

Nutrition & Diet Therapy

Chapter 5: Protein





Learning Objectives

- Describe the chemical structure of proteins and the difference between nonessential and essential amino acids.
- Summarize protein digestion and absorption.
- Explain the process of protein turnover and describe nitrogen balance.
- Identify some of the roles of body proteins.



Learning Objectives

- Describe the health effects of protein deficiency and excess, some of the people who may be harmed by taking amino acid supplements, and the assumptions underlying the protein Recommended Dietary Allowance (RDA).
- Explain the differences between high-quality and low-quality proteins, including notable food sources of each.
- Develop a well-balanced vegetarian eating pattern.



What is a Protein?

- Compound composed of carbon, hydrogen, oxygen, and nitrogen atoms arranged in strands of amino acids.



The Chemist's View of Proteins

- Structure of proteins
 - Amino Acids: “building blocks” of protein
- 20 amino acids:
 - 9 are essential
 - 11 are non-essential



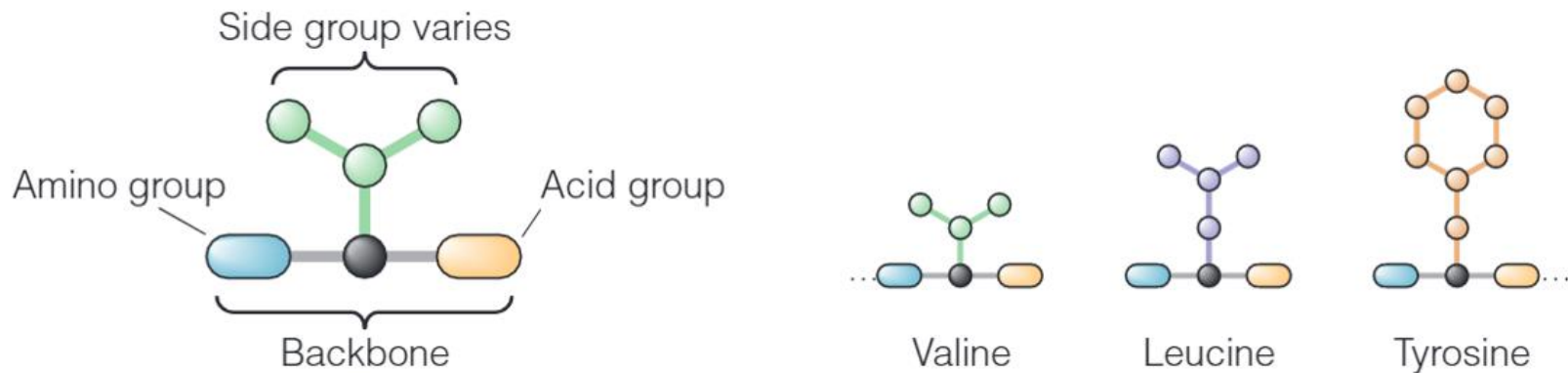
The Structure of an Amino Acid

- All share common chemical “backbone”.
 - Backbones linked together to form proteins
- Each AA carries a unique side group
 - Varies from one AA to another
 - Makes the AA differ in size, shape, & electrical charge

Different Amino Acids

The Structure of Proteins

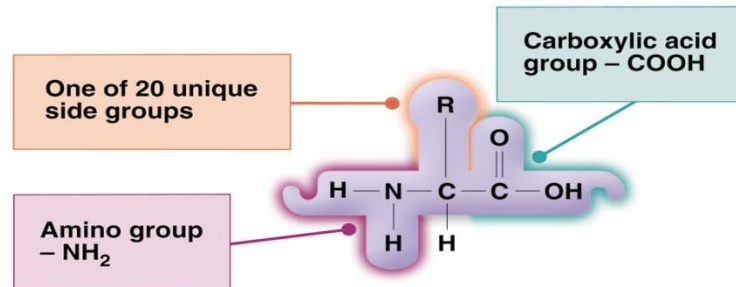
FIGURE 5-1 Amino Acid Structure and Examples of Amino Acids



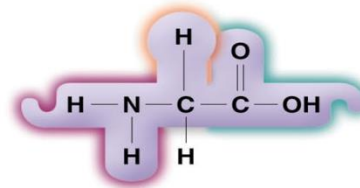
All amino acids have a “backbone” made of an amino acid group (which contains nitrogen) and an acid group. The side group varies from one amino acid to the next. Note that the side group is a unique structure that differentiates one amino acid from another.

