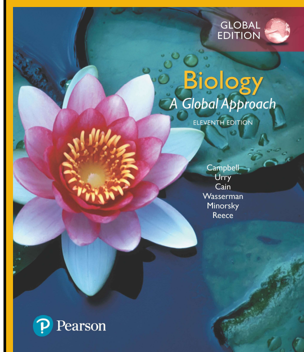


Chapter 5

Biological Macromolecules and Lipids

Lecture Presentations by
Nicole Tunbridge and
Kathleen Fitzpatrick

The Molecules of Life

- All living things are made up of four classes of large biological molecules: carbohydrates, lipids, proteins, and nucleic acids
- **Macromolecules** are large molecules and are complex
- Large biological molecules have unique properties that arise from the orderly arrangement of their atoms

Figure 5.1

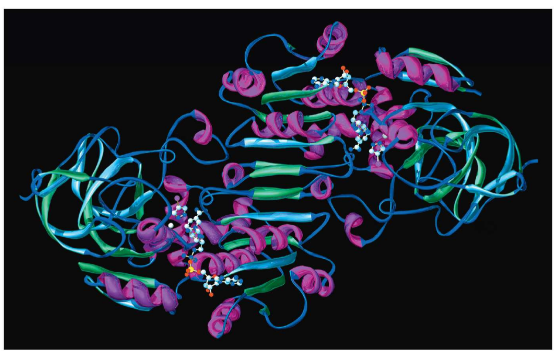


Figure 5.1a

The scientist in the foreground is using 3-D glasses to help her visualize the structure of the protein displayed on her screen.

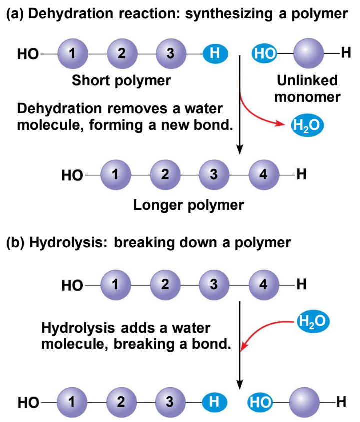
Concept 5.1: Macromolecules are polymers, built from monomers

- A **polymer** is a long molecule consisting of many similar building blocks
- The repeating units that serve as building blocks are called **monomers**
- Carbohydrates, proteins, and nucleic acids are polymers

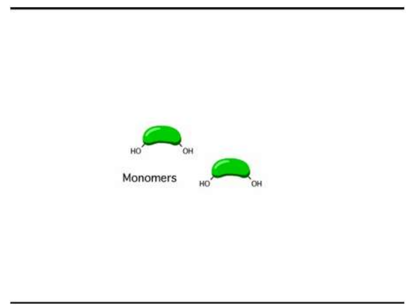
The Synthesis and Breakdown of Polymers

- **Enzymes** are specialized macromolecules that speed up chemical reactions such as those that make or break down polymers
- A **dehydration reaction** occurs when two monomers bond together through the loss of a water molecule
- Polymers are disassembled to monomers by **hydrolysis**, a reaction that is essentially the reverse of the dehydration reaction

Figure 5.2



Animation: Polymers



The Diversity of Polymers

- A cell has thousands of different macromolecules
- Macromolecules vary among cells of an organism, vary more within a species, and vary even more between species
- A huge variety of polymers can be built from a small set of monomers

Concept 5.2: Carbohydrates serve as fuel and building material

- **Carbohydrates** include sugars and the polymers of sugars
- The simplest carbohydrates are monosaccharides, or simple sugars
- Carbohydrate macromolecules are polysaccharides, polymers composed of many sugar building blocks

Sugars

- **Monosaccharides** have molecular formulas that are usually multiples of CH_2O
- Glucose ($C_6H_{12}O_6$) is the most common monosaccharide
- Monosaccharides are classified by
  - The location of the carbonyl group (as aldose or ketose)
  - The number of carbons in the carbon skeleton

Figure 5.3

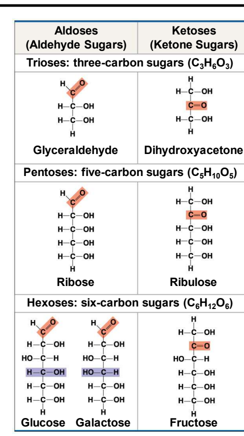


Figure 5.3a

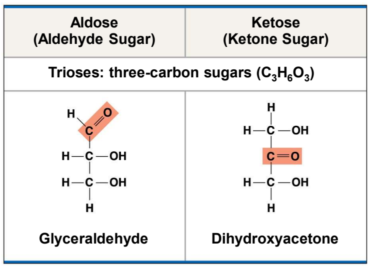


Figure 5.3b

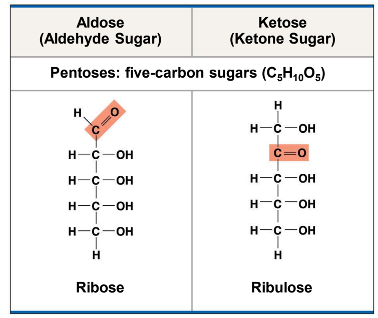
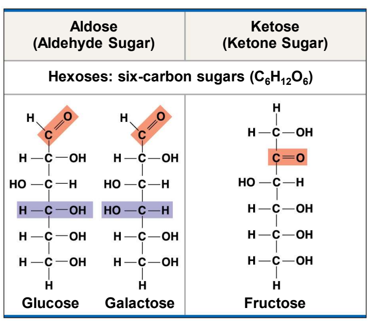
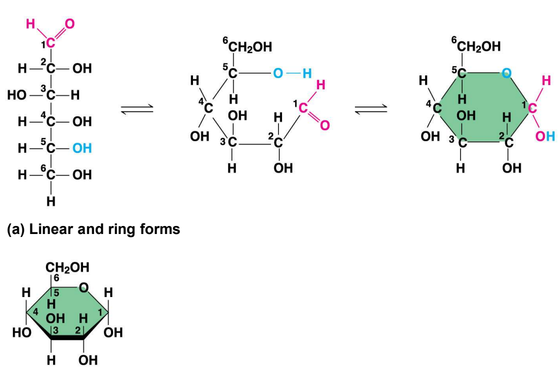


Figure 5.3c



- Though often drawn as linear skeletons, in aqueous solutions many sugars form rings
- Monosaccharides serve as a major fuel for cells and as raw material for building molecules

Figure 5.4

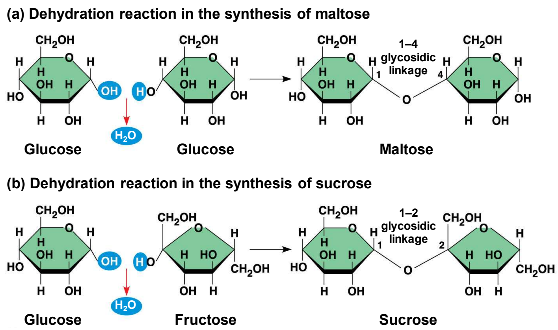


(a) Linear and ring forms

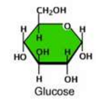
(b) Abbreviated ring structure

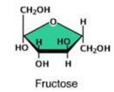
- A **disaccharide** is formed when a dehydration reaction joins two monosaccharides
- This covalent bond is called a **glycosidic linkage**

Figure 5.5



Animation: Disaccharides





Polysaccharides

- **Polysaccharides**, the polymers of sugars, have storage and structural roles
- The architecture and function of a polysaccharide are determined by its sugar monomers and the positions of its glycosidic linkages

Storage Polysaccharides

- **Starch**, a storage polysaccharide of plants, consists of glucose monomers
- Plants store surplus starch as granules within chloroplasts and other plastids
- The simplest form of starch is amylose

Figure 5.6

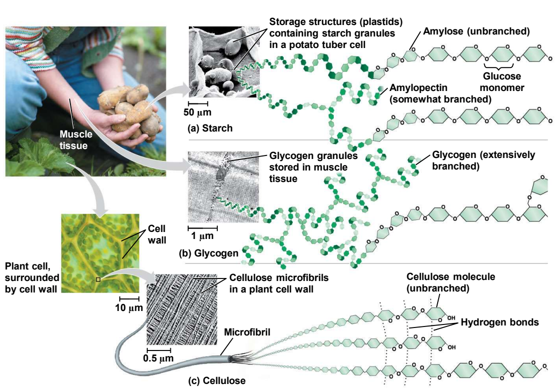


Figure 5.6a

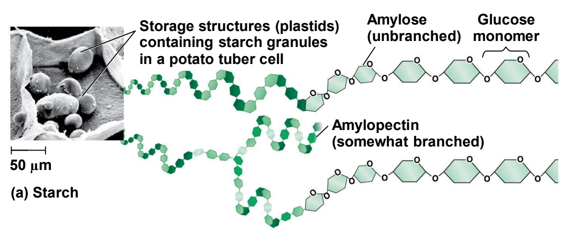


Figure 5.6aa

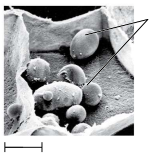


Figure 5.6b

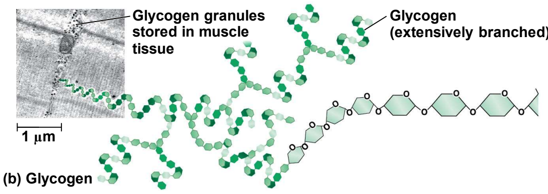


Figure 5.6ba

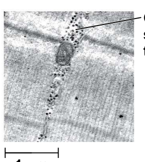


Figure 5.6c

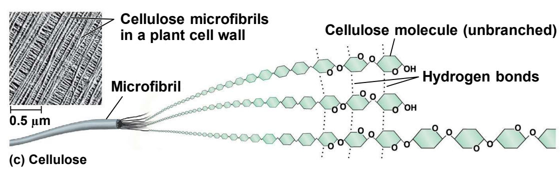


Figure 5.6ca

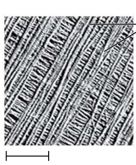
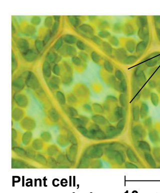
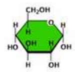


