Proteins

6

Real Life Scenario

Shannon is a freshman in college. She lives in a campus residence hall and teaches aerobics in the afternoon. She eats two or three meals a day at the residence hall cafeteria and snacks between meals. Shannon and her roommate both decided to become vegetarians because they recently read a magazine article describing the health benefits of a vegetarian diet. Yesterday her vegetarian diet consisted of a danish pastry for breakfast and a tomato-rice dish (no meat) with pretzels and a diet soft drink for lunch. In the afternoon, after her aerobics class, she had an ice cream cone and two cookies. At dinnertime, she had a vegetarian sub sandwich consisting of lettuce, sprouts, tomatoes, cucumbers, and cheese, with two glasses of fruit punch. In the evening, she had a bowl of popcorn.

What is missing from this current diet plan in terms of foods that should be emphasized in a vegetarian diet? How could she improve her new diet to meet her nutritional needs?

Check out the **Contemporary Nutrition Online Learning Center** **www.mhhe.com/wardlawcont6** *for quizzes, flash cards, other activities, and web links designed to further help you learn about proteins.*

Chapter Objectives

Chapter 6 is designed to allow you to:

1. Describe how amino acids make up proteins.
2. Distinguish between essential and nonessential amino acids.
3. Explain why adequate amounts of each of the essential amino acids are required for protein synthesis.
4. List the primary functions of protein in the body.
5. Calculate the RDA for protein for an adult when a healthy weight is given.
6. Describe what is meant by positive protein balance, negative protein balance, and protein equilibrium.
7. Distinguish between high-quality and low-quality proteins, identify examples of each, and describe the concept of complementary proteins.
8. Describe how protein-calorie malnutrition eventually can lead to disease in the body.
9. Develop vegetarian diet plans that meet the body's nutritional needs.

Chapter Outline

Consuming enough protein is vital for maintaining health. Proteins form important structures in the body, make up a key part of the blood, help regulate many body functions, and can fuel body cells.

North Americans generally eat more protein than is needed to maintain health. Our daily protein intake comes mostly from animal sources such as meat, poultry, fish, eggs, milk, and cheese. In contrast, our Stone Age ancestors obtained a greater percentage of their protein from vegetables. They primarily picked and gathered their dietary protein from plant sources, rather than hunted it in the form of animals. Not until the appearance of *Homo erectus*, our immediate ancestors, about 1 million years ago did meat displace other foods in a primarily vegetarian diet. Diets that are mostly vegetarian still predominate in much of Asia and areas of Africa, and some North Americans are currently adopting the practice.

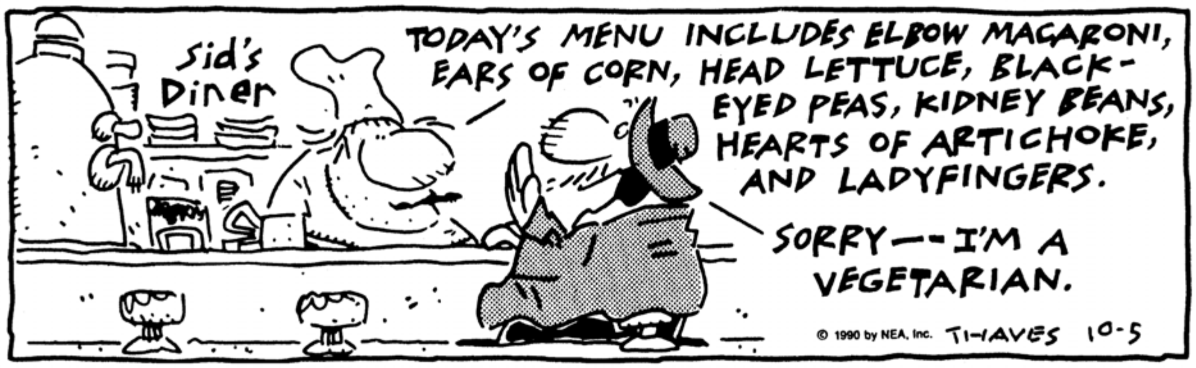
Few of us wish to exchange our comfortable modern lifestyles with those of our Stone-Age ancestors, yet we could benefit from eating more plant sources of proteins. It is possible—and desirable—to incorporate the most nutritious practices of both eras and enjoy the benefits of animal and plant protein as we meet the goal of consuming 10% to 35% of total calories as protein. Let's see why a detailed study of protein is worth your attention.

Refresh Your Memory

As you begin your study of proteins in Chapter 6, you may want to review:

- Organization of the cell in Chapter 3
- The process of digestion and absorption in Chapter 3
- The nervous system and immune system in Chapter 3
- The role of carbohydrates in preventing ketosis in Chapter 4

FRANK & ERNEST® by Bob Thaves



Can a vegetarian diet provide enough protein? What is prompting the growing interest in various forms of vegetarian diets? Why are plant protein *sources,* especially soy and nuts, gaining more attention? Should meat-eaters abandon that dietary practice? Chapter 6 provides some answers.

Protein—An Introduction

The term *protein* comes from the Greek word *protos,* which means "to come first." In the developing world, it is important to focus on protein in diet planning because diets in those areas of the world can be deficient in protein. In contrast, diets in the developed world are generally rich in protein, and therefore a specific focus on eating enough protein is, for the most part, not needed.

High-protein diets have come and gone over the past 30 years. Recently, they have re-emerged as weight-loss diets. The latest advice from the Food and Nutrition Board allows for up to 35% of total calorie intake to be supplied by protein, so in general these diets are appropriate if otherwise nutritionally sound. Still, as discussed in Chapter 10, these types of diets are hardly a magic wand for weight loss.

Proteins—Vital to Life

Thousands of substances in the body are made of proteins. Aside from water, proteins form the major part of lean body tissue, totaling about 17% of body weight. Amino acids—the building blocks for proteins—contain a special form of nitrogen: essentially, nitrogen bonded to carbon. Plants combine nitrogen from the soil with carbon and other elements to form amino acids. They then link these amino acids together to make proteins. We get the nitrogen we need by consuming dietary proteins. Proteins are thus an essential part of a diet because they supply nitrogen in a form we can readily use—namely, amino acids. Directly using simpler forms of nitrogen is, for the most part, impossible for humans.

Proteins are crucial to the regulation and maintenance of the body. Body functions such as blood clotting, fluid balance, hormone and enzyme production, visual processes, transport of many substances in the bloodstream, and cell repair require specific proteins. The body makes proteins in many configurations and sizes so that they can serve these greatly varied functions. Formation of these many body proteins begins with amino acids from both the protein-containing foods we eat and those that are synthesized from other compounds within the body. Proteins can also be broken down to supply energy for the body—on average, 4 kcal per gram.

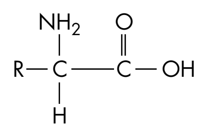
If you fail to consume an adequate amount of protein for weeks at a time, many metabolic processes slow down. This is because the body does not have enough amino acids available to build the proteins it needs. For example, the immune system

Small amounts of animal protein in a meal easily add up to meet daily protein needs.

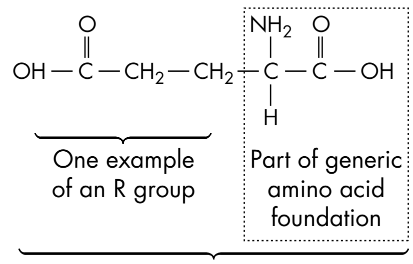
no longer functions efficiently when it lacks key proteins, thereby increasing the risk of infections, disease, and eventually death.

Amino Acids

Amino acids—the building blocks of proteins—are formed mostly of carbon, hydrogen, oxygen, and nitrogen. The following diagram shows the general form of an amino acid and what one of the amino acids looks like. The amino acids used to make protein have different chemical makeups, but all are slight variations of the generic amino acid pictured (see Appendix F).



"Generic" amino acid. The R signifies another chemical group that would be present.



Glutamic acid

Another Bite

The R group on some amino acids has a branched shape, like a tree. These so-called **branched-chain amino acids** are leucine, isoleucine, and valine (see Appendix F for the chemical structures of the amino acids). The branched-chain amino acids are the primary amino acids used by muscles for energy needs. This is one reason why proteins from milk (e.g. whey proteins) are a current rage in strength-training athletes (see Chapter 11 for details).

branched-chain amino acids Amino acids with a branching carbon backbone, these are leucine, isoleucine, and valine. All are essential amino acids.

nonessential amino acids Amino acids that can be synthesized by a healthy body in sufficient amounts; there are 11 nonessential amino acids. These are also called *dispensable amino acids.*

semiessential amino acids Amino acids that, when consumed, spare the need to use an essential amino acid for their synthesis. Tyrosine in the diet, for example, spares the need to use phenylalanine for tyrosine synthesis. Also called *conditionally essential amino acids.*

Your body needs to use 20 different types of amino acids to function (Table 6-1). Although all these commonly found amino acids are important, 11 are considered **nonessential** (also called *dispensable*) with respect to our diets. Human cells can produce these certain amino acids as long as the right ingredients are present—the key

Table 6-1 Classification of Amino Acids

Essential (Indispensable) Amino Acids	Nonessential (Dispensable) Amino Acids
Histidine	Alanine
Isoleucine*	Arginine†
Leucine*	Asparagine
Lysine	Aspartic acid
Methionine	Cysteine†
Phenylalanine	Glutamic acid
Threonine	Glutamine†
Tryptophan	Glycine†
Valine*	Proline†
	Serine
	Tyrosine†

*A branched-chain amino acid

†These amino acids are also classed as **semiessential** (or conditionally essential). This means they must be made from essential amino acids if insufficient amounts are eaten. When that occurs, the body's supply of certain essential amino acids is depleted.

factor being nitrogen that is already part of another amino acid. Therefore it is not essential that these amino acids be in our diet.

The nine amino acids the body cannot make in sufficient amounts or at all are known as **essential** (also called *indispensable*)—they must be obtained from foods. This is because body cells either cannot make the needed carbon-based foundation of the amino acid, cannot put a nitrogen group on the needed carbon-based foundation, or just cannot do the whole process fast enough to meet body needs.

Both nonessential and essential amino acids are present in foods that contain protein. If you don't eat enough essential amino acids, your body first struggles to conserve what essential amino acids it can. However, eventually your body progressively slows production of new proteins until at some point you will break protein down faster than you can make it. When that happens, health deteriorates.

essential amino acids The amino acids that cannot be synthesized by humans in sufficient amounts or at all and therefore must be included in the diet; there are nine essential amino acids. These are also called *indispensable amino acids.*

Putting Essential and Nonessential Amino Acids into Perspective

Eating a balanced diet can supply us with both the essential and nonessential amino-acid building blocks needed to maintain good health. Let's now take a more detailed look at the relationship between essential and nonessential amino acids.

Physiological Aspects

The disease phenylketonuria (PKU) illustrates the importance of one essential amino acid. Recall from Chapter 4 that a person with PKU has a limited ability to metabolize the essential amino acid phenylalanine. Normally, the body uses an enzyme to convert much of our dietary phenylalanine intake into the nonessential amino acid tyrosine.

In PKU-diagnosed persons, the enzyme activity may be grossly or mildly insufficient due to the insertion of an incorrect amino acid into the enzyme used in processing phenylalanine to tyrosine. When the enzymes cannot synthesize enough tyrosine, both amino acids must be derived from foods. The key point here is that both amino acids become *essential* in terms of dietary needs because the body can't produce enough tyrosine from phenylalanine. PKU is treated by controlling the consumption of phenylalanine with a special diet (ideally throughout life) so that phenylalanine and its by-products do not rise to toxic concentrations in the body and cause the severe mental retardation seen in untreated PKU cases.

Critical Thinking

Rina is 7 months pregnant and has read about various tests that her baby will undergo when he or she is born. How can you explain to Rina the purpose and significance of one of those tests, the one that screens for PKU?

Dietary Considerations—Protein Quality

Animal and plant proteins can differ greatly in their proportions of essential and nonessential amino acids. Animal proteins contain ample amounts of all nine essential amino acids. (Gelatin—made from the animal protein collagen—is an exception because it loses one essential amino acid during processing and is low in other essential amino acids.) With the exception of soy protein, plant proteins don't match our need for essential amino acids as precisely as animal proteins. Many plant proteins, especially those found in grains, are low in one or more of the nine essential amino acids.

As you might expect, human tissue composition resembles animal tissue more than it does plant tissue. The similarities enable us to use proteins from any single animal source more efficiently to support human growth and maintenance than we do those from any single plant source. For this reason, animal proteins, except gelatin, are considered **high-quality** (also called **complete**) **proteins,** which contain the nine essential amino acids we need in sufficient amounts. Individual plant sources of proteins, except for soy beans, are considered **lower-quality** (also called **incomplete**) **proteins** because their amino-acid patterns can be quite different from ours. Thus a single plant protein source, such as corn alone, cannot easily support body growth and maintenance. To obtain a sufficient amount of essential amino acids, a variety of plant proteins need to be consumed because each plant protein lacks adequate amounts of one or more essential amino acids.

high-quality (complete) proteins Dietary proteins that contain ample amounts of all nine essential amino acids.

lower-quality (incomplete) proteins Dietary proteins that are low in or lack one or more essential amino acids.

limiting amino acid The essential amino acid in lowest concentration in a food or diet relative to body needs.

complementary proteins Two food protein sources that make up for each other's inadequate supply of specific essential amino acids; together they yield a sufficient amount of all nine and, so, provide high-quality (complete) protein for the diet.

When only lower-quality protein foods are consumed, enough of the essential amino acids needed for protein synthesis may not be obtained. Therefore, when compared to high-quality proteins, a greater amount of lower-quality protein is needed to meet the needs of protein synthesis. Moreover, once any of the nine essential amino acids in the plant protein we have eaten is used up, further protein synthesis becomes impossible. Because the depletion of just one of the essential amino acids prevents protein synthesis, the process illustrates the *all-or-none principle:* Either all essential amino acids are available or none can be used. The remaining amino acids would then be used for energy needs, or converted to carbohydrate or fat.

The essential amino acid in smallest supply in a food or diet in relation to body needs becomes the limiting factor (called the **limiting amino acid**) because it limits the amount of protein the body can synthesize. For example, assume the letters of the alphabet represent the 20 or so different amino acids we consume. If *A* represents an essential amino acid, we need three of these letters to spell the hypothetical protein *BANANA*. If the body had a *B,* two *N*s, but only two *A*s, the "synthesis" of *BANANA* would not be possible. *A* would then be seen as the limiting amino acid.

