CHAPTER 5 Proteins

Key Questions Addressed

- Why is protein important to athletes?
- What are proteins?
- What are the main functions of proteins in the body?
- What is nitrogen balance?
- How much protein should athletes consume daily?
- Which foods contain protein?
- Are protein supplements beneficial?
- Why is protein essential for daily training?
- What type, how much, and when should protein be consumed before exercise?
- What type, how much, and when should protein be consumed during exercise?
- What type, how much, and when should protein be consumed after exercise?

You Are the Nutrition Coach

Jamar is a 17-year-old high school junior who has a chance of starting as a linebacker on the football team his senior year. He is 6 feet tall and weighs 175 pounds. His coach has recommended that he gain 10–15 pounds over the next 8 months, but not at the sacrifice of his speed and quickness. Jamar eats home-cooked, well-balanced meals for breakfast and supper. At breakfast he also drinks a mega-protein supplement that contains 56 grams of protein. For school, he packs his own lunches, which usually include two tuna or chicken sandwiches with potato chips and milk. He also has a mid-morning and mid-afternoon snack, which typically consists of a protein bar (24 grams of protein/bar). He works out in the high school weight room two to three times per week in the late afternoon. When he arrives home, he studies until the family eats supper, around 7 p.m. His final snack of the day occurs just before bedtime, when he consumes another mega-protein supplement that contains 56 grams of protein.

Questions

- Is Jamar getting enough dietary protein to achieve his goals?
- What are the recommended guidelines for protein intake for an athlete wanting to gain weight?
- Is it detrimental to consume a diet containing too much protein?

Why is protein important to athletes?

If the tissues of the body had an ingredient list similar to the ones on food labels, for most, proteins would be second on the list after water. Most athletes are well aware of the importance of proteins, particularly in regard to muscle, and tend to be concerned that they may not be consuming adequate amounts to meet the body's demands for protein resulting from training/competition. The protein–muscle mass connection is just one of many reasons protein is an essential nutrient to athletes and untrained individuals alike.

Proteins are constantly being turned over in the body. In other words, they are continuously being broken down, transformed, and/or rebuilt. They also can be metabolized for energy, which is of particular concern to athletes involved in energy-demanding endurance sports, such as triathlons or marathons. Any part of the molecular protein structure that is not used is excreted from the body. As a result, proteins, which are a macronutrient, must be replaced on a daily basis through proper diet. Research suggests that athletes engaged in endurance, strength/power, or team sports have higher protein requirements than their sedentary counterparts; however, this does not mean that protein supplementation of their diet is required. This chapter explores proteins, their constituent amino acids, their functions in the body, and specifics about food sources, supplements, and protein needs before, during, and after training.

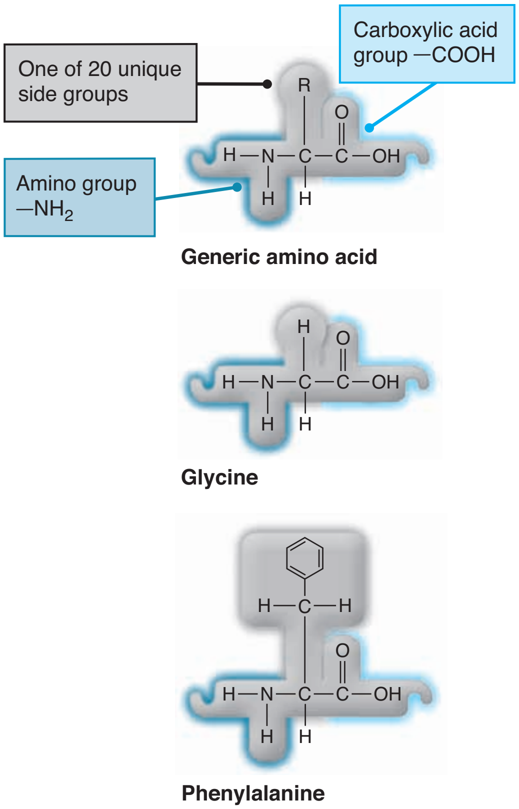

Figure 5.1 Structure of an amino acid. All amino acids have a similar structure. Attached to a carbon atom is a hydrogen (H) atom, shown here but not in later illustrations of amino acids; an amino group (NH_2); a carboxylic acid group (COOH); and a side group (R). The side group gives each amino acid its unique identity.

What are proteins?

Proteins consist of a series of amino acids. Individual **amino acids** are molecules composed of atoms of carbon (C), hydrogen (H), oxygen (O), and nitrogen (N). The different amino acids have similar basic structures (see Figure 5.1). All amino acids contain a central carbon atom that is bound to an amino group (NH_2), a carboxylic acid group (COOH), a carbon side chain, and a hydrogen atom. The presence of the nitrogen-containing amino group and the carboxylic acid group in the chemical structure of these molecules accounts for why they are called "amino acids." The carbon side chain gives each amino acid its unique structure, physical characteristics, and specific name. The side chains vary in shape, size, electrical activity, and pH. When two or more amino acids link to form a protein, it is the side chain characteristics of the amino acids that determine the protein's specialized function and shape.

amino acid A molecule that serves as the basic building block for proteins. Amino acids are composed of atoms of carbon (C), hydrogen (H), oxygen (O), and nitrogen (N).

The amino acids that make up a protein are held together via **peptide bonds**. The peptide bonds that link amino acids are formed when the amine group of one amino acid connects with the acid group of another amino acid (see Figure 5.2). In the course of peptide bond formation, a water molecule is formed. The process in which water is created during the formation of a chemical bond is known as **condensation**. Conversely, if large amounts of protein are consumed in the diet, the body must break the peptide bonds between amino acids holding the dietary proteins together. To do so, a process known as **hydrolysis**, which is the opposite of condensa-

peptide bond A type of chemical bond that links the amine group of one amino acid to the acid group of another amino acid when forming a protein.

condensation A chemical process that results in the formation of water molecules. Condensation occurs when peptide bonds are formed between amino acids.

hydrolysis A chemical process that requires utilization of water to break the chemical bond between elements or molecules. Hydrolysis is required to break peptide bonds between amino acids.

essential amino acid An amino acid that must be obtained from the diet because the body is unable to make it on its own.

nonessential amino acid A type of amino acid that can be made by the body from other amino acids or compounds and thus does not need to be supplied by diet.

conditionally essential amino acid An amino acid that under normal conditions is not considered an essential amino acid, but because of unusual circumstances (e.g., severe illness) becomes essential because the body loses its ability to make it.

tion, must occur. Hydrolysis uses water in the process of breaking the peptide bonds of the ingested proteins. As a result, the digestion of high-protein diets can contribute to water loss resulting from hydrolysis and eventually lead to dehydration if fluid intake is not maintained.

Twenty different amino acids are available for use in the human body. Nine of these are considered **essential amino acids** because they cannot be produced in the body. Therefore, they must be consumed in adequate amounts through dietary intake. Eleven additional amino acids are considered **nonessential**. They can be produced in the body and therefore do not need to be consumed in the diet (see **Table 5.1**). Two of the nonessential amino acids, tyrosine and cysteine, can become essential amino acids under certain conditions. They are considered **conditionally essential.** Under normal conditions the body makes tyrosine from phenylalanine and cysteine from methionine. If intake of phenylalanine and methionine (both essential amino acids) is low, the body will need exogenous tyrosine and cysteine from the diet, and thus they become essential. Arginine may also be considered conditionally essential during serious illness, stress, and growth spurts in young individuals.

Although the main role of amino acids is to build proteins needed by the body, they can also be metabolized in the liver and muscle for energy. However, to be used for energy, most amino acids must be converted to glucose via gluconeogenesis in the liver and then delivered via the blood to the working muscle. The branched chain amino acids (BCAAs), which are essential amino acids, can be metabolized for energy directly within the muscle itself. BCAAs comprise approximately one-third of the protein content of muscle and include the amino acids leucine, isoleucine, and valine. The BCAAs have garnered recent research attention because of their role as an energy source during exercise and because they also may play a role in regulating muscle protein synthesis. BCAAs are relatively abundant in whole foods. Dairy products, meat, wheat protein, soy, and whey protein isolates are rich sources of BCAAs.

Proteins are chains of amino acids that are linked in a very specific sequence (see Figure 5.3). The specific sequence of the amino acids in the chain gives the protein not only its physical characteristics, but also its three-dimensional shape. The shape of the protein in many instances dictates its function in the body, which is particularly true for those proteins that serve as enzymes or hormones.

Proteins can be classified according to the length of their amino acid chain. When two amino acids are linked, the result is a **dipeptide** protein. A

dipeptide A simple protein consisting of two amino acids linked via peptide bonds.

TABLE 5.1 Essential and Nonessential Amino Acids

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

*Branched chain amino acids

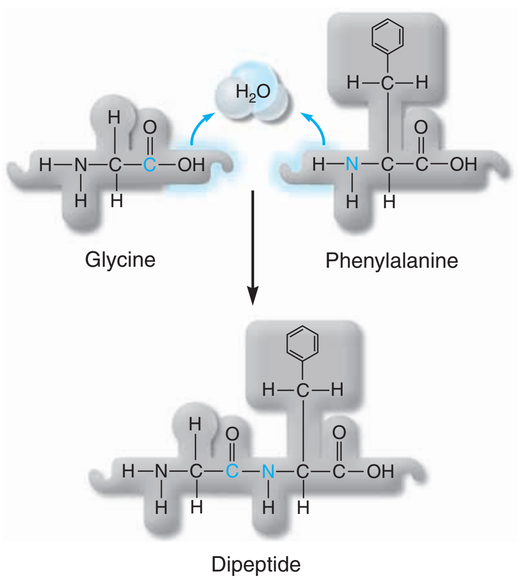

Figure 5.2 Peptide bond formation. When two amino acids join together, the carboxylic acid group of one amino acid is matched with the amino group of another.

