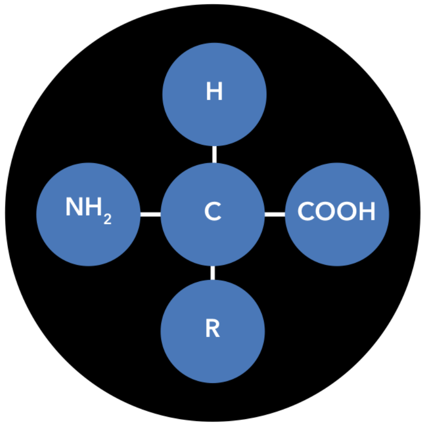
Chapter 4. Protein



4.1 Protein Needs

Dietary protein is critical in the maintenance of cellular structure and function. The limited capacity of the human body to store protein is exceeded by daily need. Consequently, protein, unlike the other macronutrients, must be procured in the diet daily to avoid immediate losses in cellular structure and function. The level of protein intake that is appropriate to sustain normal adult protein turnover and obligatory protein losses, as determined using nitrogen balance and nitrogen labeling studies, is **.8g/kilogram body weight** per day, which for the average size men and women in the US is 56 and 46 grams per day, respectively. The daily recommended intake of protein provided in the RDA is rounded up to 60 grams per day for men and 50 for women.

DAILY INTAKE	
AMDR Percent Protein Calories	10-35
RDA grams protein/day	60 men 50 women
RDA grams/kg/day	0.8
RDA ESSENTIAL AMINO ACIDS mg/kg/day	NA
HISTADINE	14
ISOLEUCINE	19
LEUCINE	42
LYSINE	38
METHIONINE + CYSTEINE	19
PHENYLALANINE + TYROSINE	33
THREONINE	20
TRYPTOPHAN	5
VALINE	24

Daily Protein and Amino Acids Requirements

American men and women consume considerably more protein each day than what is needed to sustain the requirements for normal daily protein turnover. Men consume nearly two times the RDA on average, and women could reduce protein intake by more than a third without dipping below the RDA. Although their protein intake levels exceed our biological requirements, adults in the US are within the **10–35% AMDR** for protein calories guideline; as with dietary fats, this is simply a function of our increasing intake of total calories. The wide AMDR range is explained by the large individual variances in total protein requirements among individuals within sex and age stratification groups like, for instance, those injured or recovering, vegan, or with diseases that affect protein status.

The large variability in protein requirements among otherwise comparable individuals is the reason why protein is *not* represented in the %DV on the NFP, and why the RDA for protein is expressed as a function of body weight, in addition to the absolute gram amount. Since consumers are not as familiar with how protein fits in the total diet, companies marketing protein content in foods typically use the "grams of protein per serving" approach, in addition to the "excellent source" and "high-in" type nutrient content claims typically made on fortified and high protein food products.

Nutrition Facts

8 servings per container

Serving size 2/3 cup (55g)

Amount per 2/3 cup

Calories 230

% DV*	
12%	**Total Fat** 8g
5%	Saturated Fat 1g
	Trans Fat 0g
0%	**Cholesterol** 0mg
7%	**Sodium** 160mg
12%	**Total Carbs** 37g
14%	Dietary Fiber 4g
	Sugars 1g
	Added Sugars 0g
	Protein 3g
10%	Vitamin D 2mcg
20%	Calcium 260mg
45%	Iron 8mg
5%	Potassium 235mg

* Footnote on Daily Values (DV) and calories reference to be inserted here.

Protein on the Nutrition Facts Panel

Protein in foods contains twenty **amino acids** that are needed in the human body. Eleven of them are dispensable, as they can be synthesized in the body; the other nine, however, cannot be synthesized and must, therefore, be consumed in the diet. The daily requirements for each of these latter, **essential amino acids**, has been determined using direct amino acid oxidation methods (DAAOM) and has also, along with total protein, been published as an RDA. These investigations have also identified conditions in which some of the dispensable amino acids cannot be made in the body, spawning a third class of amino acids. Two of the conditionally dispensable amino acids are included in the RDA in combination with essential amino acids that under typical conditions can be synthesized from the conditionally indispensable counterpart.

Research is needed to determine the upper levels of total protein and amino acid intake that may elicit delirious effects, especially with increasing use of supplemental fractioned proteins and amino acid supplemented products. More amino specific food marketing, like efforts to raise awareness about the essential fatty acid (i.e., omega 3 and omega 6) content of products, is on the horizon. Efforts are also needed to educate Americans about the amount needed and role of dietary protein in weight maintenance and muscle accretion separately from their associations with low-carbohydrate and/or high-fat diets. Current guidelines emphasize aiming for at least 5 oz. of protein-rich plant foods per week and reducing the amount animal protein to satisfy one-third of daily protein needs, instead of the current level of two-thirds.

NON-ESSENTIAL AMINO ACIDS
Dispensable
Alanine
Aspartic acid
Asparginine
Glutamic acid
Serine
Conditionally dispensable
Tyrosine
Cysteine
Arginine
Glutamine
Glycine
Proline

Non-Essential Amino Acids

4.1 Homework 1

Homework • Unanswered

What is the approximate range in daily protein intake (in grams) that corresponds to a 10-35% protein, 2000 calorie diet?

- A 25-75
- B 25-100
- C 50-125
- D 50-175

Explanation

2000 x 10% = 200 calories from fat. Every 1 grams of protein = 4 calories, so 200/4 = 50 grams
2000 x 35% = 700 calories from protein. Every 1 gram of protein = 4 calories, so 700/4 = 175 grams

Answered - Correct!

1 attempt left Retry

4.1 Homework 2

Homework • Unanswered

An adult weighing 75 kilograms requires approximately _____________ grams of protein per day.

- A 50
- B 60
- C 75
- D 90

Explanation

75 kg x . 8 grams = 60

Answered - Correct!

1 attempt left Retry

4.1 Homework 3
Homework • Unanswered

Which of the two amino acids below are needed in the highest amounts in the daily diet? (TWO AMINO ACIDS MUST BE SELECTED FOR FULL CREDIT)

Multiple answers: You can select more than one option

- A Histidine
- B Isoleucine
- C Leucine
- D Lysine
- E Methionine + Cysteine
- F Phenylalanine + Tyrosine
- G Threonine
- H Tryptophan
- I Valine

Explanation

Correct - Leucine and Lysine

Answered - Correct!