When two or more proteins combine to compensate for deficiencies in essential amino acid content in each protein, the proteins are called **complementary proteins** (Table 6-2). Mixed diets generally provide high-quality protein because a complementary protein pattern results. Therefore, healthy adults should have little concern about balancing foods to yield the proteins needed to obtain enough of all nine essential amino acids. Even on plant-based diets, complementary proteins need not be consumed at the same meal by adults. Meeting amino-acid needs over the course of a day is a reasonable goal because there is a ready supply of amino acids from those present in body cells and in the blood (see Fig. 6-8 on page 199). In addition, adults need only about 11% of their total protein requirement to be supplied by essential amino acids. Typical diets supply an average of 50% of protein as essential amino acids.

The estimated needs for essential amino acids for infants and preschool children are 40% of total protein intake; however, in later childhood the need drops to 20%. Consequently, diets for infants and young children must be carefully planned to make sure enough proteins are present to yield high-quality protein intake. Including some animal products in the diet, such as human milk or formula for infants, or cow's milk

When combined with vegetables, high-protein foods such as meats also help balance the amino acid content of the diet.

Table 6-2 Limiting Amino Acids in Plant Foods

Food	Limiting Amino Acids	Good Plant Source of the Limiting Amino Acids*	Traditional Food Combinations in Which the Proteins Complement Each Other in a Meal
Legumes (beans)	Methionine	Grains, nuts, seeds	Red beans and rice
Grains	Lysine, threonine, tryptophan	Legumes	Rice and red beans; lentil curry and rice; corn tortillas and beans
Nuts and seeds	Lysine	Legumes	Soybeans and ground sesame seeds (miso); peanuts, rice, and black-eyed peas; green peas and sunflower seeds
Vegetables	Methionine	Grains, nuts, seeds	Green beans and almonds

Note: As you might suspect from the information in Table 6-2, the amino acids most likely to be low in a diet are lysine, methionine, threonine, and tryptophan. If a diet is low in an amino acid, nutrition experts recommend finding a good food source to supply it. Finding the right combinations of amino acids, such as a dish of rice and beans, is recommended. Forget about amino-acid supplements—they can lead to problems, such as decreased absorption of other, similar amino acids. Amino acids as such also have a disagreeable odor and flavor and are also much more expensive than food protein.

*Animal products in the diet serve the same purpose, such as when fish is consumed with rice, or cheese with macaroni.

for children, helps ensure this. Otherwise, complementary amino acids from plant proteins should be consumed in each meal or within two subsequent meals. A major health risk for infants and children occurs in famine situations in which only one type of cereal grain is available, increasing the probability that one or more of the nine essential amino acids is lacking in the total diet. This is discussed further in a later section on protein-calorie malnutrition.

Critical Thinking

Leon, a vegetarian, has heard of the "all-or-none principle" of protein synthesis but doesn't understand how this principle applies to protein synthesis in the body. He asks you, "How important is this nutritional concept for diet planning?" How would you answer his question?

Concept Check

The human body uses 20 different amino acids from protein-containing foods. Because a healthy body can synthesize 11 of the amino acids, it is not necessary to obtain all amino acids from foods—only nine of these must come from the diet and are therefore termed *essential (indispensable) amino acids.* Foods that contain all nine essential amino acids in about the proportions we need are considered high-quality (complete) protein foods. Those low in one or more essential amino acids are lower-quality (incomplete) protein foods. When different lower-quality protein foods are eaten together, the total intake of amino acids generally makes up for the shortcomings of each individual food to yield a high-quality protein meal.

Proteins—Amino Acids Bonded Together

Amino acids are linked together by chemical bonds—technically called **peptide bonds**—to form proteins. Although these bonds are difficult to break, acids, enzymes, and other agents are able to do so—for example, during digestion.

The body can synthesize many different proteins by linking together the 20 common types of amino acids with such peptide bonds.

peptide bond A chemical bond formed between amino acids in a protein.

polypeptide A group of amino acids bonded together, from a few to 1000 or more.

Protein Synthesis

To begin a discussion of protein synthesis, we need to focus on DNA, which is present in the nucleus of the cell. Recall from Chapter 3 that DNA is a double-stranded molecule. DNA contains coded instructions for protein synthesis (i.e., which specific amino acids are to be placed in a protein and in which order).

Protein synthesis in a cell, however, takes place in the cytoplasm, not in the nucleus. Thus, the DNA code used for synthesis of a specific protein must be transferred from the nucleus to the cytoplasm to allow for such synthesis. This transfer is the job of messenger RNA (mRNA). Enzymes in the nucleus read the code on one strand of the DNA and *transcribe* that into a single-stranded mRNA molecule (Fig. 6-1). The segment that is read is the gene. This mRNA undergoes processing and then it is ready to leave the nucleus.

Once in the cytoplasm, mRNA travels to the ribosomes. The ribosomes read the mRNA code and *translate* those instructions to produce a specific protein. Amino acids are added one at a time to the growing **polypeptide** chain as directed by the instructions on the mRNA. Another key participant in protein synthesis, transfer RNA (tRNA), is responsible for bringing specific amino acids to the ribosomes as needed during protein synthesis (review Fig. 6-1). Energy input is required to add each amino acid to the chain, making protein synthesis very "costly" to the body.

Genes are present on DNA—a double-stranded helix. The cell nucleus contains most of the DNA in the body.

Once synthesis of a polypeptide is complete, it twists and folds into the appropriate three-dimensional structure of the intended protein due to interactions between the amino acids that make up the polypeptide chain (see the next section on protein organization for details). Some polypeptides, such as the hormone insulin, also undergo further metabolism in the cell before they are functional.

The important message in this discussion is the relationship between DNA and the proteins eventually produced by a cell. If the DNA contains errors, an incorrect mRNA

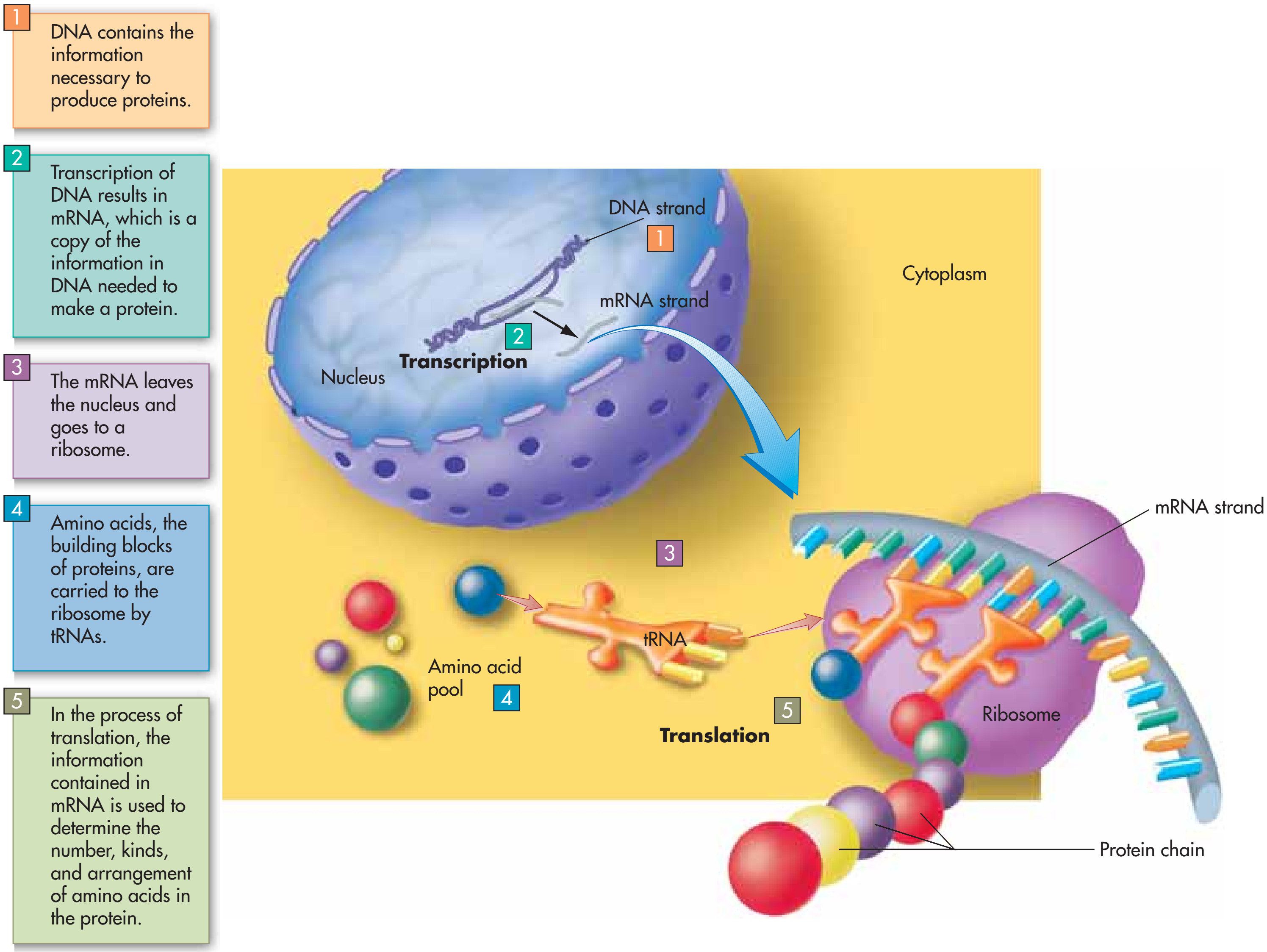


Figure 6-1 Protein synthesis (simplified). Note that once the mRNA is fully read, the polypeptide is released into the cytoplasm. It generally is then processed further to become a cell protein.

will be produced. The ribosomes will then read this incorrect message and produce an incorrect polypeptide chain. As discussed in Chapter 3, ultimately we may be able to correct many gene defects in humans, by placing the correct DNA code in the nucleus, so that the correct protein can be made by the ribosomes.

Protein Organization

As noted before, by bonding together various combinations of the 20 common types of amino acids, the body synthesizes thousands of different proteins. The sequential order of the amino acids then ultimately determines the protein's shape. The main point is that only correctly positioned amino acids can interact and fold properly to form the intended shape for the protein. The resulting unique, three-dimensional form goes on to dictate the function of each particular protein (Fig. 6-2). If it lacks the appropriate configuration, a protein cannot function.

Sickle cell disease (also called **sickle cell anemia**) is one example of what happens when amino acids are out of order on a protein. North Americans of African descent

sickle cell disease (sickle cell anemia) An illness that results from a malformation of the red blood cell because of an incorrect structure in part of its hemoglobin protein chains. The disease can lead to episodes of severe bone and joint pain, abdominal pain, headache, convulsions, paralysis, and even death.

are especially prone to this genetic disease. It originates in defective production of the protein chains of hemoglobin, a protein that carries oxygen in red blood cells. In two of its four protein chains, an error in the amino-acid order occurs. This error produces a profound change in hemoglobin structure. It can no longer form the shape needed to carry oxygen efficiently inside the red blood cell. Instead of forming normal circular disks, the red blood cells collapse into crescent or sickle shapes (Fig. 6-3). Health deteriorates, and eventually episodes of severe bone and joint pain, abdominal pain, headache, convulsions, and paralysis may occur.

These life-threatening symptoms are caused by a minute, but critical, error in the hemoglobin amino-acid order. Why does this error happen? It results from a defect in a person's genetic blueprint, DNA, which is inherited through one's parents. A defect in the DNA can dictate that a wrong amino acid will be built into the sequence of the body proteins. Many diseases stem from incorrect DNA information passed on in the body, such as cancer (see Chapter 15).

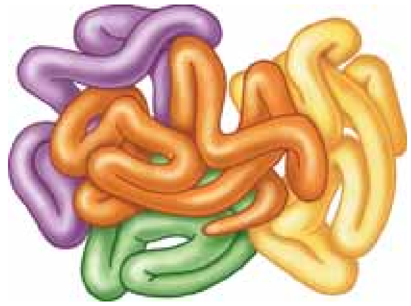


Figure 6-2 Protein organization. Proteins often form a coiled shape, as shown by this drawing of the blood protein hemoglobin. This shape is dictated by the order of the amino acids in the protein chain. To get an idea of its size, consider that each teaspoon (5 milliliters) of blood contains about 10^{18} hemoglobin molecules. Note that 1 billion is 10^9.

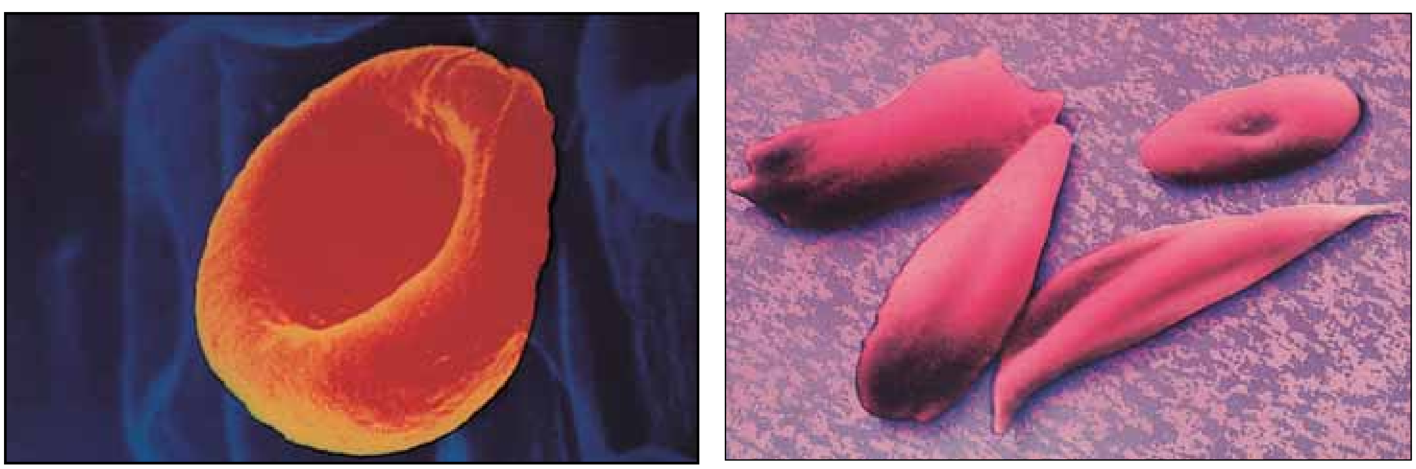
Denaturation of Proteins

Exposure to acid or alkaline substances, heat, or agitation can alter a protein's structure, leaving it unraveled or otherwise deformed. This process of altering the three-dimensional structure of a protein is called **denaturation** (Fig. 6-4). Changing a protein's shape often destroys its ability to function normally, such that it loses its biological activity.

