Biology Notes
[First Lecture]

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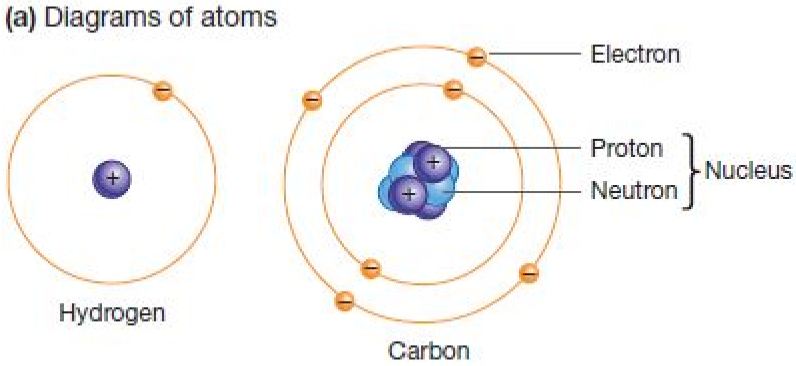
1 Atoms

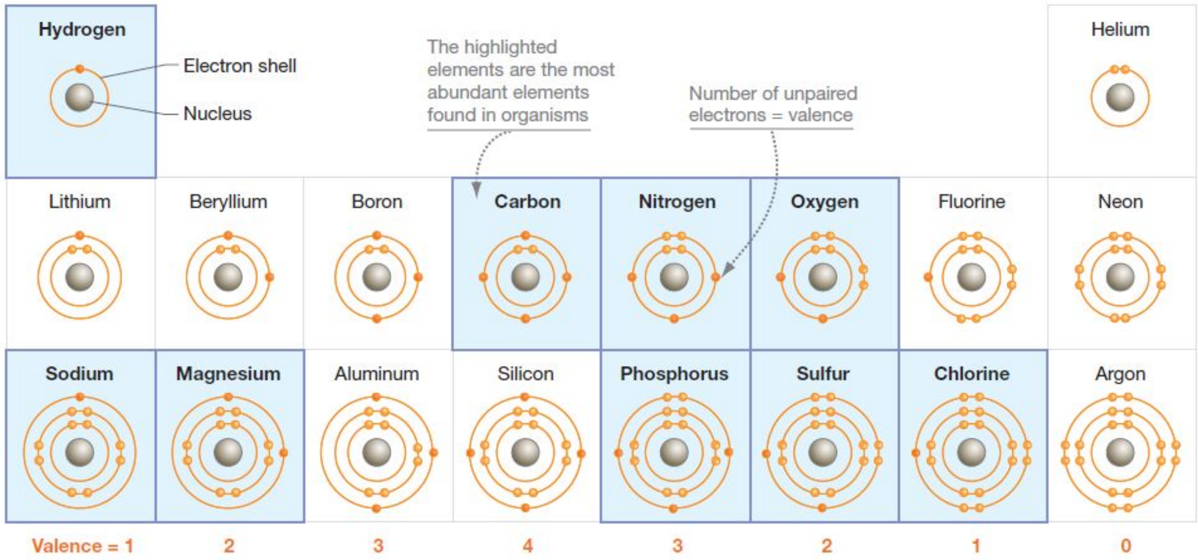
An **Atom** is the smallest constituent unit of ordinary matter. Every Atom is composed of **nucleus** and one or more **electrons**(particles with a negative charge). Nucleus is composed of **protons**(particles with a positive charge) and **neutrons**(particles with no charge).



- **Atomic number** - Identifies and is unique to each element. Always equals to number of protons.
- **Mass number** - Is defined as number of **protons** + number of **neutrons**.
- **Isotopes** - Atoms with the same Atomic number (Hence, the same elements) differentiated by number of neutrons. (literal meaning: "equal-places" in regard to position in the periodic table).
- **Atomic Weight** - Statistical Weighted average of **Mass numbers** over the isotopes.
- **Radioisotope** - Is a **Radioactive isotope**. Its nucleus will eventually decay and release energy (radiation). For instance, when $^{14}_{6}C$ decays, one of its neutrons changes into a proton, converting $^{14}_{6}C$ to the stable $^{14}_{7}N$ isotope of nitrogen.
- **Dalton** - Weight unit. **Weight(Proton) = Weight(Neutron) = 1 Dalton**.
- **Mass of electron** - The mass of an electron is so small that it is generally ignored.

