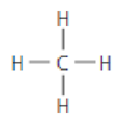
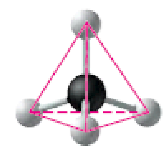
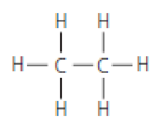
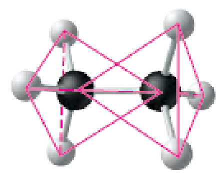
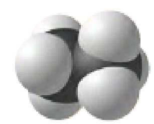
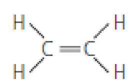
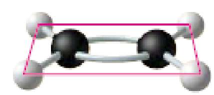
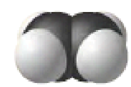
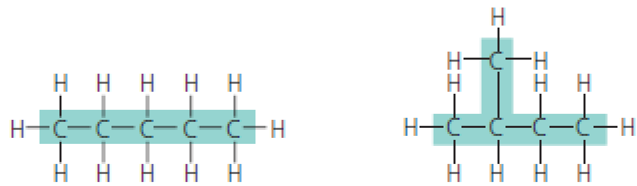
Biology Cheat Sheet

Name and Comment	Molecular Formula	Structural Formula	Ball-and-Stick Model (molecular shape in pink)	Space-Filling Model
(a) Methane. When a carbon atom has four single bonds to other atoms, the molecule is tetrahedral.	CH_4			
(b) Ethane. A molecule may have more than one tetrahedral group of single-bonded atoms. (Ethane consists of two such groups.)	C_2H_6			
(c) Ethene (ethylene). When two carbon atoms are joined by a double bond, all atoms attached to those carbons are in the same plane; the molecule is flat.	C_2H_4			

▼ Figure 4.7 Three types of isomers, compounds with the same molecular formula but different structures.

(a) Structural isomers



Structural isomers differ in covalent partners, as shown in this example of two isomers of C_5H_{12}: pentane (left) and 2-methyl butane (right).

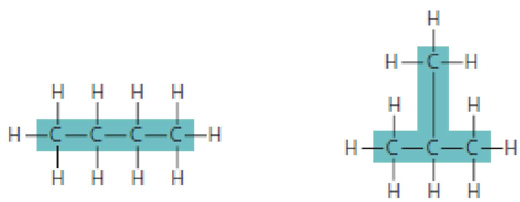
▼ **Figure 4.5 Four ways that carbon skeletons can vary.**

(a) Length

Ethane　　Propane

Carbon skeletons vary in length.

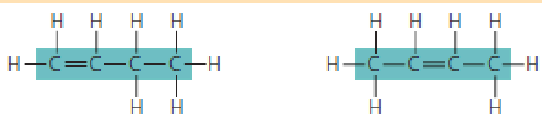
(b) Branching



Butane　　2-Methylpropane (commonly called isobutane)

Skeletons may be unbranched or branched.

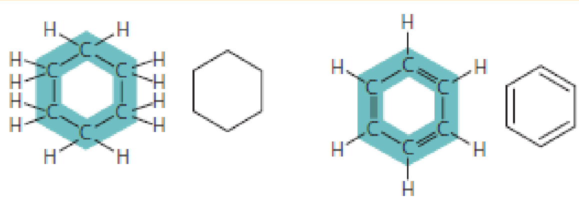
(c) Double bond position



1-Butene　　2-Butene

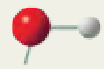
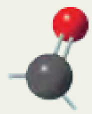
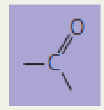
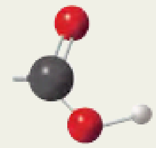
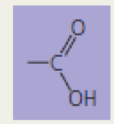
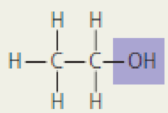
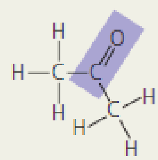
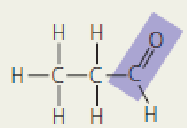
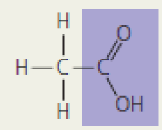
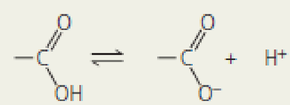
The skeleton may have double bonds, which can vary in location.

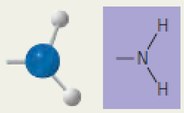
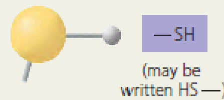
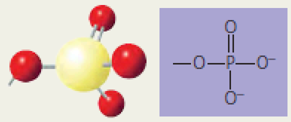
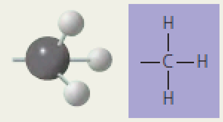
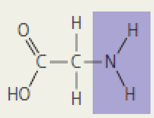
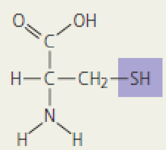
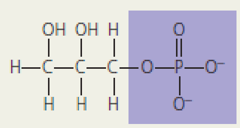
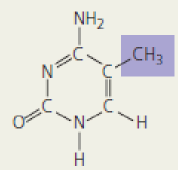
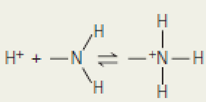
(d) Presence of rings



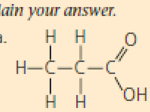
Cyclohexane　　Benzene

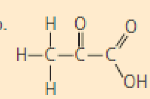
Some carbon skeletons are arranged in rings. In the abbreviated structural formula for each compound (at the right), each corner represents a carbon and its attached hydrogens.

