The Chemistry of Life

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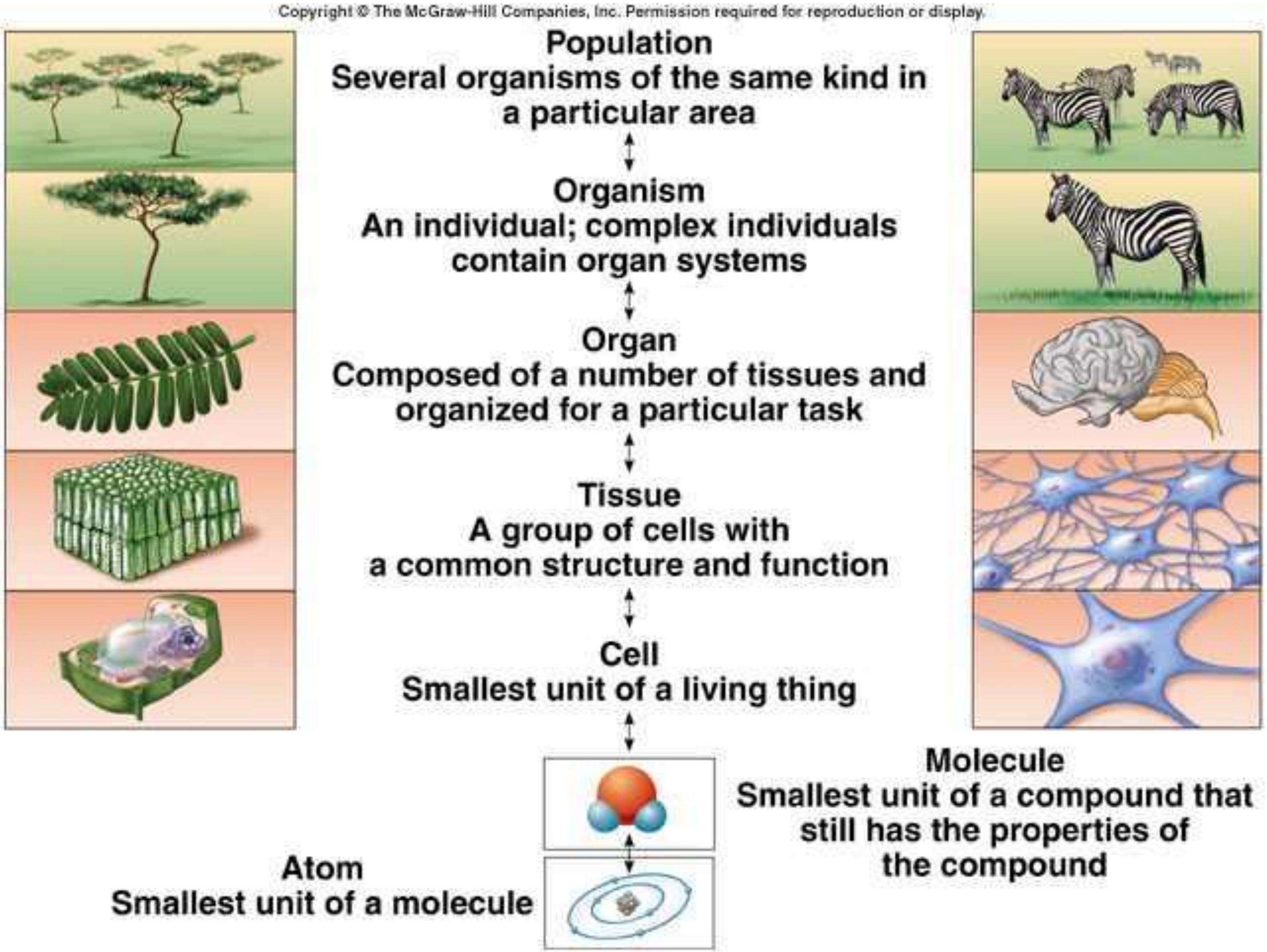
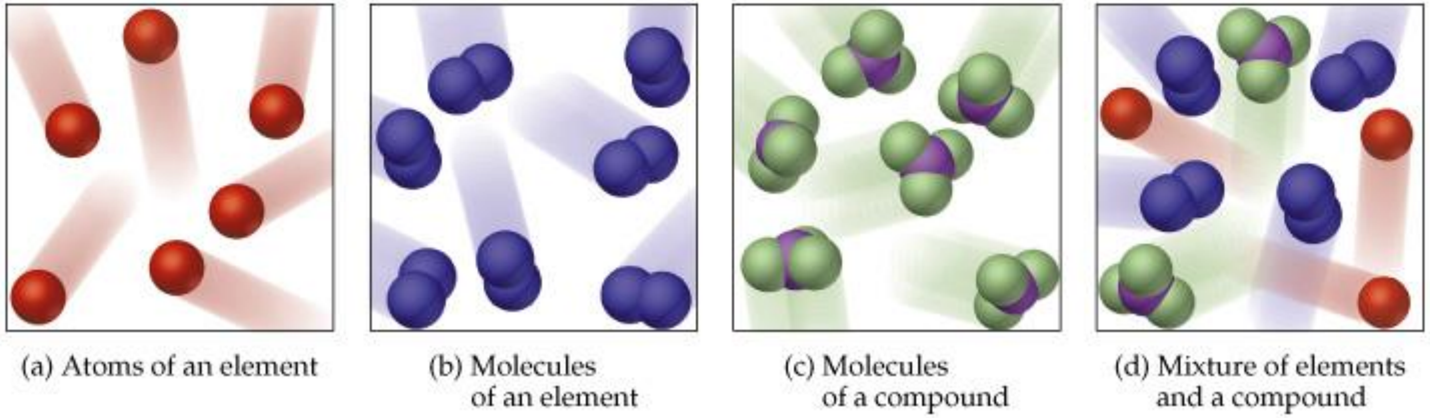
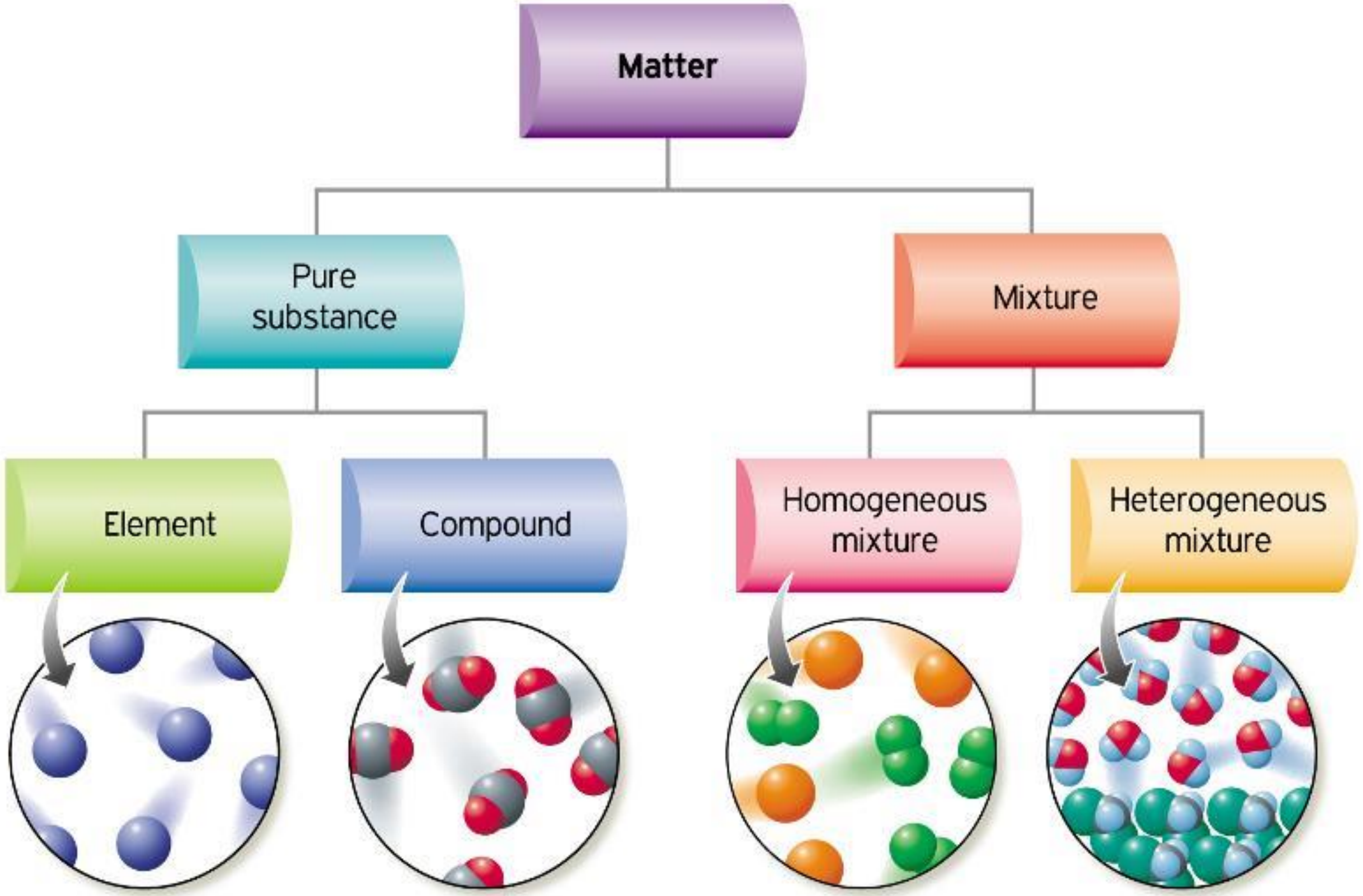
A Chemical Connection to Biology

