Basic Chemistry

Chapter 2

BIOL1000

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Chapter 2 Objectives

Following this chapter, you should be able to describe:

- Atoms, molecules, and ions
  - Composition and properties
  - Types of bonds
  - Molecular interactions
- Organic molecules
  - Carbohydrates, lipids, proteins, nucleic acids

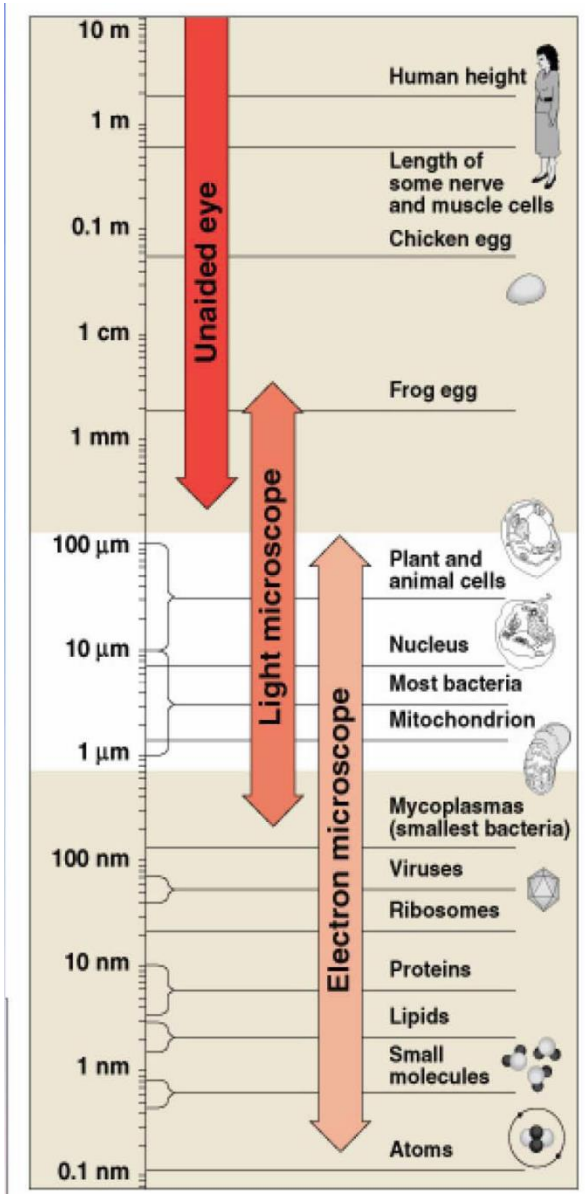
Humans are large collections of tissues and organ systems

Organ systems are large collections of cells

Cells are large collections of organelles and molecules

Molecules are small to large collections of elements whose atoms are held together by chemical bonds

Atoms are made up of subatomic particles: an atomic nucleus with neutrons and protons and a surrounding “cloud” of electrons.



Introduction and Generalities

The body is made up of atoms, ions, and molecules. Carbohydrates, proteins, lipids and nucleic acids are large molecules.

What is an element?

It is a simple form of matter, a substance that cannot be broken down into two or more different substances

Matter: anything that has a mass and occupies space

Compound: formed by atoms of 2 or more elements.

Atoms

The atom is a unit of matter that forms all chemical substances. Atoms are made up from 3 subatomic particles:

- Proton: positively charged, inside nucleus, has mass
- Neutron: no charge, inside nucleus, has mass
- Electron: negatively charged, orbits nucleus, no mass

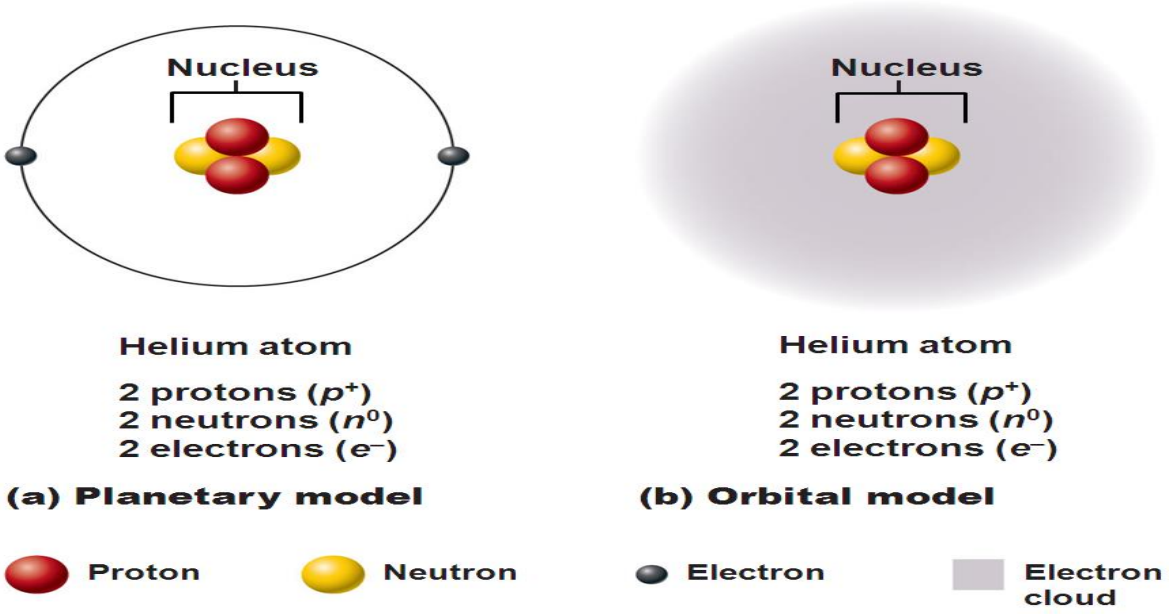
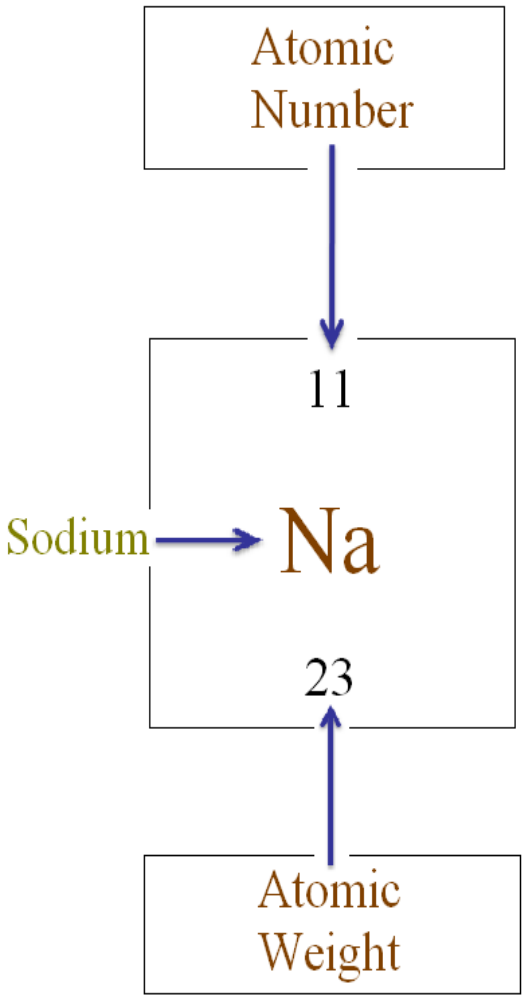


Figure 2.1

Atoms



Atomic number

- The number of protons in the atom.
- Every element has a different number of protons.
- We can identify atoms by this number

Atomic weight

- It is equal to number of protons + the number of neutrons.

