Chapter 6

Proteins: Crucial Components of All Body Tissues

6.1 What Are Proteins?

- Large, complex molecules found in the cells of all living things
- Critical components of all the tissues of the human body
- Function in metabolism, immunity, fluid balance, and nutrient transport
- In certain circumstances, provide energy
- Contain a special form of nitrogen our bodies can readily use

6.2 Amino Acids

Amino acids – the nitrogen-containing molecules that combine to form proteins

6.2.1 Essential amino acids

- Cannot be produced by our bodies
- Must be obtained from food
- Nine of 20 amino acids in our bodies are essential

6.2.2 Nonessential amino acids

- Can be made by our bodies

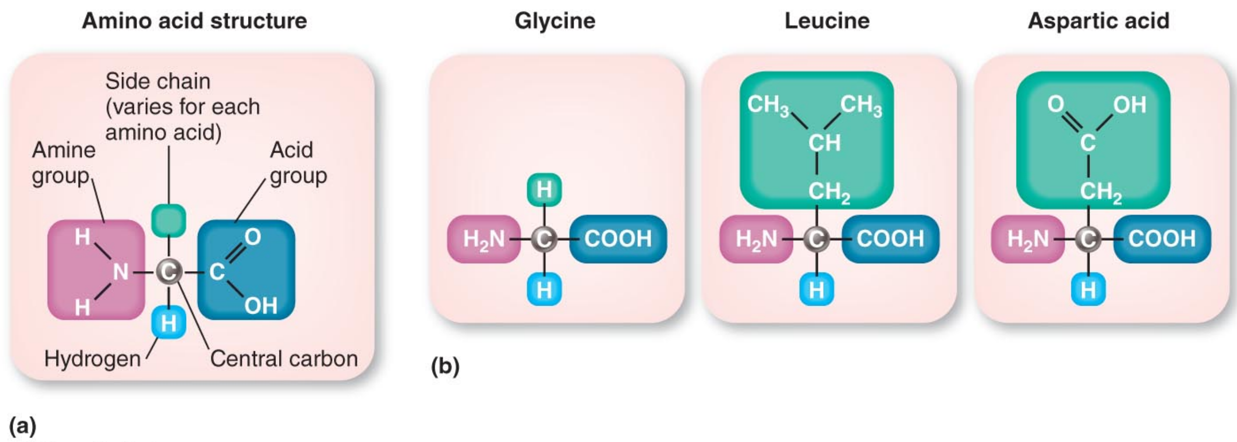

Figure 6.1: Structure of an Amino Acid

Table 6.1: Amino Acids of the Human Body

Essential Amino Acids	**Nonessential 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
	Tryosine

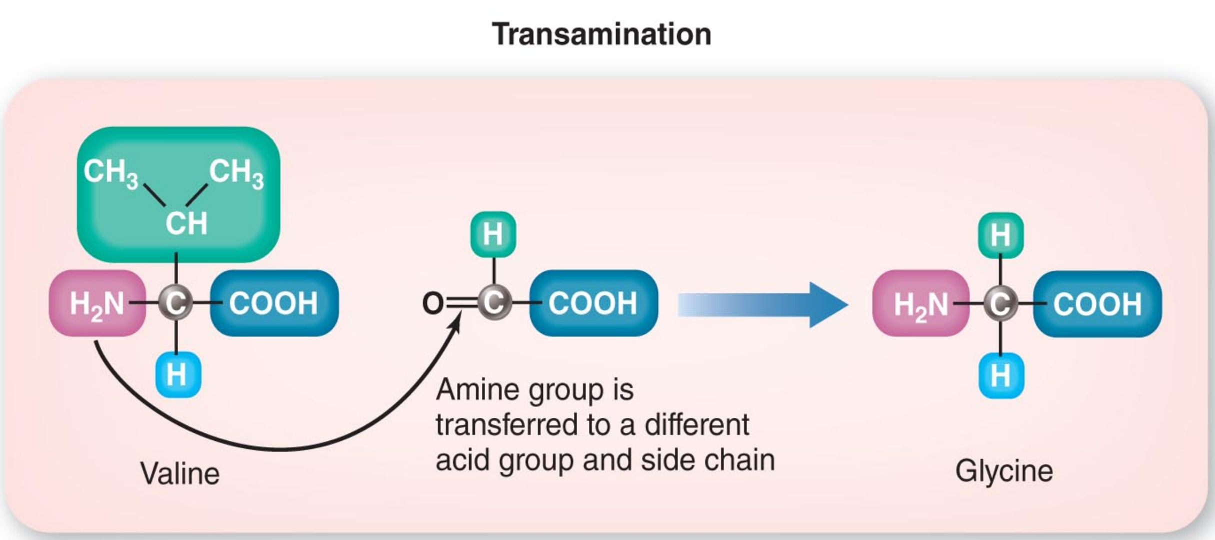

Figure 6.2: Transamination

6.3 How Are Proteins Made?

- When two amino acids join together in a peptide bond, they form a dipeptide
- Two or more amino acids bonded together form a polypeptide