*Besides the 20 common amino acids, which can all be components of proteins, others occur individually (for example, ornithine).

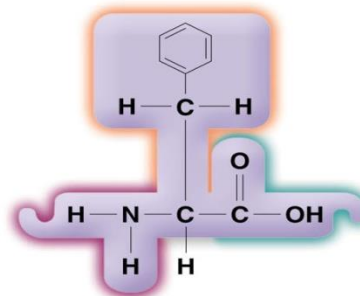
Different Amino Acids



Generic amino acid



Glycine



Phenylalanine

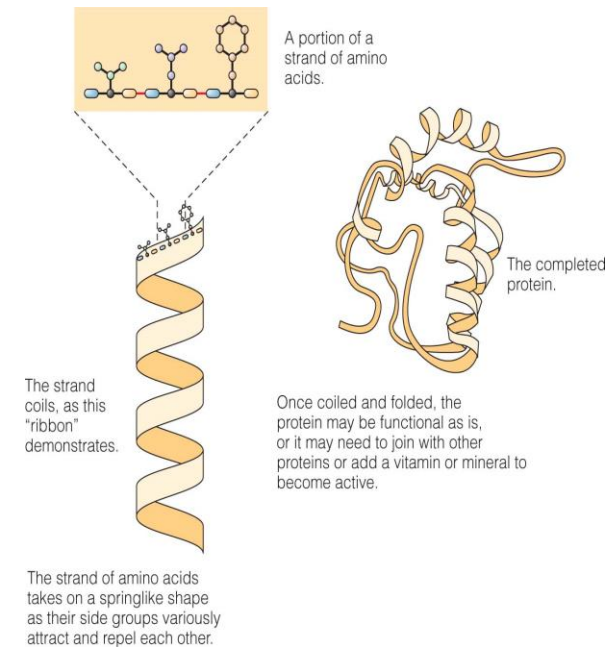


Protein Structure

- Amino Acid Sequence
 - AA bond to form protein chains
 - Joined by peptide bonds
 - **Dipeptide**: 2 AA joined by a peptide bond
 - **Tripeptide**: 3 AA joined by a peptide bond
 - **Polypeptide**: 10 plus AA joined by a peptide bond
 - Most proteins are a few dozen to several hundred AA long

