Essentials of Human Anatomy & Physiology

Seventh Edition

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Chapter 2

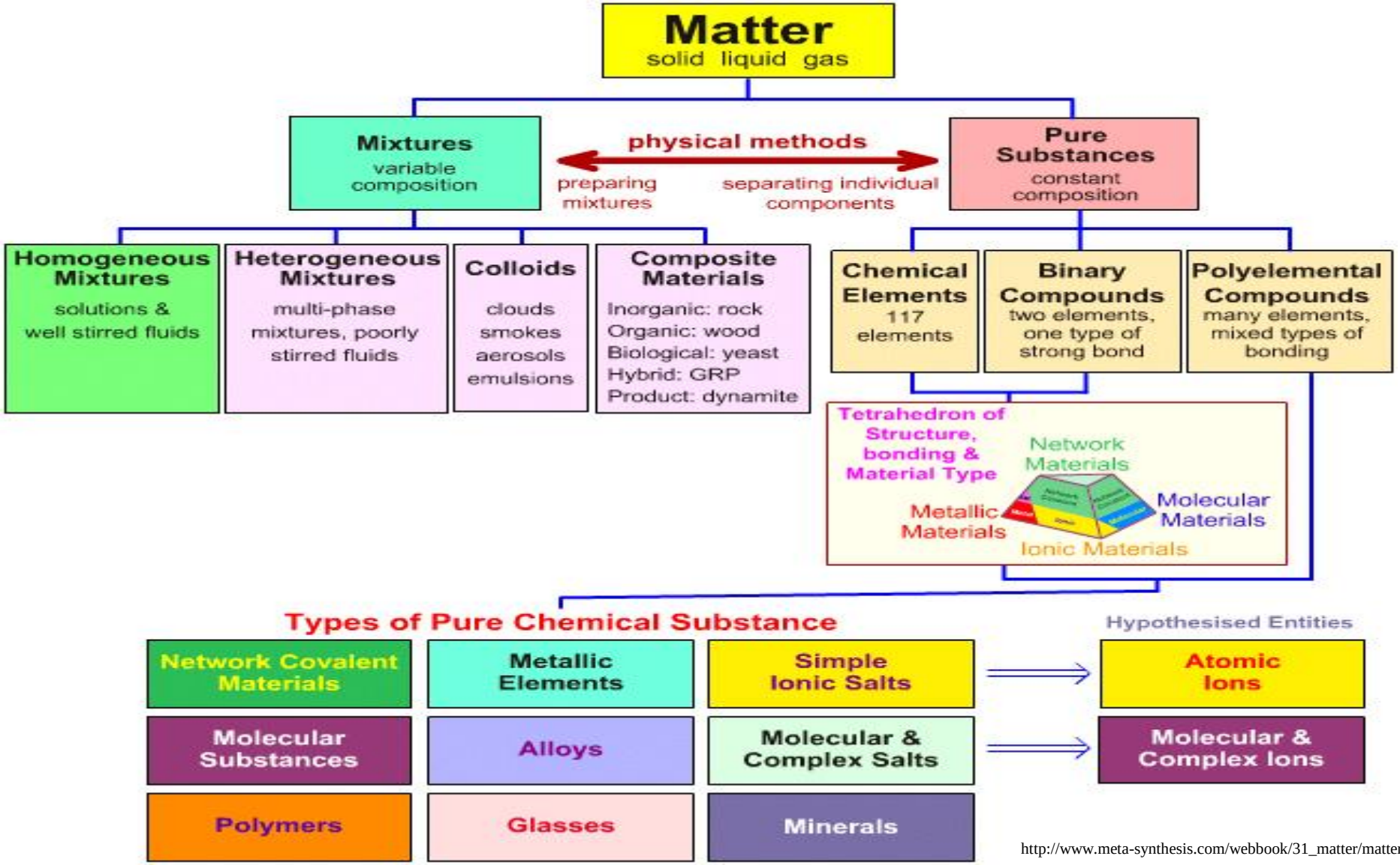
Basic Chemistry

Slides 2.1 – 2.20

Lecture Slides in PowerPoint by Jerry L. Cook

Matter

- Anything that occupies space and has mass



http://www.meta-synthesis.com/webbook/31_matter/matter.jpg

Matter and Energy

- Energy – the ability to do work
  - Potential energy- stored energy (in bonds)

    ex.- ATP (remove a phosphate to release energy), a roller coaster on top of a hill

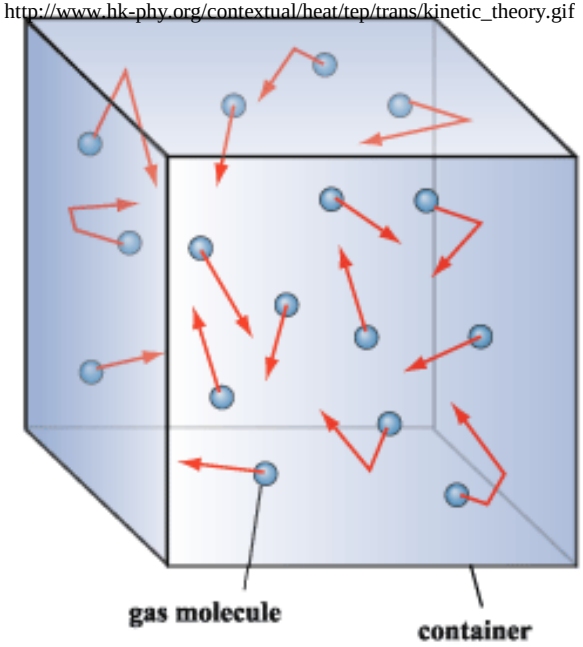
http://ffden-2.phys.uaf.edu/211_fall2002.web.dir/Shawna_Sastamoinen/Velocity&Kinetic_files/image003.jpg

Matter and Energy

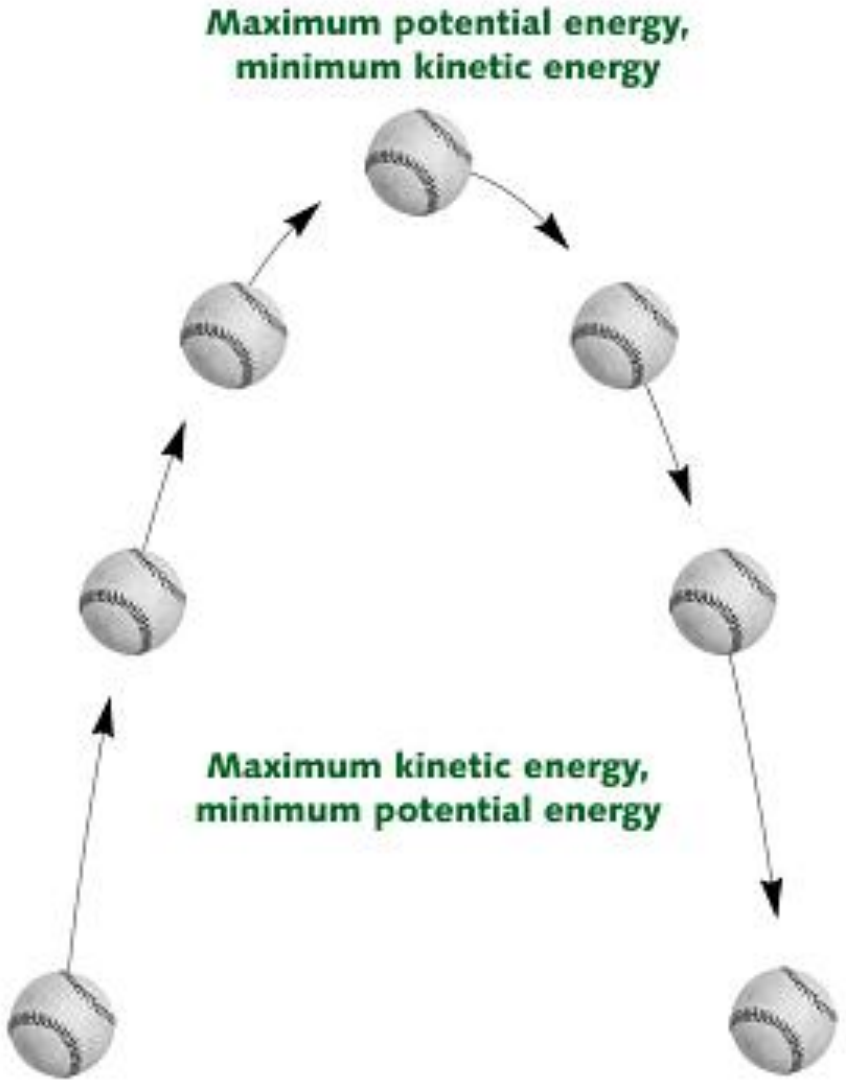
- Kinetic energy- energy of motion

  ex.- temperature (molecular movement), boats racing

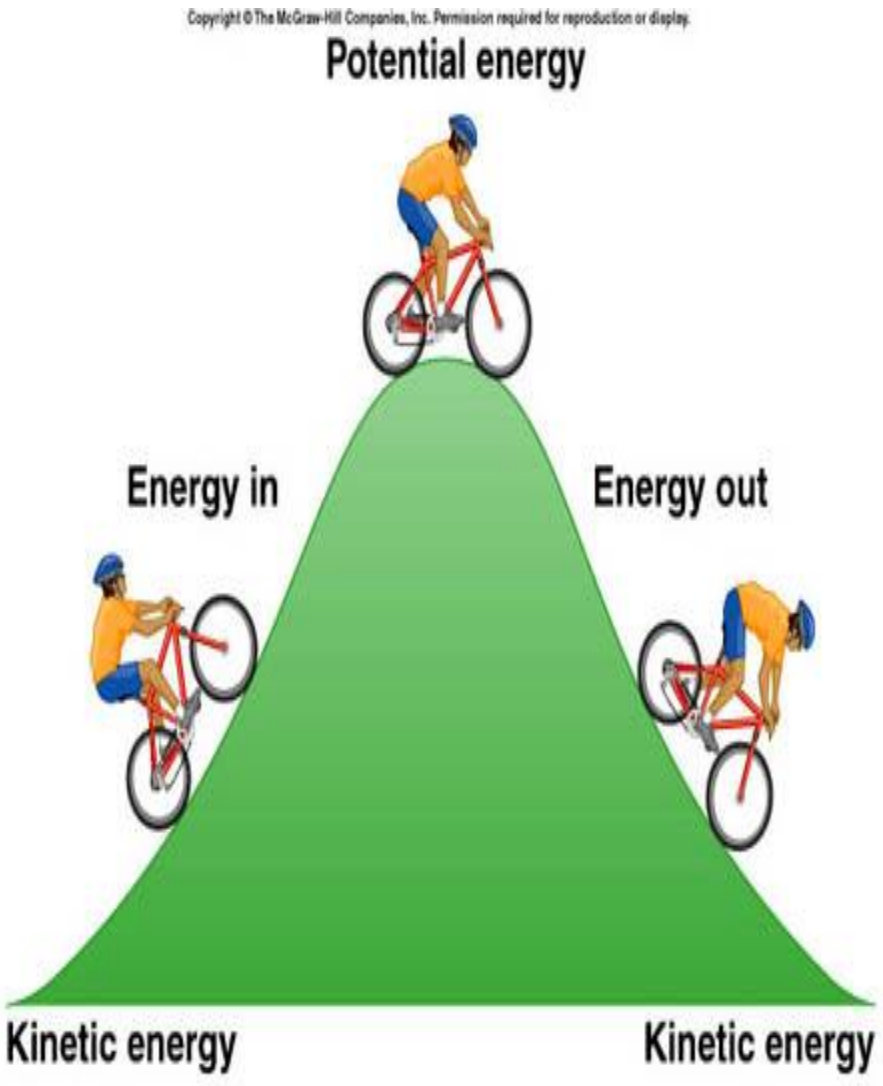
http://www.hk-phy.org/contextual/heat/tep/trans/kinetic_theory.gif



http://www.sei.ie/uploadedfiles/Education/Unit2_2C_speed_boats1.jpg



http://www.greenscreen.org/articles_sr/energy/images_potential_kinetic_energy/potential_kinetic.jpg



http://www.citruscollege.edu/pic/46/c05_05.jpg

Matter and Energy

Types of energy

- Chemical- stored in bonds

  ex.- ATP

- Electrical- flow of electrons

  ex.- nervous signals

- Mechanical- movement of parts

  ex.- locomotion, propulsion of substances through the digestive system

- Radiant- waves of particles

  ex.- light (necessary for vision)

- Thermal- heat

  ex.- created by muscles during contraction

Composition of Matter

- Elements
  - Fundamental units of matter
  - 96% of the body is made from four elements
    - Carbon (C)
    - Oxygen (O)
    - Hydrogen (H)
    - Nitrogen (N)
- Atoms
  - Building blocks of elements

Atomic Structure

- Nucleus
  - Protons (p^+)
  - Neutrons (n^0)
- Outside of nucleus
  - Electrons (e^-)

