Nutrition: A Functional Approach

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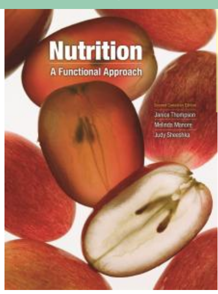


Proteins: Crucial Components of All Body Tissues

What Are Proteins?

Proteins: large complex molecules composed of amino acids.

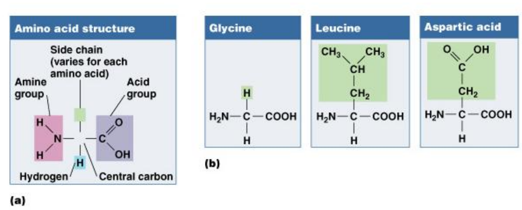
- Contain carbon, hydrogen, oxygen, nitrogen
- Structure is under the regulation of DNA
- Primary source of nitrogen in our diets
- 20 different amino acids are used to make proteins

What Are Proteins?

Proteins

- Critical components of bones, blood, hormones
- Enzymes
- Antibodies

Amino Acids



Amino Acids

Essential amino acids

- Cannot be produced by our bodies
- Must be obtained from food

Nonessential amino acids

- Can be made by our bodies
- Made by transferring amino groups (transamination)

Amino Acids

Table 6.1 Amino Acids of the Human Body

Essential Amino Acids	Non-Essential Amino Acids
These amino acids must be consumed in the diet.	*These amino acids can be manufactured by the body.*
Histidine	Alanine
Isoleucine	Arginine
Leucine	Asparagine
Lysine	Aspartic acid
Methionine	Cysteine
Phenylalanine	Glutamic acid
Threonine	Glutamine
Tryptophan	Glycine
Valine	Proline
	Serine
	Tyrosine

Amino Acids

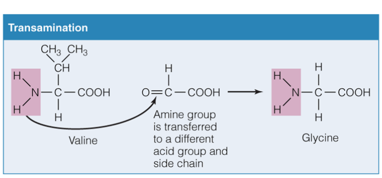


Figure 6.2 Transamination. Our bodies can make non-essential amino acids by transferring the amine group from an essential amino acid to a different acid group and side chain.

Amino Acids

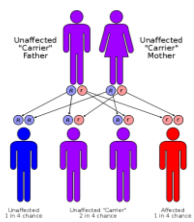
Under some conditions, a non-essential amino acid can become an essential amino acid.

Conditionally essential amino acid

Examples: tyrosine when patients are diagnosed with phenylketonuria, glutamine in patients with advanced liver disease.

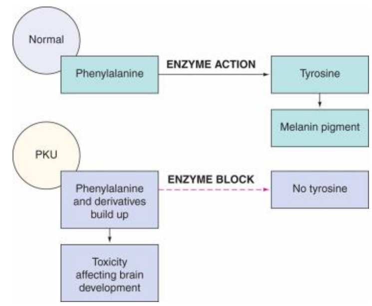
Phenylketonuria

- Genetic autosomal recessive disorder.
- Mutation of the gene for the hepatic enzyme phenylalanine hydroxylase (PAH).
- Inability to convert phenylalanine to tyrosine.



- 25% chance: both parents will pass on the defective gene → child will be born with PKU.
- 50% chance: child will inherit one defective gene from one parent and the normal gene from the other → child is a carrier like the parents.
- 25% chance: both parents will pass on the normal gene → child will not have the disease or be a carrier.

Phenylketonuria



Phenylketonuria

Signs and Symptoms:

- Lighter skin, hair, and eyes
- Delayed mental and social skills
- Head size significantly below normal
- Hyperactivity
- Jerking movements of the arms or legs
- Mental retardation
- Seizures
- Skin rashes
- Tremors
- Unusual positioning of hands

How Are Proteins Made?

Proteins are long chains of amino acids.

