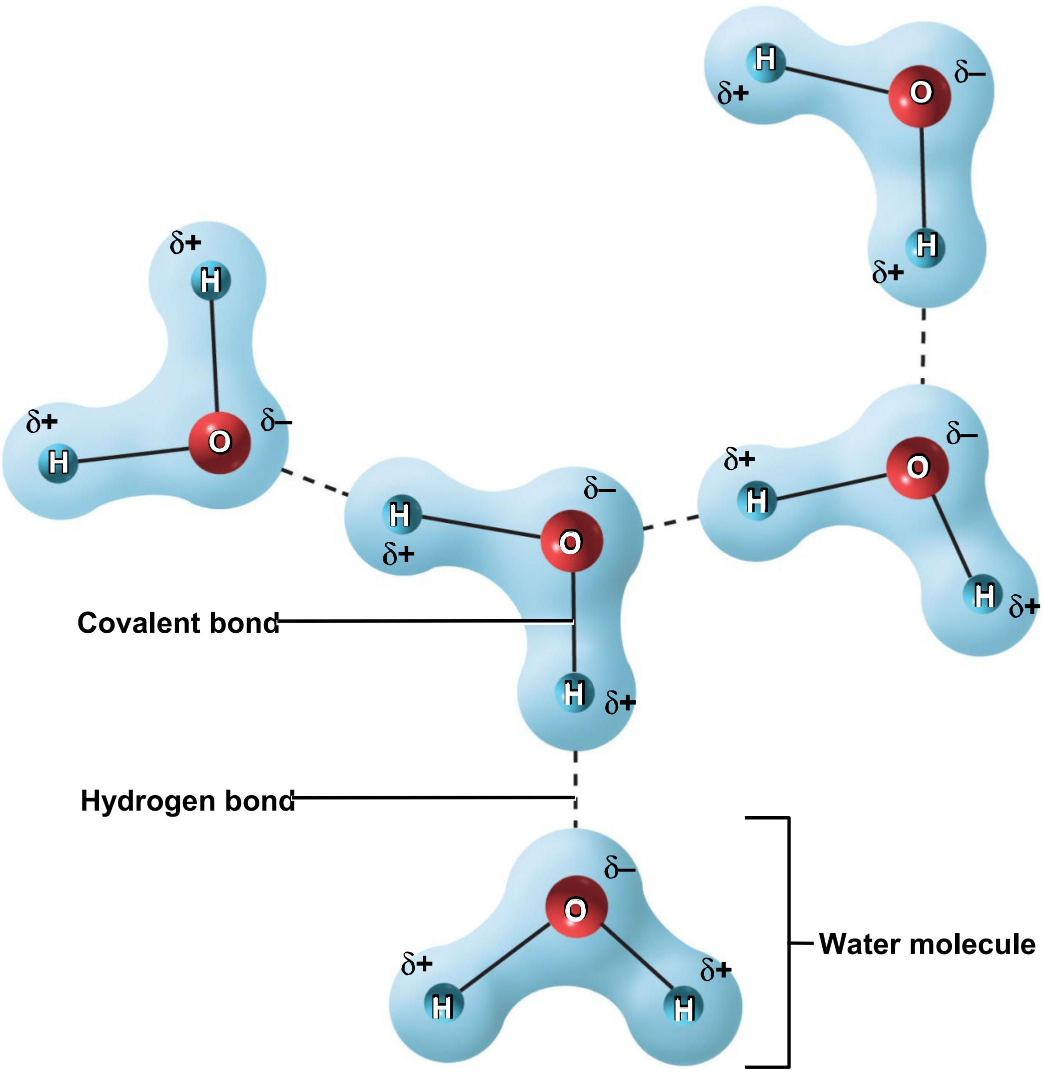
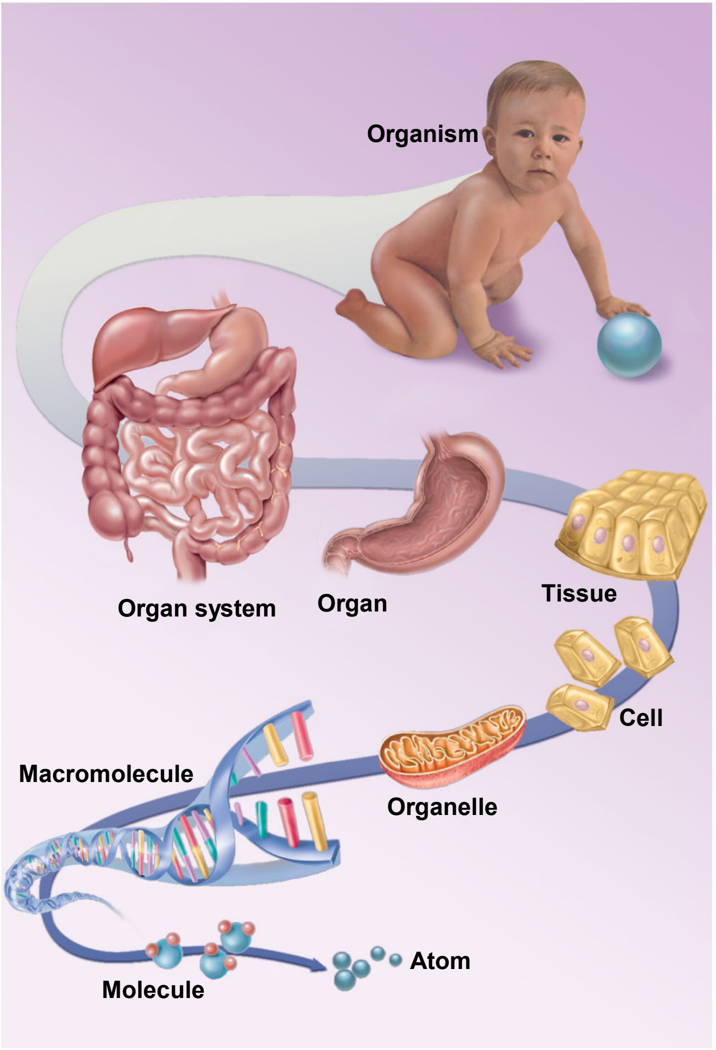
Chapter 2

Chemistry

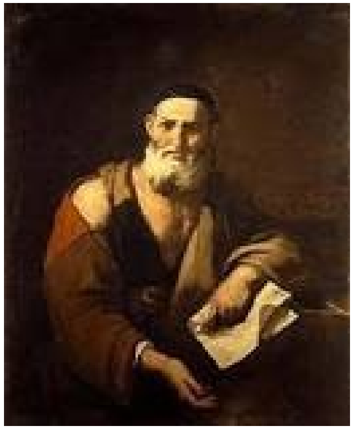


In the beginning, it is chemistry!

- Atoms make molecules
- Molecules combine to make macromoleucles
- Macromolecles organize into organelles
- Organelles combine to form cells
- Cells combine to make tissue
- Tissue combine to make organs
- Organs combine to make systems
- Eleven different systems combine to make you!



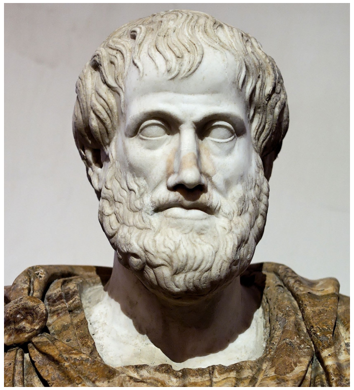
Who first suggested that matter is made up of atoms ?



Leucippus

Leucippus (died 370 BC) is credited with developing the idea of the atom as the building block of matter. Leucippus was Democritus teacher.

Democritus was an Ancient Greek pre-Socratic philosopher primarily remembered today for his formulation of an atomic theory of the universe. He advanced Leucippus idea. Democritus was born in Abdera, Thrace, around 460 and died in 370 BC.



Democritus

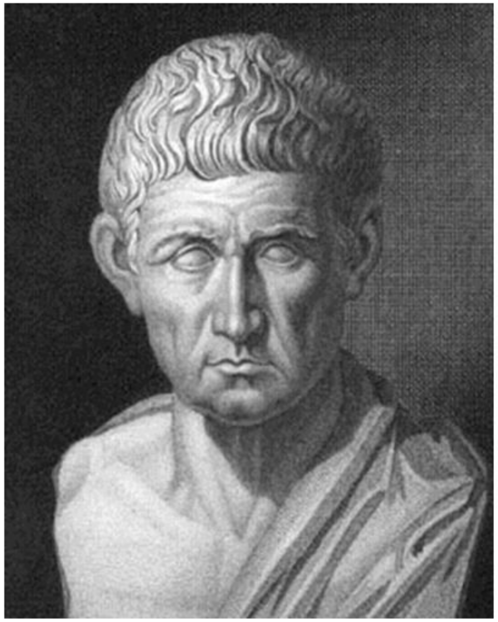
Democritus Quotes:

Nothing exists except atoms and empty space; everything else is opinion.

Happiness resides not in possessions, and not in gold, happiness dwells in the soul.

Throw moderation to the winds, and the greatest pleasures bring the greatest pains.

Largely ignored in ancient Athens, Democritus is said to have been disliked so much by Plato that the latter wished all of his books burned. He was nevertheless well known to his fellow northern-born philosopher Aristotle. Many consider Democritus to be the "father of modern science". None of his writings have survived; only fragments are known from his vast body of work.(Wiki)



Aristiotle:Later, **Aristotle** (c. 384–c. 322 B.C.) popularized the idea that all matter was made of earth, air, water, and fire in varying proportions. According to this notion, one should be able to make gold from other materials by adjusting the ratios of the four elements therein. His ideas influenced alchemy and protochemistry for 2,000 years.

Aristotle's Four Elements

Physicist in the early 1800s and into the early 1900s investigated the structure of matter and determined that matter is made up of atoms.

Atom are constructed of three atomic particles: *protons, neutrons, and electrons.* The ability of atoms to "link together" (form a chemical bond) is a function of the *electrons being shared or donated.*

The Modern Atomic Structure Time Line

In the late 1700's Scientists in France and England started to study air. They discovered air was made up of different types of air. They called these gasses “special airs”.

The special airs they discovered were oxygen, hydrogen, and carbon dioxide.

John Dalton, English scientist, developed the modern atomic theory in 1803 /// demonstrated air is constructed out of atoms and oxygen is eight times heavier than hydrogen.

The main points of Dalton's atomic theory are:

Elements are made of extremely small particles called atoms.

Atoms of a given element are identical in size, mass and other properties

Atoms of different elements differ in size, mass and other properties.

Atoms *cannot be subdivided*, created or destroyed.

Atoms of different elements combine in simple whole-number ratios to form chemical compounds.

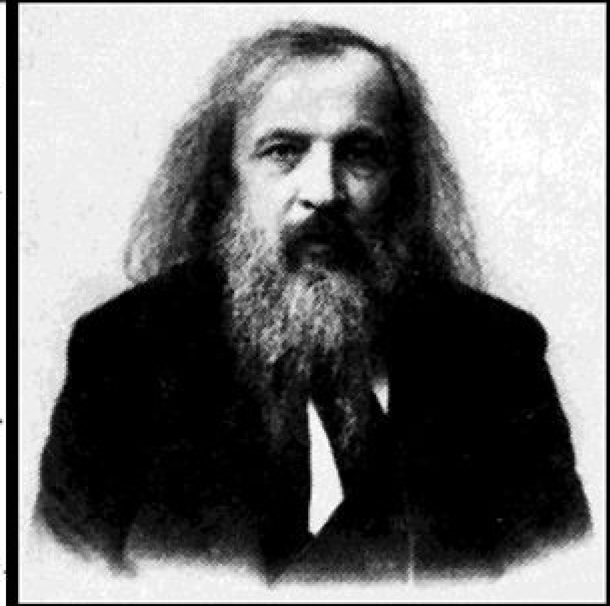
In chemical reactions, atoms are combined, separted, or rearranged.

Mendeleev's Periodic Table

TABELLE II

REIHEN	GRUPPE I. — R^2O	GRUPPE II. — RO	GRUPPE III. — R^2O^3	GRUPPE IV. RH^4 RO^2	GRUPPE V. RH^3 R^2O^5	GRUPPE VI. RH^2 RO^3	GRUPPE VII. RH R^2O^7	GRUPPE VIII. — RO^4
1	H = 1							
2	Li = 7	Be = 9,4	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27,3	Si = 28	P = 31	S = 32	Cl = 35,5	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63.
5	(Cu = 63)	Zn = 65	— = 68	— = 72	As = 75	Se = 78	Br = 80	
6	Rb = 85	Sr = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104, Pd = 106, Ag = 108.
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Te = 125	J = 127	
8	Cs = 133	Ba = 137	?Di = 138	?Ce = 140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er = 178	?La = 180	Ta = 182	W = 184	—	Os = 195, Ir = 197, Pt = 198, Au = 199.
11	(Au = 199)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	—	—	
12	—	—	—	Th = 231	—	U = 240	—	— — — —

Figure 2.5 Dmitri Mendeleev's 1872 periodic table. The spaces marked with blank lines represent elements that Mendeleev deduced existed but were unknown at the time, so he left places for them in the table. The symbols at the top of the columns (e.g., R^2O and RH^4) are molecular formulas written in the style of the 19th century.



Dmitri Mendeleev

1869

See Power Point - "Mendeleev: The Father of the Periodic Table"

ПЕРИОДИЧЕСКАЯ СИСТЕМА ЭЛЕМЕНТОВ

	I	II	III	IV	V	VI	VII	VIII		
1										
2	Li	Be								
3	Na	Mg	Al							
4	K				V	Cr	Mn	Fe	Co	Ni
	Cu	Zn	Ga		As					
5					Nb	Mo	Tc	Ru	Rh	Pd
	Ag	Cd	In	Sn	Sb					
6					Ta	W	Re	Os	Ir	Pt
	Au		Tl	Pb	Bi					
7										

		Pr					Gd	Tb		Ho				

In 1869 Mendeleev used the mass and physical characteristics of all the known atoms to construct a table consisting of rolls (periods) and columns (groups). His greatest insight occurred when he realized that the blank spaces in his table represented yet to be discovered atoms! In the following decades, chemist worked to discovered the “missing atoms”.

Periodic Table of Elements is the Alphabet of the Universe

Periodic Table - arrange atoms by the number of protons in nucleus and the atom's physical properties

- elements represented by one or two letter symbols
- atomic number and atomic mass indicated on table

24 elements have biological role /// 6 elements = 98.5% of body weight

- oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus
- additional trace elements occur in smaller amounts

Periodic Table of Elements

Key: Atomic # / Symbol / Name / Atomic Mass

- C Solid
- Hg Liquid
- H Gas
- Rf Unknown

Metals: Alkali metals | Alkaline earth metals | Lanthanoids | Actinoids | Transition metals | Poor metals

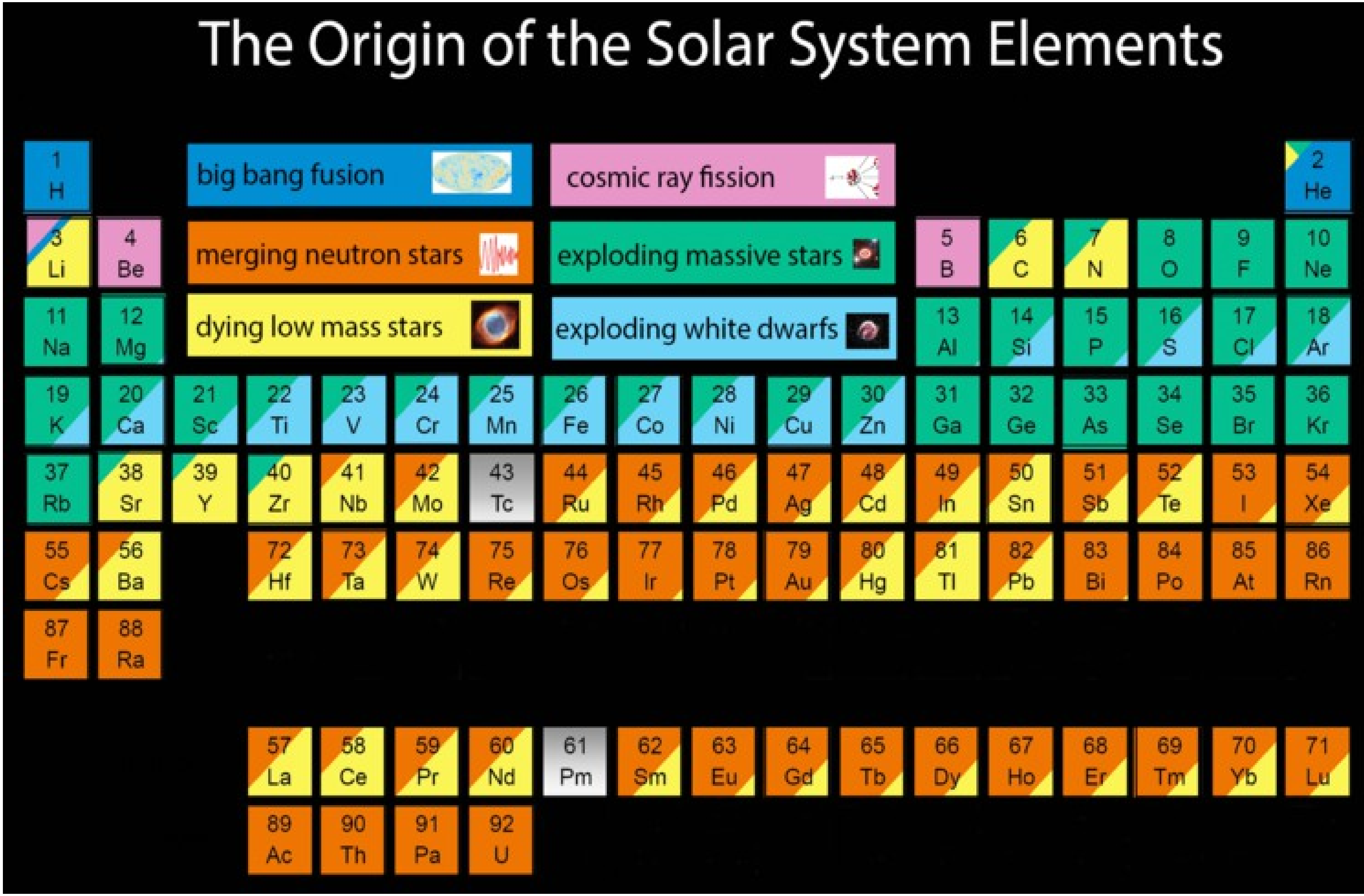
Nonmetals: Other nonmetals | Noble gases

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.00794																	2 He Helium 4.002602
2	3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
3	11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050											13 Al Aluminium 26.9815386	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
6	55 Cs Caesium 132.9054519	56 Ba Barium 137.327	57–71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (208.9824)	85 At Astatine (209.9871)	86 Rn Radon (222.0176)
7	87 Fr Francium (223)	88 Ra Radium (226)	89–103	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium	118 Uuo Ununoctium (294)

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

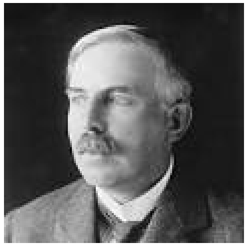
Ptable.com


The Origin of the Solar System Elements
big bang fusion
cosmic ray fission
merging neutron stars
exploding massive stars
dying low mass stars
exploding white dwarfs
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
57 La
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
89 Ac
90 Th
91 Pa
92 U

How Our Understanding of the Atomic Structure Changed

JJ Thomson discovers electrons 1897 and advanced a model of the atom called the plum pudding theory The negative electrons were "balanced" by a positive proton.

Ernest Rutherford in 1911 disproved the plum pudding model and demonstrated protons were in the center of the atom and electorns encircled the protons as a "cloud". (the electron cloud model).



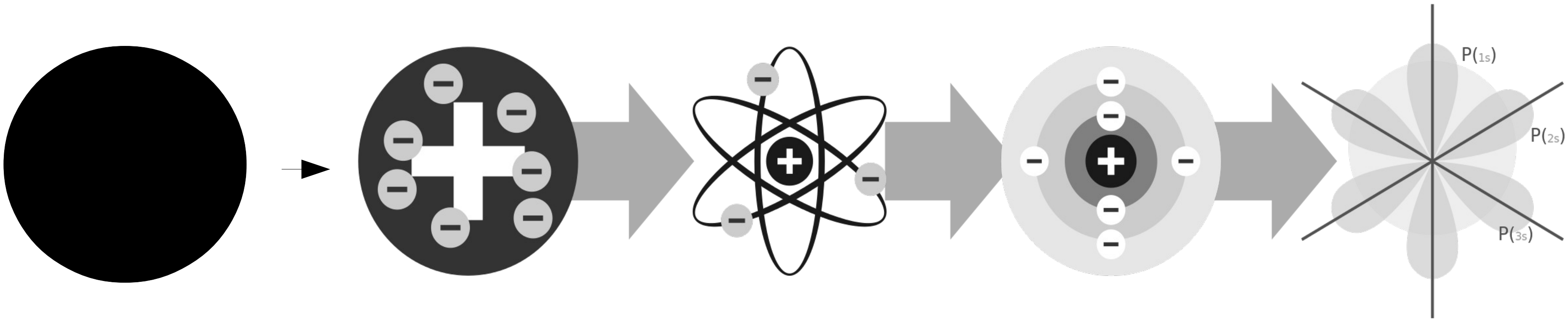
Neils Bohr, Danish physicist, proposed a planetary model of atomic structure, similar to planets orbiting the sun (1865 – 1962 He was awarded the Noble Prize 1922 for his work.

Key contribution – electrons travel not is a cloud but in discrete orbits. If electrons are "excited" (given extra energy) the electrons may move into another orbit. Bohr showed how atoms could combine to form molecules. He invented chemistry. Chemistry is the study of matter.

Atoms consist of three "elemental" atomic particles - Protons – Neutrons – Electrons (Note – neutrons were not discovered until the 1930s.

