

Chapter 2

The Chemical Context of Life

Comment

- Much of this chapter should be review from a basic chemistry course. Much of the material is unlikely to be brand new.



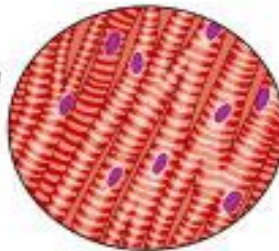
Organism level
Zebra (Includes several organ systems)

Organ system level
Circulatory system

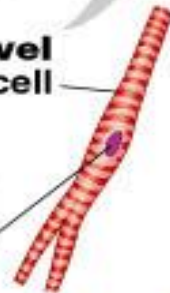


Organ level
Heart

Tissue level
Cardiac muscle
tissue

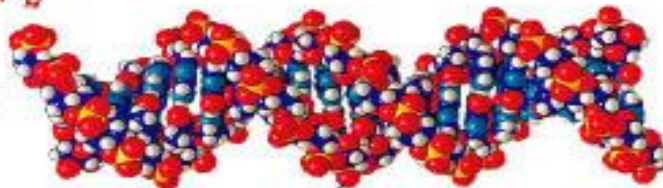


Cellular level
Cardiac muscle cell



Organelle level
Cell nucleus

Molecular level
DNA



Atomic level
Oxygen atom

Matter

- Anything that has mass and occupies space.



Atoms

- Smallest particle of elements.



Element

- Matter made up of only one type of atom.
- 92 natural elements.
- Each element has a symbol.

Compound

- Elements combined in fixed ratios.
- A compound has characteristics beyond those of its combined elements.

Question?

- What Elements are necessary For Life?
- Life requires about 25 chemical elements.

Table 2.1 Naturally Occurring Elements in the Human Body

Symbol	Element	Atomic Number (See p. 29)	Percentage of Human Body Weight
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
Ca	Calcium	20	1.5
P	Phosphorus	15	1.0
K	Potassium	19	0.4
S	Sulfur	16	0.3
Na	Sodium	11	0.2
Cl	Chlorine	17	0.2
Mg	Magnesium	12	0.1

Trace elements (less than 0.01%): 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), and zinc (Zn).

Macroelements

- Elements needed in large amounts or quantities.
- Examples: C H O P K N S Ca Fe Mg NaCl



Control



Minus Nitrogen

Microelements

- Elements needed in very small quantities.
- Also known as Trace Elements.
- Examples: Cu, Co, Zn, Mo, I, Mn



Goiter – minus Iodine

Atomic Number

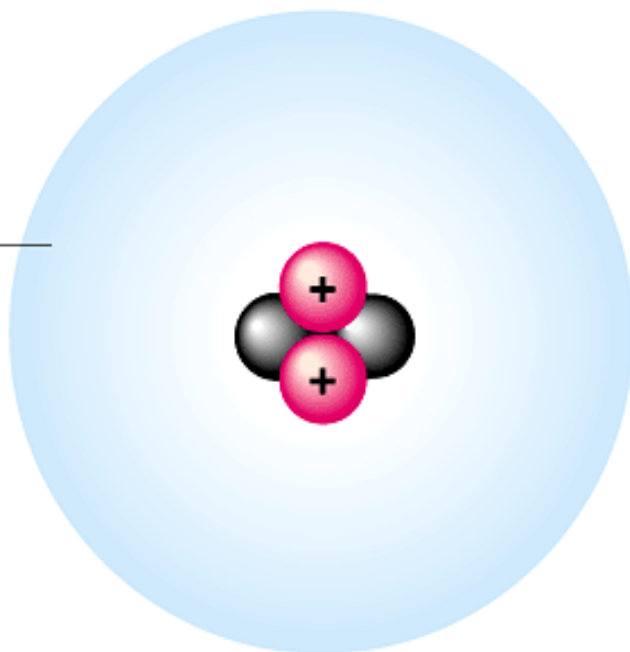
- The number of protons in the nucleus.
- Each element has its own atomic number. If you change the atomic number, you no longer have the same element.

Atomic Mass

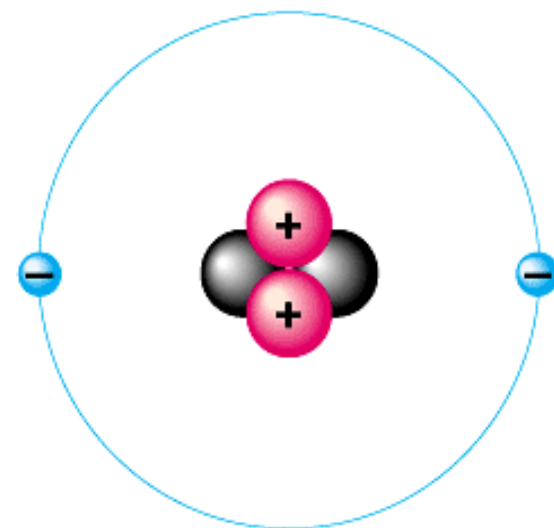
- The number of protons and neutrons in the nucleus.
- The atomic mass can change.

Atomic Model

Cloud of negative charge
(2 electrons)



(a)



(b)

Isotopes

- Atoms of the same (iso-) element with different atomic mass.
- Caused by changes in the number of neutrons.
- Used as “tracers”.

