

Chapter 2

The Chemical Context of Life

Wood Ants & Acid



Ants shoot formic acid to defend themselves from attacks from predators (birds).

You Must Know

- The three subatomic particles and their significance.
- The types of bonds and how they form.

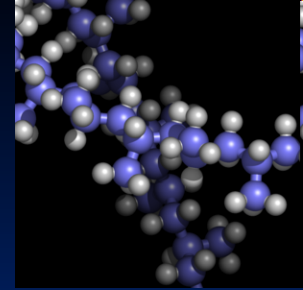
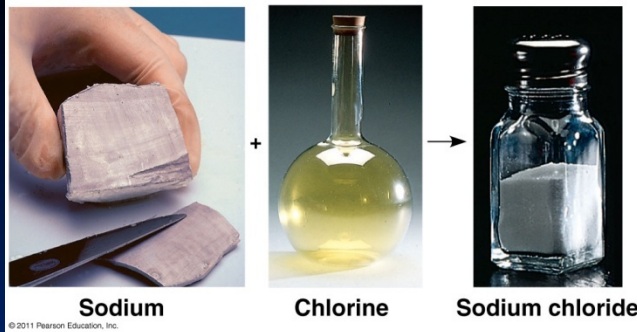
I. Matter vs. Energy

Matter

- Has mass & takes up space
- Affected by gravity
- Consists of elements and compounds

Energy

- Moves matter
- Potential, kinetic
- Ability to do work
- Conversions
- Sound, light, heat

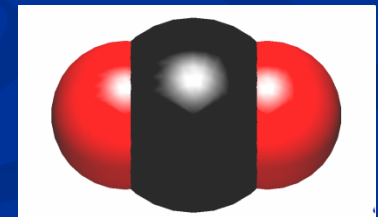
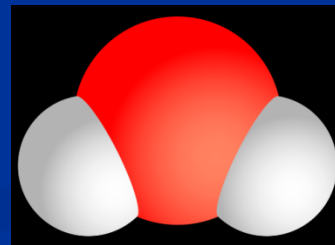


Element

- “pure” substance
- Can’t be broken down by “ordinary” means to another substance
- Ex. hydrogen (H), nitrogen (N)

Compound

- 2 or more different elements combined in a fixed ratio
- Ex. H_2O , CO_2



Elements of Life

- 25 elements
 - 96% : O, C, H, N
 - ~ 4% : P, S, Ca, K & trace elements (ex: Fe, I)

Hint: Remember **CHNOPS**

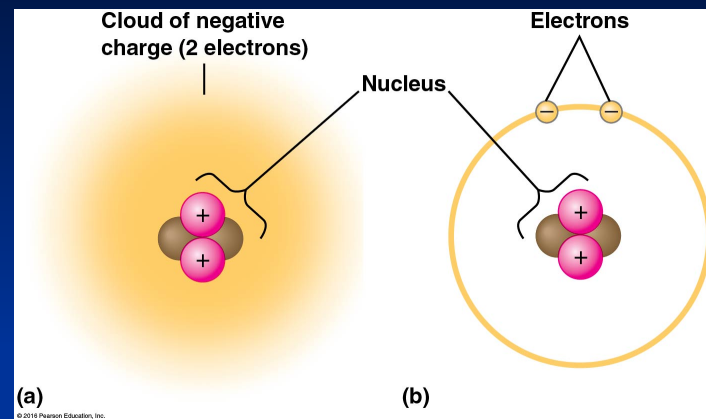
Table 2.1 Elements in the Human Body

| Element | Symbol | Percentage of Body Mass (including water) | |
|------------|--------|--|---------|
| Oxygen | O | 65.0% | } 96.3% |
| Carbon | C | 18.5% | |
| Hydrogen | H | 9.5% | |
| Nitrogen | N | 3.3% | |
| Calcium | Ca | 1.5% | } 3.7% |
| Phosphorus | P | 1.0% | |
| Potassium | K | 0.4% | |
| Sulfur | S | 0.3% | |
| Sodium | Na | 0.2% | |
| Chlorine | Cl | 0.2% | |
| Magnesium | Mg | 0.1% | |