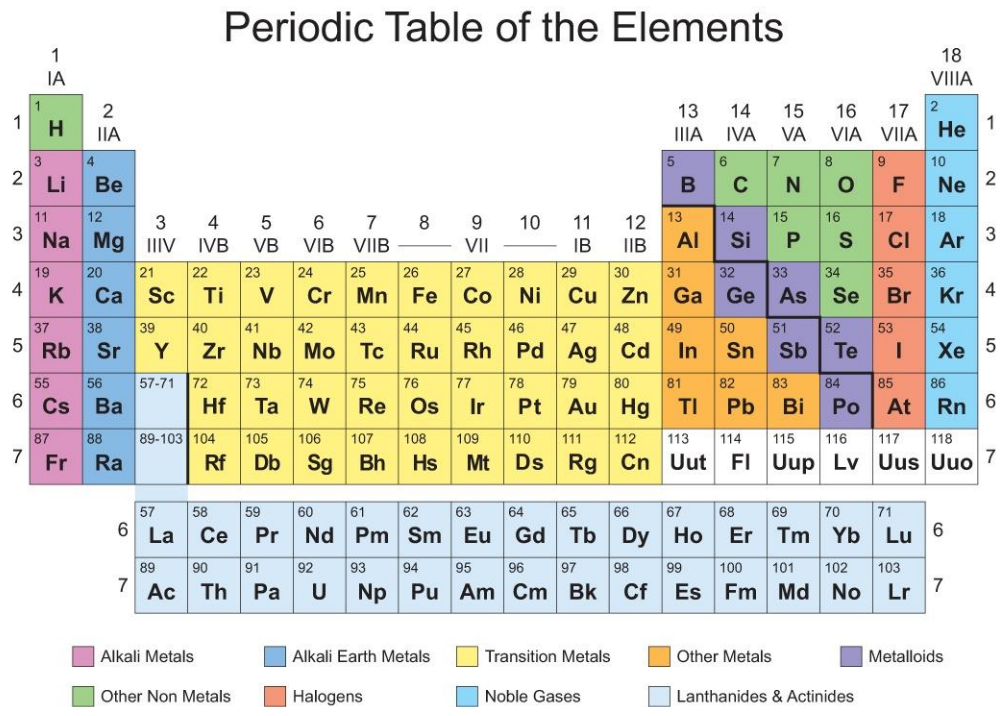




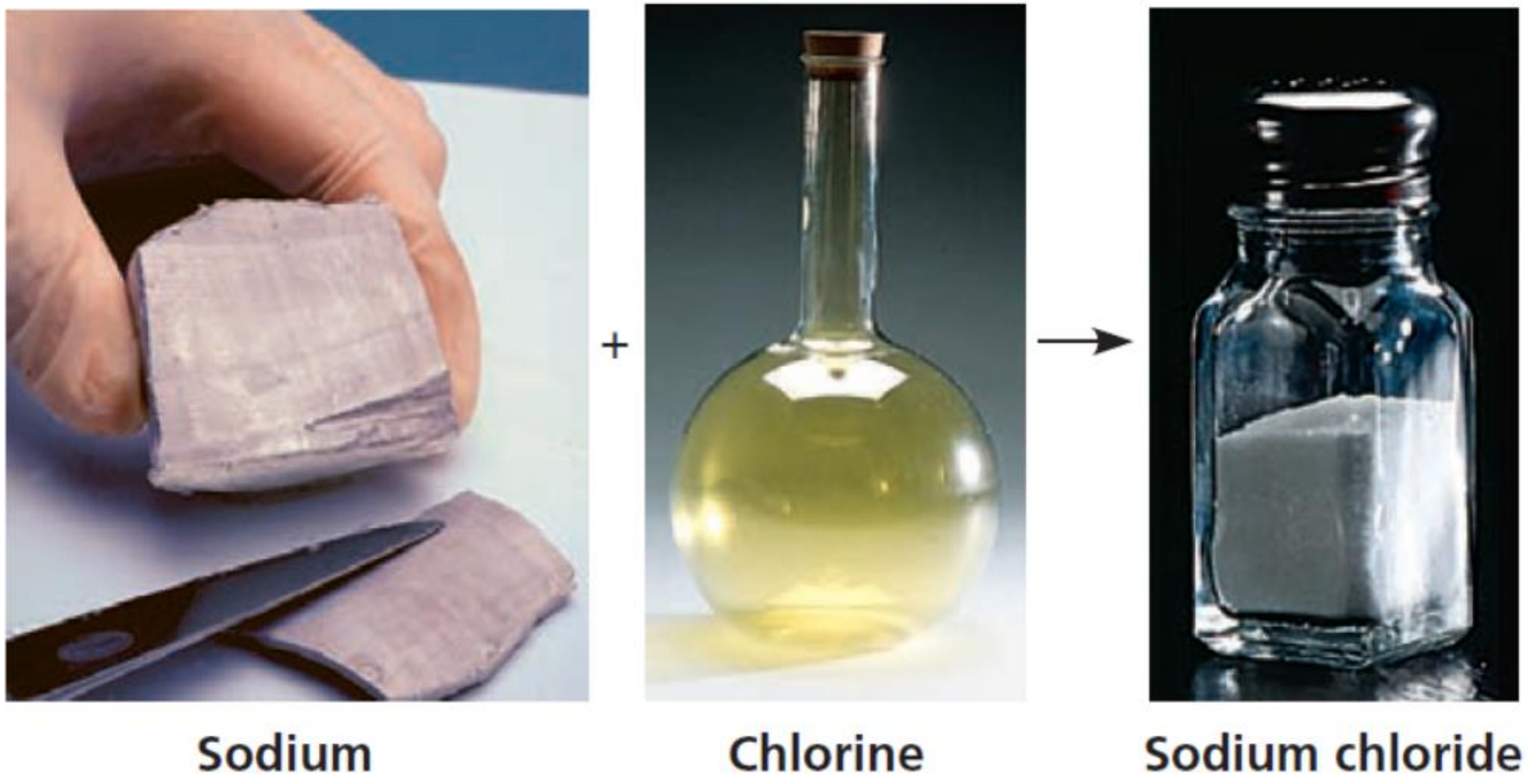


of chemical elements in pure form and in combinations called

An **element** is a substance that cannot be broken down to other substances by chemical reactions.



A **compound** is a substance consisting of two or more different elements combined in a fixed ratio.



▲ **Figure 2.2 The emergent properties of a compound.** The metal sodium combines with the poisonous gas chlorine, forming the edible compound sodium chloride, or table salt.

Today, chemists recognize 92 elements occurring in nature.