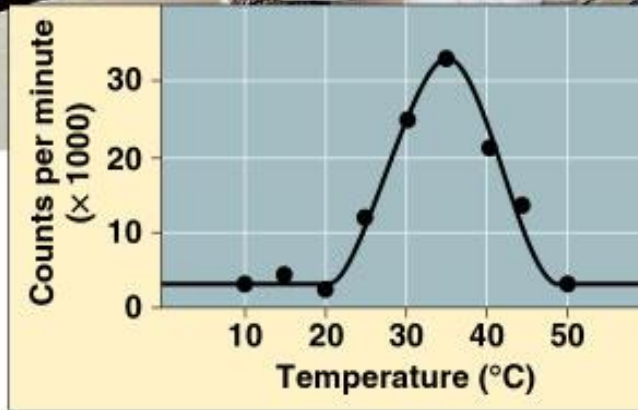
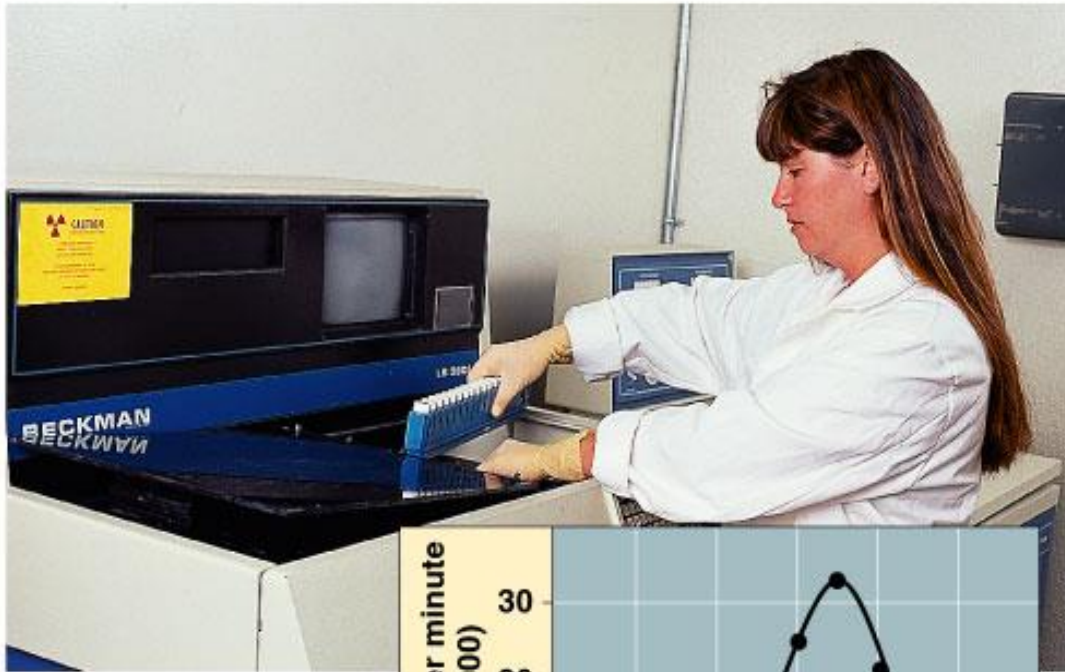
Types of Isotopes

1. Radioactive

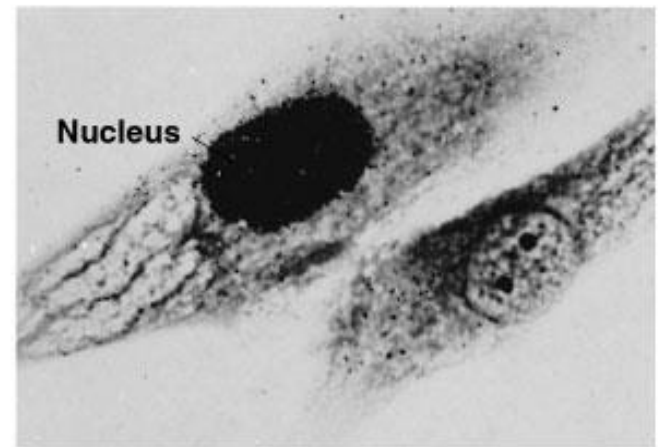
- where the nucleus decays spontaneously, giving off particles and energy.

2. Heavy

- has a stable nucleus, but masses more than the standard isotope for the element.



(a) Measuring incorporation of a radioactive starting material into new DNA, using a scintillation counter



(b) Autoradiography

25 μ m

Energy

- The ability to do work.



