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BCH 445
Biochemistry of nutrition

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Proteins

Proteins:

- Protein is a vital structural and working substance in all cells.
- protein is found in meat, milk, eggs, legumes, and many grains and vegetables.
- Chemically, proteins contain nitrogen (N) atoms in addition to carbon (C), hydrogen (H), and oxygen (O). These nitrogen atoms give the name amino (nitrogen containing) to the amino acids that make the links in the chains of proteins.
- Some amino acids also contain sulfur atoms.

Functions of Proteins:

- **Body building**

  (Structural for Mechanical Support) e.g. skin, hair [keratin, collagen, elastin], membranes, muscles [myosin and actin], teeth, bones, organs, ligaments and tendons.

- **Repair and maintenance of body tissues.**
- **Maintenance of osmotic pressure [albumin].**
- **Transport and Storage [hemoglobin, myoglobin].**
- **Synthesis of biological and vital substances [enzymes, catalyze reactions – hormones, regulate metabolic reactions – antibodies (immunoglobulins), Immune functions].**

Protein As Energy

1 gm protein → 4 Calories

- **Body will transaminate/deaminate proteins to provide glucose to maintain blood glucose to the brain and to working muscles and produce energy during prolonged, strenuous exercise.**

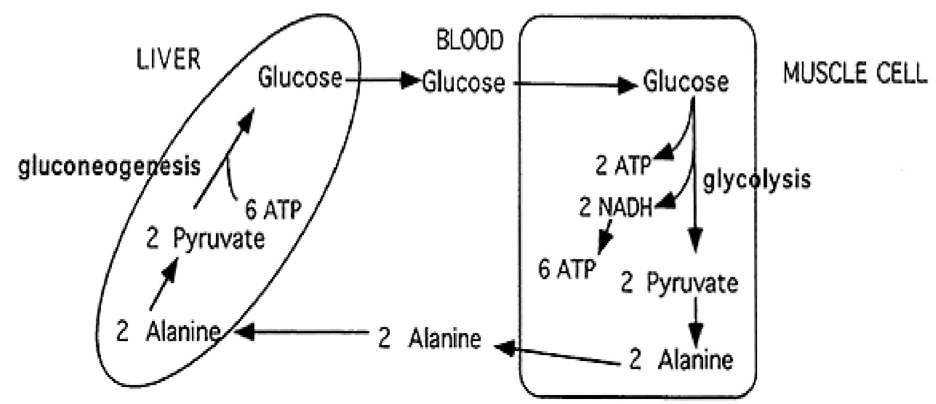
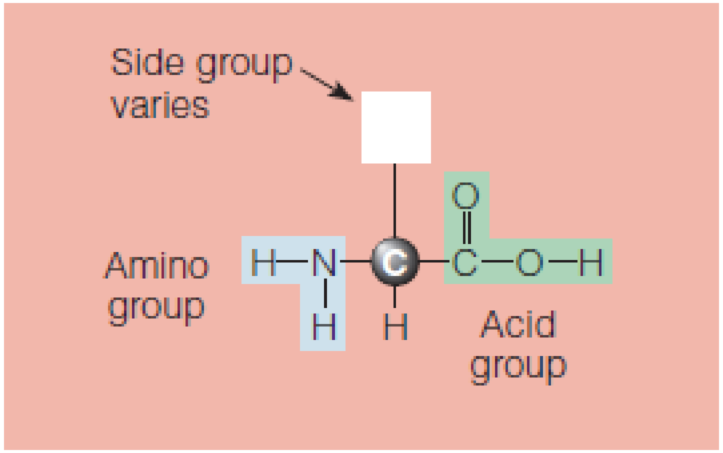


TABLE 6-3 Protein Functions in the Body

Structural materials	Proteins form integral parts of most body tissues and provide strength and shape to skin, tendons, membranes, muscles, organs, and bones.
Enzymes	Proteins facilitate chemical reactions.
Hormones	Proteins regulate body processes. (Some, but not all, hormones are proteins.)
Fluid balance	Proteins help to maintain the volume and composition of body fluids.
Acid-base balance	Proteins help to maintain the acid-base balance of body fluids by acting as buffers.
Transportation	Proteins transport substances, such as lipids, vitamins, minerals, and oxygen, around the body.
Antibodies	Proteins inactivate foreign invaders, thus protecting the body against diseases.
Energy and glucose	Proteins provide some fuel, and glucose if needed, for the body's energy needs.
Other	The protein fibrin creates blood clots; the protein collagen forms scars; the protein opsin participates in vision.

