BIOLOGY

CONCEPTS & CONNECTIONS

Fourth Edition

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CHAPTER 3

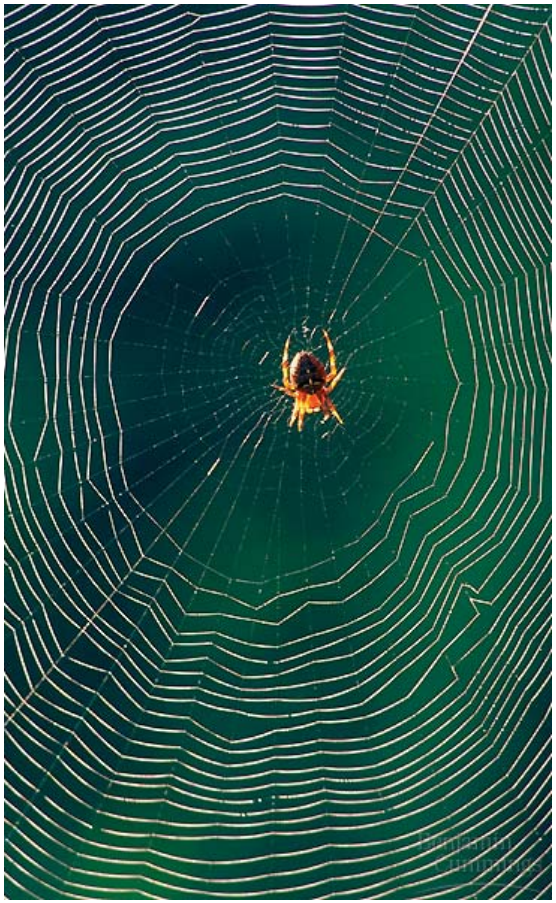
The Molecules of Cells

Modules 3.1 – 3.3

From PowerPoint® Lectures for *Biology: Concepts & Connections*

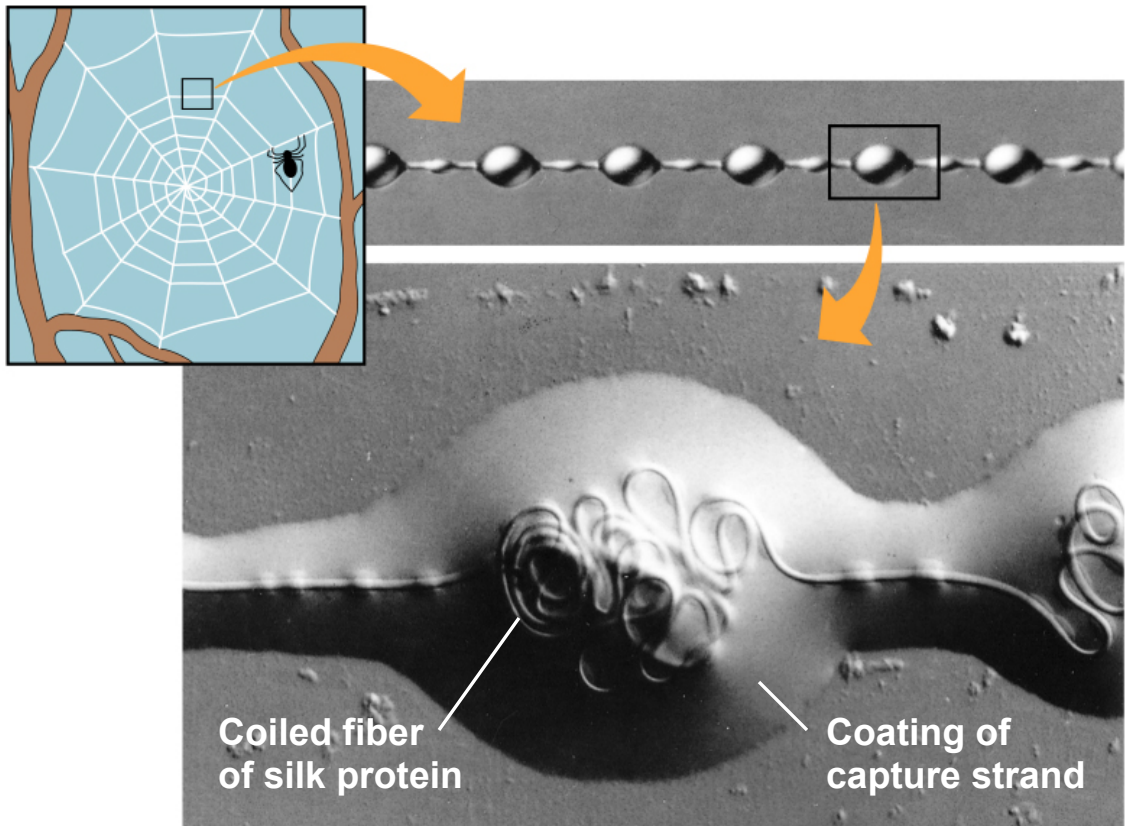
Spider Silk: Stronger than Steel

- Life's diversity results from the variety of molecules in cells
- A spider's web-building skill depends on its DNA molecules
- DNA also determines the structure of silk proteins
  - These make a spiderweb strong and resilient



- The capture strand contains a single coiled silk fiber coated with a sticky fluid

- The coiled fiber unwinds to capture prey and then recoils rapidly

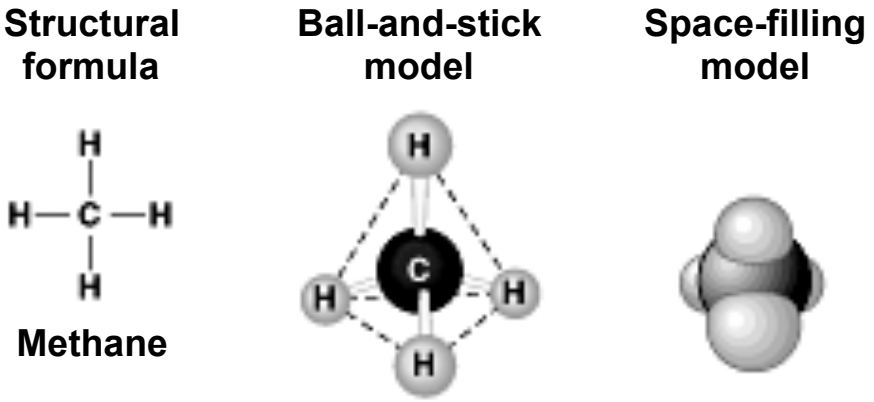


INTRODUCTION TO ORGANIC COMPOUNDS AND THEIR POLYMERS

- Life's structural and functional diversity results from a great variety of molecules
- A relatively small number of structural patterns underlies life's molecular diversity

3.1 Life's molecular diversity is based on the properties of carbon

- A carbon atom forms four covalent bonds
  - It can join with other carbon atoms to make chains or rings



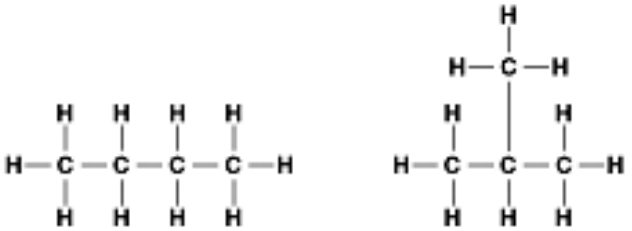
The 4 single bonds of carbon point to the corners of a tetrahedron.

Figure 3.1, top part

- Carbon skeletons vary in many ways

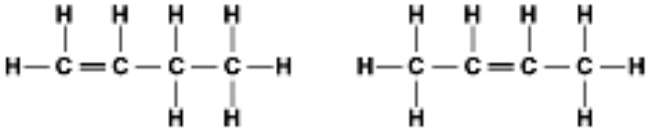
Ethane Propane

Carbon skeletons vary in length.



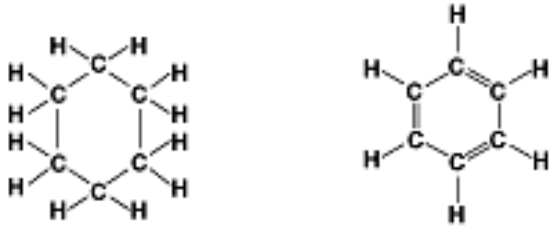
Butane Isobutane

Skeletons may be unbranched or branched.