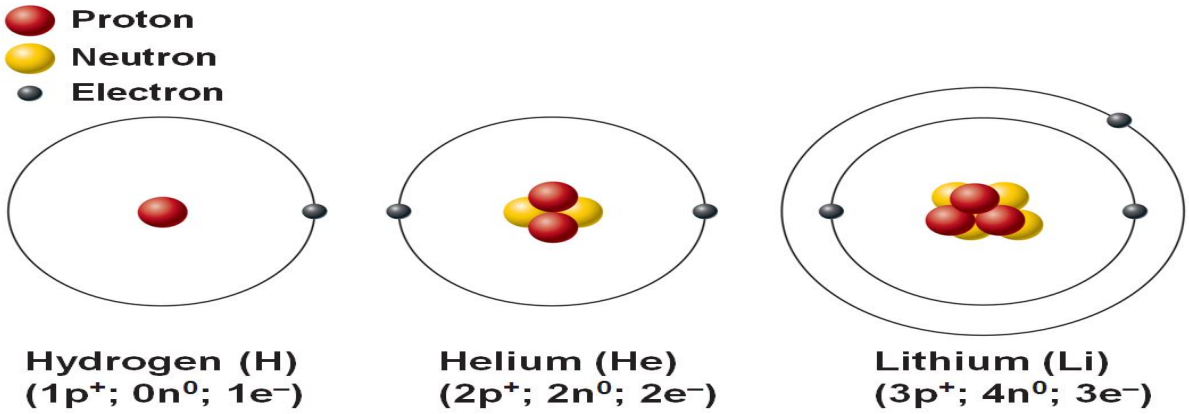
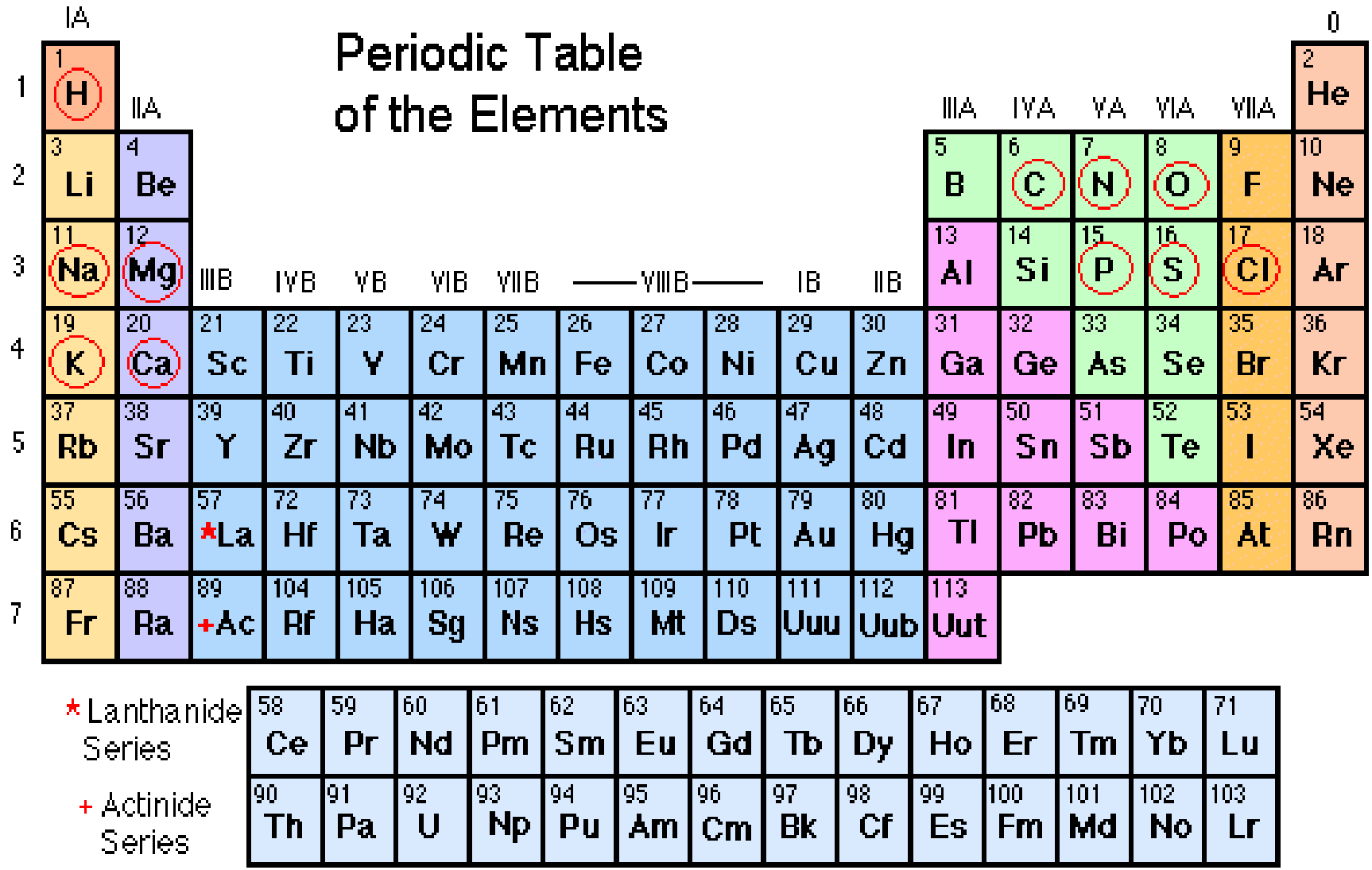


Figure 2.2



The major elements found in the body are circled

Atomic composition of the Body

Major elements in the human body:

- Carbon, Oxygen, Hydrogen, Nitrogen (accounts for 99.3% of total atoms)

Essential mineral elements of human body:

- Calcium, Phosphorus, Potassium, Sulfur, Sodium, Chlorine, Magnesium (accounts for 0.7%)

TABLE 2–1 Essential Chemical Elements in the Body

ELEMENT	SYMBOL
Major Elements: 99.3% of Total Atoms	
Hydrogen	H (63%)
Oxygen	O (26%)
Carbon	C (9%)
Nitrogen	N (1%)
Mineral Elements: 0.7% of Total Atoms	
Calcium	Ca
Phosphorus	P
Potassium	K (Latin *kalium*)
Sulfur	S
Sodium	Na (Latin *natrium*)
Chlorine	Cl
Magnesium	Mg

Atomic composition of Body

Trace Elements:

- 13 trace elements
- Essential for normal growth and function
- Accounts for less than 0.01%

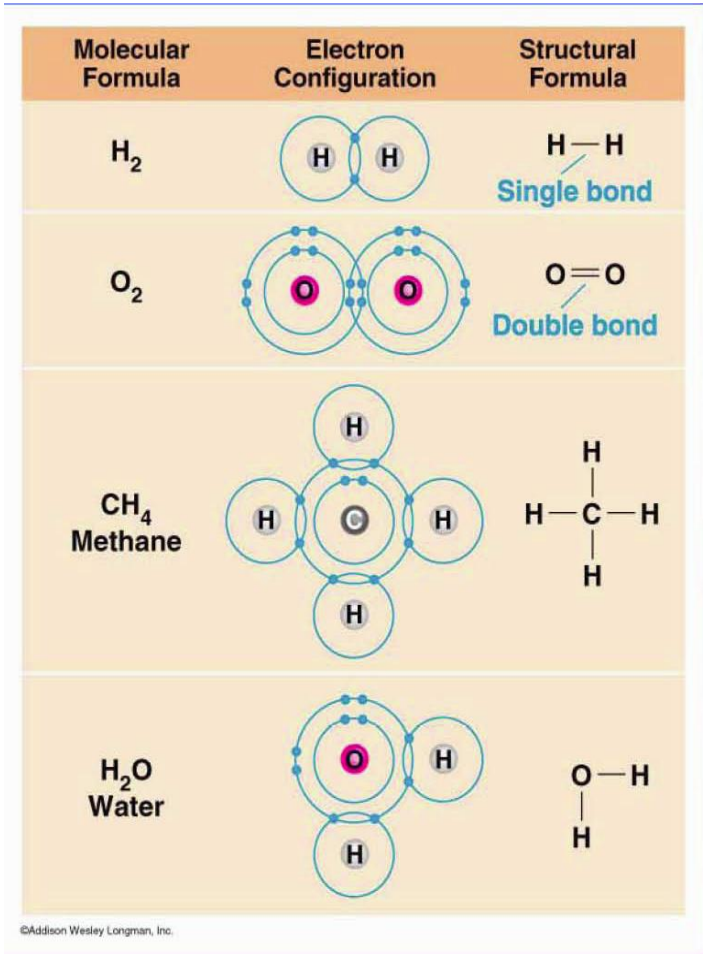
TABLE 2–1 Essential Chemical Elements in the Body

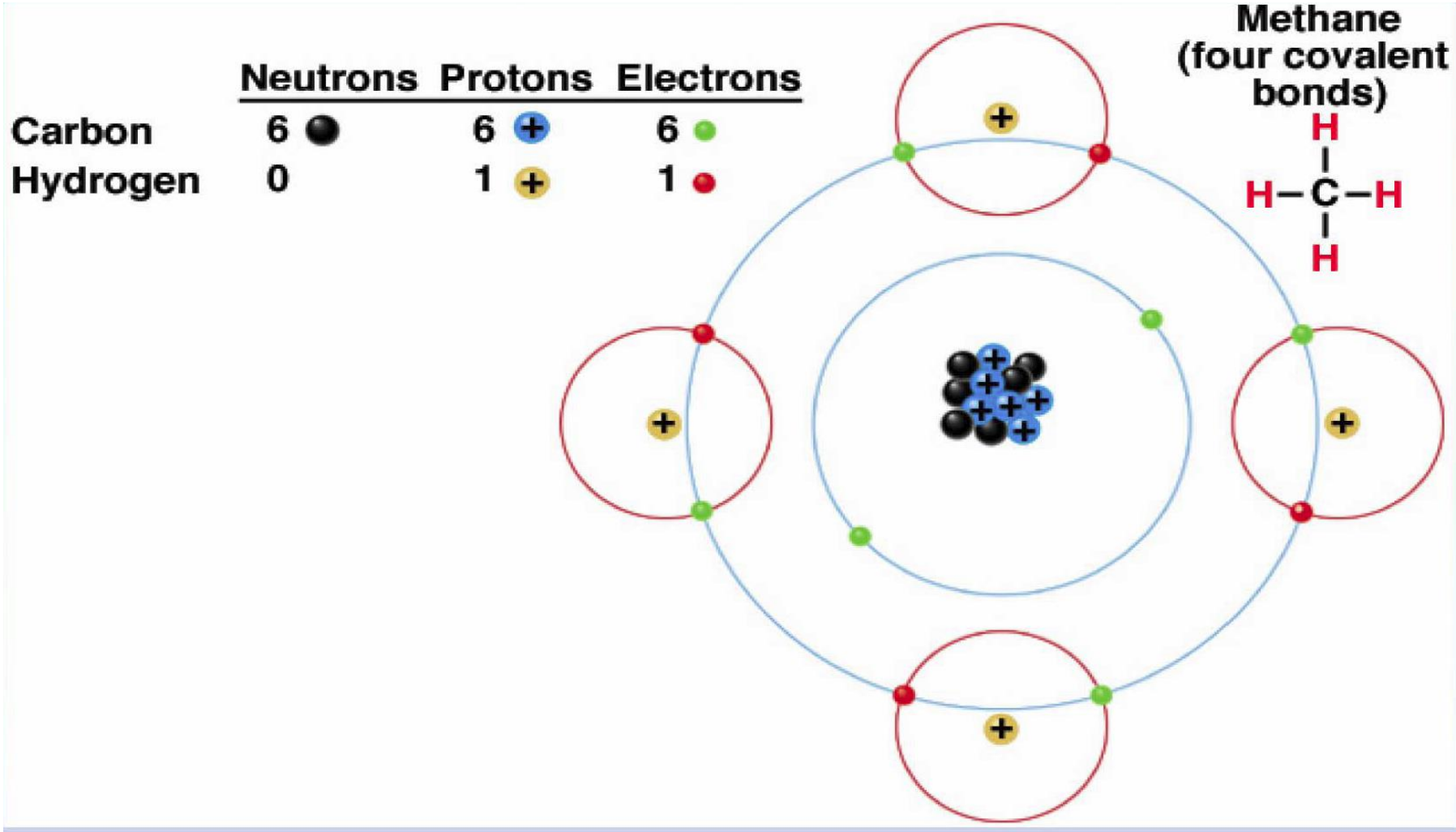
ELEMENT	SYMBOL
Trace Elements: Less Than 0.01% of Total Atoms	
Iron	Fe (Latin *ferrum*)
Iodine	I
Copper	Cu (Latin *cuprum*)
Zinc	Zn
Manganese	Mn
Cobalt	Co
Chromium	Cr
Selenium	Se
Molybdenum	Mo
Fluorine	F
Tin	Sn (Latin *stannum*)
Silicon	Si
Vanadium	V

