Essentials of Human Anatomy & Physiology

Seventh Edition

Elaine N. Marieb

Chapter 2

Basic Chemistry

Slides 2.1 – 2.42

Lecture Slides in PowerPoint by Jerry L. Cook

Matter and Energy

- Matter – anything that occupies space and has mass (weight)
  - Solids, Liquids, Gasses
  - Physical and Chemical changes
- Energy – the ability to do work
  - Kinetic – when energy is actually doing work
  - Potential – when energy is inactive or stored

Matter and Energy

- Forms of Energy
  - Chemical – stored in the bonds of chemical substances
  - Electrical – results from the movement of charged particles - ions
  - Mechanical – directly involved in moving matter - muscles
  - Radiant – travels in waves – the electromagnetic spectrum including X-rays, infrared, light, radio, and UV rays
- Can easily be converted from 1 form to another but is not 100% efficient – some lost as heat

Composition of Matter

- Elements
  - Fundamental units of matter – cannot be broken down into smaller units
  - 96% of the body is made from four elements
    - Carbon (C)
    - Oxygen (O)
    - Hydrogen (H)
    - Nitrogen (N)
- Atoms
  - Building blocks of elements

Atomic Structure

- Inside the nucleus
  - Protons (p^+)
  - Neutrons (n^0)
- Outside the nucleus
  - Electrons (e^-)

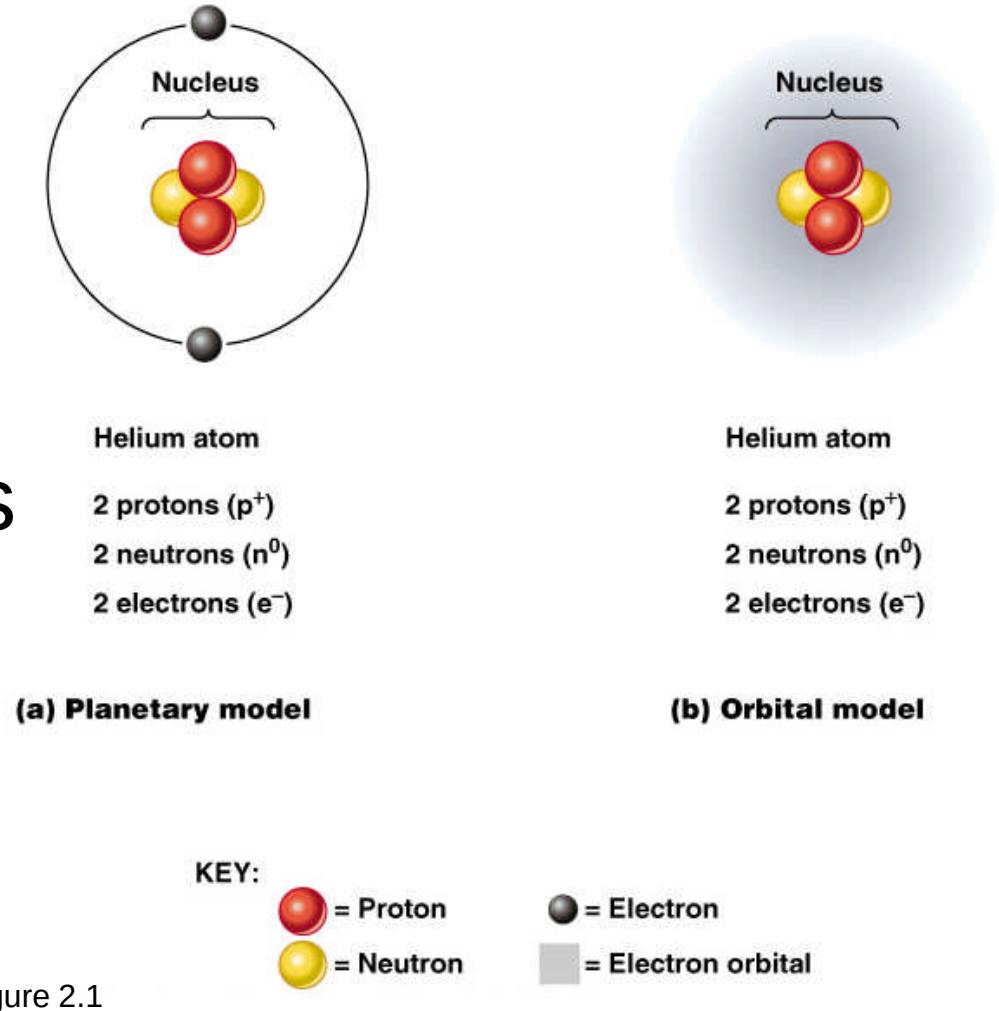


Figure 2.1

Identifying Elements

- Atomic number
  - Equal to the number of protons that the atoms contain – also equals number of electrons
- Atomic mass number
  - Sum of the protons and neutrons

Atomic Weight and Isotopes

- Isotopes
  - Have the same number of protons and electrons so same atomic number
  - Vary in number of neutrons so different atomic masses
- Atomic weight
  - Close to mass number of most abundant isotope
  - Atomic weight reflects natural isotope variation

Radioactivity

- Radioisotope
  - Heavy isotope
  - Tends to be unstable
  - Decomposes to more stable isotope
- Radioactivity
  - Process of spontaneous atomic decay
  - Releases particles – *alpha*, *beta*, and *gamma rays*

Molecules and Compounds

- Molecule – two or more atoms combined chemically
- Compound – two or more different atoms combined chemically
- Compounds have properties different from the properties of the atoms they are made of

Chemical Reactions

- Chemical reactions occur when atoms combine or dissociate from other atoms
  - Atoms are united by chemical bonds
  - Atoms dissociate from other atoms when chemical bonds are broken

Electrons and Bonding

- Electrons occupy energy levels called electron levels or shells
- Electrons closest to the nucleus are most strongly attracted
- Each shell has distinct properties
  - Number of electrons has an upper limit
  - Shells closest to nucleus usually fill first

Electrons and Bonding

- Bonding involves interactions between electrons in the outer shell (the valence shell)
- Full valence shells do not form bonds

Inert Elements

- Have complete valence shells and are stable
- Rule of 8s
  - Shell 1 has 2 electrons
  - Shell 2 has 10 electrons
    - 10 = 2 + 8
  - Shell 3 has 18 electrons
    - 18 = 2 + 8 + 8