Denaturation of proteins is useful for some body processes, especially digestion. The heat produced during cooking denatures some proteins. For example, a protein in raw eggs (avidin) binds to the vitamin biotin so that it cannot be absorbed, but cooking denatures avidin, thus preventing a potential decrease in biotin availability. After food is ingested, the secretion of stomach acid denatures some bacterial proteins, plant hormones, many active enzymes, and other forms of proteins in foods, making it safer to eat. Digestion is also enhanced by denaturation because the unraveling increases exposure of the polypeptide chain to digestive enzymes. Denaturing proteins in some foods can also reduce their tendencies to cause allergic reactions.

Recall that we need the essential amino acids that the proteins in the diet supply—not the proteins themselves. We dismantle ingested dietary proteins and use the amino acid building blocks to assemble the proteins we need.

denaturation Alteration of a protein's three-dimensional structure, usually because of treatment by heat, enzymes, acid or alkaline solutions, or agitation.



(a) (b)

Figure 6-3 An example of the consequences of errors in DNA coding of proteins. (a) Normal red cell, (b) red blood cells from a person with sickle cell disease. Note the abnormal crescent (sicklelike) shape of the red blood cell near the center.

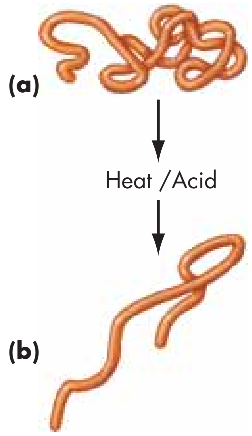


Figure 6-4 Denaturation. (a) Protein showing typical coiled state. (b) Protein is now partly uncoiled. This uncoiling can reduce biological activity.

Concept Check

Amino acids are bonded together in specific sequences to form distinct proteins. DNA provides the directions for synthesizing these new proteins. Specifically, DNA directs the order of the amino acids on the protein. The amino acid order within a protein determines its ultimate shape and function. Destroying the shape of a protein denatures it. Acid conditions present during the body's digestive processes, heat, and other factors can denature proteins, causing them to lose their biological activity.

Protein in Foods

Of the typical foods we eat, about 70% of our protein comes from animal sources (Fig. 6-5). The most nutrient-dense source of protein is water-packed tuna, which has 87% of calories as protein. The top five contributors of protein to the North American diet are beef, poultry, milk, white bread, and cheese. In North America, meat and poultry consumption amounts to about 150 pounds per person per year. Worldwide, 35% of protein comes from animal sources. In Africa and East Asia, only about 20% of the protein eaten comes from animal sources.

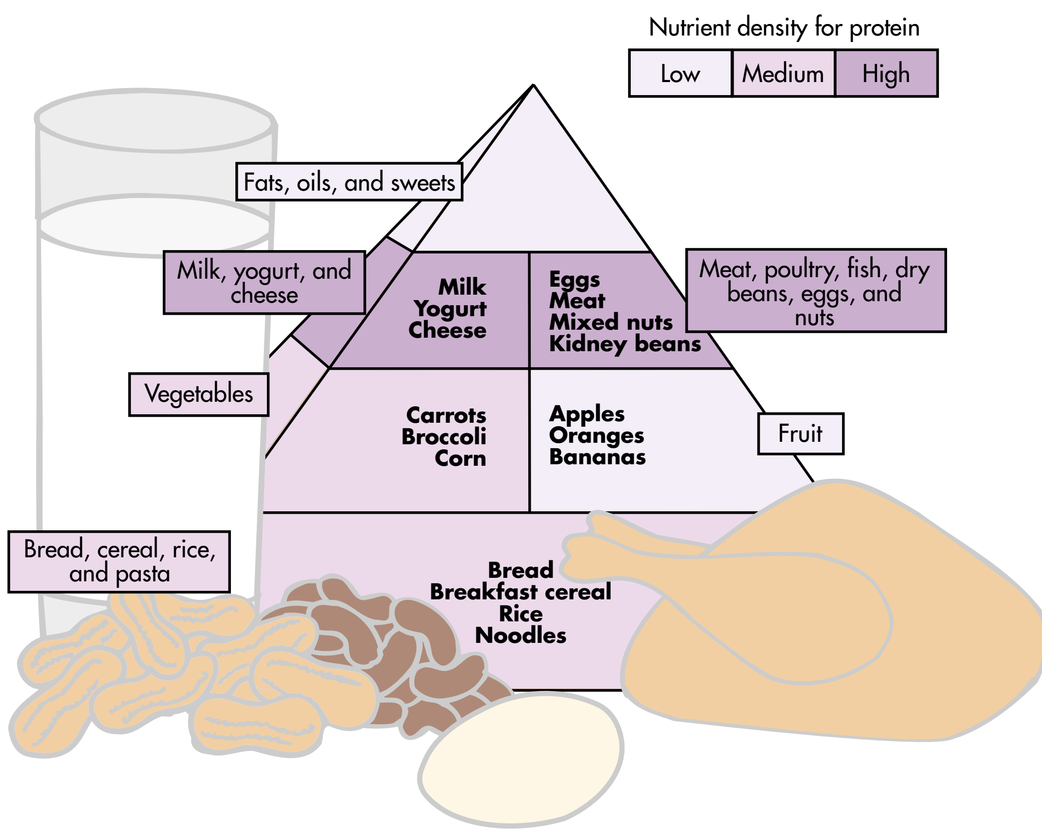


Figure 6-5 Sources of protein in the Food Guide Pyramid. The background color of each group indicates the average amount of protein in that group. Based on serving sizes listed for the Food Guide Pyramid, the fruit group and fats, oils, and sweets category contain little protein (less than 1 gram per serving). Food choices from the vegetable group and bread, cereal, rice, and pasta group provide moderate amounts of protein (2 to 3 grams per serving). The highest protein sources are milk products (8 to 10 grams per serving), nuts and beans (12 grams per serving), and meat, fish, and poultry (14 to 21 grams per serving).

Figure 6-6 Legumes are rich sources of protein. One-half cup meets about 10% of protein needs, and at a cost of only about 5% of calorie needs.

Food Sources of Protein

Food Item and Amount	Protein (grams)	Calories from Protein (%)
Canned tuna, 3 oz	21.6	87
Broiled chicken, 3 oz	21.3	40
Beef chuck, 3 oz	15.3	30
Yogurt, 1 cup	10.6	35
Kidney beans, ½ cup	8.1	29
Milk, 1 cup	8.0	31
Peanuts, 1 oz	7.3	18
Cheddar cheese, 1 oz	7.0	25
Egg, 1	5.5	32
Cooked corn, ½ cup	2.7	12
Seven grain bread, 1 slice	2.6	16
White rice, ½ cup	2.1	8
Pasta, 1 oz	1.2	16
Banana, 1	1.2	4

In general, plant sources of protein deserve more attention and use than they currently receive from many North Americans. Plant foods contribute fewer calories to the diet than most animal products and they supply an ample amount of protein, plus magnesium, plenty of fiber, and several other nutritional benefits (Fig. 6-6). The vegetable proteins we eat are a heart-healthy alternative to animal proteins since they contain no cholesterol and little saturated fat, aside from that added during processing or cooking. Soy, other legumes, and nut sources of protein have received a lot of recent attention. The first Looking Further section reviews some of the many benefits of plant proteins.

Another Bite

A relatively new source of protein comes from fermented fungus, and is called quorn. It is mixed with other food products to form various low-fat meat substitutes. Consumers can decide if these products fit into their diets; FDA has approved quorn for human use.

Looking Further

A Closer Look at Plant Sources of Proteins

Plant sources of protein are worthy of more attention from North Americans. In the early 1900s, plant sources of proteins—nuts, seeds, and legumes—were consumed just as often as animal proteins. Over the years, though, plant proteins have been sidelined by meats. During this time, nuts have been viewed as high-fat foods, and beans have gotten the inferior reputation of "the poor man's meat."

Note that processing and cooking are crucial points at which the healthiness of foods are affected. For example, canned beans may be high in added salt, but by purchasing those labeled "low-sodium," or rinsing canned beans with cool water before cooking, you can reduce the salt content. Likewise, cooking in butter or adding cheese will increase the saturated fat and cholesterol content of legumes.

Contrary to these popular misconceptions, sources of plant proteins offer a wealth of nutritional benefits—from lowering blood cholesterol to preserving bone mass. In proportion to the amount of calories they supply, plant foods provide not only protein, but also magnesium, fiber, folate, vitamin E, iron (absorption is increased by the vitamin C also present), zinc, and some calcium. In addition, phytochemicals from these foods are implicated in prevention of a wide variety of chronic diseases.

Nuts have a hard shell surrounding an edible kernel. Almonds, pistachios, walnuts, and pecans are some common examples. The defining characteristic of a nut is that it grows on a tree. (Peanuts, because they grow underground, are actually legumes.) Seeds (such as pumpkin, sesame, and sunflower seeds) differ from nuts in that seeds grow on vegetable or flowering plants, but they are similar to nuts in nutrient composition. In general, nuts and seeds supply 160 to 190 kcal, 6 to 10 grams of protein, and 14 to 19 grams of fat per 1 ounce serving. Although they are a dense source of calories, you will learn that nuts and seeds make a powerful contribution to health when consumed in moderation.

Legumes are a plant family with pods that contain a single row of seeds. Besides peanuts, examples include garden and black-eyed peas, kidney beans, great northern beans, lentils, soy beans, and soy products. Dried varieties of the mature legume seeds—what we know as beans—also make an impressive contribution to the protein, vitamin, mineral, and fiber content of a meal. A one-half cup serving of legumes provides 100 to 150 kcal, 5 to 10 grams of protein, less than one gram of fat, and about 5 grams of fiber. Unique among the legumes are soybeans. They are higher in fat than other legumes, but they contain isoflavones, which are a plant form of estrogens that, in some cases, exert health effects.

Rich sources of plant proteins add much nutritional value to a diet.

Good for Your Heart

Plant sources of proteins can positively impact heart health in several ways. First, the plant foods we eat contain no cholesterol nor *trans* fat and little saturated fat. The major type of fats in plant foods are monounsaturated and polyunsaturated fats. Nuts in particular are high in monounsaturated fat, which helps to keep blood cholesterol low.

Beans and nuts contain soluble fiber, which binds to cholesterol in the small intestine and prevents it from being absorbed by the body. Also, due to the activity of some phytochemicals, foods made from soy beans can lower production of cholesterol by the body. The effect is modest (about a 6% drop), but can help treat high blood cholesterol. In 1999, the Food and Drug Administration allowed health claims for the cholesterol-lowering properties of soy foods, and in 2000, the American Heart Association recommended inclusion of soy protein in the diets of people with high blood cholesterol. The recommended intake is 25 grams of soy protein each day to acquire the benefits. As noted in Chapter 2, a food product must have at least 6.25 grams of soy protein and less than 3 grams of fat, 1 gram of saturated fat, and 20 milligrams of cholesterol per serving to list this health claim on the label.

There are several other compounds in plant foods that are under study for their heart-protective roles. Some of the phytochemicals may help to prevent blood clots and relax the blood vessels. Nuts are an especially good source of nutrients that are implicated in heart health, including vitamin E, folate, magnesium, and copper. Frequent consumption of nuts (about 1 ounce of nuts five times per week) is associated with a decreased risk of cardiovascular disease. Recall from Chapter 2 that FDA also allows a provisional health claim to link nuts with a reduced risk of developing cardiovascular disease.

Cancer-Fighting Agents

The numerous phytochemicals in plant foods may help prevent cancer. Many of the proposed anti-cancer effects of foods containing plant protein are through antioxidant mechanisms. Plant sources of proteins are primarily thought to aid in preventing cancers of the breast, prostate, and colon.

There is some interest that regular soy intake may decrease breast cancer risk by blocking human estrogen action, but increasing soy in the diet is not recommended for women already diagnosed with breast cancer. This is because the plant estrogens (isoflavones) found in soy products can also stimulate the growth of breast cancer cells, especially after menopause when the natural output of estrogen is dwindling. Women with breast cancer (or a family history of the disease) should talk to their physicians before consuming soy foods on a regular basis.

Plant proteins, like those in walnuts, can be incorporated into one's diet in numerous ways, such as adding them to banana bread.

Protector of Bone Health

Including plant proteins in the diet may slow down the bone loss that typically accompanies aging in women. Population studies show a relationship between soy intake and lower rates of hip fracture in Asian women, despite their low intake of calcium-rich dairy products. There are several explanations for this association. During the first ten years after menopause, rapid bone loss occurs in women due to lowered estrogen output. The plant estrogens in soy act like some of the drugs that are used to prevent and treat osteoporosis. Sources of plant proteins, especially soy products and almonds, are also sources of calcium.

Topics for Future Research

Consumption of plant sources of proteins can aid in prevention of cardiovascular disease, cancer, and bone loss, but there are also other areas for future study. Some studies show that replacing animal proteins with plant proteins is beneficial for kidney health. However, since plant foods such as soy are high in oxalates, people with a history of kidney stones should probably limit intake of soy (see Chapter 9 for more about oxalates). Plants may be particularly good sources of protein for people with diabetes or impaired glucose tolerance because they lead to a slower increase in blood glucose (review Chapter 4 for a discussion of glycemic load). Women have been encouraged to experiment with consuming more soy products to relieve menopausal symptoms, but the actual intake of soy needed to produce the benefit and the specific magnitude of the effect are still under investigation.

From Theory to Practice

Now that you've seen how much you can benefit from including plant proteins in your diet, here are some suggestions for putting the theory onto your plate:

- At your next cookout, try a veggie burger instead of a hamburger. These are usually made from beans and are available in the frozen foods section of the grocery store and come in a variety of delicious flavors. Many restaurants have added veggie burgers to their menus.

Recall from Chapter 4 that consumption of beans can lead to intestinal gas because our bodies lack the enzymes to break down certain carbohydrates that beans contain. An over-the counter preparation called Beano® can greatly lessen symptoms if taken right before the meal. It is also helpful to soak dry beans in water, which leaches the indigestible carbohydrates into the water so they can be disposed. However, intestinal gas is not harmful. In fact, fermentation products of ingestible carbohydrates promote the health of your colon (review Chapter 3 for more information on probiotics and prebiotics).