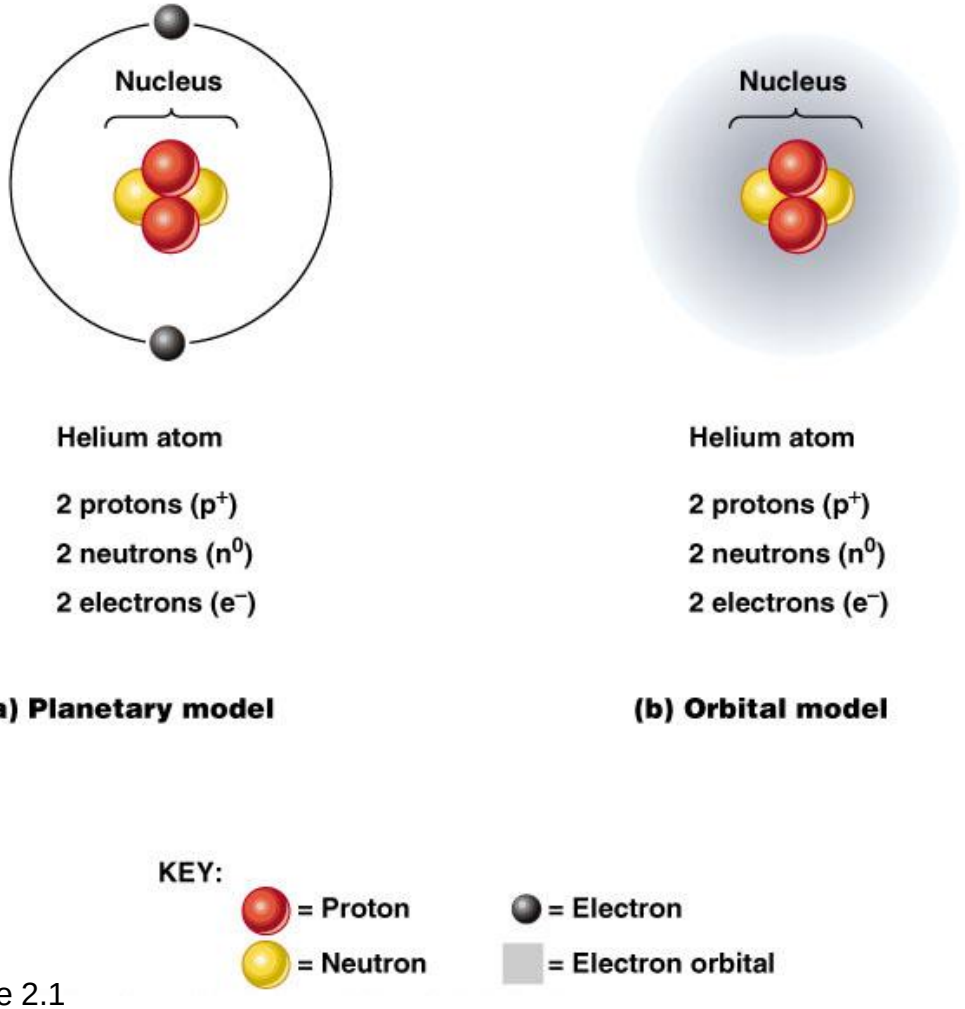


Figure 2.1

Identifying Elements

- Atomic number
  - Equal to the number of protons that the atoms contain
- Atomic mass number
  - Sum of the protons and neutrons

Atomic Weight and Isotopes

- Isotopes
  - Atoms of the same element that have the same number of protons, but vary in number of neutrons
- 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
  - Makes radioisotopes more stable

Molecules and Compounds

- Molecule – two or more like atoms combined chemically

  ex.- O_2, H_2

- Compound – two or more different atoms combined chemically

  ex.- H_2O, CO_2

Chemical Reactions

- Atoms are united by chemical bonds (synthesis reactions- anabolic)
- Atoms dissociate from other atoms when chemical bonds are broken (decomposition reactions- catabolic)

Electrons and Bonding

- Electrons occupy energy levels called electron 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 fill first

Electrons and Bonding

- Bonding involves interactions between electrons in the outer shell (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 8 electrons
    - 8 = 2 + 6
  - Shell 3 has 18 electrons
    - 18 = 2 + 8 + 8

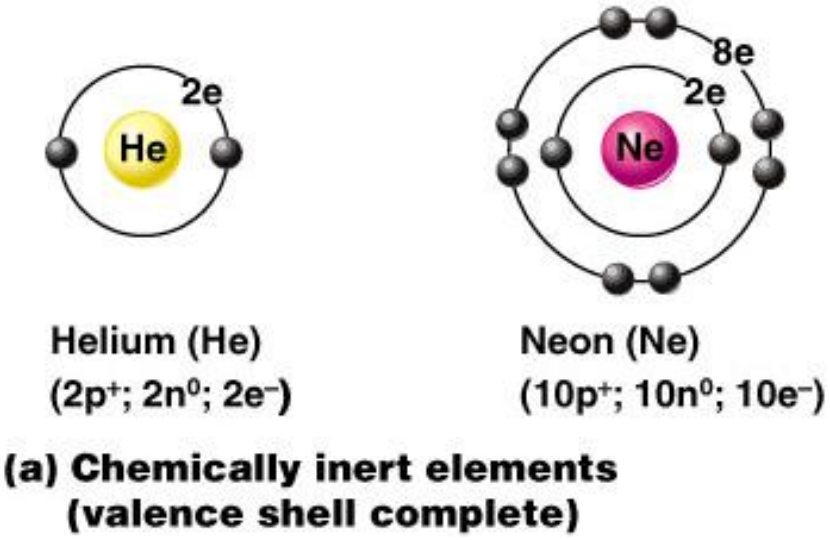


Figure 2.4a

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

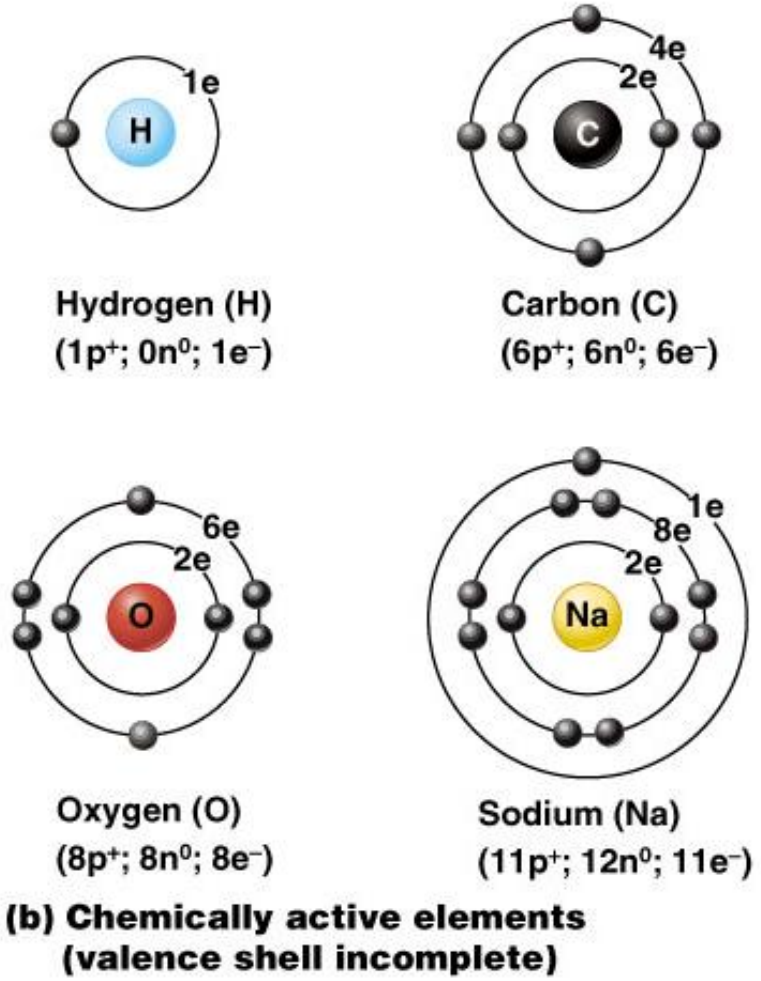


Figure 2.4b

Chemical Bonds

- Ionic Bonds
  - Form when electrons are completely transferred from one atom to another
- Ions
  - Charged particles
    - Anions are negative
    - Cations are positive
    - Either donate or accept electrons

Chemical Bonds

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

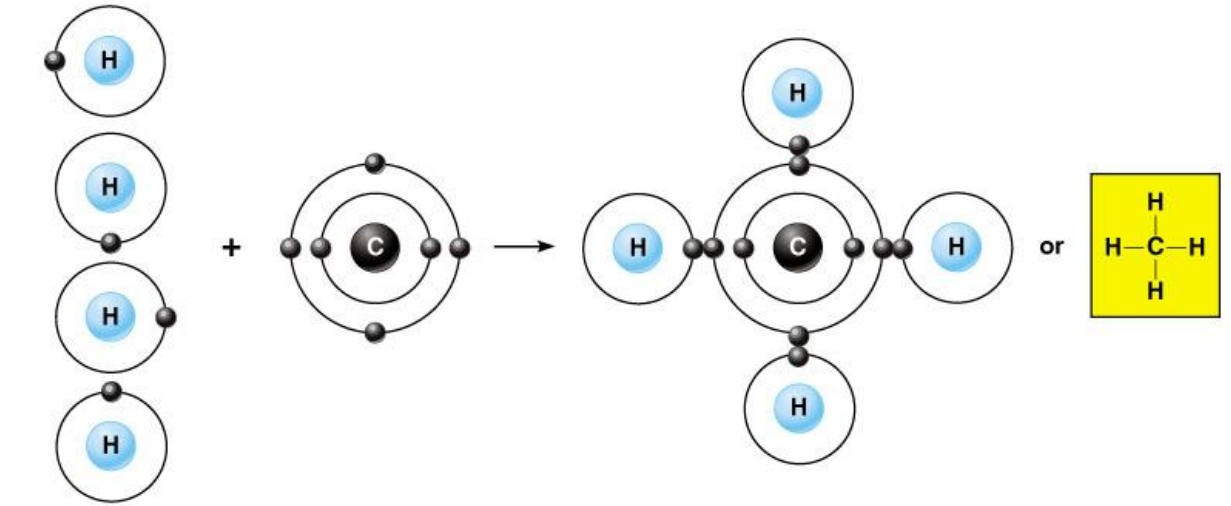


Figure 2.6c

Examples of Covalent Bonds

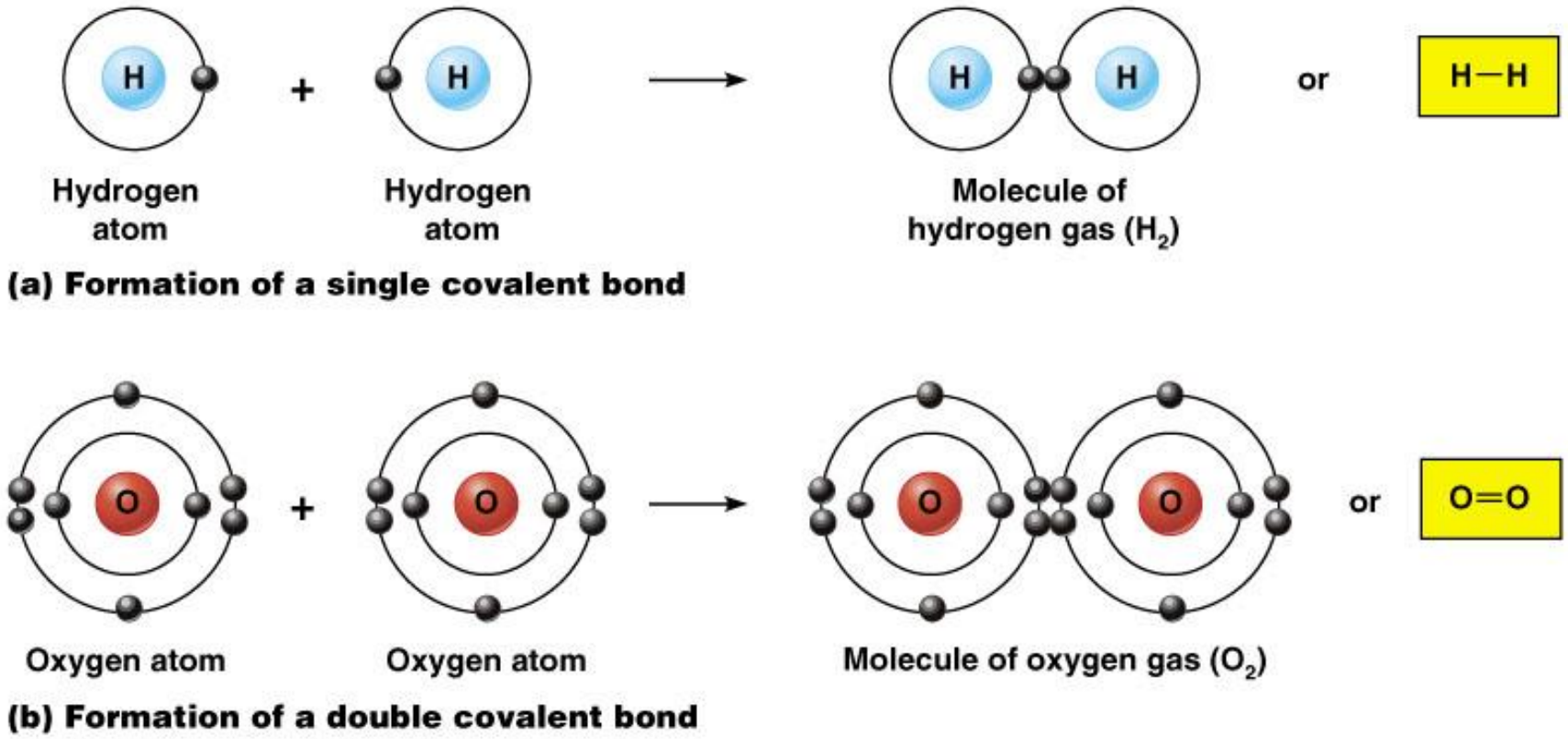


Figure 2.6a, b

Polarity

- Covalent bonded molecules
  - Some are non-polar
    - Electrically neutral as a molecule
  - Some are polar
    - Have a positive and negative side

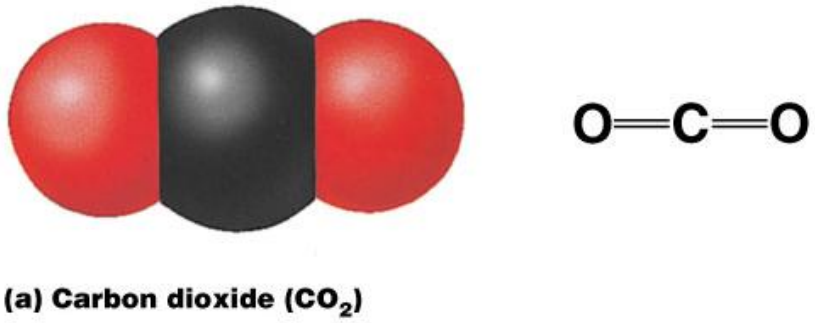
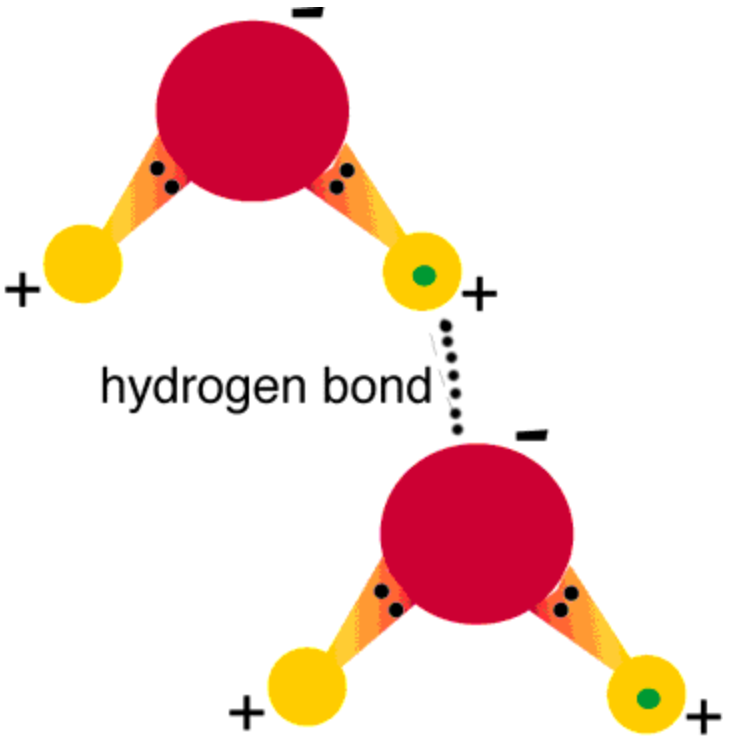


Figure 2.7

Chemical Bonds



- Hydrogen bonds
  - Weak chemical bonds
  - Hydrogen is attracted to negative portion of polar molecule
  - Provides attraction between molecules

Patterns of Chemical Reactions

- Synthesis reaction (A+B→AB)
  - Atoms or molecules combine
  - Energy is absorbed for bond formation
  - Anabolic reaction
  - Ex.- amino acids bond to form proteins
- Decomposition reaction (AB→A+B)
  - Molecule is broken down
  - Chemical energy is released
  - Catabolic reaction
  - Ex.- ATP loses a phosphate, releasing energy!