Note: In the 1960s we started to understand that the atomic particles are constructed of even smaller "subatomic particles", however. To understand basic chemistry, you only need *to understand the relationship between protons, neutrons, and electrons* *(if curious see The Standard Model – articles and videos on Web site)*

The Evolution of the Atomic Model in the 20th Century



Dalton – atoms are “indivisible” / like billiard balls

J.J. Thomson – plum pudding model

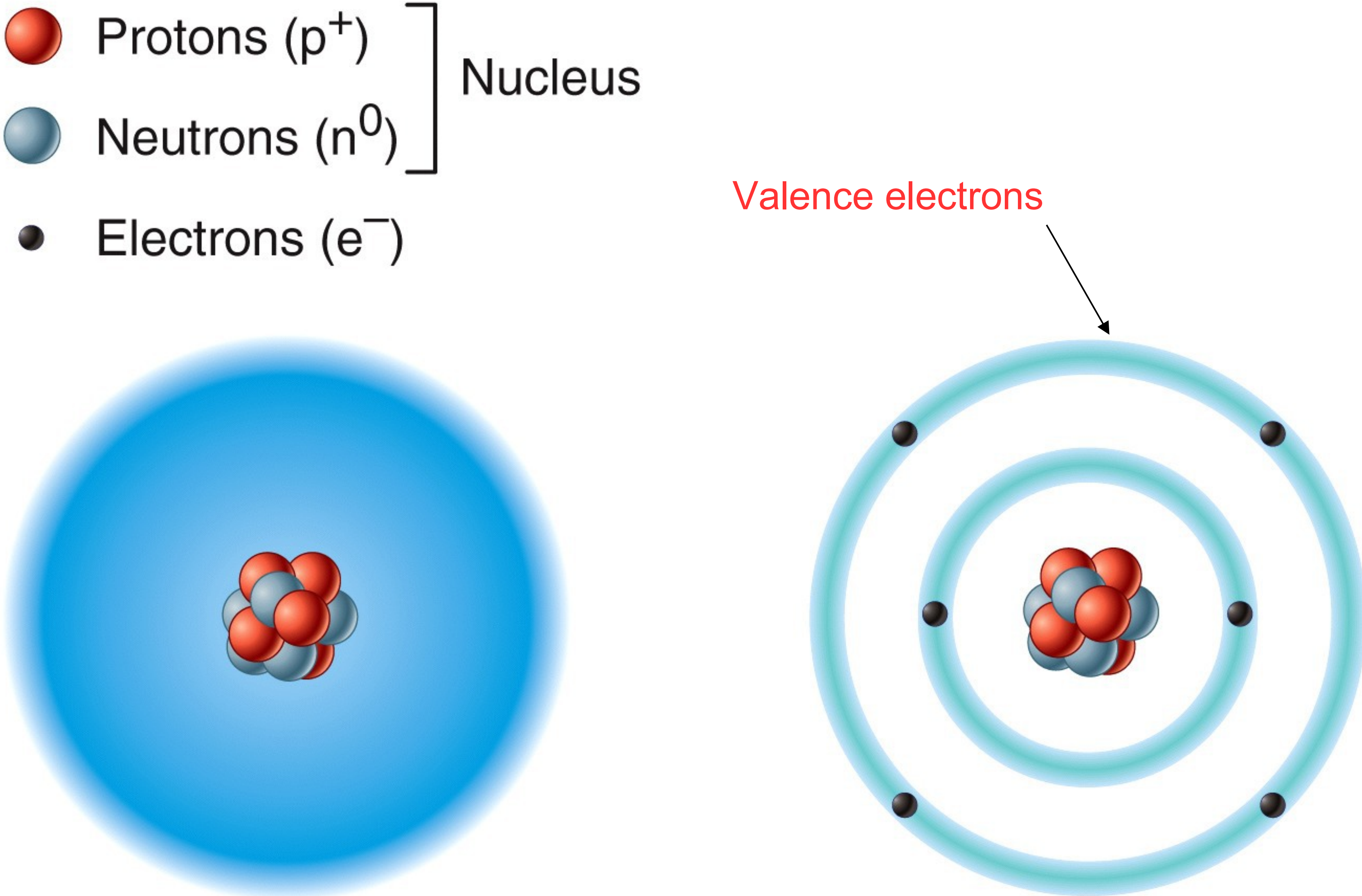
Rutherford – electron cloud model

Bohr – electron orbital model (created chemistry!)

Heisenberg & Schrodinger – electron wave model

Atomic Structure

- The nucleus = at the center of the atom
  - Protons = single positive charge, mass = 1 amu (atomic mass unit) or Dalton
  - Neutrons = no charge, mass = 1 amu (or dalton)
  - Number of protons (usually) = number of neutrons
    - Atomic number = protons
    - Atomic mass (weight) = equal to number of protons and neutrons
  - Electrons = negative charged particles / little mass (.0005 Daltons) / travel at speed of light around nucleus in discrete patterns called orbits or electron shells // outer most electrons called valence electrons
  - Atom's charge is neutral because number of electrons are equal to the number of protons



(a) Electron cloud model

(b) Electron shell model

Atomic Structure

Key Idea:

Number of protons determine the chemical properties of the atom (e.g. carbon = 6 protons and gold = 79 protons)

Valence electrons // electrons in outer most orbit determine how individual atoms bind to each other // octet rule

Chemical Bonds

- **Chemical bonds –** forces that hold two or more atoms together, or forces that attract one molecule to another molecule
- **Types of Chemical Bonds**
  - Covalent bonds
  - Hydrogen bonds
  - Ionic bonds
  - Van der Waals force (not required / omit)

TABLE 2.3 Types of Chemical Bonds

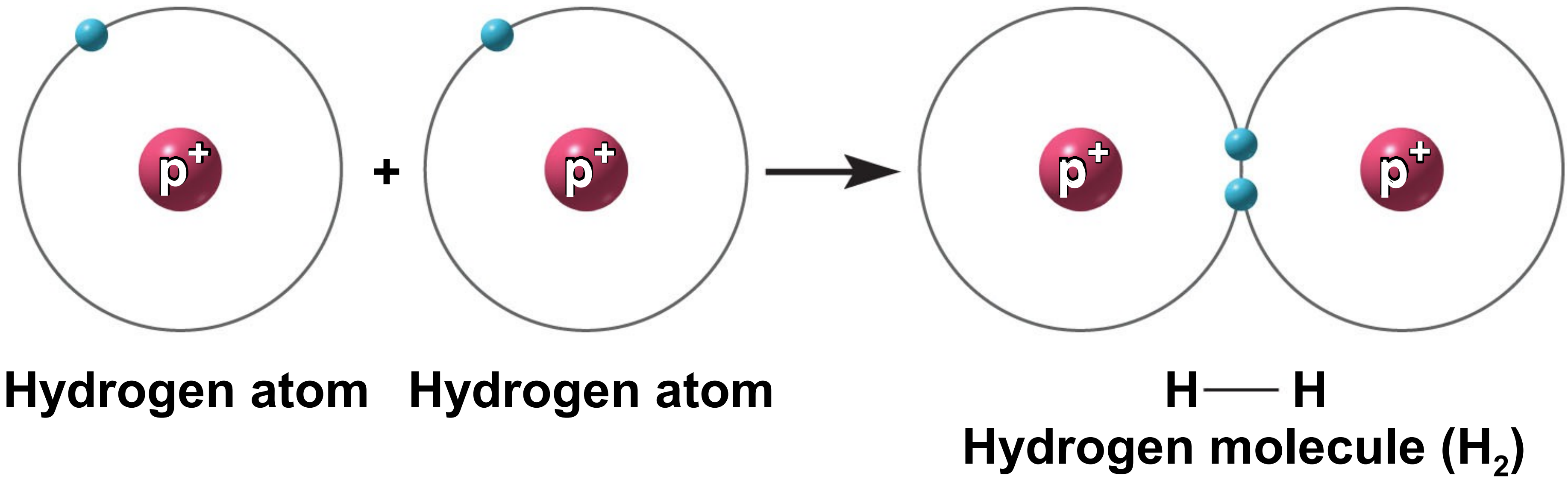
Bond Type	Definition and Remarks
Ionic bond	Relatively weak attraction between an anion and a cation. Easily disrupted in water, as when salt dissolves.
Covalent bond	Sharing of one or more pairs of electrons between nuclei.
Single covalent	Sharing of one electron pair.
Double covalent	Sharing of two electron pairs. Often occurs between carbon atoms, between carbon and oxygen, and between carbon and nitrogen.
Nonpolar covalent	Covalent bond in which electrons are equally attracted to both nuclei. May be single or double. Strongest type of chemical bond.
Polar covalent	Covalent bond in which electrons are more attracted to one nucleus than to the other, resulting in slightly positive and negative regions in one molecule. May be single or double.
Hydrogen bond	Weak attraction between polarized molecules or between polarized regions of the same molecule. Important in the three-dimensional folding and coiling of large molecules. Easily disrupted by temperature and pH changes.
Van der Waals force	Weak, brief attraction due to random disturbances in the electron clouds of adjacent atoms. Weakest of all bonds.

Covalent Bonds

- Formed by sharing "valence electrons"
- **Types of covalent bonds**
  - **single -** sharing of single pair electrons
  - **double -** sharing of 2 pairs of electrons
  - **nonpolar covalent bond**
    - shared electrons spend approximately equal time around each nucleus
    - strongest of all bonds
  - **polar covalent bond**
    - if shared electrons spend more time orbiting one nucleus than they do the other, they lend their negative charge to the area they spend most time

Single Covalent Bond

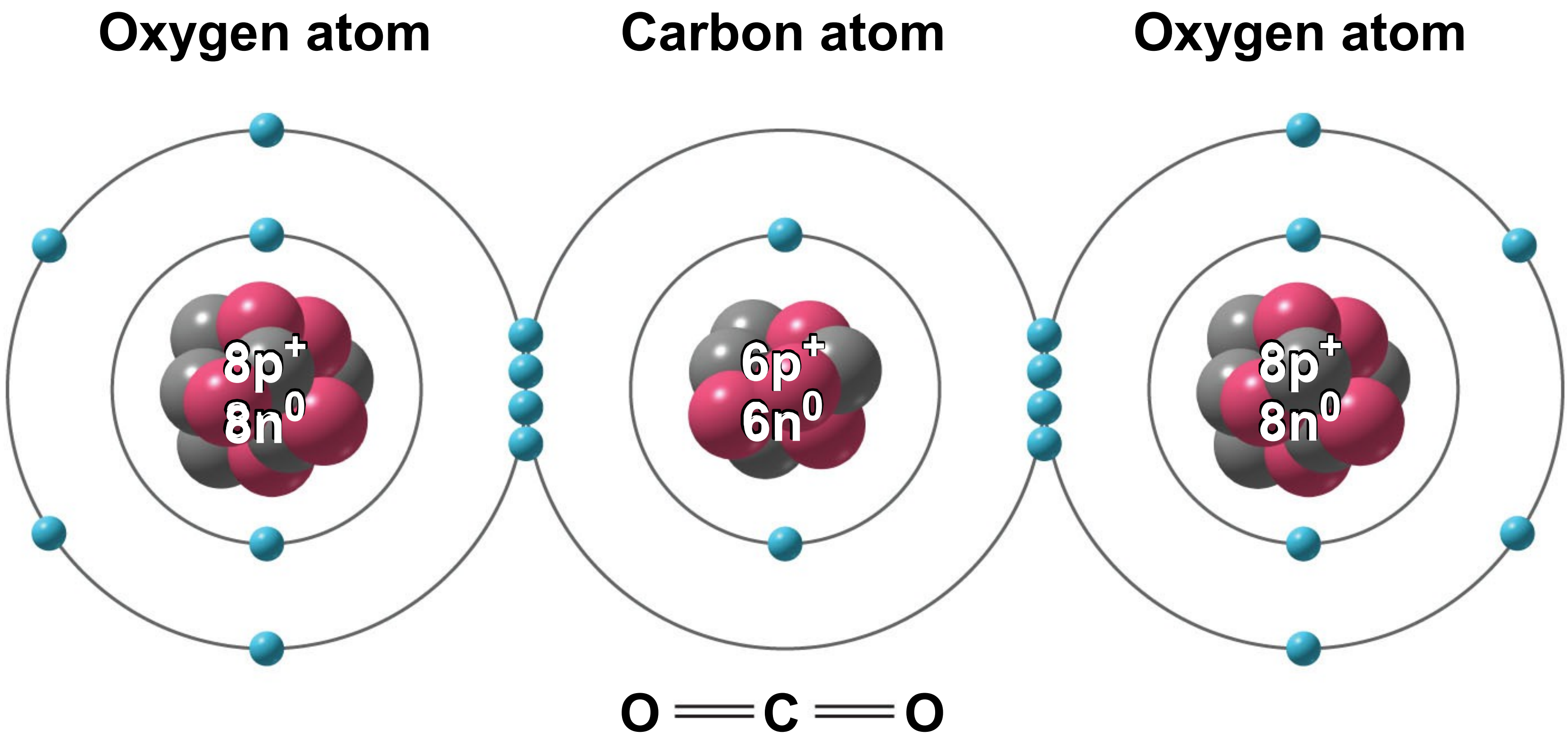
Pair of electrons are shared



Note: single line denotes two electrons are shared between two atoms.

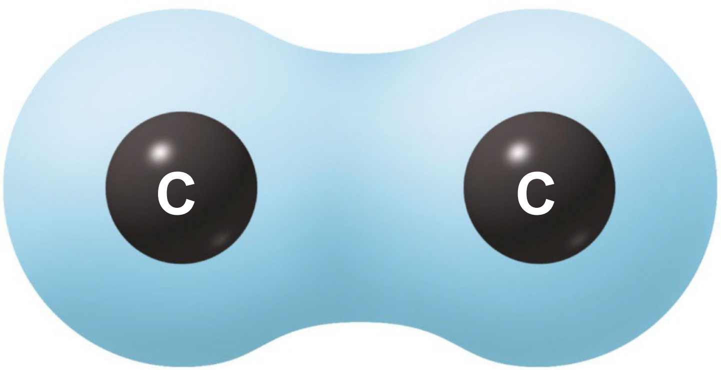
Double covalent bonds:

Two pairs of electrons are shared each C=O bond



Carbon dioxide molecule (CO_2)

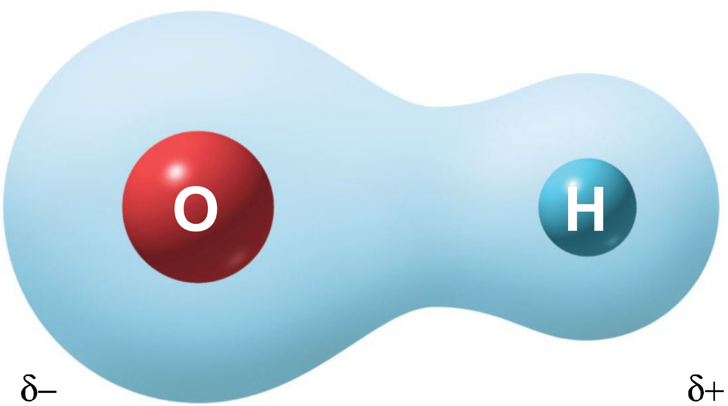
Non-Polar VS Polar Covalent Bonds



(a)

Nonpolar covalent
C —— C bond

Electrons shared equally



(b)

Polar covalent
O —— H bond

Electrons shared unequally

Molecular Formulas and Molecular Weight

Covalent Molecule = occurs when two or more atoms share electrons (chemical bond) // e.g. Oxygen or O2

Compound = substance that contains atoms of two ro more different elements // e.g. water or H20

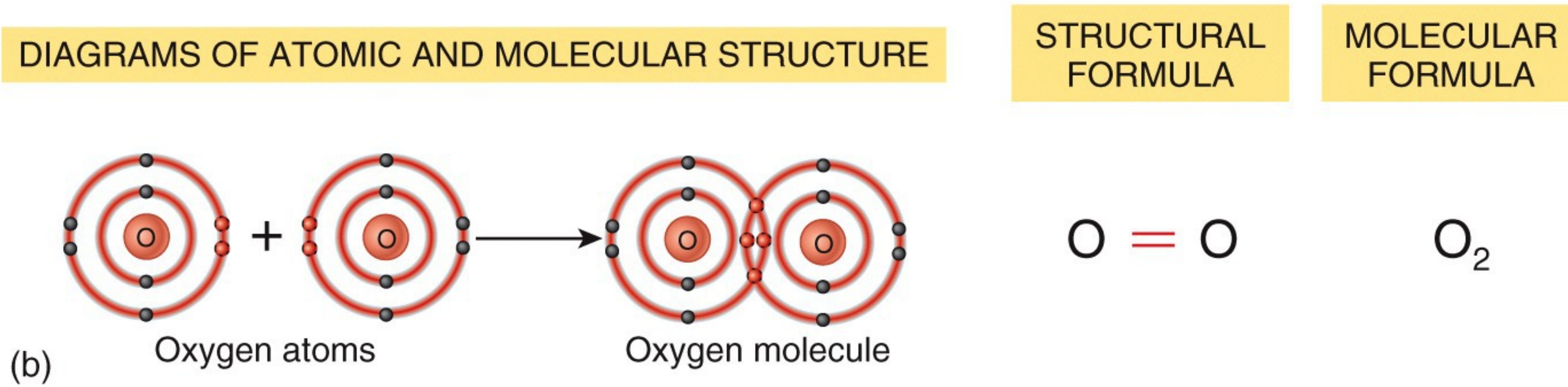
- **The molecular weight of a compound = sum of atomic weights of all the atoms**
- **Calculate: MW of glucose ($C_6H_{12}O_6$)**

6 C atoms x 12 amu each = 72 amu

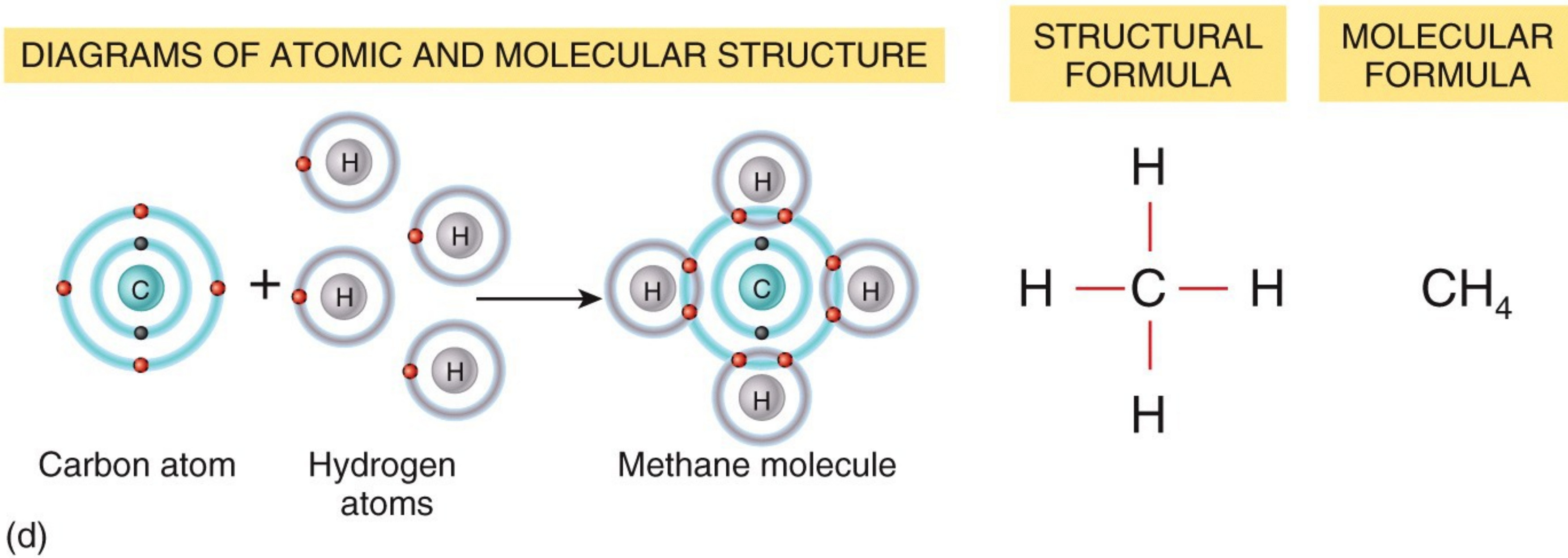
12 H atoms x 1 amu each = 12 amu

<u>6 O atoms x 16 amu each = 96 amu</u>

Molecular weight (MW) = 180 amu

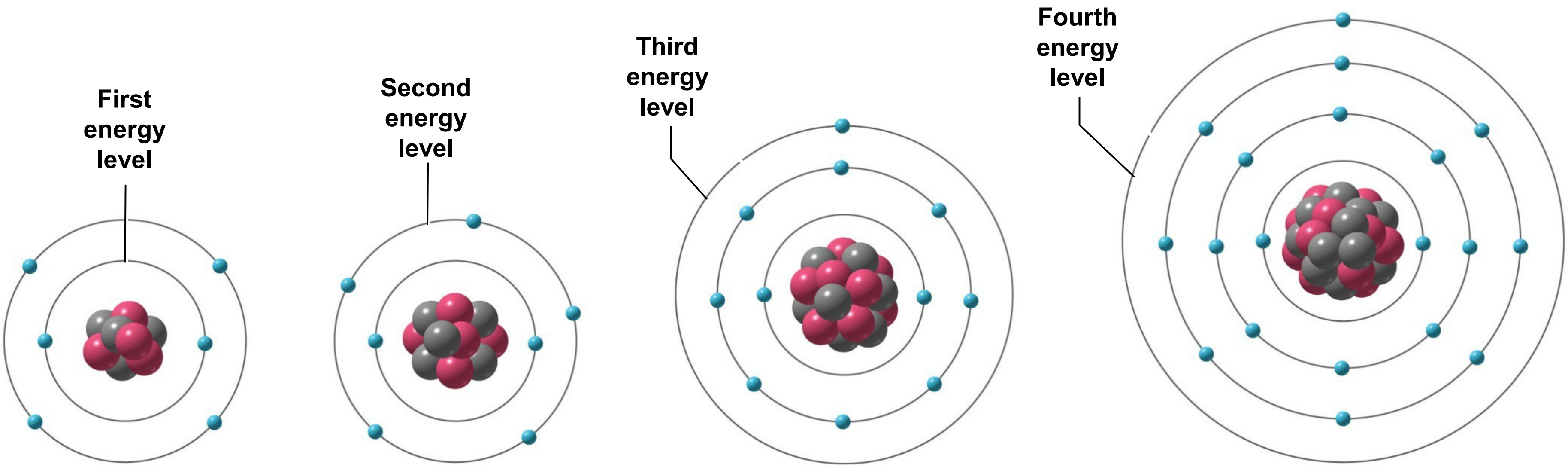

DIAGRAMS OF ATOMIC AND MOLECULAR STRUCTURE
STRUCTURAL FORMULA
MOLECULAR FORMULA
O
O
O
O
Oxygen atoms
Oxygen molecule
(b)
O = O
O_2

Molecule


DIAGRAMS OF ATOMIC AND MOLECULAR STRUCTURE
STRUCTURAL FORMULA
MOLECULAR FORMULA
C
H
H
H
H
H
C
H
H
H
H
H
H
C
H
H
CH_4
Carbon atom
Hydrogen atoms
Methane molecule
(d)

Compound

Borh Models of Elements



Carbon (C) $6p^+$, $6e^-$, $6n^0$
Atomic number = 6
Atomic mass = 12

Nitrogen (N) $7p^+$, $7e^-$, $7n^0$
Atomic number = 7
Atomic mass = 14

Sodium (Na) $11p^+$, $11e^-$, $12n^0$
Atomic number = 11
Atomic mass = 23

Potassium (K) $19p^+$, $19e^-$, $20n^0$
Atomic number = 19
Atomic mass = 39

p^+ represents protons, n^o represents neutrons

Periodic Table of Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.00794	Atomic # Symbol Name Atomic Mass																2 He Helium 4.002602
2	3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
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4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
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7	87 Fr Francium (223)	88 Ra Radium (226)	89–103	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium	118 Uuo Ununoctium (294)

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

C Solid
Hg Liquid
H Gas
Rf Unknown

Metals: Alkali metals, Alkaline earth metals, Lanthanoids, Actinoids, Transition metals, Poor metals
Nonmetals: Other nonmetals, Noble gases

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

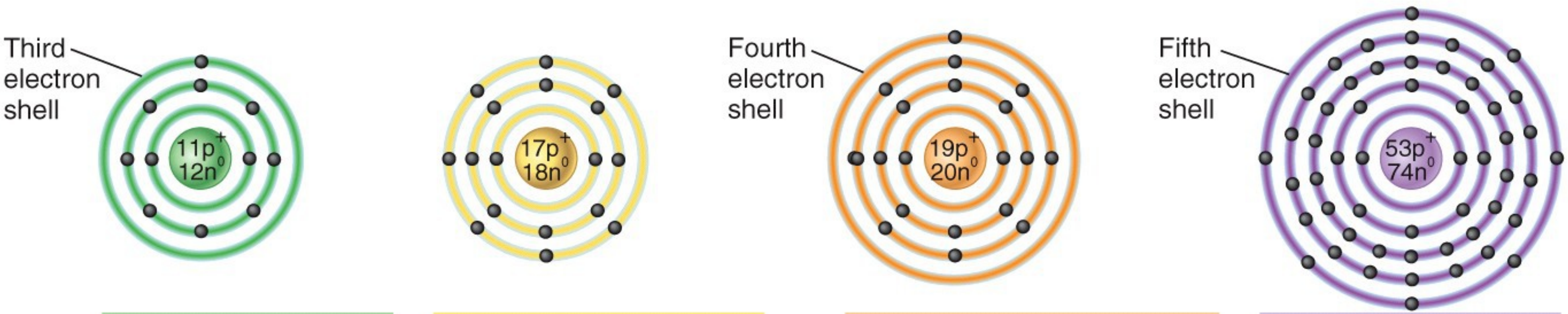
Ptable.com

Hydrogen (H)
Atomic number = 1
Mass number = **1** or 2
Atomic mass = 1.01

Carbon (C)
Atomic number = 6
Mass number = **12** or 13
Atomic mass = 12.01

Nitrogen (N)
Atomic number = 7
Mass number = **14** or 15
Atomic mass = 14.01

Oxygen (O)
Atomic number = 8
Mass number = **16**, 17, or 18
Atomic mass = 16.00



Sodium (Na)
Atomic number = 11
Mass number = **23**
Atomic mass = 22.99

Chlorine (Cl)
Atomic number = 17
Mass number = **35** or 37
Atomic mass = 35.45

Potassium (K)
Atomic number = 19
Mass number = **39**, 40, or 41
Atomic mass = 39.10

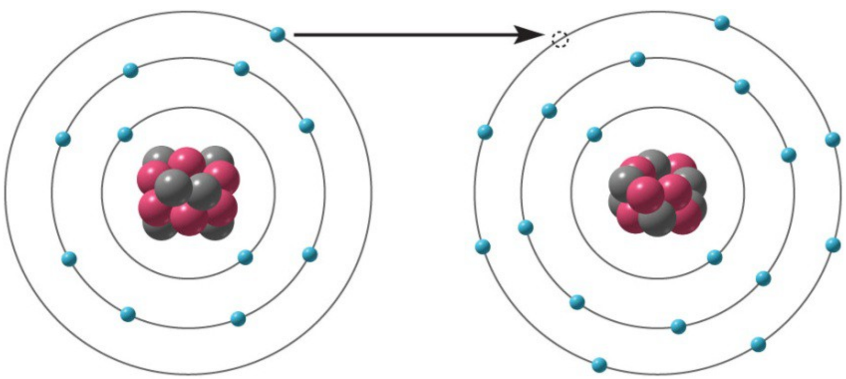
Iodine (I)
Atomic number = 53
Mass number = **127**
Atomic mass = 126.90

Atomic number = number of protons in an atom
Mass number = number of protons and neutrons in an atom (boldface indicates most common isotope)
Atomic mass = average mass of all stable atoms of a given element in daltons

Ionic Bonds

- The attraction of a cation (positive charged atom) to an anion (negative charge atom)
- Electrons are donated by one atom and received by a different atom
- Relatively weak attraction -- easily disrupted in water (e.g. when table salt dissolves in water)
- This is not a covalent bonds because electrons are not “shared' but donated!

