Chapter 6: Proteins & Amino Acids

James P. Blair/NG Image Collection

Student learning outcomes: At the end of this chapter, you should be able to:

- Describe the role of proteins and amino acids in health and disease
- Plan a diet to meet protein recommendations

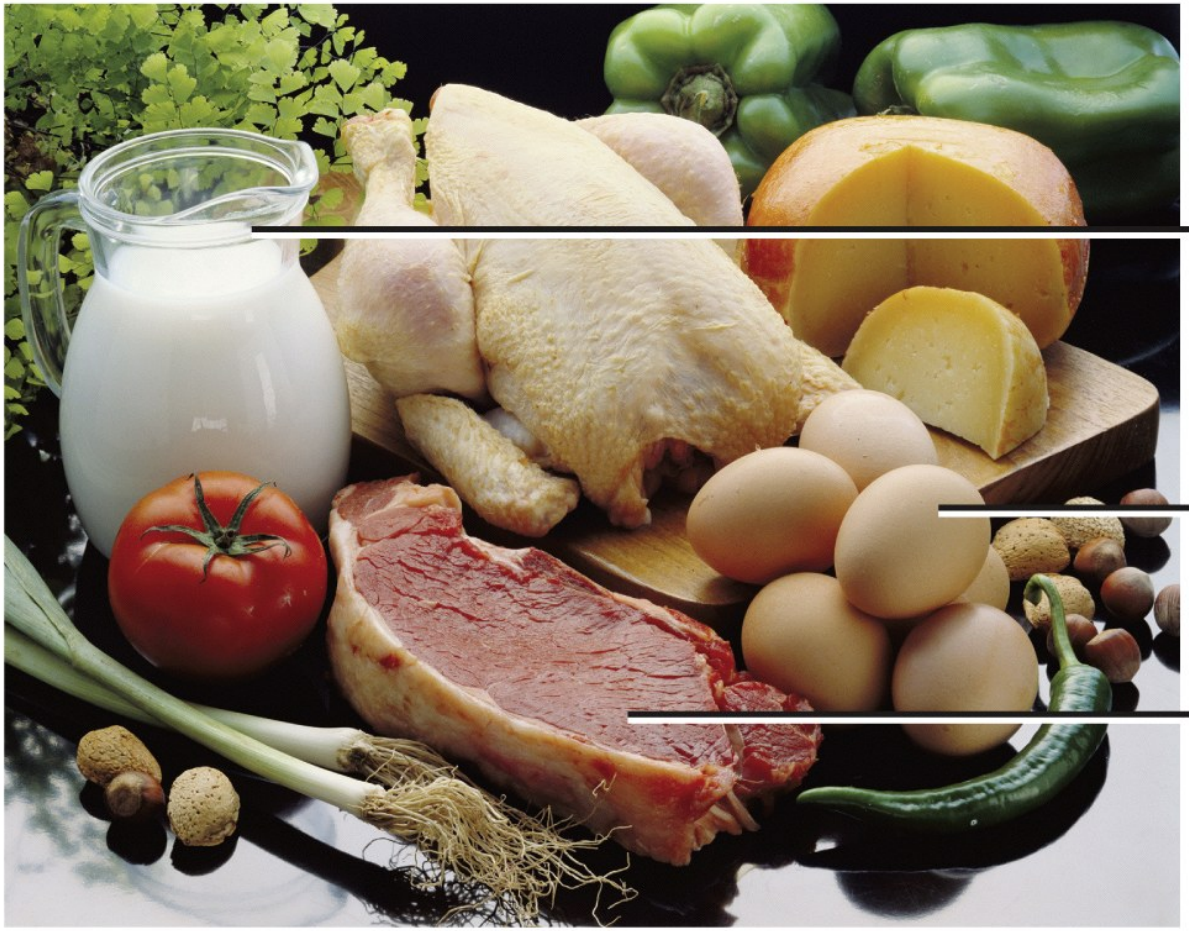
THINK about this – then share within a PAIR – then SHARE with the class

- What do you know about proteins and amino acids?
- What are benefits of eating plant foods over animal foods?

Sources of protein

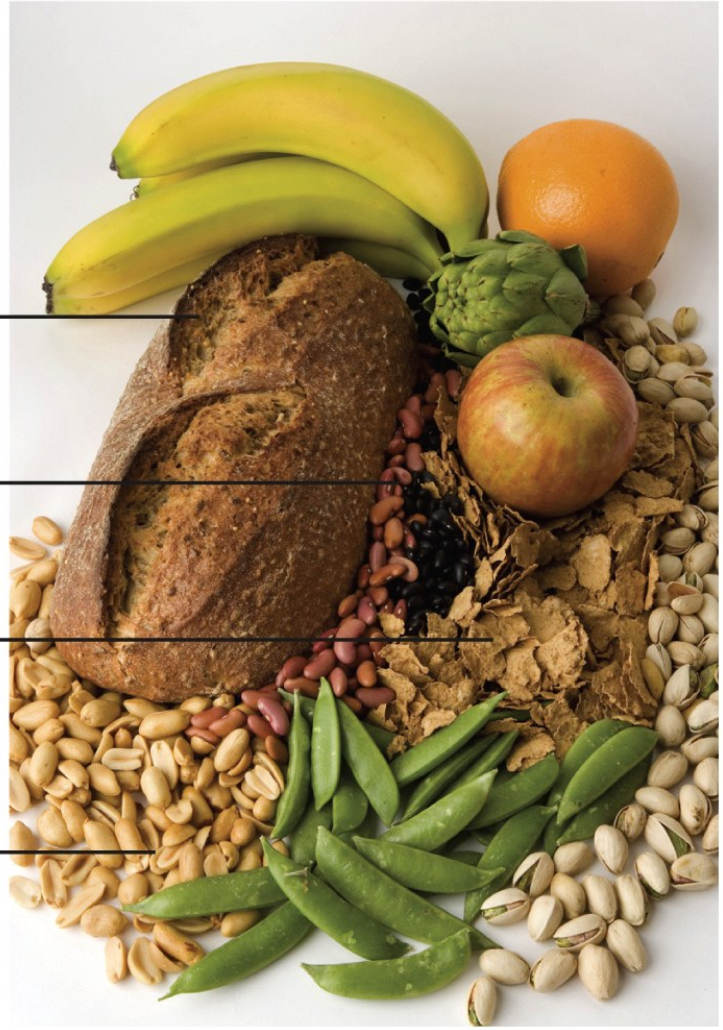
- Animal: meat, eggs, dairy products
  - High in saturated fat and cholesterol
  - provide B vitamins and some absorbable minerals
- Plant: grains, nuts, legumes
  - Low in saturated fat and cholesterol /// high in fiber, phytochemicals, and unsaturated fat
  - Legumes: starchy plant seeds producing bean pods, including peas, peanuts, beans, soybeans, lentils

Sources of protein



Pixtal/SUPERSTOCK

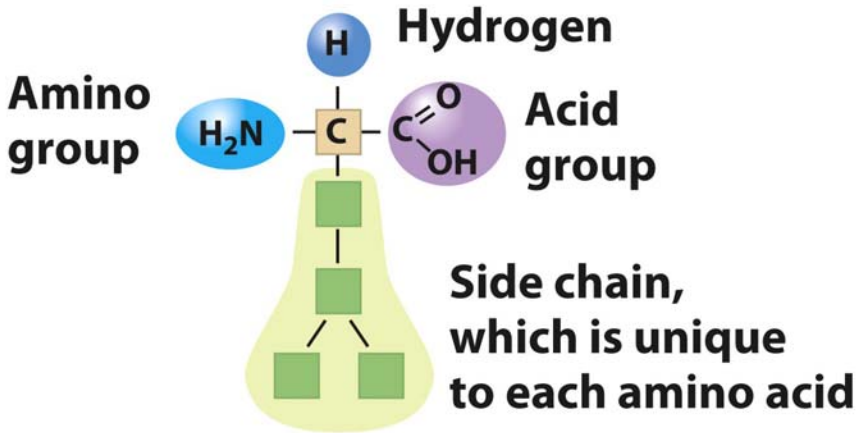
Sources of protein



Michael Newman/PhotoEdit

Amino acids

- Amino acids: building blocks of proteins
  - Carbon, hydrogen, amino group (contains nitrogen), acid group, and side chain
  - 20 different side chains make 20 different amino acids