Figure 5.6d



Animation: Polysaccharides

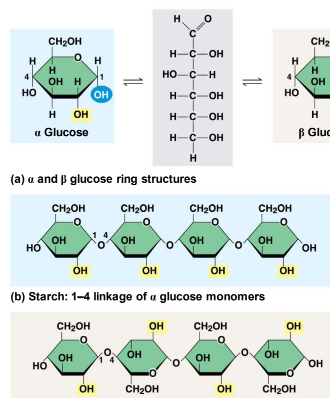


- **Glycogen** is a storage polysaccharide in animals
- Glycogen is stored mainly in liver and muscle cells
- Hydrolysis of glycogen in these cells releases glucose when the demand for sugar increases

Structural Polysaccharides

- The polysaccharide **cellulose** is a major component of the tough wall of plant cells
- Like starch, cellulose is a polymer of glucose, but the glycosidic linkages differ
- The difference is based on two ring forms for glucose: alpha (α) and beta (β)

Figure 5.7

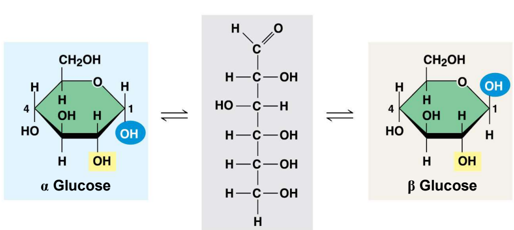


(a) α and β glucose ring structures

(b) Starch: 1–4 linkage of α glucose monomers

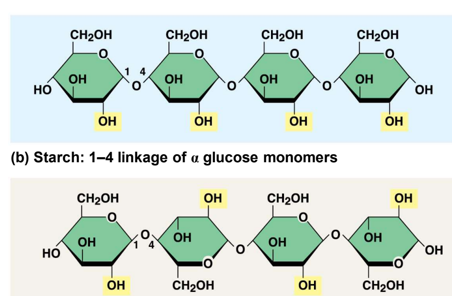
(c) Cellulose: 1–4 linkage of β glucose monomers

Figure 5.7a



(a) α and β glucose ring structures

Figure 5.7b



(b) Starch: 1–4 linkage of α glucose monomers

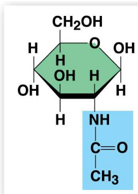
(c) Cellulose: 1–4 linkage of β glucose monomers

- Starch (α configuration) is largely helical
- Cellulose molecules (β configuration) are straight and unbranched
- Some hydroxyl groups on the monomers of cellulose can hydrogen-bond with hydroxyls of parallel cellulose molecules

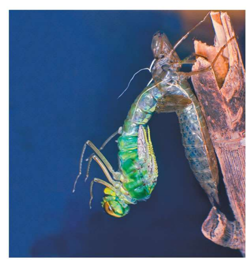
- Enzymes that digest starch by hydrolyzing α linkages can't hydrolyze β linkages in cellulose
- The cellulose in human food passes through the digestive tract as "insoluble fiber"
- Some microbes use enzymes to digest cellulose
- Many herbivores, from cows to termites, have symbiotic relationships with these microbes

- **Chitin**, another structural polysaccharide, is found in the exoskeleton of arthropods
- Chitin also provides structural support for the cell walls of many fungi

Figure 5.8



The structure of the chitin monomer



Chitin, embedded in proteins, forms the exoskeleton of arthropods.

Figure 5.8a

Chitin, embedded in proteins, forms the exoskeleton of arthropods.

Concept 5.3: Lipids are a diverse group of hydrophobic molecules

- **Lipids** are the one class of large biological molecules that does not include true polymers
- The unifying feature of lipids is that they mix poorly, if at all, with water
- Lipids consist mostly of hydrocarbon regions
- The most biologically important lipids are fats, phospholipids, and steroids

Fats

- **Fats** are constructed from two types of smaller molecules: glycerol and fatty acids
- Glycerol is a three-carbon alcohol with a hydroxyl group attached to each carbon
- A **fatty acid** consists of a carboxyl group attached to a long carbon skeleton

Figure 5.9

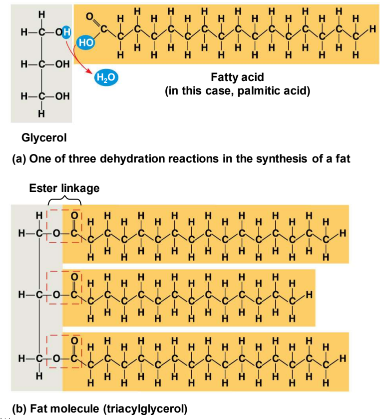
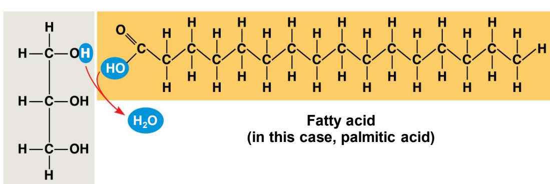


Figure 5.9a

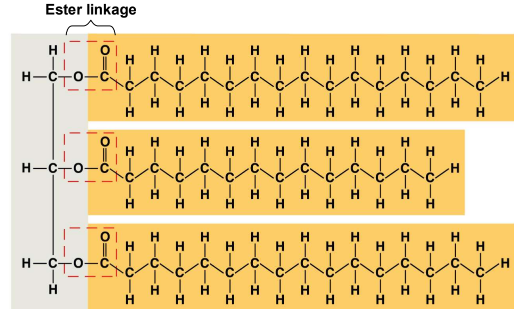


Glycerol

(a) One of three dehydration reactions in the synthesis of a fat

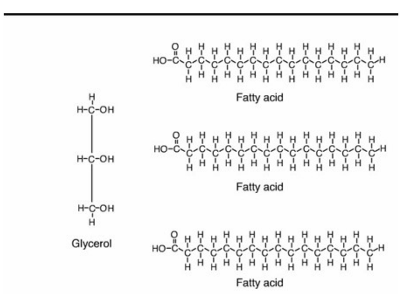
Figure 5.9b

Ester linkage



(b) Fat molecule (triacylglycerol)

Animation: Fats



- Fats separate from water because water molecules hydrogen-bond to each other and exclude the fats
- In a fat, three fatty acids are joined to glycerol by an ester linkage, creating a **triacylglycerol**, or triglyceride
- The fatty acids in a fat can be all the same or of two or three different kinds

- Fatty acids vary in length (number of carbons) and in the number and locations of double bonds
- **Saturated fatty acids** have the maximum number of hydrogen atoms possible and no double bonds
- **Unsaturated fatty acids** have one or more double bonds

Figure 5.10

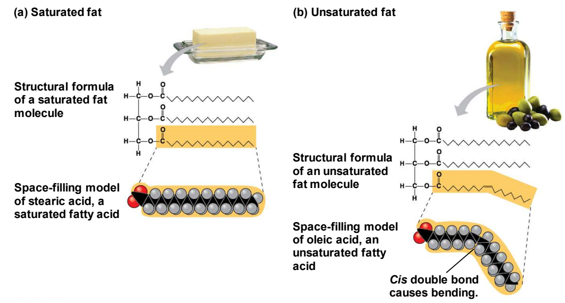


Figure 5.10a

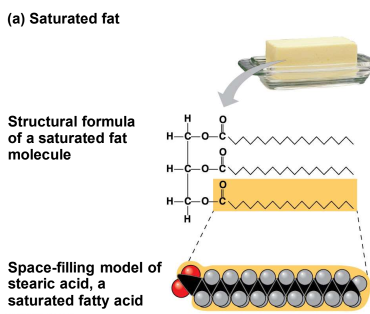


Figure 5.10aa

Figure 5.10b

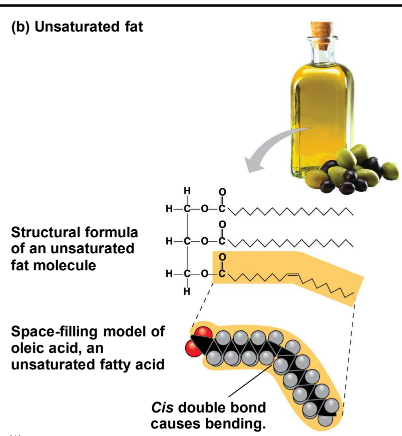


Figure 5.10ba

- Fats made from saturated fatty acids are called saturated fats and are solid at room temperature
- Most animal fats are saturated
- Fats made from unsaturated fatty acids are called unsaturated fats or oils and are liquid at room temperature
- Plant fats and fish fats are usually unsaturated

- A diet rich in saturated fats may contribute to cardiovascular disease through plaque deposits
- Hydrogenation is the process of converting unsaturated fats to saturated fats by adding hydrogen
- Hydrogenating vegetable oils also creates unsaturated fats with *trans* double bonds
- These ***trans* fats** may contribute more than saturated fats to cardiovascular disease

