Introduction to Organic Compounds

Pearson

3.1 Life's Molecular Diversity Is Based on the Properties of Carbon (1 of 2)

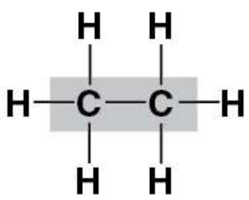
- Carbon's ability to bond with four other atoms is the basis for building large and diverse **organic compounds**.
- Carbon chains form the backbone of most organic molecules.
- **Isomers** have the same molecular formula but different structures.
- **Hydrocarbons** are composed of only carbon and hydrogen.

3.1 Life's Molecular Diversity Is Based on the Properties of Carbon (2 of 2)

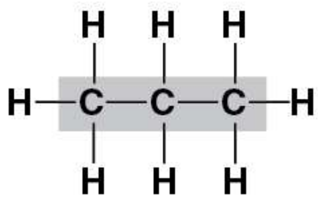
Checkpoint question Methamphetamine occurs as two isomers: one is the addictive illegal drug known as "crank"; the other is a sinus medication. How can you explain these differing effects?

Isomers have different structures, or shapes, and the shape of a molecule usually determines the way it functions in the body.

Figure 3.1b

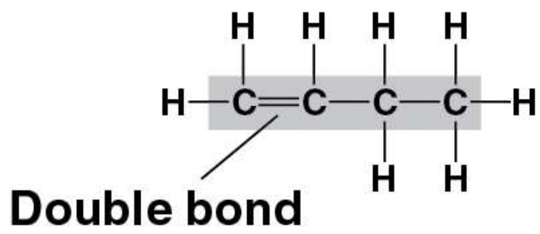


Ethane

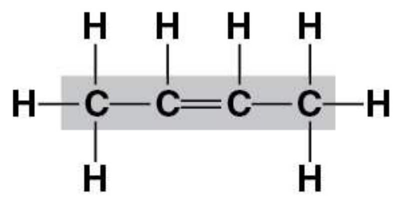


Propane

Length: Carbon skeletons vary in length.

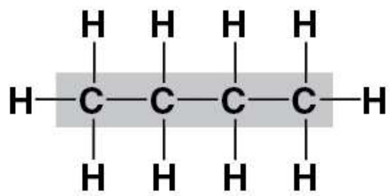


1-Butene

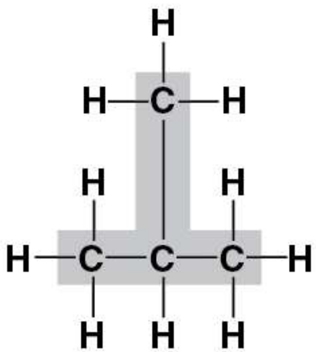


2-Butene

Double bonds: Carbon skeletons may have double bonds, which can vary in location.

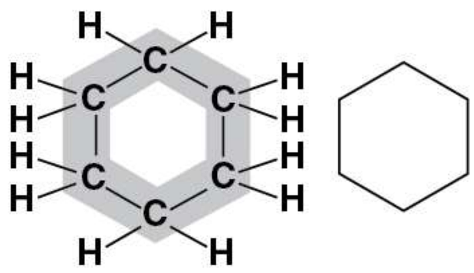


Butane

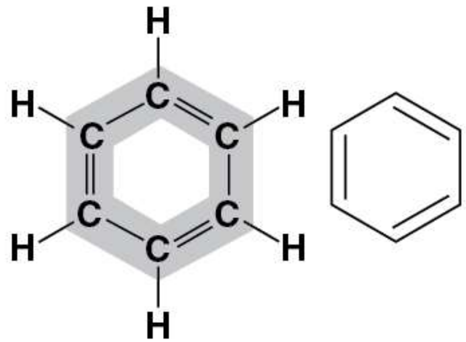


Isobutane

Branching: Carbon skeletons may be unbranched or branched.



Cyclohexane



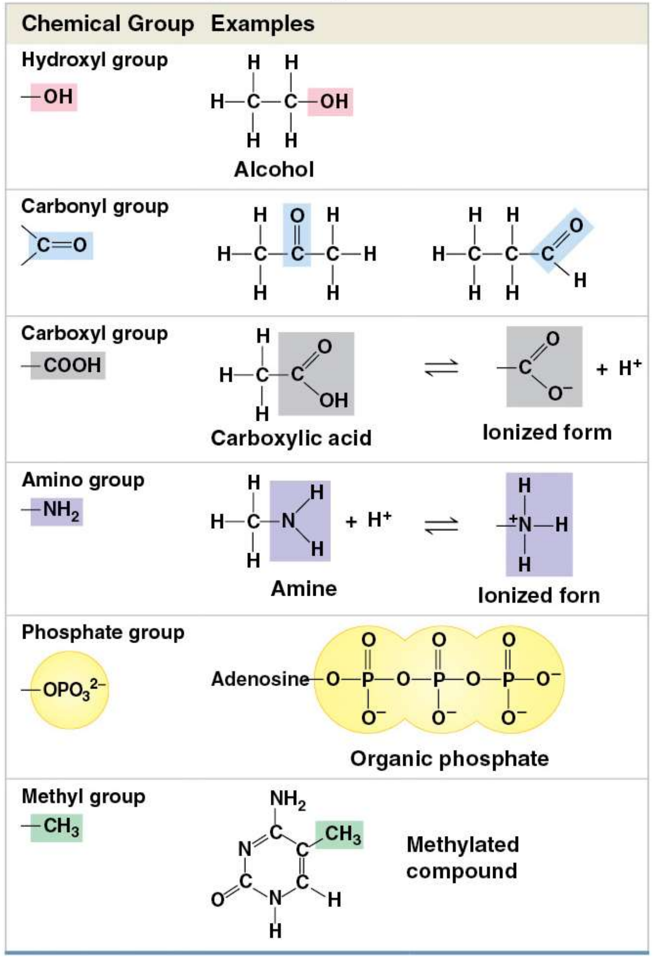
Benzene

Rings: Carbon skeletons may be arranged in rings. (In the abbreviated ring structures, each corner represents a carbon and its attached hydrogens.)

3.2 A Few Chemical Groups are Key to the Functioning of Biological Molecules (1 of 2)

- An organic compound's properties depend on the
  - size and shape of its carbon backbone and
  - atoms attached to that skeleton.
- Hydrophilic **functional groups** give organic molecules specific chemical properties.
- Table 3.2 illustrates six important chemical groups.

Table 3.2 Important Chemical Groups Of Organic Compounds (1 of 3)



Checkpoint question Identify the chemical groups that do not contain carbon. The hydroxyl, amino, and phosphate groups

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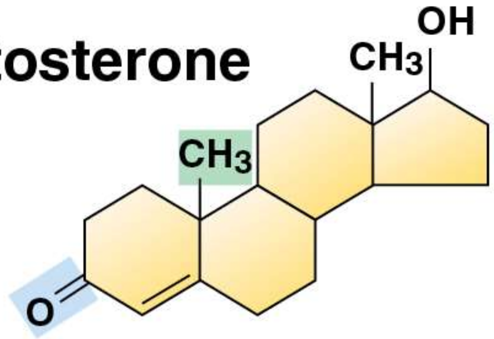
3.2 A Few Chemical Groups Are Key to the Functioning of Biological Molecules (2 of 2)

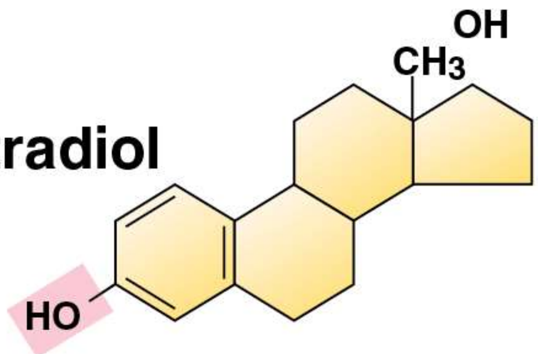
- The sex hormones testosterone and estradiol (a type of estrogen) differ only by a few atoms BUT this has dramatic effects

Figure 3.2

Testosterone



Estradiol



3.3 Cells Make Large Molecules from a Limited Set of Small Molecules (1 of 2)

- The four classes of biological molecules contain very large molecules.
  - They are often called **macromolecules** because of their large size.
  - They are also called **polymers** because they are made from identical or similar building blocks strung together.
  - The building blocks of polymers are called **monomers**.

3.3 Cells Make Large Molecules from a Limited Set of Small Molecules (2 of 2)

- Monomers are linked together to form polymers through **dehydration reactions**.
- Polymers are broken apart by **hydrolysis**.
- These reactions are mediated by **enzymes**, specialized macromolecules that speed up reactions.

Checkpoint question Suppose you eat some cheese. What reactions must occur for the protein of the cheese to be broken down into its amino acid monomers and then for these monomers to be converted to proteins in your body?