- Proteins are made by combining multiple amino acids

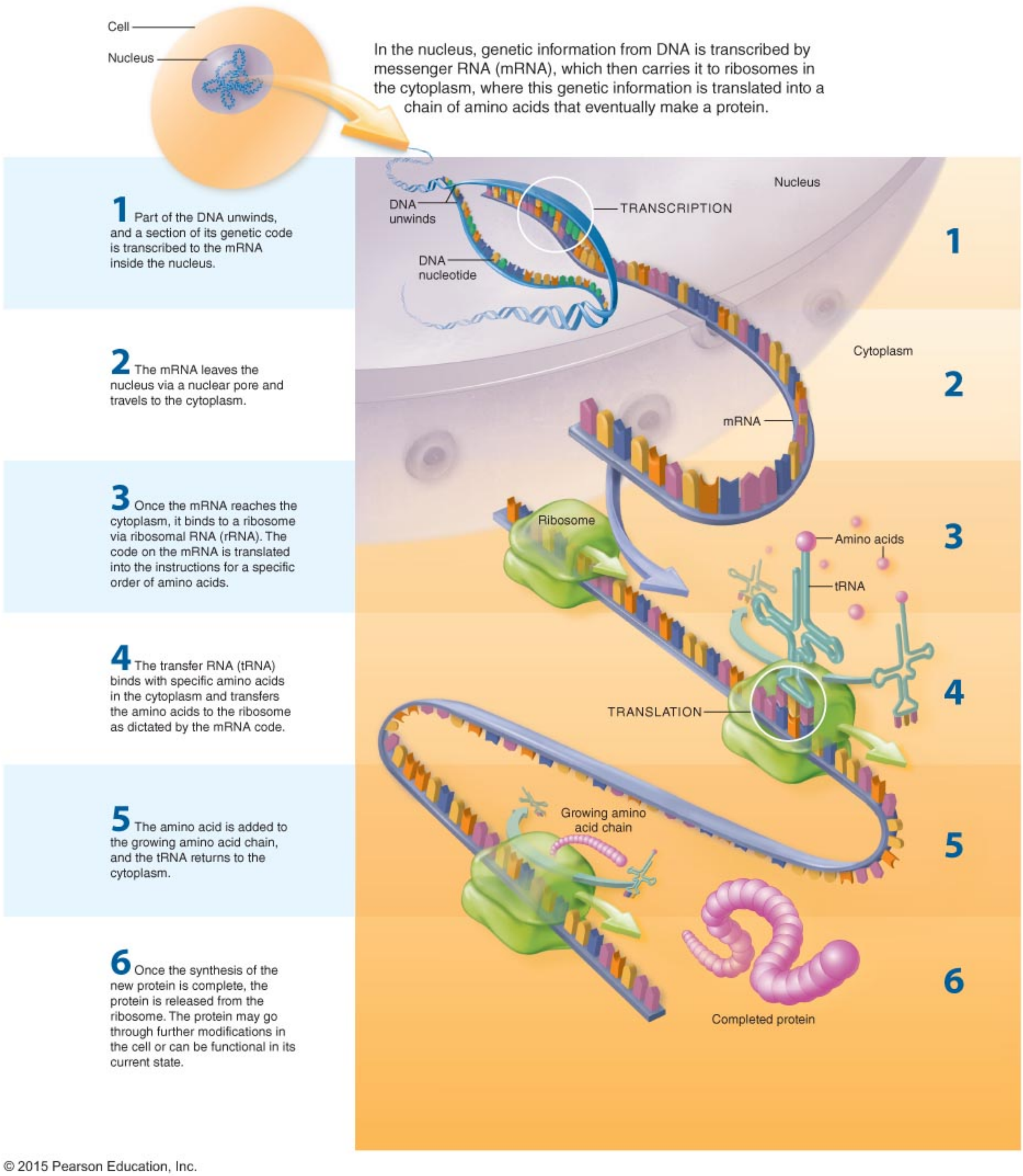

Figure 6.3: Protein Synthesis

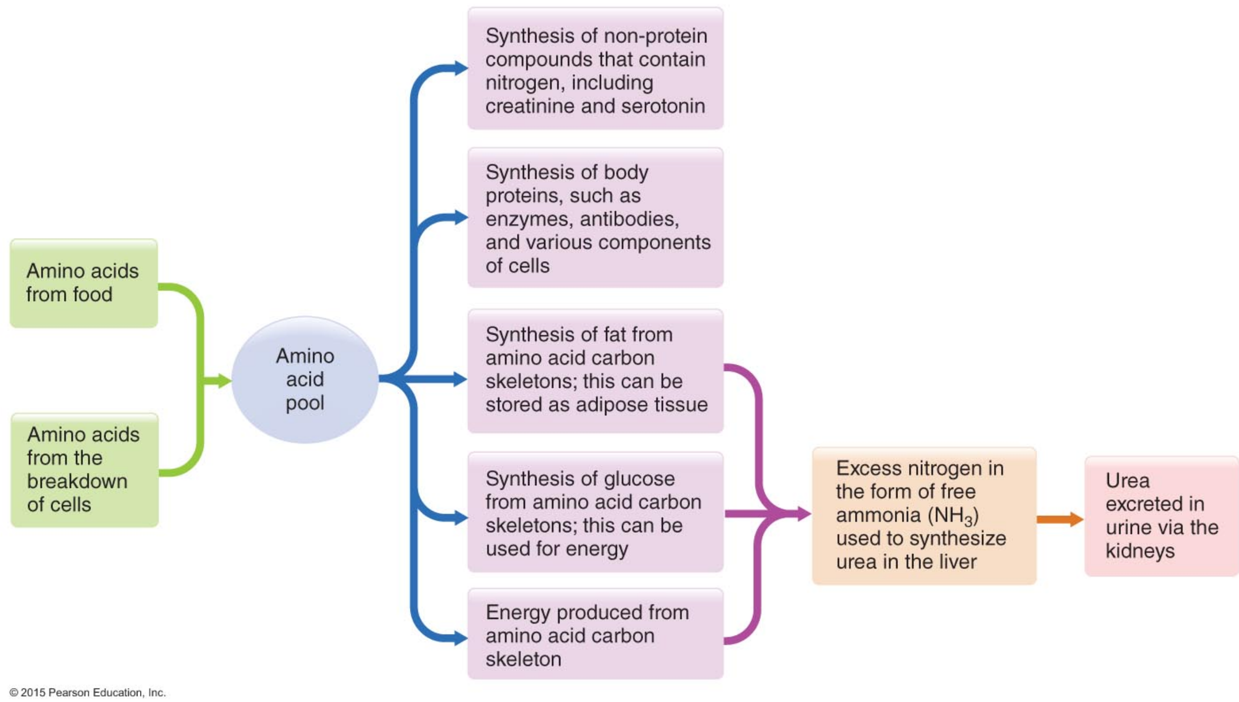

Figure 6.4: Protein Turnover: Synthesis and Breakdown

Transcription – use of the genetic information in DNA to make RNA

- mRNA copies the genetic information and carries it to the ribosome

Translation – conversion of genetic information in RNA to assemble amino acids in the proper sequence to synthesize a protein on the ribosome

6.4 Protein Organization Determines Function

- Protein structure has four levels
  - Primary structure
    - Sequential order of amino acids
  - Secondary structure
    - Spiral shape due to the chemical bonding between the amino acids
  - Tertiary and quaternary structure
    - Further folding into a unique three-dimensional shape that may be globular or fibrous