- The major function of fats is energy storage
- Humans and other mammals store their long-term food reserves in adipose cells
- Adipose tissue also cushions vital organs and insulates the body

Phospholipids

- In a **phospholipid**, two fatty acids and a phosphate group are attached to glycerol
- The two fatty acid tails are hydrophobic, but the phosphate group and its attachments form a hydrophilic head

Figure 5.11

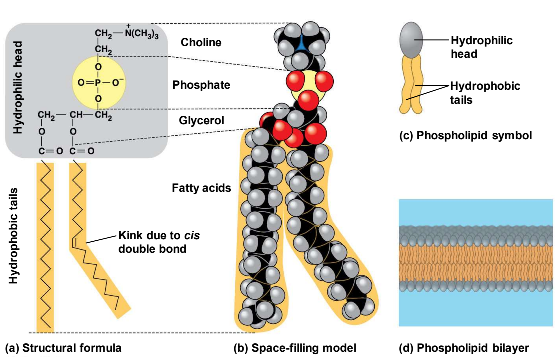


Figure 5.11a

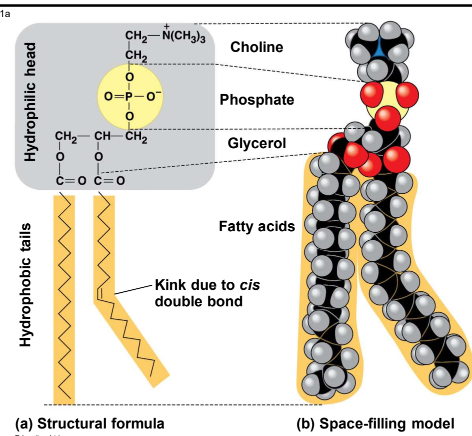
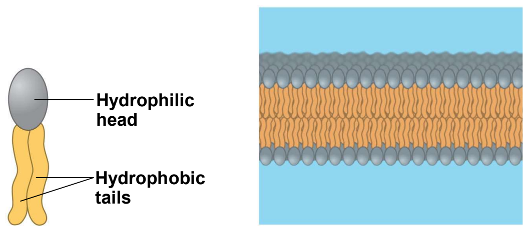


Figure 5.11b



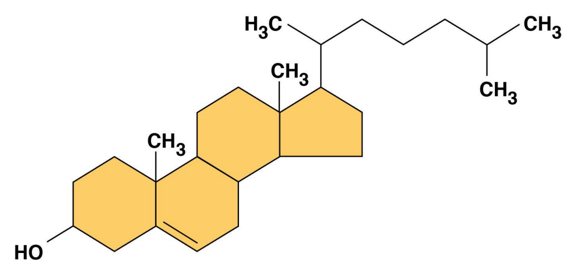
(c) Phospholipid symbol (d) Phospholipid bilayer

- When phospholipids are added to water, they self-assemble into double-layered sheets called bilayers
- At the surface of a cell, phospholipids are also arranged in a bilayer, with the hydrophobic tails pointing toward the interior
- The phospholipid bilayer forms a boundary between the cell and its external environment

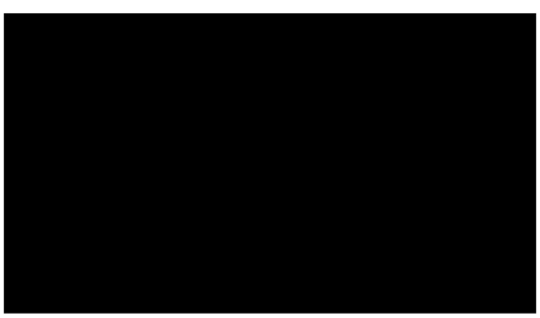
Steroids

- **Steroids** are lipids characterized by a carbon skeleton consisting of four fused rings
- **Cholesterol**, a type of steroid, is a component in animal cell membranes and a precursor from which other steroids are synthesized
- A high level of cholesterol in the blood may contribute to cardiovascular disease

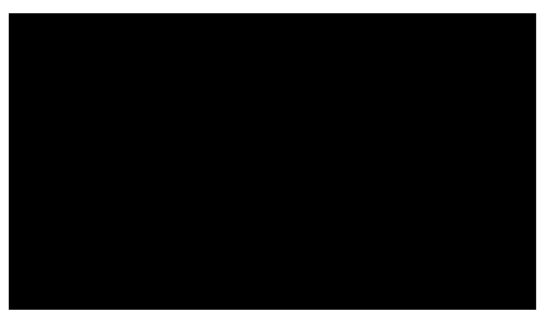
Figure 5.12



Video: Space-filling Model of Cholesterol



Video: Stick Model of Cholesterol



Concept 5.4: Proteins include a diversity of structures, resulting in a wide range of functions

- Proteins account for more than 50% of the dry mass of most cells
- Some proteins speed up chemical reactions
- Other protein functions include defense, storage, transport, cellular communication, movement, and structural support

Figure 5.13a

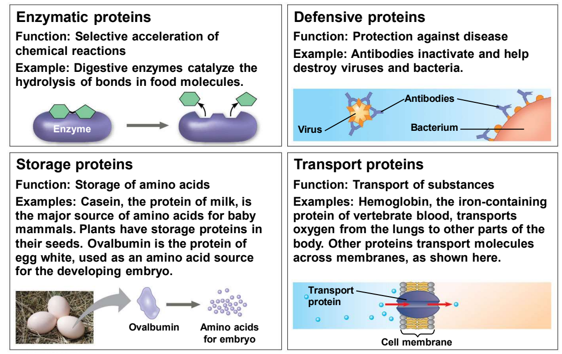


Figure 5.13aa

Enzymatic proteins

Function: Selective acceleration of chemical reactions

Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.

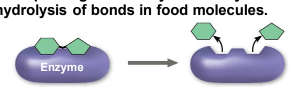


Figure 5.13ab

Defensive proteins

Function: Protection against disease

Example: Antibodies inactivate and help destroy viruses and bacteria.

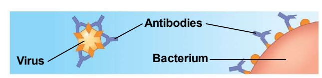


Figure 5.13ac

Storage proteins

Function: Storage of amino acids

Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.

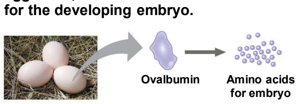


Figure 5.13aca

Figure 5.13ad

Transport proteins

Function: Transport of substances

Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across membranes, as shown here.

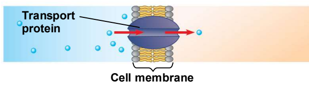
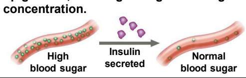


Figure 5.13b

Hormonal proteins

Function: Coordination of an organism's activities

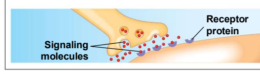
Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.



Receptor proteins

Function: Response of cell to chemical stimuli

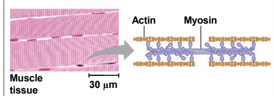
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.



Contractile and motor proteins

Function: Movement

Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.



Structural proteins

Function: Support

Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.

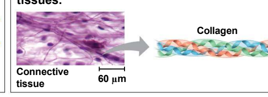


Figure 5.13ba

Hormonal proteins

Function: Coordination of an organism's activities

Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.

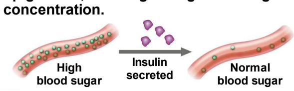


Figure 5.13bb

Receptor proteins

Function: Response of cell to chemical stimuli

Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.

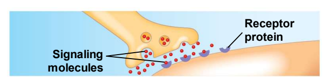


Figure 5.13bc

Contractile and motor proteins

Function: Movement

Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.

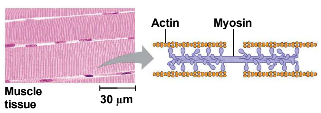


Figure 5.13bca

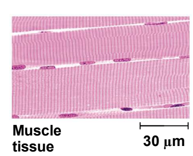


Figure 5.13bd

Structural proteins

Function: Support

Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.

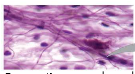
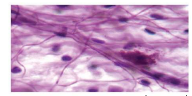
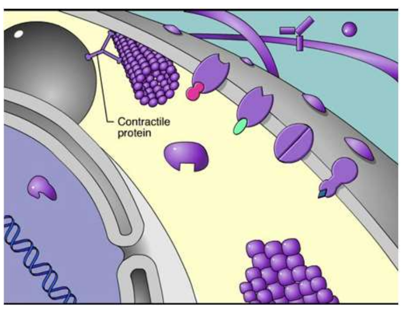