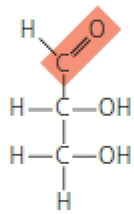
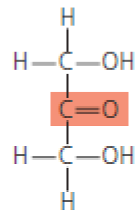
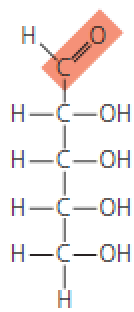
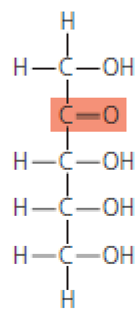
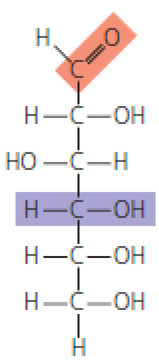
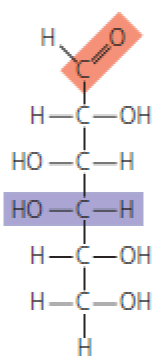
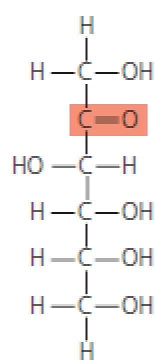
	Hydroxyl	Carbonyl	Carboxyl
:	 —OH (may be written HO—) In a **hydroxyl group** (—OH), a hydrogen atom is bonded to an oxygen atom, which in turn is bonded to the carbon skeleton of the organic molecule. (Do not confuse this functional group with the hydroxide ion, OH^-.)	  The **carbonyl group** (>CO) consists of a carbon atom joined to an oxygen atom by a double bond.	  When an oxygen atom is double-bonded to a carbon atom that is also bonded to an —OH group, the entire assembly of atoms is called a **carboxyl group** (—COOH).
D	**Alcohols** (Their specific names usually end in *-ol*.)	**Ketones** if the carbonyl group is within a carbon skeleton **Aldehydes** if the carbonyl group is at the end of the carbon skeleton	**Carboxylic acids**, or organic acids
	 **Ethanol**, the alcohol present in alcoholic beverages	 **Acetone**, the simplest ketone  **Propanal**, an aldehyde	 **Acetic acid**, which gives vinegar its sour taste
AL S	• Is polar as a result of the electrons spending more time near the electronegative oxygen atom. • Can form hydrogen bonds with water molecules, helping dissolve organic compounds such as sugars. (Sugars are shown in Figure 5.3.)	• A ketone and an aldehyde may be structural isomers with different properties, as is the case for acetone and propanal. • Ketone and aldehyde groups are also found in sugars, giving rise to two major groups of sugars: ketoses (containing ketone groups) and aldoses (containing aldehyde groups).	• Acts as an acid; can donate an H^+ because the covalent bond between oxygen and hydrogen is so polar:  Nonionized Ionized • Found in cells in the ionized form with a charge of 1− and called a carboxylate ion.

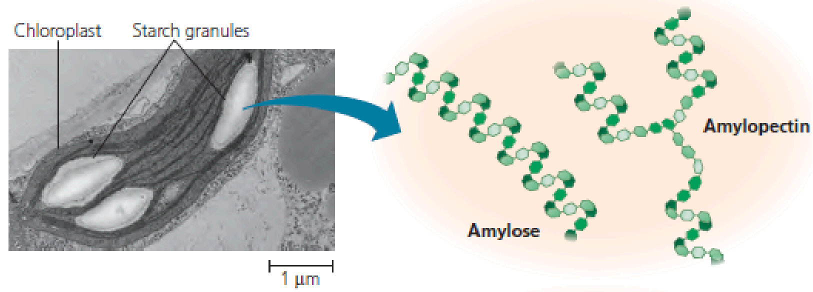
Amino	Sulfhydryl	Phosphate	Methyl
	 (may be written HS—)		
The **amino group** (—NH_2) consists of a nitrogen atom bonded to two hydrogen atoms and to the carbon skeleton.	The **sulfhydryl group** (—SH) consists of a sulfur atom bonded to an atom of hydrogen; it resembles a hydroxyl group in shape.	In the **phosphate group** shown here, a phosphorus atom is bonded to four oxygen atoms; one oxygen is bonded to the carbon skeleton; two oxygens carry negative charges (—OPO_3^{2-}). In this text, Ⓟ represents an attached phosphate group.	A **methyl group** (—CH_3) consists of a carbon bonded to three hydrogen atoms. The carbon of a methyl group may be attached to a carbon or to a different atom.
Amines	**Thiols**	**Organic phosphates**	**Methylated compounds**
			
Glycine, a compound that is both an amine and a carboxylic acid because it has both an amino group and a carboxyl group; compounds with both groups are called **amino acids**	**Cysteine**, an important sulfur-containing amino acid	**Glycerol phosphate**, which takes part in many important chemical reactions in cells; glycerol phosphate also provides the backbone for phospholipids, the most prevalent molecules in cell membranes	**5-Methyl cytidine**, a component of DNA that has been modified by addition of a methyl group
• Acts as a base; can pick up an H^+ from the surrounding solution (water, in living organisms):  Nonionized Ionized • Found in cells in the ionized form with a charge of 1+.	• Two sulfhydryl groups can react, forming a covalent bond. This "cross-linking" helps stabilize protein structure (see Figure 5.20, Tertiary Structure). • Cross-linking of cysteines in hair proteins maintains the curliness or straightness of hair. Straight hair can be "permanently" curled by shaping it around curlers and then breaking and re-forming the cross-linking bonds.	• Contributes negative charge to the molecule of which it is a part (2– when at the end of a molecule, as above; 1– when located internally in a chain of phosphates). • Molecules containing phosphate groups have the potential to react with water, releasing energy.	• Addition of a methyl group to DNA, or to molecules bound to DNA, affects the expression of genes. • Arrangement of methyl groups in male and female sex hormones affects their shape and function (see p. 63).

MAKE CONNECTIONS *Given the information in this figure and what you know about the electronegativity of oxygen (see Concept 2.3, p. 39), predict which of the following molecules would be the stronger acid (see Concept 3.3, p. 53). Explain your answer.*

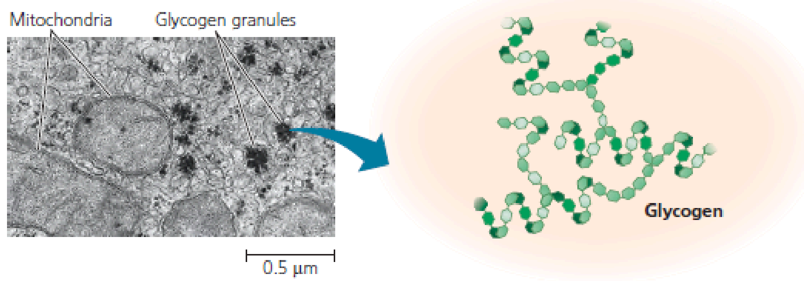
a. 

b. 

