

# Protein

The building blocks of human proteins are twenty amino acids that may be consumed from both plant and animal sources. Of these 20 amino acids, 9 are considered to be essential because their carbon skeletons cannot be synthesized by human enzymes. The remaining “nonessential” amino acids can be synthesized endogenously with transfer of amino groups to carbon compounds that are formed as intermediates of glucose (glucogenic amino acids) and lipid (ketogenic amino acids) metabolism.

Protein is the basic structural material of all cells. Biologically active proteins include enzymes, immunoglobulins, hormones, neurotransmitters, nutrient transport and storage compounds, and cell membrane receptors. Plasma proteins (e.g., albumin) contribute to oncotic pressure that directs the flow of fluid and metabolic waste from the intracellular compartment into the capillary venules. These proteins (e.g., hemoglobin) also contribute to plasma buffering capacity and oxygen-carbon dioxide transport (e.g., hemoglobin, myoglobin). Acute phase reactant proteins (e.g., ferritin, prealbumin) secreted by the liver bind minerals such as iron and zinc rendering them unavailable to support microbial proliferation.

## Biological Value

Biological value of a dietary protein is determined by the amount and proportion of essential amino acids it provides. If any one of the essential amino acids is not available in sufficient amounts or is present in excessive amounts relative to other essential amino acids, protein synthesis will not be supported. Under these circumstances, labile body proteins such as plasma albumin will be catabolized to provide the limiting amino acid so that protein synthesis may continue.

Protein from animal sources (meat, fish, dairy products, egg white) is considered high biological value protein or a "complete" protein because all nine essential amino acids are present in these proteins. An exception to this rule is collagen-derived gelatin which is lacking in tryptophan.

Plant sources of protein (grains, legumes, nuts, and seeds) generally do not contain sufficient amounts of one or more of the essential amino acids. Thus protein synthesis can occur only to the extent that the limiting amino acids are available. These proteins are considered to have intermediate biological value or to be partially complete because, although consumed alone they do not meet the requirements for essential amino acids, they can be combined to provide amounts and proportions of essential amino acids equivalent to high biological proteins from animal sources.

Plants that are entirely lacking in essential amino acids are considered incomplete proteins or sources of low biological value protein. These sources include most fruits and vegetables. A low biological value means that it is difficult or impossible to compensate for insufficient amounts of essential amino acids by combining different sources as with partially complete proteins.

| <b>Classification of Amino Acids</b> |                                 |
|--------------------------------------|---------------------------------|
| <b>Essential Amino Acids</b>         | <b>Nonessential Amino Acids</b> |
| 1. Histidine                         | 1. Alanine                      |
| 2. Isoleucine                        | 2. Arginine*                    |
| 3. Leucine                           | 3. Aspartic acid                |
| 4. Lysine                            | 4. Cysteine*                    |
| 5. Methionine                        | 5. Cystine                      |
| 6. Phenylalanine                     | 6. Glutamic acid                |
| 7. Threonine                         | 7. Glutamine*                   |

|               |              |
|---------------|--------------|
| 8. Tryptophan | 8. Glycine   |
| 9. Valine     | 9. Proline   |
|               | 10. Serine   |
|               | 11. Tyrosine |

\*These amino acids, along with taurine, may be considered conditionally essential in that their requirements are increased during periods of catabolic stress.

## Deficiency

If protein needs are not adequately met by dietary sources, an imbalance may develop. This imbalance is reflected by levels of urinary nitrogen which exceed the amounts being consumed from dietary protein. This increase in urinary nitrogen is due to the catabolism of visceral proteins and lean body mass to provide the essential amino acids that are not available in adequate amounts from dietary sources. Negative nitrogen balance may result from consumption of insufficient quantity of high biological protein, consumption of poor quality dietary protein of any quantity, or consumption of intermediate quality protein sources that are not appropriately mixed because the quantities of essential amino acids consumed will not be sufficient to support demand for synthesis of vital proteins. In addition to appropriate quantity and quality of protein consumed, sufficient energy must also be consumed to support protein metabolism or negative nitrogen balance will develop regardless of the quality or quantity of protein consumed.

Protein malnutrition or kwashiorkor is the clinical consequence of uncorrected negative nitrogen balance. Protein deficiencies rarely occur when energy intake is adequate except in impoverished areas where adequate quality or quantity of protein is not consumed due to high costs of protein sources. The most common cause of protein deficiency insufficient energy intake, which is exacerbated when demand for both protein and energy is high. Protein-energy malnutrition (PEM) or marasmus may develop clinically from malabsorption syndrome, with excessive protein losses from burns, wound exudates, or fistula drainage, or with losses in urine from renal disease. Risk of PEM is also increased under conditions of metabolic stress, such as infection, trauma, burns, AIDS and surgery, where high levels of catabolic hormones increase protein catabolism. Clinical features of PEM include weight loss, diarrhea, loss of lean body mass, muscle weakness, depigmented hair and skin, pressure sores, and depressed immune function.