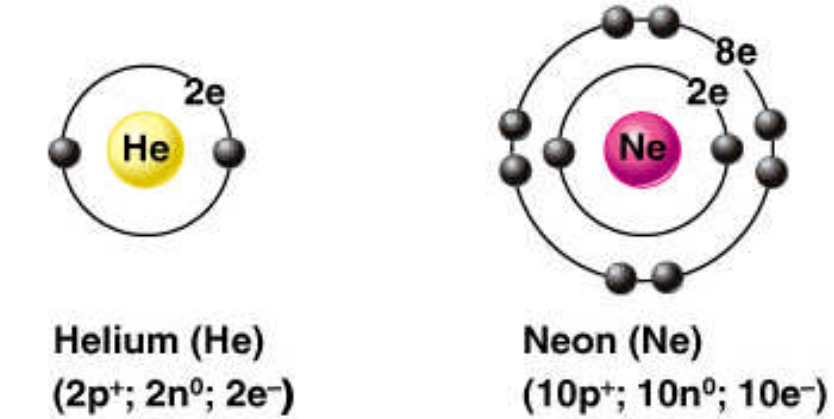


Figure 2.4a

Reactive Elements

- Valence shells are not full and are unstable
- Tend to gain, lose, or share electrons
  - Allows for bond formation, which produces stable valence

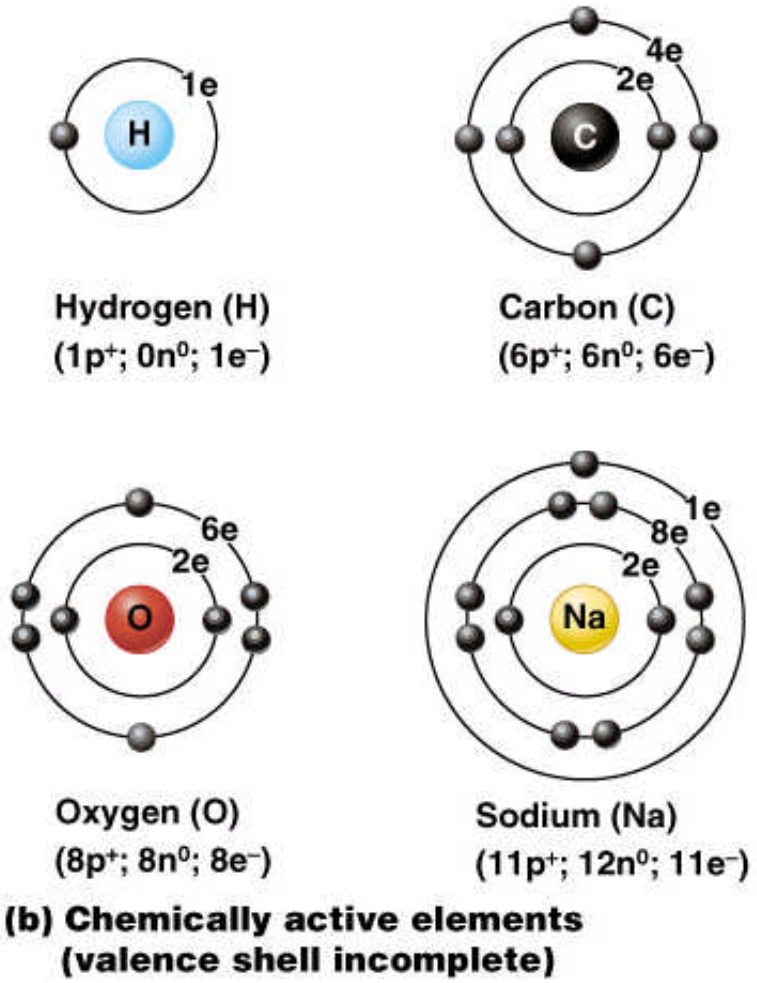


Figure 2.4b

Chemical Bonds

- Ionic Bonds
  - Form when electrons are completely transferred from one atom to another
- Ions
  - Charged particles
    - Either donate or accept electrons
      - Anions are negative – have accepted
      - Cations are positive – have donated
  - Opposites attract so stick together – most form salts

Chemical Bonds

- Covalent Bonds
  - Atoms become stable through shared electrons
  - Single covalent bonds share one electron
  - Double covalent bonds share two electrons