Synthesis and Decomposition Reactions

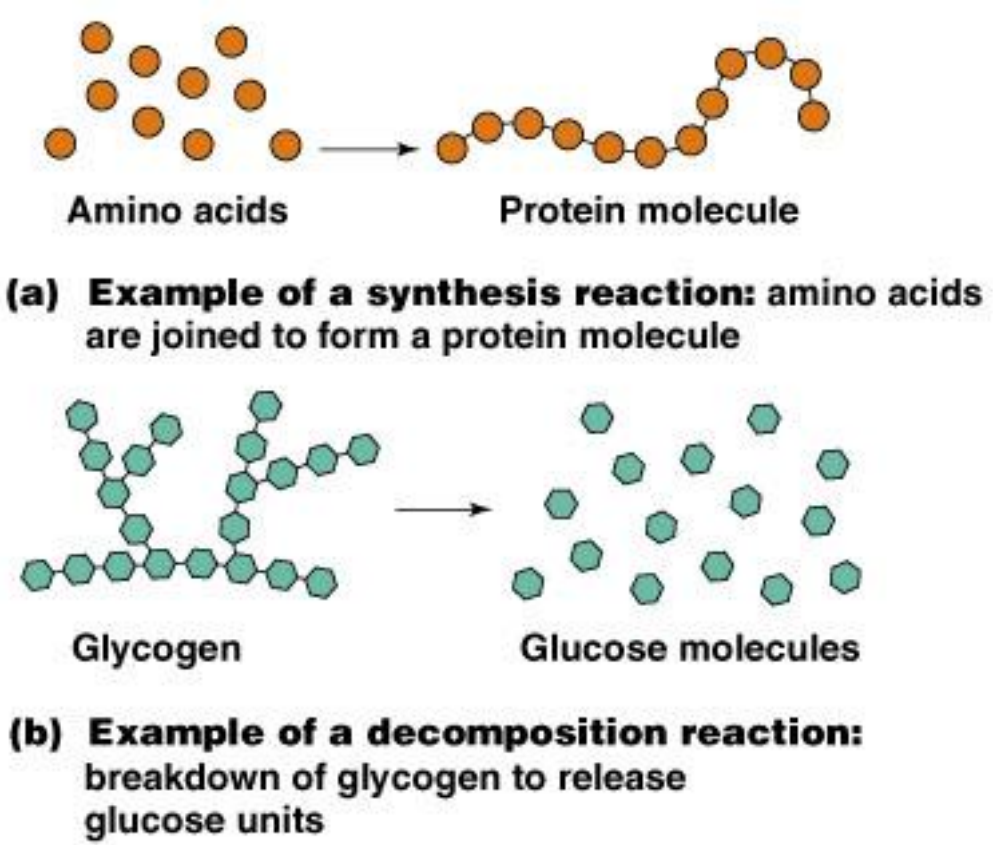


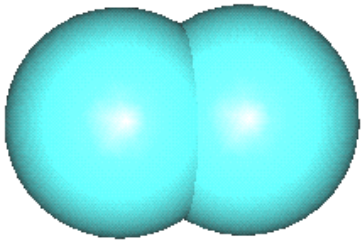
Figure 2.9a, b

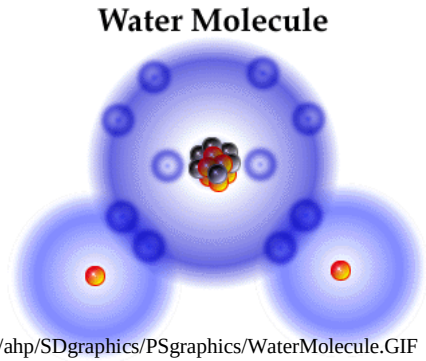
Patterns of Chemical Reactions

- Exchange reaction (AB + C→AC+B)
  - Involves both synthesis and decomposition reactions
  - Switch is made between molecule parts and different molecules are made
  - Ex.- Glucose 6 phosphate gives up a phosphate to ADP to make ATP

Biochemistry: Essentials for Life

- Inorganic compounds
  - Lack carbon
  - Tend to be simpler compounds
  - Example: H_2O (water), NaCl (sodium chloride), CO_2 (carbon dioxide), O_2 (oxygen)





http://www.brooklyn.cuny.edu/bc/ahp/SDgraphics/PSgraphics/WaterMolecule.GIF

Important Inorganic Compounds

- **Water**
  - **Most abundant inorganic compound**
  - **Vital properties**
    - **High heat capacity- does not change temperature easily**
    - **Chemical reactivity- serves as a base for reactions**
    - **Cushioning**
    - **Expands when it freezes**
    - **pH of 7 (neutral)**

Important Inorganic Compounds

Water is polar:

- Good solvent- able to dissolve many substances if they are polar

- Surface tension- water molecules adhere to one another across its surface

- Capillarity- water will rise up in a tube due to cohesion and adhesion

Important Inorganic Compounds

- Salts- ionic compounds
  - Easily dissociate into ions in the presence of water
  - Vital to many body functions
  - Include electrolytes which conduct electrical currents
  - ex.- NaCl = sodium chloride, $Ca_3(PO_4)_2$= calcium phosphate

Important Inorganic Compounds

- **Acids**
  - **Can release detectable hydrogen ions (H+)**
  - **Low pH (below 7), Taste sour**
  - **Ex.-**

    Common- lemon juice, coffee, carbonic acid in soda

    In body- Gastric juice, uric acid, vitamin C, amino acids, nucleic acids, lactic acid, fatty acids, vaginal fluid

Bases

- Proton (H+) acceptors (most have hydroxide ions- OH-)
- High pH (above 7), Taste bitter, Slippery
- Ex.-
  - Common- Tums, baking soda, egg whites, sea water, Draino, bleach, oven cleaner
  - In body- blood, semen

Important Inorganic Compounds

- Neutralization reaction
  - Acids and bases react to form water and a salt
  - Ex.-

    $HCl + NaOH \rightarrow H_2O + NaCl$

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

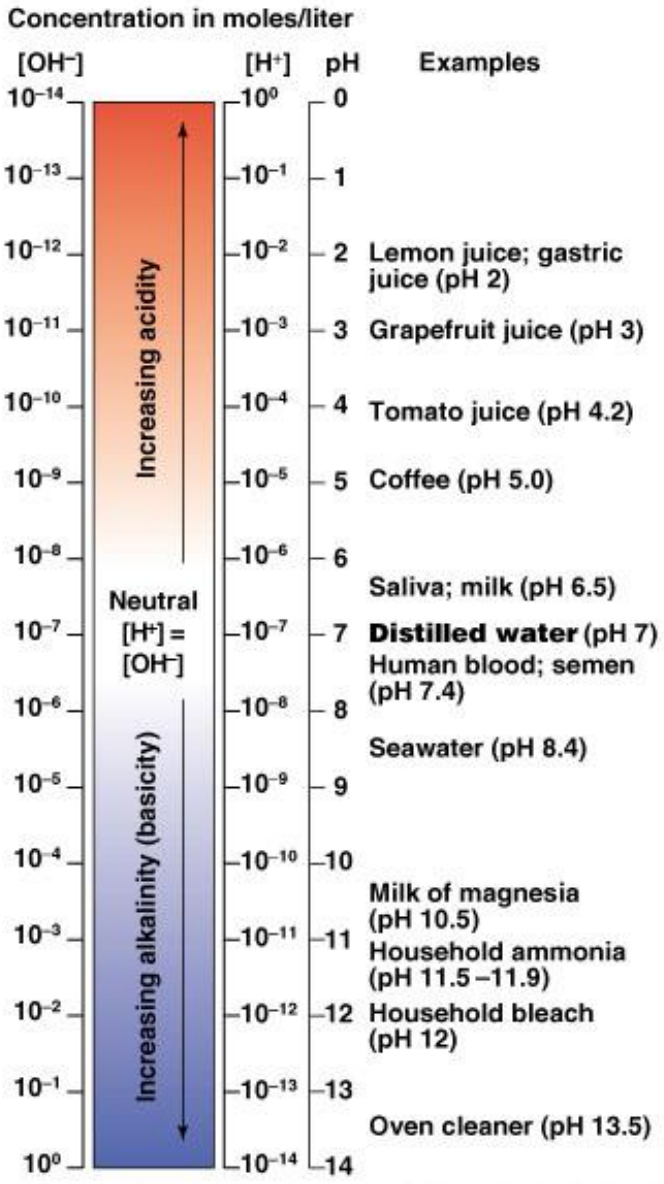


Figure 2.11

Organic compounds

- Contain carbon

- Most are covalently bonded

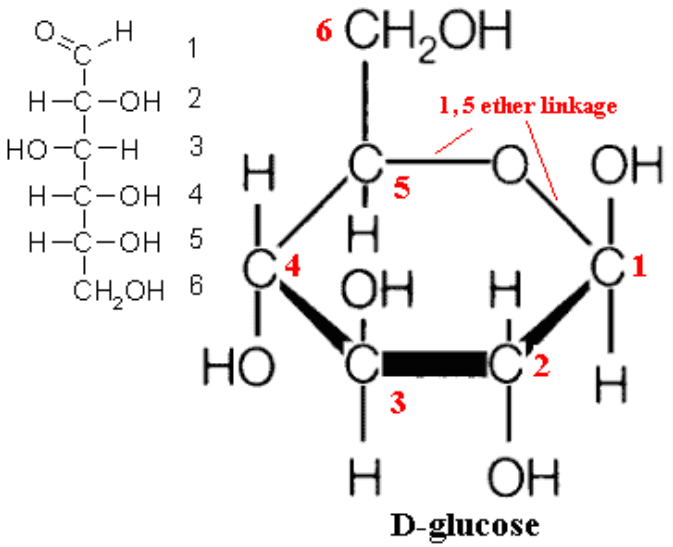
- Ex.- $C_6H_{12}O_6$ (glucose)

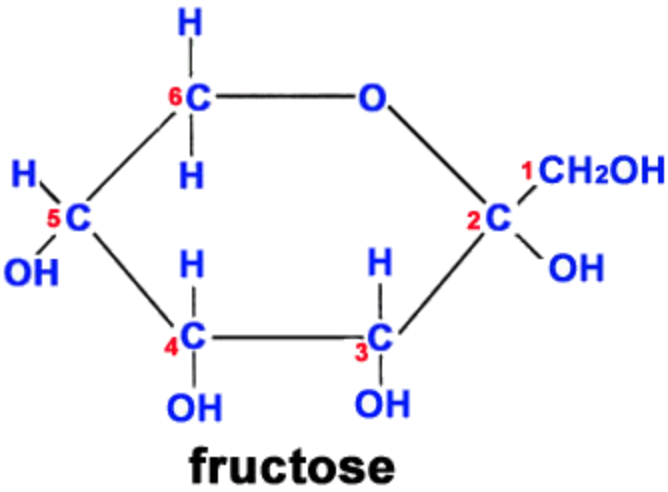
Important Organic Compounds

- Carbohydrates
  - Contain carbon, hydrogen, and oxygen in roughly a 1:2:1 ratio
  - Include sugars and starches
  - Classified according to size

Important Organic Compounds

- Monosaccharides – simple sugars
- In linear or ring forms
  - Glucose
  - Fructose
  - Ribose
  - Galactose
  - Deoxyribose



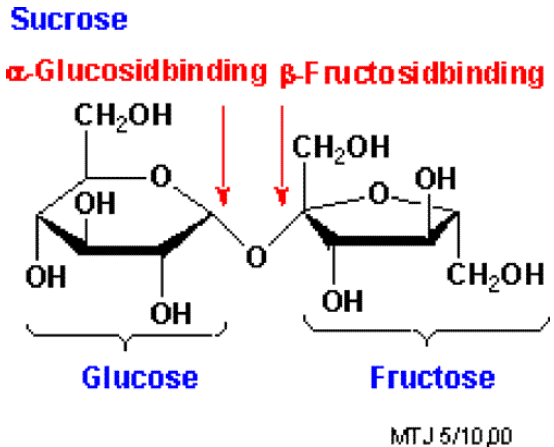


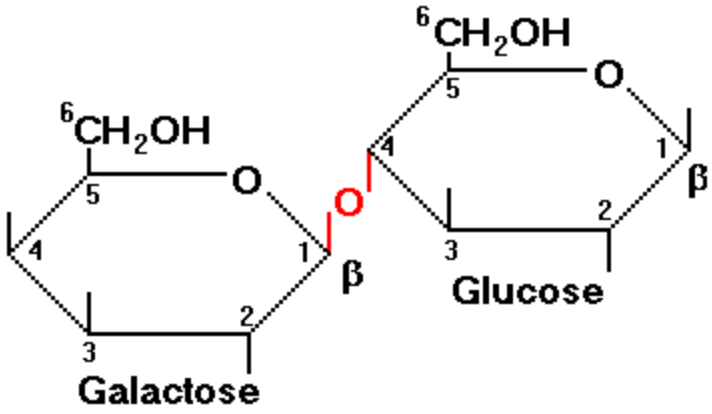
Important Organic Compounds

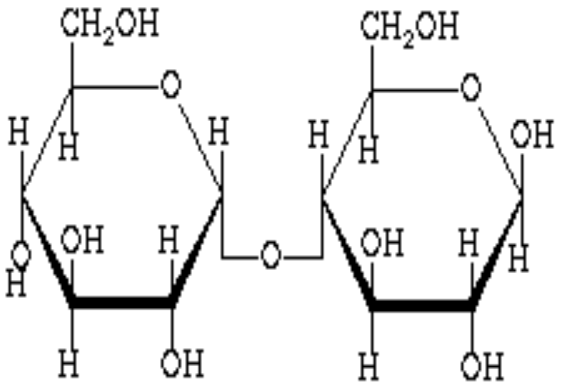
- Disaccharides – two simple sugars joined by dehydration synthesis- removal of water to form a bond (hydrogen from one and hydroxide from another form water)

