

Inquiry into Life

Eleventh Edition

Sylvia S. Mader

Chapter 2 Lecture Outline

Prepared by: Wendy Vermillion
Columbus State Community College

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2.1 Basic Chemistry




- *Matter*- substance which occupies space
 - Composes all living and nonliving things
 - Can exist in solid, liquid, or gaseous form
- An *element*- pure substance considered a building block of matter
 - 92 naturally occurring elements
 - organized into the *periodic table*
 - Based on number of subatomic particles
 - Biologically significant elements:
 - Carbon
 - Hydrogen
 - Nitrogen
 - Oxygen
 - Phosphorus
 - Sulfur

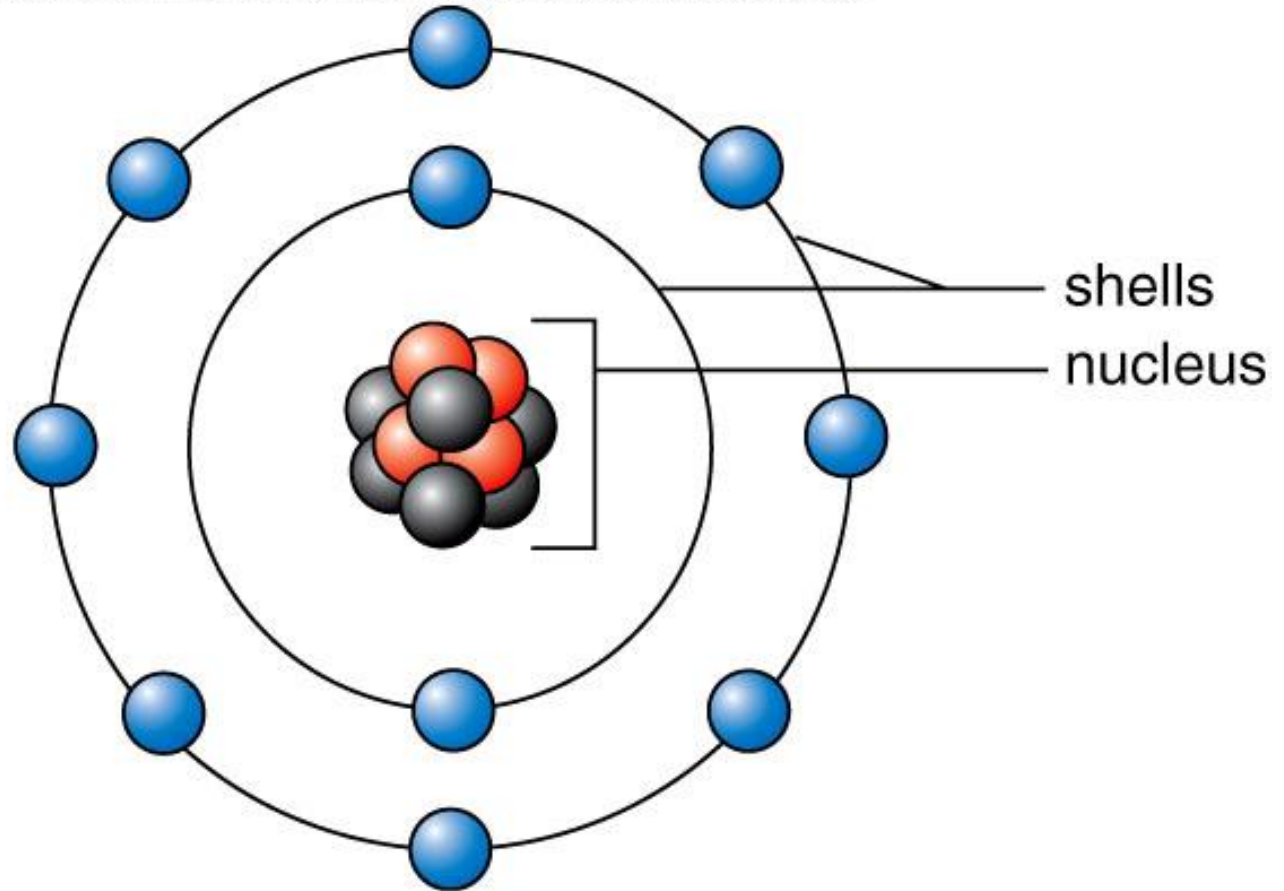
Elements and atoms

- Composed of *atoms*
- Atom- smallest unit of an element
- Atomic structure
 - *Central nucleus*
 - *Protons*- positive charge
 - *Neutrons*-negative charge
 - *Electrons*
 - Circle nucleus
 - Arranged in energy “shells”
 - Inner shell-lower energy
 - Outer shells-higher energy

Model of an atom

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-  = protons
-  = neutrons
-  = electrons



• Fig. 2.2

Elements and atoms cont'd.

- **Electron shells**
 - The inner shell holds 2 electrons
 - The outer shells can hold 8 electrons each
- **Atomic number and mass**
 - **Atomic number** = number of protons an atom has
 - **Atomic mass** = number of protons + neutrons
 - An electrically neutral atom has # protons = # electrons

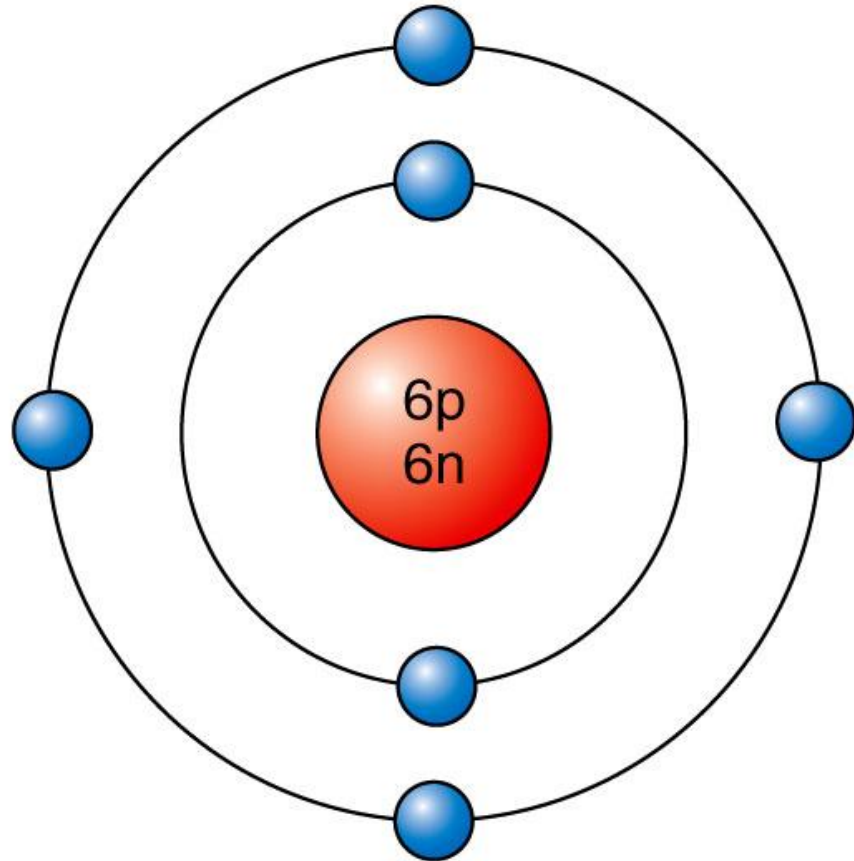
Carbon atom

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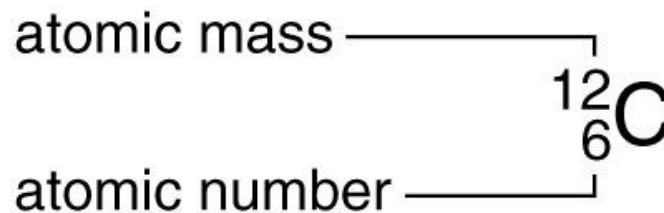
p = protons

n = neutrons

 = electrons



Carbon



- Fig. 2.3

Elements and atoms cont'd.

- **Periodic table**
 - first letter of name of atom is used as symbol
 - atomic number is placed above the atomic symbol
 - atomic mass is placed below the atomic symbol
 - arranged horizontally by increasing atomic number
 - arranged vertically by the number of electrons in the outermost shell

Periodic table of the elements

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I	II	III	IV	V	VI	VII	VIII
1 H Hydrogen 1						atomic number — 2 atomic symbol — He Helium atomic mass — 4	
3 Li Lithium 7	4 Be Beryllium 9	5 B Boron 11	6 C Carbon 12	7 N Nitrogen 14	8 O Oxygen 16	9 F Fluorine 19	10 Ne Neon 20
11 Na Sodium 23	12 Mg Magnesium 24	13 Al Aluminum 27	14 Si Silicon 28	15 P Phosphorus 31	16 S Sulfur 32	17 Cl Chlorine 35	18 Ar Argon 40
19 K Potassium 39	20 Ca Calcium 40						