- **Bulk element**
- **Trace element**
- **Ultra trace element**

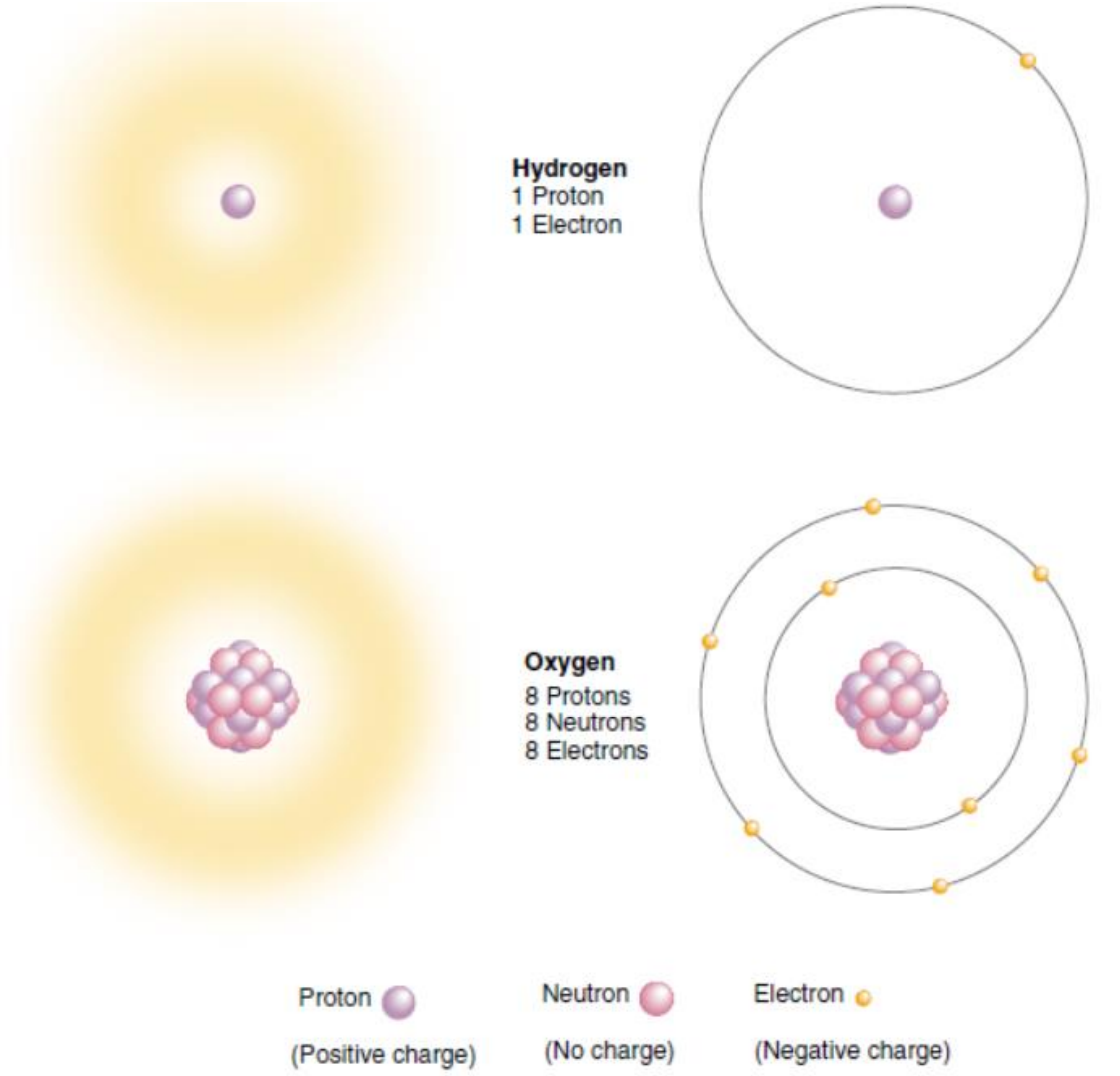
Table 2.1 Elements in the Human Body

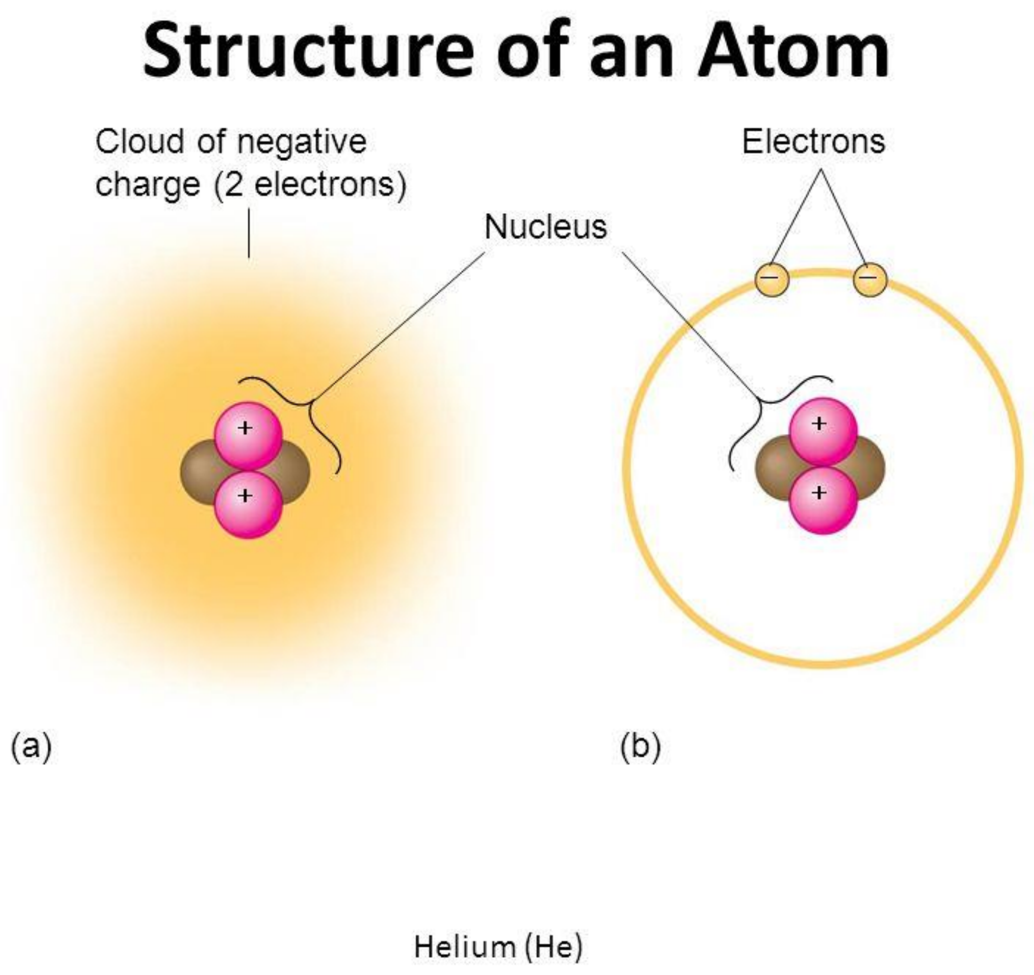
Element	Symbol	Percentage of Body Mass (including water)	
Oxygen	O	65.0%	96.3%
Carbon	C	18.5%	
Hydrogen	H	9.5%	
Nitrogen	N	3.3%	
Calcium	Ca	1.5%	3.7%
Phosphorus	P	1.0%	
Potassium	K	0.4%	
Sulfur	S	0.3%	
Sodium	Na	0.2%	
Chlorine	Cl	0.2%	
Magnesium	Mg	0.1%	

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)

▲ **Figure 2.3 Serpentine plant community.**
These plants are growing on serpentine soil, which contains elements that are usually toxic to plants. The insets show a close-up of serpentine rock and one of the plants, a Tiburon Mariposa lily.

An element's properties depend on the structure of its atoms.





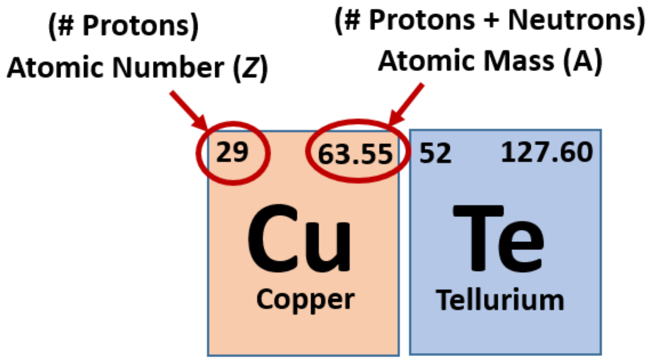
Atomic Number and Atomic Mass

Mass number = number of protons + neutrons
= 23 for sodium

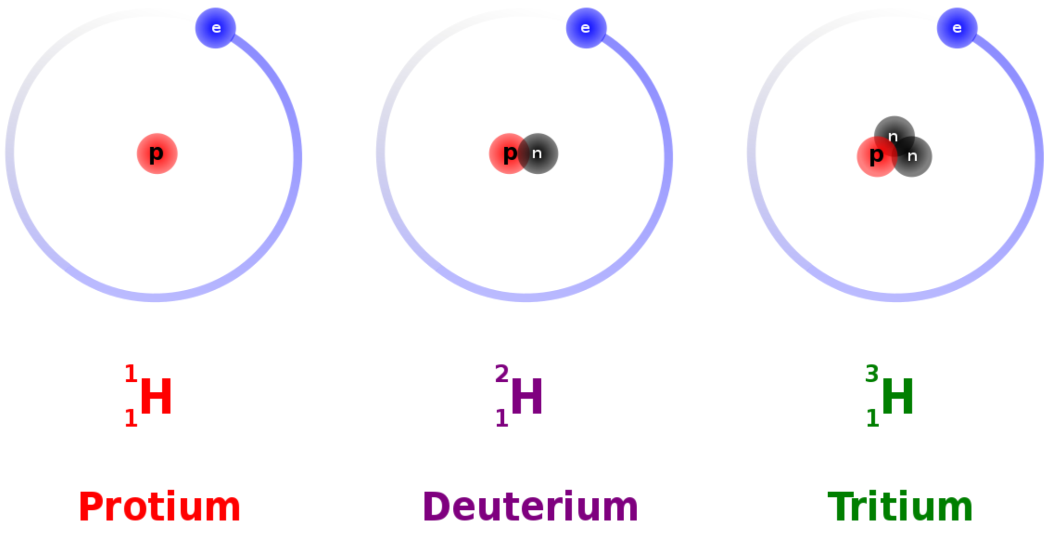
$^{23}_{11}\mathrm{Na}$

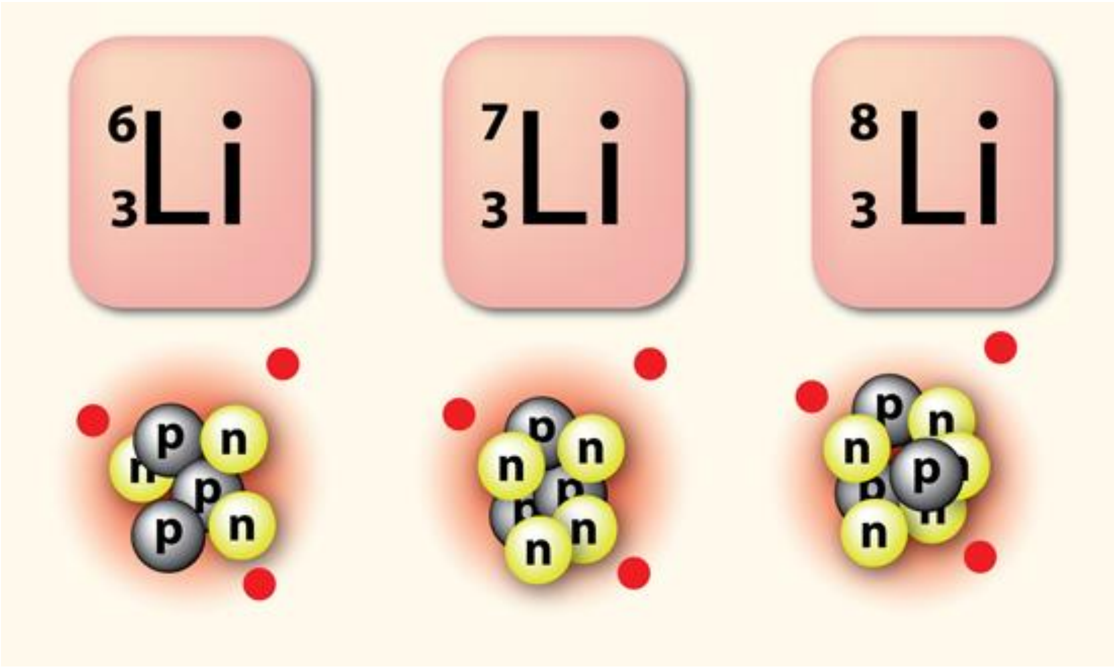
Atomic number = number of protons
= number of electrons in a neutral atom
= 11 for sodium

