Proteins
Chapter 7
What Are Proteins?

• Complex organic molecules
  – Composed of carbon, hydrogen, and oxygen
  – Proteins also contain nitrogen

• The human body contains an estimated 200,000 different proteins.
## Protein’s functions in the Body

### TABLE 7.1 Proteins in the Body

<table>
<thead>
<tr>
<th>The body uses proteins to make or function as:</th>
</tr>
</thead>
<tbody>
<tr>
<td>New cells and many components of cells</td>
</tr>
<tr>
<td>Structures such as hair and nails</td>
</tr>
<tr>
<td>Enzymes</td>
</tr>
<tr>
<td>Lubricants</td>
</tr>
<tr>
<td>Clotting compounds</td>
</tr>
<tr>
<td>Antibodies</td>
</tr>
<tr>
<td>Compounds that help maintain fluid and pH balance</td>
</tr>
<tr>
<td>Certain hormones and neurotransmitters</td>
</tr>
<tr>
<td>Energy source (minor, under usual conditions)</td>
</tr>
</tbody>
</table>
Types and Functions of Proteins

All cells in the body contain proteins. Specific types of proteins include:

- Structural proteins in cartilage, ligaments, bones, hair, skin, and nails
- Contractile proteins that enable muscles to move
- Pigment proteins such as melanin determine color of eyes, hair, and skin
- Clotting proteins that are needed for blood clotting
Types of Proteins (cont)

• Certain hormones are proteins.
  – *Hormones* are chemical messengers that regulate body processes and responses.
    • Examples: insulin and glucagon

• Enzymes are proteins.
  – Compounds that speed up (*catalyze*) chemical reactions without becoming part of the products.
Functions of Proteins (cont.)

• Transport proteins
  – Oxygen and many nutrients are transported in blood by special proteins.

• Proteins aid in fluid balance.
Fluid Balance and Proteins

- Proteins in blood help maintain the proper distribution of fluids within bloodstream and body tissues.
Acid-Base Balance and Proteins

- **Acid-base balance**
  - Maintaining the proper pH of body fluids
- Blood and tissue fluid must maintain a pH of 7.35 to 7.45
  - Acidic - having an excess of H^+
  - Too basic – not enough H^+
- Proteins act as buffers by accepting or releasing H^+
Amino Acids

• Proteins are made of smaller units called amino acids.
  – 20 different amino acids in human proteins

• Each amino acid is composed of:
  1) An amino or a nitrogen-containing group
     • Amino group has nitrogen bonded to 2 hydrogen atoms
  2) R-group (side chain) — varies with each amino acid
  3) Acid group – acid portion
Amino Acid: Basic Chemical Structure

![Carbon skeleton diagram]

- **R group**: CH₃
- **Amino group**: NH₂
- **Acid group**: OOH

*Alanine molecule*
Classifying Amino Acids

**Essential Amino Acids**
- Cannot be made by the body
  - must be supplied by the diet
- **9** of the 20 amino acids

**Nonessential Amino Acids**
- Can be made by the body
- **11** of the 20 amino acids
The Essential and Nonessential Amino Acids

<table>
<thead>
<tr>
<th>Essential</th>
<th>Nonessential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histidine</td>
<td>Threonine</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>Tryptophan</td>
</tr>
<tr>
<td>Leucine</td>
<td>Valine</td>
</tr>
<tr>
<td>Lysine</td>
<td>Glutamic acid</td>
</tr>
<tr>
<td>Methionine</td>
<td>Serine</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>Arginine*</td>
</tr>
<tr>
<td></td>
<td>Alanine</td>
</tr>
<tr>
<td></td>
<td>Aspartic acid</td>
</tr>
<tr>
<td></td>
<td>Asparagine</td>
</tr>
<tr>
<td></td>
<td>Glutamine*</td>
</tr>
<tr>
<td></td>
<td>Glycine*</td>
</tr>
<tr>
<td></td>
<td>Proline*</td>
</tr>
<tr>
<td></td>
<td>Tyrosine*</td>
</tr>
</tbody>
</table>

* Under certain conditions, this amino acid can become essential.
Proteins in Foods

• Nearly all foods contain some protein, but no natural food is 100% protein.