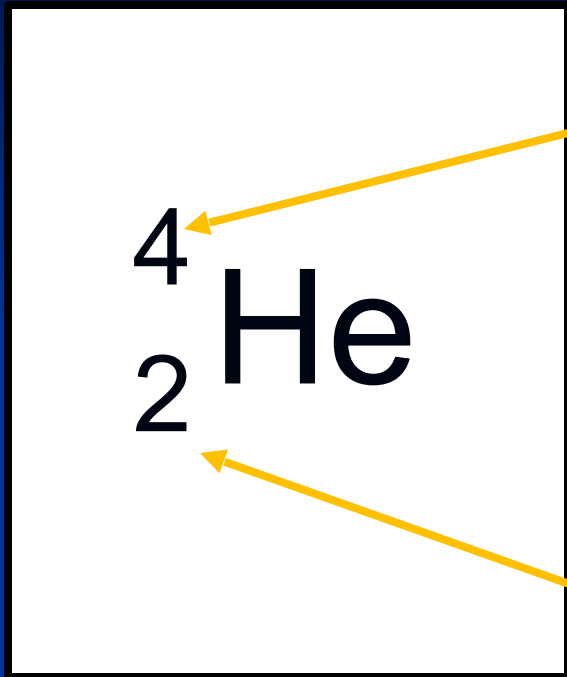
Trace elements (less than 0.01% of mass): Boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), zinc (Zn)

II. Atomic Structure

- **Atom** = smallest unit of matter that retains properties of an element
- **Subatomic particles:**



| | Mass (dalton or AMU) | Location | Charge |
|----------|-------------------------|----------|--------|
| neutron | 1 | nucleus | 0 |
| proton | 1 | nucleus | +1 |
| electron | negligible | shell | -1 |



Mass # (protons + neutrons)

symbol

Atomic # (protons or electrons)

Isotopes

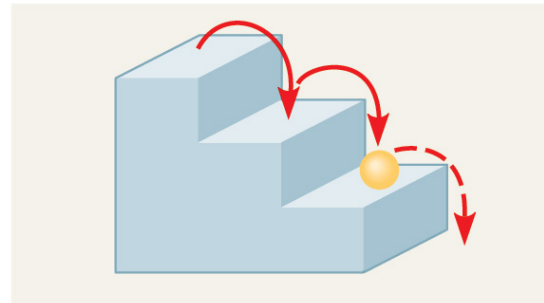
- # neutrons varies, but same # of protons
- Radioactive isotopes used as tracers (follow molecules, medical diagnosis)
- Uncontrolled exposure causes harm

TABLE 2.4 ISOTOPES OF CARBON

| | Carbon-12 | Carbon-13 | Carbon-14 |
|-----------|-----------|-----------|-----------|
| Protons | 6 | 6 | 6 |
| Neutrons | 6 | 7 | 8 |
| Electrons | 6 | 6 | 6 |

Electrons exist only at fixed levels of potential energy called **electron shells**

(a) A ball bouncing down a flight of stairs can come to rest only on each step, not between steps.