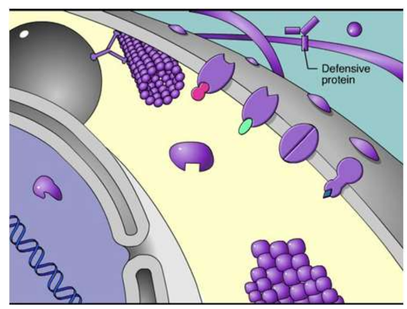
Figure 5.13bda



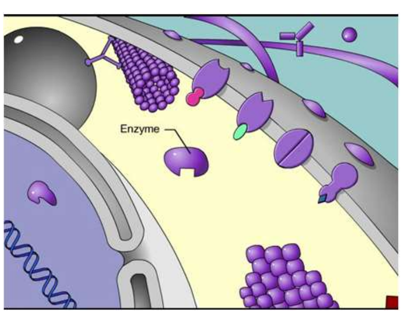
Animation: Contractile Proteins



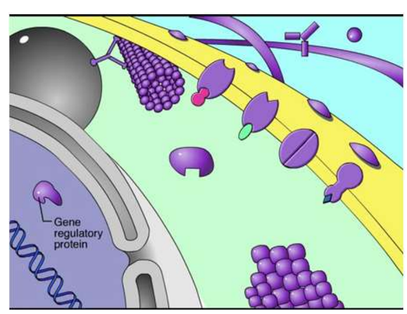
Animation: Defensive Proteins



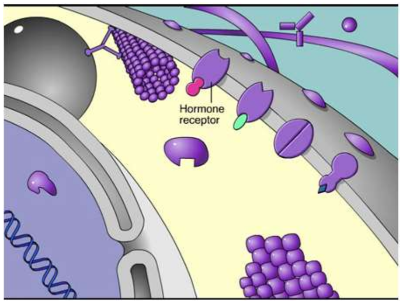
Animation: Enzymes



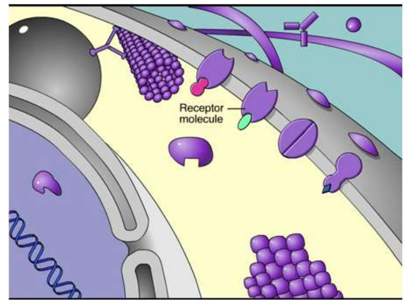
Animation: Gene Regulatory Proteins



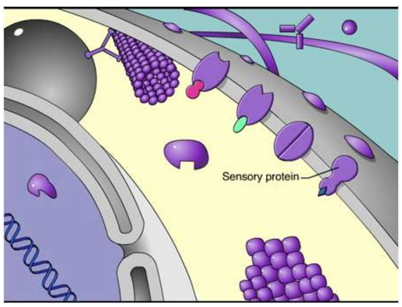
Animation: Hormonal Proteins



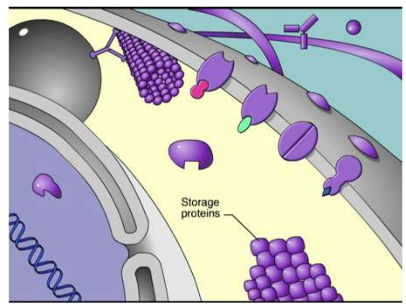
Animation: Receptor Proteins



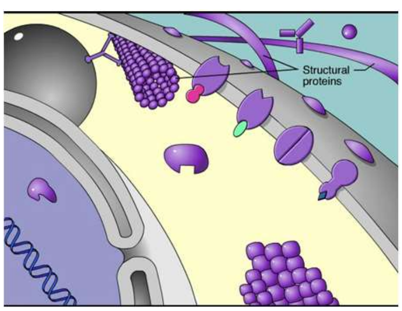
Animation: Sensory Proteins



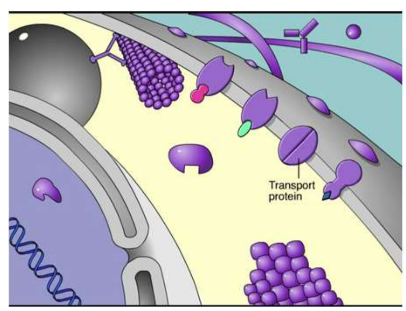
Animation: Storage Proteins



Animation: Structural Proteins



Animation: Transport Proteins



- Enzymes are proteins that act as **catalysts** to speed up chemical reactions
- Enzymes can perform their functions repeatedly, functioning as workhorses that carry out the processes of life

- Proteins are all constructed from the same set of 20 amino acids
- **Polypeptides** are unbranched polymers built from these amino acids
- A **protein** is a biologically functional molecule that consists of one or more polypeptides

Amino Acid Monomers

- **Amino acids** are organic molecules with amino and carboxyl groups
- Amino acids differ in their properties due to differing side chains, called R groups

Figure 5.UN01

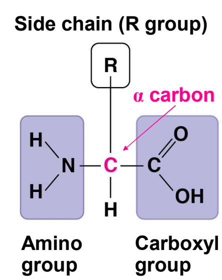


Figure 5.14

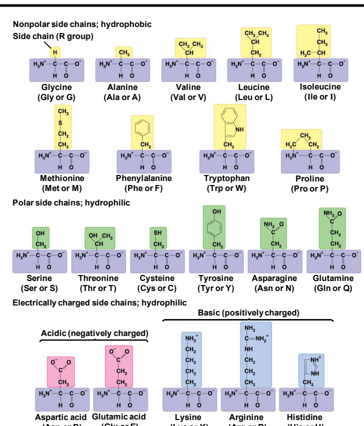


Figure 5.14a

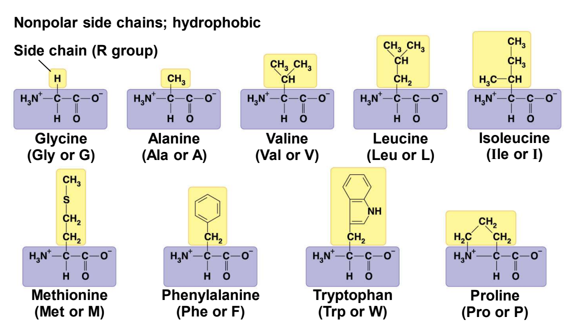


Figure 5.14b

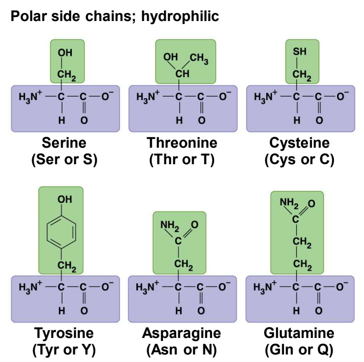
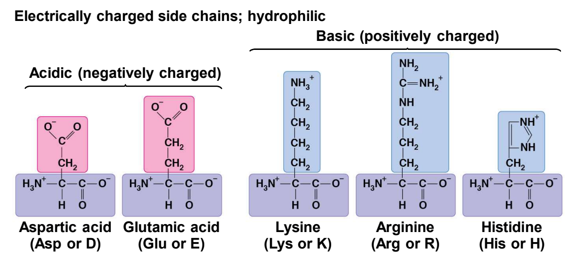


Figure 5.14c



Polypeptides (Amino Acid Polymers)

- Amino acids are linked by covalent bonds called **peptide bonds**
- A polypeptide is a polymer of amino acids
- Polypeptides range in length from a few to more than 1,000 monomers
- Each polypeptide has a unique linear sequence of amino acids, with a carboxyl end (C-terminus) and an amino end (N-terminus)

Figure 5.15

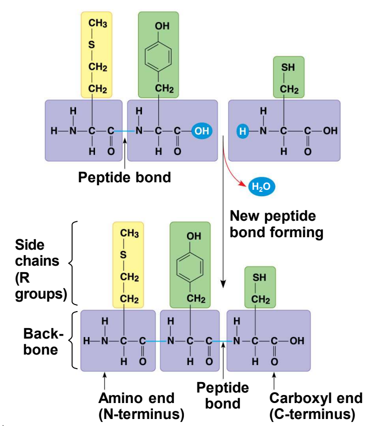


Figure 5.15a

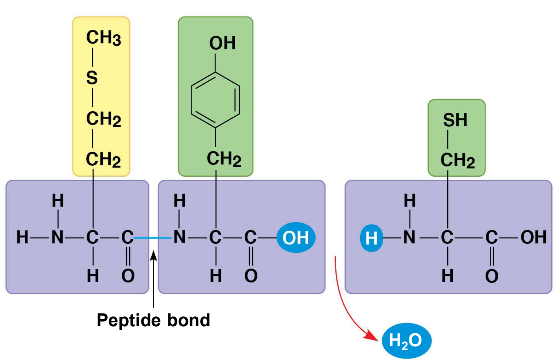
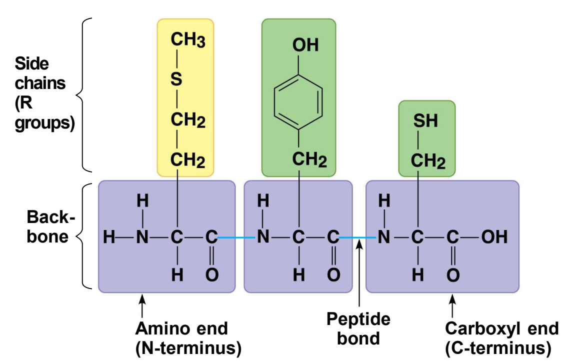


Figure 5.15b



Protein Structure and Function

- The specific activities of proteins result from their intricate three-dimensional architecture
- A functional protein consists of one or more polypeptides precisely twisted, folded, and coiled into a unique shape