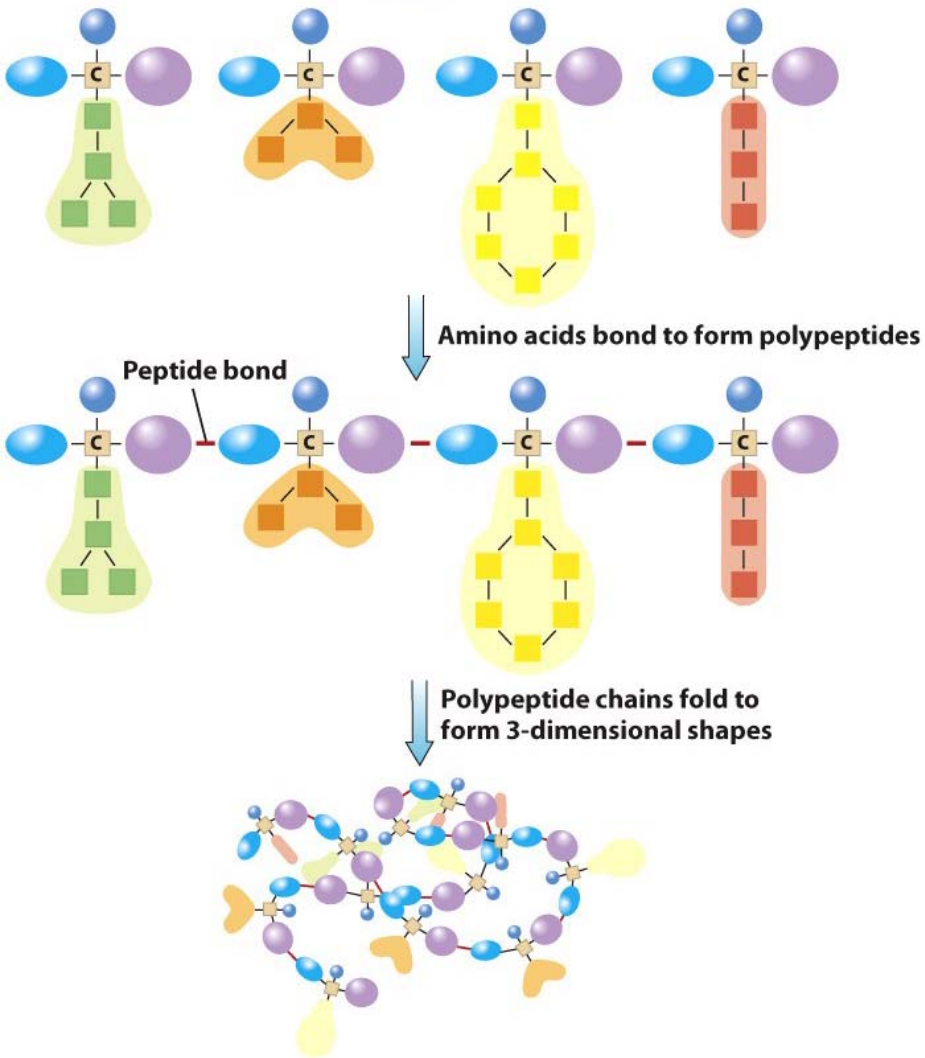


Building blocks

Match the building blocks with the nutrient:

____ complex carbohydrates	a) amino acids
____ triglycerides	b) fatty acids and glycerol
____ proteins	c) monosaccharides

Amino acids link to form proteins



Amino acids link to form proteins

- We obtain amino acids from eating plant and animal foods.
- Our bodies reassemble the amino acid building blocks into our body proteins.

Essential vs. non-essential amino acids

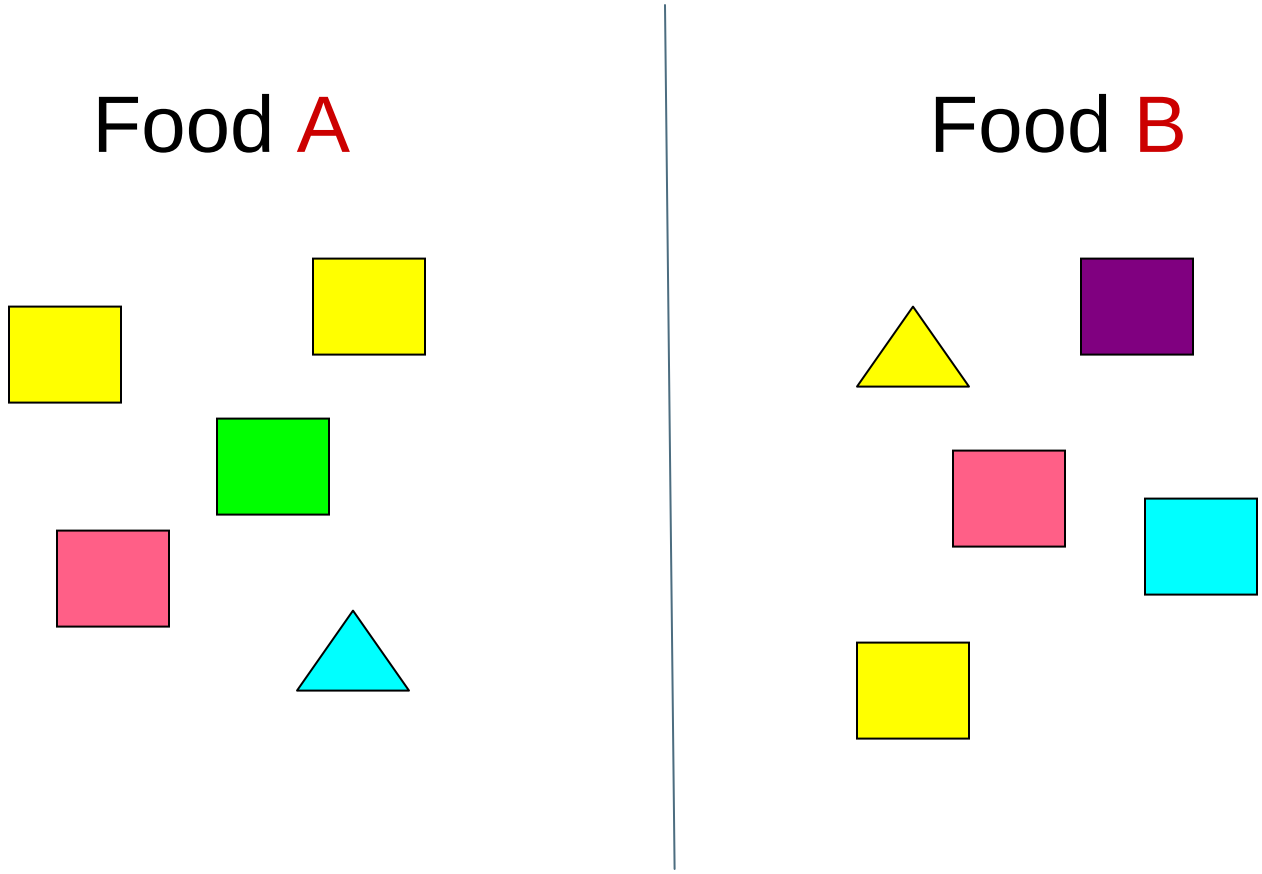
- Essential: Cannot be made in the body so “essential” to eat them
  - If one essential a.a. is missing, body proteins must be broken down to release the missing essential a.a. from protein polymer or new protein synthesis can not occur
- Non-essential: Body can make them from other proteins so not essential to eat them

Essential vs. non-essential amino acids

Essential Amino Acids	Nonessential Amino Acids
Histidine	Alanine
Isoleucine	Arginine*
Leucine	Asparagine
Lysine	Aspartic acid
Methionine	Cysteine*
Phenylalanine	Glutamic acid
Threonine	Glutamine*
Tryptophan	Glycine*
Valine	Proline*
	Serine
	Tyrosine*

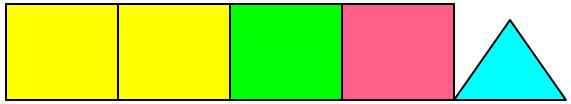
*Considered conditionally essential by the Institute of Medicine, Food and Nutrition Board

Essential vs. non-essential amino acids



Essential vs. non-essential amino acids

Can you use only the amino acids from Food A to make this protein?



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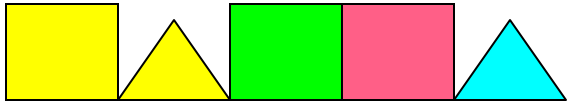
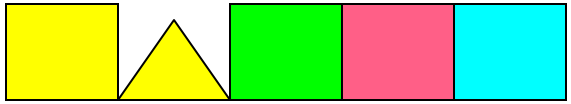


The yellow triangle is a non-essential amino acid

Essential vs. non-essential amino acids

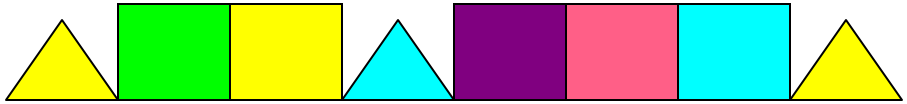
Can you use only the amino acids from Food A to make this protein?



The blue square is a limiting amino acid

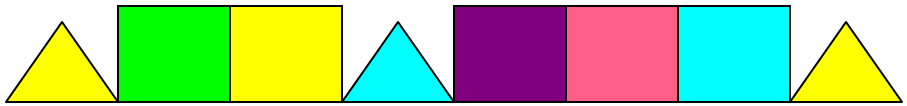
Essential vs. non-essential amino acids

Can you use only the amino acids from Food A to make this protein?



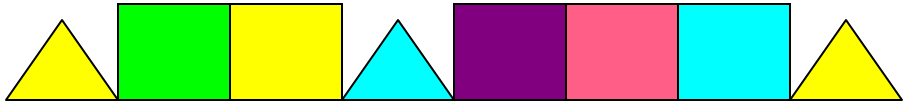
Essential vs. non-essential amino acids

Can you use only the amino acids from Food B to make this protein?