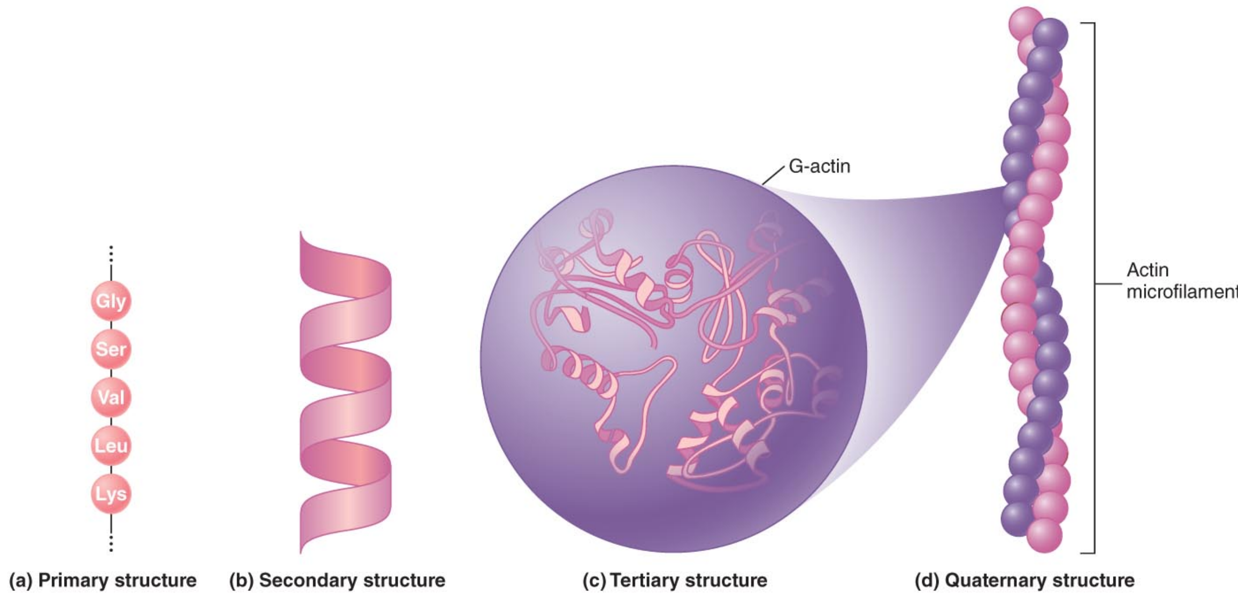

Figure 6.5: Levels of Protein Structure

6.5 Protein Function

- Proteins lose shape (denaturation) when subject to
  - Heat
  - Acids and bases
  - Heavy metals
  - Alcohol
- Denaturation results in an irreversible loss in protein function

Figure 6.6: Protein Shape Determines Function

6.6 Protein Synthesis Can Be Limited

Incomplete protein – does not contain all essential amino acids in sufficient quantites

- Growth and health are compromised
- Considered a “low-quality” protein

Complete protein – Contains sufficient amounts of all nine essential amino acids

- Considered a “high-quality” protein

6.7 Protein Synthesis Can Be Enhanced

Mutual supplementation – combining two incomplete proteins to make a complete protein

Complementary proteins – two protein sources that together supply all nine essential amino acids

- Example: beans and rice

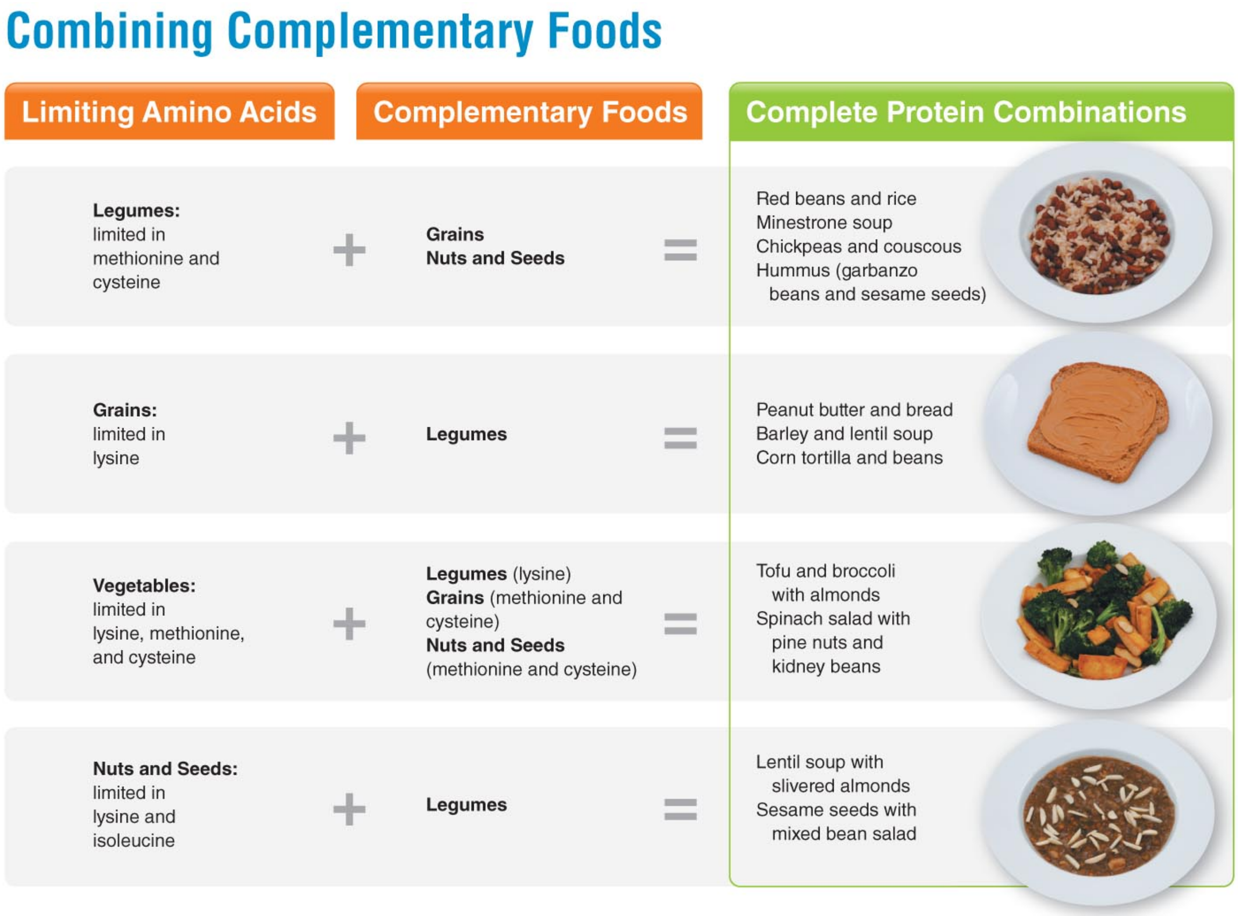

Figure 6.7: Combining Complementary Foods

6.8 Why Do We Need Proteins?

- Cell growth, repair, and maintenance
- Enzymes
- Hormones
- Fluid and electrolyte balance
- pH balance
- Antibodies to protect against disease
- Energy source
- Transport and storage of nutrients
- Compounds such as neurotransmitters, fibrin, and collagen