1 attempt left Retry

4.2 Protein Sources

Dietary protein in food comes from whole plant and animal foods as well as concentrated protein products. Proteins in foods are synthesized in the cells of plants and animals in a series of **dehydration synthesis** reactions that yield large, heavy and complex whole proteins. In these reactions polypeptides interact with neighboring elements in the peptide chain to create secondary and tertiary polypeptides that join together to form oligomeric proteins.

The total protein content of foods is determined by measuring the amount of nitrogen (as reduced ammonia) that is liberated by heat or acid treatments and then multiplying by a conversion factor that represents the proportion of nitrogen in the total protein in the food. While there is a range from 5.25-6.5 among many types of protein-rich foods, 6.25 (i.e., 16% nitrogen) is the value that has been standardized for industry use to report the protein content of foods on labels. Click HERE for an example of the protein grams per serving calculation.

The protein qualities of many types of protein-rich foods have been quantified and expressed in a number of scoring systems that evaluate the digestibility and amino acid composition of test foods compared to reference foods and human amino acid requirements. **The Protein Digestibility Corrected Amino Acid Scoring** (PDCAAS) rating was adopted by the US Food and Drug Administration (FDA) and the Food and Agricultural Organization of the United Nations/World Health Organization (FAO/WHO) in 1993 as the standard method to determine protein quality. Using the PDCAAS method, a test protein is scored a value from 0-1; a value representative of the percentage of the protein that is available for human use after digestion and with consideration of the **limiting indispensable amino acid**. For instance, a food with a PDCAAS score of .50 is only 50% useful and, under circumstances of controlled protein intake, would need to be consumed in twice the amounts to meet daily human amino acid requirements. **Digestible Indispensable Amino Acid Score** (DIAAS) is a more evolved method that unlike the PDCAAS does not truncate to 1.0 for protein types that exceed the essential amino acid (EAA) requirements. So, for example, while both soy protein isolate and whey isolate are ranked 1.0 according to PDCAAS, in the DIAAS system, whey has a higher score than soy.

$$\text{PDCASS} = \frac{\textbf{mg}\text{ limiting amino acid/gram }\textbf{test}\text{ protein}}{\textbf{mg}\text{ same amino acid/gram protein requirement}} \times \text{\% digestibility}$$

Figure 4.1. Amino Acid Scoring for Protein Quality

Previous measures of protein quality less effectively scored the quality among foods but provided a better understating of the variability in growth efficiency and nitrogen utilization among various dietary proteins. Growth efficiency ratings were developed in animal models and are expressed as whole numbers between 1-4, with higher numbers representing a greater ability to support rapid rates infant animal growth. The utility of the **Protein Efficiency Ratio** specifically, was low in human models, so more precise methods that

$$\text{PROTEIN EFFICIENCY} = \frac{\text{Weight gain (g)}}{\text{Protein intake (g)}}$$

$$\text{BIOLOGICAL VALUE} = \frac{\text{N retained}}{\text{N absorption}}$$

Figure 4.2. Other Protein Quality Calculations

evaluated nitrogen absorption and retention were developed. The **biological value (BV)** of a protein is expressed as a percentage of nitrogen utilization whereby of foods can be compared to a highly biologically valuable comparative test protein. Since processed proteins (e.g., soy and whey isolates) have nitrogen absorption and retention values exceeding that of the natural proteins the in which the scoring methods were derived, BV may exceed 100%. While the BV method is commonly used as a way to stratify proteins by quality, it does not take into account certain digestibility factors, nor, is it a true estimate of quality in terms of fitness for human amino acid requirements.

Egg 3 oz.	whole egg	egg white
grams protein	10.5	9

Figure 4.3 Protein In Egg

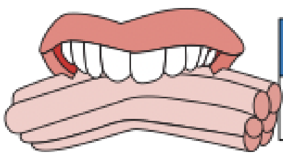
The most biologically valuable natural whole protein is from eggs. The genetic sequencing of amino acids in stored egg protein is designed to support the efficient reproductive growth of the egg embryo. Egg protein is 97% digestible and closest of any other natural source, to mirroring human amino acid protein requirements. There are several egg proteins; **ovalbumin** is the most concentrated, representing around 50% of the total egg protein. When heated, the ovalbumin undergoes a conformational change from its soluble structure into an insoluble structure with exposed hydrophobic regions, the proteins aggregate and cause the solidification associated with cooked egg white. Other proteins in eggs include ovotransferrin, lysozyme and ovomucin, the commonly known egg allergen. Three ounces of whole eggs provides 10.5 grams of protein, with the yolk portion providing slightly more (3 g/serving) biologically inferior protein. Eggs produced from cage-free poultry have a comparable amount of total protein to those that are caged. Dried egg power is one of the most concentrated form of protein, with just over 50% of the total serving weight as protein. While the suggested serving size is 2 TBSP, an equivalent 3-ounce serving contains approximately 66 grams of protein.

Dairy milk and the milk protein fraction **whey** have biological values comparable to and exceeding the standard score for egg, respectively. Stored milk proteins have amino acid profiles that are designed to sustain fast pace tissue growth and ease in digestibility; therefore, milk, like eggs, has a perfect PDCASS protein quality multiple of 1. Whole and reduced-fat milk provide 1 gram of protein per 9.3 calories, or 8 grams of protein per cup. The primary protein in milk is **casein** (80%), which can be precipitated from milk with enzymes and acids as part of cheese making. [The precipitation occurs as a result of lost solubility and subsequent coagulation] The amino acid composition of casein is biologically inferior to the protein fraction that remains suspended in liquid milk, otherwise known as whey. **Lactoglobulin and lactalbumin** are the primary proteins in whey, which comprise most of the remaining 20% total milk protein. Whey protein has a higher BV than casein due to a faster absorption rate, and more

milk	yogurt (greek) 1 C	milk 1 C	whey 28 g	whey isolate 28 g	cheese (mozterlla) 1 oz
grams protein	24	8	10	16	6

Figure 4.4 Milk Protein Sources

fitting amino acid profile for stimulating whole body protein synthesis (casein gelatinizes upon digestion, more LEU in whey). Whey protein is most often concentrated by eliminating carbohydrates (i.e., lactose) to yield products anywhere from 35-80% protein, or they can be isolated/extracted from liquid whey to yield a product that is 90% isolated whey. Concentrates and isolates of whey protein are used to make supplemental protein powders that pack a tremendous punch for protein in relatively small serving size. For instance, just one ounce of whey isolate provides 25 grams of protein that may be used in formulas for high protein shakes, meal bars and other marketable protein supplement products. Both casein and whey are relatively inexpensive, but for direct consumers, not as much so as processed nonfat milk solids. Powdered NFMS are available in grocery stores, shelf-stable, and more much concentrated in protein than liquid milk, containing approximately 10 grams of protein per one ounce. Another cost savings protein supplementation tip is to add a smaller amount of whey to whole milk for a dialed-in (not excessive) amino acid profile or to eat double strained yogurt, which provides up to 30 grams per 8-ounce serving.