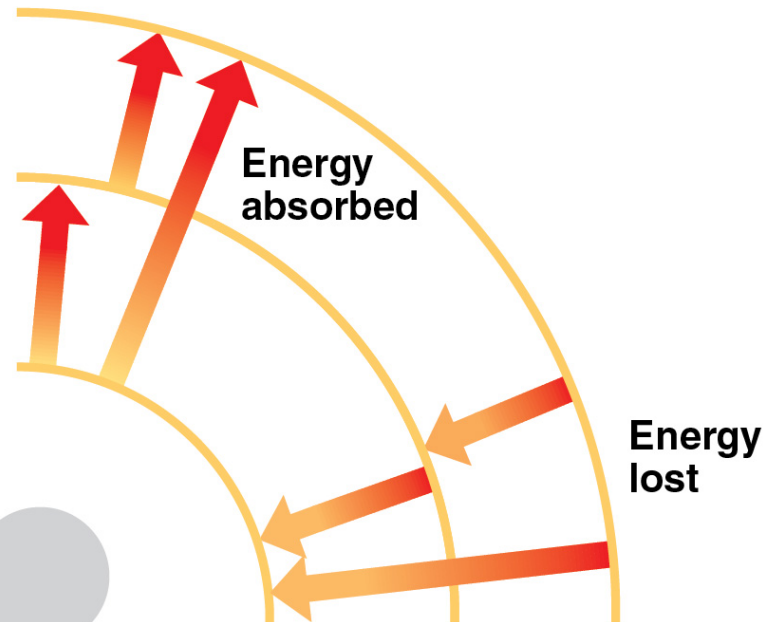


Third shell (highest energy level in this model)

Second shell (higher energy level)

First shell (lowest energy level)

Atomic nucleus



(b)

The Periodic Table of the Elements, in Pictures

Periods
1
2
3
4
5
6
7
8

Alkali Metals Group 1

H 1 1
Hydrogen

Sun and Stars

Li 3 3
Lithium

Batteries

Na 11 11
Sodium


Salt

K 19 19
Potassium

Fruits and Vegetables

Rb 37 37
Rubidium

Global Navigation

Cs 55 55
Cesium

Atomic Clocks

Fr 87 87
Francium

Laser Atom Traps

Alkali Earth Metals 2

Be 4 4
Beryllium

Emeralds

Mg 12 12
Magnesium

Chlorophyll

Ca 20 20
Calcium

Shells and Bones

Sr 38 38
Strontium

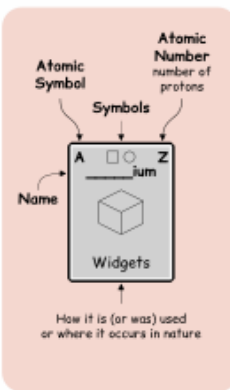
Fireworks

Ba 56 56
Barium

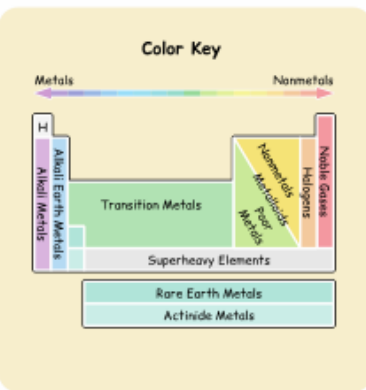
X-Ray Diagnosis

Ra 88 88
Radium


Luminous Watches



- Solid
- Liquid
- Gas at room temperature
- Human Body: top ten elements by weight
- Earth's Crust: top eight elements by weight
- Magnetic: ferromagnetic at room temperature
- Noble Metals: corrosion-resistant
- Radioactive: all isotopes are radioactive
- Only Traces Found in Nature: less than a millionth percent of earth's crust
- Never Found in Nature: only made by people



Noble Gases 18

He 2 2
Helium

Balloons

Ne 10 10
Neon

Advertising Signs

Ar 18 18
Argon


Light Bulbs

Kr 36 36
Krypton

Flashlights

Xe 54 54
Xenon

High-Intensity Lamps


Rn 86 86
Radon

Surgical Implants

Og 118 118
Oganesson


Boron Group 13 Carbon Group 14 Nitrogen Group 15 Oxygen Group 16 Halogens 17


B 5 5
Boron

Sports Equipment

C 6 6
Carbon

Basis of Life's Molecules

N 7 7
Nitrogen

Protein

O 8 8
Oxygen

Air

F 9 9
Fluorine

Toothpaste

Al 13 13
Aluminum

Airplanes

Si 14 14
Silicon

Stone, Sand, and Soil

P 15 15
Phosphorus

Bones

S 16 16
Sulfur

Eggs

Cl 17 17
Chlorine


Swimming Pools

Ga 31 31
Gallium

Light-Emitting Diodes (LEDs)