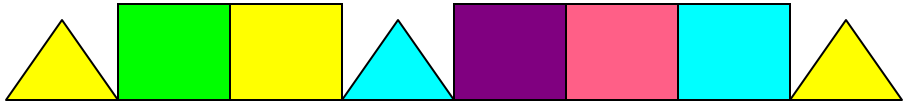
Essential vs. non-essential amino acids

Can you use only the amino acids
from Foods A and B to make this protein?



Essential vs. non-essential amino acids

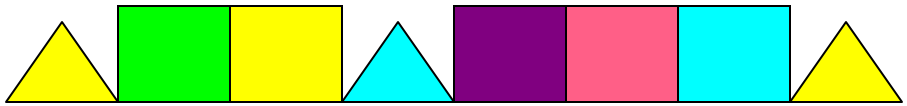
Did you use all of the amino acids
from Foods A and B to make this protein?



It not, what did the body do with the extras?

Essential vs. non-essential amino acids

Foods A and B are complementary: each supplies some amino acids for the full set of needed amino acids



Essential vs. non-essential amino acids

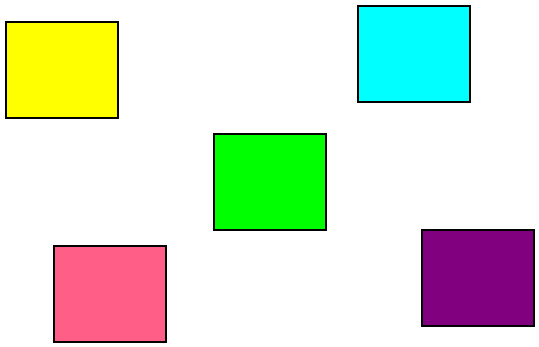
Essential amino acids

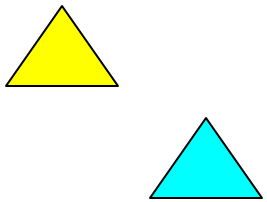
Cannot be made

Need to be eaten

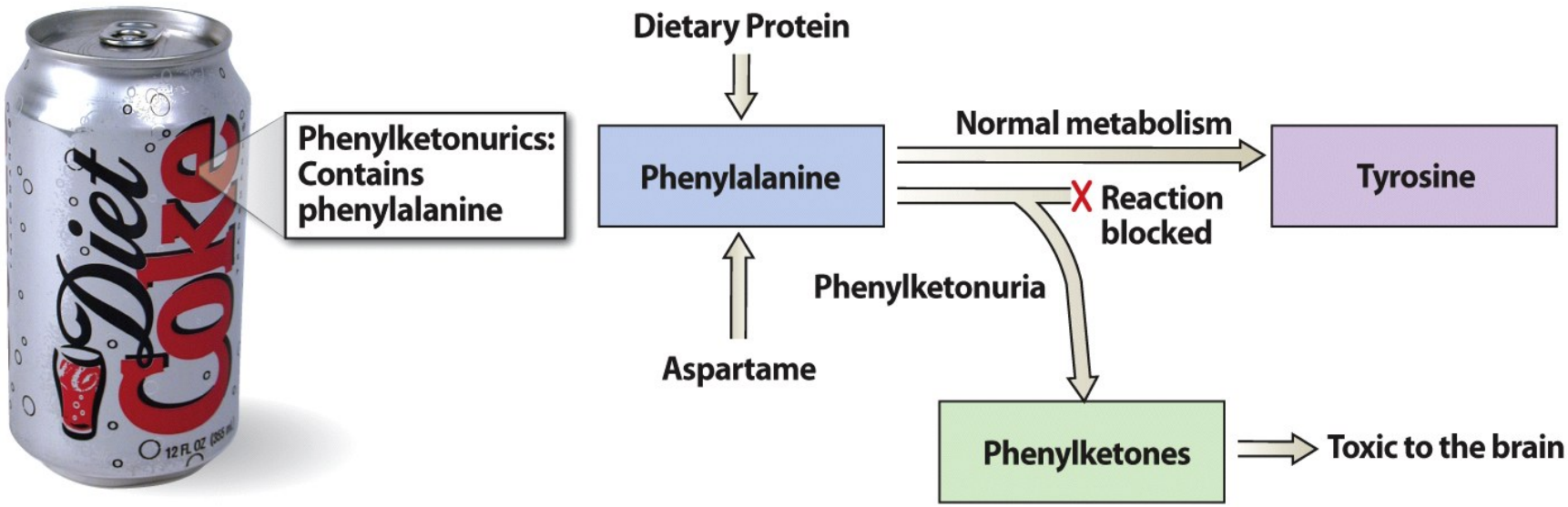
Non-essential amino acids

Can be made from others



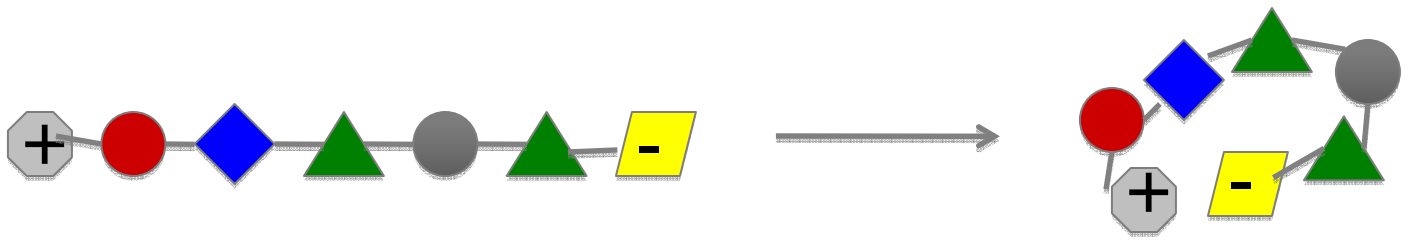


What a scientist sees

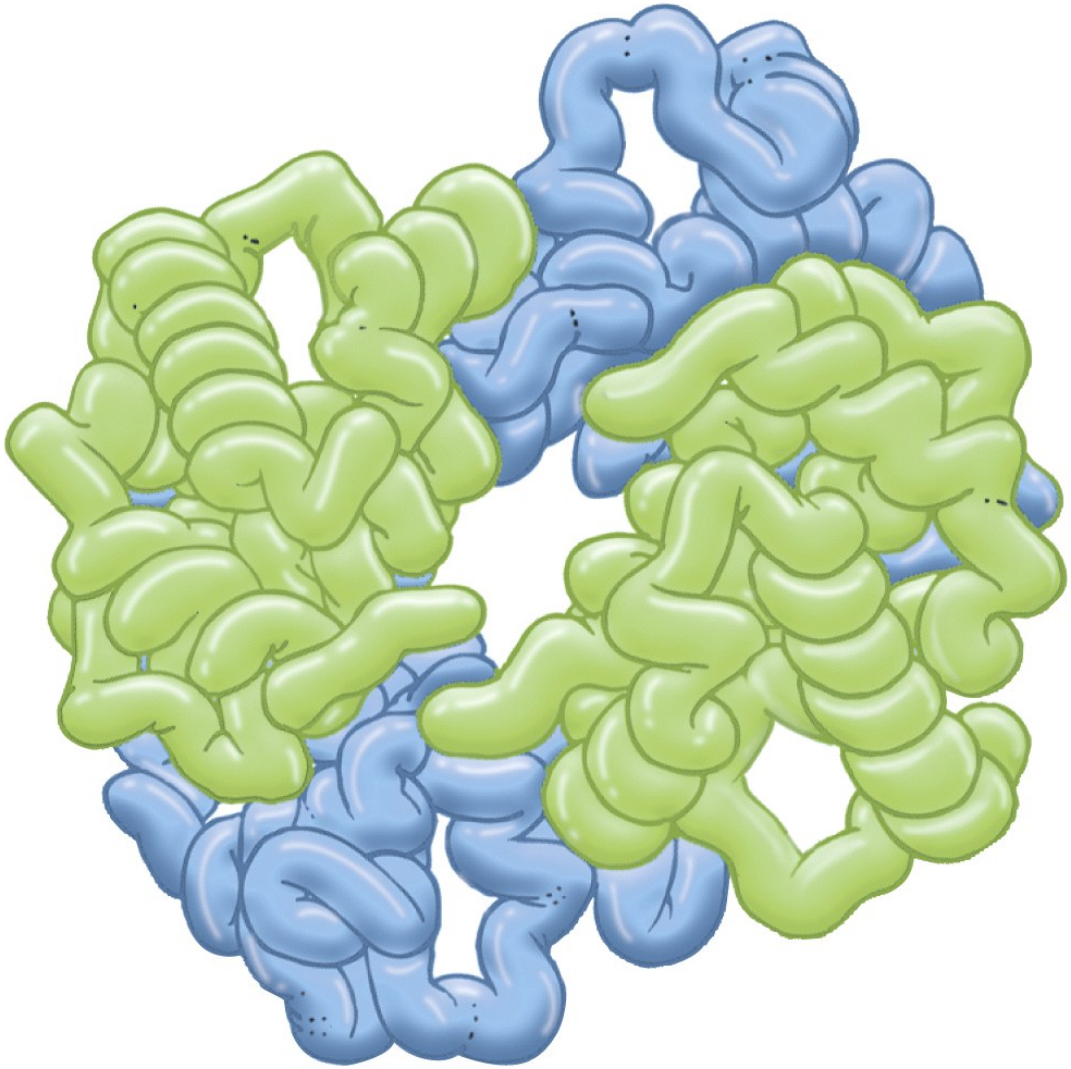


Protein folding

- Amino acids interact to form the 3-dimensional structures of proteins
- Structures of proteins determines their functions
  - If protein structure is changed, then protein function may change