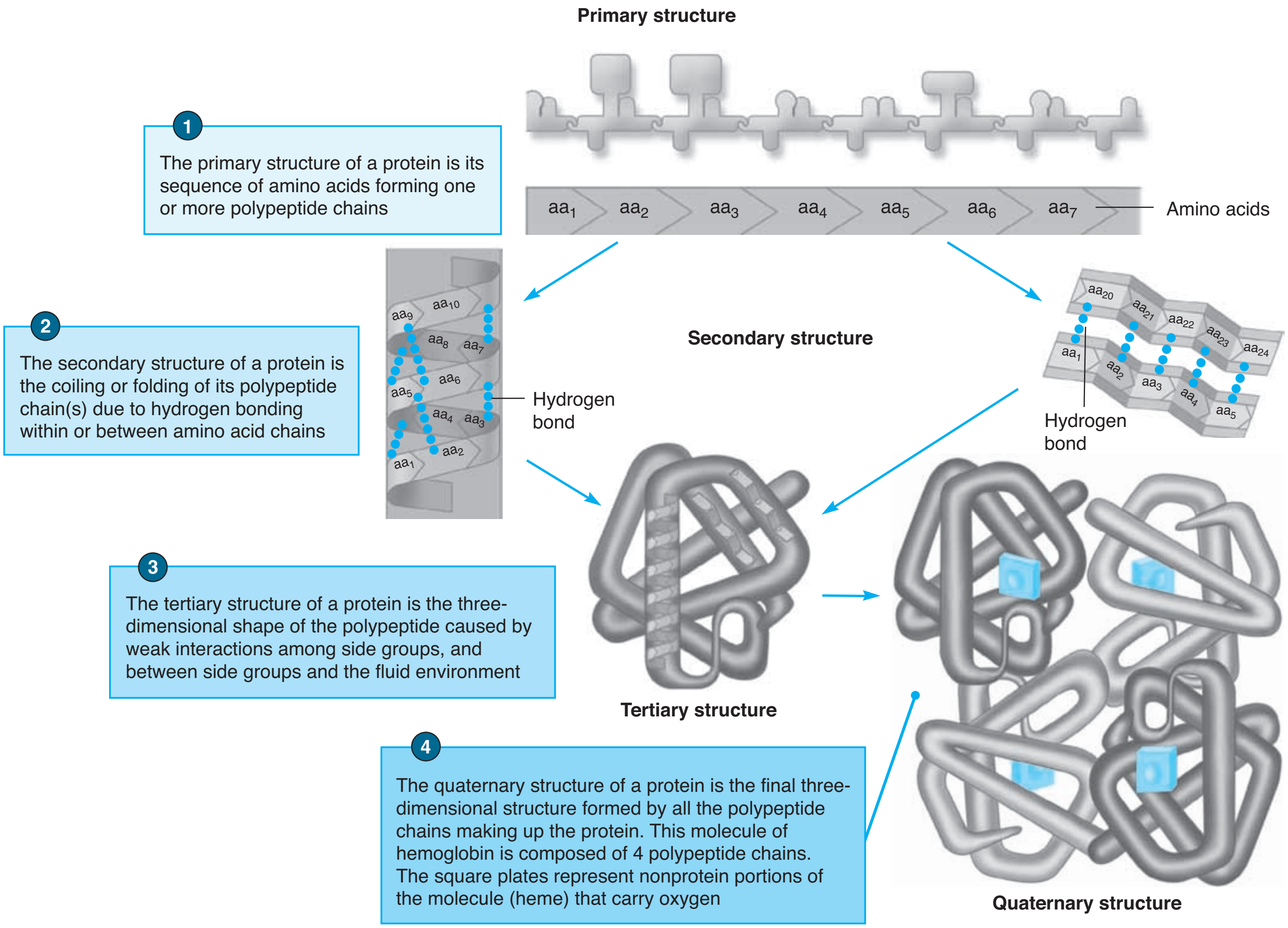

Figure 5.3 Primary protein structure. Each protein becomes folded, twisted, and coiled into a shape all its own. This shape defines how a protein functions in your body. The simplest depiction of a protein reveals its unique sequence of amino acids.

tripeptide A protein molecule made up of three amino acids linked via peptide bonds.

oligopeptide A protein molecule made up of 4 to 10 amino acids that are linked via peptide bonds.

polypeptide A protein molecule made up of more than 10 amino acids that are linked via peptide bonds.

tripeptide is a protein made of three amino acids. There are also **oligopeptides** (chains of 4 to 10 linked amino acids) and **polypeptides** (chains with more than 10 amino acids). Most proteins found in the body and in foods are polypeptides made up of hundreds of amino acids. Foods eaten daily must provide the amino acids required to maintain these complex polypeptides found in the body.

What is the difference between a "complete" and an "incomplete" protein?

Consuming protein-rich foods on a daily basis is necessary to obtain appropriate amounts of the essential amino acids. Protein is found in both animal- and plant-based foods. The terms *complete* and *incomplete* often are used to categorize protein sources. It should be noted that these terms should not be inferred to mean "superior" and "inferior." Each food provides a unique profile of proteins and amino acid content, as well as other health benefits, and therefore a variety of protein sources should be consumed throughout the day.

Animal proteins, such as eggs, dairy products, meat, and fish, contain all of the essential amino acids in high amounts and therefore are considered **complete proteins**. Animal proteins are also commonly referred to as **high-quality proteins**. A

complete protein A protein source that supplies the body with all of the essential amino acids in high amounts.

high-quality protein Source of protein that contains a full complement of all the essential amino acids, has extra amino acids that are available for nonessential amino acid synthesis, and has good digestibility.

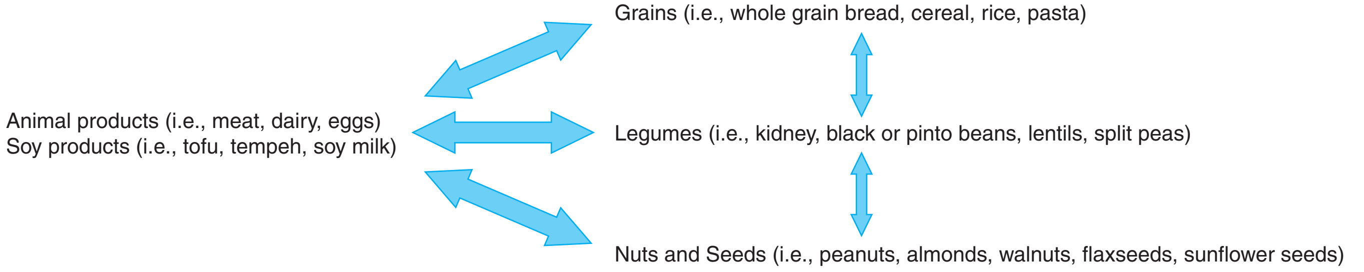

Figure 5.4 Complementary protein combinations. Because animal and soy products contain high levels of all essential amino acids, they can be consumed with any grain, legume, or nut/seed. Grains are complemented by legumes, and legumes are complemented by nuts/seeds. Grains are not a complementary match to nuts/seeds, but these two groups make a tasty combination in recipes.

high-quality protein (1) contains all of the essential amino acids, (2) has extra amino acids available for nonessential amino acid synthesis, and (3) has good digestibility. Animal proteins provide all of the essential amino acids, as well as extra nonessential amino acids, and are about 95% digestible (as compared to plant proteins, which are 85% digestible); animal proteins thus deserve the high-quality rating.

incomplete protein Sources of proteins that do not contain the full complement of essential amino acids.

limiting amino acid The essential amino acid that is in short supply in an incomplete protein source.

complementing proteins A group of two or more incomplete protein foods that when eaten together provide the full complement of essential amino acids.

An **incomplete protein** source lacks one or more essential amino acids. The essential amino acid that is in short supply in a specific food is called the **limiting amino acid**. All plant products (grains, beans, vegetables, fruits, nuts, and seeds), with the exception of soy, are categorized as incomplete proteins. Soy is unique in that it is the only plant product that provides a full profile of essential amino acids in high amounts, similar to animal proteins; thus, soy is considered a complete protein. In regard to other plant proteins, a variety of foods should be consumed daily to consume all the amino acids in sufficient amounts. Consuming proteins from a variety of food sources so that the diet contains all the essential amino acids in a meal or within a day is called **complementing proteins**. If two different foods are eaten in the same meal or in the same day, one food may contain all but one essential amino acid in sufficient amounts while the other may provide this limiting amino acid, thus complementing both foods. For example, grains' limiting amino acid is lysine, but grains are high in the amino acid methionine. Therefore, grains match well with legumes, which are low in methionine but high in lysine. Refer to Figure 5.4 for examples of complementary protein combinations. Examples of plant-based meals combining complementing proteins include the following:

- Stir-fried vegetables and tofu over rice (soy and grains).
- Vegetable chili with cornbread (legumes and grains).
- Barbecued tempeh on whole wheat bun (soy and grains).
- Oatmeal with nuts and soy milk (grains, nuts, and soy).
- Spinach salad with vegetables, garbanzo beans, and sunflower seeds (legumes and seeds).

Table 5.2 provides the protein content of a variety of plant-based foods.

TABLE 5.2 Protein Content of Plant-Based Foods

Protein Source	Protein Content (g)
Grains	
Brown rice, 1 cup	5
Wheat bread, 2 slices	6
Spaghetti, 1 cup	6.7
Legumes	
Lentils, 1 cup	7.9
Kidney beans, 1 cup	15.4
Chickpeas, 1 cup	14.5
Nuts/Seeds	
Peanut butter, 2 tbsp	9
Walnuts, 1 oz	6.9
Sunflower seeds, 1 oz	6.5
Soy Products	
Soy milk, 1 cup	7
Tempeh, ½ cup	16
Soybeans, 1 cup cooked	26
Soy nuts, ¼ cup	8

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For health and optimal sport performance, the body requires adequate amounts of essential amino acids on a daily basis. Athletes can meet protein needs by consuming a variety of protein-rich foods from both plant and animal sources.

Complementing proteins also can occur when combining a plant food with an animal product. The bottom line is that variety is best. Adequate protein can be consumed through all animal foods, all plant foods, or a combination of the two. The variety of protein sources and the daily meal plan developed for athletes should be derived from their preferences and tolerances for various protein sources.

The term *incomplete* given to most plant protein sources is often misinterpreted as meaning "inadequate" or "useless" because of the concept of a limiting amino acid. Not only can sufficient amounts of all amino acids be obtained by consuming a variety of plant protein sources throughout the day, but additional health benefits also can be derived from focusing heavily on a plant-based diet. Plant proteins contain fiber, are low in fat, contain no cholesterol, and are usually lower in calories than animal proteins. They also contain antioxidants and phytochemicals that can provide protection against heart disease and some cancers.

What are the main functions of proteins in the body?

Proteins have a role in almost all major body functions (see Figure 5.5). They provide structure to muscles and other tissues, act as regulators of cell functions, assist in maintaining fluid and acid–base balance, help transport substances throughout the body, and serve as an energy source when needed. Overall health and sport performance can be impaired if protein intake is too low or if protein catabolism is too high.

Proteins make up the constituent parts of many structures, including bones, ligaments, tendons, hair, fingernails/toenails, muscles, teeth, and organs. Without adequate protein intake, these structures, particularly muscle, cannot be maintained, much less strengthened, in response to training. Thus the end result of chronic low dietary protein intake is decreased sport performance and increased risk for injury.

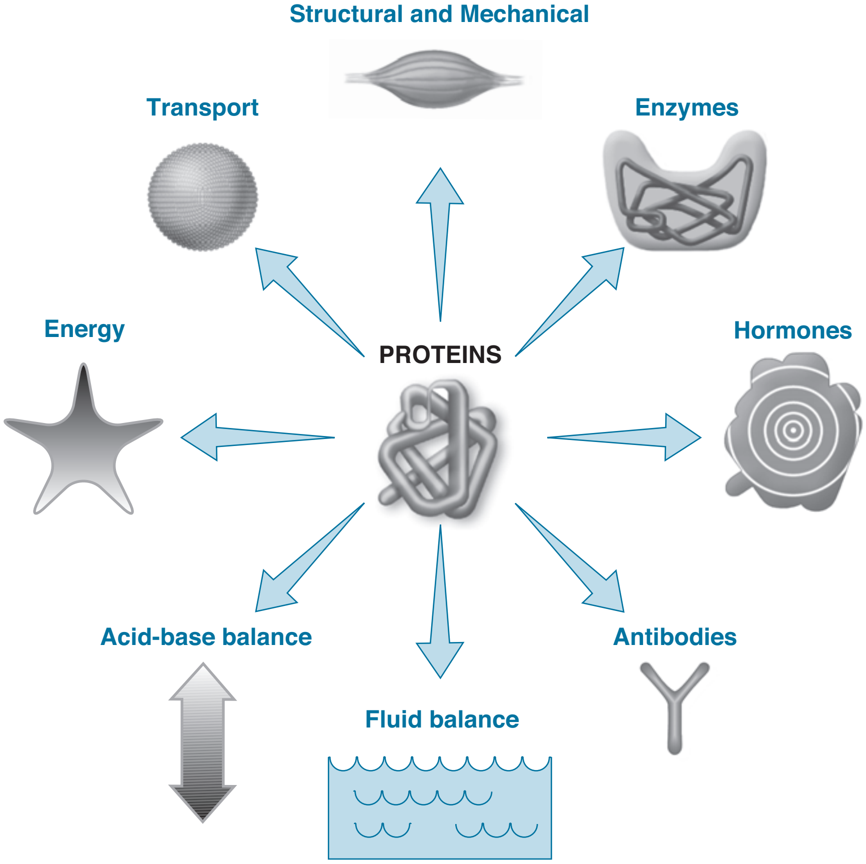

Figure 5.5 Functions of protein in the body.

enzymes A group of complex proteins whose function is to catalyze biochemical reactions in the body.