1-Butene 2-Butene

Skeletons may have double bonds, which can vary in location.



Cyclohexane Benzene

Skeletons may be arranged in rings.

Figure 3.1, bottom part

3.2 Functional groups help determine the properties of organic compounds

- Functional groups are the groups of atoms that participate in chemical reactions
  - Hydroxyl groups are characteristic of alcohols
  - The carboxyl group acts as an acid

SOME COMMON FUNCTIONAL GROUPS

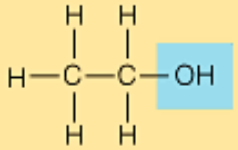
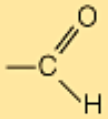
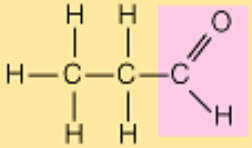
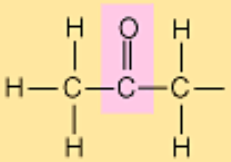
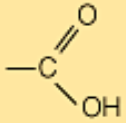
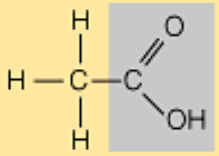
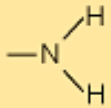
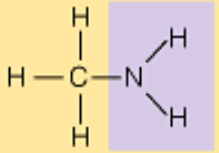
Functional Group	General Formula	Name of Compounds	Example	Where Else Found
Hydroxyl —OH (or HO—)	—O—H	Alcohols	 Ethanol	Sugars; water-soluble vitamins
Carbonyl 		Aldehydes	 Propanal	Some sugars; formaldehyde (a preservative)
		Ketones	 Acetone	Some sugars; "ketone bodies" in urine (from fat breakdown)
Carboxyl —COOH		Carboxylic acids	 Acetic acid	Amino acids; proteins; some vitamins; fatty acids
Amino —NH_2 (or H_2N —)		Amines	 Methylamine	Amino acids; proteins; urea in urine (from protein breakdown)

Table 3.2

3.3 Cells make a huge number of large molecules from a small set of small molecules

- Most of the large molecules in living things are macromolecules called polymers
  - Polymers are long chains of smaller molecular units called monomers
  - A huge number of different polymers can be made from a small number of monomers