Protein folding



Protein denaturation

Denaturation: change in a protein's three-dimensional shape

Occurs with:

Heat from cooking or a fever

Low pH in the stomach or when the body becomes acidic (for example, in diabetic ketoacidosis)

Neurodegenerative diseases such as Alzheimer's disease, mad cow disease, Parkinson's disease

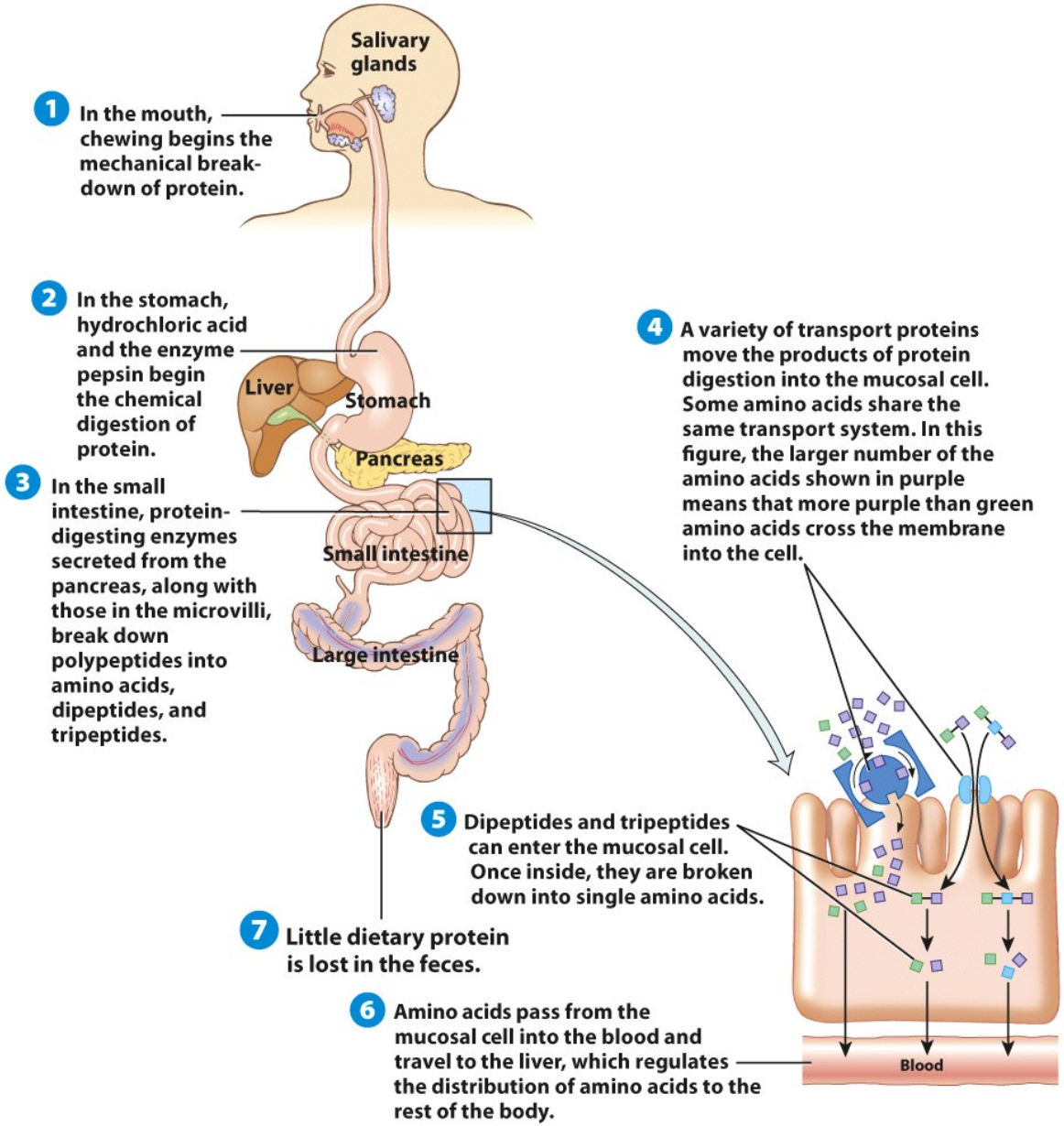
Protein denaturation

Charles D. Winters

Concept check

- Which chemical element is found in protein but not in carbohydrate or lipid?
- What determines whether an amino acid must be consumed in the diet?
- What determines the shape of a protein?
- How does denaturation affect protein function?

Protein digestion



Application

Insulin is a protein.

Why do diabetics need to inject insulin rather than take it orally?

Protein digestion

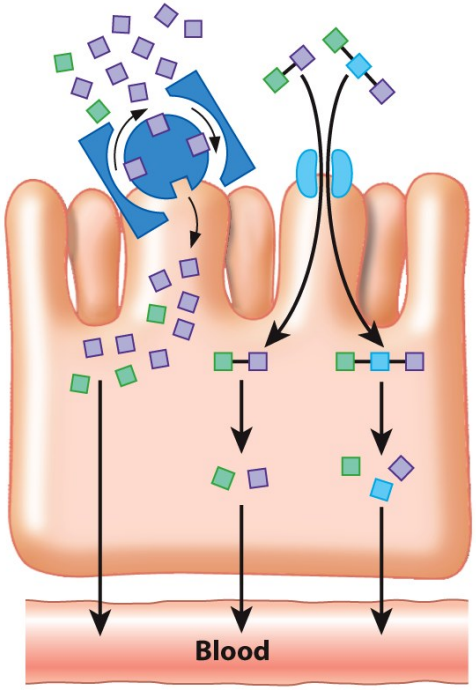
The purple amino acids are absorbed by the same transport system as the green amino acids. If you consume a sports drink that is supplemented with the green amino acids what will happen to the absorption of the purple ones.

a) nothing

b) the larger amount of green ones will limit the absorption of the purple ones

c) the small amount of the purple ones will be absorbed first

d) both will be absorbed equally because the body needs them



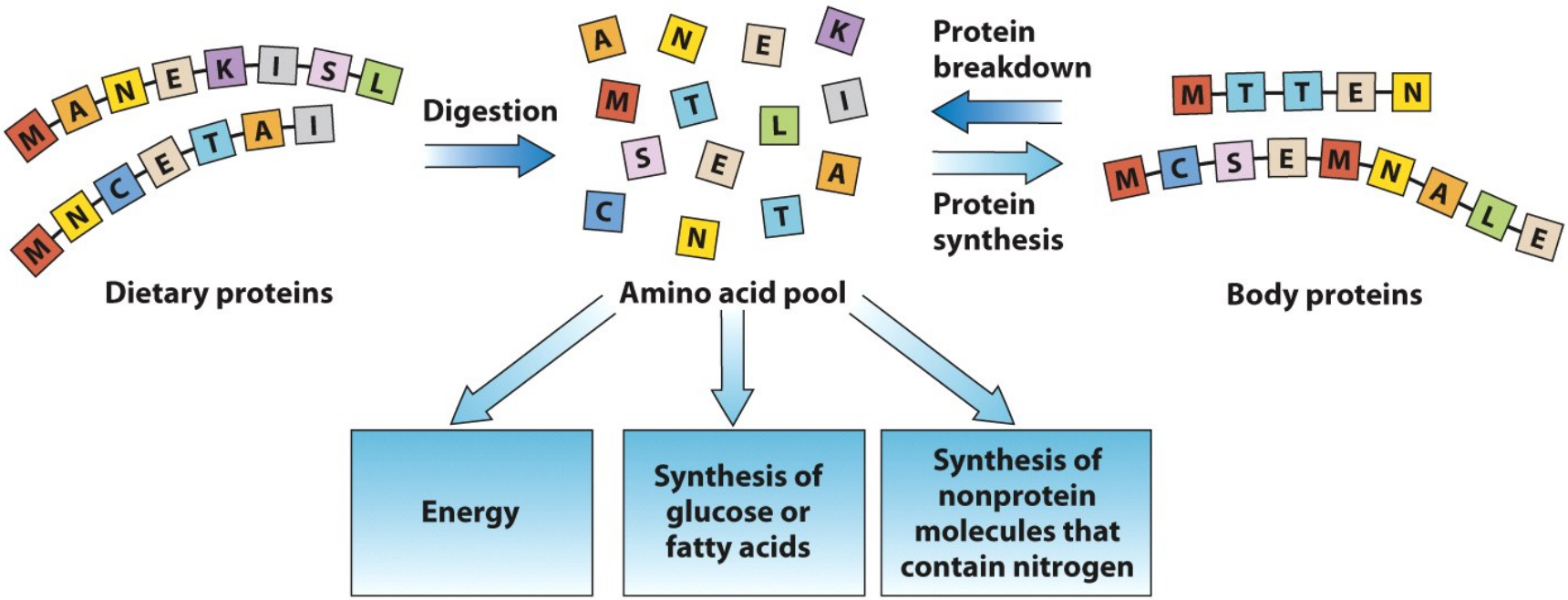
Concept check

- Where does the chemical digestion of protein begin?
- Why might supplementing one amino acid reduce the absorption of other amino acids?