Amino Acids

- **All amino acids have a central carbon with an amino group(NH_2), an acid group (COOH), a hydrogen (H), and a side group attached.**
- **The side group is a unique chemical structure that differentiates one amino acid from another. The side groups on the central carbon vary from one amino acid to the next.**
- **A protein, is made up of about 20 different amino acids, each With a different side group.**



There are two categories of amino acids

- **Essential Amino Acids**
- **Nonessential Amino Acids**

Essential Amino Acids (indispensable)

- **The human body either cannot make at all or cannot make in sufficient quantity to meet its needs.**
- **These nine amino acids must be supplied by the diet.**

Nonessential Amino Acids (dispensable)

- **More than half of the amino acids.**
- **The body can synthesize them for itself. Proteins in foods usually deliver these amino acids.**
- **The body can make all nonessential amino acids, given nitrogen to form the amino group and fragments from carbohydrate or fat to form the rest of the structure.**

In a newborn, only five amino acids are truly nonessential; the other nonessential amino acids are conditionally essential until the metabolic pathways are developed enough to make those amino acids in adequate amounts.

Conditionally Essential Amino Acids

- **Sometimes a nonessential amino acid becomes essential under special circumstances.**
- **For example, the body normally uses the essential amino acid phenylalanine to make tyrosine (a nonessential amino acid). But if the diet fails to supply enough phenylalanine, or if the body cannot make the conversion for some reason (as happens in the inherited disease phenylketonuria, then tyrosine becomes a conditionally essential amino acid.**

Proteins are made up of about 20 common amino acids. The first column lists the essential amino acids for human beings (those the body cannot make—that must be provided in the diet). The second column lists the nonessential amino acids. In special cases, some nonessential amino acids may become conditionally essential.

Essential Amino Acids		Nonessential Amino Acids	
Histidine	(HISS-tuh-deen)	Alanine	(AL-ah-neen)
Isoleucine	(eye-so-LOO-seen)	Arginine	(ARJ-ih-neen)
Leucine	(LOO-seen)	Asparagine	(ah-SPAR-ah-geen)
Lysine	(LYE-seen)	Aspartic acid	(ah-SPAR-tic acid)
Methionine	(meh-THIGH-oh-neen)	Cysteine	(SIS-teh-een)
Phenylalanine	(fen-il-AL-ah-neen)	Glutamic acid	(GLU-tam-ic acid)
Threonine	(THREE-oh-neen)	Glutamine	(GLU-tah-meen)
Tryptophan	(TRIP-toe-fan, TRIP-toe-fane)	Glycine	(GLY-seen)
Valine	(VAY-leen)	Proline	(PRO-leen)
		Serine	(SEER-een)
		Tyrosine	(TIE-roe-seen)

*These 20 amino acids can all be commonly found in proteins. In addition, other amino acids do not occur in proteins but can be found individually (for example, taurine and ornithine). Some amino acids occur in related forms (for example, proline can acquire an OH group to become hydroxyproline).