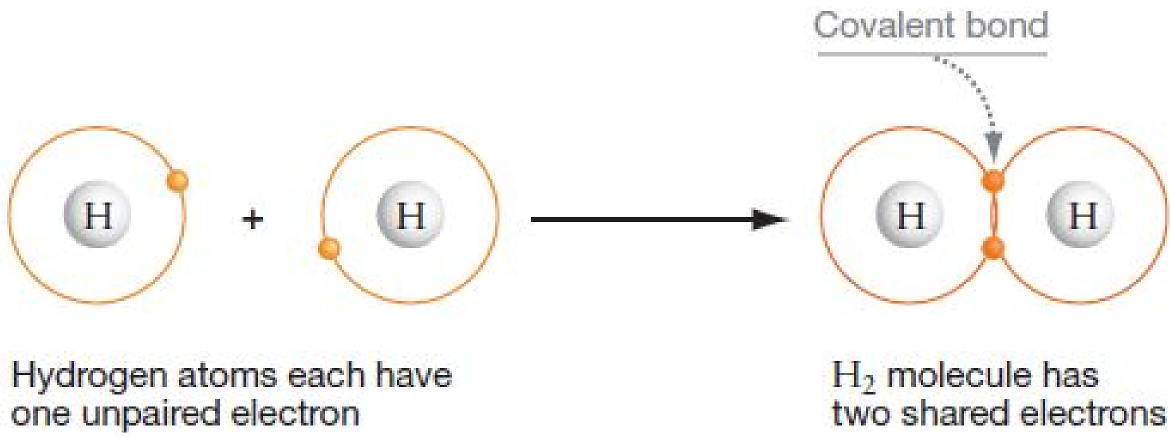
- Electron Arrangement in atom: -

- **Orbitals** - Specific regions in atom, around nucleus, where electrons are most likely to be. Each orbital can hold up to 2 electrons with different spins.
- **Shells** - Groups of orbitals. Split into levels (1,2,3..). Lower level indicates lower energy and closeness to the nucleus. Shells contain specific number of electrons (Depending on the consisting subshell types) which is dependant to the number of orbitals in the shell. Electrons occupy innermost shell first.
- **Valence shell** - Outermost shell of atom.
- **Valence Electrons** - Electrons on the valence shell.
- **Valence number** - Number of unpaired valence electrons.



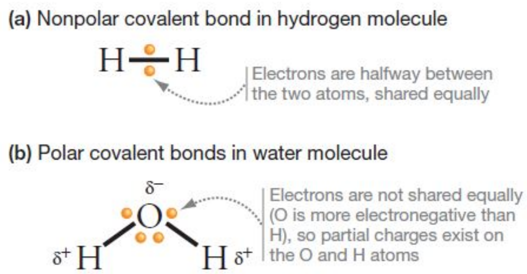
1.1 Bonds between atoms

- **Covalent bond** - A strong attraction, where two atoms share one or more pairs of unpaired covalent electrons.