- Cells link monomers to form polymers by dehydration synthesis

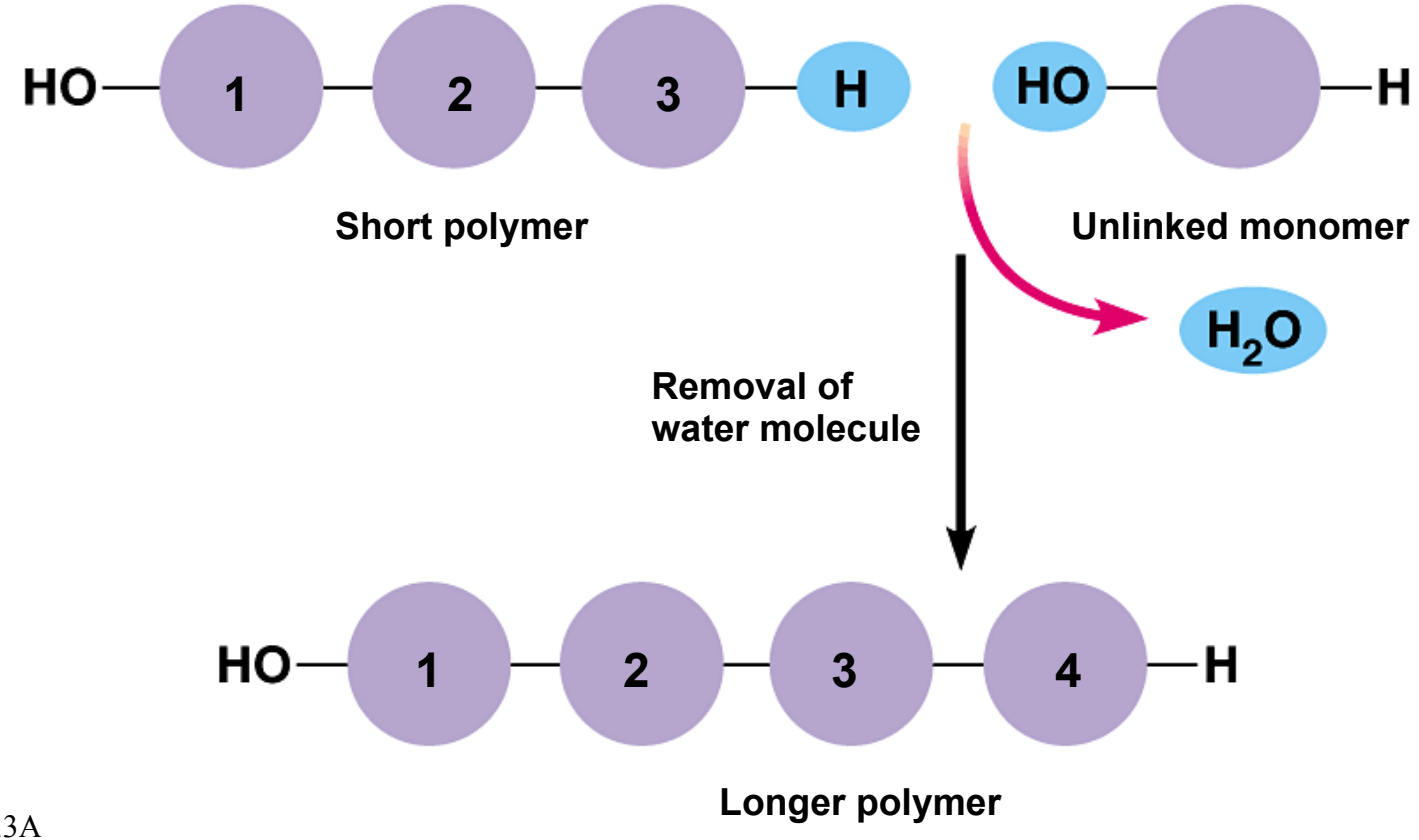


Figure 3.3A

- Polymers are broken down to monomers by the reverse process, hydrolysis

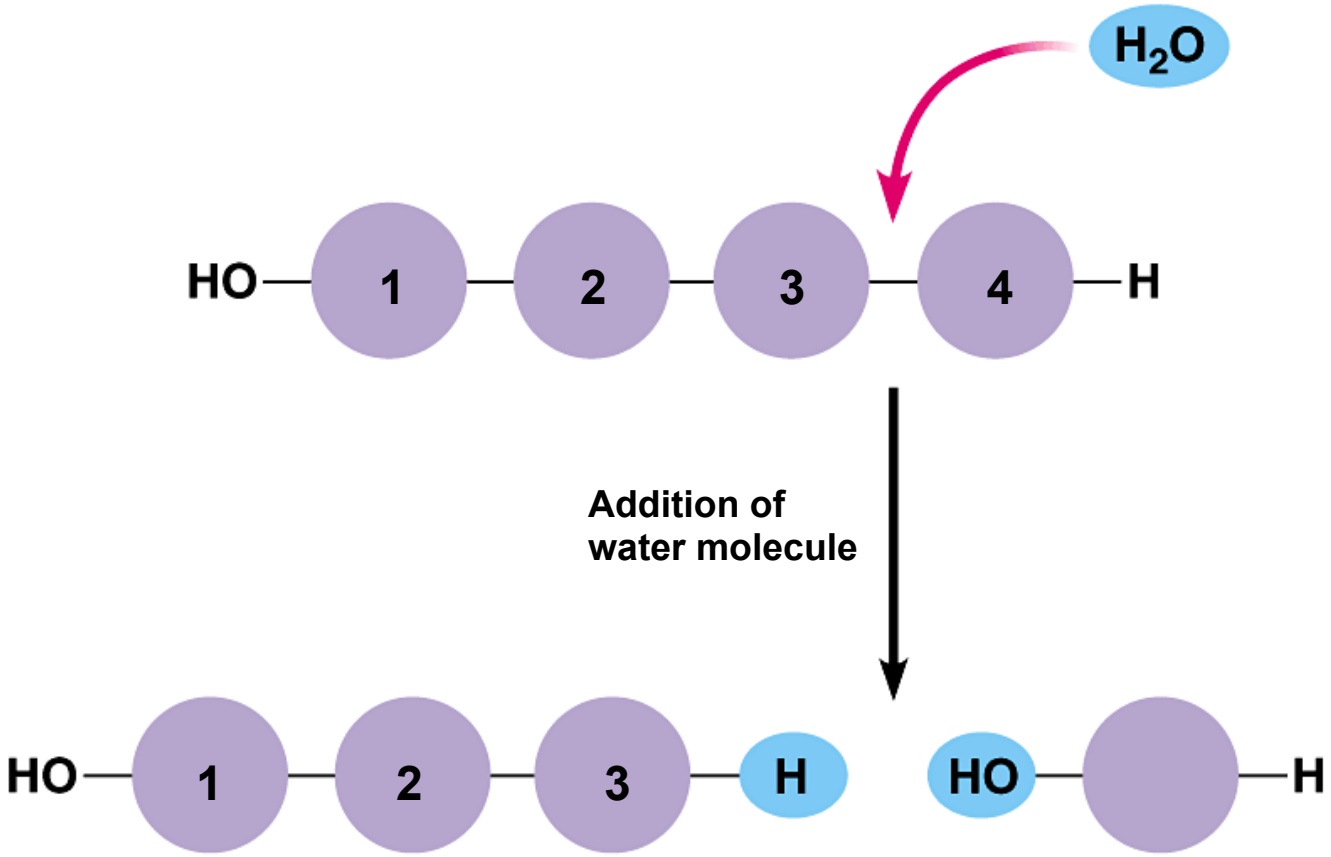


Figure 3.3B

CARBOHYDRATES

- Carbohydrates are a class of molecules
  - They range from small sugars to large polysaccharides
  - Polysaccharides are long polymers of monomers

3.4 Monosaccharides are the simplest carbohydrates

- Monosaccharides are single-unit sugars
- These molecules typically have a formula that is a multiple of CH_2O
- Each molecule contains hydroxyl groups and a carbonyl group
- Monosaccharides are the fuels for cellular work

Figure 3.4A

- The monosaccharides glucose and fructose are isomers
  - They contain the same atoms but in different arrangements

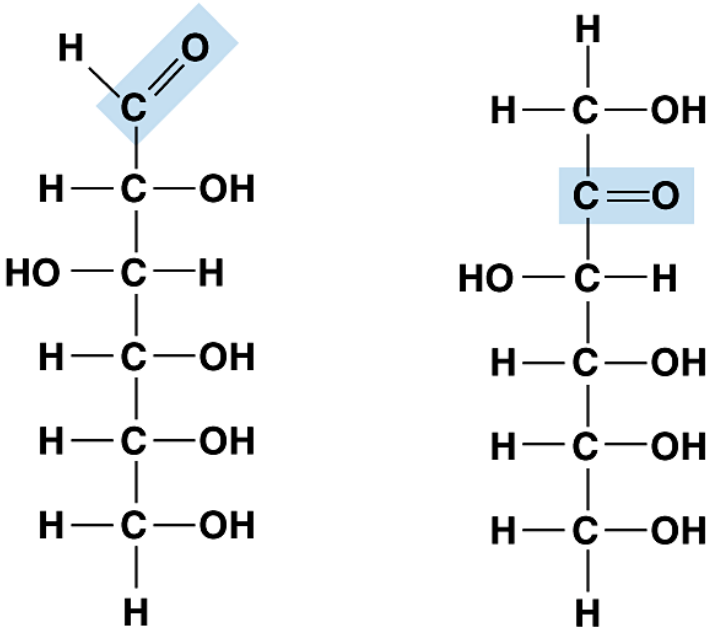


Figure 3.4B

- Many monosaccharides form rings, as shown here for glucose

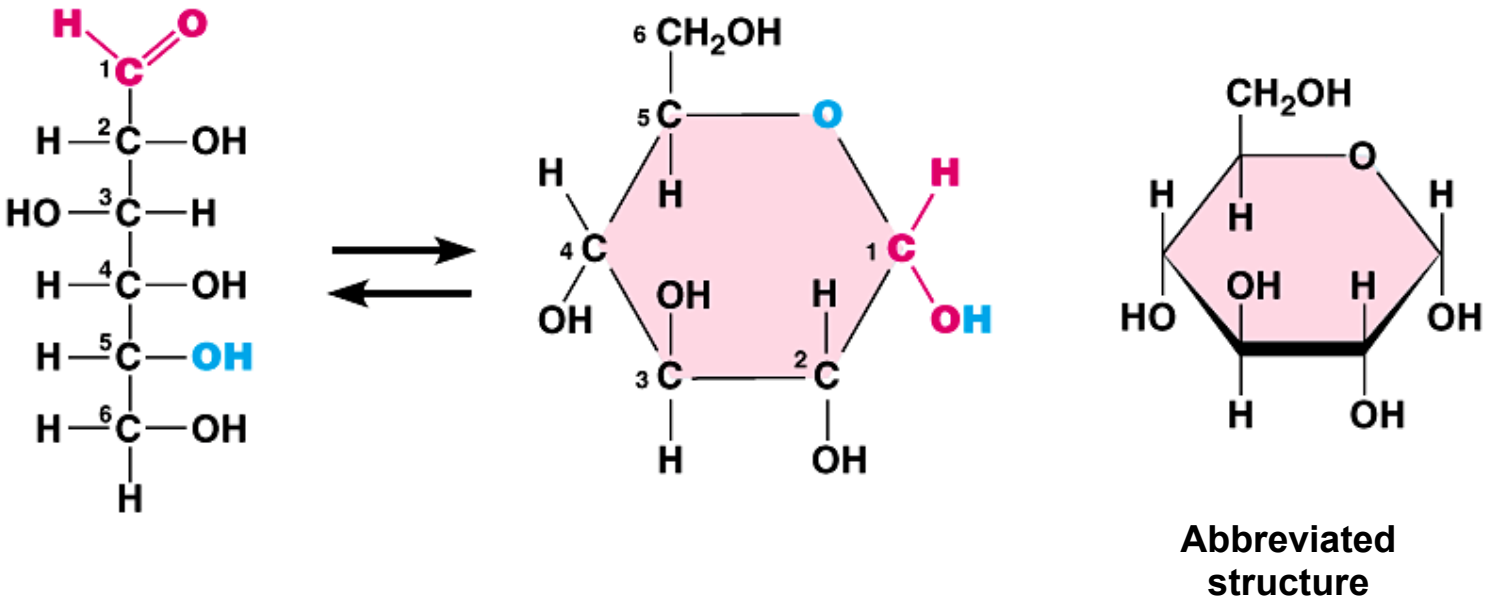
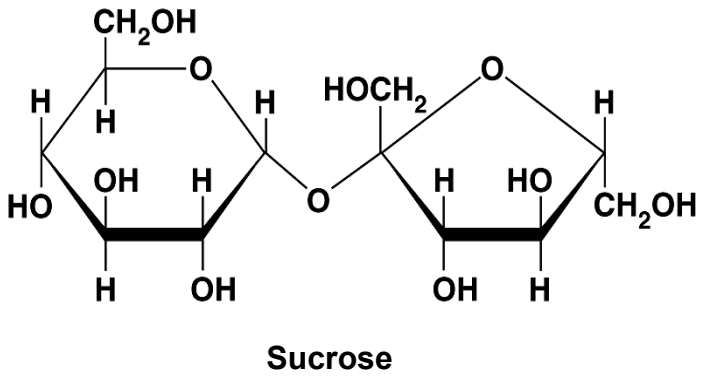


Figure 3.4C

3.5 Cells link single sugars to form disaccharides

- Monosaccharides can join to form disaccharides, such as sucrose (table sugar) and maltose (brewing sugar)



