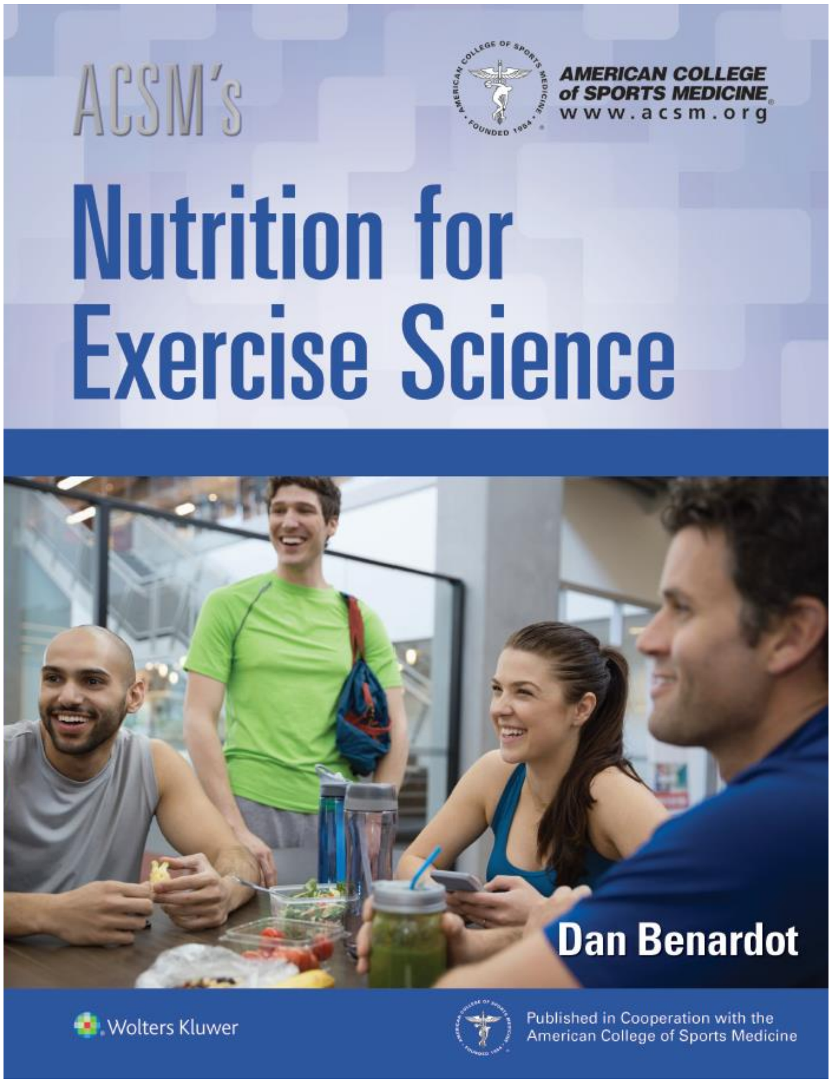

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CHAPTER 3

Protein

CHAPTER OBJECTIVES

- Understand the differences between essential amino acids and nonessential amino acids and the primary functions of the essential amino acids.
- Be capable of calculating the daily protein requirement for yourself and for others, both athlete and nonathlete, and to calculate the optimal distribution of the protein to optimize tissue utilization.
- Know the health risks associated with consumption of too much or too little protein and how other energy substrates help to "spare" protein so that it can be used anabolically.
- Explain how proteins are digested and absorbed, including the location and source of the major protein digestive enzymes.
- Understand protein energy metabolic pathways, and the by-products produced when proteins are used as a source of cellular energy.
- Know how supplements of amino acids and other protein-related substances, such as creatine monohydrate, may have an impact on health risks and performance.
- Understand how the presence and distribution of essential amino acids influence protein quality.
- Recognize the primary functions of proteins as they relate to immunity, tissue structure, hormones and enzymes, transportation, and fluid balance.
- Discriminate between food sources that are good sources of high-biologic-value (BV) protein and food sources that are moderate to poor sources of high BV protein.
- Determine foods that, when combined, can improve the protein quality to a level better than if these foods were consumed individually.
- Identify the common methods used for determining the protein quality.
- Describe the factors that are involved in improving muscle mass size and function.