Ge 32 32
Germanium

Semiconductor Electronics

As 33 33
Arsenic

Poison

Se 34 34
Selenium

Copiers

Br 35 35
Bromine


Photography Film

In 49 49
Indium

Liquid Crystal Displays (LCDs)

Sn 50 50
Tin

Plated Food Cans

Sb 51 51
Antimony

Car Batteries

Te 52 52
Tellurium


Thermoelectric Coolers


I 53 53
Iodine

Disinfectant

Tl 81 81
Thallium

Low-Temperature Thermometers

Pb 82 82
Lead

Weights

Bi 83 83
Bismuth

Fire Sprinklers

Po 84 84
Polonium

Anti-Static Brushes

At 85 85
Astatine

Radioactive Medicine

Superheavy Elements
radioactive, never found in nature, no uses except atomic research

Rare Earth Metals


Actinide Metals


La 57 57
Lanthanum

Telescope Lenses

Ce 58 58
Cerium

Lighter Flints

Pr 59 59
Praseodymium

Torchworkers' Eyeglasses

Nd 60 60
Neodymium

Electric Motor Magnets

Pm 61 61
Promethium

Luminous Dials

Sm 62 62
Samarium

Electric Motor Magnets

Eu 63 63
Europium

Color Televisions

Gd 64 64
Gadolinium

MRI Diagnosis

Tb 65 65
Terbium

Fluorescent Lamps

Dy 66 66
Dysprosium


Smart Material Actuators

Ho 67 67
Holmium

Laser Surgery

Er 68 68
Erbium

Optical Fiber Communications


Tm 69 69
Thulium

Laser Surgery

Yb 70 70
Ytterbium

Scientific Fiber Lasers

Ac 89 89
Actinium

Radioactive Medicine


Th 90 90
Thorium

Gas Lamp Mantles

Pa 91 91
Protactinium

Radioactive Waste

U 92 92
Uranium

Nuclear Power

Np 93 93
Neptunium

Radioactive Waste

Pu 94 94
Plutonium

Nuclear Weapons

Am 95 95
Americium


Smoke Detectors

Cm 96 96
Curium

Mineral Analyzers


Bk 97 97
Berkelium

Radioactive Waste

Cf 98 98
Californium

Mineral Analyzers

Es 99 99
Einsteinium

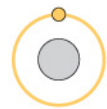

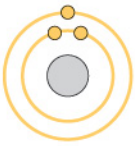
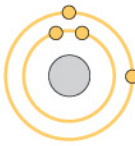
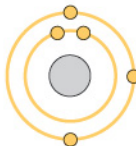
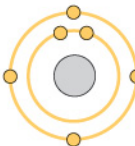
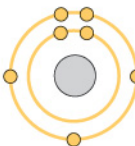
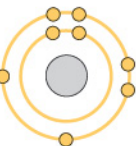
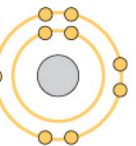
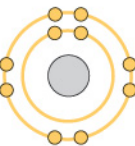
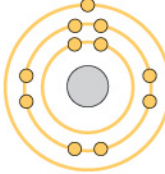
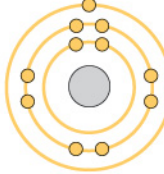
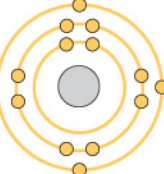
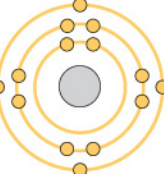
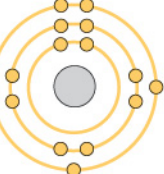
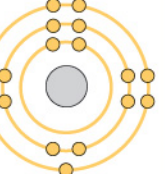
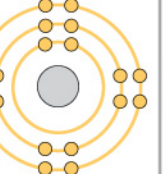
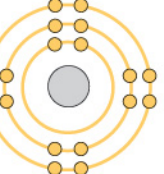