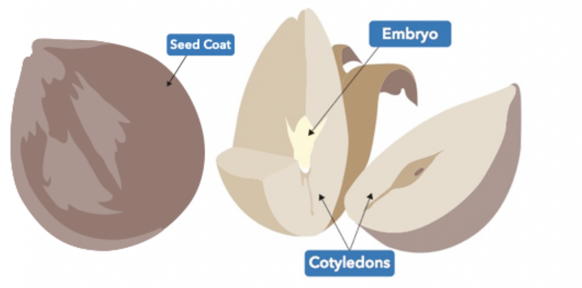


MEAT 3 OZ.	Beef	Chicken	Tuna
grams protein	25	26	25

Figure 4.5 Protein in Meats

The genetic sequencing of amino acids that are used to construct muscle tissue in animal meat are also consistent with that of human prokaryotes. Like human tissue, most dietary meat protein consists of around 70% structural myofibrillar and stromal protein. Sarcoplasmic proteins that are stored intracellularly contribute the other 30% protein in meat. Red meat has higher levels of myoglobin, a type of intracellular protein that is naturally red-pigmented. Red meat and chicken are major sources of protein in the US diet, but both are an inferior quality protein and more calories per gram of protein compared to egg. Fish meat is more favorable than chicken or beef in terms of calories per gram of protein, but is generally lower in total protein because of a lesser amount of connective tissues, such as collagen. Long-distance migrating fish like tuna are exceptions in that they contribute an equivalent amount of protein as beef. Generally speaking, lean meat provides around 25 grams per 3 ounces, and are relatively consistent across body part (thigh and breast), diet (grass vs. corn fed), and activity levels (cage free vs restrained). The later trend can also be seen in wild game meats, which provide a comparable amount of protein calories to that of chicken and beef (1/3). Partially dehydrated meat (jerkies and packed meats) provide10-50% more protein per serving, depending on level of dehydration, compared to equivalent 3 oz. servings of their higher-moisture counterparts.

Plant protein is consumed in the dry fruit or seed portion of germinating plants in tree and bush species, cereal and pseudocereal grasses, and leguminous plant families**.** Plant protein, like egg protein, is a metabolically inactive store of nutrients that exists only to support the developing plant embryo's growth needs. Plants, however, while containing equivocal and in some cases, exceeding amounts of total protein compared to animal foods, are constructed using a eukaryotic gene order that sequences the amino acids together in a proportion that is less fit for humans in terms of meeting daily amino acid requirements. Plant protein bio-availability is limited compared to animal foods as plants are generally less digestible and more variable in their protein content with fluctuations in soil nutrients (i.e., nitrogen and sulphur) and preparation methods.



SEEDS 28g	Hemp	Water Melon	Sunflower	Pumpkin	Chia	Flax
grams protein	9	8	8	5.2	4.7	2.5

Figure 4.6 Protein in 1 Ounce of Seeds

Seeds can provide up to 30% protein by weight and on average approximately 10 grams of protein per one ounce serving. Watermelon and hemp seeds particularly, have gained popularity and market share from competitor seeds such as those from sunflower and pumpkin. Hemp seeds have a relatively high digestibility, but a low overall protein quality score PDCAAS score of .61. Other popular edible seeds such as those from chia and flax do contain some protein but in amounts less significant than their glowing EFA profile. The predominant proteins in seeds are a group of soluble **albumins** and a group of semi-insoluble **globulins** and **glutelins** that are also found in nuts, legumes and grains.

NUTS 28 g	almonds	pistachios	cashews	walnuts
grams protein	6	5.8	5.2	4.3

4.7 Protein in 1 Ounce of Nuts

Nuts are generally the most energy-dense source of plant protein, providing approximately 19 calories per gram of protein. Nuts provide less protein as a percent of weight than seeds, with even the highest protein nuts mad of just under 20% protein on average. Nuts alone provide on average 5 grams of protein per ounce, but with PSCAAS scores around .20-.30, as much as five times more nuts are needed to reach the amino acid content of perfectly scored proteins. Nuts are also processed into many types of products including butters/pastes and drinking milks. Cashew and almond milk varieties are formulated to provide a pretty low average of 1 gram of protein per 8 oz. serving. Nut butters are a more concentrated source of protein (20%), providing on average 6 grams of protein per two-tablespoon serving.

LEGUMES 85 grams	Soybeans Mature	Soybeans Edamame	Tofu Firm	Tempeh	Mung Beans	Pea	Peanuts
grams protein	31	10.5	8.5	17	15	7.5	22

Figure 4.8 Protein in 3.5 ounces cooked legumes (peanuts raw)

Legumes that are consumed intact as part of the fruit are typically higher in water and fiber and lower protein. More often though, legume seeds are extracted from the pod and eaten alone, yielding a higher percent protein food. Higher-protein pulse type legumes (e.g., beans) and soybeans are half as energy-dense per gram of protein than are nuts and provide on average 15 grams of protein per 3 ounces serving. Legumes are rich in **legumelin**, a legume-specific type of glutelins. Mature bean varieties have a higher protein content than less mature, younger varieties. For instance, immature, green soybeans (edamame) have significantly less protein than mature, yellow soybeans that are more often used to make tofu and tempeh. Soybeans are particularly high in protein and have a relatively high PDCAAS score (i.e., .92). Soybeans have higher amino acid scores (grams per mg/protein), and are less limited in amino acids compared to pulse beans, peas, and lentils, but are still significantly less biologically available competed to animal proteins. Soybean protein is often isolated and used in supplemental protein products markets in all food categories, including but not limited to protein-textured meat alternatives as well as soy protein concentrate and isolate rich protein bars, shakes and milks. Other common legume seeds in the US diet include peas, peanuts, and chickpeas provide anywhere from 5 to 12 grams per 3-ounce serving.