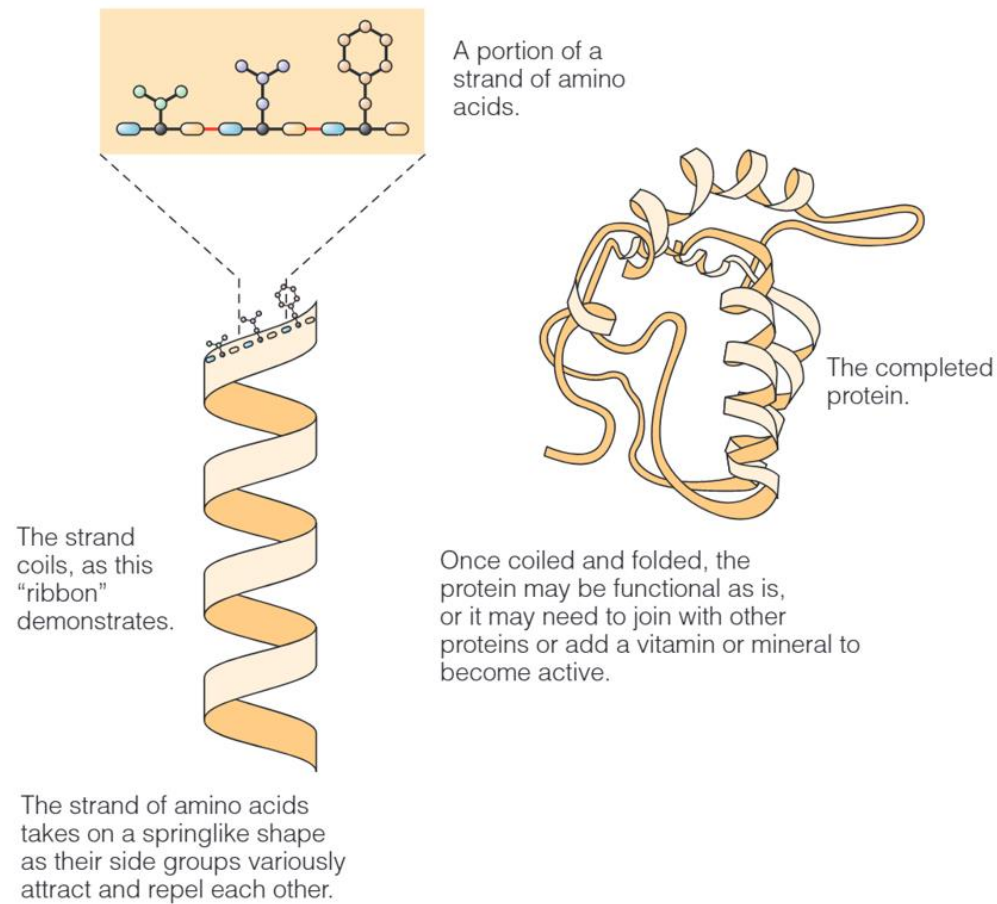
Protein Shapes

- Polypeptide chains are twisted complex molecules
 - As the AA interact or link together, the polypeptide chains fold and intertwine into coils



The Structure of Proteins

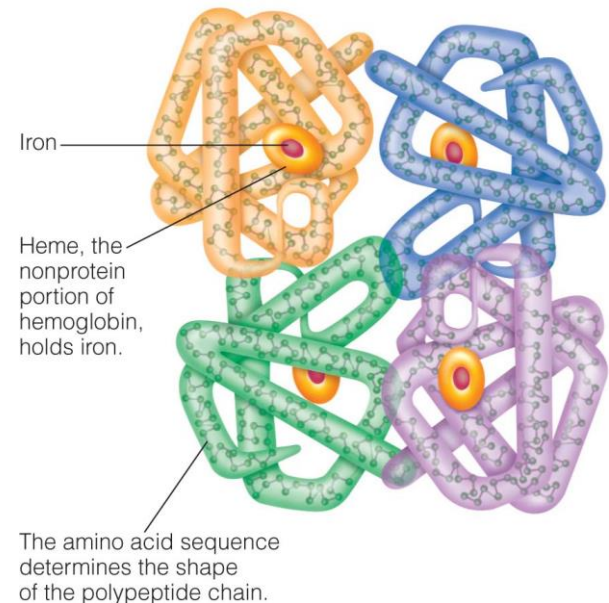
FIGURE 5-2 The Coiling and Folding of a Protein Molecule



Protein Functions

- Depends on the shape of protein
 - Different shapes enable them to perform different jobs in the body
- Hemoglobin-globular ir

Four highly folded polypeptide chains form the globular hemoglobin protein.