Case Study: Lots of Protein but Poor Delivery Inhibits Benefits

T.J. was a massive freshman defensive guard on his college football team, and he learned from the very beginning, when he was playing football in the Pop Warner league as a 6-year-old, that lots of protein was needed to ensure he could grow and build the muscle needed for a career in football. He was already bigger, heavier, and taller than nearly all of the other players, but he wanted to be bigger still, even as a youngster. So, he ate lots of food and made sure that a high proportion of it was protein. Steak and chicken were his favorite, but he ate fish when his mother made it. He did not care much for veggies, but that did not matter much to him because he "knew" that protein would get him where he wanted to go.

The massive amount of food T.J. ate did help him get bigger, but as a collegiate athlete there was a great deal more being asked of him than ever before. His coach also wanted him to be fast and be able to play as hard in the fourth quarter as he did in the first. Right away, the defensive coach saw a problem: T.J. was certainly big, but he was not as quick as he should be and his endurance was terrible. The coach put him on a more severe training regimen to build his strength, quickness, and endurance. Of course, T.J. did what he thought he needed to do, and that was to increase his protein intake, but it did not help. T.J. kept getting fatter from all the extra food he was consuming, but the extra fat he was carrying around made him slower and his endurance kept getting worse. So, they sent him to talk with the sports nutritionist who just started working with the university teams, and the nutritionist immediately found the problem. T.J. was consuming a huge amount of protein, but at the expense of carbohydrate. To make matters worse, his intake of food, including protein, was not spread out well throughout the day. He mainly had two large meals: breakfast and a late dinner, and nearly nothing in-between. This type of eating pattern is associated with many problems that made it difficult to build muscle but easy to store fat. The nutritionist showed him that the typical daily requirement for an athlete is 1.2–2.0 g/kg/day, which is ideally consumed by providing moderate amounts of protein spread out during the day and following a strenuous training session. T.J. was consuming a great deal more protein than the requirement, and he was not distributing it well throughout the day to optimize his body's capacity to use it efficiently for building and repairing muscle. So, the nutritionist showed him how to have seven eating opportunities (breakfast, mid-morning snack, lunch, afternoon snack, dinner, evening snack, and bedtime snack), with about 30 g of protein each time both to provide the recommended level of intake and to optimize protein utilization. Almost immediately T.J. saw the difference. His body fat was decreasing and his muscle mass was increasing. He learned one of the secrets of nutrition: It is not just how much you eat, but how and when you eat it that matters most.

CASE STUDY DISCUSSION QUESTIONS

1. Calculate the protein in your diet to see if you are consuming an amount that satisfies need, and that you are distributing the protein in a way that would optimize protein utilization.
2. Is it likely that active people who eat the standard three meals/day could distribute protein intake in a way that could enable optimal protein utilization?
3. What happens to the excess protein consumed? List the potential problems that may arise from this.
4. How would you set up an athlete environment to help ensure that the athletes could consume foods in a pattern that would be most useful?

Introduction

Important Factors to Consider

- There is limited evidence that increasing protein consumption above the recommended intake levels as a means of improving musculature is a useful strategy and it may cause problems with kidney health, dehydration, and low bone mineral density. In addition, high-protein intake interferes with a balanced intake of other foods/nutrients.
- It is far better to consume the recommended level of protein in amounts that can be efficiently used by tissues, especially when the athlete's energy intake level is satisfied with sufficient intake of carbohydrates and fats.
- Consumption of single amino acids for the purpose of initiating a desired metabolic outcome (*i.e.*, greater muscle acquisition) may be associated with problems that could interfere with the desired outcomes (*i.e.*, muscle protein synthesis [MPS], reduced muscle soreness, improved muscle repair) and is not likely to be a successful strategy.
- It is far better to eat foods that contain a wide array of essential amino acids to ensure an adequate energy intake and to allow tissues to acquire the amino acids they require for metabolic purposes. It is easy to get too much of a single amino acid that may result in the opposite of the desired effect. For instance, the **branched-chain amino acid** (BCAA) leucine is known to be a MPS stimulator, and studies suggest that 20 g of good-quality protein containing leucine has been found to maximally stimulate MPS.