- Sprinkle sunflower seeds or chopped almonds on top of your salad to add taste and texture.
- Mix chopped walnuts into the batter of your banana bread to boost your intake of monounsaturated fats.
- Eat soy nuts (oil-roasted soy beans) as a great snack.
- Spread some peanut butter on your bagel instead of butter or cream cheese.
- Instead of having beef or chicken tacos for dinner, heat up a can of great northern beans in your skillet with one half of a packet of taco seasoning and chopped tomatoes. Use this as a filling in a tortilla shell.
- Consider using soy milk, especially if you have lactose malabsorption. Look for varieties that are fortified with calcium.

Plant proteins are a nutritious alternative to animal proteins. They are inexpensive, versatile, tasty, add color to your plate, and benefit health beyond their contribution of protein to the diet. Simply adding these foods, particularly nuts, to your diet can lead to weight gain, but learning to substitute plant proteins in place of other, less healthy foods is one way to reduce your risk for many diseases. Keep an eye out for news about additional research progress into this area.

Protein Digestion and Absorption

As with carbohydrates, cooking food can be viewed as a first step in protein digestion. Cooking unfolds (denatures) proteins and softens tough connective tissue in meat. Cooking also makes many protein-rich foods easier to chew, swallow, and break down during later digestion and absorption. As you will see in Chapter 16, cooking also makes many protein-rich foods, such as meats, eggs, fish, and poultry, much safer to eat.

Digestion

The enzymatic digestion of protein begins in the stomach (Fig. 6-7). Proteins are first denatured by stomach acid, then **pepsin,** a major enzyme for digesting proteins, goes to work on the unraveled polypeptide chains. Pepsin attacks these and breaks them down into shorter chains of amino acids. Pepsin does not completely separate proteins into amino acids because it can break only a few of the many peptide bonds found in these large molecules.

The release of pepsin is controlled by the hormone gastrin. Thinking about food or chewing food stimulates gastrin release in the stomach. Gastrin also strongly stimulates the stomach to produce acid.

The partially-digested proteins move with the rest of the nutrients and other substances in a meal (chyme) from the stomach into the small intestine. Once in the small intestine, the partially-digested proteins (and any fats accompanying them) trigger the release of the hormone cholecystokinin (CCK) from the walls of the small intestine. CCK, in turn, travels through the bloodstream to the pancreas. Its arrival causes the pancreas to release protein-splitting enzymes, such as **trypsin.** These digestive enzymes further divide the partially-digested proteins into segments of two to three amino acids and some individual amino acids. Eventually, digestion of this mixture into amino acids occurs, using other enzymes secreted into the intestine by glands located in the lining of the small intestine, as well as enzymes present in the absorptive cells themselves.

pepsin A protein-digesting enzyme produced by the stomach.

trypsin A protein-digesting enzyme secreted by the pancreas to act in the small intestine.

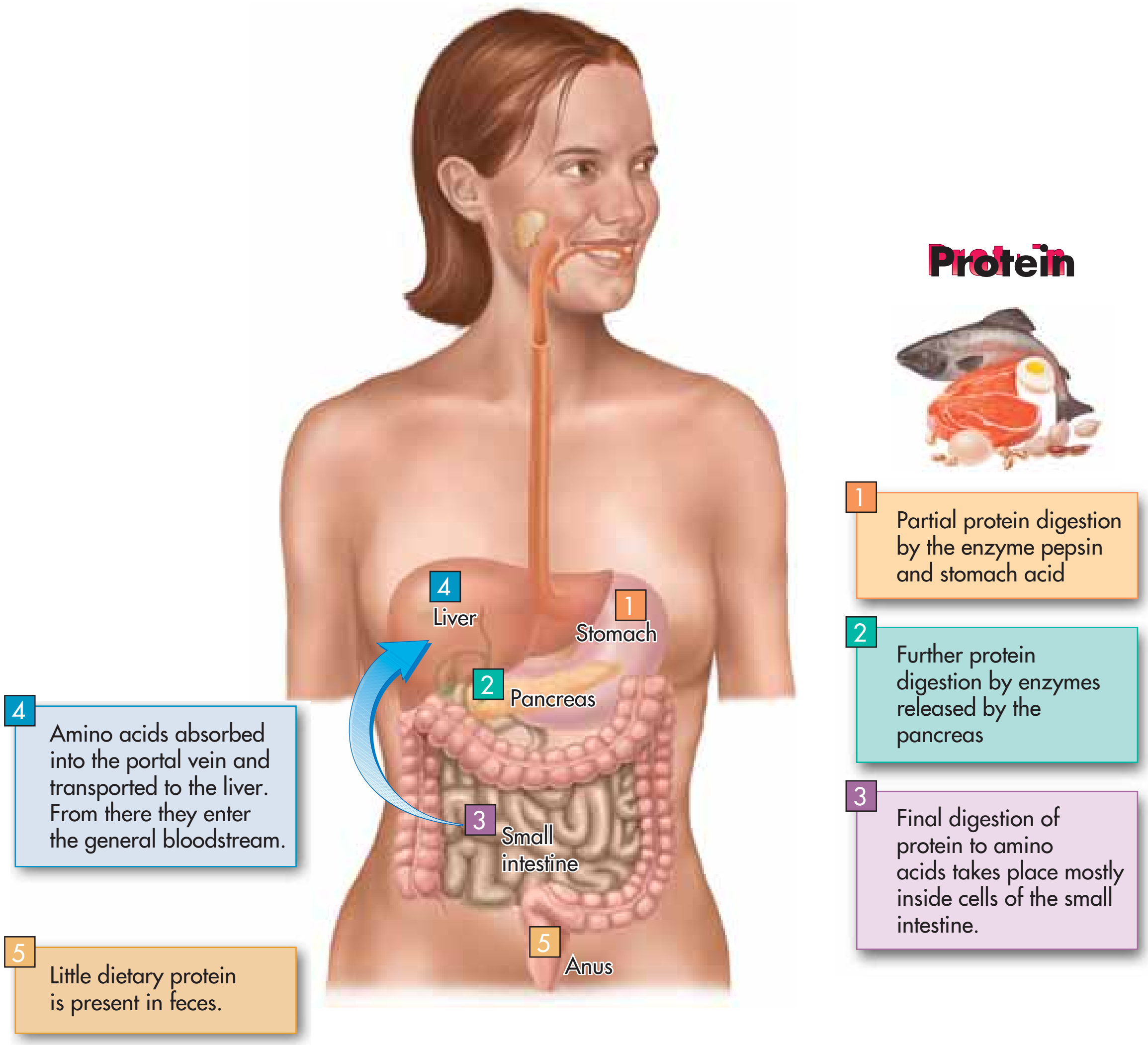


Figure 6-7 A summary of protein digestion and absorption. Enzymatic protein digestion begins in the stomach and ends in the absorptive cells of the small intestine, where any remaining short groupings of amino acids are broken down into single amino acids. Stomach acid and enzymes contribute to protein digestion. Absorption from the intestinal lumen into the absorptive cells requires energy input.

Absorption

The short chains of amino acids and any individual amino acids in the small intestine are taken up by active transport into the absorptive cells lining the small intestine. Any remaining peptide bonds are broken down to yield individual amino acids inside the intestinal cells. Since they are water-soluble, the amino acids travel to the liver via the portal vein which drains absorbed nutrients from the intestinal tract. In the liver, individual amino acids can undergo several modifications, depending on the requirements of the body. Individual amino acids may be combined into the proteins needed by the body, broken down for energy needs, released into the bloodstream, or converted to nonessential amino acids, glucose, or fat. With excess protein intake, conversion of amino acids to fat comes last.

Except during infancy, it is uncommon for intact proteins to be absorbed from the digestive tract. In the period of infancy (up to 4 to 5 months of age), the gastrointestinal tract is somewhat permeable to small proteins, so some whole proteins can be absorbed. Because proteins from some foods (e.g., cow's milk and egg whites) may predispose an infant to food allergies, pediatricians and dietitians recommend waiting until an infant is at least 6 to 12 months of age before introducing commonly allergenic foods (see Chapter 14 for details).

Concept Check

Protein digestion begins with cooking, as proteins are denatured by heat. Once protein reaches the stomach, enzymes cleave proteins into smaller segments of amino acids. As food travels through the small intestine, protein breakdown products formed in the stomach are broken down further to individual amino acids or short segments of amino acids, and taken up into the absorptive cells of the small intestine lining where final breakdown into amino acids occurs. The amino acids then travel via the portal vein that connects to the liver.

Putting Proteins to Work in the Body

As you have learned, proteins function in many crucial ways in human metabolism and in the formation of body structures. We rely on foods to supply the amino acids needed to form these proteins. Note, however, that only when we also eat enough carbohydrate and fat can food proteins be used most efficiently. If we don't consume enough calories to meet needs, some amino acids from proteins are broken down to produce energy, rendering them unavailable to build body proteins.

Producing Vital Body Structures

Every cell contains protein. Muscles, connective tissue, mucus, blood-clotting factors, transport proteins in the bloodstream, lipoproteins, enzymes, immune bodies, some hormones, visual pigments, and the support structure inside bones are primarily made of protein (Fig. 6-8). Excess protein in the diet doesn't enhance the synthesis of these body components, but eating too little can impede it.

Most vital body proteins are in a constant state of breakdown, rebuilding, and repair. For example, the intestinal tract lining is constantly sloughed off. The digestive tract treats sloughed cells just like food particles, digesting them and absorbing their amino acids. In fact, most of the amino acids released throughout the body can be recycled to become part of the pool of amino acids available for synthesis of future proteins. Overall, **protein turnover** is a process by which a cell can respond to its changing environment by producing proteins that are needed and disassembling proteins that are not needed.

During any day, an adult makes and degrades about 250 grams of protein, recycling many of the amino acids. Relative to the 65 to 100 grams of protein typically consumed by adults in North America, recycled amino acids make an important contribution to total protein metabolism.

If a person's diet is low in protein for a long period of time, the processes of rebuilding and repairing body proteins slow. Over time, skeletal muscles, blood proteins, and vital organs, such as the heart and liver, will decrease in size or volume. Only the brain resists protein breakdown.

Maintaining Fluid Balance

Blood proteins maintain body fluid balance. Normal blood pressure in the arteries forces blood into capillary beds. The blood fluid then moves from the **capillary beds** into the spaces between nearby cells **(extracellular spaces)** to provide nutrients to

protein turnover The process of breaking down proteins and then resynthesizing new proteins by cells. In this way the cell will have the proteins it needs to function at that time.

capillary bed Network of one-cell thick vessels that create a junction between arterial and venous circulation. It is here that gas and nutrient exchange occurs between body cells and the blood.

extracellular space The space outside cells; represents one-third of all body fluid.

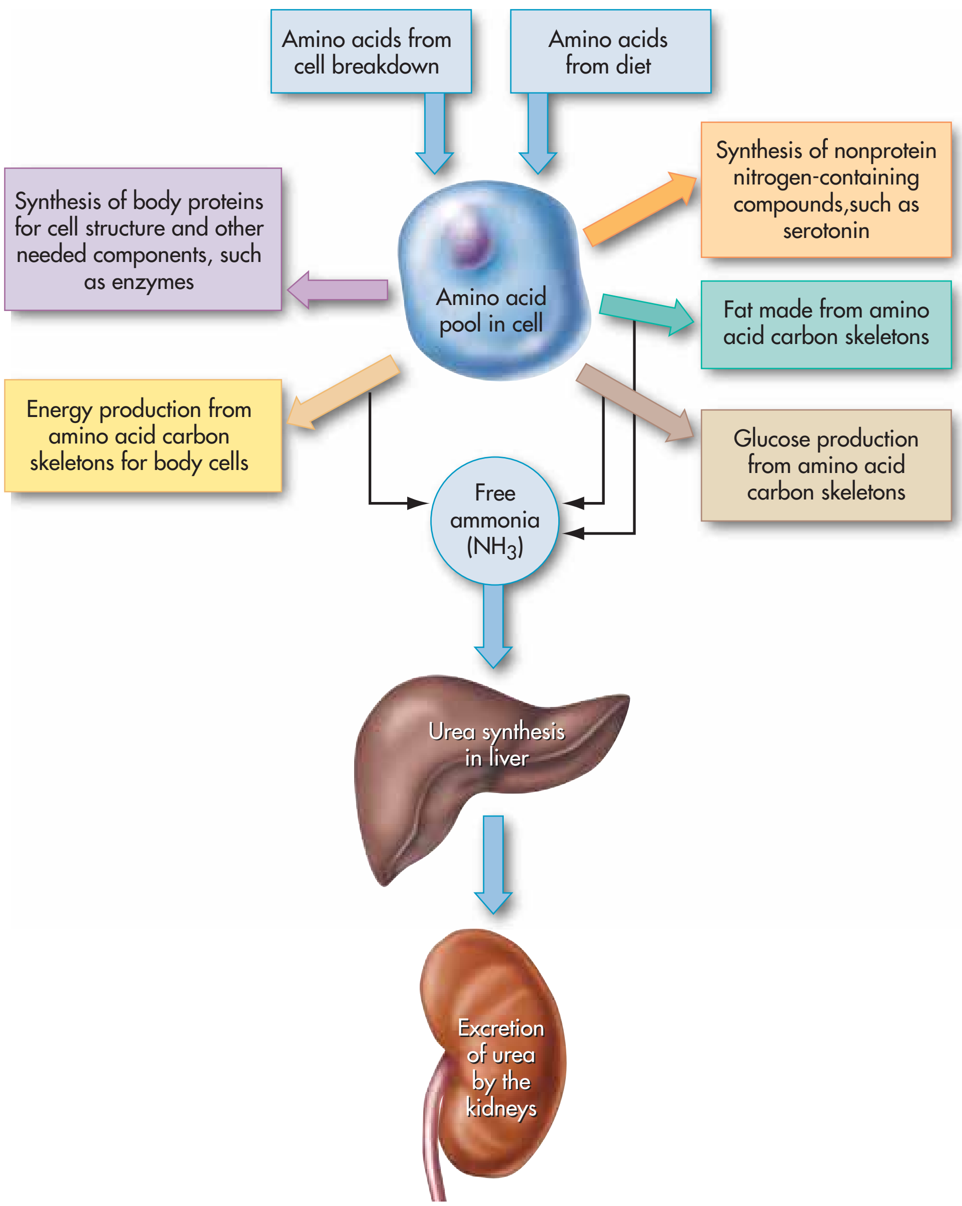


Figure 6-8 Amino acid metabolism. The amino acid **pool** in a cell can be used to form body proteins, as well as a variety of other possible products—from fat and glucose from amino acid **carbon skeletons** to **urea.** The urea is a waste product made from the nitrogen-containing ammonia (NH_3) released during amino acid breakdown. It is excreted in the urine.

those cells (Fig. 6-9). Proteins in the bloodstream are too large however, to move out of the capillary beds into the tissues. The presence of these proteins in the capillary beds attracts the proper amount of fluid back to the blood, partially counteracting the force of blood pressure.

