

# Some Basic Chemistry: Elements and Compounds

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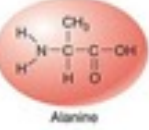


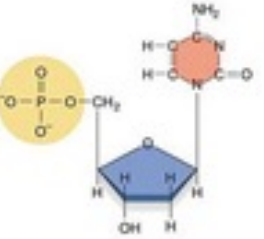
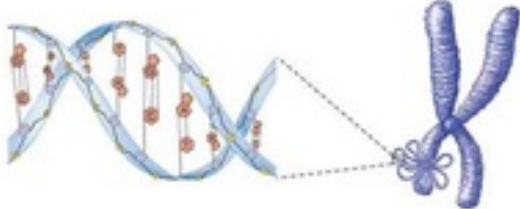

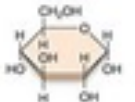
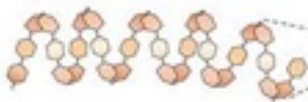


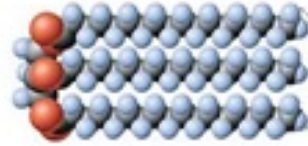
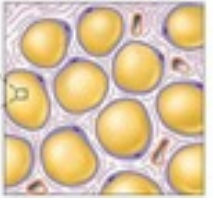
School of Biomedical Sciences

LKS Faculty of Medicine

HKU

# Elements for life

TABLE 4.1 MACROMOLECULES

Monomer	Polymer	Cellular structure
<p>Amino Acid</p>  <p>Alanine</p>	<p>Polypeptide</p> 	<p>Intermediate filament</p> 
<p>Nucleotide</p> 	<p>DNA strand</p> 	<p>Chromosome</p> 
<p>Monosaccharide</p> 	<p>Starch</p> 	<p>Starch grains in a chloroplast</p> 
<p>Fatty acid</p> 	<p>Fat molecule</p> 	<p>Adipose cells with fat droplets</p> 

- You could start really small...
- Particles of matter
  - Atoms
  - - Elements
  - - Molecules
  - - Macromolecules
  - - Cell organelles
  - Cells
  - Tissues
  - Organs
  - Systems
  - **Organisms**
  - Populations
  - Ecosystems
  - Biospheres
  - Planets
  - Planetary Systems with Stars
  - Galaxies
  - The Universe
- .And finish really big.

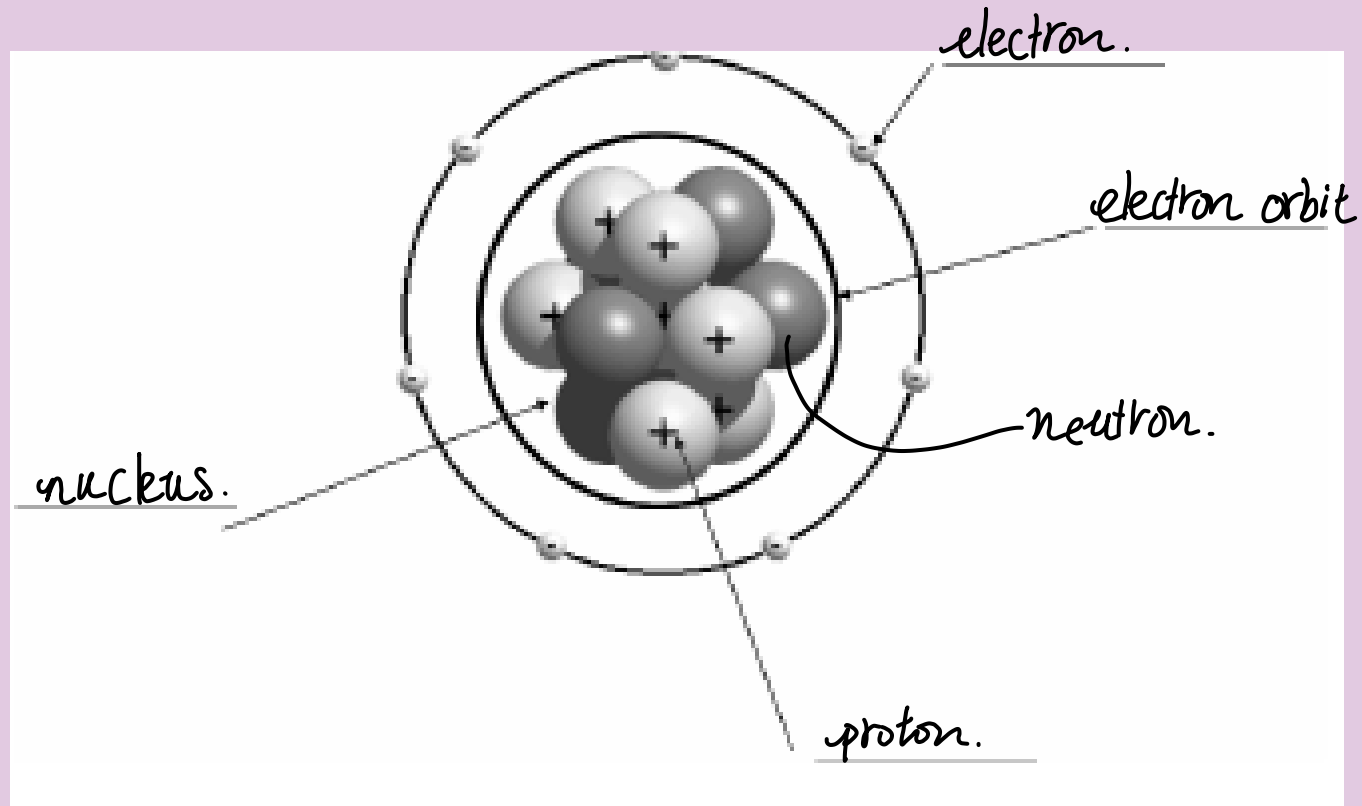
## ■ Learning Objectives

- *Explain* the anatomy of an atom.
  - Know the general structure of an atom
  - Understand the meaning of relative atomic weight, in that an atom may have isotopes.
- *Recognise* the elements of life.
  - List the four common elements of life
  - Aware the other less common and trace elements of life
- *Show* different types of chemical bonds.
  - Know Ionic bonds / covalent bonds / hydrogen bonds
  - Aware of the term electronegativity
- *Illustrate* how atoms are organized into molecules.
  - Know the terms of cations and anions
  - Understand van der waals interaction / hydrophobic force
  - Know about different molecular states

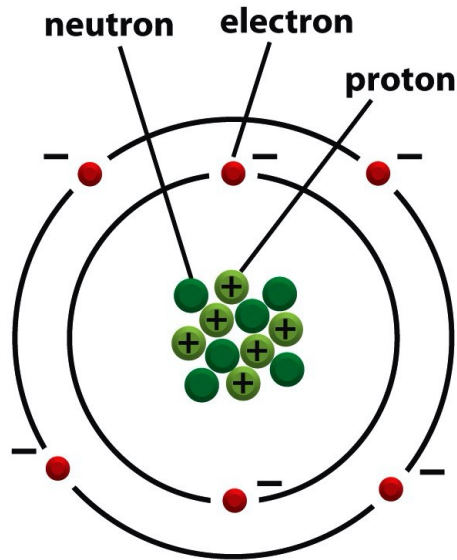
## From atoms to molecules



## Anatomy of an atom

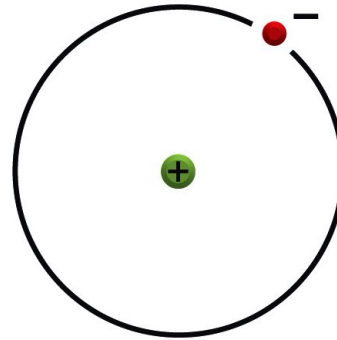


## Elements for life



**carbon atom**

**atomic number = 6**  
**atomic weight = 12**



**hydrogen atom**

**atomic number = 1**  
**atomic weight = 1**

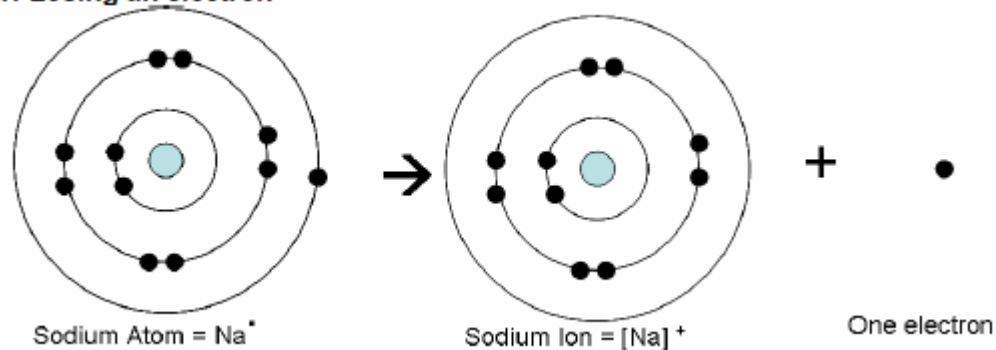
**Atomic number:**  
The number of protons in the nucleus of an atom of an element.