Potential Energy

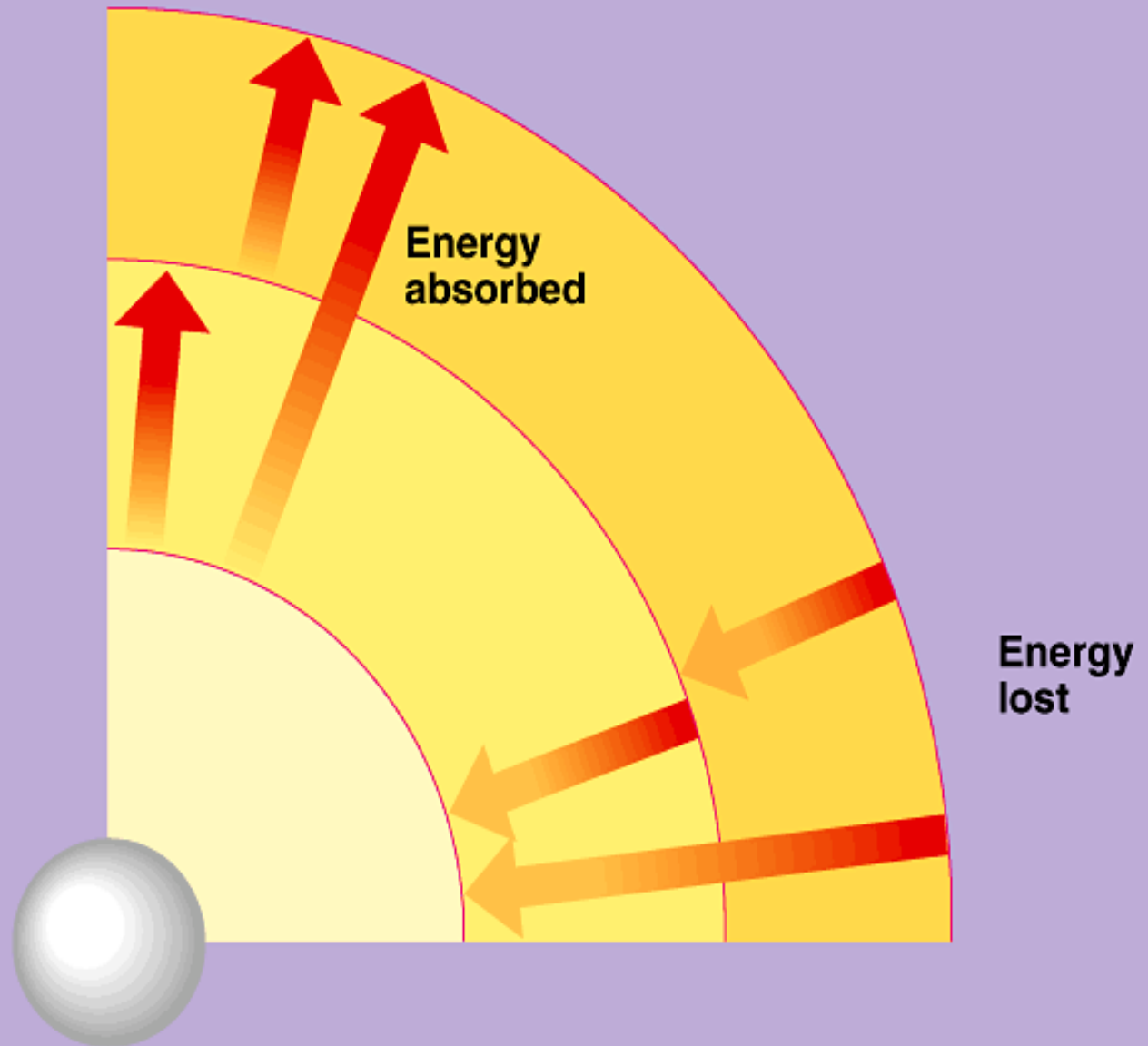
- Is the energy that matter stores because of its position or location.
- Electrons have potential energy because of their position relative to the nucleus.

Third energy level (shell)

Second energy level (shell)

First energy level (shell)

