 mg (men)</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 9.11 Trace Minerals Known to Be Essential for Humans with No Established RDA

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Sources</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium</td>
<td>Refried beans, wheat germ, liver, nuts, microbrewery beer</td>
<td>Aids action of insulin</td>
</tr>
<tr>
<td>Copper</td>
<td>Grains, legumes, nuts</td>
<td>Part of many enzymes</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Fluoridated water, toothpaste</td>
<td>Makes teeth strong</td>
</tr>
<tr>
<td>Manganese</td>
<td>Spinach, nuts, legumes, tea</td>
<td>Connective tissue formation</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Whole grains, vegetables</td>
<td>Part of some enzymes</td>
</tr>
</tbody>
</table>
Phytochemicals

Caffeic acid (found in apples, plums, tomatoes, grapes)

Genistein (found in soybeans)

Catechin (found in grapes, chocolate, tea)

Quercetin (found in onions, tea)
**Good Dietary Sources of Phytochemicals**

<table>
<thead>
<tr>
<th>TABLE 9.12 Good Dietary Sources of Phytochemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allium vegetables (garlic, onions, chives, leeks)</td>
</tr>
<tr>
<td>Cruciferous vegetables (broccoli, cauliflower, cabbage, Brussels sprouts, bok choy)</td>
</tr>
<tr>
<td>Solanaceous vegetables (tomatoes, peppers)</td>
</tr>
<tr>
<td>Umbelliferous vegetables (carrots, celery, cilantro, parsley, parsnips)</td>
</tr>
<tr>
<td>Fruits and berries (grapes, blueberries, apples, oranges)</td>
</tr>
<tr>
<td>Herbs (ginger, mint, basil, fennel, thyme, borage)</td>
</tr>
<tr>
<td>Tea (green and black)</td>
</tr>
</tbody>
</table>
Chapter Outline

• Food Additives
  a. GRAS (Generally Recognized As Safe) List which contains a zero tolerance for agents that cause cancer (carcinogens) in any animal in any amount.
    1. preservatives, coloring agents, flavoring agents, sweeteners, or nutrients
  b. Incidental Additives — traces of unintentional materials make their way into the food supply, including remnants of packaging, pesticides, herbicides, antibiotics fed to cattle, and insect parts
Vitamin C reduces browning of apples from oxidation.
Chapter Outline

• Food Labels
  a. Food labels reveal the ingredients, serving size, caloric content, and types of nutrients in packaged food.
  b. Fats: 9 Cal/g; proteins: 4 Cal/g; carbs: 4 Cal/g.
Food Labels

The food label is colored coded to draw attention to key aspects. Yellow boxes indicate nutrients that should be limited; blue boxes indicate important nutrients to obtain insufficient amounts.

**Label includes the following:** Serving size, total calories, calculate the total calories from the grams of each of the major nutrients, total fat breakdown, carbohydrate content, vitamins and minerals, percent daily value based on regular daily allowances (RDA) for a person on a 2000-calorie diet.
Chapter Outline

• Dieting
  a. Energy Balance
    1. Energy is expended through basal metabolism, physical activity, and thermogenesis.
  b. Dieting Affects Energy Expenditure
    1. The body adapts to less food by reducing its energy expenditure.
  c. Low Fats vs. Low Carbs
    1. Diets low in carbohydrates lead to production of ketone bodies from fat stores, which can lead to a dangerous drop in blood pH.
### Energy Allocation in People with Different Activity Levels

<table>
<thead>
<tr>
<th></th>
<th>Relatively Inactive Individual</th>
<th>Physically Active Individual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal metabolism</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td>Physical activity</td>
<td>20%</td>
<td>40%</td>
</tr>
<tr>
<td>Thermogenesis</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>
Increasing prevalence of obesity

Metabolism of glycogen stores for use as energy

Muscle and liver convert glycogen stores to glucose.

Adipose tissue converts triglycerides to fatty acids.
Effects of Carbohydrate Depletion

Muscle

Proteins in muscle are converted to glucose. Ammonia (NH₃) is a byproduct.

Glucose provides energy to the brain.

Energy

Kidneys

Kidneys convert NH₃ to urea, which is excreted.

Brain

Energy

Fat Cell

Triglycerides in adipose tissue are converted to fatty acids and then to ketone bodies.

Water-soluble ketone bodies travel via the bloodstream to provide energy to the brain.