**Atomic weight:**  
The average mass of an atom of an element, usually expressed relative to the atomic mass of carbon 12.

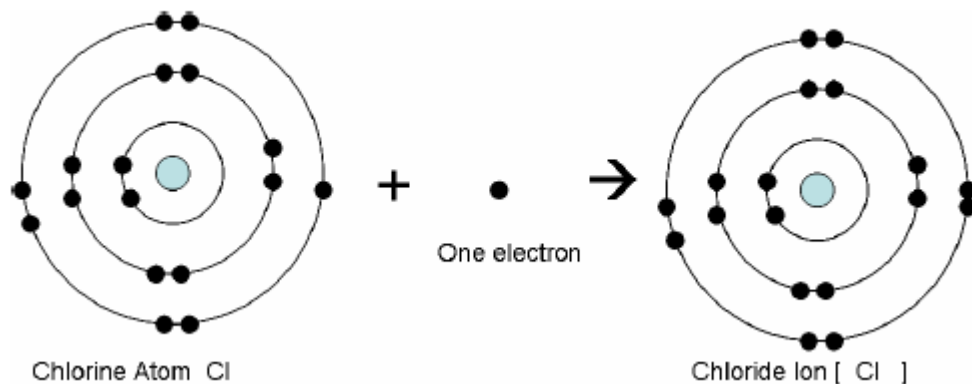
Figure 2-1 Molecular Biology of the Cell 5/e (© Garland Science 2008)

- Protons are positively charged and in the nucleus of the atom
- Neutrons are uncharged in the nucleus of the atom
- Electrons are negatively charged and in orbitals around the nucleus

### Case 1: Losing an electron



### Case 2: Gaining an electron



### Types of Bonds:

1. **Ionic bond** = form between a metal and a non-metal and have opposite charges. (I.e. sodium and chloride ions). They generally form **compounds**.
2. **Metallic bond** = form when metal atoms share their pooled electrons (i.e. silver atoms)
3. **Covalent Bond** = form between non-metals when they shared electrons. ( $\text{Cl}_2$  – chlorine molecule, or  $\text{SO}_3$  – sulfur trioxide). They generally form **molecules**.



**atomic number**

**atomic weight**



Hydrogen (H)  
Carbon (C)  
Nitrogen (N)  
Oxygen (O)



**Sodium (Na)**  
**Magnesium (Mg)**  
**Phosphorus (P)**  
**Sulphur (S)**  
**Chloride (Cl)**  
**Potassium (K)**  
**Calcium (Ca)**

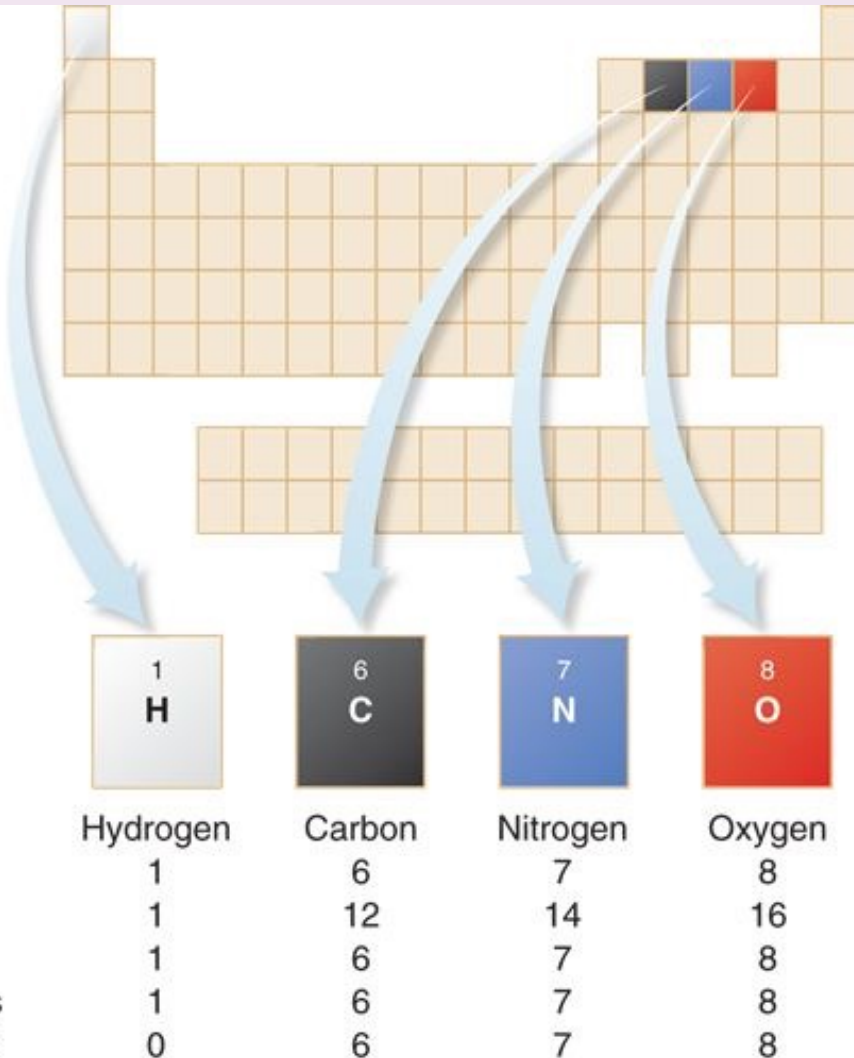


Fluorine (F)	Copper (Cu)
Vanadium (V)	Zinc (Zn)
Chromium (Cr)	Selenium (Se)
Manganese (Mn)	Molybdenum (Mo)
Iron (Fe)	Iodine (I)
Cobalt (Co)	





caffeine  
(C<sub>8</sub>H<sub>10</sub>N<sub>4</sub>O<sub>2</sub>)