GRAINS 85g	Brown rice	Corn	Amaranth	Quinoa	Corn meal	Whole grain bread	Oats
grams protein	2.3	2.9	3.2	3.75	6.9	9	11

Grain seeds are distinguished from legumes by their inseparable thin, hard fruit cap exterior that lowers total protein as a percentage of weight than the separable seeds of legume fruit. Grains store protein in the cotyledons of the cell, which are dispersed throughout the grain seed endosperm. The primary proteins in cereal grains are **protamines and globulins**. Grain-specific globulins such as **recin** in rice and **zein** in corn, like wheat protein, have relatively low PDCAAS scores ranging from .4 to .5, due to limiting amino acids and low digestive efficiency scores. Many types of commonly consumed grass species including wheat, rye, and barley, contain a particular type of globulin called, **gluten**. Gluten has two sub-fractions (gliadin and glutein), which both contribute elastic qualities to doughs used for breads, pastas and cereals. Gluten-free products have taken many consumer markets in healthy, fad diet and even home cooking and baking categories by storm as awareness about gluten sensitivity and diseases that affect the processing of gluten protein fractions is strengthened.

Amino Acids in Foods

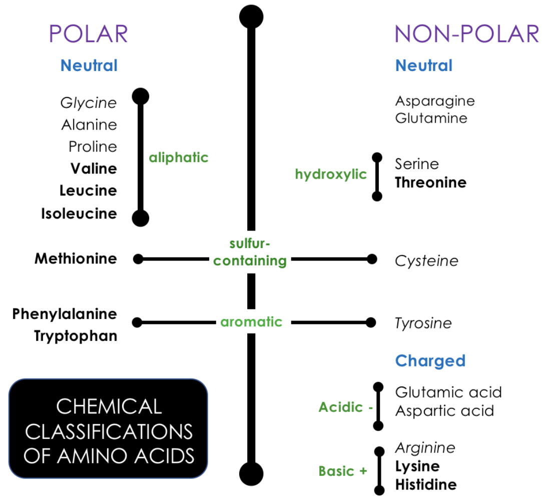


Figure 4.10 Amino Acid Classifications by Side Chain Chemistry

Protein amino acids are organic compounds comprised of a central alpha carbon flanked by an acid (carboxyl), hydrogen, nitrogen (amine) and a "side chain." The amino nitrogen and the hydroxyl groups are the attachment sides for complex oligosaccharides that form whole body proteins. The carboxyl-containing groups are ion binding proteins that interact with other charges that together elicit protein function (i.e., heme-binding, troponin-calcium binding for muscle contraction). The amino side chain lends to the functional uniqueness of each amino acid, as well as the primary chemical classification systems.

The 20 amino side chain variations are grouped based on size, charge at physiological pH, and polarity in solutions. The most basic chemical description of amino acid side chains is their willingness be in contact with a solvent like water (e.g., blood). Hydrophobic, or **non-polar**, amino acids do not like to mix with water and are therefore found more at the center of most complex protein structures in higher concentrations. Hydrophobic **sulphur-containing** amino acids at the protein core form cross bridges to neighboring polypeptides to strengthen the foundation of the protein configuration. **Polar,** hydrophilic amino acids readily dissolve in solutions, and are therefore found more exteriorly positioned in the protein. **Hydroxylic** amino acids on the protein exterior are equipped with either hydrogen-containing side chains for intramolecular bonding, or ionically **charged** side chains (i.e., basic and acidic amino acids) that provide rigidity to the configuration by forming salt bridges. **Aromatic** amino acids feature a ring configuration in their side chain that provide characteristics fitting into both polar and non-polar amino acid families.

Human diets are generally highest in essential **alanine** and **glycine** and conditionally dispensable glutamine **.** These three amino acids and/or their acid salts represent around 25% of the total amino acid intake in both vegan and animal meat containing diets. Vegans have comparable or higher intakes of certain indispensable acids, but are typically below the intake levels of vegetarians and meat-eaters for the essential branch chain amino acids and several limiting amino acids in lower concentration in plants.

Branched-chain amino acids are part of the non-polar, aliphatic family. BCAA represent just under half of the total essential amino acids contributed from plant and animal foods in the US diet. Chicken and beef flesh have the highest BCAA content of natural foods typically consumed, whereas milk proteins have the most ideal BCAA proportional ratio of (i.e., 2:1:1). The ratio of **leucine**: **isoleucine**: **valine** is important for protein quality, especially for leguminous soy and pulse beans, which have up to 30-35% more total BCAA than egg and milk, and some types of seeds (i.e., watermelon and hemp) that are comparable to, or higher than beef in %BCAA (5%), as they are proportionately lower in leucine and isoleucine. Protein powder supplements are rich sources of branched chain amino acids, containing approximately 5 grams of BCAAs per 25 grams in the ideal 2:1:1 ratio.

Grams BCAA per 100g Protein	MEAT			MILK		SEED		NUT		LEGUME		
	BEEF	CHICKEN	EGG	MILK	WHEY	WATER-MELON	HEMP	ALMOND	CASHEW	SOY	SOY ISOLATE	PEANUTS
LEUCINE	2.3	1.5	1.0	1.1	1.1	2.1	2.1	1.4	1.2	0.9	6.7	1.6
ISOLEUCINE	1.3	1.6	0.7	0.5	0.5	1.3	1.3	0.7	0.7	0.6	4.2	0.9
VALINE	0.9	1.5	0.7	0.5	0.5	1.5	1.7	0.8	1	0.6	4.0	1.0
TOTAL BCAA	**4.5**	**5.4**	**2.4**	**2.2**	**2.2**	**4.9**	**5.1**	**2.9**	**3**	**2**	**14.9**	**3.5**

Figure 4.11. Branched-Chain Amino Acid Content of Plant and Animal Protein Sources