Amino acid pool

- Amino acid pool: amino acids available for use in the body
  - From the diet or breakdown of body proteins
  - Used to make other proteins or chemicals (for example: DNA, RNA, histamine, etc.)
  - Used to provide energy or make glucose or fatty acids

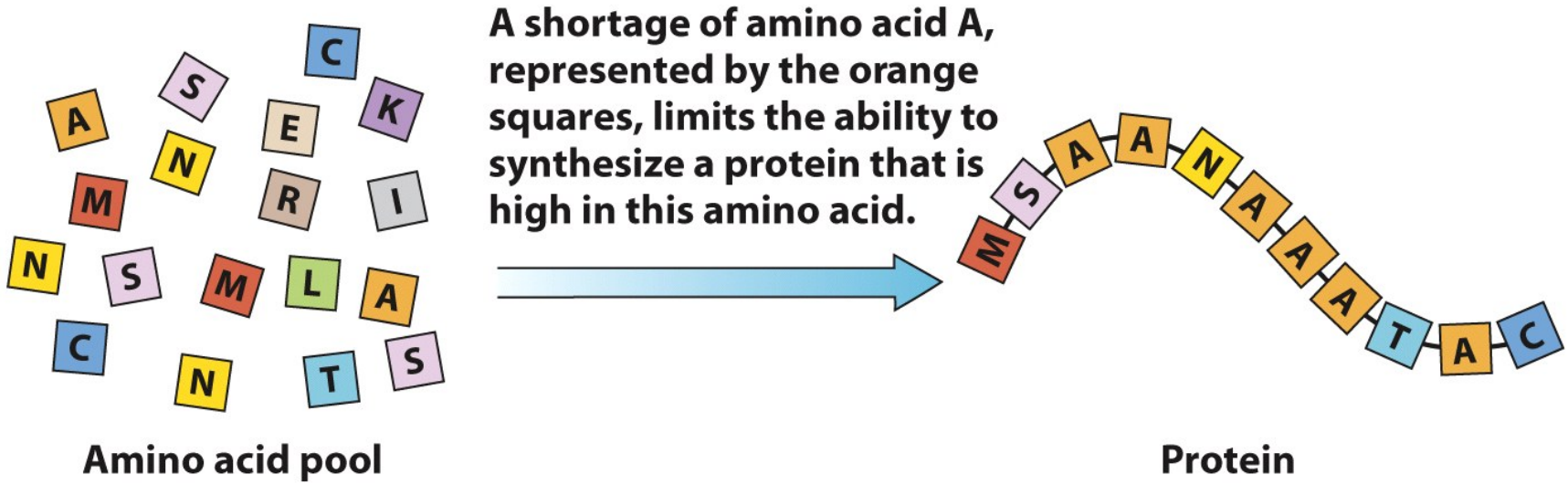
Amino acid pool



Genes contain instructions for proteins

- Each gene contains the instructions for one RNA molecule. RNA is transcribed (re-written) from DNA.
- Messenger RNA (mRNA) molecules exit the nucleus and contain instructions for the order of amino acids in a protein.
- The nucleotide instructions in DNA and RNA are translated to the amino acid language of proteins.

Genes contain instructions for proteins



Gene mutations

- Changes in gene sequence can change the sequence of the amino acids in a protein
- Changes in (amino acid) sequence can change how a protein folds and change its structure
- Changes in protein structure can change protein function

Gene regulation

- All cells contain the same DNA. During development, some genes are turned on and others are turned off so cells can carry out specific functions.
  - For example, insulin-producing cells turn on the insulin gene and turn off muscle contraction genes.
- Chemicals can turn genes on and off.
  - For example, high iron turns on the ferritin gene to make more ferritin which is needed for iron storage.

Concept check

Building blocks of proteins are:

a) nucleotides
b) amino acids
c) DNA and RNA
d) codons

Concept check

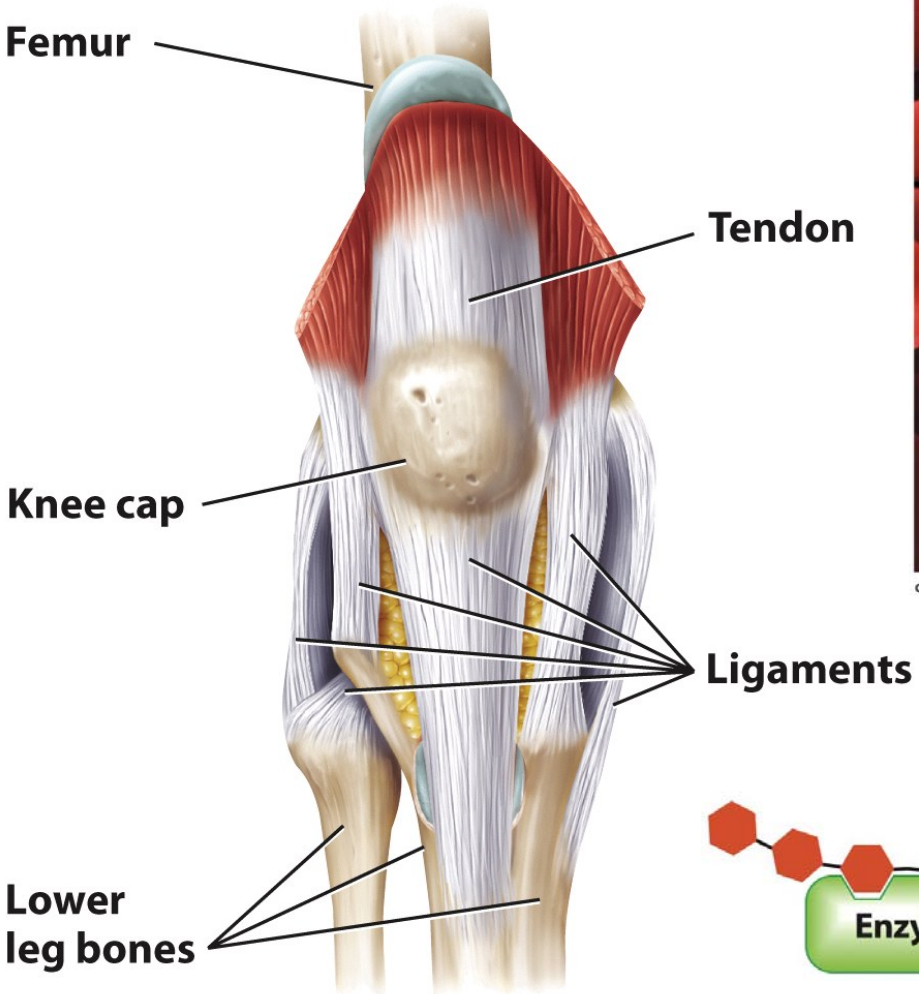
Amino acids are linked together:

a) During translation
b) In the nucleus
c) When DNA is made from RNA
d) During transcription

Protein functions

- **Speed up chemical reactions**
- **Structures**
- **Some chemical signals (for example, hormones)**
- **Transportation of substances**
- **Movement of muscles**
- **Immunity (for example, antibodies)**
- **Blood clotting**
- **Fluid balance**

Protein functions

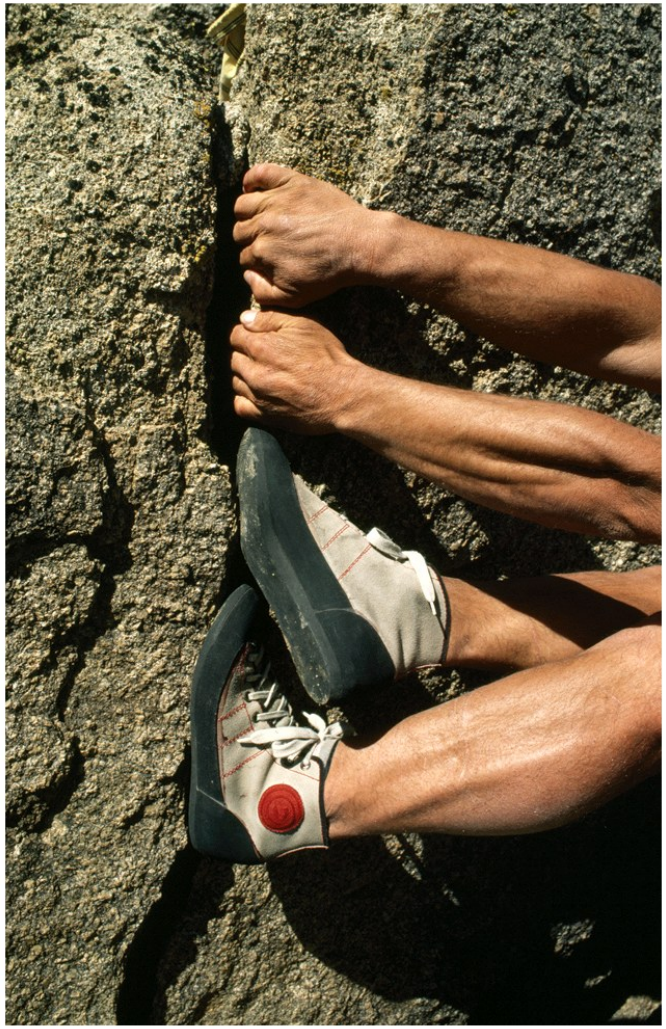


Cheryl Power/Photo Researchers

Protein functions

Karen Kasmauski/NG Image Collection

SPL/Photo Researchers, Inc.