Atomic nucleus



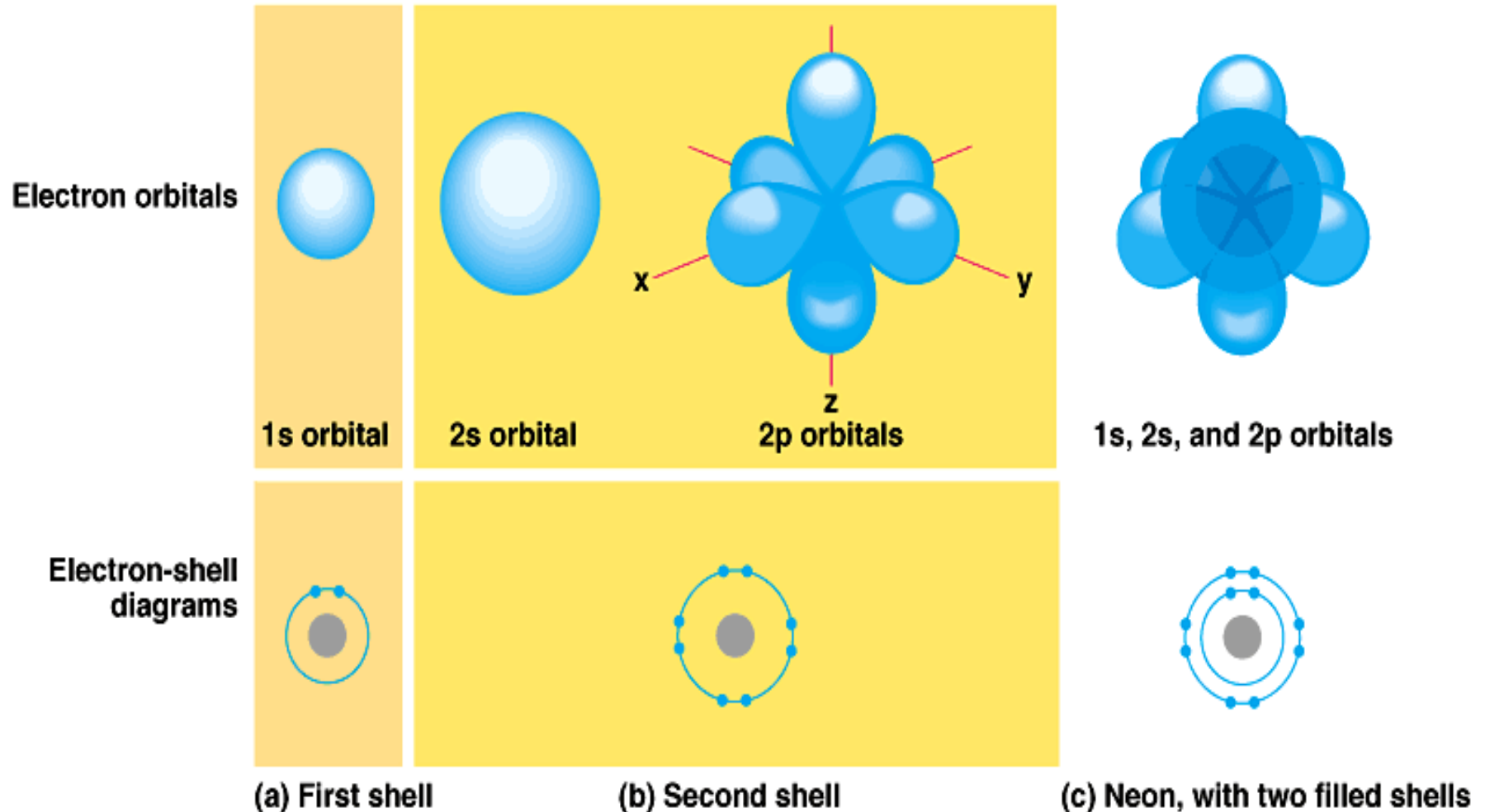
Electron Energy Levels

- Energy levels around the nucleus of an atom.
- 1st level can have 2 electrons and has the lowest potential energy.
- Other levels can hold more than 2 electrons and have higher energy levels.

Electron Orbitals

- The three dimensional space where an electron is found 90% of the time.
- Different orbitals have different shapes.
- Each orbital can hold only 2 electrons.

Electron Orbitals



Chemical Behavior Of An Atom

- Is determined by its electron configuration in the energy levels and orbitals.














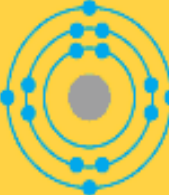




Valence Electrons

- The electrons in the outermost energy level.
- Electrons available for chemical bonds.

Octet Rule

- The most stable condition is to have an outer level of 8 electrons.
- Exception - 1st level is stable with only 2 electrons.
- When stable - no chemical reactions will take place. Ex: Ne, He, (Noble gases)

Electrons of the first elements

First shell	Hydrogen ${}_1\text{H}$ 							Helium ${}_2\text{He}$ 
Second shell	Lithium ${}_3\text{Li}$ 	Beryllium ${}_4\text{Be}$ 	Boron ${}_5\text{B}$ 	Carbon ${}_6\text{C}$ 	Nitrogen ${}_7\text{N}$ 	Oxygen ${}_8\text{O}$ 	Fluorine ${}_9\text{F}$ 	Neon ${}_{10}\text{Ne}$ 
Third shell	Sodium ${}_{11}\text{Na}$ 	Magnesium ${}_{12}\text{Mg}$ 	Aluminum ${}_{13}\text{Al}$ 	Silicon ${}_{14}\text{Si}$ 	Phosphorus ${}_{15}\text{P}$ 	Sulfur ${}_{16}\text{S}$ 	Chlorine ${}_{17}\text{Cl}$ 	Argon ${}_{18}\text{Ar}$ 

Chemical Bonds

- Forces that join atoms together to form molecules/ionic compounds.
- Usually caused by sharing or transferring valence electrons.

Bond Formation Depends On:

- The number of valence electrons that must be gained, lost, or shared to reach the stable condition.

Chemical Bonds & Intermolecular Forces

- Nonpolar Covalent
- Polar Covalent
- Ionic
- Hydrogen
- van der Waals Interactions

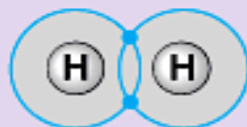
Nonpolar Covalent

- When electrons are shared equally between atoms.
- Very strong bond.
- Important in many molecules found in living things.
 - Ex: carbon to hydrogen

Nonpolar Covalent

- Can be single, double, or triple between two atoms.
- Each nonpolar covalent bond involves a pair of electrons.