Branched-Chain Amino Acids

The amino acids isoleucine, valine, and leucine that can be metabolized locally in muscle tissue and that promote MPS and are involved in glucose metabolism.

Proteins are one of the energy substrates (with carbohydrates and fats), meaning that we are capable of producing adenosine triphosphate (ATP, or energy) from protein molecules, primarily through their conversion to carbohydrate and fat. Besides this energy-producing capacity, however, proteins have many other critical functions that require consideration. Many physically active people consider

Proteins

Molecules consisting of multiple amino acids held together by peptide bonds in a sequence and structure that influence protein function.

protein consumption to be the key to athletic performance success, and even a cursory review of the magazines and other literature targeting athletes demonstrates this point, with advertisements for protein supplements and protein-added foods that are intended to, ultimately, enhance winning potential. Often, physically active people consume far more protein than is needed, and an obvious problem with excess protein consumption is that this necessarily translates into consuming too little of other nutrients that are equally important (6). There is evidence that consuming ~30 g protein in a single meal maximally enhances MPS in both young and elderly subjects, suggesting that higher protein meals (*i.e.*, those providing more than 30 g protein) may fail to produce greater muscle enlargement (29, 71). In addition, high-protein consumption may displace carbohydrate, which is well established as the optimal fuel for all sporting endeavors, ranging from endurance to short-duration, high-intensity events (6, 56, 73). In addition, although physically active people often consume far more protein than body tissues can use to fulfill nonenergy anabolic (*i.e.*, MPS) requirements, the manner in which this protein is consumed may inhibit the utilization of the consumed protein (52). Poor protein utilization will result in at least a portion of the protein having the nitrogen removed and converted to fat and carbohydrate to be used or stored as fuel. Although it is clear that athletes may have a requirement that is more than double the requirement of nonathletes (1.2–2.0 vs. 0.8 g/kg/day), the manner in which the protein is consumed is important, as is the equal importance on seeking a balanced intake that exposes athletes to all of the nutrients they require. This chapter will review food sources of protein, protein functions, protein requirements, and eating patterns that can help derive the most out of the protein being consumed. There are many questions that this chapter will answer, including:

- Does increasing protein intake beyond a certain level help to increase muscle mass?
- Does supplemental or high-protein intake provide an ergogenic (performance-enhancing) benefit?
- Does supplemental or high-protein intake improve strength and power?
- Is there evidence that, when normalized on a protein/kg basis, athletes tend to overemphasize protein to the detriment of other nutrients?

Structure of Protein

Proteins are made of amino acids, which contain carbon, oxygen, hydrogen, and nitrogen (Figure 3.1).

Of the energy substrates, only protein contains nitrogen. The nitrogen content of proteins is an important consideration because when proteins are broken down to be used for energy or stored as fat, this nitrogen must be removed from the protein molecule, and this nitrogen waste is potentially toxic and must be removed from body tissues. The nitrogenous waste produced from protein breakdown produces toxic compounds, which must be excreted via the kidneys using a large dilutional water volume for this excretion (Figure 3.2).

Blood Urea Nitrogen

Blood urea nitrogen (BUN) is a measure of the urea nitrogen content in the blood that mainly represents the nitrogen released from the metabolism of protein. It is from the waste product urea. Urea is produced when amino acids are catabolized and the carbon chain is used to supply energy or stored as fat. The nitrogen removed from the amino acid forms urea, which is removed from the body via urine.

Urine

Urine is a liquid produced by the kidneys to excrete the by-products of metabolism. A primary function of urine is to excrete nitrogenous waste (urea) that is a by-product of protein catabolism. High-protein diets that exceed the tissue capacity to use the protein anabolically result in protein catabolism and higher nitrogenous waste that must be excreted via urine.