Gordon Wiltsie/NG Image Collection

Using proteins

- Amino acids from the diet are used to make proteins and nitrogen-containing molecules
- Extra amino acids cannot be stored
- Extra amino acids are used for energy or stored as fat

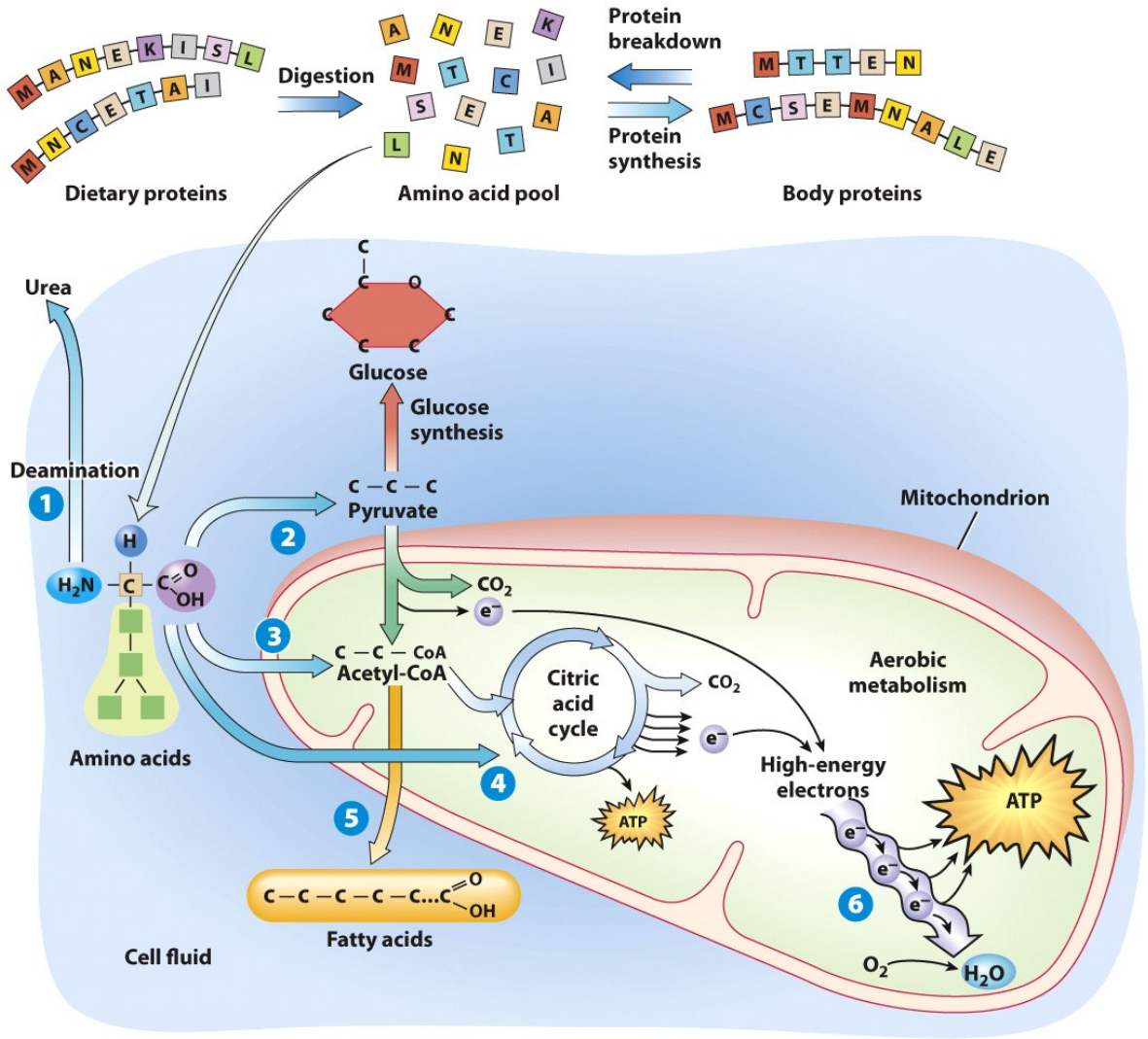
Using proteins for energy

- When we do not consume enough calories to meet needs, body proteins are broken down since amino acids are not stored

- Deamination removes amino group (NH_2) ///
  Produces urea which is excreted in urine

- Carbon, hydrogen, and oxygen can be broken down to produce ATP or used to make glucose or fatty acids

Using proteins for energy



Concept check

- Why does protein synthesis stop when the supply of an amino acid is limited?
- How does the body know in what order to assemble the amino acids when making a protein?
- When is protein used as an energy source?

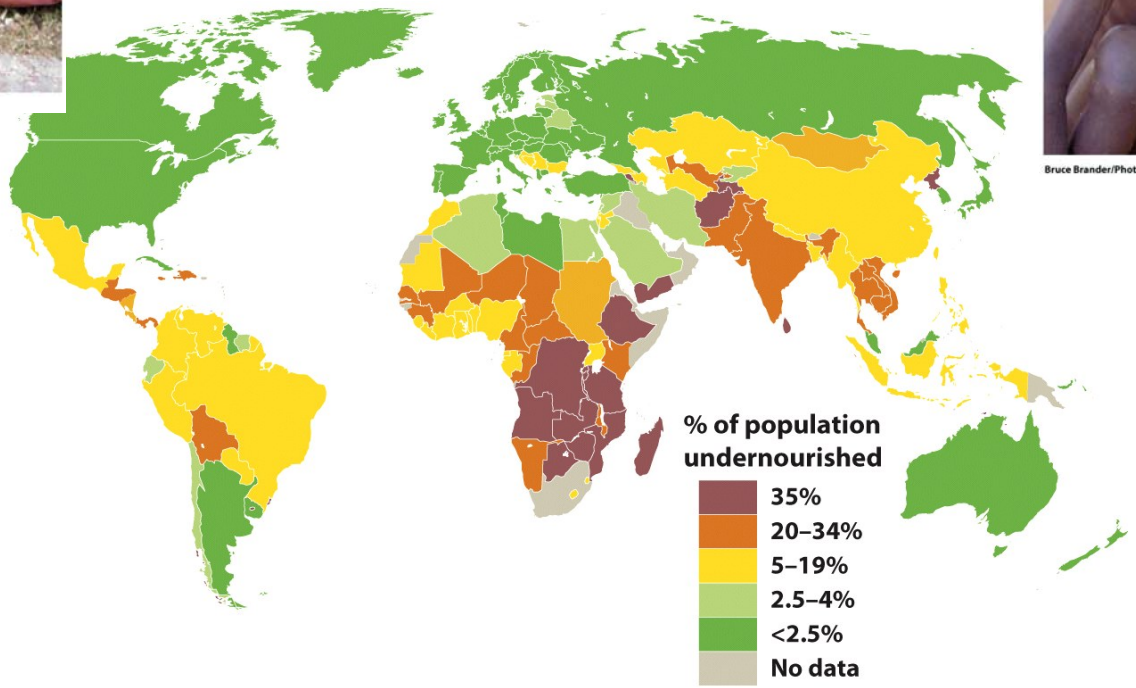
Protein-energy malnutrition (PEM)

- Loss of fat and muscle and decreased immunity from long-term protein and calorie deficiencies

- Types:
  - Kwashiorkor: pure protein deficiency
  - Marasmus: overall energy deficiency

Protein-energy malnutrition (PEM)

ALISON WRIGHT/NG Images



Bruce Brander/Photo Researchers, Inc.

Protein excess

- Increased urea output
  - Increased demands on the kidneys
  - Increased loss of water from the body
  - Possible increased loss of calcium
  - Increased risk of kidney stones

High-protein diets

Usually:

- high in animal proteins with high saturated fat and cholesterol and low in fiber
- low in grains, fruits, and vegetables
- high in calories and fat
- Increased risk of heart disease, cancer, obesity, and diabetes

Protein allergies

- When a protein is absorbed intact, the immune system can recognize it as an antigen and start cellular reactions
- The second time immune system detects that same allergen (allergy-causing antigen), there is an allergic reaction
- Major food allergens: milk, eggs, peanuts, tree nuts, fish, shellfish, soy, and wheat

Protein on food labels

The ingredient list includes sources of protein in food as well as sources of hydrolyzed protein or protein hydrolysates. These are proteins that have been treated with acid or enzymes to break them down into amino acids and small peptides. They are added as flavorings, flavor enhancers, stabilizers, and thickening agents.