- Decomposed by hydrolysis- breaking of bonds by adding water back in

Sucrose= Glucose and Fructose Maltose= Glucose and Glucose
Lactose= Glucose and Galactose





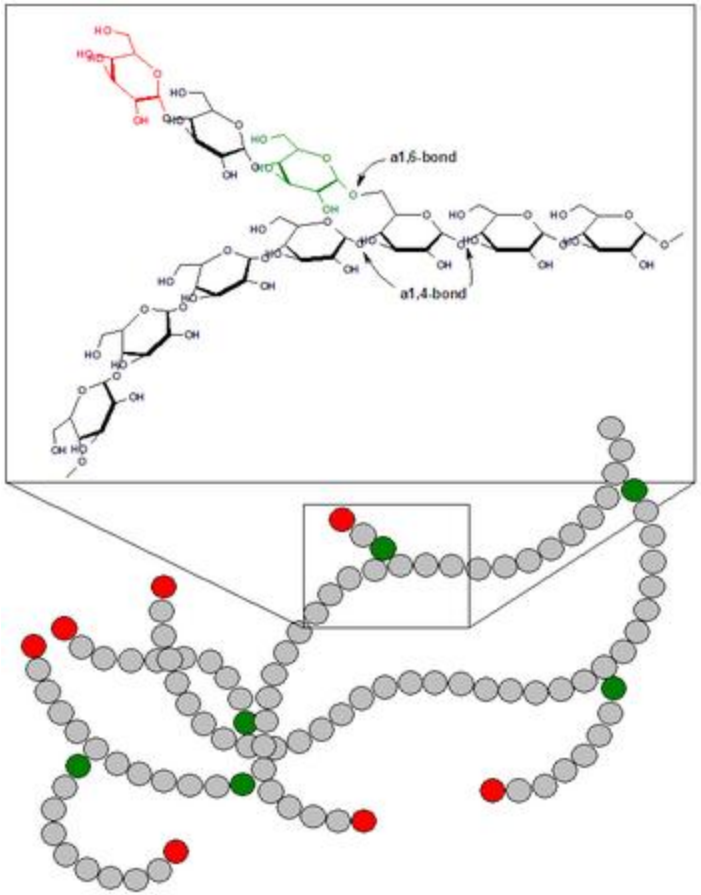


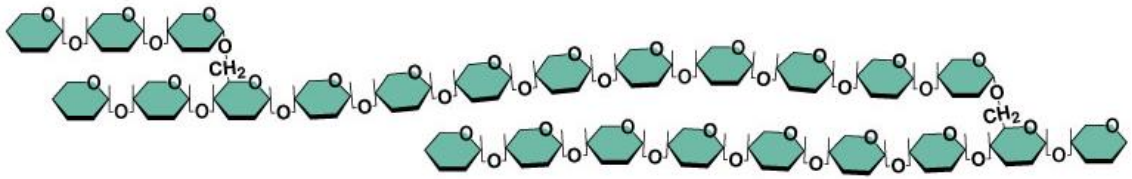
Important Organic Compounds

Polysaccharides – long branching chains of linked simple sugars

Ex.-

- Starch and cellulose- plant polysaccharides (cellulose is indigestible)
- Glycogen- animal polysaccharide
  - Stored in muscle and liver





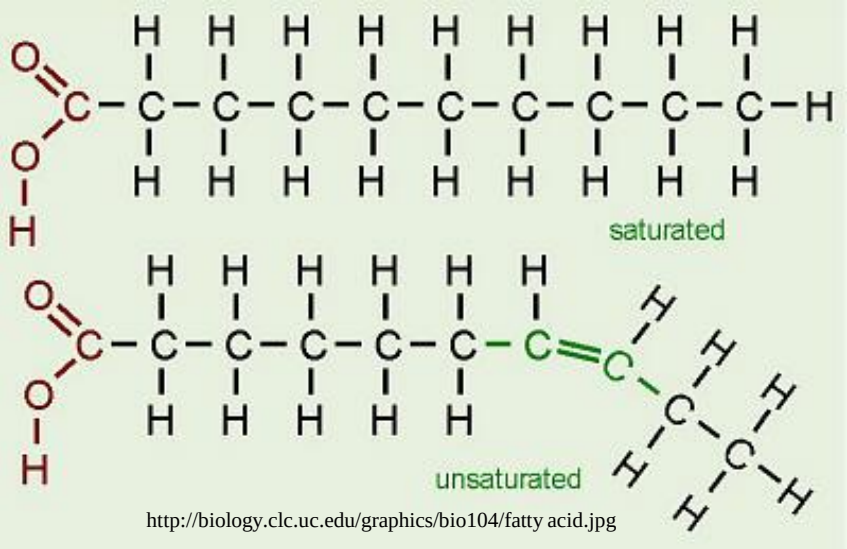
(c) Starch (polysaccharide)

Important Organic Compounds

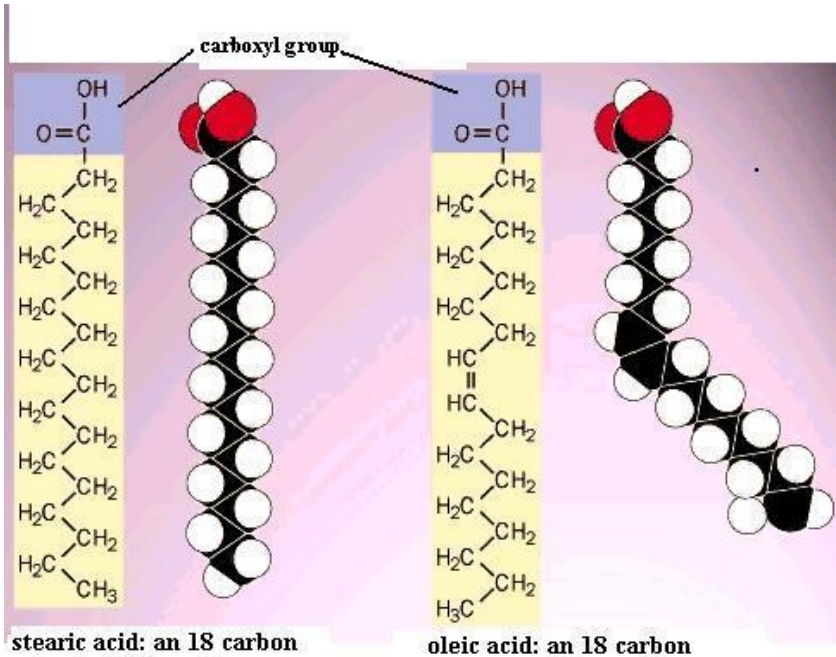
- Lipids
  - Contain carbon, hydrogen, and oxygen
    - Carbon and hydrogen outnumber oxygen
    - Monomers are fatty acids and glycerol
- Most are insoluble in water
  - Most are non-polar
  - Some have polar heads

Lipids

- Saturated- all single bonds
  - Solids at room temp.
  - Animal fats
  - “Pile up” on sides of vessels
- Unsaturated- some double bonds
  - Liquids at room temp.
  - Plant fats



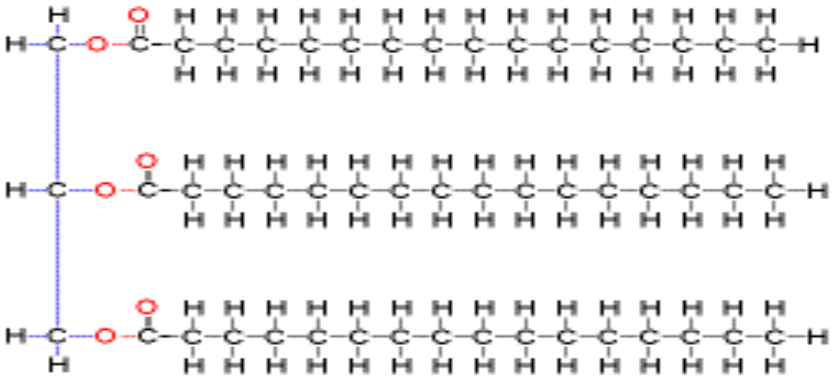
http://biology.clc.uc.edu/graphics/bio104/fatty acid.jpg



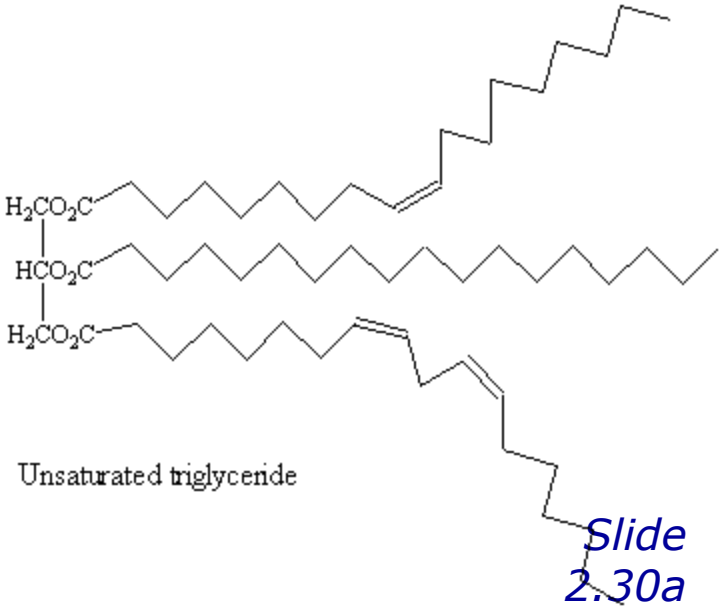
http://pirate.shu.edu/~rawncarr/molmodel/fattyacids.jpg

Important Organic Compounds

- Common lipids in the human body
  - Neutral fats (triglycerides)
    - Found in fat deposits
    - Composed of 3 fatty acids and glycerol
    - Source of stored energy



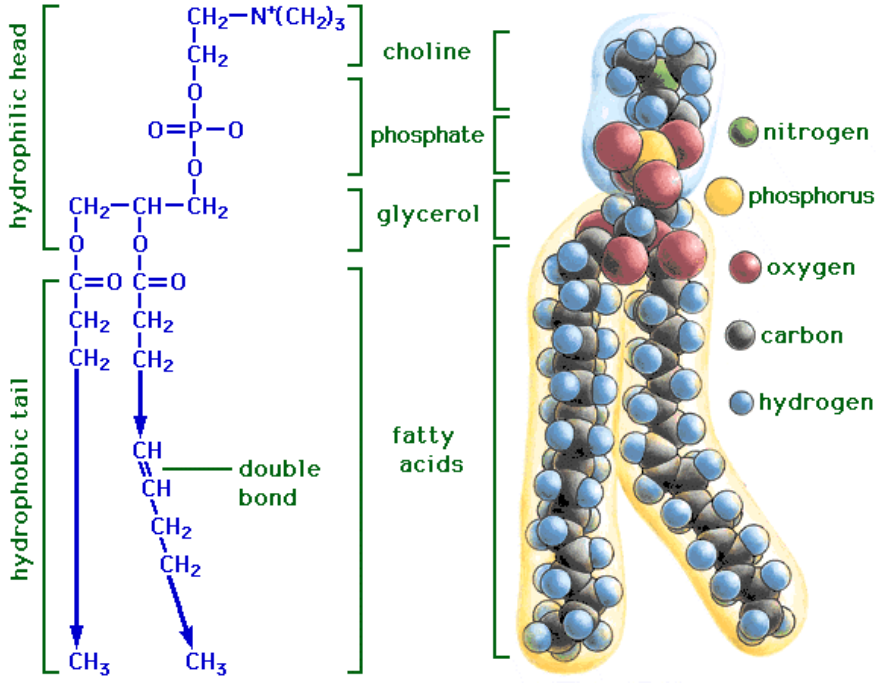
Triglyceride



Unsaturated triglyceride

Important Organic Compounds

- Common lipids in the human body (continued)
  - Phospholipids
    - Form cell membranes
    - Composed of:
      - 2 Fatty acids
      - Glycerol
      - Phosphate head