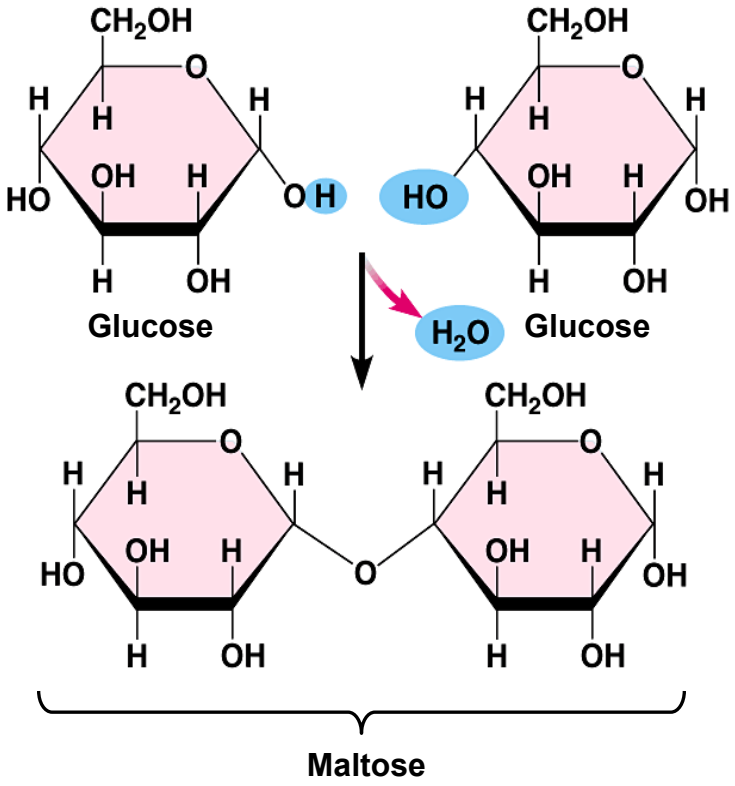


Figure 3.5

3.6 Connection: How sweet is sweet?

- Various types of molecules, including non-sugars, taste sweet because they bind to "sweet" receptors on the tongue

SWEETNESS SCALE

Compound	Sweetness Relative to Sucrose
Natural sugars	
Lactose	Not as sweet
Maltose	Same sweetness
Glucose	Slightly sweeter
Fructose	4 times sweeter
Artificial sweeteners	
Cyclamate	30 times sweeter
Aspartame	150 times sweeter
Saccharine	450 times sweeter
Sucralose	600 times sweeter

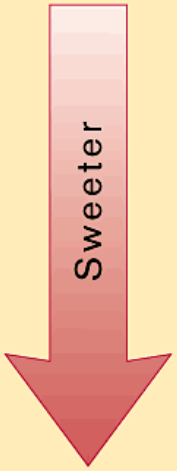


Table 3.6

3.7 Polysaccharides are long chains of sugar units

- These large molecules are polymers of hundreds or thousands of monosaccharides linked by dehydration synthesis

- Starch and glycogen are polysaccharides that store sugar for later use
- Cellulose is a polysaccharide in plant cell walls

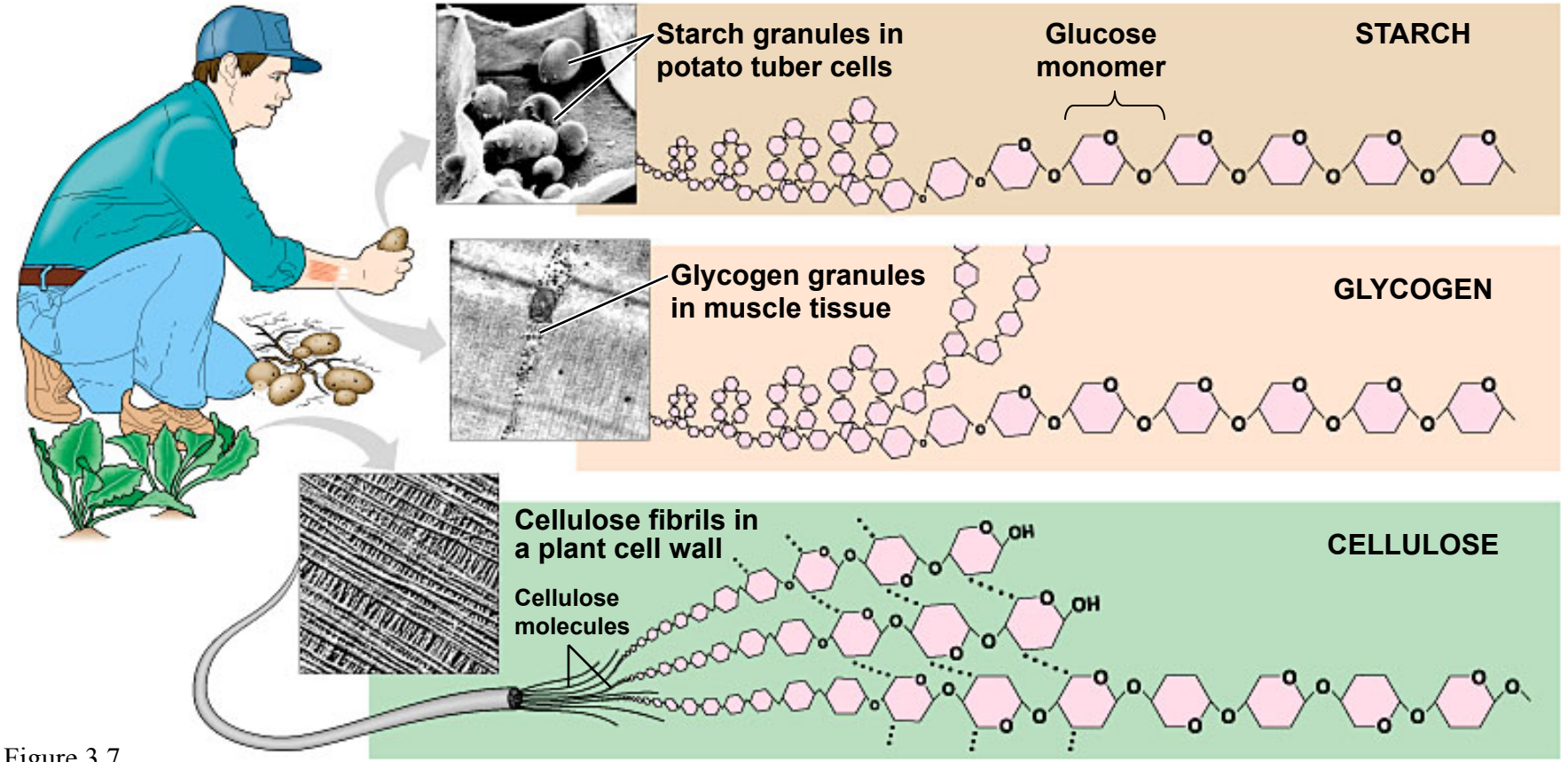


Figure 3.7

3.8 Lipids include fats, which are mostly energy-storage molecules

- These compounds are composed largely of carbon and hydrogen
  - They are not true polymers
  - They are grouped together because they do not mix with water

Figure 3.8A

- Fats are lipids whose main function is energy storage
  - They are also called triglycerides
- A triglyceride molecule consists of one glycerol molecule linked to three fatty acids

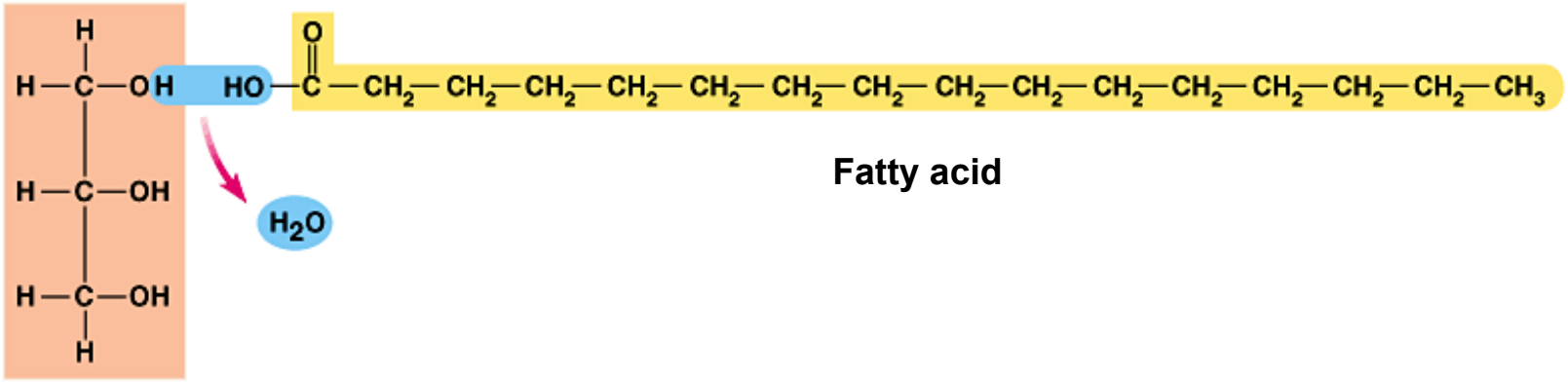


Figure 3.8B

- The fatty acids of unsaturated fats (plant oils) contain double bonds
  - These prevent them from solidifying at room temperature
- Saturated fats (lard) lack double bonds
  - They are solid at room temperature