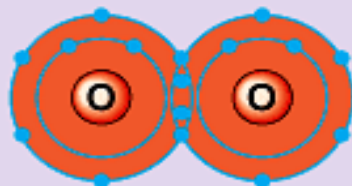
H₂



H—H

(a) Hydrogen

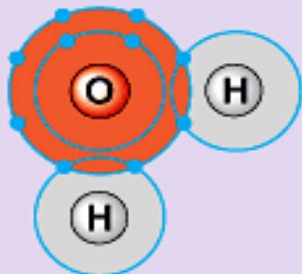
O₂



O=O

(b) Oxygen

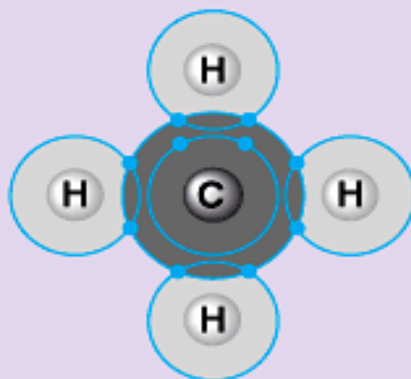
H₂O



O—H
|
H

(c) Water

CH₄



H
|
H—C—H
|
H

(d) Methane

Polar Covalent

- When electrons are shared unequally between atoms.
- Results in “polar” molecules that have charged areas.
 - Ex: Water, H to O bonds

Ionic Bonds

- Formed when electrons are transferred from one atom to another and ions are formed.

