Chapter 6

Proteins and Amino Acids

Slide Show developed by:
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Learning Outcomes for Chapter 6

1. Explain how proteins are different from carbohydrates and lipids.
2. Describe the basic structure of an amino acid.
3. Explain the difference between essential and non-essential amino acids.
4. Identify the key steps in digesting protein.
5. Identify the functions of protein in the body.
Learning Outcomes for Chapter 6

6. Identify sources of lean protein in the diet and make the distinction between animal and plant proteins.

7. Create a diet plan that achieves the Recommended Dietary Allowance for protein.

8. Calculate the recommended protein intake for an individual based on the Dietary Reference Intakes.

9. Explain the health consequences of consuming too little or too much protein.

10. Describe the benefits and risks of a vegetarian diet.
Animation: The Building Blocks of Proteins
What Are Proteins and Why Are They Important?

Proteins are the predominant structural and functional materials in every cell.

- Contain carbon, hydrogen, oxygen (like carbohydrates and fats)
- In addition, also contain nitrogen
- Each amino acid has:
  - Acid group (COOH)
  - Amine group (NH₂)
  - Side chain (unique)
- All proteins consist of some combination of 20 unique amino acids
The Structure of an Amino Acid

Amino acid structure. All amino acids contain carbon, hydrogen, and oxygen, similar to carbohydrates and fat. They also contain a nitrogen-containing amine group and an acid group.

Different amino acids showing their unique side chains. A unique side chain (shown in yellow) distinguishes the various amino acids.
Essential, Nonessential, and Conditional Amino Acids

Nine essential amino acids

- Cannot be made by the body
- It is “essential” to obtain them from the diet

Eleven non-essential amino acids

- Can be synthesized in the body from other amino acids or by adding nitrogen to carbon-containing structures

Conditionally essential amino acids

- Under certain conditions, some non-essential amino acids cannot be made in body (arginine in “preemies”)
The Making of a Protein (hemoglobin)

Amino acids are joined together by peptide bonds in specific sequences to form proteins. This shows part of the sequence of the protein hemoglobin.

The attractions and interactions between the amino acids cause the protein to spiral, bend, and curl.

The protein folds into a precise three-dimensional shape.

Some proteins, such as hemoglobin, consist of several separate protein chains linked together. The shape of the protein determines its function.
# The Mighty Twenty

<table>
<thead>
<tr>
<th>Essential Amino Acids</th>
<th>Nonessential Amino Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histidine (His)\textsuperscript{a}</td>
<td>Alanine (Ala)</td>
</tr>
<tr>
<td>Isoleucine (Ile)</td>
<td>Arginine (Arg)\textsuperscript{b}</td>
</tr>
<tr>
<td>Leucine (Leu)</td>
<td>Aspartic acid (Asp)</td>
</tr>
<tr>
<td>Lysine (Lys)</td>
<td>Asparagine (Asn)</td>
</tr>
<tr>
<td>Methionine (Met)</td>
<td>Cysteine (Cys)\textsuperscript{b}</td>
</tr>
<tr>
<td>Phenylalanine (Phe)</td>
<td>Glutamic acid (Glu)</td>
</tr>
<tr>
<td>Threonine (Thr)</td>
<td>Glutamine (Gln)\textsuperscript{b}</td>
</tr>
<tr>
<td>Tryptophan (Trp)</td>
<td>Glycine (Gly)\textsuperscript{b}</td>
</tr>
<tr>
<td>Valine (Val)</td>
<td>Proline (Pro)\textsuperscript{b}</td>
</tr>
<tr>
<td></td>
<td>Serine (Ser)</td>
</tr>
<tr>
<td></td>
<td>Tyrosine (Tyr)\textsuperscript{b}</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Histidine was once thought to be essential only for infants. It is now known that small amounts are also needed for adults.
Denaturing a Protein

Heat

Normal protein

Denatured protein

Figure 6.3
Denaturation of Proteins Changes Their Shape

- **Denaturation:** The alteration (unfolding) of a protein’s shape, which changes the structure and function of the protein.

