# CHAPTER 2: THE CHEMICAL CONTEXT OF LIFE

AP Biology

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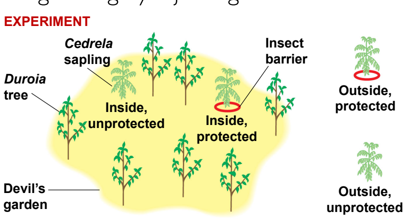
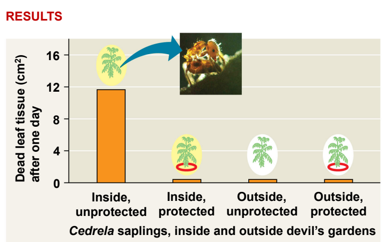
# CASE STUDY: DEVIL'S GARDEN

- Ants use formic acid to maintain the garden of a single flowering tree called *Duroia hirsuta*
- Ants live in the hollow tree stems and prevent other species from growing by injecting the intruders with formic acid




Figs. 2.1 & 2.2

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# MATTER

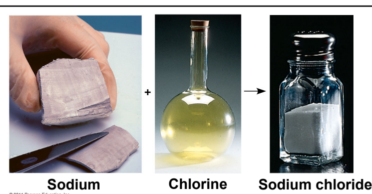


Fig. 2.3

- Matter - anything that takes up space and has mass
  - Made up of elements
- Elements - substance that can not be broken down to other substances by chemical reactions
- Compound - substance containing two or more different elements combined together in a fixed ratio
  - Compounds have characteristics different from those of their constituent elements

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# ESSENTIAL ELEMENTS

- 25 elements are essential for life
- Four make up 96% of living matter
- Trace elements - required by an organism in only minute quantitates

**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)





# ATOMS

- Atom - smallest unit of matter that still retains the property of that element
  - Made up of subatomic particles: protons, neutrons, and electrons
- Atomic number - number of protons
- Mass number - roughly the sum of protons and neutrons

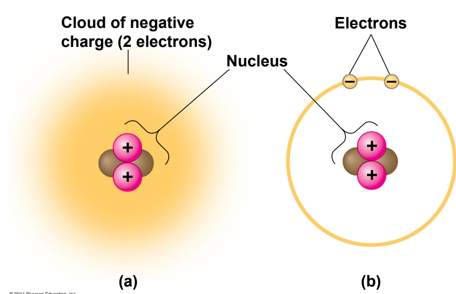





Fig. 2.5

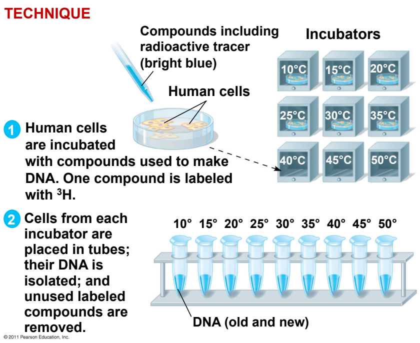


# ISOTOPES

- Isotopes - atoms of a given element with more neutrons (thus a larger mass)
- Carbon isotopes - most common isotope of carbon is carbon-12 (99%), but some isotopes have extra neutrons (carbon-13 and carbon-14)
  - Carbon-14 is not stable (radioactive)
- Radioactive isotope - an isotope in which the nucleus decays spontaneously, giving off particles of energy
  - Radioactive isotopes are very useful in biology

# RADIOACTIVE ISOTOPE USES

- Carbon dating
- Tracers





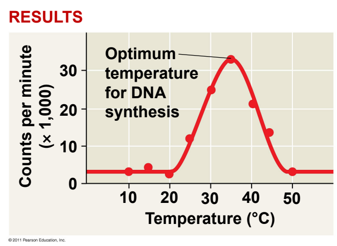



Fig. 2.6

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# RADIOACTIVE ISOTOPE USES

- PET scan allows radioactive isotopes to be used for medicine

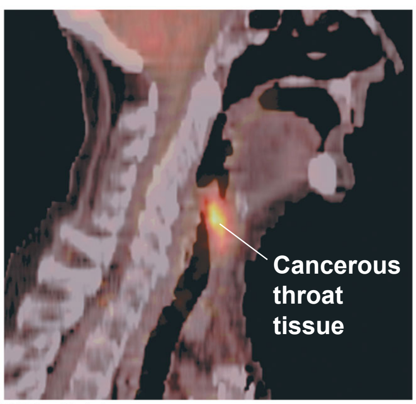




Fig. 2.7

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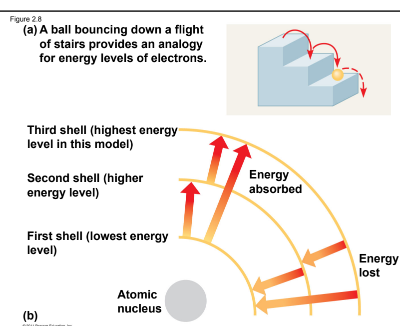
Fig. 2.8