Number of neutrons = mass number − atomic number
= 23 − 11 = 12 for sodium



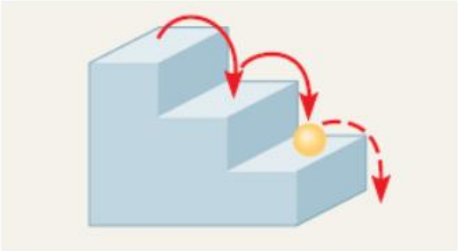
Isotopes

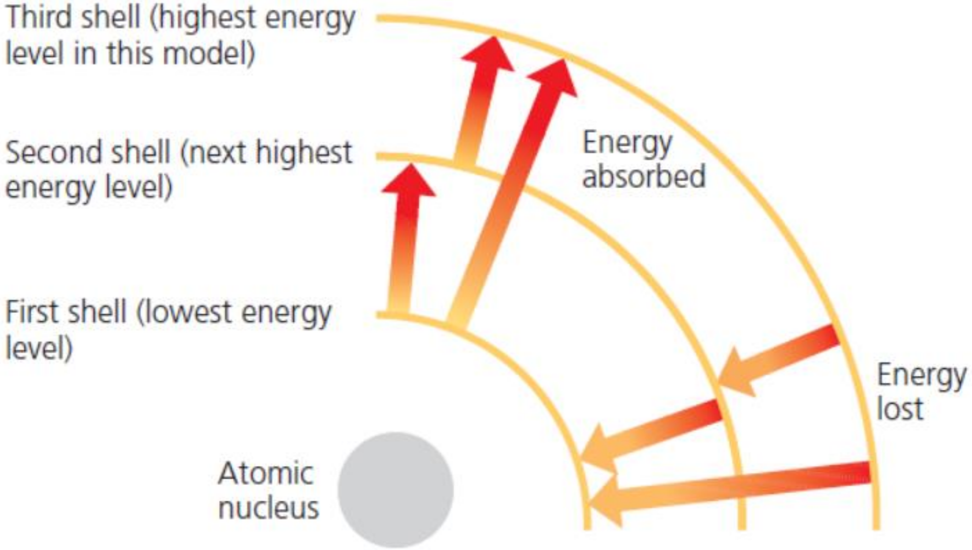




The Energy Levels of Electrons

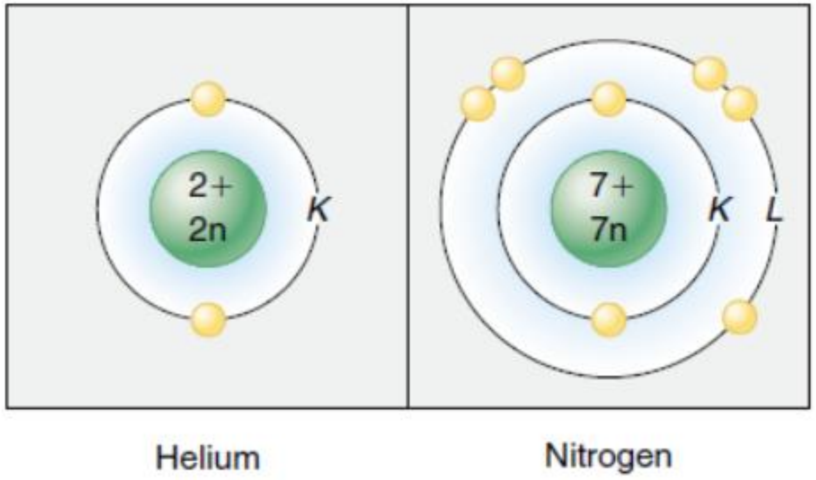
(a) A ball bouncing down a flight of stairs provides an analogy for energy levels of electrons, because the ball can come to rest only on each step, not between steps.

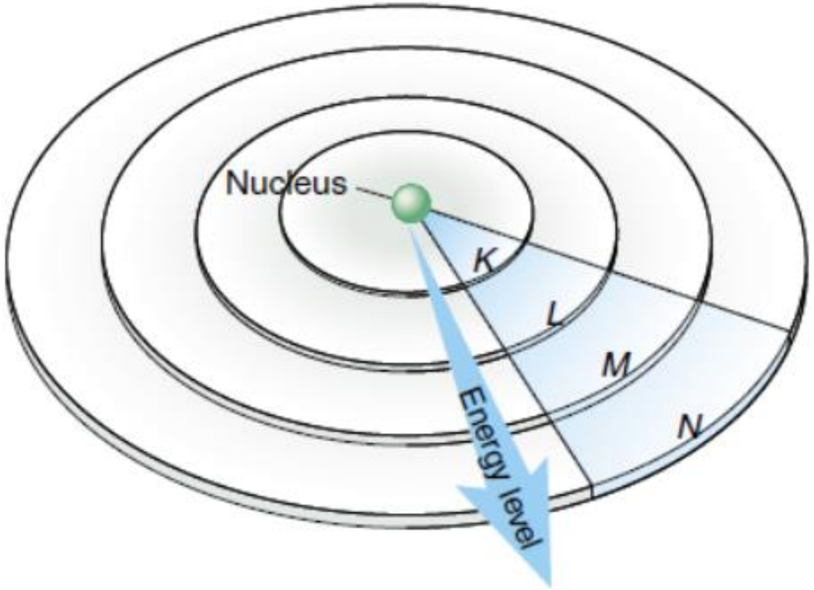


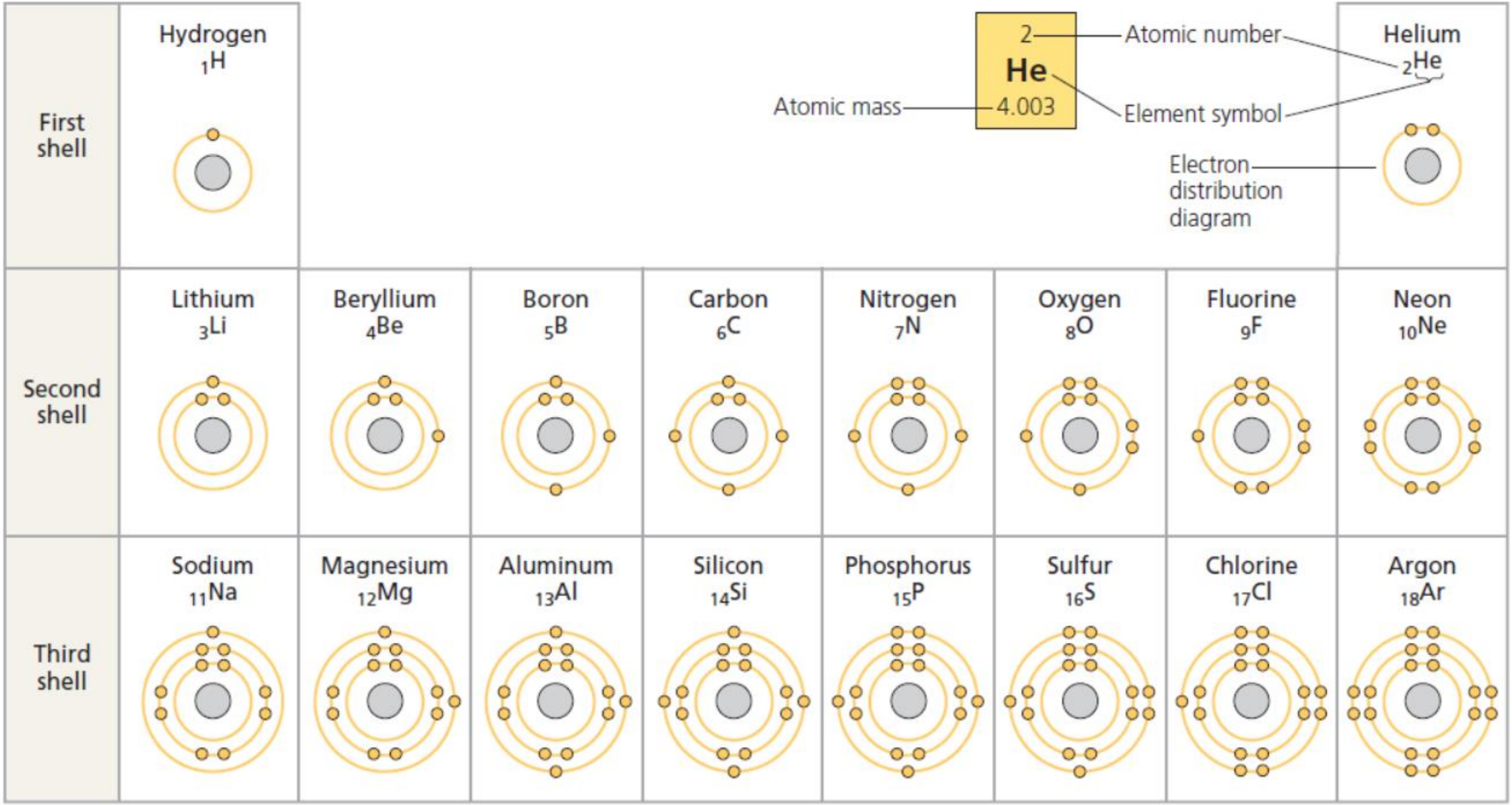


(b) An electron can move from one shell to another only if the energy it gains or loses is exactly equal to the difference in energy between the energy levels of the two shells. Arrows in this model indicate some of the stepwise changes in potential energy that are possible.

