

2.1: Introduction

Why study chemistry in an Anatomy and Physiology class?

- Body functions depend on cellular functions
- Cellular functions result from chemical changes
- Biochemistry helps to explain physiological processes

2.2: Structure of Matter

Matter – anything that takes up space and has mass (weight).
It is composed of elements.

Elements – composed of chemically identical atoms:

- Bulk elements – required by the body in large amounts
- Trace elements - required by the body in small amounts
- Ultratrace elements – required by the body in very minute amounts

Atoms – smallest particle of an element

Table 2.1 Some Particles of Matter

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TABLE 2.1 | Some Particles of Matter

Name	Characteristic	Name	Characteristic
Atom	Smallest particle of an element that has the properties of that element	Neutron (n^0)	Particle with about the same weight as a proton; uncharged and thus electrically neutral; found within an atomic nucleus
Electron (e^-)	Extremely small particle with almost no weight; carries a negative electrical charge and is in constant motion around an atomic nucleus	Ion	Particle that is electrically charged because it has gained or lost one or more electrons
Proton (p^+)	Relatively large atomic particle; carries a positive electrical charge and is found within an atomic nucleus	Molecule	Particle formed by the chemical union of two or more atoms

Elements and Atoms

- All matter is composed of elements
- Elements are the parts of compounds
- Elements are:
 - Bulk elements
 - Trace elements
 - Ultratrace elements
- The smallest parts of atoms are elements

Atomic Structure

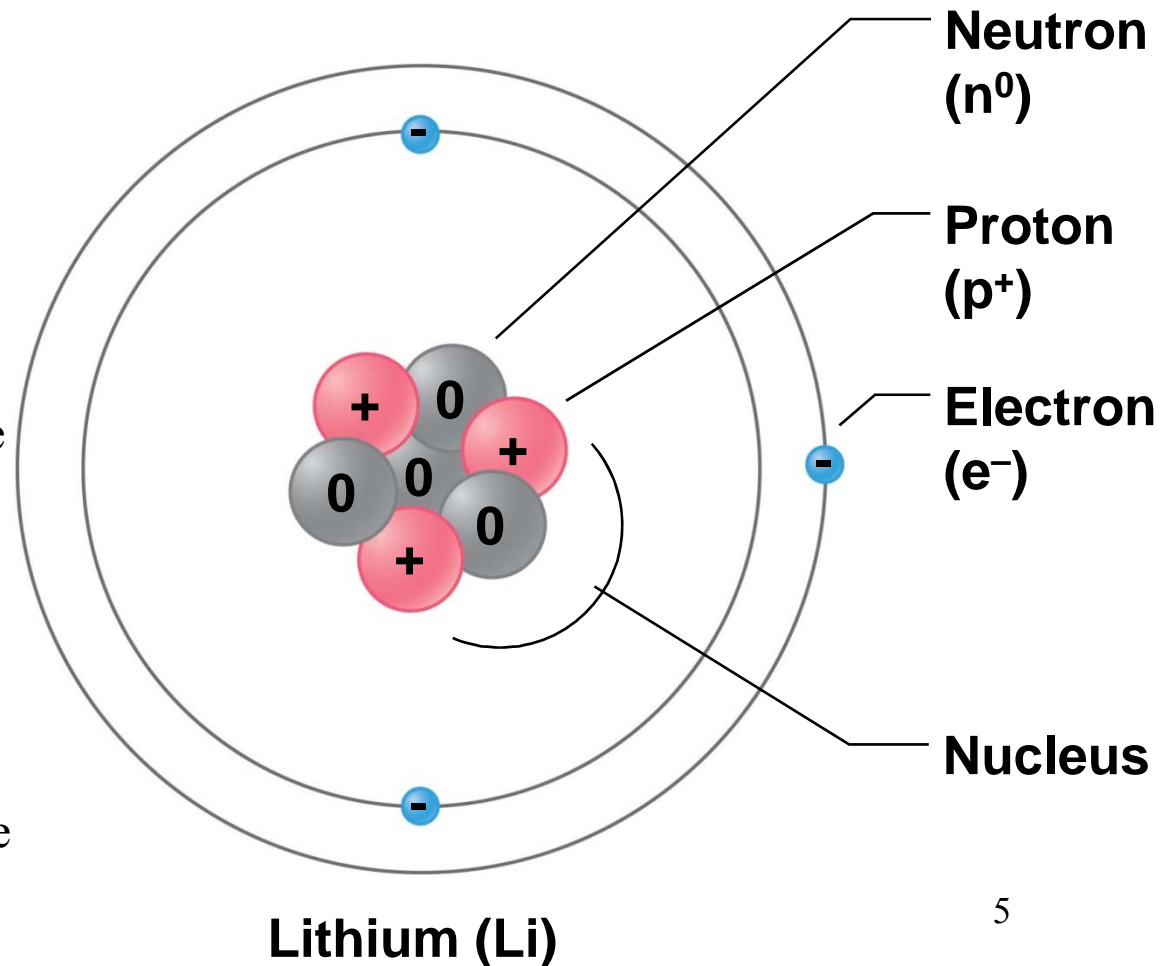
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Atoms - composed of subatomic particles:

- **Proton** – carries a single positive charge
- **Neutron** – carries no electrical charge
- **Electron** – carries a single negative charge

Nucleus

- Central part of atom
- Composed of protons and neutrons
- Electrons move around the nucleus



Atomic Number, Mass Number and Atomic Weight

Atomic Number

- Number of protons in the nucleus of one atom
- Each element has a unique atomic number
- Equals the number of electrons in the atom

Mass Number

- The number of protons plus the number of neutrons in one atom
- Electrons do not contribute to the weight of the atom