  - Examples:
    1. Cooking meat, eggs changing texture
    2. Stomach acid untangles proteins to aid in digestion
What Happens to the Protein You Eat?

Dietary proteins are digested and absorbed in the stomach and small intestine.

1. Stomach acids denature protein and:
   - Activate pepsin, which breaks down protein into shorter polypeptides.

2. In the small intestine, polypeptides are broken down into tripeptides, dipeptides, and amino acids.
   - Amino acids enter blood and travel to liver.
Animation: Protein Absorption
Digesting and Absorbing Proteins

1. In the stomach, acidic juices denature the protein and activate the enzyme pepsin, which breaks the protein into shorter strands.

2. These strands enter the small intestine. Pepsin is inactivated. Other enzymes further break down the polypeptide strands into tripeptides and dipeptides and single amino acids.

3. These protein remnants are absorbed through the small intestine lining. They are further broken down to single amino acids, which enter the blood and travel directly to the liver.

4. The liver uses some of the amino acids to make new proteins, or glucose, or for other purposes. Other amino acids will pass through the blood to be picked up and used by the cells.
The Fate of Amino Acids in Your Body

a. The foods that you eat contain both essential and nonessential amino acids.

b. A limited supply of all the amino acids exists in amino acid pools in your blood and inside your cells; this supply is used to create proteins.

c. Some amino acids in the pools are used to make nonprotein products, such as some hormones.

d. Protein turnover involves the degradation (breaking down) of protein and synthesis of its amino acids into new proteins.

e. Amino acids are degraded and their nitrogen-containing amine groups are removed. The nitrogen generates ammonia (NH₃), which is converted to urea and excreted in urine. The carbon-containing remains are either used to make glucose or energy, or are stored as fat.
Your Body Degrades and Synthesizes Proteins

Amino acids come from:

- **Diet**
- Breakdown of proteins in the body
- A limited supply is stored in **amino acid pools** in blood and cells for needed protein synthesis

**Protein turnover:** process of continuous breakdown and synthesis of protein from its amino acids
Your Body Degrades and Synthesizes Proteins

- Amino acids can be used to make:
  - **Body proteins**
  - **Non-protein substances**
    - Examples: thyroid hormone, melanin (skin pigment)
- After amine groups removed, converted to urea, excreted in urine, amino acids can also be:
  - Burned for energy
  - Stored as fat
  - Made into glucose
Protein Synthesis

Each strand of DNA holds the code to create specific proteins. Because the DNA can’t leave the nucleus of the cell, a copy of the code, called messenger RNA (mRNA), is made.

The mRNA takes this information outside the nucleus and brings it to the ribosome.

The ribosome moves along the mRNA, reading the code.

Another type of RNA, called transfer RNA (tRNA), collects the specific amino acids that are needed to make the protein. There are 20 different tRNAs, one for each amino acid.

The tRNA brings the amino acid to the ribosome.

The ribosome then builds a chain of amino acids (the protein) in the proper sequence, based on the code in the mRNA.

The ribosome continues to move down the mRNA strand until all the appropriate amino acids are added and the protein is complete.
DNA Directs Synthesis of New Proteins

- DNA in the cell nucleus contains instructions for protein synthesis
- **Gene**: DNA segment that codes for specific protein
- Specialized RNA molecules carry out instructions for protein synthesis
  - **Messenger RNA (mRNA) and transfer RNA (tRNA)** perform very specific roles during protein synthesis
- When abnormalities occur during protein synthesis, serious medical conditions may result
  - Examples: Sickle-cell anemia, Tay Sachs Disease, BRCA1 mutations (related to cancer risk)
How Does Your Body Use Protein?