Figure 3.3

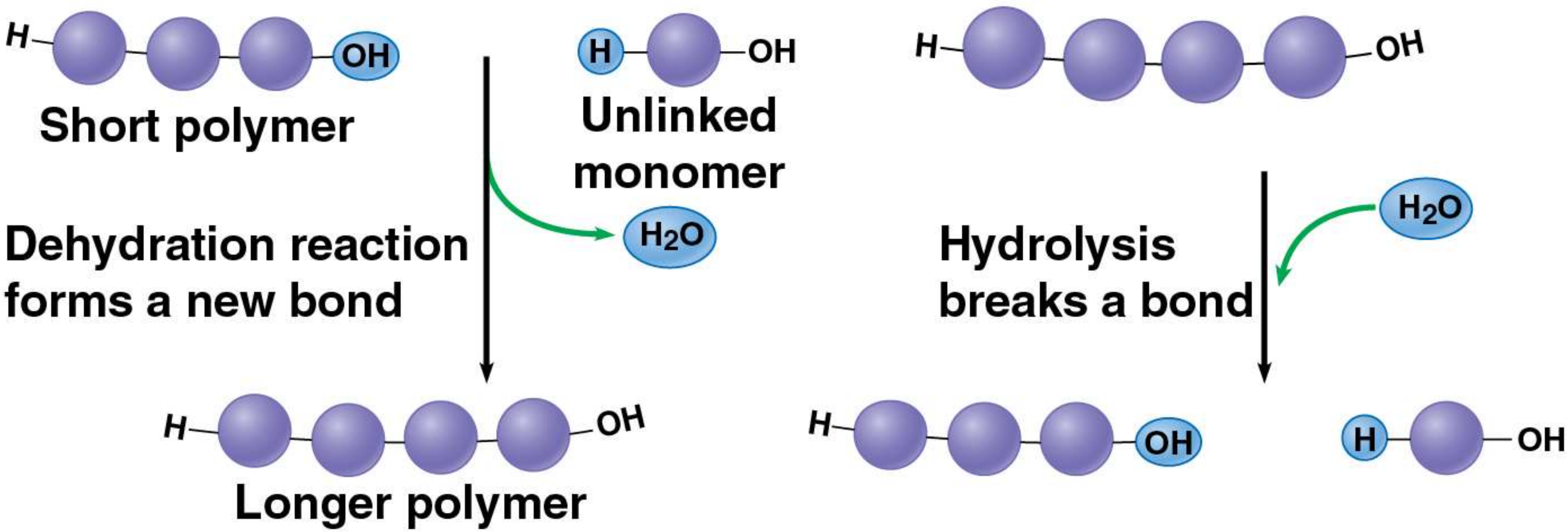


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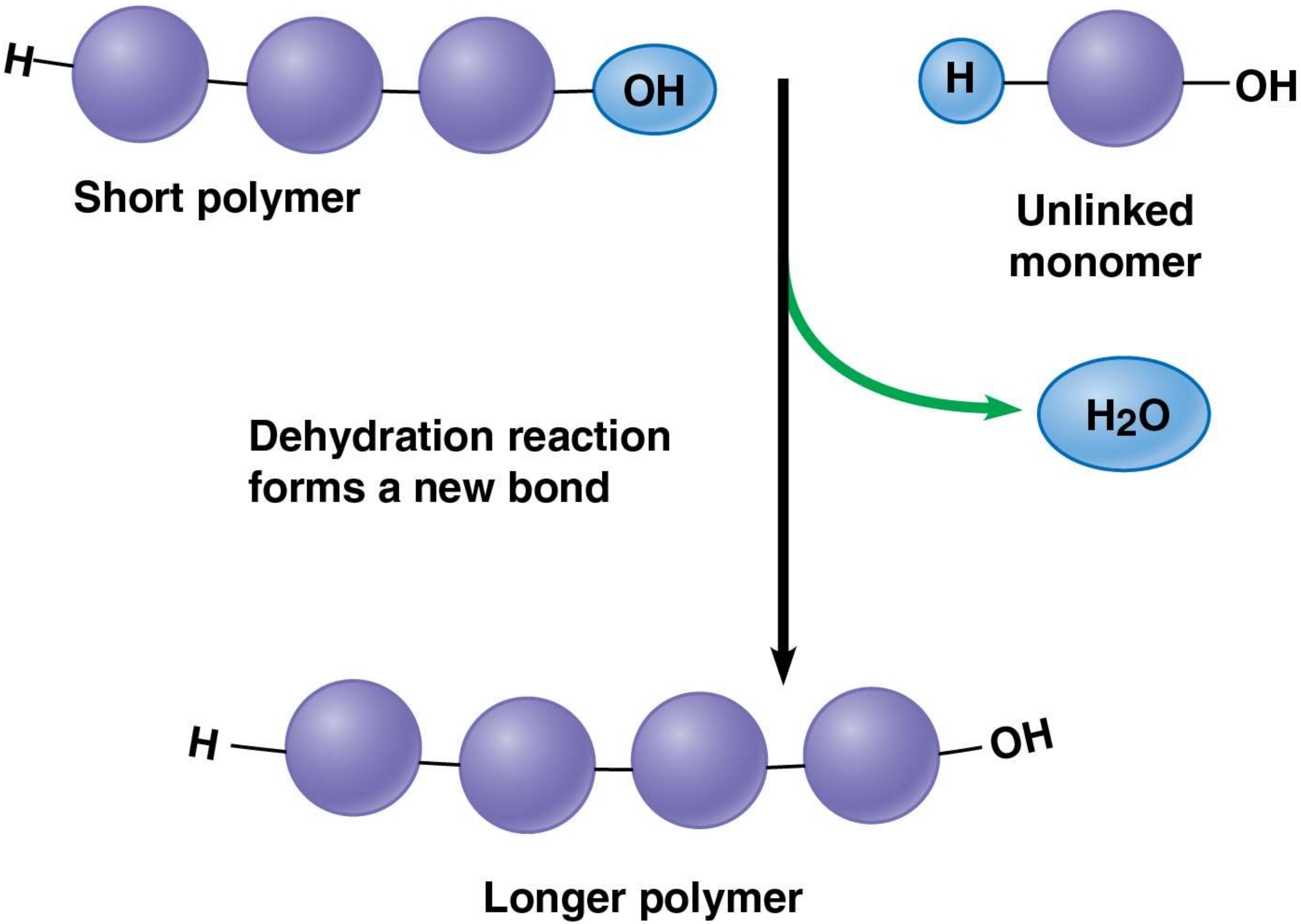
Figure 3.3_1_2



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Carbohydrates

3.4 Monosaccharides are the Simplest Carbohydrates

- **Carbohydrates** range from small sugar molecules (monomers) to large polysaccharides.
  - Sugar monomers are **monosaccharides.**
  - A monosaccharide generally has a formula that is a multiple of CH_2O and contains hydroxyl groups and a carbonyl group.

Checkpoint question Write the formula for a monosaccharide that has three carbons.

$C_3H_6O_3$

Figure 3.4b

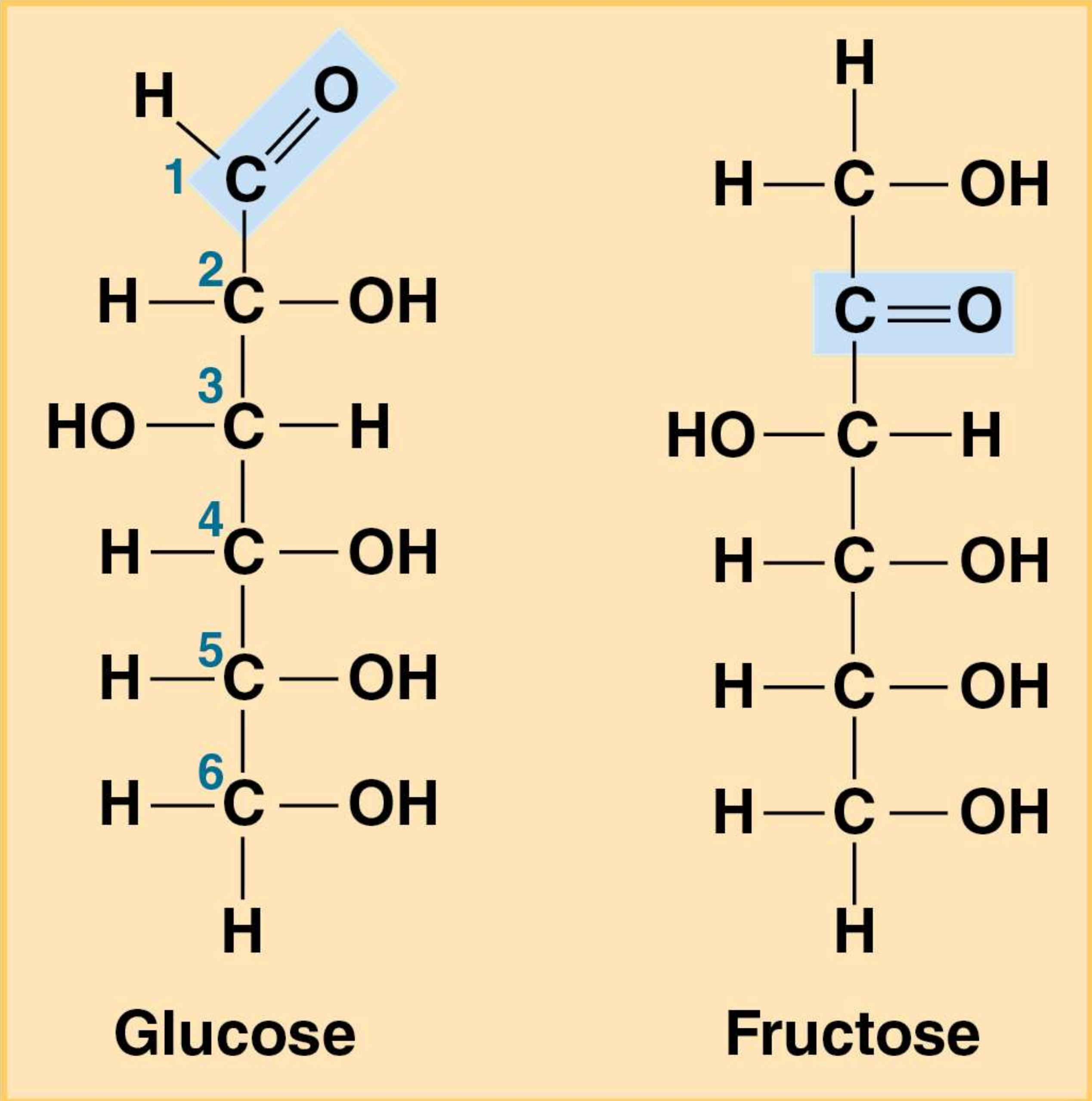
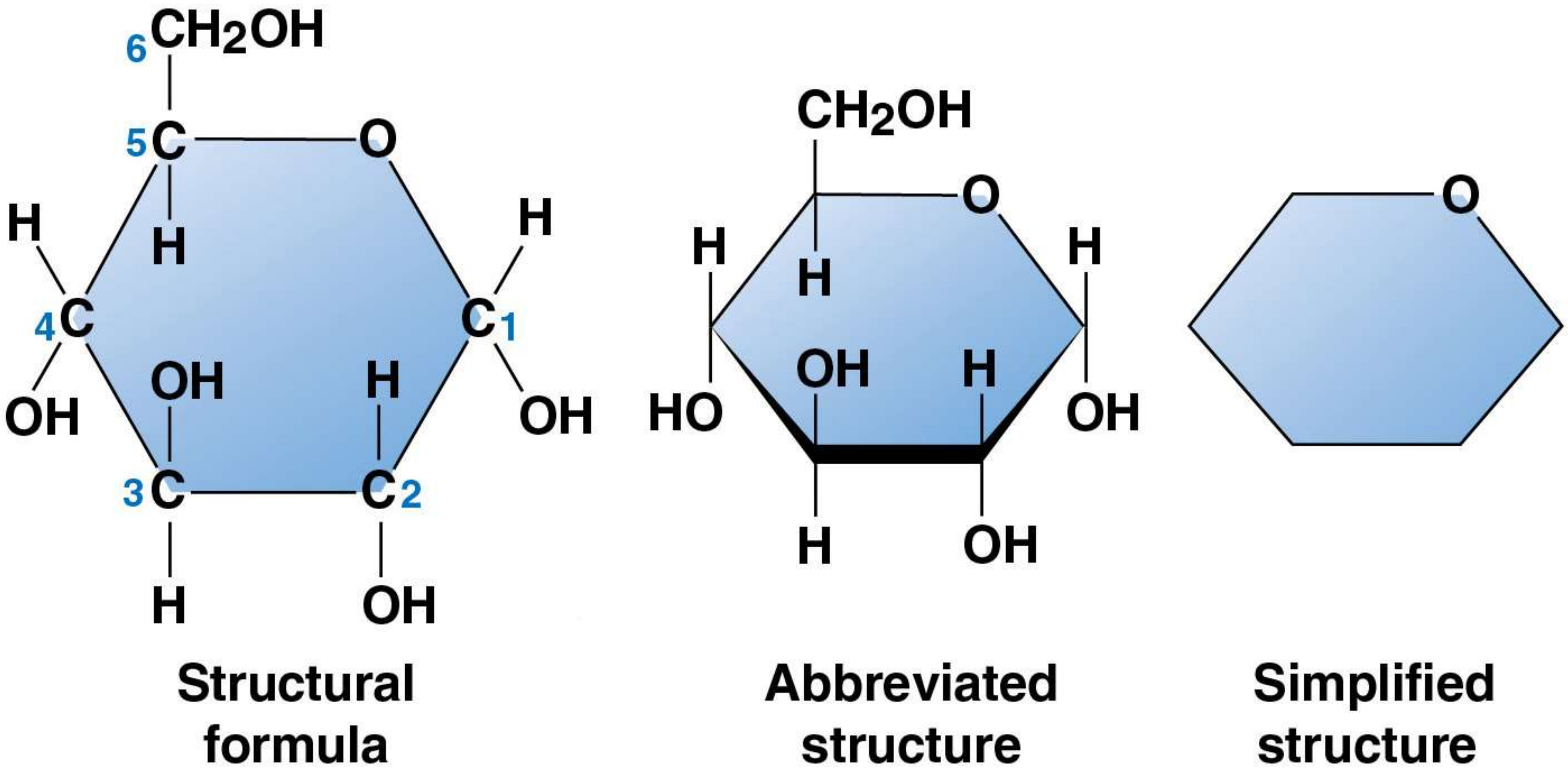