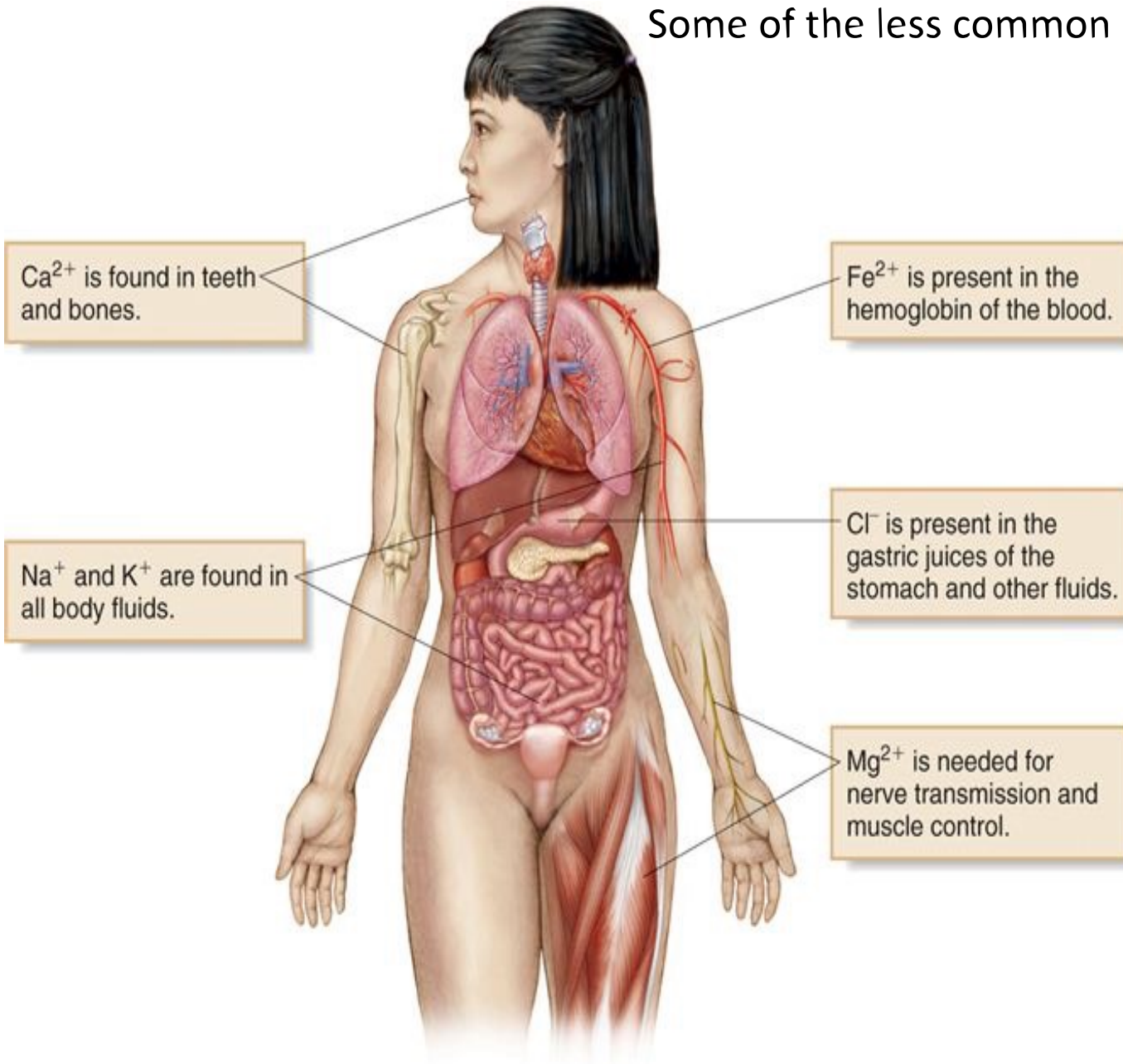


## Atomic composition of four building-block elements

- **Carbon (C)**
  - Form backbones of organic molecules; can form four bonds with other atoms
- **Nitrogen (N)**
  - Component of all proteins and nucleic acids
- **Oxygen (O)**
  - For cellular respiration; found in most organic compound, eg. food stuff
- **Hydrogen (H)**
  - Present in all organic compounds; maintain acid-base balance

Elements that  
make up the  
human body

## Some of the less common and trace elements



# Elements that make up the human body

## ■ Sodium (Na)

- Major positive ions in tissue fluid; vital in fluid balance; vital for conduction of nerve impulses

## ■ Magnesium (Mg)

- Needed in blood and other body tissues; vital as a co-enzyme

## ■ Phosphorus (P)

- Part of nucleic acids; structural part of bone and cell walls; vital in energy transfer

## ■ Sulphur (S)

- Part of most proteins; activation of enzymes

## ■ Chlorine (Cl)

- Major negative ion in tissue fluid; vital for fluid balance; part of NaCl and gastric juice

## ■ Potassium (K)

- Major positive ion within the cells; vital in nerve function; affect muscle contraction, fluid and electrolyte balance

## ■ Calcium (Ca)

- Structural component of bones and teeth; acid-base balance; vital in muscle contraction; conduction of nerve impulses and blood clotting

# Approx. composition by weight

▶ **O 65%**

▶ **C 18%**

▶ **H 10%**

▶ **N 3%**

▶ **Common elements**

▶ **Ca 1.5%**

▶ **P 1%**

▶ **K 0.4%**

▶ **S 0.3%**

▶ **Na 0.2%**

▶ **Mg 0.1%**

▶ **Cl 0.1%**

▶ **Less common elements**

# The trace Elements in the human body

- **Fluorine (F)**
  - Incorporated into the tooth enamel, and into bone structure
- **Vanadium (V)**
  - *In vitro* and animal studies suggest in function as an oxidation-reduction catalyst, and may regulate the sodium, potassium and adenosine triphosphatase enzyme, however, this has not been proven.
- **Chromium (Cr)**
  - Helps to maintain blood sugar level by assisting insulin to uptake of glucose into cells
- **Manganese (Mn)**
  - It is a co-factor for many several enzymes, found mostly in liver and kidney, and specifically in mitochondria
- **Iron (Fe)**
  - Component of hemoglobin and myoglobin; and certain enzymes
- **Cobalt (Co)**
  - It is part of vitamin B12, which is required for maturation of red blood cells (erythrocytes)



# The trace Elements in the human body

- **Copper (Cu)**

- It is part of several enzymes used for oxidation

- **Zinc (Zn)**

- It is part of many enzymes; needed in saliva for the taste buds development; vital for growth, sexual development and taste awareness, also has roles in protein synthesis and cell division

- **Selenium (Se)**

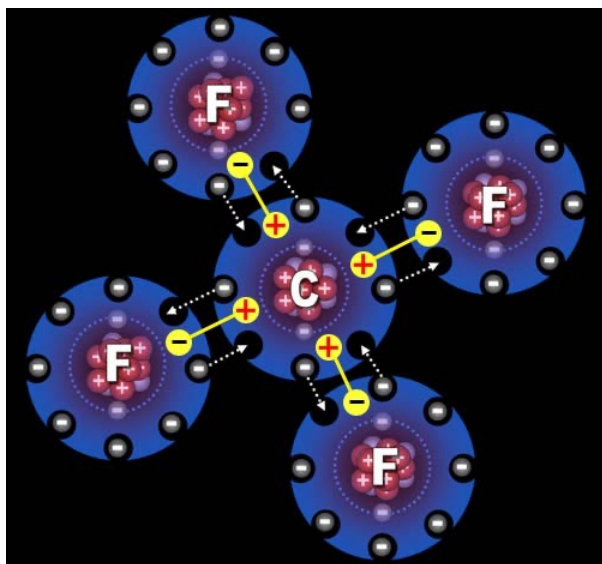
- It is believed to be closely linked to function of vitamin E; part of the glutathione peroxidase, which removes hydrogen peroxide and organic peroxides

- **Molybdenum (Mo)**

- Part of some enzymes, has similar functions to copper, ie oxidation

- **Iodine (I)**

- Part of the thyroid hormones



How do atoms  
hold together?

- The answer is by chemical bonds
- These bonds is all about how the outer shell of electrons of an atom interact with the electrons of another atom.