- Proteins provide structural and mechanical support and help maintain body tissues
  - **Collagen**: a ropelike, fibrous protein that is the most abundant protein in your body
  - **Connective tissue**: the most abundant tissue type in the body; made up primarily of collagen, it supports and connects body parts as well as provides protection and insulation

- Proteins build most **enzymes** and many **hormones**

- Proteins help maintain **fluid balance**
An Enzyme in Action

1. A compound approaches a specific enzyme.
2. The compound binds to the enzyme.
3. The enzyme changes shape.
4. Two products are released and the enzyme is available for another reaction.
The Functions of Proteins

1. Proteins help maintain acid-base balance
   - **Buffers**: substances that help maintain the proper pH in a solution by attracting or donating hydrogen ions

2. Proteins transport substances throughout the body
   - **Transport proteins** shuttle oxygen, waste products, lipids, some vitamins, and sodium and potassium through your blood and into and out of cells through cell membranes

3. Proteins contribute to a healthy immune system
   - Specialized protein “soldiers” called **antibodies** eliminate potentially harmful substances

4. Proteins can provide energy

5. Protein improves satiety and appetite control
Proteins as Transport Channels

Outside cell

Transport protein

Potassium

Sodium

Sodium binds to transport protein

Transport protein releases sodium outside of cell

Potassium binds to transport protein

Transport protein releases potassium inside the cell

Inside cell

Figure 6.9
# The Many Roles of Protein

<table>
<thead>
<tr>
<th>Role of Proteins</th>
<th>How It Works</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Provide structural and mechanical support and maintenance</td>
<td>Proteins are your body’s building materials, providing strength and flexibility to your tissues, tendons, ligaments, muscles, organs, bones, nails, hair, and skin. Proteins are needed for the ongoing maintenance of your body.</td>
</tr>
<tr>
<td>2. Build enzymes and hormones</td>
<td>Proteins are needed to make most enzymes that speed up reactions in your body and many hormones that direct specific activities, such as regulating your blood glucose level.</td>
</tr>
<tr>
<td>3. Maintain fluid balance</td>
<td>Proteins play a major role in ensuring that your body fluids are evenly dispersed in your blood and inside and outside your cells.</td>
</tr>
<tr>
<td>4. Maintain acid-base balance</td>
<td>Proteins act as buffers to help keep the pH of your body fluids balanced within a tight range. A drop in pH will cause your body fluids to become too acidic, whereas a rise in pH can make them too basic.</td>
</tr>
<tr>
<td>5. Transport substances</td>
<td>Proteins shuttle substances such as oxygen, waste products, and nutrients (such as sodium and potassium) through your blood and into and out of your cells.</td>
</tr>
<tr>
<td>6. Affect antibodies and the immune response</td>
<td>Proteins create specialized antibodies that attack pathogens in your body that can make you sick.</td>
</tr>
<tr>
<td>7. Provide energy</td>
<td>Because proteins provide 4 calories per gram, they can be used as fuel or energy in your body.</td>
</tr>
<tr>
<td>8. Improves satiety</td>
<td>Protein increases satiety, which can help control your appetite and weight.</td>
</tr>
</tbody>
</table>

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Healthy adults should be in nitrogen balance, the state in which an individual is consuming the same amount of nitrogen from protein in the diet as he or she is excreting in the urine.
Animation: Nitrogen Balance
You Can Determine Your Personal Protein Needs

Protein requirements determined by nitrogen balance studies

**Nitrogen Balance:** Amount of protein consumed = amount of protein used (nitrogen excreted)

- **Nitrogen Imbalances**
  - **Positive Nitrogen Balance:** more nitrogen is retained (for protein synthesis) than is excreted
    - Examples: infants, children, pregnant women
  - **Negative Nitrogen Balance:** more nitrogen is excreted than consumed (body proteins broken down)
    - Examples: starvation, serious injury, or illness
Nitrogen Balance and Imbalance

Nitrogen intake → Positive nitrogen balance → Nitrogen excretion

Nitrogen intake → Equilibrium → Nitrogen excretion

Nitrogen intake → Negative nitrogen balance → Nitrogen excretion

Pregnant women, growing children and adolescents, and some athletes tend to be in positive nitrogen balance.

A healthy adult is typically in nitrogen balance.

An individual who is experiencing a medical trauma or not eating a healthy diet is often in negative nitrogen balance.