Figure 5.16

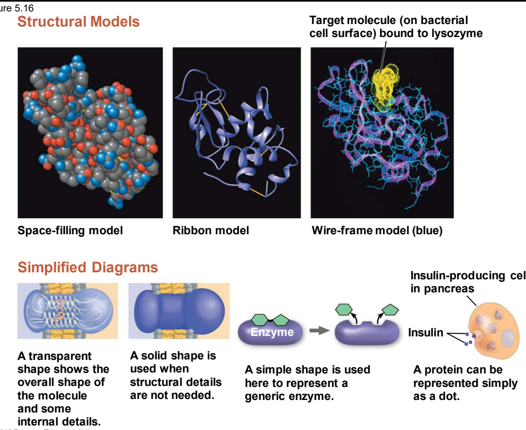


Figure 5.16a

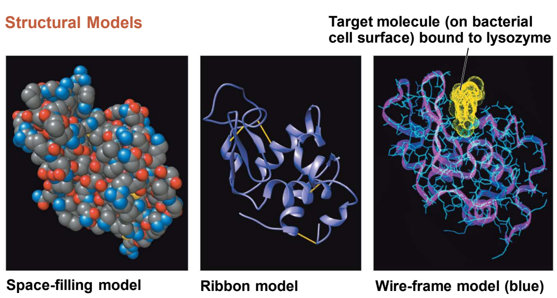
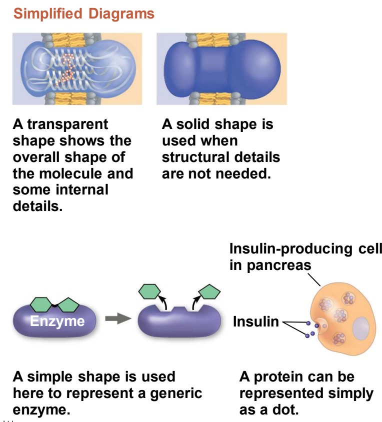
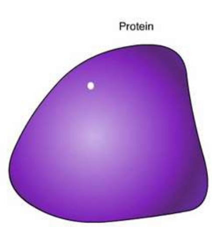


Figure 5.16b

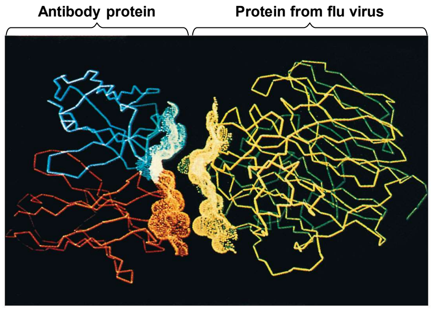


Animation: Protein Structure Introduction



- The sequence of amino acids determines a protein's three-dimensional structure
- A protein's structure determines how it works
- The function of a protein usually depends on its ability to recognize and bind to some other molecule

Figure 5.17



Four Levels of Protein Structure

- The primary structure of a protein is its unique sequence of amino acids
- Secondary structure, found in most proteins, consists of coils and folds in the polypeptide chain
- Tertiary structure is determined by interactions among various side chains (R groups)
- Quaternary structure results when a protein consists of multiple polypeptide chains

Figure 5.18a

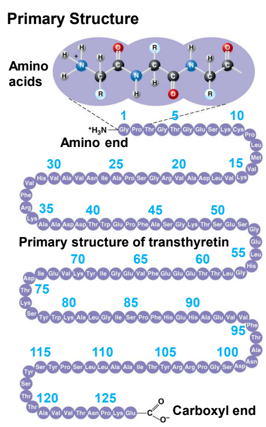


Figure 5.18aa

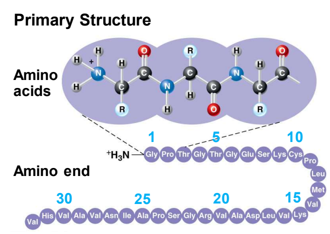


Figure 5.18b

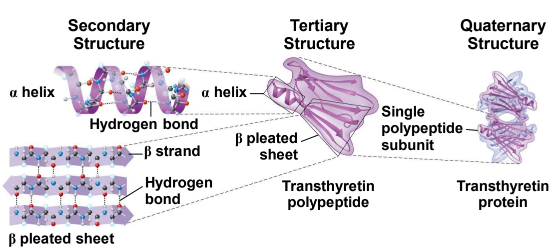


Figure 5.18ba

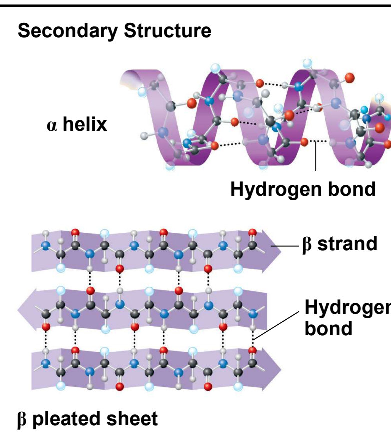


Figure 5.18bb

Tertiary Structure

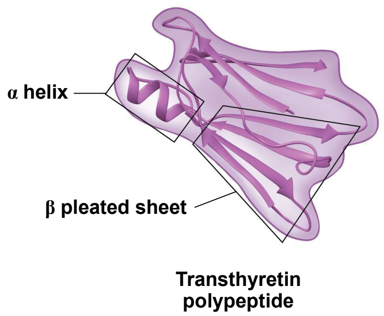


Figure 5.18bc

Quaternary Structure

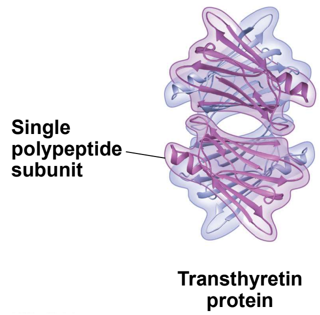


Figure 5.18c

Figure 5.18d

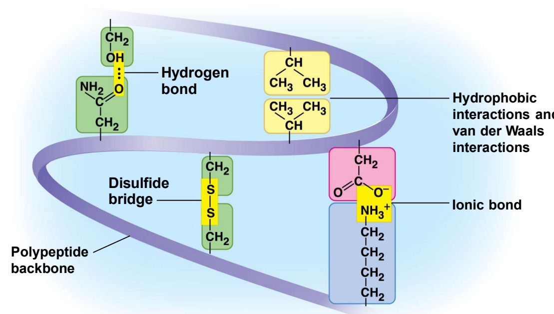


Figure 5.18e

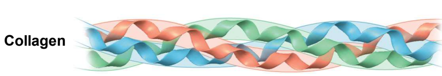
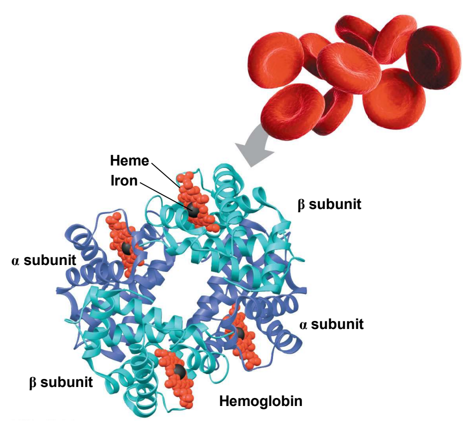
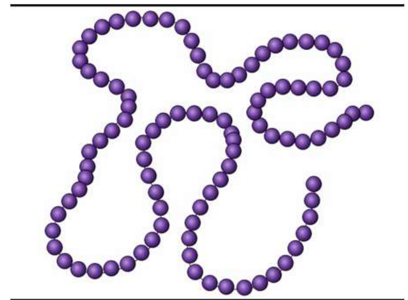


Figure 5.18f



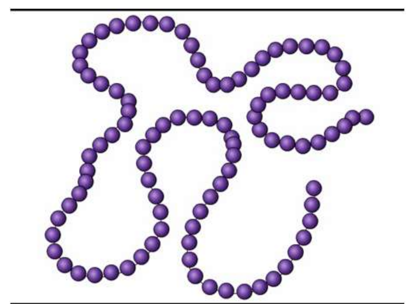
- The **primary structure** of a protein is its sequence of amino acids
- Primary structure is like the order of letters in a long word
- Primary structure is determined by inherited genetic information

Animation: Primary Protein Structure

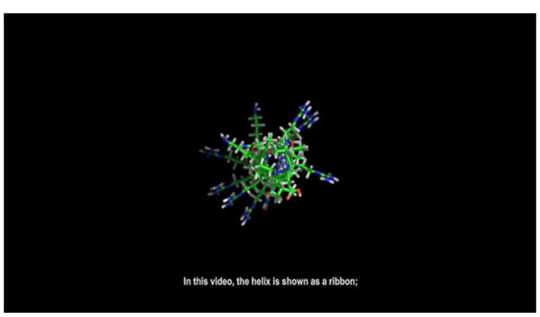


- The coils and folds of **secondary structure** result from hydrogen bonds between repeating constituents of the polypeptide backbone
- Typical secondary structures are a coil called an **α helix** and a folded structure called a **β pleated sheet**

Animation: Secondary Protein Structure

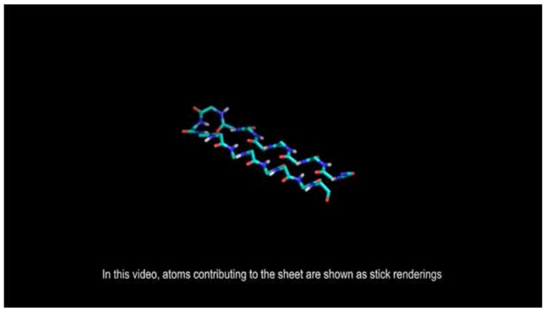


Video: An Idealized α Helix

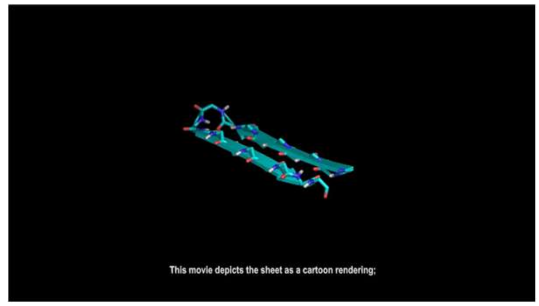


Video: An Idealized α Helix: No Sidechains

Video: An Idealized β Pleated Sheet

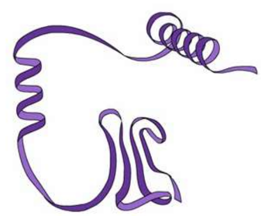


Video: An Idealized β Pleated Sheet Cartoon



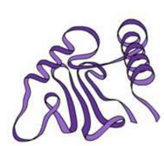
- **Tertiary structure**, the overall shape of a polypeptide, results from interactions between R groups, rather than interactions between backbone constituents
- These interactions include hydrogen bonds, ionic bonds, **hydrophobic interactions**, and van der Waals interactions
- Strong covalent bonds called **disulfide bridges** may reinforce the protein’s structure