Nonessential & Essential Amino Acids

- Body can make over half of AA it needs-
nonessential amino acids
 - Usually comes from proteins in foods, but not necessary (or “nonessential”)
- **9 essential amino acids**
 - Cannot be made by the body (“essential” we obtain these from food)
 - Histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine
 - Some may be considered **conditionally essential** at times
 - Ex.- **PKU (phenylketonuria)**: unable to convert phenylalanine to tyrosine. Tyrosine becomes an essential AA



Protein Turnover and Nitrogen Balance

Protein Turnover

- Continual body process of making and breaking down proteins
- Amino acids must be available to build proteins of new tissues
 - Also helps replace worn out cells and internal cell structures



Protein Turnover and Nitrogen Balance

- When proteins breakdown, component amino acids are liberated or released into bloodstream
 - Protein Denaturation:
 - First step in protein digestion
 - Lose the ability to function
 - Acidity, alkalinity, heat, alcohol, oxidation, and agitation
- Some of these amino acids are recycled into other proteins
 - Through re-use, the body conserves and recycles a valuable commodity
- 25% of available amino acids used for energy
 - Amino acids from food are needed for new growth and maintenance of cells

Protein Turnover and Nitrogen Balance

Nitrogen Balance

- Nitrogen intake from protein in food balances with nitrogen excreted
 - Intake = Output
- Positive nitrogen balance:
 - Body synthesizes more than it degrades
 - Intake > Output
 - Growing children, pregnant women, and other life stages
- Negative nitrogen balance:
 - Body uses/degrades more than is made
 - Intake < Output
 - Occurs in the starving, and people who have severe burns, injuries, infections, or fever



Proteins in the Body

- Roles of proteins in the body:
 - Structural Components
 - Enzymes
 - Transport Proteins
 - Fluid & electrolyte balance
 - Acid-base balance
 - Antibodies
 - Hormones
 - Growth, maintenance, repair
 - Energy



Structural Components

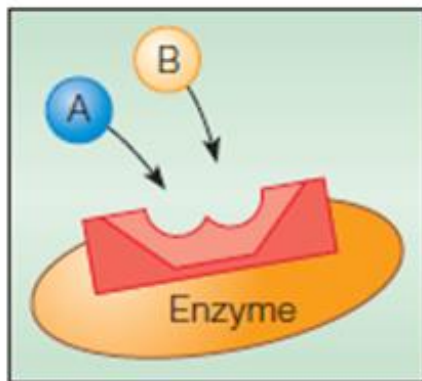
- Muscle tissue
 - Amino acids can be released when needed for energy
- Bones, teeth tendons, blood, and other tissue

Enzymes

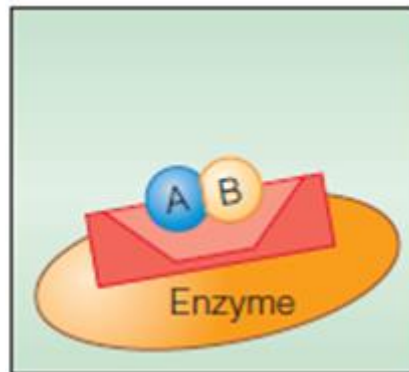
- Essential to all of your body processes
 - put together sugars to make disaccharides, starch, glycogen, etc.
 - Break down CHO, Fat, Protein to yield energy
 - put proteins together to make amino acids (proteins can make proteins because all enzymes are proteins)
- What happens in the body?
 - You eat protein.
 - Food protein is broken down by the body's proteins (enzymes) into amino acids
 - AA's enter the cells where enzymes put AA's back together
 - These chains fold and twist to form proteins
 - Some proteins become enzymes, etc. Process repeats itself.

FIGURE 5-4 Enzyme Action

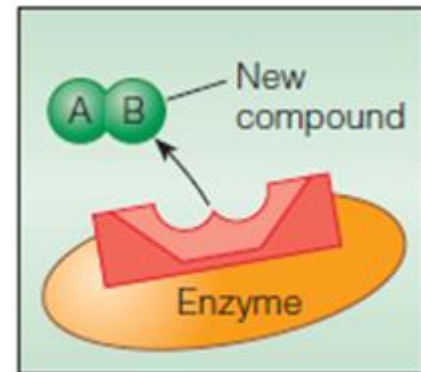
Each enzyme facilitates a specific chemical reaction. In this diagram, an enzyme enables two compounds to make a more complex structure, but the enzyme itself remains unchanged.