• Fig. 2.1

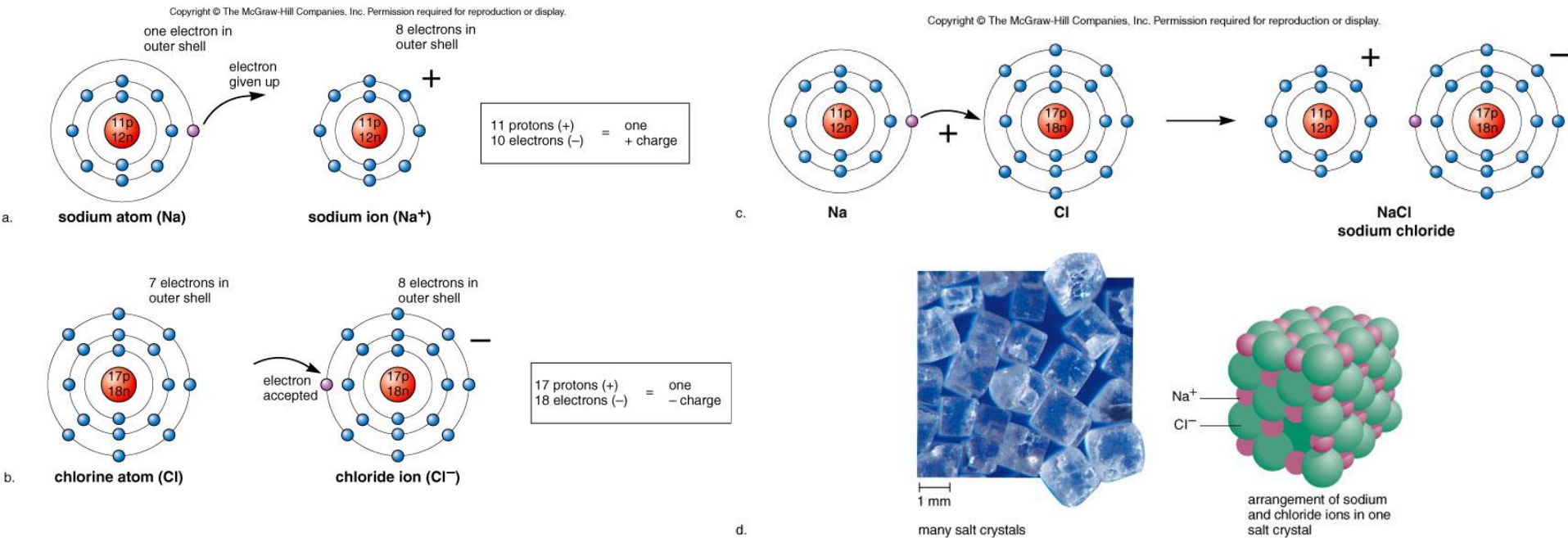
Elements and atoms, cont'd.

- *Isotopes*-atoms of the same element that have the same atomic number but different numbers of neutrons
 - atomic mass represents an average for atoms of each element
 - Some isotopes are unstable
 - when they decay they emit radioactive particles
 - Radiation can be both harmful (carcinogenic) and useful
 - Uses for radioactive isotopes include
 - Carbon dating
 - Radioactive tracers in medical tests
 - Medical imaging
 - Radiation therapy

Molecules and compounds

- Definitions
 - *Molecule*-formed by the bonding of 2 or more atoms
 - *Compound*- a molecule composed of atoms of 2 or more different elements
- *Ions and ionic bonds*
 - An atom which has lost or gained electrons in a chemical reaction
 - Atoms react with other atoms in order to attain a full outer electron shell
 - Electrostatic interaction between a positive ion (cation) and a negative ion (anion) is called an ionic bond

Formation of an ionic compound

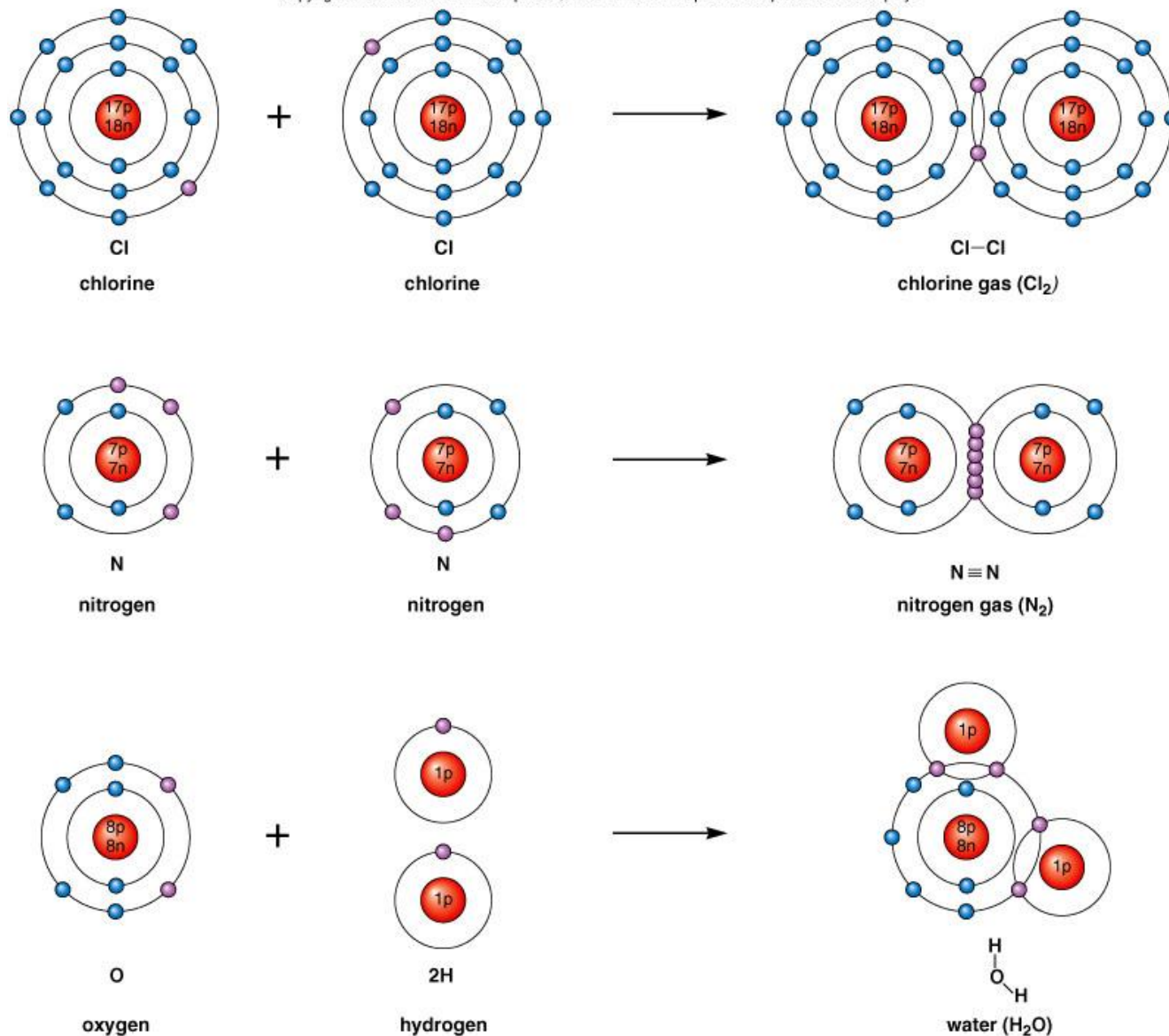


Molecules and compounds, cont'd.

- *Covalent bonds*
 - Formed by sharing of electrons between atoms
 - Each atom contributes one electron to the shared pair
 - Results in a stable outer shell for both atoms
- More than one pair of electrons can be shared
 - Double covalent bond- 2 pairs shared
 - Triple covalent bond-3 pairs shared

Formation of covalent compounds

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• Fig. 2.6

Molecules and compounds, cont'd.

- **Symbolic formulas**-”short hand” representations of molecules
 - **Electron-dot formula**-shows only outermost electrons
 - **Structural formula**-lines represent shared electrons
 - **Molecular formula**-only the number of each type of atom in a molecule is represented

Electron-dot, structural, and molecular formulas

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Electron-Dot Formula	Structural Formula	Molecular Formula
$:\ddot{\text{O}}::\text{C}::\ddot{\text{O}}:$ <p>carbon dioxide</p>	$\text{O}=\text{C}=\text{O}$ <p>carbon dioxide</p>	CO_2 <p>carbon dioxide</p>
$\begin{array}{c} \text{H} \\ \vdots \\ :\text{N}:\text{H} \\ \vdots \\ \text{H} \end{array}$ <p>ammonia</p>	$\begin{array}{c} \text{H} \\ \\ \text{N}-\text{H} \\ \\ \text{H} \end{array}$ <p>ammonia</p>	NH_3 <p>ammonia</p>
$\begin{array}{c} \text{H} \\ \vdots \\ :\text{O}:\text{H} \\ \vdots \end{array}$ <p>water</p>	$\begin{array}{c} \text{H} \\ \\ \text{O}-\text{H} \end{array}$ <p>water</p>	H_2O <p>water</p>
$\begin{array}{c} \text{H} \\ \vdots \\ \text{H}:\text{C}:\text{H} \\ \vdots \\ \text{H} \end{array}$ <p>methane</p>	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$ <p>methane</p>	CH_4 <p>methane</p>

- Fig. 2.7

Molecules and compounds, cont'd.

