CONSUMER CORNER

Protein and Amino Acid Supplements

Why do people take protein supplements? Athletes often take them when trying to build muscle. Dieters may take them in hopes of speeding the process of weight loss or preserving lean tissue. Some women take them to strengthen their fingernails. People take individual amino acids, too—to cure herpes, to make themselves sleep better, to lose weight, and to relieve pain and depression. Do protein and amino acid supplements really do these things? Probably not. Are they safe? Not always.

In the skilled hands of clinical registered dietitians, formulas with supplemental protein or amino acids may help to reverse malnutrition in some critically ill patients. Not every patient is a candidate for such therapy, however, because supplemental amino acids may also stimulate inflammation and so worsen some illnesses.

PROTEIN SUPPLEMENTS

Protein supplements are popular with athletes but well-fed athletes do not need them (see Controversy 10 for details). True, dietary protein is necessary for building muscle tissue and, true, consuming protein in conjunction with resistance exercise helps muscles build new proteins.[1] But protein supplements do not improve athletic performance beyond the gains from well-timed meals of ordinary foods. And, if supplements create a surplus of protein or certain amino acids, the excess must be metabolized, placing a burden on the kidneys to excrete excess nitrogen.

Weight-loss dieters may benefit from making a habit of consuming the needed protein-rich foods because protein often satisfies the appetite, while insufficient protein may increase it.[2] However, extra protein from powders, pills, or beverages is unlikely to dampen the appetite further, although it contributes unneeded calories—the wrong effect for weight loss. Evidence does not support taking protein supplements for weight loss, and common sense opposes it.

AMINO ACID SUPPLEMENTS

Enthusiastic popular reports have led to widespread use of individual amino acids. One such amino acid is lysine, touted to prevent or relieve the infections that cause herpes sores on the mouth or genital organs. Lysine does not cure herpes infections. Whether it reduces outbreaks or even whether it is safe is unknown because scientific studies are lacking.

Tryptophan supplements are advertised to relieve pain, depression, and insomnia. Tryptophan plays a role as a precursor for the brain neurotransmitter serotonin, an important regulator of sleep, appetite, mood, and sensory perception. The DRI committee concludes that high doses of tryptophan may induce sleepiness, but they may also cause side effects, such as nausea and skin disorders. A serious blood disorder, EMS, probably caused by contaminants, once threatened takers of tryptophan supplements, but improved regulations have reduced this risk.*[3]

The body is designed to handle whole proteins best. It breaks them into manageable pieces (dipeptides and tripeptides), then splits these a few at a time, simultaneously releasing them into the blood. This slow, bit-by-bit assimilation is ideal because groups of chemically similar amino acids compete for the carriers that absorb them into the blood. An excess of one amino acid can tie up a carrier and disturb amino acid absorption, creating a temporary imbalance.[4] Amino acids are key players in complex mechanisms for gene regulation, and excesses may affect these processes in unpredictable ways.[5] In mice, for example, excess methionine causes the blood buildup of an amino acid associated with heart disease (homocysteine) and increases inflammation in the liver. No one knows if the same is true in people.[6] Many supplement takers experience digestive disturbances. Amino acids in concentrated supplements cause excess water to flow into the digestive tract, causing diarrhea.[7]

A lack of research prevents the DRI committee from setting Tolerable Upper Intake Levels for amino acids.[8] Therefore, no level of amino acid supplementation can be assumed safe; Table 6-2 lists people most likely to be harmed. In fact, Canada bans sales of single amino acids to consumers.† The warning is

*EMS is short for eosinophilia-myalgia syndrome.