Lipids

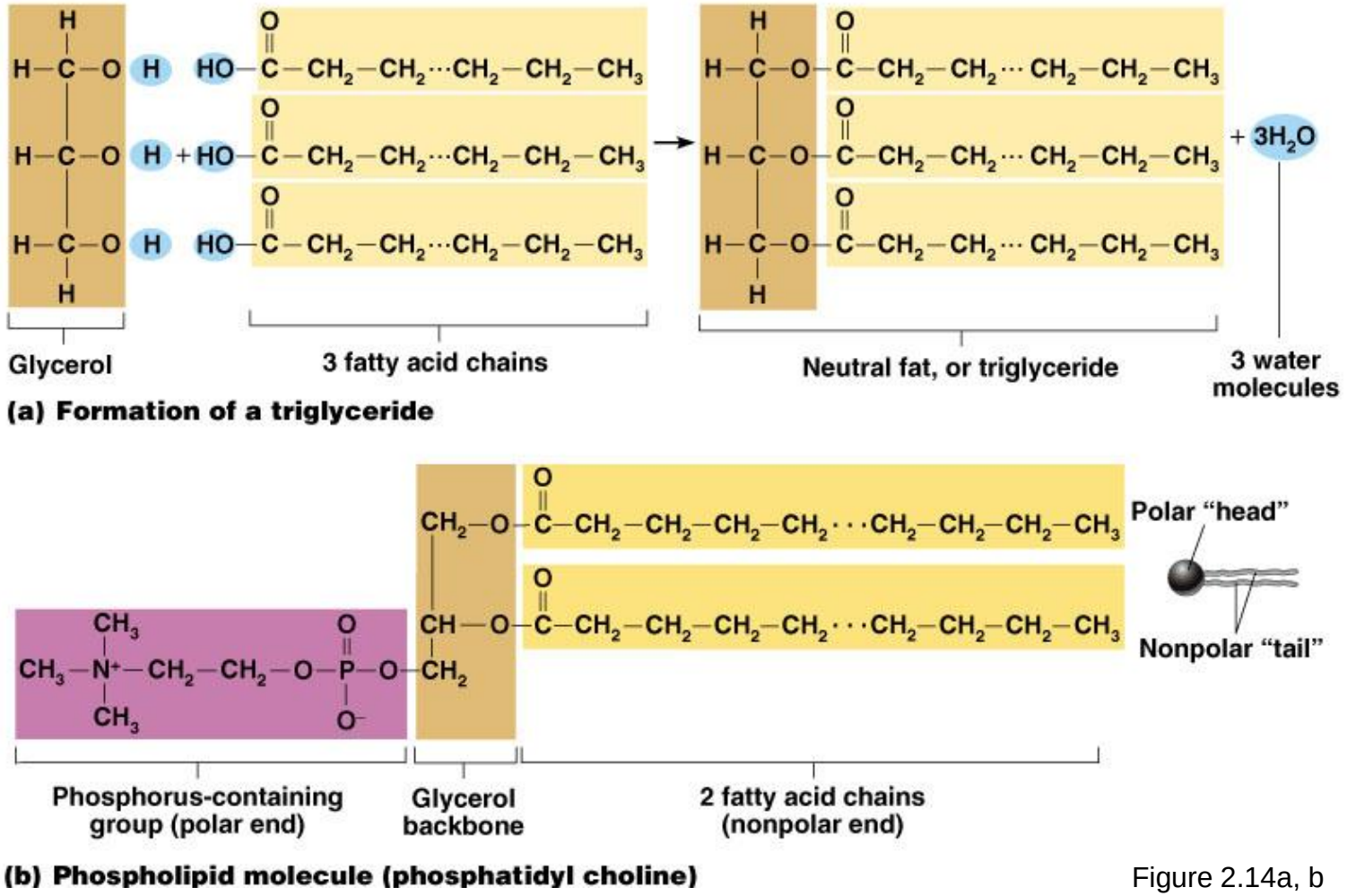
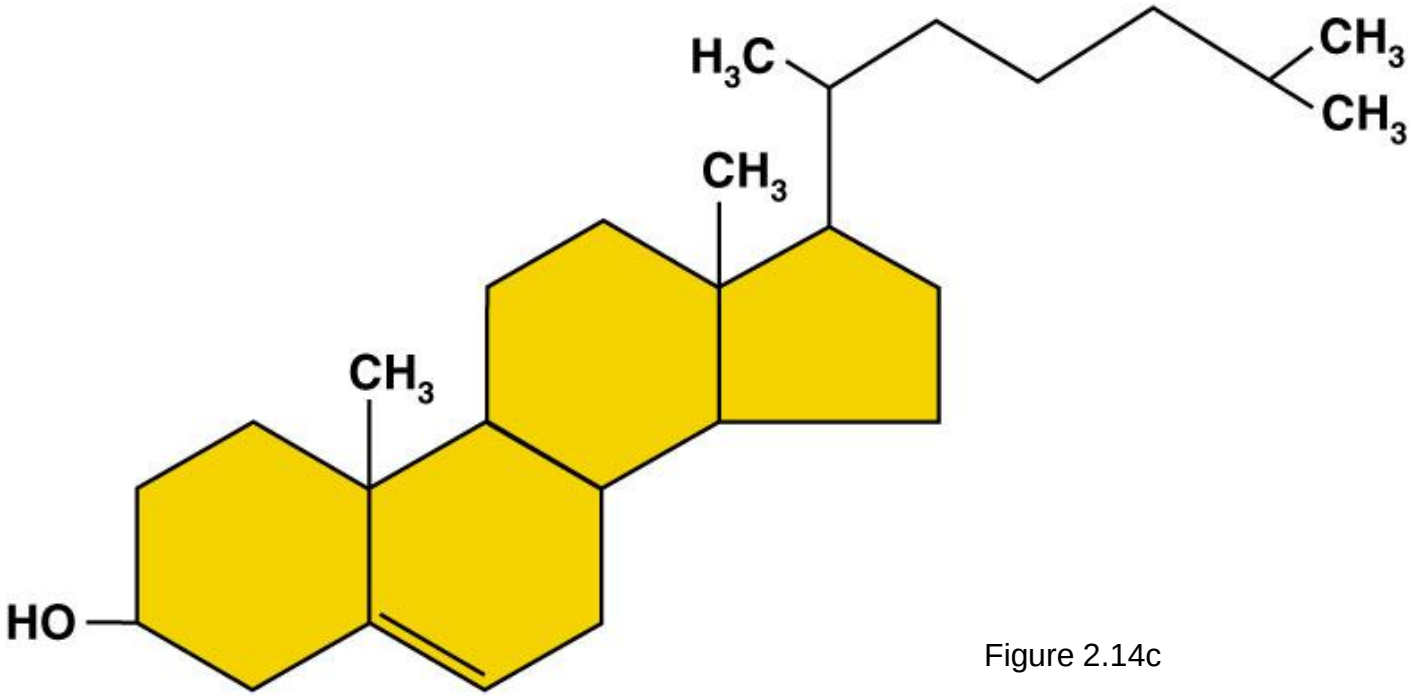


Figure 2.14a, b

Steroids

- 3 interlocking 6-C rings, a 5-C ring, and a fatty acid chain
- Ex.- cholesterol, bile salts, vitamin D, and some hormones

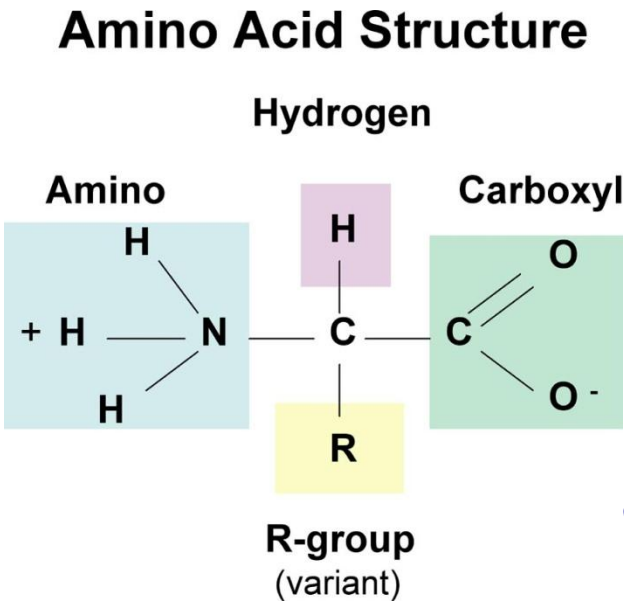


(c) Cholesterol

Figure 2.14c

Proteins

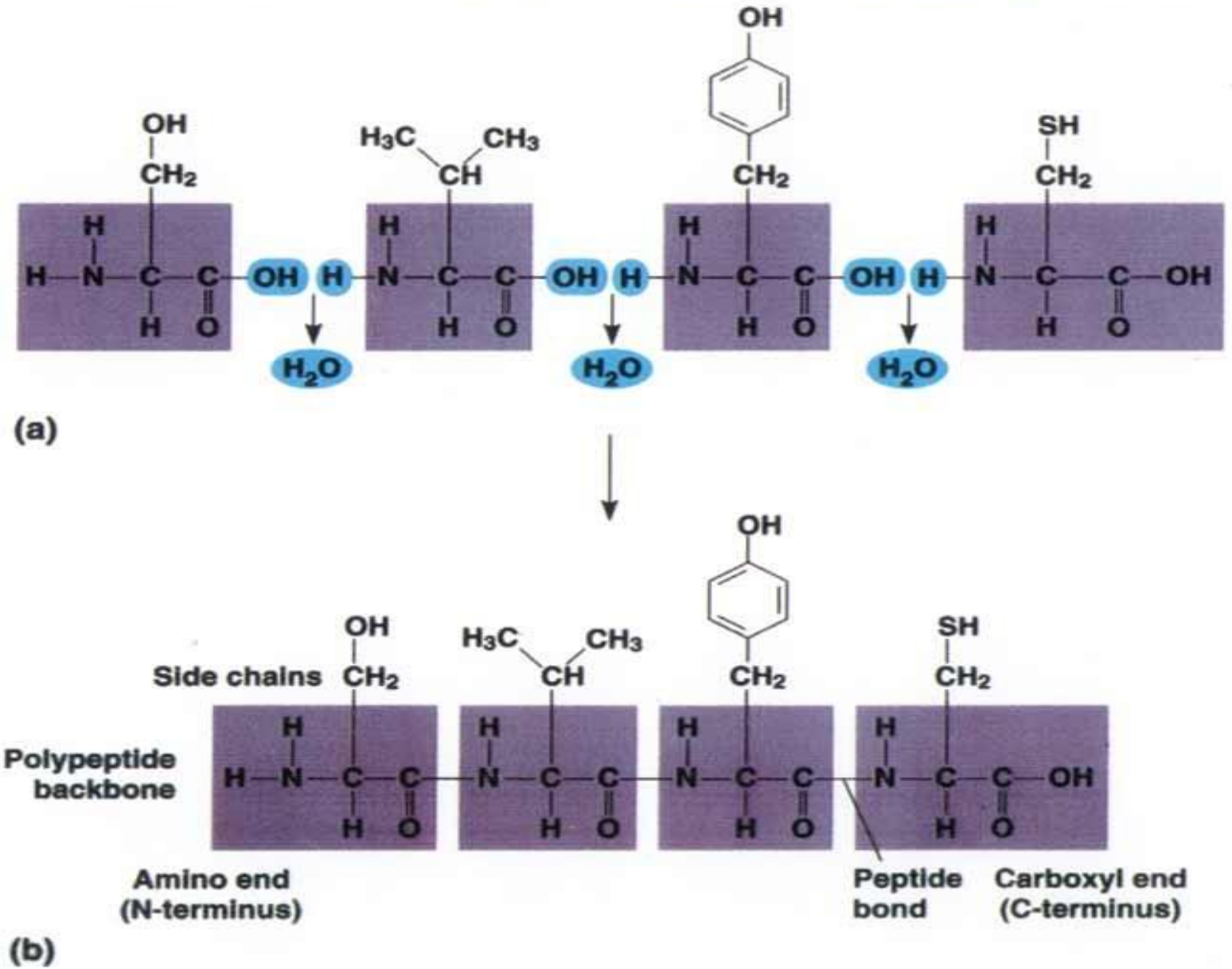
- Made of amino acids- 20 different ones
- Contain carbon, oxygen, hydrogen, nitrogen, and sometimes sulfur
- Each amino acid differs from others by a variable “R” group
- Form peptide bonds through dehydration synthesis

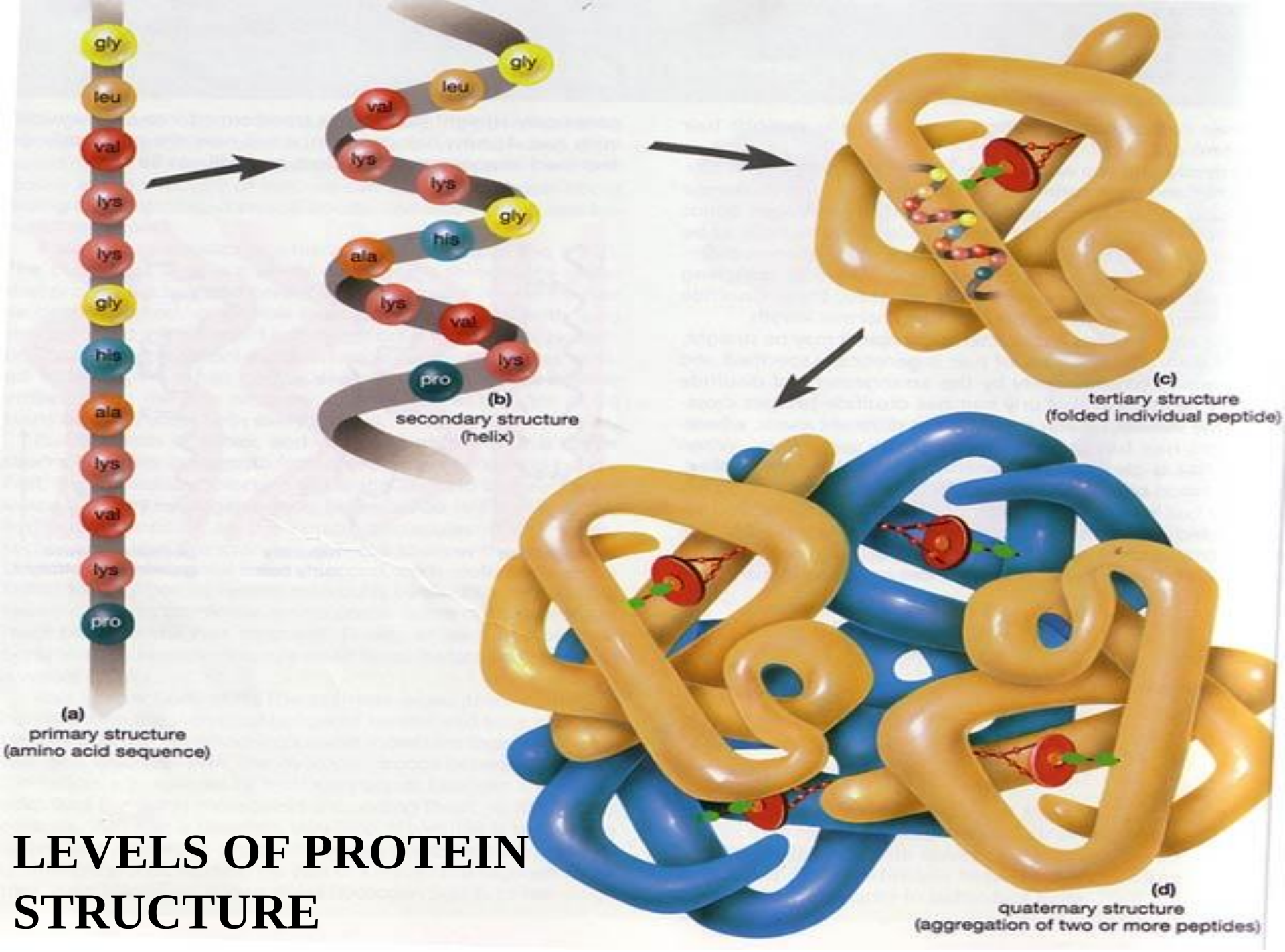


Proteins

- Essential amino acids- needed in diet
- Non-essential amino acids- made in body
- 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