Na
11 electrons
11 protons

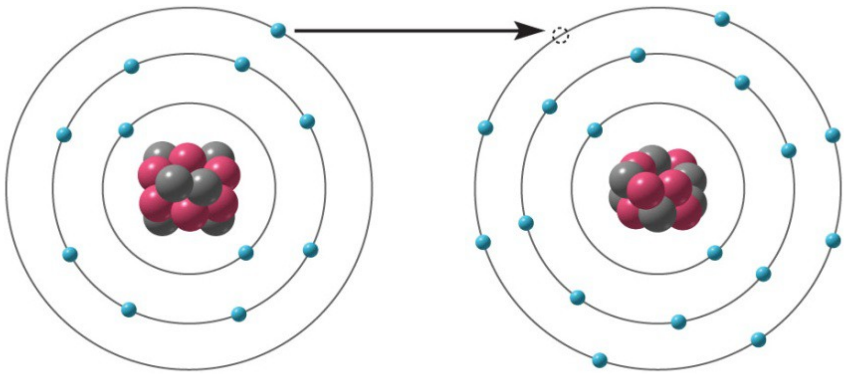


Cl
17 electrons
17protons

What happens to the charge of each atom after electron moves?

Ions and Ionization

- **Ions –** charged particles with unequal number of protons and electrons
- **Ionization -** transfer of electrons from one atom to another
- Key idea is to have atom with either “two or eight electrons” in the valence shell
- First orbit = maximum two electrons
- Second and third orbits = maximum eight electrons



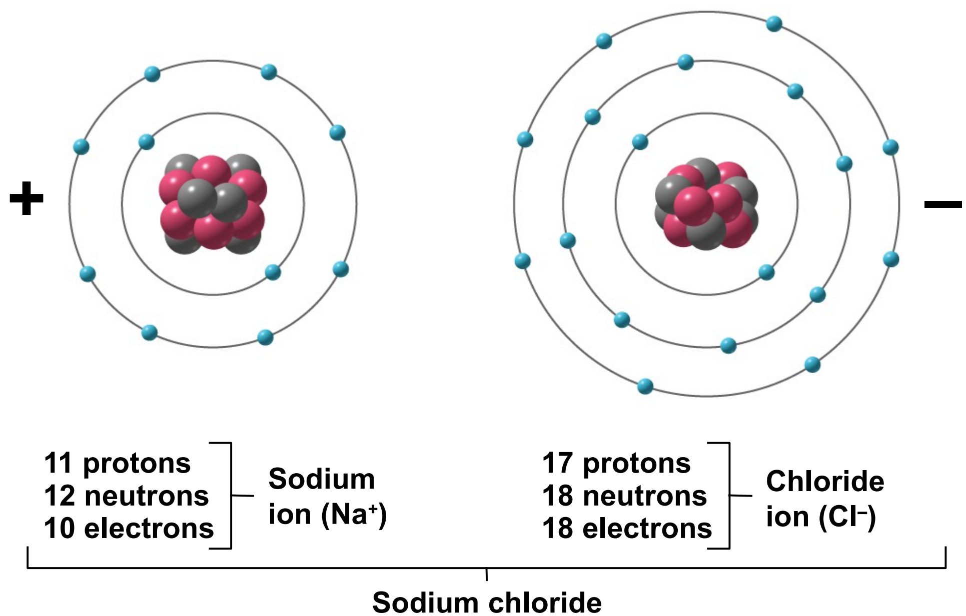
11 protons
12 neutrons
11 electrons
Sodium atom (Na)

17 protons
18 neutrons
17 electrons
Chlorine atom (Cl)

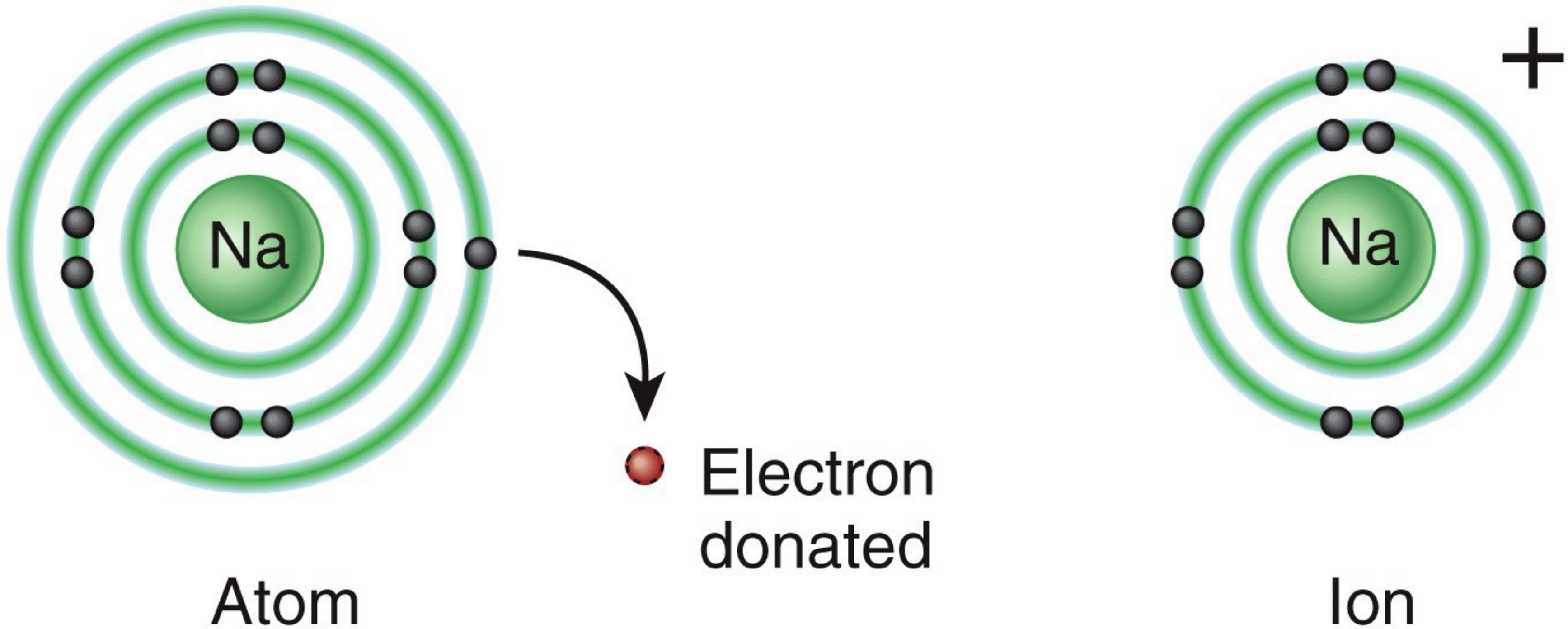
1 Transfer of an electron from a sodium atom to a chlorine atom

Anions and Cations

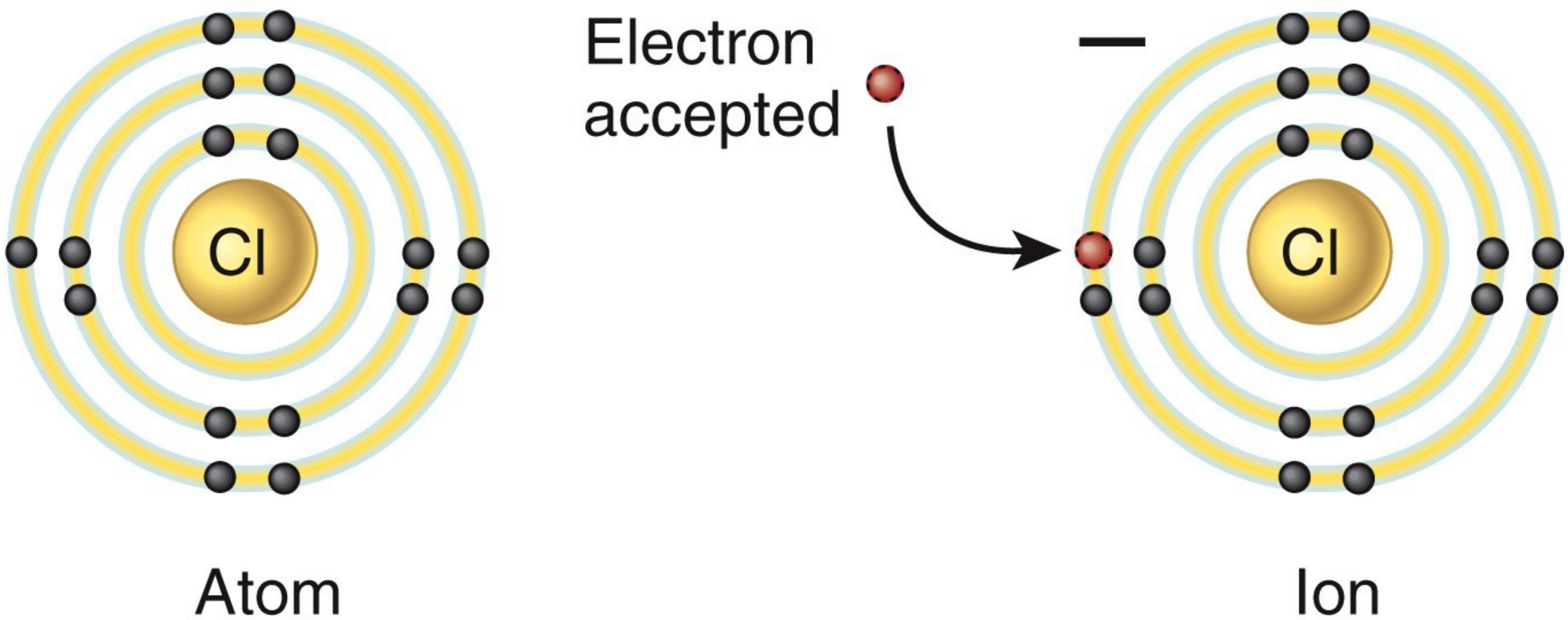
- **Anion //** atom that gained electrons (net negative charge)
- **Cation //** atom that lost an electron (net positive charge)
- Ions with opposite charges are attracted to each other



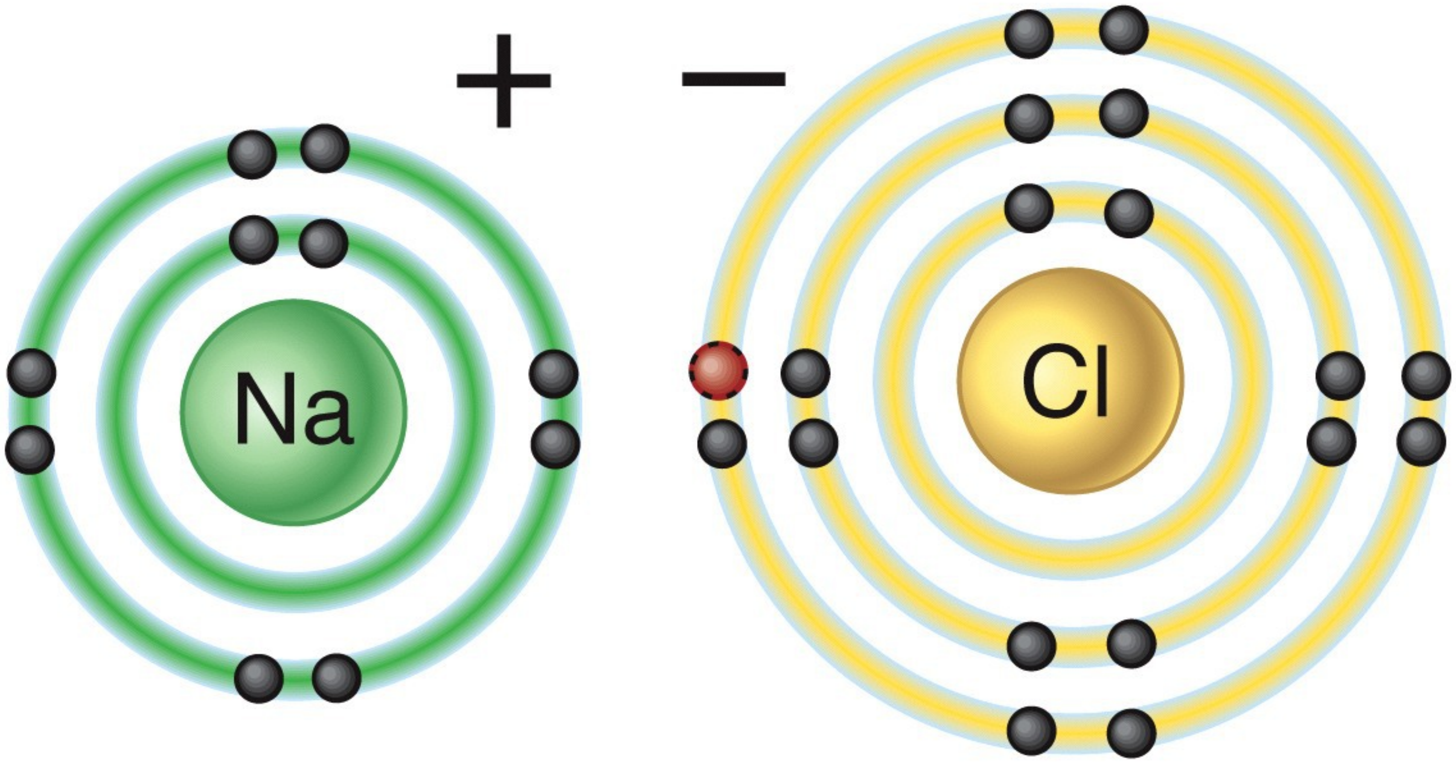
2 The charged sodium ion (Na^+) and chloride ion (Cl^-) that result



(a) Sodium: 1 valence electron

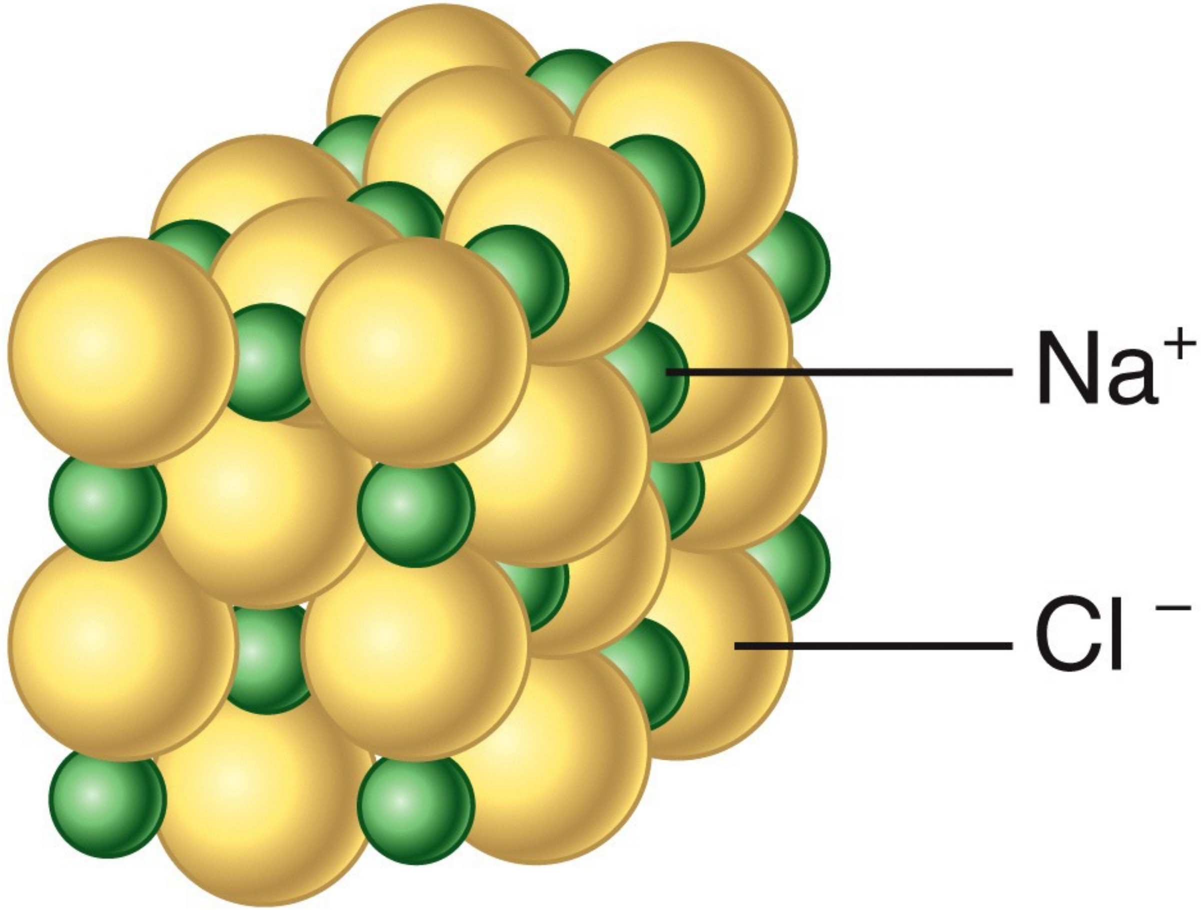


(b) Chlorine: 7 valence electrons



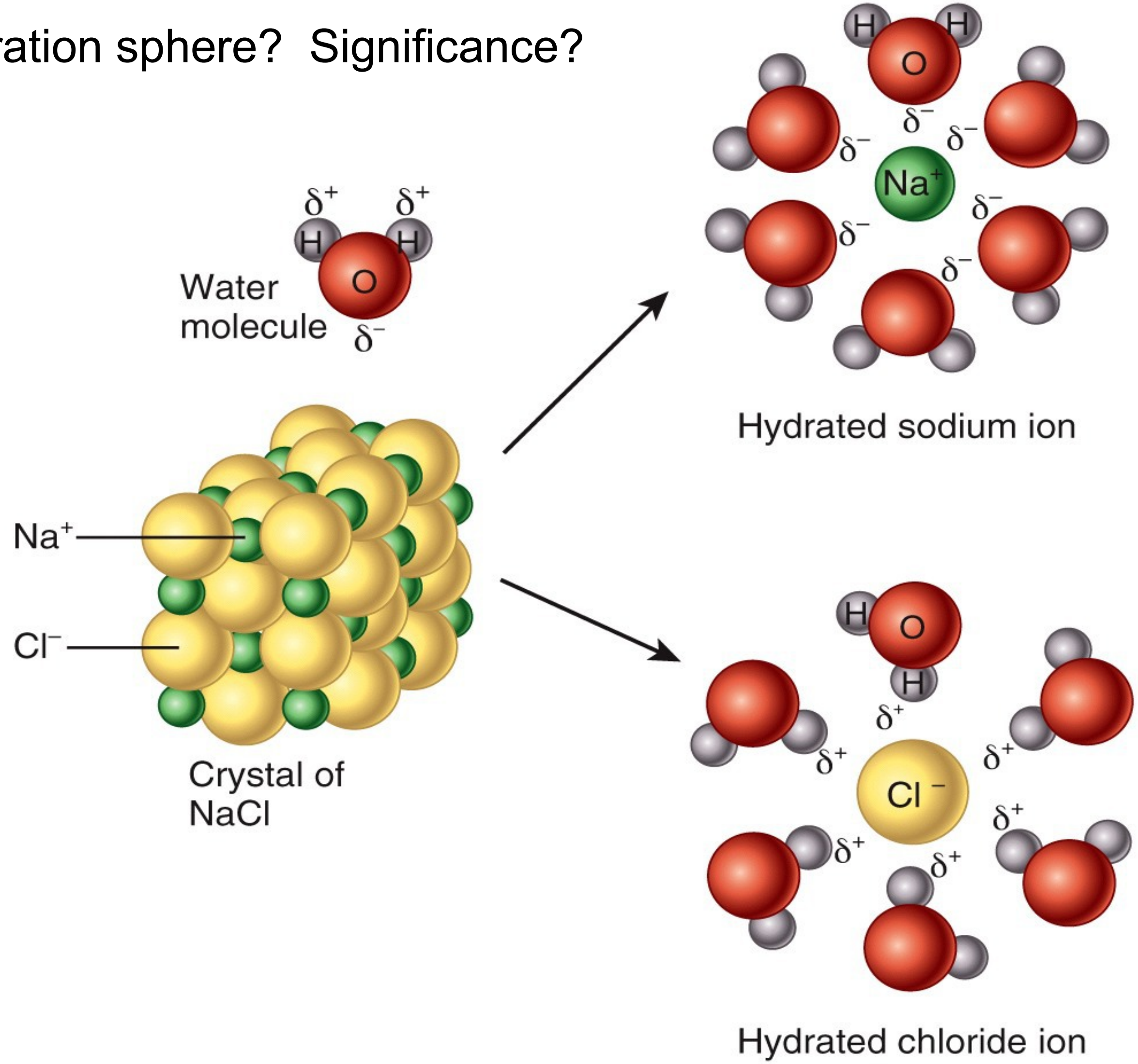
(c) Ionic bond in sodium chloride (NaCl)