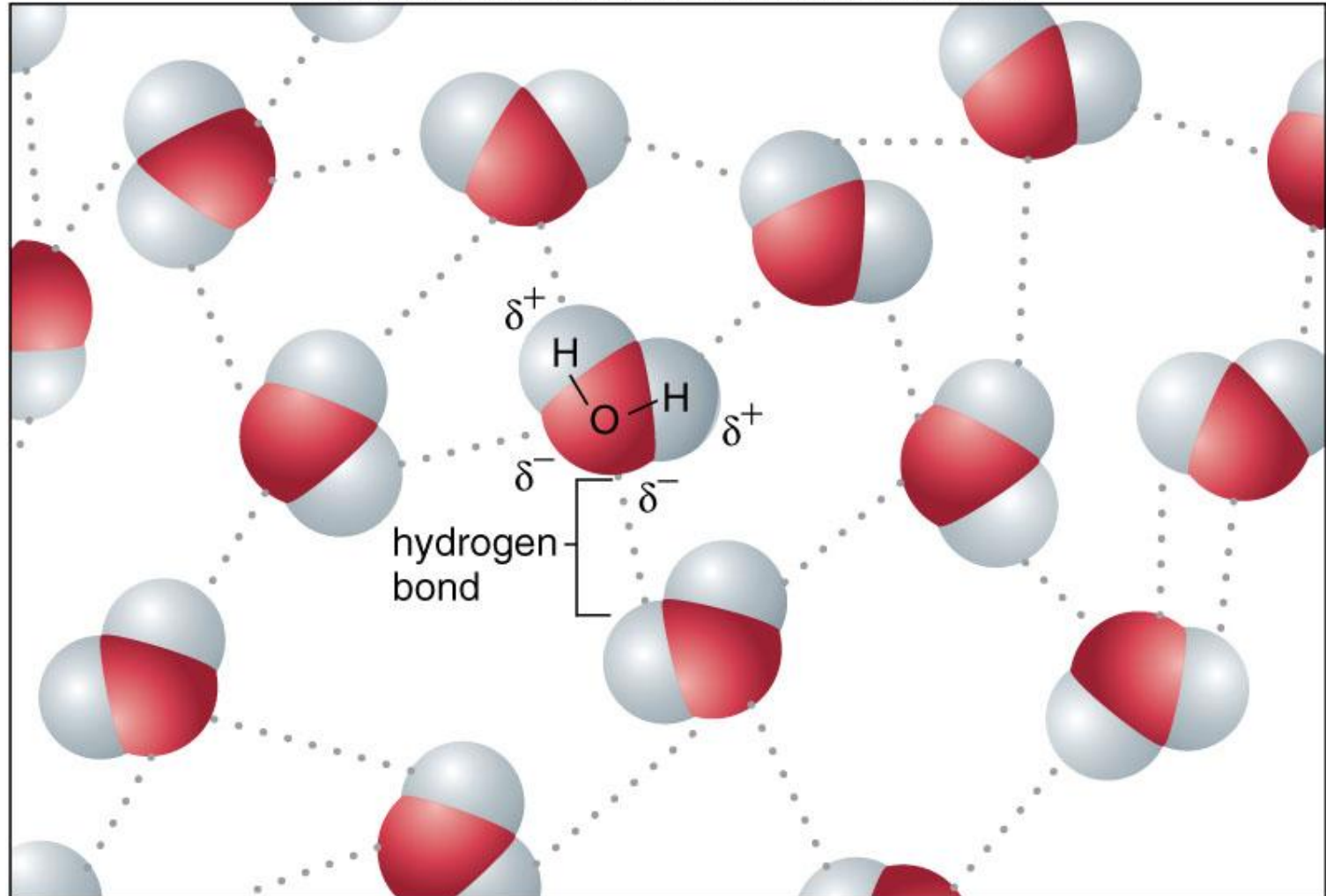
- Shapes of molecules
 - Molecules are 3 dimensional
 - Molecular shape can determine function
 - Ex: enzymes
 - Space-filling models represent the 3 dimensional shape

2.2 Water and living things

- Water-comprises 70% of living matter
- Most functional characteristics due to polarity of water molecule-hydrogen bonds
 - Oxygen end is slightly negative
 - Hydrogen ends are slightly electropositive

Hydrogen bonding between water molecules

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• Fig.2.8

Water, cont'd.

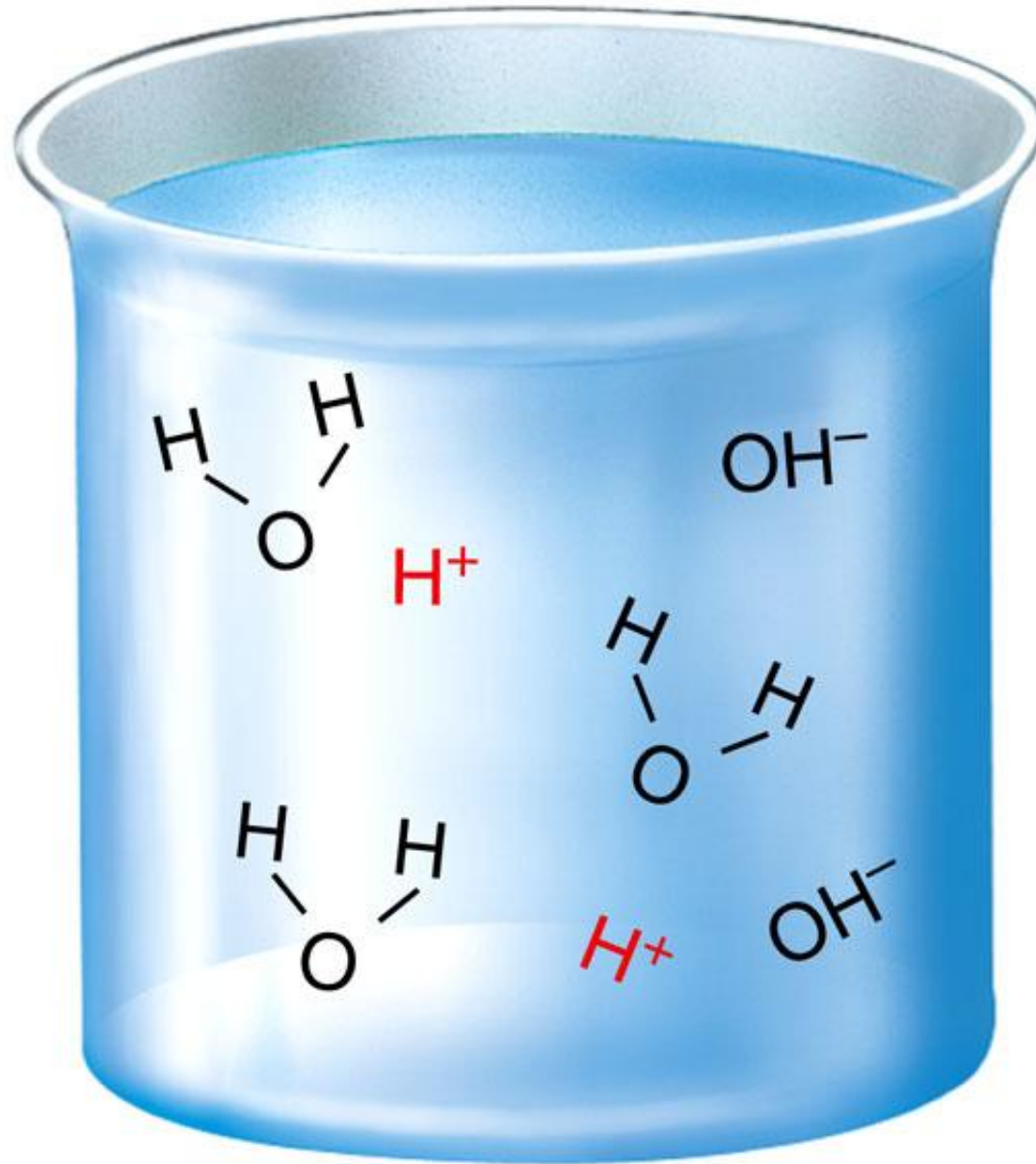
- **Properties of water**-due to hydrogen bonding and polarity
 - Universal solvent
 - Liquid at room temperature and body temperature
 - Water molecules are cohesive
 - High specific heat- resists change in temperature
 - High heat of vaporization-keeps the body from overheating
 - Water is least dense at 4 degrees C so ice floats on liquid water

Water, cont'd.

- **Acidic and basic solutions**
 - Water dissociates into an equal number of hydrogen ions (H^+) and hydroxyl ions (OH^-)
 - Acids release H^+
 - Bases release OH^- , or take up H^+

Dissociation of molecules

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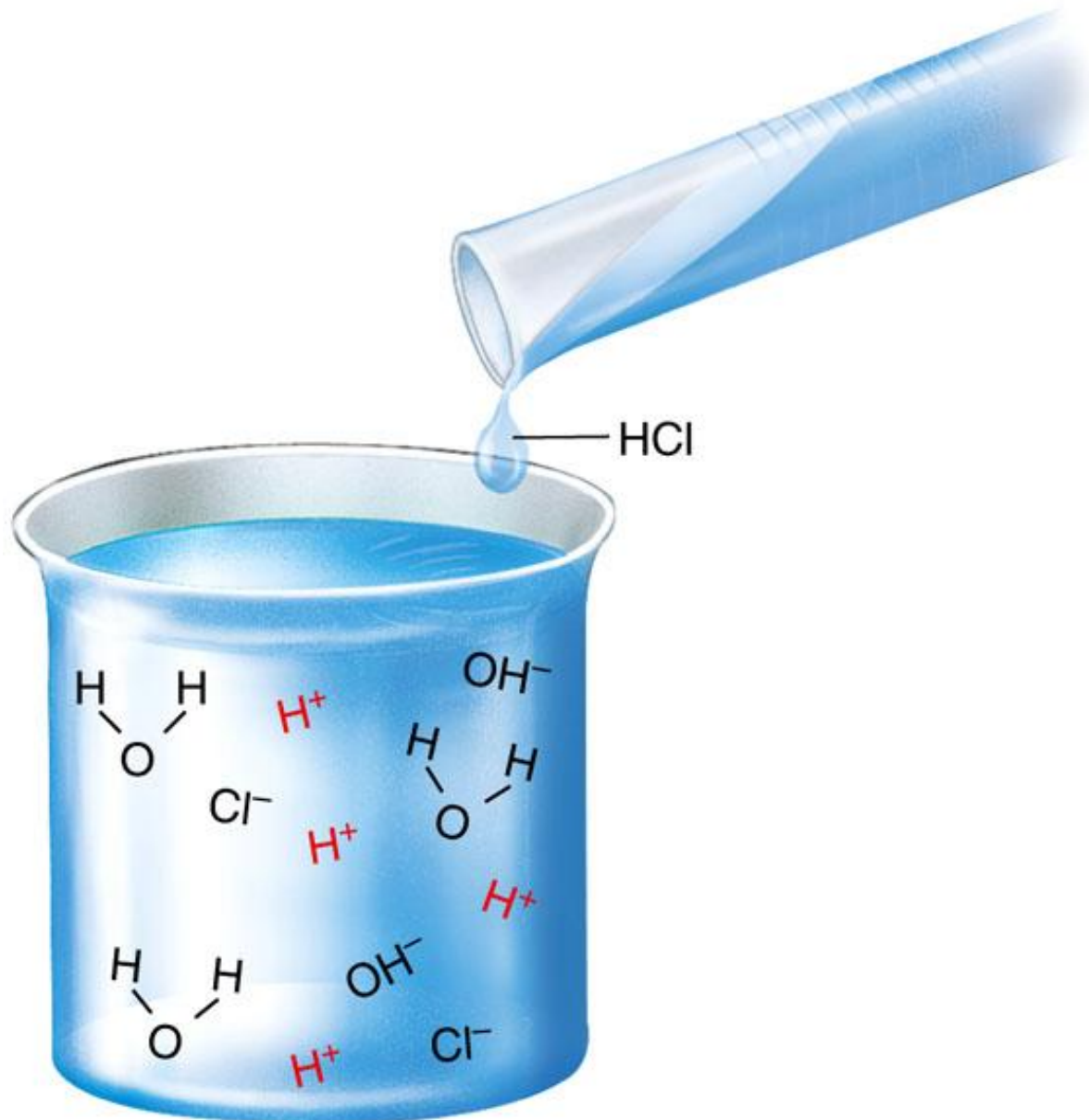
• Fig. 2.10

Water and living things, cont'd.