Atomic Weight

- Average of mass numbers of the **isotopes** of an element

Isotopes

Isotopes

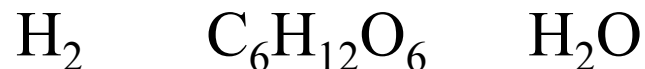
- Atoms with the same atomic numbers but with different mass numbers
- Different number of neutrons
- Oxygen often forms isotopes (O^{16} , O^{17} , and O^{18})

Molecules and Compounds

Molecule – particle formed when two or more atoms chemically combine

Compound – particle formed when two or more atoms of different elements chemically combine

Molecular formulas – depict the elements present and the number of each atom present in the molecule



Bonding of Atoms

- Bonds form when atoms combine with other atoms
- Electrons of an atom occupy regions of space called **electron shells** which circle the nucleus
- For atoms with atomic numbers of 18 or less, the following rules apply:
 - The first shell can hold up to 2 electrons
 - The second shell can hold up to 8 electrons
 - The third shell can hold up to 8 electrons

2.1 From Science to Technology

Radioactive Isotopes Reveal Physiology

2.2 From Science to Technology

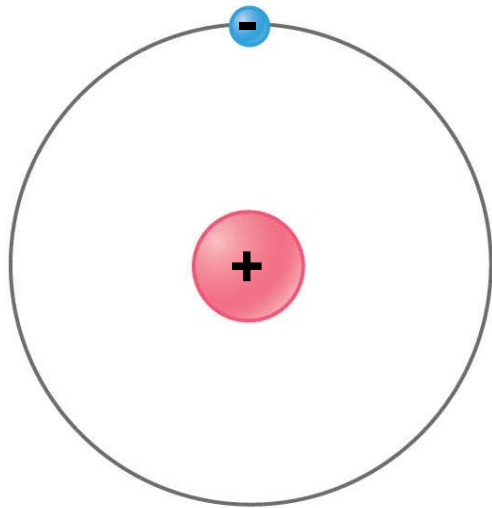
Ionizing Radiation:

From the Cold War to Yucca Mountain

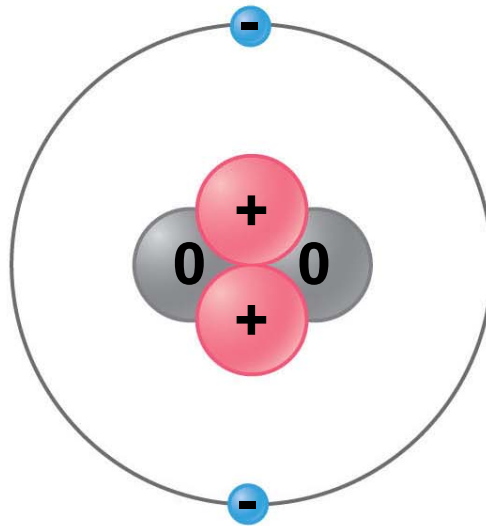
Bonding of Atoms

- Lower shells are filled first

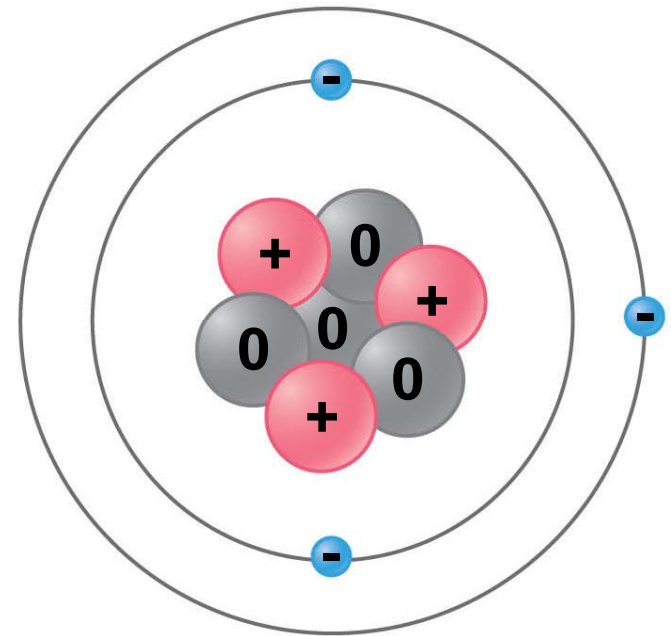
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Hydrogen (H)



Helium (He)



Lithium (Li)

Bonding of Atoms: Ions

Ion

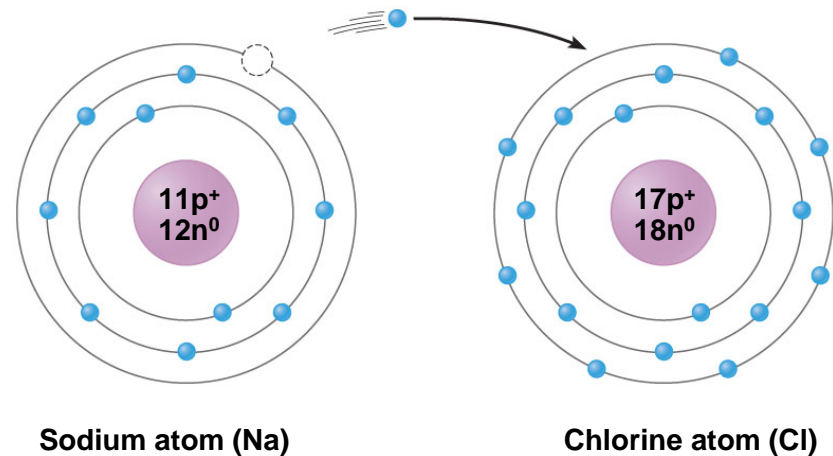
- An atom that gains or loses electrons to become stable
- An electrically charged atom