Note: octet rule



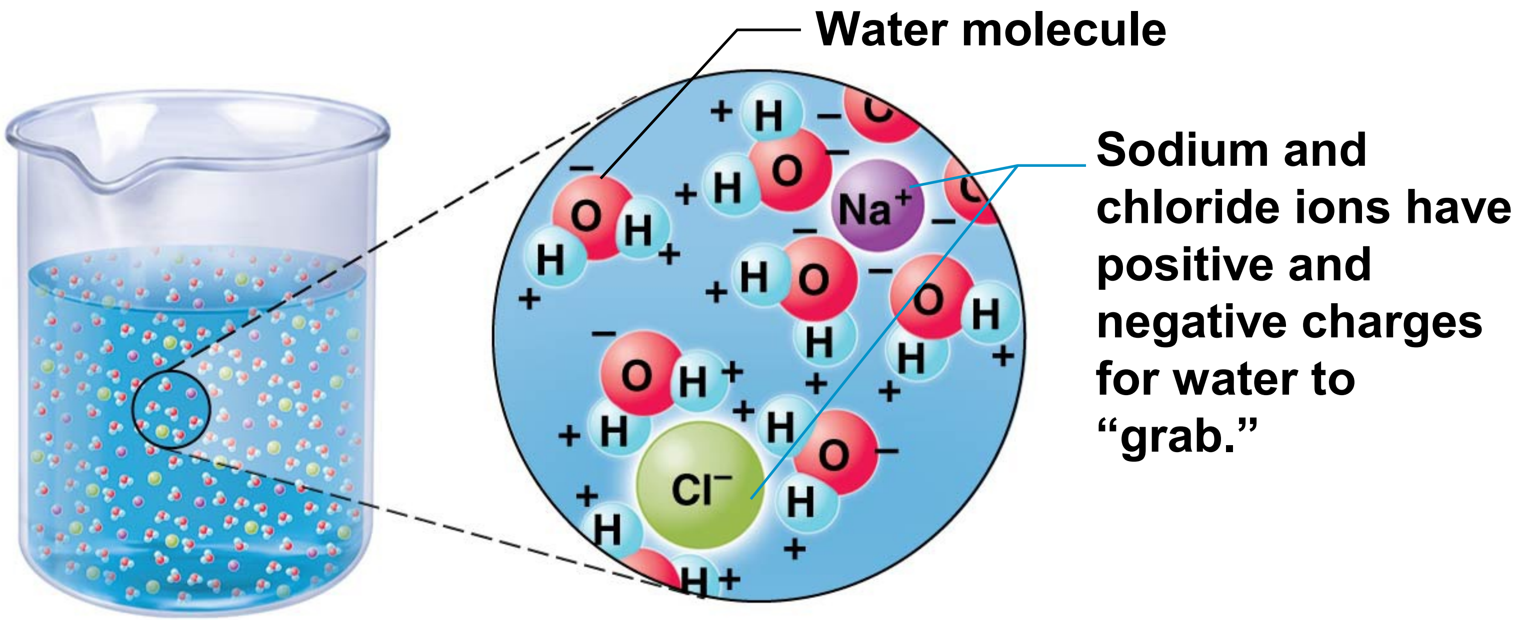
(d) Packing of ions in a crystal of sodium chloride

What is a hydration sphere? Significance?



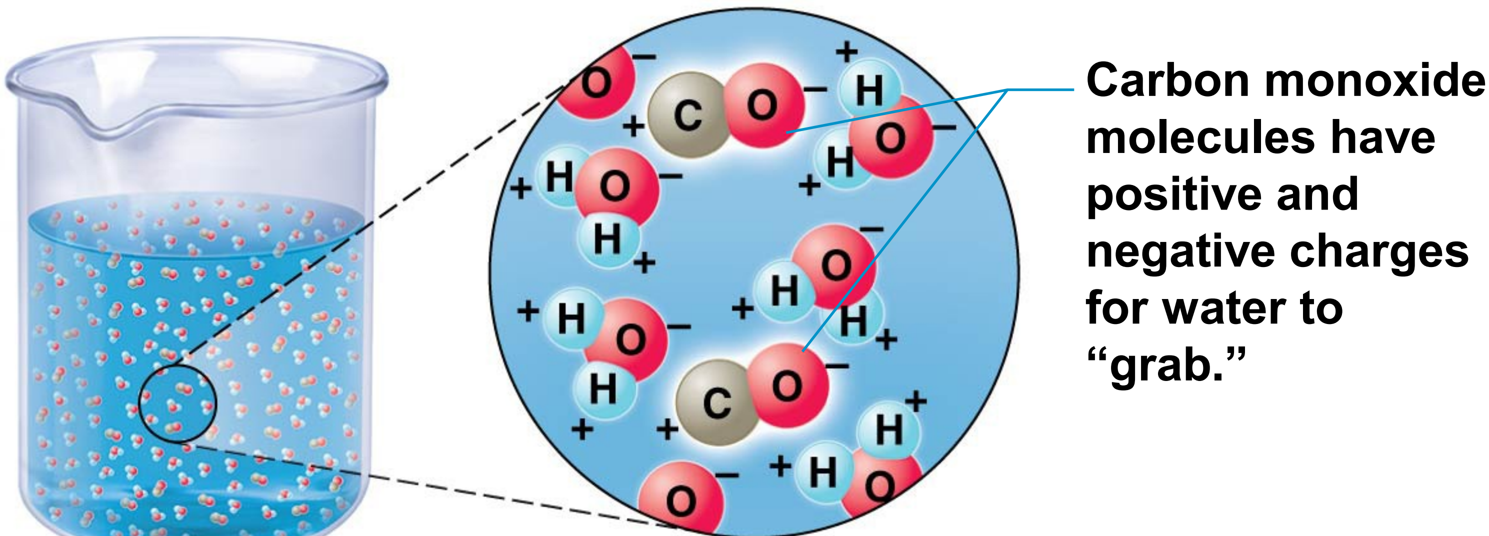
1. What is the orientaton of water molecule?
2. What is the difference between water soluble (hydrophillic) and non-water soluble (hydrophobic)?
3. How will water molecules interact with protein and fat? Why?

The behavior of hydrophilic molecules in water.



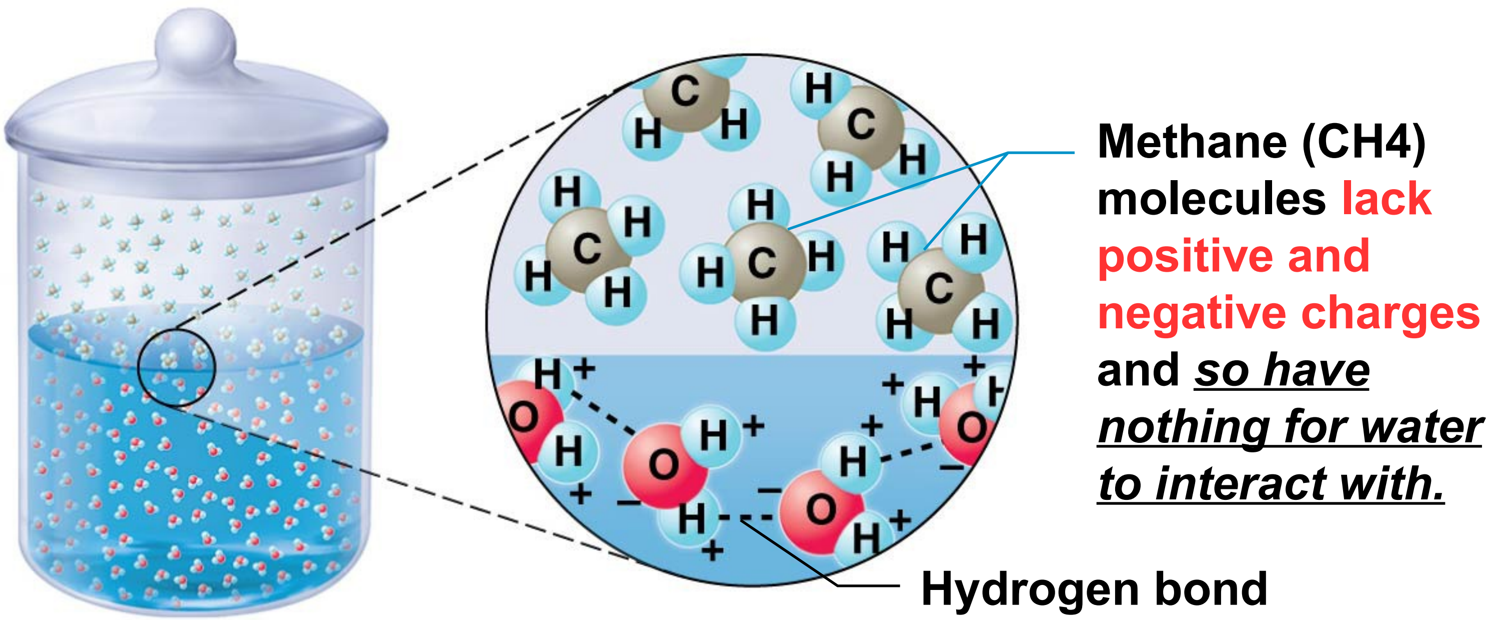
(a) Ionic compounds are hydrophilic.

What is the behavior of hydrophilic molecules in water?



(b) Polar covalent compounds are hydrophilic.

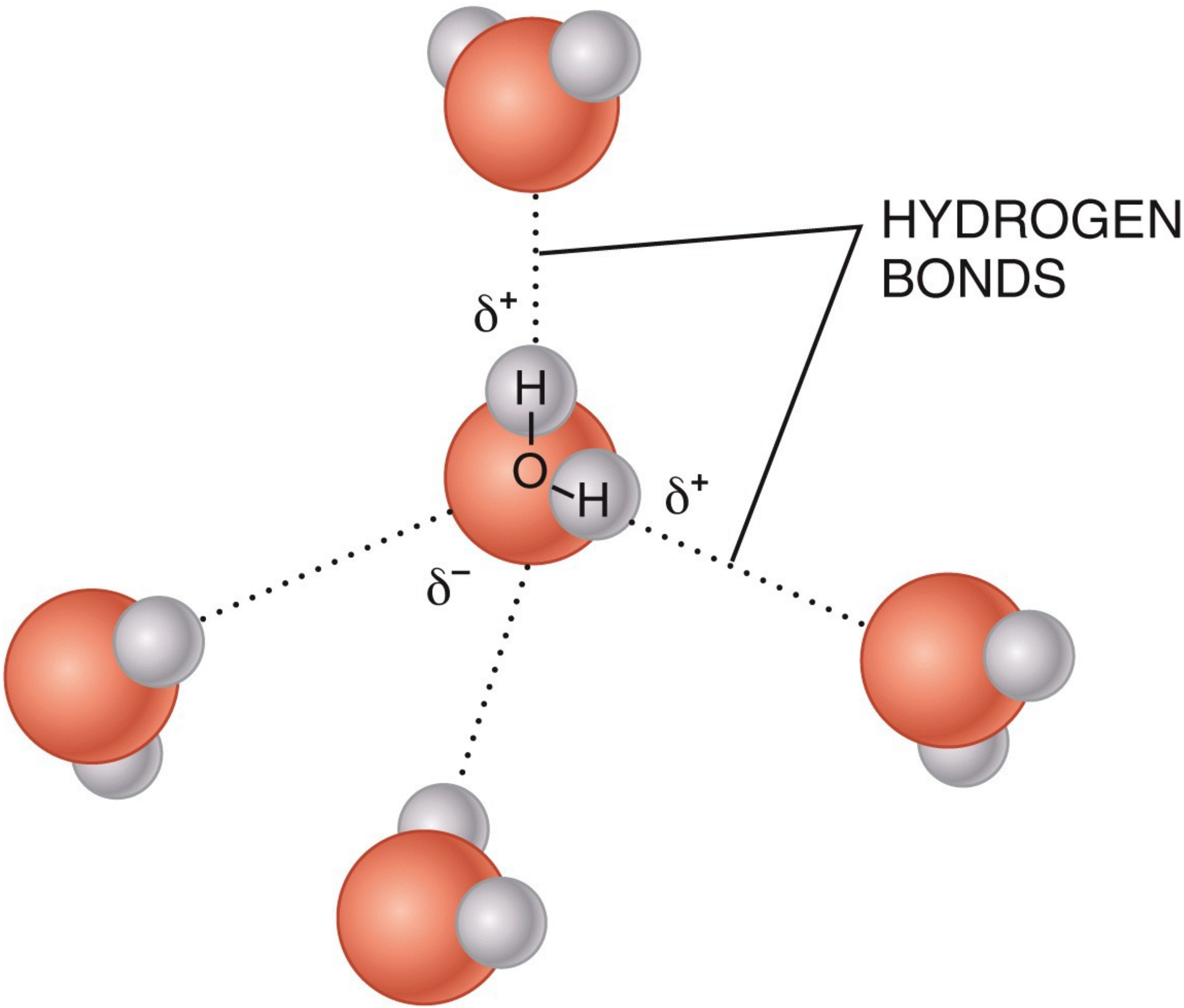
What is the behavior of hydrophobic molecules in water?



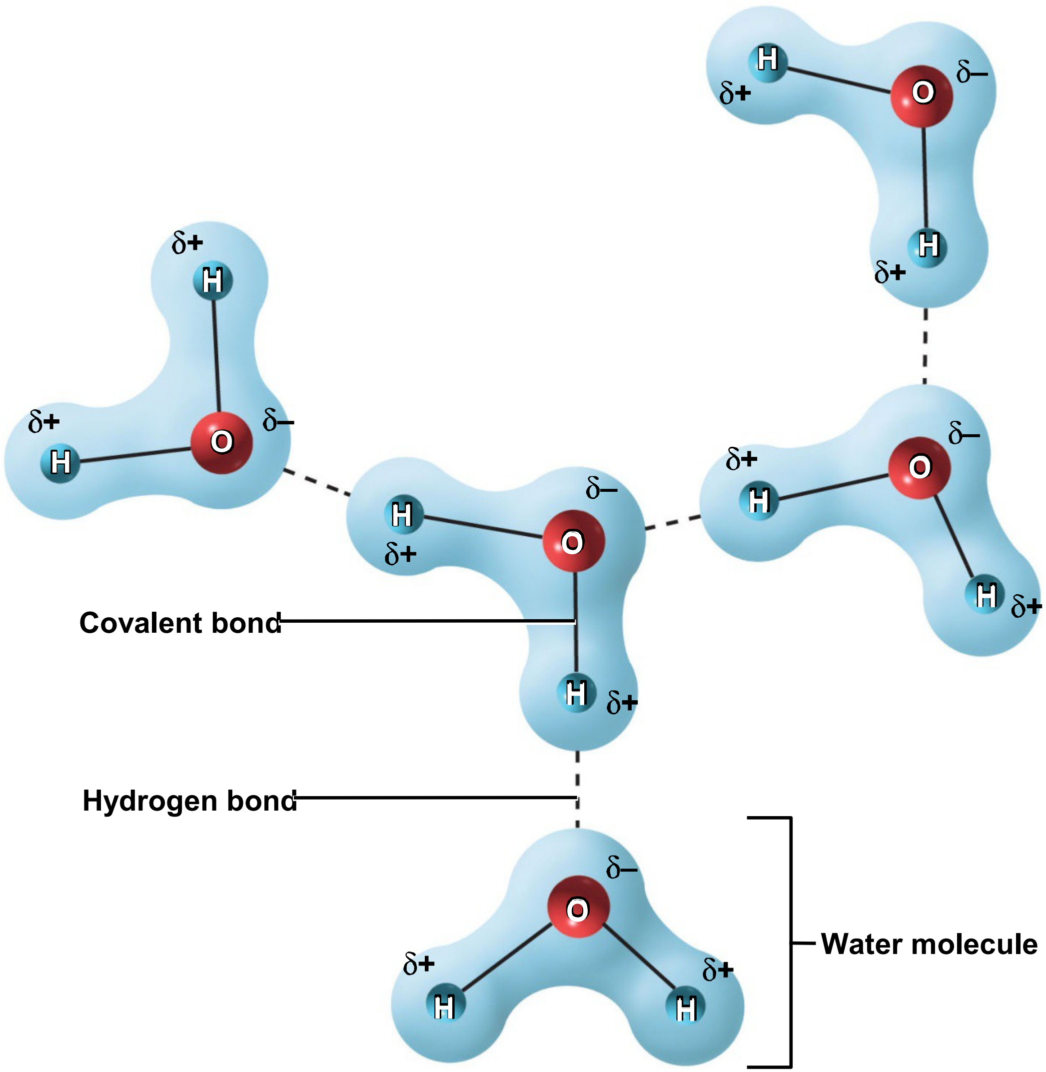
(c) Nonpolar covalent compounds are hydrophobic.

Hydrogen Bonds

- **Hydrogen bond =** a weak attraction between a slightly positive hydrogen atom in one molecule and a slightly negative oxygen or nitrogen atom in another molecule.
- Water molecules are weakly attracted to each other by hydrogen bonds
- Relatively weak bonds
- Very important to physiology structure and function
  - Structure - Protein structure & DNA structure
  - Function - Respiratory failure of premature infants
- Note – Hydrogen bonds do not hold atoms together so they don't form compound, however.
- Hydrogen bonds are opposite charge between two molecules or across from opposite charges in the same molecule. Therefore, hydrogen bonds....
  - 1) Hold 3D shape of same molecule together (e.g. protein)
  - 2) Hold different molecules together (e.g. water molecules)


HYDROGEN BONDS
δ+
H
O
H
δ+
δ−

Hydrogen Bonding in Water



What is a gel state?

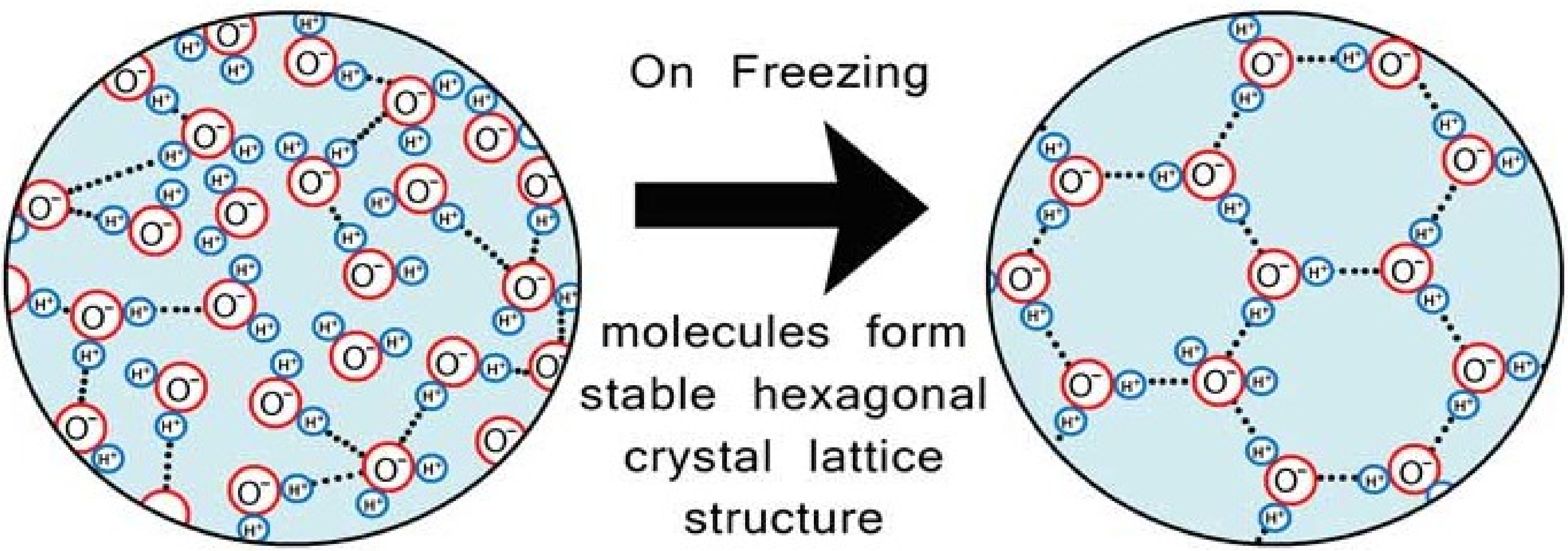
What is water tension?

What happens when water freezes?

Why does ice float?

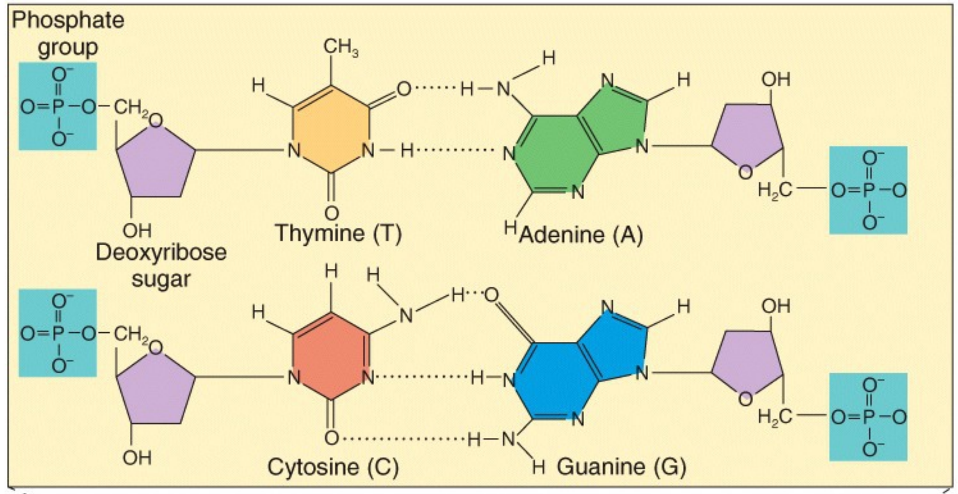
Why Does Water Expand When It Freezes

As water freezes the hydrogen bonds push the H_2O molecules farther apart from each other increasing the intermolecular space resulting in expansion.