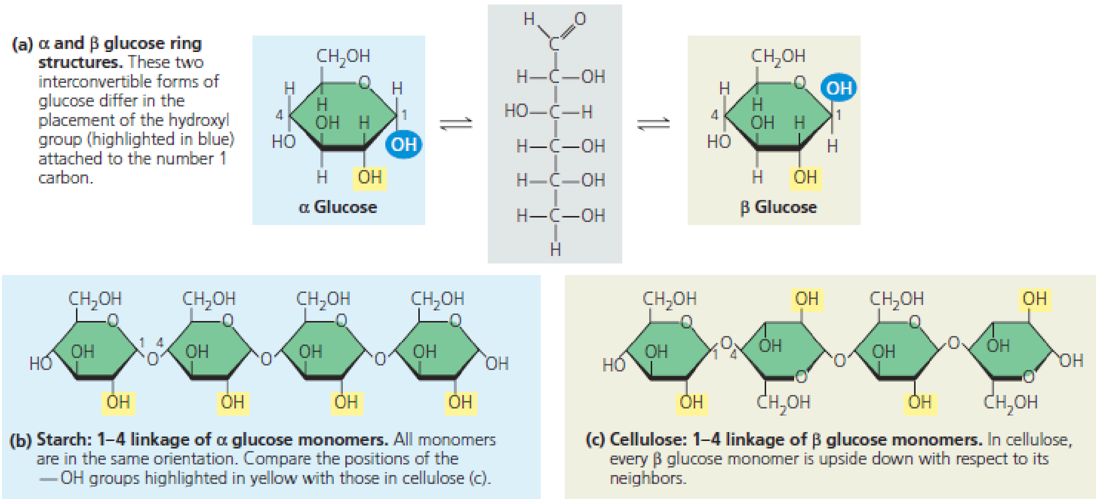
Aldoses (Aldehyde Sugars) Carbonyl group at end of carbon skeleton	**Ketoses (Ketone Sugars)** Carbonyl group within carbon skeleton
Trioses: 3-carbon sugars ($C_3H_6O_3$)	
 **Glyceraldehyde** An initial breakdown product of glucose	 **Dihydroxyacetone** An initial breakdown product of glucose
Pentoses: 5-carbon sugars ($C_5H_{10}O_5$)	
 **Ribose** A component of RNA	 **Ribulose** An intermediate in photosynthesis
Hexoses: 6-carbon sugars ($C_6H_{12}O_6$)	
  **Glucose** **Galactose** Energy sources for organisms	 **Fructose** An energy source for organisms



(a) Starch: a plant polysaccharide. This micrograph shows part of a plant cell with a chloroplast, the cellular organelle where glucose is made and then stored as starch granules. Amylose (unbranched) and amylopectin (branched) are two forms of starch.



(b) Glycogen: an animal polysaccharide. Animal cells stockpile glycogen as dense clusters of granules within liver and muscle cells, as shown in this micrograph of part of a liver cell. Mitochondria are cellular organelles that help break down glucose released from glycogen. Note that glycogen is more branched than amylopectin starch.

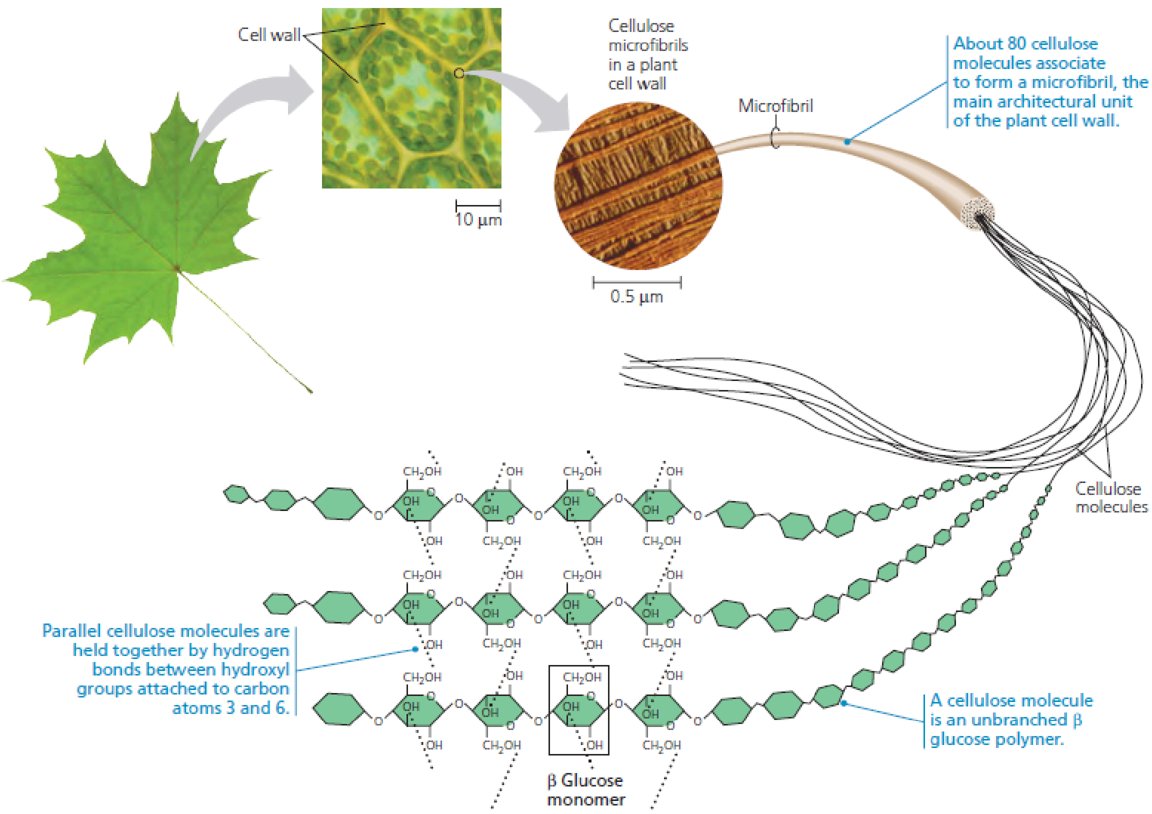


(a) α and β glucose ring structures. These two interconvertible forms of glucose differ in the placement of the hydroxyl group (highlighted in blue) attached to the number 1 carbon.