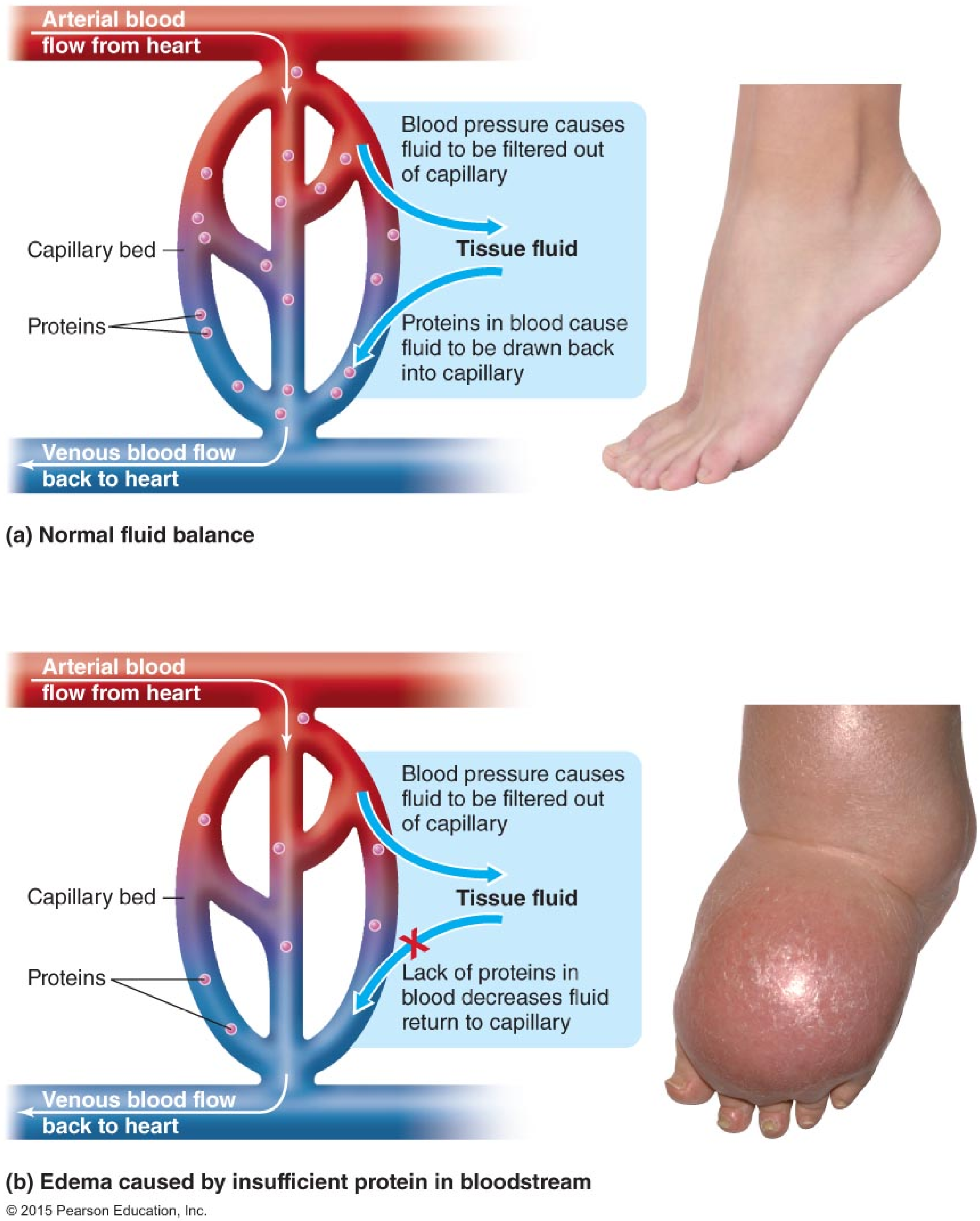

Figure 6.8: Role of Proteins in Fluid Balance

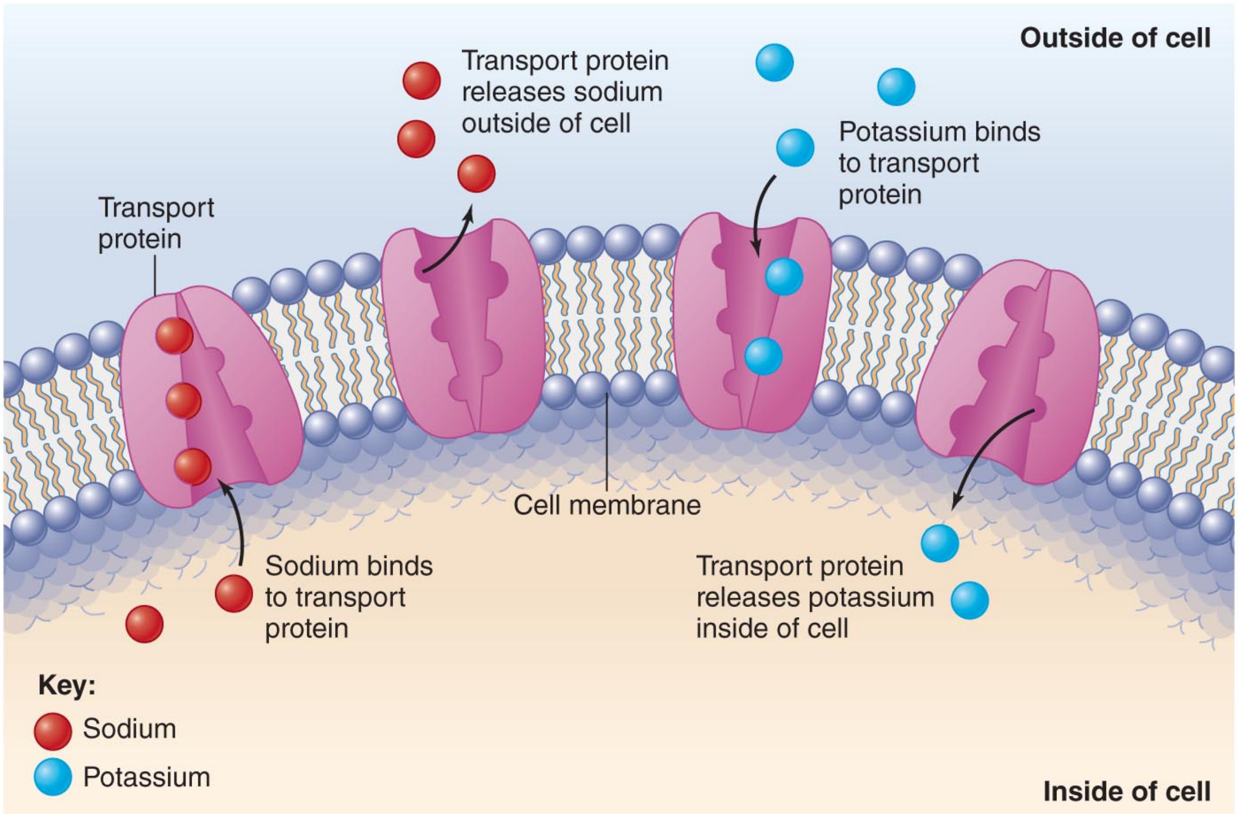

Figure 6.9: Role of Proteins in Electrolyte Balance

6.9 How Do We Break Down Proteins?

- Stomach acids and enzymes break proteins into short polypeptides
- Digestion of proteins continues in the small intestine, where the polypeptides are further broken down
  - Pancreatic enzymes called proteases complete the digestion of proteins into single amino acids