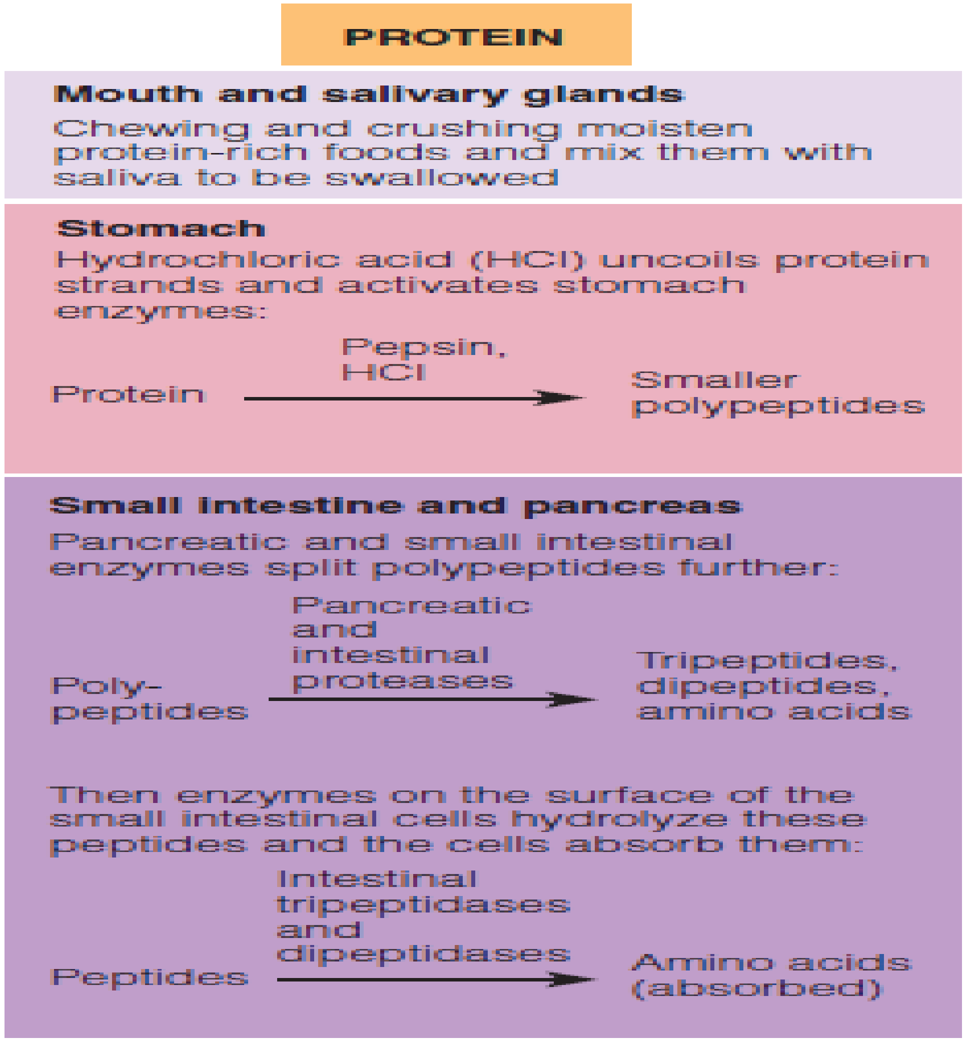
Proteins

Cells link amino acids end-to-end in a variety of sequences to form thousands of different proteins. A peptide bond unites each amino acid to the next.

Amino Acid Chains

Condensation reactions connect amino acids. Two amino acids bonded together form a dipeptide. By another such reaction, a third amino acid can be added to the chain to form a tripeptide. As additional amino acids join the chain, a polypeptide is formed. Most proteins are a few dozen to several hundred amino acids long.

Digestion and Absorption of Proteins



HYDROCHLORIC ACID AND THE DIGESTIVE ENZYMES

In the stomach:

Hydrochloric acid (HCl)
- Denatures protein structure
- Activates pepsinogen to pepsin

Pepsin
- Cleaves proteins to smaller polypeptides and some free amino acids
- Inhibits pepsinogen synthesis

In the small intestine:

Enteropeptidase
- Converts pancreatic trypsinogen to trypsin

Trypsin
- Inhibits trypsinogen synthesis
- Cleaves peptide bonds next to the amino acids lysine and arginine
- Converts pancreatic procarboxypeptidases to carboxypeptidases
- Converts pancreatic chymotrypsinogen to chymotrypsin

Chymotrypsin
- Cleaves peptide bonds next to the amino acids phenylalanine, tyrosine, tryptophan, methionine, asparagine, and histidine

Carboxypeptidases
- Cleave amino acids from the acid (carboxyl) ends of polypeptides

Elastase and collagenase
- Cleave polypeptides into smaller polypeptides and tripeptides

Intestinal tripeptidases
- Cleave tripeptides to dipeptides and amino acids

Intestinal dipeptidases
- Cleave dipeptides to amino acids

Intestinal aminopeptidases
- Cleave amino acids from the amino ends of small polypeptides (oligopeptides)

Protein Turnover and the Amino Acid Pool

Protein turnover: the degradation and synthesis of protein.

Amino acid pool: the supply of amino acids derived from either food proteins or body proteins that collect in the cells and circulating blood and stand ready to be incorporated in proteins and other compounds or used for energy.

Nitrogen balance: the amount of nitrogen consumed (N in) as compared with the amount of nitrogen excreted (N out) in a given period of time.