Cation

- A positively charged ion
- Formed when an atom loses electrons

Anion

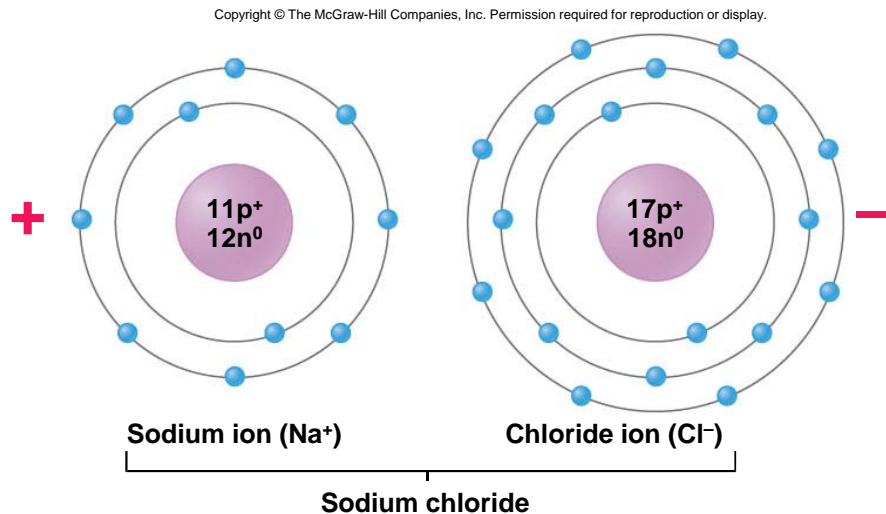
- A negatively charged ion
- Formed when an atom gains electrons



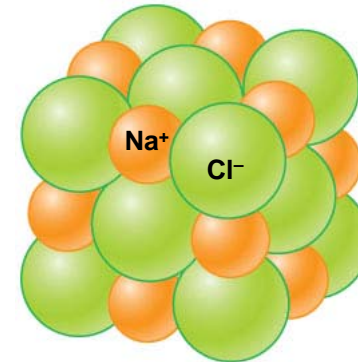
Ionic Bonds

Ionic Bonds

- An attraction between a cation and an anion
- Formed when electrons are transferred from one atom to another atom



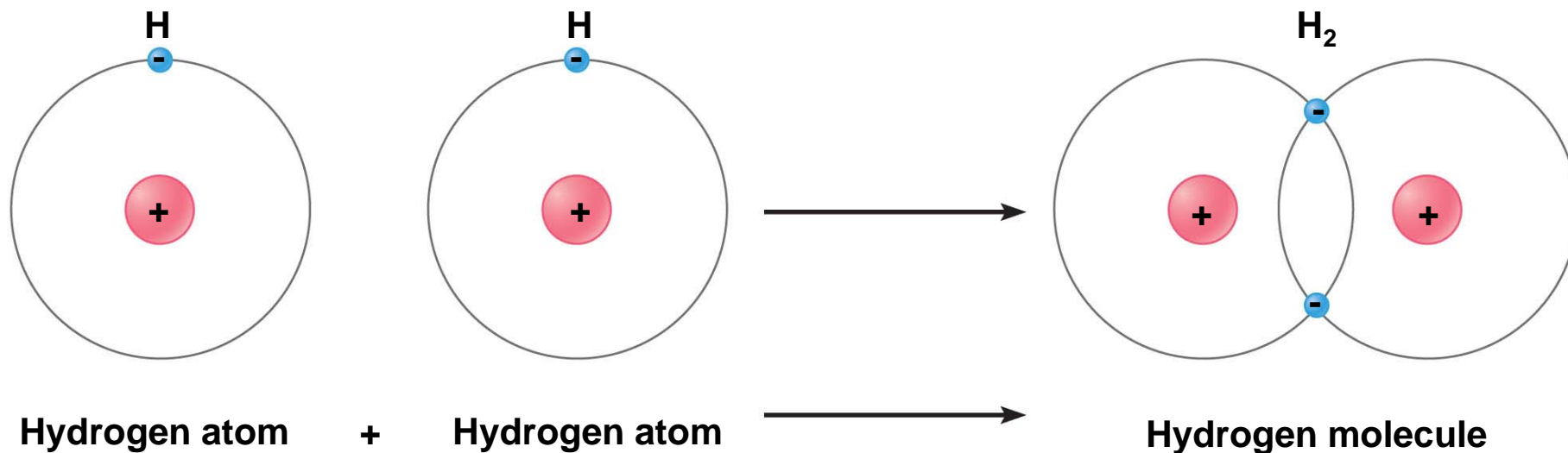
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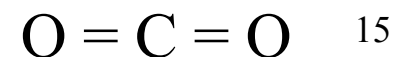
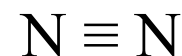
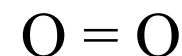
Covalent Bonds

- Formed when atoms share electrons

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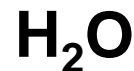
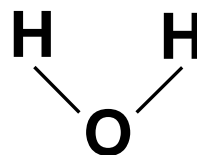
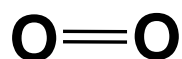
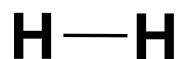
- Hydrogen atoms form single bonds
- Oxygen atoms form two bonds
- Nitrogen atoms form three bonds
- Carbon atoms form four bonds



Bonding of Atoms: Structural Formula

- **Structural formulas** show how atoms bond and are arranged in various molecules