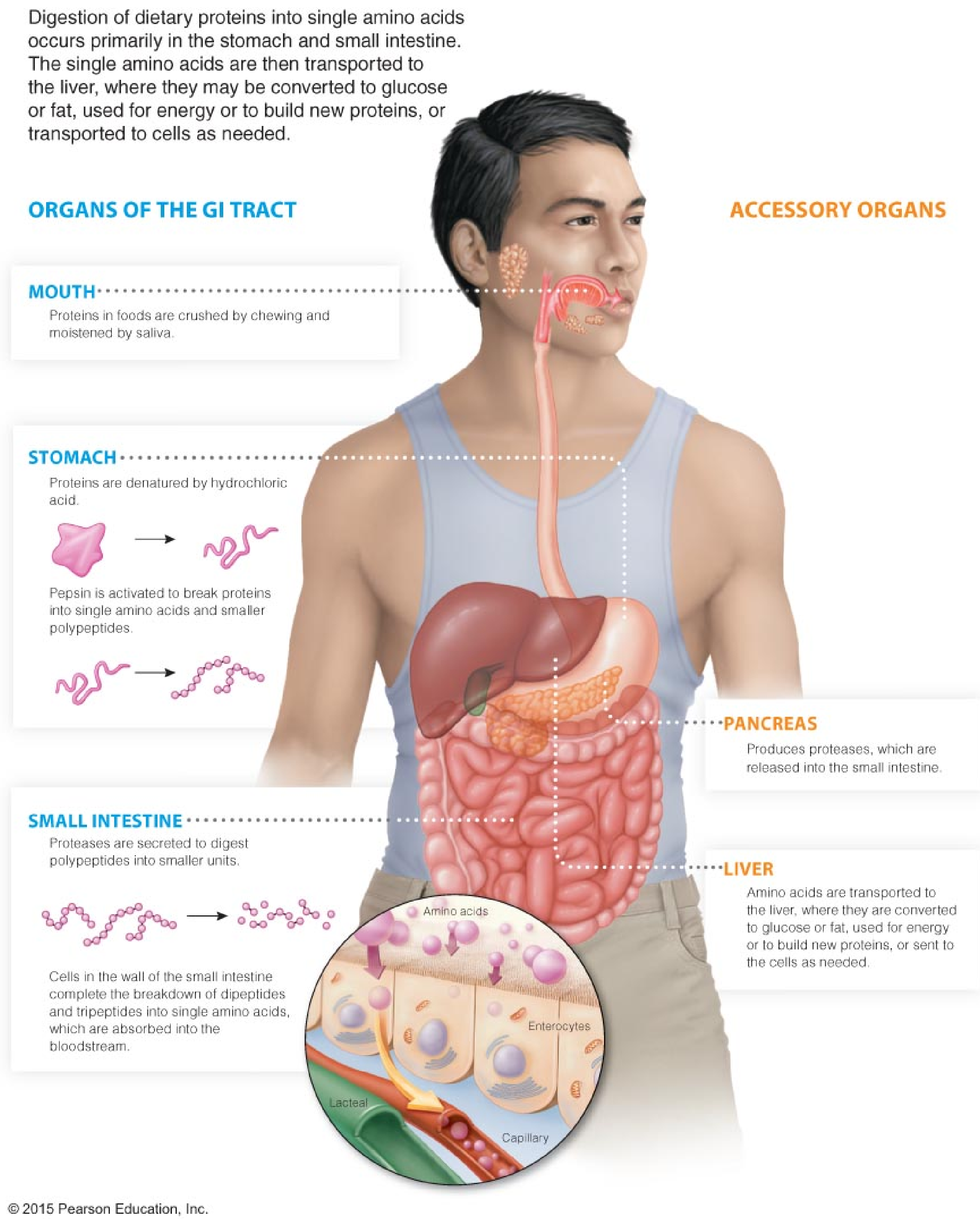

Figure 6.10: Protein Digestion

- Protein digestibility affects protein quality
- Animal protein sources (meat, dairy), soy products, and legumes are highly digestible

- Grains and vegetable proteins are less digestible

6.10 How Much Protein Should We Eat?

- People who require more protein include
  - Children
  - Adolescents
  - Pregnant or lactating women
  - Athletes
  - Vegetarians
- Nitrogen balance describes the relationship between how much nitrogen (or protein) we consume and excrete each day