[https://www.youtube.com/watch?v=\\_M9khs87xQ8](https://www.youtube.com/watch?v=_M9khs87xQ8)

## CHEMICAL BONDS FOR MOLECULES

- **Covalent** bonds happen when two atoms share electrons
  - kind of like 2 atoms holding hands. When at least 2 atoms get together by sharing electrons, they form a *molecule*.
- Four types of non-covalent interactions to bring molecules together in a cell
  - i. Ionic bonds
  - ii. Hydrogen bonds
  - iii. van der Waals attraction
  - iv. Hydrophobic force

[http://www.yellowtang.org/animations/bond\\_types.swf](http://www.yellowtang.org/animations/bond_types.swf)

# Chemical bonds for molecules

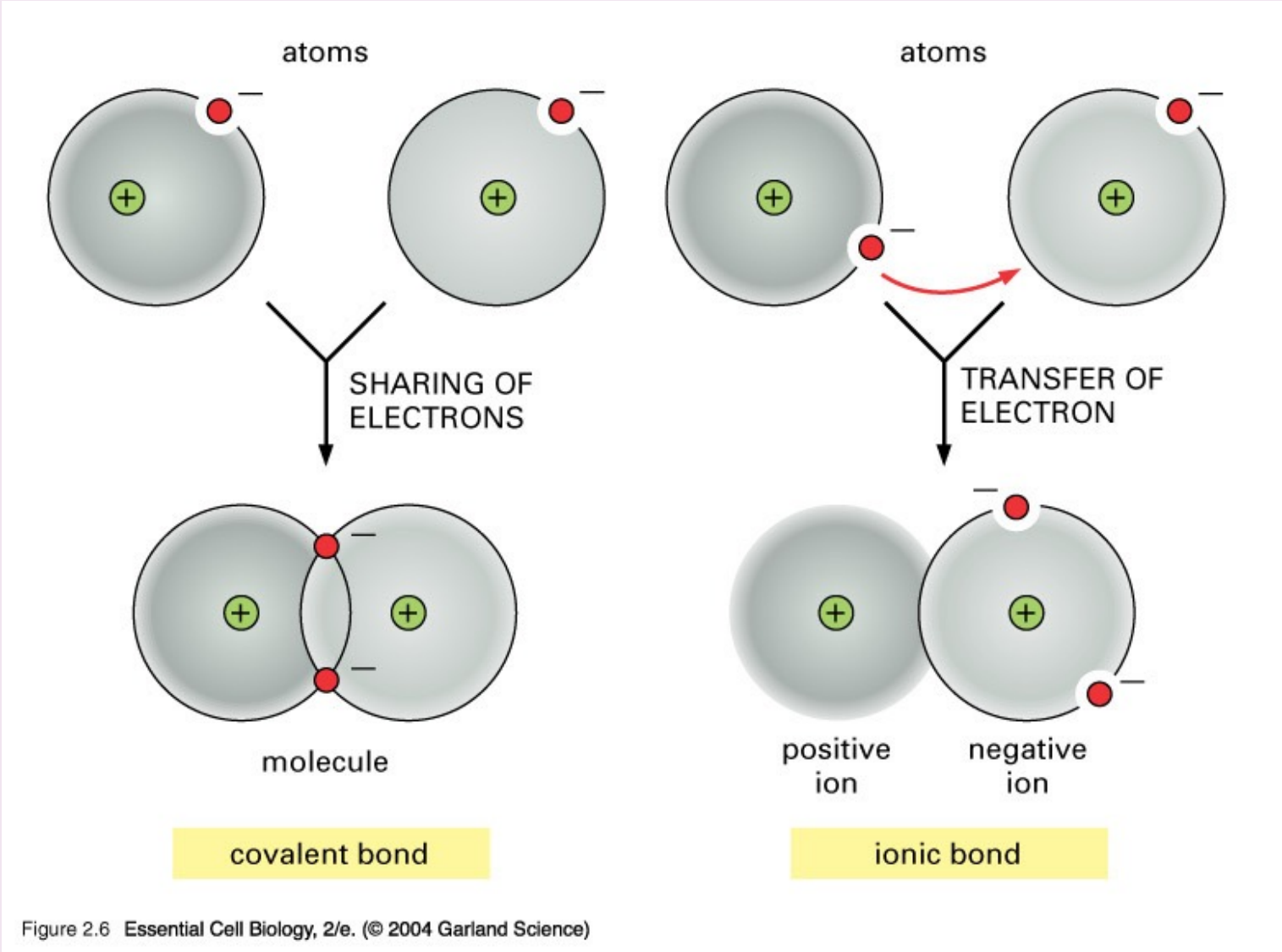
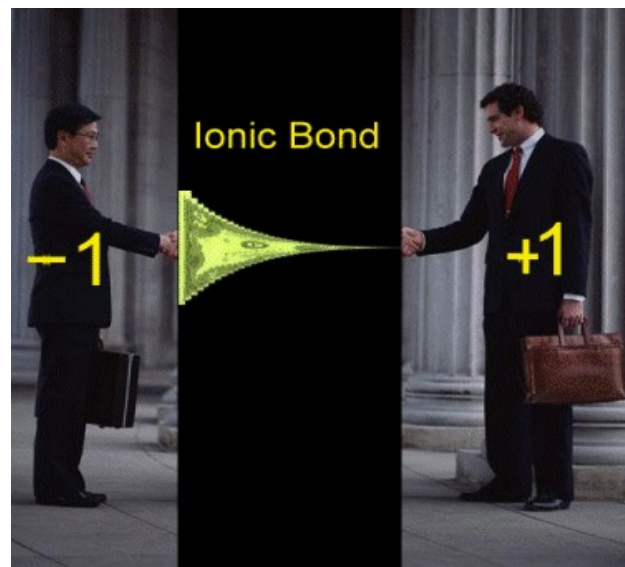


Figure 2.6 Essential Cell Biology, 2/e. (© 2004 Garland Science)

# Chemical bonds for molecules



- *Electronegativity* is a measure of an atom's attraction for electrons in a bond.
- Electronegativity tells us how much a particular atom “*wants*” electrons.
- The symbol  $\delta^+$  is given to the less electronegative atom.
- The symbol  $\delta^-$  is given to the more electronegative atom.

## Covalent bonds and covalent compounds



## Covalent bonds

### Electronegativity Difference and Bond Type

<b>Electronegativity Difference</b>	<b>Bond Type</b>	<b>Electron Sharing</b>
Less than 0.5 units	Nonpolar	Electrons are equally shared.
0.5–1.9 units	Polar covalent	Electrons are unequally shared; they are pulled towards the more electronegative element.
Greater than 1.9 units	Ionic	Electrons are transferred from the less electronegative element to the more electronegative element.

### Lone pairs of electrons

	$\text{—H}$	$\begin{array}{c}   \\ \text{—C—} \\   \end{array}$	$\begin{array}{c} \cdot\cdot \\ \text{—N—} \\   \end{array}$	$\begin{array}{c} \cdot\cdot \\ \text{—O—} \\ \cdot\cdot \end{array}$	$\begin{array}{c} \cdot\cdot \\ \text{—X:} \\ \cdot\cdot \end{array}$	$\text{X = F, Cl, Br, I}$
	hydrogen	carbon	nitrogen	oxygen	halogen	
Number of bonds	1	4	3	2	1	
Number of nonbonded electron pairs	0	0	1	2	3	

Covalent bonds

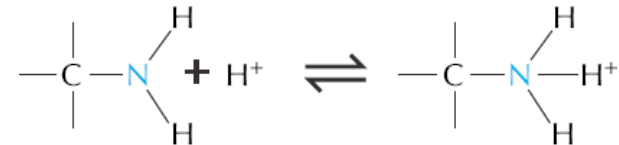
# Chemical bonds for molecules

## Commonly seen C-N chemical groups in biochemistry

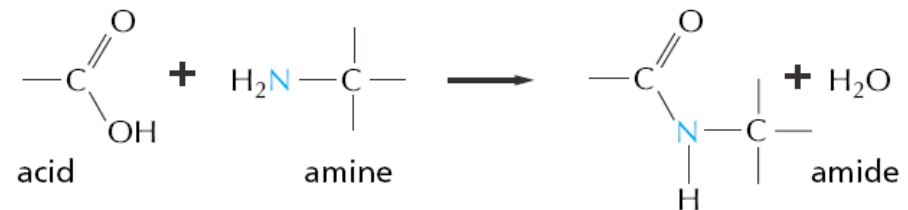
### C-N CHEMICAL GROUPS

Amines and amides are two important examples of compounds containing a carbon linked to a nitrogen.

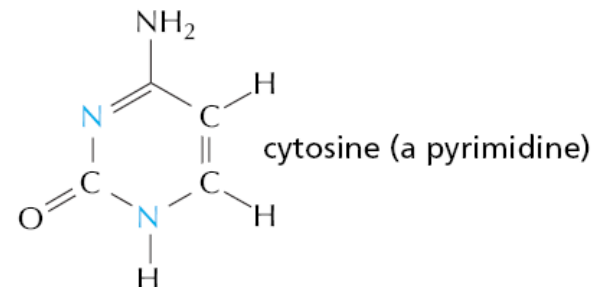
**Amines** in water combine with an  $H^+$  ion to become positively charged.