†*Canada only allows single amino acid supplements to be sold as drugs or used as food additives.*

TABLE 6-2 People Most Likely to Be Harmed by Amino Acid Supplements

Growth or altered metabolism makes these people especially likely to be harmed by self-prescribed amino acid supplements:

- All women of childbearing age.
- Pregnant or lactating women.
- Infants, children, and adolescents.
- Elderly people.
- People with inborn errors of metabolism that affect their bodies' handling of amino acids.
- Smokers.
- People on low-protein diets.
- People with chronic or acute mental or physical illnesses.

this: much is still unknown, and the taker of amino acid supplements cannot be certain of their safety or effectiveness.[9]

CONCLUSION

Many chapters of this book present evidence that whole foods are superior sources for nutrients and phytochemicals for human health.[10] The Consumer Corner in Chapter 4 showed that a nutritionally inferior food (refined bread) enriched with a few added nutrients is still inadequate in many others compared with whole grains. The Controversy section in Chapter 7 points out potential dangers of vitamin and mineral supplements and their lack of efficacy for preventing any disease except nutrient deficiencies. The same is true of amino acids—whole food proteins, in balance with other needed foods, best support human health. Even with all that we know about science, it is hard to improve on nature.

- The DRI recommended intake for protein (adult) = 0.8 g/kg.
- To figure out your protein need:
  1. Find your body weight in pounds.
  2. Convert pounds to kilograms (by dividing pounds by 2.2).
  3. Multiply kilograms by 0.8 to find total grams of protein recommended.

For example:

- *Weight = 130 lb.*
- *130 lb ÷ 2.2 = 59 kg.*
- *59 kg × 0.8 = 47 g.*

healthy body weight, the DRI recommended intake is set at 0.8 gram for each kilogram (or 2.2 pounds) of body weight (see inside front cover). The minimum amount is set at 10 percent of total calories. As mentioned in the Think Fitness feature earlier, athletes may need slightly more protein but the increased need is well covered by most people's diets.[11]

For infants and growing children, the protein recommendation, like all nutrient recommendations, is higher per unit of body weight. The DRI committee set an upper limit for protein intake of no more than 35 percent of total calories, an amount significantly higher than average intakes. Table 6-3 reviews recommendations for protein intake, and the margin provides a method for determining your own protein need. The DRI committee suggests that vegetarians need more iron than the general population. The following factors also modify protein needs.

The Body's Health Malnutrition or infection may greatly increase the need for protein while making it hard to eat even normal amounts of food. In malnutrition, secretion of digestive enzymes slows as the tract's lining degenerates, impairing protein digestion and absorption. When infection is present, extra protein is needed for enhanced immune functions.

Other Nutrients and Energy The need for ample energy, carbohydrate, and fat has already been emphasized. To be used efficiently by the cells, protein must also be accompanied by the full array of vitamins and minerals.

Protein Quality The remaining factor, protein quality, helps determine how well a diet supports the growth of children and the health of adults. Two factors influence protein quality: a protein's digestibility and its amino acid composition, discussed later.

Recommendations for protein intake assume a normal mixed diet, that is, a diet that includes sufficient nutrients and a combination of animal and plant protein. Because not all proteins are used with 100 percent efficiency, the recommendation is generous. Many healthy people can consume less than the recommended amount and still meet their bodies' protein needs. What this means in terms of food selections is presented in this chapter's Food Feature.

TABLE 6-3 Protein Intake Recommendations for Healthy Adults

DRI Recommended Intake[a]

- 0.8 gram protein per kilogram of body weight per day.
- Women: 46 grams per day; men: 56 grams per day.
- Acceptable intake range: 10 to 30 percent of calories from protein.

USDA Food Guide, MyPyramid

- Every day most adults should eat 5- to 6½-ounce equivalents of lean meat, poultry without skin, fish, legumes, eggs, nuts, or seeds.
- Every day most adults need 3 cups of fat-free or low-fat milk or yogurt, or the equivalent of fat-free cheese or vitamin- and mineral-fortified soy beverage.
- Eat a variety of foods to provide small amounts of protein from other sources.

[a]Protein recommendations for infants, children, and pregnant and lactating women are higher; see inside front cover, page B.

MY TURN

© Cengage Learning

Aira

© Cengage Learning

Joshua

Veggin' Out

Have you ever considered not eating meat? Listen to two students discuss how becoming vegetarian affected their social life.

CENGAGENOW To hear their stories, log on to www.cengage.com/sso.

KEY POINT The protein intake recommendation depends on size and stage of growth. The DRI recommended intake for adults is 0.8 gram of protein per kilogram of body weight. Factors concerning both the body and food sources modify an individual's protein need.