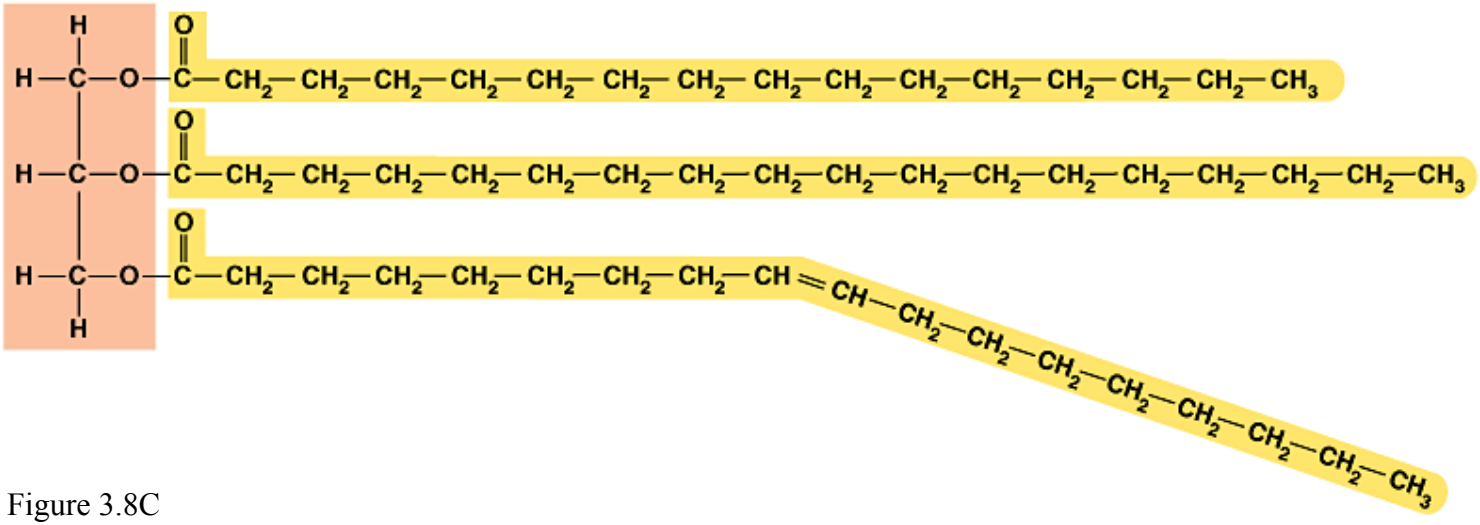


Figure 3.8C

3.9 Phospholipids, waxes, and steroids are lipids with a variety of functions

- Phospholipids are a major component of cell membranes
- Waxes form waterproof coatings
- Steroids are often hormones

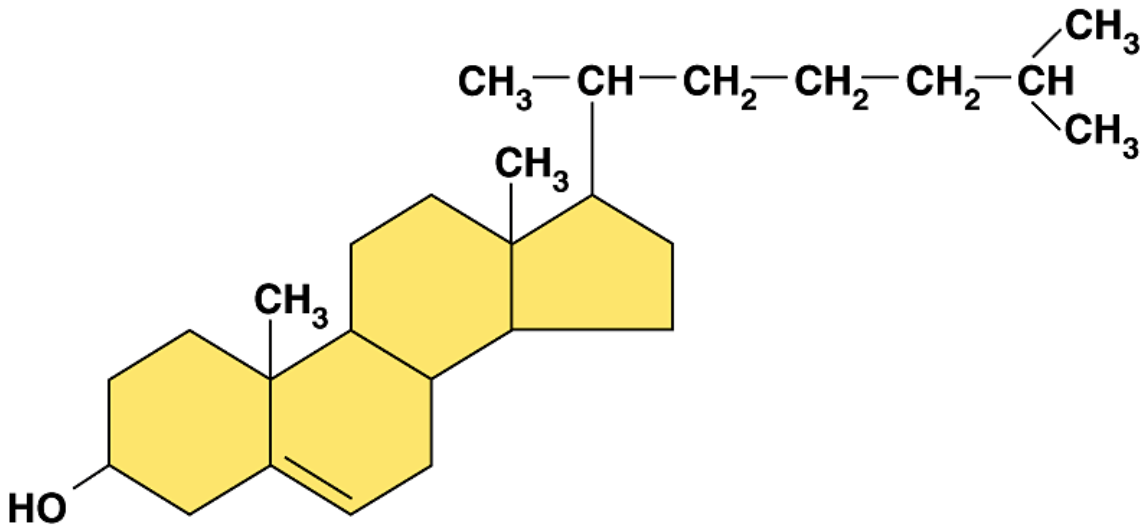


Figure 3.9

3.10 Connection: Anabolic steroids and related substances pose health risks

- Anabolic steroids are usually synthetic variants of testosterone
- Use of these substances can cause serious health problems

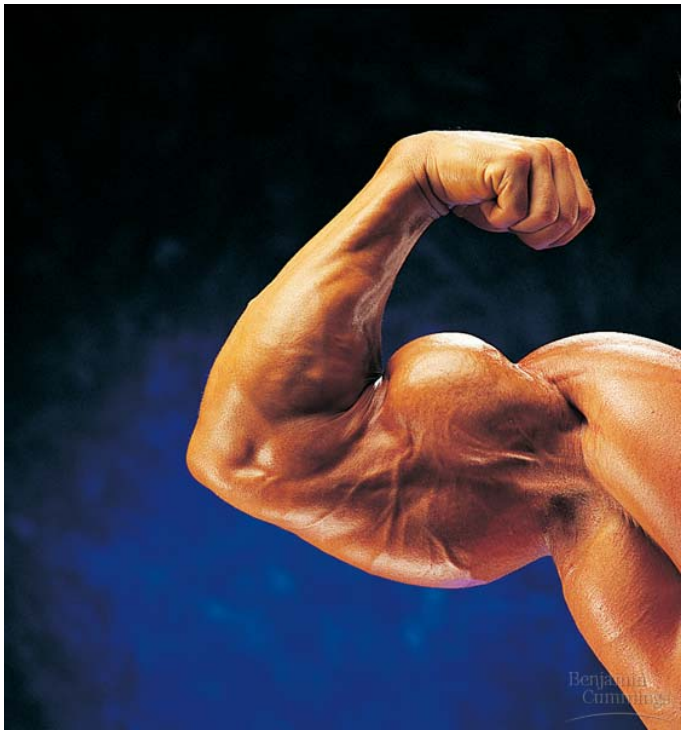


Figure 3.10

PROTEINS

3.11 Proteins are essential to the structures and activities of life

- Proteins are involved in
  - cellular structure
  - movement
  - defense
  - transport
  - communication

Figure 3.11

- Mammalian hair is composed of structural proteins
- Enzymes regulate chemical reactions

3.12 Proteins are made from just 20 kinds of amino acids

- Proteins are the most structurally and functionally diverse of life's molecules
  - Their diversity is based on different arrangements of amino acids

- Each amino acid contains:
  - an amino group
  - a carboxyl group
  - an R group, which distinguishes each of the 20 different amino acids