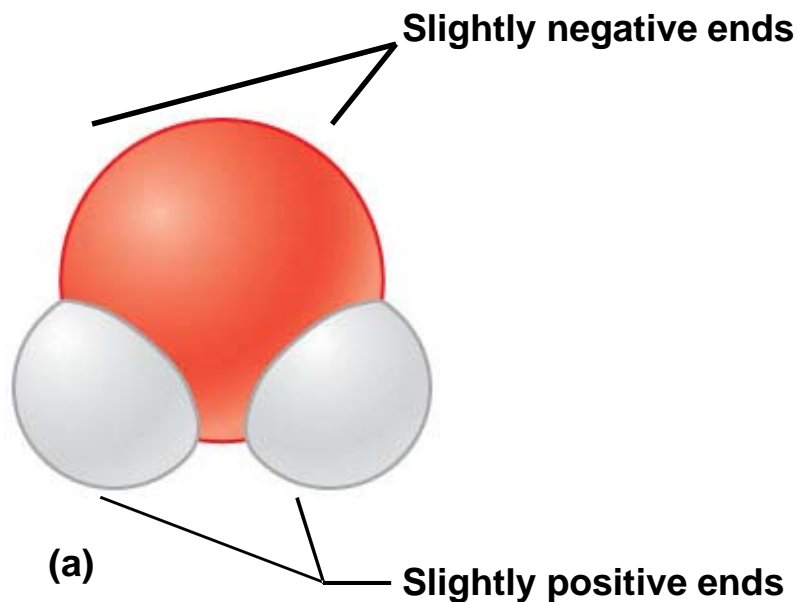
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Bonding of Atoms: Polar Molecules

Polar Molecules

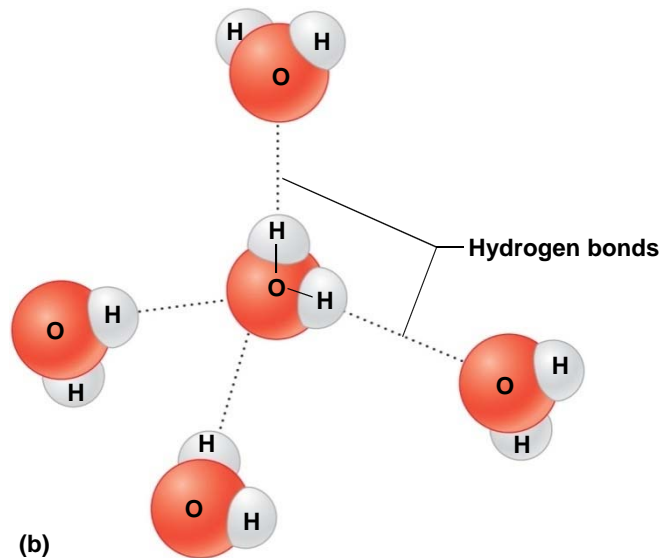
- Molecule with a slightly negative end and a slightly positive end
- Results when electrons are not shared equally in covalent bonds
- Water is an important polar molecule



Hydrogen Bonds

Hydrogen Bonds

- A weak attraction between the positive end of one polar molecule and the negative end of another polar molecule
- Formed between water molecules
- Important for protein and nucleic acid structure



Chemical Reactions

Chemical reactions occur when chemical bonds form or break among atoms, ions, or molecules

Reactants are the starting materials of the reaction - the atoms, ions, or molecules

Products are substances formed at the end of the chemical reaction

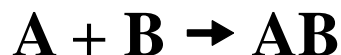


Reactant

Products

Types of Chemical Reactions

Synthesis Reaction – more complex chemical structure is formed



Decomposition Reaction – chemical bonds are broken to form a simpler chemical structure



Exchange Reaction – chemical bonds are broken and new bonds are formed



Reversible Reaction – the products can change back to the reactants



Acids, Bases, and Salts

Electrolytes – substances that release ions in water



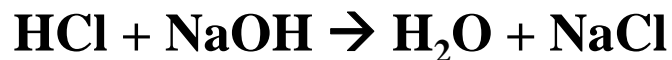
Acids – electrolytes that dissociate to release hydrogen ions in water



Bases – substances that release ions that can combine with hydrogen ions



Salts – electrolytes formed by the reaction between an acid and a base



Acid and Base Concentration

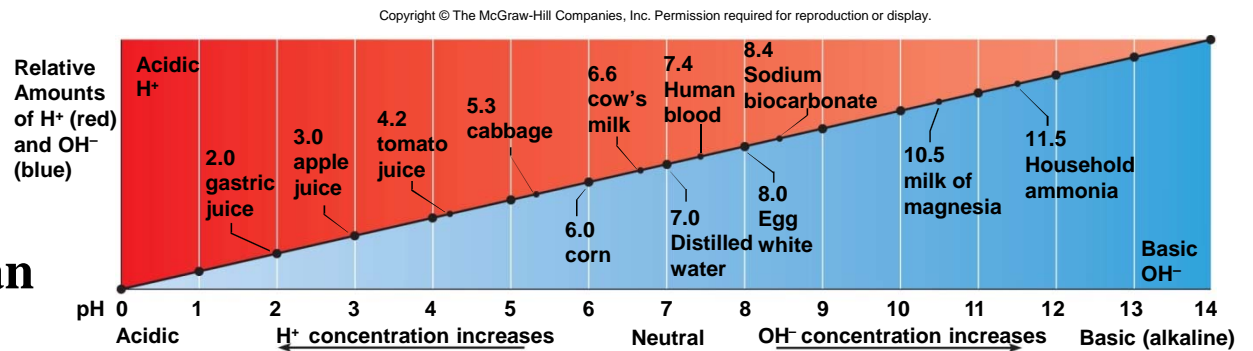
pH scale - indicates the concentration of hydrogen ions in solution

Neutral – pH 7;

indicates equal concentrations of H^+ and OH^-

Acidic – pH less than 7; indicates a greater concentration of H^+

Basic or alkaline – pH greater than 7; indicates a greater concentration of OH^-



Neutralization and Buffers

- Neutralization occurs when an acid and base react to form a salt and water in a displacement reaction.
 - $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$
 - Termed **neutralization** because water is formed neutralizing the solution.
- **Buffers act as acids when pH is high and bases when pH is low.**
 - **Carbonic acid-bicarbonate system.**