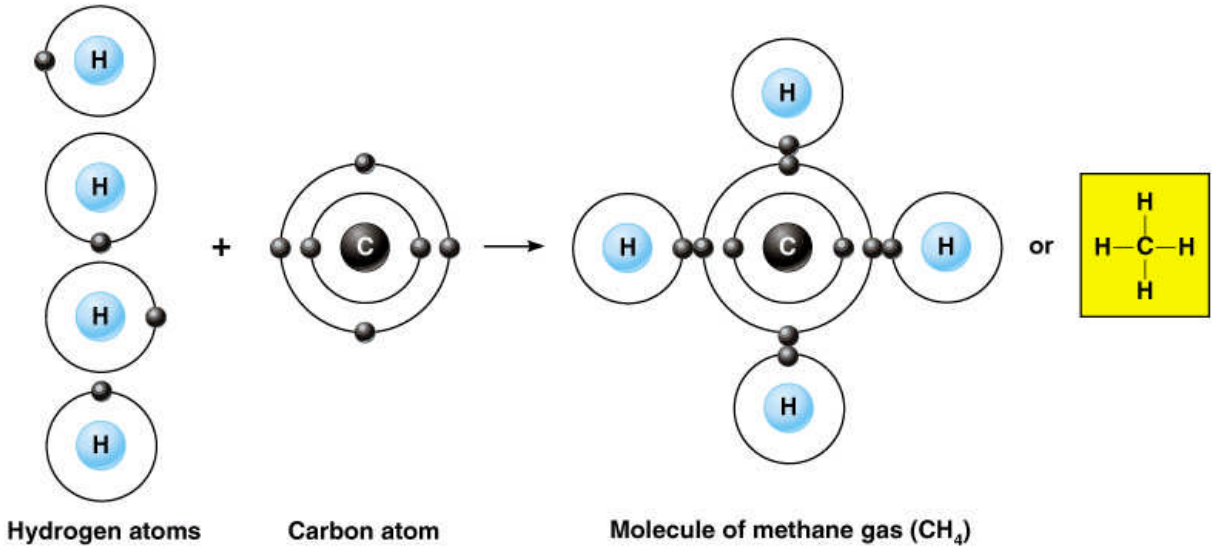


Figure 2.6c

Examples of Covalent Bonds

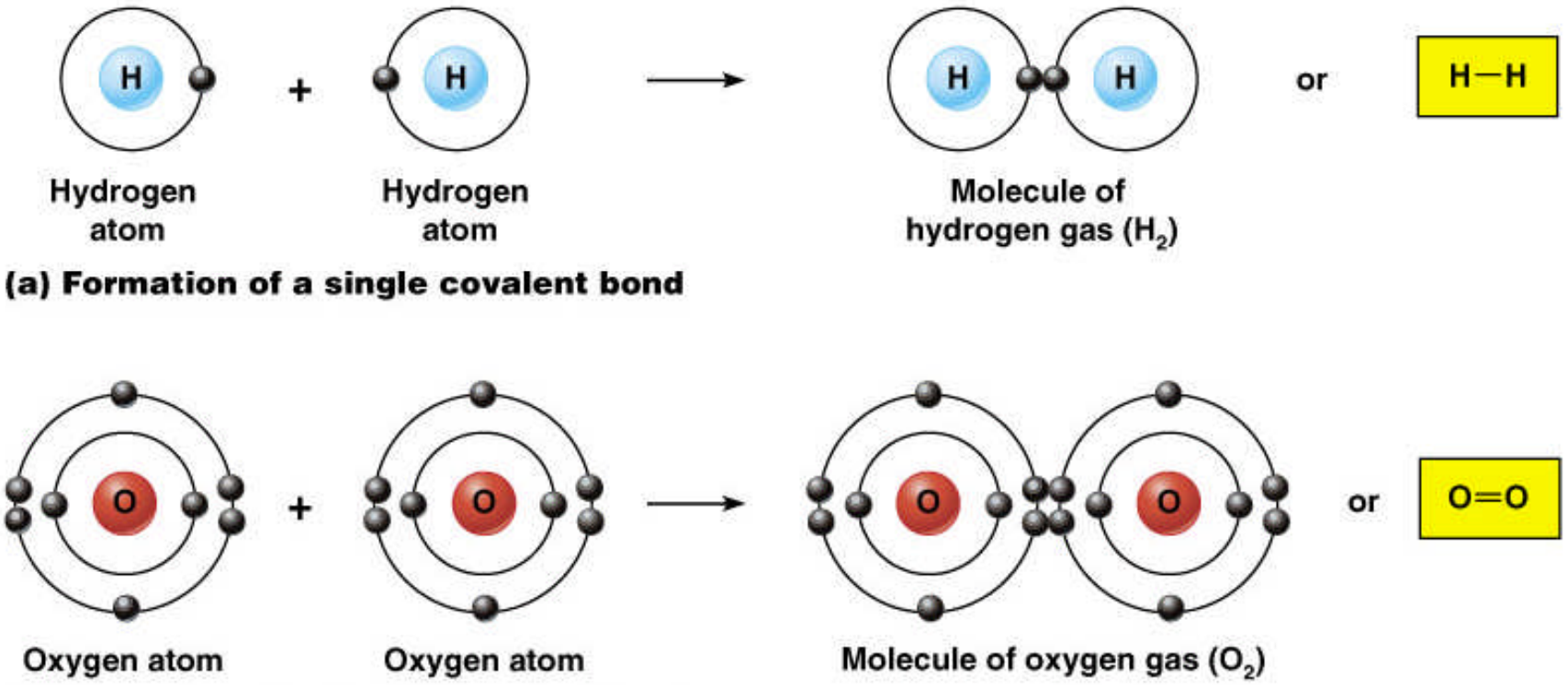
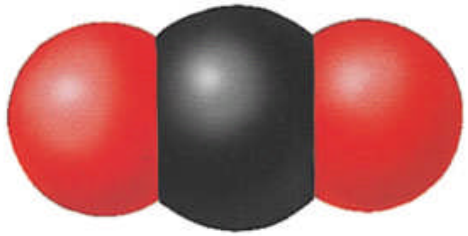
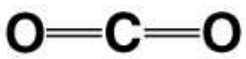


Figure 2.6a, b

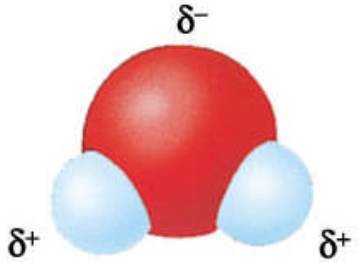
Polarity

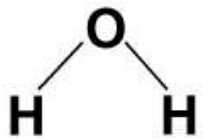
- Covalent bonded molecules
  - Some are non-polar
    - Electrically neutral as a molecule
  - Some are polar
    - Have a positive and negative side
    - Polar molecules orient themselves toward other polar or charged particles





(a) Carbon dioxide (CO_2)





(b) Water (H_2O)

Figure 2.7

Chemical Bonds

- Hydrogen bonds
  - Weak chemical bonds
  - Hydrogen is attracted to negative portion of polar molecule
  - Provides attraction between molecules
    - Surface tension – bonds between water molecules
    - Intramolecular bonds – binding of different parts of the same molecule to form a 3D shape such as proteins

Patterns of Chemical Reactions

- Synthesis reaction (A+B→AB)
  - Atoms or molecules combine
  - Energy is absorbed for bond formation
  - Anabolic activities – constructive activities
- Decomposition reaction (AB→A+B)
  - Molecule is broken down
  - Chemical energy is released when bonds are broken
  - Catabolic processes – decomposition activities