With an inadequate consumption of protein, the concentration of proteins in the bloodstream drops below normal. Excessive fluid then builds up in the surrounding tissues because the counteracting force produced by the smaller amount of blood proteins is too weak to pull enough of the fluid back from the tissues into the bloodstream. As fluids accumulate in the tissues, the tissues swell, causing **edema.** Because edema may be a symptom of a variety of medical problems, the cause must be identified. An important step in diagnosing the cause is to measure the concentration of blood proteins.

Contributing to Acid-Base Balance

Proteins help regulate acid-base balance in the blood. Proteins located in cell membranes pump chemical ions in and out of cells. The ion concentration that results from the pumping action, among other factors, keeps the blood slightly alkaline. In

pool The amount of a nutrient stored within the body that can be mobilized when needed.

carbon skeleton Amino acid structure that remains after the amino group (—NH_2) has been removed.

urea Nitrogenous waste product of protein metabolism; major source of nitrogen in the urine, chemically $NH_2—\overset{\overset{O}{||}}{C}—NH_2$.

edema The buildup of excess fluid in extracellular spaces.

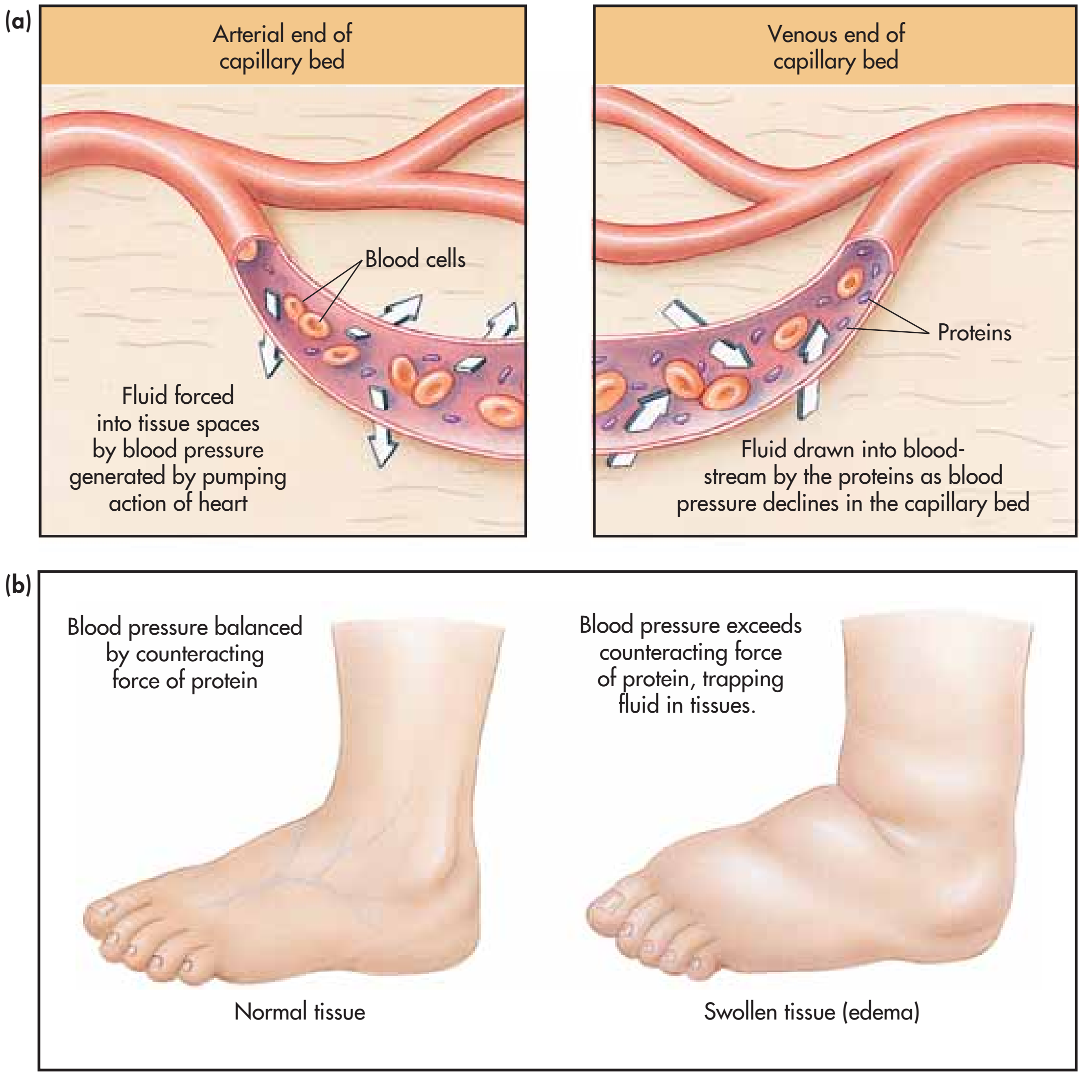


Figure 6-9 Blood proteins in relation to fluid balance. (a) Blood proteins are important for maintaining the body's fluid balance. (b) Without sufficient protein in the bloodstream, edema develops.

buffers Compounds that cause a solution to resist changes in acid-base conditions.

addition, some blood proteins are especially good **buffers** for the body. Buffers are compounds that maintain acid-base conditions within a narrow range.

Forming Hormones and Enzymes

Amino acids are required for the synthesis of many hormones—our internal body messengers. Some hormones, such as the thyroid hormones, are made from only one type of amino acid, tyrosine. Insulin, on the other hand, is composed of 51 total amino acids. Almost all enzymes also are proteins or have a protein component.

Neurotransmitters, released by nerve endings, are often derivatives of amino acids. This is true for dopamine (synthesized from the amino acid tyrosine), norepinephrine (synthesized from the amino acid tyrosine), and serotonin (synthesized from the amino acid tryptophan).

Contributing to Immune Function

Proteins are a key component of the cells used by the immune system. Also, the antibodies produced by one type of white blood cell are proteins. These antibodies can bind to foreign proteins in the body, an important step in removing invaders from the body. Without sufficient dietary protein, the immune system lacks the materials needed to function properly. For example, a compromised protein status can turn measles into a fatal disease for a malnourished child.

Forming Glucose

In Chapter 4 you learned that the body must maintain a fairly constant concentration of blood glucose to supply energy for the brain, red blood cells, and nervous tissue. At rest, the brain uses about 19% of the body's energy requirements, and it gets most of that energy from glucose. If you don't consume enough carbohydrate to supply the glucose, your liver (and kidneys, to a lesser extent) will be forced to make glucose from amino acids present in body tissues (review Fig. 6-8).

Making some glucose from amino acids is normal. For example, when you skip breakfast and haven't eaten since 7 P.M. the preceding evening, glucose must be manufactured. In an extreme situation, however, such as in starvation, the conversion of amino acids into glucose wastes much muscle tissue and can produce edema.

The vitamin niacin can be made from the amino acid tryptophan, illustrating another role of proteins.

Providing Energy

Proteins supply very little energy for a weight-stable person. Two situations in which a person does use protein to meet energy needs are during prolonged exercise (see Chapter 11 for information about the use of amino acids for energy needs during exercise) and during calorie restriction, as with a weight-loss diet. In these cases, the amino group ($-NH_2$) from the amino acid is removed and the remaining carbon skeleton is metabolized for energy needs (review Fig. 6-8). Still, under most conditions, cells primarily use fats and carbohydrates for energy needs. Although proteins contain the same amount of calories (on average, 4 kcal per gram) as carbohydrates, proteins are a very costly source of calories, considering the amount of processing the liver and kidneys must perform to use this calorie source.

Concept Check

Vital body constituents—such as muscle, connective tissue, blood transport proteins, enzymes, hormones, buffers, and immune factors—are mainly proteins. The degradation of existing proteins and synthesis of new proteins takes place constantly, amounting to a turnover rate of about 250 grams a day for the entire human body. Proteins can also be used for glucose and other fuel production.

Protein Needs

How much protein (actually, amino acids) do we need to eat each day? People who aren't growing need to eat only enough protein to match whatever they lose daily from protein breakdown. The amount of breakdown can be determined by measuring the amount of urea and other nitrogen-containing compounds in the urine, as well as losses of protein from feces, skin, hair, nails, and so on. In short, people need to balance protein intake with such losses to maintain a state of **protein equilibrium,** also called *protein balance* (Figs. 6-10 and 6-11).

When a body is growing or recovering from an illness or injury, it needs a **positive protein balance** to supply the raw materials required to build new tissues. To achieve this, a person must eat more protein daily than he or she loses. In addition, the hormones insulin, growth hormone, and testosterone all stimulate positive protein balance. Resistance exercise (weight training) also enhances positive protein balance. Consuming less protein than needed leads to **negative protein balance,** such as when acute illness reduces the desire to eat and so one loses more protein than consumed.

For healthy people, the amount of dietary protein needed to maintain protein equilibrium (wherein intake equals losses) can be determined by increasing protein intake until it equals losses of protein and its related breakdown products (e.g., urea). Calorie needs must also be met so that amino acids are not diverted for such use.

Today, the best estimate for the amount of protein required for nearly all adults to maintain protein equilibrium is 0.8 grams of protein per kilogram of healthy body

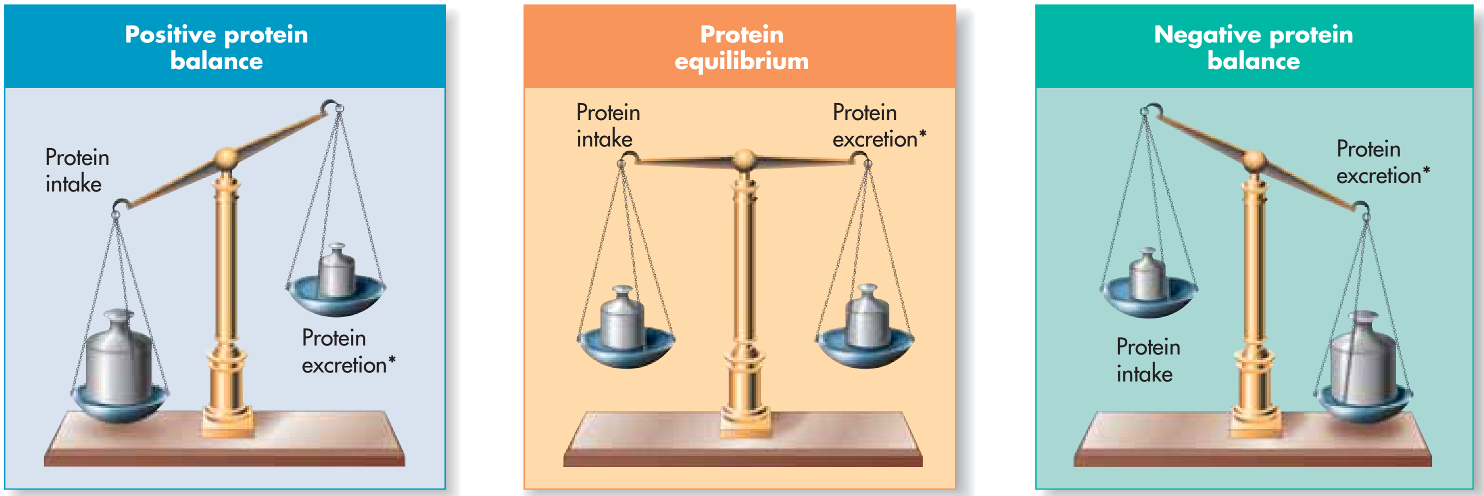
protein equilibrium A state in which protein intake is equal to related protein losses; the person is said to be in protein balance.

positive protein balance A state in which protein intake exceeds related protein losses, such as during times of growth.

negative protein balance A state in which protein intake is less than related protein losses, such as often seen during acute illness.

The RDA for protein translates into about 10% of total calories. Many experts recommend up to 15% of total calories to provide more flexibility in diet planning, in turn allowing for the variety of protein-rich foods North Americans typically consume. As noted earlier, the Food and Nutrition Board has set an upper range for protein intake at 35% of calories consumed.

(a) (b) (c)



Situations in which protein balance is positive:

Growth
Pregnancy
Recovery stage after illness, injury
Athletic training**
Increased secretion of certain hormones, such as insulin, growth hormone, and testosterone

Situations in which protein balance is negative:

Inadequate intake of protein (fasting, intestinal tract diseases)
Inadequate calorie intake
Conditions such as fevers, burns, and infections
Bed rest (for serveral days)
Deficiency of essential amino acids (e.g., poor-quality protein comsumed)
Increased protein loss (as in some forms of kidney disease)
Increased secretion of certain hormones, such as thyroid hormone and cortisol

*Based on losses of urea and other nitrogen-containing compounds in the urine, as well as protein itself lost from feces, skin, hair, nails, and other minor routes.

**Only when additional lean body mass is being gained. Nevertheless, the athlete is probably already eating enough protein to support this extra protein synthesis; protein supplements are not needed.

Figure 6-10 Protein balance in practical terms: (a) positive protein balance; (b) protein equilibrium; (c) negative protein balance.

(a) (b) (c)

Figure 6-11 Protein balance throughout the lifecycle. (a) Growing children will be in positive protein balance. (b) Adults generally are in protein equilibrium. (c) Illness, particularly in one's older years, typically leads to negative protein balance.

weight. This is the RDA for protein. Requirements are higher during periods of growth, such as infancy and pregnancy (see Chapters 13 and 14 for specific values for infants, children, and pregnant women). Healthy weight is used as a reference in the determination of protein needs because excess fat storage doesn't contribute much to protein needs (see Chapter 10 for insight into the concept of healthy weight). Calculations using this RDA are shown in the margin and estimate a requirement of about 56 grams of protein daily for a typical 70-kilogram (154-pound) man and about 46 grams of protein daily for a typical 57-kilogram (125-pound) woman.