Figure 6.10
Not All Protein Is Created Equal

Plant proteins “upgraded” to complete proteins by:

- Consuming modest amounts of soy or animal protein, or being complemented with other plant proteins which provide enough of the limiting amino acid

- **Protein Digestibility Corrected Amino Acid Score (PDCAAS)**
  - Measure of protein quality taking into account digestibility and amino acid profile
  - Basis of protein as percent daily value on food labels
How to Calculate Your Personal Protein Needs

Protein recommendations (DRI):

- 10 to 35 percent of total daily calories from protein
  - Average intake in the United States = 15 percent
- 0.8 g of protein/kg of body weight needed daily

Calculating your daily protein needs:

- Convert weight to pounds by dividing by 2.2 lbs/kg:
  
  If you weigh: \( \frac{130 \text{ lbs}}{2.2} = 59 \text{ kg} \)

  \[ 59 \text{ kg} \times 0.8 \text{ g} = 47 \text{ g of protein/day} \]
## Calculating Your Daily Protein Needs

<table>
<thead>
<tr>
<th>If You Are</th>
<th>You Need</th>
</tr>
</thead>
<tbody>
<tr>
<td>14–18 years old</td>
<td>0.85 g/kg</td>
</tr>
<tr>
<td>≥19 years old</td>
<td>0.80 g/kg</td>
</tr>
</tbody>
</table>

To calculate your needs, first convert your body weight from pounds (lb) to kilograms (kg) by dividing by 2.2, like this:

Your weight in pounds: ____________ lb ÷ 2.2 = ____________ kg

Then, multiply your weight in kilograms by 0.8 or 0.85:

Your weight in kilograms: ____________ kg × 0.8 g = ____________ g/day

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# Protein Supplements

## Protein Shakes and Powders

Sometimes used by athletes in the belief that they’ll help build muscle, or as meal replacers by those looking to lose weight. In both cases, they are expensive, and unnecessary. Athletes and bodybuilders can obtain adequate protein through a healthy diet, and don’t need extra shakes to bulk up. In fact, excessive amounts of protein can be unhealthy and produce undesirable results (see Chapter 11). While dieters may lose weight using a high-protein meal replacer, the same results can occur with a calorie-controlled meal of whole foods. When it comes to losing weight, it’s the calories that count.

## Amino Acid Supplements

Including those for individual amino acids such as tryptophan and lysine, these are marketed as remedies for a range of health issues, including pain, depression, insomnia, and certain infections, even though there are conflicting results from research studies. The reality is that consuming too much of any one amino acid can impede absorption of other amino acids in the intestinal tract. Further, overconsuming specific amino acids can lead to side effects, such as nausea, light-headedness, vomiting, and drowsiness. Your diet can provide all the amino acids you need.

## Digestive Enzyme Supplements

Useless because they are broken down in the intestinal tract, and thus made ineffective. Your body manufactures all the enzymes needed to efficiently aid in the digestion of your foods. Spending money on these items is literally akin to flushing your hard-earned money down the toilet.

A variety of protein-related products are heavily marketed and sold to young adults as the key to building muscle, losing weight, or curing a host of health problems. With very few exceptions, purchasing and consuming these products is, at best, a waste of money, and at worst, potentially harmful.
“The Blue Zones” Sardinian Diet

The Sardinian Diet (4 minutes)
What Are the Best Food Sources of Protein?

- **Complete protein sources**
  - meat, fish, poultry, and most dairy products

- **Incomplete protein sources**
  - meat alternatives such as dried beans, peanut butter, nuts, grains, legumes, and soy
What Americans Are Eating