Limiting amino acids will determine the nutritional value of total protein in the diet. The primary limiting amino acids are lysine (cereals, nuts and seeds), methionine (cow milk), threonine (wheat and rye) and tryptophan (casein, corn, rice). **Lysine** is the first limiting amino acid in seeds and grains, which contain around one third the amount of lysine as milk, eggs, leguminous beans and potatoes – or less. Lysine is commonly supplemented in the diets of farm animals to account for the limited lysine in grain based-feeds, and is a target of rice and cereal flour bio-fortification. The first limiting amino acids in leguminous seeds are sulphur-containing amino acids, **methionine and cysteine,** which are also relatively lower in cow's milk, but not to extend to affect the PDACAS score. The BV value of milk, however, is slightly lower than other animal foods. MET is also a second limiting amino acid to lysine in oats. Sulphur amino acids are difficult to incorporate into supplemental food products as they have a distinguishably bitter taste and insoluble behavior. Masking agents and strong emulsification agents are used to develop supplemental SAA products. **Threonine** is the second limiting amino acid to lysine in most cereal grains, except corn, which is second limited by **tryptophan**. Tryptophan and threonine, depending on the type of grain-based diet the animal is on, are most commonly used in feed manufacturing. Wheat grains are actually higher in tryptophan, making multi-grain flours slightly more favorable in protein quality than those milled from single grains. Contrary to legends of turkey and tryptophan, meat, especially fish, tend to be lower in TRYP, and the other two aromatic amino acids, tyrosine and phenylalanine, compared to milk and egg, which on average have 15-20 times more combined PHE+TYR. Tryptophan is also the first limiting amino acid in peanuts, but is not delineated as a major limiter in peanut protein because of the adequate levels of phenylalanine, a pre-cursor to tryptophan. Since the RDA combines PHE and TRYP, this is not considered as significant as the limited levels of MET. Phenylalanine is also used to make aspartame, so low-calorie artificially sweetened beverages are also a significant source of dietary phenylalanine.

Limiting amino acids in plant foods have not stopped vegans from forming essentially complete diets by pairing incomplete foods that are complementary to partner food deficiencies. A good analogy arises in discussing the polarity of married couples, where one partner has an excellent quality that can partially equalize another partner's extreme shortcoming, and vice versa. Food pairing techniques are simply put the same, in that each protein has a limitation and a strength that when combined are better, and more complete as a food protein source. **Protein complementation** techniques are exemplified in many of the customary meals and recipes that are used in all societies.

4.2 Homework 1

Homework • Unanswered

Put these protein sources in order from low to high quality.

1	D	Rice
2	B	seeds
3	A	legumes
4	C	Whey

Answered - Correct!

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4.2 Homework 2

Homework • Unanswered

Match each protein to a food source

Premise		Response
1 Legumelin	→	D Soybeans
2 Recin	→	B Rice
3 Zein	→	A Corn
4 Gluten	→	C Wheat

Answered - Correct!

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Assigned as Homework

4.2 Homework 3

Visit: https://ndb.nal.usda.gov/ndb/search/list
Perform a FOOD SEARCH for 100 grams of the following flours

1. Pea flour
2. Potato flour
3. Defatted peanut flour
4. Chickpea flour

Note the protein content of each of these flours along with a couple of ideas you find elsewhere about how to use these flours in cooking
Share here at least one cooking application for each of the flours in order from the lowest to highest in protein.

4.2 Homework 3
Homework • Unanswered

The primary limiting amino acid in grains is ______________ , and in legumes is ______________ .

- A methionine and lysine
- B alanine and lysine
- C lysine and methionine
- D sulfur amino acids, alanine

Answered - Correct!

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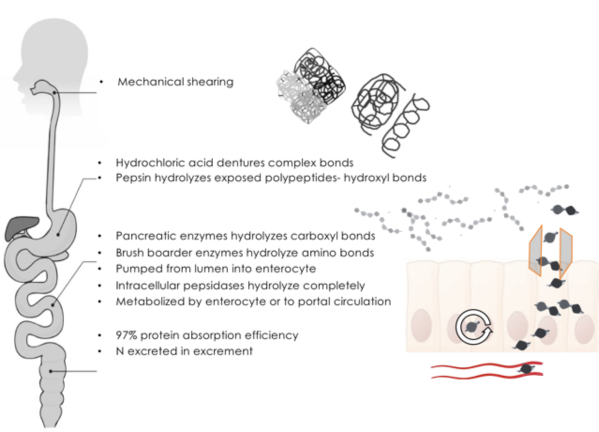
4.3 Protein and Amino Acid Processing

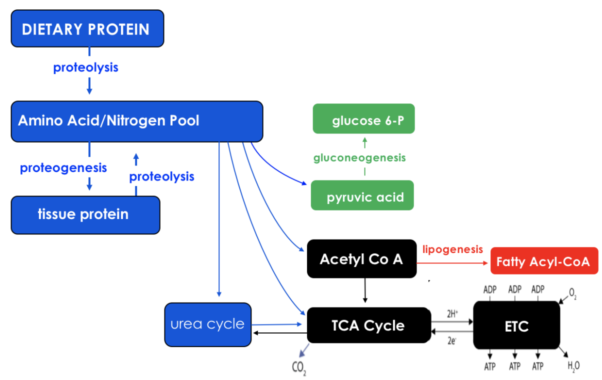
Mechanical digestion of dietary protein begins in the mouth with chewing and shearing food into a lubricated bolus that is propelled down the esophagus to the stomach. Gastrin, a sensory hormone activated by the sight, and smell of food, along with **hydrochloric acid** secreted from the lining of the stomach, initiates chemical protein digestion. Hydrochloric acid denatures quaternary and tertiary protein structures to yield more accessible polypeptide chains, and reduces the acidity in the stomach to initiate the conversion of pepsinogen to pepsin. **Pepsin** hydrolyzes uncoiled (i.e., denatured) areas to yield short and long polypeptides.



Partially denatured proteins and a number of lengths of peptides move along to the duodenum of the small intestine, the primary protein digestion and absorption site. The pancreas releases several bond-specific **protease enzymes** that must be activated first by interkinase on the surface of the intestinal cell wall, and then subsequently by activated **trypsinogen** (i.e., trypsin). Activated **carboxypeptidases** and **amino peptidases** hydrolyze long peptide chains at the carboxyl and amino terminals, respectively, to form shorter peptides and free amino acids. Di-peptides continue for hydrolysis on the surface of the brush border by **dipeptidase**.