- **Acidic solutions**
 - Have a sour taste
 - Release hydrogen ions when they dissociate in water
 - Examples are lemon juice, coffee, and vinegar

Addition of HCl

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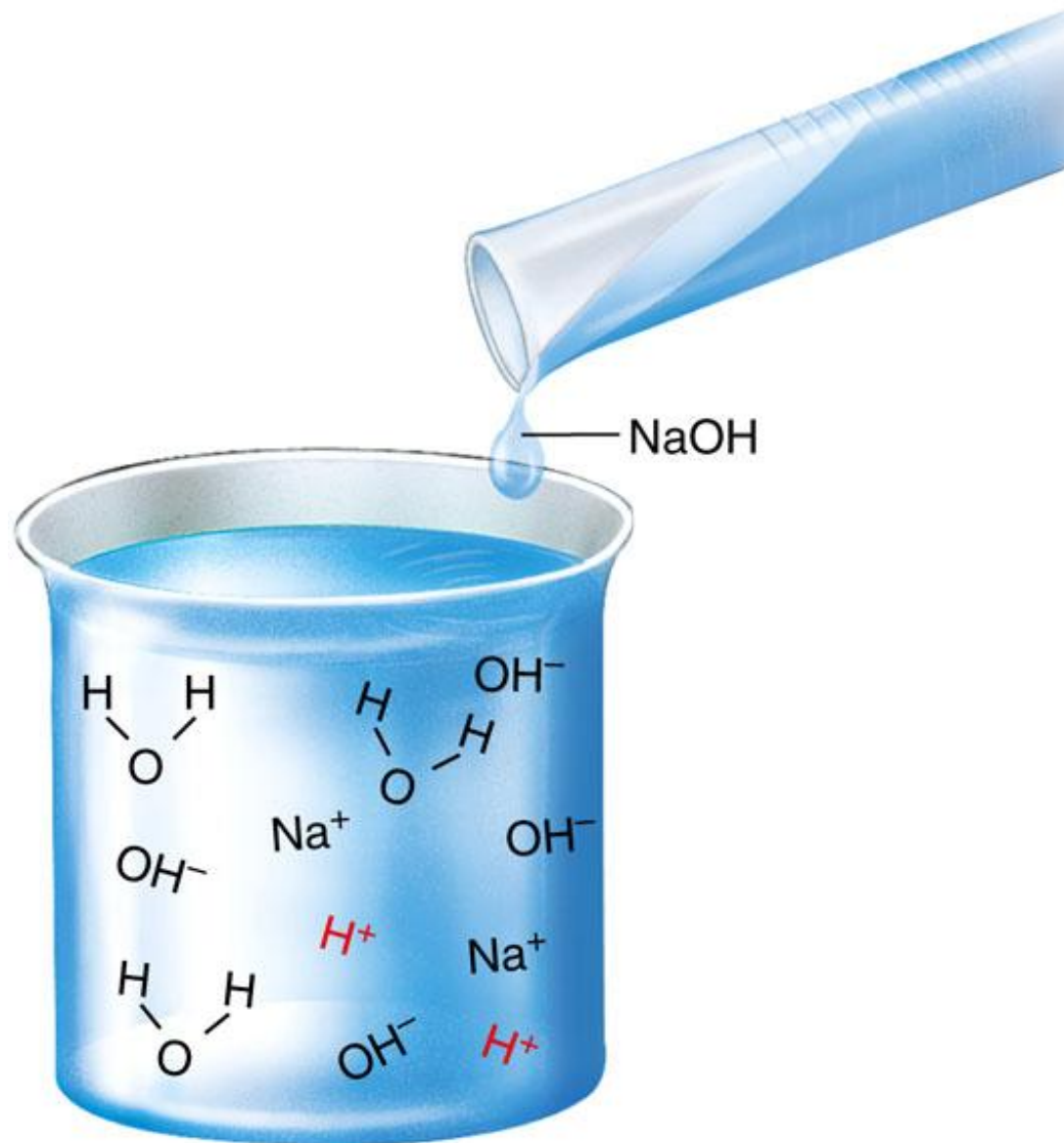
• Fig. 2.11

Water and living things, cont'd.

- **Basic solutions**
 - Have a bitter taste
 - Feel slimy or slippery to the touch
 - Release hydroxyl ions or take up hydrogen ions
 - Ammonia and sodium hydroxide are examples

Addition of sodium hydroxide

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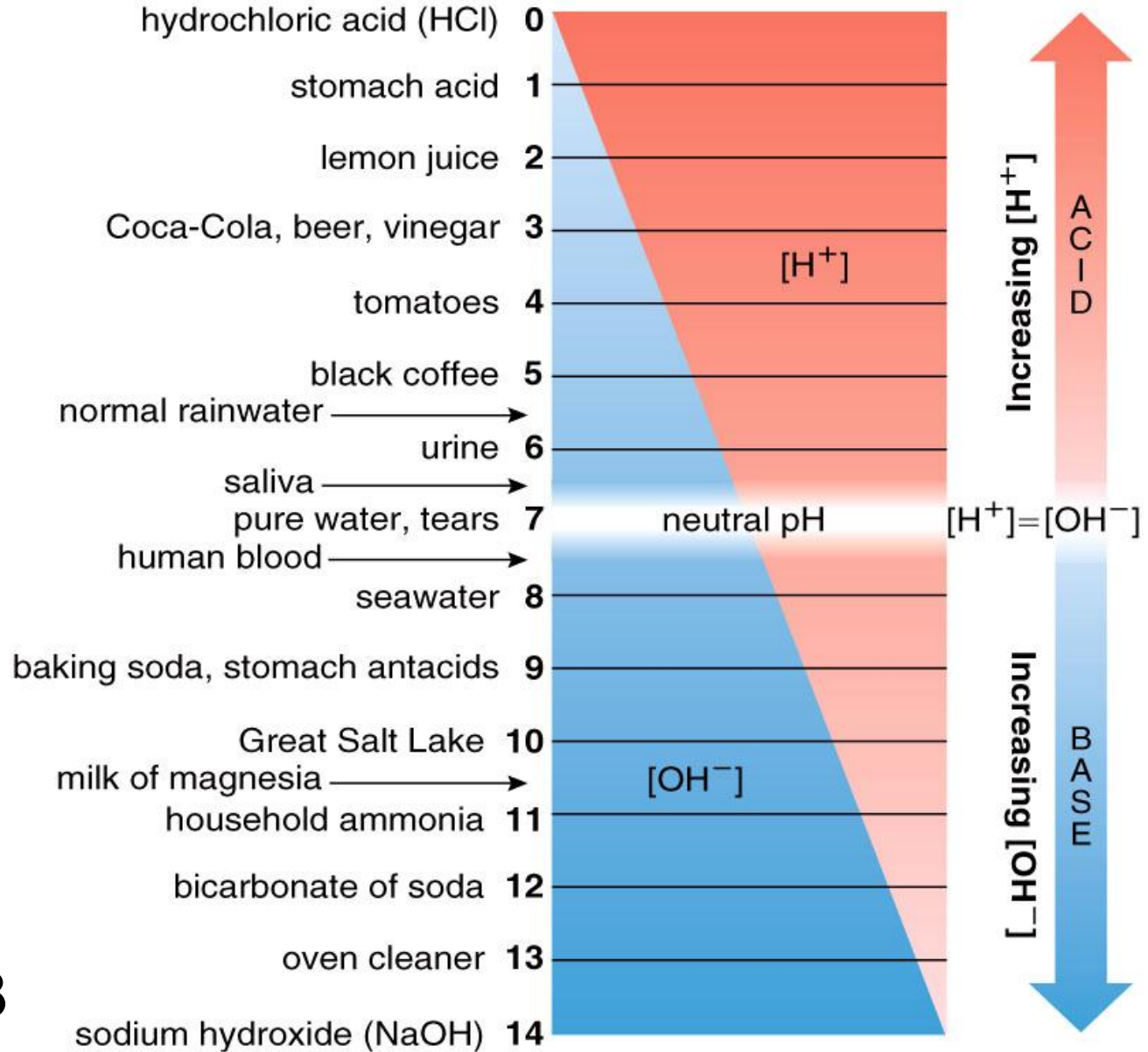
• Fig. 2.12

Water and living things, cont'd.

- pH scale
 - Ranges from 0 (most acidic) to 14 (most basic)
 - pH of 7 is neutral
 - Equal amounts of hydrogen ions and hydroxyl ions
 - A pH below 7
 - More hydrogen ions
 - Acidic
 - A pH above 7
 - More hydroxyl ions
 - Basic

The pH scale

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• Fig. 2.13

Water and living things, cont'd.