© IT International/eStock Photography/PictureQuest/ Jupiter Images

Growing children end each day with more bone, blood, muscle, and skin cells than they had at the beginning of the day.

Nitrogen Balance

Underlying the protein recommendation are **nitrogen balance** studies, which compare nitrogen lost by excretion with nitrogen eaten in food. In healthy adults, nitrogen-in (consumed) must equal nitrogen-out (excreted). Scientists measure the body's daily nitrogen losses in urine, feces, sweat, and skin under controlled conditions and then estimate the amount of protein needed to replace these losses.[‡12]

How Nitrogen Balance Varies Under normal circumstances, healthy adults are in nitrogen equilibrium, or zero balance; that is, they have the same amount of total protein in their bodies at all times. When nitrogen-in exceeds nitrogen-out, people are said to be in positive nitrogen balance; somewhere in their bodies more proteins are being built than are being broken down and lost. When nitrogen-in is less than nitrogen-out, people are said to be in negative nitrogen balance; they are losing protein. Figure 6-13 illustrates these different states.

Positive Nitrogen Balance Growing children add new blood, bone, and muscle cells to their bodies every day, so children must have more protein, and therefore more nitrogen, in their bodies at the end of each day than they had at the beginning. A growing child is therefore in positive nitrogen balance. Similarly, when a woman is pregnant, she must be in positive nitrogen balance until after the birth, when she once again reaches equilibrium.

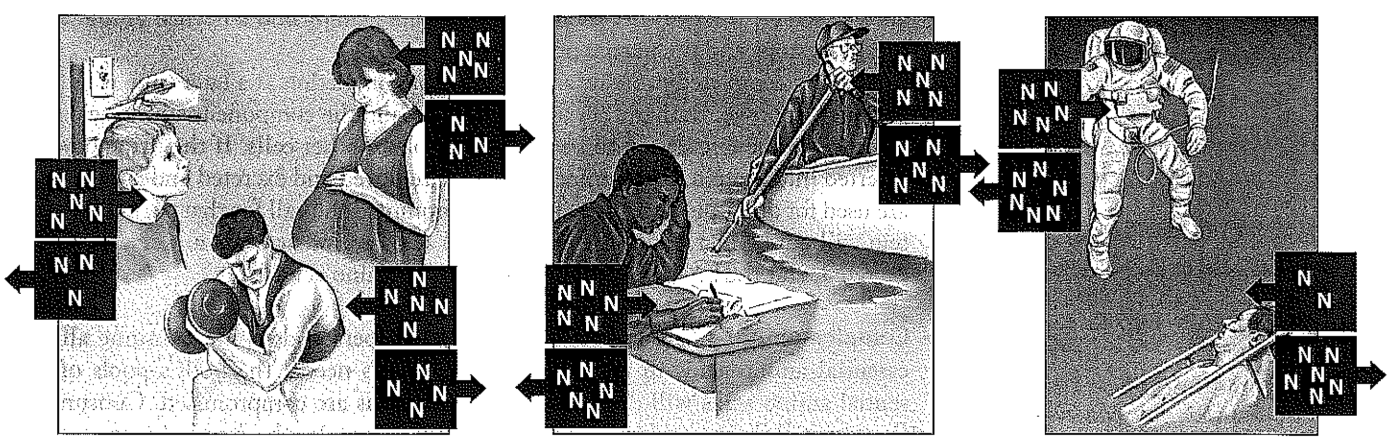
Negative Nitrogen Balance Negative nitrogen balance occurs when muscle or other protein tissue is broken down and lost. Illness or injury triggers the release of powerful messengers that signal the body to break down some of the less vital proteins, such as those of the skin and even muscle.[§] This action floods the blood with

nitrogen balance the amount of nitrogen consumed compared with the amount excreted in a given time period.

‡The average protein is 16 percent nitrogen by weight; that is, each 100 grams of protein contain 16 grams of nitrogen. As a general rule, multiply the nitrogen's weight by 6.25 to estimate the protein's weight.

§The messengers are cytokines.

FIGURE 6-13 **Nitrogen Balance**



Positive Nitrogen Balance
These people—a growing child, a person building muscle, and a pregnant woman—are all retaining more nitrogen than they are excreting.