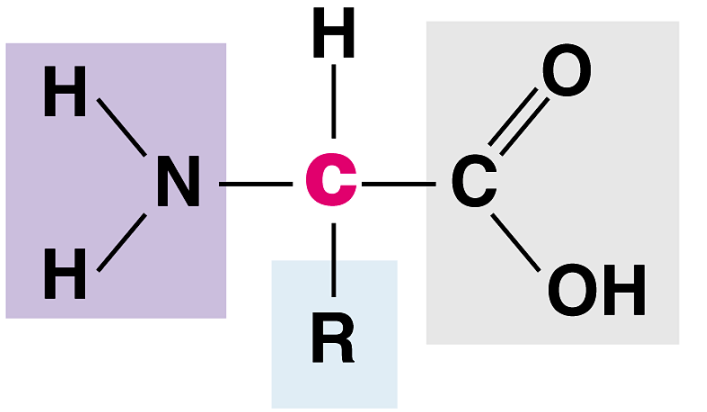


Figure 3.12A

- Each amino acid has specific properties

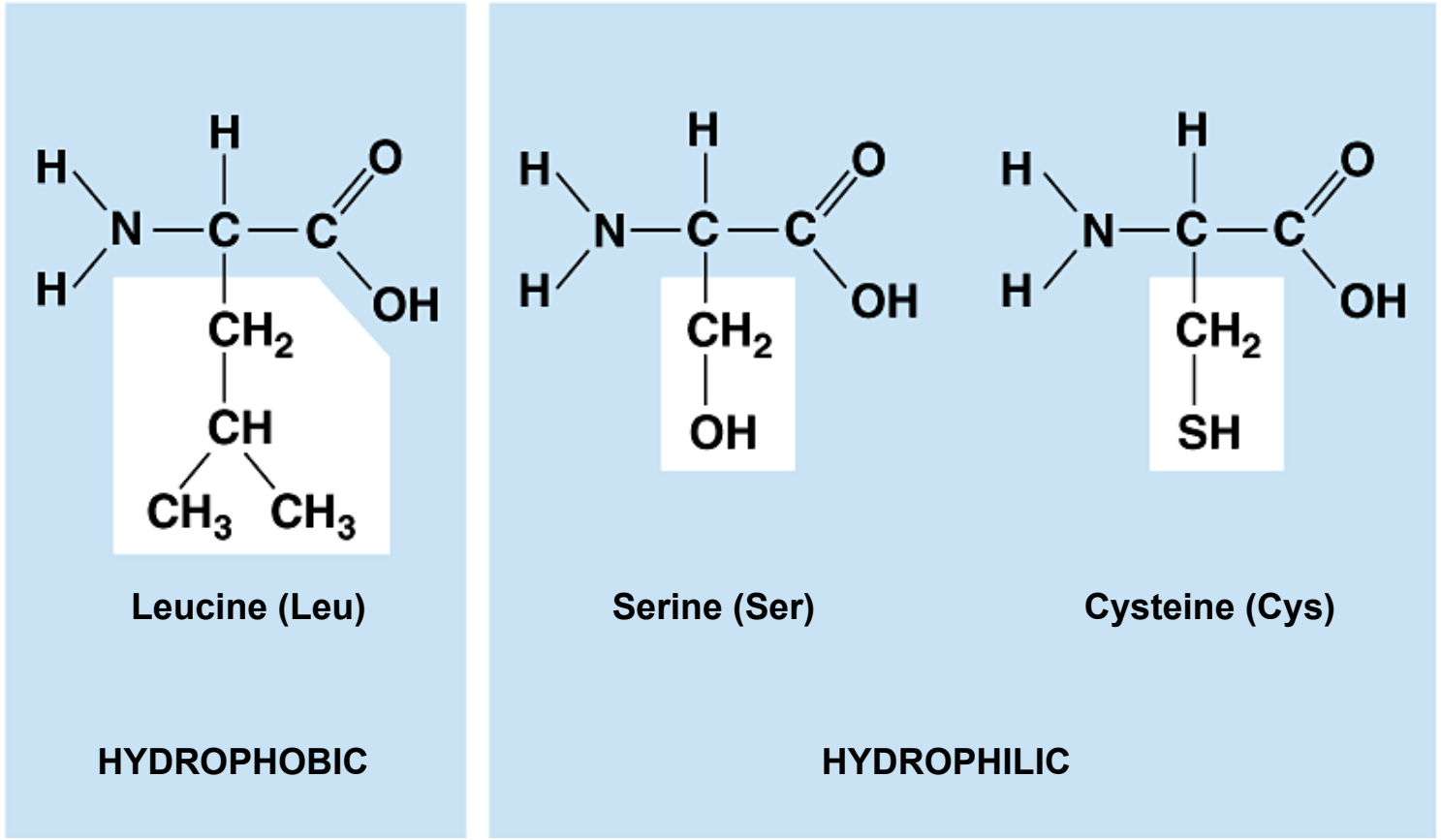


Figure 3.12B

3.13 Amino acids can be linked by peptide bonds

- Cells link amino acids together by dehydration synthesis
- The bonds between amino acid monomers are called peptide bonds

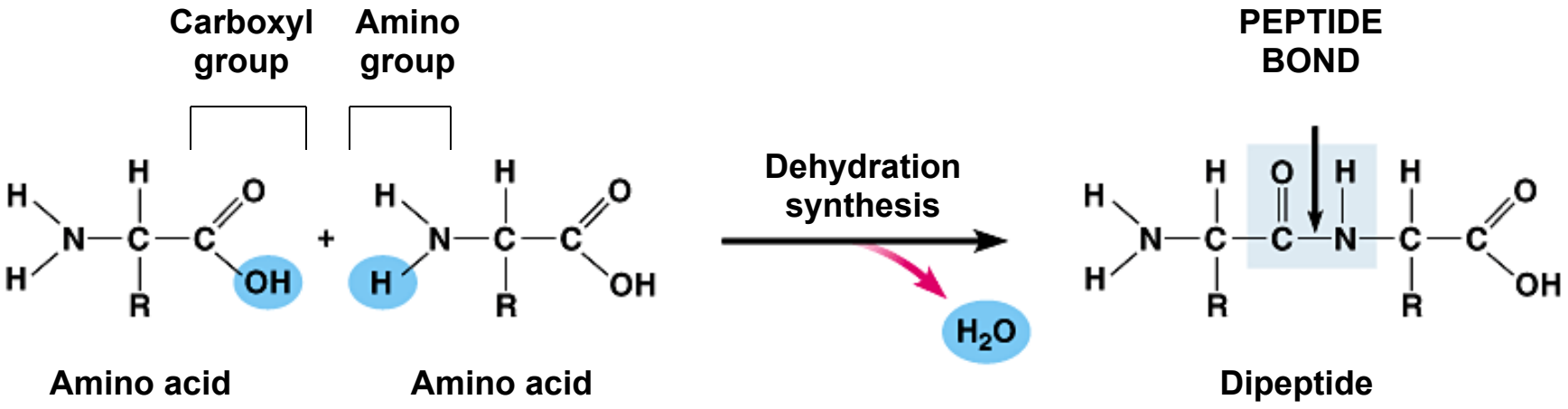


Figure 3.13

3.14 Overview: A protein's specific shape determines its function

- A protein, such as lysozyme, consists of polypeptide chains folded into a unique shape
  - The shape determines the protein's function
  - A protein loses its specific function when its polypeptides unravel