2.3: Chemical Constituents of Cells

Organic v. Inorganic Molecules

Organic molecules

- *Contain C and H*
- *Usually larger than inorganic molecules*
- *Dissolve in water and organic liquids*
- *Carbohydrates, proteins, lipids, and nucleic acids*

Inorganic molecules

- Generally do not contain C and H
- Usually smaller than organic molecules
- Usually dissociate in water, forming ions
- Water, oxygen, carbon dioxide, and inorganic salts

Inorganic Substances

Water

- Most abundant compound in living material
- Two-thirds of the weight of an adult human
- Major component of all body fluids
- Medium for most metabolic reactions
- Important role in transporting chemicals in the body
- Absorbs and transports heat

Oxygen (O₂)

- Used by organelles to release energy from nutrients in order to drive cell's metabolic activities
- Necessary for survival

Inorganic Substances

Carbon dioxide (CO₂)

- Waste product released during metabolic reactions
- Must be removed from the body

Inorganic salts

- Abundant in body fluids
- Sources of necessary ions (Na⁺, Cl⁻, K⁺, Ca²⁺, etc.)
- Play important roles in metabolism

Marshmallow Review

Follow worksheets



Organic Substances

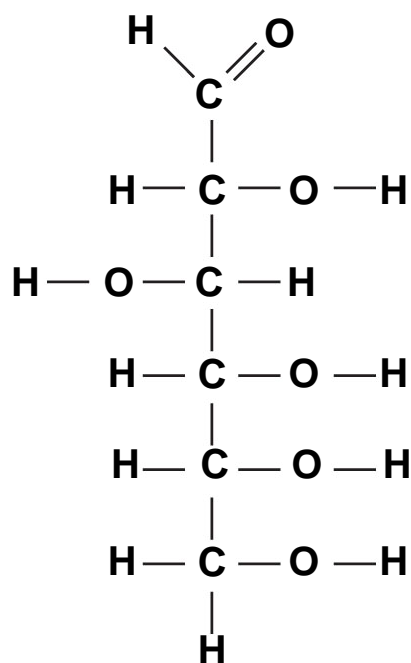
Carbohydrates

- Provide energy to cells
- Supply materials to build cell structures
- Water-soluble
- Contain C, H, and O
- Ratio of H to O close to 2:1 ($C_6H_{12}O_6$)
- Monosaccharides – glucose, fructose
- Disaccharides – sucrose, lactose
- Polysaccharides – glycogen, cellulose

Organic Substances

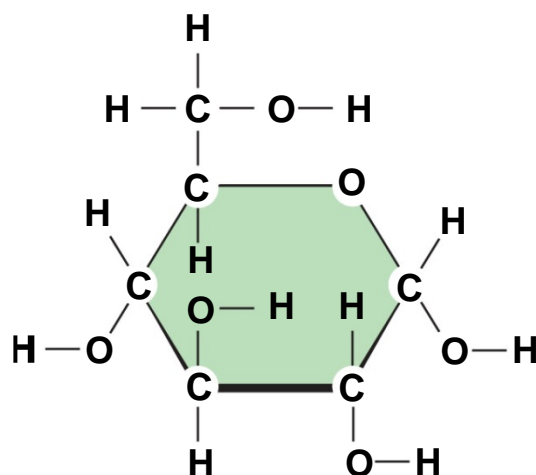
Carbohydrates

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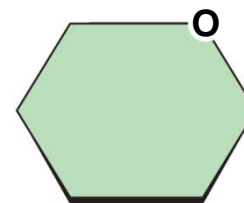
(a) Some glucose molecules ($C^6H^{12}O^6$) have a straight chain of carbon atoms.

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(b) More commonly, glucose molecules form a ring structure.

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(c) This shape symbolizes the ring structure of a glucose molecule.

Organic Substances

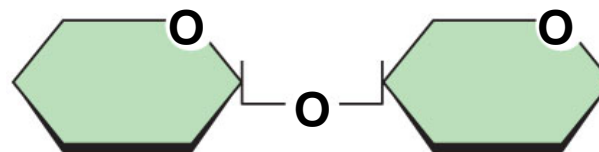
Carbohydrates

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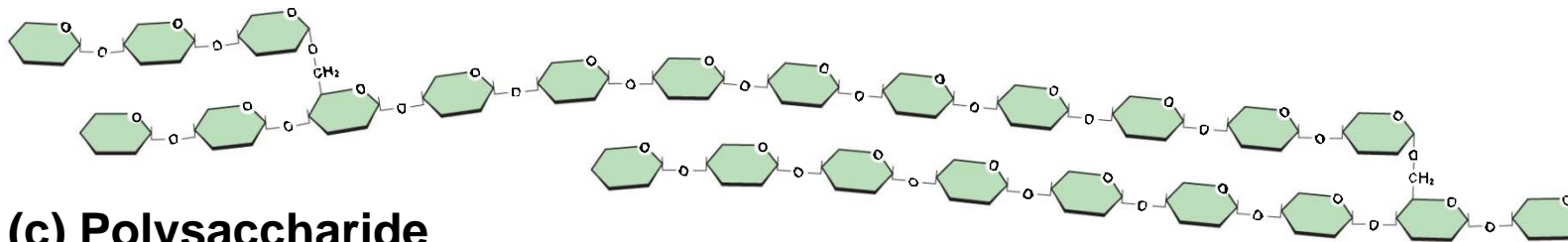
(a) Monosaccharide