Animation: Tertiary Protein Structure



- **Quaternary structure** results when two or more polypeptide chains form one macromolecule
- Collagen is a fibrous protein consisting of three polypeptides coiled like a rope
- Hemoglobin is a globular protein consisting of four polypeptides: two α and two β subunits

Animation: Quaternary Protein Structure



Sickle-Cell Disease: A Change in Primary Structure

- A slight change in primary structure can affect a protein’s structure and ability to function
- **Sickle-cell disease**, an inherited blood disorder, results from a single amino acid substitution in the protein hemoglobin
- The abnormal hemoglobin molecules cause the red blood cells to aggregate into chains and to deform into a sickle shape

Figure 5.19

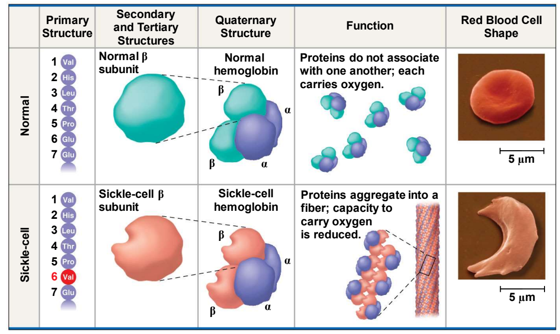


Figure 5.19a

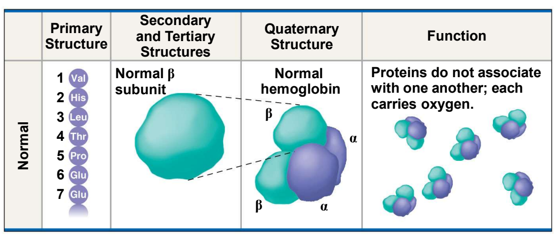


Figure 5.19aa

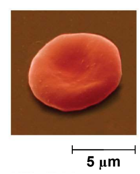


Figure 5.19b

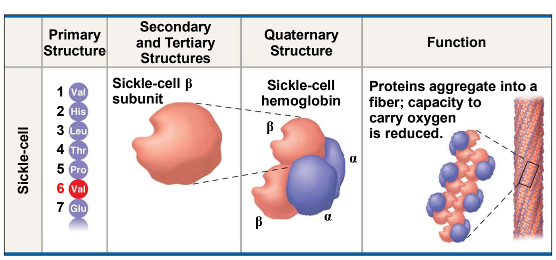
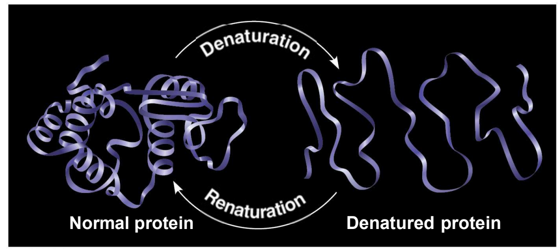


Figure 5.19ba

What Determines Protein Structure?

- In addition to primary structure, physical and chemical conditions can affect structure
- Alterations in pH, salt concentration, temperature, or other environmental factors can cause a protein to unravel
- This loss of a protein's native structure is called **denaturation**
- A denatured protein is biologically inactive

Figure 5.20

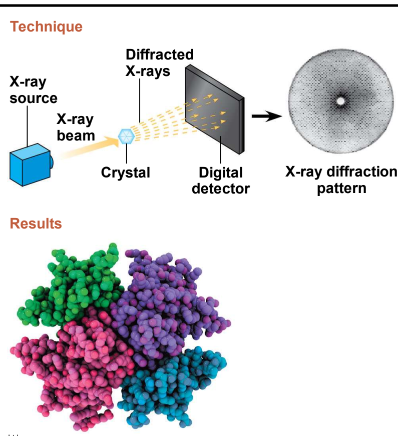


Protein Folding in the Cell

- It is hard to predict a protein's structure from its primary structure
- Most proteins probably go through several stages on their way to a stable structure
- Diseases such as Alzheimer's, Parkinson's, and mad cow disease are associated with misfolded proteins

- Scientists use **X-ray crystallography** to determine a protein's structure
- Another method is nuclear magnetic resonance (NMR) spectroscopy, which does not require protein crystallization
- Bioinformatics is another approach to prediction of protein structure from amino acid sequences

Figure 5.21



MA1

Concept 5.5: Nucleic acids store, transmit, and help express hereditary information

- The amino acid sequence of a polypeptide is programmed by a unit of inheritance called a **gene**
- Genes consist of DNA, a **nucleic acid** made of monomers called nucleotides

Slide 144

MA1 Monday 6Jul2020
Mamoon Al-Rshaidat, 7/6/2020

The Roles of Nucleic Acids

- There are two types of nucleic acids
  - **Deoxyribonucleic acid (DNA)**
  - **Ribonucleic acid (RNA)**
- DNA provides directions for its own replication
- DNA directs synthesis of messenger RNA (mRNA) and, through mRNA, controls protein synthesis
- This process is called **gene expression**

Figure 5.22_1

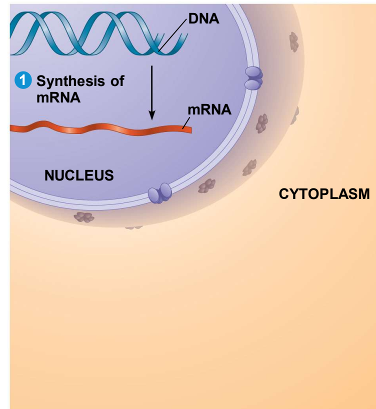


Figure 5.22_2

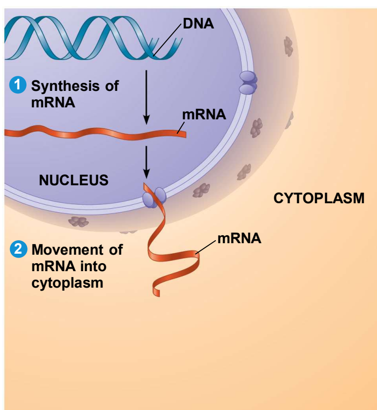
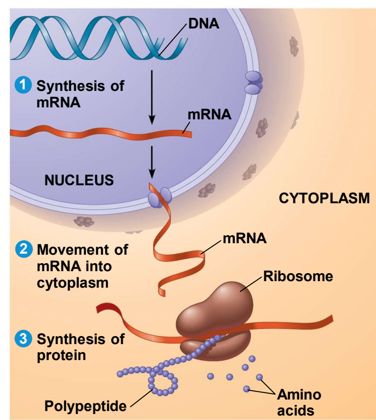


Figure 5.22_3



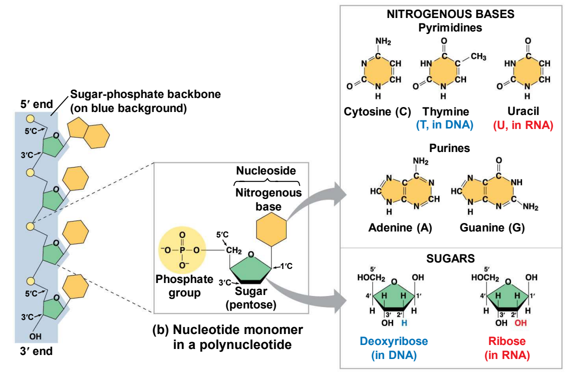
- Each gene along a DNA molecule directs synthesis of a messenger RNA (mRNA)
- The mRNA molecule interacts with the cell's protein-synthesizing machinery to direct production of a polypeptide
- The flow of genetic information can be summarized as DNA → RNA → protein

The Components of Nucleic Acids

- Nucleic acids are polymers called **polynucleotides**
- Each polynucleotide is made of monomers called **nucleotides**
- Each nucleotide consists of a nitrogenous base, a pentose sugar, and one or more phosphate groups
- The portion of a nucleotide without the phosphate group is called a nucleoside

- Nucleoside = nitrogenous base + sugar
- There are two families of nitrogenous bases
  - **Pyrimidines** (cytosine, thymine, and uracil) have a single six-membered ring
  - **Purines** (adenine and guanine) have a six-membered ring fused to a five-membered ring
- In DNA, the sugar is **deoxyribose**; in RNA, the sugar is **ribose**
- Nucleotide = nucleoside + phosphate group