Figure 3.4c


6
CH2OH
5
C
O
H
H
H
4
C
C
1
OH
H
OH
OH
3
C
C
2
H
OH
Structural formula
CH2OH
O
H
H
H
OH
H
HO
OH
H
OH
Abbreviated structure
O
Simplified structure

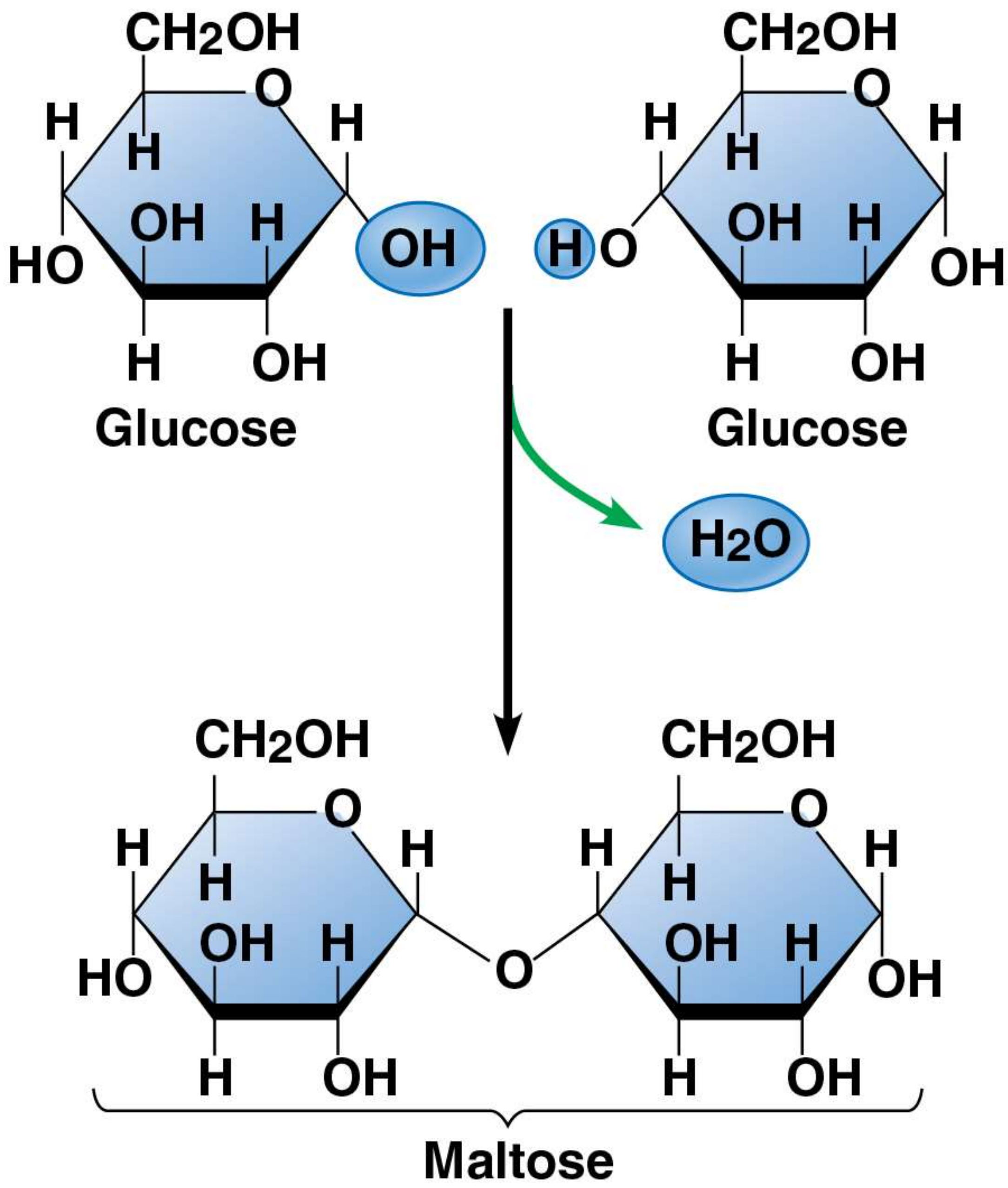
3.5 Two Monosaccharides Are Linked to Form a Disaccharide

- Two monosaccharides (monomers) can bond to form a **disaccharide** in a dehydration reaction.

Checkpoint question Lactose, as you read in the chapter introduction, is the disaccharide sugar in milk. It is formed from glucose and galactose. The formula for both these monosaccharides is $C_6H_{12}O_6$. What is the formula for lactose?

$C_{12}H_{22}O_{11}$

Figure 3.5_2



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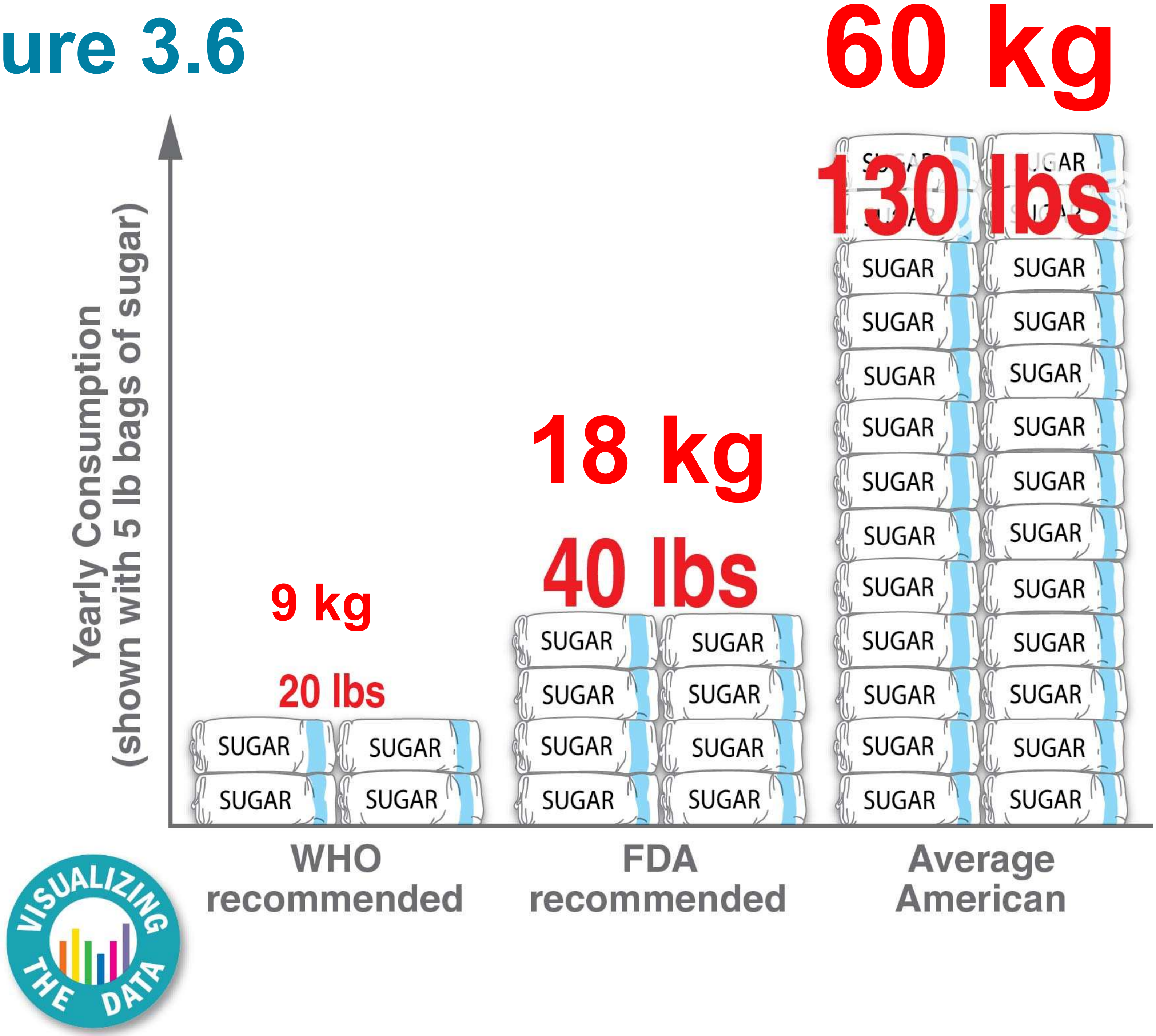
3.6 Connection: Are We Eating Too Much Sugar?