The separate compounds A and B, are attracted to the enzyme's active site, making a reaction likely.



The enzyme forms a complex with A and B.



The enzyme is unchanged, but A and B have formed a new compound, AB.



Transport Proteins

- Some proteins transport nutrients and other molecules from one organ to another.
 - Ex.-hemoglobin:
 - Carries oxygen from the lungs to the body's cells
 - Ex.- lipoproteins:
 - Carry lipids around the body (in the watery blood)



Fluid & Electrolyte Balance

- Proteins in the body's fluids help to distribute fluids within the body.
 - Two reasons for this:
 - 1.) Proteins cannot pass freely across membranes
 - 2.) Proteins are attracted to water (hydrophilic)
- Fluids normally flow out of the blood into cells and spaces and back into the blood.
 - Pumping of the heart forces fluid out of the blood into the cells and spaces
 - Proteins that remain in the blood (hydrophilic) attract water from the cells and spaces back into the blood
- edema: too much fluid is in the spaces between the cells (can result from too little protein)

Blood from heart
to body

Capillary bed

Blood from body
back to heart

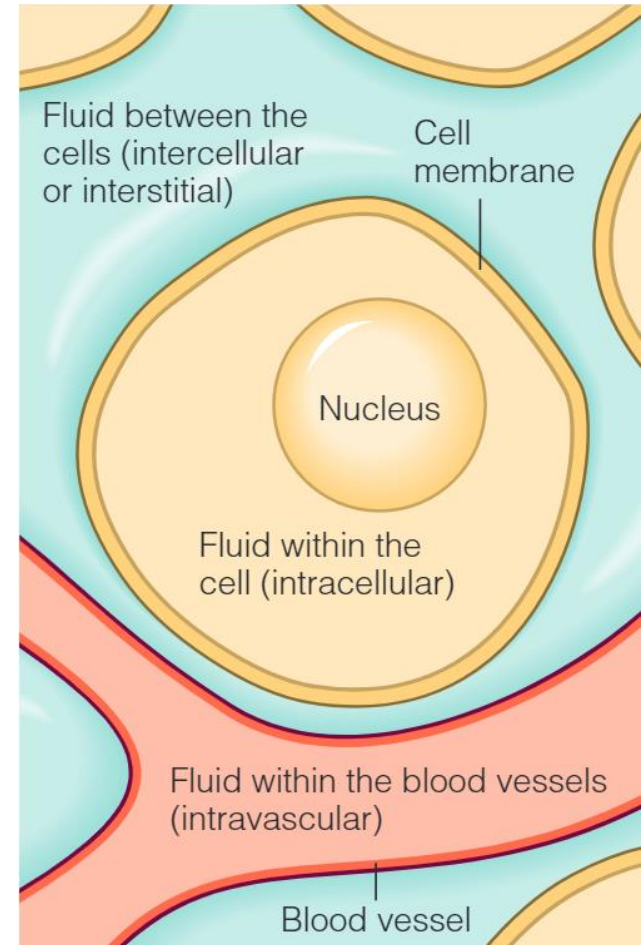
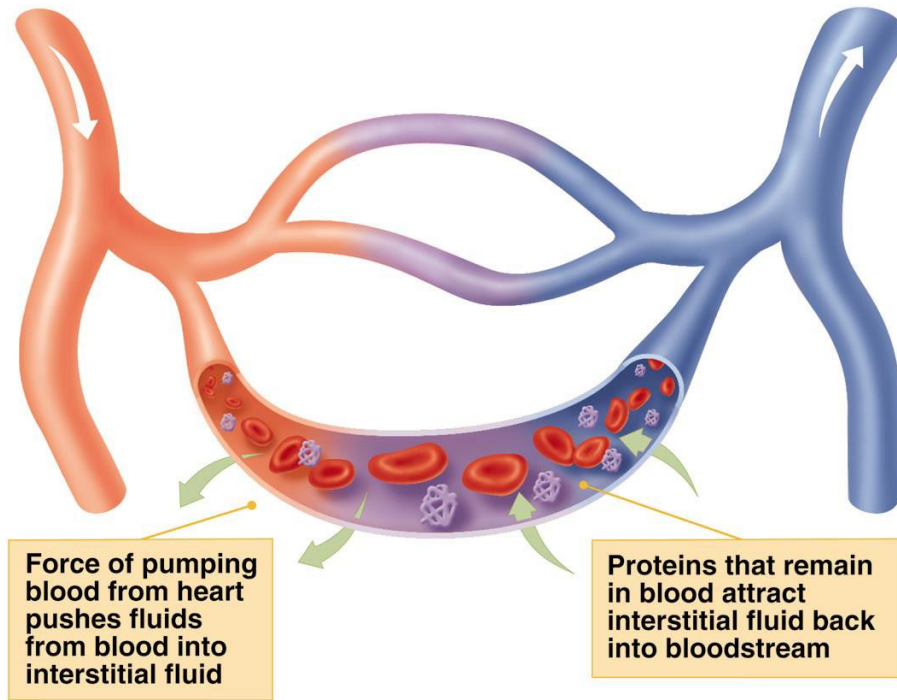