• Animal foods typically have more protein than plant foods.
  – Seeds, tree nuts, and legumes supply more protein than fruit or the edible leaves, roots, flowers, and stems of vegetables.
# Protein Contents of Some Commonly Eaten Foods

<table>
<thead>
<tr>
<th>Food</th>
<th>Serving Size</th>
<th>Protein g/serving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicken, breast, roasted, meat only</td>
<td>4 oz</td>
<td>40</td>
</tr>
<tr>
<td>Hamburger, 80% lean, broiled</td>
<td>4 oz</td>
<td>34</td>
</tr>
<tr>
<td>Tuna, canned, water-packed, drained</td>
<td>4 oz</td>
<td>34</td>
</tr>
<tr>
<td>Ham, lean, cooked</td>
<td>4 oz</td>
<td>30</td>
</tr>
<tr>
<td>Pepperoni pizza, regular crust, 14” pie</td>
<td>2 slices (200 g)</td>
<td>25</td>
</tr>
<tr>
<td>Miso (soybean product)</td>
<td>½ cup</td>
<td>16</td>
</tr>
<tr>
<td>Lasagna with meat sauce</td>
<td>8 oz</td>
<td>15</td>
</tr>
<tr>
<td>Cottage cheese, 2% low-fat</td>
<td>4 oz</td>
<td>16</td>
</tr>
<tr>
<td>Milk, fat-free</td>
<td>1 cup</td>
<td>8</td>
</tr>
<tr>
<td>Peanut butter</td>
<td>2 Tbsp</td>
<td>8</td>
</tr>
<tr>
<td>Tofu, regular</td>
<td>½ cup</td>
<td>8</td>
</tr>
<tr>
<td>Bagel, plain</td>
<td>1 (3½” diam)</td>
<td>7</td>
</tr>
<tr>
<td>American processed cheese</td>
<td>1 oz</td>
<td>7</td>
</tr>
<tr>
<td>Baked beans, vegetarian</td>
<td>½ cup</td>
<td>6</td>
</tr>
<tr>
<td>Egg, hard cooked</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Vanilla ice cream</td>
<td>1 cup</td>
<td>4</td>
</tr>
<tr>
<td>White rice</td>
<td>1 cup</td>
<td>4</td>
</tr>
<tr>
<td>Peas, green</td>
<td>½ cup</td>
<td>4</td>
</tr>
<tr>
<td>Banana</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
What Are Legumes?

- **Legumes**
  - Plants that produce pods with a single row of seeds

Examples:
- Soybeans, peas, peanuts, lentils, and beans
Protein Quality

• High-quality protein (complete protein)
  – Contains all 9 essential amino acids in amounts that support growth
  – Most animal products
  – High-quality plant foods: quinoa and processed soy

• Low-quality protein (incomplete protein)
  – Lacks or has inadequate amounts of 1 or more essential amino acid
  – Most plant foods and gelatin (animal tissue byproduct)
What Happens to Protein in Your Body?

• How Your Body Synthesizes Proteins
  – Cells assemble the 20 amino acids in specific sequences according to information provided in DNA.
  – Amino acids are connected by peptide bonds.
  – Peptides
    • Chains of < 15 amino acids
  – Polypeptides
    • Proteins made of > 50 amino acids
Amino Acids form Proteins

- Each distinctive bead in the illustration represents a different amino acid.

- The “hook” that connects the “beads” represents a peptide bond.
Peptide Bond

Amino acid 1 + Amino acid 2

Dipeptide

Peptide bond

H₂O
Protein Synthesis

1. Protein synthesis begins when a section of DNA unwinds, exposing a single portion (a gene). The gene contains coded information about the order of amino acids that comprise a specific protein.

2. The gene undergoes transcription, that is, the sequence of its amino acids is copied in a special manner, forming messenger RNA (mRNA) in the process.

3. mRNA transfers the information concerning the amino acid sequence from the nucleus to ribosomes, protein manufacturing sites in the cytoplasm.

4. During the translation process, ribosomes “read” mRNA. The coded instructions indicate which amino acid to add to the polypeptide chain and its sequence.