- The FDA recommends that only 10% of daily calories come from added sugar.
- Research supports the correlation between high sugar intake and adverse health effects.

Checkpoint question Sugars are often described as "empty calories." What do you think that means from a nutrition standpoint?

Added sugars provide energy but they do not provide other nutrients, such as protein, fats, vitamins, or minerals.

Figure 3.6



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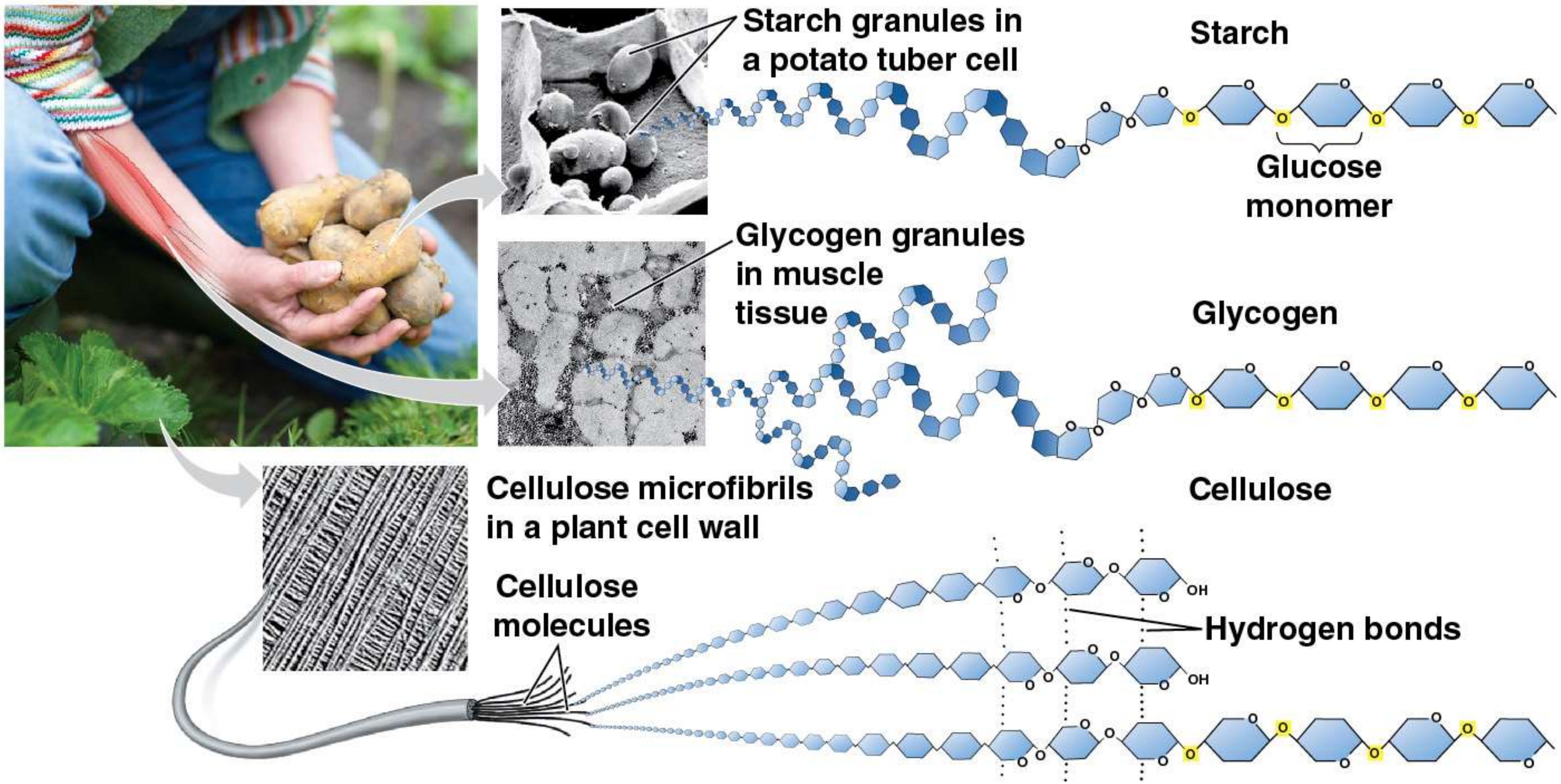
3.7 Polysaccharides Are Long Chains of Sugar Units

- **Starch** and **glycogen** are storage **polysaccharides**.
- **Cellulose** is structural, found in plant cell walls.
- **Chitin** is a component of insect and crustacean and fungal cell walls.

Checkpoint question Compare and contrast starch and cellulose, two plant polysaccharides.

Both are polymers of glucose, but the bonds between glucose monomers have different shapes. Starch functions mainly for sugar storage. Cellulose is a structural polysaccharide that is the main material of plant cell walls.

Figure 3.7


Starch granules in a potato tuber cell
Starch
Glucose monomer
Glycogen granules in muscle tissue
Glycogen
Cellulose microfibrils in a plant cell wall
Cellulose
Cellulose molecules
Hydrogen bonds

Lipids

3.8 Fats Are Lipids That Are Mostly Energy-Storage Molecules (1 of 2)

- **Lipids** are diverse **hydrophobic** (water-fearing) compounds composed largely of carbon and hydrogen.
  - **Fats** (triglycerides) consist of glycerol linked to three fatty acids.
  - Some fatty acids contain one or more double bonds, forming **unsaturated fatty acids**. Unsaturated fatty acids are typical of plant oils.
  - Fats with the maximum number of hydrogens are called **saturated fatty acids**. Saturated fatty acids are found in animal fats.

3.8 Fats Are Lipids That Are Mostly Energy-Storage Molecules (2 of 2)

- Hydrogenated vegetable oils are unsaturated fats that have been converted to saturated fats by adding hydrogen.
- This hydrogenation creates **trans fats**, which are associated with health risks.

Checkpoint question Explain why fats are hydrophobic.

The three fatty acid tails of a fat molecule contain only nonpolar C—H bonds, which do not mix well with polar water molecules.

Figure 3.8a

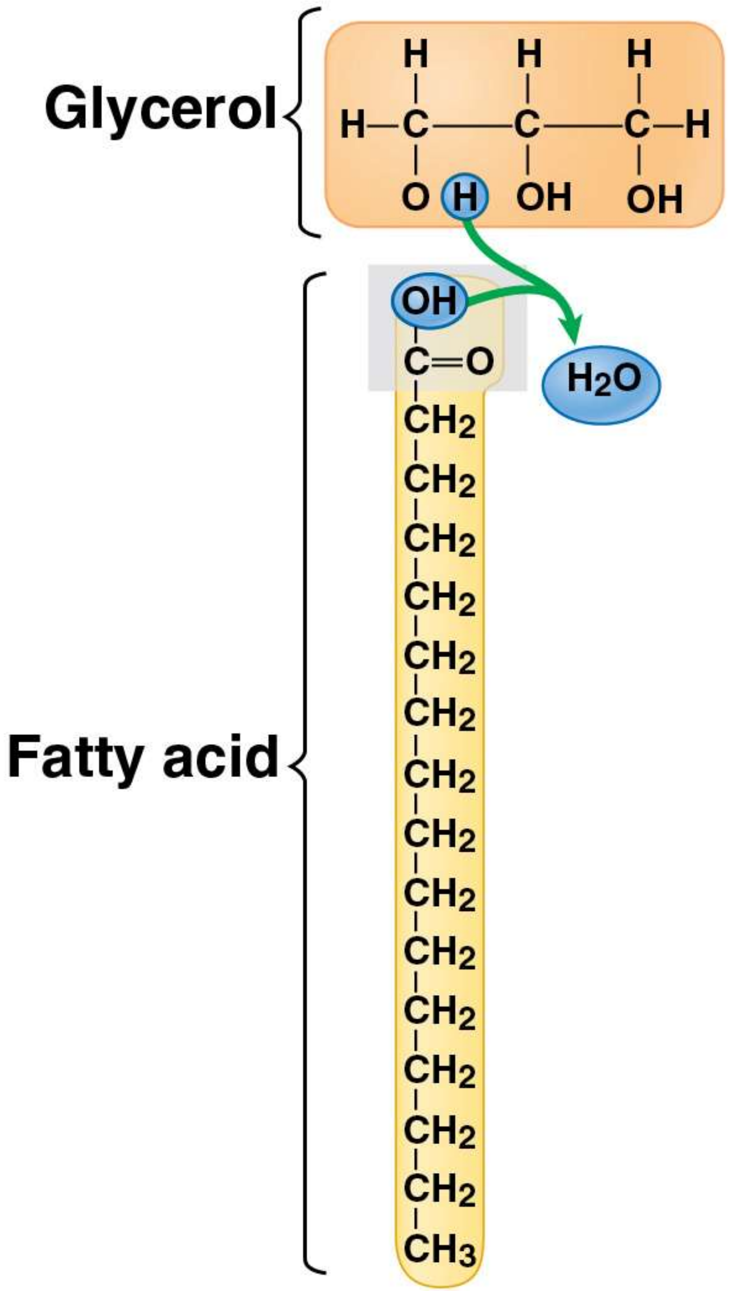
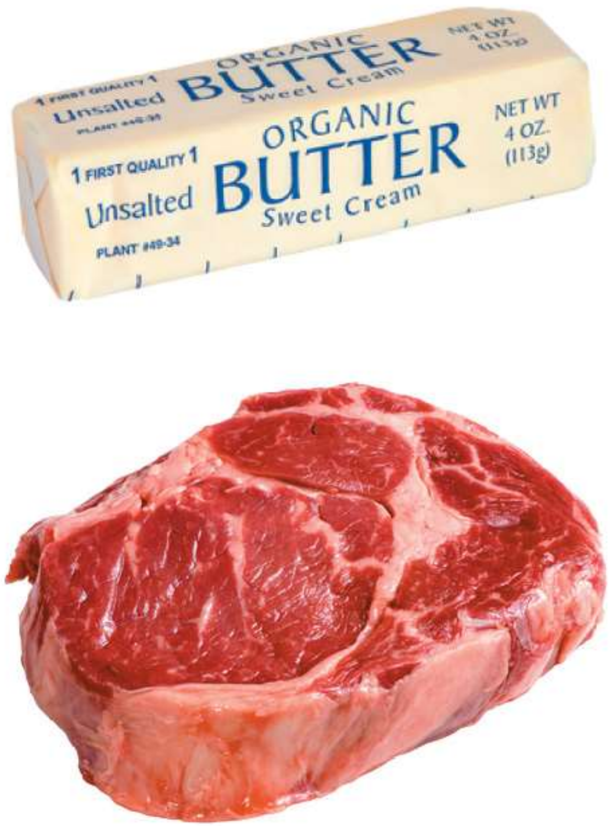