(b) Starch: 1–4 linkage of α glucose monomers. All monomers are in the same orientation. Compare the positions of the —OH groups highlighted in yellow with those in cellulose (c).

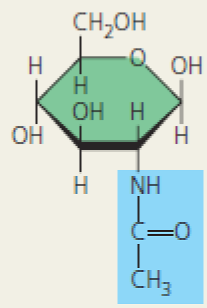
(c) Cellulose: 1–4 linkage of β glucose monomers. In cellulose, every β glucose monomer is upside down with respect to its neighbors.

▲ **Figure 5.7 Starch and cellulose structures.**



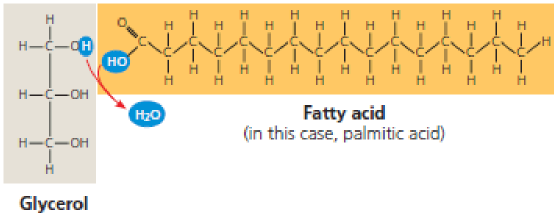
▲ **Figure 5.8 The arrangement of cellulose in plant cell walls.**

Another important structural polysaccharide is **chitin**, the carbohydrate used by arthropods (insects, spiders, crustaceans, and related animals) to build their exoskeletons (**Figure 5.9**). An exoskeleton is a hard case that surrounds the soft parts of an animal. Pure chitin is leathery and flexible, but it becomes hardened when encrusted with calcium carbonate, a salt. Chitin is also found in many fungi, which use this polysaccharide rather than cellulose as the building material for their cell walls. Chitin is similar to cellulose, with β linkages, except that the glucose monomer of chitin has a nitrogen-containing appendage (see Figure 5.9, top right).

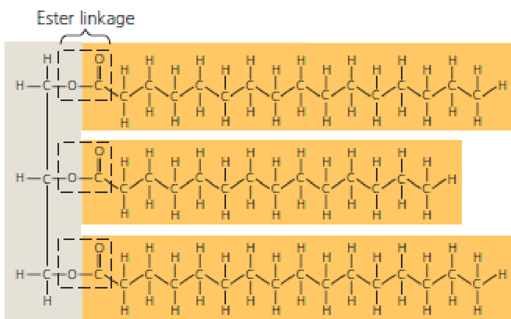


◀ The structure of the chitin monomer

◀ Chitin forms the exoskeleton of arthropods. This cicada is molting, shedding its old exoskeleton and emerging in adult form.



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



(b) Fat molecule (triacylglycerol)

▲ **Figure 5.10 The synthesis and structure of a fat, or triacylglycerol.** The molecular building blocks of a fat are one molecule of glycerol and three molecules of fatty acids. **(a)** One water molecule is removed for each fatty acid joined to the glycerol. **(b)** A fat molecule with three fatty acid units, two of them identical. The carbons of the fatty acids are arranged zigzag to suggest the actual orientations of the four single bonds extending from each carbon (see Figure 4.3a).

triglyceride, a word often found in the list of ingredients on packaged foods.) The fatty acids in a fat can be the same, or they can be of two or three different kinds, as in **Figure 5.10b**.

The terms *saturated fats* and *unsaturated fats* are commonly used in the context of nutrition (**Figure 5.11**). These terms refer to the structure of the hydrocarbon chains of the fatty acids. If there are no double bonds between carbon atoms composing a chain, then as many hydrogen atoms as possible are bonded to the carbon skeleton. Such a structure is said to be *saturated* with hydrogen, and the resulting fatty acid therefore called a **saturated fatty acid** (**Figure 5.11a**). An **unsaturated fatty acid** has one or more double bonds, with one fewer hydrogen atom on each double-bonded carbon. Nearly all double bonds in naturally occurring fatty acids are *cis* double bonds, which cause a kink in the hydrocarbon

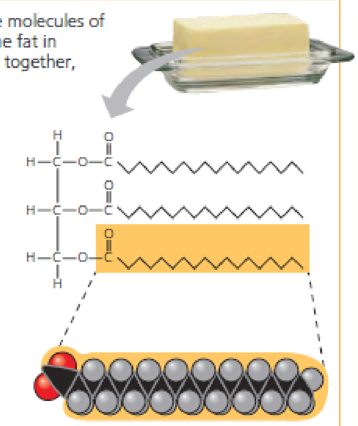
▼ **Figure 5.11 Saturated and unsaturated fats and fatty acids.**

(a) Saturated fat

At room temperature, the molecules of a saturated fat, such as the fat in butter, are packed closely together, forming a solid.

Structural formula of a saturated fat molecule (Each hydrocarbon chain is represented as a zigzag line, where each bend represents a carbon atom and hydrogens are not shown.)

Space-filling model of stearic acid, a saturated fatty acid (red = oxygen, black = carbon, gray = hydrogen)