## Toxicity

Dietary protein consumed in excess of requirements is not stored, but is deaminated followed by oxidation of the carbon skeleton through pathways of glucose or fat metabolism, or its storage as glycogen or fat, depending upon the specific amino acid and the energy balance at the time. The nitrogen waste generated is excreted in the urine as either urea or ammonia.

High protein intakes can increase urinary calcium excretion, but the effect on calcium balance is controversial since amino acids also increase the efficiency of intestinal absorption. Other health effects of high protein intakes are less clear including the relationship of long-term high protein intakes to risk of renal disease or of diabetic nephropathy.

The effect of exercise on protein requirements is not as much as commonly believed. Endurance athletes actually have a higher requirement than body-builders due to catabolic losses of lean body mass following aerobic exercise. Nevertheless, this increased requirement can be readily met without supplementation when the high energy intakes required by athletes are consumed. Use of amino acid supplements may actually interfere with synthesis of body protein by creating imbalances. Since amino acids compete for absorption, presentation of large quantities of free amino acids to the intestinal mucosal surface reduces the amount that can be absorbed from the available supply.

## Requirements

Approximately 10-15% of total daily energy intake should be consumed as protein. Protein needs for sedentary adults average about 50 grams. Growth, pregnancy, lactation, and exercise increase protein needs as indicated in the table below.

| <b>Protein Requirements</b>   |          |
|---|----------|
| Infants (0-6 months) g/lb   | 1.0      |
| Infants (6-12 months) g/lb  | 0.72     |
| Children (1-3 years) g/lb   | 0.55     |
| Children (4-6 years) g/lb   | 0.50     |
| Children (7-10 years) g/lb  | 0.45     |
| Adolescence (11-14 years)   |          |
| total g/day females   | 46       |
| total g/day males   | 45       |
| Adolescence (15-18 years)   |          |
| total g/day females   | 44       |
| total g/day males   | 59       |
| Young adults (19-24 years)  |          |
| total g/day females   | 46       |
| total g/day males   | 58       |
| Pregnancy total g/day   | 60       |
| Lactation total g/day   | 65       |
| Sedentary Adult g/lb  | 0.4      |
| Recreational Activity   | 0.5-0.75 |
| Competitive Athletics g/lb  | 0.6-0.9  |
| Muscle Building g/lb  | 0.7-0.9  |
| Maximum Usable Amount<br>Adults g/lb  | 1.0      |
| References:   |          |
| <ul style="list-style-type: none"> <li>Mahan, L.K. and Escott-Stump, S. <u>Krause's Food, Nutrition &amp; Diet Therapy</u>, 10<sup>th</sup> ed., 2000.</li> <li>Rosenbloom, Christine. <u>Sports Nutrition. A Guide for Working Professionals</u>, 3<sup>rd</sup> ed., 2000.</li> </ul> |          |

## Dietary Sources of Protein

Meat, poultry and fish are rich sources of high biological value protein. Plant sources of protein (legumes, nuts, and seeds) contribute additional amounts of protein. See the table below for a detailed list of dietary protein sources.

| Food                          | Protein (grams) | Food                    | Protein (grams) |
|-------------------------------|-----------------|-------------------------|-----------------|
| <b>Dairy</b>                  |                 | <b>Meat Substitutes</b> |                 |
| Skim milk, 1 cup              | 8.3             | Tofu, 3 oz              | 6.9             |
| Whole milk, 1 cup             | 8.0             | Veggie burger, 3 oz     | 25.7            |
| Ice cream, regular, 1 cup     | 5.0             | Peanut butter, 2 Tbl    | 8.1             |
| Yogurt, low-fat, 1 cup        | 10.7            | Almonds, 1 oz           | 5.4             |
| Cottage cheese, 1% fat, 1 cup | 28.0            | Sesame seeds, 1 oz      | 7.5             |
| American cheese, 1 oz         | 7.0             | Black beans, 1/2 cup    | 7.5             |

|                                 |      |                           |     |
|---------------------------------|------|---------------------------|-----|
| Egg, 1 large                    | 6.3  | Pinto beans, 1/2 cup      | 7.0 |
| <b>Fish, Meat &amp; Poultry</b> |      | Garbanzo beans, 1/2 cup   | 7.3 |
| Tuna, 3 oz drained              | 21.7 | <b>Fruits</b>             |     |
| Salmon, 3 oz ckd                | 16.8 | Banana, 1 medium          | 1.2 |
| Ground beef, 3 oz, ckd          | 25.7 | Apple, large              | 0   |
| Beef, round steak, 3 oz ckd     | 27.0 | Orange, large             | 1.7 |
| Pork chop, 3 oz ckd             | 24.5 | <b>Vegetables</b>         |     |
| Ham, 1 oz                       | 5.9  | Corn, ckd, 1/2 cup        | 2.2 |
| Chicken breast, 3 oz            | 18.9 | Carrots, ckd, 1/2 cup     | 0.8 |
| Chicken, dark meat, 3 oz        | 23.6 | Green beans, ckd, 1/2 cup | 1.0 |
| Turkey breast, 3 oz             | 25.7 | Green peas, ckd, 1/2 cup  | 4.1 |
| Turkey, dark meat, 3 oz         | 24.3 | Potatoes, white, 1/2 cup  | 1.2 |