Molecules

Molecule

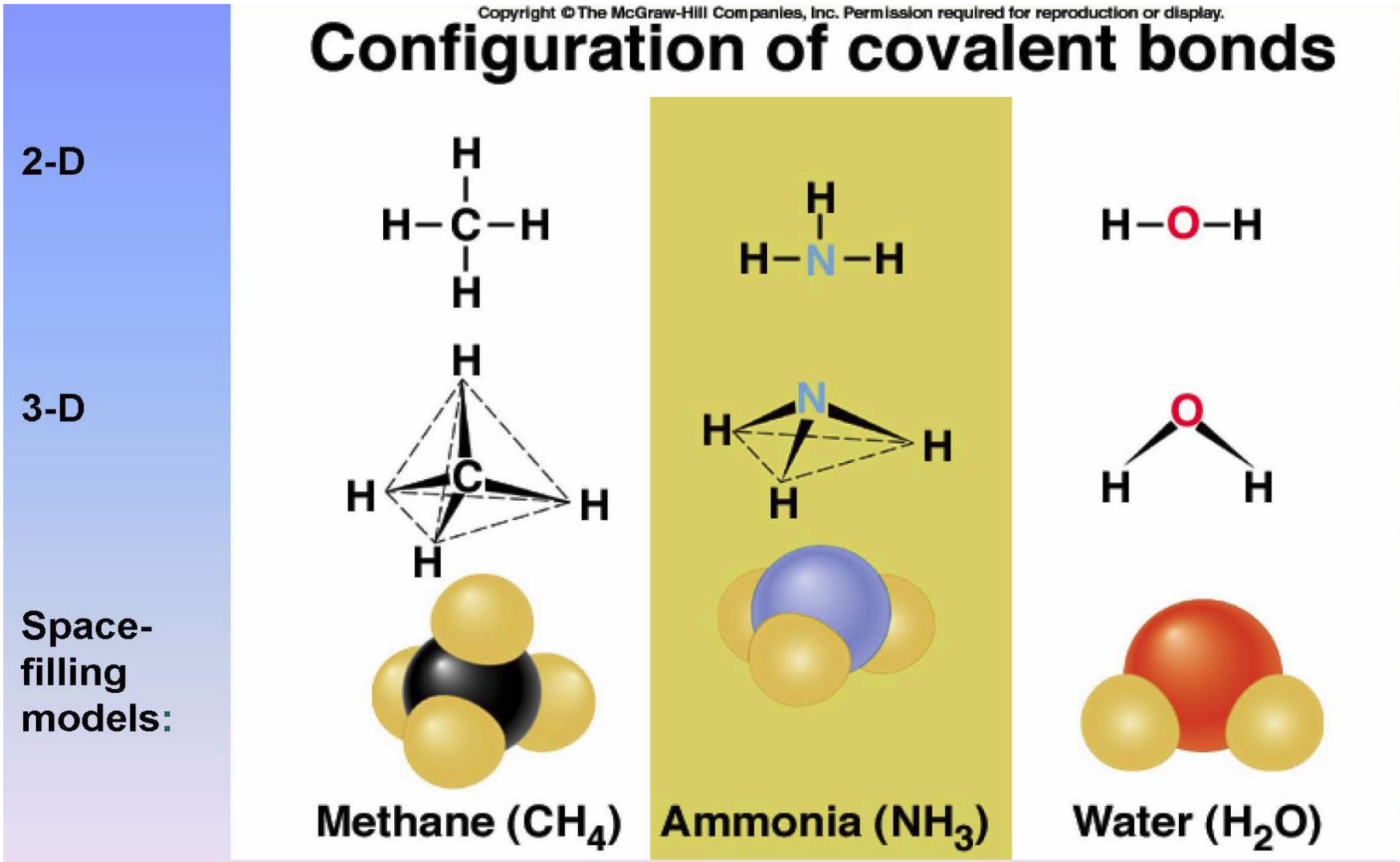
- 2 or more atoms bonded together
- Bonds can be ionic, covalent, and metallic bonds.
- Most common type of bond is covalent bond
- Orientation of bonds determines molecular shape which, in turn determines function





Here, we can see a methane molecule. Notice how each of the 4 hydrogen atoms is covalently bonded (sharing electrons with) to a carbon atom.

Here you can see the molecular structures of various molecules.



Ions

- An ion is an atom which has gained or lost electrons
- Ions are charged atoms
- Cations: are positively charged ions, where atoms have lost electrons, example: Na^+
- Anions: are negatively charged ions, where atoms have gained electrons, example: Cl^-

Ions

Some common ions encountered in the body are included in this table

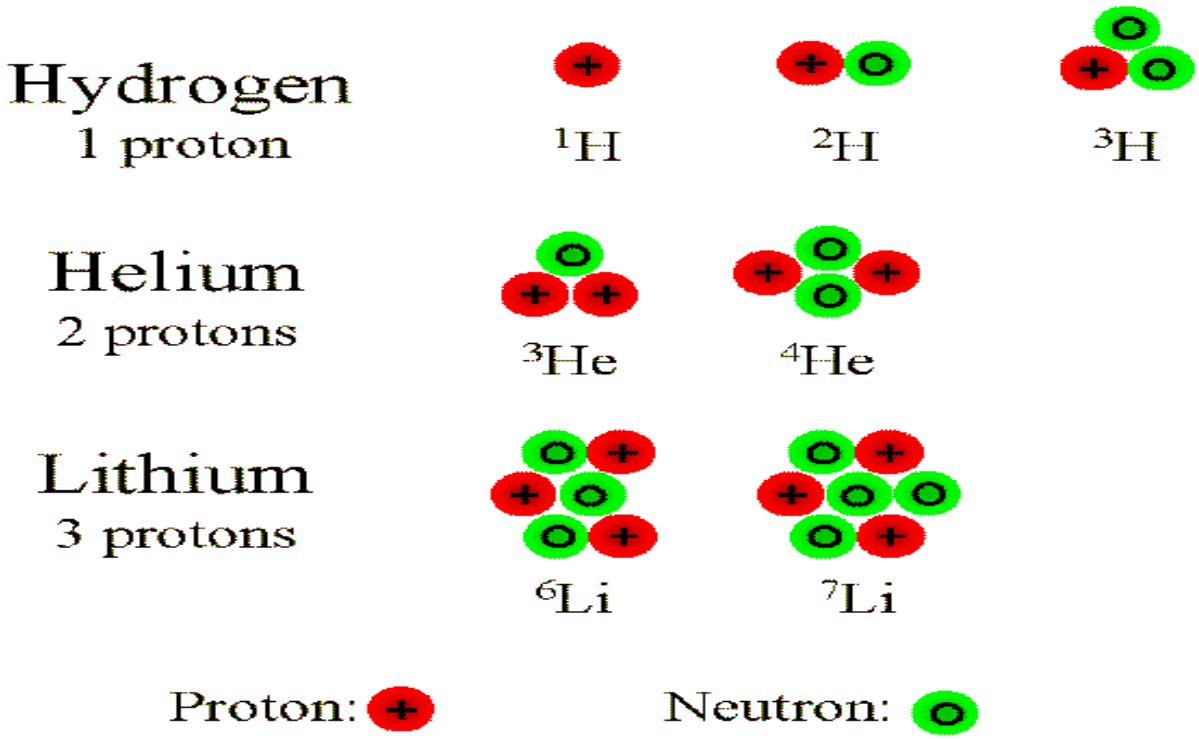
TABLE 2–3 Most Frequently Encountered Ionic Forms of Elements

ATOM	CHEMICAL SYMBOL	ION	CHEMICAL SYMBOL	ELECTRONS GAINED OR LOST
Hydrogen	H	Hydrogen ion	H^+	1 lost
Sodium	Na	Sodium ion	Na^+	1 lost
Potassium	K	Potassium ion	K^+	1 lost
Chlorine	Cl	Chloride ion	Cl^-	1 gained
Magnesium	Mg	Magnesium ion	Mg^{2+}	2 lost
Calcium	Ca	Calcium ion	Ca^{2+}	2 lost

isotopes

Contains the same number of protons but different number of neutrons.