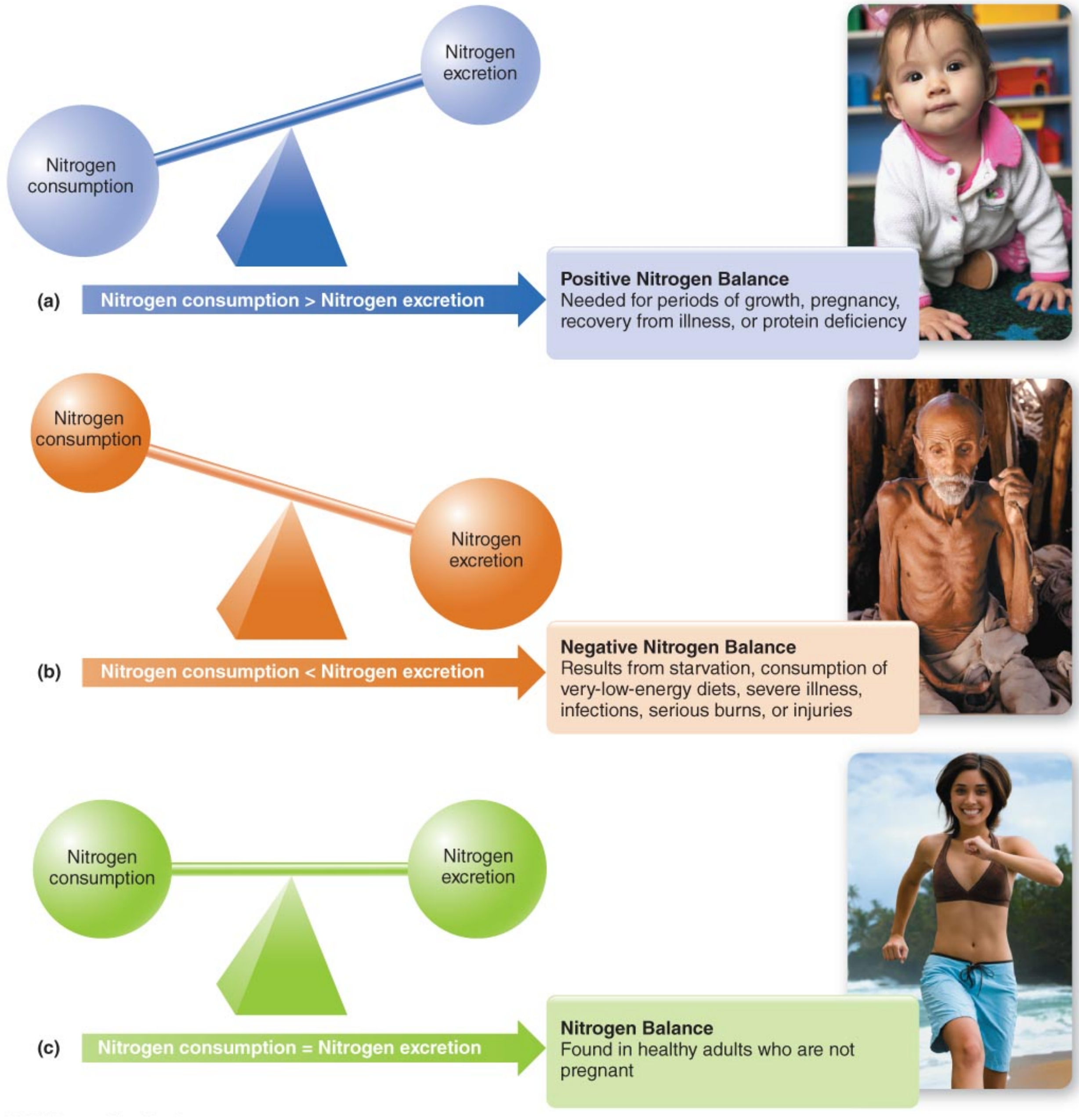

Figure 6.11: Nitrogen Balance

- Recommended Dietary Allowance (RDA)
  - 0.8 grams of protein per kilogram of body weight per day
  - 10–35% of total intake should be from protein
- Most Americans meet or exceed the RDA for dietary protein
- This is true for many athletes as well

- Certain groups of athletes, such as distance runners, figure skaters, female gymnasts, and wrestlers who are dieting, are at risk for low protein intake

6.11 Protein Sources

- Protein sources include much more than just mean
  - Legumes
  - Nuts
  - "New" foods
    * quorn
    * quinoa
    * amaranth
    * teff
    * millet
    * sorghum

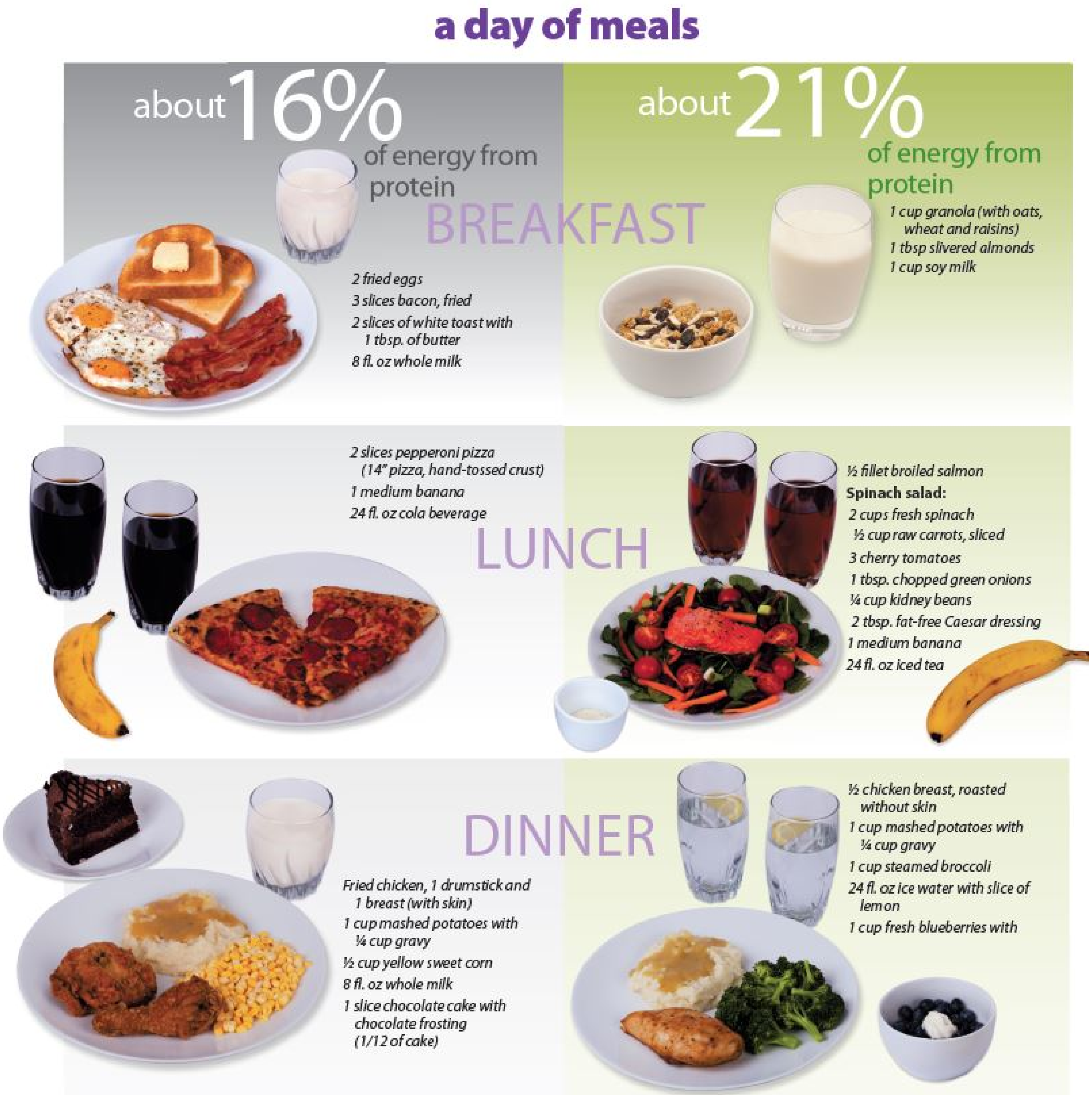

Figure 6.12: Protein Needs

6.12 Too Much Dietary Protein Can Be Harmful

- The risks of too much dietary protein include
  - High cholesterol and heart disease
    - Diets high in protein from animal sources are associated with high blood cholesterol
  - Kidney disease

