

Introduction to Proteins and Amino Acids

This lecture is the introduction to the proteins unit. In this unit we will describe some of the important functions of protein and their constituent amino acids including why some amino acids are essential (or conditionally essential), how they are interconverted and how they are used for energy. Amino acids also are the precursors for many other important biological molecules, so we will discuss these non-protein functions of amino acids as well.

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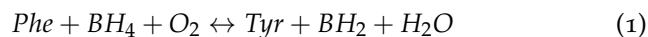
Learning Objectives

- Apply your knowledge of amino acid biochemistry to explain why proteins are essential macronutrients
- Understand the basic structure of protein
- Identify the property that makes an amino acid different from another
- Describe different functional roles of protein
- Identify the major proteins present in food
- Differentiate between the different classifications of amino acids
- Understand how nonessential amino acids can become essential
- Explain the nutritional requirements of collagen synthesis

Proteins, Amino Acids and Essentiality

Glucose and other carbohydrates are not strictly essential. As we described in the unit on gluconeogenesis, we can generate glucose even if dietary supplies are low or absent. The same is not true for proteins, which are macromolecule comprised of amino acids. While plants, bacteria and fungi can often synthesize their own amino acids, during evolution we have lost the ability to make certain amino acids (see Table 1). Since most proteins consist of at least some of each of the amino acids that means that we cannot generate new proteins unless we have a dietary supply of the essential amino acids. In this context, dispensible means that we can make these amino acids from other fuels in our body, such as glucose¹. Essential means that we must get those amino acids in our diet.

WHEN WE SAY THAT AN AMINO ACID IS CONDITIONAL, that means that we need another amino acid in order to make that amino acid. For example, we can make Tyrosine, but only if we have sufficient amounts of Phenylalanine as catalyzed by the enzyme phenylalanine hydroxylase²:



Recommended Protein Intake

The USDA recommends increasing protein levels over the lifespan (see Table 2), but suggests a wide range where <35% of calories are

Table 1: Amino Acid Essentiality.

Dispensible	Essential	Conditional
Ala	Phe	Arg
Asp	Trp	Tyr
Asn	Thr	Cys
Glu	Ile	Pro
Gly	Met	Gln
Ser	Val	
	Leu	
	His	
	Lys	

¹ Recall from the glycolysis lecture that pyruvate can be converted to alanine as part of the Cahill cycle.

² BH₄ in this equation indicates tetrahydrobiopterin, a cofactor for this reaction.

from protein. From an essentiality perspective, the amounts of each amino acid needed from the diet depend on the amino acid content of the food. As an example, legumes (beans and nuts) tend to be low in the amino acid methionine while grains often contain low levels of lysine. When thinking about an appropriate protein amount, two things are important; are there sufficient dietary levels of the essential amino acids, and if protein levels are low are calories coming from lipids or carbohydrates.

Diseases of Protein Malnutrition

In the developed world, protein deficiency is rare, however in some developing nations protein deficiency is a major public health problem. Protein deficiency can present in two main ways, *kwashiorkor* which is a deficiency of protein, but an acceptable total calorie intake; and *marasmus* which is a deficiency of both protein and calories. Protein deficiencies can lead to impaired physical and mental development, fatty liver, hair loss and characteristic distended abdomen.

Protein Storage and the Amino Acid Pool

BRANCHED-CHAIN AMINO ACIDS ARE SPECIAL SUBGROUP OF ESSENTIAL AMINO ACIDS.

Major Proteins in Human Nutrition

There are many thousands of different proteins, each of which have different synthetic requirements and nutritional components. However, some proteins are much more abundant in the food we eat, or in our bodies. Some of the major proteins we will discuss are collagen, actin and myosin. In terms of amino acids, collagen is particularly enriched in glycine proline and hydroxyproline.

Whey

Casein

Pea Proteins

Collagen

Collagen is a triple helical protein that makes up much of our connective tissue³. Collagen is also a major component in ligaments, tendons and the skin. Collagen is the most abundant protein mammals, making up 25-35% of the whole body content. Collagen has

Table 2: Acceptable Macronutrient Distribution Range (AMDR) for protein intake over the lifespan in percent of calories (from [U.S. Department of Health and Human Services and U.S. Department of Agriculture., 2015]).

Age	Amount
1-3	5-20
4-19	10-30
19+	10-35

³ Connective tissue includes the extracellular matrices that hold cells in place

quite a unique amino acid composition, with extremely high levels of both proline and hydroxyproline. Collagen synthesis is especially important during growth, wound healing and tissue remodelling.

HYDROXYPROLINE IS NOT ONE OF THE STANDARD AMINO ACIDS.

It is synthesized from the conditionally essential amino acid Proline⁴ via the enzyme *Proline hydroxylase*. Collectively proline and hydroxyproline comprise about a third of the weight of collagen [Bowes and Kenten, 1948]. The conversion of Proline to Hydroxyproline occurs post-translationally, meaning that collagen is translated first, then the reaction occurs on the already assembled protein. Proline hydroxylase requires Vitamin C (also known as ascorbate) to catalyze the reaction. The instability of collagen due to Vitamin C deficiency is the biochemical basis of scurvy⁵.

⁴ Proline can be generated from Arginine, so is therefore conditionally essential on arginine levels.

⁵ James Lind. *A Treatise of the Scurvy in Three Parts. Containing an Inquiry into the Nature, Causes and Cure of that Disease, Together with a Critical and Chronological View of what has been Published on the Subject*. London, 1753

References

J H Bowes and R H Kenten. The amino-acid composition and titration curve of collagen. *The Biochemical journal*, 43(3):358–65, 1948. ISSN 0264-6021. URL <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1274697&tool=pmcentrez&rendertype=abstract>.

James Lind. *A Treatise of the Scurvy in Three Parts. Containing an Inquiry into the Nature, Causes and Cure of that Disease, Together with a Critical and Chronological View of what has been Published on the Subject*. London, 1753.

U.S. Department of Health and Human Services and U.S. Department of Agriculture. Dietary Guidelines for Americans 2015-2020. Technical report, 2015. URL <http://health.gov/dietaryguidelines/2015/guidelines>.