Fm 100 100
Fermium


Md 101 101
Mendelevium


No 102 102
Nobelium


Lr 103 103
Lawrencium


Valence Electrons

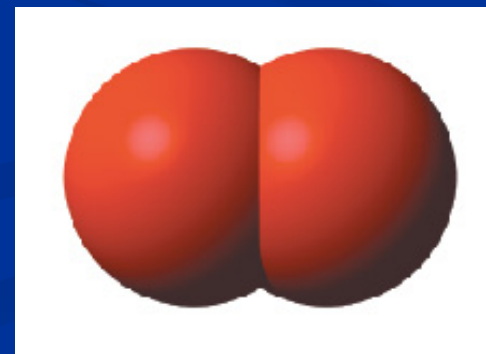
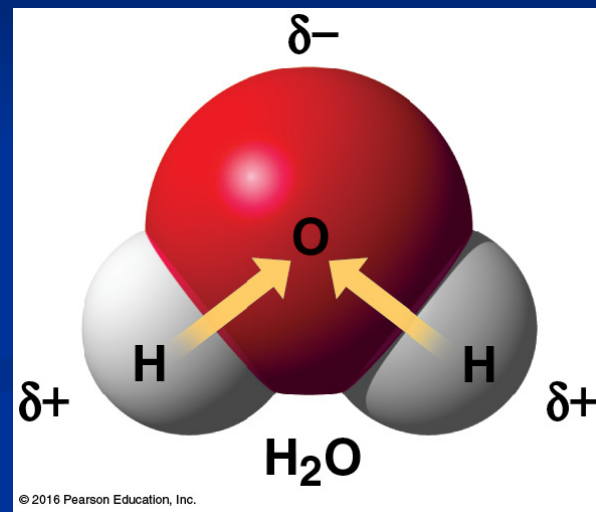
| | | | | | | | | |
|---------------------|---|---|---|---|--|--|---|--|
| <p>First shell</p> | <p>Hydrogen ${}_1\text{H}$</p>  | <div style="display: flex; align-items: center; justify-content: center;"> <div style="border: 1px solid black; padding: 5px; margin-right: 10px;"> <p>2 He 4.003</p> </div> <div style="margin-right: 10px;"> <p>Atomic number</p> </div> <div style="margin-right: 10px;"> <p>Element symbol</p> </div> <div style="margin-right: 10px;"> <p>Atomic mass</p> </div> <div style="margin-right: 10px;"> <p>Electron distribution diagram</p> </div> </div> | | | | | | <p>Helium ${}_2\text{He}$</p>  |
| <p>Second shell</p> | <p>Lithium ${}_3\text{Li}$</p>  | <p>Beryllium ${}_4\text{Be}$</p>  | <p>Boron ${}_5\text{B}$</p>  | <p>Carbon ${}_6\text{C}$</p>  | <p>Nitrogen ${}_7\text{N}$</p>  | <p>Oxygen ${}_8\text{O}$</p>  | <p>Fluorine ${}_9\text{F}$</p>  | <p>Neon ${}_{10}\text{Ne}$</p>  |
| <p>Third shell</p> | <p>Sodium ${}_{11}\text{Na}$</p>  | <p>Magnesium ${}_{12}\text{Mg}$</p>  | <p>Aluminum ${}_{13}\text{Al}$</p>  | <p>Silicon ${}_{14}\text{Si}$</p>  | <p>Phosphorus ${}_{15}\text{P}$</p>  | <p>Sulfur ${}_{16}\text{S}$</p>  | <p>Chlorine ${}_{17}\text{Cl}$</p>  | <p>Argon ${}_{18}\text{Ar}$</p>  |

III. Chemical Bonds

Strongest Bonds:

1. Covalent: sharing of e^-

- Polar: covalent bond between atoms that differ in *electronegativity*
 - Eg. H_2O
- Nonpolar: e^- shared equally;
 - Eg. O_2 or H_2