5. Each specific transfer RNA (tRNA) molecule conveys a particular amino acid to the ribosome.

6. At the ribosome, the amino acid that has been delivered by tRNA attaches to the peptide chain, lengthening it.

7. When the translation process is complete, the ribosome releases the polypeptide, and the new protein generally undergoes further processing at other sites within the cytoplasm.
Step by step: Protein Synthesis

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3-D Shape of a Protein
Sickle Cell Anemia

- If the DNA code is faulty, the wrong amino acid may be inserted into a protein, causing detrimental effects, such as defective hemoglobin.
  - *Sickle cell anemia* is an inherited condition that affects red blood cells.
Protein Denaturation

Denaturation

• Altering a protein’s natural shape and function by exposing its various conditions, including heat, alcohol, acid, and physical agitation
  – Heat denatures protein in raw eggs.
  – Acidic lemon juice “curdles” protein in milk.
  – Hydrochloric acid denatures food proteins in the stomach, making them easy to digest.
  – Physical agitation includes whipping foods, such as beating egg whites to incorporate air into them.
Denaturation

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Protein Digestion and Absorption

1. **Stomach**
   - Proteins undergo denaturation by stomach acid and partial digestion by pepsin.

2. **Small intestine**
   - Further digestion occurs as the pancreas secretes protein-splitting enzymes including trypsin and chymotrypsin.

3. **Small intestinal cells**
   - Final digestion occurs within absorptive cells.

4. **Liver**
   - After being absorbed, amino acids enter the portal vein and travel to the liver.

5. **Rectum**
   - Very little dietary protein is excreted in feces.
Protein Digestion

• Protein digestion begins in the stomach.
  – Hydrochloric acid denatures proteins.
  – The enzyme pepsin digests proteins into smaller polypeptides.

• Polypeptides enter the small intestine.
  – The enzymes trypsin and chymotrypsin break down polypeptides into shorter peptides and individual amino acids.
Protein Absorption

• Absorption occurs in the small intestine
  – Absorptive cells release enzymes that digest most small peptides into individual amino acids.
  – Individual amino acids and some di- and tripeptides enter absorptive cells, where they are completely digested to amino acids.
Protein Turnover

• Protein turnover
  – Breaking down old or unneeded proteins into amino acids and recycling the amino acids

• Amino acid “pool”
  – Amino acids that have not been incorporated into proteins
    1) *Endogenous* amino acids
      – Those available from the amino acid pool
    2) *Exogenous* proteins
      – Those from dietary sources
Transamination and Deamination

Transamination
- Transfer of nitrogen-containing group from an unneeded amino acid to a carbon skeleton, forming an amino acid

Deamination
- Removal of nitrogen-containing group from an unneeded amino acid
Example of Transamination and Deamination

- **Transamination**
  - Glutamic acid (amino acid) → Alanine (amino acid)
  - Pyruvic acid

- **Deamination**
  - Glutamic acid (amino acid) → Carbon skeleton

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Deamination and Urea Formation

Ammonia (NH$_3$) is converted to urea that the kidneys excrete in urine.
Nitrogen Balance

_Nitrogen balance_ (or nitrogen equilibrium)
Balancing nitrogen intake with nitrogen losses

*Positive nitrogen balance*
Body retains more nitrogen than it loses

*Negative nitrogen balance*
Body loses more nitrogen than it retains
Positive Nitrogen Balance

Occurs during growth, pregnancy, recovery from illness, and as a result of certain hormones and resistance exercise.
Nitrogen Equilibrium

*Occurs when healthy adults meet protein and energy needs*
Negative Nitrogen Balance

Occurs with ↓ protein intake, kidney disease, blood loss, bed rest, fever, injuries, burns, or ↑ thyroid hormone or cortisol
How Much Protein Do You Need?

- Daily protein needs of healthy adults:
  - RDA = 0.8 g/kg body wt

- Protein needs increase during periods of growth, pregnancy, lactation, and recovery from illness or injury.
Determining Protein Needs

- Using the RDA formula of 0.8 g of protein/kg of body wt, what is the RDA for protein for a person weighing 165 lbs?

1) Convert weight in lbs to weight in kg
   
   \[ \frac{165}{2.2} = 75 \text{ kg} \]

2) Multiply kg of body wt by 0.8
   
   \[ 75 \times 0.8 = 60 \]

- Therefore, a person weighing 165 lbs will meet his/her RDA for protein by consuming 60 g of protein per day
What Is A Food Allergy?