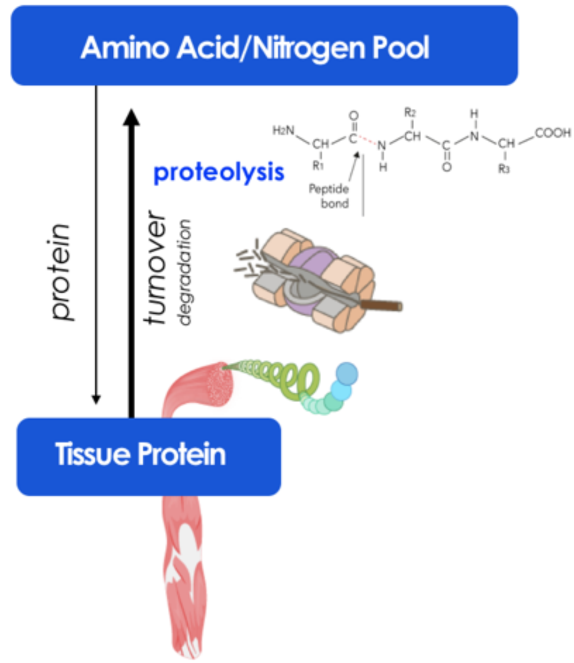
The large majority (96-98%) of free amino acids are absorbed across the brush border of small intestine through **hydrogen pumps** or **sodium-dependent carriers**. Most free amino acids are moved through to portal circulation, while a significant portion of indispensable amino acids are used by the intestinal, sphlanic cells for energy. Amino acids travel to the liver where they are either used or passed through to general circulation to join the various pools of free, dissolved amino acids in the plasma and peripheral tissues.

Free amino acids pools are very small relative to the bound amino proteins. Cellular amino pools are static in their composition but are typically highest in glutamine (15 g N), glycine and threonine, and lowest in leucine and phenylalanine. Concentrations of some amino acids (i.e., glutamine, glutamic acid and glycine) are 10-50 times higher inside the cell than in the plasma whereas larger, neutral aromatic amino acids (phenylalanine, tyrosine and tryptophan) are at equilibrium across cellular spaces and plasma. The amino acid pools mainly sustain an average 250 grams per day of **protein turnover**, while the tissues of the intestines and liver sustain approximately half of that amount.

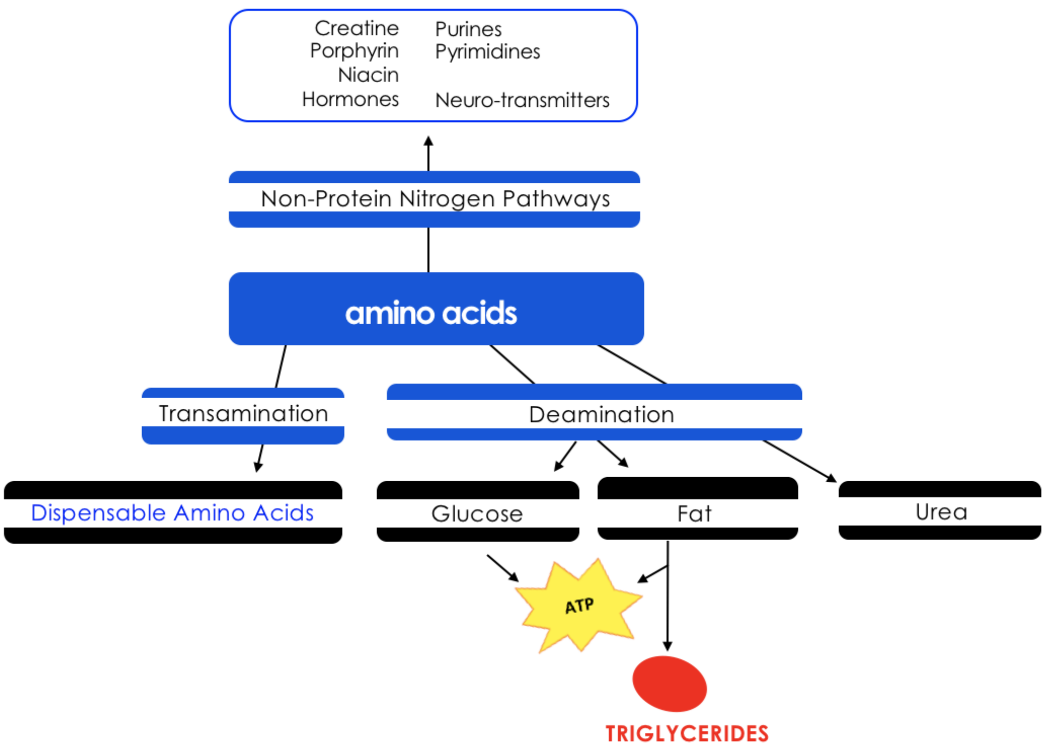


Protein synthesis takes place in the cytoplasm when cellular protein levels are adequate. Since the genetic orders for construction of proteins are derived in the nucleus of the cytoplasm, RNA (i.e., tRNA transcription/transfer & mRNA translation/translate) must transcribe and transfer the order to the cytoplasmal ribosomes. The ribosomes read the order from mRNA and signal for the sequencing and covalent peptide bonding between the amine (i.e., nitrogen) group and the carboxyl end (i.e., acid group) of two L-alpha amino acids. One by one amino acids join together to form di-peptides, tri-peptides and polypeptide chains that are anywhere from 3-50 amino acids in length. Adequate levels of essential amino acids are needed for protein tissue synthesis. Adequate levels of functional proteins, including growth factors (human growth hormone), anabolic hormones (insulin), immune response proteins (insulin-like growth factor, and C-reactive protein), and free amino acids (leucine) are all required to stimulate the muscle protein synthesis pathway (i.e., MTor). The average person, under those adequate intake conditions, synthesizes around 3 grams of protein per kg body weight per day.

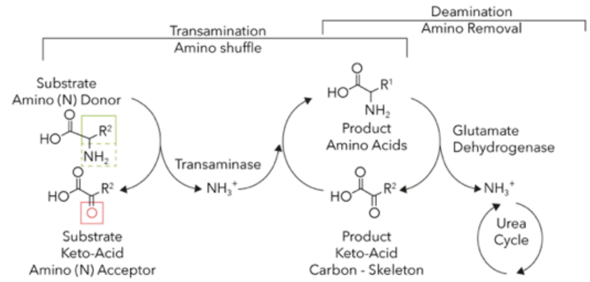
Protein degradation (i.e., **proteolysis**) takes place between meals or in times of more extended restrictions in protein intake and functions to restore amino acid pools. Approximately 1% of total body proteins, mainly in the visceral and liver tissues, are thought to serve as the body's labile protein reserve as these tissues are the first to amass and shrink with increasing and decreasing protein intake. Brain, heart and central nervous system tissues are most resistant to proteolysis, and in longer term protein restrictions, skeletal muscle protein, and then collagen, become the primary sites of protein degradation. Tissue proteins are degraded inside of cells by lysosomal engulfment of proteins and cytoplasm, and for the majority, subsequent enzymatic proteolysis by intracellular peptidases. A portion of intracellular proteins are directed out of the cell for degradation elsewhere, such as pancreatic enzymes, which are recycled in the enterocytes of the small intestine, and some join the extracellular free amino acid pools.