Figure 6.11
Fish to Avoid

Food Sources of Protein

Figure 6.12
## Protein Bars

<table>
<thead>
<tr>
<th>Product</th>
<th>Price ($)</th>
<th>Calories</th>
<th>Protein (g)</th>
<th>Total Carb (g)</th>
<th>Total Fat (g)</th>
<th>Sat. Fat (g)</th>
<th>Sugars (tsp)</th>
<th>Fiber (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanut butter (1 tbs) on 2 slices whole-wheat bread</td>
<td>0.22</td>
<td>234</td>
<td>9</td>
<td>29</td>
<td>11</td>
<td>2</td>
<td>&lt;1</td>
<td>5</td>
</tr>
<tr>
<td>Dr Soy Double Chocolate</td>
<td>1.40</td>
<td>180</td>
<td>12</td>
<td>27</td>
<td>3</td>
<td>2.5</td>
<td>2.5 (22%)</td>
<td>1</td>
</tr>
<tr>
<td>Balance Chocolate</td>
<td>1.28</td>
<td>200</td>
<td>14</td>
<td>22</td>
<td>6</td>
<td>3.5</td>
<td>4.5 (36%)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Zoneperfect Chocolate Peanut Butter</td>
<td>1.31</td>
<td>210</td>
<td>16</td>
<td>20</td>
<td>7</td>
<td>3</td>
<td>3.5 (25%)</td>
<td>1</td>
</tr>
<tr>
<td>EAS AdvantEdge Chocolate Peanut Crisp</td>
<td>1.10</td>
<td>220</td>
<td>13</td>
<td>32</td>
<td>6</td>
<td>3</td>
<td>5 (26%)</td>
<td>1</td>
</tr>
<tr>
<td>Atkins Advantage Chocolate Decadence</td>
<td>2.29</td>
<td>220</td>
<td>17</td>
<td>25</td>
<td>11</td>
<td>7</td>
<td>0</td>
<td>11</td>
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<tr>
<td>Genisoy Ultimate Chocolate Fudge Brownie</td>
<td>1.15</td>
<td>230</td>
<td>14</td>
<td>33</td>
<td>4.5</td>
<td>3</td>
<td>7 (49%)</td>
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<tr>
<td>Carb Solutions Creamy Chocolate Peanut Butter</td>
<td>2.24</td>
<td>240</td>
<td>24</td>
<td>14</td>
<td>10</td>
<td>3.5</td>
<td>0.5 (3%)</td>
<td>1</td>
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</table>
## More Bars....

<table>
<thead>
<tr>
<th>Product</th>
<th>Price ($)</th>
<th>Calories</th>
<th>Protein (g)</th>
<th>Carb (g)</th>
<th>Fat (g)</th>
<th>Fat (%)</th>
<th>Sugars (tsp)</th>
<th>Fiber (g)</th>
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</thead>
<tbody>
<tr>
<td><strong>PowerBar ProteinPlus</strong></td>
<td>1.99</td>
<td>270</td>
<td>24</td>
<td>36</td>
<td>5</td>
<td>3</td>
<td>5 (38%)</td>
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</tr>
<tr>
<td>Chocolate Fudge Brownie</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Met-Rx Protein Plus</strong></td>
<td>2.57</td>
<td>320</td>
<td>31</td>
<td>29</td>
<td>9</td>
<td>4.5</td>
<td>0.5 (3%)</td>
<td>1</td>
</tr>
<tr>
<td>Chocolate Roasted Peanut</td>
<td></td>
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<td></td>
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<td><strong>PowerBar Pria</strong></td>
<td>0.94</td>
<td>110</td>
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<td>2.5 (36%)</td>
<td>0</td>
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<tr>
<td>Double Chocolate Cookie</td>
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<td></td>
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<tr>
<td><strong>Clif Luna</strong></td>
<td>1.40</td>
<td>180</td>
<td>10</td>
<td>24</td>
<td>4.5</td>
<td>2.5</td>
<td>3 (27%)</td>
<td>2</td>
</tr>
<tr>
<td>Nutz Over Chocolate</td>
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<td></td>
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<tr>
<td><strong>Kellogg’s Krave</strong></td>
<td>0.53</td>
<td>200</td>
<td>7</td>
<td>31</td>
<td>6</td>
<td>3.5</td>
<td>5.5 (44%)</td>
<td>2</td>
</tr>
<tr>
<td>Chocolate Delight</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Slim-Fast Meal Options</strong></td>
<td>1.02</td>
<td>220</td>
<td>8</td>
<td>35</td>
<td>5</td>
<td>3</td>
<td>6 (44%)</td>
<td>2</td>
</tr>
<tr>
<td>Rich Chocolate Brownie</td>
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<tr>
<td><strong>Ensure</strong></td>
<td>1.13</td>
<td>230</td>
<td>9</td>
<td>35</td>
<td>6</td>
<td>4</td>
<td>6 (42%)</td>
<td>1</td>
</tr>
<tr>
<td>Chewy Chocolate Peanut</td>
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<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Key:  = 1 tsp sugar
= 1 g fiber
* = % of calories