It is easy to meet currently suggested daily protein needs (Table 6-3). On a daily basis, typical North American protein intakes are about 100 grams of protein for men and 65 grams for women. Thus, most of us consume much more protein than the RDA recommends because we like many high-protein foods and can afford to buy them. Our bodies cannot store excess protein once it is consumed, so the carbon skeletons are turned into glucose or fat and then stored as fat or metabolized for energy needs (review Fig. 6-8).

Note that mental stress, physical labor, and recreational weekend sports activities do not require an increase in the protein RDA. For some highly trained athletes, such as those participating in endurance or strength training, protein consumption may need to exceed the RDA. This is an area of debate in sports nutrition: the Food and Nutrition Board does not support an increased need, but some experts suggest an increase to about 1.2 to 1.8 grams per kilogram. Many North Americans already consume that much protein, especially men.

Convert weight from pounds to kilograms:

$$\frac{154 \text{ pounds}}{2.2 \text{ pounds/kilogram}} = 70 \text{ kilograms}$$

$$\frac{125 \text{ pounds}}{2.2 \text{ pounds/kilogram}} = 57 \text{ kilograms}$$

Calculate protein RDA:

$$70 \text{ kilograms} \times \frac{0.8 \text{ grams protein}}{\text{kilogram body weight}} = 56 \text{ grams}$$

$$57 \text{ kilograms} \times \frac{0.8 \text{ grams protein}}{\text{kilogram body weight}} = 46 \text{ grams}$$

Table 6-3 The Protein Contents of a 1200 kcal Diet and a 2400 kcal Diet*

1200 kcal Diet	Protein (grams)	2400 kcal Diet	Protein (grams)
Breakfast			
Nonfat milk, 1 cup	8	2% reduced-fat milk, 1 cup	8
Cheerios, 1 cup	2	Cheerios, 1 cup	2
Orange	1	Eggs, soft cooked, 2	12
		Orange	1
Lunch			
Whole-wheat bread, 2 slices	5	Whole-wheat bread, 2 slices	5
Chicken breast, 2 ounces	17	Chicken breast, 2 ounces	17
Mayonnaise, 1 teaspoon	—	Provolone cheese, 2 ounces	15
Tomato slices, 2	—	Tomato slices, 2	—
Carrot sticks, 1 cup	1	Mayonnaise, 1 teaspoon	—
Fig, 1 large	0.5	Oatmeal-raisin cookies, 2	2
Diet soda	—	Figs, 2	1
		Diet soda	—
Dinner			
Mixed green salad, ½ cup	—	Mixed green salad, ½ cup	—
Italian dressing, 2 teaspoons	—	Italian dressing, 2 teaspoons	—
Beef tenderloin, 2 ounces	14	Beef tenderloin, 4 ounces	28
Spinach pasta, 1 cup, with garlic butter, 1 teaspoon	7	Spinach pasta, 1 cup, with garlic butter, 1 teaspoon	7
Zucchini, ½ cup, sauteed in oil, 1 teaspoon	0.5	Zucchini, ½ cup, sauteed in oil, 1 teaspoon	0.5
Nonfat milk, 1 cup	8	Carrot sticks, ½ cup	0.5
		2% reduced-fat milk, 1 cup	8
Snack		**Snack**	
Bagel, toasted, ½ of a 3½-inch bagel	4	Bagel, toasted, ½ of 3½-inch bagel	4
Jam, 2 teaspoons	—	Jam, 2 teaspoons	—
		Fruited yogurt, 1 cup	10
TOTAL	70		122

*This table illustrates how few calories need be consumed while still meeting the RDA for protein. It also shows how much protein we eat when we consume typical calorie intakes. The amounts work out to be about 25% of total calories as protein, quite a generous amount.

Looking Further

Vegetarian Diets

Vegetarianism has evolved over the centuries from a necessity into an option. Historically, vegetarianism was linked with specific philosophies and religions or with science.

Today, about 1 in 40 adults in the United States (and about 1 in 25 in Canada) is a vegetarian. Over the past decades, vegetarian diets have gone from dull to delicious, with the inclusion of such new products as soy-based sloppy joes, chili, tacos, burgers, and more. In addition, cookbooks that feature the use of a variety of fruits, vegetables, and seasonings are enhancing food selection for vegetarians of all degrees.

Vegetarianism is popular among college students. Fifteen percent of college students in one survey said they select vegetarian options at lunch or dinner on any given day. In response, dining services offer vegetarian options at every meal, such as pastas with meatless sauce and pizza. Many teenagers are also turning to vegetarianism. In addition, a survey by the National Restaurant Association found that 20% of its customers want a vegetarian option when they eat out. Many customers cite health and taste as reasons for choosing vegetarian meals.

Vegetarian adaptations of traditional foods are a growing trend in our society.

As nutrition science has grown, new information has enabled the design of nutritionally adequate vegetarian diets. It is important for vegetarians to take advantage of this information because a diet of only plant-based foods has the potential to promote various nutrient deficiencies and substantial growth retardation in infants and children. People who choose a vegetarian diet can meet their nutritional needs by following a few basic rules and knowledgeably planning their diets.

Studies show that death rates from some chronic diseases, such as certain forms of cardiovascular disease, cancer, type 2 diabetes, and obesity, are lower for vegetarians than for nonvegetarians. These individuals also often live longer, as has been shown in religious groups that practice vegetarianism. However, healthful lifestyles (not smoking, abstaining from alcohol and drugs, and regular physical activity) and social class bias probably partially account for these findings.

As you learned in Chapter 2, several sets of guidelines including the Food Guide Pyramid and the Dietary Guidelines for Americans, emphasize a plant-based diet of whole-grain breads and cereals, fruits, and vegetables. In addition the American Institute for Cancer Research promotes "The New American Plate" with plant-based foods covering two-thirds (or more) of the plate and meat, fish, poultry, or low-fat dairy covering one-third (or less) of the plate. Although these recommendations do allow the inclusion of animal products, they are definitely more "vegetarian-like" than typical North American diets.

Why Do People Become Vegetarian?

People choose vegetarianism for a variety of reasons. Some believe that killing animals for food is unethical. Hindus and Trappist monks eat vegetarian meals as a practice of their religion. In North America, many Seventh Day Adventists base their practice of vegetarianism on biblical texts and believe it is a more healthful way to live.

Some advocates of vegetarianism base their food preference upon the inefficient use of animals as a source of protein. Note that 40% of the world's grain production is used to raise meat-producing animals. Although animals that humans eat sometimes eat grasses that humans cannot digest, many also eat grains that humans can eat.

People might also practice vegetarianism because while encouraging a high intake of carbohydrates, vitamins A, E, and C, carotenoids, magnesium, and fiber, it limits saturated fat and cholesterol intake.

Food Planning for Vegetarians

There are a variety of vegetarian diet styles. **Vegans,** or "total vegetarians," eat only plant foods (and do not use animal products for other purposes, such as leather shoes or feather pillows). **Fruitarians** primarily eat fruits, nuts, honey, and vegetable oils. This plan is not recommended because it can lead to nutrient deficiencies in people of all ages. **Lactovegetarians** modify vegetarianism a bit—they include dairy products and plant foods. **Lactoovovegetarians** modify the diet even further and eat dairy products and eggs, as well as plant foods. Including these animal products makes food planning easier because they are rich in some nutrients that are missing or minimal in plants. The more variety in the diet, the easier it is to meet nutritional needs. Thus, the practice of eating no animal sources of food significantly separates the vegans and fruitarians from all other semivegetarian styles.

It has been suggested that "almost vegetarians" (those who allow some dairy and regular fish intake) are the healthiest group of all vegetarians. Perhaps this is due to the health benefits of a high fruit and vegetable diet, rather than the complete exclusion of all animal products.

Most people who call themselves vegetarians consume at least some dairy products, if not all dairy products and eggs. A food-group plan has been developed for lactovegetarians and vegans (Table 6-4). This plan includes servings of nuts, grains, legumes, and seeds to help meet protein needs. There is also a vegetable group, a fruit group, and a milk group.

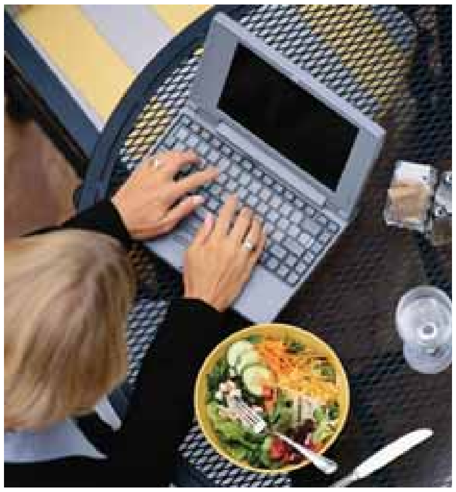
Figure 6-12 shows a diet pyramid for vegetarians developed by Oldways Preservation & Exchange Trust. The base consists of fruits, vegetables, whole grains, and legumes (at every meal). The middle tier is nuts, seeds, egg whites, soy milks, dairy products, and plant oils (daily). Whole eggs and sweets form the tip (weekly). Alcohol intake in moderation is optional and daily physical activity is recommended (see the Oldways Preservation & Exchange Trust website at www.oldwayspt.org for further information). Another vegetarian pyramid is provided in the June 2003 issue of the *Journal of the American Dietetic Association.*

vegan A person who eats only plant foods.

fruitarian A person who primarily eats fruits, nuts, honey, and vegetable oils.

lactovegetarian A person who consumes plant products and dairy products.

lactoovovegetarian A person who consumes plant products, dairy products, and eggs.



A salad containing numerous types of vegetables and legumes is a healthy vegetarian choice.

Table 6-4 Food-Group Plan for Lactovegetarians and Vegans[§]

	Servings		
Group[†]	**Lactovegetarian**[‡]	**Vegan**[§‖]	**Key Nutrients Supplied**
Grains[¶]	6–11	8–11	Protein, thiamin, niacin, folate, vitamin E, zinc, phosphorus, magnesium, iron, and fiber
Legumes	1–2	2	Protein, vitamin B-6, zinc, phosphorus, magnesium, and fiber
Nuts, seeds	1–2	2	Protein, vitamin E, and magnesium
Vegetables	3–5 (include one dark green or leafy variety daily)	4–6 (include one dark green or leafy variety daily)	Vitamin A, vitamin C, and folate
Fruits	2–4	4	Vitamin A, vitamin C, and folate
Milk	2–3	—	Protein, riboflavin, vitamin D, vitamin B-12, and calcium and phosphorus

[†]Base serving size on those listed for the Food Guide Pyramid (see Chapter 2). This plan yields about 1600 to 1800 kcal. Increase the number of servings, or add other foods to meet higher calorie needs.

[‡]Contains about 75 grams of protein in 1650 kcal.

[§]A calcium-fortified food, such as orange juice or soy milk, is needed unless a calcium supplement is used. In addition, use of or foods fortified with vitamin B-12 a supplemental source of vitamin B-12 is a must. Use of iodized salt is also important.

[‖]Contains about 79 grams of protein in 1800 kcal.

[¶]One serving of vitamin- and mineral-enriched breakfast cereal is recommended. Alternately, a balanced multivitamin and mineral supplement can be used to help close possible nutrient gaps.

Table 6-2, earlier in Chapter 6, lists traditional dishes in which vegetable proteins combine to provide high-quality (complete) protein in the meal.

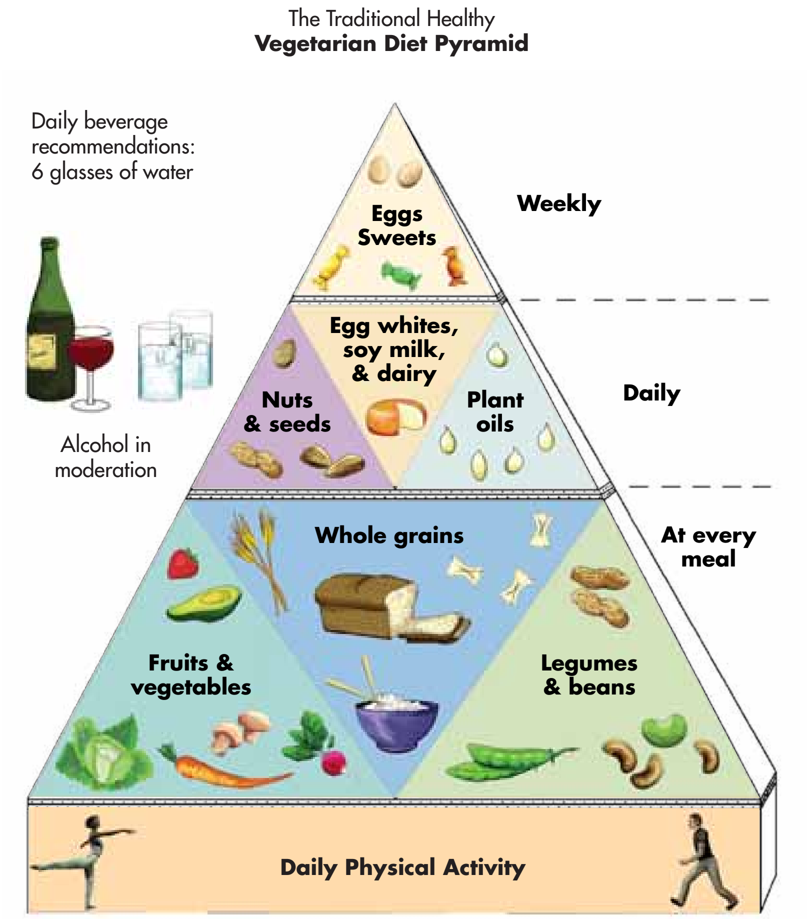


Figure 6-12 The Oldways Preservation & Exchange Trust traditional vegetarian diet. Note that alcohol should only be used by adults of legal age. The organization emphasizes that such a diet has the advantage of being low in saturated fat, high in fiber, and rich in antioxidants. However, it can pose a risk for inadequate iron, vitamin D, and vitamin B-12 intake. Exposure to sunlight for vitamin D and inclusion of some fortified foods, such as whole-grain breakfast cereals are advised. A balanced vitamin and mineral supplement may also be needed in some cases, especially when dairy and eggs are omitted.