Dietary proteins are also used by the body to make enzymes. Enzymes serve as catalysts for a variety of biochemical reactions. Every cell contains and/or produces many types of enzymes, each with its own purpose. Digestive enzymes are produced and released by cells found in the stomach, intestines, and pancreas to break down carbohydrates, proteins, and fats into monosaccharides, amino acids, and fatty acids, respectively, so that they can be absorbed and utilized by the body. In regard to sport performance, all of the bioenergetic pathways responsible for the formation of ATP, which is the ultimate energy source for muscles, are dependent on enzymes. Without adequate dietary intake of protein, the body cannot maintain enzyme levels, and critical body functions begin to decline.

Many of the body's hormones are structurally derived from proteins. Most hormones are produced by specialized glands located throughout the body and serve a variety of regulatory functions. The pancreas produces insulin and glucagon, protein-derived hormones that help regulate blood glucose levels. Hormones also stimulate certain tissues to assist the body in meeting physical challenges. For example, the adrenal glands produce epinephrine and norepinephrine, which are protein-derived hormones that play a large role in preparing and helping the body to perform physical activity. These hormones stimulate the heart to beat faster and more forcefully so that more blood can be delivered to working muscles. They also stimulate enzymes in fat cells to release fatty acids into the bloodstream, supplying the muscles with energy. Hormones clearly play an important role in the athlete's ability to perform, and thus dietary proteins are required to ensure normal hormone production.

Proteins also are important to the body's immune function. Protein-derived antibodies attack and destroy bacteria, viruses, and other foreign substances. Immunizations such as the flu shot include inactive viruses. When injected into the body, these viruses stimulate the body to develop antibodies to the specific virus. The antibodies "remember" the virus to which they were exposed. If an individual is exposed to the virus again, the body initiates its defense mechanism and produces more antibodies to fight off the infection. If dietary protein needs are not met, the immune system can be compromised and the athlete's risk for illness is increased.

Circulating proteins in the blood play a role in maintaining the body's fluid balance. Proteins cannot diffuse freely through cell membranes, so they help establish an osmotic pressure within the blood. To maintain equilibrium, fluids must be moved back and forth between the blood and the intracellular (inside the cells) or extracellular (outside the cells) spaces. Albumin is the major blood protein that helps maintain fluid balance between the tissues and the blood. If inadequate blood protein levels occur, the osmotic pressure within the blood is high, and fluid "leaks" into the surrounding tissues, causing swelling, or edema.

intracellular A term used to describe structures, fluids, or other substances found inside the cell.

extracellular A term used to describe structures, fluids, or other substances found outside of the cell.

Proteins also help control the acidity level (i.e., pH balance) within the body. Under normal conditions the body's fluids are close to neutral, neither acidic nor basic. However, during exercise, lactic acid is produced. Lactic acid increases the acidity of body fluids, and if not buffered can cause fatigue within the muscle. Proteins buffer the lactic acid and thus delay the onset of fatigue, which is critical to an athlete's performance.

Many of the body's transporter molecules also are made of protein. A prime example is hemoglobin. Hemoglobin is a protein-derived carrier molecule that transports oxygen in the blood to tissues throughout the body. If hemoglobin levels are low, less oxygen is delivered to muscle cells, greatly reducing exercise capacity and endurance.

Although not a major source of energy, protein can be used as energy during or following exercise. The body prefers to burn carbohydrates and fats for energy at rest and during exercise; however, if carbohydrate stores are low, energy expenditure is high, and/or calorie intake is inadequate, proteins can be converted to glucose and used for energy. This is one of the reasons why endurance athletes must ensure that they consume adequate carbohydrate and protein in their diet.

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Without adequate protein intake, many key enzymes, hormones, and other compounds cannot be made by cells. In addition, body structures, such as muscle, cannot be maintained, repaired, or strengthened with intense training. Athletes should consume protein-rich foods daily to ensure overall health, optimize performance, and prevent athletic-related injuries.

What is nitrogen balance?

Because proteins in the body are constantly breaking down and have to be resynthesized, daily input of new amino acids into the body's amino acid pool is required. The goal of any dietary plan should be to supply enough amino acids to support the increase in protein synthesis resulting from training and competition, while at the same time meeting the body's basic maintenance needs. One way to determine whether an individual's protein needs are being met is through the measurement of **nitrogen balance**.

nitrogen balance A way of monitoring nitrogen status in the body. When dietary input of nitrogen (i.e., protein gain) equals the output of nitrogen (i.e., protein loss), then nitrogen balance has been achieved.

Nitrogen balance occurs in the body when dietary input of nitrogen (i.e., protein gain) equals the output of nitrogen (i.e., protein loss). The state of nitrogen balance can be calculated using the following equation:

$$(\text{nitrogen in}) - (\text{nitrogen out}) = \text{nitrogen status}$$

Because dietary protein is the main source of nitrogen, the amount of "nitrogen in" can be estimated by monitoring daily protein intake. Determining "nitrogen out" is much more complicated.

Proteins are constantly being lost from the body. Some proteins are lost from the external surface of the body as a result of mechanical wear (e.g., sloughed off skin, broken fingernails, lost hair), but the majority are lost via cellular metabolism. When amino acids are broken down internally, the nitrogen group is cleaved from the molecule. The released nitrogen can be lost from the body via the formation of urea in the liver or, to a much lesser extent, as ammonia. By measuring the urea levels in urine and sweat, it is possible to estimate nitrogen loss. If the body is in nitrogen balance, then the difference between nitrogen in (i.e., dietary protein intake) and nitrogen out (i.e., urea excreted) is zero.

A positive nitrogen balance indicates that dietary protein intake (nitrogen in) is greater than protein loss (nitrogen out). When nitrogen is being retained by the body, it indicates that it is being used to make lean tissue.[1] A positive nitrogen balance can occur in an athlete who is weight training to build muscle mass and is consuming adequate calories along with a high, but appropriate, protein intake.[1] Conversely, some athletes may find themselves in negative nitrogen balance. For example, an endurance athlete who is training intensely but not eating enough food to meet her or his daily caloric needs will start mobilizing proteins for energy and thus increase nitrogen loss.[2] A negative nitrogen status is not desirable because it is an indication that lean body tissue is being metabolized by the body. At a minimum, the goal for any athlete is to maintain nitrogen balance; ideally, he or she should try to achieve a positive nitrogen balance.

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By consuming adequate daily calories and protein, athletes can maintain nitrogen balance or even achieve positive nitrogen status. A positive nitrogen balance indicates that an athlete is in a "protein-building state" versus one of protein breakdown, which can negatively affect athletic performance.

How much protein should athletes consume daily?

It is clear that protein is critical for optimal athletic performance. It is also known that athletes have higher protein needs than their sedentary counterparts. However, even among athletes, protein recommendations are not one-size-fits-all. Recommendations exist for different categories of athletes, with variances in individual protein requirements based on a variety of factors. Current body weight, total energy intake, desire to lose or gain weight, carbohydrate availability, exercise intensity and duration, training status, quality of dietary protein, and the age of the individual all need to be considered when calculating protein recommendations and developing a dietary plan for athletes.

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Current research indicates that athletes have higher protein needs than nonathletes.

How can protein requirements be calculated based on body weight?

The easiest and most reliable way to determine individual protein needs is to calculate daily requirements based on current body weight. The RDA for the general public is 0.8 grams of protein per kilogram of body weight (0.8 g/kg).[3] The adult AMDR for protein is 10–35% of daily calories.[3] Current research suggests that athletes need more protein than the general public, but the recommended ranges are still under debate.

A majority of the recent research has focused on the amount of protein required to keep strength athletes in positive nitrogen balance despite the breakdown of muscle tissue and the subsequent increased protein synthesis during and after resistance training. The current daily protein recommendations for strength athletes range from 1.4–2.0 g/kg.[4–7] Some recommendations suggest an upper limit as high as 2.5 g/kg. The exact upper limit of protein intake that is safe and effective for athletes has yet to be determined. Intakes of 1.4–2.0 g/kg mean that the percentage of total calories coming from protein will typically range from 15–20%, which is well within the AMDR range.

Endurance athletes also have increased daily needs for dietary protein. Because of factors such as repetitive muscle contractions, high-impact activities, increased demand for mitochondria and enzymes involved in aerobic metabolism, and some oxidation of amino acids during aerobic exercise, it is suggested that endurance athletes consume at least 1.2 g/kg of protein daily.[8–13] Individual needs can range up to 2.0 g/kg, especially for the ultra-endurance athlete who trains 4 to 6 hours or more a day. Because calorie needs for endurance and ultra-endurance athletes can range from 3000–6000 or more per day, the relative contribution of protein at levels of 1.2–2.0 g/kg will typically fall between 12% and 18% of total calories.

Research regarding the protein needs of team sport athletes is sparse. Because of the nature of most team sports, which use a combination of strength/power and endurance, it can be assumed that protein needs would fall in the middle of the ranges for both strength and endurance athletes. Therefore, the current protein recommendation for team sport athletes ranges from 1.2–1.6 g/kg daily. This amount of dietary protein typically contributes 12–16% of the total calories ingested per day. **Table 5.3** provides a summary of the protein needs for various athletes.

As already stated, protein intake for athletes should contribute approximately 12–20% of total calories. After calculating an estimated range of protein requirements (in grams) for an athlete based on body weight, always compare the recommendation

TABLE 5.3 Daily Protein Recommendations for Athletes

Type of Athlete	Daily Grams of Protein/ Kilogram Body Weight	Percentage of Total Calories Contributed by Protein
Sedentary individual	0.8 g/kg	12–15%
Strength athlete	1.4–2.0 g/kg	15–20%
Endurance athlete	1.2–2.0 g/kg	12–18%
Team sport athlete	1.2–1.6 g/kg	12–16%
Weight gain/loss	1.6–2.0 g/kg	16–20%

to total calorie requirements. The percentage of total calories from protein is calculated as follows:

> total grams of protein × 4 calories per gram of protein = total calories from protein
> (total calories from protein ÷ total calorie requirements) × 100 = % of total calories contributed by protein

For example, a team sport athlete who weighs 82 kilograms requires 98–131 grams of protein per day (1.2–1.6 g/kg). If this individual consumes 2800–3300 calories per day, protein will be contributing 14–16% of total calories:

> 98 × 4 = 392 calories from protein
> (392 ÷ 2800) × 100 = 14% of total calories from protein

or

> 131 × 4 = 524 calories from protein
> (524 ÷ 3300) × 100 = 16% of total calories from protein

Calculating the percentage of total calories from protein is an excellent way to double-check the accuracy and appropriateness of estimated individual protein recommendations. Ideally, protein should contribute at least 12–20% of total calories. Although no tolerable upper limit (UL) has been set for protein, it is suggested that all Americans, including athletes, consume no more than 30–35% of total calories from protein to decrease the risk of chronic disease.[3]

How do various dietary and training factors affect protein recommendations?