Source: Adapted from *Consumer Reports* 68 (June 2003): 19–21.
What Happens if You Eat Too Much or Too Little Protein?

- Eating too much protein:
  - May increase risk of heart disease, kidney stones, calcium loss from bones
  - Can displace other nutrient- and fiber-rich foods associated with a reduced risk of chronic diseases:
    - Whole grains, fruits, vegetables
What Happens if You Eat Too Much or Too Little Protein?

- Eating too little protein:
  - Low-protein diets associated with loss of bone mass

- **Protein Energy Malnutrition (PEM)**
  - Inadequate calories and/or protein
  - More common in children, because they are growing
  - Factors: poverty, poor food quality, insufficient food, unsanitary living conditions, ignorance, stopping lactation (nursing) too early
Where’s the Protein and Saturated Fat in Your Food?
Eating Too Little Protein Can Lead to Poor Bone Health and Malnutrition

- **Kwashiorkor**: severe deficiency of dietary protein
  - Signs: edema, muscle loss, skin rashes, hair changes, water and electrolyte imbalances
  - Seen in children weaned to low-protein cereals

- **Marasmus**: severe deficiency of calories
  - Signs: emaciation, lack of growth, loss of fat stores

- **Marasmic Kwashiorkor**: worst of both conditions

- Medical treatment and food: three-step approach
How Do Vegetarians Meet Protein Needs?

Vegetarians can meet protein needs by consuming:

- Variety of plant foods
- Protein-rich meat alternatives:
  1. Soy
  2. Dried beans and other legumes
  3. Nuts
  4. Eggs, dairy (lacto-ovo-vegetarians)
## The Many Types of Vegetarians

<table>
<thead>
<tr>
<th>Type</th>
<th>Does Eat</th>
<th>Doesn’t Eat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semivegetarian</td>
<td>A vegetarian diet that occasionally includes meat, fish, and poultry</td>
<td>Meat, fish, and poultry on occasion</td>
</tr>
<tr>
<td>Lacto-ovo-vegetarian</td>
<td>Grains, vegetables, fruits, legumes, seeds, nuts, dairy foods, eggs</td>
<td>Meat, fish, and poultry</td>
</tr>
<tr>
<td>Lacto-vegetarian</td>
<td>Grains, vegetables, fruits, legumes, seeds, nuts, dairy foods</td>
<td>Meat, fish, poultry, and eggs</td>
</tr>
<tr>
<td>Ovo-vegetarian</td>
<td>Grains, vegetables, fruits, legumes, seeds, nuts, eggs</td>
<td>Meat, fish, poultry, dairy foods</td>
</tr>
<tr>
<td>Vegan</td>
<td>Grains, vegetables, fruits, legumes, seeds, nuts</td>
<td>Any animal foods, meat, fish, poultry, dairy foods, eggs</td>
</tr>
</tbody>
</table>

Table 6.6
Potential Benefits and Risks of Vegetarian Diets

Benefits:
- May reduce risk of heart disease, high blood pressure, diabetes, cancer, stroke, and obesity
- Vegetarian diet food staples are rich in fiber, low in saturated fat and cholesterol

Risks:
- Potential deficiencies of nutrients found in animal foods
  - Protein, iron, zinc, calcium, vitamin D, riboflavin, vitamins B₁₂ and A, omega-3 fatty acids
### Table 6.7a