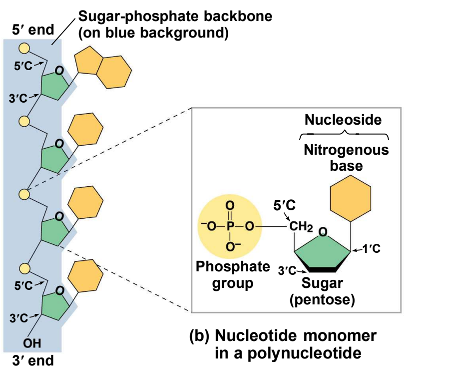
Figure 5.23



(a) Polynucleotide, or nucleic acid

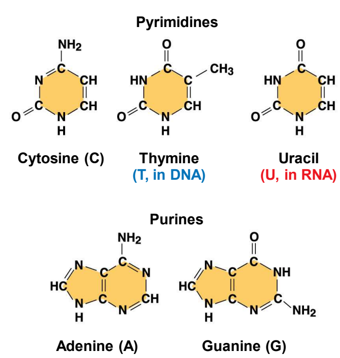
(c) Nucleoside components

Figure 5.23a



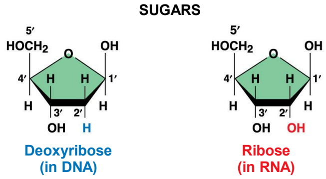
(a) Polynucleotide, or nucleic acid

Figure 5.23b



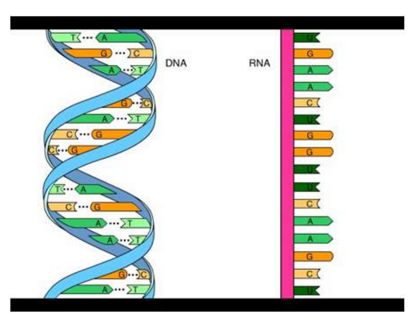
(c) Nucleoside components

Figure 5.23c



(c) Nucleoside components

Animation: DNA and RNA Structure



Nucleotide Polymers

- Nucleotides are linked together by a phosphodiester linkage to build a polynucleotide
- A phosphodiester linkage consists of a phosphate group that links the sugars of two nucleotides
- These links create a backbone of sugar-phosphate units with nitrogenous bases as appendages
- The sequence of bases along a DNA or mRNA polymer is unique for each gene

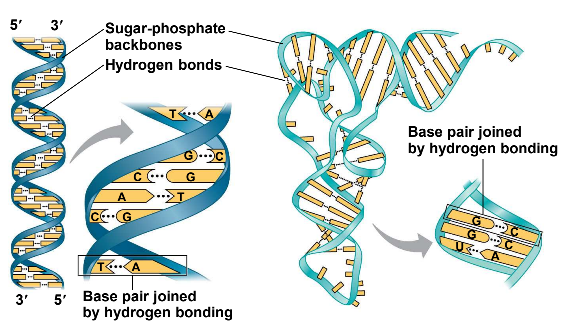
The Structures of DNA and RNA Molecules

- DNA molecules have two polynucleotides spiraling around an imaginary axis, forming a **double helix**
- The backbones run in opposite 5′ → 3′ directions from each other, an arrangement referred to as **antiparallel**
- One DNA molecule includes many genes

- Only certain bases in DNA pair up and form hydrogen bonds:
  - adenine (A) always with thymine (T)
  - guanine (G) always with cytosine (C)
- This is called **complementary base pairing**
- This feature of DNA structure makes it possible to generate two identical copies of each DNA molecule in a cell preparing to divide

- **RNA**, in contrast to DNA, is single-stranded
- Complementary pairing can also occur between two RNA molecules or between parts of the same molecule
- In RNA, thymine is replaced by uracil (U), so A and U pair
- While DNA always exists as a double helix, RNA molecules are more variable in form

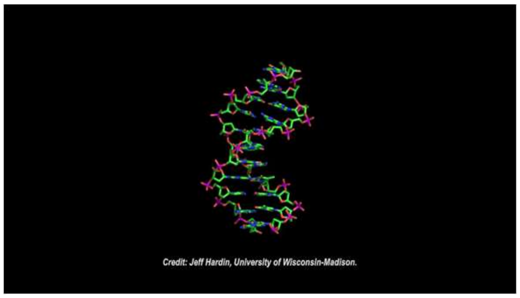
Figure 5.24



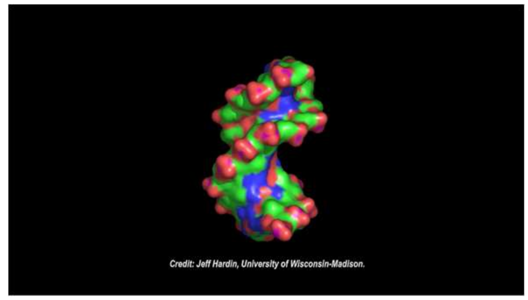
(a) DNA (b) Transfer RNA

Animation: DNA Double Helix

Video: Stick Model of DNA (Deoxyribonucleic Acid)



Video: Surface Model of DNA (Deoxyribonucleic Acid)



Chapter Summary

- Functional groups from Chapter 4
  (PDF file found in E-Learning)
- Macromolecular of Life
  - Carbohydrates
  - Lipids
  - Proteins
  - Nucleic Acids

Figure 5.UN04

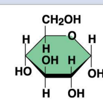
Components	Examples	Functions
 Monosaccharide monomer	Monosaccharides: glucose, fructose	Fuel; carbon sources that can be converted to other molecules or combined into polymers
	Disaccharides: lactose, sucrose	
	Polysaccharides: ▪ Cellulose (plants) ▪ Starch (plants) ▪ Glycogen (animals) ▪ Chitin (animals and fungi)	 ▪ Strengthens plant cell walls ▪ Stores glucose for energy ▪ Stores glucose for energy ▪ Strengthens exoskeletons and fungal cell walls

Figure 5.UN05

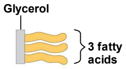
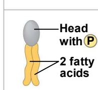
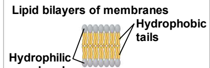
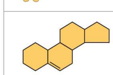
Components	Examples	Functions
Glycerol 	Triacylglycerols (fats or oils): glycerol + three fatty acids	Important energy source 
	Phospholipids: glycerol + phosphate group + two fatty acids	Lipid bilayers of membranes 
 Steroid backbone	Steroids: four fused rings with attached chemical groups	▪ Component of cell membranes (cholesterol) ▪ Signaling molecules that travel through the body (hormones)

Figure 5.UN06

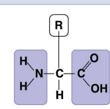
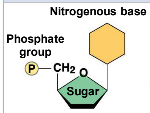
Components	Examples	Functions
 Amino acid monomer (20 types)	▪ Enzymes ▪ Defensive proteins ▪ Storage proteins ▪ Transport proteins ▪ Hormones ▪ Receptor proteins ▪ Motor proteins ▪ Structural proteins	▪ Catalyze chemical reactions ▪ Protect against disease ▪ Store amino acids ▪ Transport substances ▪ Coordinate organismal responses ▪ Receive signals from outside cell ▪ Function in cell movement ▪ Provide structural support

Figure 5.UN07

Components	Examples	Functions
 Nucleotide (monomer of a polynucleotide)	DNA:  ▪ Sugar = deoxyribose ▪ Nitrogenous bases = C, G, A, T ▪ Usually double-stranded	Stores hereditary information
	RNA:  ▪ Sugar = ribose ▪ Nitrogenous bases = C, G, A, U ▪ Usually single-stranded	Various functions in gene expression, including carrying instructions from DNA to ribosomes

- The seven functional groups that are most important in the chemistry of life
  - Hydroxyl group
  - Carbonyl group
  - Carboxyl group
  - Amino group
  - Sulfhydryl group
  - Phosphate group
  - Methyl group

Figure 4.9

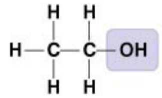
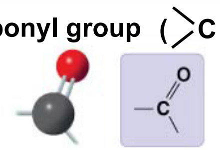
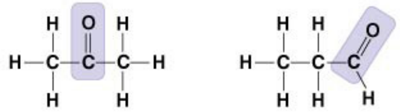
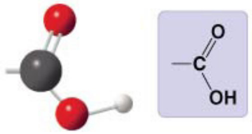
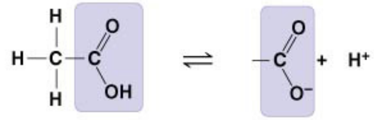
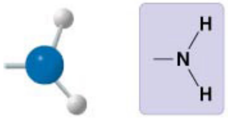
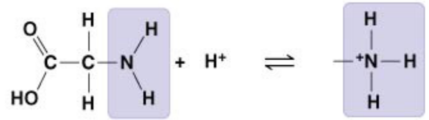
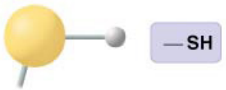
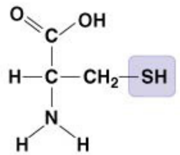
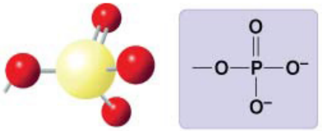
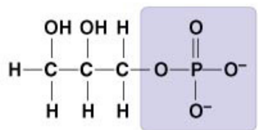
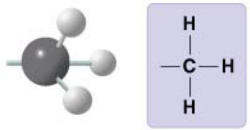
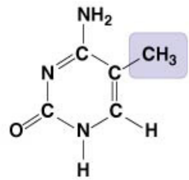
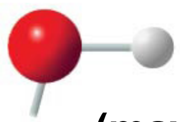
Chemical Group	Compound Name	Examples
Hydroxyl group (—OH) 	Alcohol	 Ethanol
Carbonyl group ($>C{=}O$) 	Ketone Aldehyde	 Acetone Propanal
Carboxyl group (—COOH) 	Carboxylic acid, or organic acid	 Acetic acid
Amino group ($—NH_2$) 	Amine	 Glycine
Sulfhydryl group (—SH) 	Thiol	 Cysteine
Phosphate group ($—OPO_3^{2-}$) 	Organic phosphate	 Glycerol phosphate
Methyl group ($—CH_3$) 	Methylated compound	 5-Methyl cytosine