As mentioned previously, individual protein requirements will vary based on a variety of factors. When calculating daily protein needs for a specific athlete, begin with the recommended ranges stated in the previous section, based on the sport. Then consider the following factors to ultimately determine whether protein requirements will be calculated at the low or high end of the recommended ranges:

Total energy intake

If an athlete is consuming an adequate number of calories, protein requirements can be calculated in the middle of the recommended range. Adequate energy intake, particularly in the form of carbohydrates, spares muscle protein and promotes protein synthesis. In general, athletes who consume adequate calories tend to have adequate protein intakes as well, even meeting their increased needs for training and competition.[14] However, it is not always easy for athletes to maintain an adequate calorie and protein intake. For example, athletes who train one or more times a day and those involved in endurance sports have higher calorie and protein needs. It is often difficult for these athletes to have the time, energy, desire, and appetite to eat the number of calories needed to maintain nitrogen balance. Athletes should focus on consuming calorie-dense foods and fluids, along with additional snacks, during intense training sessions and long-duration exercise to spare protein.

Desire to lose or gain weight

Many athletes have the goal of either gaining or losing weight. In both of these situations, protein needs are increased and should be calculated at the high end of the recommended range. For example, a football player may be working intensely in the weight room during preseason training to increase muscle mass, which requires a higher level of protein to ensure proper recovery from training and to assist the body in synthesizing new muscle tissue. Conversely, a triathlete may be aiming to lose 5–10 pounds during off-season training, which typically consists of weekly swim, bike, and run workouts with long-duration sessions of each discipline, plus an emphasis on strength training in the weight room. More protein is required, not only to recover from the workouts, but also to ensure that the athlete stays in positive nitrogen balance when calorie intake is lower than normal.

In either scenario, adequate daily calories should be consumed in order to maximize the use of ingested protein. If caloric intake is inadequate, proteins will be increasingly relied upon to provide energy both at rest and during exercise. When amino acids become an energy source, it is at the expense of being used for their primary purposes, such as making enzymes and hormones, repairing and developing structural tissues, and providing transport needs. In addition, low calorie and protein intake can lead to a loss of muscle mass, which will ultimately decrease an athlete's strength, power, endurance, and metabolism. It is imperative that sports nutrition professionals counsel athletes on the detrimental impact of not meeting total energy needs, on the consequences of following a very low calorie diet, and on athletes' ability to meet their weight goals as well as to recover from and adapt to physical training.

> ***gaining the performance edge***
>
> Adequate calorie intake reduces the need for amino acid oxidation and thus spares dietary protein and muscle tissue.

Carbohydrate availability

Carbohydrates are the primary fuel for working muscles at moderate and high exercise intensities. Carbohydrates are the only fuel that can be metabolized anaerobically and thus become the primary source during intense aerobic activity. Because of their energetic value and their role in maintaining blood sugar levels, if carbohydrate stores become depleted the body will begin manufacturing carbohydrates (i.e., glucose) from proteins. Adequate daily carbohydrate intake keeps carbohydrate stores at an optimal level and thus spares proteins. In short, as carbohydrate availability increases, protein metabolized for energy decreases, thus moderating protein requirements.

> ***gaining the performance edge***
>
> Adequate daily carbohydrate intake keeps carbohydrate stores at an optimal level and thus spares proteins.

Exercise intensity and duration

Training intensity and duration both increase protein requirements. Exercise intensity refers to how much effort is being put forth to perform an exercise. In other words, as the intensity of exercise increases, so does an athlete's rating of perceived exertion. Duration refers to how long the exercise bout lasts. Although the role of protein in the body is more functional and structural than energetic, whenever the body's metabolism increases, the energetic role of proteins in the body also increases. Protein utilization appears to be positively related to both the intensity and the duration of exercise. This is particularly the case with endurance-type exercise and is exacerbated when carbohydrate stores are depleted or low during exercise. Increasing the duration of exercise begins to deplete glycogen reserves in the liver and muscle, and, as already noted, whenever carbohydrate levels fall in the body, protein utilization increases. This is often seen when athletes exercise in an already glycogen-depleted state or when carbohydrate stores become depleted during a single bout of long-duration or highly intense exercise.

Unlike endurance training, single sessions of resistance exercise, regardless of the length or intensity of the workout, do not appear to increase the use of protein during the workout itself. However, amino acid uptake after the resistance training session does increase, indicating that the amino acids are being used for muscle repair and construction rather than for energy. The additional use of protein for energy in endurance athletes, and for muscle repair and synthesis with intense resistance training, explains the recommendations for increased daily protein intakes.

Training state/fitness level

Protein utilization appears to be higher for athletes who are less fit. When endurance training is initiated, nitrogen balance may be negative for the first 2 weeks. When strength training is first initiated, protein requirements may be higher in the first weeks to support new muscle growth.[4] As both strength- and endurance-focused athletes continue their training, nitrogen balance becomes neutral or positive. After 1 to 2 weeks on the program, the utilization of protein decreases as the body adapts to the training. The take-home message is that protein needs appear to increase during the first couple weeks of a new training regimen and return to baseline levels soon thereafter. Based on this knowledge, temporarily increasing the protein intake of individuals starting a new training program or athletes starting a new phase in their training cycle (i.e., from off-season training to in-season training) may be a practice worth considering.

Dietary protein quality

Athletes need to consume adequate amounts of all essential amino acids to sustain protein functions. Athletes who consume animal proteins (complete proteins) will have all the essential amino acids available for protein functions. Vegetarian athletes have slightly higher protein needs because of the intake of incomplete proteins, and therefore protein intake levels should be calculated at the high end of the recommended range. Vegetarians may also need to plan more diligently to consume adequate levels of daily protein through complementary plant protein sources. Whether athletes consume animal or plant proteins, variety is the key to consuming all of the essential amino acids.

Age

The RDAs for young people are 0.95 g/kg per day for those ages 4 to 13 years and 0.85 g/kg per day for those 14 to 18 years.[3] Youth and teenage athletes have a slightly higher RDA for protein for several reasons. Body growth and development increase greatly around puberty, which place tremendous energy and protein demands on the body. When combined with the physiologic energy and protein demands imposed by training and sport participation, the concern regarding calorie and protein intake becomes evident. The concern surrounding young athletes is further exacerbated by their typically poor dietary habits, particularly in the teenage group. Young athletes need to focus on achieving adequate energy and protein intakes for growth and development, as well as for the added energy demands of sport training/competition. Doing so will help spare body proteins needed not only for growth and development, but also for recovery and adaptive purposes.

The number of older adults (i.e., individuals 65 years of age and older) exercising and/or competing in sports is rising. Unlike young athletes, protein needs caused by growth and development are not an issue; however, this does not mean that protein intake is inconsequential. Research clearly indicates that older individuals can tolerate and respond to exercise training. Their tissues retain the ability to adapt by becoming larger and stronger. For example, Esmark et al. found a 25% increase in mean muscle fiber area in elderly males after a 12-week resistance training program.[15] This program also included a protein/carbohydrate supplement (10 grams protein + 7 grams carbohydrate) immediately after resistance training to aid in muscle recovery and construction. Amino acids are needed to meet older adults' adaptive needs, similar to younger athletes. Unfortunately, elderly individuals often have poor nutritional habits, may lack an appetite, or lack the knowledge to purchase and prepare high-quality, nutrient-dense foods. Sports nutrition professionals should pay close attention to total calories consumed and protein intake of older athletes. Despite previous misconceptions, the bodies of older adults are capable of adapting to training regardless of age. Educating older adult athletes on the importance of consuming adequate total calories and nutrient-dense protein sources is essential.

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Youth and teenage athletes have increased protein requirements to support growth and development, as well as sport performance. Despite previous misconceptions, the bodies of older adults are capable of adapting to training regardless of age. Educating older adult athletes on the importance of consuming adequate total calories and nutrient-dense protein sources is essential.

Can too much protein be harmful?

Although adequate protein consumption is of great importance to athletes, more is not always better. Based on the AMDR for protein, individuals should not exceed 35% of total calories from protein. Protein is a hot topic for athletes, particularly strength/power athletes and those attempting to lose weight. Many of these athletes consume more than 35% of their

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Athletes should be encouraged to achieve adequate protein intakes but not by carelessly consuming excessive amounts through large quantities of food or supplementation.

total calories from protein. Although these athletes believe they are enhancing their performance, very high levels of protein can actually hinder health and performance. All athletes need to understand the potential safety and health concerns associated with excessive protein intake.

A considerable number of questions have been raised about the effects of high protein intake on kidney function. The kidneys filter waste from the liver, including urea, which is one of the waste products of protein metabolism. When protein intake exceeds the body's ability to use it, the excess protein is stripped of its amine group and the remaining carbon skeleton is used for energy or converted to fat. The nitrogen-containing amine group forms urea, which is then carried via the blood to the kidneys for excretion in the urine. As a result, high-protein diets can place additional stress on the kidneys to remove urea. Although a concern, the increased strain on the kidneys does not appear to affect athletes with normal kidney function—at least short term.[4,10] Long-term studies on the effects of high protein intakes on healthy athletes are currently not available. However, athletes with kidney disease or chronic conditions that may lead to kidney malfunction, such as diabetes or high blood pressure, should avoid excessive protein consumption, maintaining an adequate but moderate intake of protein daily.

Dehydration also can be a result of a high-protein diet. The breaking of peptide bonds during digestion of proteins requires water. In addition, the excretion of urea resulting from protein degradation increases body water loss in the form of urine. If athletes consume excessive amounts of protein via food or through supplementation, the body's fluid needs are increased. Failure to meet fluid needs results in dehydration, which can jeopardize not only athletic performance, but also the athlete's health and safety.

The fat and total calorie content typically associated with high protein intake is also of concern. Many high-protein foods, such as full-fat meat and dairy products, are a significant source of total fat, saturated fat, and cholesterol. All of these factors have been associated with an increased risk of cardiovascular disease and some cancers. If high-protein food selections are also high in total calories, weight gain is possible, which will negatively affect health and performance.

Often an emphasis on high-protein foods displaces other lower calorie, nutrient-dense foods such as fruits, vegetables, whole grains, and plant proteins. More research is needed to identify the specific role of protein in chronic diseases and weight management versus other nutritional factors. Until that information becomes available, adequate but not excessive intake of protein is recommended.

High protein consumption increases the excretion of calcium from the bones. A large amount of acid is generated when excessive amounts of protein are consumed, requiring the body to either excrete or buffer the acid to maintain pH balance. When acid levels rise, the body responds by leaching calcium, a buffering agent, from the bones.[16] Over time, this can contribute to bone mineral losses, potentially increasing the risk of osteoporosis. This leaching effect has been documented to be more profound with the excessive consumption of animal versus plant proteins.[17] Therefore, athletes should be encouraged to consume appropriate amounts of protein, including a variety of protein sources, while also obtaining adequate levels of calcium daily. Sports nutrition professionals need to screen athletes for potentially excessive protein intakes. Athletes should be encouraged to achieve adequate protein intake through whole foods versus supplements. Additional protein intake, if needed, should not be at the expense of other macro- and micronutrients. If protein intake is increased, athletes should be counseled to also increase fluid intake to prevent any potential for dehydration.