#### Vegetarian Nutrients and Food Sources

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Risks</th>
<th>Vegetarian Food Sources</th>
<th>Table Tips</th>
</tr>
</thead>
</table>
| **Protein** | A vegetarian’s protein needs can be met by consuming a variety of plant foods. A combination of protein-rich soy foods, legumes, nuts, and/or seeds should be eaten daily. | Soybeans, soy burgers, tofu, tempeh, nuts, peanuts, peanut butter, legumes, sunflower seeds, milk, soy milk, yogurt, cheese | • Add nuts to your morning cereal.  
• Add beans to your salads, soups, and main entrées.  
• Have a soy burger for lunch.  
• Use tofu in stir-fries, rice and pasta dishes, and casseroles.  
• Snack on a soy milk and banana or berry shake. |
| **Iron** | The form of iron in plants is not as easily absorbed as the type in meat, milk, and poultry. Also, phytate in grains and rice and polyphenols in tea and coffee can inhibit iron absorption. The iron needs of vegetarians are about 1½ times higher than those of nonvegetarians. Vitamin C enhances the absorption of the iron in plant foods. | Iron-fortified cereals, enriched grains, pasta, bread, oatmeal, potatoes, wheat germ, cashews and other nuts, sunflower seeds, legumes, soybeans, tofu, bok choy, broccoli, mushrooms, dried fruits | • Make sure your morning cereal is iron fortified.  
• Add soybeans to your lunchtime salad.  
• Eat bread with your salad lunch or make a sandwich.  
• Pack a trail mix of dried fruits and nuts for a snack.  
• Add vitamin C–rich foods (broccoli, tomatoes, citrus fruits) to all your meals. |
| **Zinc** | The absorption of zinc is enhanced by animal protein. Eating a vegetarian diet means that you lose out on this benefit and are more likely to develop a deficiency. Phytate also binds zinc, making it unavailable to your body. A vegan’s zinc needs may be as much as 50 percent higher than a nonvegetarian’s. | Soybeans, soy milk, tofu, tempeh, fortified soy burgers, legumes, nuts, sunflower seeds, wheat germ, fortified ready-to-eat cereals, mushrooms, low-fat or nonfat milk, yogurt, and cheese | • Douse your morning cereal with low-fat milk.  
• Add low-fat cheese and soybeans to your lunchtime salad.  
• Snack on sunflower seeds.  
• Top an afternoon yogurt with wheat germ.  
• Add soybeans to your dinner rice. |
| **Calcium** | Calcium is abundant in lean dairy foods such as nonfat or low-fat milk, yogurt, and cheese, so obtaining adequate amounts shouldn’t be difficult if you consume these foods. Calcium-fortified soy milk and orange juice, as well as tofu, can provide about the same amount of calcium per serving as is found in dairy foods. | Low-fat or nonfat milk, yogurt, and cheese, fortified soy milk, soy yogurt, and soy cheese, calcium-fortified orange juice, legumes, sesame tahini, tofu processed with calcium, bok choy, broccoli, kale, collard greens, mustard greens, okra | • Add milk to your morning cereal and coffee.  
• Have at least one yogurt a day.  
• Have a glass of calcium-fortified orange juice with lunch.  
• Snack on low-fat cheese or yogurt in the afternoon.  
• Eat green vegetables often at dinner. |