Amino acids are joined to each other by peptide bonds.

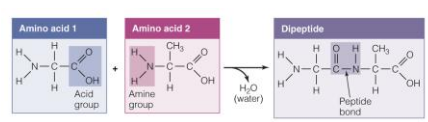
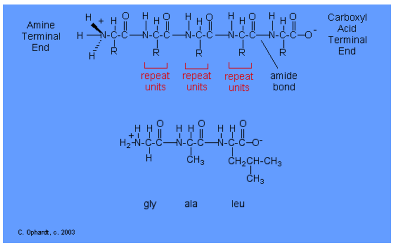


Figure 6.3 Amino acid bonding. Two amino acids join together to form a dipeptide. By combining multiple amino acids, proteins are made.

How are Proteins Made?



http://www.elmhurst.edu/~chm/vchembook/565proteins.html

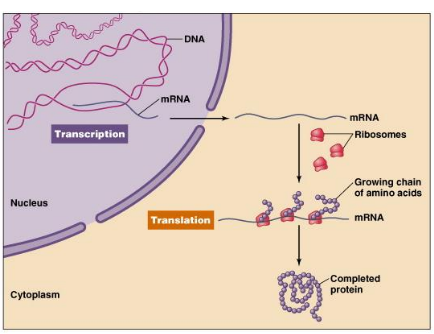
How Are Proteins Made?

The structure of each protein is dictated by the DNA of a gene.

Transcription: use of the genetic information in DNA to make messenger RNA (mRNA).

Translation: conversion of genetic information in mRNA to a chain of amino acids to form a protein.

How Are Proteins Made?



Proteins in the Diet

Incomplete protein: does not contain all essential amino acids in sufficient amounts.

- Not sufficient for growth and health
- Considered a "low quality" protein

Complete protein: contains sufficient amounts of all 9 essential amino acids.

- Considered a "high quality" protein

Proteins in the Diet

Mutual supplementation: using two incomplete proteins together to make a complete protein.

Complementary foods: protein sources (foods) that together supply all 9 essential amino acids.

- Example: beans and rice

Complete Protein Sources

Complete Protein Sources	Incomplete Protein Sources
Whey	Vegetables
Casein	Fruits
Milk	Rice
Eggs	Grains
Beef	Oats
Cheese	Nuts
Chicken	Pasta
Fish	Bread
Yoghurt	Sunflower Seeds
Cottage Cheese	
Turkey	

Complementary Food Combinations

Table 6.2 Complementary Food Combinations: Turning Incomplete Proteins into Complete Proteins

Food	Limiting Amino Acid	Foods High in Limiting Amino Acid	Complementary Food Combination
Legumes	Methionine and cysteine	Grains, nuts, and seeds	Rice and lentils Red beans and rice Rice and black-eyed peas Hummus (chickpeas and sesame seeds)
Grains	Lysine	Legumes	Peanut butter and bread Barley and lentil soup Corn tortilla and beans
Vegetables	Lysine, methionine, cysteine	Legumes (lysine), grains, nuts, and seeds (methionine and cysteine)	Tofu and broccoli with almonds Spinach salad with pine nuts and kidney beans

Protein Quality

Two factors determine quality:

1. Amount of essential amino acids
2. Protein digestibility
   - Animal foods are highly digestible
   - Soy foods are highly digestible
   - Legumes are highly digestible
   - Other plant foods are less digestible