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The recommended protein intake is 1.4–2.0 g/kg per day for strength athletes, 1.2–2.0 g/kg per day for endurance athletes, and 1.2–1.6 g/kg per day for team sport athletes.

Which foods contain protein?

Proteins are found within most food groups of the MyPlate food guidance system. The richest sources of protein are found in the dairy/alternative and protein foods groups. Grain products as well as vegetables provide a small to moderate amount of protein. Fruits and oils provide minimal to no protein. Because protein is not found universally within each food group, it is imperative that athletes include a variety of protein sources in sufficient amounts daily for optimal performance and health.

Which foods in the grains group contain protein?

Foods from the grains group are moderate sources of protein. The grains are considered an incomplete protein source because they contain lower levels of lysine. The key is to consume whole grain products in

TABLE 5.4 Protein Content of Various Foods

Protein Source	Protein Content (g)
Grains	
Whole wheat bread, 1 slice	3
Brown rice, $\frac{1}{2}$ cup	3
Pasta, $\frac{1}{2}$ cup	3.5
Fruits/Vegetables	
Apple, 1 medium	0.3
Banana, 1 medium	1.2
Carrots, $\frac{1}{2}$ cup	1
Broccoli, $\frac{1}{2}$ cup	1.3
Dairy/Alternative	
Skim milk, 8 fl oz	8
Low-fat yogurt, 6 oz	6
Cheddar cheese, 1 oz	7
Soy milk, 8 fl oz	5
Soy yogurt, 6 oz	7
Protein Foods	
Beef, 3 oz	25
Chicken, 3 oz	27
Turkey, 3 oz	26
Pork, 3 oz	24
Tuna, 3 oz	22
Black beans, 1 cup	15
Lentils, 1 cup	18
Tofu, $\frac{1}{2}$ cup	20
Tempeh, $\frac{1}{2}$ cup	16
Mixed nuts, 1 oz	5

Source: Adapted from Pennington JA, Douglass JS. *Bowes & Church's Food Values of Portions Commonly Used*. 18th ed. Philadelphia, PA: Lippincott Williams and Wilkins; 2005.

conjunction with legumes, nuts, or seeds throughout the day to balance the intake of amino acids. **Table 5.4** lists a variety of healthy whole grain options and their respective protein levels. **Training Table 5.1** provides some menu ideas for including whole grain sources of protein in the diet.

Which foods in the fruit and vegetable groups contain protein?

Vegetables contain a small amount of protein, contributing approximately 1–2 grams of protein per serving. Fruits contain minimal amounts of protein and therefore should not be considered a protein source. However, both fruits and vegetables contribute valuable nutrients such as fiber, vitamins, minerals, and water that high-protein foods are often lacking. One vitamin that is of particular importance when eating high-protein foods is vitamin C. The nonheme iron present in beans and grains can be absorbed much more readily when consumed with vitamin C. Therefore, fruits and vegetables should accompany plant-based protein sources in meals. Table 5.4 lists a variety of vegetables and their respective protein levels. **Training Table 5.2** includes menu ideas for including protein-containing fruits and vegetables in the diet.

Training Table 5.1: Menu Ideas for Grain Sources of Protein

- Beans and rice make a balanced, hearty meal. (See *Badminton Beans and Rice* recipe.)
- Pack an almond butter and wheat bread sandwich for long days away from home.
- Make a beef barley soup with extra vegetables for a hot dinner in the winter months that also freezes well for quick meals during the week.
- Add ground turkey to marinara sauce and serve over whole wheat pasta.

Badminton Beans and Rice

1 cup brown rice, uncooked
1–2 tbsp olive oil
1 medium onion, chopped
2 cloves of garlic, minced
4 oz can of chopped green chilies
1$\frac{1}{2}$ tsp chili powder
2 tsp cumin powder
2 tbsp chopped fresh cilantro
juice of 1–2 limes
3 cans pinto beans, drained and rinsed

Cook brown rice according to package directions. Sauté onion, garlic, and green chilies in oil until onions are translucent. Add the lime juice and seasonings; cook several minutes to blend the seasonings. Add the beans to the onion mixture and cook over low to medium heat for 10–15 minutes. Serve over brown rice.

Serving Size: 2$\frac{1}{4}$ cups (Recipe makes four servings)

Calories: 316 kcals

Protein: 15 grams

Carbohydrate: 53 grams

Fat: 6 grams

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Fruits and vegetables round out any meal, providing carbohydrates, vitamins, minerals, and phytochemicals. Therefore, a high-protein-containing food should be paired with a fruit and/or a vegetable at every meal.

Training Table 5.2: Menu Ideas for Combining Fruits and Vegetables with Protein Foods

- Drink a glass of orange juice with an iron-fortified cereal and milk.
- Add onions, carrots, and extra tomatoes to a meat and bean chili.
- Include spinach in meat lasagna.
- Alternate chicken and peppers, squash, and/or mushrooms for grilled kabobs.

Training Table 5.3: Menu Ideas for Dairy/Alternative Sources of Protein

- Drink a cold glass of milk with lunch and dinner.
- Top tomatoes or potatoes with ½ cup cottage cheese.
- Keep yogurt on hand to have as a midday snack.
- Sprinkle parmesan or romano cheese on top of cooked vegetables.

Which foods in the dairy/alternative group contain protein?

Dairy/alternative foods and beverages provide an excellent source of protein. Most dairy and soy products contain approximately 6–8 grams of protein per serving. However, some dairy/alternative products, other than soy, may not be excellent sources of protein. Rice and other grain or nut milks often provide only 2–3 grams of protein per serving, but, if fortified, are still good sources of calcium and vitamin D. Low-fat dairy products contain lower levels of saturated fat and cholesterol compared to their full-fat dairy counterparts while contributing equivalent levels of protein. Table 5.4 lists a variety of dairy/alternative products and their respective protein levels. **Training Table 5.3** includes menu ideas for how to include dairy/alternative sources of protein in the diet.

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Athletes should focus on protein sources from the "heavy hitters" in the dairy/alternative and meat and protein foods groups. Grains and vegetables make up the "second string," while fruits are "bench warmers" in regard to sources for daily protein.

Which foods make up the protein foods group?

Meat, fish, poultry, eggs, and soy products are excellent sources of a complete protein, containing the highest level of protein per serving within the MyPlate food guidance system. Legumes, nuts, and seeds are also rich in protein; however, these should be combined with grains, soy, meat, or dairy throughout the day to obtain high levels of all amino acids. A 3-ounce serving of food within this group provides approximately 20–30 grams of protein. Table 5.4 lists a variety of protein foods and their respective protein levels. **Training Table 5.4** contains menu ideas for incorporating protein foods.

Training Table 5.4: Menu Ideas for Protein Food Sources

- Coat chicken breast with breadcrumbs, bake with marinara sauce, and serve alone or over pasta. (See *Cross-Country Chicken Parmesan* recipe.)
- Order salads in restaurants with grilled lean meats and lots of extra vegetables.
- Try a tofu sandwich with cheese, lettuce, and cucumber—flavored, baked tofu tastes the best for sandwiches.
- Make a weekend omelet with spinach and peppers, and serve with whole wheat toast topped with peanut butter.

Cross-Country Chicken Parmesan

4 chicken breasts
3 egg whites
½–1 cup Italian-flavored breadcrumbs
32 oz jar of spaghetti sauce
8–12 oz dry pasta, any shape
Grated parmesan cheese

Preheat oven to 400° F. Place breadcrumbs in a shallow bowl. Lightly beat the egg whites with a fork in a separate bowl. Dip the chicken breasts in the egg whites, then the breadcrumbs to coat on both sides, and repeat. Place chicken breasts in a greased 9 × 13 pan and cover with spaghetti sauce. Cover the pan with foil and bake in the oven for 30–40 minutes or until the centers of the breasts are no longer pink. Cook pasta according to the package directions. Serve one chicken breast plus sauce over 1–2 cups of cooked pasta. Sprinkle parmesan cheese on top.

Serving Size: 1 chicken breast, 1–2 cups pasta (Recipe makes four servings)

Calories: 740 kcals

Protein: 58 grams

Carbohydrate: 89 grams

Fat: 16 grams

Do foods in the oils and empty calories group contain protein?

Foods in this category do not contain protein. However, these foods complement other protein-rich foods to make meals and snacks more flavorful and enjoyable. Sweets, highly sugared, and high-fat foods make up empty calories and will have variable amounts of protein depending on the food item.

Training Table 5.5: Menu Ideas for Complementing Protein-Rich Foods with Oils and Empty Calories

- Sauté beef or chicken and vegetables in 1–2 tbsp of olive oil for a stir-fry.
- Brush chicken or pork with a sweet barbeque sauce while cooking on the grill.
- Use 1–2 tbsp of sesame oil in an oriental salad including grains, lentils, and vegetables.
- Mix honey with orange juice as a glaze for a roast.

Sugars and artificial sweeteners are often found in protein supplements, including bars, powders, and drinks. **Training Table 5.5** contains menu ideas for combining fats with protein-rich foods.

Are protein supplements beneficial?

A variety of protein supplements are heavily marketed to athletes; some purport to increase muscle-building capacity, enhance endurance performance, and speed recovery from exercise. Intact protein and amino acid supplements come in a variety of forms including bars, shakes, powders, and pills. Before choosing to use or not to use a protein supplement, athletes should consider the following:

- What is the quantity of protein or amino acids in the product? Is the supplement necessary?
- What is the supplement's cost?
- Will the supplement enhance performance?
- Are there any risks associated with taking the supplement?

What is the quantity of protein or amino acids in the product? Is the supplement necessary?

Most athletes consume plenty of protein to meet their needs through their daily diet, if they are consuming enough total calories. Similar to carbohydrates and fats, adequate protein intake is essential to optimal sport performance; however, if protein is consumed in quantities greater than daily needs, the excess calories will lead to fat weight gain. A common misconception is that consuming large quantities of protein, often through supplements, will lead to greater gains in muscle mass. Protein intake and overall nutrition are certainly part of the muscle growth equation, but are not the sole reason for muscle mass gains. The other components of the formula include the athlete's strength training program and genetic predisposition for muscle mass. Protein supplements may be indicated for an athlete with huge calorie and protein needs, but for most athletes, the focus should be placed on whole foods. **Table 5.5** provides a comparison of various types of protein supplements. The quantity of protein or amino acids can vary greatly from one product to another. As a result, athletes should look for the Supplement Facts label on protein supplement products, which provides information similar to that found on food labels.

Protein supplements can be used when athletes are traveling or do not have easy access to food or refrigeration, and before or after training or competitions. For example, a dry protein powder can be mixed with water and poured over cereal when a cooler or refrigerator is not available for fluid milk. However, when athletes have access to other food sources, protein supplements should not be used preferentially over whole foods.