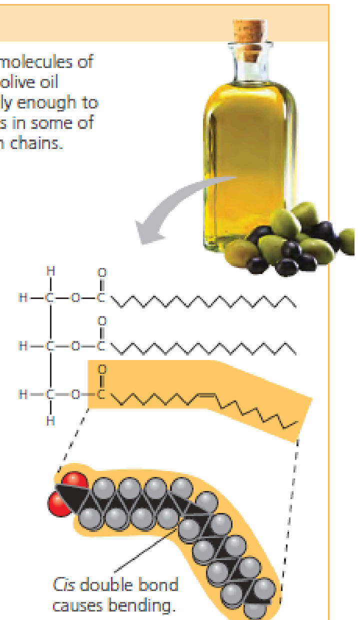


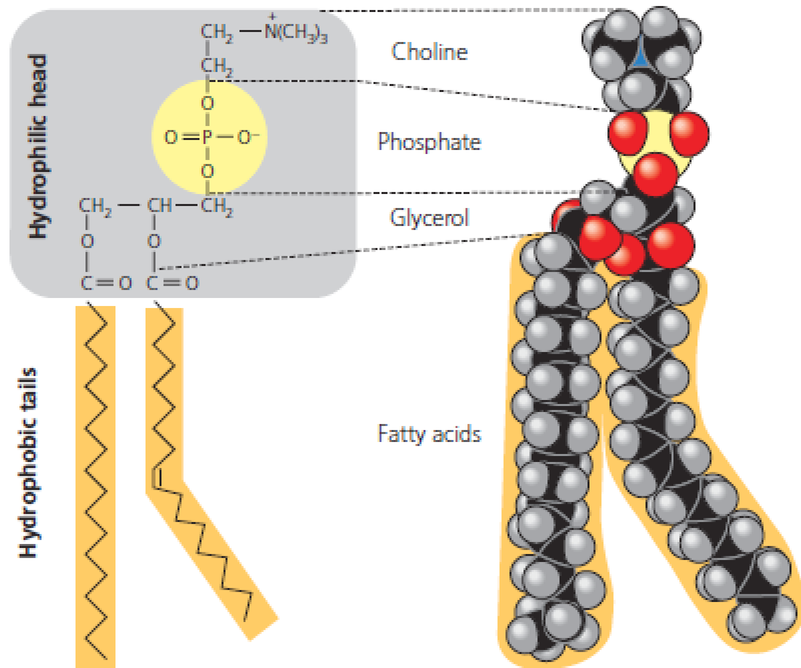
(b) Unsaturated fat

At room temperature, the molecules of an unsaturated fat such as olive oil cannot pack together closely enough to solidify because of the kinks in some of their fatty acid hydrocarbon chains.

Structural formula of an unsaturated fat molecule

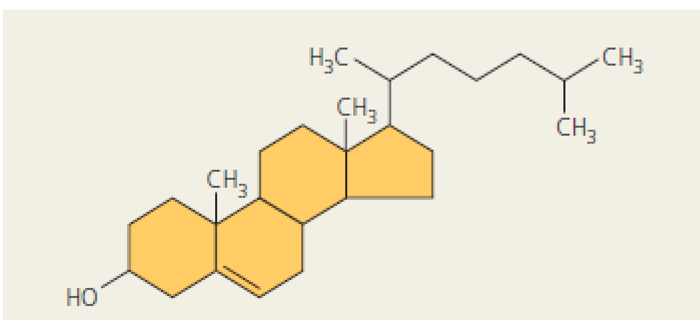
Space-filling model of oleic acid, an unsaturated fatty acid





(a) Structural formula **(b) Space-filling model**

thesized. In vertebrates, cholesterol is synthesized in the liver

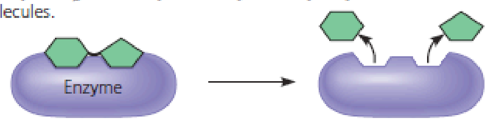


▼ **Figure 5.15 An overview of protein functions.**

Enzymatic proteins

Function: Selective acceleration of chemical reactions

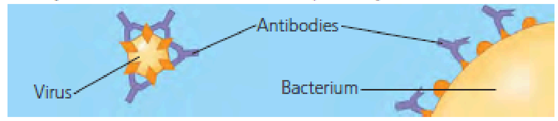
Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.



Defensive proteins

Function: Protection against disease

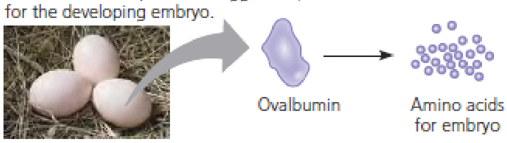
Example: Antibodies inactivate and help destroy viruses and bacteria.



Storage proteins

Function: Storage of amino acids

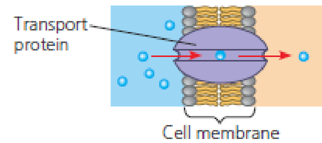
Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.



Transport proteins

Function: Transport of substances

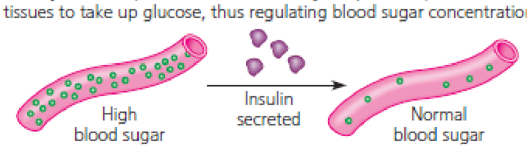
Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across cell membranes.



Hormonal proteins

Function: Coordination of an organism's activities

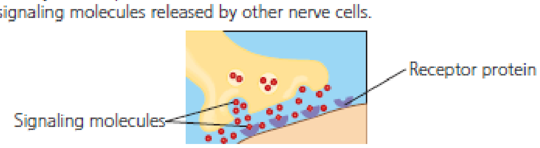
Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.



Receptor proteins

Function: Response of cell to chemical stimuli

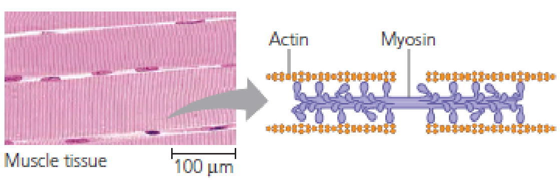
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.



Contractile and motor proteins

Function: Movement

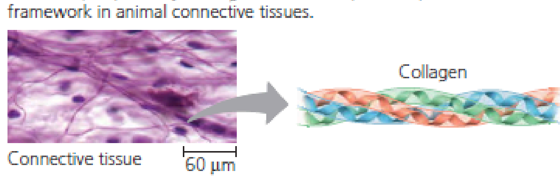
Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.