Figure 3.8c



Saturated fats

Unsaturated fats

3.9 Scientific Thinking: Scientific Studies Document the Health Risks of Trans Fats (1 of 2)

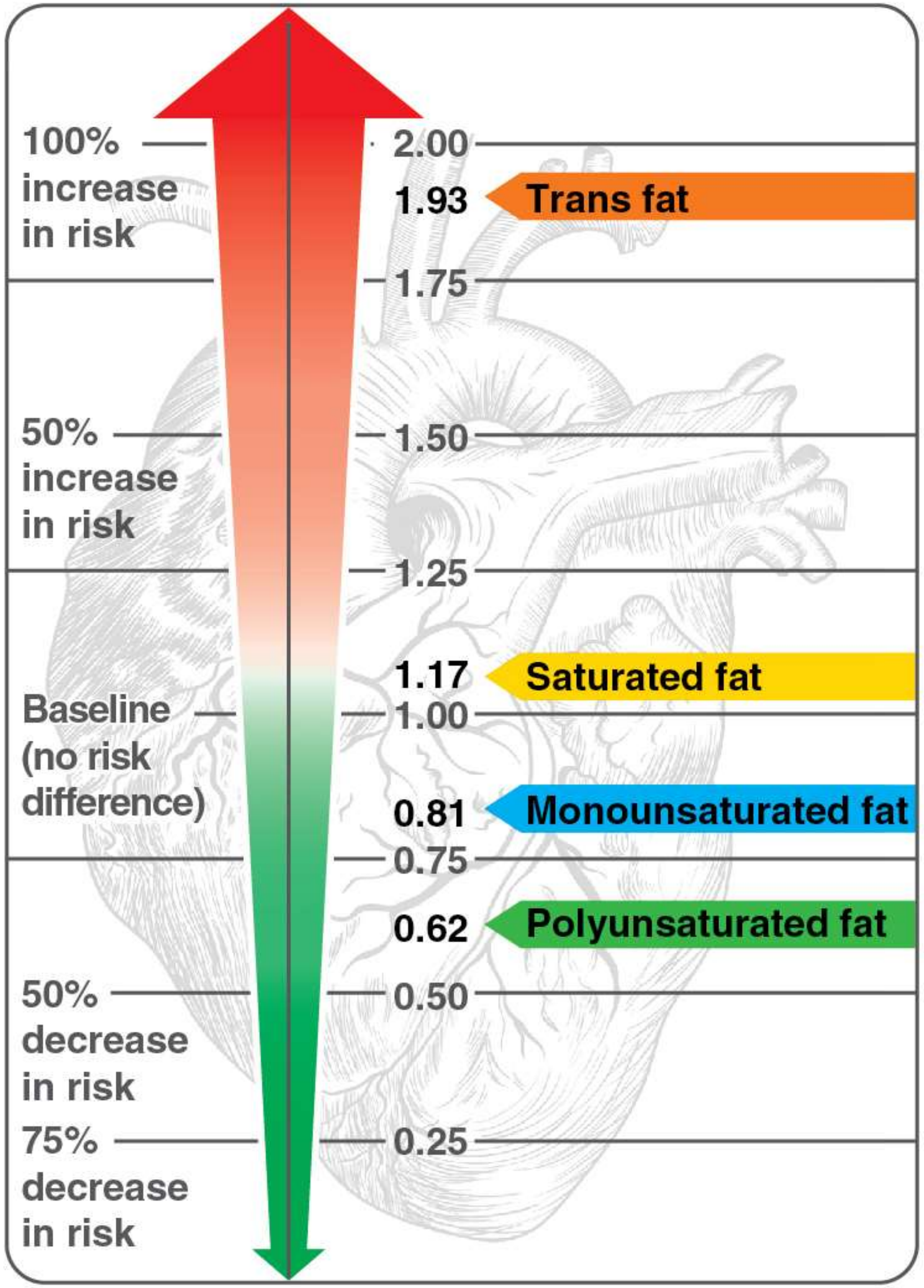
- By the 1990s, partially hydrogenated oils were common in countless foods.
- Recent research has shown that trans fats pose an even greater health risk than saturated fats.
- The scientific studies establishing the risks of trans fats were of two types.
  1. In experimental controlled feeding trials, diets contained different proportions of saturated, unsaturated, and partially hydrogenated fats.
  2. Many other scientific studies on dietary health effects are observational.

3.9 Scientific Thinking: Scientific Studies Document the Health Risks of Trans Fats (2 of 2)

Checkpoint question What is the difference between a retrospective and a prospective study?

A retrospective study "looks backward" to assess risk factors or benefits that correlate with current health status. A prospective study follows a group forward, monitoring certain factors and recording health outcomes over a period of time.

Figure 3.9



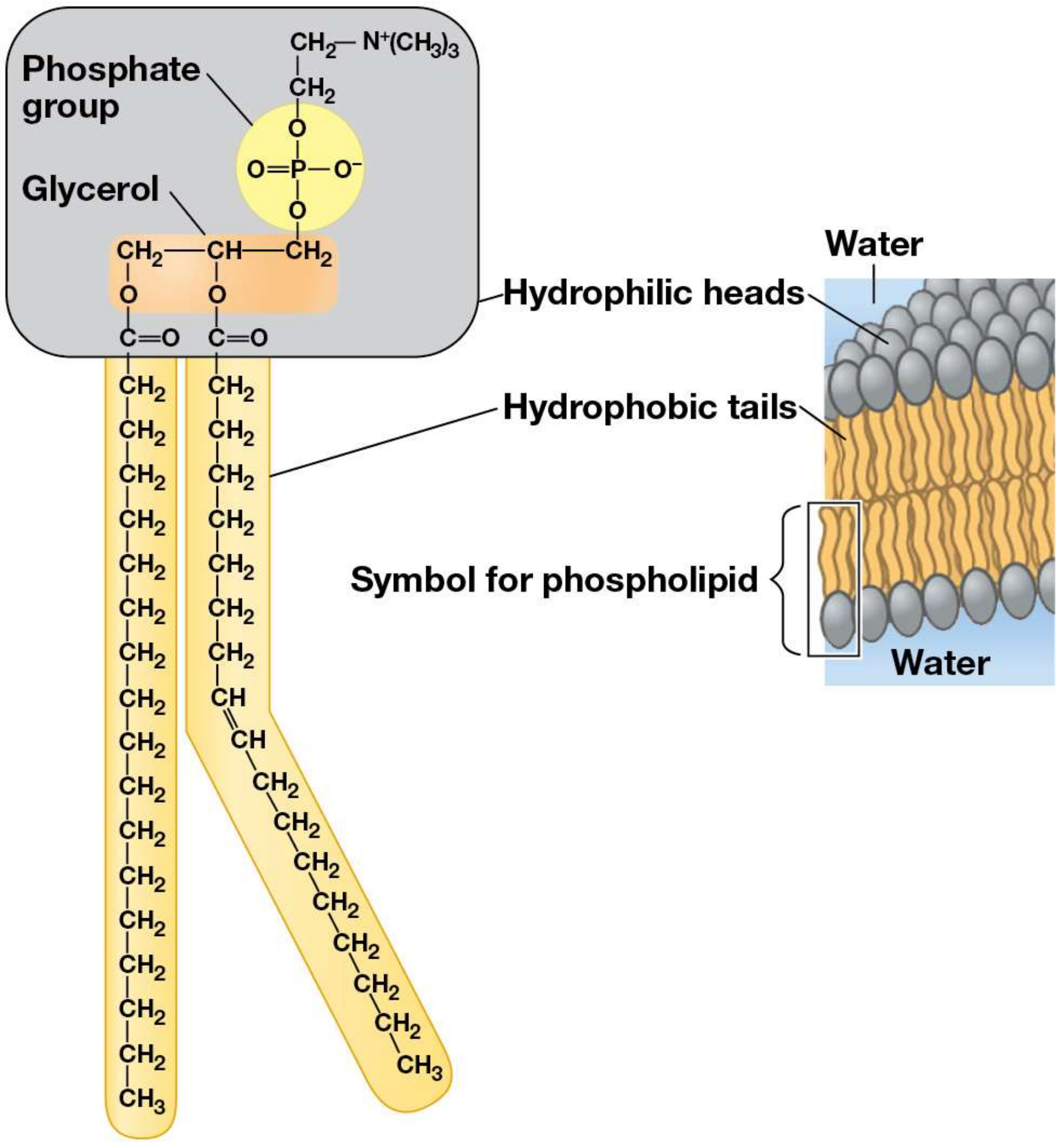
100% increase in risk
50% increase in risk
Baseline (no risk difference)
50% decrease in risk
75% decrease in risk
2.00
1.93
Trans fat
1.75
1.50
1.25
1.17
Saturated fat
1.00
0.81
Monounsaturated fat
0.75
0.62
Polyunsaturated fat
0.50
0.25

3.10 Phospholipids and Steroids Are Important Lipids with a Variety of Functions

- **Phospholipids** are components of cell membranes.
- **Steroids** include cholesterol and some hormones.
- **Cholesterol** is a common component in animal cell membranes and is also the precursor for making other steroids, including sex hormones.