Examples:



Chemical Bonds

Interactions between atoms:

- Chemical interaction: interaction between 2 or more atoms that occurs as a result of activity between electrons in their outermost shells

Ionic Bond

Formed by transfer of electrons

Example: NaCl

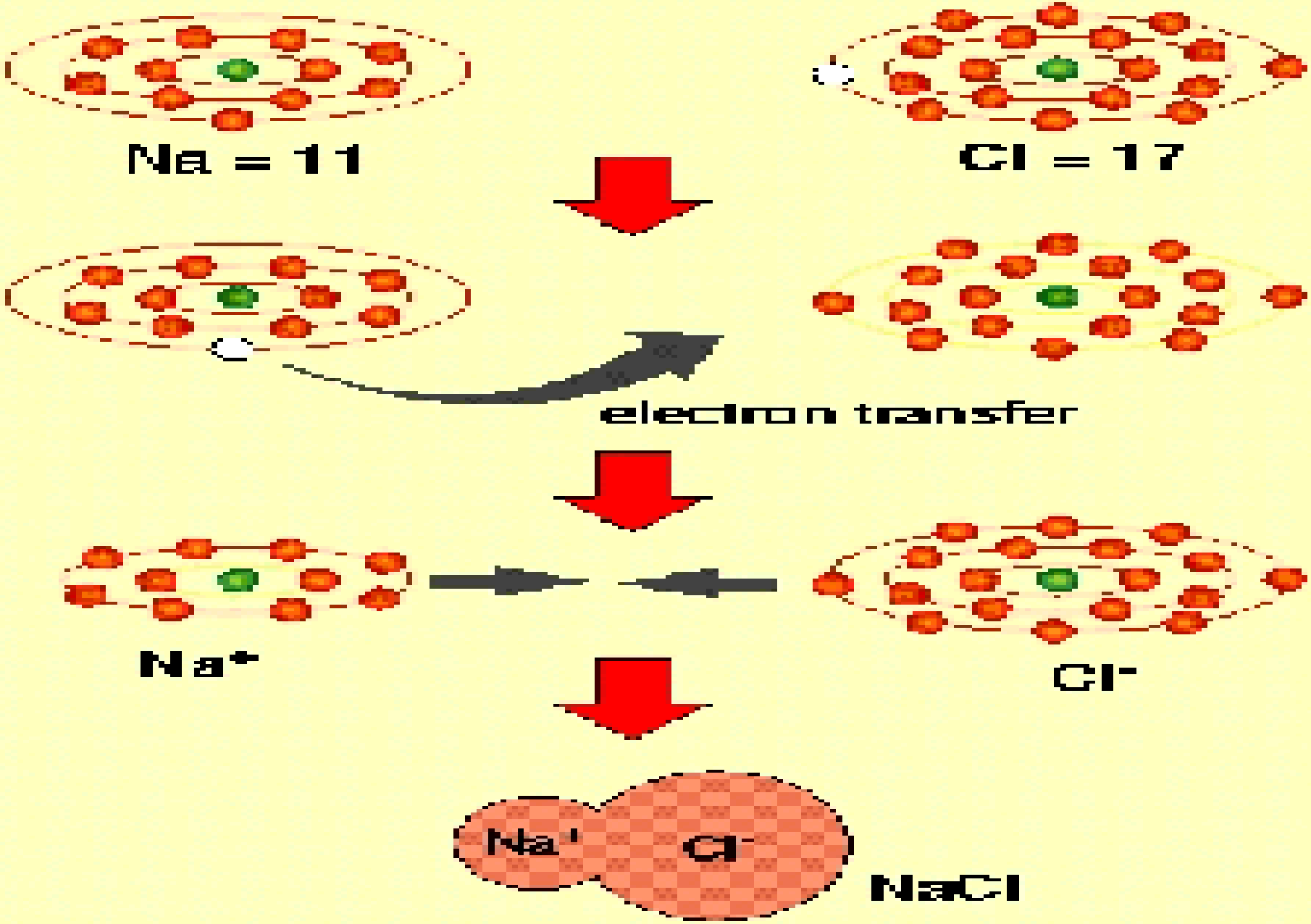
Na atom: 11 protons and 11 electrons.

Loses an electron →11 protons, 10 electrons = positive charge

Cl atom: 17 protons and 17 electrons.

Gains an electron →17 protons, 18 electrons = negative charge.

IONIC BONDING



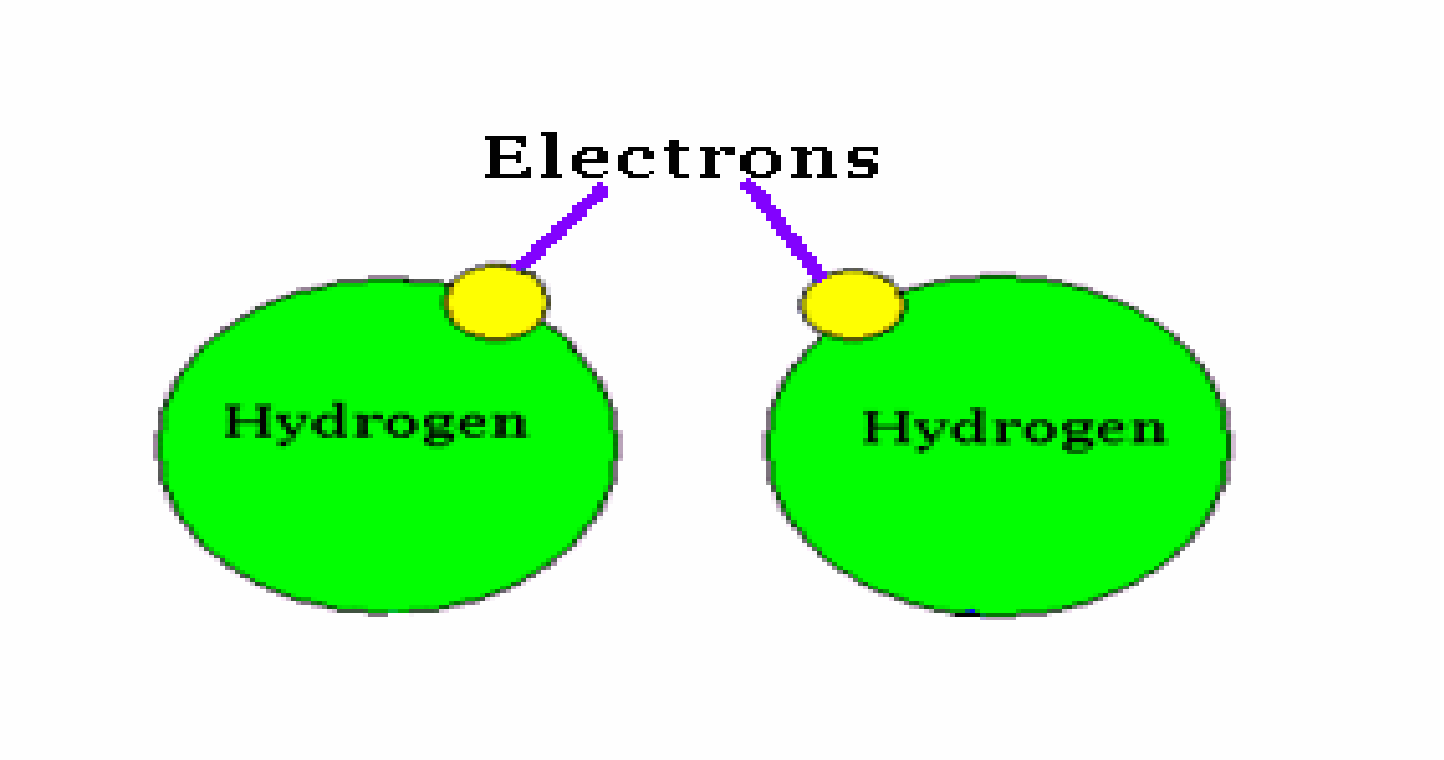
Covalent bond

Formed by sharing of one or more pairs of electrons between atoms.

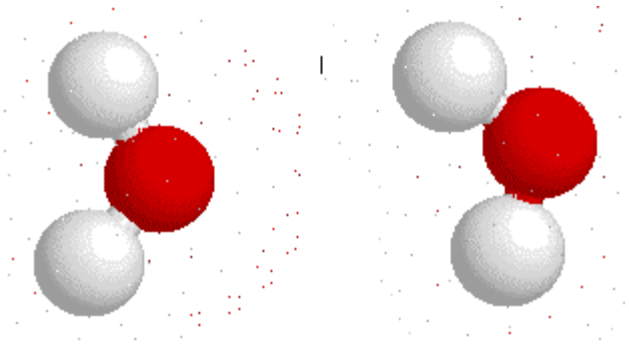
Examples: CO_2, H_2O

- Polar covalent bond: unequal sharing of electrons; example: water (H_2O). Relative positive and negative charges in molecule.
- Non-polar covalent bond: equal sharing of electrons; example: CO_2

Example of Covalent bond, formation of H_2

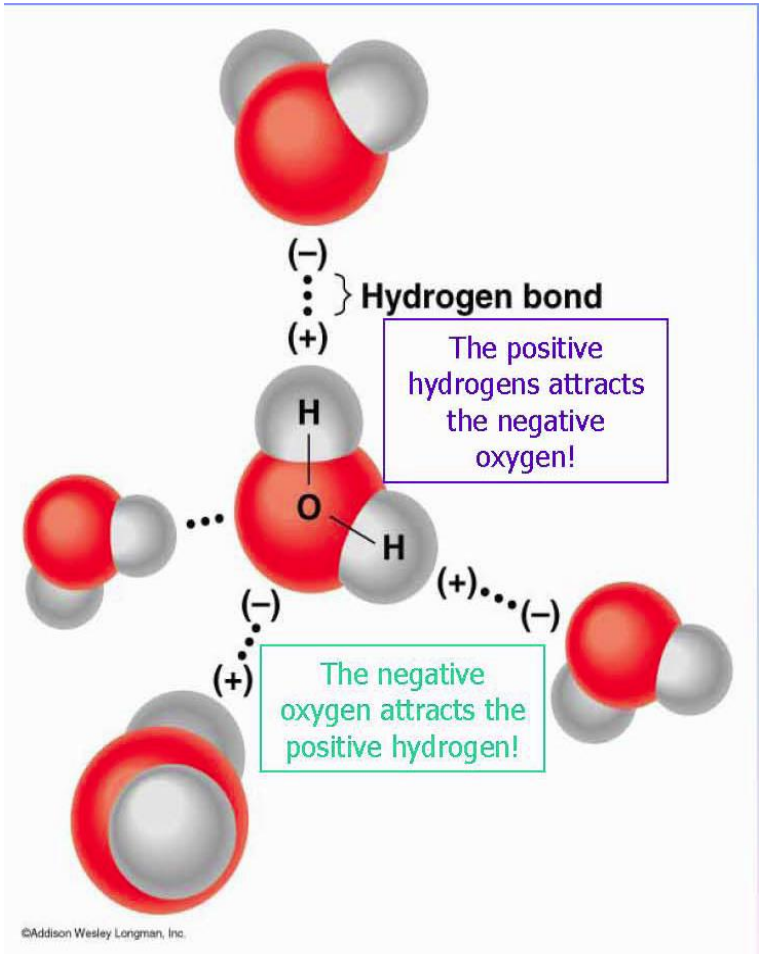


Formation of hydrogen bond between two water molecules (H_2O)