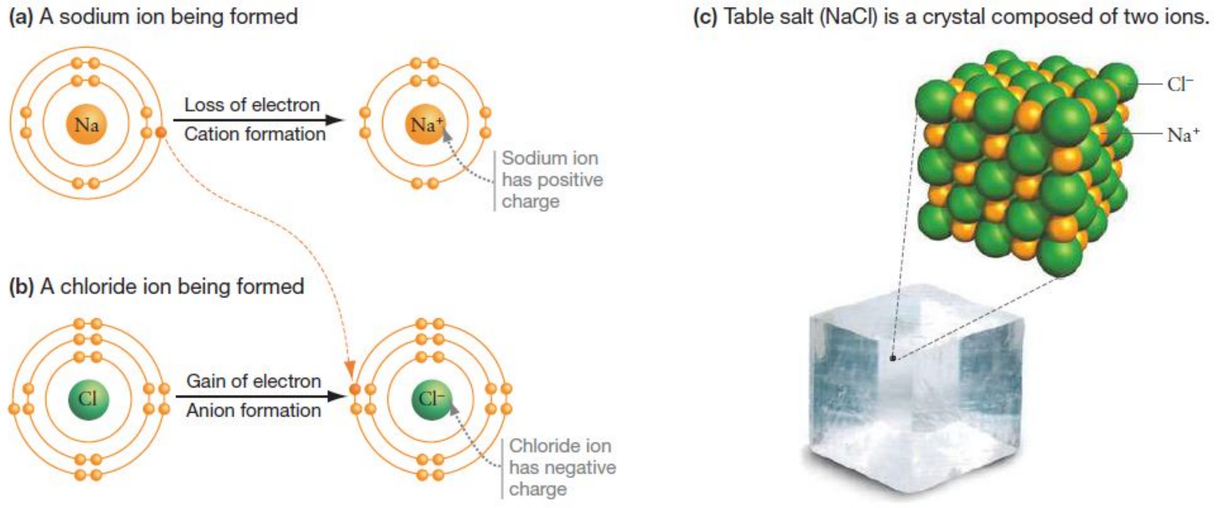


- **Electronegativity** - Is atoms ability to attract valence electrons. Depends on number of protons and distance of the valence shell from nucleus. Oxygen is among the most electronegative of all elements. It attracts covalently-bonded electrons more strongly than does any other atom commonly found in organisms. Electronegativity of four most abundant element in organisms goes as: O>N>C =H.

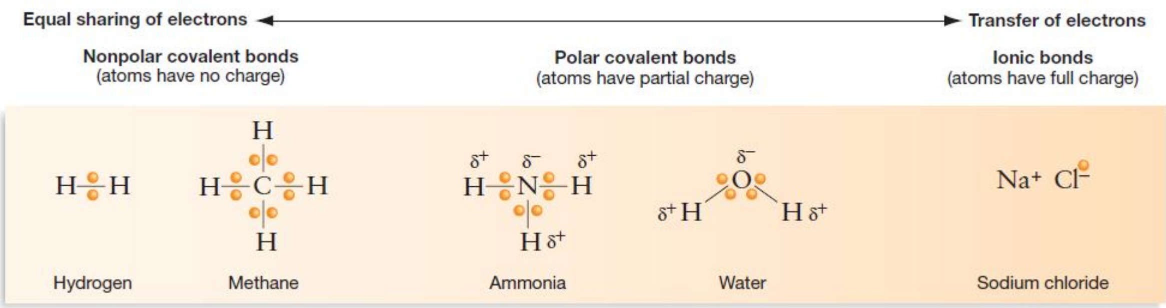
- **Polar/Non-polar covalent bond** - When atoms have covalent bonds and there is big difference between electronegativity of those atoms, Covalent bond is said to be **Polar**. Which means that shared electrons are more likely to be on the one (more electronegative) side of the bond, hence one side of the molecule gets partial positive and the other side negative charge. For instance H_2O, since electronegativity of Oxygen is much higher than hydrogen. Non-polar covalent bond is found between atoms with nearly the same electronegativity. For instance CH_4.



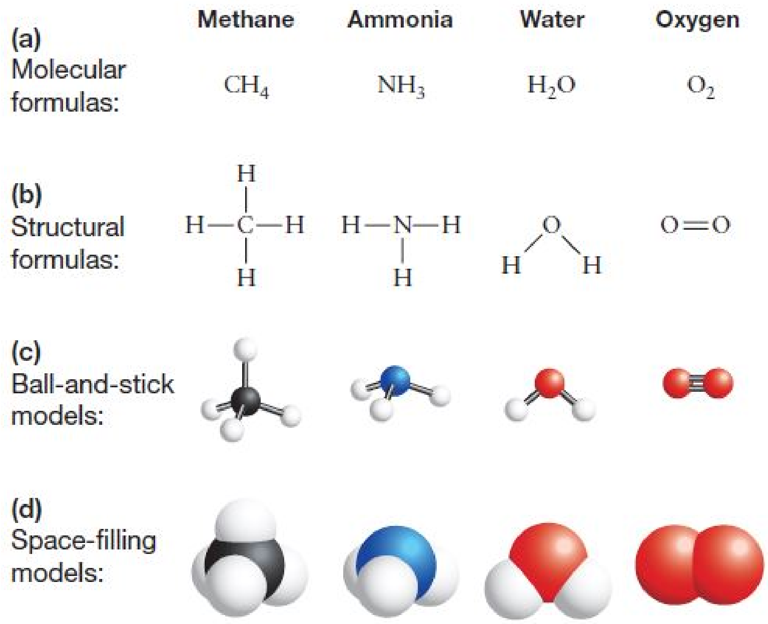
- **Ion** - Charged atom. Positively charged atom are called **Cations**, negatively charged - **Anions**.
- **Ionic bond** - Is similar in principle to covalent bonds, but instead of sharing an electron, one of the atoms in the bond completely takes it and strong-electromagnetic bond is formed between charged atoms. For example, Sodium atom (Na) tend to lose an electron and with it third shell. Leaving it with completed second shell, much more stable state and a positive charge (Na^+). Chlorine atoms (Cl), in contrast, tend to gain an electron, filling their outermost shell and becoming cations (Cl^+). Together those two atoms form Sodium-Chloride or more commonly known as table salt.