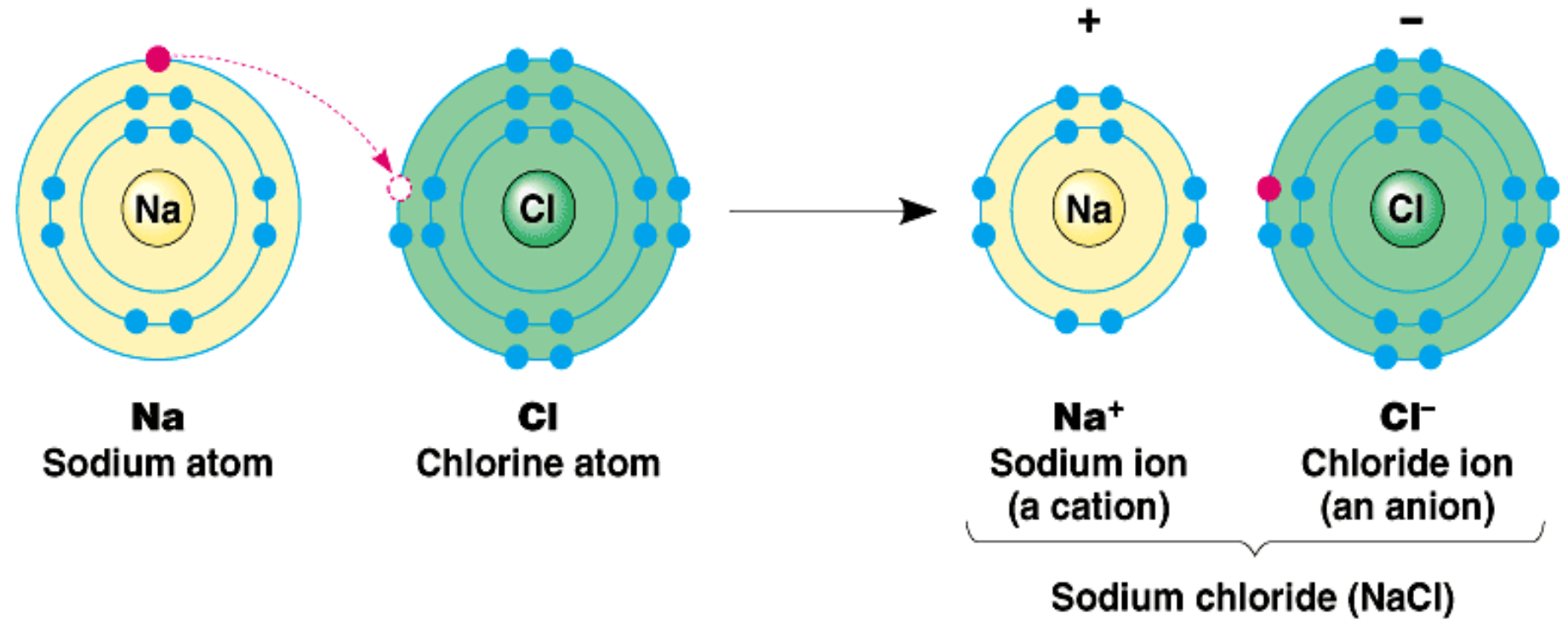
Types of Ions

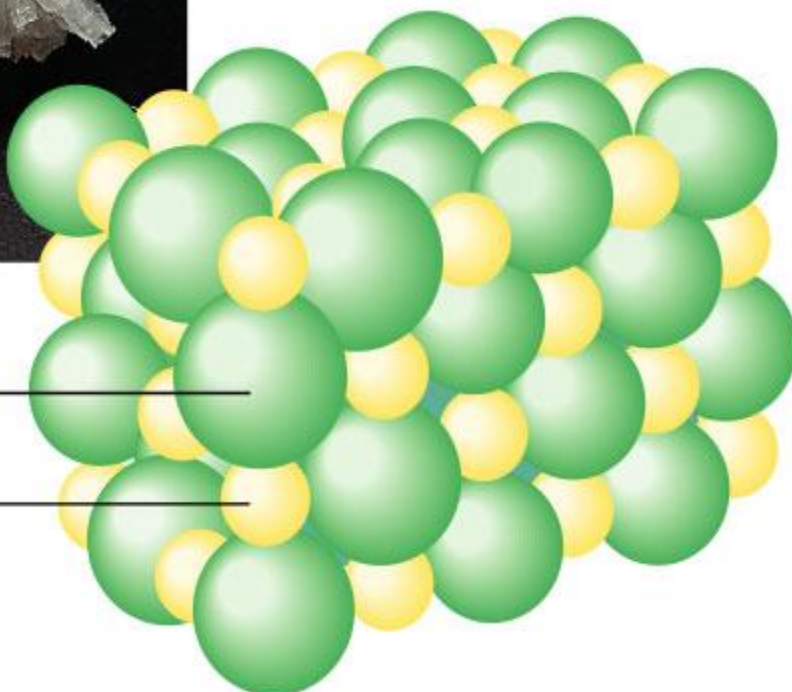
- Cations - have lost electrons ($p^+ > e^-$) giving them a positive charge.
- Anions - have gained electrons ($p^+ < e^-$) giving them a negative charge.

Ionic Bonds

- Formed when cations and anions attract each other.
- Weak chemical bond.

Ionic Bonds





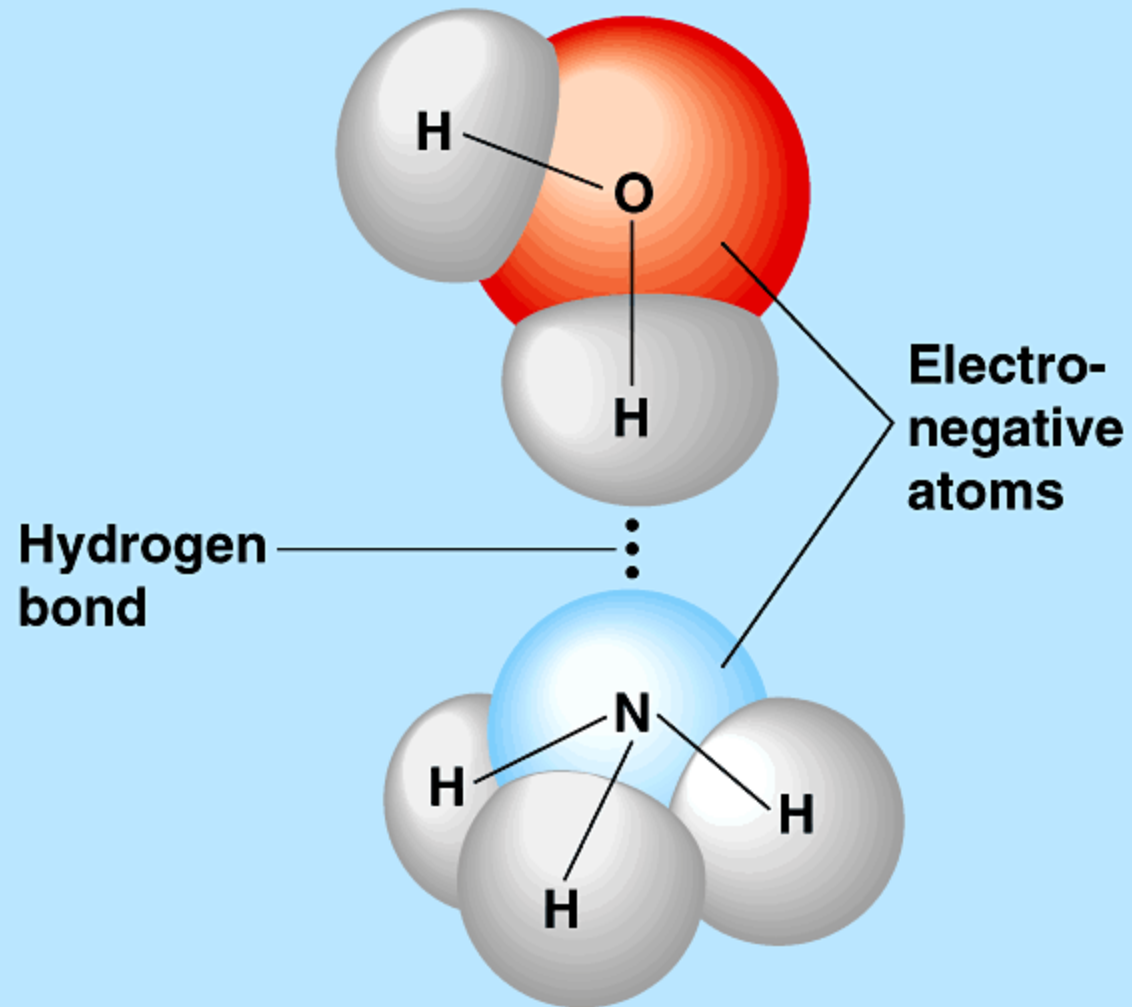
Cl⁻ —————

Na⁺ —————

Hydrogen Bonds

- When a hydrogen atom bonded to one molecule is attracted to the slightly negative area (often N or O) of another molecule.
- Very weak individual “bond” (intermolecular force –IMF).
- Can be a “strong” force if there are many H bonds.