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(b) Disaccharide

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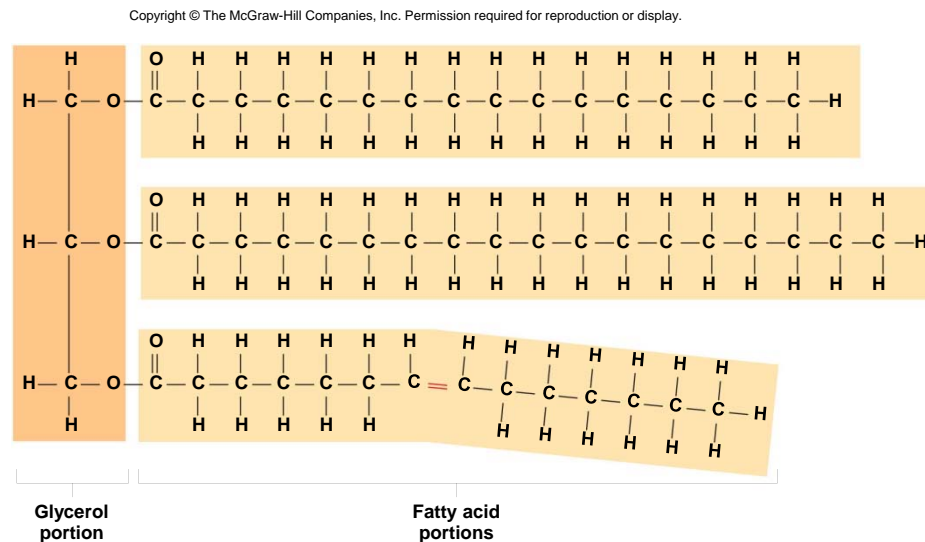


(c) Polysaccharide

Organic Substances

Lipids

- Soluble in organic solvents; insoluble in water
- Fats (triglycerides)
 - Used primarily for energy; most common lipid in the body
 - Contain C, H, and O but less O than carbohydrates ($C_{57}H_{110}O_6$)
 - Building blocks are 1 glycerol and 3 fatty acids per molecule
 - Saturated and unsaturated



Neutral Fats

- Triglycerides are formed from a fatty acid and glycerol (a sugar).
- They are the most plentiful source of stored energy to our bodies.
 - Two types:
 - Saturated- contain only single bonds
 - Unsaturated- contains one(mono) or more(poly) double bonds
- Short, unsaturated fats are liquids (oils) and come from plants.
- Long, saturated fats are solid (butter and meat fat) and come from animals.

Organic Substances

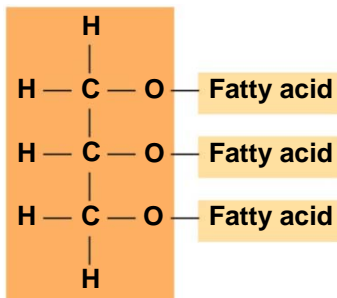
Lipids

- Phospholipids

- Building blocks are 1 glycerol, 2 fatty acids, and 1 phosphate per molecule
- Hydrophilic and hydrophobic
- Major component of cell membranes

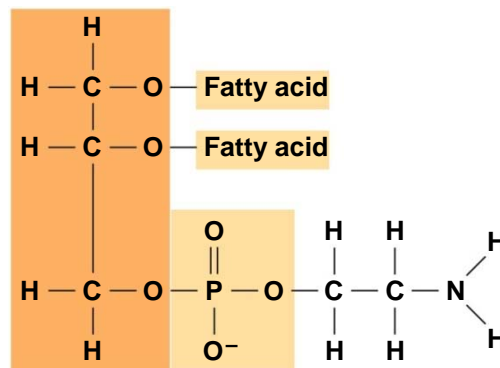
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Glycerol portion

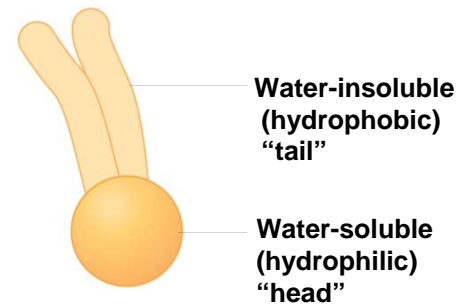
(a) A fat molecule



Phosphate portion

(b) A phospholipid molecule
(the unshaded portion may vary)

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(c) Schematic representation
of a phospholipid molecule

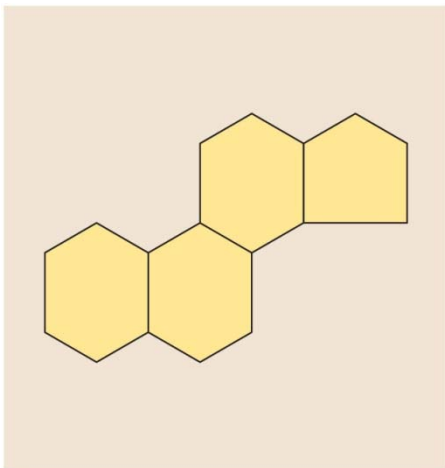
Organic Substances

Lipids

- Steroids

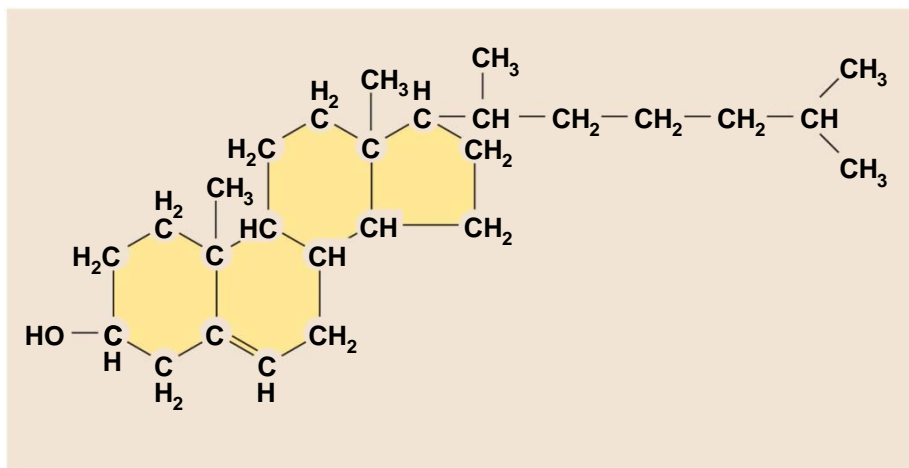
- Four connected rings of carbon
- Widely distributed in the body, various functions
- Component of cell membrane
- Used to synthesize hormones
- Cholesterol