# ENERGY LEVELS




- Energy - the capacity to cause change (to do work)
- Potential Energy - matter possesses it because of location and structure
- Energy levels
  - describe the potential energy of an atom
  - correlated with the average distance from the nucleus
  - the average distances is represented symbolically as **electron shells**

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# ELECTRON SHELL DIAGRAMS

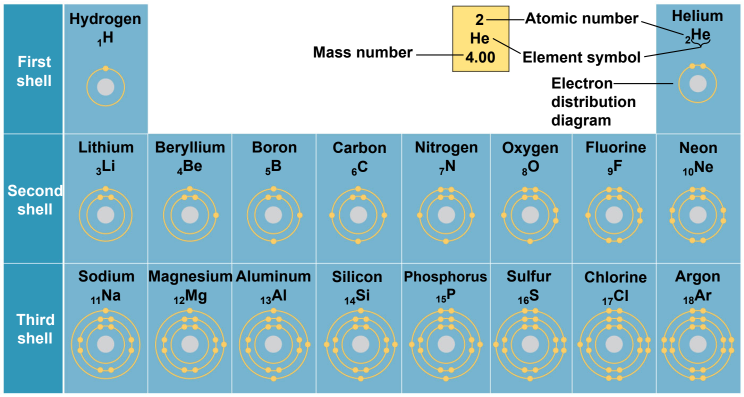





Fig. 2.9



# VALENCE ELECTRONS

- Valence electrons - outer electrons
- Valence shell - outermost shell
  - Most chemical behaviors are dependent on the number of valence electrons



# ELECTRON ORBITALS

- In reality we never know the exact path of an electron
- We then concentrate on where the electron spends the majority of its time
- Orbital - the three-dimensional space an electron spends 90% of its time
  - no more than TWO electrons can occupy an orbital

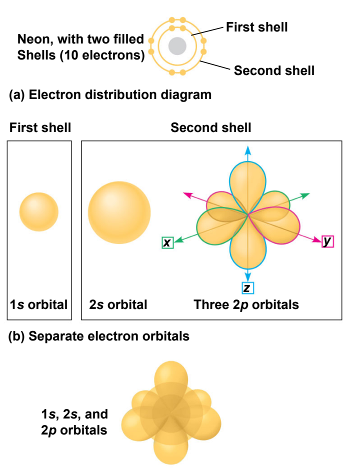



Fig. 2.10

# CHEMICAL BONDING

- Covalent Bonds - sharing of a pair of valence level electrons by two atoms
- Molecule - two or more atoms held together by covalent bonds
- Types of covalent bonds:
  - single bond - one shared pair of electrons
  - double bonds - two shared pairs of electrons
- Structural formula vs. molecular formula

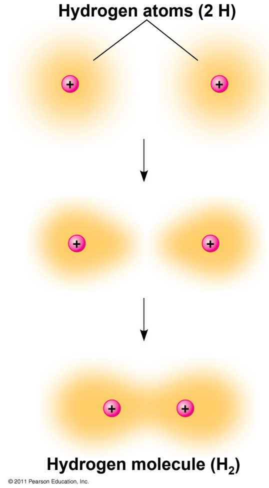



Fig. 2.11



# COVALENT BONDING

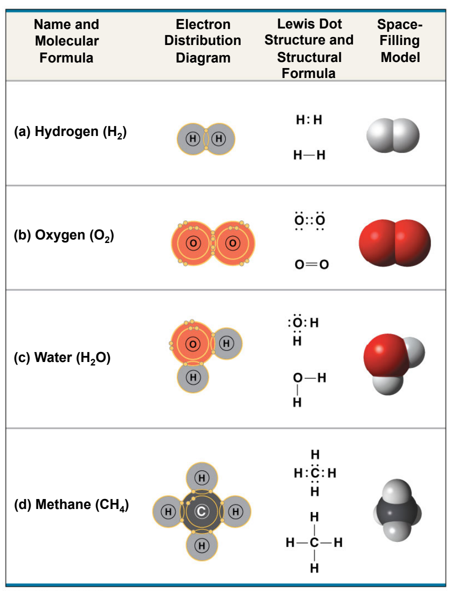



Fig. 2.12



# ELECTRONEGATIVITY

- Electronegativity - attraction of a particular kind of atom for the electrons of a covalent bond
  - The more electronegative an atom, the more strongly it pulls its shared electrons toward itself
- Non-polar covalent bond - electrons are shared equally (usually because the elements are the same)
- Polar covalent bond - electrons are not shared equally