Measure of Protein Quality

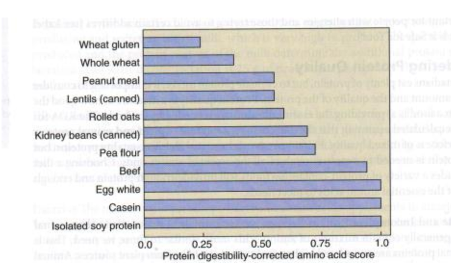
Table 6.3 Measures of Protein Quality

Chemical or Amino Acid Score =	$\frac{\text{mg of limiting amino acid per g of test protein}}{\text{mg of limiting amino acid per g of reference protein}} \times 100$
Protein Digestibility-Corrected Amino Acid Score (PDCAAS) =	amino acid score × digestibility factor
Protein Efficiency Ratio (PER) =	$\frac{\text{wt gain when fed test protein}}{\text{wt gain when fed reference protein}}$
Net Protein Utilization (NPU) =	$\frac{\text{nitrogen retained}}{\text{nitrogen consumed}} \times 100$
Biological Value (BV) =	$\frac{\text{nitrogen retained}}{\text{nitrogen absorbed}} \times 100$

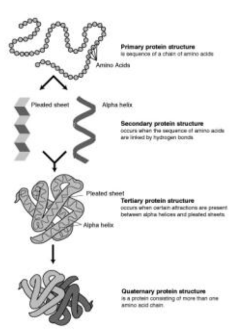
Protein Quality

Protein digestibility-corrected amino acid score: measurement of protein quality that considers the balance of essential amino acids AND digestibility of the protein in the food.

Measure of Protein Quality



Protein Shape



http://keartine.blogspot.ca/2009/09/paulings-pleated-sheets.html

Protein Shape Determines Function

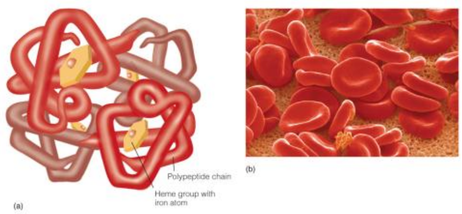
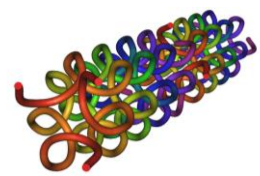


Figure 6.5 Protein shape determines function. (a) Hemoglobin, the protein that forms red blood cells, is globular in shape. (b) The globular shape of hemoglobin results in red blood cells being shaped like flattened discs.

Protein Shape Determines Function

Collagen

- Most abundant protein in mammals.
- Found in tendons, ligaments, skin, cornea, cartilage, bone, blood vessels, gut



Amino Acids

Denaturation: permanent change in shape of proteins.

Function is lost.

Heat, acids, bases, alcohol, damaging substance cause denaturation.

Examples: egg whites when whipped, curdling of milk when lemon juice is added, when we digest proteins.

Digestion of Proteins

Digestion of proteins begins in the stomach.

- Hydrochloric acid breaks down protein structure (denatures)
- Hydrochloric acid converts inactive enzyme, pepsinogen, into its active form, pepsin.

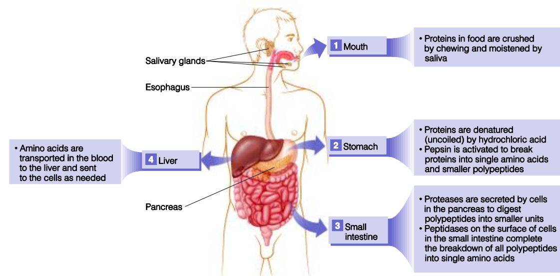
Pepsin: an enzyme that breaks down proteins into short polypeptides and amino acids.

Digestion of Proteins

Digestion of proteins continues in the small intestines.

- Pepsin is active in the neutral pH of the small intestine.
- Pancreatic enzymes called proteases break proteins into smaller polypeptides.
- Intestinal enzymes called peptidases complete the digestion of proteins into single amino acids.