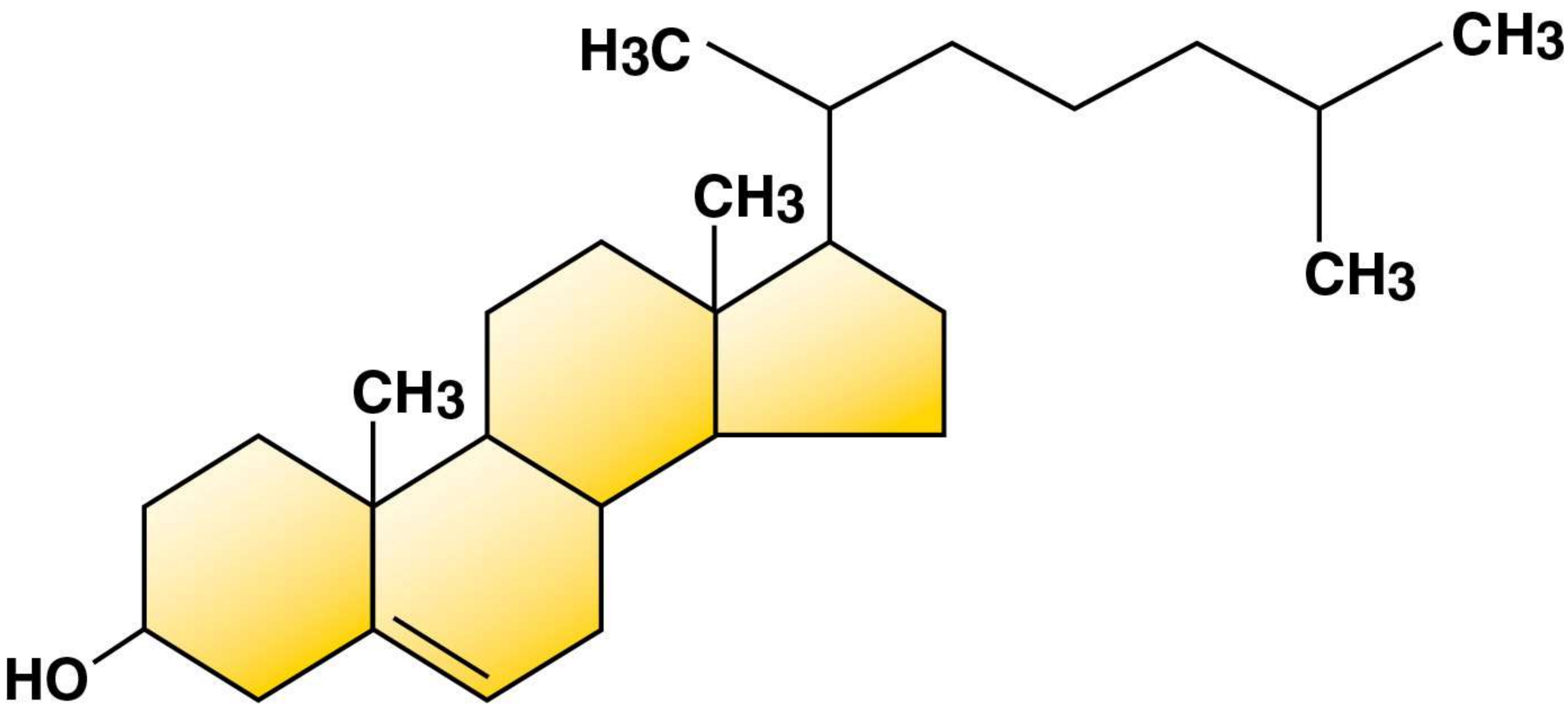
Checkpoint question Compare the structure of a phospholipid with that of a fat.

Figure 3.10



Phosphate group
Glycerol
Hydrophilic heads
Hydrophobic tails
Symbol for phospholipid
Water
Water

Figure 3.10c



3.11 Connection: Anabolic Steroids Pose Health Risks

- **Anabolic steroids** are synthetic variants of the male hormone testosterone that are abused by some athletes with serious consequences.

  Checkpoint question Explain why fats and steroids, which are structurally very different, are both classed as lipids.

  The three fatty acid tails of a fat molecule contain only nonpolar C—H bonds, which do not mix well with polar water molecules.

Proteins

3.12 Proteins Have a Wide Range of Functions and Structures (1 of 2)

- **Proteins** are involved in nearly every dynamic function in your body and are very diverse.
- Proteins function as
  - enzymes,
  - transport proteins embedded in cell membranes,
  - defensive proteins, such as antibodies,
  - signal proteins such as many hormones,
  - receptor proteins,
  - contractile proteins found within muscle cells,
  - structural proteins such as collagen, and
  - storage proteins.

3.12 Proteins Have a Wide Range of Functions and Structures (2 of 2)

- Proteins are composed of differing arrangements of a common set of just 20 amino acid monomers.
- The functions of different types of proteins depend on their individual shapes.
- In the process of **denaturation**, a protein unravels, loses its specific shape, and loses its function.

Checkpoint question Why does a denatured protein no longer function normally?

3.13 Proteins Are Made from Amino Acids Linked by Peptide Bonds (1 of 2)

- Protein diversity is based on different sequences of **amino acids**, monomers that contain
  - an amino group,
  - a carboxyl group,
  - an H atom, and
  - an R group, all attached to a central carbon.
- The R groups distinguish 20 amino acids, each with specific properties.

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3.13 Proteins Are Made from Amino Acids Linked by Peptide Bonds (2 of 2)

- Amino acid monomers are linked together in a dehydration reaction,
  - joining the carboxyl group of one amino acid to the amino group of the next amino acid, and
  - creating a **peptide bond**.
- Additional amino acids can be added by the same process to create a chain of amino acids called a **polypeptide**.

Checkpoint question By what process do you digest the proteins you eat into their individual amino acids?’

By hydrolysis, adding a molecule of water back to break each peptide bond

Figure 3.13b

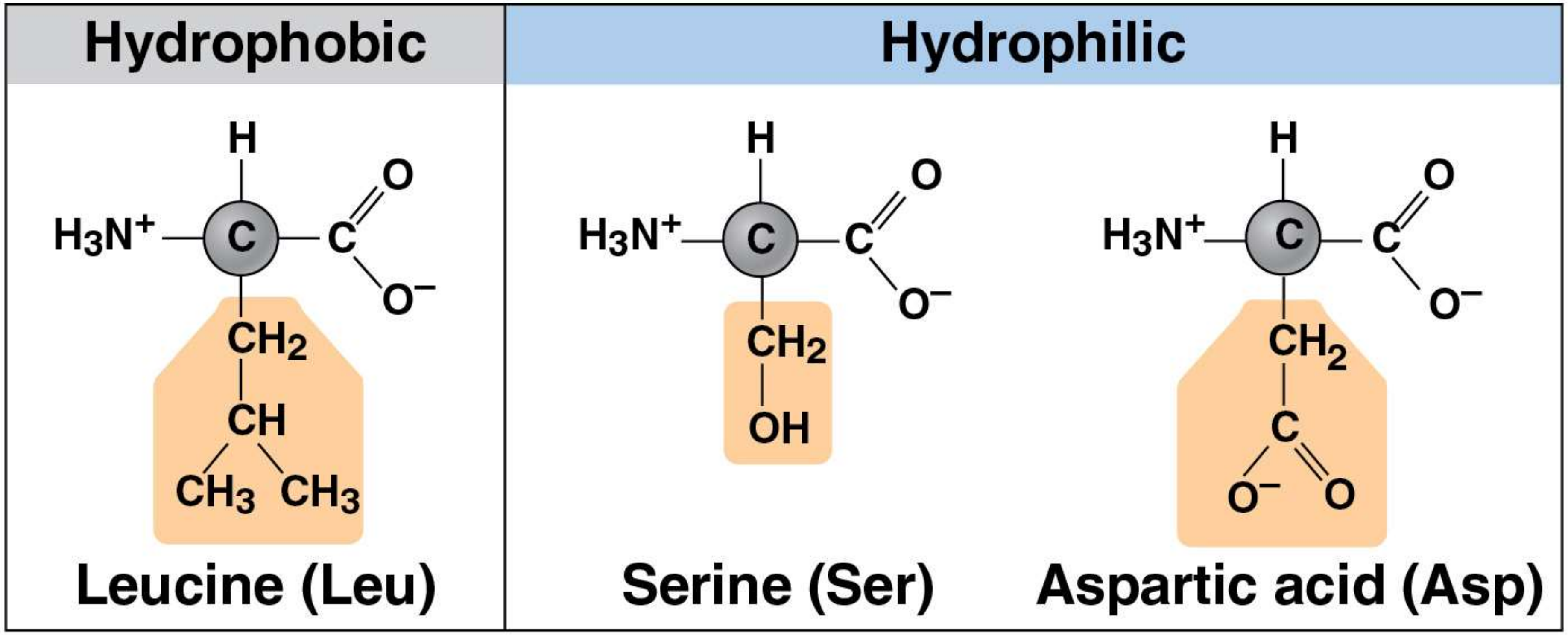
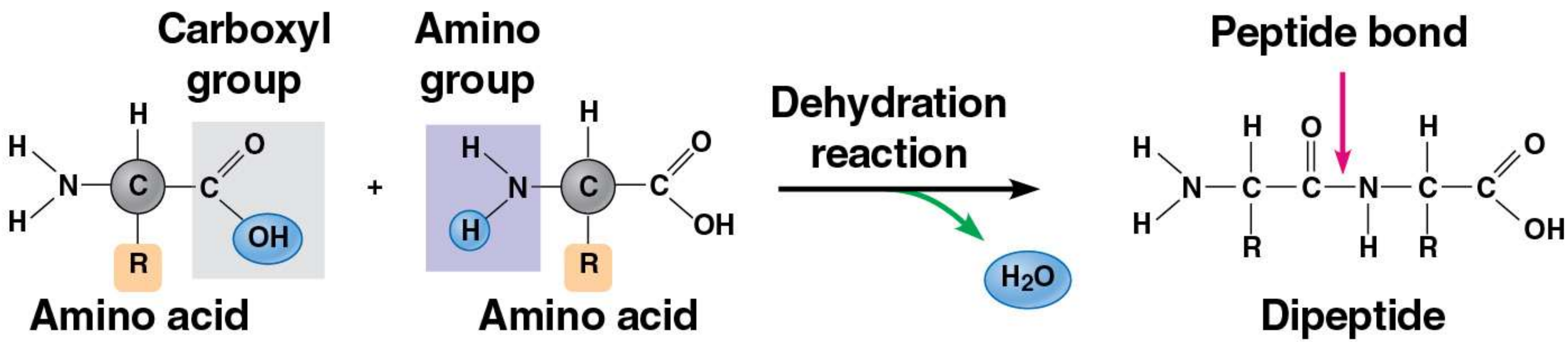