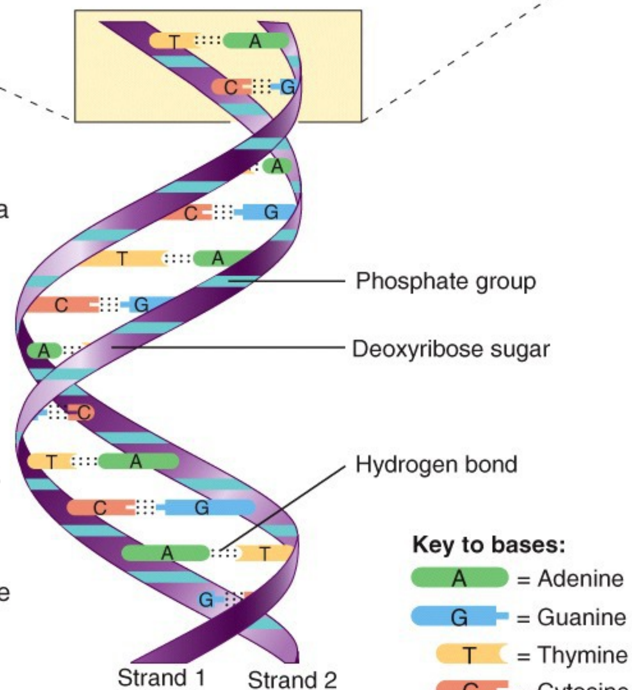
Liquid water
Unstable and irregularly formed hydrogen bonds

Ice
Stable hydrogen bonds

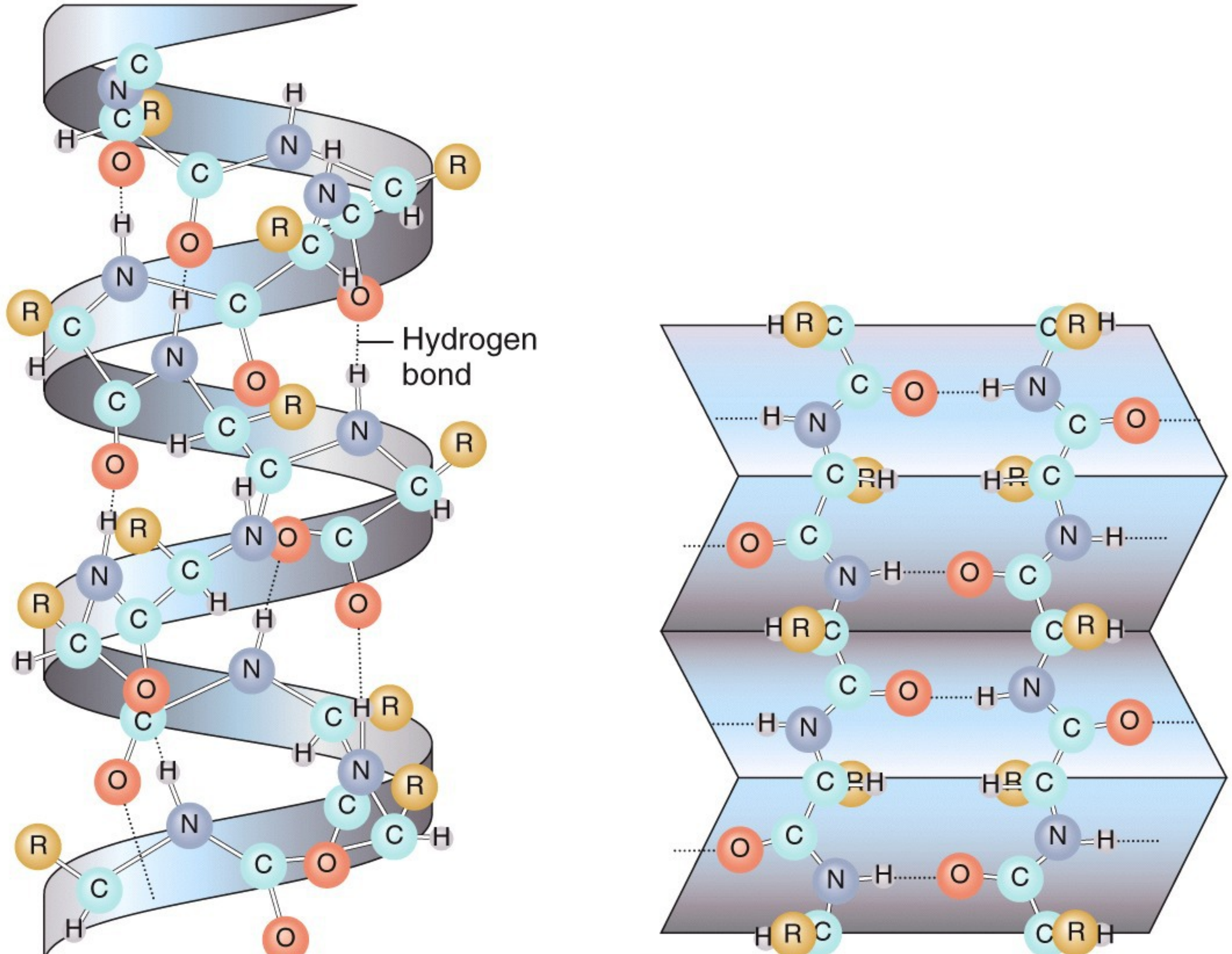


(a) Components of nucleotides

- DNA is made of two strands twisted in a spiral staircase-like structure called a double helix.
- Each strand consists of nucleotides bound together.
- Each nucleotide consists of a deoxyribose sugar bound to a phosphate group and one of 4 nitrogenous bases [adenine (A), thymine (T), guanine (G), cytosine (C)].
- The nitrogenous bases pair together through hydrogen bonding to form the "steps" of the double helix.
- Adenine pairs with thymine and guanine pairs with cytosine.



(b) Portion of a DNA molecule



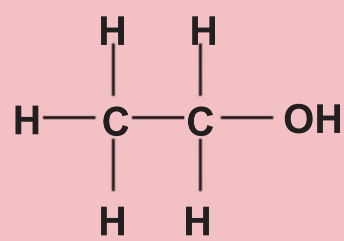
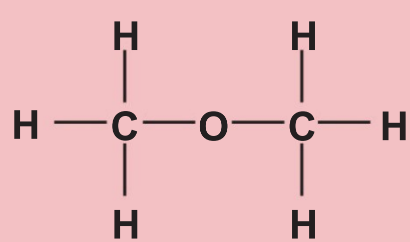
Alpha helix

(b) Secondary structure (twisting and folding of neighboring amino acids, stabilized by hydrogen bonds)

Beta pleated sheet

What is an isomer?

Isomers – molecules with identical molecular formulae but different arrangement of their atoms

	Structural formulae	Condensed Structural formulae	Molecular formulae
Ethanol		CH_3CH_2OH	C_2H_6O
Ethyl ether		CH_3OCH_3	C_2H_6O

Free Radicals

- FR are chemical particles with an odd number of electrons // *FR need another electron to make themselves stable.*

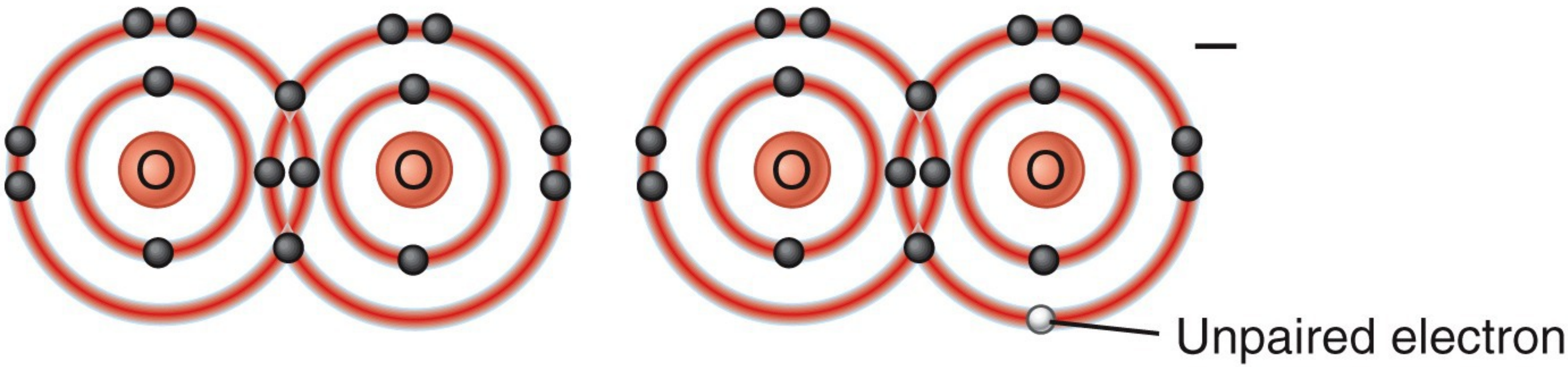
- *FR will "take" an electron from another molecule which then makes that molecule unstable. The second molecule then takes an electron off another molecule. This starts a chain reaction which could eventually kill the cell.*

- Produced by /// normal metabolic reactions, radiation, or toxic chemicals

- FR damage tissue / may cause cell death!
  - reactions that destroy cellular molecules
  - may cause cancer, death of heart tissue and aging

- Antioxidants - neutralize free radicals
  - in our tissues we have the enzyme superoxide dismutase (SOD)
  - in diet (Selenium, vitamin E, vitamin C, carotenoids)

How Do We Neutralize Free Radicals?



(a) Oxygen molecule (O_2) (b) Superoxide free radical (O_2^-)

$O_2^- + O_2^- + 2H^+ \text{------->} H\text{-}O\text{-}O\text{-}H + O_2$

Superoxide dimutase

Hydrogen peroxide

$2H_2O_2 \text{------->} 2H_2O + O_2$

Catalase

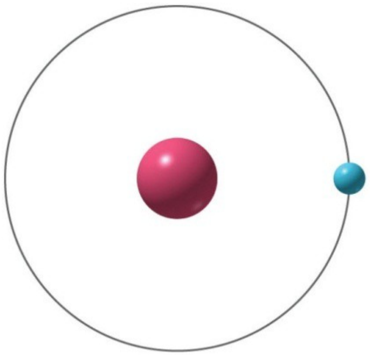
$H_2O_2 + 2H^+ \text{------->} 2\,H_2O$

Peroxidase

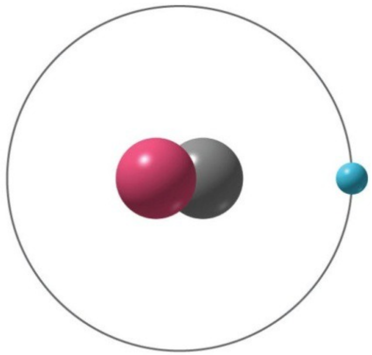
Isotopes and Radioactivity

- **Isotopes –** same element that differ from one another only in the number of neutrons and therefore in atomic mass
  - extra neutrons increase atomic weight
  - isotopes of an element are chemically similar // have same valence electrons
- **Atomic weight** of an element accounts for the fact that an element is a mixture of atoms (atoms with equal protons and neutrons and those atoms that are isotopes)

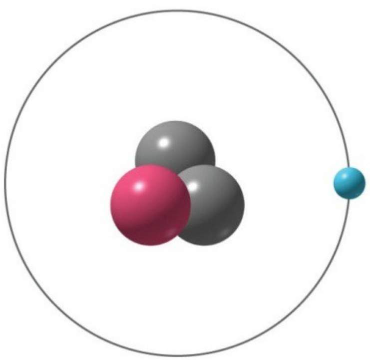
Isotopes of Hydrogen



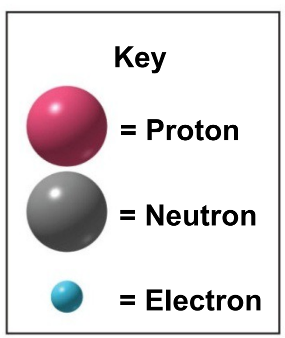
Hydrogen (^{1}H)
($1p^{+}$, $0n^{0}$, $1e^{-}$)



Deuterium (^{2}H)
($1p^{+}$, $1n^{0}$, $1e^{-}$)



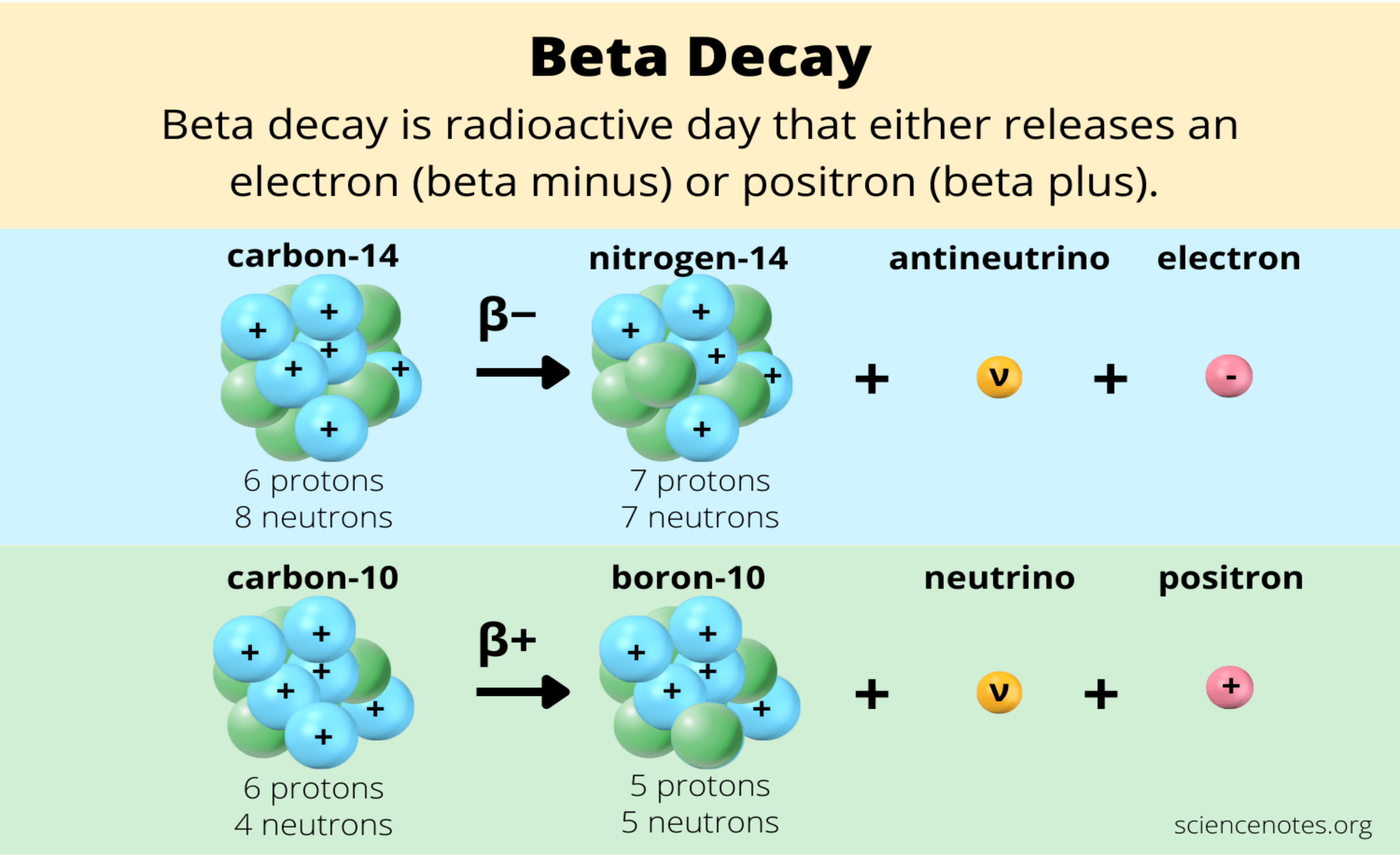
Tritium (^{3}H)
($1p^{+}$, $2n^{0}$, $1e^{-}$)



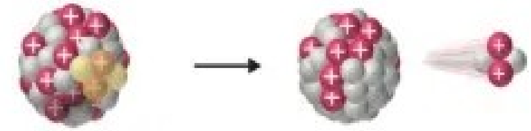
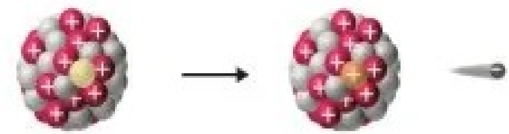
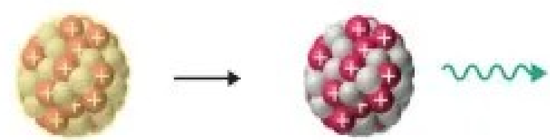
Tritium beta emissions cause phosphorous to glow

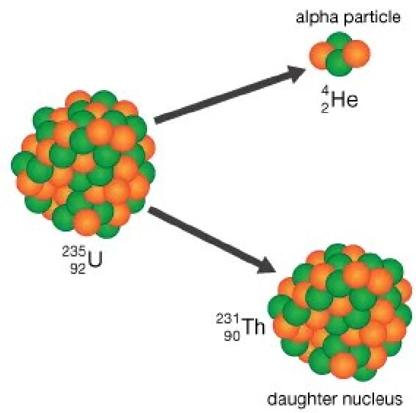
Radioisotopes and Radioactivity

- **Radioisotopes**
  - unstable isotopes that give off radiation // beta particle
  - every element has at least one radioisotope
- **Radioactivity**
  - radioisotopes decay to stable isotopes by releasing radiation
  - atom has an imbalance in number of protons to neutrons
  - See next slide



Beta decay – In beta minus (β−) decay, a neutron is converted to a proton, and the process creates an electron and an electron antineutrino; while in beta plus (β+) decay, a proton is converted to a neutron and the process creates a positron and an electron neutrino. β+ decay is also known as positron emission.

Decay Type	Radiation Emitted	Generic Equation	Model
Alpha decay	${}^{4}_{2}\alpha$	${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X' + {}^{4}_{2}\alpha$	
Beta decay	${}^{0}_{-1}\beta$	${}^{A}_{Z}X \longrightarrow {}_{Z+1}^{A}X' + {}^{0}_{-1}\beta$	
Gamma emission	${}^{0}_{0}\gamma$	${}^{A}_{Z}X^{*} \xrightarrow{\text{Relaxation}} {}^{A}_{Z}X' + {}^{0}_{0}\gamma$	



Electrolytes

- **Salts that ionize in water and form solutions capable of conducting an electric current.**

- **Electrolyte importance**
  - chemical reactivity
  - osmotic effects (influence water movement)
  - electrical effects on nerve and muscle tissue

- **Electrolyte balance is one of the most important considerations in patient care.**

- Imbalances have ranging effects from muscle cramps, brittle bones, to coma, cardiac arrest, and death.

TABLE 2.2 Major Electrolytes and the Ions Released by their Dissociation

Electrolyte		Cation	Anion
Calcium chloride ($CaCl_2$)	→	Ca^{2+}	2 Cl^-
Disodium phosphate (Na_2HPO_4)	→	2 Na^+	HPO_4^{2-}
Magnesium chloride ($MgCl_2$)	→	Mg^{2+}	2 Cl^-
Potassium chloride (KCl)	→	K^+	Cl^-
Sodium bicarbonate ($NaHCO_3$)	→	Na^+	HCO_3^-
Sodium chloride (NaCl)	→	Na^+	Cl^-

Minerals

- Inorganic elements extracted from soil by plants and passed up the food chain to humans
  - Ca, P, Cl, Mg, K, Na, I, Fe, Zn, Cu, and S
- constitute about 4% of body weight
  - structure (teeth, bones, etc)
  - enzymes
- **Electrolytes** – required for nerve and muscle function = mineral salts

TABLE 2.1 Elements of the Human Body

Name	Symbol	Percentage of Body Weight
Major Elements (Total 98.5%)		
Oxygen	O	65.0
Carbon	C	18.0
Hydrogen	H	10.0
Nitrogen	N	3.0
Calcium	Ca	1.5
Phosphorus	P	1.0
Lesser Elements (Total 0.8%)		
Sulfur	S	0.25
Potassium	K	0.20
Sodium	Na	0.15
Chlorine	Cl	0.15
Magnesium	Mg	0.05
Iron	Fe	0.006

Trace Elements (Total 0.7%)

Chromium	Cr	Molybdenum	Mo
Cobalt	Co	Selenium	Se
Copper	Cu	Silicon	Si
Fluorine	F	Tin	Sn
Iodine	I	Vanadium	V
Manganese	Mn	Zinc	Zn

Van der Waals Forces

(not a learning objective)

- **Van der Waals Forces –** weak, brief attractions between neutral atoms
- Fluctuations in electron density in electron cloud of a molecule creates polarity for a moment, and can attract adjacent molecules in the region for a very short instant in time
- Only 1% as strong as a covalent bond
- when two surfaces or large molecules meet, the attraction between large numbers of atoms can create a very strong attraction
  - important in protein folding
  - important with protein binding with hormones
  - association of lipid molecules with each other

More About Water

- **Polar covalent bonds** and its **V-shaped molecule** gives water a set of properties that account for its ability to support life.
- Water's unique features include.......
  - **solvency**
  - **cohesion**
  - **adhesion**
  - **chemical reactivity**
  - **thermal stability**

Solvency

- **Solvency** - ability to dissolve other chemicals

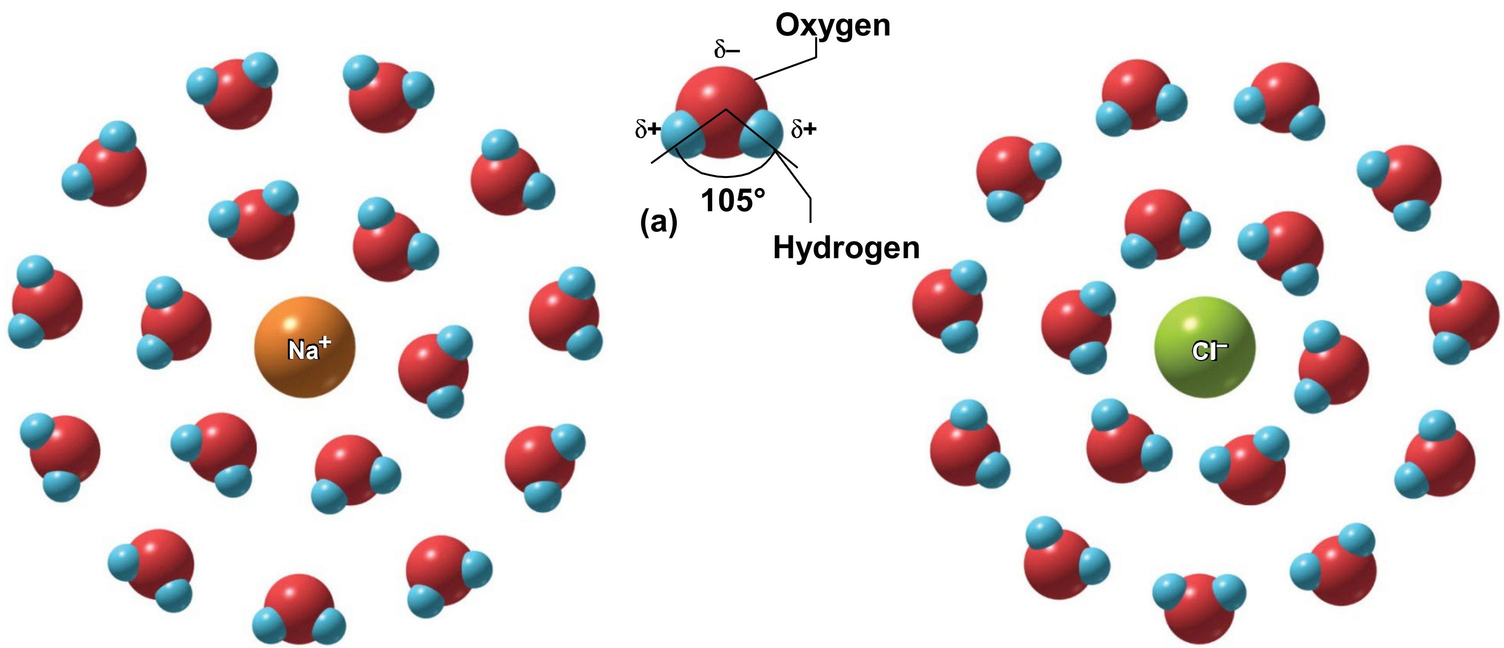
- Water is called the **Universal Solvent**

  - **Hydrophilic –** substances that dissolve in water // These molecules must be polarized or charged (e.g. proteins)

  - **Hydrophobic -** substances that do not dissolve in water // These molecules are non-polar or neutral (e.g. fat)

- All biologic chemical reactions depend on the solvency of water

Water as a Solvent



- Polar water molecules overpower the ionic bond in Na^{+} Cl^{-}
  - forming hydration spheres around each ion
  - water molecules: negative pole faces Na^{+}, positive pole faces Cl^{-}
  - Water also interacts with surface charge on proteins // water is responsible for folding proteins into 3D shape!