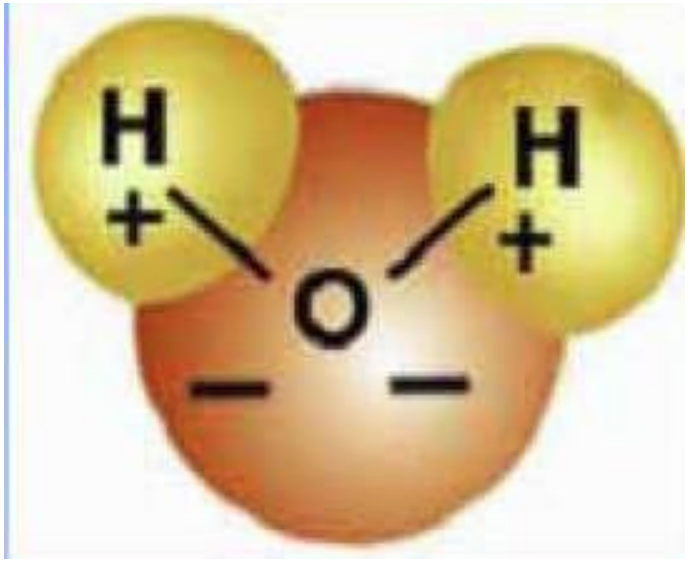
Hydrogen Bonds

- Most important polar covalent bond interaction
- Created when two highly polar molecules align their opposing partial charges.
- Because opposing charges attract each other, a hydrogen bond is created.



Water is the most common molecule in the body, and contains hydrogen bonds:

in each water molecule, the shared electrons spend more time close to the larger oxygen atom, making that area slightly negative compared to the area near the hydrogen atoms.

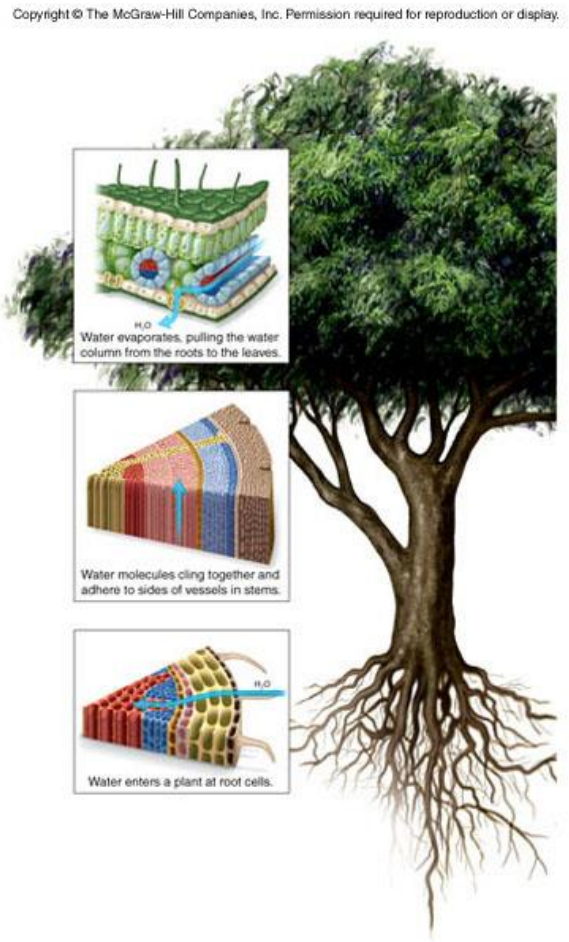


Water is the universal solvent. Yet not everything can dissolve in water though. Solubility is determined by molecular properties:

- hydrophilic: molecules with polar groups that readily dissolve in water (COOH/NH2/OH)
- Hydrophobic: electrically neutral bonds are not attracted to water, thus insoluble (C-H)
- Amphipathic: molecules that have polar region at one end and non-polar at other.

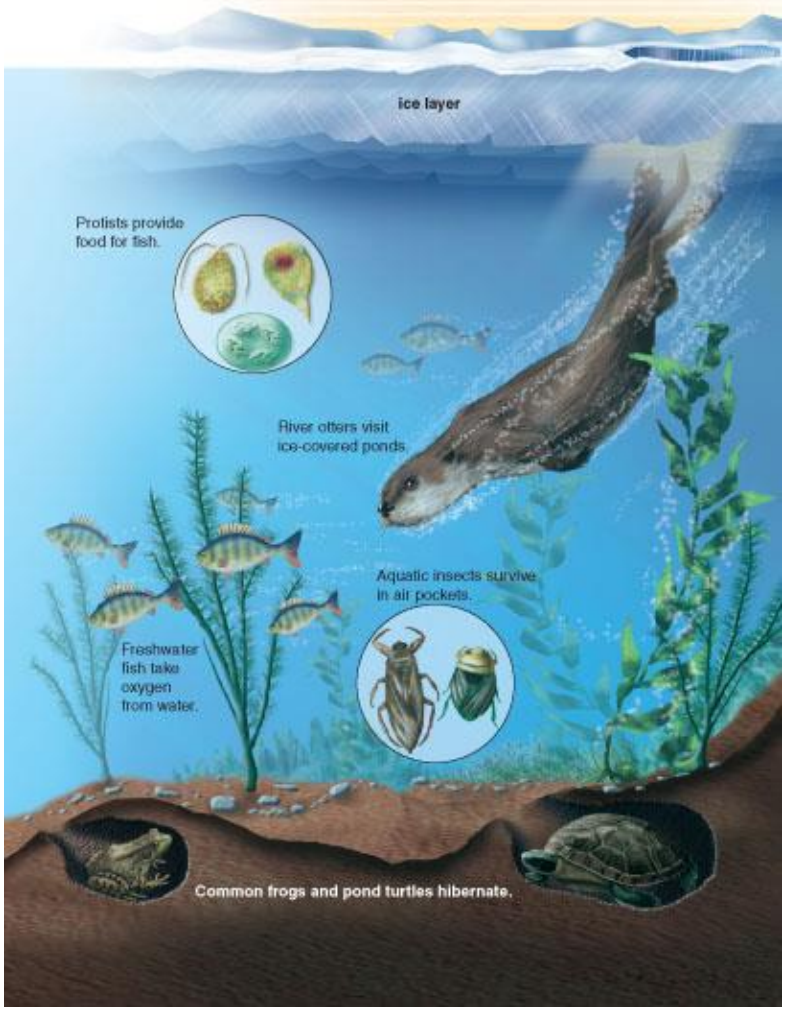
Properties of Water

- **Water molecules are cohesive and adhesive.**
  - **Cohesion** is the ability of water molecules to cling to each other due to hydrogen bonding.
  - **Adhesion** is the ability of water molecules to cling to other polar surfaces.
    - Adhesion is due to water's polarity.
  - Cohesion and adhesion account for water transport in plants as well as transport in blood vessels.



Properties of Water

- **Ice is less dense than liquid water.**
  - At temperatures below 4°C, hydrogen bonds between water molecules become more rigid but also more open.
  - Water expands as it reaches 0°C and freezes.
  - Ice floats on liquid water.
    - Acts as an insulator on top of a frozen body of water