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(a) General structure of a steroid

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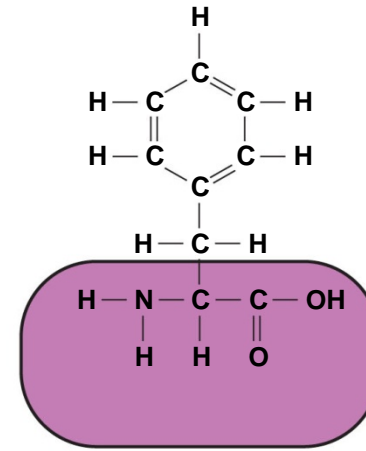
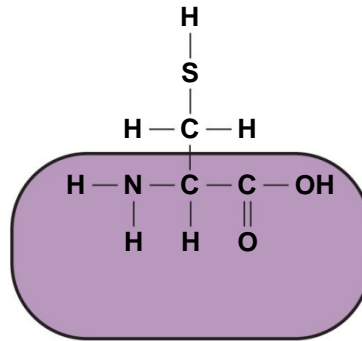
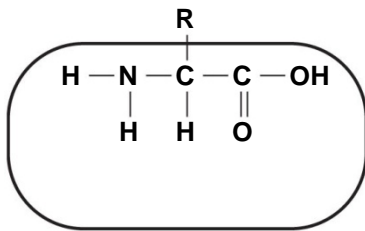


(b) Cholesterol

Organic Substances

Proteins

- Structural material
- Energy source
- Hormones
- Receptors
- Enzymes
- Antibodies
- Protein building blocks are amino acids
- Amino acids held together with **peptide bonds**



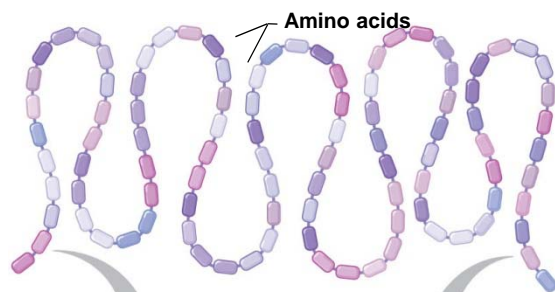
Organic Substances

Proteins

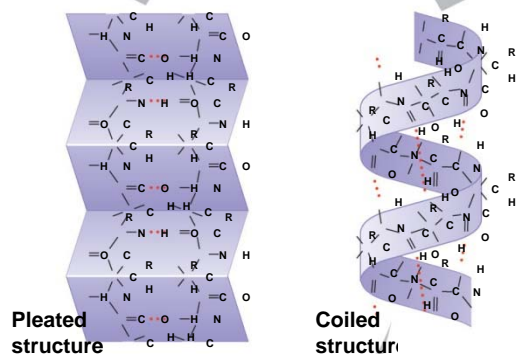
Four Levels of Protein Structure

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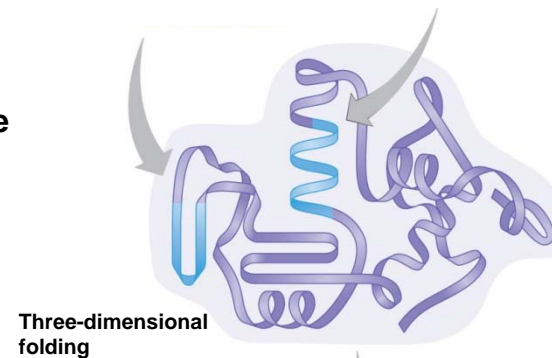
Primary structure



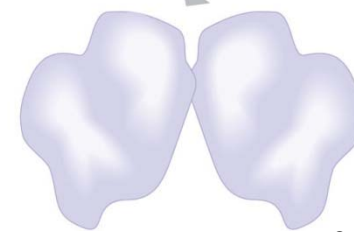
Secondary structure



Tertiary structure



Quaternary structure



Animation: Protein Denaturation

 **Protein Denaturation**



Protein denaturation changes the solubility of individual protein molecules, entrapping solvent water into a semisolid gel structure.

▶ Play ⏸ Pause 🔊 Audio 📄 Text

This familiar gelatin dessert actually is a good example of the process of coagulation of proteins into a three dimensional latticework that entraps water molecules to produce a semisolid gel.

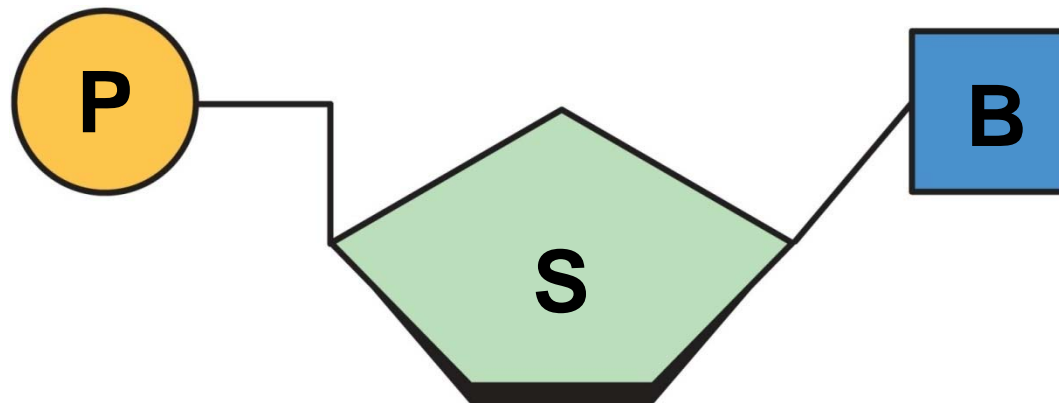
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Organic Substances