Fatty Acids

\[
\begin{align*}
\text{Fatty Acids} & : \quad \text{H}_3\text{C} - \text{C} - \text{CH}_3 \\
\text{Ketone Bodies} & : \quad \text{O} - \text{C} - \text{C} - \text{CH}_3 \\
& \quad \text{O} - \text{C} - \text{C} - \text{CH}_3
\end{align*}
\]
Chapter Outline

- Nucleic Acids (DNA and RNA)
  a. Building Blocks: Nucleotides
    1. Contain a phosphate group, a sugar ring, and a nitrogen-containing purine (A or G) or pyrimidine (C or T [U replaces T in RNA]).
  b. Structure
    1. DNA is a two-chained helix with the chains running in opposite directions.
    2. Strands interact through specific hydrogen-bonding interactions (A with T and G with C).
Human chromosome

Contains all the genetic material needed with 46 total chromosomes, 23 chromosomes from the male and 23 from the female.
Nucleotides, the building block of ourselves

The instructions to assemble each molecule in the cell can be found in the genetic material, which consists of nucleic acids. The name arises because these molecules were first found in the nuclei of pus (white blood) cells and were determined to be *acidic* in nature.

DNA and RNA are both polymers of nucleotide subunits linked by phosphate groups to form long chains. **Nucleotide** contains 3 important groups, (1) a phosphate group, (2) a carbohydrate, and (3) and a nitrogen-containing base.
The fundamental building block of DNA and RNA is the nucleotide.

**DNA** = Deoxyribonucleic acid is the carrier of genetic information.

**RNA** = Ribonucleic acid plays a role in using the info. Contained within DNA to make new molecules in the cell.

Functional group difference of DNA vs. RNA:

- **DNA has thymine; RNA has uracil instead.**

**4 base pairs for DNA and RNA**:

- **Adenine**
- **Guanine**
- **Cytosine**
- **Thymine (DNA)**
- **Uracil (RNA)**
Rosalind Franklin, pioneer in DNA structure

Key experiment were being performed in the early 1950s by X-ray crystallographers at King’s College in London. **Dr. Rosalind Franklin** and her research assistant obtained evidence that DNA actually exists in two different structures depending on the amount of water present. Based on Franklin’s X-ray data and others work, **James Watson and Francis Crick** at Cambridge proposed a model for DNA as a **Double Helix**.

Watson and Crick were awarded the Nobel Prize in 1962 in Physiology or Medicine.
Watson and Crick's model

(a) The DNA Double Helix

(b) Hydrogen Bonds Between Base Pairs
DNA is copied during replication

- Parent strands
- Base pairs
- Complementary new strands
• Nucleic Acids (cont)
  
c. DNA Replication
   1. To copy DNA, the two strands come apart and the information in each strand is used to make a new copy.

d. The Genetic Code
   1. Specific stretches of DNA called genes code for proteins.

e. DNA Repair
   1. DNA damage can lead to mutations. Cellular proteins repair DNA damage to prevent disease.
Complementary strand means that where one strand has a particular base, the other strand has the base-pairing partner (A for T (for DNA), A for U (for RNA), and G for C).

Examples of complementary DNA or RNA strands

[Table]

<table>
<thead>
<tr>
<th>DNA</th>
<th>RNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAAAGGGGTTTTTCCCCC</td>
<td>AAAAGGGGUUUUCCCCC</td>
</tr>
<tr>
<td>TTTTCCCCCAAAAAGGGG</td>
<td>UUUUCCCCCAAAAGGGG</td>
</tr>
</tbody>
</table>

DNA RNA

A gene is a region of DNA that serves as the instructions to make a biological product.

A codon is a three-base DNA sequence that codes for a particular amino acid or gives instructions to stop the peptide chain.
Translation:
mRNA "reads" to synthesize a polypeptide
A mutant is an organism different from the norm.
Causes of DNA mutations

(a) Errors During Replication

(b) Damage by External Agent
Cellular enzymes repair DNA damage from carcinogens or UV light.
Key Words

- Macronutrients
- Micronutrients
- Complex carbohydrate
- Blood sugar
- Glycogen
- Fiber
- Glycemic Index (GI)

- Essential amino acids
- Cholesterol
- Lipoprotein complexes
- Atherosclerosis
- Trans fats
- Omega-6 fatty acids
- Omega-3 fatty acids
Key Words

- Vitamins
- Antioxidant
- Minerals
- Macrominerals
- Phytochemicals
- Food additives

- GRAS list
- Carcinogen
- Basal metabolism
- Thermogenesis
- Ketosis
- Ketone bodies