FIGURE 5-5 One Cell and its Associated Fluids



Acid-Base Balance

- Blood pH is tightly controlled in the body
 - Too acidic.... Proteins denature and cannot function properly.
 - Imbalances in pH can lead to alkalosis or acidosis (can be fatal)
- Proteins act as buffers (pick up H ions (extra acid) when there are too many and release them when there are too few .
 - Ex. - Albumin



Antibodies

- Large proteins of the blood and body fluids.
- Each designed to destroy a specific antigen
 - *Anti* = against
 - Act against viruses, bacteria, other disease agents.
- Must have enough protein to maintain the body's resistance to disease.



Hormones

- Messenger molecules
- *Some* hormones are proteins
 - Examples: glucagon & insulin



Growth, Maintenance, & Repair

- AA used to build proteins for all new tissues in the body.
- Help replace worn-out cells in the body.
- Help repair damaged tissues
 - Ex.-collagen
- Protein-rich foods important daily



Protein as an Energy Source

- Proteins sacrificed to yield energy & glucose when glucose & fatty acids not available
- No specialized storage form of protein
 - Body must use its tissues' proteins for energy
 - starvation→wasting of lean body tissue

TABLE 5-2 Summary of Protein Functions

Structural components. Proteins form integral parts of most body tissues and confer shape and strength on bones, skin, tendons, and other tissues. Structural proteins of muscles allow movement.

Enzymes. Proteins facilitate chemical reactions.

Transporters. Proteins transport substances such as lipids, vitamins, minerals, and oxygen around the body.

Fluid and electrolyte balance. Proteins help to maintain the distribution and composition of various body fluids.

Acid-base balance. Proteins help maintain the acid-base balance of body fluids by acting as buffers.

Antibodies. Proteins inactivate disease-causing agents, thus protecting the body.

Hormones. Proteins regulate body processes. Some, but not all, hormones are proteins.

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.



Protein Deficiency

- When diet supplies too little protein or lacks essential amino acids
 - Body slows synthesis of proteins while increasing breakdown of body tissue protein
- Breakdown of tissue proteins liberates needed amino acids
 - Acids build critically important proteins
- Consequences of protein deficiency
 - Impaired brain function, weakened immune defenses and slow growth in children



Malnutrition

- Condition when the diet delivers too little protein or too little energy or both
- **Protein-energy malnutrition (PEM)**
 - Occurs when diet delivers too little protein
- **Severe acute malnutrition (SAM)**
 - Describes severely malnourished infants and children (deficiency of protein, energy, vitamins, & minerals)
 - 6.3 million children under age five die each year from SAM