Synthesis and Decomposition Reactions

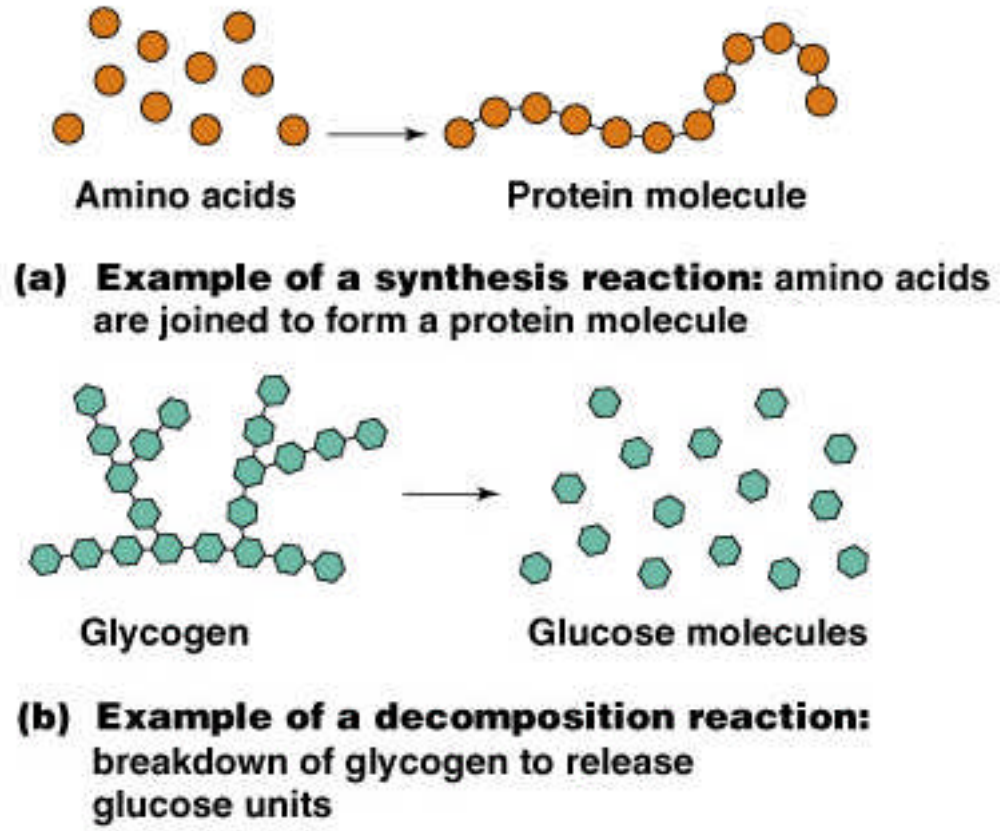


Figure 2.9a, b

Patterns of Chemical Reactions

- Exchange reaction (AB+C→AC+B)
  - Involves both synthesis and decomposition reactions
  - Switch is made between molecule parts and different molecules are made

Biochemistry: Essentials for Life

- Organic compounds
  - Contain carbon
  - Most are covalently bonded
  - Example: $C_6H_{12}O_6$ (glucose)
- Inorganic compounds
  - Lack carbon
  - Tend to be simpler compounds
  - Example: H_2O (water)

Important Inorganic Compounds

- Water
  - Most abundant inorganic compounds
  - Vital properties
    - High heat capacity
    - Polarity/solvent properties
      - Solute, Solvent, Mixture, Solution, Suspension, Colloid
    - Chemical reactivity
      - hydrolysis reactions
    - Cushioning

Important Inorganic Compounds

- Salts
  - Easily dissociate into ions in the presence of polar water molecules
  - Vital to many body functions
  - Include electrolytes, which conduct electrical currents in solution

Important Inorganic Compounds

- Like salts, acids and bases are electrolytes
- Acids – H^+
  - Can release detectable hydrogen ions
  - Sour taste and can “burn”
  - Proton donors
- Bases – OH^-
  - Bitter taste, slippery
  - Proton acceptors
- Neutralization reaction
  - Acids and bases react to form water and a salt

pH

- Measures relative concentration of hydrogen ions
  - pH 7 = neutral
  - pH below 7 = acidic
  - pH above 7 = basic
  - Buffers
    - Chemicals that can regulate pH change