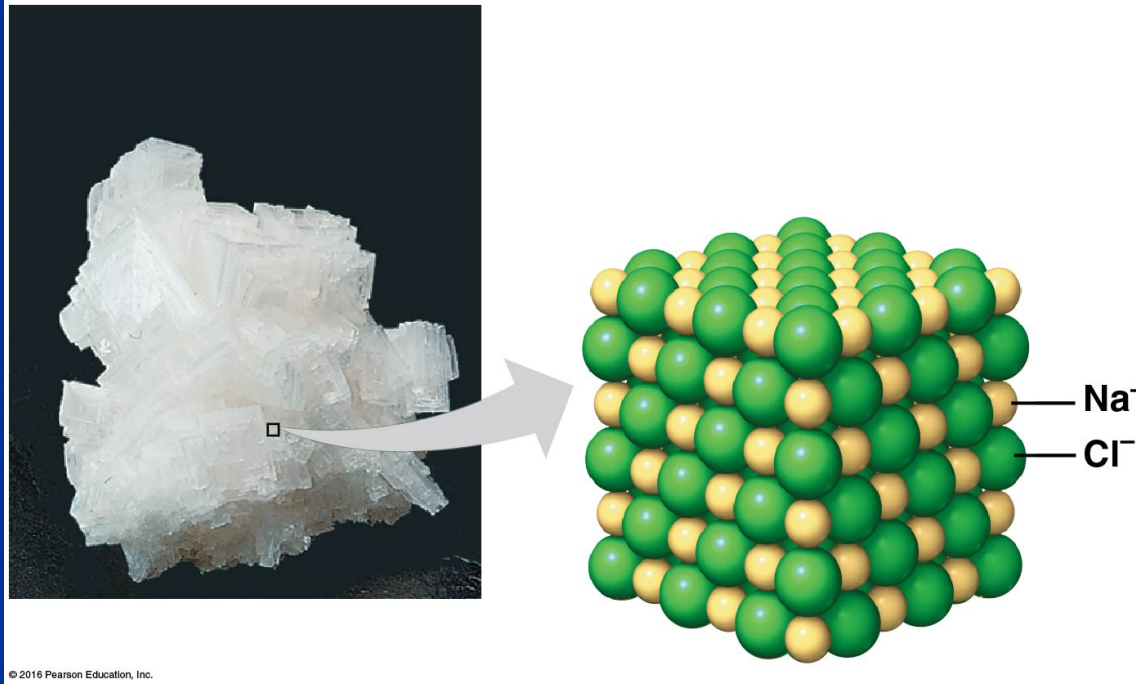


| Name and Molecular Formula | Electron Distribution Diagram | Structural Formula | Space-Filling Model |
|--------------------------------|-------------------------------|---|---------------------|
| (a) Hydrogen (H ₂) | | H—H | |
| (b) Oxygen (O ₂) | | O=O | |
| (c) Water (H ₂ O) | | $\begin{array}{c} \text{O—H} \\ \\ \text{H} \end{array}$ | |
| (d) Methane (CH ₄) | | $\begin{array}{c} \text{H} \\ \\ \text{H—C—H} \\ \\ \text{H} \end{array}$ | |