Nitrogen Equilibrium
These people—a healthy college student and a young retiree—are in nitrogen equilibrium.

Negative Nitrogen Balance
These people—an astronaut and a surgery patient—are losing more nitrogen than they are taking in.

amino acids and energy needed to fuel the body's defenses and fight the illness. The result is negative nitrogen balance. Astronauts, too, experience negative nitrogen balance. In the stress of space flight, and with no need to support the body's weight against gravity, the astronauts' muscles waste and weaken. To minimize the inevitable loss of muscle tissue, the astronauts must do special exercises in space.

KEY POINT Protein recommendations are based on nitrogen balance studies, which compare nitrogen excreted from the body with nitrogen ingested in food.

Which Foods Provide High-Quality Protein?

Put simply, **high-quality proteins** provide enough of all the essential amino acids needed by the body to create its own working proteins, whereas low-quality proteins don't. In making their required proteins, the cells need a full array of amino acids. If a nonessential amino acid (that is, one the cell can make) is unavailable from food, the cell synthesizes it and continues attaching amino acids to the protein strands being manufactured. If the diet fails to provide enough of an essential amino acid (one the cell cannot make), the cells begin to adjust their activities. The cells:

- Break down more internal proteins to liberate the needed essential amino acid.
- Conserve the essential amino acid by limiting their synthesis of proteins.[13]

As the deprivation continues, tissues make one adjustment after another in the struggle to survive.

Just as each letter of the alphabet is important in forming whole words, each amino acid must be available to build finished proteins.

high-quality proteins dietary proteins containing all the essential amino acids in relatively the same amounts that human beings require. They may also contain nonessential amino acids.

limiting amino acid an essential amino acid that is present in dietary protein in an insufficient amount, thereby limiting the body's ability to build protein.

complementary proteins two or more proteins whose amino acid assortments complement each other in such a way that the essential amino acids missing from one are supplied by the other.

mutual supplementation the strategy of combining two incomplete protein sources so that the amino acids in one food make up for those lacking in the other food. Such protein combinations are sometimes called *complementary proteins.*

Limiting Amino Acids

The measures just described help the cells to channel the available **limiting amino acid** to its wisest use: making new proteins. Even so, the normally fast rate of protein synthesis slows to a crawl as the cells make do with the proteins on hand. When the limiting amino acid once again becomes available in abundance, the cells resume their normal protein-related activities. If the shortage becomes chronic, however, the cells begin to break down their protein-making machinery. Consequently, when protein intakes become adequate again, protein synthesis lags behind until the needed machinery can be rebuilt. Meanwhile, the cells function less and less effectively as their proteins wear out and are only partially replaced.

Thus, a diet that is short in any of the essential amino acids limits protein synthesis. An earlier analogy likened amino acids to letters of the alphabet. To be meaningful, words must contain all the right letters. For example, a print shop that has no letter "N" cannot make personalized stationery for Jana Johnson. No matter how many Js, As, Os, Hs, and Ss are in the printer's possession, they cannot replace the missing Ns. Likewise, in building a protein molecule, no amino acid can fill another's spot. If a cell that is building a protein cannot find a needed amino acid, synthesis stops and the partial protein is released.

Partially completed proteins are not held for completion at a later time when the diet may improve. Rather, they are dismantled and the component amino acids are returned to the circulation to be made available to other cells. If they are not soon inserted into protein, their amine groups are removed and excreted and the residues are used for other purposes. The need that prompted the call for that particular protein will not be met. Since the other amino acids are wasted, the amine groups are excreted, and the body cannot resynthesize the amino acids later.

Complementary Proteins

It follows that if a person does not consume all the essential amino acids in proportion to the body's needs, the body's pools of essential amino acids will dwindle until body organs are compromised. Consuming the essential amino acids presents no problem to people who regularly eat proteins containing ample amounts of all of the essential amino acids, such as those of meat, fish, poultry, cheese, eggs, milk, and most soybean products.