Nucleic Acids

- Carry genes
- Encode amino acid sequences of proteins
- Building blocks are nucleotides

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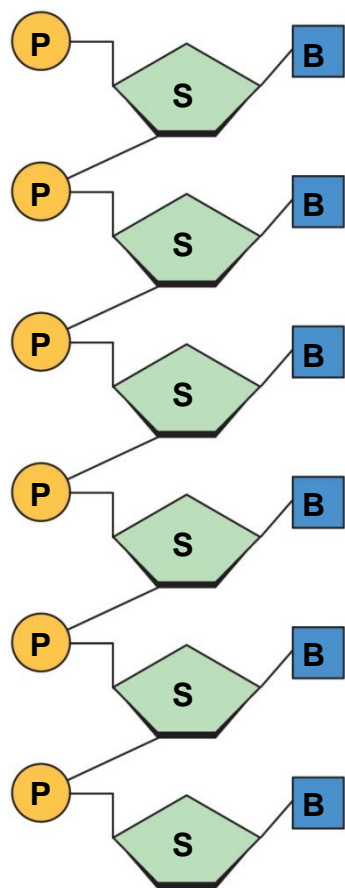
- DNA (deoxyribonucleic acid) – double polynucleotide
- RNA (ribonucleic acid) – single polynucleotide

Organic Substances

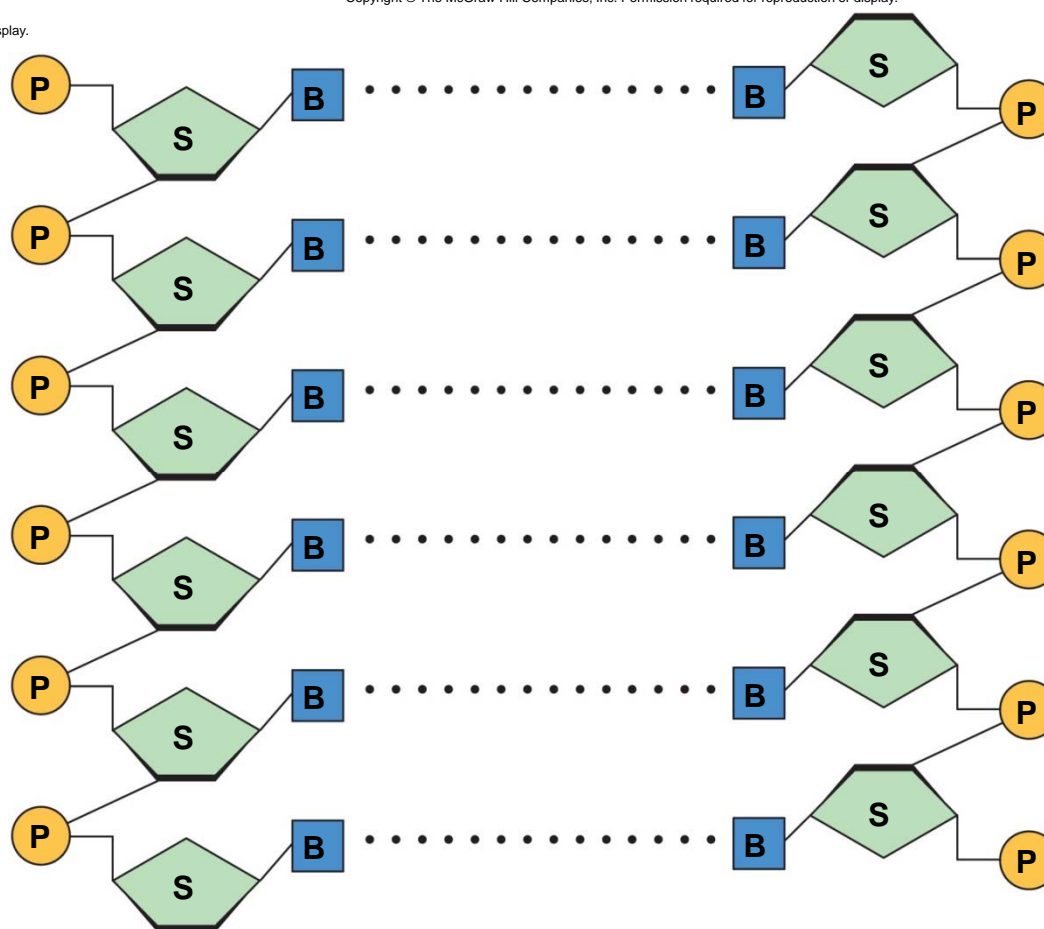
Nucleic Acids

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(a)



(b)

Computer Activity

The Tree of Life Macromolecules

[http://molo.concord.org/database/
activities/226.html](http://molo.concord.org/database/activities/226.html)

2.3 From Science to Technology

CT Scanning and PET Imaging

Important Points in Chapter 2:

Outcomes to be Assessed

2.1: Introduction

- ✓ Give examples of how the study of living materials requires and understanding of chemistry.

2.2: Structure of Matter

- ✓ Describe how atomic structure determines how atoms interact.
- ✓ Describe the relationships among matter, atoms, and molecules.
- ✓ Explain how molecular and structural formulas symbolize the composition of compounds.
- ✓ Describe three types of chemical reactions.
- ✓ Explain what acids, bases, and buffers are.
- ✓ Define pH.

Important Points in Chapter 2:

Outcomes to be Assessed Continued

2.3: Chemical Constituents of Cells

- ✓ List the major groups of inorganic chemicals common in cells.
- ✓ Describe the general functions of the main classes of organic molecules in cells.

Quiz 2

Complete Quiz 2 now!

Read Chapter 3.