- **Buffers and pH**
 - Functions to minimize changes in pH
 - Consists of a chemical or group of chemicals
 - Function by binding excess hydrogen ions or hydroxyl ions

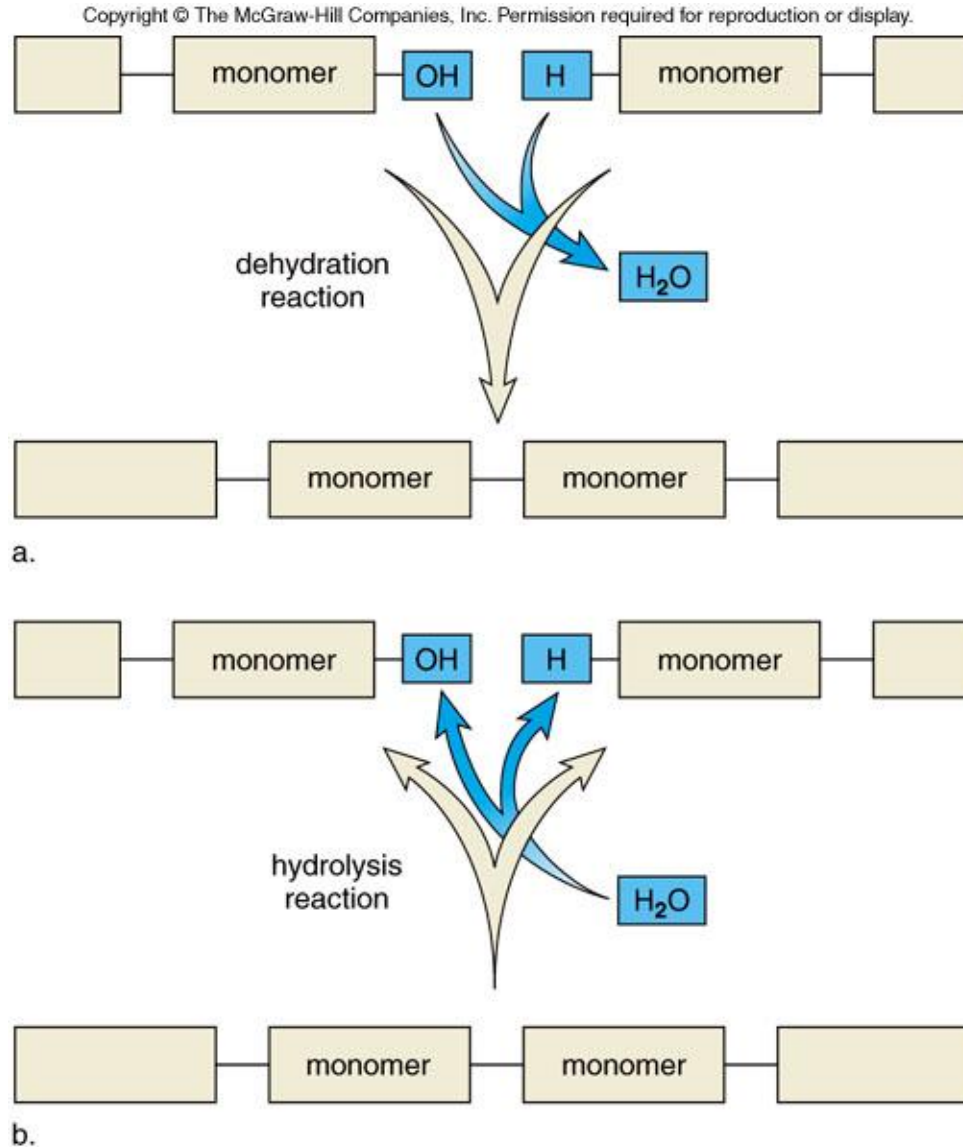
2.3 Organic molecules

- **General structure**
 - Contain carbon and hydrogen
 - Have characteristic functional groups
 - Many organic molecules important to living organisms are large macromolecules (**polymers**)
 - Composed of smaller subunits called **monomers**
 - Monomers are small organic molecules
 - Can either exist separately or can be bonded together into long chains to form polymers
 - Carbohydrates, proteins, and lipids are examples
 - Each has a characteristic monomer

Organic molecules, cont'd.

- **Dehydration synthesis**
 - Links monomers together to form a polymer
 - 2 hydrogens and an oxygen removed in the reaction and unite to form water
 - Water is also always a byproduct
- **Hydrolysis**
 - Polymer is broken down to monomers
 - Water is required to replace 2 hydrogens and the oxygen

Synthesis and degradation of macromolecules



• Fig. 2.15

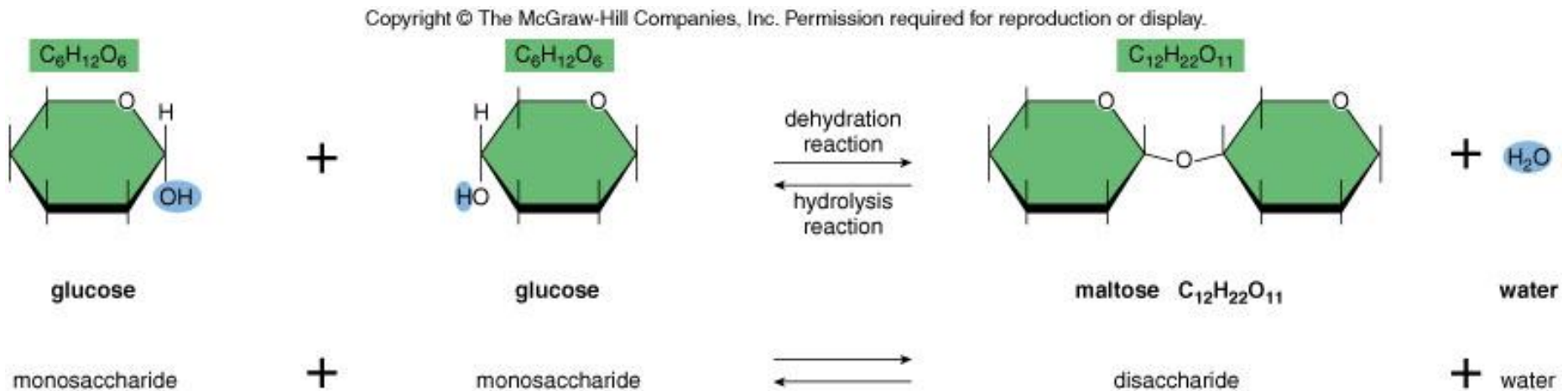
2.4 Carbohydrates

- **General structure**
 - Ratio of hydrogen atoms to oxygen atoms is 2:1
 - Characteristic atomic grouping of H-C-OH
 - “hydrates of carbon”
- **Functions**
 - Principal energy source for cells
 - Short term energy storage
 - Structural components
 - Cell to cell recognition- surface antigens

Carbohydrates, cont'd.

- Simple carbohydrates-monosaccharides and disaccharides
 - Monosaccharides are simple sugars such as glucose (blood sugar), fructose, and lactose
 - Disaccharides are 2 monosaccharides bonded together- examples are sucrose (glucose+fructose), galactose (glucose+lactose), and maltose (glucose+glucose)

Synthesis and degradation of maltose



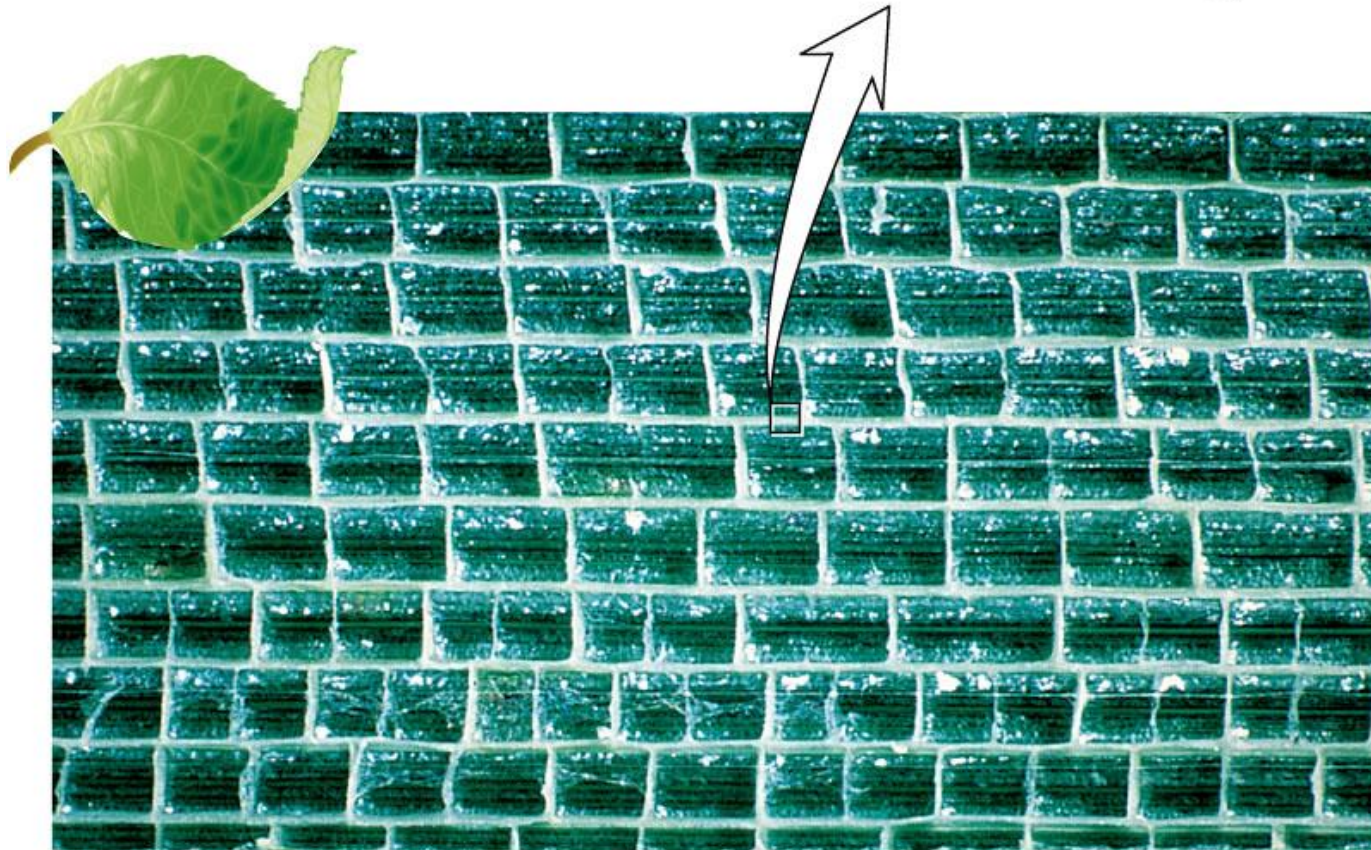
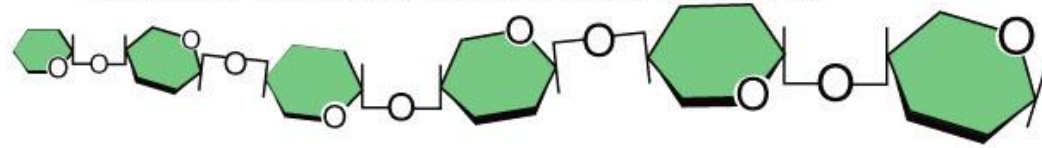
• Fig. 2.17

Carbohydrates, cont'd.