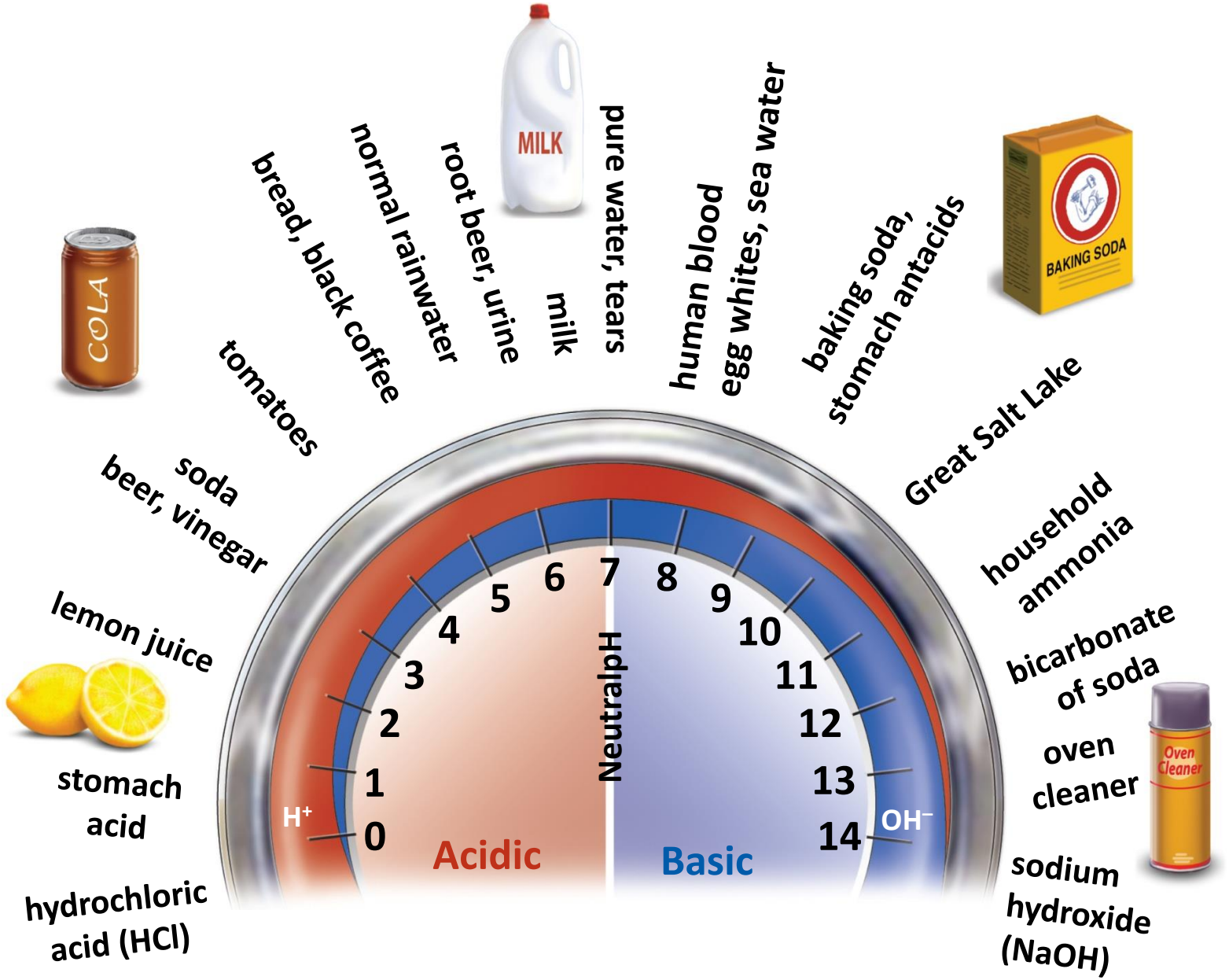
Chemical reactions

- Synthesis reaction: formation of a new chemical bond: A+B  AB. This is also called dehydration reaction or **anabolic reaction**.
- Decomposition reaction: breaking of a chemical bond: AB  A+B. This is also called hydrolysis reaction or **catabolic reaction**.
- Exchange reaction: AB +CD  AD +CB

- Organic compounds: contain carbon to carbon bond or carbon to hydrogen bond. Example: carbohydrates, proteins, lipids, and nucleic acids.
- Inorganic compounds: do not contain Carbon to carbon or carbon to hydrogen bond. Example: water, oxygen, carbon dioxide, electrolytes

Electrolytes

- Acid: a molecule that releases H+ in solution, thereby increasing acidity. Example: HCl and acetic acid
- Base: a substance that accepts H+ ions, thereby decreasing the acidity of a solution. Examples: NaOH, NH3.
- Acidity is measured in units of pH (*quantitative method*), and by litmus paper that changes color according to the degree of acidity or alkalinity (*qualitative method*).
- Buffer: is a substance that can be added to a solution to prevent drastic change in pH
- Salt: is a compound that results from any chemical interaction of an acid and a base (i.e. neutralization reaction).



Organic Molecules
Chapter-3

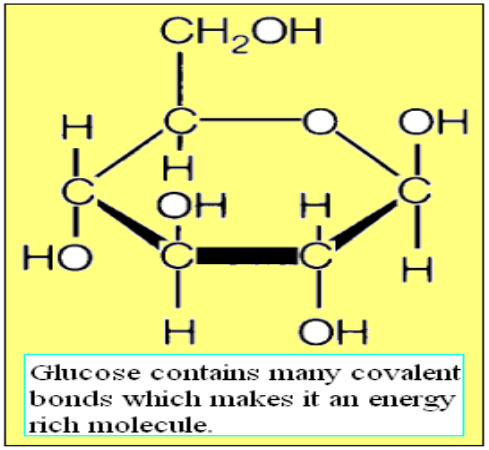
- Carbohydrates
- Lipids
- Proteins
- Nucleic acids

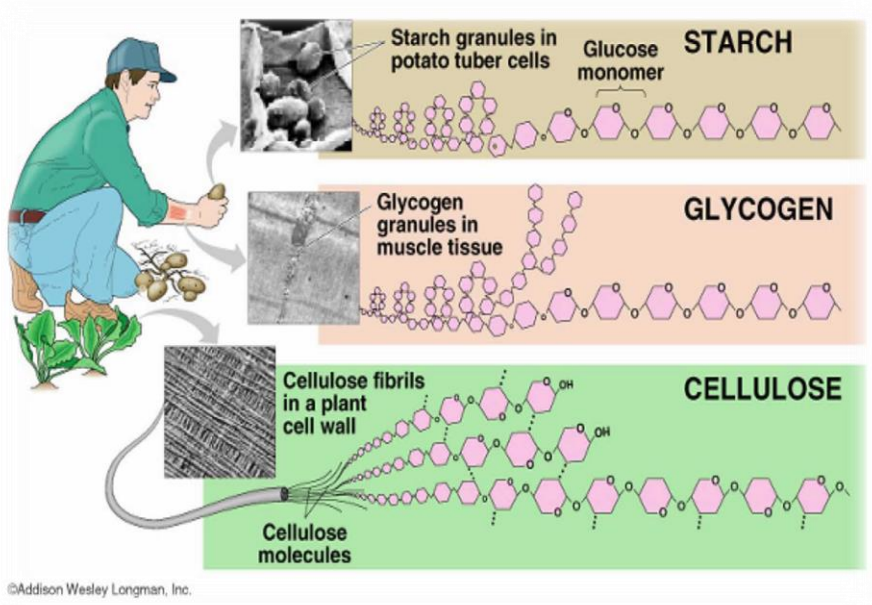
Carbohydrates

- Provide cells with energy
- 1% of body weight
- Composed of C,H,O in a ratio of $C_nH_{2n}O_n$
- OH groups make carbohydrates water soluble.

Carbohydrates

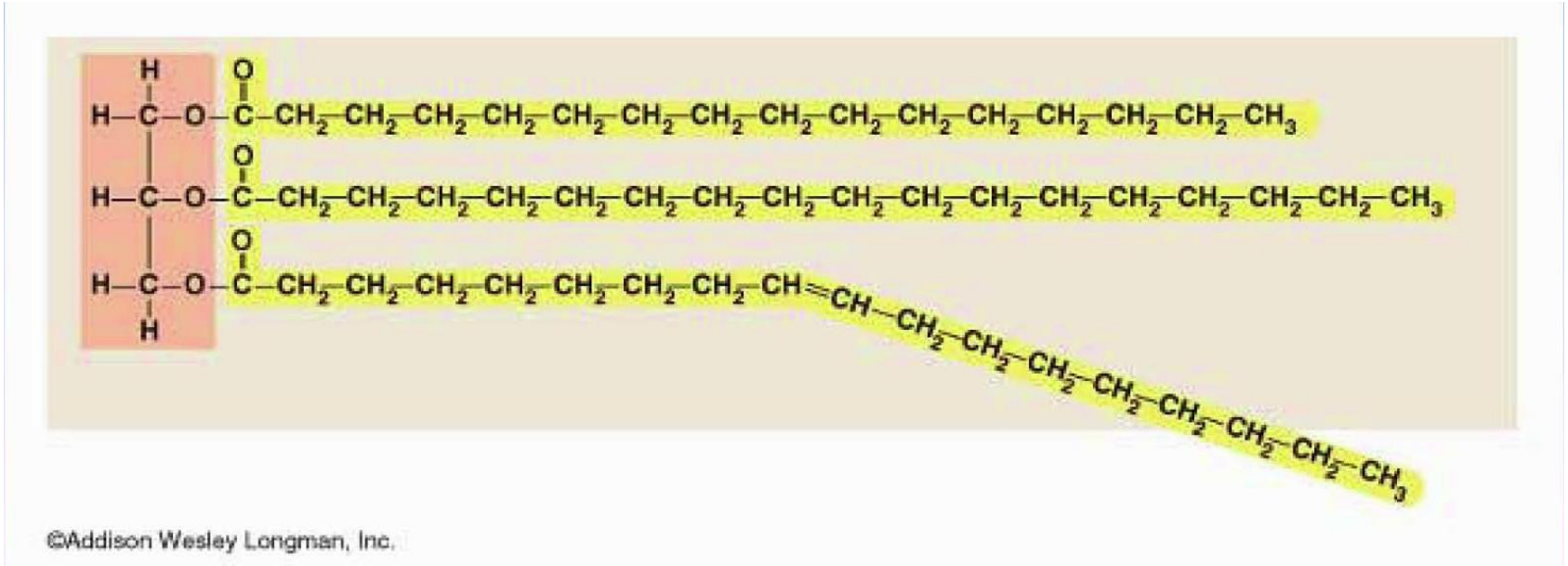
- Monosaccharide: One 6-carbon sugar molecule. Example: glucose (most useful), galactose, and fructose (in fruits)
- Disaccharide: Two monos linked together. Example: sucrose (table sugar).
- Polysaccharide: Many saccharide molecules linked together. Example: Glycogen (in meat), cellulose (in plant cell walls), and starch (in vegetables and grains).