An equally sound choice is to eat a combination of foods from plants so that amino acids that are low in some foods will be supplied by the others. The protein-

FIGURE 6-14 Complementary Protein Combinations

Healthful foods like these contribute substantial protein (42 grams total) to this day's meals without meat. Additional servings of nutritious foods, such as milk, bread, and eggs, can easily supply the remainder of the day's need for protein (14 additional grams for men and 4 for women).

John A. Rizzo/Photodisc/Getty Images

3/4 c oatmeal = 5 g
Protein total 5 g

© Polara Studios, Inc.

1 c rice = 4 g
1 c beans = 16 g
Protein total 20 g

© Michael Newman/PhotoEdit

1½ c pasta = 11 g
1 c vegetables = 2 g
2 tbs Parmesan cheese = 4 g
Protein total 17 g

FIGURE 6-15 How Complementary Proteins Work Together

Legumes provide plenty of the amino acids isoleucine (Ile) and lysine (Lys), but fall short in methionine (Met) and tryptophan (Trp). Grains have the opposite strengths and weaknesses, making them a perfect match for legumes.

	Ile	Lys	Met	Trp
Legumes	✓	✓		
Grains			✓	✓
Together	✓	✓	✓	✓

rich foods are combined to yield **complementary proteins** (see Figure 6-14), or proteins containing all the essential amino acids in amounts sufficient to support health.[14] This concept, called **mutual supplementation,** is illustrated in Figure 6-15. The figure demonstrates that the amino acids of **legumes** and grains balance each other to provide all of the needed amino acids. The complementary proteins need not be eaten together, so long as the day's meals supply them all and the diet provides enough energy and total protein from a variety of sources.

Protein Digestibility In measuring a protein's quality, digestibility is important. Simple measures of the total protein in foods are not useful by themselves—even animal hair and hooves would receive a top score by those measures alone. They are made of protein, but not in a form that people can use.

The digestibility of protein varies from food to food and bears profoundly on protein quality. The protein of oats, for example, is less digestible than that of eggs. In general, amino acids from animal proteins, such as chicken, beef, and pork, are most easily digested and absorbed (over 90 percent). Those from legumes are next (about 80 to 90 percent). Those from grains and other plant foods vary (from 70 to 90 percent). Cooking with moist heat improves protein digestibility, whereas dry heat methods can impair it.

© Amana Images Inc./Alamy

Cooking with moist heat improves protein digestibility, whereas frying makes protein harder to digest.

KEY POINT Digestibility of protein varies from food to food, and cooking can improve or impair it.

Perspective on Protein Quality Concern about the quality of individual food proteins is of only theoretical interest in settings where food is abundant. Most people in the United States and Canada eat a variety of nutritious foods to meet their energy needs. Healthy adults in these places would find it next to impossible not to meet their protein needs, even if they were to eat no meat, fish, poultry, eggs, or cheese products at all. They need not pay attention to mutual supplementation, so long as the diet is varied, nutritious, and adequate in energy and other nutrients—not made up just of, say, cookies, potato chips, or alcoholic beverages. Protein sufficiency follows effortlessly behind a balanced, nutritious diet.

For people in areas where food sources are less reliable, protein quality can make the difference between health and disease. When food energy intake is limited (where malnutrition is widespread) or when the selection of foods available is severely limited (where a single low-protein food, such as **fufu** made from cassava root,** provides

legumes (leg-GOOMS, LEG-yooms) plants of the bean, pea, and lentil family that have roots with nodules containing special bacteria. These bacteria can trap nitrogen from the air in the soil and make it into compounds that become part of the plant's seeds. The seeds are rich in protein compared with those of most other plant foods. Also defined in Chapter 1.

fufu a low-protein staple food that provides abundant starch energy to many of the world's people; fufu is made by pounding or grinding root vegetables or refined grains and cooking them to a smooth semisolid consistency.