Hydrogen Bonds

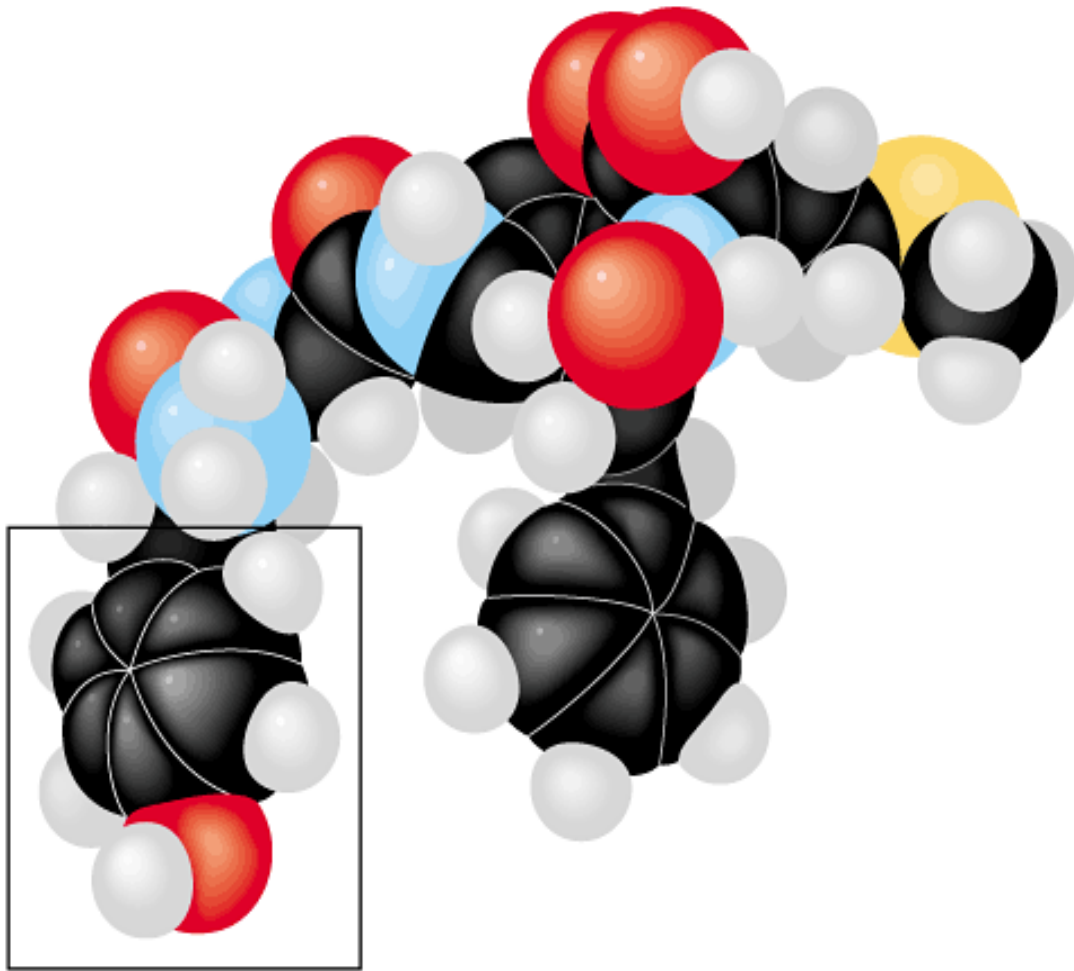


Van der Waals Interactions

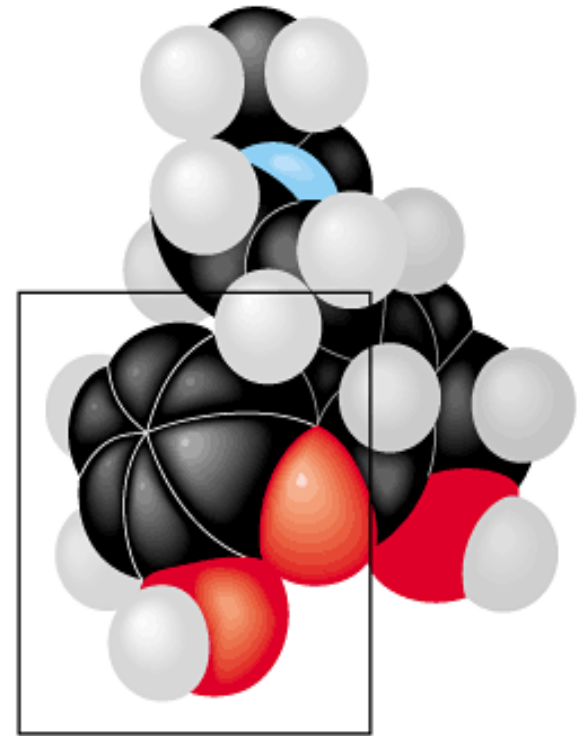
- Weak attractions between molecules or parts of molecules that result from transient local partial charges
- Occur only when atoms/molecules are very close to each other

Molecular Shape

- Determined by the positions of the atom's orbitals.
- Molecular shape is crucial in Biology because it determines how most molecules of life recognize and respond to one another.