MAKING A POLYPEPTIDE CHAIN





LEVELS OF PROTEIN STRUCTURE

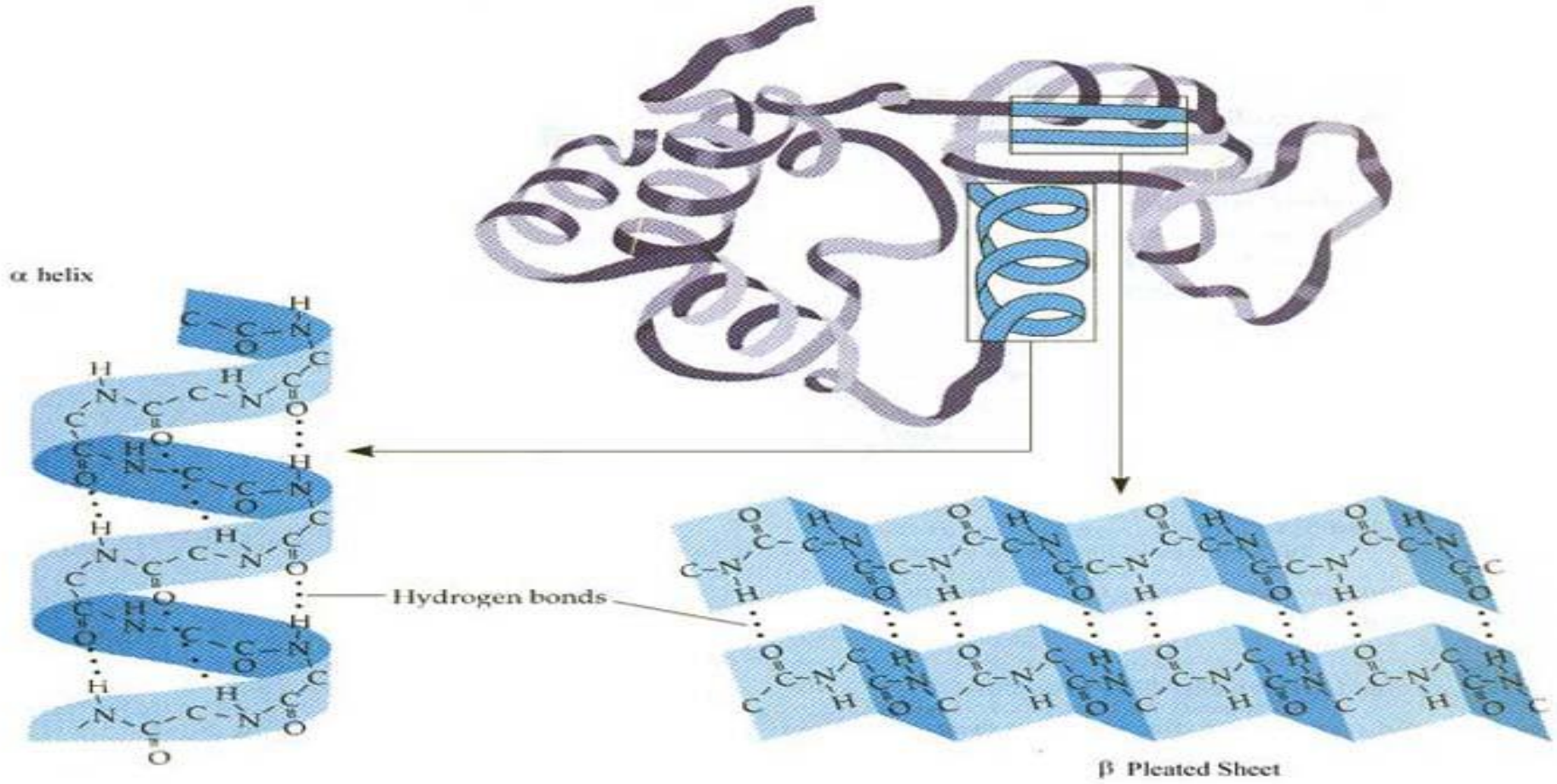
PRIMARY PROTEIN STRUCTURE

- Sequence of amino acids

SECONDARY PROTEIN STRUCTURE

-Alpha helix or beta pleated sheet

-Chain folded back on itself and held in place by hydrogen bonds



Fibrous (structural) proteins- building materials

In secondary form:

Human growth hormone

Immunoglobulins

Cytokines

Actin

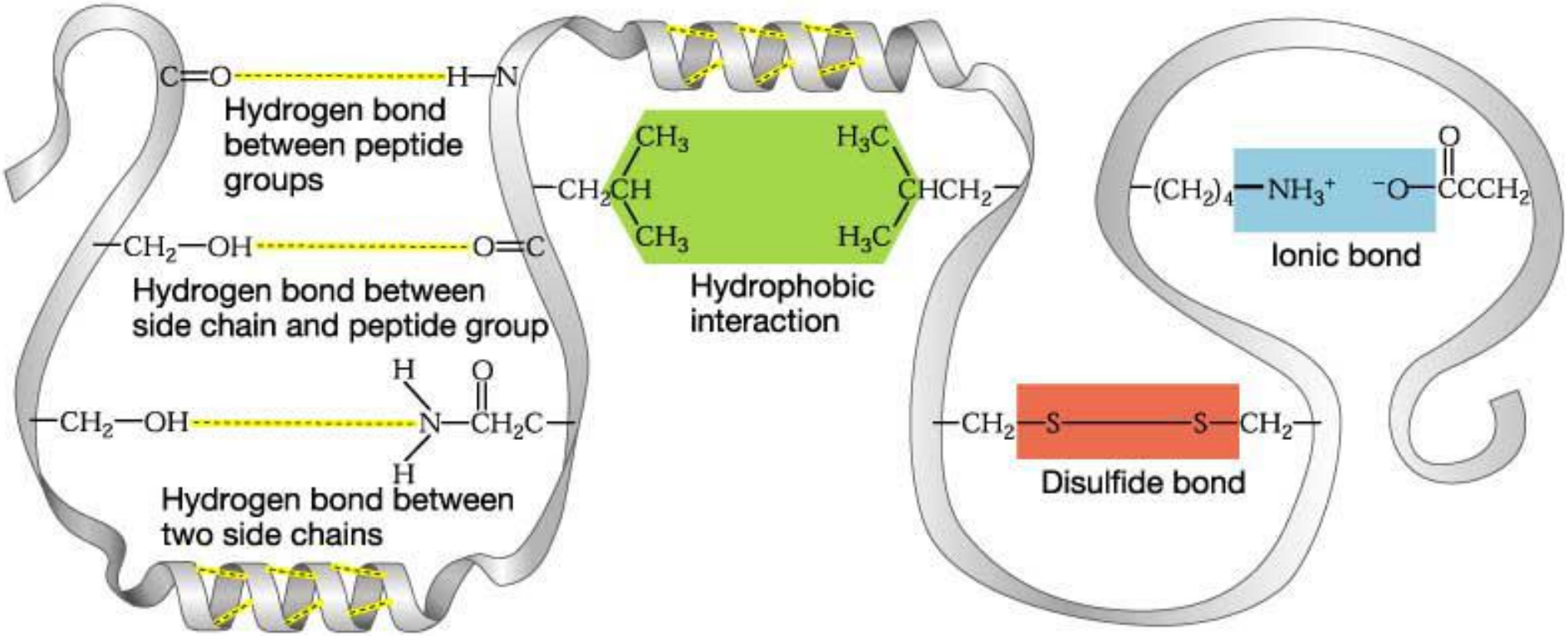
In Quaternary form:

Keratin

Collagen

TERTIARY STRUCTURE

- Secondary structure loops back on itself and bonds again

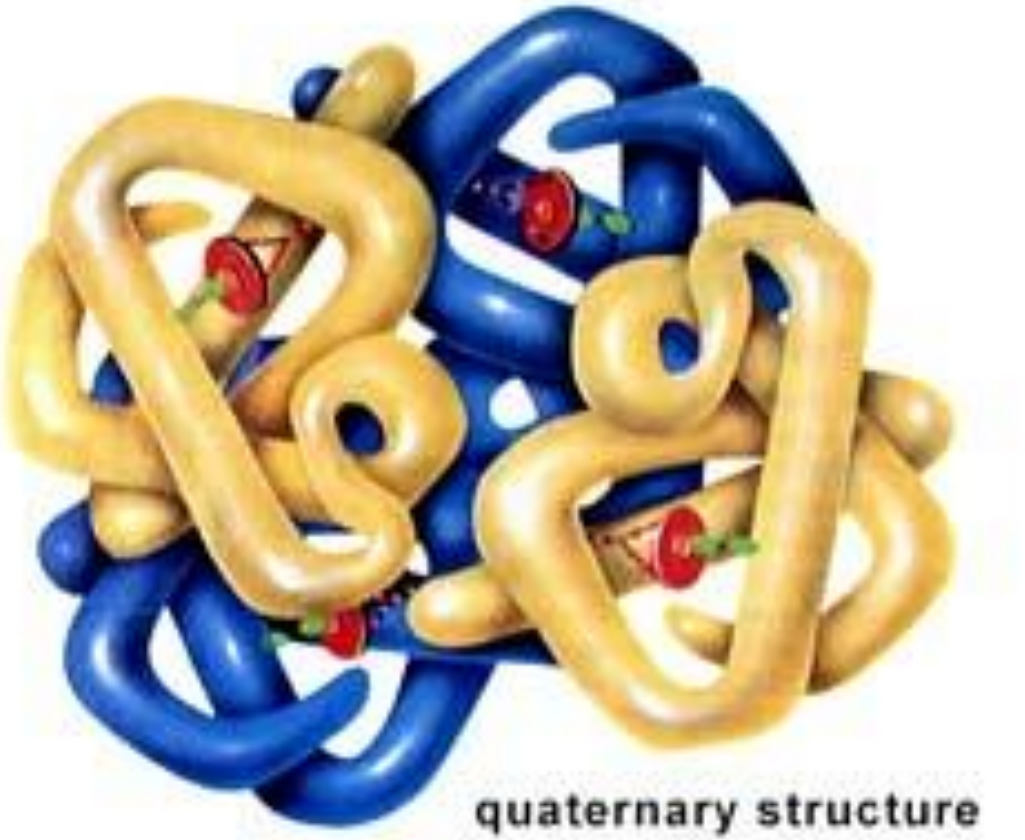


Tertiary structure of a protein = final three dimensional structure.
Involves short and long range bonding using hydrogen bonding, ionic bonding, hydrophobic interaction and disulfide covalent bonding,

Figure 3.11a from Scott Freeman / Biological Science

QUATERNARY STRUCTURE

- Two or more chains in tertiary structure bonded together



quaternary structure
(aggregation of two or more peptides)

Globular (functional) proteins- perform actions within the body

Tertiary Structure:

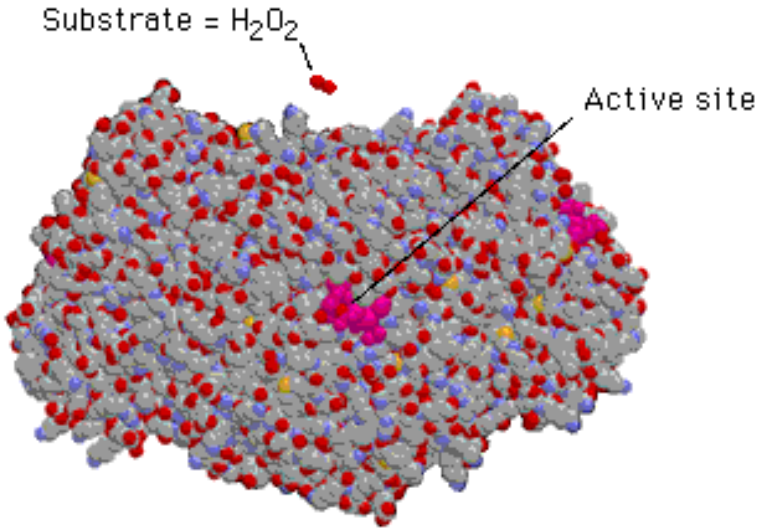
Lactase
Myoglobin

Quaternary Structure:

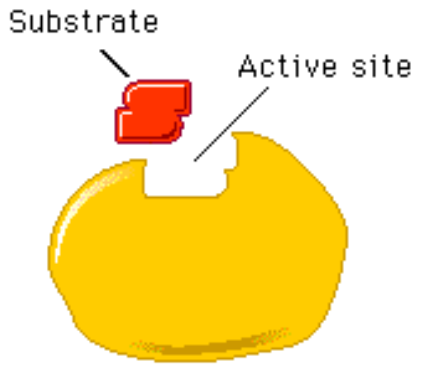
Hemoglobin

Enzymes

- Act as biological catalysts
- Increase the rate of chemical reactions
- End in “–ase”
- In tertiary or quaternary structure