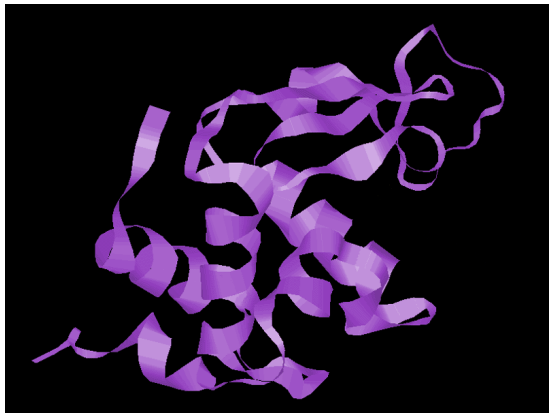


Figure 3.14A

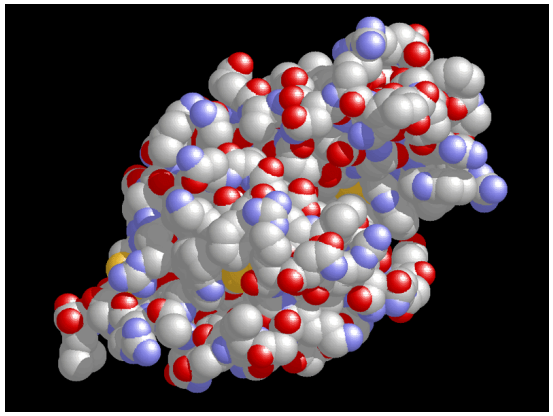


Figure 3.14B

3.15 A protein's primary structure is its amino acid sequence

3.16 Secondary structure is polypeptide coiling or folding produced by hydrogen bonding

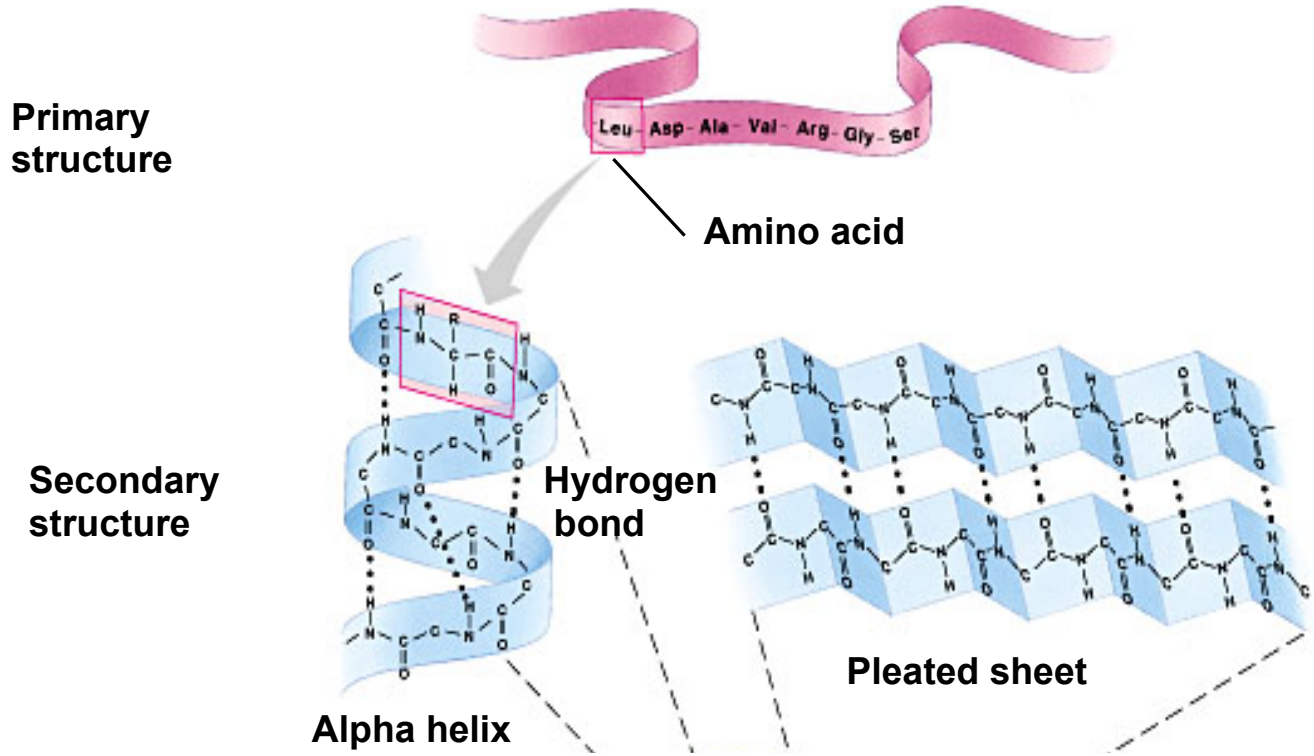


Figure 3.15, 16

3.17 Tertiary structure is the overall shape of a polypeptide

3.18 Quaternary structure is the relationship among multiple polypeptides of a protein

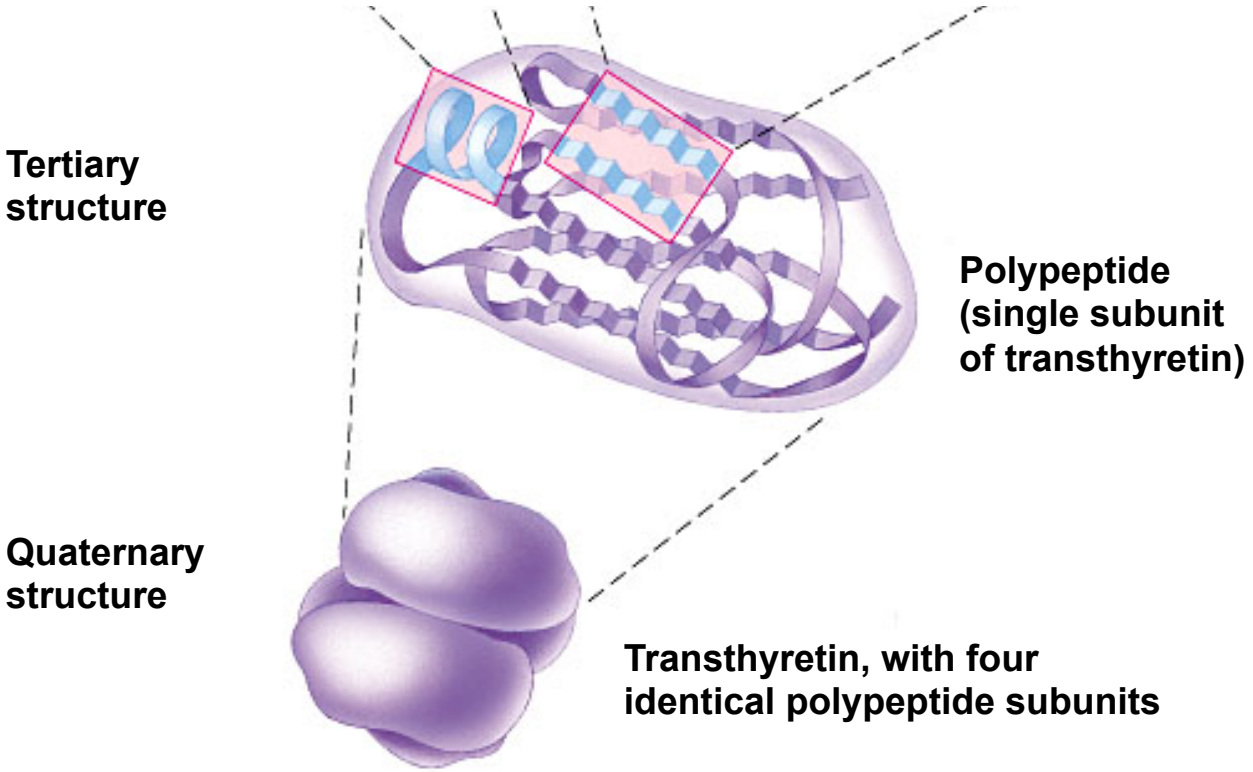


Figure 3.17, 18

3.19 Talking About Science: Linus Pauling contributed to our understanding of the chemistry of life

- Pauling made important contributions to our understanding of protein structure and function

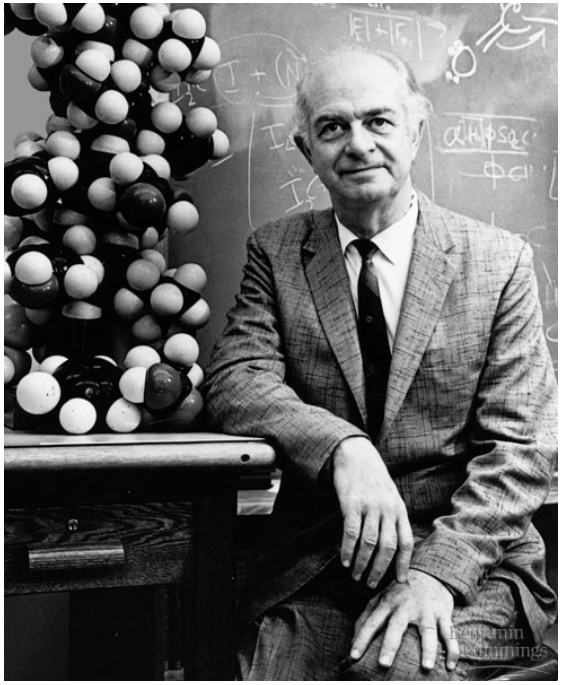


Figure 3.19

NUCLEIC ACIDS

3.20 Nucleic acids are information-rich polymers of nucleotides

- Nucleic acids such and DNA and RNA serve as the blueprints for proteins
- They ultimately control the life of a cell