The Supplement Facts label on protein supplement products will list the grams of protein or milligrams of amino acids in one serving of the product (see Figure 5.6). Often, the quantity of protein supplied in a bar or shake is equivalent to a well-balanced meal. Athletes should be aware when reviewing the label of amino acid supplements that the content will most likely be expressed in milligrams versus grams. For example, a product might contain 500 milligrams of an amino acid, or 0.5 grams. One ounce of beef, chicken, or turkey contains 7 grams, or 7000 milligrams, of amino acids in the form of whole proteins. Obviously, in this example, if an athlete is aiming to consume more amino acids and protein, the food option would be a better choice than the amino acid supplement.

A variety of protein sources is used in protein supplements. Whey protein is quite popular and is heavily promoted as an ideal protein source for athletes. Soy, casein, and egg proteins or combinations of any of these proteins and/or amino acids are also commonly found in protein supplements. Some supplements contain specific single amino acids, or they may contain primarily BCAAs. Manufacturers often trademark (™) their specific formulation of protein and use that formulation in their products. Although there are differences in the absorption rate of the various proteins used in supplements, the actual gram amount of protein in supplements is important to review when choosing a supplement. Food sources of protein can provide as many or more grams of protein than many supplements. Whether soy or whey, casein or amino acids, many whole food sources provide a complement of amino acids

TABLE 5.5 Protein Supplement Comparison*

Supplement Product	Serving Size	Calories per Serving (kcal)	Protein per Serving (g)	Protein Source	Carbs per Serving (g)	Fat per Serving (g)	Other Ingredients
Designer Whey Protein Powder	1 scoop (28 g)	100	18	Whey	6	2	Natural flavors, stevia leaf extract
Optimum Nutrition 100% Egg Protein	1 scoop (30 g)	100	22	Egg	4	0	Natural and artificial flavors, sucralose
MuscleTech NITRO-TECH Hardcore	1 scoop (33 g)	130	25	Whey	3	1.5	Natural and artificial flavors, acesulfame K, sucralose
Naturade 100% Soy Protein	1 scoop (30 g)	110	25	Soy	0	1	Natural flavors
Optimum Nutrition 100% Soy Protein	1 scoop (31.5 g)	120	25	Soy	2	1.5	Natural and artificial flavors, sucralose, acesulfame K
MET-Rx Protein Plus	1 scoop (31 g)	110	23	Milk, casein, egg, whey	4	1	Natural and artificial flavors, acesulfame K, sucralose
EAS Myoplex Original Ready-to-Drink Shakes	500 ml	300	42	Milk, casein, whey	20	7	Natural and artificial flavors, fortified with vitamins and minerals, acesulfame K, sucralose
EAS Myoplex Strength Formula Ready-to-Drink	414 ml	210	25	Milk, soy, whey, casein	23	2.5	Natural and artificial flavors, fortified with vitamins and minerals, acesulfame K, sucralose
EAS 100% Whey Protein Powder	2 scoops (39 g)	150	26	Whey	7	2	Natural and artificial flavors, acesulfame K, sucralose
CytoSport Muscle Milk Ready-to-Drink	500 ml	340	34	Milk, casein, whey	17	16	Natural and artificial flavors, fortified with vitamins minerals, MCT, acesulfame K, sucralose
PROLAB N-Large 2	4 scoops (152 g)	600	52	Whey	86	6	Natural and artificial flavors, sucralose
PROLAB Premium Whey Powder	1 scoop (30 g)	120	23	Whey	3	0	Natural and artificial flavors, sucralose, acesulfame K
Champion Nutrition Heavyweight Gainer 900	4 scoops (154 g)	600	30	Beef, whey, egg	102	7	Fortified with vitamins and minerals, MCT, natural and artificial flavors, aspartame, acesulfame K
ABB XXL Weight Gainer	4 scoops (154 g)	1040	42	Whey, casein, egg	208	4	Creatine, artificial flavors, fortified with vitamins and minerals, medium-chain triglycerides, acesulfame K
Champion Nutrition Pure Whey Shot 45	88 ml	190	45	Whey, casein	4	0	Natural flavors, acesulfame K, sucralose
Champion Nutrition Heavyweight Gainer	4 scoops (154 g)	600	30	Beef, whey, egg	102	7	Medium-chain triglycerides, fortified with vitamins and minerals, natural and artificial flavors, aspartame, acesulfame K
Genisoy Soy Protein Powder	1 scoop (30 g)	100	25	Soy	0	0	Natural flavors

*Nutrition information obtained from manufacturers' websites.

Oven Roasted Turkey Slices

Nutrition Facts

Serving Size: 3oz

Amount Per Serving

Calories	112	
Calories from Fat	27	
	% Daily Value*	
Total Fat 3g	1%	
Saturated Fat 0g	0%	
Trans Fat 0g	0%	
Cholesterol 38mg	13%	
Sodium 788mg	33%	
Total Carbohydrate 6g	2%	
Sugars 2g		
Protein 15g		

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholest	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carb		300g	375g
Fiber		25g	30g

L-Tyrosine, 500 mg
100 Capsules

Supplement Facts

Serving Size: 1 Capsule
Servings Per Container: 100

	Amount Per Serving	% Daily Value*
L-Tyrosine	500 mg	

*Percent Daily Values are based on a 2,000 calorie diet. Certified Free of: Yeast, Wheat, Corn, Milk, Eggs, Soy, Glutens, Sugar, Starch, Artificial Colors, and Added Preservatives

Other Ingredients: Magnesium Stearate, Gelatin (Capsule).

Recommended Use: As a Dietary Supplement, take 1–3 Capsules Daily, or as Directed by your Qualified Health Consultant.

Figure 5.6 Supplement versus sliced turkey nutrition labels. Amino acid supplements often have far fewer amino acids and less total protein than protein-rich foods.

that meets protein needs for muscle maintenance, repair, and growth.

What is the cost of protein supplements?

Protein supplements are often much more expensive than whole foods. Products will vary greatly in cost. Examine the Supplement Facts labels carefully to determine the number of servings in one container and then calculate the cost per serving. In general, by choosing whole foods, athletes can obtain protein, plus many other nutrients, for a significantly lower cost. See **Table 5.6** for a comparison of various protein sources and their respective costs per serving.

Will protein supplements enhance performance?

Research based on monitoring changes in nitrogen balance has shown that athletes have higher protein needs than the sedentary population. Other studies have examined changes in body composition (i.e., lean body mass) in response to training while manipulating dietary protein intake and have indicated that higher protein intakes may be beneficial, particularly when using supplements that contain essential amino acids. However, no studies have been conducted directly investigating the effects of protein supplements on sport performance. Any protein supplement claims related to performance are based on the positive impact supplementation has on protein synthesis, which may or may not ultimately affect physical capabilities. Furthermore, there is little to no research showing a conclusive benefit of engineered protein supplements over whole food products.

Some athletes find it challenging to meet their protein needs through only whole food in the diet because of the large volume of total calories and protein required in one day. In this case, a supplement that supplies the protein lacking in the diet, hence preventing a deficiency, may enhance performance. However, a poorly planned and executed diet should not be remedied by relying on a supplement;

> ***gaining the performance edge***
>
> The need for a protein supplement should be evaluated on an individual basis. Adequate protein consumption is particularly important to individuals beginning a new exercise program or athletes who have increased the intensity or volume of their training.

TABLE 5.6 Cost Comparison of Protein Supplied from Protein Supplements Versus Whole Foods

Protein Source	Grams of Protein per Serving	Cost per Serving	Cost per 8 Grams of Protein
Supplement Products (serving size)			
EAS 100% Whey Protein Powder (39 g)	26 g	$2.29	$0.70
Genisoy UltraSoy-XT Protein Powder (36 g)	25 g	$1.71	$0.55
Optimum Nutrition 100% Egg Protein Powder, 29.4 g	22 g	$2.00	$0.73
MLO BioProtein Bar (1 bar)	21 g	$1.96	$0.75
PowerBar Protein Plus Bar (1 bar)	23 g	$2.49	$0.87
Meso-tech Bar (1 bar)	25 g	$2.99	$0.96
PROLAB Amino 2000 Tablets (6 tablets)	12 g	$0.72	$0.48
Twinlab Amino Fuel Liquid (3 tbsp)	15 g	$1.80	$0.96
PBL Liquid Muscle (2 tbsp)	10 g	$0.94	$0.75
Whole Food Items			
Chicken breast (3 oz)	26 g	$0.44	$0.13
Turkey (white meat) (3 oz)	26 g	$0.44	$0.13
Ground beef, chuck (3 oz)	24 g	$0.66	$0.22
Salmon, canned (3 oz)	22 g	$1.52	$0.55
Whole egg, 3	19 g	$0.48	$0.20
Skim milk, 8 oz	8 g	$0.20	$0.20
Tofu, 1 cup	20 g	$0.82	$0.33
Lentils, 1½ cups	27 g	$0.46	$0.14
Walnuts, 1 oz	4 g	$0.51	$1.02

focus should first be placed on consuming a well-balanced diet, and then if needs are still not being met, a protein supplement can be considered.

Are there any risks associated with taking the supplement?

There are a few specific precautions related to protein supplementation. Look at the ingredients listing closely. Many protein supplements will include artificial flavors, sweeteners, or colorings that may cause allergic reactions in some individuals. Supplements can also include other substances that are purported to "increase muscle size and strength," such as creatine or androstenedione. These substances, as well as other chemicals or additives, can cause unwanted side effects. Without a close review, athletes can potentially be putting themselves at risk for disqualification if a substance in a consumed supplement is on their sport's list of banned agents. Also, consuming large amounts of one amino acid may affect the absorption of other amino acids in the digestive tract. Because amino acids share carriers for absorption, excess consumption of one amino acid may impair the absorption of other amino acids that share the same carriers in the digestive tract. However, the actual risk of consuming excessive amounts of one single amino acid is currently unknown.

Food for Thought 5.1

Protein Intake for Athletes

In this activity, you will compare the protein content of whole foods and supplements, as well as calculate protein recommendations for an athlete.

Why is protein essential for daily training?

Carbohydrates and fats provide the main sources of energy for training and competition. Protein, conversely, is not a significant source of energy during most forms of exercise because of the slow conversion of amino acids to glucose or ATP. Protein has been shown to contribute as little as 5% of the energy used during exercise. The percentage can increase to 15–18%, but only during prolonged exercise. The small amount of amino acids used can be converted into energy through oxidation as well as by providing the substrates for gluconeogenesis.[18] Proteins complement carbohydrates and fats in providing the resources for growth and maintenance of muscles and other tissues, enzymes, hormones, and hemoglobin, as well as sustaining normal functioning of the immune system.

Sufficient dietary protein is required to maximize protein synthesis in the body in response to daily training. Exercise induces changes in protein and amino acid metabolism, which translate into a greater need for protein. Training and competition cause an increased breakdown of protein resulting from microtrauma sustained by muscle tissue.[19] If an athlete does not consume adequate amounts of protein, the body will rely on endogenous sources of protein for repair and resynthesis, ultimately leading to protein loss. If this process continues over time, performance will decline and illness may ensue.

sports anemia A condition caused by the combination of intense training and poor protein intake; it results in reduced levels of hemoglobin in the blood.