Molecular model of catalase

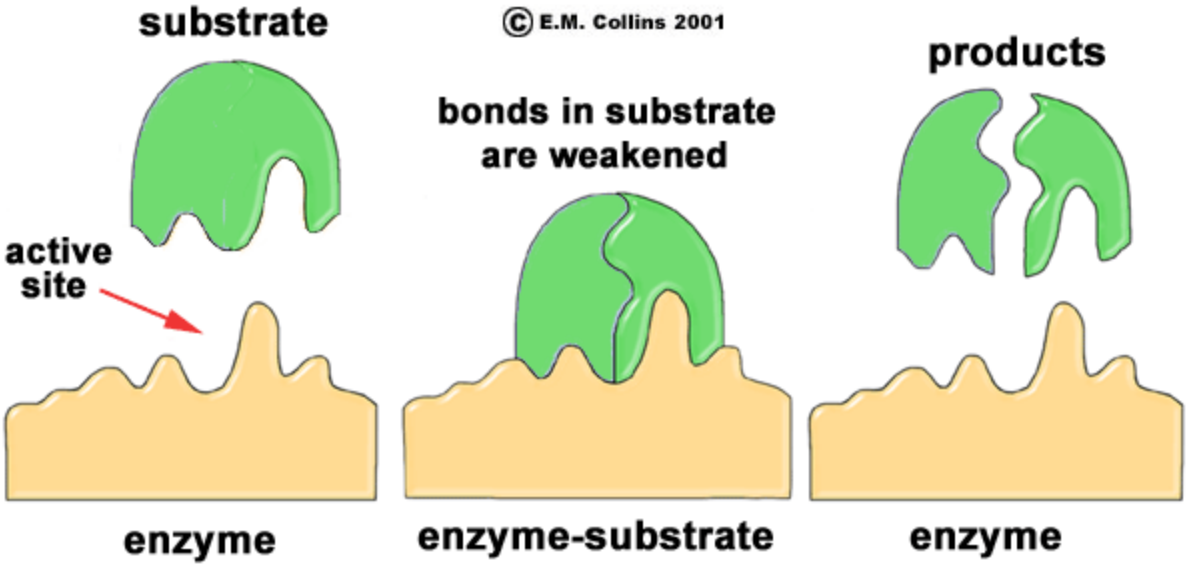


Schematic model of an enzyme

http://www.phschool.com/science/biology_place/labbench/lab2/images/enzyme.gif

Enzymes

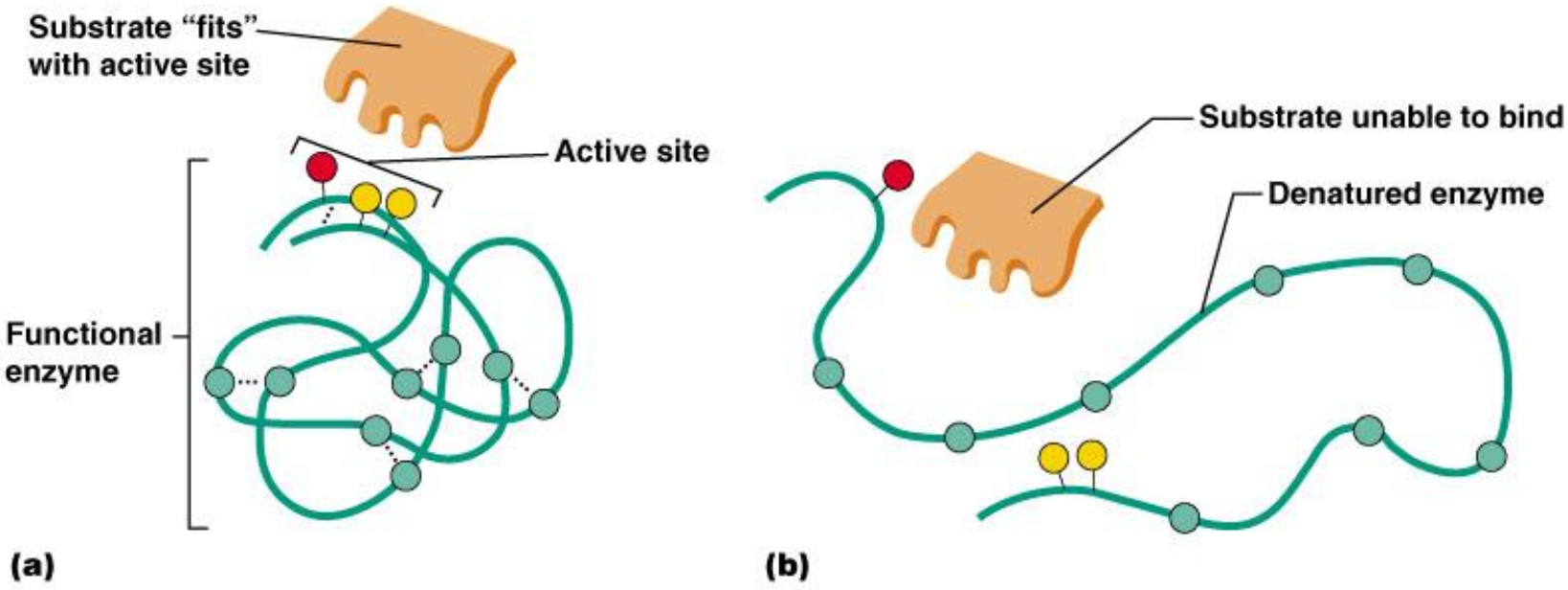
- Substrate- the substance on which an enzyme is acting
- Active site- the area on the enzyme to which the substrate binds



http://waynesword.palomar.edu/images/enzyme5.gif

Enzymes

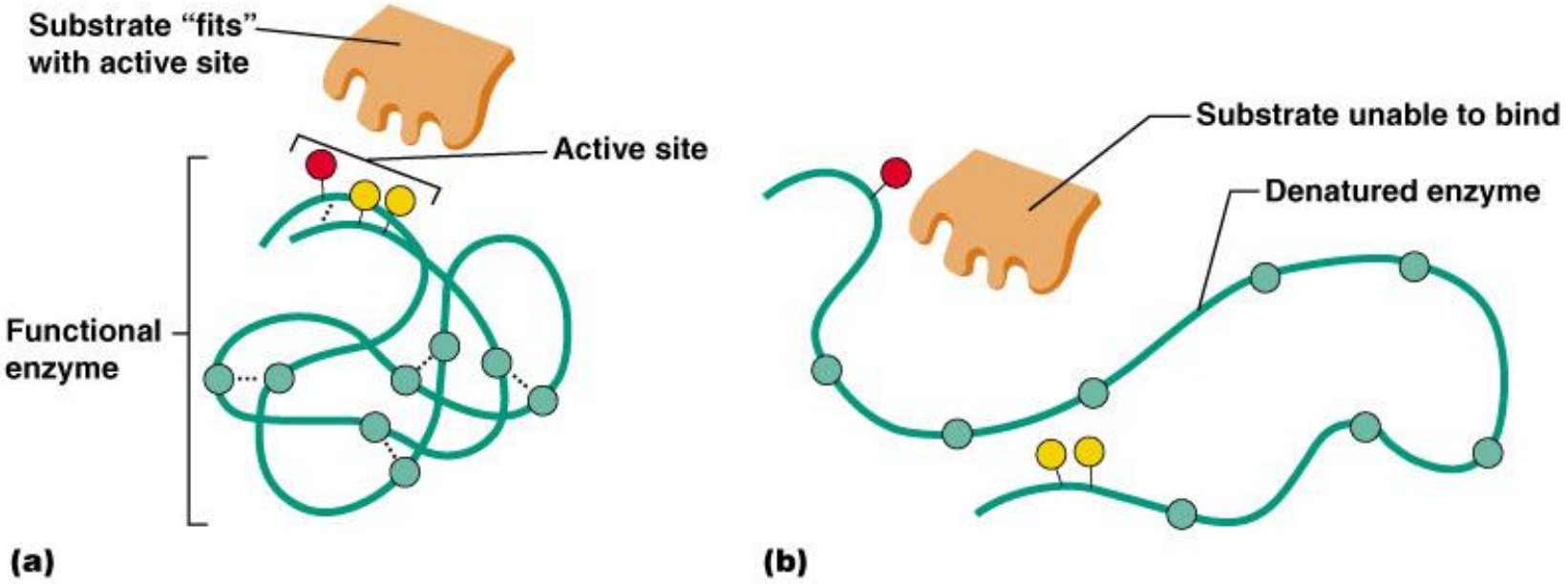
- Denature- when an enzyme unfolds (looses its structure) and is rendered nonfunctional



Enzymes

- Things that denature enzymes:
  - Heat
  - pH change
  - Addition of ionic substances

Animation- http://www.lewport.wnyric.org/JWANAMAKER/animations/Enzyme activity.html

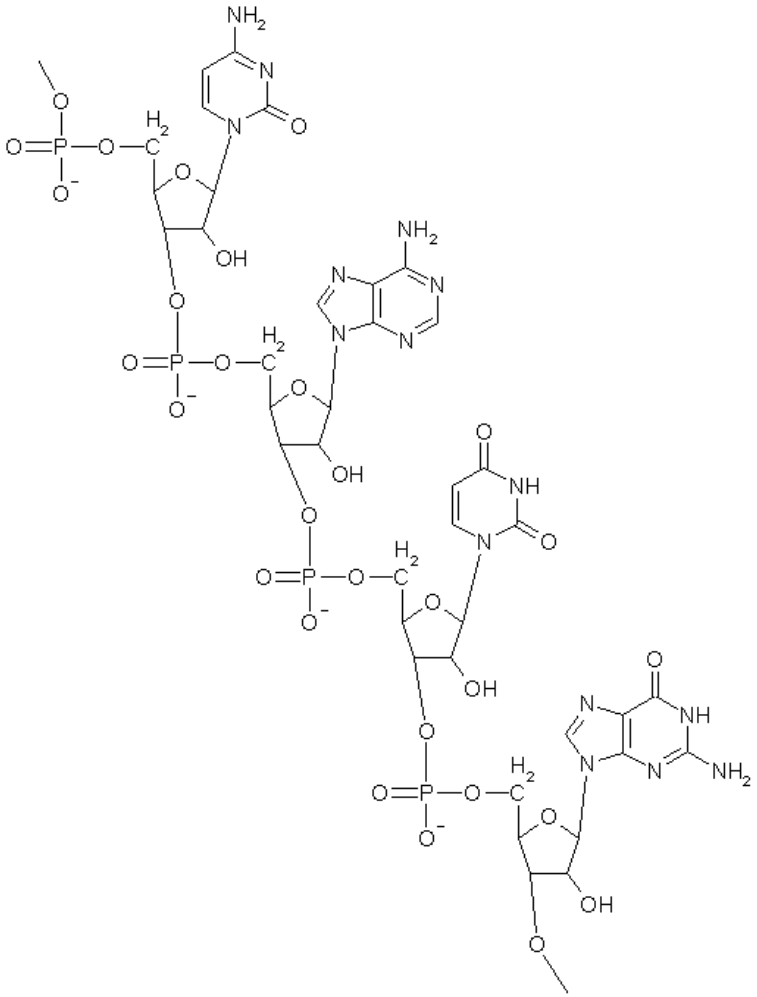


Nucleic Acids

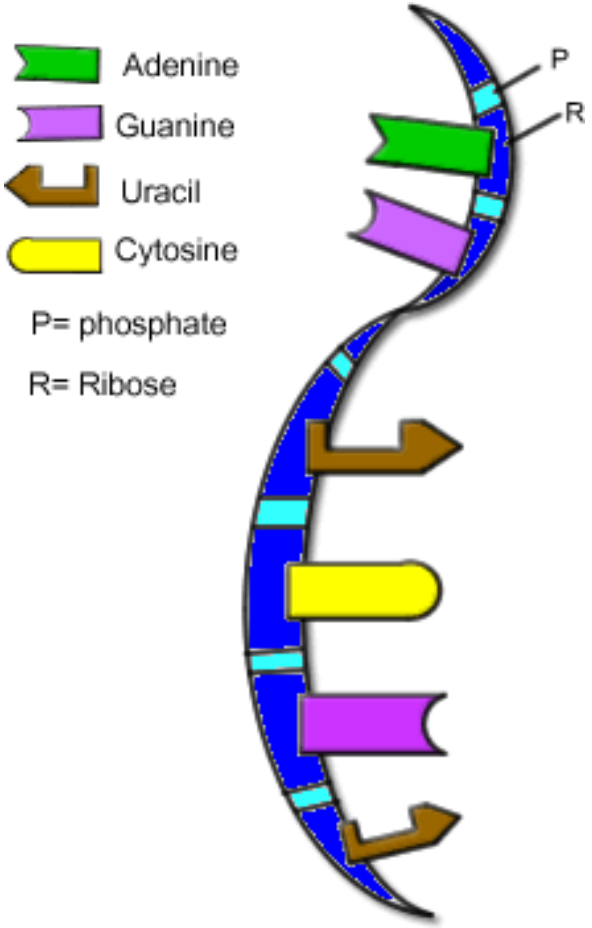
- Composed of nucleotides
  - Sugar (ribose or deoxyribose)
  - Phosphate
  - Nucleotide bases
    - A = Adenine
    - G = Guanine
    - C = Cytosine
    - T = Thymine (Only in DNA)
    - U = Uracil (Only in RNA)
    - A bonds to T (U), G to C

Ribonucleic Acid (RNA)

- Single strand, has U instead of T, has ribose sugar



http://www.steve.gb.com/images/molecules/nucleotides/ssRNA.png

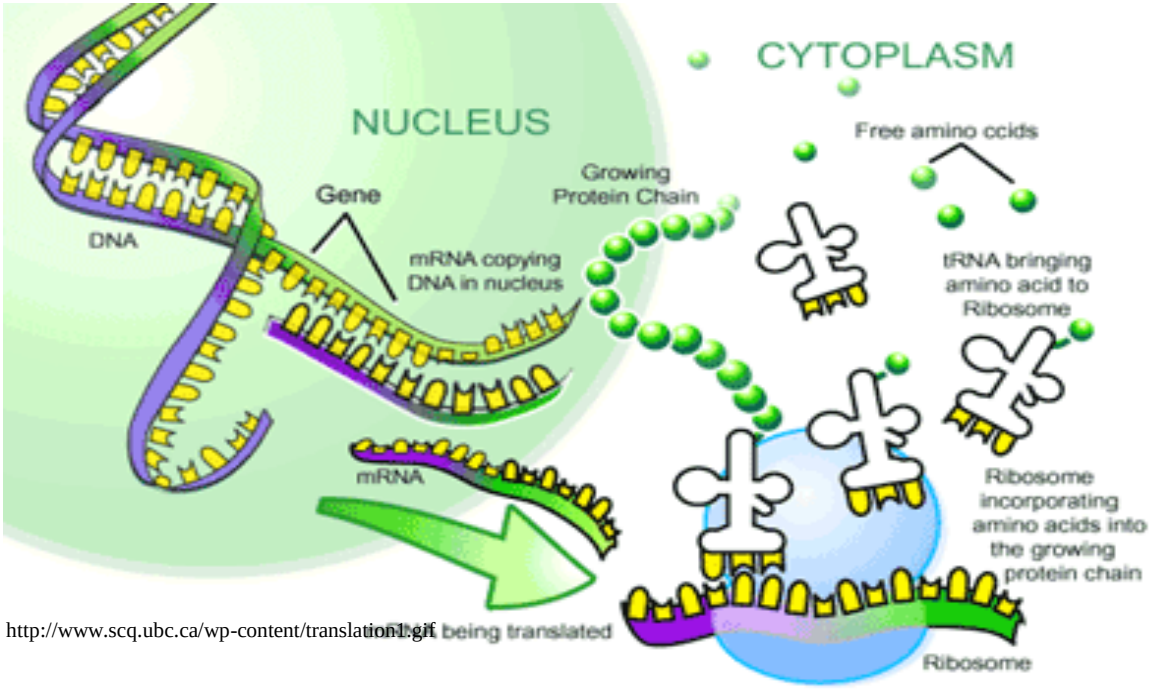


http://www.biologycorner.com/resources/mRNA-colored.gif

Ribonucleic Acid (RNA)