- **Polysaccharides**-large polymers of monosaccharides
- **Cellulose**
 - Structural carbohydrate in plants
 - “fiber”
 - Indigestible by human enzymes
- **Starches and glycogen**
 - Quick energy storage
 - Starches are long chains of glucose in plant cells
 - Glycogen is “animal starch”, composed of long chains of glucose in animal cells

Cellulose structure and function

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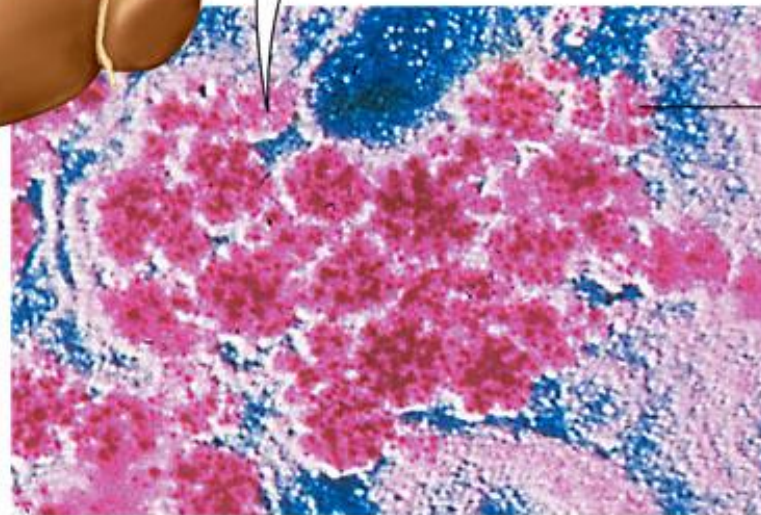
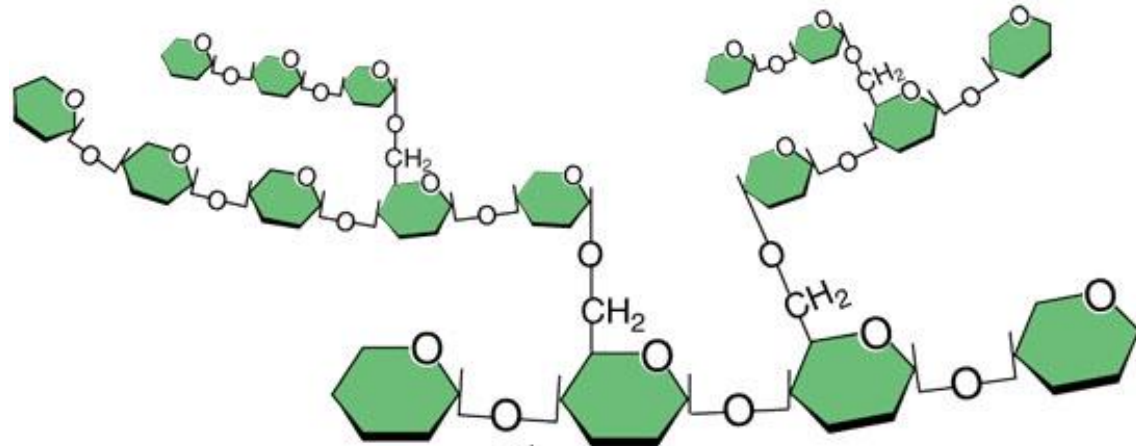


leaf cell walls

- Fig. 2.20

Glycogen structure and function

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glycogen granules

• Fig. 2.19

liver cells

2.5 Lipids

- **General characteristics**
 - Extremely diverse group including fats, oils, steroids, waxes, phospholipids
 - Common characteristic- nonpolar molecules which are insoluble in water
 - Contain more calories of energy per gram so are ideal energy storage molecules
 - Also function as structural components, insulation, cushioning of organs, and hormones

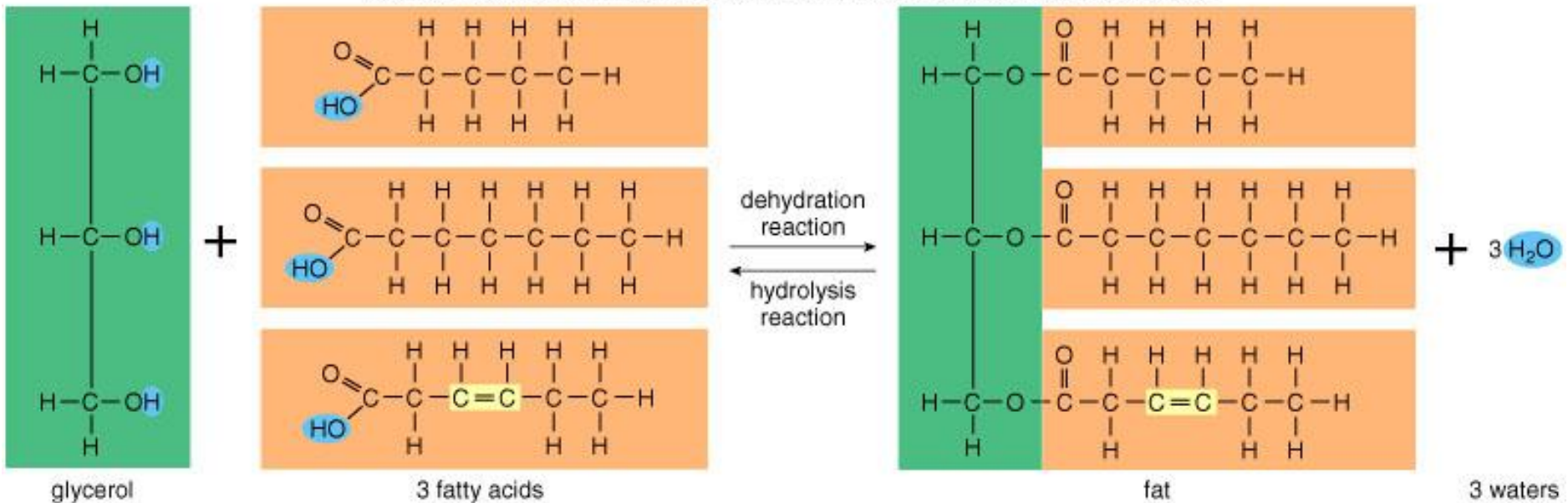
Lipids, cont'd.

- Fats and oils

- Oils tend to be liquid at room temperature and are usually of plant origin
- Fats tend to be solid at room temperature and are usually of animal origin
- Fats are often called triglycerides, as they are composed of one glycerol and 3 fatty acids
- Note that synthesis of a triglyceride yields 3 water molecules as byproducts
- Fats are important in energy storage and insulation

Synthesis and degradation of a fat molecule

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• Fig. 2.21

Lipids, cont'd.

- Emulsification

- Fats are nonpolar; they do not dissolve in water and tend to form “globules” (think of oil and vinegar salad dressing)
- Emulsifier breaks down the globules of fat into smaller droplets
- Emulsifiers have a nonpolar end which attaches to the fat, and a polar end which interacts with water molecules so that the droplets can disperse

- Saturated and unsaturated fatty acids

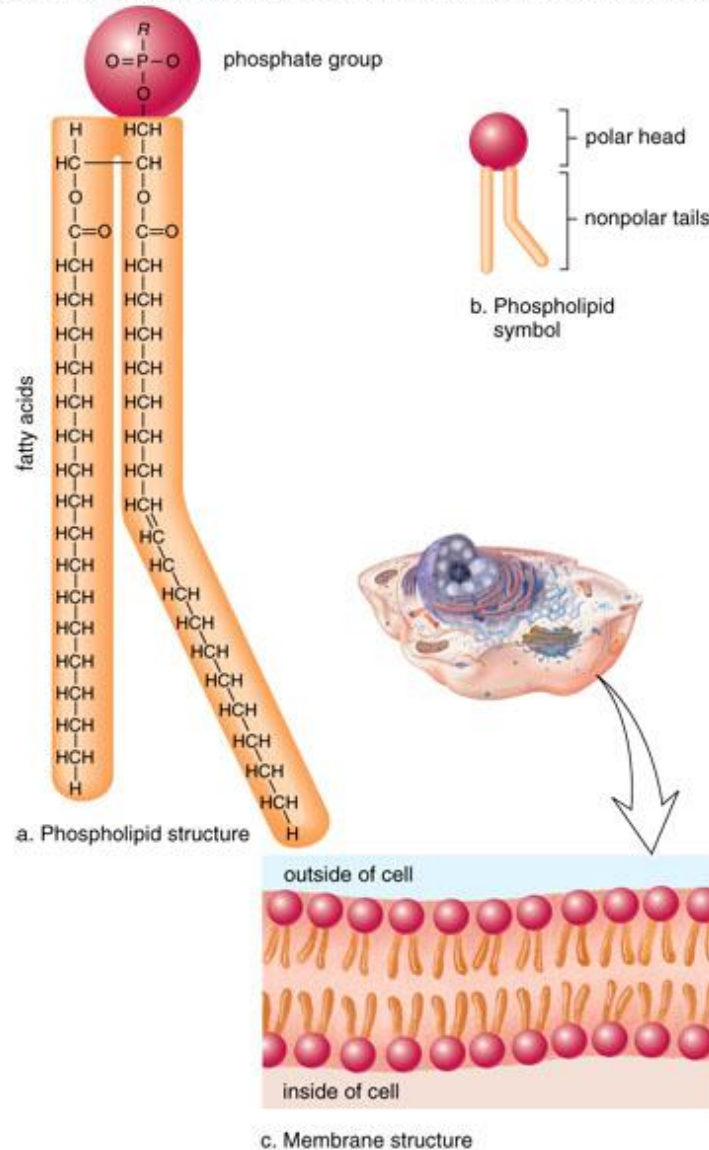
- Saturated have no double bonds between carbon atoms, and tend to be more solid at room temperature
- Unsaturated have at least one double bond between carbons
- Polyunsaturated have multiple double bonds- the more polyunsaturated the fatty acids, the more liquid the fat will be at room temperature

Lipids, cont'd.