  * High-protein diets are associated with an increased risk of kidney disease in people who are susceptible

- There is no evidence that high-protein diets lead to bone loss, except in people consuming inadequate calcium

TABLE 6.2 Protein Content of Commonly Consumed Foods

Food	Serving Amount	Protein (g)
Beef		
Ground, lean, broiled (15% fat)	3 oz	22
Beef tenderloin steak, broiled (1/8-in. fat)	3 oz	24.7
Top sirloin, broiled (1/8-in. fat)	3 oz	23
Poultry		
Chicken breast, broiled, no skin (bone removed)	1/2 breast	27
Chicken thigh, bone and skin removed	1 thigh	28
Turkey breast, roasted, luncheon meat	3 oz	18.7
Seafood		
Salmon, Chinook, baked	3 oz	22
Shrimp, cooked	3 oz	20.4
Tuna, in water, drained	3 oz	16.5
Pork		
Pork loin chop, broiled	3 oz	22
Ham, roasted, extra lean (5% fat)	3 oz	18.7
Dairy		
Whole milk (3.25% fat)	8 fl. oz	7.7
Skim milk	8 fl. oz	8.8
Low-fat, plain yogurt	8 fl. oz	12
Cottage cheese, low-fat (2%)	1 cup	23.6
Soy Products		
Tofu, firm	1/2 cup	10
Tempeh, cooked	3 oz	5.5
Soy milk beverage	1 cup	8
Beans		
Refried	1/2 cup	6.4
Kidney, red	1/2 cup	6.7
Black	1/2 cup	7.2
Nuts		
Peanuts, dry roasted	1 oz	6.9
Peanut butter, creamy	2 tbsp.	7
Almonds, blanched	1 oz	6

Source: Data from U.S. Department of Agriculture, Agricultural Research Service. 2015. USDA National Nutrient Database for Standard Reference, Release 28.

Figure 6.13: Protein Content of Common Foods

6.13 Disorders Related to Protein Intake

Protein-energy malnutrition – a disorder caused by inadequare intake of protein and energy

- There are two common, serious forms
  - Marasmus
  - Kwashiorkor

6.13.1 Marasmus

Disease resulting from severely inadequate intakes of protein, energy, and other nutrients

- It is characterized by extreme tissue wasting and stunted growth and development

6.13.2 Kwashiorkor

Disease resulting from extremely low protein intake

- Kwashiorkor symptoms include
  - Some weight loss and muscle wasting
  - Edema resulting in distention of the belly
  - Retarded growth and development
- Kwashiorkor is often seen in children in developing countries

6.14 Can Vegetarian Diets Provide Protein?

Vegetarianism – restricting the diet to foods of plant origin

- There are many versions of vegetarianism
- There are many reasons to adopt a vegetarian diet

Table 6.2: Terms and Definitions of a Vegetarian Diet

Type of Diet	**Foods Consumed**	**Comments**
Semivegetarian (also called flexitarian or plant-based diet)	Vegetables, grains, nuts, fruits, legumes; sometimes meat, seafood, poultry, eggs and dairy products	Typically excluded or limit red meat; may also avoid other meats
Pescovegetarian	Similar to semivegitarian but excludes poultry	*Pesco* means "fish," the only animal source of protein in this diet
Lacto-ovovegetarian	Vegetables, grains, nuts, fruits, legumes, dairy products (*lacto*), and eggs *(ovo)*	Excludes animal flesh and seafood
Lacto-vegetarian	Similar to lacto-ovovegetarian but excludes eggs	Relies on milk and cheese for animal sources of protein
Ovovegetarian	Vegetables, grains, nuts, fruits, legumes and eggs	Excludes dairy, flesh, and seafood products
Vegan (also called strict vegetarian)	Only plant-based foods (vegetables, grains, nuts, seeds, fruits, legumes)	May not provide adequate vitamin B_{12}, zinc, iron, or calcium
Macrobiotic diet	Vegan-type diet; becomes progressively more strict until almost all foods are eliminated; at the extreme, only brown rice and small amounts of water or herbal tea	Taken to the extreme, can cause malnutrition and death
Fruitarian	Only raw or dried fruit, seeds, nuts, honey, and vegetable oil	Very restrictive diet; deficient in protein, calcium, zinc, iron, vitamin B_{12}, riboflavin, and other nutrients

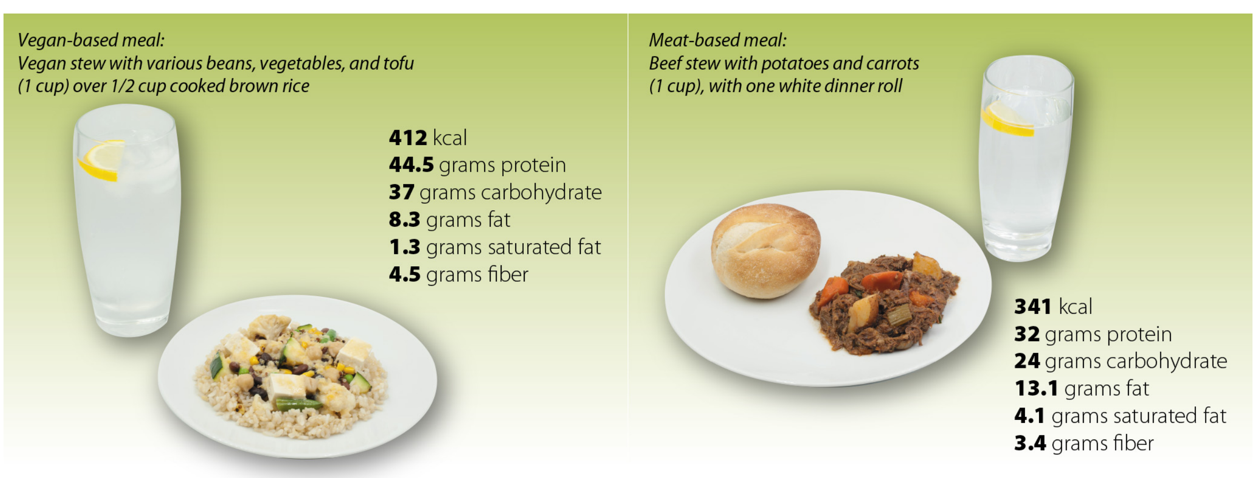

Figure 6.14: Vegetarian Diet

6.15 Why Vegetarianism?

- People chose vegetarianism because of
  - Health benefits
  - Ecological reasons
  - Religious reasons
  - Ethical reasons
  - Concerns over food safety

6.16 Health Benefits of Vegetarianism

- Lower intake of fat and total energy
- Lower blood pressure
- Reduced risk of heart disease
- Reduced risk of some types of cancer
- Fewer digestive problems
- Reduced risk of kidney disease, kidney stones, and gallstones