**Amides** are formed by combining an acid and an amine. Unlike amines, amides are uncharged in water. An example is the peptide bond that joins amino acids in a protein.



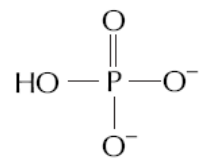
Nitrogen also occurs in several ring compounds, including important constituents of nucleic acids: purines and pyrimidines.



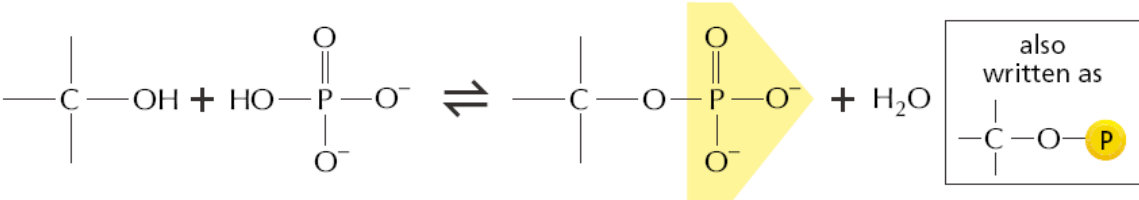
# Chemical bonds for molecules

## Commonly seen phosphate groups in biochemistry

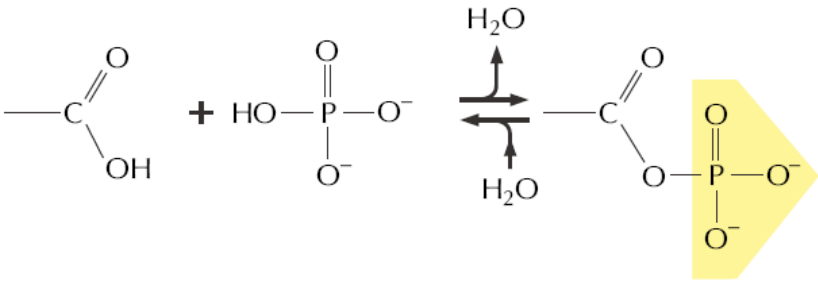
Inorganic phosphate is a stable ion formed from phosphoric acid,  $\text{H}_3\text{PO}_4$ . It is often written as  $\text{P}_i$ .



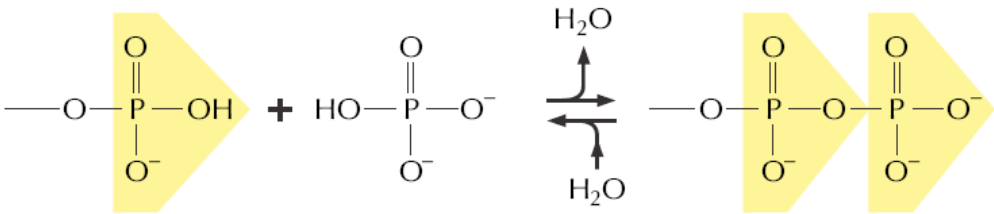
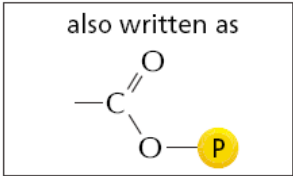
Phosphate esters can form between a phosphate and a free hydroxyl group. Phosphate groups are often attached to proteins in this way.



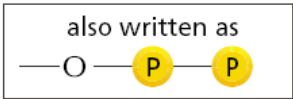
The combination of a phosphate and a carboxyl group, or two or more phosphate groups, gives an acid anhydride.



high-energy acyl phosphate bond (carboxylic-phosphoric acid anhydride) found in some metabolites