In hepatic and skeletal tissues, amino acids are liberated of their nitrogen for alternate uses such as amino acid recycling, oxidative metabolism, or non-protein pathways of nitrogen utilization. In the **transamination** pathway, amino nitrogen is transferred from free amino acids in the cellular pool, to glucose-derived cell by-products, like pyruvate, to form the dispensable amino acids arginine, alanine, and glutamine. The latter two are the primary exporters of cellular nitrogen from muscles to the periphery and small intestine.



Deamination is another N transfer mechanism occurring only in the liver, whereby amino acid products aspartate and glutamate are formed by dehydration in the **purine nucleotide cycle**. Deaminated carbon skeletons are directed to the liver and either directly oxidized for ATP recycling, or they are converted to glucose, or fat if protein energy is in excess. A few amino acids can be converted to both glucose and fat, but most of the amino acids are either **ketogenic** (i.e., valine, leucine glutamine alanine) or **glycogenic**. Ketogenic amino acids enter into the TCA cycle as acetyl co A and ketone formation, whereas glycogenic amino acids are converted to glucose via gluconeogenesis. Both transamination and deamination yields ammonia, and urea, the primary nitrogen elimination solutions, as well as other nitrogen-rich urinary compounds, uric acid, and creatinine. The average sized adult excretes approximately 15 grams of nitrogen in the urine per day, which outside of intestinal and small insensible losses is equivalent to the amount the consumed.



4.3 Homework 1

Homework • Unanswered

Match each digestive compound to a protein digestion function.

Premise		Response
1 interkinase	→	C activates protein-digesting enzymes
2 di-peptidase	→	A hydrolyzes di-peptide bonds
3 pepsin	→	B hydrolyzes poly-peptide bonds
4 Hydrochloric acid	→	D denatures protein bonding and structure

Answered - Correct!

1 attempt left Retry

4.3 Homework 2

Homework • Unanswered

Watch this video and answer the question below:
https://www.youtube.com/watch?v=gG7uCskUOrA
The ______________ RNA delivers amino acids to the ______________ RNA during protein peptide synthesis

- (●) **A** transfer, messenger
- ( ) **B** deoxy, transfer
- ( ) **C** ribonucleic, deoxy
- ( ) **D** messenger, transfer

Answered - Correct!

1 attempt left Retry

4.3 Homework 3

Homework • Unanswered

What answer best explains how protein is degraded in the cell cytoplasm?

- (●) **A** lysosomal engulfment
- ( ) **B** receptor-mediated diffusion
- ( ) **C** oxidation
- ( ) **D** decarboxylation

Explanation

Correct. Cytosol and proteins are degraded by lysosomal engulfment

Answered - Correct!

1 attempt left Retry

4.3 Homework 4
Homework • Unanswered

N can be used to synthesize arginine, alanine and glutamine in this muscle and hepatic cellular process.

A Autophagy

B Transamination

C Deamination

D Catabolism

Explanation

B. Transamination

Answered - Correct!

1 attempt left Retry

4.4 Protein Function

Proteins in the diet are essential to contribute indispensable amino acids that can be broken down by the body and used to construct new body proteins. Proteins are in every cell of the human body (50% dry matter) and perform a number of important bodily functions.

The average adult oxidizes amino acids to satisfy approximately 10-15% of their daily energy needs, which corresponds to the amount of protein calories intake. Protein oxidation yields **4 kilocalories per gram** of protein and may be increased in instances of depleted glycogen levels and in instances of tissue trauma. So, while proteins do provide a small amount of oxidized energy, a more important biological role is as building material for body proteins.

A healthy, hydrated adult is approximately 15% **structural fibrous protein.** Fibrous protein is long and narrow, generally insoluble in water because of exteriorly positioned hydrophobic side chain, and configured in a relatively repetitive amino acid sequence. The chemical composition of fibrillar protein provides **structural** and **mechanical integrity** to the muscles, skin bone and organs.

Skeletal muscles are made of **contractile proteins** (i.e., actin, myosin, and tropomyosin) are rich in carboxyl containing amino acids (i.e., histamine glutamic acid, aspartic acid) that are able to ion bind to facilitate the calcium binding action needed for muscle contraction (i.e., troponin) Contractile proteins, in conjunction with fibrous (i.e., tendons and ligaments), work to support **human locomotion**.

Connective tissue proteins are comprised of a tough fiber network that fills extracellular spaces between organs and tissues, and like skeletal muscle, they act as a reserve of amino acids that is critical to maintaining indispensable amino acid pools in times of restricted food intake. **Collagen** serves as a reserve of indispensable proline and lysine, which are converted to hydroxyproline and hydroxylysine after being integrated into collagen. Similar proteins, **hydroxyapatite** provide structure and rigidity to tissues of the bone and teeth. Other connective tissue proteins, such as **elastin**, and **keratin** provide elasticity to vessels and lung tissues, and structure to the skin, nails, and hair.

The other large majority of body proteins are functional, **globular proteins**. Globular proteins are spherical in shape and are generally soluble in water. Globular proteins are high in exteriorly positioned hydrophilic amino acids. There are many types of functional proteins that are critical in regular bodily functioning, including but not limited to **enzyme** catalysts (lipase, protease, sucrase, trypsin, etc.), signaling and communications **hormones** (insulin, glucagon, CCK, growth hormones of pituitary and parathyroid), and **antibodies** that fight infection. The role of protein in immunity is important as proteins make WBC produced immunoglobulins that identify and flag foreign proteins for destruction, and also anti-clotting proteins like fibrinogen.