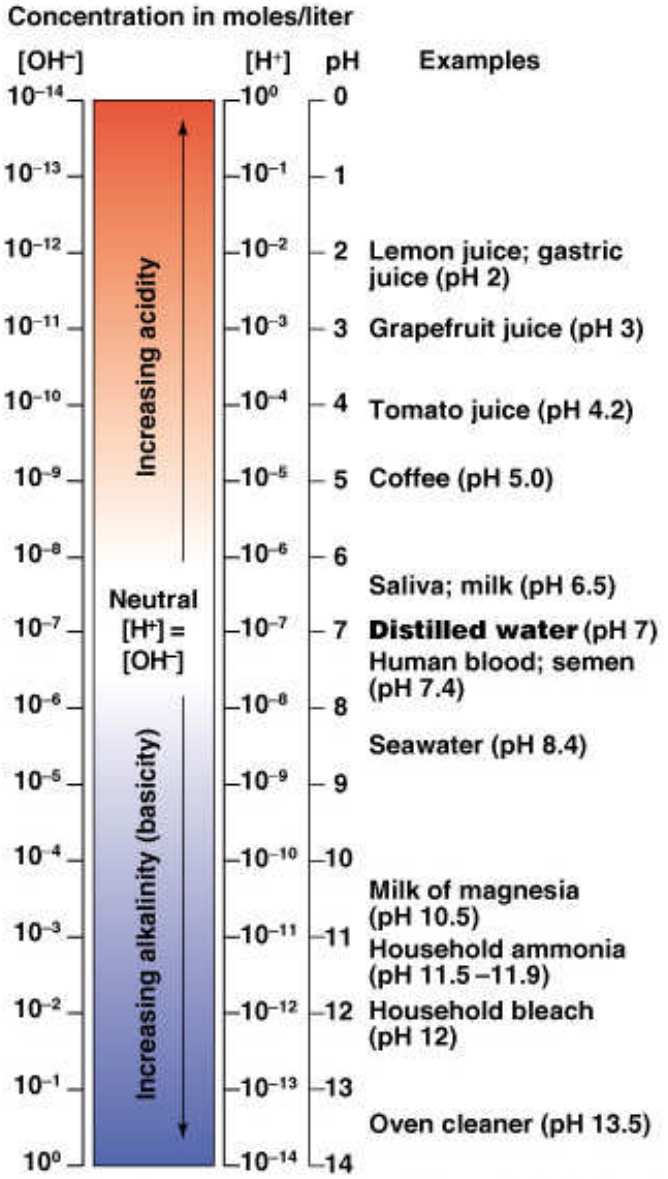


Figure 2.11

Important Organic Compounds

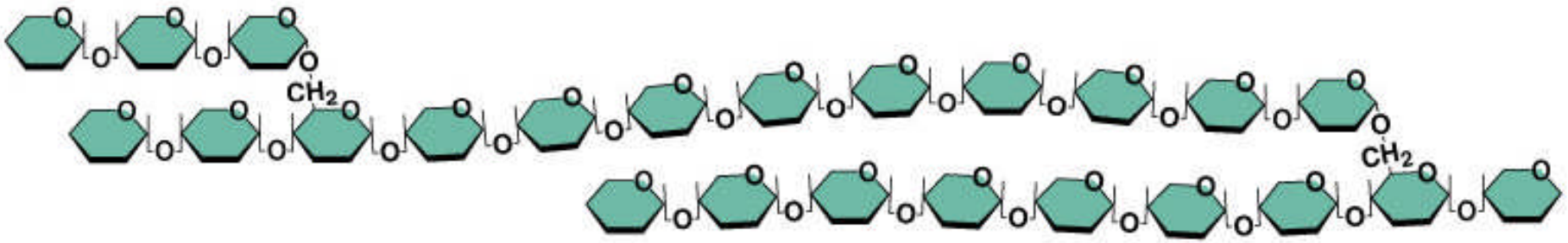
- Carbohydrates
  - Contain carbon, hydrogen, and oxygen in a 1:2:1 ratio
  - Include sugars and starches
  - Classified according to size
    - Monosaccharides – simple sugars
    - Disaccharides – two simple sugars joined by dehydration synthesis – H_2O is lost
    - Polysaccharides – long branching chains of linked simple sugars

Carbohydrates

- Provide a ready, easily used source of food energy for cells

Figure 2.12a, b

Carbohydrates



(c) Starch (polysaccharide)

Figure 2.12c

Important Organic Compounds

- Lipids
  - Contain carbon, hydrogen, and oxygen
    - Carbon and hydrogen outnumber oxygen
- Insoluble in water but soluble in other lipids
  - “Like dissolves like”

Important Organic Compounds

- Common lipids in the human body
  - Neutral fats (triglycerides)
    - Found in fat deposits
    - Composed of fatty acids and glycerol
    - Solid (animal fats) or liquid (plant fats)
    - Saturated – animal fats or unsaturated – plant fats
    - Source of stored energy

Important Organic Compounds

- Common lipids in the human body (continued)
  - Phospholipids
    - Form cell membranes – polar properties
  - Steroids
    - Four interlocking rings
    - Fat-soluble
    - Include cholesterol, bile salts, vitamin D, and some hormones

Lipids

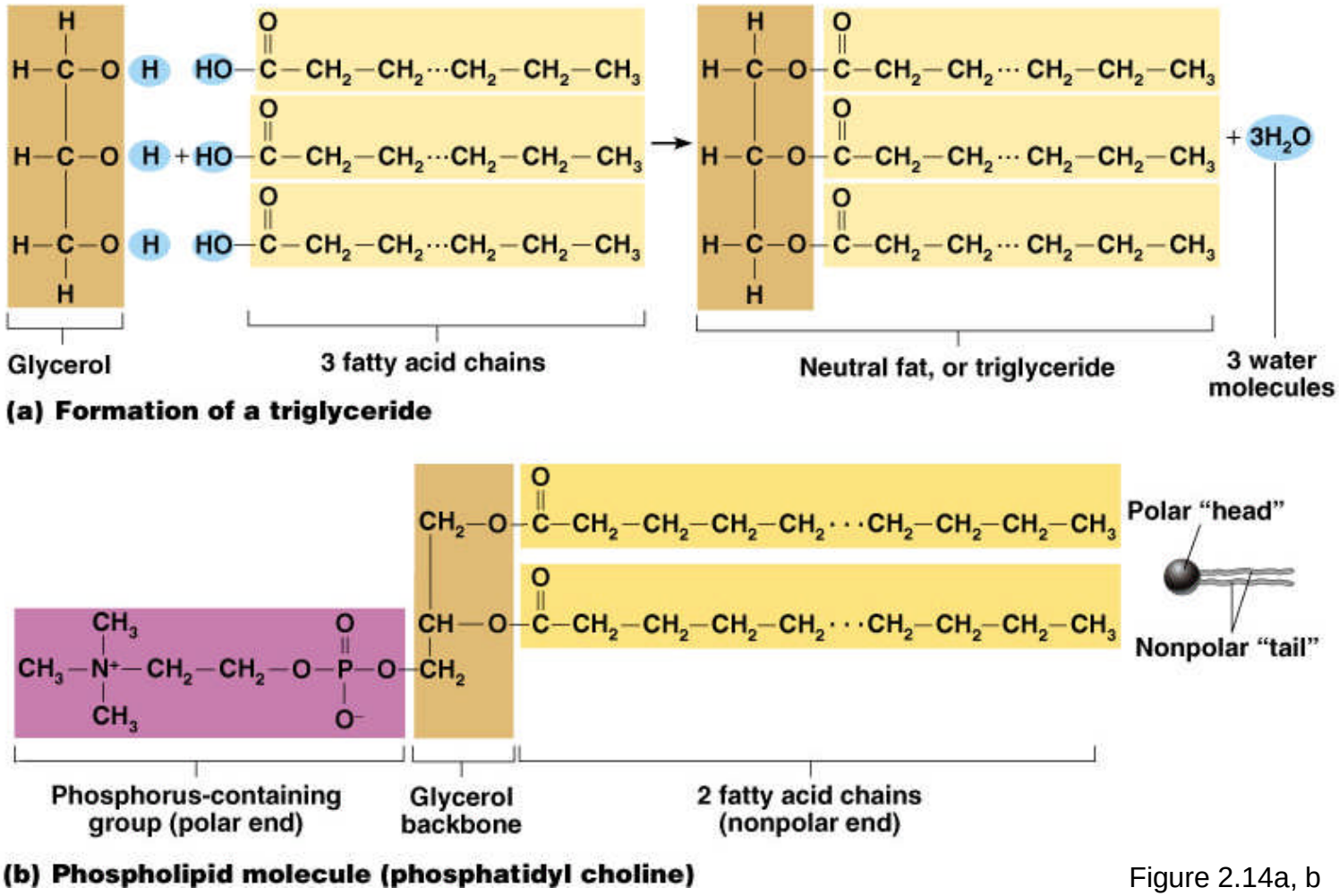
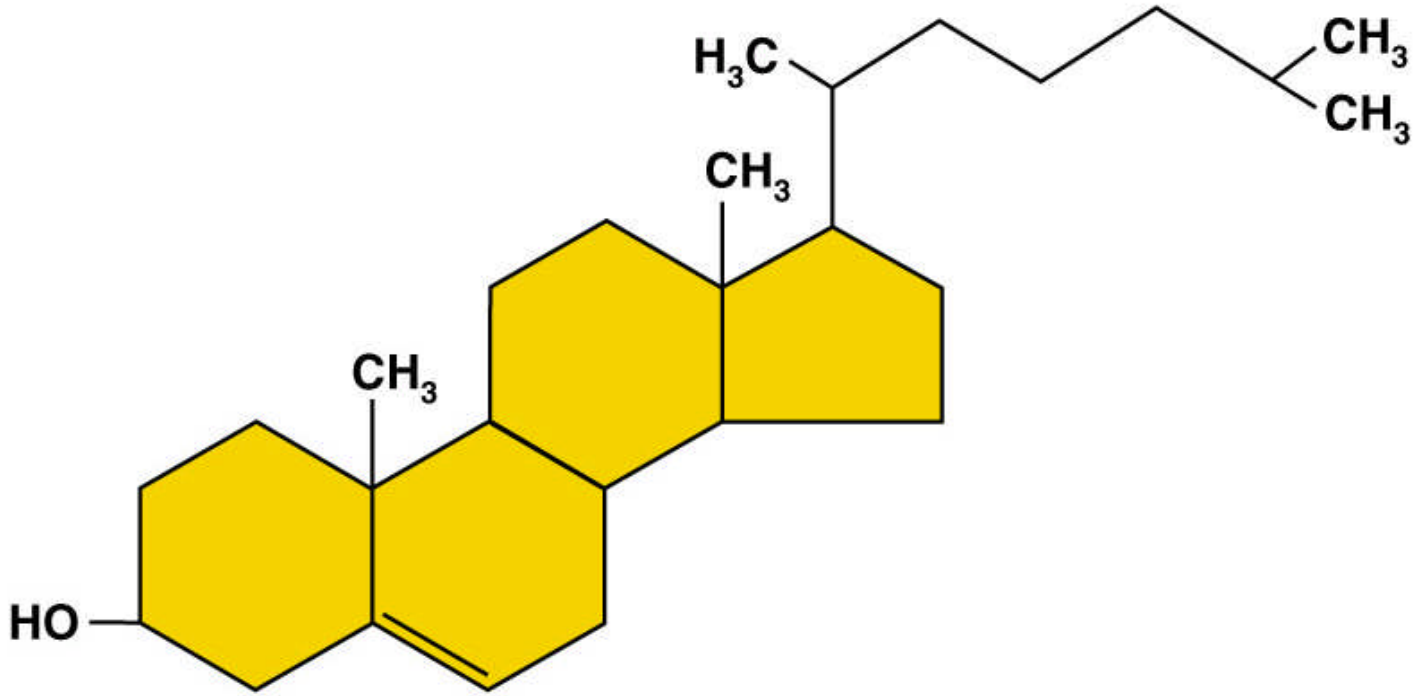