INGREDIENTS: CHICKEN BROTH, CARROTS, COOKED WHITE CHICKEN MEAT (WHITE CHICKEN MEAT, WATER, SALT, SODIUM PHOSPHATE, ISOLATED SOY PROTEIN, MODIFIED CORN STARCH, CORN STARCH, CARRAGEENAN), TOMATOES, WILD RICE, RICE, CELERY. LESS THAN 2% OF: SALT, MONOSODIUM GLUTAMATE, HYDROLYZED CORN PROTEIN, CHICKEN FAT, ONION POWDER, AUTOLYZED YEAST EXTRACT, PARSLEY FLAKES, NATURAL FLAVOR. **CONTAINS SOY INGREDIENTS.**

Nutrition Facts

Serving Size 1 cup (239g)
Servings Per Container about 2

Amount Per Serving	
Calories 100 Calories from Fat 30	
	% Daily Value*
Total Fat 1.5g	**2%**
Saturated Fat 2g	**10%**
Trans Fat 0g	
Cholesterol 15mg	**5%**
Sodium 850mg	**35%**
Total Carbohydrate 15g	**5%**
Dietary Fiber 1g	**4%**
Sugars 1g	
Protein 7g	

Vitamin A 25% • Vitamin C 0%
Calcium 0% • Iron 2%

*Percent Daily Values (DV) are based on a 2,000 calorie diet.

There is little emphasis on protein in the Nutrition Facts panel, where the grams of protein are given without any % Daily Value. A % Daily Value for protein is required only on products that make a claim about the product's protein content.

Food sensitivities

- Do not involve the immune system
- Trigger various symptoms after consumption
- Examples:
  - MSG symptom complex or Chinese restaurant syndrome
  - Gluten intolerance or Celiac disease /// Consumption of gluten in rye, wheat or barley triggers an autoimmune reaction against villi in the small intestines

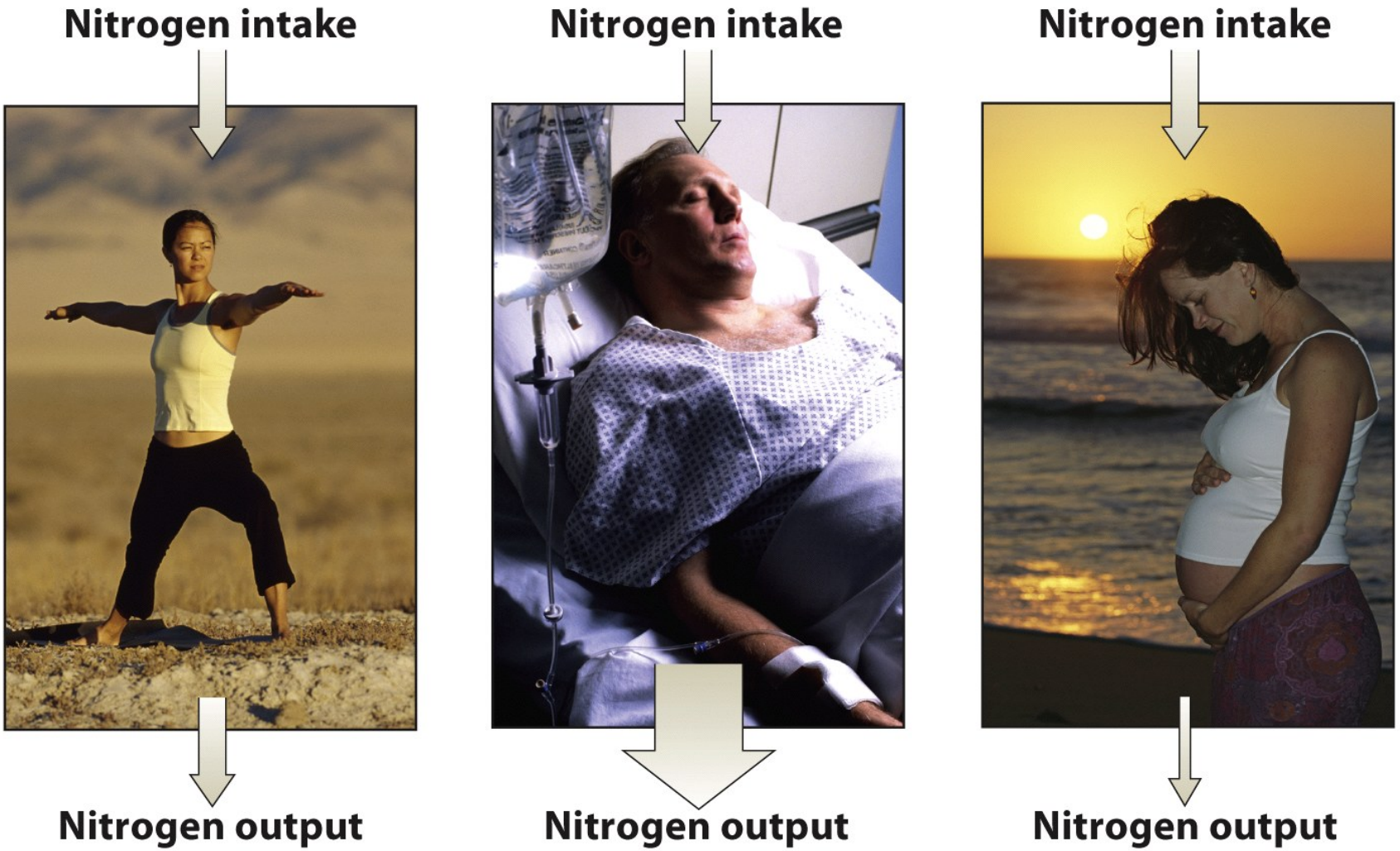
Concept check

- What are consequences of low or high protein diets?

Nitrogen balance

- Nitrogen intake equals nitrogen loss
- Maintaining body protein and weight
- Negative nitrogen balance /// more nitrogen lost than consumed /// From illness, injury, or decreased consumption
- Positive nitrogen balance /// more nitrogen consumed than lost /// From growth, pregnancy, or weight training

Nitrogen balance

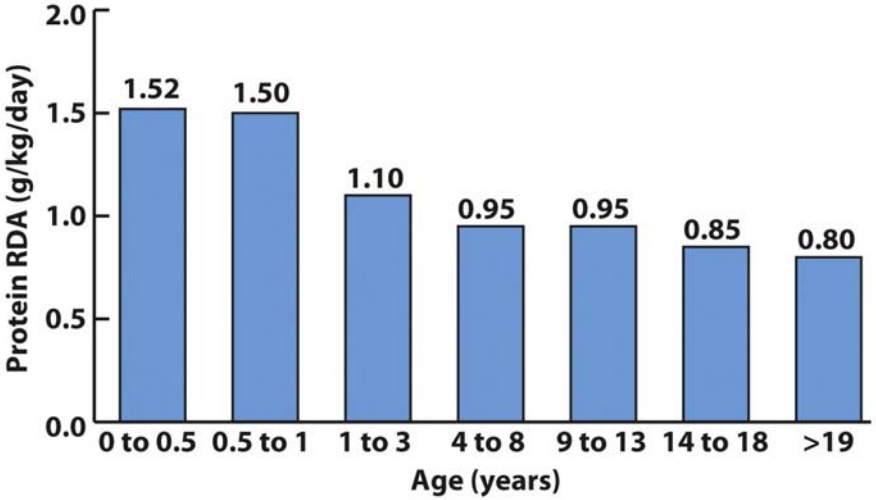


Cameron Lawson/NG Image Collection; Brian Yarvin/Photo Researchers, Inc.; Roy Toft/NG Image Collection

Protein recommended daily allowance

During the first year of life, growth is rapid, so a large amount of protein is required per unit of body weight. As growth rate slows, requirements per unit of body weight decrease but continue to be greater than adult requirements until age 19. What is the RDA for a 2-year-old child who weighs 14 kilograms?

a) 14 g/day
b) 15.4 g/day
c) 11.2 g/day
d) 21 g/day



Protein recommended daily allowance

- 0.8 g/kilogram of body weight for adults
  - With more weight, more protein is needed for maintenance and repair
  - 70 kg (154 lb) adult = 56 g of protein/day
  - Average consumption = 70 g of protein/day

Protein recommended daily allowance

- Higher needs in infants, during pregnancy and lactation (breast feeding), after injury, and in endurance athletes
  - Pregnant / lactating women: add 25 g of protein/day

Calculate

- 100 pound adult
- weight in kilograms equals weight in pounds x0.45 kg/lb
- Protein RDA = 0.8 g/kilogram of body weight

How much protein does this person need?

Protein intake in athletes

JOHN BURCHAM/NG Images

Michael Nichols/NG Image Collection

Protein supplements

Protein supplements are marketed to promote proper immune function, make hair healthy, and stimulate muscle growth, but increasing protein intake above the level required for good health does not protect you from disease, make your hair shine, or give you larger biceps.

Many promises are made about amino acid supplements, from aiding sleep to enhancing athletic performance. There is weak evidence to support some of these, but consuming large amounts of one amino acid may interfere with the absorption of others. Due to insufficient research, no ULs have been set for amino acids.

Supplements of enzymes that function inside body tissues provide no benefits because the enzyme is broken down into amino acids during digestion. Supplements of enzymes that function in the gut, such as lactase for lactose intolerance, retain enzyme activity long enough to breakdown the lactose but are also eventually digested.

Charles D. Winters/Photo Researchers, Inc.