Malnutrition

- Chronic malnutrition
 - Affects 25 percent of children worldwide
 - Causes stunted growth
- Kwashiorkor and Marasmus
 - Clinical expressions of malnutrition
 - Can occur individually or together

Malnutrition

TABLE 5-3 Severe Acute Malnutrition and Chronic Malnutrition Compared

	Severe Acute Malnutrition	Chronic Malnutrition
Food deprivation	Current or recent	Long-term
Physical features	Rapid weight loss, Wasting (underweight for height; small upper arm circumference), Edema	Stunting (low height for age)

Note: Vitamin and mineral deficiencies are common in both of these types of malnutrition.

Marasmus

- Most severe form of SAM
- Lean & fat tissue wasting
- Small upper arm circumference
- Often feel cold & ill (slowed metabolism)
- No edema
- Sparse, thin hair
- Dry, wrinkled skin
- Shriveled and lean all over



Kwashiorkor

- Less common form of SAM
- Loss of hair color
- Develop patchy, scaly skin
- Sores of skin
- **Edema**



Stephen Dorey ABIPP/Alamy Stock Photo



Protein Excess

- Common in developed countries
- **No benefits to over consumption of protein;** health risks:
 - Obesity, heart disease, diet inadequate in other nutrients, kidney problems, weak bones
 - Heart Disease
 - High intake of protein from red meat, processed meats, & high fat dairy products increase risk of heart disease
 - Kidney Disease
 - High protein intake will:
 - Increase work of kidneys
 - Accelerate kidney decline



Protein & Amino Acid Supplements

- **NOT needed in well-fed people!**
- Do not improve athletic performance
- Weight loss dieters
 - May benefit from consistently eating lean, protein-rich foods
 - Protein satisfies appetite (keeps us “full” longer)
 - Not the same effects on appetite with supplements



Protein & Amino Acid Supplements

- Researchers conclude supplements are discouraged and no level can be assumed safe
 - Lysine
 - Safety unknown
 - Does not cure herpes
 - Tryptophan
 - High doses may induce sleepiness
 - Causes nausea and skin disorders
- Body designed to handle whole proteins (from food) best
- **Most people in the US consume too much protein any way... why supplements??**

Protein Recommendations

- RDA = **0.8 gm/kg** of healthy body weight
 - Kg = 2.2 pounds
- For healthy adults
 - Stress (burns, fevers, surgery, infections, pregnancy, growth):
 - ↑ needs
- Assumptions regarding protein intake
 - Protein should be of high quality
 - Should also consume adequate energy from carbohydrate & fat
 - Other nutrients in diet will be adequate

So...How Much Protein Do You Need?

- Example Calculation:
 - A male weighs 180#. How much protein should he eat daily on a 2000 kcal diet?
- $180/2.2 = 81.81\text{kg}$
- $81.81 \times 0.8 \text{ gm/kg} =$
65.5 grams protein /day
- $65.5 \text{ gm} \times 4 \text{ kcal/gm} = 261 \text{ kcals}$
- $261 \text{ kcals}/2000 = 13\%$ of total kcals from protein



Protein Quality

- High-quality proteins
 - Provide all essential amino acids to support body's work
 - Digestibility
 - Depends on protein's source and other foods consumed together with it
 - Amino acid composition
 - To prevent protein breakdown, dietary protein must supply at least the nine essential amino acids
 - Generally, proteins derived from animal foods
 - Eggs, meat, etc.