Allergy

- Inflammatory response resulting when body’s immune system reacts inappropriately to a substance that is typically harmless
  - Allergen — the offending substance
- Most food allergens are proteins that escape digestion and are absorbed as whole proteins.
Common Signs of Food Allergies

Signs occur within a few minutes or couple of hours and typically include:

- Hives (red raised bumps on skin)
- Swollen or itchy lips
- Skin flushing
- Scaly skin rash (*eczema*)
- Difficulty swallowing
- Wheezing and difficulty breathing
- Abdominal pain, vomiting, and diarrhea
# Common Food Allergens

<table>
<thead>
<tr>
<th>Protein-rich foods</th>
<th>Nonproteins</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Cow’s milk</td>
<td>- Food dyes</td>
</tr>
<tr>
<td>- Eggs</td>
<td>- Sulfites added to:</td>
</tr>
<tr>
<td>- Peanuts</td>
<td>• Wine</td>
</tr>
<tr>
<td>- Wheat</td>
<td>• Potatoes</td>
</tr>
<tr>
<td>- Soybeans</td>
<td>• Shrimp</td>
</tr>
<tr>
<td>- Fish &amp; shellfish</td>
<td></td>
</tr>
</tbody>
</table>
Who Develops Food Allergies?

• People with family history of food or environmental allergies
• ~ 6% of children
  • Most children outgrow their allergies by age 5 yrs
    – Allergies to nuts, seafood, and wheat are typically not outgrown
• ~ 3-4% of adults
Treatment of Food Allergies

- Avoid offending foods
- Read food labels to check for allergens
  - Food Allergen Labeling & Consumer Protection Act requires manufacturers to identify allergenic ingredients on product labels.
- Educate teachers and other adults of allergic children’s need to avoid certain foods
Treating Severe Allergic Reactions

- Emergency treatment for *anaphylaxis* may involve injecting a special medication.
Gluten and Celiac Disease

• Gliadin
  – Protein found in gluten of wheat, buckwheat, barley, and rye
  – Triggers inflammatory response in small intestine
  – Condition called celiac disease

• Symptoms include
  – Chronic diarrhea, weight loss, and poor growth in children

• Treatment
  – Avoid gluten-containing foods
What Is PKU?

Phenylketonuria (PKU)

– Genetic disorder
– Affects ~ 1/10,000 to 1/15,000 infants
– Caused by lack of enzyme that converts the amino acid phenylalanine to another compound
– If undiagnosed, infant will develop mental retardation by first birthday.
Low Phenylalanine Diet

Infancy

Phenylalanine-free formula and low-phenylalanine foods

Childhood and adult years

*Allowed*: fruits, vegetables, and special low-phenylalanine foods

*Avoided*: nuts, milk and milk products, eggs, meats, as well as foods and beverages containing aspartame (e.g., Nutrasweet or Equal)
Protein Consumption Patterns

- **Meat, fish, and poultry**
- **Grains**
- **Other sources**

Protein intake:
- **1909–1919**
- **2005**

Percent of total protein intake:
- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50

(Roast), (Fish): © Photodisc/PunchStock RF; (Turkey): © Paul Poplis/StockFood Creative/Getty Images; (Rice): © The McGraw-Hill Companies, Inc./Jacques Cornell, photographer; (Bread): © C Squared Studios/Getty Images RF; (Beans): © Burke/Triolo Productions/Getty Images RF; (Egg): © Siede Preis/Getty Images RF; (Nuts): © C Squared Studios/Getty Images RF; (Dairy): © Photodisc/Getty Images RF
MyPlate: Recommendations for Protein Intake

• Choose lean or low-fat meat and poultry
  – Lean cuts of beef include:
    • Round steaks, top round, loin, top sirloin, chuck and arm roasts
  – Lean pork cuts include:
    • Loin, tenderloin, and center loin
• Choose “extra lean” ground beef
  – At least 90% lean
• Trim visible fat from meats
Understanding Nutritional Labeling

- *Nutrition Facts* panel does not provide information concerning protein quality
  - Judge protein quality by reviewing items in the ingredient list
Eating Well for Less

- Substitute eggs, milk, cheese, and yogurt for meat, fish, or poultry.

- Make meals that contain less animal proteins and more plant proteins.

- Extend cereal proteins with eggs & milk (e.g., pancakes, waffles, crepes, or cereal with milk).