Involved in the manufacture of proteins

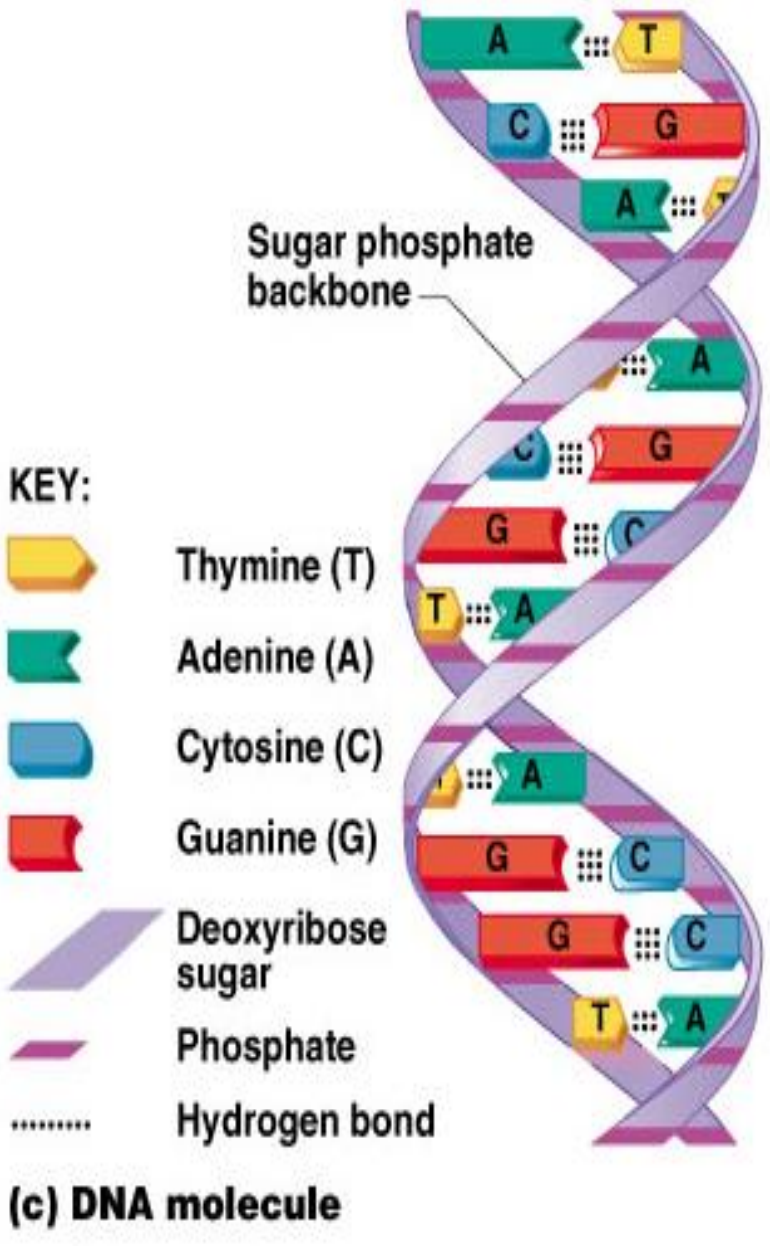
- mRNA copies the DNA (transcription)
- tRNA brings amino acids to the mRNA to make protein chains (translation)
- rRNA makes up ribosomes



http://www.scq.ubc.ca/wp-content/translation1.gif

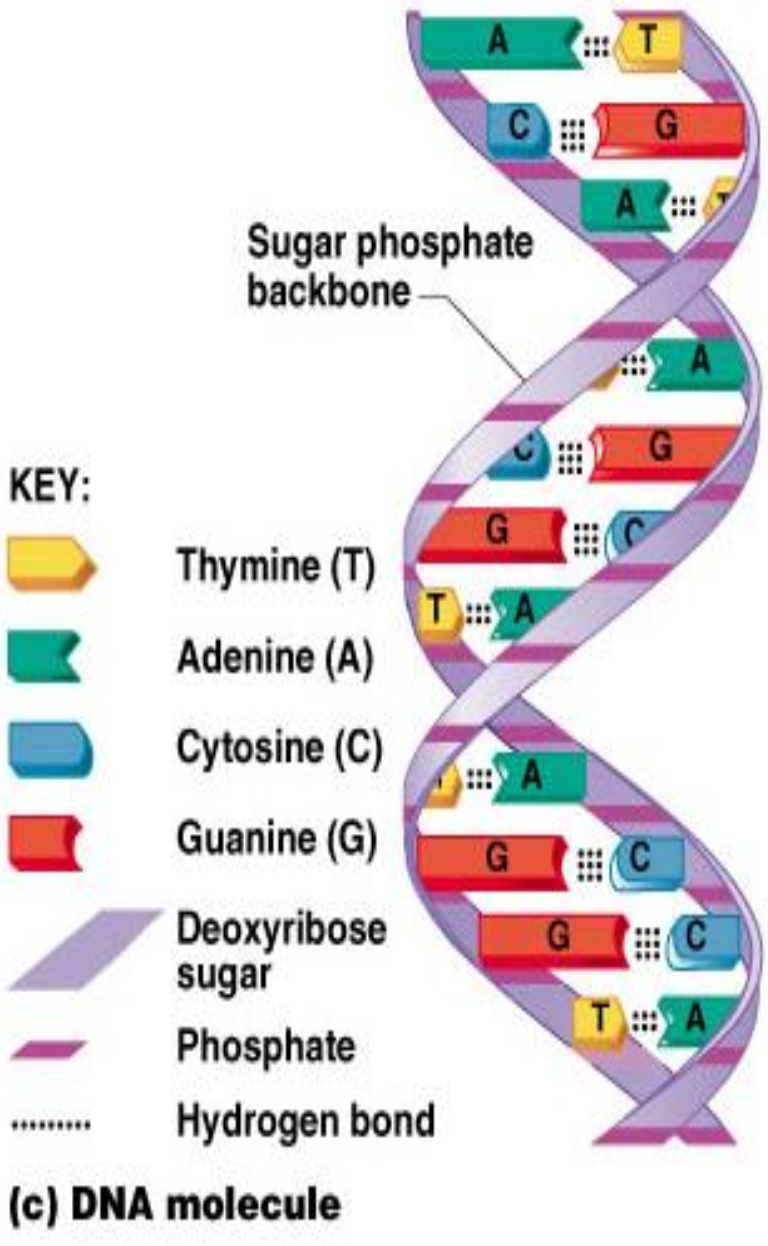
DNA (Deoxyribonucleic Acid)

- Contains deoxyribose sugar, T instead of U
- The “Blueprint” of life
- Provides instruction for every protein in the body
- Directs growth and development
- Contains genes



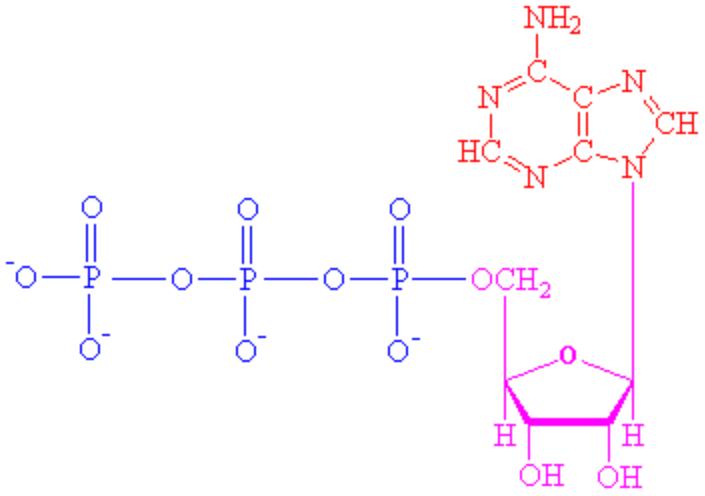
DNA (Deoxyribonucleic Acid)

- Organized by complimentary bases to form double helix- 2 strands
- Replicates (copies itself) before cell division
- Makes up chromosomes/ chromatin



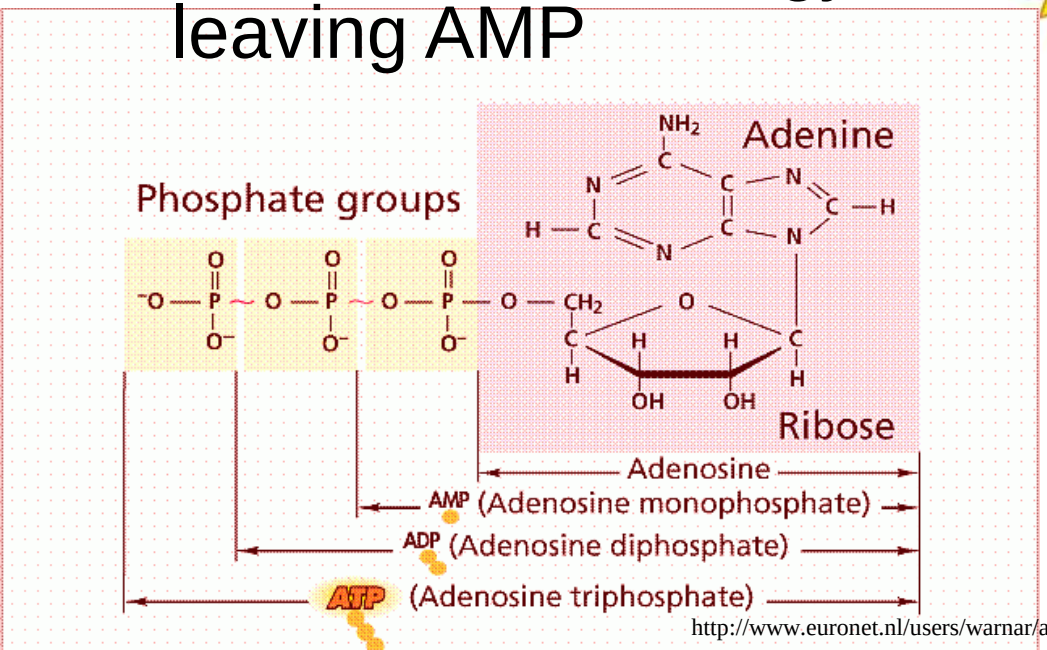
Adenosine Triphosphate (ATP)

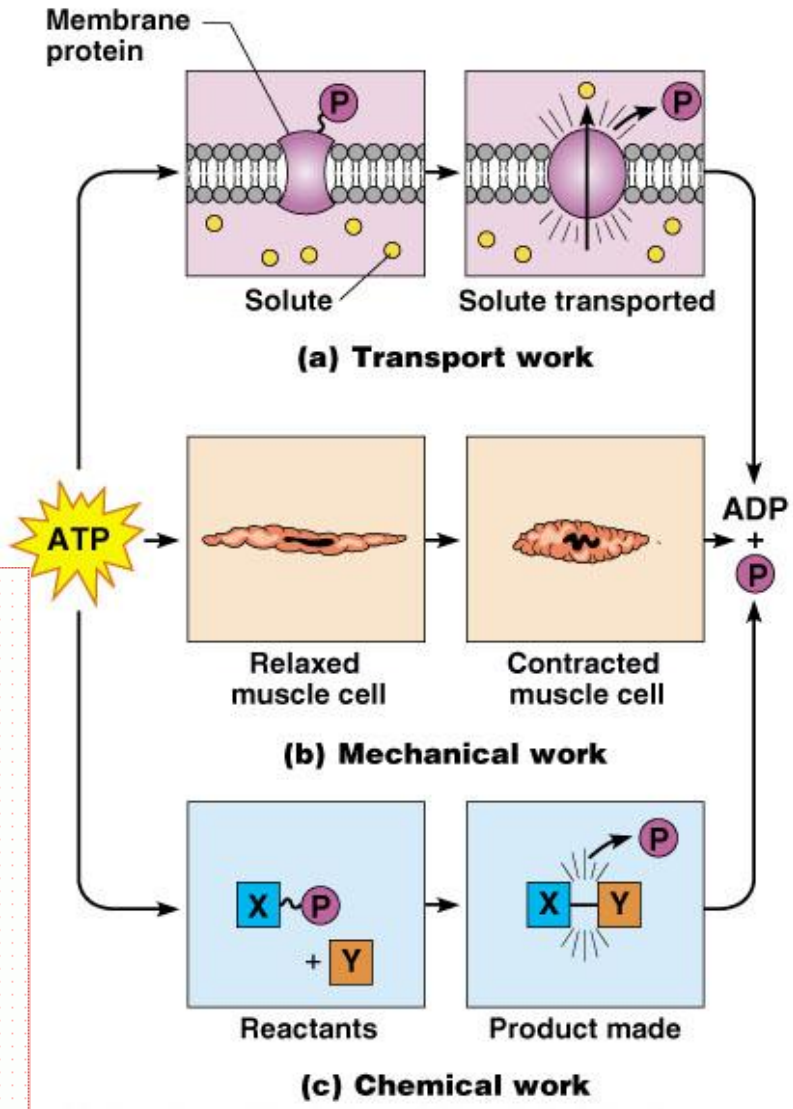
- Chemical energy used by all cells
- Energy is released by breaking high energy phosphate bond
- ATP is replenished by oxidation of food fuels



How ATP Drives Cellular Work

- ATP has 3 phosphates attached (P)
- Removal of a P releases energy from the bond, leaving ADP
- Removal of another P releases less energy, leaving AMP





http://www.euronet.nl/users/warnar/atp.gif