Figure 2.14a, b

Cholesterol



(c) Cholesterol

Figure 2.14c

Important Organic Compounds

- Proteins
  - Made of strings of the 20 amino acids
    - Contain carbon, oxygen, hydrogen, nitrogen, and sometimes sulfur
    - Amino acids have three main parts
      - Amine group – gives basic properties
      - Acid group – allows them to act as acids
      - R-group – variable
    - Strung together with peptide bonds to make polypeptides (proteins)

Important Organic Compounds

- Account for over half of the body's organic matter
  - Provides for construction materials for body tissues
  - Plays a vital role in cell function
    - Act as enzymes, hormones, and antibodies
  - Classified in two divisions
    - Fibrous (structural) proteins
    - Globular (functional) proteins
  - Can be denatured by heat, pH changes – changes the active site (structure and function)

Enzymes

- Act as biological catalysts – names end in *ase*
  - Increase the rate of chemical reactions by lowering the level of activation energy required for the reaction
- Do not get changed by the reactions they work with
- Can be used multiple times – only need small amounts
- Determine which reactions can take place – enzyme must be present for reaction to occur
- Specific for their individual job

Figure 2.16

Enzymes

- Structure of enzyme (really a protein) must be correct before it can bind to the substrate – structure and function
  - Just like proteins, can be denatured by heat or changes in pH
  - Can be activated or deactivated according to bodies need for the enzyme