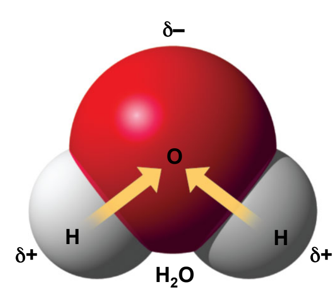
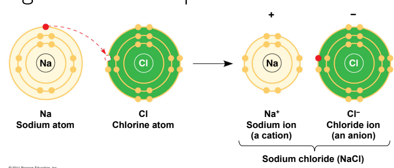
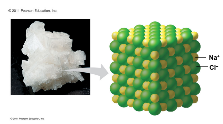



Fig. 2.13

# IONIC BONDS

- Electrons are so unequal in attraction to valence electrons that the more electrons the more electronegative atom strips the electron from its partner
  - Ex. NaCl
- Ion - charged atom
- Cation - positively charged ion
- Anion - negatively charged ion
- Attraction between cation and anion causes ionic bonds
- Compounds formed by ionic bonding are called ionic compounds or salts




Figs. 2.14 & 2.15

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# HYDROGEN BONDS

- Extremely important form of bonding in biological systems
- Forms when a hydrogen atom is covalently bonded to one electronegative atom is also attracted to another electronegative atom
  - These electronegative atoms are usually oxygen or nitrogen

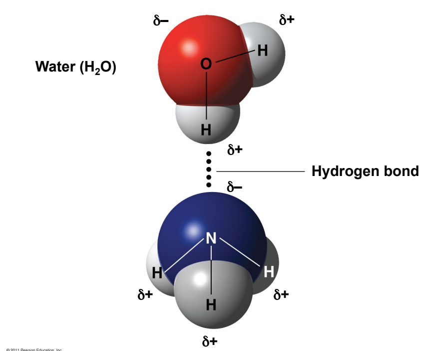




Fig. 2.16

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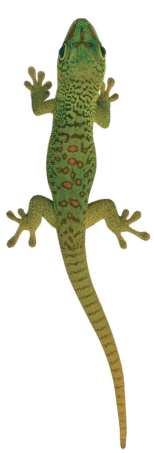
# VAN DER WAALS INTERACTIONS





- Even molecules with nonpolar covalent bonds have positive and negative regions
- Because electrons are in constant motion, at any instant they may accumulate by chance in one part of the molecule
- Van der Waals Interactions are very weak and occur only when molecules are very close together
- Give geckos the ability to climb up a surface

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# MOLECULAR SHAPE

- Shape is directly related to function
- Determined by the position of electrons in the valence shell
- Orbital hybridization
- In covalent bonding, s and p orbitals hybridize creating specific shapes
- Tetrahedral shape (bond angles = 109 degrees)

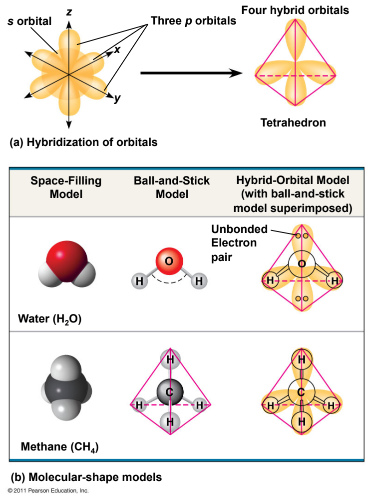


Fig. 2.17



# MOLECULAR SHAPE

- Molecular shape also determines how biological molecules recognize and respond to one another
- Only molecules with complementary shape are able to bind to each other (usually with hydrogen bonds)
  - Ex. endorphins

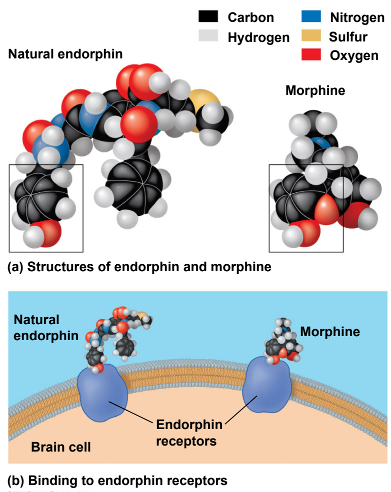


Fig. 2.18



# CHEMICAL REACTIONS

- Making and breaking of chemical bonds leading to changes in the composition of matter
- Eventually the the relative concentrations of reactants and products stop changing. This is called **chemical equilibrium**.