Digestion of Proteins



Functions of Proteins

- Cell growth, repair, and maintenance
- Enzymes
- Hormones
- Fluid and electrolyte balance
- pH balance
- Antibodies to protect against disease
- Energy source

Protein as Enzymes

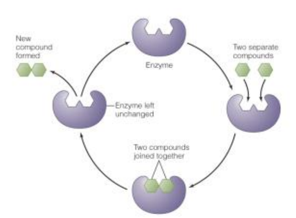
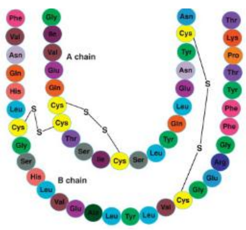


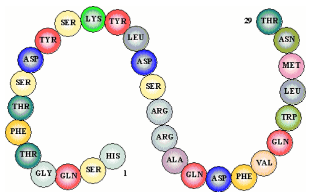
Figure 6.7 Proteins act as enzymes. Enzymes facilitate chemical reactions, such as joining two compounds together.

Protein as Hormones

Insulin



Glucagon



Protein as Transporters

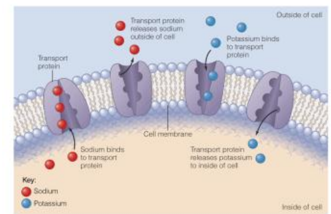


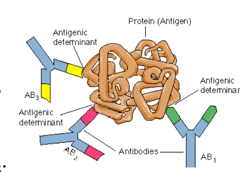
Figure 6.8 Transport proteins help maintain electrolyte balance. Transport proteins in the cell membrane pick up potassium and sodium and transport them across the cell membrane.

Protein Deficient Conditions

Proteins and the Immune System

Antigens and antibodies are proteins

- Body produces antibodies to defend against foreign invaders (antigens)
- Antigens: bacteria, viruses, allergens
- Inadequate protein = ↓ resistance to illness and disease
- Increased protein intake above needs: **does not mean** ↑ immune function



Amino Acid Pool

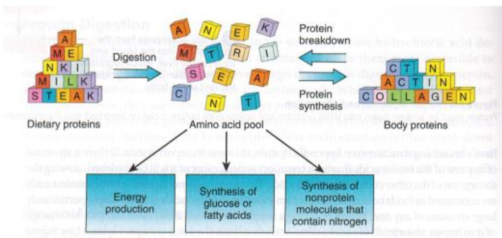


Figure 6.9 Amino acid pool
Amino acids in the available pool come from the diet and from the breakdown of body proteins. They are used to synthesize body proteins and nonprotein molecules, and to generate ATP, or to synthesize glucose or fatty acids.

Amino Acid Pool

Proteins do not have a special storage form for fuel.

Humans are efficient at recycling amino acids → protein needs are low.

When there are more amino acids than needed, the liver removes them from the blood and cleaves off the amine group = deamination.

Amino Acid Pool

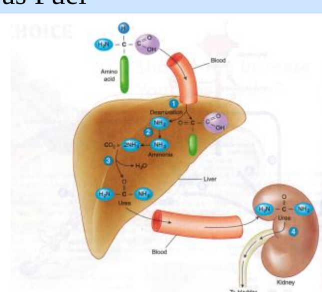
Average adult body contains 10g of protein.

6 g are involved in metabolism.

Protein pool turns over at a rate of 3-5 g/kg body weigh/day.

The degradative and synthetic reactions are estimated to account for 20% of resting metabolic rate.

Protein as Fuel



1. Amino acids are deaminated before they can be metabolized to produce ATP or used to synthesize glucose or fat.
2. The amino group forms toxic ammonia.
3. Ammonia is converted into urea in the liver.
4. Urea can safely travel in the blood and is filtered out of the blood by the kidney and eliminated from the body in the urine.

Figure 6.13 Urea Synthesis
The nitrogen from amino acid breakdown is eliminated from the body as urea.