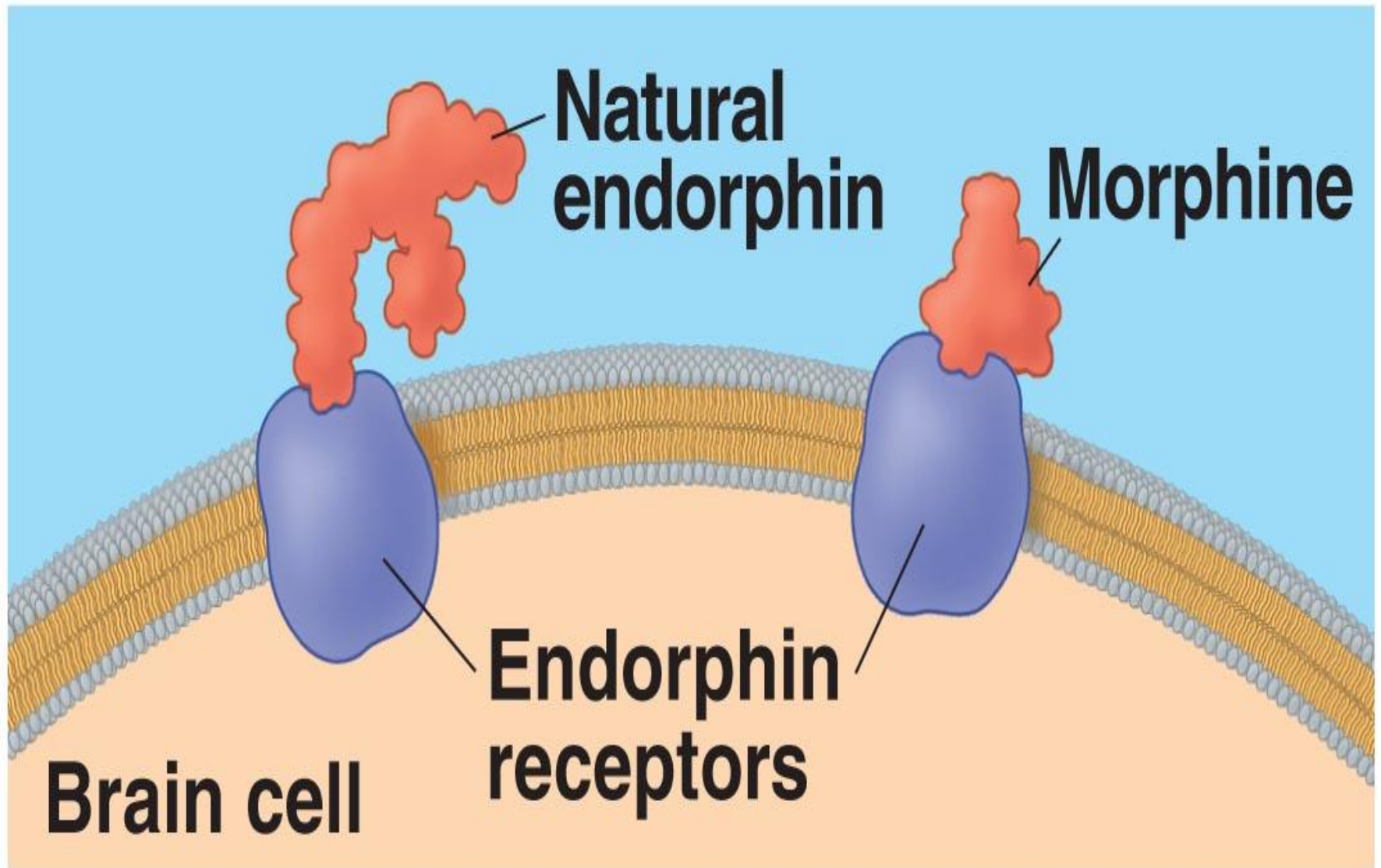


An endorphin



Morphine



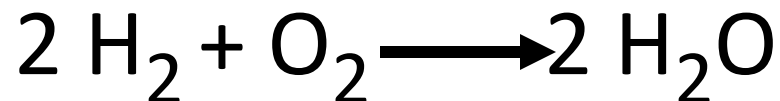


(b) Binding to endorphin receptors

Chemical Reactions

- The making and breaking of chemical bonds.
- Reactions do not destroy matter, they only rearrange it.

Parts of the Equation



- **Reactants:**
 - the starting materials.
- **Products:**
 - the ending materials.
- Note - all atoms of the reactants must be accounted for in the products.

Chemical Equilibrium

- When the conversion of reactants to products is balanced to the reverse reaction.

Ex:



Summary

- Element vs. compound
- Macro and micro elements
- Atomic Number and Mass
- Isotopes
- Valence electrons
- Chemical Bonds
- We will now put elements together to form molecules and build the next level in the hierarchy.