6.17 Challenges of Vegetarianism

- Vegetarian diets can be low in some vitamins and minerals (iron, calcium, zinc, vitamins D and B_{12})
- Vegetarians must plan a balanced and adequate diet
- Soy products are an excellent protein source
- Vegetarians should include complementary proteins
- Vegetarians can find health eating tips for vegetarians at MyPlate online

Table 6.3: Nutrients of Concern in a Vegan Diet

Nutrient	Functions	Nonmeat/Nondairy Food Sources
Vitamin B_{12}	Assists with DNA synthesis; protection and growth of nerve fibers	Vitamin B_{12}–fortified cereals, yeast, soy products, and other meat analogs; vitamin B_{12} supplements
Vitamin D	Promotes bone growth	Vitamin D–fortified cereals, margarines, and soy products; adequate exposure to sunlight; supplementation may be necessary for those who do not get adequate exposure to sunlight
Riboflavin (Vitamin B_2)	Promotes release of energy; supports normal vision and skin health	Whole and enriched grains, green leafy vegetables, mushrooms, beans, nuts, and seeds
Iron	Assists with oxygen transport; involved in making amino acids and hormones	Whole-grain products, prune juice, dried fruits, beans, nuts, seeds, and leafy vegetables (such as spinach)
Calcium	Maintains bone health; assists with muscle contraction, blood pressure, and nerve transmission	Fortified soy milk and tofu, almonds, dry beans, leafy vegetables, calcium-fortified juices, and fortified breakfast cereals
Zinc	Assists with DNA and RNA synthesis, immune function, and growth	Whole-grain products, wheat germ, beans, nuts, and seeds

6.18 In Depth: Vitamins and Minerals

6.18.1 Macronutrients

- Carbohydrates
- Fats
- Protein
- Provide energy
- Required in relatively large amounts

6.18.2 Micronutrients

- Vitamins
- Minerals

- Do not supply energy
- Required in relatively small amounts
- Assist body functions (e.g., energy metabolism, maintenance of healthy cells and tissues)
- Absorption may be very low (3–10%) when compared to macronutrients (85–99%)
- Many micronutrients need to be chemically altered before they are active in the body

6.18.3 Vitamins

- Organic compounds
- Thirteen are essential
- Nine are soluble in water
- Four are soluble in fat

6.18.4 Characteristics of Fat-Soluble Vitamins

- Large storage capability
- Toxicity is possible
- Deficiency symptoms may take many months to develop
- May occur in numerous chemical forms

Table 6.4: Fat-Soluble Vitamins

Vitamin Name	Primary Functions	Recommended Intake*	Reliable Food Sources	Toxicity/Deficiency Symptoms
A (retinol, retinal, retinoic acid)	Required for ability of eyes to adjust to changes in light Protects color vision Assists cell differentiation Required for sperm production in men and fertilization in women Contributes to healthy bone Contributes to healthy immune system	RDA: Men: 900 μg/day Women: 700 μg/day UL: 3,000 μg/day	Preformed retinol: beef and chicken liver, egg yolks, milk Carotenoid precursors: spinach, carrots, mango, apricots, cantaloupe, pumpkin, yams	*Toxicity*: Fatigue, bone and joint pain, spontaneous abortion and birth defects of fetuses in pregnant women, nausea and diarrhea, liver damage, nervous system damage, blurred vision, hair loss, skin disorders *Deficiency*: Night blindness and xerophthalmia; impaired growth, immunity, and reproductive function
D (cholecalciferol)	Regulates blood calcium levels Maintains bone health Assists cell differentiation	RDA: Adults aged 19-70: 15μg/day Adults aged >70: 20 μg/day UL 100 μg/day	Canned salmon and mackerel, milk, fortified cereals	*Toxicity*: Hypercalcemia *Deficiency*: Rickets in children, osteomalacia and/or osteoporosis in adults
E (tocopherol)	As a powerful antioxidant, protects cell membranes, polyunsaturated fatty acids, and vitamin A from oxidation Protects white blood cells Enhances immune function Improves absorption of vitamin A	RDA: Men: 15 mg/day Women: 15 mg/day UL: 1,000 mg/day	Sunflower seeds, almonds, vegetable oils, fortified cereals	*Toxicity*: Rare *Deficiency*: Hemolytic anemia; impairment of nerve, muscle, and immune function
K (phylloquinone, menaquinone, menadione)	Serves as a coenzyme during production of specific proteins that assist in blood coagulation and bone metabolism	AI: Men: 120 μg/day Women: 90 μg/day	Kale, spinach, turnip greens, brussels sprouts	*Toxicity*: None known *Deficiency*: Impaired blood clotting, possible effect on bone health

*RDA: Recommended Dietary Allowance; UL: upper limit; Al: Adequate Intake.

6.18.5 Characteristics of Water-Soluble Vitamins

- Minimal storage capacity
- Toxicity is rare
- Deficiency symptoms occur quickly
- Excreted in urine when tissues are saturated

6.18.6 General Properties of Minerals

- Inorganic
- Cannot be synthesized by plants or animals
- Not digested or broken down prior to absorption
- Two classifications based on need

6.18.7 Characteristics of Major Minerals

- Required in amounts of at least 100 mg/day
- Body contains 5 g or higher
- Seven major minerals

6.18.8 Characteristics of Trace Minerals

- Required in amounts of less than 100 mg/day
- Body contains less than 5 g
- Eight trace minerals are essential for human health
- Absorption of micronutrients depends on numerous factors
  - Chemical form (e.g., absorption of heme iron from meats, fish, poultry is ∼25%, whereas non-heme iron from plant products is ∼3–5%)
  - Numerous factors in foods bind micronutrients and prevent absorption
  - Other nutrients within a meal alter absorption
- Supplementation of micronutrients is controversial
  - Easier to develop toxicity with supplements
  - Some may be harmful to certain subgroups of consumers
  - Most minerals are better absorbed from animal food sources

  - Eating a variety of foods provides many other nutrients (e.g., phytochemicals)
  - Supplements may alter the balance between nutrients

- Adequate intake of these minerals has been as been associated with lowered disease risk
  - Vitamin D and colon cancer
  - Vitamin E and complications of diabetes
  - Vitamin K and osteoporosis
  - Calcium and hypertension
  - Chromium and type 2 diabetes in older adults
  - Magnesium and muscle wasting in older adults
  - Selenium and certain types of cancer
- Do more essential micronutrients exist?
- Nutrition researchers continue to explore the possibility of other substances being essential
- Vitamin-like factors (e.g., carnitine) and numerous minerals (e.g., boron, nickel, silicon) may prove to be essential in our diet