Proteins as Fuel

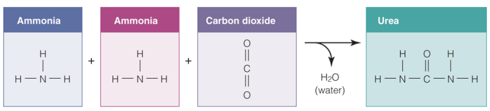
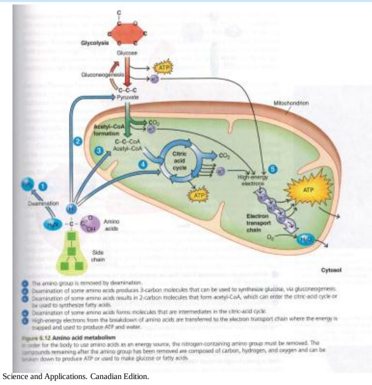


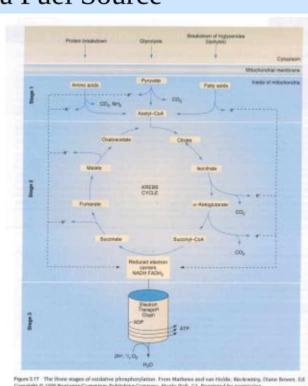
Figure 6.9 To make ammonia less toxic before it enters the bloodstream, it is combined in the liver with carbon dioxide to produce urea.

Protein as Fuel



Smolin et al. Nutrition Science and Applications. Canadian Edition.

Protein as a Fuel Source



Protein as Fuel

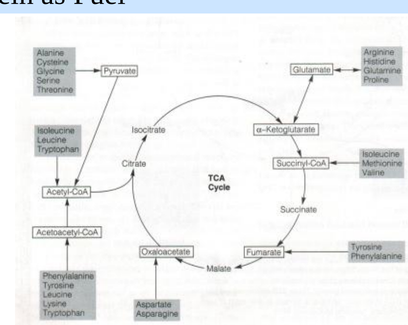
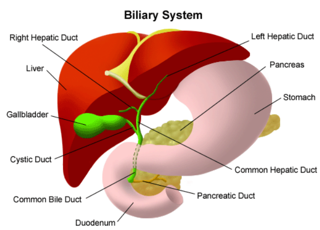


Figure 8-8 Carbon skeletons of the various amino acids gain access to the TCA cycle by various pathways. Leucine carbon enters only as acetyl-CoA.
Source: Lehninger, 1970. Used with permission.

Brooks et al. 2005. Human Bioenergetics and Its Applications.4e.

Role of Protein in Gluconeogenesis

The amazing 3 lbs. liver.



Role of Protein in Gluconeogenesis

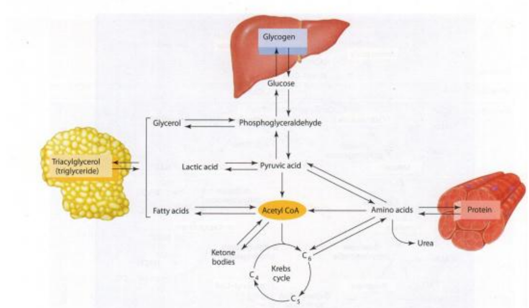


Figure 3.19 The relationships among the metabolism of proteins, carbohydrates, and fats. The overall interaction between the metabolic breakdown of these three foodstuffs is often referred to as the metabolic pool.

Role of Protein in Gluconeogenesis

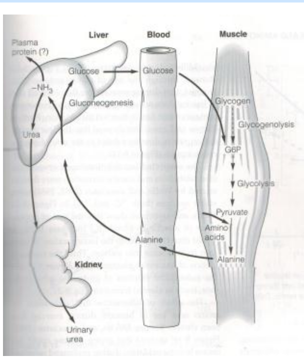


Figure 8-10 The glucose–alanine cycle as proposed by Cahill complements the Cori cycle and lactate shuttle and provides a means for transporting carbon atoms from skeletal muscle to the liver for gluconeogenesis. According to Odessey and Goldberg (1972), the branched-chain amino acids (mainly leucine) provide the nitrogen for amino acid formation in muscle. According to them, the carbon source for alanine formation is glycolytic.

Brooks et al. 2005. Human Bioenergetics and Its Applications.4e.

What Do You Think?