Lipids

- Nonpolar, hydrophobic (water-insoluble) compounds.
- ~15% of body weight
- Composed of C, H and O
- Energy source
- Structural role
- Form integral parts of cell membranes



Lipids

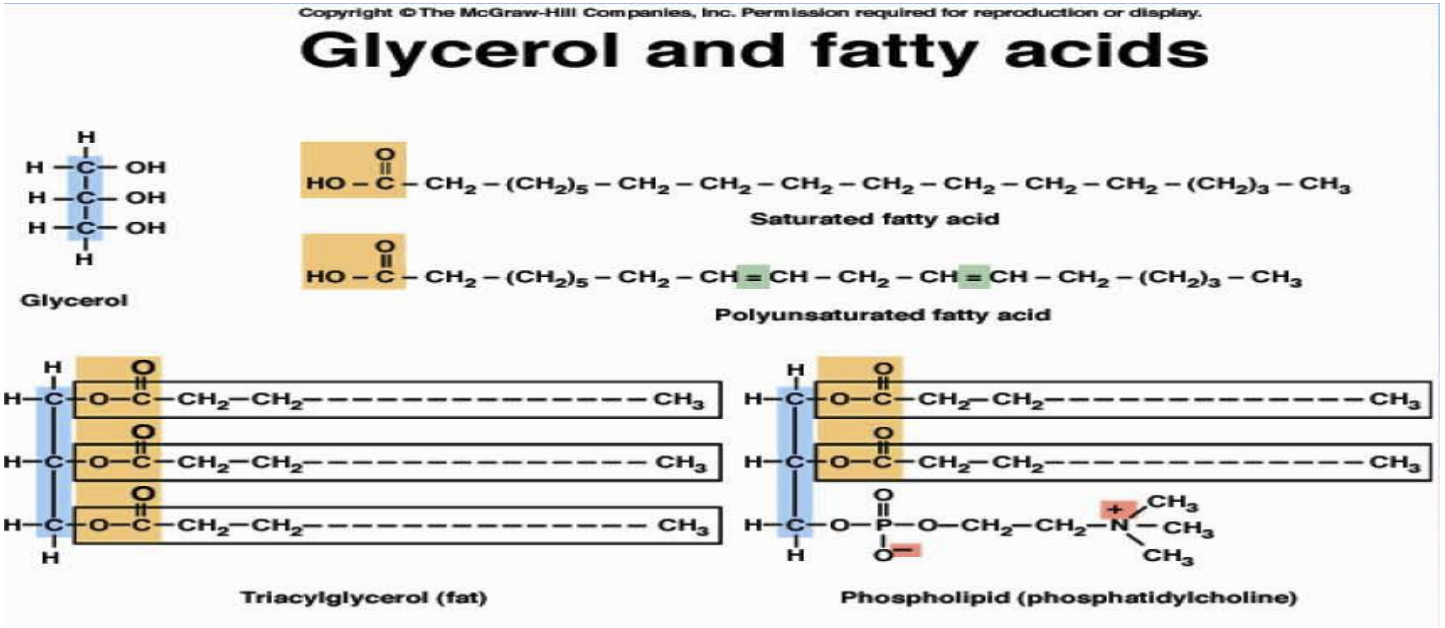
Subclasses of lipids:

1- Fatty acids

2- Triglycerides (most abundant)

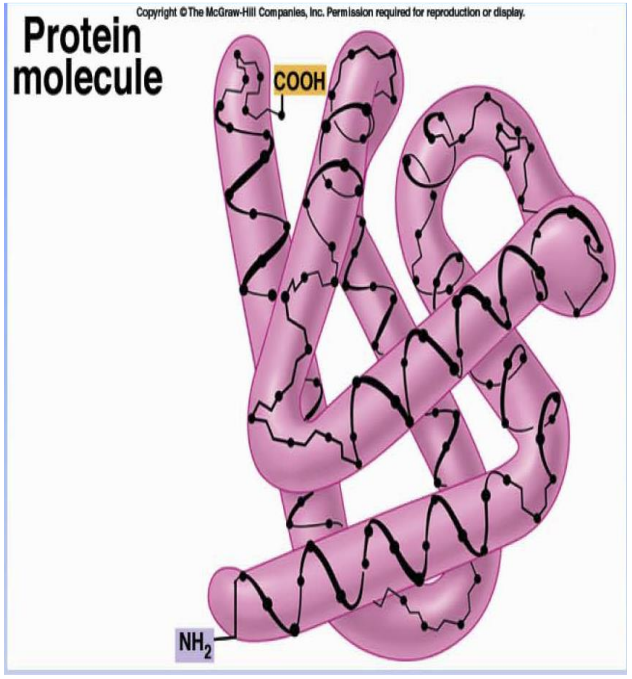
3- Phospholipids (hydrophilic, hydrophobic, lipid bi-layer)

4- Steroids (involved in many structural and functional roles)



Proteins

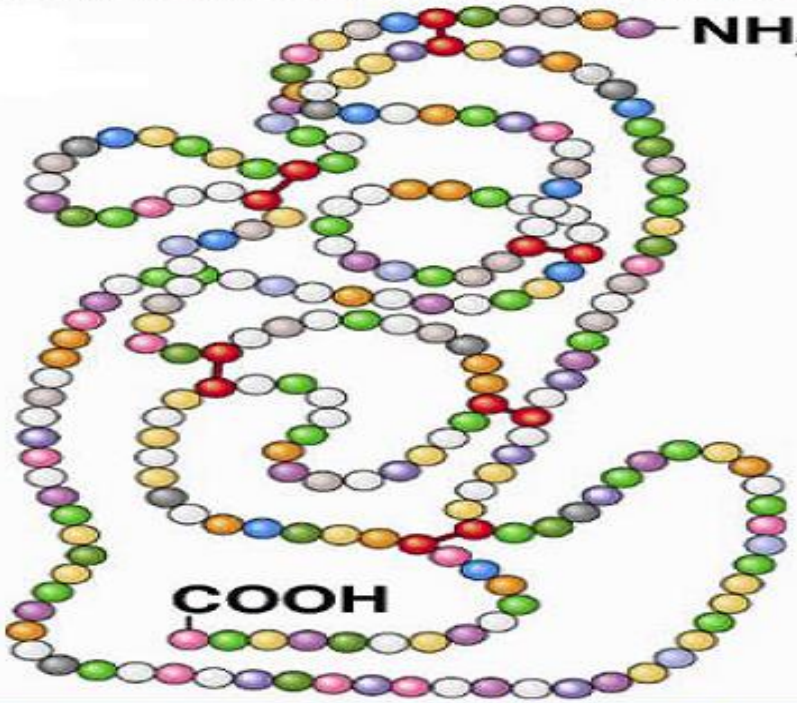
- Composed of C,H,N,O
- Account for ~17% of body weight
- Are large macromolecules with amino acid subunits
- 20 different amino acids linked by peptide bonds.
- Structural conformation determines functional properties



Levels of Protein Structure

- Primary structure
- Secondary structure
- Tertiary structure
- Quaternary structure

Primary protein structure is determined by the amino acid sequence.



This "necklace cartoon" indicates the linear sequence of neighboring amino-acid components in a protein. Each colored bead represents one of the component amino acids.

Secondary and tertiary structures

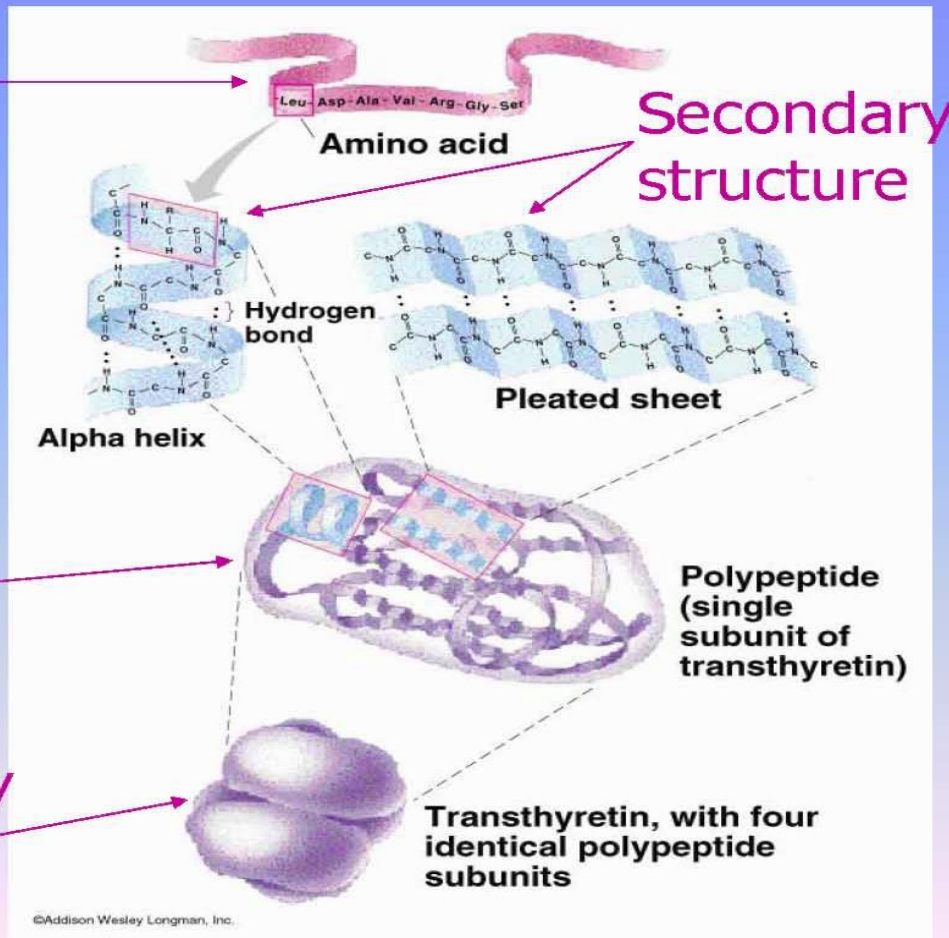
- Make up the 3D shape of molecule

Primary structure

Here you can see all four structure categories… Notice how the secondary, tertiary, and quarternary structures depend on the primary structure.