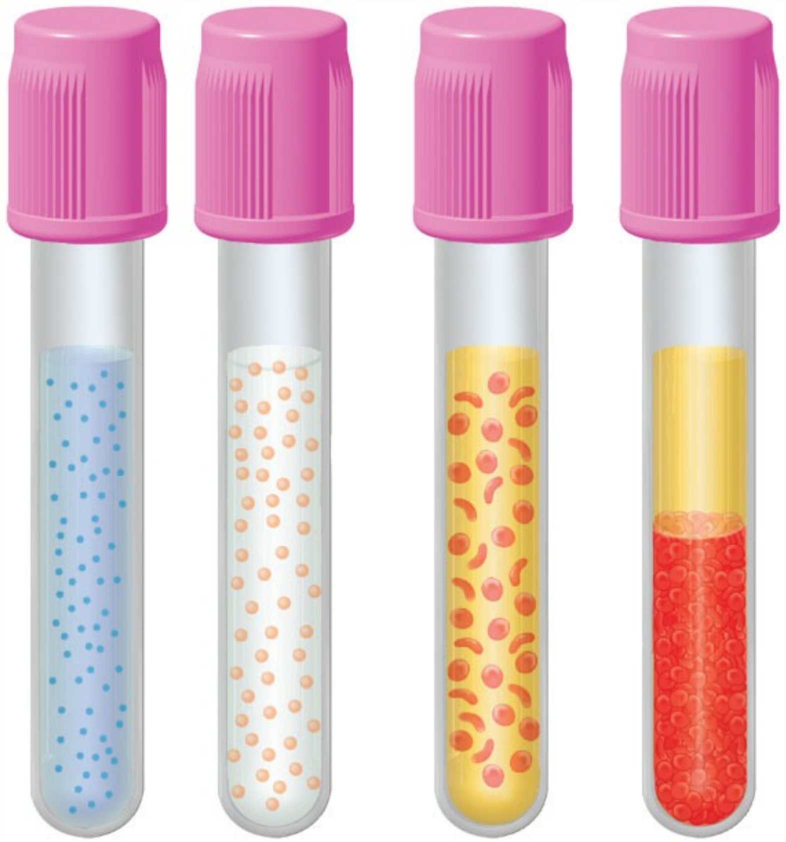
Chemical Reactivity of Water

- **It is the ability of water to participate in chemical reactions**
  - **water ionizes** into H^+ and OH^-
  - **water ionizes** other chemicals (acids and salts)
  - water involved in **hydrolysis** and **dehydration synthesis** reactions

Thermal Stability of Water

- **Water helps stabilize the internal temperature of the body**
  - has high **heat capacity** **–** the amount of heat required to raise the temperature of 1 g of a substance by 1 degree C.
  - **calorie (cal)** – the amount of heat that raises the temperature of 1 g of water 1 degree C.
    - hydrogen bonds inhibit temperature increases by inhibiting molecular motion (note: heat is actually a measurement of velocity!)
    - water absorbs heat without changing temperature very much
    - **effective coolant //**   1 ml of perspiration removes 500 calories

Three Types of Mixtures
Solution, Colloid and Suspension



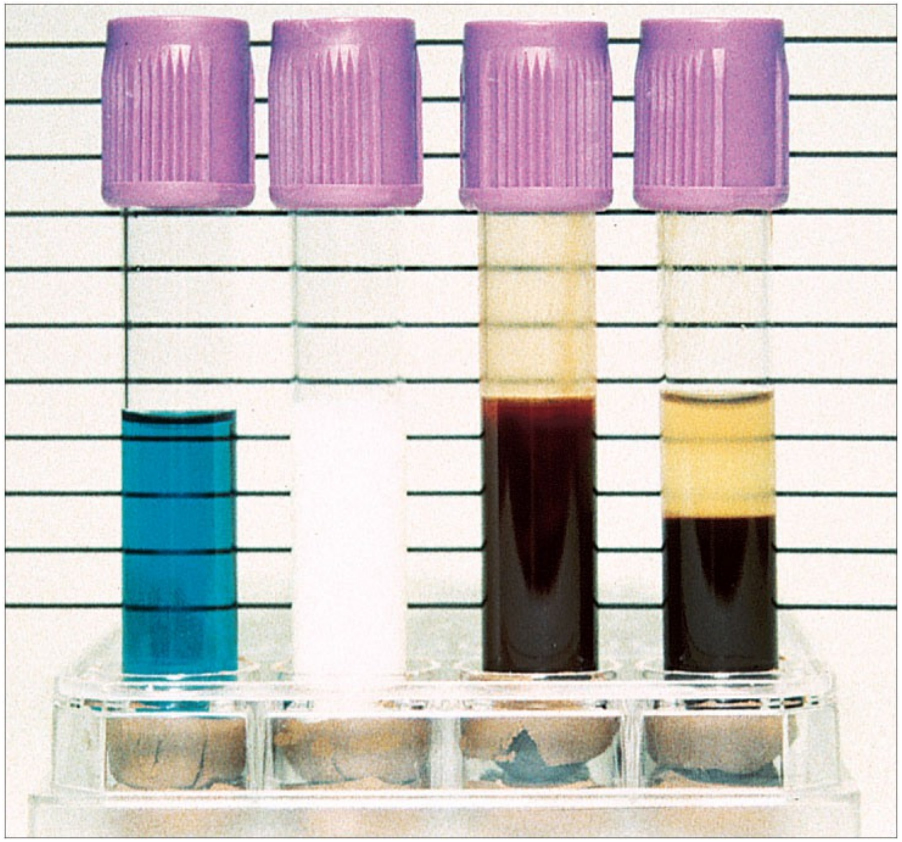
Solution **Colloid** **Suspension**

Water and Mixtures
Three Types of Mixtures

- **Mixtures –** consists of substances physically blended, but not chemically combined
- Our body fluids are complex mixtures of chemicals
- Each substance in a mixture maintains its own chemical properties (no chemical bonding occurs)
- Most mixtures in our bodies consist of chemicals dissolved or suspended in water
- Water 50-75% of body weight // depends on age, sex, fat content, etc.

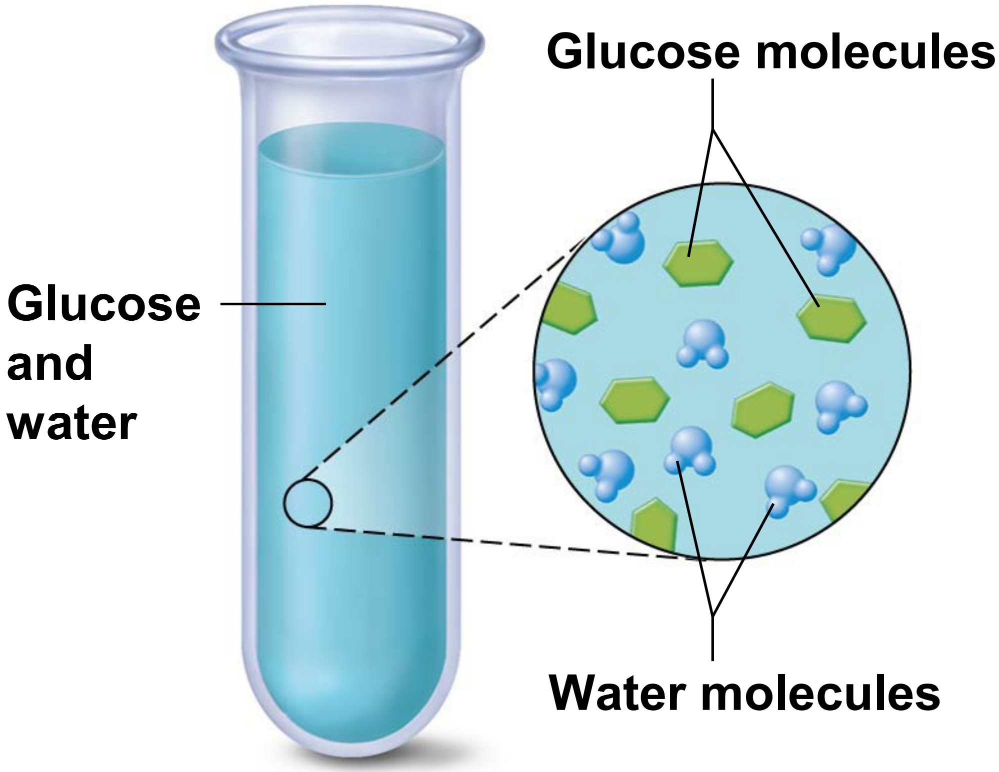
Solutions

- **Solution –** consists of particles of matter called the **solute** mixed with a more abundant substance (usually water) called the **solvent**
- **Solute** can be gas, solid or liquid
- **Solutions are defined by the following properties:**
  - solute particles under 1nm
  - solute particles do not scatter light
  - will pass through most membranes
  - will not separate on standing



(a) (b) (c) (d)

The three types of mixtures.

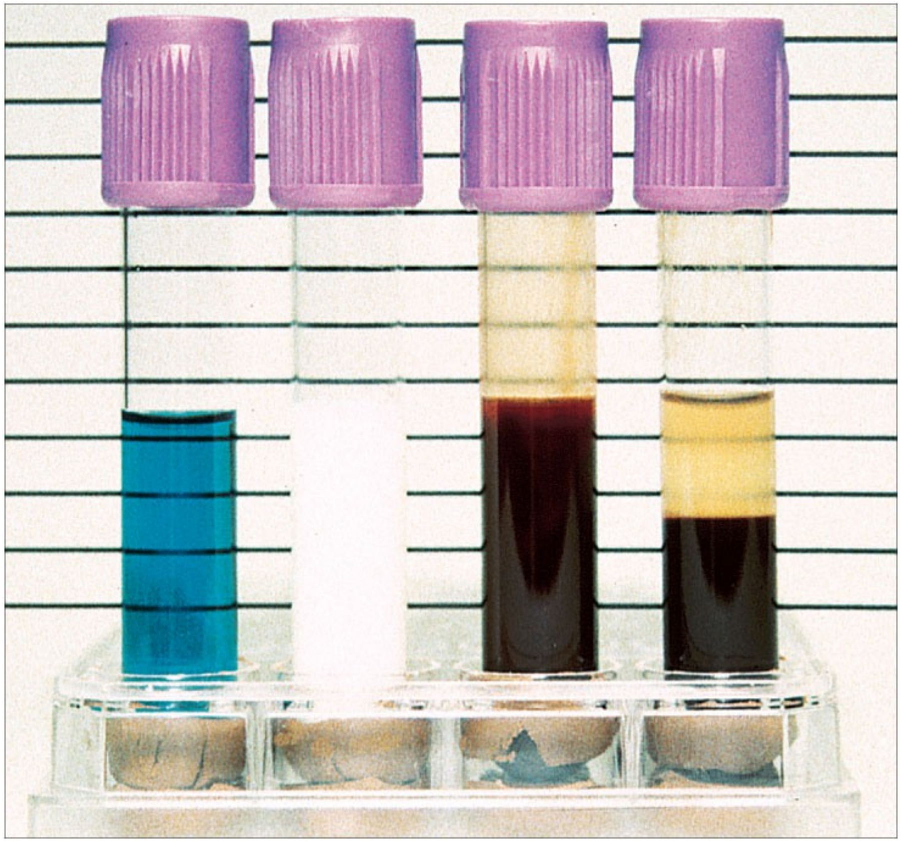


Solution

Particles extremely small and not visible; do not settle out; one component dissolves in the other component.

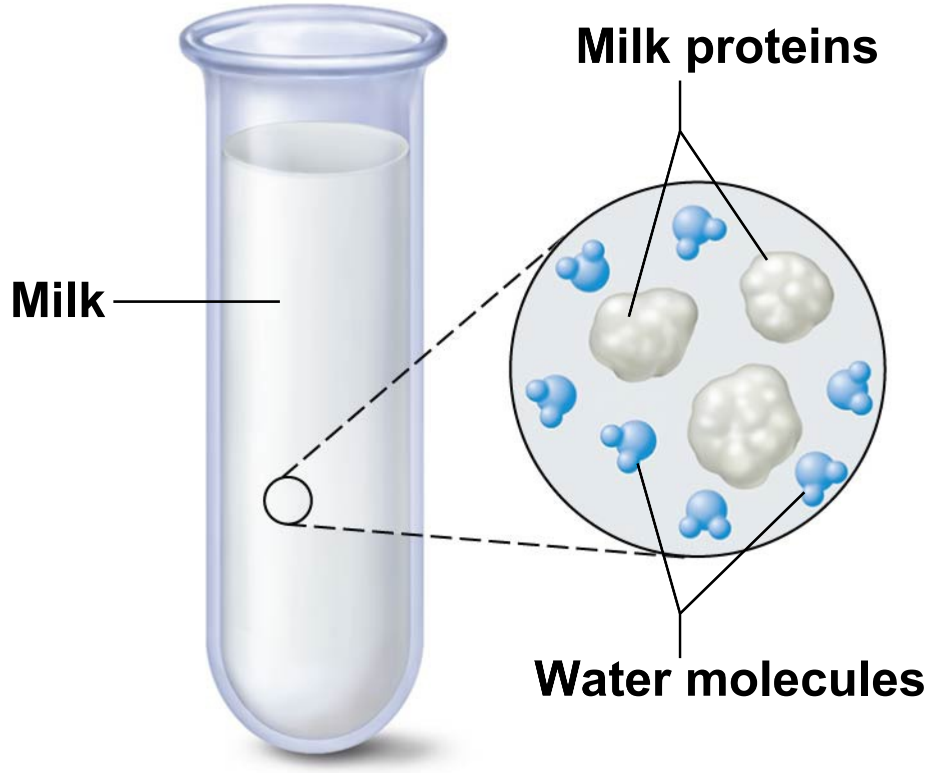
Colloids

- Most common colloids in the body are mixtures of protein and water
- Many can change from liquid to gel state within and between cells
- Colloids defined by the following physical properties:
  - particles range from 1 – 100 nm in size
  - scatter light and are usually cloudy
  - particles too large to pass through semipermeable membrane
  - particles remain permanently mixed with the solvent when mixture stands



(a) (b) (c) (d)

The three types of mixtures.

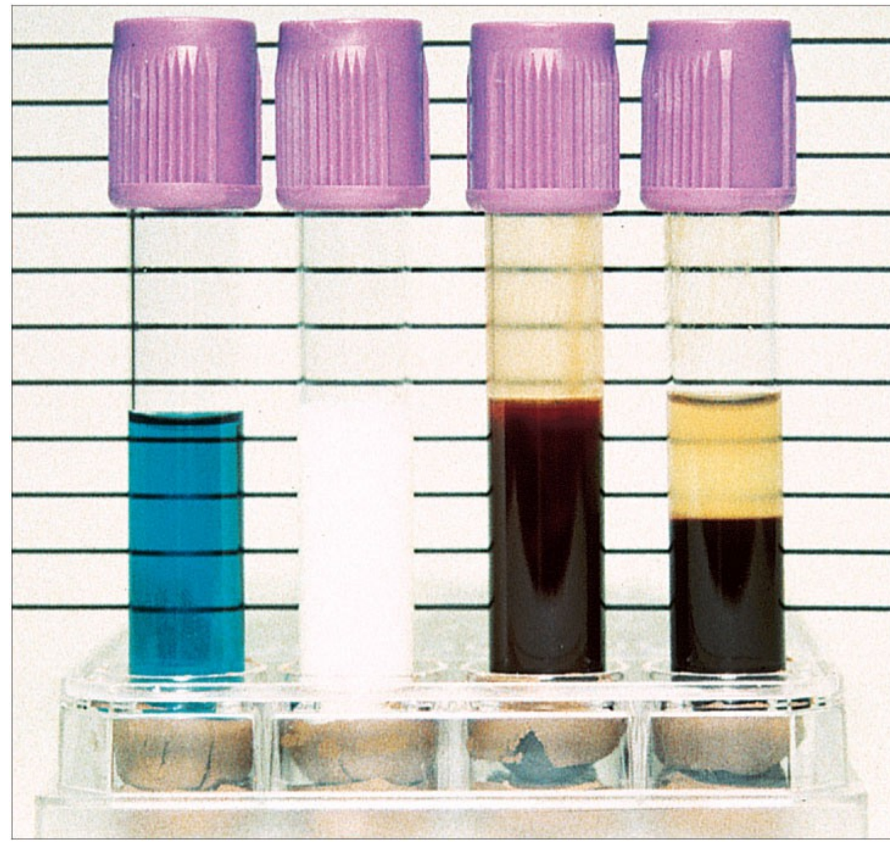


Colloid

Two distinct components;
particles small and not visible; but do not settle out; hydrated.

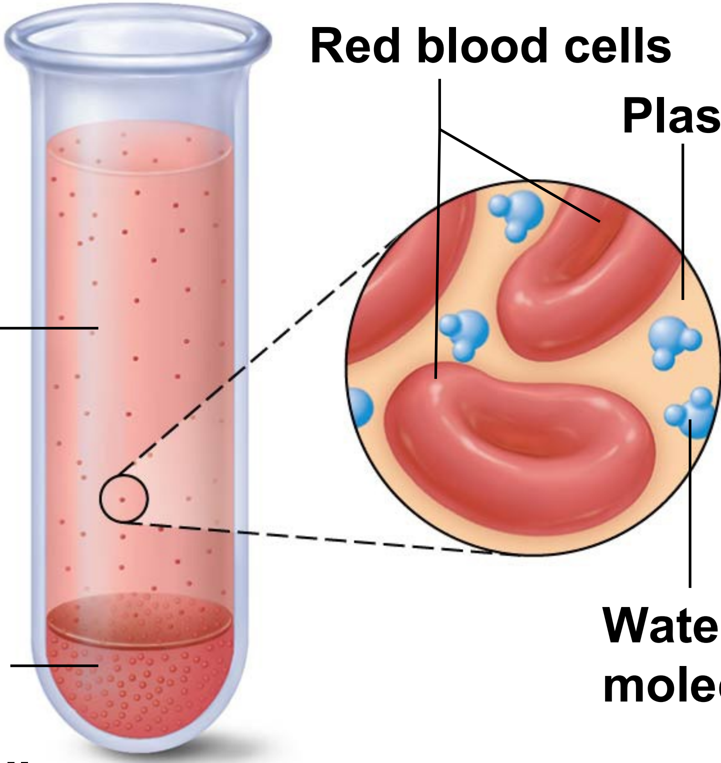
Suspensions and Emulsions

- **Suspension**
  - Defined by the following physical properties
    - particles exceed 100nm
    - too large to penetrate selectively permeable membranes
    - cloudy or opaque in appearance
    - separates on standing
- **Emulsion //** suspension of one liquid in another // e.g. fat in milk



(a) (b) (c) (d)

The three types of mixtures.



Suspension

Particles large and usually visible; settle out.

TABLE 2.4 Types of Mixtures

	Solution	**Colloid**	**Suspension**
Particle Size	< 1 nm	1–100 nm	> 100 nm
Appearance	Clear	Often cloudy	Cloudy-opaque
Will particles settle out?	No	No	Yes
Will particles pass through a selectively permeable membrane?	Yes	No	No
Examples	Glucose in blood O_2 in water Saline solutions Sugar in coffee	Proteins in blood Intracellular fluid Milk protein Gelatin	Blood cells Cornstarch in water Fats in blood Kaopectate

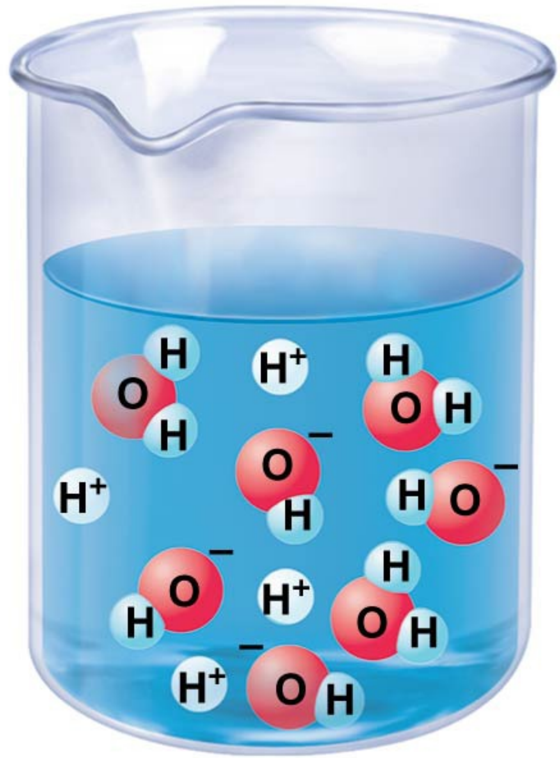
pH

- pH is a scale that measures the number of “free” hydrogen protons (H+) in the water
- The greater the hydrogen ion concentration, the lower the pH number
- Strong acid = pH 0 // Strong base = pH 14 // water's pH is 7
- Measurement of molarity of H^+ [H+] on a logarithmic scale
  - pH scale invented by Soren Sorensen in 1909 to measure acidity of beer
  - $pH = -\log [H^+]$ thus $pH = -\log [10^{-3}] = 3$