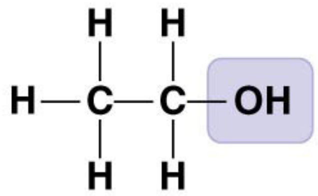
Figure 4.9aa

Hydroxyl group (—OH)



—OH

(may be written HO—)

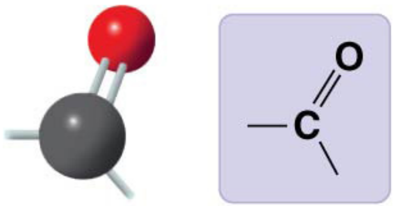


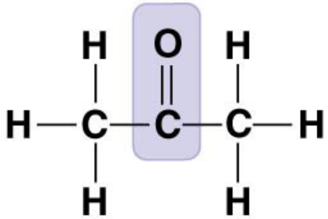
Ethanol, the alcohol present in alcoholic beverages

Polar due to electronegative oxygen. Forms hydrogen bonds with water.
Compound name: Alcohol

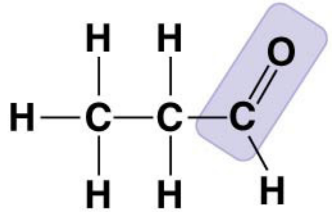
Figure 4.9ab

Carbonyl group (>C=O)





Acetone,
the simplest ketone

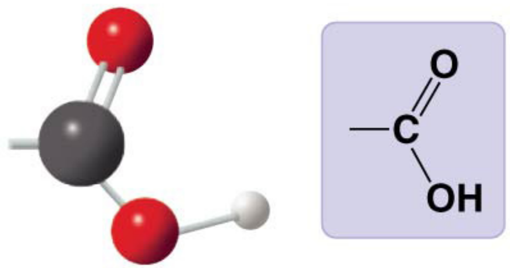


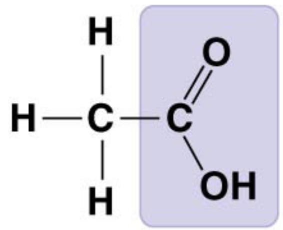
Propanal,
an aldehyde

Sugars with ketone groups are called ketoses; those with aldehydes are called aldoses.
Compound name: Ketone or aldehyde

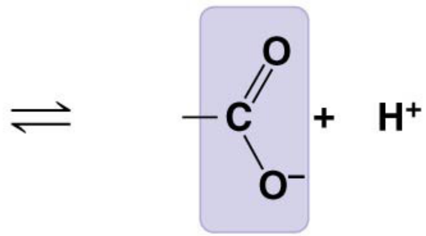
Figure 4.9ac

Carboxyl group (—COOH)





Acetic acid, which gives vinegar its sour taste

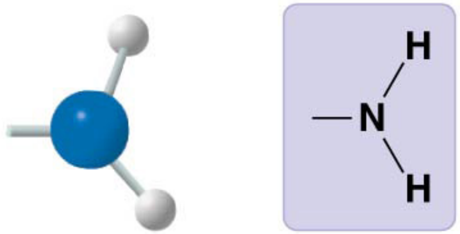


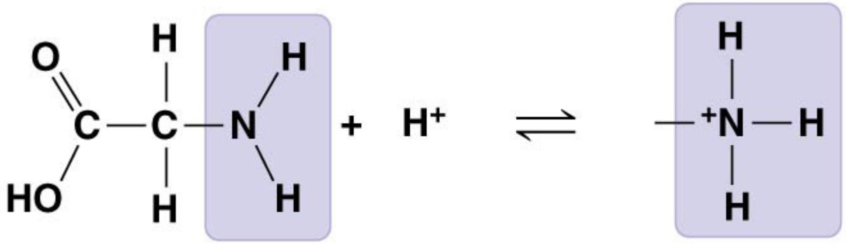
Ionized form of —COOH (carboxylate ion), found in cells

Acts as an acid.
Compound name: Carboxylic acid, or organic acid

Figure 4.9ad

Amino group (—NH_2)





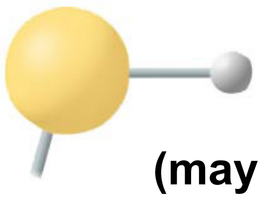
Glycine, an amino acid (note its carboxyl group)

Ionized form of —NH_2, found in cells

Acts as a base.
Compound name: Amine

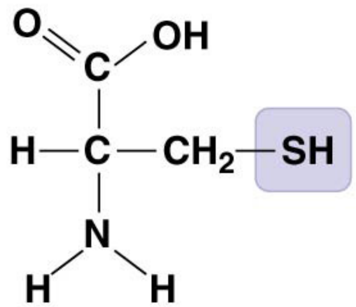
Figure 4.9ba

Sulfhydryl group (—SH)



—SH

(may be written HS—)

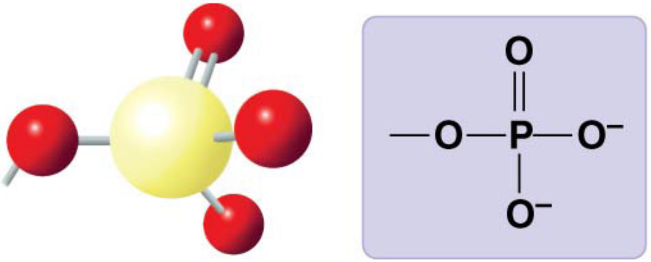


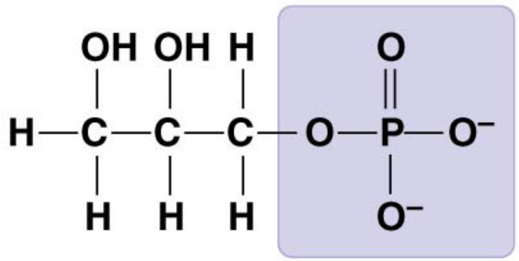
Cysteine, a sulfur-containing amino acid

Two —SH groups can react, forming a “cross-link” that helps stabilize protein structure.
Compound name: Thiol

Figure 4.9bb

Phosphate group ($—OPO_3^{2-}$)



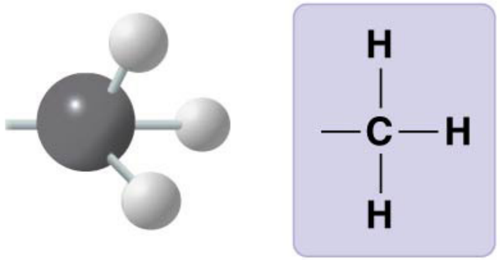


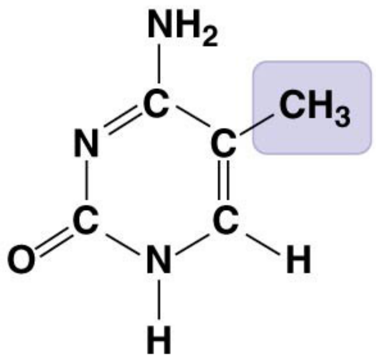
Glycerol phosphate, which takes part in many important chemical reactions in cells

Contributes negative charge. When attached, confers on a molecule the ability to react with water, releasing energy.
Compound name: Organic phosphate

Figure 4.9bc

Methyl group (—CH_3)





5-Methyl cytosine, a component of DNA that has been modified by addition of a methyl group

Affects the expression of genes. Affects the shape and function of sex hormones.
Compound name: Methylated compound

Polymers are made of monomer subunits that are joined by what type of bonds?

a) ionic bonds
b) covalent bonds
c) hydrogen bonds
d) hydrophobic bonds

1

Which polysaccharide has the greatest number of branches?

a) cellulose
b) chitin
c) amylose
d) amylopectin
e) glycogen

2

A polysaccharide you are studying contains unbranched β glucose molecules and cannot be digested by humans. Which polysaccharide are you studying?

a) cellulose
b) DNA
c) chitin
d) starch
e) glycogen

3

Lipids cannot be considered polymers because

a) they contain polar covalent bonds.
b) their structure includes carbon rings.
c) they can be artificially created.
d) their monomers are connected via ionic bonds.
e) they are not composed of monomer subunits.

4

All lipids

a) are made from glycerol and fatty acids.
b) contain nitrogen.
c) have low energy content.
d) are acidic when mixed with water.
e) do not dissolve well in water.

5

Which is a function of a molecule that is not a protein?

a) helps make up membranes
b) carries the code for translation from the nucleus to the ribosome
c) binds to hormones (hormone receptor)
d) can be a hormone
e) speeds chemical reactions

6

How does RNA differ from DNA?

a) DNA encodes hereditary information; RNA does not.
b) DNA forms duplexes; RNA does not.
c) DNA contains thymine; RNA contains uracil.
d) all of the above

7

If you heat a cell to a moderately higher temperature than it is normally used to, which molecule will stop working first?

a) RNA
b) DNA
c) protein
d) lipid
e) carbohydrate

8

In which pair does the first molecule determine the structure of the second?

a) DNA, protein
b) RNA, carbohydrate
c) Lipid, DNA
d) DNA, RNA
e) a and d

9

If you wanted to extract the heaviest component of a membrane, you would need a protocol to extract

a) sterols.
b) phospholipids.
c) glycerol.
d) fatty acids.
e) none of the above.

10