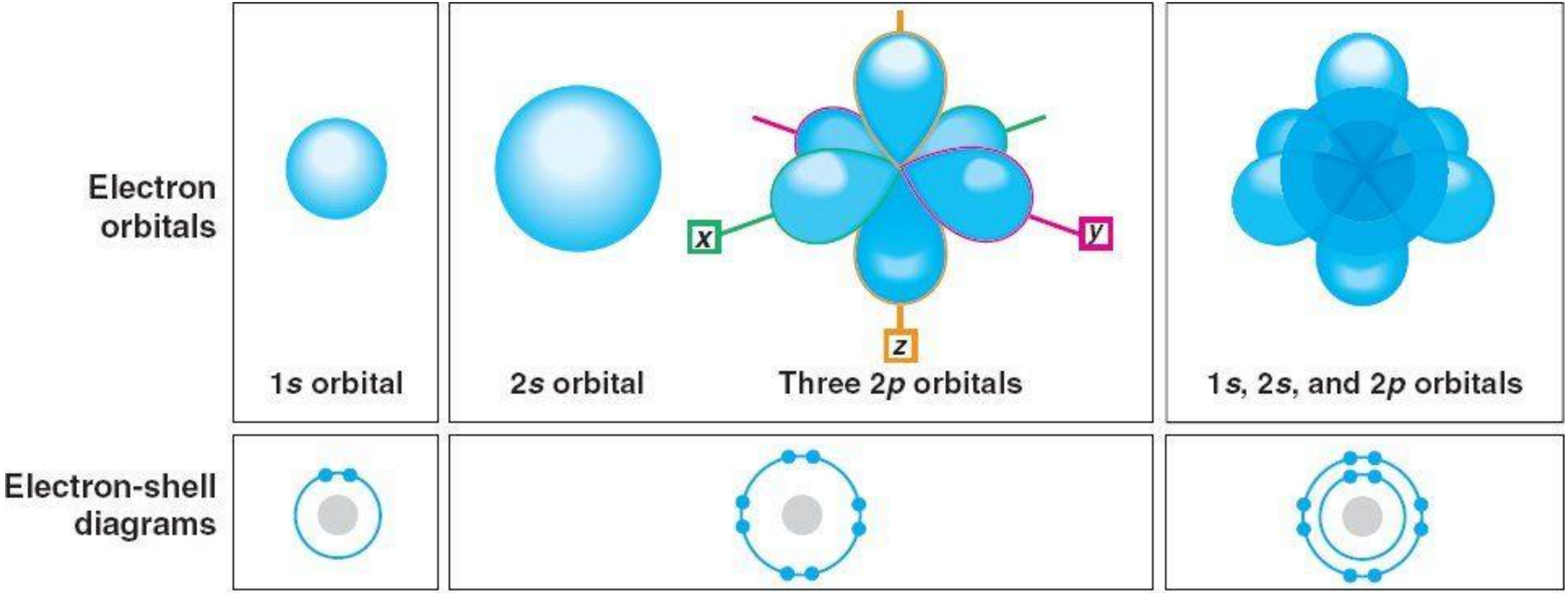
▲ **Figure 2.6 Energy levels of an atom's electrons.** Electrons exist only at fixed levels of potential energy called electron shells.







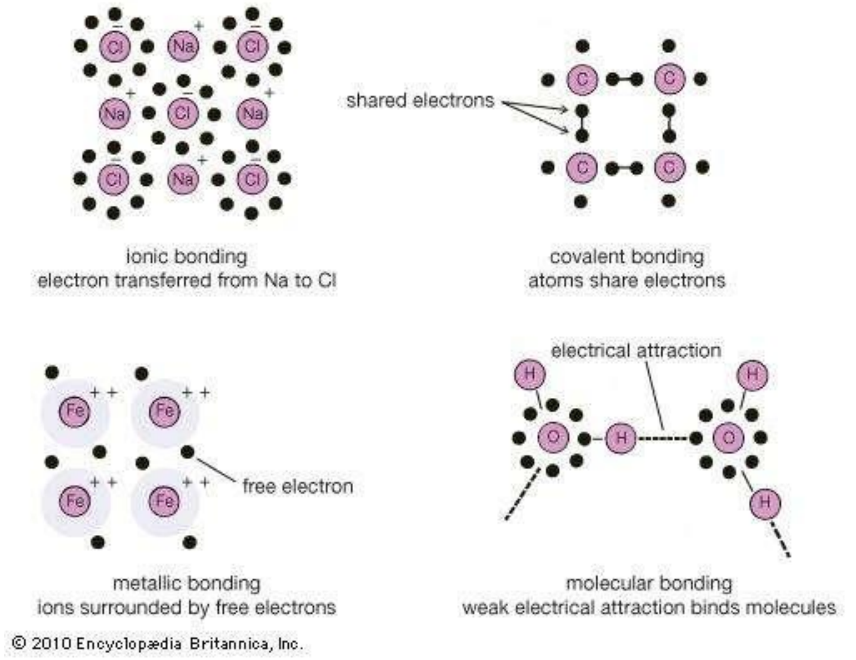
Electron distribution diagrams for the first 18 elements in the periodic table.



(a) First shell (maximum 2 electrons)

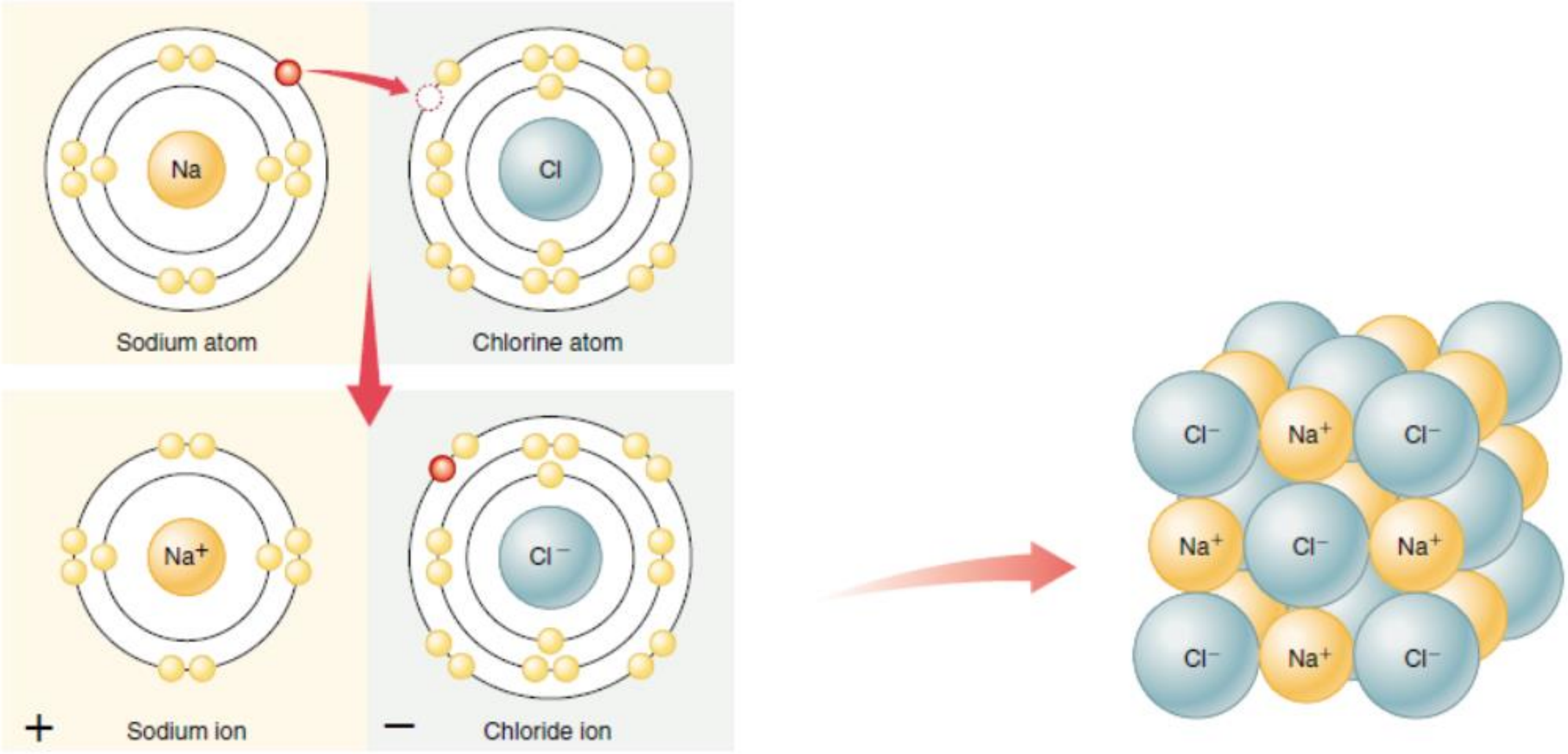
(b) Second shell (maximum 8 electrons)

(c) Neon, with two filled shells (10 electrons)