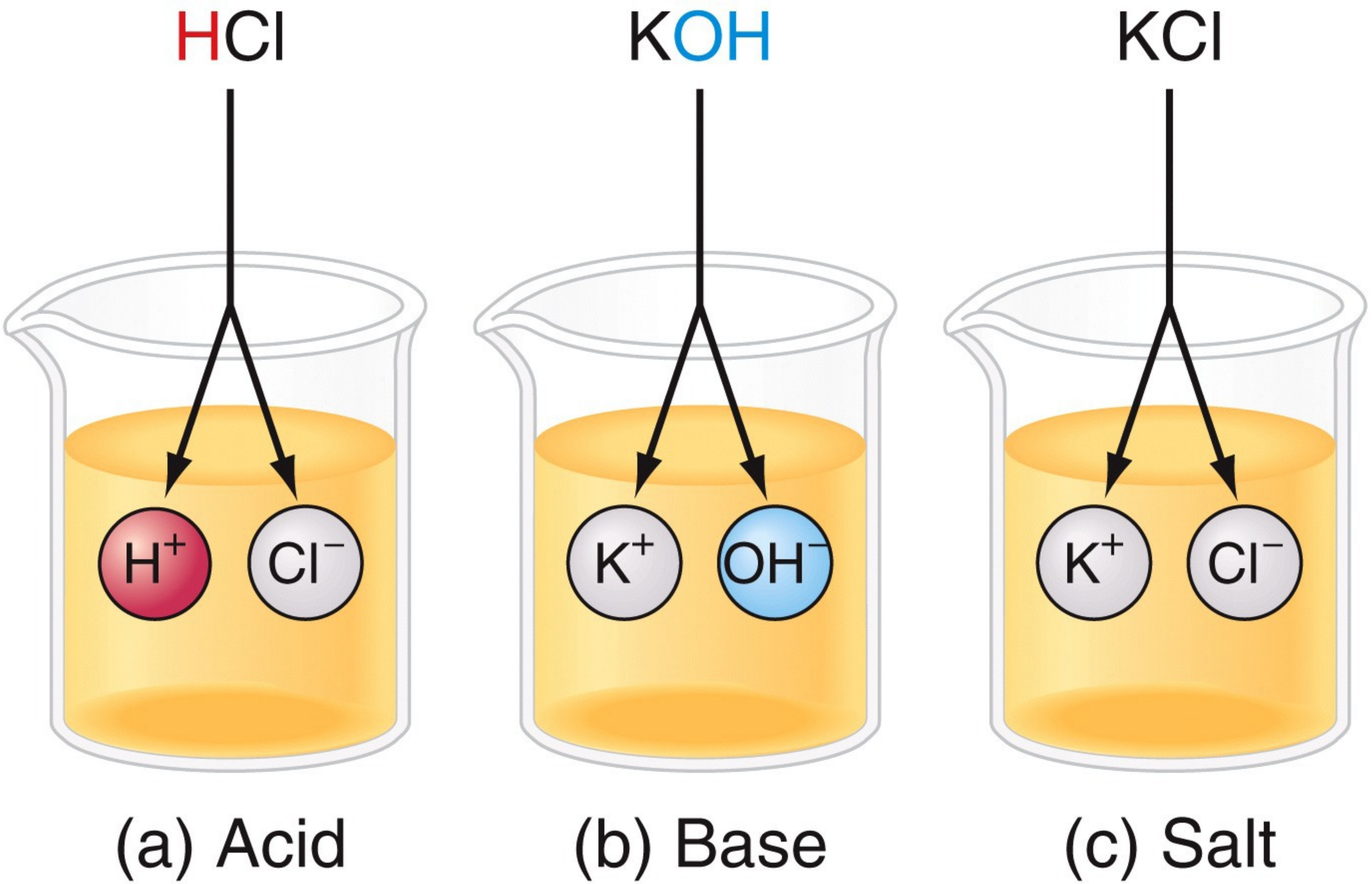
Acids, Bases, and Salts

- An **acid** is proton donor (releases H^+ ions in water)
- A **base** is proton acceptor (accepts H^+ ions) // (or releases OH- ions in water)
- **pH** – a measure derived from the molarity of H+
  - a pH of 7.0 is neutral pH (H$^+$ = OH-)
  - a pH of less than 7 is acidic solution (H$^+$ > OH-)
  - a pH of greater than 7 is basic solution (OH- > H$^+$)
- *What is the difference in water's pH if the proton is attached to a protein by a hydrogen bond or the proton is "free" in the water?*

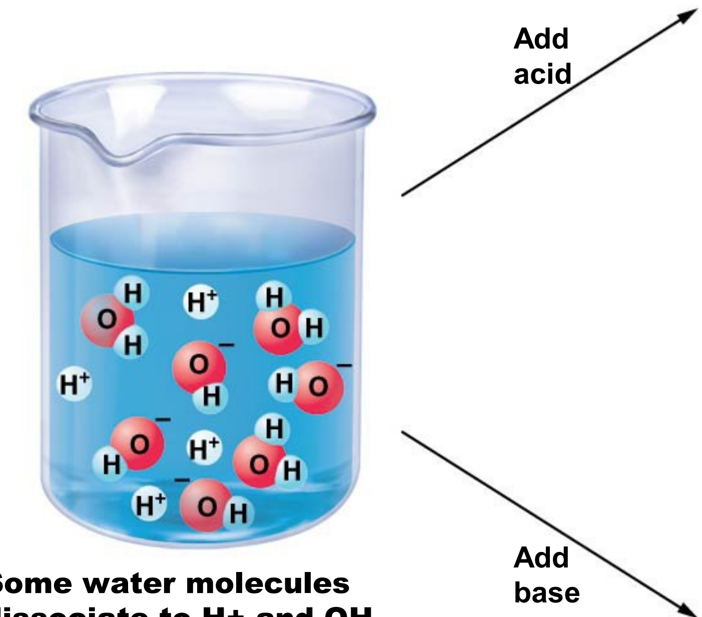
The behavior of acids and bases in water.



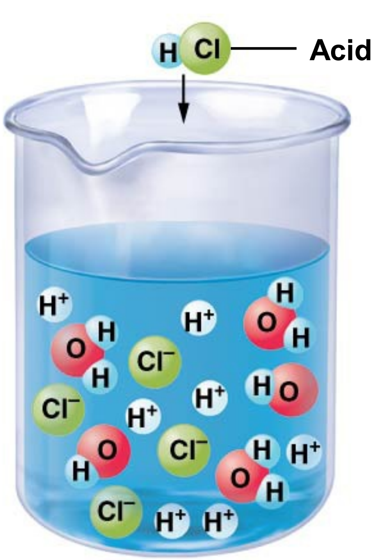
(a) Some water molecules dissociate to H+ and OH–. In pure water, the numbers of H+ and OH– are equal.


HCl
KOH
KCl
H+
Cl−
K+
OH−
K+
Cl−
(a) Acid
(b) Base
(c) Salt

The behavior of acids and bases in water.



(a) **Some water molecules dissociate to H+ and OH–. In pure water, the numbers of H+ and OH– are equal.**



(b) **An acid (HCl) releases H+ and so increases the H+ concentration of the solution.**

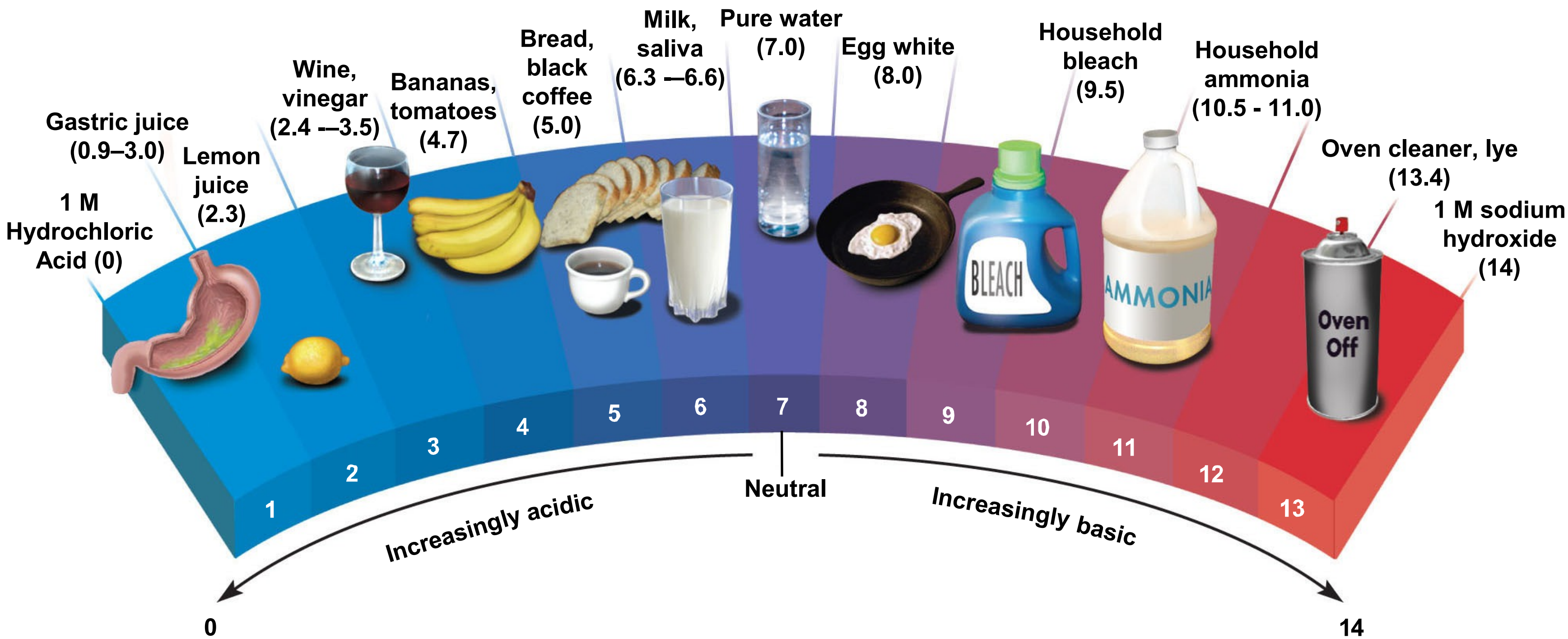
(c) **A base (NaHCO3) binds free H+ and so decreases the H+ concentration of the solution.**

pH

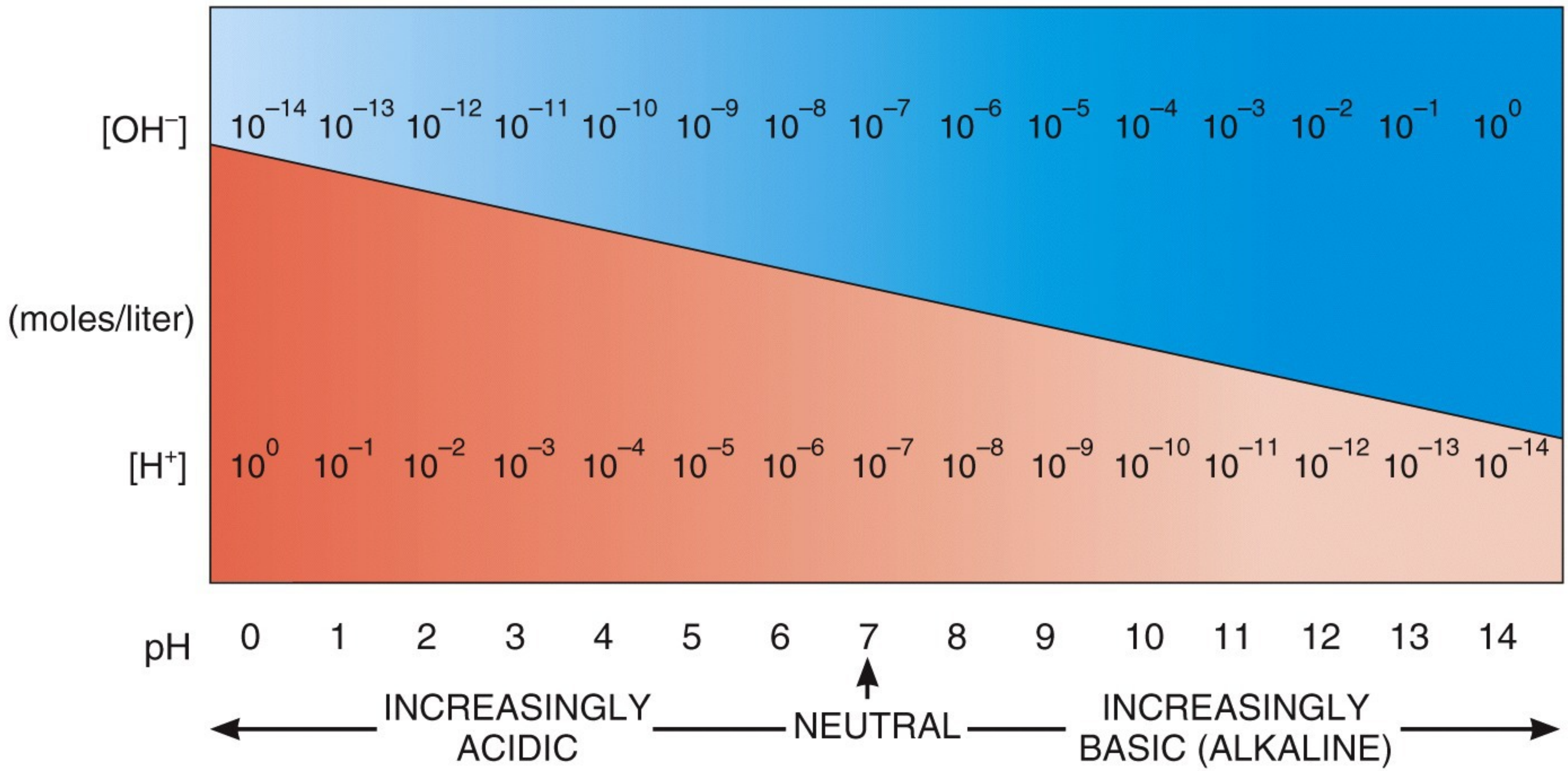
- A **change of one number** on the pH scale represents a 10 fold change in H^+ concentration
  - a solution with pH of 4.0 is 10 times as acidic as one with pH of 5.0

- Our body uses **buffers** to resist changes in pH
  - slight pH disturbances can disrupt physiological functions and alter drug actions
  - pH of blood ranges from 7.35 to 7.45
  - deviations from this range cause tremors, paralysis or even death

pH Scale



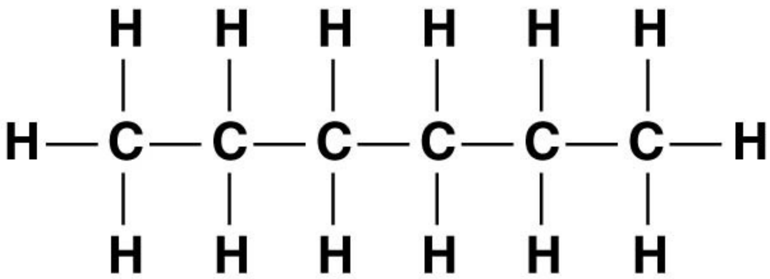
1 M Hydrochloric Acid (0)
Gastric juice (0.9–3.0)
Lemon juice (2.3)
Wine, vinegar (2.4 —3.5)
Bananas, tomatoes (4.7)
Bread, black coffee (5.0)
Milk, saliva (6.3 —6.6)
Pure water (7.0)
Egg white (8.0)
Household bleach (9.5)
Household ammonia (10.5 - 11.0)
Oven cleaner, lye (13.4)
1 M sodium hydroxide (14)
BLEACH
AMMONIA
Oven Off
1
2
3
4
5
6
7
8
9
10
11
12
13
Neutral
Increasingly acidic
Increasingly basic
0
14


[OH⁻]
10^{-14} 10^{-13} 10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0}
(moles/liter)
[H⁺]
10^{0} 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12} 10^{-13} 10^{-14}
pH
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
INCREASINGLY ACIDIC
NEUTRAL
INCREASINGLY BASIC (ALKALINE)

Chemical Reaction

- chemical reaction – a process in which a covalent or ionic bond is formed or broken
- chemical equation – symbolizes the course of a chemical reaction
  - reactants (on left) $\rightarrow$ products (on right)
- classes of chemical reactions_
  - decomposition reactions
  - synthesis reactions
  - exchange reactions

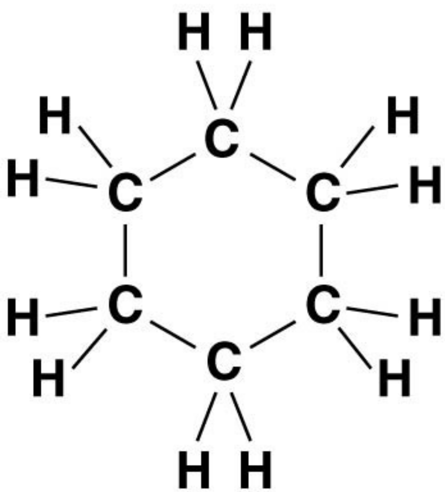
Carbon atoms forms the “backbone” for the macromolecules of life. Carbon's four valence electrons allow carbon to make macromolecules that form linear chains, branching chains, and ring structures.



Hydrocarbon chain

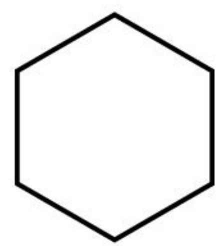
=

Another way to show a hydrocarbon chain; the C atoms are at each point, and the H atoms are not shown.



Hydrocarbon ring

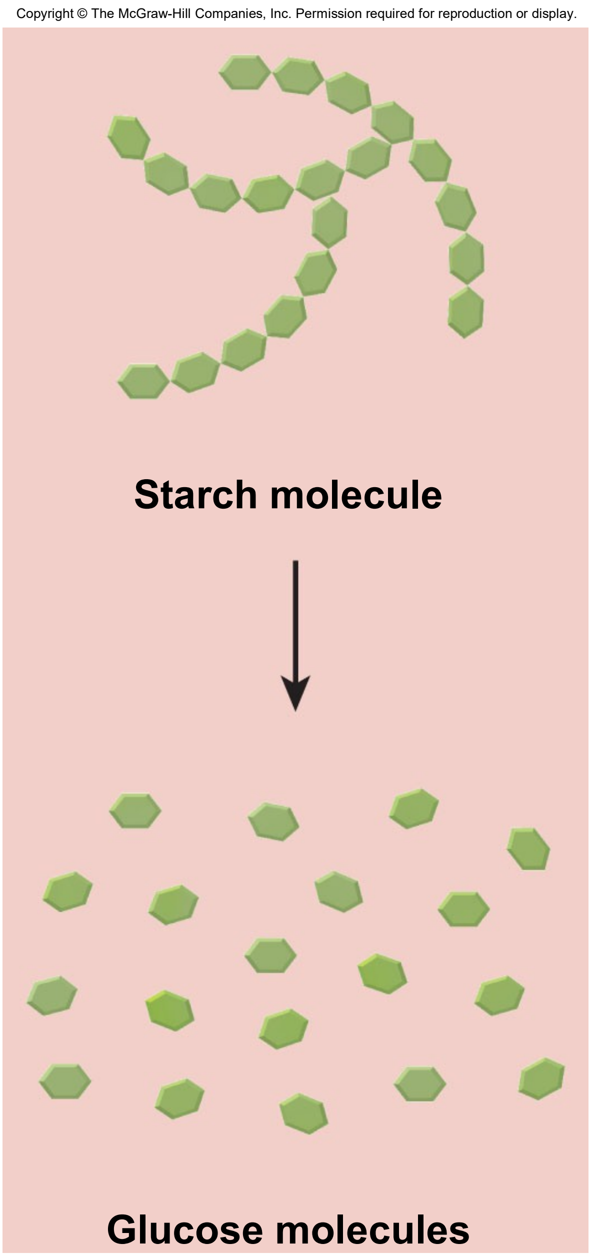
=



Another way to show a hydrocarbon ring; the C atoms are at each corner, and the H atoms are not shown.

Decomposition Reactions

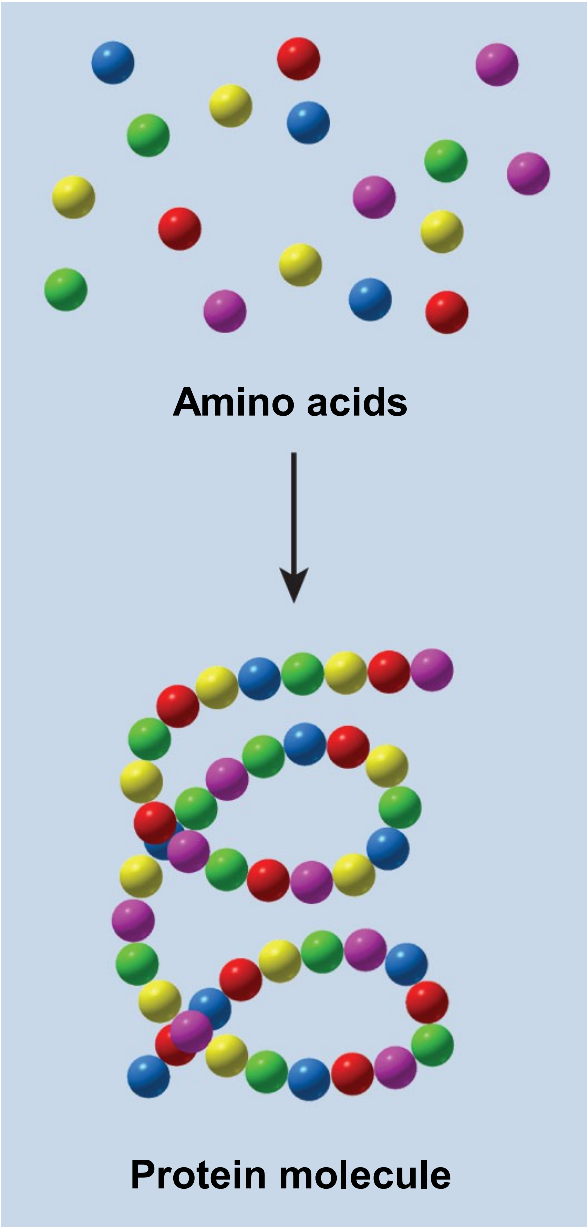
- Large molecule breaks down into two or more smaller ones
- **AB → A + B**



(a) Decomposition reaction

Synthesis Reactions

- Two or more small molecules combine to form a larger one
- **A + B → AB**

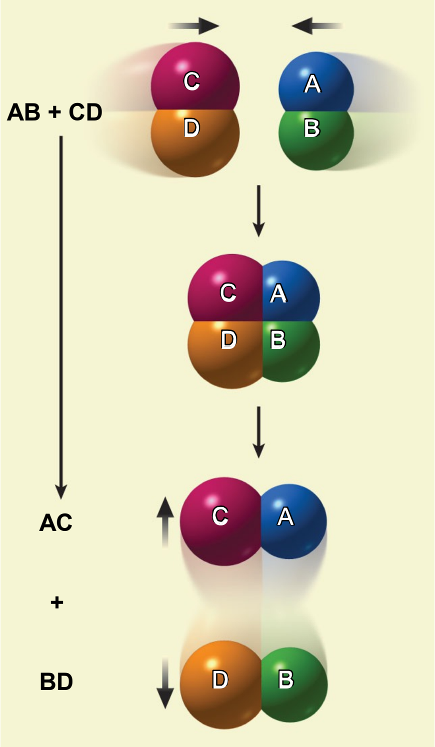


(b) Synthesis reaction

Exchange Reactions

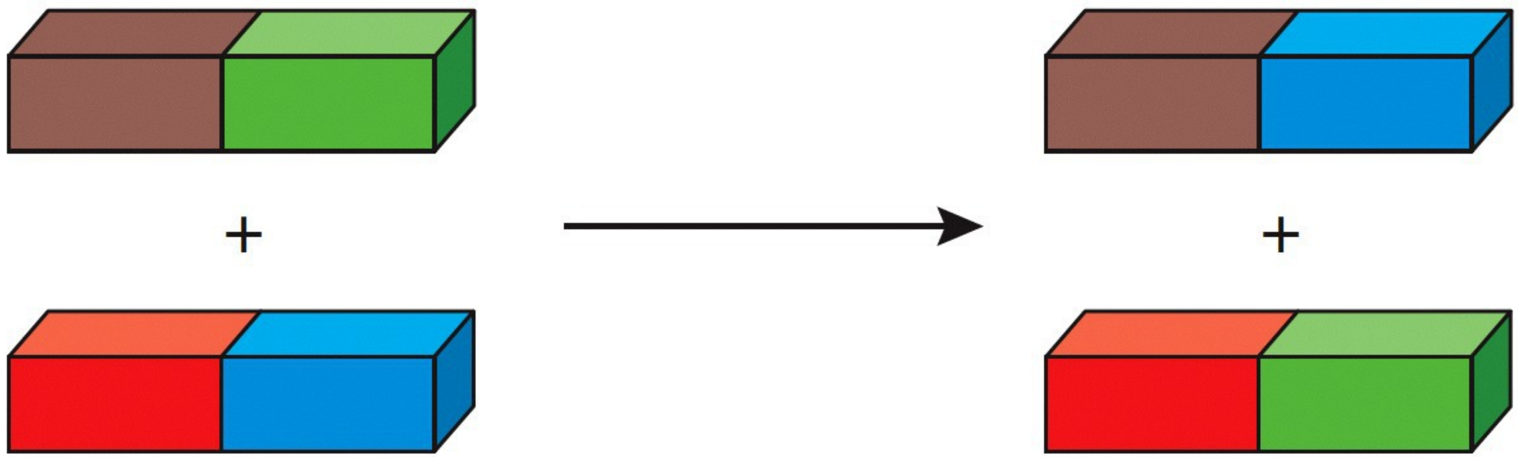
- Two molecules exchange atoms or group of atoms
- **AB+CD → ABCD → AC + BD**

Stomach acid (HCl) and sodium bicarbonate ($NaHCO_3$) from the pancreas combine to form NaCl and H_2CO_3.