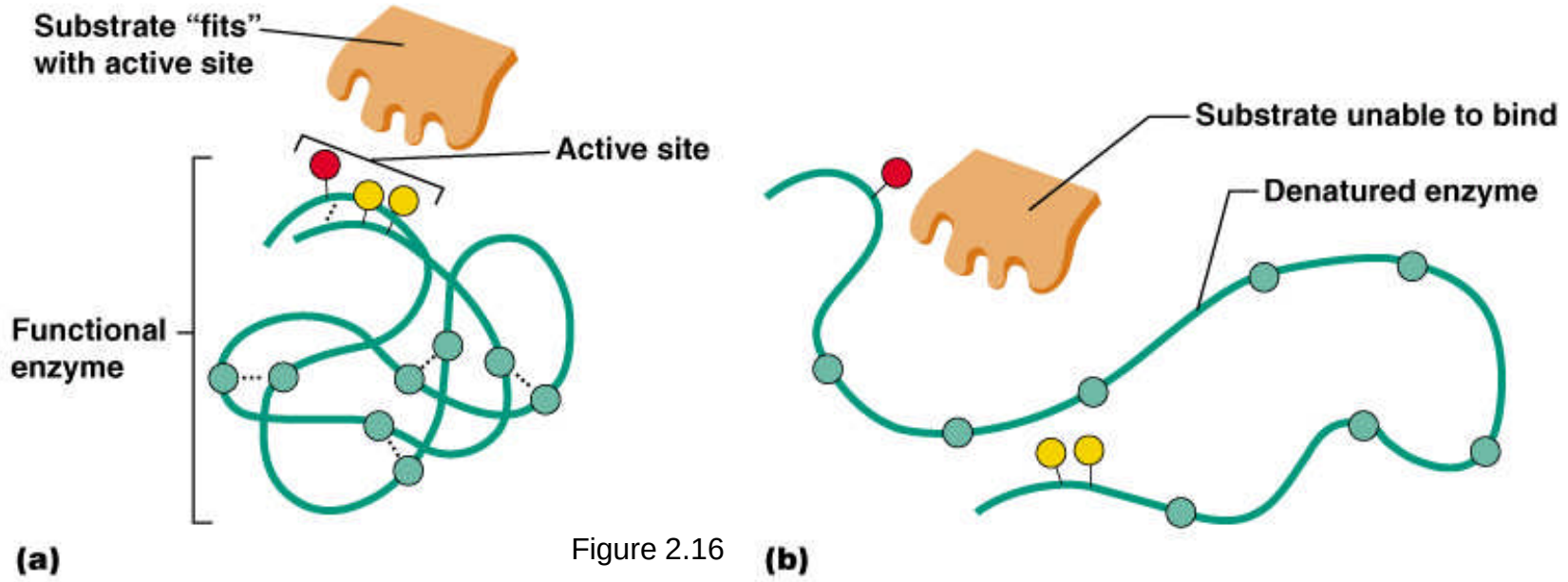


Figure 2.16

Important Organic Compounds

- Nucleic Acids
  - Provide blueprint of life
  - Nucleotide bases
    - A = Adenine
    - G = Guanine
    - C = Cytosine
    - T = Thymine
    - U = Uracil
  - Make DNA and RNA

- Nucleotides – 3 parts
  - Nitrogen-containing base
  - A pentose sugar – either deoxyribose or ribose
  - A phosphate group

Important Organic Compounds

- Deoxyribonucleic acid (DNA)
  - Organized by complimentary bases to form double helix
  - Replicates before cell division
  - Provides instruction for every protein in the body

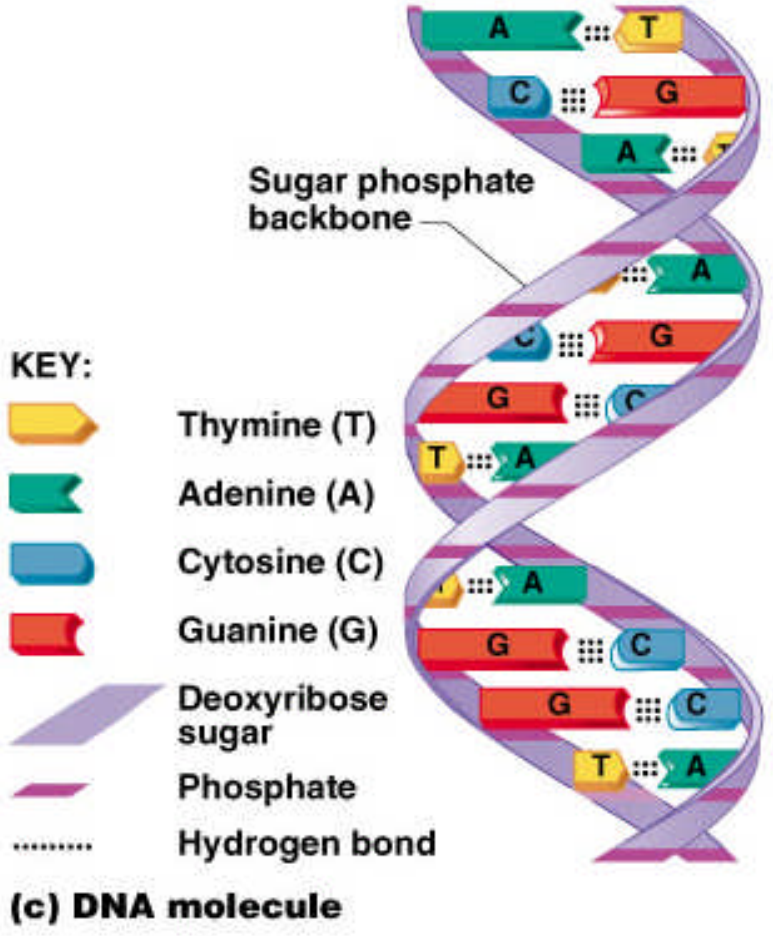


Figure 2.17c

Important Organic Compounds

- Ribonucleic acid (RNA)
  - Single stranded
  - Three types
    - mRNA, tRNA, rRNA
  - Used in protein synthesis