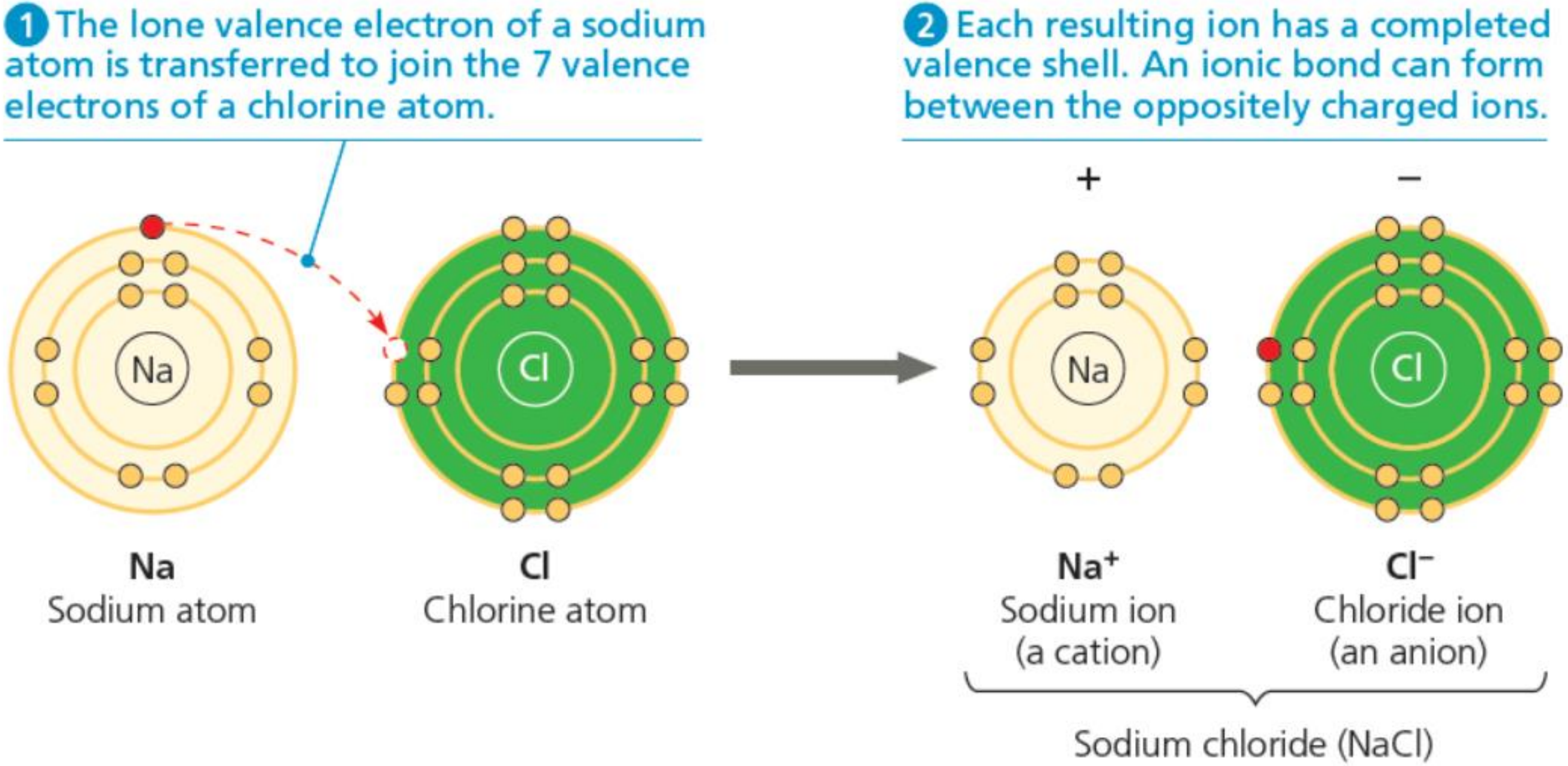


The formation and function of molecules depend on chemical bonding between atoms.

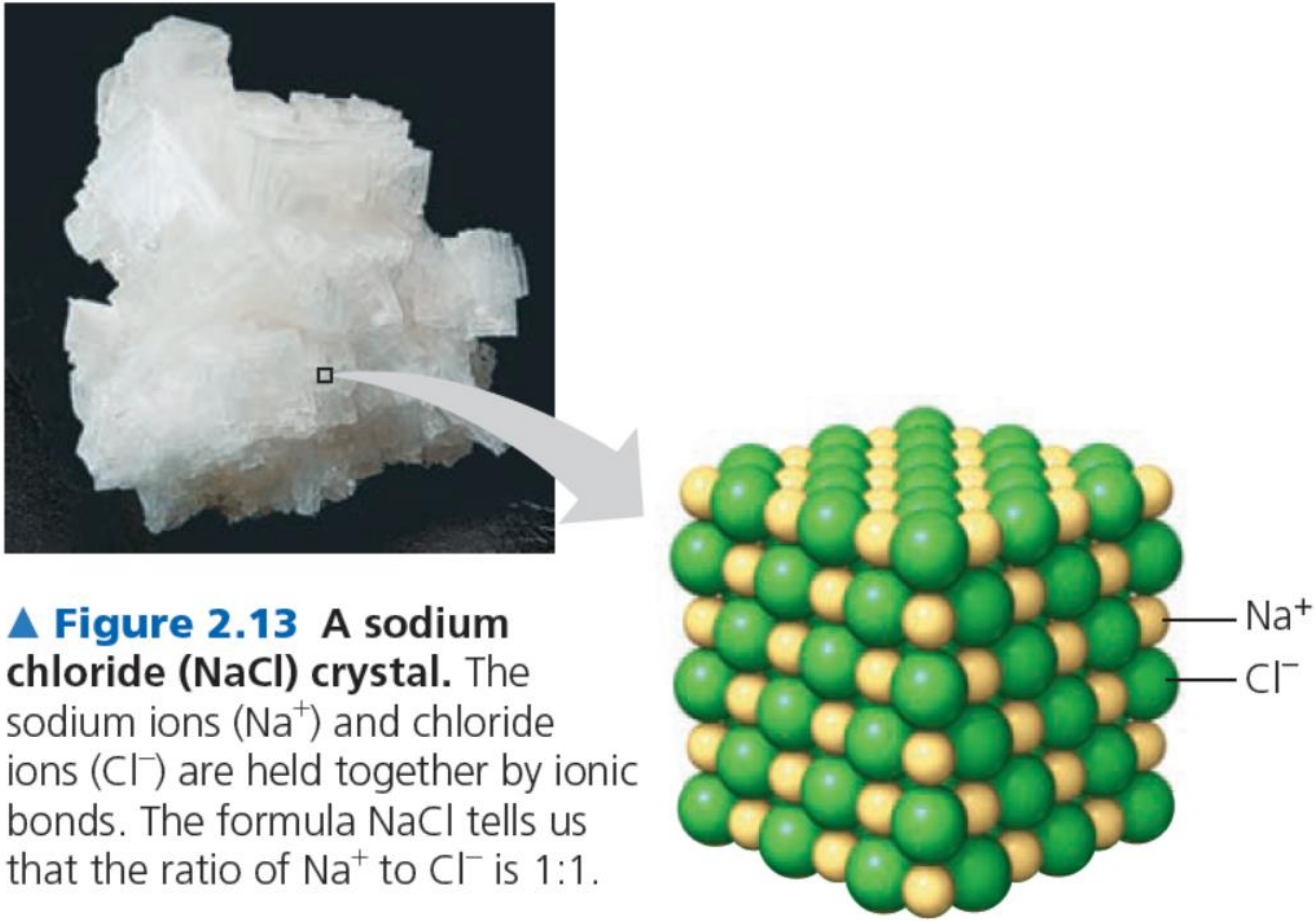
Ionic Bond



(a) (b) NaCl crystal

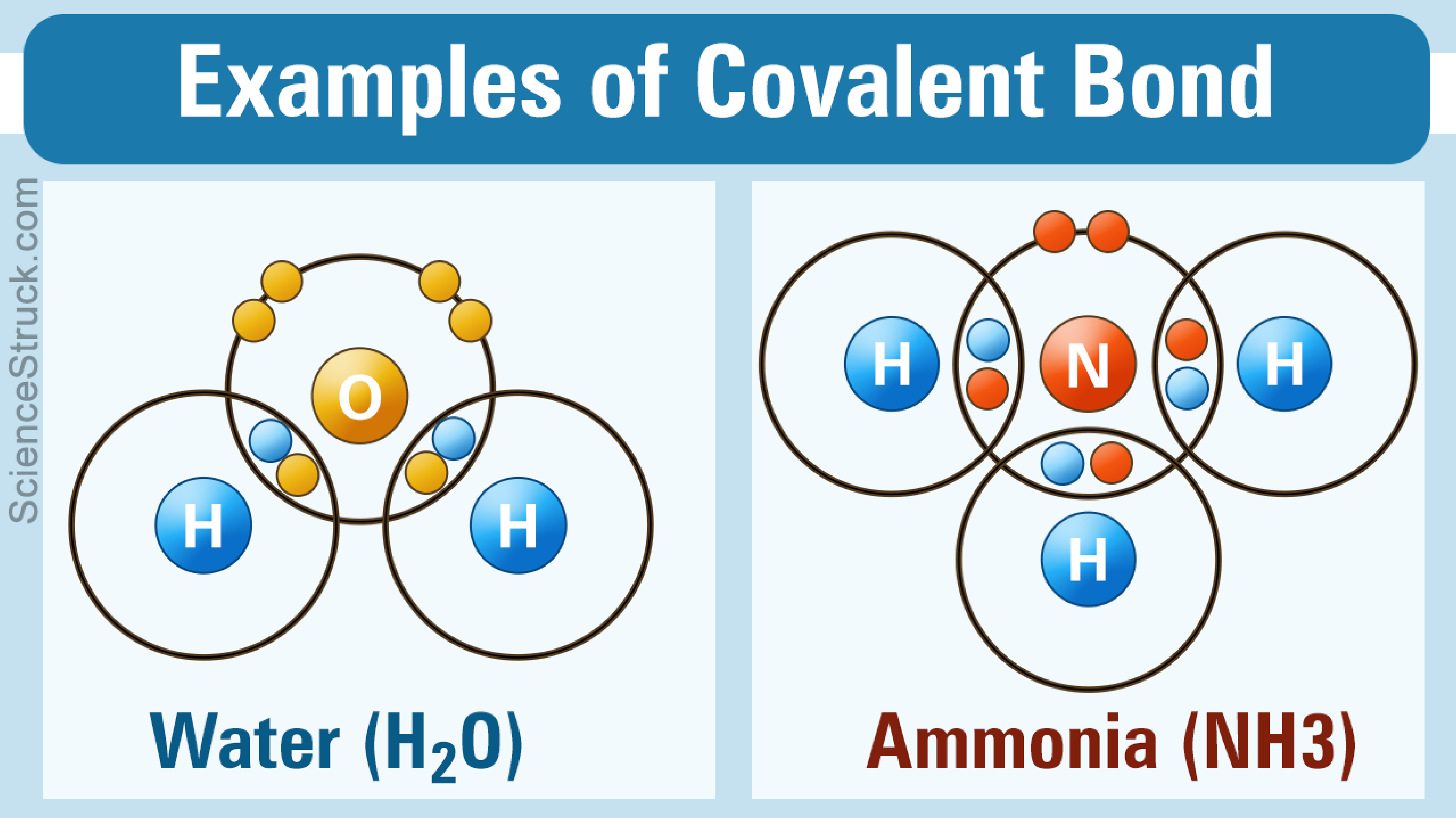


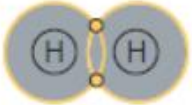
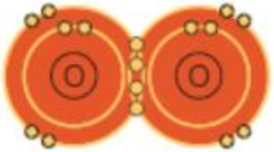
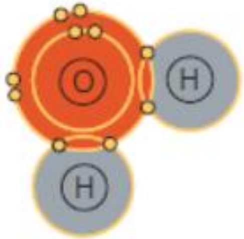
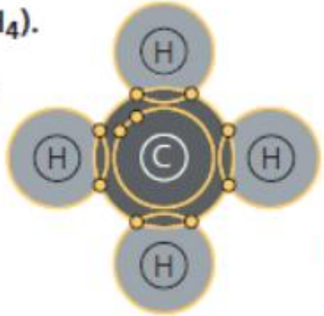
▲ **Figure 2.12 Electron transfer and ionic bonding.** The attraction between oppositely charged atoms, or ions, is an ionic bond. An ionic bond can form between any two oppositely charged ions, even if they have not been formed by transfer of an electron from one to the other.