Protein dietary recommendations

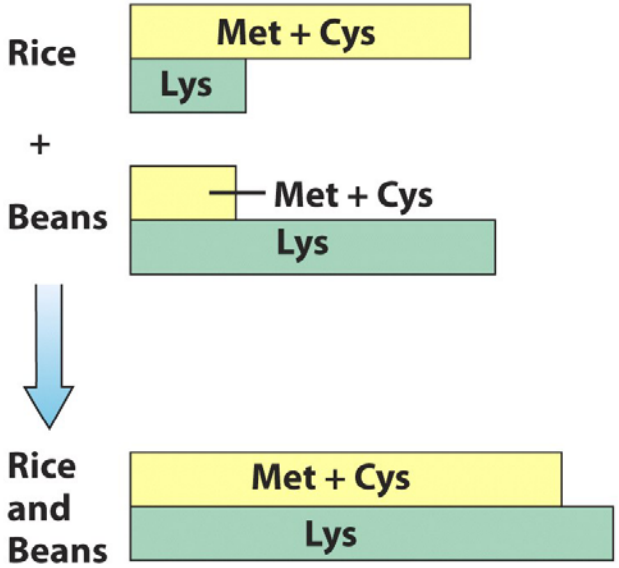
- Acceptable Macronutrient Distribution Range for protein:10% to 35% of calories

- Dietary Guidelines 2010 recommend that we choose a variety of protein foods, including seafood, lean meat and poultry, eggs, beans, soy products, and unsalted nuts and seeds

Protein quality

- High-quality, or complete dietary, proteins
  - Contain all amino acids to meet body's needs
  - More easily digested
  - Animal proteins and soy
- Incomplete proteins
  - Lower in one or more essential amino acids
  - Most plant proteins
  - Use complementary proteins

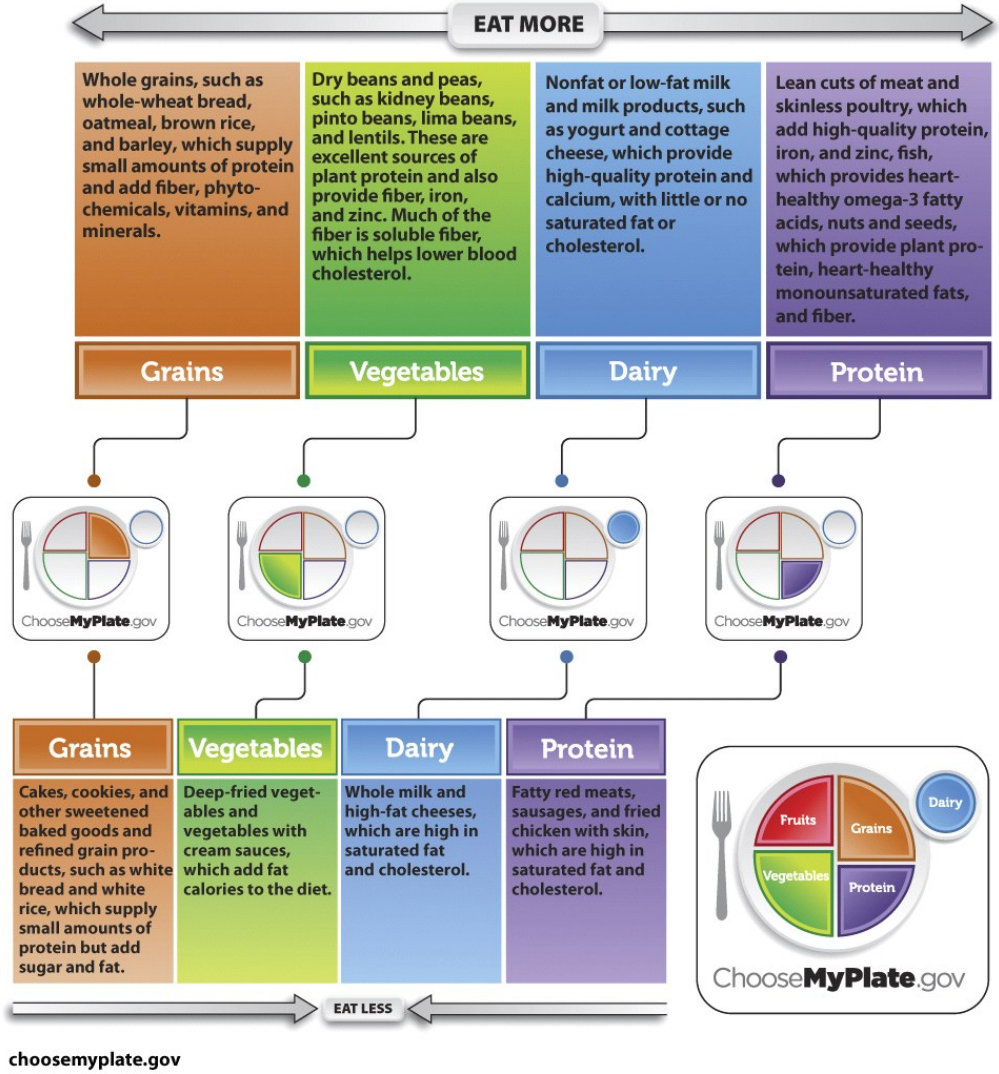
Complementary proteins



Melanie Acevedo/FoodPix/Getty Images, Inc.

When rice, which is limited in lys but high in met and cys, is eaten with beans, which are high in lys but limited in met and cys, the combination provides all the amino acids needed by the body.

Choosing healthy proteins



Debate

Should you switch to soy?

Soy milk is a substitute for cow's milk

Soy flour can be incorporated into baked goods.

Texturized soy protein (TSP), also known as texturized vegetable protein (TVP), is formed into chunks, woven or spun into fibers, or otherwise shaped and flavored to produce vegetarian versions of burgers, hotdogs, meatballs, and chicken.

Soy butter is similar to peanut butter and can be spread on crackers and sandwiches.

Tofu, also known as bean curd, is added to soups, salads, and stir-fries.

Teri Stratford/Six-Cats Research, Inc.

What should I eat?

- Get protein without too much saturated fat
- Eat both animal and plant proteins
- Go with beans

What are some menu items you could consume?

Calculate

Which foods provide the cheapest source of protein?

Vegetarian diets

- Reasons to be vegetarian:
  - Limited land and/or resources
  - Health
  - Religion
  - Personal ethics
  - Environmental concerns
- Benefits: lower cost and healthier
- Risks: amino acid, mineral, and B vitamin deficiency

Types of vegetarian diets

- Semivegetarian: Excludes red meat but may include fish and poultry, as well as dairy products and eggs
- Pescetarian: Excludes all animal flesh except fish
- Lacto-ovo vegetarian: Excludes all animal flesh but includes eggs and dairy products
- Lacto vegetarian: Excludes animal flesh and eggs but includes dairy products
- Vegan: Excludes all food of animal origin

Meeting dietary needs with a vegan diet

Meeting nutrient needs with a vegan diet[18] Table 6.2

Nutrient at risk	Sources in vegan diets
Protein	Soy-based products, legumes, seeds, nuts, grains, and vegetables
Vitamin B_{12}	Products fortified with vitamin B_{12}, such as soy beverages, rice milk, and breakfast cereals; fortified nutritional yeast; dietary supplements
Calcium	Tofu processed with calcium; broccoli, kale, bok choy, and legumes; products fortified with calcium, such as soy beverages, rice milk, grain products, and orange juice
Vitamin D	Sunshine; products fortified with vitamin D, such as soy beverages, rice milk, breakfast cereals, and margarine
Iron	Legumes, tofu, dark green leafy vegetables, dried fruit, whole grains, iron-fortified grain products (absorption is improved when iron-containing foods are consumed with vitamin C found in citrus fruit, tomatoes, strawberries, and dark green vegetables)
Zinc	Whole grains, wheat germ, legumes, nuts, tofu, and fortified breakfast cereals
Iodine	Iodized salt, sea vegetables (seaweed), and foods grown near the sea
Omega-3 fatty acids	Canola oil, flaxseed and flaxseed oil, soybean oil, walnuts, and sea vegetables (seaweed), which provide fatty acids that can be used to synthesize EPA and DHA; DHA-rich microalgae

Concept check

- How can nitrogen balance be maintained?
- What are benefits and risks of consuming a plant-based diet?
- How can vegetarians avoid nutrient deficiencies?

Think critically

Sickle cell anemia is an inherited disease caused by an abnormality in the gene for the protein hemoglobin. It causes red blood cells to take on a sickle shape.

- *Sickle cell hemoglobin differs from normal hemoglobin by one amino acid. Why might this difference change the shape of the hemoglobin?*
- *Do you think sickle-shaped red blood cells can travel easily through narrow capillaries?*
- *How might this disorder affect the ability to get oxygen to the body's cells?*

What are similarities and differences between:

- Proteins and amino acids?
- Chromsomes and genes?
- DNA and mRNA?
- Plant and animal proteins?
- Kwashiorkor and marasmus?
- Vegetarian and vegan diets?

Applications

What advice could you give to a loved on about protein consumption to decrease disease risk?

Nutrition in the news

- Atkins diets
- Protein supplements for weight lifters

Checking student learning outcomes

- How do proteins contribute to health and disease?
- What advice would you give to a loved one about protein consumption?