- **Phospholipids**
 - Attached phosphate gives “polarity”
 - Has a hydrophilic head and a hydrophobic tail
 - Important components of membranes
- **Steroids**
 - “Skeleton” of 4 carbon rings
 - Cholesterol is a steroid which functions in membrane structure and hormone synthesis

Phospholipid structure and function

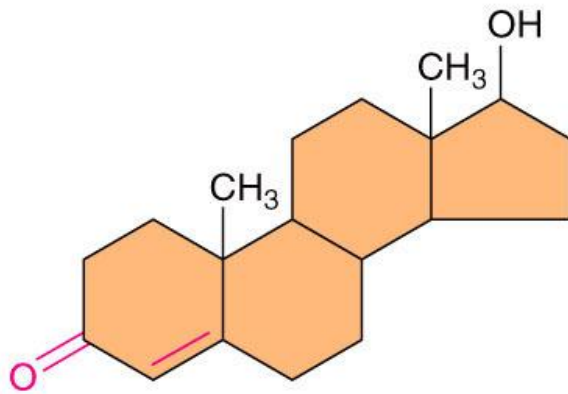
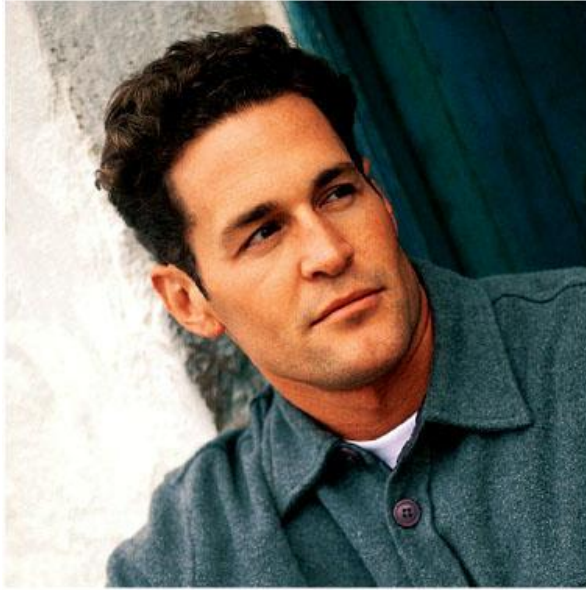
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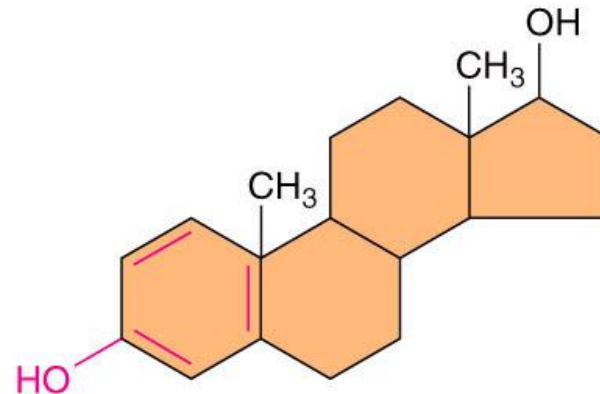
- Fig. 2.22

Steroids

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a. Testosterone



b. Estrogen

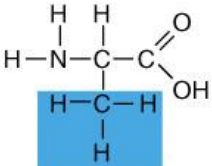
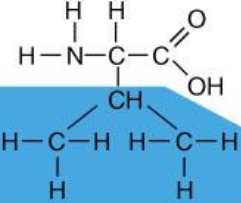
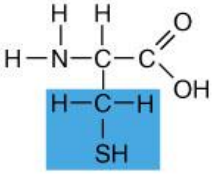
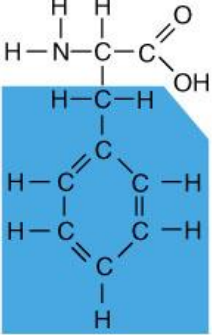
- Fig. 2.23

2.6 Proteins

- **General characteristics**
 - Composed of amino acids
 - An amino acid has a central carbon atom with a carboxyl group (COOH) at one end and an amino group at the other (NH₂)
 - There are 20 different amino acids
 - The portion of the molecule that varies between the different types is called the R group (“remainder”)

Representative amino acids

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Name	Structural Formula	<i>R</i> Group
alanine	 $ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{N}-\text{C}-\text{C} \\ \quad \quad \\ \text{H}-\text{C}-\text{H} \quad \text{O} \\ \quad \quad \quad // \\ \text{H} \quad \quad \quad \text{OH} \end{array} $ <p>or</p> $ \begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\ \\ \text{CH}_3 \end{array} $	<p><i>R</i> group has a single carbon atom</p>
valine	 $ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{N}-\text{C}-\text{C} \\ \quad \quad \\ \text{H}-\text{C}-\text{H} \quad \text{O} \\ \quad \quad // \\ \text{H} \quad \quad \text{OH} \\ \\ \text{CH} \\ / \quad \backslash \\ \text{H}-\text{C}-\text{H} \quad \text{H}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \quad \text{H} \end{array} $ <p>or</p> $ \begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\ \\ \text{CH} \\ / \quad \backslash \\ \text{CH}_3 \quad \text{CH}_3 \end{array} $	<p><i>R</i> group has a branched carbon chain</p>
cysteine	 $ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{N}-\text{C}-\text{C} \\ \quad \quad \\ \text{H}-\text{C}-\text{H} \quad \text{O} \\ \quad \quad // \\ \text{SH} \quad \quad \text{OH} \end{array} $ <p>or</p> $ \begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\ \\ \text{CH}_2 \\ \\ \text{SH} \end{array} $	<p><i>R</i> group contains sulfur</p>
phenylalanine	 $ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{N}-\text{C}-\text{C} \\ \quad \quad \\ \text{H}-\text{C}-\text{H} \quad \text{O} \\ \quad \quad // \\ \text{H} \quad \quad \text{OH} \\ \\ \text{C} \\ / \quad \backslash \\ \text{H}-\text{C} \quad \text{C}-\text{H} \\ \quad \quad \\ \text{H}-\text{C} \quad \text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \quad \text{H} \end{array} $ <p>or</p> $ \begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\ \\ \text{CH}_2 \\ \\ \text{C}_6\text{H}_5 \end{array} $	<p><i>R</i> group has a ring structure</p>

• Fig. 2.24

Proteins, cont'd.

- **Peptides**

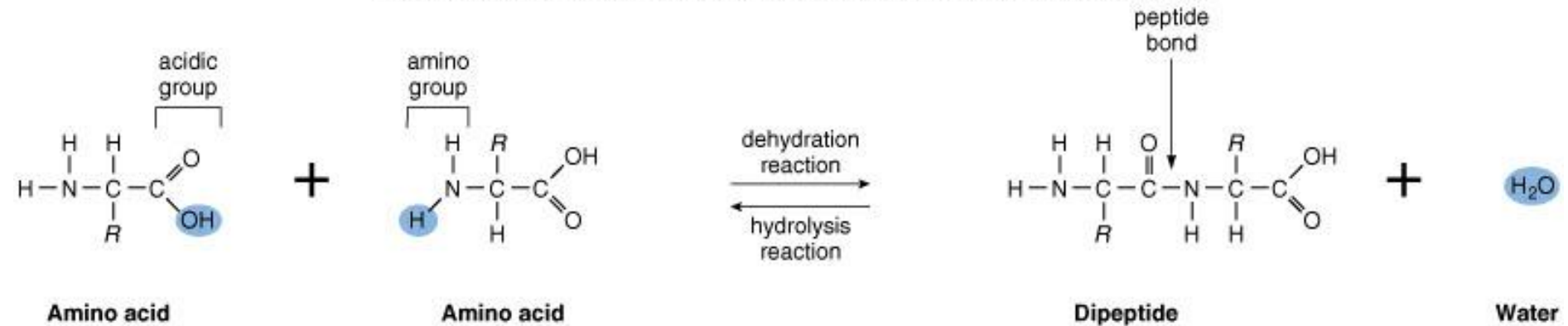
- Bonds between amino acids are called *peptide bonds*
- A peptide bond forms between the carboxyl group of one amino acid and the amino group of the next, hence the molecule has “linearity”
 - Peptide bonds are polar covalent bonds

- **Levels of protein organization**

- The shape of a protein molecule is critical to its function
- Protein molecules have at least 3 levels of organization
 - Primary- shape held together by bonds between r groups chain of amino acids linked by peptide bonds
 - Secondary-coiling or folding of the primary structure to form a helix or a pleated sheet held together by hydrogen bonds
 - Tertiary-three-dimensional

Synthesis and degradation of a dipeptide

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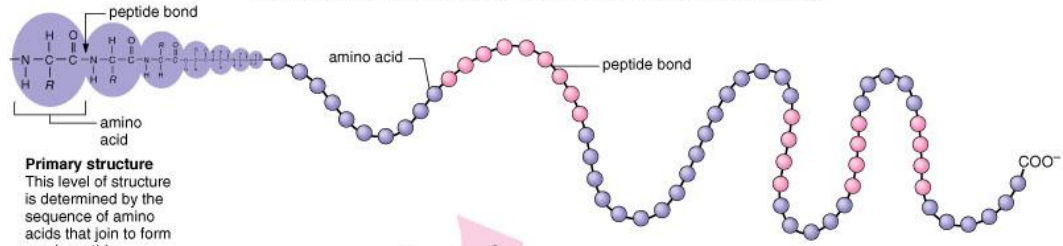