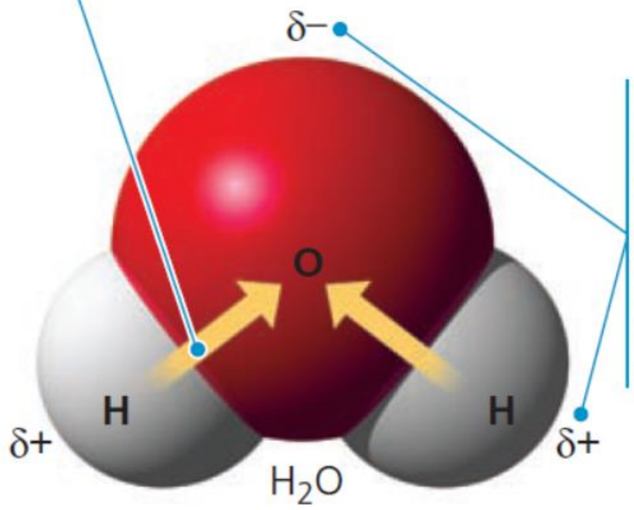
▲ **Figure 2.13 A sodium chloride (NaCl) crystal.** The sodium ions (Na^+) and chloride ions (Cl^-) are held together by ionic bonds. The formula NaCl tells us that the ratio of Na^+ to Cl^- is 1:1.

Covalent Bond



Name and Molecular Formula	Electron Distribution Diagram	Lewis Dot Structure and Structural Formula	Space-Filling Model
(a) Hydrogen (H_2). Two hydrogen atoms share one pair of electrons, forming a single bond.		H:H H—H	
(b) Oxygen (O_2). Two oxygen atoms share two pairs of electrons, forming a double bond.		Ö::Ö O═O	
(c) Water (H_2O). Two hydrogen atoms and one oxygen atom are joined by single bonds, forming a molecule of water.		:Ö:H H O—H | H	
(d) Methane (CH_4). Four hydrogen atoms can satisfy the valence of one carbon atom, forming methane.		H H:C:H H H | H—C—H | H	

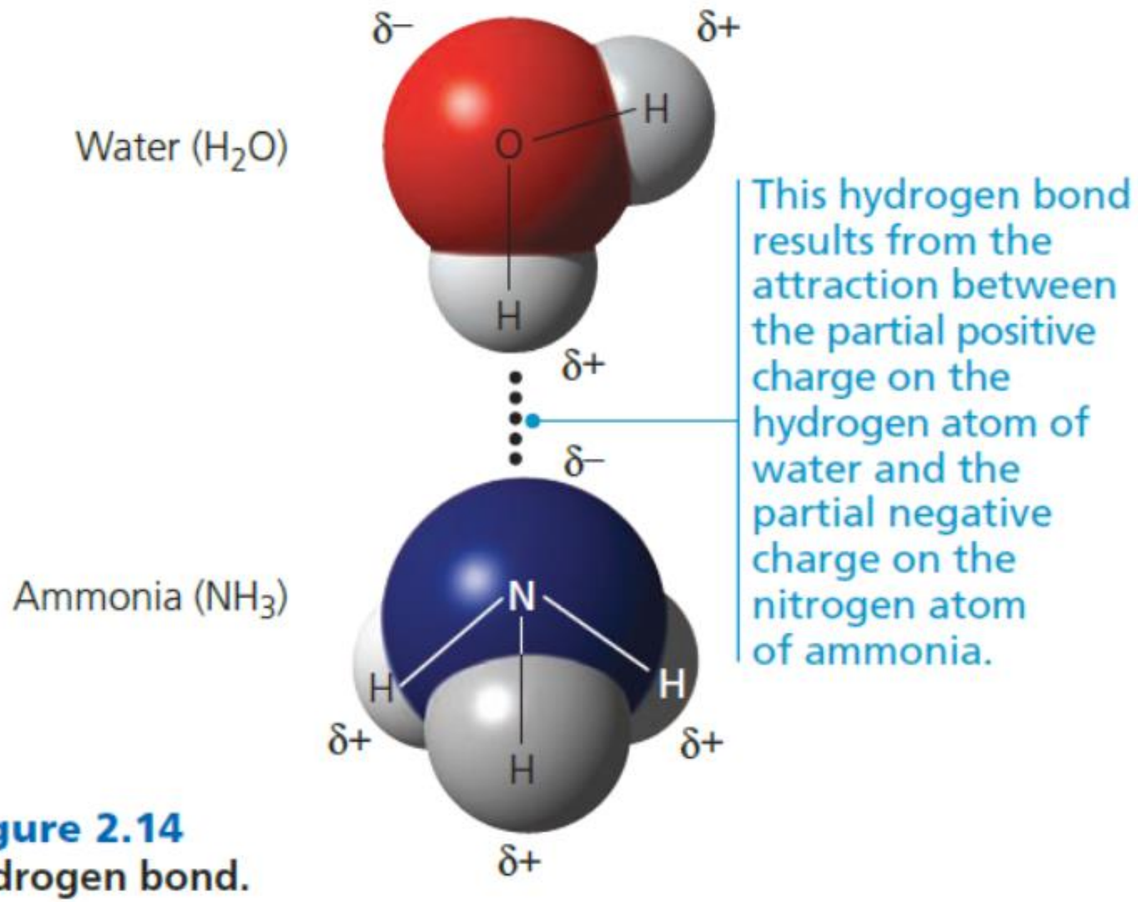
Because oxygen (O) is more electronegative than hydrogen (H), shared electrons are pulled more toward oxygen.



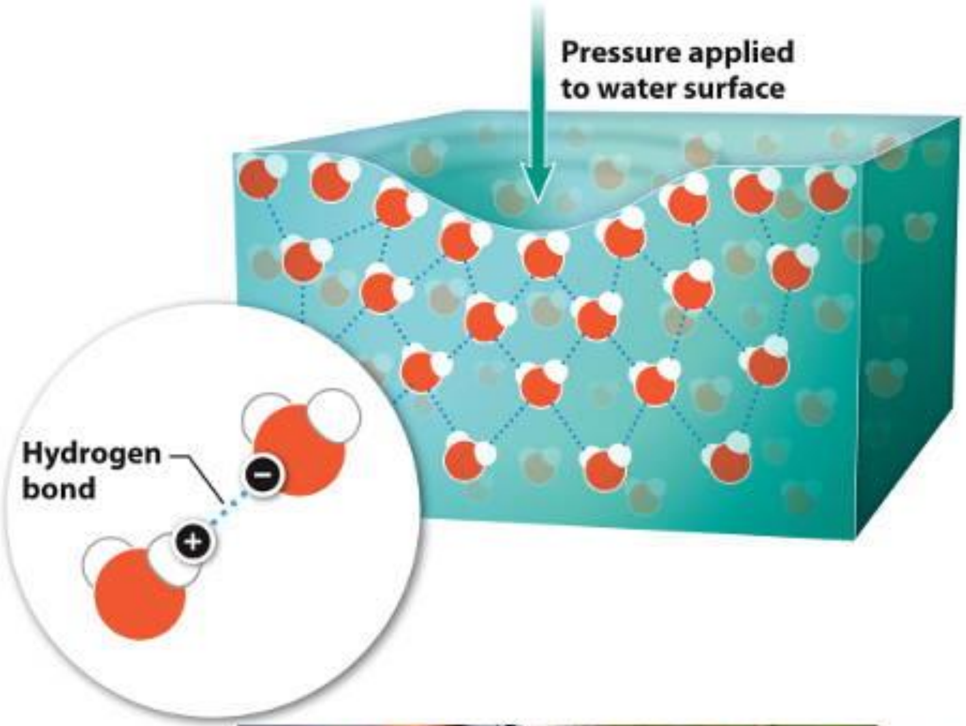
This results in a partial negative charge on the oxygen and a partial positive charge on the hydrogens.