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<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Risks</th>
<th>Vegetarian Food Sources</th>
<th>Table Tips</th>
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<tbody>
<tr>
<td>Vitamin D</td>
<td>Some vegetarians will need to consume vitamin D-fortified milk or soy products.</td>
<td>Low-fat or nonfat milk, egg yolk, fortified yogurt, soy milk, soy yogurt, ready-to-eat cereals; a vitamin supplement</td>
<td>- Have a glass of milk or soy milk at breakfast every day. &lt;br&gt;- Make sure your morning cereal is vitamin D fortified. &lt;br&gt;- Use fortified evaporated skim milk as a base for cream sauces. &lt;br&gt;- Snack on fortified cereals. &lt;br&gt;- Have a fortified yogurt each day.</td>
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<tr>
<td>Vitamin B₁₂</td>
<td>Animal foods are the only naturally occurring food source of B₁₂; it is extremely important that vegetarians, especially strict vegans, look to fortified cereals and soy milk or a supplement to meet their daily needs.</td>
<td>Low-fat and nonfat milk, yogurt, or cheese, eggs, fortified soy milk, ready-to-eat cereals, soy burgers, egg substitutes; vitamin supplement</td>
<td>- Make sure your morning cereal is fortified with vitamin B₁₂. &lt;br&gt;- Drink a cup of milk or fortified soy milk with your meals. &lt;br&gt;- Top an afternoon yogurt snack with a fortified cereal. &lt;br&gt;- Try an egg-substitute omelet for lunch. &lt;br&gt;- Use fortified soy &quot;meat&quot; alternatives at dinner.</td>
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<tr>
<td>Vitamin A</td>
<td>Vitamin A is found only in animal foods. However, vegetarians can meet their needs by consuming the vitamin A precursor, beta-carotene.</td>
<td>Fortified low-fat or nonfat milk and soy milk, apricots, cantaloupe, mangoes, pumpkin, kale, spinach</td>
<td>- Enjoy a slice or bowl of cantaloupe in the morning. &lt;br&gt;- Snack on dried apricots. &lt;br&gt;- Add spinach to your lunchtime salad. &lt;br&gt;- Drink a glass of fortified milk or soy milk with dinner. &lt;br&gt;- Try mangoes for a sweet dessert.</td>
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<tr>
<td>Omega-3 fatty acids</td>
<td>If your vegetarian diet doesn’t include fish, you may not be consuming enough of the essential omega-3 fatty acid called alpha-linolenic acid.</td>
<td>Fish, especially fatty fish such as salmon and sardines, walnuts, flaxseed and flaxseed oil, soybean and canola oil</td>
<td>- Add walnuts to baked breads and muffins. &lt;br&gt;- Try canned salmon on top of your lunchtime salad. &lt;br&gt;- Top your yogurt with ground flaxseeds. &lt;br&gt;- Have fish regularly for dinner. &lt;br&gt;- Cook with canola and flaxseed oil.</td>
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How Does a Vegetarian Meal Compare?

Similar to meat meals, vegetarian meals can provide a robust amount of protein and iron with less heart-unhealthy saturated fat and cholesterol. While a tofu stir-fry doesn’t provide as much zinc or vitamin $B_{12}$ as meat, it is a fabulous source of calcium, a mineral many adults are falling short of.

<table>
<thead>
<tr>
<th></th>
<th>Beef Stir-Fry (per Serving)</th>
<th>vs.</th>
<th>Tofu Stir-Fry (per Serving)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>38 grams</td>
<td></td>
<td>26 grams</td>
</tr>
<tr>
<td>Saturated Fat</td>
<td>3.3 grams</td>
<td></td>
<td>1.8 grams</td>
</tr>
<tr>
<td>Dietary Cholesterol</td>
<td>105 milligrams</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Iron</td>
<td>3.9 grams</td>
<td></td>
<td>5.1 grams</td>
</tr>
<tr>
<td>Calcium</td>
<td>34 milligrams</td>
<td></td>
<td>450 milligrams</td>
</tr>
<tr>
<td>Zinc</td>
<td>6.8 milligrams</td>
<td></td>
<td>2.9 milligrams</td>
</tr>
<tr>
<td>Vitamin $B_{12}$</td>
<td>2.5 micrograms</td>
<td></td>
<td>0</td>
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</tbody>
</table>
Nutrition in the Real World: The Joy of Soy

Benefits of soy:
1. High-quality protein source
2. Low in saturated fat
3. Contains *isoflavones* (phytoestrogens)
   - May have anticancer functions
   - May relieve menopausal symptoms
4. Lowers blood cholesterol levels
5. May reduce risk of heart disease, certain cancers
The Joy of Soy

Soy products include:

- edamame
- tofu
- soy milk
- soy flour
- tempeh
- miso
- soy meat analogs
- textured soy protein
The End

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