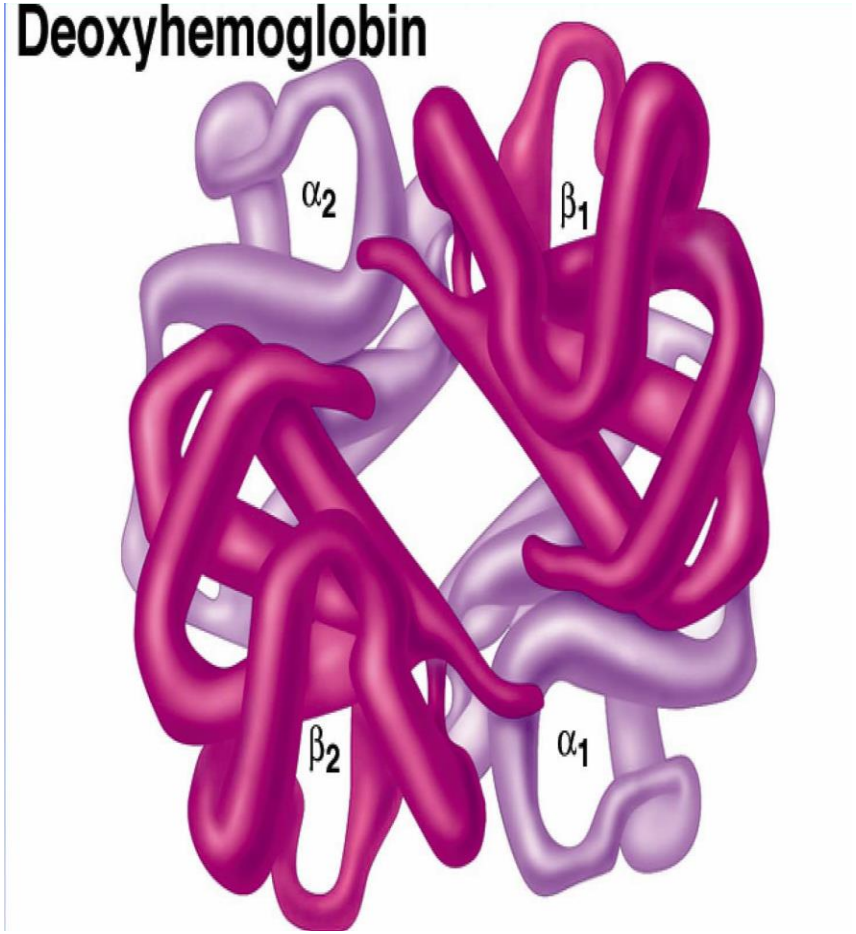
Tertiary structure

Quarternary structure



Quaternary structure

- Different protein chains bind together and act as one functional unit
- To the right is a 3D cartoon of hemoglobin.



Nucleic Acids

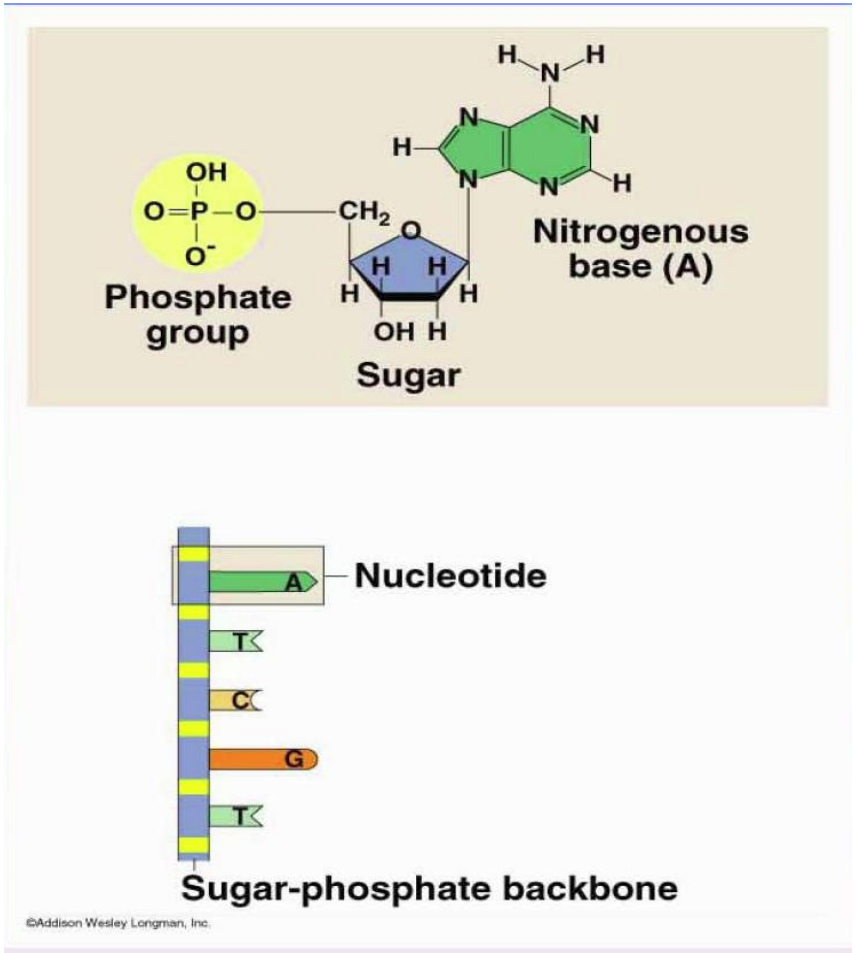
- store, express, and transmit genetic information
- ~2% of body weight
- Classes:

1- DNA (Deoxyribonucleic acid): **stores genetic information**

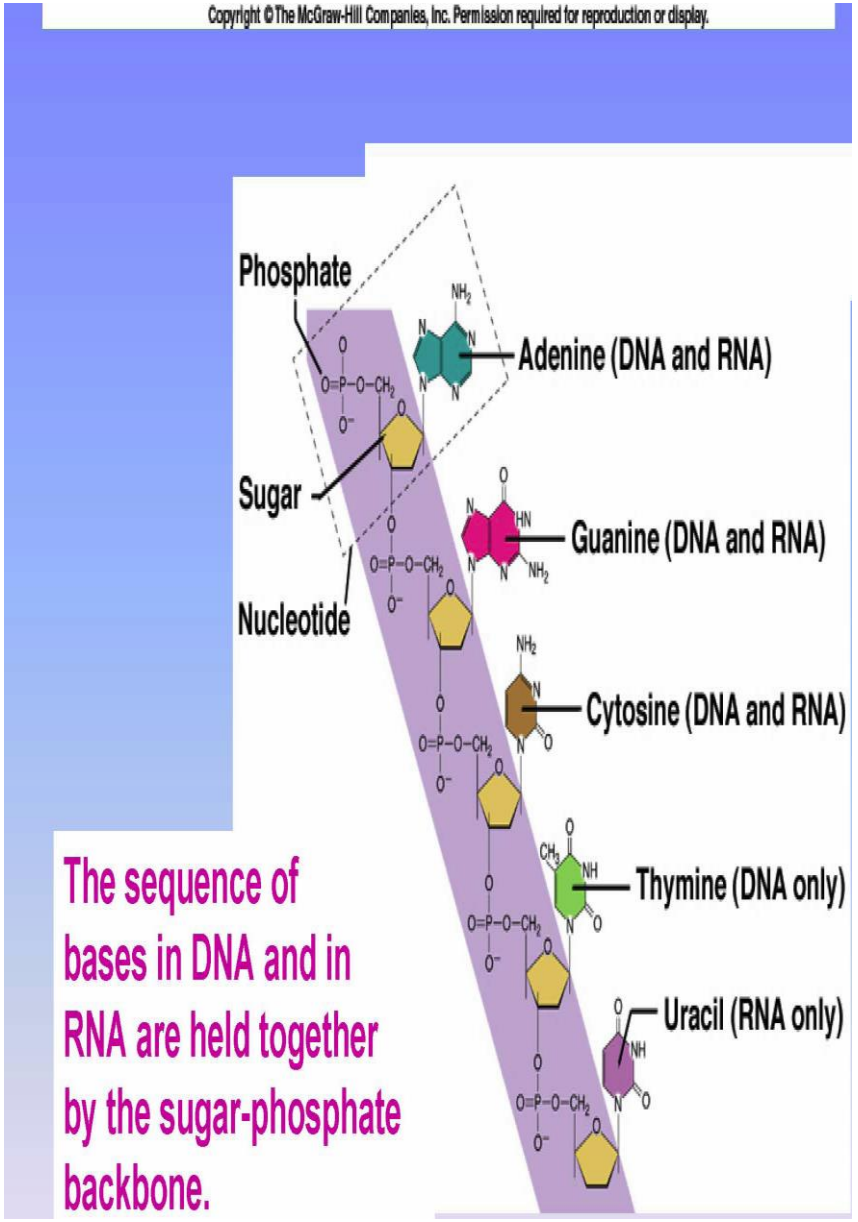
2- RNA (Ribonucleic acid): **plays role in protein synthesis**

Nucleic Acids

- Long polymers of nucleotides
- Nucleotides have 3 parts: 1- Phosphate group, 2- Sugar, 3- Base



Nucleic acids are hooked together between the sugar and the phosphate group, creating a sugar-phosphate backbone.



Comparison between DNA and RNA

TABLE 2–7 Comparison of DNA and RNA Composition

	DNA	RNA
Nucleotide sugar	Deoxyribose	Ribose
Nucleotide bases		
Purines	Adenine	Adenine
	Guanine	Guanine
Pyrimidines	Cytosine	Cytosine
	Thymine	Uracil
Number of chains	Two	One

Metabolism

All the chemical reactions that occur in body cells

Catabolism:

- Releases energy
- Breaks down molecules

Anabolism

- Requires energy
- Builds up molecules

Adenosine triphosphate (ATP)

- Ribose: a pentose sugar
- Adenine
- 3 phosphate subunits

Chapter 2 conclusions

In this lecture, we have learned about the smallest units, the atoms, and linked them up into large biological molecules. These biological molecules include lipids, carbohydrates, proteins, and nucleic acids. These biological molecules are the basis for all kind of life, and we will revisit these molecules often in future lectures.