Hydrophobic
Hydrophilic
H
H_3N^+
C
C
O
O^-
CH_2
CH
CH_3
CH_3
OH
Leucine (Leu)
Serine (Ser)
Aspartic acid (Asp)

Figure 3.13c_2



3.14 Visualizing the Concept: A Protein’s Functional Shape Results from Four Levels of Structure (1 of 2)

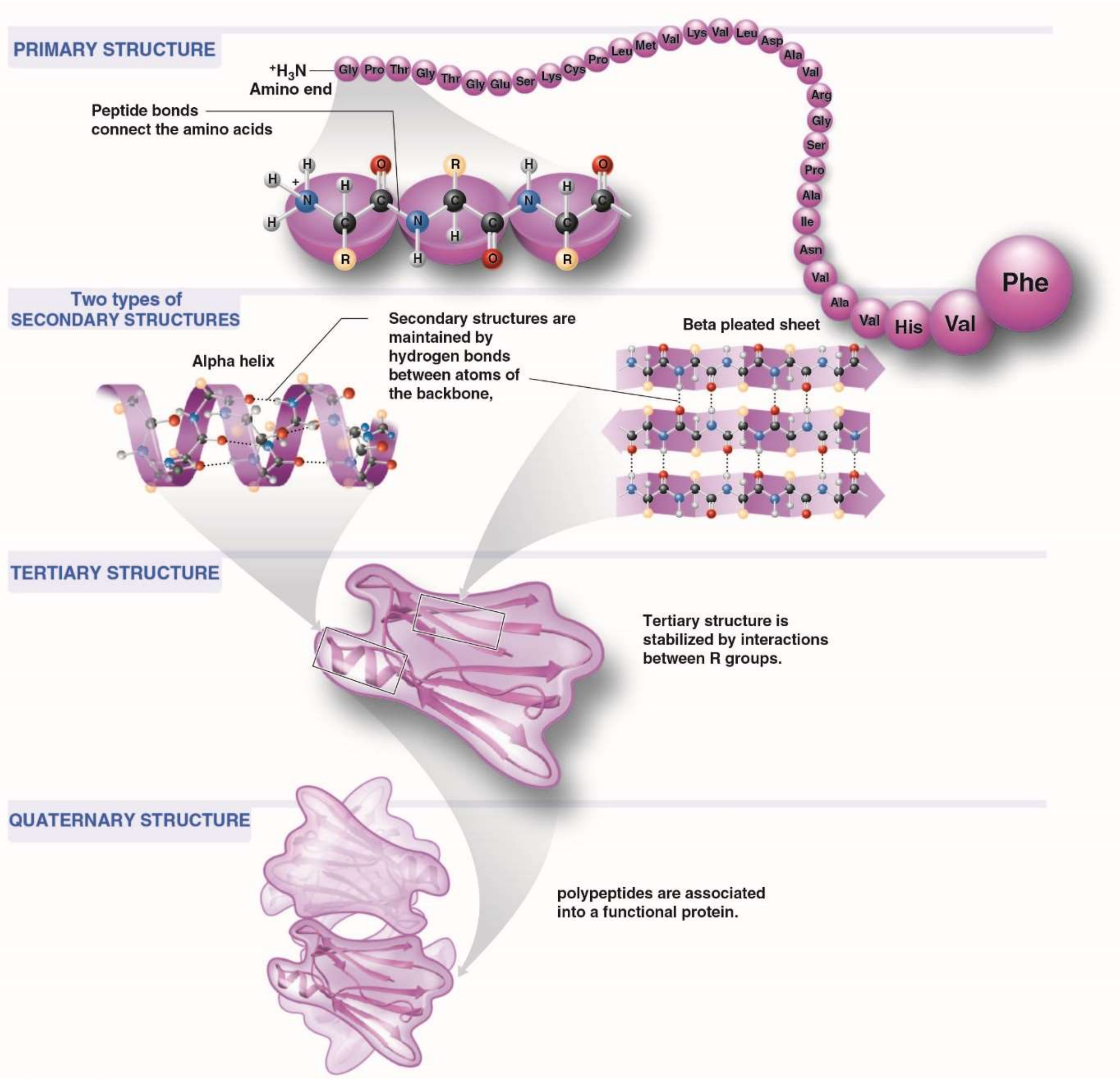
- A protein can have four levels of structure:
  1. A protein’s **primary structure** is the sequence of amino acids in its polypeptide chain.
  2. Its **secondary structure** is the coiling or folding of the chain, stabilized by hydrogen bonds.
  3. The **tertiary structure** is the overall three-dimensional shape of a polypeptide, resulting from interactions among R groups.
  4. Proteins made of more than one polypeptide have **quaternary structure**.

3.14 Visualizing the Concept: A Protein’s Functional Shape Results from Four Levels of Structure (2 of 2)

Checkpoint question If a genetic mutation changes the primary structure of a protein, how might this destroy the protein’s function?

Primary structure determines the secondary and tertiary structure due to the chemical nature of the R groups of the amino acids in the chain. Even a slight change may affect a protein’s shape and thus its function.

Figure 3.14



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Nucleic Acids

3.15 The Nucleic Acids DNA and RNA Are Information-Rich Polymers of Nucleotides (1 of 2)

- The monomers that make up nucleic acids are **nucleotides**.
- Nucleotides are composed of a sugar, a phosphate group, and a nitrogenous base.
  - **DNA** is a **double helix**.
  - **RNA** is a single polynucleotide chain.
  - DNA and RNA serve as the blueprints for proteins and thus control the life of a cell.
  - DNA is the molecule of inheritance.

Figure 3.15a

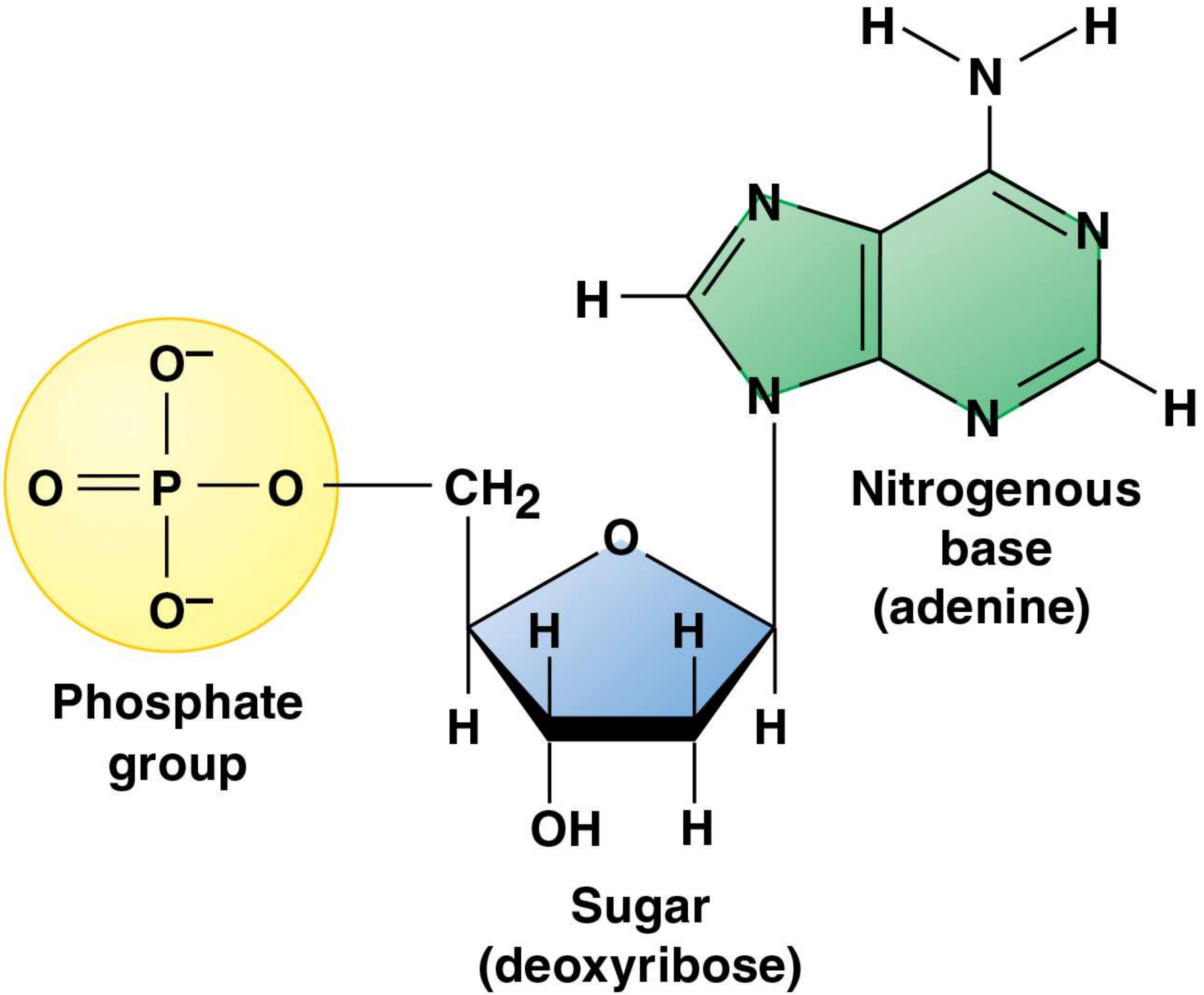

H
N
H
N
N
H
N
N
H
O⁻
O
P
O
CH₂
O⁻
O
H
H
H
H
OH
H
Nitrogenous base (adenine)
Phosphate group
Sugar (deoxyribose)