This discussion of covalent and ionic bonding supports an important general observation: The degree to which electrons are shared in chemical bonds forms a continuum from equal sharing in non-polar covalent bonds to unequal sharing in polar covalent bonds to the transfer of electrons in ionic bonds.



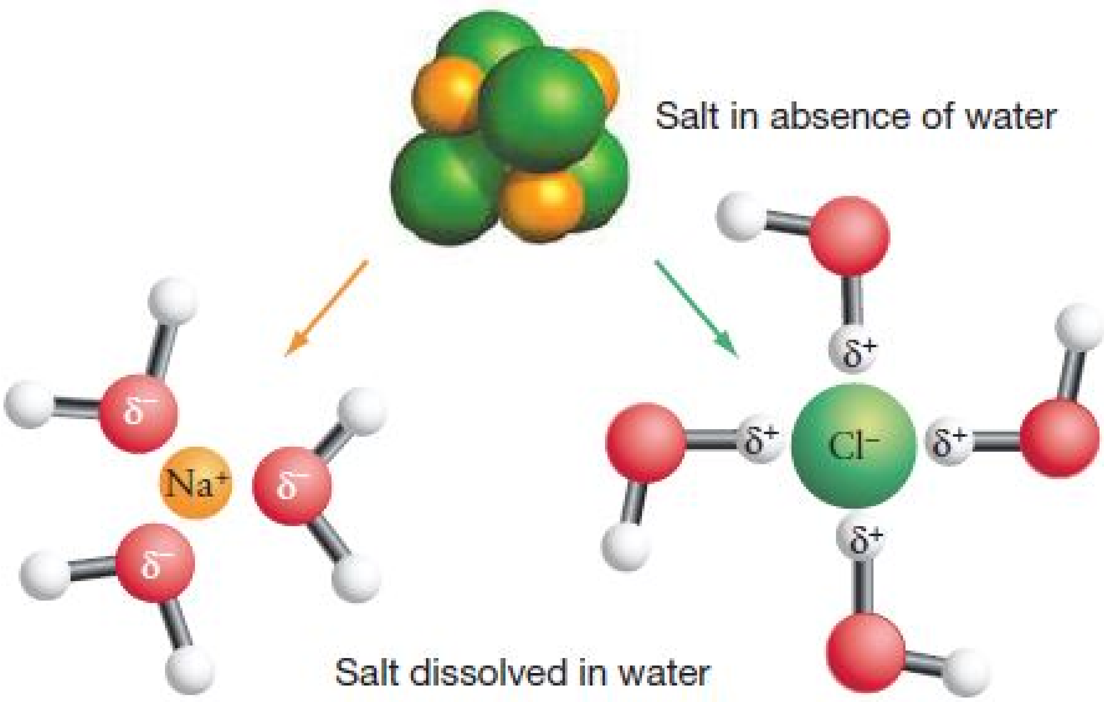
1.2 Some Simple Molecules Formed from C, H, N, and O



2 Properties of water

Water is vital for a simple reason: It is an excellent solvent— that is, an agent for dissolving substances and getting them into solution. This is due to shape of water molecule and an opposing partial charges on it.

- **Hydrogen bond** - Is a weak electrical attraction. Which is formed, When two water molecules approach each other and the partial positive charge on hydrogen attracts the partial negative charge on oxygen. In an aqueous solution, hydrogen bonds also form between water molecules and other polar molecules.
- **Hydrophilic / Hydrophobic** - "Water-loving" and "water-fearing" respectively. Almost all charged or polar molecules are hydrophilic, that is, can dissolve in water. In contrast, molecules with neutral charge are hydrophobic and do not dissolve in water.