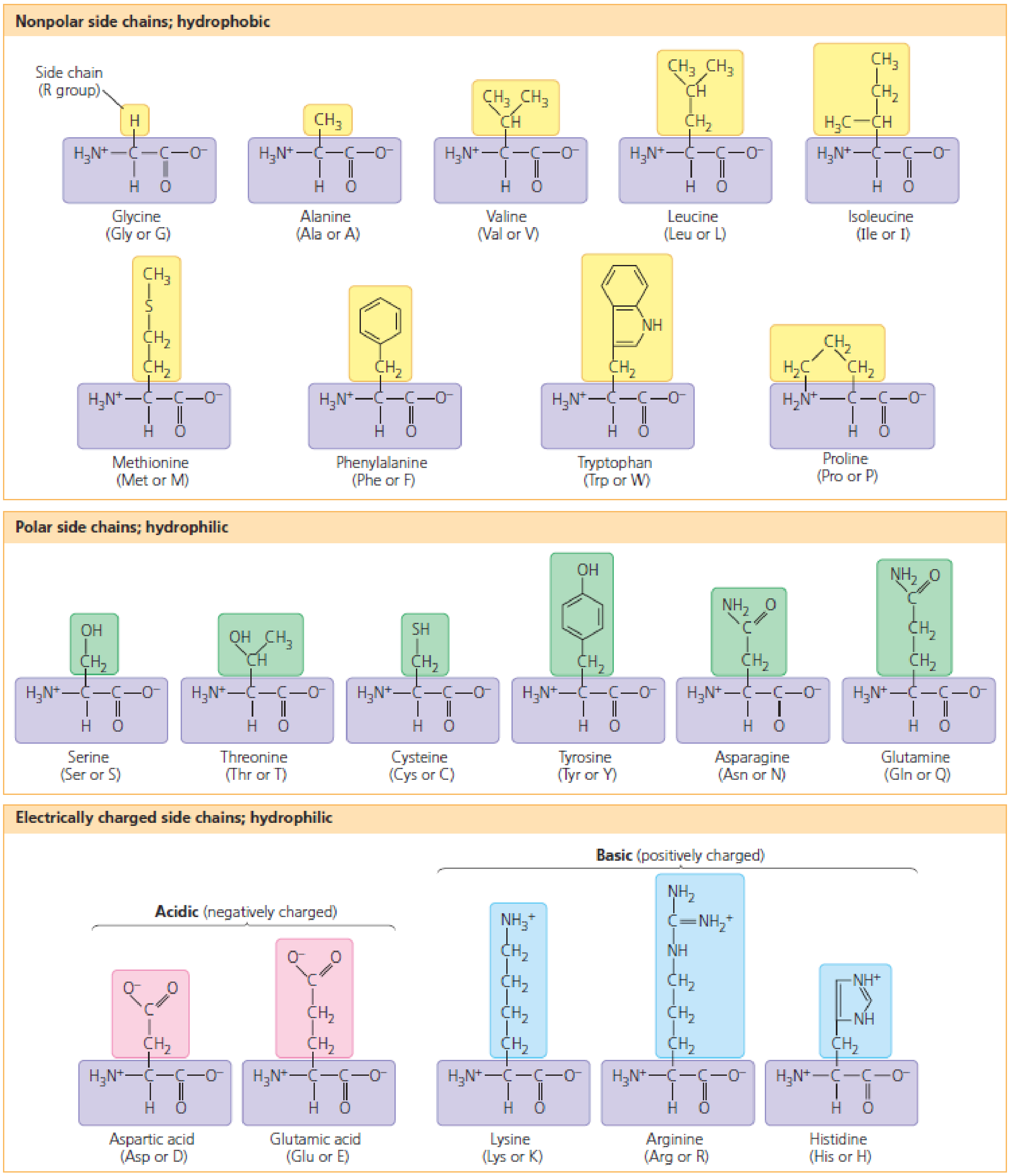
Structural proteins

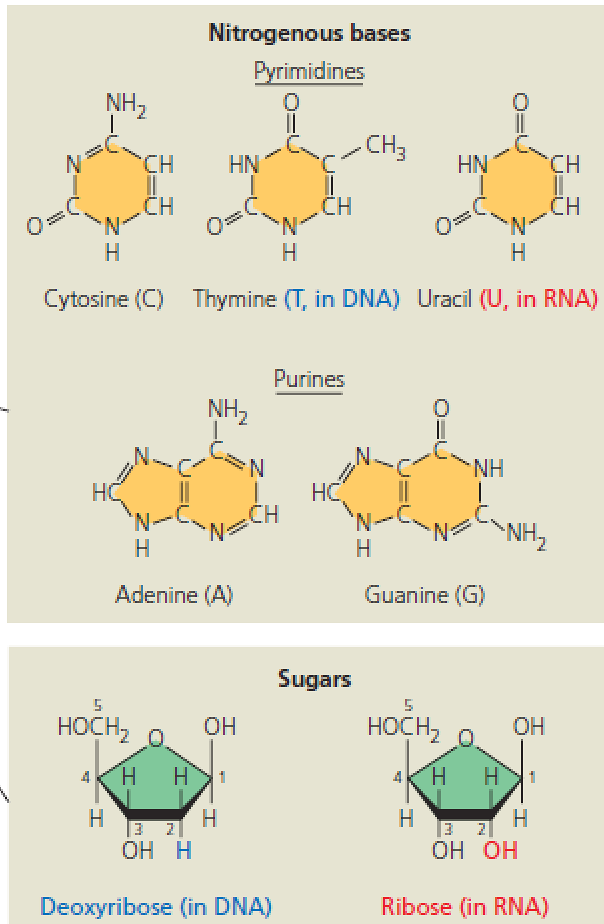
Function: Support

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.