Vegan Diet Planning

Planning a vegan diet requires knowledge and creativity to yield high-quality protein and other key nutrients without animal products. Earlier in this chapter, you learned about complementing proteins, whereby the essential amino acids deficient in one protein source are supplied by those of another consumed at the same meal or the next. Recall that many legumes are deficient in the essential amino acid methionine, while cereals are limited in lysine. Eating a combination of legumes and cereals, such as beans and rice, will supply the body with adequate amounts of all essential amino acids. As for any diet, variety is an especially important characteristic of a nutritious vegan diet.

As noted in Chapter 5, a vegan diet coupled with regular exercise and other lifestyle changes can lead to a reversal of atherosclerotic plaque in various arteries in the body.

Aside from amino acids, low intakes of certain micronutrients can be a problem for the vegan. At the forefront of nutritional concerns are riboflavin, vitamins D and B-12, iron, zinc, iodide, and calcium. The following dietary advice should be implemented. In addition, use of a balanced multivitamin and mineral supplement can help as well.

Riboflavin can be obtained from green leafy vegetables, whole grains, yeast, and legumes—components of most vegan diets. Alternate sources of vitamin D include fortified foods (e.g., margarine), as well as regular sun exposure (see Chapter 8).

Vitamin B-12 only occurs naturally in animal foods. Plants can contain soil or microbial contaminants that provide trace amounts of vitamin B-12, but these are negligible sources of the vitamin. Because the body can store vitamin B-12 for about 4 years, it may take a long time after removal of animal foods from the diet for a vitamin B-12 deficiency to surface. If dietary B-12 inadequacy persists, deficiency can lead to a form of anemia, nerve damage, and mental dysfunction. These dire deficiency consequences have been noted in the infants of vegetarian mothers whose breast milk was low in vitamin B-12. Chronically low vitamin B-12 consumption may also result in excess blood concentration of homocysteine, which likely is a risk factor for cardiovascular disease. As you can see, vegans need to be careful to prevent a vitamin B-12 deficiency. This can be achieved by finding a reliable source of vitamin B-12, such as fortified soybean milk, ready-to-eat breakfast cereals, and special yeast grown on media rich in vitamin B-12.

For iron, the vegan can consume whole grains (especially ready-to-eat breakfast cereals), dried fruits and nuts, and legumes. Note that the iron in these foods is not absorbed as well as iron in animal foods, but a good source of vitamin C taken with these foods helps with the absorption. Thus, a recommended strategy is to consume vitamin C with every meal that contains iron-rich plant foods. Cooking in iron pots and skillets can also add iron to the diet (see Chapter 9).

The vegan can find zinc in whole grains (especially ready-to-eat breakfast cereals), nuts, and legumes, but phytic acid and other substances in these foods limit zinc absorption. Grains are most nutritious when either fortified with zinc or consumed as breads. The latter is because the leavening process (rising of the bread dough) reduces the influence of phytic acid. Iodized salt is a reliable source of iodide. It should be used instead of plain salt, both of which are found in U.S. supermarkets.

Of all nutrients, calcium is the most difficult to consume in sufficient quantities for vegans. Fortified foods are the vegan's best option for obtaining calcium. These include fortified soy milk, fortified orange juice, calcium-rich tofu (check the label), as well as certain ready-to-eat breakfast cereals and snacks. Green leafy vegetables and nuts also contain calcium, but the mineral is either not well absorbed or not very plentiful from these sources. Calcium supplements are another option (see Chapter 9). Special diet planning is always required, because even a multivitamin and mineral supplement will not supply enough calcium to meet the needs of the body.

Keep in mind that amino acids in vegetables are best used when a combination of sources is consumed.

Special Concerns for Infants and Children

The populations at highest risk for nutrient deficiencies as a result of improperly planned vegetarian and vegan diets are infants and children, who are notoriously picky eaters in the first place. With the use of complementary proteins and good sources of problem nutrients just discussed, the calorie, protein, vitamin, and mineral needs of vegetarian and vegan infants and children can be met. The most common nutritional concerns for infants and children following vegetarian and vegan diets are deficiencies of iron, vitamin B-12, vitamin D, and calcium.

Vegetarian and vegan diets tend to be high in bulky, high-fiber, low-calorie foods that cause a feeling of fullness. While this is a welcome advantage for adults, children have small stomach volume and relatively high nutrient needs compared to their size, and therefore may feel full before their calorie needs are met. For this reason, the fiber content of a child's diet may need to be decreased by replacing high-fiber sources with some refined grain products, fruit juices, and peeled fruit. Other concentrated sources of calories for vegetarian and vegan children include fortified soy milk, nuts, dried fruits, avocados, and cookies made with vegetable oils or tub margarine.

Overall, vegetarian and vegan diets can be appropriate during infancy and childhood, but these diets must be implemented with knowledge and, ideally, professional guidance. An especially informative website on vegetarianism in general is www.ivu.org, supported by the International Vegetarian Union. See also www.vrg.org and www.vegetariannutrition.net.

Consuming adequate quantities of omega-3 fatty acids is yet another nutritional concern for vegetarians, especially vegans. Fish and fish oils, which are abundant sources of these heart-healthy fats, are omitted from many types of vegetarian diets. Alternative plant sources of omega-3 fatty acids include canola oil, soybean oil, seaweed, microalgae, flax seeds, and walnuts.

Real Life Scenario Follow-Up

Shannon's dietary intake for this day, although vegetarian, is not as healthy as it could be since it does not come close to following the recommendations provided in the Looking Further section on vegetarian diets. Many components of a healthy vegetarian diet—whole grains, nuts, soy products, beans, two to four servings of fruits, and three to five servings of vegetables per day—are missing. With so few fruits and vegetables, her diet is also low in the many phytochemicals that are under study for numerous health benefits. It is apparent that she has not yet learned to implement the concept of complementary proteins, so the quality of protein in her diet is low. Unless she makes a more informed effort at diet planning, Shannon will not reap the health benefits she had hoped for when she chose to follow a vegetarian diet.

Animal protein foods are typically our main sources of protein in the North American diet.

High-protein diets increase urine output, in turn posing a risk for dehydration. This is a special concern for athletes (see Chapter 11).

Does Eating a High-Protein Diet Harm You?

People frequently ask about the potential harm of protein intakes in excess of the RDA. The extra vitamin B-6, iron, and zinc that accompany protein-rich foods are often beneficial. However, diets that are high in protein foods typically rely on animal sources of protein and may be simultaneously low in plant sources, and therefore low in fiber, some vitamins (e.g., folate), some minerals (e.g., magnesium), as well as phytochemicals. Additionally, high-protein foods from animals are rich in saturated fat and cholesterol, and thus do not follow the recommendations of the Dietary Guidelines for Americans or the Food and Nutrition Board in terms of reducing risk for cardiovascular disease.

Some, but not all, studies show that high-protein diets can increase calcium losses in urine. Certain types of amino acids—especially those that are predominant in animal proteins—produce this effect. Still, when seen, it is typically minimal. For people with adequate calcium intakes, little concern about this relationship is warranted, but keep in mind that calcium is commonly deficient in North American diets.

Meat is one of the richest sources of protein. Excessive intake of red meat, however, especially processed forms, is linked to colon cancer in population studies. There are several possible explanations for this connection. The curing agents used to process meats such as ham and salami may cause cancer. Substances that form during cooking of red meat at high temperatures may also cause cancer (for a discussion of heterocyclic amines (HCAs), see the Looking Further section in Chapter 15). The excessive fat or low-fiber contents of diets rich in red meat may also be a contributing factor. Because of these concerns, some nutrition experts suggest we focus more on poultry, fish, nuts, legumes, and seeds to meet protein needs. In addition, any red or other type of meat should be trimmed of all visible fat before grilling.

Some researchers have expressed concern that a high-protein intake may overburden the kidneys by forcing them to excrete the extra nitrogen as urea. Additionally, animal proteins may contribute to kidney stone formation in certain individuals. To prevent these problems, there is some support for limiting protein intake. For instance, for people in the early stages of kidney disease, low-protein diets somewhat slow the decline in kidney function. Also, laboratory animal studies show that protein intakes that just meet nutritional needs preserve kidney function over time better than high-protein diets. Because preserving kidney function is especially important for those who have diabetes, early signs of kidney disease, or only one functioning kidney, a high-protein diet is not recommended for these people. For individuals without diabetes or kidney disease, the risk of suffering kidney failure is minimal; thus, the risk of kidney disease (aside from kidney stones) as a by-product of a high-protein diet is low.

Another Bite

Earlier in this chapter, you learned that the body is designed to handle whole proteins as a dietary source of amino acids. When individual amino acid supplements are taken, they can overwhelm the absorptive mechanisms in the small intestine, triggering amino acid imbalances in the body. Imbalances occur because groups of chemically similar amino acids compete for absorption sites in the absorptive cells. For example, lysine and arginine are absorbed by the same transporter, so an excess of lysine can impair absorption of arginine. The amino acids most likely to cause toxicity when consumed in large amounts are methionine and tyrosine. Due to the potential for imbalances and toxicities of individual amino acids, the best advice to ensure adequacy is to stick to whole foods rather than supplements as sources of amino acids.

Concept Check

The Recommended Dietary Allowance (RDA) for adults is 0.8 grams of protein per kilogram of healthy body weight. This is approximately 56 grams of protein daily for a 70-kilogram (156-pound) person. The average North American man consumes about 100 grams of protein daily, and a woman consumes about 65 grams. Thus, typically we eat more than enough protein to meet our needs. This even includes well-balanced vegetarian diets. Diets high in protein can compromise kidney health in people with diabetes and those with kidney disease, and animal protein sources likely increase cardiovascular disease and kidney stone risk when consumed in high amounts.

Protein-Calorie Malnutrition

Protein deficiency is rarely an isolated condition and usually accompanies a deficiency of calories and other nutrients resulting from insufficient food intake. In developing areas of the world, people often have diets low in calories and also in protein. This state of undernutrition stunts the growth of children and makes them more susceptible to disease throughout life. (Note that undernutrition is a main focus of Chapter 17.) People who consume too little protein calories can eventually develop **protein-calorie malnutrition (PCM),** also referred to as *protein-energy malnutrition (PEM)*. In its milder form, it is difficult to tell if a person with PCM is consuming too little calories or protein, or both. But if the nutrient deficiency—especially for calories—becomes quite severe, a deficiency disease called **marasmus** can result. When an inadequate intake of nutrients, including protein, is combined with an already existing disease, a form of malnutrition called **kwashiorkor** can develop. Both conditions are seen primarily in children, but also may develop in adults, even in those hospitalized in North America. These two conditions form the tip of the iceberg with respect to states of undernutrition, and symptoms of these two conditions can even be present in the same person (Fig. 6-13).

Kwashiorkor

Kwashiorkor is a word from Ghana that means "the disease that the first child gets when the new child comes." From birth, an infant in developing areas of the world is usually breastfed. Often by the time the child reaches 1 to 1.5 years of age, the mother is pregnant or has already given birth again, and the new child gets preference for breastfeeding. The older child's diet then abruptly changes from nutritious human milk to starchy roots and **gruels.** These foods have low-protein densities, compared with total energy. Additionally, the foods are usually full of plant fibers, which are often bulky, making it difficult for the child to consume enough to meet calorie needs. The child generally also has infections, which acutely raise calorie and protein needs. For these reasons, calorie needs of these children are met just barely, at best, and their protein consumption is grossly inadequate, especially in view of the increased amount needed to combat infections. Many vitamin and mineral needs are also far from being fulfilled. Famine victims face similar problems.

The major symptoms of kwashiorkor are apathy, diarrhea, listlessness, failure to grow and gain weight, and withdrawal from the environment. These symptoms complicate other diseases present. For example, a condition such as measles, a disease that normally makes a healthy child ill for only a week or so, can become severely debilitating and even fatal. Further symptoms of kwashiorkor are changes in hair color, potassium deficiency, flaky skin, fatty liver, reduced muscle mass, and massive edema in the abdomen and legs. The presence of edema in a child who has some subcutaneous fat (i.e., directly under the skin) is the hallmark of kwashiorkor

protein-calorie malnutrition (PCM) A condition resulting from regularly consuming insufficient amounts of calories and protein. The deficiency eventually results in body wasting, primarily of lean tissue, and an increased susceptibility to infections.

marasmus A disease resulting from consuming a grossly insufficient amount of protein and calories; one of the diseases classed as protein-calorie malnutrition. Victims have little or no fat stores, little muscle mass, and poor strength. Death from infections is common.

kwashiorkor A disease occurring primarily in young children who have an existing disease and consume a marginal amount of calories and insufficient protein in relation to needs. The child generally suffers from infections and exhibits edema, poor growth, weakness, and an increased susceptibility to further illness.

gruels A thin mixture of grains or legumes in milk or water.

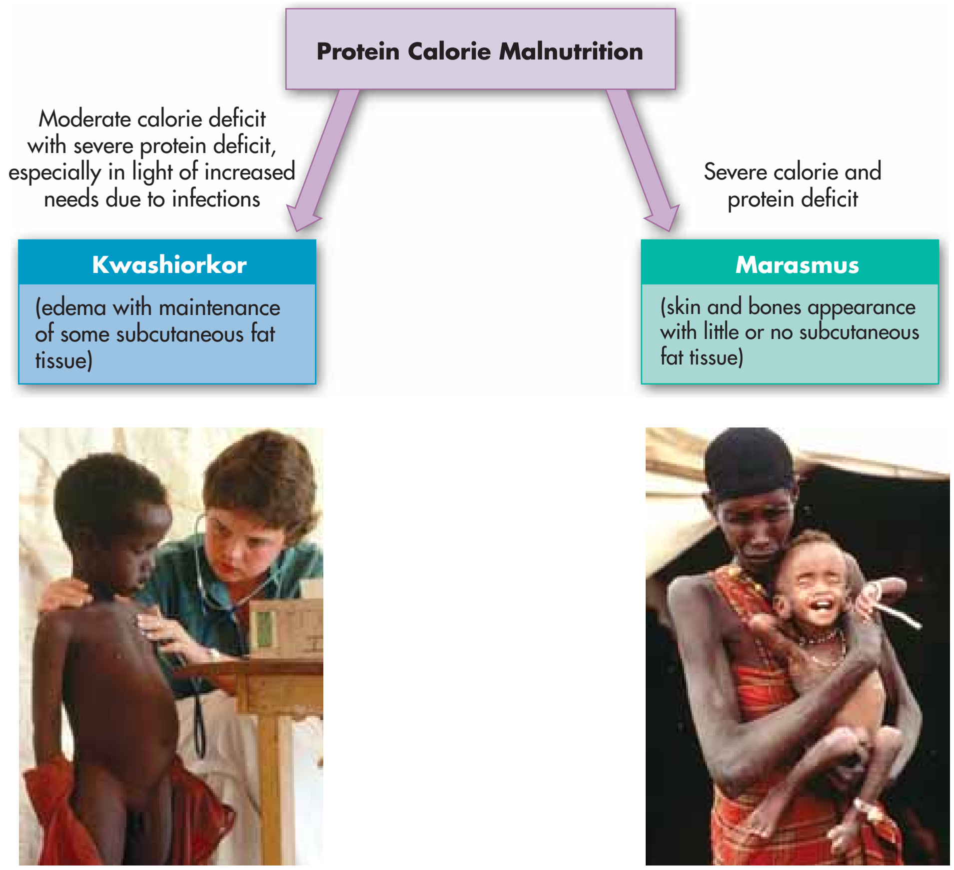


Figure 6-13 Schema for classifying undernutrition in children. The presence of subcutaneous fat (directly underneath the skin) is a diagnostic key for distinguishing kwashiorkor from marasmus.