Figure 3.15c

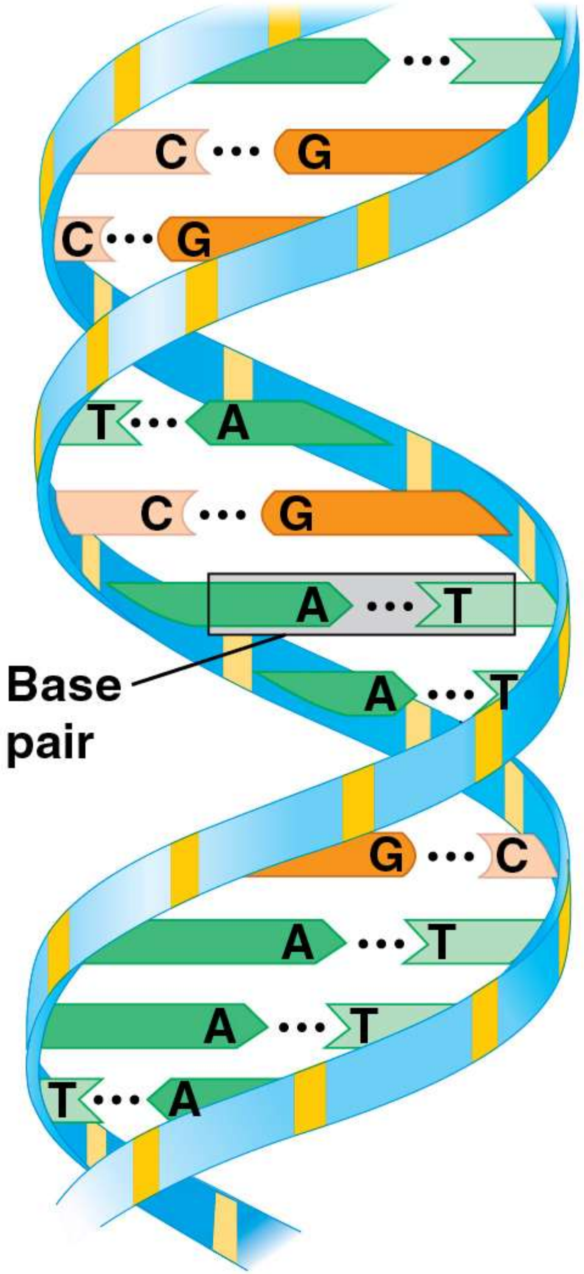
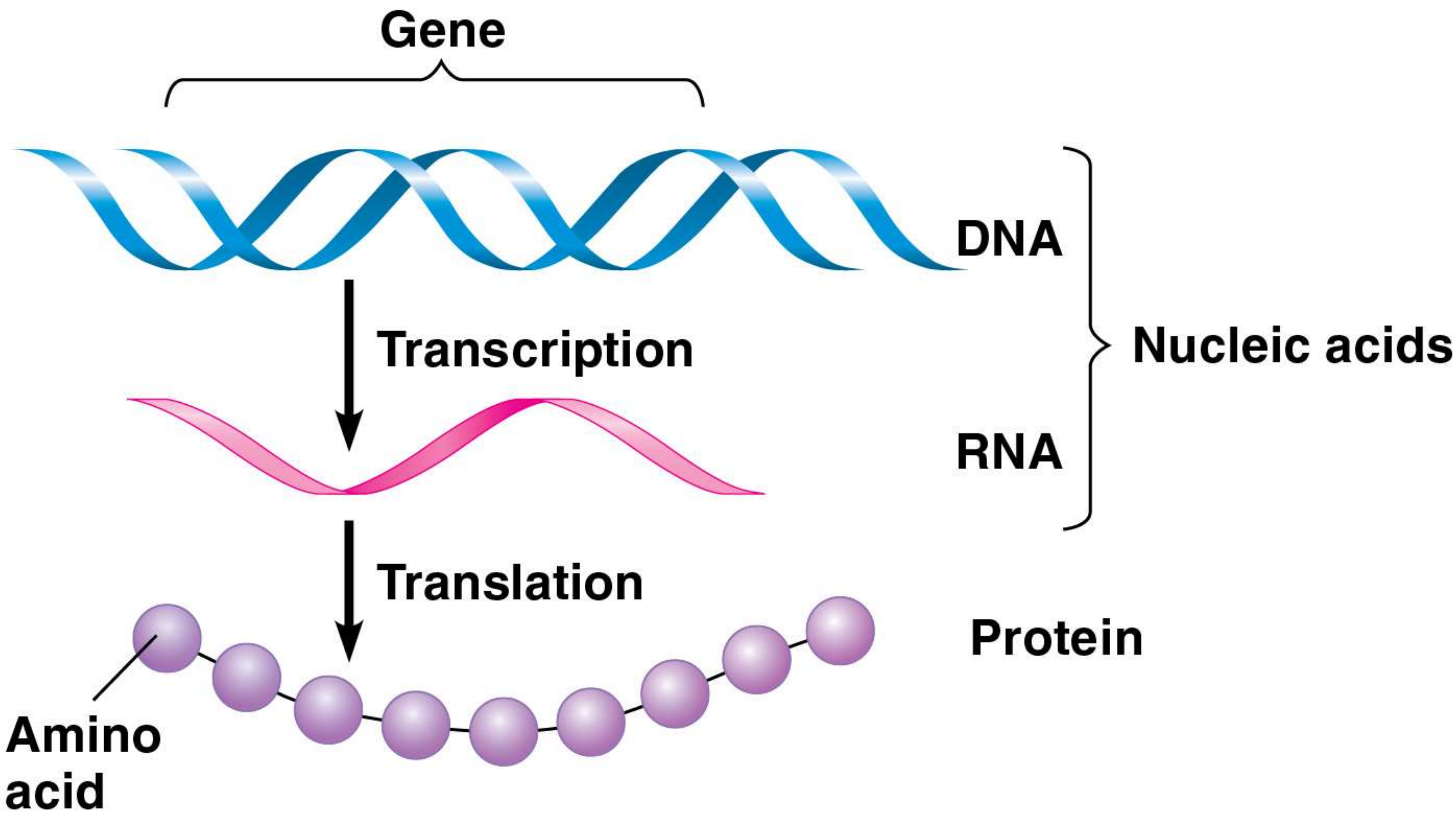


Figure 3.15d_3



3.15 The Nucleic Acids DNA and RNA Are Information-Rich Polymers of Nucleotides (2 of 2)

Checkpoint question What roles do complementary base pairing play in the functioning of DNA?

Complementary base pairing makes possible the precise replication of DNA, ensuring that genetic information is faithfully transmitted every time a cell divides. It also ensures that RNA molecules carry accurate instructions from DNA for the synthesis of proteins.

3.16 Evolution Connection: Lactose Tolerance Is a Recent Event in Human Evolution

- Different mutations in DNA have led to lactose tolerance in several human groups whose ancestors raised dairy cattle.
- Researchers identified three new mutations in 43 ethnic groups in East Africa that keep the lactase gene permanently turned on.

Checkpoint question Explain how lactose tolerance involves three of the four major classes of biological macromolecules.

By hydrolysis, adding a molecule of water back to break each peptide bond

Table 3.2 Important Chemical Groups of Organic Compounds (2 of 3)

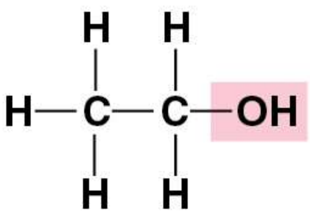
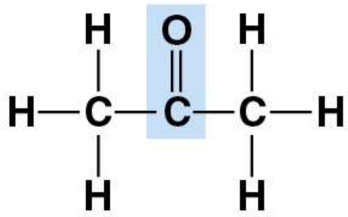
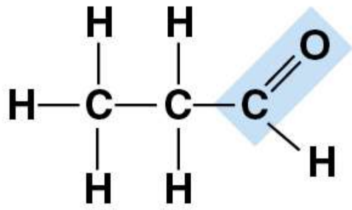
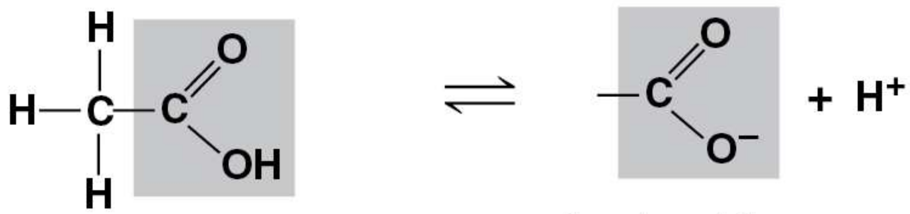
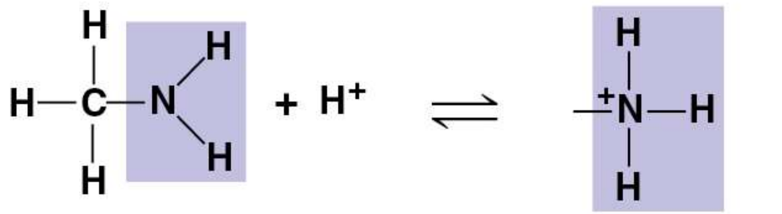
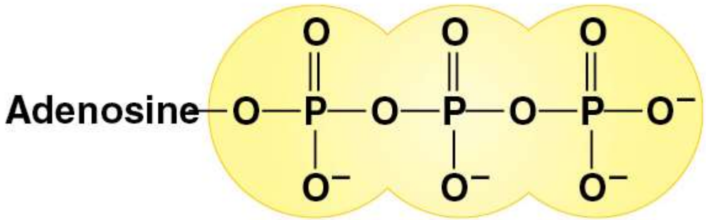
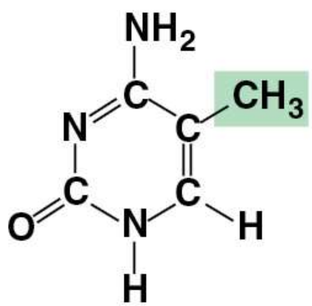
Chemical Group	Examples
Hydroxyl group —OH	 Alcohol
Carbonyl group $>$C=O	 
Carboxyl group —COOH	 Carboxylic acid Ionized form

Table 3.2 Important Chemical Groups of Organic Compounds (3 of 3)

Chemical Group	Examples
Amino group $-NH_2$	 Amine Ionized forn
Phosphate group $-OPO_3^{2-}$	 Organic phosphate
Methyl group $-CH_3$	 Methylated compound