Amino acids are the building blocks of protein, with several amino acids held together to form **polypeptides** and several polypeptides held together to form a protein. There are 20 different amino acids, and humans can manufacture 11 amino acids by using the nitrogen discarded by the breakdown of proteins and the carbon, hydrogen, and

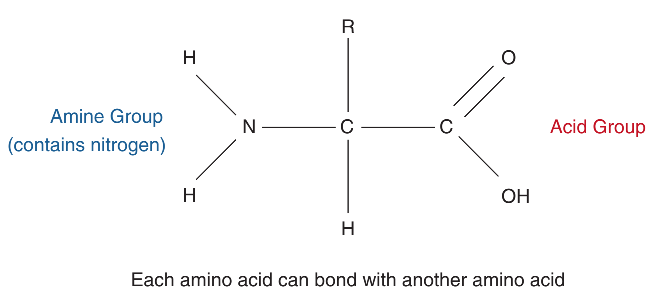

FIGURE 3.1: Basic structure of an amino acid, the building block of proteins.

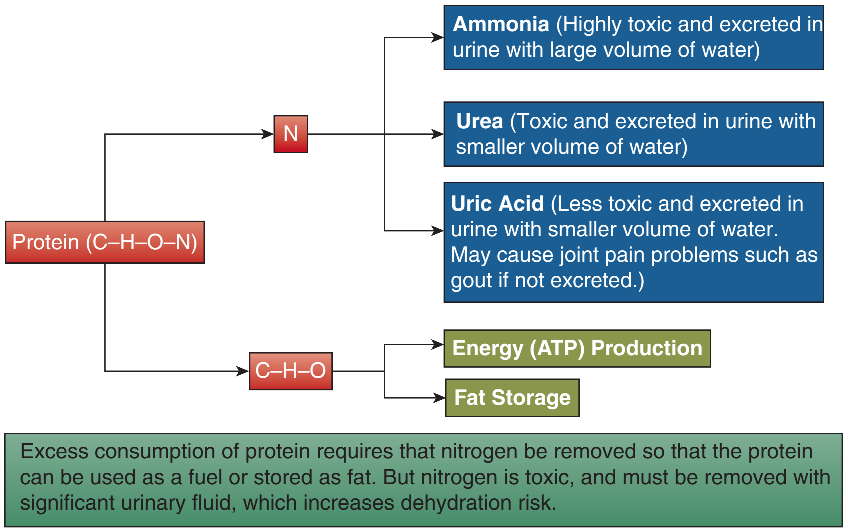

FIGURE 3.2: Protein breakdown and nitrogen excretion. ATP, adenosine triphosphate

oxygen available from carbohydrate. The 11 amino acids that we can manufacture are referred to as nonessential or dispensable amino acids, because it is *not essential* that we obtain them from the foods we consume since they can be manufactured. However, do not misinterpret nonessential as meaning unimportant, as these nonessential amino acids are just as metabolically important as the nine **essential amino acids**, which we cannot manufacture and must be obtained from the foods we consume (Table 3.1).

To make proteins, amino acids are held together via peptide bonds, where the acid end of one amino acid connects with the nitrogen of another amino acid and, in the process, water is formed (Figure 3.3). The sequence of how these amino acids are connected determines the function of the protein. So, although a protein may contain the same amino acids, how they are ordered will determine what the protein will do.

Amino Acids

Organic compounds characterized by an amine group (NH_2) on one end of the molecule and a carboxyl group (COOH) on the other end of the molecule. Amino acids are held together in different sequences to compose polypeptides and proteins.

Polypeptide

A molecule consisting of a chain of amino acids held together by peptide bonds. The molecule is too small to be called a protein.

Essential Amino Acids

Amino acids that humans are incapable of synthesizing from other amino acid skeletons, making it essential that they be in consumed foods. Essential amino acids are also referred to as indispensable amino acids.

Table 3.1 Essential and Nonessential Amino Acids

Nonessential Amino Acids (Synthesized by humans from carbohydrate and fragments of other amino acids)			Essential Amino Acids (Cannot be synthesized by humans, so must be consumed from foods)		
Amino Acid	**Abbr**	**Notes**	**Amino Acid**	**Abbr**	**Notes**
Alanine	Ala	Can be converted to glucose in the liver (gluconeogenesis) via the alanine–glucose cycle **(Glucogenic)**	Histidine	His	Unlike the other essential amino acids, does not induce a protein-deficient state (negative nitrogen balance) when removed from the diet. Involved in production of histamine (Glucogenic)

(*continued*)