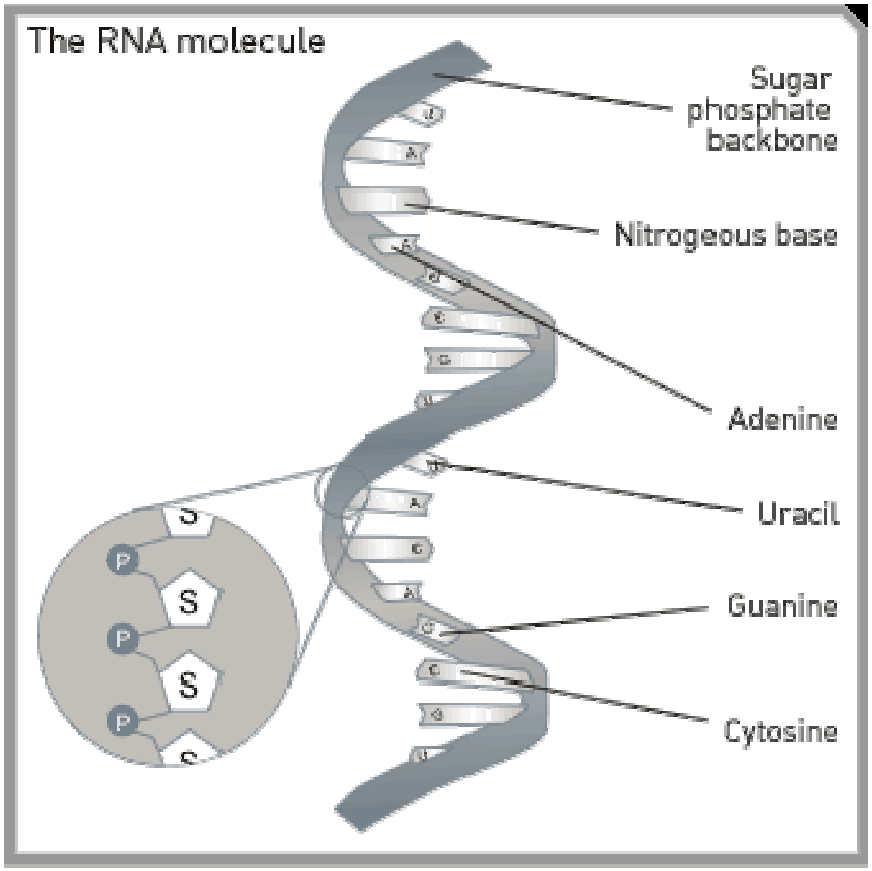


Figure 2.17c

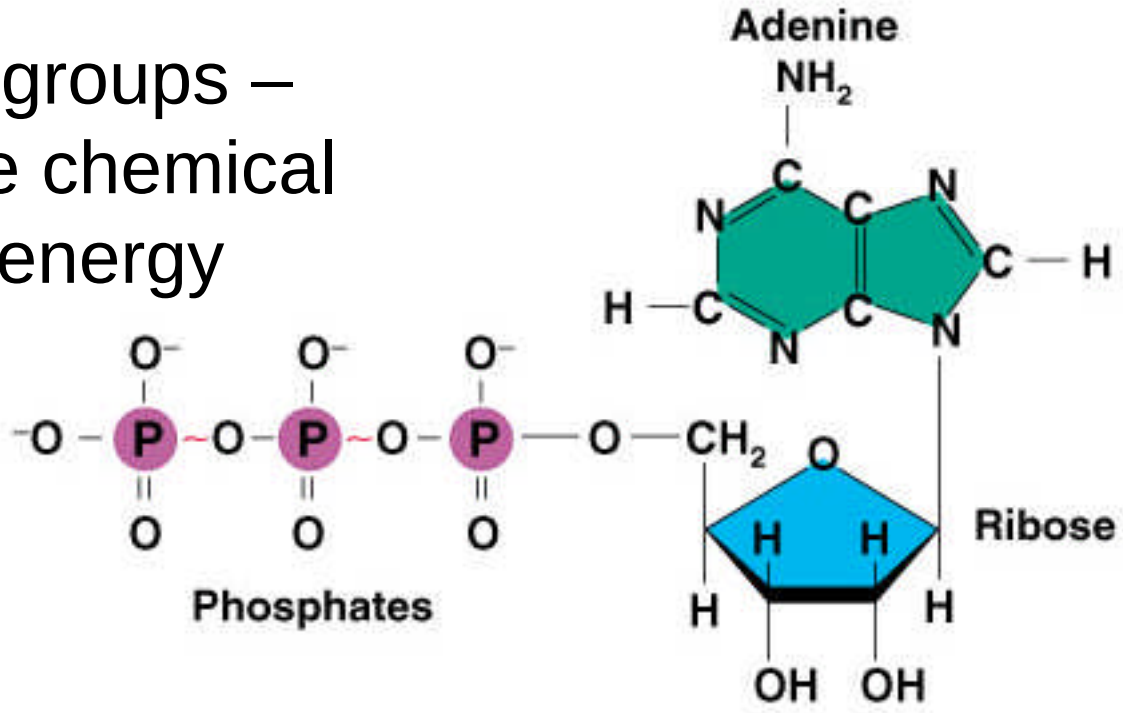
Important Organic Compounds

- Adenosine triphosphate (ATP)
  - Chemical energy used by all cells
  - Energy is released by breaking high energy phosphate bond
  - ATP is replenished by oxidation of food fuels

Adenosine Triphosphate (ATP)

- Modified nucleotide
  - Adenine base
  - Ribose sugar
  - Three phosphate groups – attached by unique chemical bonds called high-energy phosphate bonds

- ATP → ADP + P + E



(a) Adenosine triphosphate (ATP)

Figure 2.18a

How ATP Drives Cellular Work

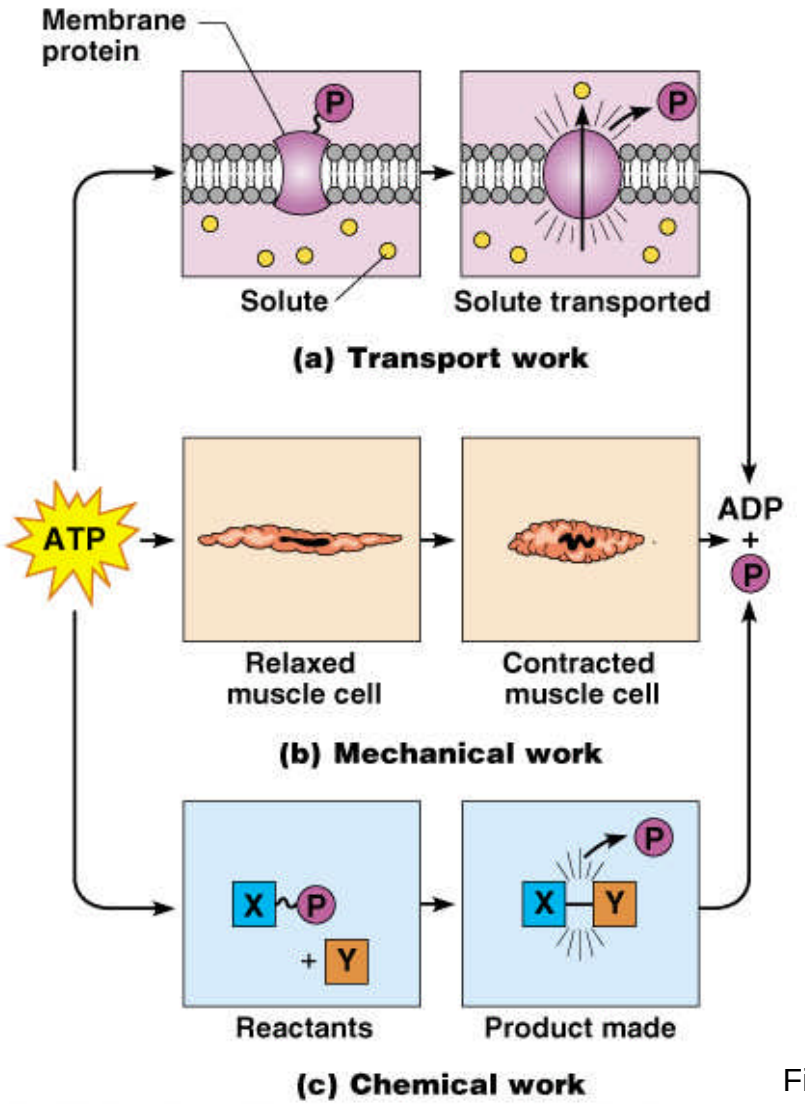


Figure 2.19