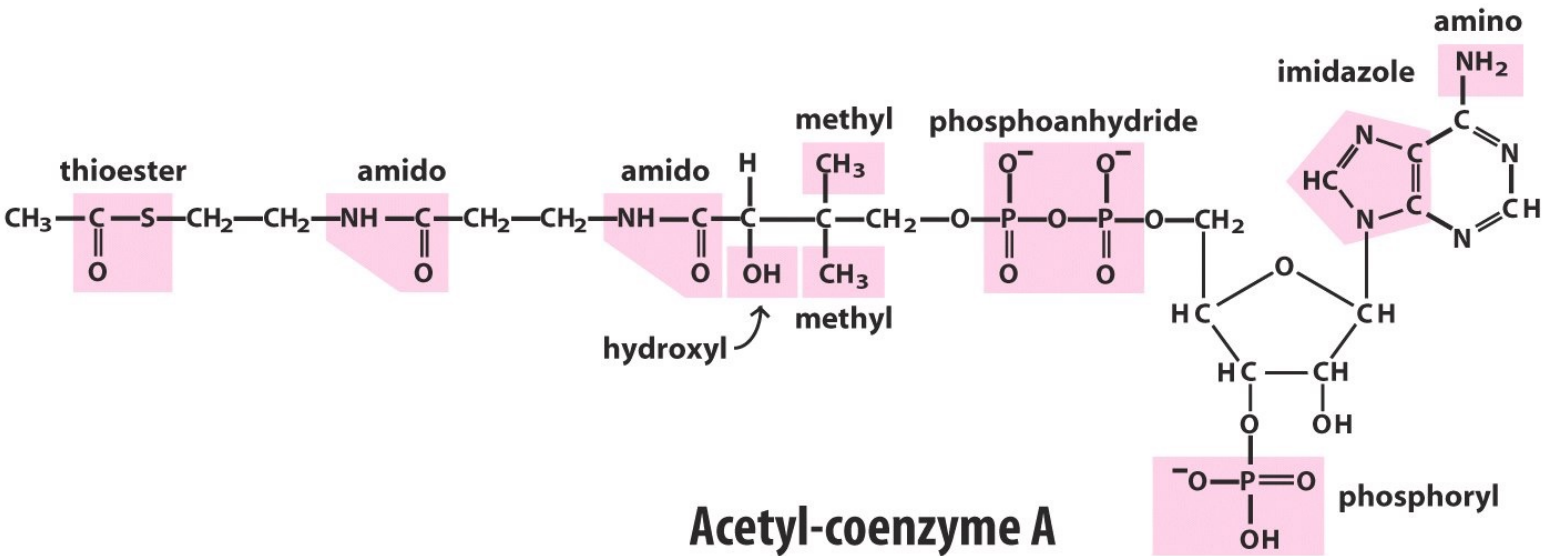


phosphoanhydride—a high-energy bond found in molecules such as ATP



# Chemical bonds for molecules

A typical molecule and its functional groups



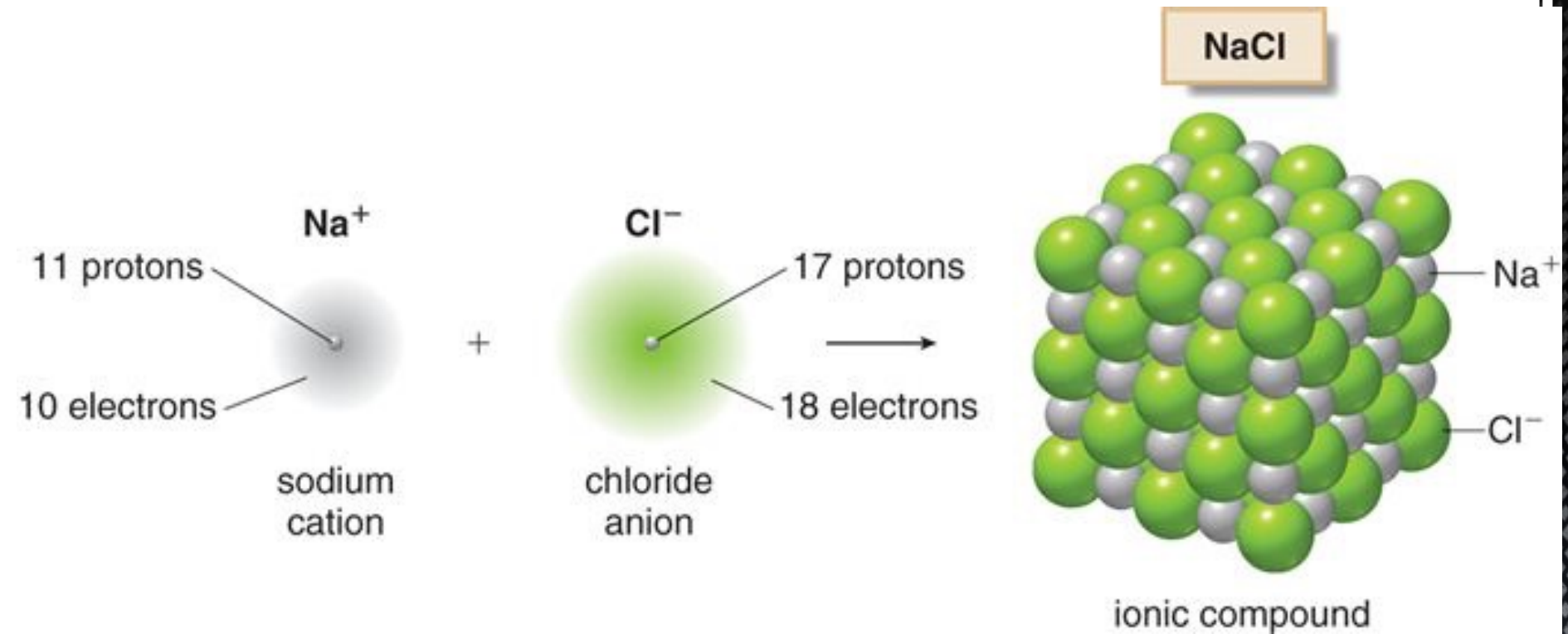
# Ionic bonds and ionic compounds

- *Ionic bonds* result from the transfer of electrons from one element to another.
- *Cations* are positively charged ions. A cation has fewer electrons than protons.
- *Anions* are negatively charged ions. An anion has more electrons than protons.
- *Ionic compounds* consist of oppositely charged ions that have a strong electrostatic attraction for each other.



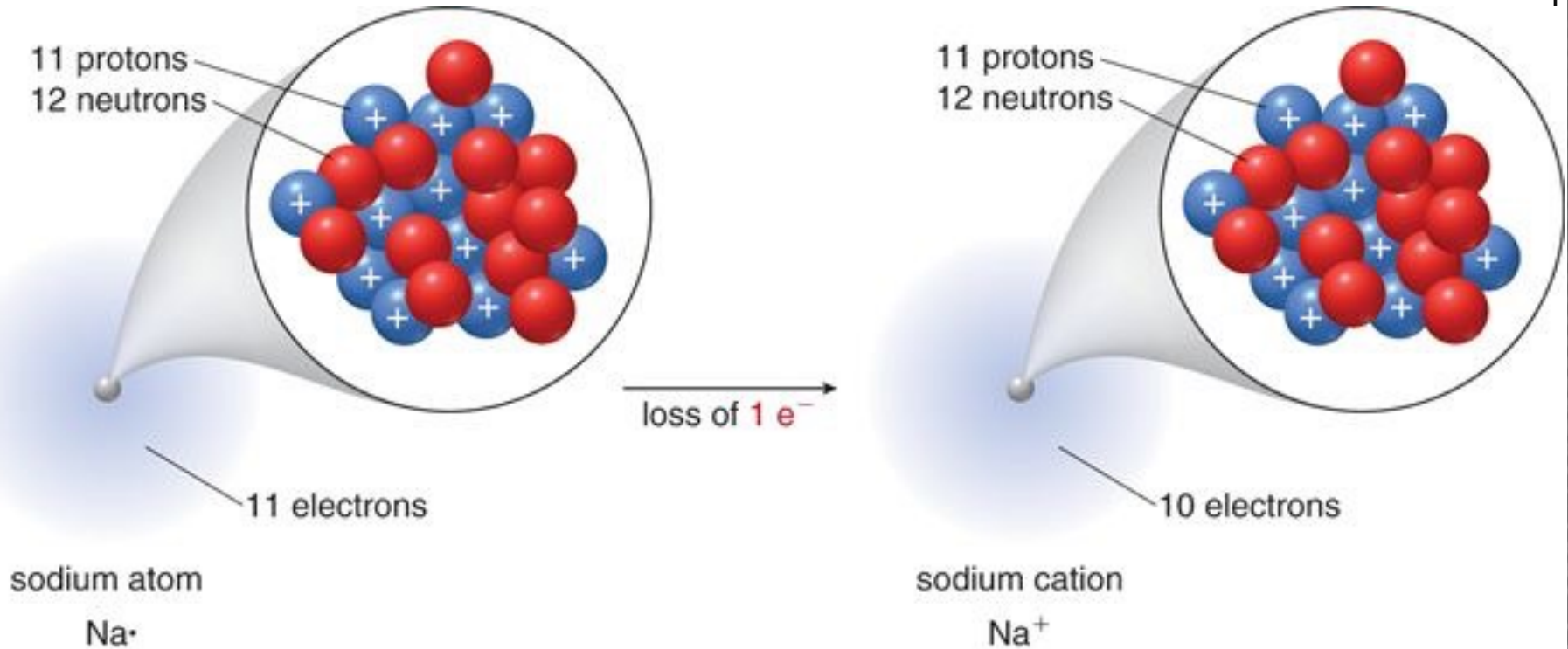
# Ionic compound contain anions and cations

Note: the overall sum of charge should be zero!



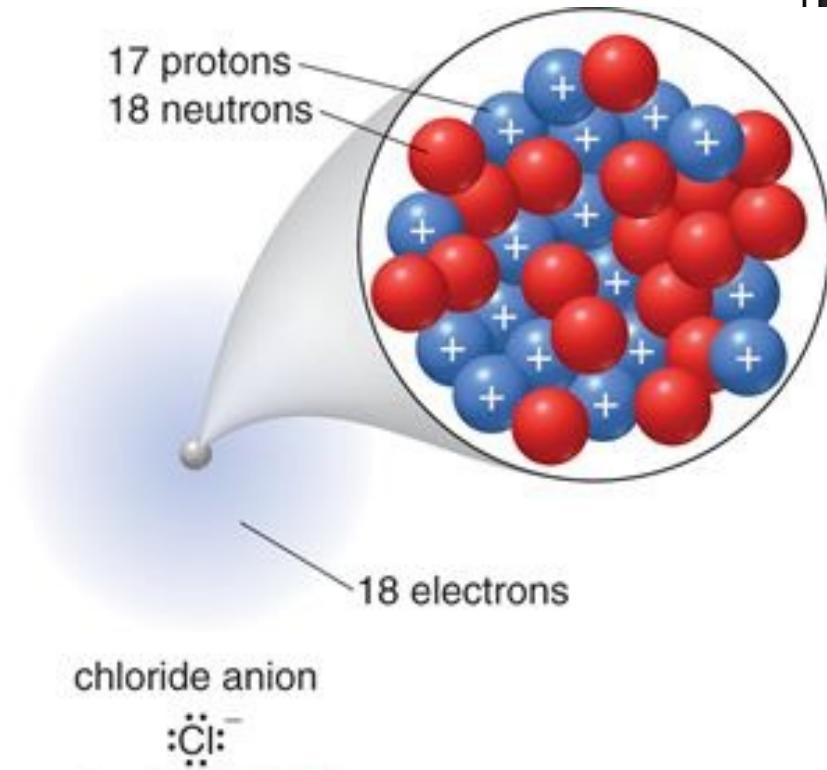
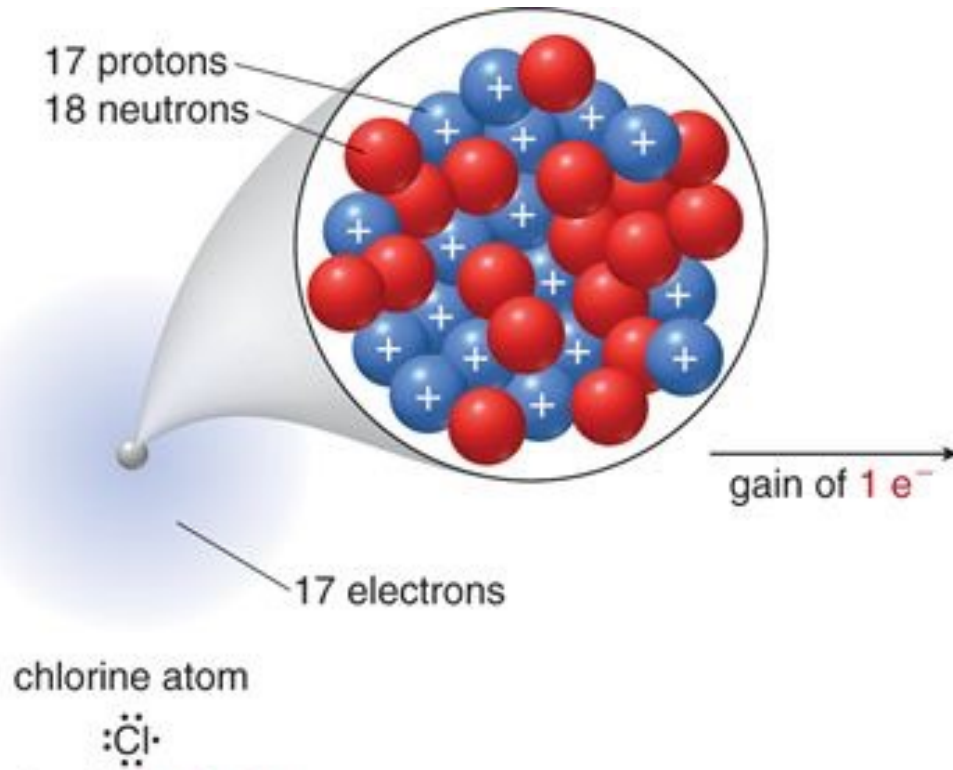
# Examples of Ions