III. Chemical Bonds

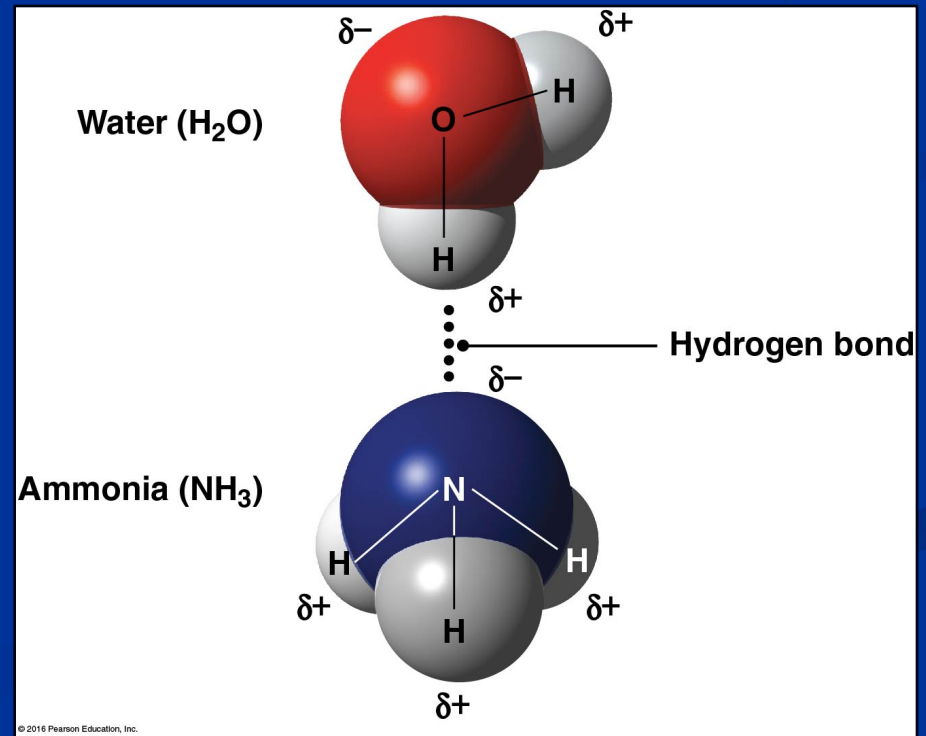
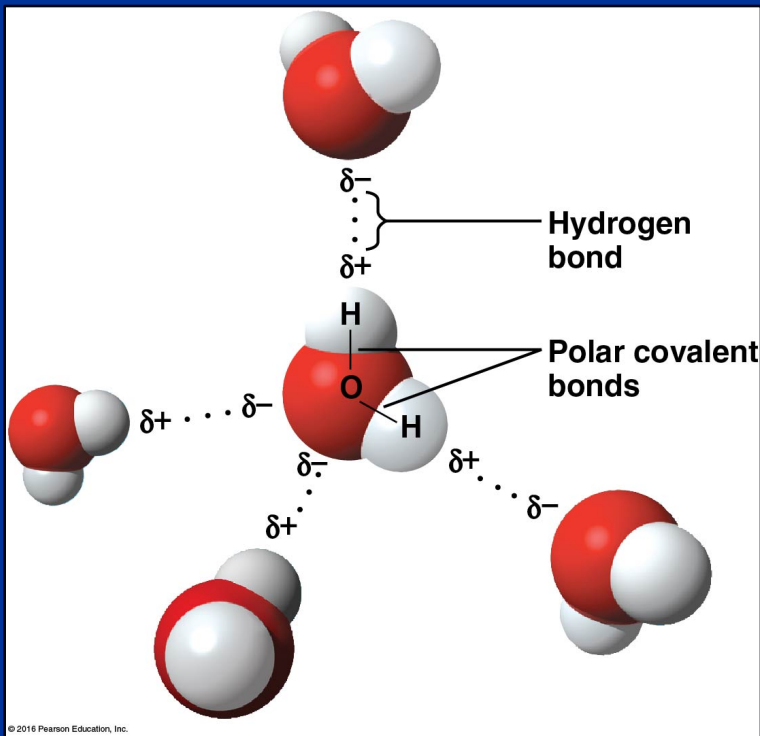
Strongest Bonds:

2. Ionic: 2 ions (+/-) bond (givers/takers)
 - Na^+Cl^-
 - Affected by environment (eg. water)



Weaker Bonds:

3. Hydrogen: H of *polar covalent* molecule bonds to electronegative atom of *other polar covalent* molecules



Weaker Bonds:

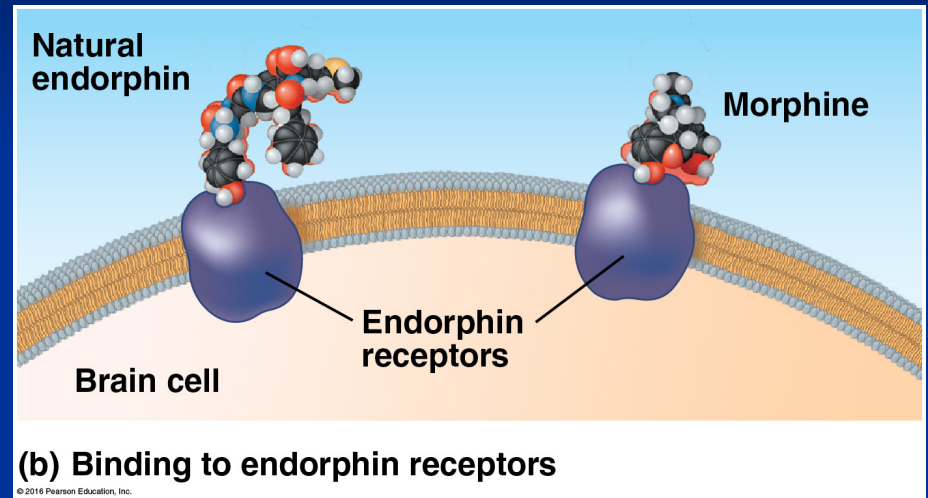
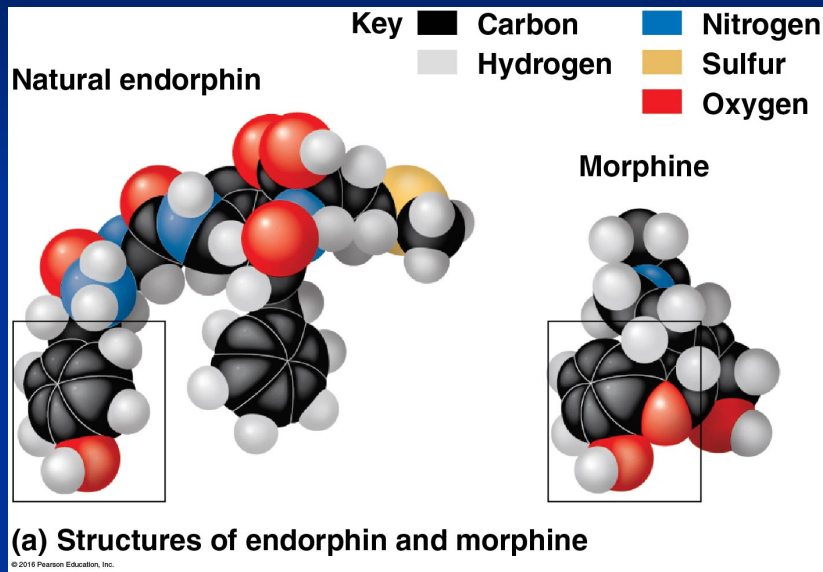
4. Van der Waals Interactions: slight, fleeting attractions between atoms and molecules close together
- Weakest bond
 - Eg. gecko toe hairs + wall surface



Bonds

| Covalent | Ionic | Hydrogen |
|---------------------------------------|---|--|
| All important to life | | |
| Form cell's molecules | Quick reactions/ responses | H bonds to other electronegative atoms |
| Strong bond | Weaker bond (esp. in H ₂ O) | Even weaker |
| Made and broken by chemical reactions | | |

A molecule's **STRUCTURE (SHAPE)** affects a molecule's **FUNCTION**



- **Similar shapes = mimic**
 - morphine, heroin, opiates mimic endorphin (euphoria, relieve pain)

Chemical Reactions

- **Reactants** → **Products**



- Some reactions are reversible:



- **Chemical equilibrium**: point at which forward and reverse reactions offset one another exactly

- Reactions still occurring, but **no net change** in concentrations of reactants/products