- **Cohesion** - Attraction between like molecules. Water is cohesive. This enhanced attraction results in tension that minimizes the total surface area of water.
- **Adhesion** - Attraction between unlike molecules. Adhesion is usually analyzed in regard to interactions between a liquid and a solid surface. Water adheres to surface that has any polar or charged components. *Cohesion and adhesion are important in explaining how water can move from the roots of plants to their leaves against the force of gravity.*
- **Water is denser as a Solid than as a Liquid** - Important for ice formation on top of the water surface.
- **pH** - expresses the concentration of protons in a solution, and thus whether it is acidic or basic, with a logarithmic notation. pH = -log[H^+], *Where H^+ is concentration of hydrogen cations measured in moles.* Neutral pH is said to be 7, since it's pH of water.
- **Homeostasis** - Constant condition.

3 Chemical Reactions

Chemical reactions are written in a format similar to mathematical equations: The initial, or **reactant**, molecules are shown on the left and the resulting reaction **product(s)** shown on the right. For example, the most common reaction in the mix of gases and water vapor that emerges from volcanoes results in the production of carbonic acid, which can be precipitated with water as acid rain: $CO_2 + H_2O \rightleftharpoons CH_2O_3$

- **Chemical equilibrium** - When the forward and reverse reactions proceed at the same rate, the quantities of reactants and products remain constant.Changing the concentration of reactants or products can disturb a chemical equilibrium. A chemical equilibrium can also be altered by changes in temperature. Change in equilibrium will drive the reaction to one side, until new equilibrium is reached.
- **Endothermic/Exothermic reactions** - Literally "Whiting heating" and "Outside heating". Reactions that **consume heat** are endothermic and ones that release are exothermic.
- **Entropy** - The amount of disorder in a system.
- **Spontaneous reaction** - Chemical reactions are spontaneous if they are able to proceed on their own, without any continuous external influence, such as added energy. Two factors determine if a reaction will proceed spontaneously:

  1. Reactions tend to be spontaneous when the product molecules are less ordered than the reactant molecules
  2. Reactions tend to be spontaneous if the products have lower potential energy than the reactants.

  To summarize: In general, physical and chemical processes proceed in the direction that results in increased entropy and lower potential energy.

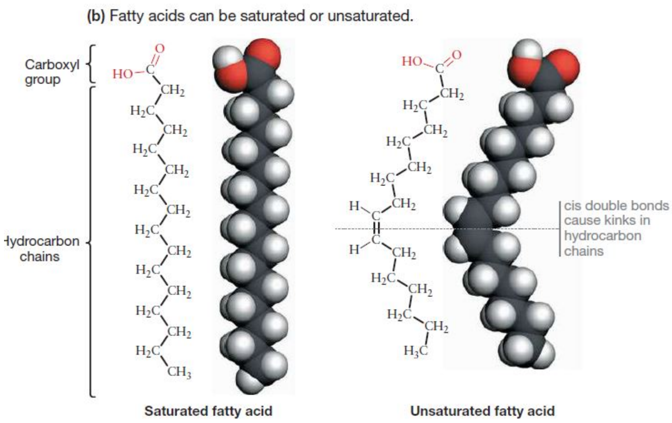
4 Carbohydrates

this unit highlights the four types of macromolecules that were key to the evolution of the cell: proteins, nucleic acids, carbohydrates, and lipids.

- **Carbohydrate(Sugar)** - The term encompasses the monomers called **monosaccharides**("one-sugar"), small polymers called **oligosaccharides** ("few-sugars"), and the large polymers called **polysaccharides** ("many-sugars"). The name **carbohydrate** is logical because the molecular formula of many of these molecules is $(CH_2O)n$, where the n refers to the number of "carbon-hydrate" groups. they are molecules with a **carbonyl**(C=O) and several **hydroxyl**(-OH) functional groups, along with several to many **carbon–hydrogen**(C-H) bonds. Even seemingly simple changes in structure—like the location of a single hydroxyl group—can have enormous consequences for function.
- **Polysaccharides** - Simple sugars can be covalently linked into chains of varying lengths, also known as complex carbohydrates. especially long chained monomers are called polysaccharides.
- **disaccharides** - Two sugars linked together.