## Cations

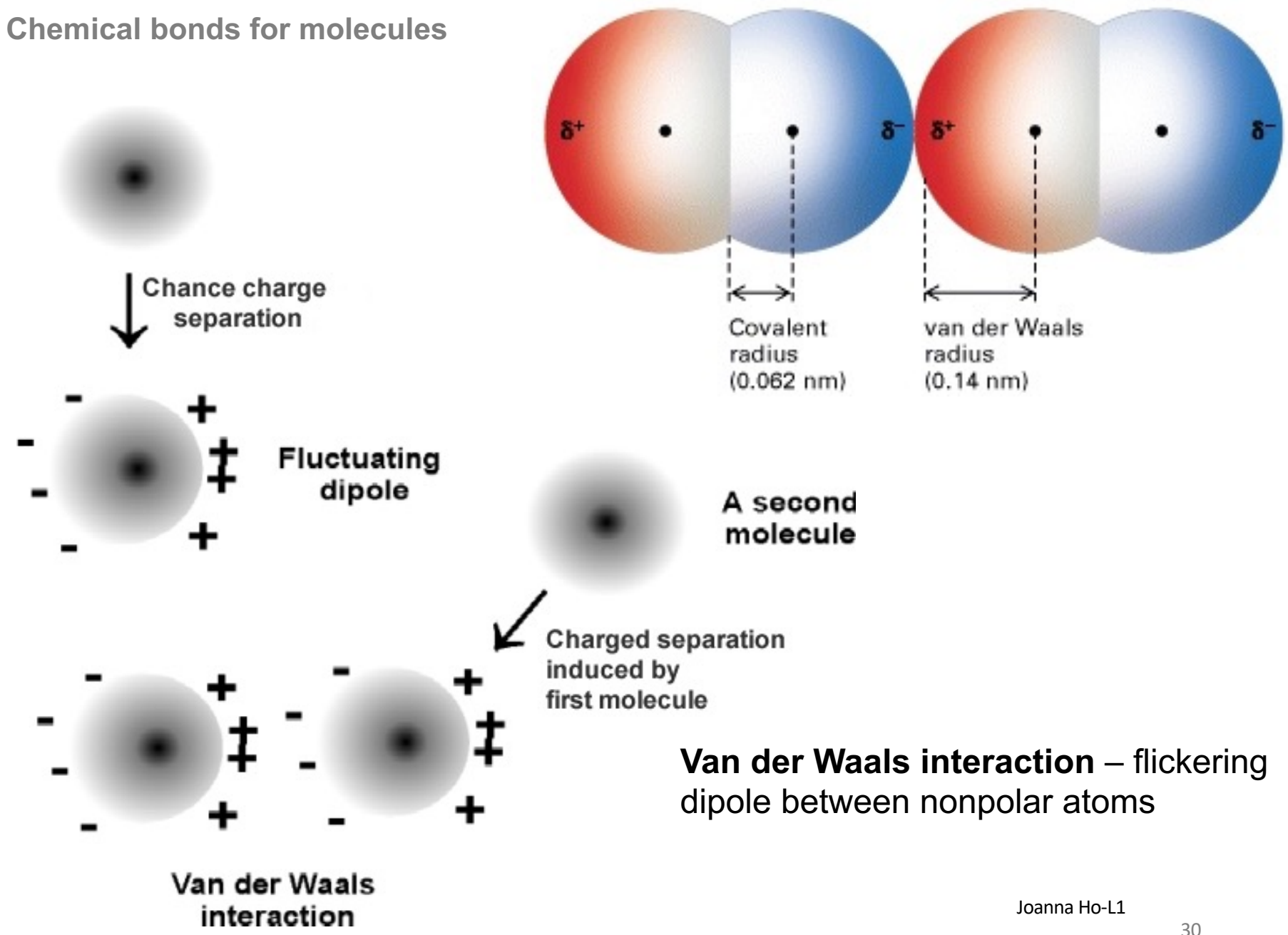


# Examples of Ions

## Anions



# Chemical bonds for molecules



**Van der Waals interaction** – flickering dipole between nonpolar atoms

# Hydrogen bonds

Electropositive hydrogen partially shared with two electronegative atoms.