- The monomers of nucleic acids are nucleotides
  - Each nucleotide is composed of a sugar, phosphate, and nitrogenous base

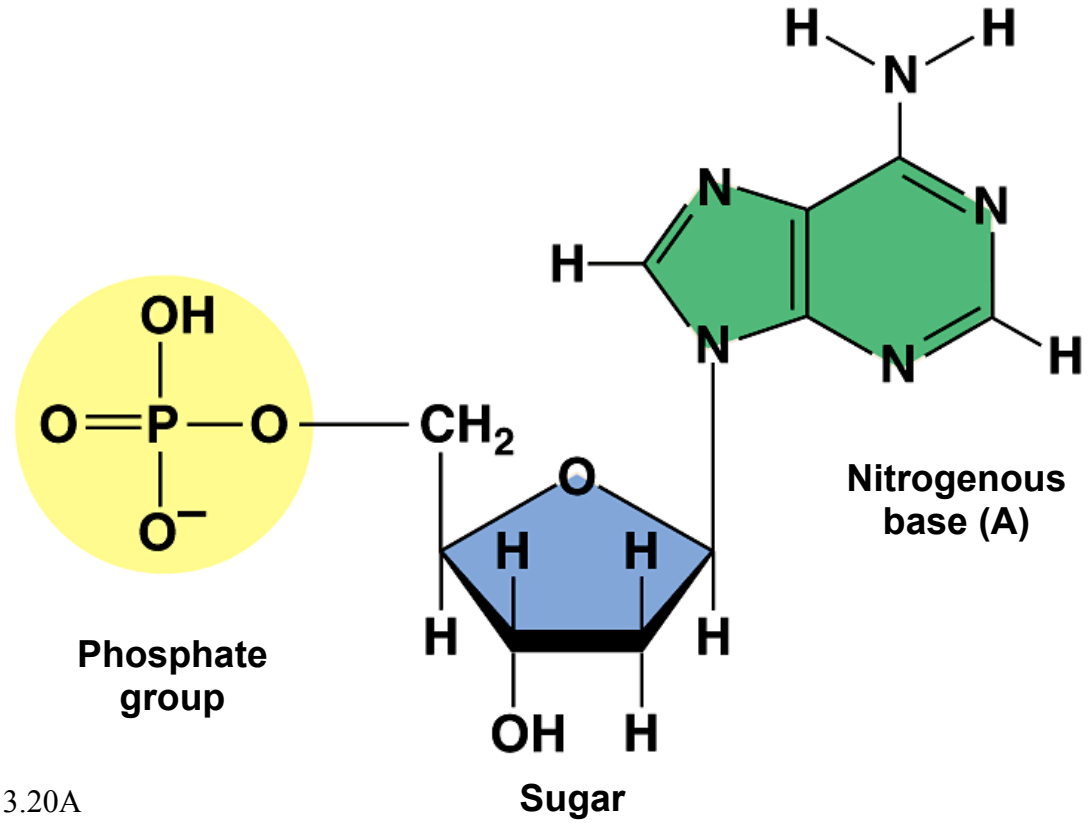


Figure 3.20A

- The sugar and phosphate form the backbone for the nucleic acid

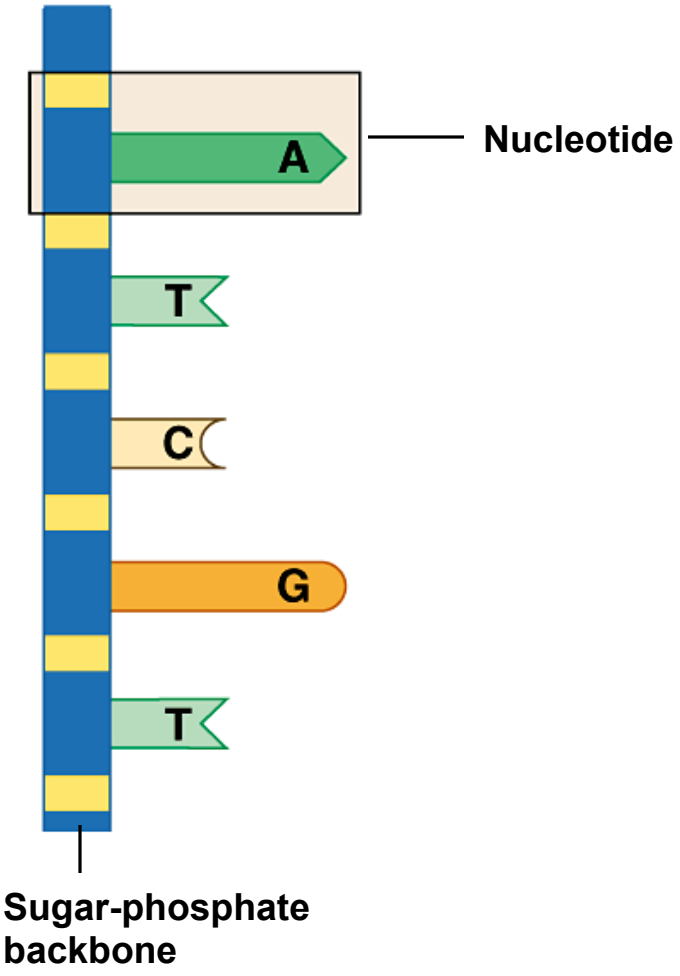


Figure 3.20B

- DNA consists of two polynucleotides twisted around each other in a double helix
  - The sequence of the four kinds of nitrogenous bases in DNA carries genetic information

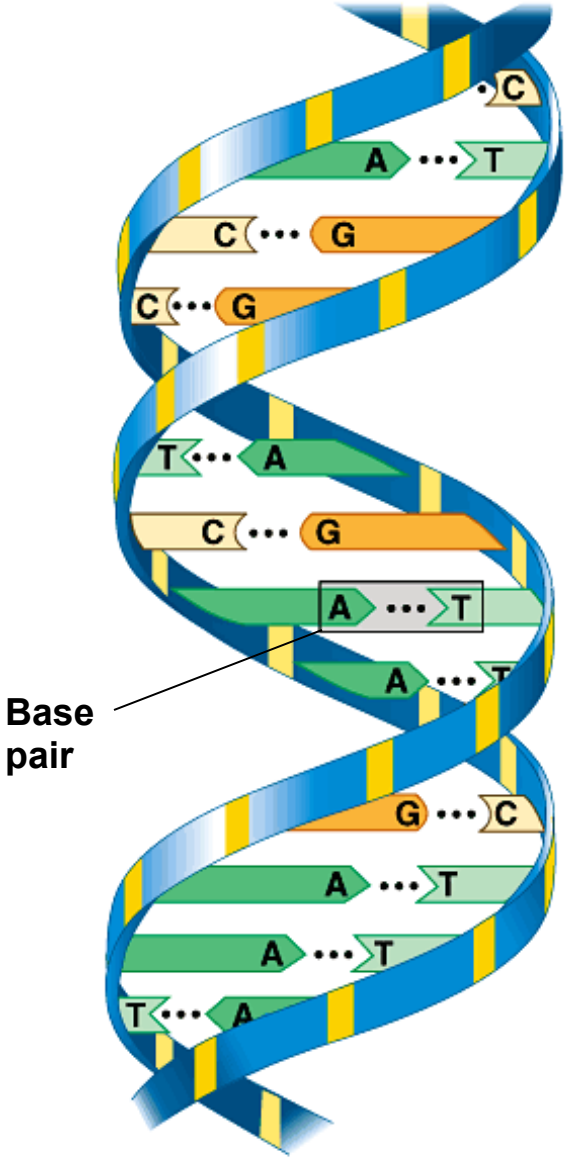


Figure 3.20C

- Stretches of a DNA molecule called genes program the amino acid sequences of proteins
  - DNA information is transcribed into RNA, a single-stranded nucleic acid
  - RNA is then translated into the primary structure of proteins