Low dietary protein intake is one of several purported causes of what is referred to as **sports anemia**. Sports anemia is not considered a real clinical condition; however, it gives the appearance of anemia in that hemoglobin concentration in the blood is decreased.[20] The appearance of sports anemia is more prevalent in untrained individuals who are beginning exercise or in athletes who have undergone a recent increase in the intensity or volume of their training.[20] If protein intake is inadequate during these new or adjusted training bouts, then a competition between tissues for amino acids occurs.[3,21] The available amino acids are used to synthesize more myoglobin, mitochondrial proteins, and muscle proteins that are essential for oxygen utilization in the muscle during exercise instead of being used to make more hemoglobin.[22] In addition, endurance training, particularly in untrained individuals, causes blood plasma volume to increase, sometimes by as much as 20%.[23,24] The expanded plasma volume decreases hemoglobin concentration, despite the fact that hemoglobin levels are relatively unchanged. Therefore, the combination of increased plasma volume and little to no change in hemoglobin levels gives the appearance of anemia. The ramifications of this apparent sports anemia appear to be relatively benign, and the decreased hemoglobin concentration does not significantly alter aerobic capacity or endurance performance. In addition, hemoglobin levels begin to return to normal levels after the body has had several weeks to adjust to the new training.

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Protein has many roles in the body; however, it is particularly important for handling the stress of daily training and competition. Adequate protein consumption not only will lead to optimal performance, but also will prevent adverse health conditions such as sports anemia.

For the body to maximize its utilization of daily protein intake, total calorie and carbohydrate needs should also be met. If an athlete is consuming too few calories or restricting intake of carbohydrates, the body will increase protein catabolism. Maintaining an appropriate total calorie intake will ensure that protein is not being used for energy on a daily basis. Adequate carbohydrate intake will decrease amino acid oxidation as well as spare dietary and muscle protein, ultimately leading to improved athletic performance.

What type, how much, and when should protein be consumed before exercise?

Much of the research concerning the optimal preactivity/competition diet has focused on the importance of carbohydrates. However, recent studies investigating methods to manipulate the diet to enhance muscle building have provided insight into the role of protein in preactivity meal planning.

Several reports by Lemon,[25] Wolfe,[26] and Tipton[27] have demonstrated that muscle building is optimized when amino acids are consumed prior to training and thus circulating in the blood while exercising. The amino acids aid in:

- Providing energy for the muscle cells; however, as discussed earlier, only minimal amounts of energy are supplied by amino acids during exercise.
- Decreasing catabolism of protein in muscle tissue.
- Increasing protein synthesis in muscle tissue.

An additional benefit of consuming protein prior to training or competition relates to the speed of digestion. Protein-rich foods take slightly longer to empty from the stomach than do carbohydrates, thus providing a satiety effect and a more gradual delivery of nutrients to the bloodstream. These actions will prevent an athlete from getting hungry before training, which can be mentally distracting, and will sustain energy levels for a longer duration, potentially increasing the amount of work an athlete can perform before fatiguing.

To allow time for the longer digestion of proteins and absorption of amino acids into the bloodstream, protein-containing foods need to be consumed 1 to 4 hours prior to the onset of exercise. Keep in mind that the preactivity meal should be a combination of proteins, carbohydrates, and fats. Carbohydrate foods should be predominant in the meal or snack, while protein foods are the complement. Athletes should always experiment with the timing of the preexercise meal to determine the ideal quantity and timing of food and beverage consumption before training or competition.

There is some evidence that it is best to ingest protein at least 3 hours prior to exercise to avoid unnecessary elevations in respiratory exchange ratio and perceived exertion during higher intensity activities. A study conducted by Wiles et al.[28] tested individuals running on a treadmill at 60, 80, 90, and 100% of VO_2max after consuming a protein beverage 1 hour or 3 hours prior to exercise compared to the ingestion of only water. The results of the study revealed that the ingestion of the protein beverage, containing 0.4 g protein/kg body weight, led to a higher VO_2 level and perceived exertion at all exercise intensities. The explanation of this finding focused on the increased metabolism, or thermic effect of food, in the hours immediately following protein ingestion. The authors noted that only a small increase in the thermic effect of food was noted after 3 hours; therefore, it can be implied that an athlete should consume a meal containing protein at least 3 hours prior to exercise. This notion requires more investigation before exact recommendations can be established.

What type and how much protein should be consumed 4 to 24 hours prior to training or competition?

Similar to the guidelines for daily protein intake, athletes should choose lean protein sources such as lean cuts of beef, chicken, turkey, fish, low-fat dairy, or soy products in the 4 to 24 hours prior to training or a competition. Athletes should plan a meal that contains 3–6 ounces of a lean protein or 8–12 fl oz of dairy/alternative, as well as a significant source of carbohydrates and a small amount of fat. Legumes, which are very high in fiber, should be limited or consumed in small amounts in the 24 hours leading up to an important training session or competition. The extra fiber may cause gastrointestinal distress for some athletes. However, individuals who eat beans, lentils, and other legumes on a regular basis can generally tolerate these foods without consequence.

What type and how much protein should be consumed 1 to 4 hours prior to training or competition?

Small amounts of lean protein sources (2–4 oz) can be consumed in the 4 hours prior to exercise. However, the focus should be placed mainly on carbohydrate-rich foods during this period. Athletes need to find a balance between consuming enough carbohydrates and proteins to enhance performance, while moderating the quantity of food and total calories ingested to avoid nausea, vomiting, cramping, or diarrhea. Individuals should plan meals with at least three different food groups, one of which is a protein-rich food and one of which is a carbohydrate-rich food.

Training Table 5.6: Menu Ideas for Precompetition Protein Foods (grams of protein)

- 1½ cups cereal, 1 cup skim milk/soy milk, ½ cup blueberries, 1 slice wheat toast, 2 tbsp peanut butter (24 g)
- 2 scrambled eggs, 1 English muffin, 2 slices cheddar cheese, 8 oz orange juice (29 g)
- Ham sandwich [2 slices rye bread, 6 slices ham], banana, 6 oz low-fat yogurt (22 g)
- Large salad [2 cups romaine lettuce, ½ cup red pepper, ½ tomato, ½ cup cottage cheese, 3 slices turkey, ¼ cup garbanzo beans, 2 tbsp fat-free dressing], 1 cup skim milk (32 g)

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Preactivity protein consumption can increase satiety, slow the digestion of carbohydrates to sustain energy levels, and decrease the catabolism of proteins, while also enhancing the synthesis of proteins during training. Intake of protein-rich foods and beverages should remain moderate in the 1 to 4 hours prior to training, focusing on low-fat, nutrient-dense protein source.

Protein sources that are higher in fat, such as high-fat cuts of meat, full-fat dairy, nuts, and seeds, should be consumed in minimal amounts, if not eliminated, in the hours directly leading up to an exercise session. These foods take longer to digest and therefore can disrupt performance because of a sense of a "full stomach" or intestinal distress. In daily training, nuts and seeds are an excellent choice because of their favorable protein, fiber, and fat profile. However, instead of eating nuts and seeds prior to training, athletes can pack a small bag for a great postexercise snack. **Training Table 5.6** contains some ideas for protein-rich foods to eat prior to competition.

What type, how much, and when should protein be consumed during exercise?

In the last couple of decades, the role of exogenous amino acids administered during exercise has garnered research attention. Amino acids ingested

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Although some of the research regarding the ergogenic effect of amino acid ingestion during exercise is promising, consumption guidelines have not been established and do not appear warranted at this time. If future research reveals a benefit, researchers will need to develop recommendations on the type, timing, and quantity of amino acid ingestion for enhancing sport performance.

during exercise have been hypothesized to improve sport performance in several ways. Most of the current research has focused on the use of amino acids for energy production during exercise and the potential role of the BCAAs in attenuating central fatigue.

Amino acids can be used as a source of energy during exercise. They can be transported via the blood to the liver, converted to glucose via gluconeogenesis, and released into the bloodstream. Thus, glucose formed from amino acids can help to prevent hypoglycemia (low blood glucose) during exercise and continue to provide glucose for sustained physical effort. Unfortunately, this gluconeogenic avenue for deriving energy from amino acids is a slow, involved process that lacks the ability to support the rapid energy needs of intense exercise or sport competition.

As discussed in the previous paragraph, most amino acids must be transported to the liver, converted into substrates or intermediates in the liver, and then transported through the blood back to the active muscle cells where they can finally be used for energy. The exceptions to this rule are the BCAAs, which are leucine, isoleucine, and valine. These amino acids are different because they can be metabolized for energy in the muscle itself (see Figure 5.7) instead of needing to be processed by the liver. Therefore, the energy supplied by BCAAs can be used directly in the muscle cell.

BCAAs started receiving more attention, especially for endurance sports, when researchers discovered that after 3 hours of exercise BCAA levels in the blood drop dramatically.[29] During long-duration aerobic exercise, the activity of the enzyme responsible for the catabolism of BCAAs, keto acid dehydrogenase, increases. The activity of this enzyme is greatest when carbohydrate stores are low, thus supporting the theory that BCAAs may be providing energy to the active muscles.[19] In addition, falling levels of BCAAs in the blood have been linked to central nervous system fatigue,[30] which leads to decreased sport performance. Accordingly, ingestion of BCAAs may prevent the decrease of BCAAs in the blood, and thus be potentially beneficial,

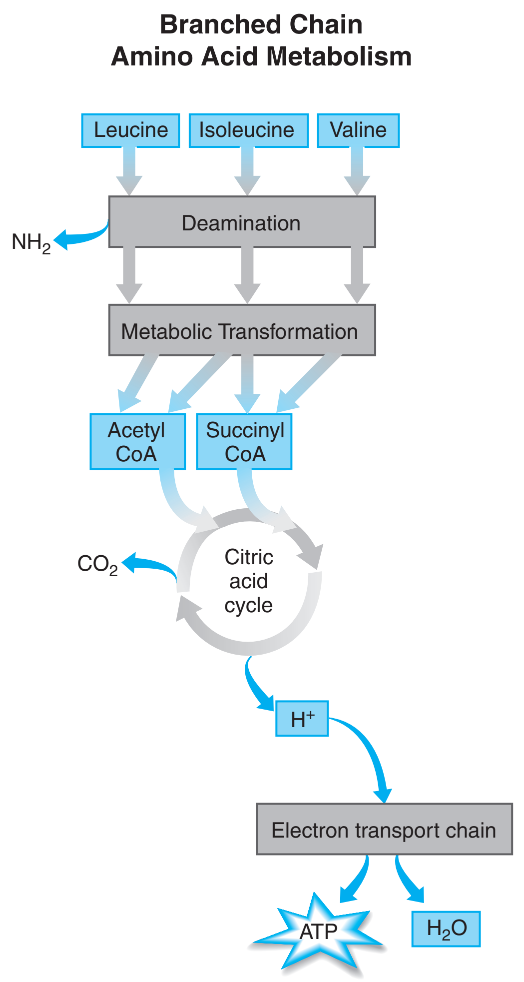

Figure 5.7 Metabolism of BCAAs for energy. BCCAs are unique because they can be metabolized for energy within the muscle itself instead of needing to first be processed by the liver.

especially during prolonged endurance exercise. Unfortunately, studies involving endurance athletes ingesting BCAAs during exercise have not yielded consistent results, and, in fact, most have shown little to no positive effect on endurance. Although more investigation on the role of BCAAs during exercise is indicated, recommending the ingestion of BCAAs to improve performance is not currently warranted.

What type, how much, and when should protein be consumed after exercise?