Toxic products in moldy grains may also contribute to kwashiorkor.

(review Fig. 6-13). In addition, these children seldom move. If you pick them up, they don't cry. When you hold them, you feel the plumpness of edema, not muscle and fat tissue.

Many symptoms of kwashiorkor can be explained based on what we know about proteins. Proteins play important roles in fluid balance, lipoprotein transport, immune function, and production of tissues, such as skin, cells lining the GI tract, and hair. We should not expect children with an insufficient protein intake to grow and mature normally, and they don't.

If children with kwashiorkor are helped in time—if infections are treated and a diet ample in protein, calories, and other essential nutrients is provided—the disease process reverses. They begin to grow again and may even show no signs of their previous condition, except perhaps shortness of stature. Unfortunately, by the time many of these children reach a hospital or care center, they already have severe infections. In spite of the best care, they still die. Or, if they survive, they return home only to become ill again.

Marasmus

Marasmus typically occurs as an infant slowly starves to death. It is caused by diets containing minimal amounts of calories, as well as too little protein and other nutrients. As previously noted, the condition is also commonly referred to as *protein-calorie malnutrition*, especially when experienced by older children and adults. The word *marasmus* means "to waste away," in Greek. Victims have a "skin-and-bones" appearance, with little or no subcutaneous fat (review Fig. 6-13).

Marasmus commonly develops in infants who either are not breastfed or have stopped breastfeeding in the early months. Often the weaning formula used is improperly prepared because of unsafe water and because the parents cannot afford sufficient infant formula for the child's needs. The latter problem may lead the parents to dilute the formula to provide more feedings, not realizing that this provides only more water for the infant.

Marasmus in infants commonly occurs in the large cities of poverty-stricken countries. When people are poor and sanitation is lacking, bottle feeding often leads to marasmus. In the cities, bottle feeding is often necessary because the infant must be cared for by others when the mother is working or away from home. An infant with marasmus requires large amounts of calories and protein—like a **preterm** infant—and, unless the child receives them, full recovery from the disease may never occur. The majority of brain growth occurs between conception and the child's first birthday. In fact, the brain is growing at its highest rate after birth. If the diet does not support brain growth during the first months of life, the brain may not grow to its full adult size. This reduced or retarded brain growth may lead to diminished intellectual function. Both kwashiorkor and marasmus plague infants and children; mortality rates in developing countries are often 10 to 20 times higher than in North America.

preterm An infant born before 37 weeks of gestation; also referred to as premature.

Concept Check

Most undernutrition consists of mild deficits in calories, protein, and often other nutrients. If a person needs more nutrients because of disease and infection but does not consume enough calories and protein, a condition known as kwashiorkor can develop. The person suffers from edema and weakness. Children around age 2 are especially susceptible to kwashiorkor, particularly if they already have other diseases. Famine situations in which only starchy root products are available to eat contribute to this problem. Marasmus is a condition wherein people—infants, especially—starve to death. Symptoms include muscle wasting, absence of fat stores, and weakness. Both an adequate diet and the treatment of concurrent diseases must be promoted to regain and then maintain nutritional health.

Summary

1. Amino acids, the building blocks of proteins, contain a very usable form of nitrogen for humans. Of the 20 common types of amino acids found in food, 9 must be consumed as food (essential) and the rest can be synthesized by the body (nonessential).
2. High-quality (complete) protein foods contain ample amounts of all nine essential amino acids. Furthermore, foods derived from animal sources provide high biological value protein. Lower-quality (incomplete) protein foods lack sufficient amounts of one or more essential amino acids. This is typical of plant foods, especially cereal grains. Different types of plant foods eaten together often complement each other's amino-acid deficits, thereby providing high-quality protein in the diet.
3. Individual amino acids are bonded together to form proteins. The sequential order of amino acids determines the protein's ultimate shape and function. This order is directed by DNA in the cell nucleus. Diseases such as sickle cell anemia can occur if the amino acids are incorrect on a polypeptide chain. When the three-dimensional shape of a protein is unfolded—denatured—by treatment with heat, acid or alkaline solutions, or other processes, the protein also loses its biological activity.
4. Almost all animal products are nutrient-dense sources of protein. The high quality of these proteins means that they can be easily converted into body proteins. Rich plant sources of protein, are also available, such as beans.
5. Protein digestion begins in the stomach, dividing the proteins into breakdown products containing shorter polypeptide chains of amino acids. In the small intestine, these polypeptide chains eventually separate into amino acids in the absorptive cells. The free amino acids then travel via the portal vein that connects to the liver. Some then enter the bloodstream.
6. Important body components—such as muscles, connective tissue, transport proteins in the bloodstream, visual pigments, enzymes, some hormones, and immune bodies—are made of proteins. These proteins are in a state of constant turnover. The carbon chains of proteins may be used to produce glucose when necessary.
7. The protein RDA for adults is 0.8 grams per kilogram of healthy body weight. For a typical 70-kilogram (154-pound) person, this corresponds to 56 grams of protein daily; for a 57-kilogram (125-pound) person, this corresponds to 46 grams per day. The North American diet generally supplies plenty of protein. Men

typically consume about 100 grams of protein daily, and women consume closer to 65 grams. These usual protein intakes are also of sufficient quality to support body functions. This is even true for well-balanced vegetarian diets.

8. Undernutrition can lead to protein-calorie malnutrition in the form of kwashiorkor or marasmus. Kwashiorkor results primarily from an inadequate calorie and protein intake in comparison with body needs, which often increase with concurrent disease and infection. Kwashiorkor often occurs when a child is weaned from human milk and fed mostly starchy gruels. Marasmus results from extreme starvation—a negligible intake of both protein and calories. Marasmus commonly occurs during famine, especially in infants.

Study Questions

1. Discuss the relative importance of essential and nonessential amino acids in the diet. Why is it important for essential amino acids lost from the body to be replaced in the diet?
2. Describe the concept of complementary proteins.
3. What is a limiting amino acid? Explain why this concept is a concern in a vegetarian diet. How can a vegetarian compensate for limiting amino acids in specific foods?
4. Briefly describe the organization of proteins. How can this organization be altered or damaged? What might be a result of damaged protein organization?
5. Describe four functions of proteins. Provide an example of how the structure of a protein relates to its function.
6. How are DNA and protein synthesis related?
7. What would be one health benefit of reducing high-protein intake(s) to RDA amounts for some people?
8. What characteristics of vegetable proteins could improve the North American diet? What foods would you include to provide a diet that has ample protein from both plant and animal sources but is moderate in fat?
9. Outline the major differences between kwashiorkor and marasmus.
10. What are the possible long-term effects of an inadequate intake of dietary protein among children between the ages of 6 months and 4 years?

Further Readings

1. ADA Reports: Position of the American Dietetic Association and Dietitians of Canada: vegetarian diets. *Journal of the American Dietetic Association* 103:748, 2003.

   It is the position of the American Dietetic Association and Dietitians of Canada that appropriately planned vegetarian diets are healthful, nutritionally adequate, and provide health benefits in the prevention and treatment of certain diseases. In some cases, however, use of fortified foods or a multivitamin and mineral supplement may be needed to meet recommendations for individual nutrients.

2. Antony AC: Vegetarianism and vitamin B-12 (colbalamin) deficiency. *American Journal of Clinical Nutrition* 78:3, 2003.

   It is vital that a vegetarian focus on meeting vitamin B-12 needs. Use of vitamin B-12-fortified foods or a vitamin and mineral supplement are two options.

3. Borghi L and others: Comparison of two diets for the prevention of recurrent stones in idiopathic hypercalciuria. *The New England Journal of Medicine* 346:77, 2002.

   In men with a history of calcium oxalate stones and exhibiting increased calcium in the urine, restricted intakes of animal protein and salt, combined with normal calcium intakes, provided protection against recurrence of such stones.

4. Davis BC, Kris-Etherton PM: Achieving optimal essential fatty acid status in vegetarians: Current knowledge and practical implications. *American Journal of Clinical Nutrition* 78(suppl): 640S, 2003.

   Most of the fat in a vegetarian diet should come from nuts, seeds, olives, avocados, soy foods, and monounsaturated-rich oils, such as canola oil, olive oil, and nut oils. This practice provides a sufficient amount of essential fatty acids. Seaweed and microalge are two possible sources for vegans of the very-long-chain omega-3 fatty acids found in fish.

5. Dawson-Hughes B: Interaction of dietary calcium and protein in bone health in humans. *Journal of Nutrition* 133:852S, 2003.

   It is important to meet calcium needs to offset any possible protein-related calcium loss in the urine. In this way the combination of meeting protein and calcium needs can be beneficial to bone health.

6. Eating a high protein diet may accelerate kidney problems. *Today's Dietitian* p. 26, April 2004.

   High-protein diets may accelerate kidney disease in people who show evidence of the disease. Note that the National Kidney Foundation suggests one in nine North American adults show evidence of at least mild kidney disease.

7. Food and Nutrition Board: *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids.* Washington DC: The National Academy Press, 2002.

   This report provides the latest guidance for macronutrient intakes. With regard to protein intake, the RDA has been set at 0.8 grams per kilogram per day. Protein intake can range from 10% to 35% of calorie intake. The 10% allotment approximates the RDA, based on typical calorie intakes.

8. Hu F: Plant-based foods and prevention of cardiovascular disease: An overview. *American Journal of Clinical Nutrition* 78(suppl):544S, 2003.

   Plant-based diets provide numerous factors that reduce cardiovascular disease risk, such as unsaturated fats, phytochemicals, and fiber. The whole-grain breads and cereals, fruits, and vegetables in such a diet are the primary source of these factors. If desired, some lean/low-fat animal products can be added to round out a plant-based diet without decreasing its benefits.

9. Norat T, Riboli E: Meat consumption and colorectal cancer: A review of epidemiologic evidence. *Nutrition Reviews* 59(2):37, 2001.

   The risks of colorectal cancer are somewhat higher in people who consume diets rich in processed meat and red meat compared to individuals who consume small amounts.

10. Nuts are on a roll. *UC Berkeley Wellness Letter,* p. 1, May 2003.

    Nuts are a rich source of many nutrients and fiber, but also are very energy-dense. Thus it is best to substitute nuts for other protein sources, especially those rich in saturated fat.

11. Schart D: Got soy? *Nutrition Action Healthletter,* p. 8, November 2002.

    The best evidence for regular soy protein intake is the ability to lower blood cholesterol. The ability of soy protein to treat menopausal symptoms (or prevent breast and prostate cancer) is possible but has not been conclusively demonstrated.

12. "Vegging out" for better health? *HealthNews,* p. 8, November 2003.

    Well-balanced plant-based diets can lead to numerous health benefits. One benefit may be a longer life.

I. Is Your Protein Intake Sufficient to Meet Your Needs?

1. How much protein do you eat in a typical day? Look at the nutrition assessment you completed at the end of Chapter 2. Review it closely. Find the figure indicating the amount of protein you consumed on that day, and write it in the following space:

TOTAL PROTEIN ______ grams per day

Compare your protein intake with your RDA for protein. Find your healthy weight for height in pounds using Table 10-1 in Chapter 10. Choose a midrange value. Divide this number by 2.2 to reveal your healthy weight in kilograms. Next, multiply this weight (or your current body weight if the numbers are close) by 0.8 grams per kilogram. This will indicate the RDA for protein for your weight and gender. Write it in the following space:

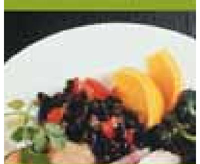
RDA FOR PROTEIN ______ grams per day

How does your consumption compare with your RDA for protein? ____________________

If you consumed either more or less than the RDA, what foods could you add, delete, or eat more or less of? (Look at the foods you ate.)

Was most of your protein from animal or plant sources? ____________________

If your protein intake was primarily from plants, did this come from a wide variety to encourage protein complementarity for the day?



II. Protein and the Vegetarian

Alana is excited about all the health benefits that might accompany a vegetarian diet. However, she is concerned that she will not consume enough protein to meet her needs. She is also concerned about possible vitamin and mineral deficiencies. Use your diet analysis software or Appendix J software to calculate her protein intake and see if her concerns are valid.

Breakfast

Calcium fortified orange juice, 1 cup

Soy milk, 1 cup

Fortified bran flakes, 1 cup

Banana, medium

Snack

Calcium-enriched granola bar

Lunch

Garden Burger, 4 ounces

Whole-wheat bun

Mustard, 1 tablespoon

Soy cheese, 1 ounce

Apple, medium

Green leaf lettuce, 1½ cups

Peanuts, 1 ounce

Sunflower seeds, ¼ cup

Tomato slices, 2

Mushrooms, 3

Vinaigrette salad dressing, 2 tablespoons

Iced tea

Dinner

Kidney beans, ½ cup

Brown rice, ¾ cup

Soft margarine, 2 tablespoons

Mixed vegetables, ¼ cup

Hot tea

Dessert

Strawberries, ½ cup

Angel food cake, 1 small slice

Soy milk, ½ cup

Alana's diet contained 2150 kcal, with ______ grams (you fill in) of protein (is this plenty for her?), 360 grams of carbohydrate, 57 grams of total dietary fat (only 9 grams of which came from saturated fat), and 50 grams of fiber. Her vitamin and mineral intake with respect to those of concern to vegetarians—such as vitamin B-12, vitamin D, calcium, iron, and zinc—met her needs.