(c) Exchange reaction

HCl	+	$NaHCO_3$	$\longrightarrow$	H_2CO_3	+	$NaCl$
Hydrochloric acid		Sodium bicarbonate		Carbonic acid		Sodium chloride



Reversible Reactions

- Can go in either direction under different circumstances
- Symbolized with double-headed arrow

•$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows HCO^{3-} + H^+$

  - **This is one of the most important equations in human physiology**
  - **Memorize this equation: /// carbon dioxide plus water forms carbonic acid which dissociates into bicarbonate and a proton. (What is a proton?)**
  - **It plays a critical role in respiratory system, urinary system, digestive system, and many other physiologic mechanisms**
  - **What determines the direction of the reaction? (see next slide)**

Reversible Reactions

- **Law of mass action** determines direction
  - proceeds from the side of equation with greater quantity of reactants to the side with the lesser quantity
  - Required enzyme (biocatalyst) carbonic anhydrase
- **Equilibrium** exists in reversible reactions when the ratio of products to reactants is stable

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

What will happen to this proton? Significance?

CO2 is produced inside the mitochondria of our cells throughout body. High CO2 and low bicarbonate concentrations push equation to the right.

CO2 becomes carbonic acid

Carbonic anhydrase changes carbonic acid into bicarbonate. Now the CO2 is transported in the blood as bicarbonate.

When bicarbonate reaches the lung tissue, there is very little CO2 but very high concentrations of bicarbonate. This now moves the equation to the left and CO2 forms. Now lungs excretes CO2

Reaction Rates

- Basis for chemical reactions is **molecular motion** and **collisions**
  - reactions occur when molecules collide with enough force and the correct orientation

- **Reaction Rates** affected by:

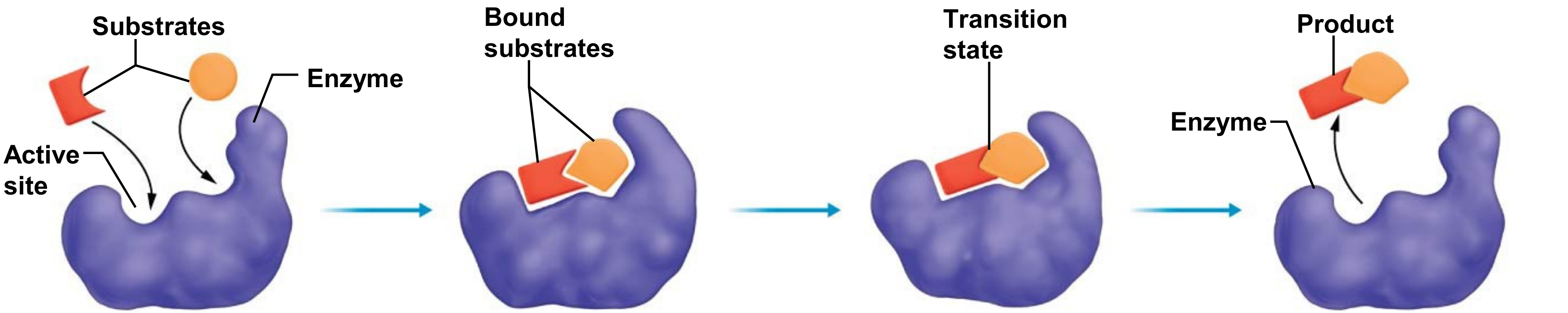
  - **Concentration //** reaction rates increase when the reactants are more concentrated

  - **Temperature //** reaction rates increase when the temperature rises

  - **Catalysts** –substances that temporarily bond to reactants, hold them in favorable position to react with each other, and may change the shapes of reactants in ways that make them more likely to react.

    - speed up reactions without permanent change to itself
    - holds reactant molecules in correct orientation
    - catalyst not permanently consumed or changed by the reaction
    - Enzymes are important biological catalysts

What is an enzyme? What is a substrate?



1. The substrates approach the enzyme.
2. When the substrates bind the enzyme, both the substrates and the enzyme change shape.
3. The substrates enter the transition state and are converted into products.
4. The product and enzyme dissociate, and the enzyme returns to its original shape.

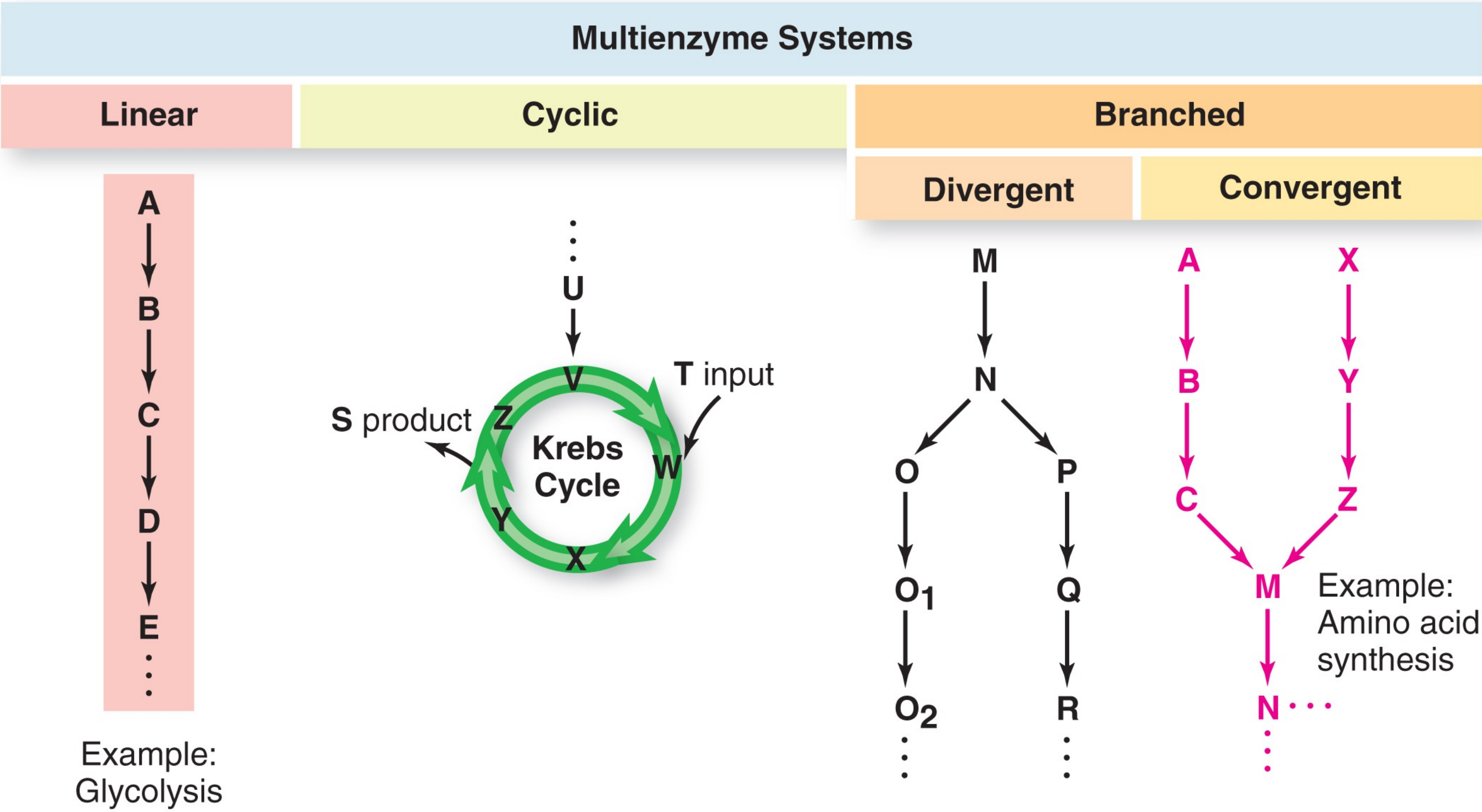
What macromolecules make enzyme's structure?

Where is the information in a cell stored to make this macromolecule?

What maintains the shape of an enzyme?

How may you “damage” an enzyme?

Why is the enzyme called a functional protein and not a structural protein?



Examples of metabolic pathways.

Metabolism

- Metabolism = All the chemical reactions that occur within a cell
- Catabolic // energy releasing (exergonic) decomposition reactions
    - breaks covalent bonds
    - produces smaller molecules
    - releases useful energy
- Anabolic // energy storing (endergonic) synthesis reactions
    - requires energy input
    - E.g. production of protein or fat
    - driven by energy that catabolism releases
- Catabolism and Anabolism are inseparably linked

Table 7.6 Amphibolic Pathways of Glucose Metabolism

Anabolic Pathways

Intermediates from glycolysis are fed into the amino acid synthesis pathway. From there, the compounds are formed into proteins. Amino acids can then contribute nitrogenous groups to nucleotides to form nucleic acids.

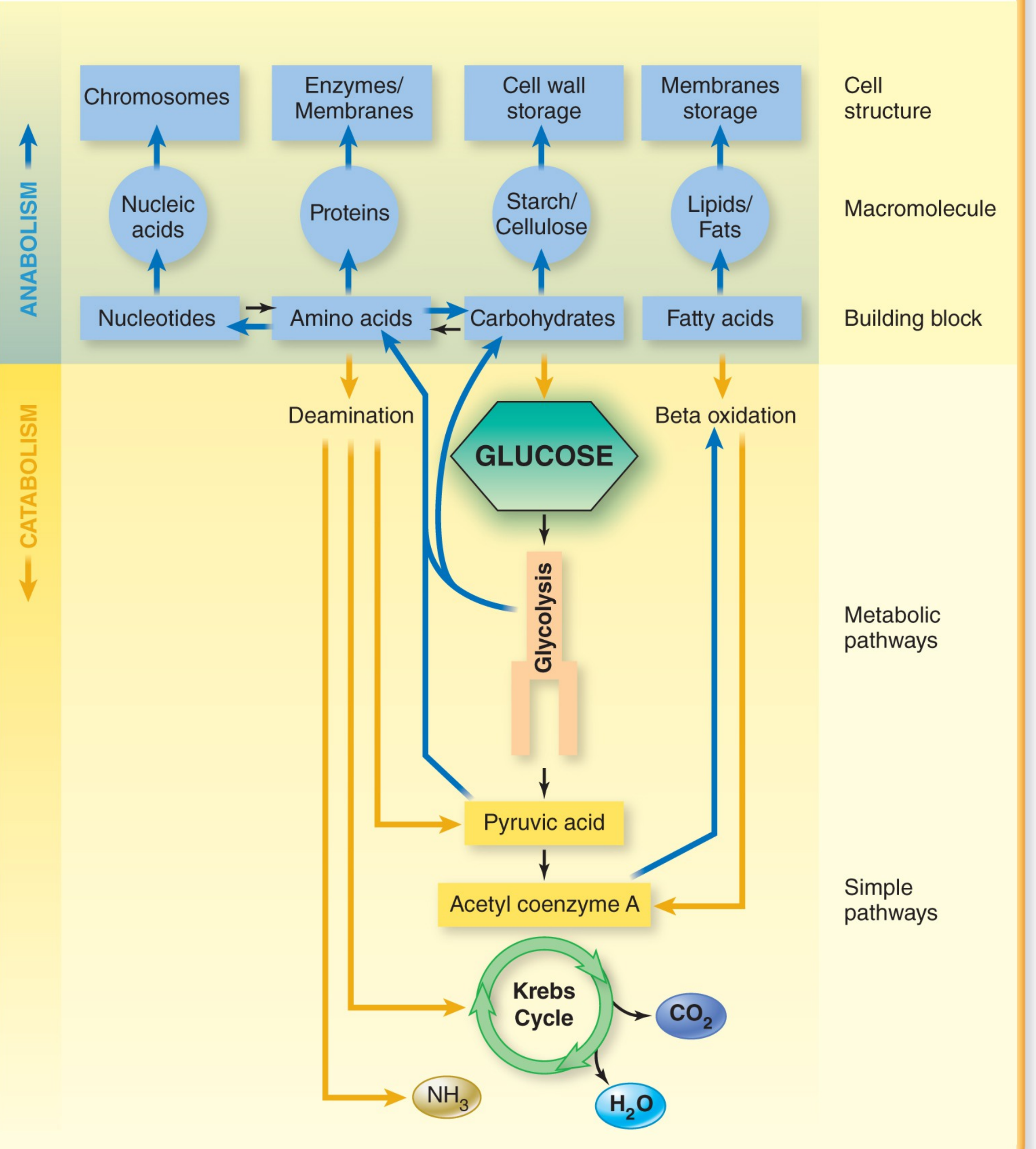
Glucose and related simple sugars are made into additional sugars and polymerized to form complex carbohydrates.

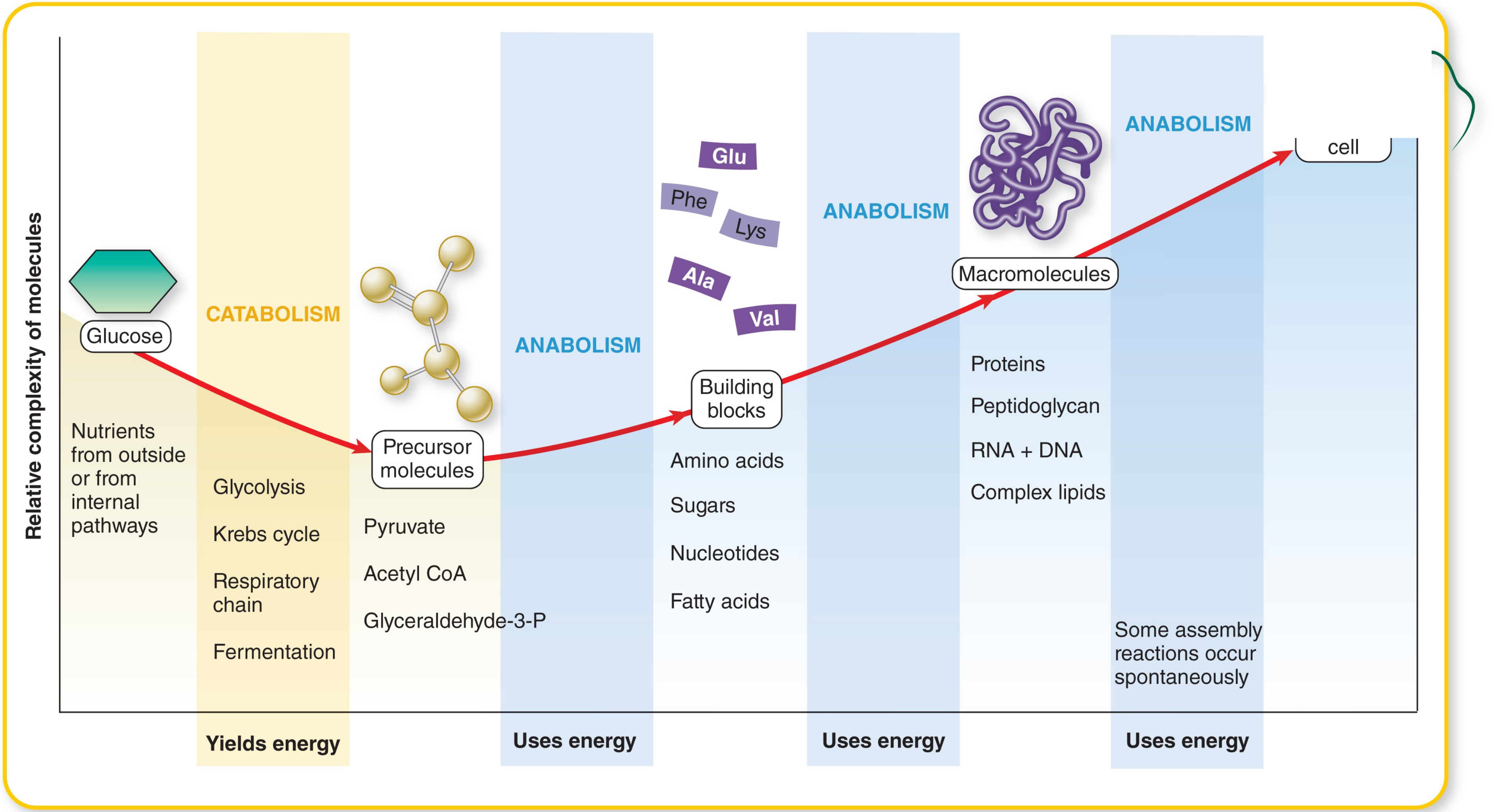
The glycolysis product acetyl CoA can be oxidized to form fatty acids, critical components of lipids.

Catabolic Pathways

In addition to the respiration and fermentation pathways already described, bacteria can deaminate amino acids, which leads to the formation of a variety of metabolic intermediates, including pyruvate and acetyl CoA.

Also, fatty acids can be oxidized to form acetyl CoA.




Relative complexity of molecules
Glucose
Nutrients from outside or from internal pathways
CATABOLISM
Glycolysis
Krebs cycle
Respiratory chain
Fermentation
Yields energy
Precursor molecules
Pyruvate
Acetyl CoA
Glyceraldehyde-3-P
ANABOLISM
Uses energy
Glu
Phe
Lys
Ala
Val
Building blocks
Amino acids
Sugars
Nucleotides
Fatty acids
ANABOLISM
Uses energy
Macromolecules
Proteins
Peptidoglycan
RNA + DNA
Complex lipids
ANABOLISM
cell
Some assembly reactions occur spontaneously
Uses energy

Oxidation-Reduction Reactions

- **These reactions transfer an electron from one atom to another (or transfer an electron from one molecule to another molecule)**

- **Oxidation**
  - any chemical reaction in which a molecule gives up electrons and releases energy
  - molecule is said to be **oxidized** in this process
  - electron acceptor molecule is the **oxidizing agent //** oxygen is often involved as the electron acceptor

- **Reduction**
  - any chemical reaction in which a molecule gains electrons and also gains energy
  - molecule is said to be **reduced** when it accepts electrons
  - molecule that donates electrons is the **reducing agent**

- **Oxidation-reduction (redox) reactions**
  - oxidation of one molecule is always accompanied by the reduction of another
  - electrons are often transferred as hydrogen atoms
  - molecules like NAD and FAD (i.e. co-enzymes) are used to transfer H+ and electron

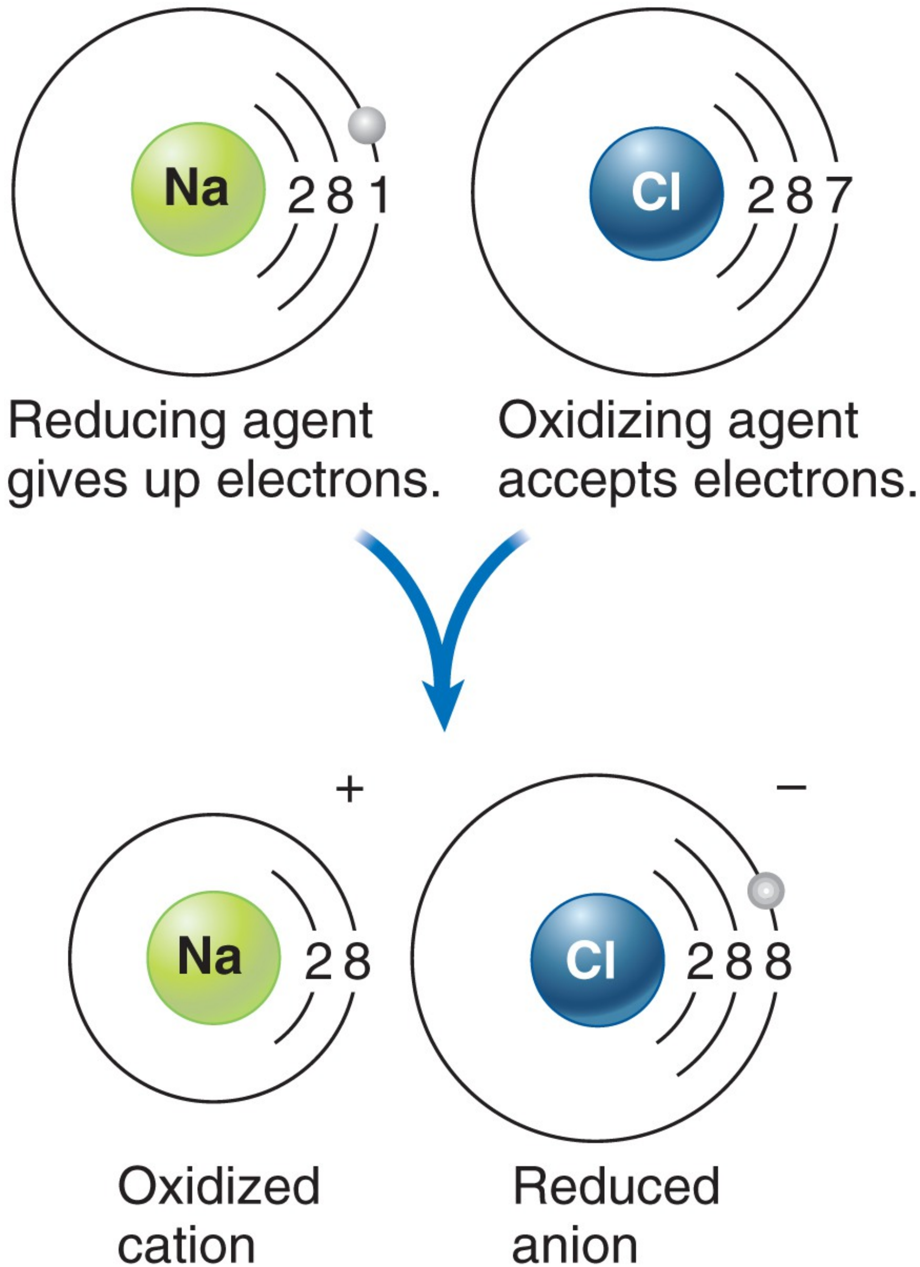

Na
2 8 1
Cl
2 8 7
Reducing agent gives up electrons.
Oxidizing agent accepts electrons.
+
Na
2 8
−
Cl
2 8 8
Oxidized cation
Reduced anion

TABLE 2.5	Energy-Transfer Reactions in the Human Body
Exergonic Reactions	Reactions in which there is a net release of energy. The products have less total free energy than the reactants did.
Oxidation	An exergonic reaction in which electrons are removed from a reactant. Electrons may be removed one or two at a time and may be removed in the form of hydrogen atoms (H or H_2). The product is then said to be oxidized.
Decomposition	A reaction such as digestion and cell respiration, in which larger molecules are broken down into smaller ones.
Catabolism	The sum of all decomposition reactions in the body.
Endergonic Reactions	Reactions in which there is a net input of energy. The products have more total free energy than the reactants did.
Reduction	An endergonic reaction in which electrons are donated to a reactant. The product is then said to be reduced.
Synthesis	A reaction such as protein and glycogen synthesis, in which two or more smaller molecules are combined into a larger one.
Anabolism	The sum of all synthesis reactions in the body.

- **Biochemistry –** the study of the arrange of different elements molecules that compose living organisms

  – Carbohydrates
  – Fats
  – Proteins
  – Nucleic acids

  – Note: See Chapter Two Second Power Point Presentation // Organic and Biochemistry