▲ **Figure 2.11 Polar covalent bonds in a water molecule.**

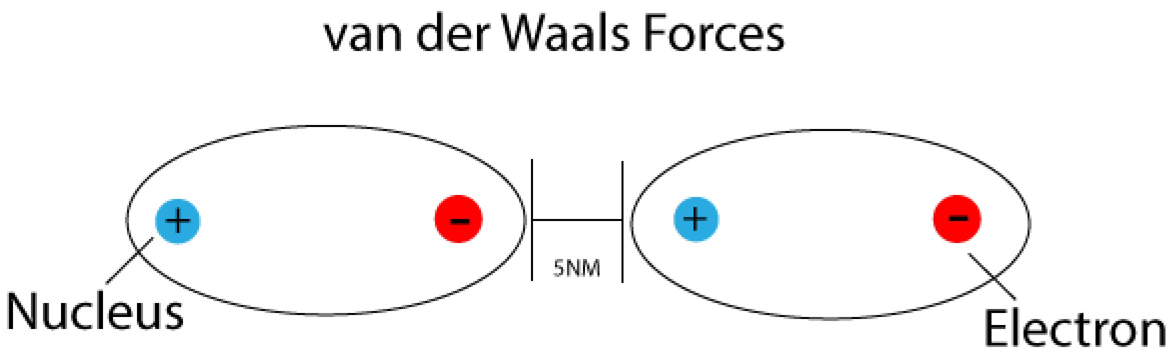
Hydrogen Bonds

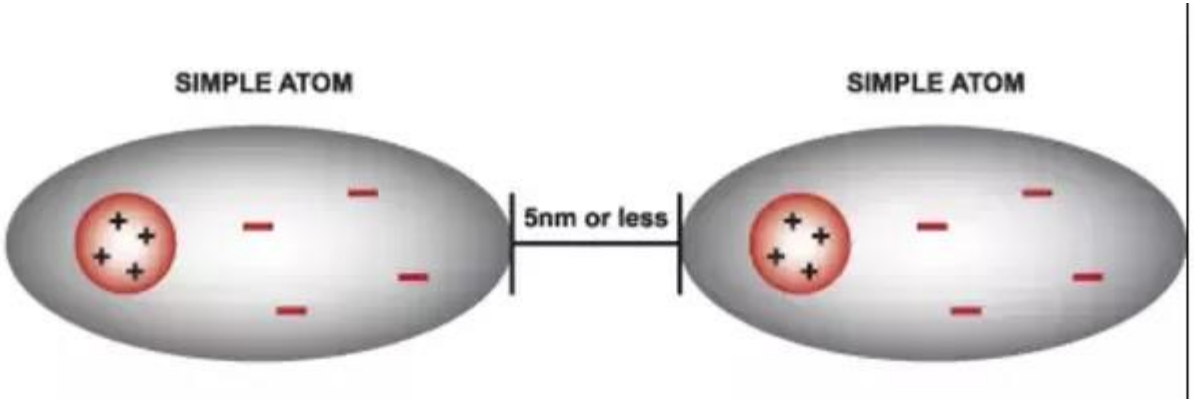


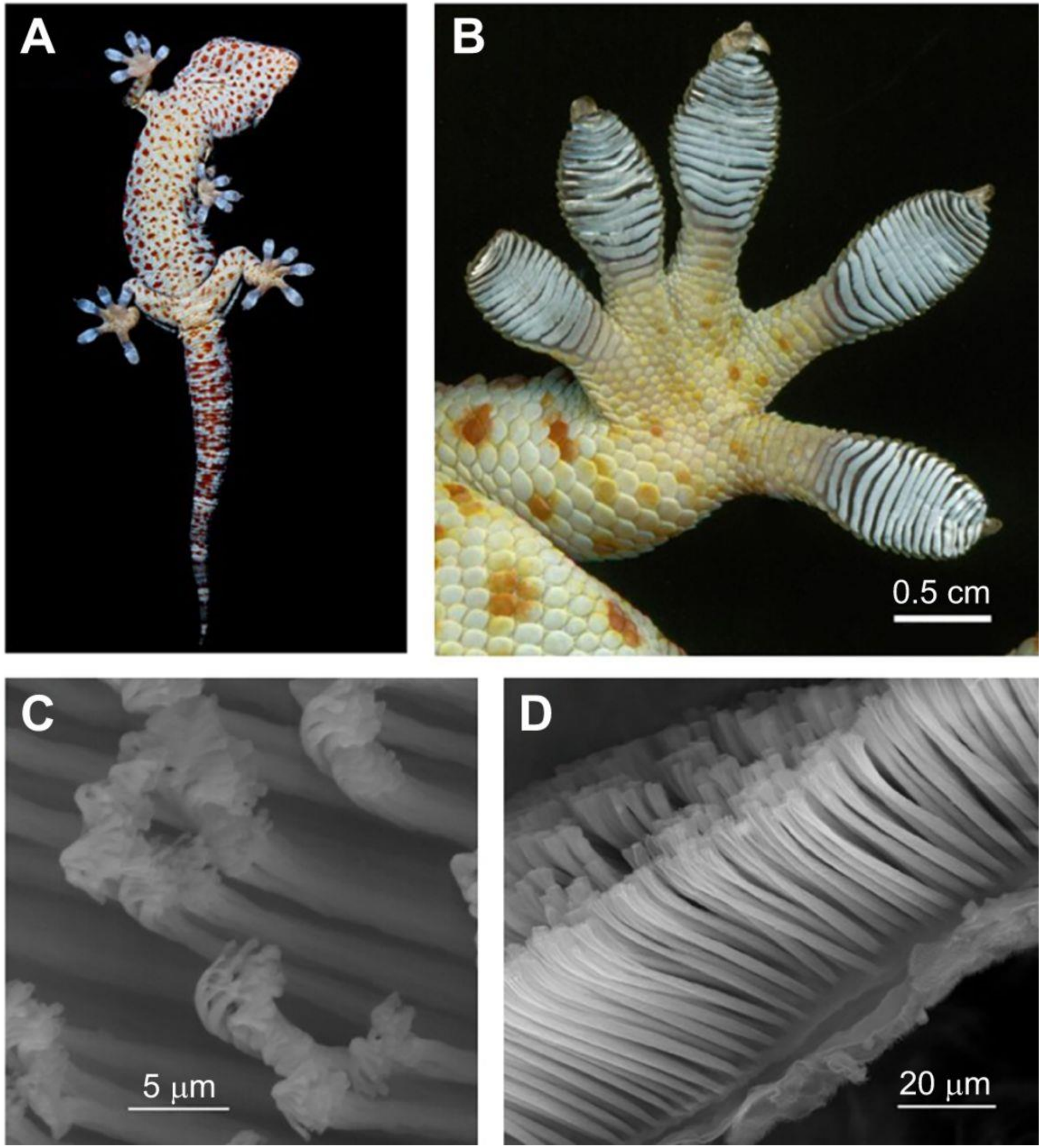
▲ **Figure 2.14**
A hydrogen bond.



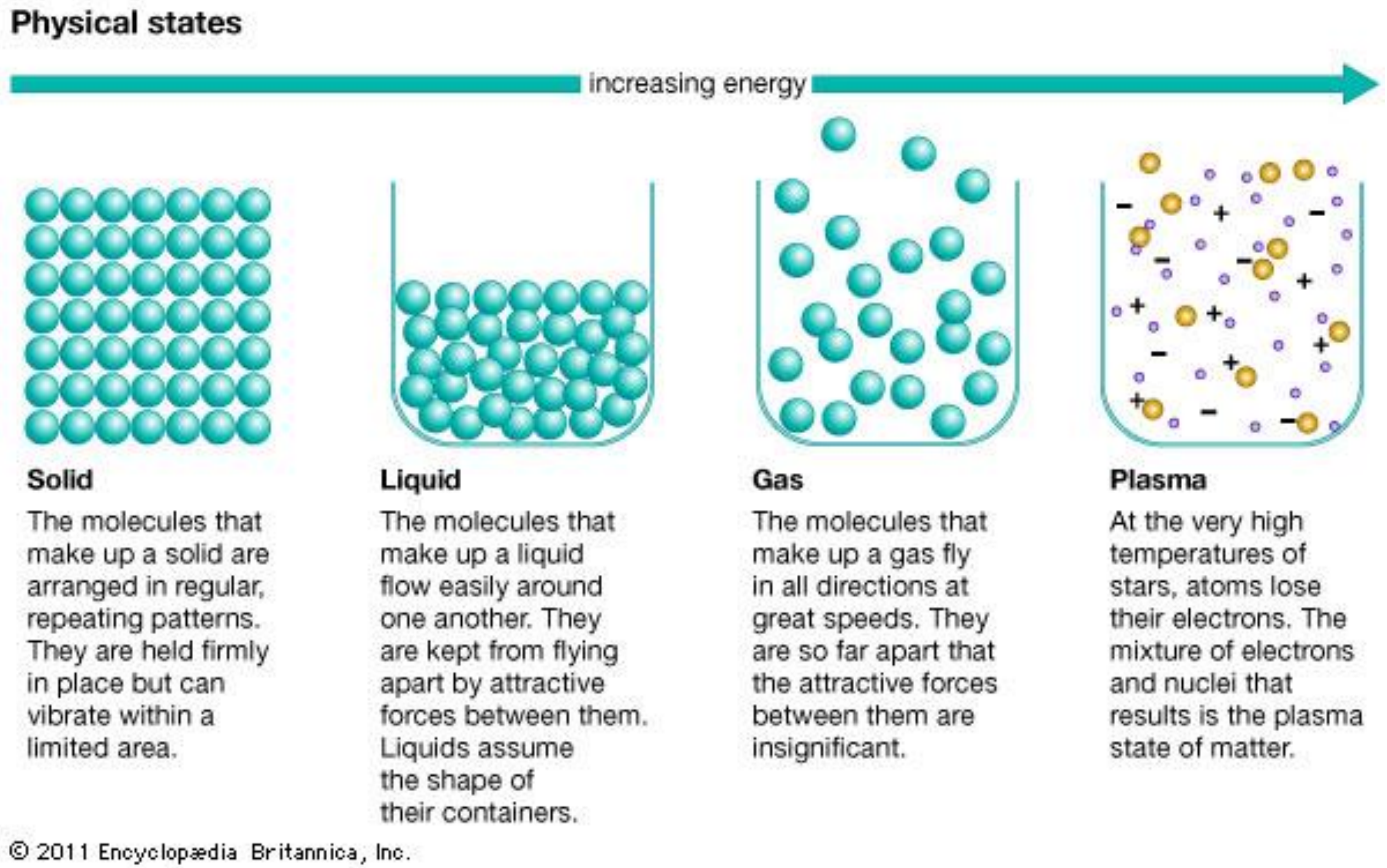
Van der Waals Interactions







State of matter



- bose einstein condensate
- Solid
- Liquid
- Gas
- Plasma
- Filament
- Fermionic condensate