- Nitrogen equilibrium (zero nitrogen balance): N in = N out

Positive nitrogen: N in > N out - **Negative nitrogen:** N in < N out

Protein Quality: the protein quality of the diet determines, **High-quality proteins** provide enough of all the essential amino acids needed to support the body's work, (dietary proteins containing all the essential amino acids in relatively the same amounts that human beings require. They may also contain nonessential amino acids) and **low-quality proteins** don't.

Two factors influence protein quality: the protein's digestibility and its amino acid composition.

Protein digestibility: a measure of the amount of amino acids absorbed from a given protein intake.

Protein digestibility-corrected amino acid score (PDCAAS):

Protein digestibility X amino acid score

Reflects a protein's digestibility as well as the proportions of amino acids that it provides. (Protein sources that are most readily digested and most perfectly balanced for meeting human needs) high scale (Scale 0-100).

- **100: egg white, ground beef, tuna fish, etc.**
- **94: soybean**
- **50-60: most legumes**
- **40-50: rice, corn**
- **25: wheat protein**

Limiting amino acid: **the essential amino acid found in the shortest supply relative to the amounts needed for protein synthesis in the body. Four amino acids are most likely to be limiting:**

- **Lysine**
- **Methionine**
- **Threonine**
- **Tryptophan**

Reference protein: a standard against which to measure the quality of other proteins. The quality of a food protein is determined by comparing its amino acid composition with the essential amino acid requirements of preschool age children. Such a standard is called a reference protein. The rationale behind using the requirements of this age group is that if a protein will effectively support a young child's growth and development, then it will meet or exceed the requirements of older children and adults.

Measuring of protein quality

Index of Nutritional Quality (INQ): Nutritional quality of a food source is measured by it's Index of Nutritional Quality.

$$INQ = \frac{(\text{Nutrient* per 100g / U.S. RDA})}{(\text{Kcal per 100g / U.S. RDA for Kcal})}$$

INQ < 1 (inadequate source), = 2 – 6 (good), > 6 (excellent)

Example: INQ of Egg

$$INQ = \frac{(\text{12.4 g protein/ 63 g protein per day})}{(\text{0.141 Kcal per 100 g egg/ 2.9 Kcal per day})} = 4.0$$

Recommended Dietary Allowances (RDA)

Complementary Proteins:

- **Plant proteins are lower quality than animal proteins, and plants also offer less protein (per weight or measure of food). Many vegetarians improve the quality of proteins in their diets by combining plant-protein foods that have different but complementary amino acid pattern.**
- **Two or more dietary proteins whose amino acid assortments complement each other in such a way that the essential amino acids missing from one are supplied by the other.**

Complementary Proteins:

In general, legumes provide plenty of isoleucine (Ile) and lysine (Lys) but fall short in methionine (Met) and tryptophan (Trp). Grains have the opposite strengths and weaknesses, making them a perfect match for legumes.

	Ile	Lys	Met	Trp
Legumes	✔	✔		
Grains			✔	✔
Together	✔	✔	✔	✔

Biological value (BV) of a Protein measures its efficiency in supporting the body’s needs. Two nitrogen balance studies are done. No protein is fed, and nitrogen (N) excretions in the urine and feces are measured (endogenous N is “urinary N on a zero-protein diet”). The N lost in the feces, (called metabolic N) is the amount the body invariably loses into the intestine each day, whether or not food protein is fed.

An amount of protein slightly below the requirement is fed. Intake and losses are measured.

$$BV = \frac{\text{N retained}}{\text{N absorbed}} \times 100$$

Egg	100
Milk	93
Beef	75
Fish	75
Corn	72

NOTE: 100 is the maximum BV a food protein can receive.

High biological value (HBV) proteins include: meat, fish, eggs, cheese, and milk.

Low biological value (LBV) proteins include: cereals, pulses, some nuts and vegetables.

In general, animal protein sources have a higher biological value, than vegetable sources.

- **Vegetarians and vegans need to eat wisely to ensure they are getting all the indispensable amino acids. The amino acid that is in the shortest supply in relation to need is termed the limiting amino acid.**

DRI

- **Infants = 2 to 4 g / kg of body weight**
- **Pregnant women = by 10 g /day**
- **Nursing women = by 20 g / day**
- **Adult = 0.8 g / kg of body weight**

The protein requirements tends to decrease somewhat with age Conversely, stress, disease, injury, and prolonged heat exposure increase the protein requirement