**Cassava is also called *manioc* or *yucca*.

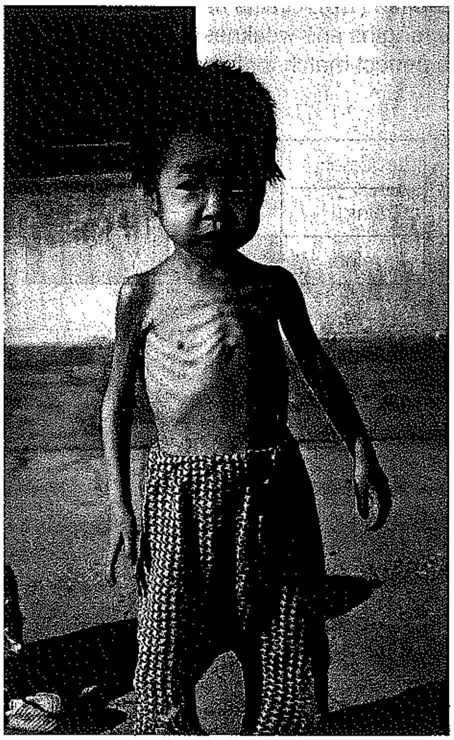
90 percent of the calories), the primary food source of protein must be checked because its quality is crucial.

KEY POINT A protein's amino acid assortment greatly influences its usefulness to the body. Proteins lacking essential amino acids can be used only if those amino acids are present from other sources.

LO 6.6

Protein Deficiency and Excess

Protein deficiencies are well known because, together with energy deficiencies, they are the world's leading form of malnutrition. The health effects of too much protein are far less well known. Both deficiency and excess are of concern.



© AP/Wide World Photos

The extreme loss of muscle and fat characteristic of marasmus is apparent in this child's "matchstick" arms.

What Happens When People Consume Too Little Protein?

Protein deficiency and energy deficiency go hand in hand. This combination—**protein-energy malnutrition (PEM)**—is the most widespread form of malnutrition in the world today. Over 500 million children face imminent starvation and suffer the effects of severe malnutrition and **hunger.** Most of the 33,000 children who die each day are malnourished. PEM is prevalent in Africa, Central America, South America, the Middle East, and East and Southeast Asia, but developed countries, including those in North America, are not immune to it.

PEM strikes early in childhood, but it endangers many adults as well. Inadequate food intake leads to poor growth in children and to weight loss and wasting in adults. Stunted growth due to PEM is easy to overlook because a small child can look normal. The small stature of children in impoverished nations was once thought to be a normal adaptation to the limited availability of food; now it is known to be an avoidable failure of growth due to a lack of food during the growing years.

PEM takes two different forms, with some cases exhibiting a combination of the two. In one form, the person is shriveled and lean all over—this disease is called **marasmus.** In the second, a swollen belly and skin rash are present, and the disease is named **kwashiorkor.**†† In the combination, some features of each type are present. Marasmus reflects a chronic inadequate food intake and therefore inadequate energy, vitamins, and minerals as well as too little protein. Kwashiorkor may result from severe acute malnutrition, with too little protein to support body functions.

KEY POINT Protein-deficiency symptoms are always observed when either protein or energy is deficient. Extreme food-energy deficiency is marasmus; extreme protein deficiency is kwashiorkor. The two diseases most often overlap and together are called PEM.

protein-energy malnutrition (PEM) the world's most widespread malnutrition problem, including both marasmus and kwashiorkor and states in which they overlap; also called *protein-calorie malnutrition (PCM).*

hunger the physiological craving for food; the progressive discomfort, illness, and pain resulting from the lack of food. See also Chapters 9 and 15.

marasmus (ma-RAZ-mus) a form of PEM related to protein malnutrition and infections, with a set of recognizable symptoms, such as edema.

kwashiorkor (kwash-ee-OR-core, kwashee-or-CORE) a form of PEM related to protein malnutrition and infections, with a set of recognizable symptoms, such as edema.

Marasmus

Marasmus occurs most commonly in children from 6 to 18 months of age in overpopulated city slums. Children in impoverished nations subsist on a weak cereal drink with scant energy and protein of low quality; such food can barely sustain life, much less support growth. A starving child often looks like a wizened little old person—just skin and bones.

Muscle Wasting and Other Impairments Without adequate nutrition, muscles, including heart muscle, waste and weaken. Brain development is stunted and learning is impaired. Metabolism is so slow that body temperature is subnormal. There is

††A term gaining acceptance for use in place of kwashiorkor is *hypoalbuminemic-type PEM.*