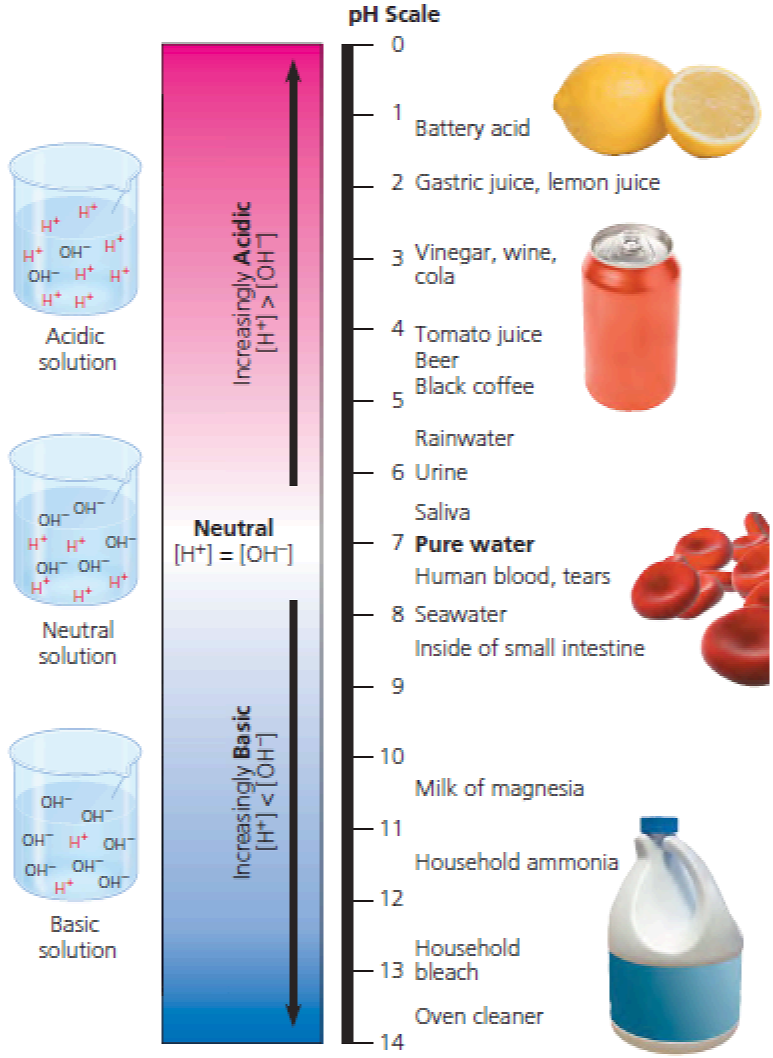


▼ **Figure 5.16 The 20 amino acids of proteins.** The amino acids are grouped here according to the properties of their side chains (R groups) and shown in their prevailing ionic forms at pH 7.2, the pH within a cell. The three-letter and one-letter abbreviations for the amino acids are in parentheses. All amino acids used in proteins are L enantiomers, the form shown here (see Figure 4.7).

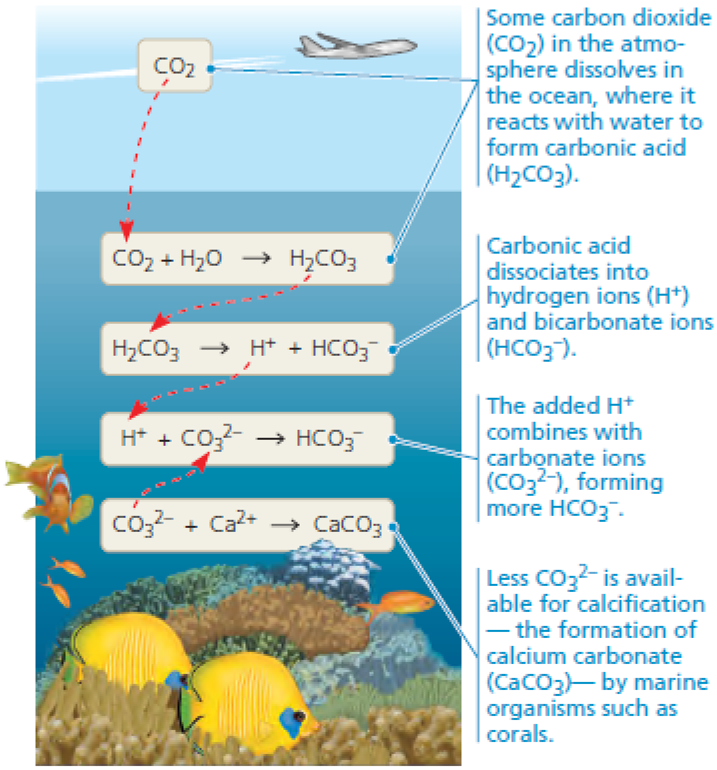




(c) Nucleoside components



▲ **Figure 3.10 The pH scale and pH values of some aqueous solutions.**



CO_2
$CO_2 + H_2O \rightarrow H_2CO_3$
$H_2CO_3 \rightarrow H^+ + HCO_3^-$
$H^+ + CO_3^{2-} \rightarrow HCO_3^-$
$CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3$
Some carbon dioxide (CO_2) in the atmosphere dissolves in the ocean, where it reacts with water to form carbonic acid (H_2CO_3).
Carbonic acid dissociates into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-).
The added H^+ combines with carbonate ions (CO_3^{2-}), forming more HCO_3^-.
Less CO_3^{2-} is available for calcification — the formation of calcium carbonate ($CaCO_3$)— by marine organisms such as corals.

Biology Worksheet

Draw the following compounds (for amino acids, draw only side chain, write abbreviations, and write whether side chains are polar, non polar, positively charged, or negatively charged):

1. 2-Methyl Butane	1. Amino Acid Base
2. Methane	2. Glycine
3. Dihydroxyacetone	3. Cysteine
4. Butane	4. Serine
5. 2-Methylpropane (Isobutane)	5. Methionine
6. 1-Butene	6. Threonine
7. Ribulose	7. Glutamic acid
8. 2-Butene	8. Aspartic acid
9. Cyclohexane	9. Lysine
10. Benzene	10. Glutamine
11. Ethanol	11. Alanine
12. Ribose	12. Phenylalanine
13. Guanine	13. Arginine
14. Thymine	14. Histidine
15. Pentane	15. Asparagine
16. Propane	16. Tyrosine
17. Acetone	17. Proline
18. Propanal	18. Tryptophan
19. Stearic Acid	19. Isoleucine
20. Acetic Acid	20. Valine
21. 5-Methyl cytidine	21. Leucine
22. Glycerol Phosphate	22. Estradiol
23. Glyceraldehyde	23. Testosterone
24. Glucose	24. Carbon Dioxide
25. Galactose	25. Urea
26. Ethene (Ethylene)	26. Chitin
27. Fructose	27. Maltose
28. Phosphatidylcholine	28. Sucrose
29. Palmitic Acid	29. Lactose
30. Ethane	30. Glycerol
31. Oleic Acid	
32. Cholesterol	
33. Cytosine	
34. Uracil	
35. Adenine	
36. Deoxyribose	

Fill out the following chart:

Group Name	Compound Name	Info	Formula/Drawing
Hydroxyl			
Carbonyl			
Carboxyl			
Sulfhydryl			
Methyl			
Amino			
Phosphate			

Fill out the following chart:

Polysaccharide Name	Linkages	Extra Info
Amylose		
Amylopectin		
Glycogen		
Cellulose		
Chitin		

Fill out the following chart:

Compound Name	pH
Battery Acid	
Vinegar	
Lemon Juice	
Gastric Juice	
Wine	
Saliva	

Tomato juice	
Cola	
Black Coffee	
Rainwater	
Inside of Small Intestine	
Urine	
Pure Water	
Human Blood	
Household ammonia	
Sea Water	
Milk of Magnesia	
Beer	
Tears	
Household bleach	
Oven Cleaner	

Answer the following questions:

1. **What is the protein of milk?**
2. **What is the protein of egg white?**
3. **What secretes insulin and what does insulin do?**
4. **What is the protein of hair, horns, feathers, and other skin appendages?**
5. **What do collagen and elastin proteins do?**
6. **How many joules are in a calorie? How many calories are in a joule?**
7. **What is the specific heat of ethanol?**
8. **What is the heat of vaporization of water?**
9. **What is Avogadro's number?**
10. How much is the ocean expected to acidify by the end of century?
11. How many structural isomers of $C_{20}H_{42}$ are there?
12. What is the enantiomer of crank?

13. By how many amino acids do the ß-polypeptide chains of hemoglobins in humans and gorillas differ? How about in humans and frogs?
14. What was the cost of sequencing one million base pairs in 2001? How about one million base pairs in 2016?
15. **What is the alpha carbon, C-terminus, and N-terminus (amino acids)?**
16. **What is the pH in a cell?**
17. **What is crystallin?**
18. **What are *Drosophila melanogaster*, *Arabidopsis thaliana*, *Caenorhabditis elegans*, *Danio rerio*, *Mus musculus*, and *Escherichia coli*?**
19. **What produces formic acid?**
20. **What are the essential elements?**
21. **What are two trace elements are required by vertebrates?**
22. **Carbon 12 accounts for how much of carbon in nature?**
23. What does PET stand for?
24. **What are the orbitals of the first electron shell?**
25. **What are the orbitals of the second electron shell?**
26. **What is the maximum number of electrons per orbital?**
27. **What are anions and cations?**
28. **What is another name for ionic compounds?**
29. **What is the angle between hydrogens in a water molecule?**
30. Why do opiates relieve pain and alter mood?
31. **What is chemical equilibrium?**
32. How did Wohler create urea?
33. **What occurs during ocean acidification?**
34. Which forms of Ibuprofen and Albuterol are most effective?
35. **What causes lactose intolerance?**
36. **How is starch stored in plants?**
37. **What is the difference in 3D structure between cellulose and starch?**
38. **What are microfibrils?**
39. **What steroid is the precursor for the production of other steroids, where is it produced in vertebrates?**
40. **What is transthyretin?**
41. **What is an α-helix?**
42. **What is a ß-pleated sheet?**
43. **What is a hydrophobic interaction?**
44. **When is water densest?**
45. **What is a disulfide bridge?**
46. **What is main secondary structure of α and ß subunits of hemoglobin?**
47. **What occurs in sickle-cell disease?**
48. **What are intrinsically disordered proteins?**
49. **What is the structure of a nucleotide?**
50. **What are the 5’ and 3’ ends of nucleic acids?**

Answer Key

1. Casein
2. Ovalbumin
3. Pancreas, causes tissues to take in glucose
4. Keratin
5. Provide connective framework for tissues
6. 0.239, 4.184
7. 0.6
8. 40.65 kJ/mol, 540 cal/g/C°
9. $6.0221x10^{23}$
10. 0.3-0.5 pH
11. 366319
12. Methamphetamine
13. 1, 67
14. $5,000 and $0.02
15. carbon connected to side chain
16. 7.2
17. Protein that focuses light when packed together
18. model organisms; fruit fly, mustard plant, soil worm, zebrafish, mouse, bacteria
19. ants
20. Oxygen, Carbon, Hydrogen, Nitrogen
21. Iodine = essential ingredient of hormone produced by thyroid gland (0.15 mg required daily), Iron
22. 99%
23. Positron-emission tomography
24. Single spherical 1s orbital
25. Single spherical 2s orbital and three dumbbell-shaped 2p orbitals
26. 2
27. Anions are negatively charged, cations positively
28. Salts
29. 104.5°
30. Drugs have similar structures to endorphins (signaling molecules from pituitary gland that bind to receptors, relieving pain and producing euphoria)
31. Dynamic equilibrium where forward and reverse reactions occur at same rate, so concentrations of reactants and products do not change
32. Ammonium + cyanate ions
33. Carbon dioxide reacts with water to form carbonic acid, carbonic acid dissociates into bicarbonate and hydrogen ions, hydrogen ions react with carbonate ions to form bicarbonate ions, less carbonate ions for calcification (formation of calcium carbonate from carbonate and calcium ions)
34. S-Ibuprofen (v. R-Ibuprofen) and R-Albuterol (v. S-Albuterol)
35. Lack of lactase enzyme, causing intestinal bacteria to break it down and form gas, causing cramping

36. Granules in plastids
37. Starch is helical, cellulose is straight
38. Units of parallel cellulose molecules held together by hydrogen bonds between hydroxyl groups
39. Cholesterol, Liver
40. Globular blood protein that transports vitamin A and one of the the thyroid hormones throughout body (made of 4 identical polypeptide chains of 127 amino acids each)
41. Coil held together by hydrogen bonding between every fourth amino acid.
42. Segments of polypeptide chain lying side by side (ß strands), connected by hydrogen bonds between parts of the polypeptide backbone, make up core of many globular proteins, dominate silk protein of spider's web (makes it strong)
43. Polypeptide folds into function shape, hydrophobic side chains end up in core of protein, van der Waals interactions help hold together
44. 4° C
45. Bond between sulfhydryl groups of two cysteine monomers (-S-S-)
46. α-helix
47. Valine replaces glutamic acid in 6th amino acid position in hemoglobin, causing hemoglobin to aggregate in chains and deform blood cell, reducing oxygen capacity
48. Proteins that do not have distinct 3-D structure until they interact with target molecule
49. Pentose, nitrogenous base, one to three phosphate groups; Beginning monomer has 3 phosphates, 2 lost in polymerization, nucleoside is part of nucleotide without any phosphate groups; Also called nucleoside monophosphate
50. 5' end is phophate group connected to 5' carbon, 3' end is hydroxyl group connected to 3' carbon