Protein Quality

TABLE 5-5 Protein-Containing Foods

Milk and Milk Products

- Each of the following provides about 8 grams of protein:
- 1 c milk, buttermilk, or yogurt (choose low-fat or fat-free)
- 1 oz regular cheese (for example, cheddar or Swiss; choose low-fat)
- $\frac{1}{4}$ c cottage cheese (choose low-fat or fat-free)

Protein Foods

Each of the following provides about 7 grams of protein:

- 1 oz meat, poultry, or fish (choose lean meats to limit saturated fat intake)
- $\frac{1}{2}$ c legumes (navy beans, pinto beans, black beans, lentils, soybeans, and other dried beans and peas)
- 1 egg
- $\frac{1}{2}$ c tofu (soybean curd)
- 2 tbs peanut butter
- 1 to 2 oz nuts or seeds

Grains

- Each of the following provides about 3 grams of protein:
- 1 slice of bread
- $\frac{1}{2}$ c cooked rice, pasta, cereals, or other grain foods

Vegetables

- Each of the following provides about 2 grams of protein:
- $\frac{1}{2}$ c cooked vegetables
- 1 c raw vegetables

Complimentary Proteins

- Complimentary
 - Combining incomplete proteins to make a complete protein
 - 2 or more proteins whose amino acids “complement” each other
 - Essential amino acids missing from one are supplied by another
- Examples:
 - Beans and rice
 - Usually a plant source with a meat source

	Ile	Lys	Met	Trp
Legumes	✓	✓		
Grains			✓	✓
Together	✓	✓	✓	✓

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.



Protein Sparing

- The “**protein-sparing**” effect of carbohydrate and fat
 - Must have adequate supply of carbohydrate & fat to use for energy
 - Fats & carbohydrates are therefore considered “protein-sparing” nutrients
 - Proteins can then be used to build body proteins (and not have to be broken down to meet energy needs)



Protein on Food Labels

- Lists quantity of protein in grams
- Percent Daily Value required in some cases
 - If food makes protein claim
 - If food intended for children under four
 - Represents both quantity and quality of protein



Vegetarian Diets

- Reasons:

- Philosophies, health attitudes, convenience, environmental concerns

- Types:

- Lacto-ovo vegetarians (milk & eggs)
- Lacto-vegetarians (milk)
- Ovo-vegetarian (eggs)
- Partial (semi) vegetarians (some animal-derived foods-ex., fish)
- Vegans (strict or total vegetarians)
 - Only plant-based foods



Vegetarian Diets

- Quality of diet depends on food choices based on sound nutrition principles
 - Adequacy of nutrient intakes
 - Balance and variety of foods chosen
 - Appropriate energy intake
 - Moderate intakes of saturated and *trans* fats, sugars, sodium, and alcohol



Vegetarian Diets

- Exclusion of meat and other animal-derived foods affect nutrition and health
- Variety of foods important
 - To provide all needed nutrients within an energy allowance that maintains healthy body weight
 - Protein intake usually satisfactory with varied sources
 - Whole grains, legumes, seeds, nuts, and vegetables



Benefits of Vegetarian Diet

- Diet contains less fat, saturated fat and cholesterol
- Contains more antioxidants and phytochemicals which help fight against disease
- Have lower cholesterol and lower risk of cardiovascular (heart) disease
- Better digestive function
- Usually weigh less and have lower blood cholesterol levels



Possible Risks of Vegetarian Diets

- Lacto-ovo vegetarians may have a diet high in fat and cholesterol
- Vegan may have problem with Vitamin B12, Vitamin D, Riboflavin, & calcium
- All vegetarians: concern with iron and zinc



Recommendations

- Depends on degree of vegetarian
- Variety of foods important
- Every meal: eat fruits and veggies, whole grains, legumes or beans
- Daily: eat nuts, seeds, egg whites, soy milk, dairy, and plant oils
- Weekly: eggs and sweets
- Include one cup of dark green vegetables daily to help meet iron requirements
- If no milk: include soy milk fortified with calcium, vitamin D, and vitamin B12



References

- Nutrition & Diet Therapy, DeBruyne, Pinna, and Whitney, 10th edition/2020
- Nutrition & Diet Therapy, DeBruyne, Pinna, and Whitney, Wadsworth, 8th Edition/2012
- Nutrition & Diet Therapy, Cataldo, DeBruyne, and Whitney, Thomson Wadsworth, 6th Edition/2003