Protein is a critical nutrient for the postexercise recovery process in muscle. After exercise, protein breakdown diminishes while protein synthesis increases, resulting in a positive muscle protein balance (i.e., an anabolic state). The success of achieving a positive muscle protein balance appears to be dependent on the amino acid composition of the food ingested, the amino acid concentration of the blood supplying the muscle cells, and the timing of the protein feeding.[4]

Which type of protein or amino acid source is most beneficial to consume after exercise?

The availability of amino acids to the muscles positively influences muscle protein synthesis. Food sources that cause hyperaminoacidemia (i.e., high blood amino acid levels) have been shown to increase amino acid delivery to the muscle and transport into the muscle, thereby increasing the intracellular availability for muscle protein synthesis.[26,31] Contrary to the belief of some athletes, hyperaminoacidemia is not solely dependent on the ingestion of free-form amino acid supplements. Consuming complete proteins, such as whey and casein found in milk, has been shown to increase amino acid levels in the blood, thus aiding in the recovery process.[25,32]

The amino acid composition of foods ingested following both resistance and endurance exercise appears to affect hyperaminoacidemia and subsequent muscle protein synthesis. Ingesting foods or supplements supplying essential amino acids, rather than nonessential amino acids, is necessary for the greatest positive influence on muscle protein synthesis.[27,33,34] Whey and casein proteins are high-quality proteins that contain essential amino acids. In addition, whey protein has a relatively high proportion of BCAAs.[29,35] Soy protein is another postworkout protein option that also provides all the essential amino acids for muscle rebuilding and repair.[36] Several studies have been conducted comparing soy and milk proteins on muscle protein anabolism during the first few hours of recovery with varying results.[37–39] Additional research in the area of the type of protein to promote optimal muscle anabolism and recovery is warranted.

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Essential amino acids stimulate protein synthesis. Therefore, postexercise protein sources should consist of high-quality or complementing proteins that provide all of the essential amino acids.

Research has focused not only on the importance of essential amino acids for triggering hyperaminoacidemia, but also on the form in which essential amino acids are consumed. Studies have investigated the potential difference in protein absorption, synthesis, and catabolism after exercise between various protein and amino acid sources. In general, intact proteins are digested and absorbed more slowly than are hydrolyzed proteins. Hydrolyzed protein sources are usually in supplement form and contain proteins that have undergone a predigestion process, breaking the more complex proteins into smaller di- and tripeptide complexes. The hydrolyzed proteins are also absorbed slightly faster than are supplements composed primarily of free amino acid mixtures.[40] The differences in absorption of these protein sources are most noticeable in special circumstances, such as when athletes are fasting or following a low-calorie diet, and are least noticeable in individuals who are generously well fed, which is the case for most athletes. When various proteins are consumed without other energy sources such as carbohydrates or fats, whey proteins and amino acid mixtures appear to be absorbed more quickly than casein proteins. However, when any of these proteins or amino acids are ingested with carbohydrates or fats, the differences in absorption are diminished.[41] The bottom line is that the consumption of essential amino acids should be of greatest importance, regardless of the exact form in which they are ingested. Athletes should be encouraged to consume whole foods, containing essential amino acids, to provide the protein and other important nutrients for muscle recovery and synthesis.

hyperaminoacidemia A condition describing abnormally high levels of amino acids in the blood.

hydrolyzed protein A source of protein that is usually in supplement form and contains proteins that have undergone a predigestion process, breaking the more complex proteins into smaller di- and tripeptide complexes.

Is there a recovery benefit of combining carbohydrates and proteins after exercise?

Some literature has suggested that consuming a combination of proteins and carbohydrates, versus only carbohydrates or only proteins, enhances the recovery process. A study conducted by Zawadzki et al.[42] compared the effects of carbohydrate, protein, and carbohydrate–protein beverages after 2 hours of cycling. The researchers found that the combination beverage produced the greatest circulating levels of insulin, which in theory would enhance protein and carbohydrate intake into the muscle cells and promote protein synthesis, thus improving the recovery process. Another study by Miller et al.[43] reported that ingesting both proteins and carbohydrates together within 3 hours after exercise resulted in the greatest uptake of amino acids compared to ingesting proteins or carbohydrates alone. Timing of the

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Research suggests that ingesting carbohydrates and proteins immediately after or within 3 hours after exercise is a prudent dietary practice for athletes.

ingestion of the postexercise carbohydrate–protein recovery drink or meal is important. Berardi et al.[44] found that carbohydrate plus protein supplements given early after exercise enhance glycogen resynthesis relative to carbohydrate only or placebo given later in recovery. Other studies have focused on other substances in the blood, such as levels of growth hormone or creatine kinase, and have also found positive results from a carbohydrate–protein combination after exercise. Taken together, it appears that ingesting carbohydrates and proteins as soon as possible and at least within 3 hours after exercise would be a prudent dietary practice for athletes.

How much protein should be consumed after exercise?

Ingestion of as little as 6 grams of essential amino acids, both with and without carbohydrates, has been shown to increase muscle protein synthesis.[27,33] Although highly variable depending on the protein source, a rule of thumb is that 15 grams of high-quality protein should provide approximately 6 grams of essential amino acids. Nonessential amino acids, in and of themselves, do not appear to have the same protein synthesis effect. Although the availability of essential amino acids does increase protein synthesis, there appears to be a ceiling to the dose response, above which increasing levels of essential amino acids do not increase protein synthesis.[45] When net protein synthesis was compared between athletes consuming 20 grams or 40 grams of essential amino acids, there was no difference in synthetic rates between groups after resistance training.[45] To date, the threshold and ceiling doses of essential amino acids (i.e., the ideal range) needed for optimal protein synthesis have not been determined and are most likely specific to the individual.

However, based on current research, ingesting approximately 6–20 grams of essential amino acids in the postexercise meal will aid in the recovery process. Combining proteins with carbohydrates maximizes glycogen synthesis, causes hormones favorable for muscle growth to be secreted, and enhances protein synthesis. Six to 20 grams of essential amino acids, along with a source of carbohydrates, can be obtained by consuming any one of the following (total grams protein, grams of essential amino acids):

- 6 oz low-fat yogurt, ¼ cup mixed nuts, 1 cup strawberries (14 g, 6 g)
- 3 oz tofu, 1½ cups mixed vegetables, 1 cup brown rice (20 g, 8 g)
- 2 hard-boiled eggs, 1 slice wheat toast with 1 tbsp peanut butter, 8 oz orange juice (22 g, 8 g)
- 2 cups pasta, ½ cup marinara sauce, 3 oz lean ground beef, 1 cup broccoli (49 g, 16 g)
- 4 oz chicken breast sandwich with 1 oz mozzarella cheese, 1 pear, 8 oz skim milk (55 g, 22 g)

When should protein or amino acids be consumed after exercise?

The timing of protein feeding after exercise is also important. Several studies have demonstrated the importance of essential amino acids in stimulating muscle protein synthesis within 3 hours of exercise.[27,33,34,43] Eating protein sources as soon as possible after physical activity takes advantage of the increased blood flow and hormonal milieu (i.e., potential increases in growth hormone and testosterone) caused by the previously performed exercise. Therefore, in practical terms, postexercise protein consumption should occur within 3 hours of exercise and include protein sources that provide all the essential amino acids.

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Ingest 6–20 grams of essential amino acids (i.e., at least 15 grams of a high-quality protein) immediately after exercise for optimal recovery. Consuming carbohydrates in addition to this amount of protein appears to further enhance exercise recovery.

Food for Thought 5.2

You Are the Nutrition Coach

Apply the concepts from this chapter to several case studies.

The Box Score

Key Points of Chapter

- The protein–muscle mass connection is just one of many reasons protein is an essential nutrient to athletes and untrained individuals alike. Proteins also provide structure to many parts of the body, are needed for building and repairing body tissues, serve as enzymes that initiate cellular processes, and form hormones that help regulate a variety of processes in the body.
- Proteins are chains of amino acids that are linked via peptide bonds in a very specific sequence. The specific sequence of the amino acids in the chain gives the protein not only its physical characteristics, but also its three-dimensional shape. The shape of the protein in many instances dictates its function in the body.
- The body uses 20 different amino acids to make proteins. Nine are essential and must be obtained from diet. Complete, high-quality proteins tend to come from animal sources and provide all the essential amino acids needed by the body. However, plant-derived complementary protein sources can also provide all essential amino acids.
- Monitoring nitrogen status is one way of determining whether dietary protein intake is adequate to meet protein needs. When dietary input of nitrogen (i.e., protein gain) equals the output of nitrogen (i.e., protein loss), then nitrogen balance has been achieved. At a minimum, the goal for any athlete is to maintain nitrogen balance and, in most cases, to achieve a positive nitrogen balance.
- Current research suggests that athletes have higher protein needs than nonathletes. The recommended daily protein intake is 1.4–2.0 g/kg for strength athletes, 1.2–2.0 g/kg for endurance athletes, and 1.2–1.6 g/kg for team sport athletes.
- The protein needs of athletes can vary depending on their current body weight, training status, total caloric intake, desire to lose or gain weight, carbohydrate intake, quality of protein sources consumed, type of training, intensity of training, duration of training, and age.
- The richest sources of dietary protein are found in the dairy/alternative and protein foods groups. Grain products as well as vegetables provide a small to moderate amount of protein, while fruits provide little to none.
- The need for a protein supplement should be evaluated on an individual basis. Athletes should focus first on obtaining plenty of protein-rich foods in their daily diet; if protein needs are still not being met, then an appropriate and safe supplement can be considered.
- Protein has many roles in the body; however, it is particularly important for enduring the stress of daily training and competition. Adequate protein consumption not only will lead to optimal performance, but also will prevent adverse health conditions such as sports anemia.
- The pregame or preactivity meal should include a combination of proteins, carbohydrates, and fats. The carbohydrate foods should predominate in the preactivity meal, whereas protein foods should serve as a complement. To allow time for digestion, foods should be consumed 1 to 4 hours prior to the onset of exercise.
- Protein ingestion during sport competition or training has not consistently been shown to enhance performance. Deriving energy from amino acids is a slow, involved metabolic process that lacks the ability to support the rapid energy needs of intense exercise or sport competition.
- Consumption of high-quality proteins that elevate blood levels of amino acids within 1 to 3 hours after competition or training has been shown to increase protein synthesis. Research suggests that ingesting carbohydrates along with proteins after exercise may actually enhance the recovery process.

Study Questions

1. How do proteins differ from carbohydrates and fats in regard to their molecular structure?
2. Discuss the various roles of proteins in the body. How does each of these roles apply to training, recovery, and/or sport performance?
3. How would the nitrogen balance of an athlete be determined? Once determined, what does nitrogen balance indicate?
4. What are "complete proteins," and what food sources provide them? What are the ramifications of eating foods that do not provide complete sources of protein?
5. What are "incomplete proteins," and what food sources provide them? Give several examples of complementary incomplete protein sources that provide all essential amino acids.
6. What are branched chain amino acids? What relationship, if any, do they have to athletic performance?
7. Discuss the relationship between carbohydrate intake and protein requirements.
8. What are the recommended protein intake levels for athletes? Discuss why requirements for athletes are higher than for sedentary individuals.

9. What dietary protein intake recommendations would you make to an elite athlete training for a marathon? How would those recommendations compare to recommendations for an Olympic weightlifter training 12 to 15 hours a week?
10. What factors should be considered when determining the protein needs of an athlete?
11. Provide two suggestions for well-balanced preactivity meals containing protein, as well as two examples of quick and easy postexercise snacks containing 15 grams of protein.

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