**(A)**

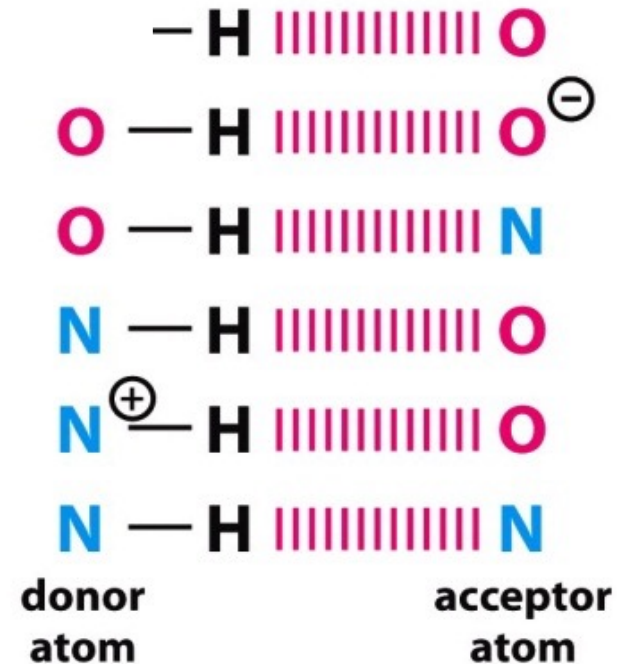
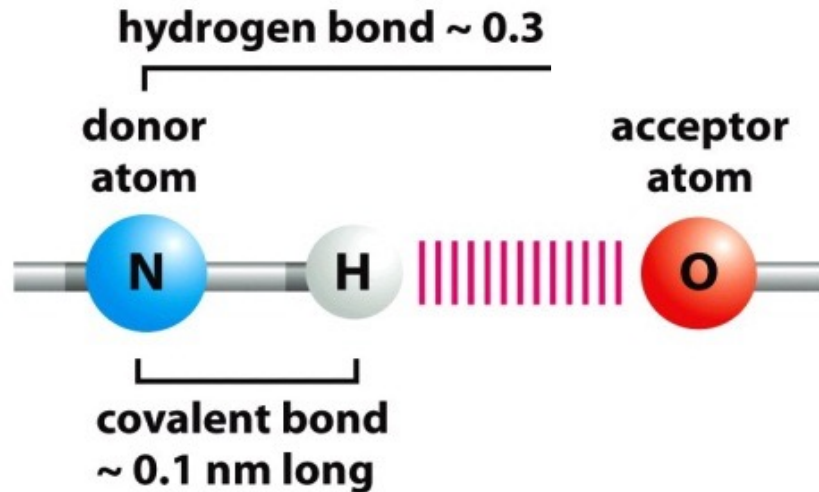
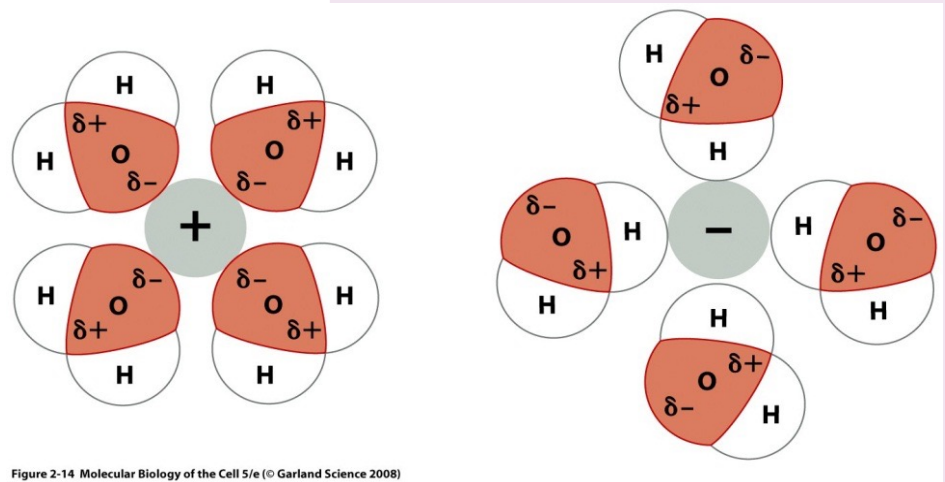


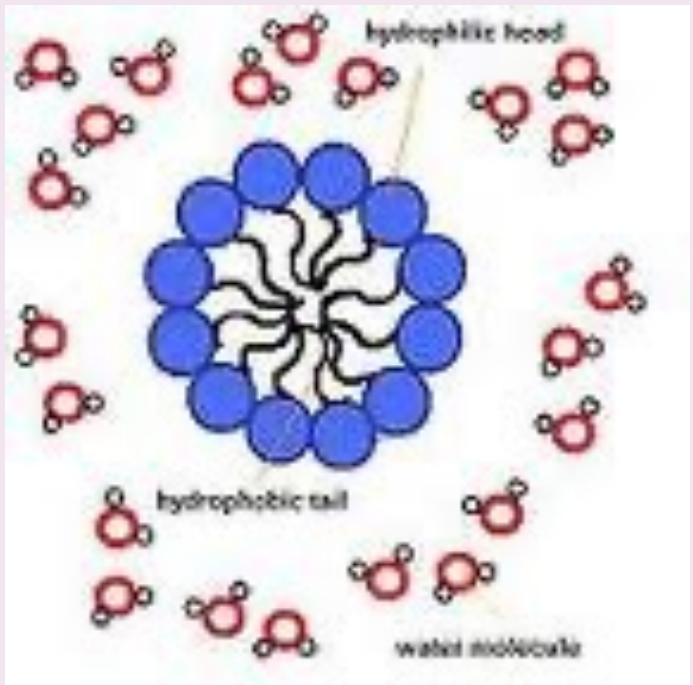
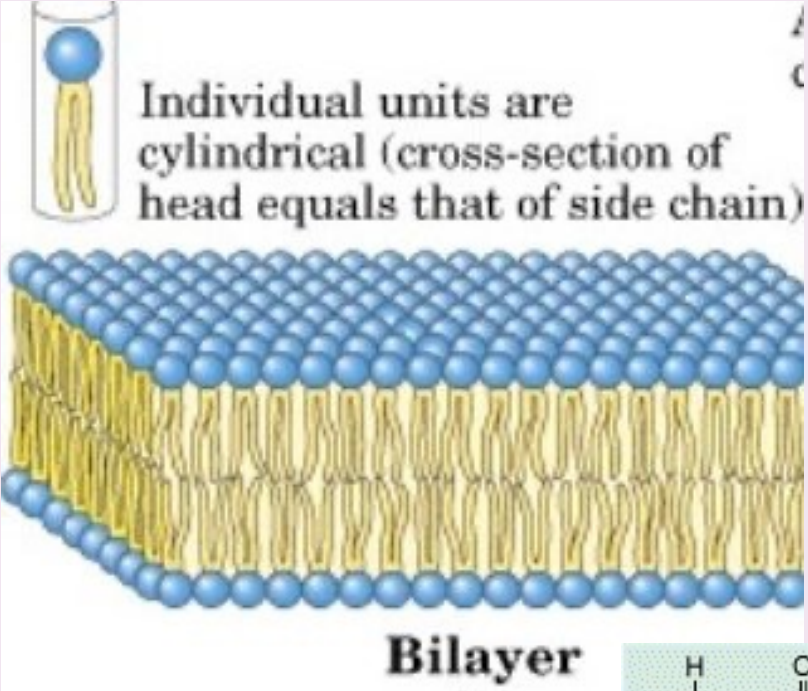
Figure 2-15 Molecular Biology of the Cell 5/e (© Garland Science 2008)



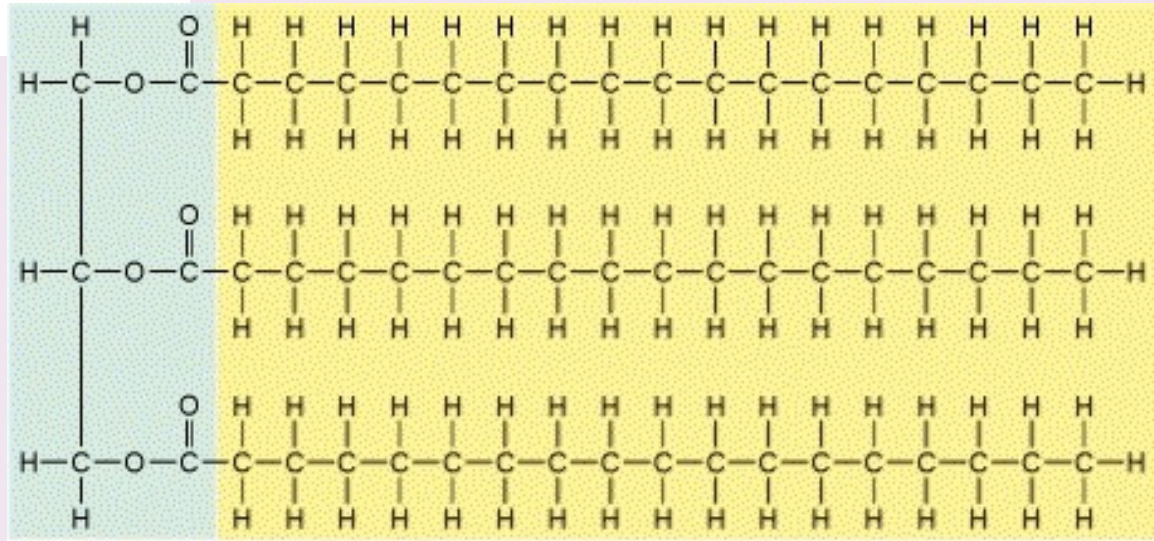
**Figure 2-14 Molecular Biology of the Cell 5/e (© Garland Science 2008)**



# Chemical bonds for molecules



**Hydrophobic forces** – pushing nonpolar surfaces out of hydrogen-bonded water network





## ■ Learning Objectives

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## From atoms to molecules