- Include more legumes in meals (e.g., chili, bean soups, and stews) while reducing meat content.
Combining Complementary Proteins

*Complementary combinations*
- Mixing certain plant foods to provide all essential amino acids without adding animal proteins

Amino acids often low or limiting in plant proteins:
  - tryptophan, threonine, lysine, and methionine
Complementary Dishes

Peanut Butter (legume)
On Bread (grain)

Couscous (grain) with Chickpeas (legume)
# Complementary Protein Dishes

**TABLE 7.5 Complementary Protein Dishes**

<table>
<thead>
<tr>
<th>Dish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red beans and rice</td>
</tr>
<tr>
<td>Peanut or soy nut butter on bagel, sprinkled with wheat germ</td>
</tr>
<tr>
<td>Hummus (mashed chickpeas/garbanzo beans) with sesame seeds*</td>
</tr>
<tr>
<td>Hummus on whole-grain pita bread</td>
</tr>
<tr>
<td>Black beans and cornmeal tortilla*</td>
</tr>
<tr>
<td>Split pea soup with toasted whole-wheat bread</td>
</tr>
<tr>
<td>Meatless kidney bean chili with macaroni</td>
</tr>
<tr>
<td>Cornmeal tortilla with black bean salsa</td>
</tr>
<tr>
<td>Peanut butter on whole-grain crackers, sprinkled with wheat germ</td>
</tr>
<tr>
<td>Green beans with brown rice and cashews</td>
</tr>
</tbody>
</table>

* See the “Recipes for Healthy Living” feature for a black bean recipe.
Vegetarianism

Vegetarians - People who eat plant-based diets

Types of Vegetarians
- *Lactovegetarian*
  - Consumes milk and milk products
- *Ovovegetarian*
  - Consumes eggs
- *Lactoovovegetarian*
  - Consumes eggs, milk, and milk products
- *Vegan*
  - Consumes only plant foods
Is Vegetarianism a Healthy Lifestyle?

**Pros**
- Compared to nonvegetarians, vegetarians tend to:
  - Weigh less
  - Have less heart disease (*eat less saturated fat and cholesterol*)
  - Often exercise more, meditate for relaxation, and avoid tobacco & alcohol

**Cons**
- If diets are poorly planned, vegetarians may lack:
  - Calories
  - High-quality protein
  - Omega-3 fatty acids
  - Vitamins B-12 and D
  - Zinc, iron, and calcium
Vegetarian Children and Teens

Children

• May be difficult to consume adequate protein and energy, because plant foods tend to be filling.
  – Growth rates of vegan children need close monitoring.

Teens

Pro: Can be healthy diet because more fruits and vegetables are consumed

Con: May be at risk of anorexia nervosa
Vegetarian Women

Pregnancy
- May need vitamin B-12 supplements
  - Infant could be deficient in B-12

Breastfeeding
- Breastmilk may be deficient in vitamin B-12
  - Infant may develop severe developmental delays if fed breast milk that lacks vitamin B-12
Meatless Menu Planning Ideas

<table>
<thead>
<tr>
<th>TABLE 7.8  Meatless Menu Ideas</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cooked pasta with marinara sauce and grated Parmesan or part-skim mozzarella cheese</td>
</tr>
<tr>
<td>• Vegetable lasagna with layers of thinly sliced zucchini, mushrooms, and bell peppers</td>
</tr>
<tr>
<td>• Vegetable stir-fry with bits of tofu and cheese</td>
</tr>
<tr>
<td>• Grilled vegetable kabobs served over cooked rice and black beans</td>
</tr>
<tr>
<td>• Black or red bean burritos</td>
</tr>
<tr>
<td>• Bean and corn tacos</td>
</tr>
</tbody>
</table>
Protein Adequacy

Excessive Meat Intake

– May ↑ risk of heart disease and cancers of the colon/rectum and possibly prostate

What about High-Protein Weight-Loss Diets?

– Such diets decrease feelings of hunger and increase sense of fullness.
– Chapter 10 provides more info about safety of high-protein weight loss diets.
Protein Deficiency

Uncommon in the U.S.

– May occur in:
  • elderly or low-income people
  • persons with alcoholism, anorexia nervosa, or intestinal tract disorders
Kwashiorkor and Marasmus

Undernutrition
– Results from chronic lack of food or poor food choices

Two types of protein-energy undernutrition:
– Kwashiorkor
  • Adequate energy intake but intake of high-quality protein is low
    » Edema
– Marasmus
  • Starvation—extreme weight loss
Marasmic Kwashiorkor

Characterized by edema in the abdomen, lower legs, and feet
Severe Protein-Energy Undernutrition
Proteins: General Advice for Athletes

How to increase muscle mass?

- *Resistance training is the only safe and reliable way.*
- *Protein and amino acids supplements are not needed.*
What About Protein Supplements?

• Healthy people adapt to protein intakes higher than the AMDR with no problems.

• Best to avoid supplements with individual amino acids.