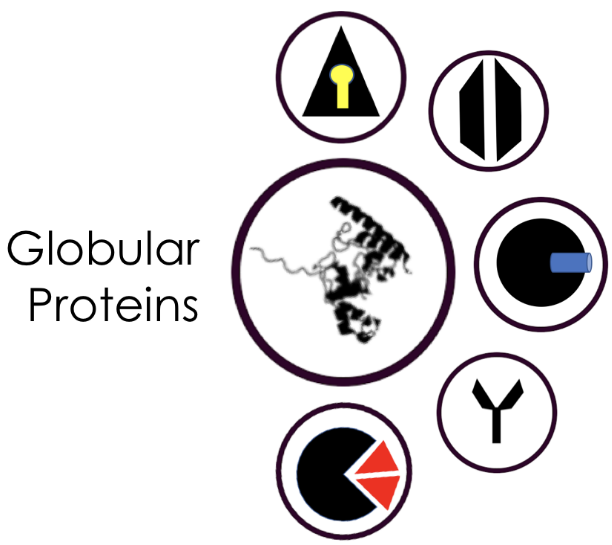


Figure 4.16. Globular Protein Functions

Proteins are also functional **transporters.** Cell membrane proteins are carrier and pump structures that contain neutral/charged amino acids that are exteriorly positioned. The ionic exchanges that occur in the cellar protein pumps also play a critical role in maintaining the slightly alkaline blood and intracellular **pH level**. Serum proteins (i.e., albumin, transferrin, hemoglobin, lipoproteins) also function to maintain body pH levels, by removing excess hydrogen while simultaneously delivering nutrients and oxygen to cells. Transport proteins, along with membrane and intracellular proteins (i.e., myoglobin) are also critical in maintaining the **water balance** between body compartments as the osmotic pressure from large proteins attracts water from cells and capillary spaces back to the bloodstream.

Many protein-containing and non-protein substances that are critical to body function are reliant on dietary protein and amino acids. For instance, the hemoglobin precursor, porphyrins, is made of glycine, an iron-binding amino acid. Amino acids are also the metabolic intermediates in biosynthetic pathways of many important **neurotransmitters** (gamma-amino-butyric acid (GABA). Tryptophan is a precursor of the neurotransmitter serotonin; Tyrosine (and its precursor phenylalanine) are precursors of the catecholamine neurotransmitters dopamine, epinephrine and norepinephrine and various trace amines. Phenylalanine is a precursor of phenethylamine and tyrosine in humans. Arginine is a precursor of **nitric oxide**, Ornithine and S-adenosylmethionine are precursors of polyamines. Aspartate, glycine, and glutamine are precursors of **nucleotides** for DNA and RNA (i.e., purines, pyrimidines).

4.5 Protein Status Measures

As cellular proteins are in a constant state of turnover and adaptation, exogenous protein is critical. **Protein homeostasis** is maintained in the body when protein and nitrogen intake are equal to protein and nitrogen utilization and losses.

The acute and long-term effects of exceeding and restrictive protein intake is most commonly assessed in the urine and the serum. Urinary nitrogen is the fastest and most reliable indicator of **protein nitrogen status**. If N levels in the urine are higher than the nitrogen levels consumed in the diet, the body is in a negative N balance. A **negative nitrogen balanc**e is indicative of a catabolic state whereby body tissue degradation (i.e., proteolysis) is more rapid than the rate of protein synthesis. Imbalances in protein turnover and N balance can occur as a result of serious burns, injuries, diseases that affect renal protein and nitrogen losses. In longer-term restrictions in protein intake, lasting more than 7-10 days, N levels re-equilibrate as the body adjusts to fat-derived ketones as a primary fuel source.

Protein deficiency can occur as a result of reduced dietary intake, or from increased protein losses or needs. The most common biochemical measures of protein status that are used in clinical settings are serum proteins. **Albumin** is the most sensitive serum protein for measuring acute protein status (up to 24 hours), and acute protein loss. Clinical proteinuria is characterized by a more than tenfold increase in urinary albumin excretion. (a normal healthy adult excretes around 30mg of urinary albumin per, whereas clinical proteinuria results in losses exceeding 300mg day). In longer-term protein deficiencies, protein-calorie malnutrition (PCM) or protein-energy malnutrition (PEM) occurs. PEM is a major problem in hospitals in patients of all ages who have an injury or illness that has increased needs for protein beyond what can be sustained by dietary intake. A more appropriate indicator of protein status for restrictions lasting more than 7-10 days is transferrin, valued for its longer half-life and concomitant assessment of iron status.

Substantial changes in plasma and cellular proteins occur within one to two days of restricted protein intake (depending on the level of restriction). When concentrations of serum proteins begin to fall, whether as the result of reduced intake or increased degradation and subsequent integration into other higher priority building orders, the water begins to collect in capillary spaces. Without proteins to create pressure gradients that keep the solute: solvent balance. The pooling of water in capillary spaces manifests into a **clinical** condition called **edema.** Edema is characterized by swelling that causes pitting or an indentation that stays even after removing pressure. This symptom can be used in combination with other visual assessments to diagnose severe, long-term (30+ days) protein deficiencies such as marasmus and kwashiorkor, which are relatively uncommon in the US. In protein deficiency diseases like these, the other clinical symptoms of protein deficiency include dull and thinning skin from declining collagen, thinner hair that stops growing due to lack of lower-priority keratin, and most evident on the short-term, significant reduction in lean body mass. Anthropometric measurements to gauge **lean mass losses** range in sophistication and precision. Commonly in clinics, **mid-upper arm circumference** – which can reflect a 30-60-day protein deficiency. Other significant clinical outcomes of protein deficiency include a higher risk of infection (less immune proteins) and lesser resistant gut mucosa.

Like with inadequate protein intake, **excessive protein intake** can also result in biochemical and anthropometric changes. Firstly, excess amino acids that are converted to fatty acids result in increases in **body fat** and serum lipoprotein (i.e., cholesterol levels). Since the carbon skeletons that are converted to fatty acids are liberated of nitrogen, nitrogen balance is maintained. (While amino acids can also be converted to glucose, these are in times of energy and carbohydrate restriction specifically). In instances of growth or mechanically induced cellular trauma, an immune response elicits growth hormones to synthesize body proteins. When protein and amino acids levels are surpluses of regular metabolic requirements, new body proteins retain N, thus urinary nitrogen output is reduced and **nitrogen balance is positive**. On the contrary, **creatinine,** a byproduct of powerful hypoxic muscle contractions increases in the urine when protein intake is adequate, and the tissue is in favor of anabolism (i.e., muscle protein synthesis). While creatinine isn't a great measure of protein status per se, it is reflective of changes in muscle mass and use of the muscle-exclusive phosphocreatine system. Other less direct indicators of positive protein status include skeletal muscle hypertrophy and hyperplasia, which can be measured by muscle diameter, thickness, and even mechanical power (i.e., 1 RM).

Ingesting one amino acid or a particular group of amino acids that use the same carrier system may create, depending on the amount ingested, a competition between the amino acids for absorption. Peptides from natural whole protein are more balanced and provide a more appropriate proportion of each amino acids, and this balance minimizes the possibility of impaired or **imbalanced amino acid absorption**. In addition, excessive levels of whole protein and single amino acids may result in chronic **kidney dysfunction.**