Levels of protein structure

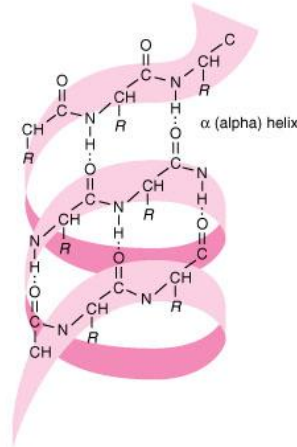
- The final shape of a protein molecule is often critical to its function
 - Ex: enzyme molecules have an active site which is part of the tertiary structure
- Note some proteins have a quaternary structure- 2 or more polypeptides linked together
 - Ex: hemoglobin has 4 polypeptide chains

Levels of protein organization

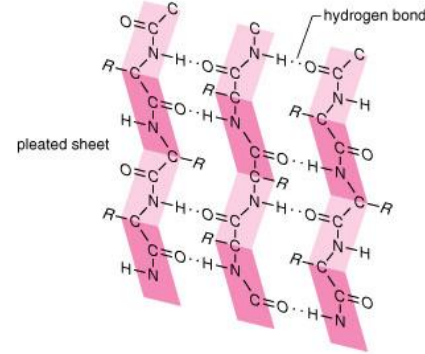
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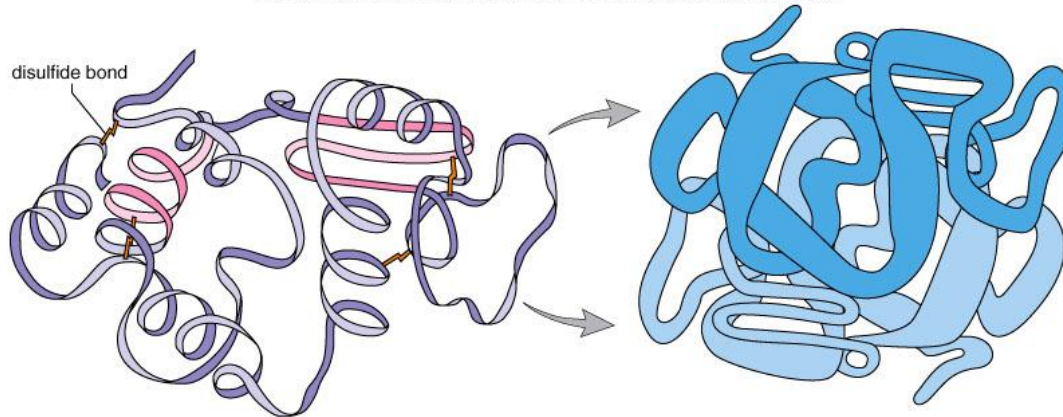
Primary structure
This level of structure is determined by the sequence of amino acids that join to form a polypeptide.



Secondary structure
Hydrogen bonding between amino acids causes the polypeptide to form an alpha helix or a pleated sheet.



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Tertiary structure
The helix folds into a characteristic globular shape due in part to covalent bonding between R groups.

Quaternary structure
This level of structure occurs when two or more polypeptides join to form a single protein.

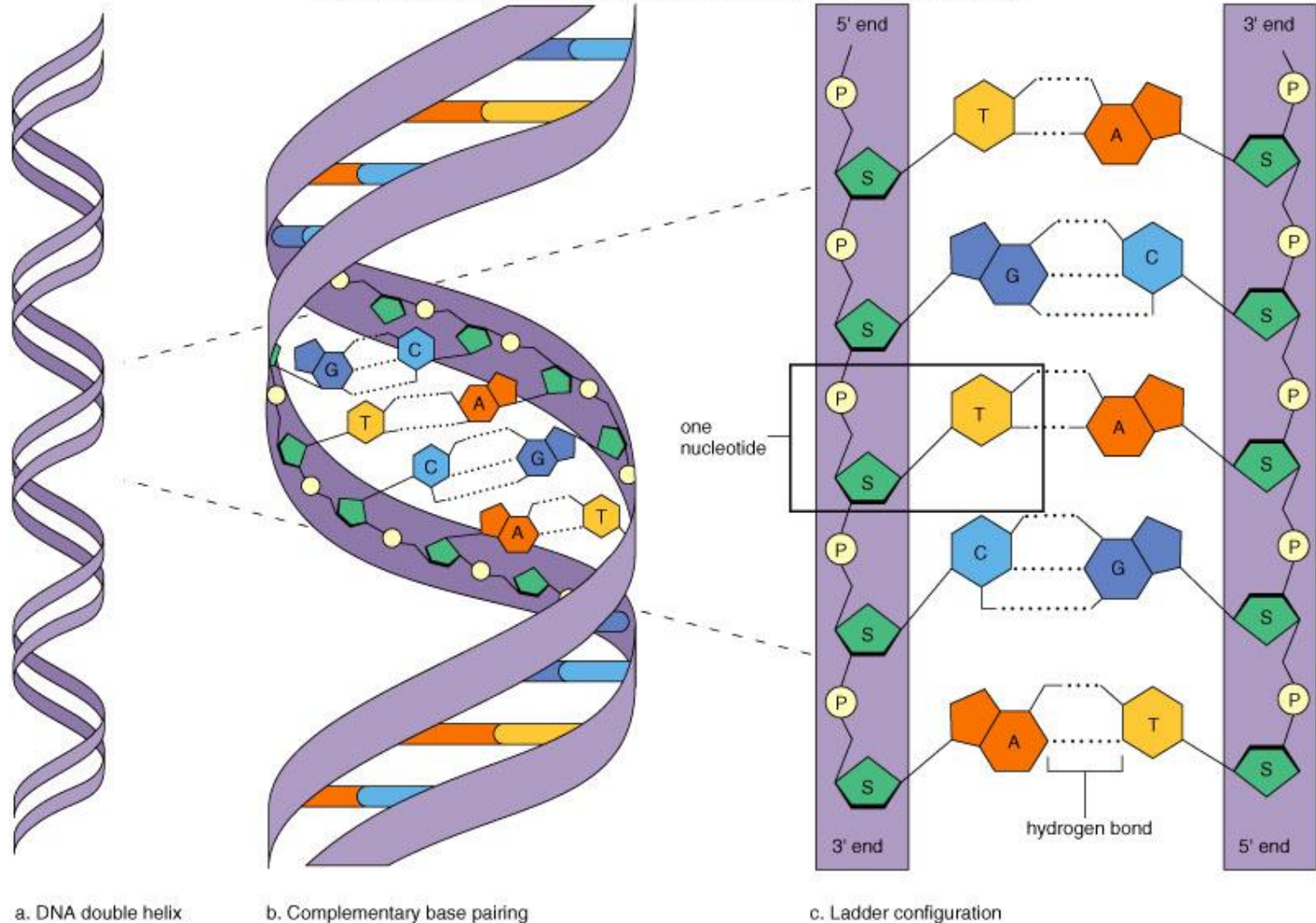
• Fig. 2.26

2.7 Nucleic acids

- Two types- DNA and RNA
 - DNA- codes for the order of amino acids needed to make proteins
 - RNA-functions in synthesis of protein
- Polymers of nucleotides
 - Nucleotides are composed of a pentose sugar, a phosphate, and a nitrogen base

Overview of DNA structure

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a. DNA double helix

b. Complementary base pairing

c. Ladder configuration

- Fig. 2.27

Nucleic acids, cont'd.

- DNA characteristics
 - Deoxyribose sugar
 - Nitrogen bases
 - Cytosine
 - Guanine
 - Adenine
 - Thymine
 - Double-stranded molecule

DNA structure compared to RNA structure

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TABLE 2.3 DNA STRUCTURE COMPARED TO RNA STRUCTURE

	DNA	RNA
Sugar	Deoxyribose	Ribose
Bases	Adenine, guanine, thymine, cytosine	Adenine, guanine, uracil, cytosine
Strands	Double stranded with base pairing	Single stranded
Helix	Yes	No

- Table 2.3

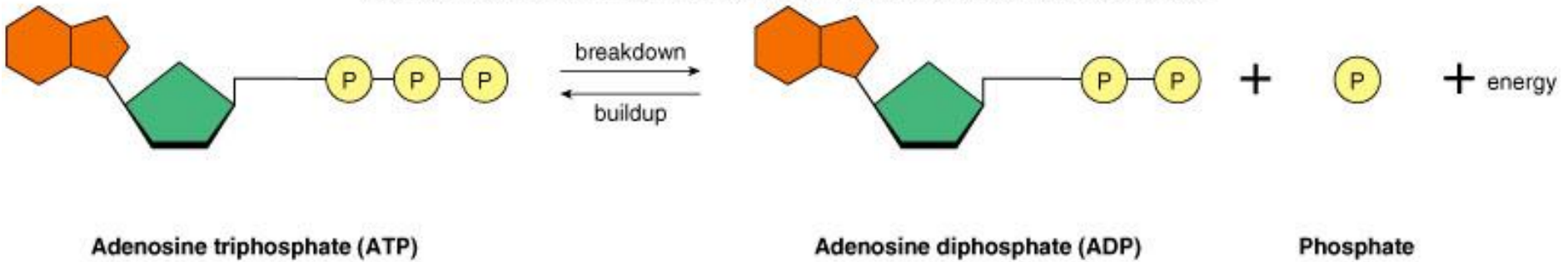
Nucleic acids, cont'd.

- ATP

- Adenine combined with ribose to form adenosine
- Three phosphate groups
- Energy carrier in cells
- High energy molecule
 - Last 2 phosphate bonds are unstable and easily broken
 - Terminal phosphate bond is cleaved releasing energy
 - Leaves ADP and an inorganic phosphate
- Energy released is used for many cell functions
 - Synthesis of macromolecules
 - Muscle contraction
 - Nerve conduction
- ATP is reformed with input of energy

ATP reaction

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- Fig. 2.28