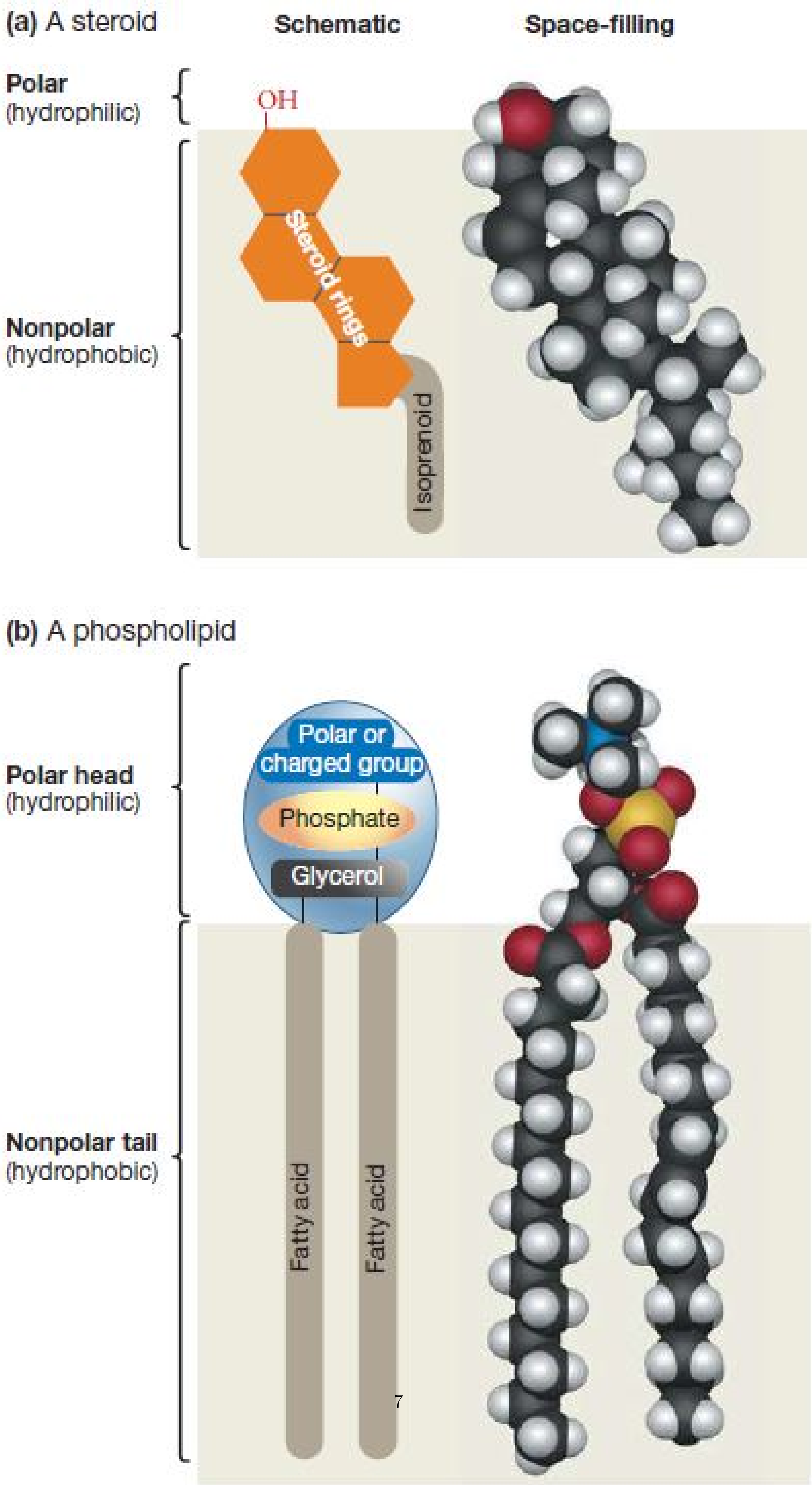
5 Lipids, Membranes, and the First Cells

- **Lipid -** Is a catchall term for carbon-containing compounds that are found in organisms and are largely non-polar and hydrophobic. This insolubility is based on the high proportion of non-polar C-C and C-H bonds.
- **Hydrocarbon** - C-H group, which has non-polar covalent bond.
- **Fatty acid** - a simple lipid consisting of a hydrocarbon chain bonded to a carboxyl −COOH functional group.
- **Fatty acid Saturation** - C-C bond in the hydrocarbon chains is the key factor for the lipids. Fatty acid is said to be saturated if there are no double bonds between carbon atoms (Meaning that every unpaired valence electron has been used to connect to hydrogen). Fatty acid is unsaturated if it has one or more doubly bonded carbon atoms (It didn't use all of it's resources "to be saturated" by hydrogen).

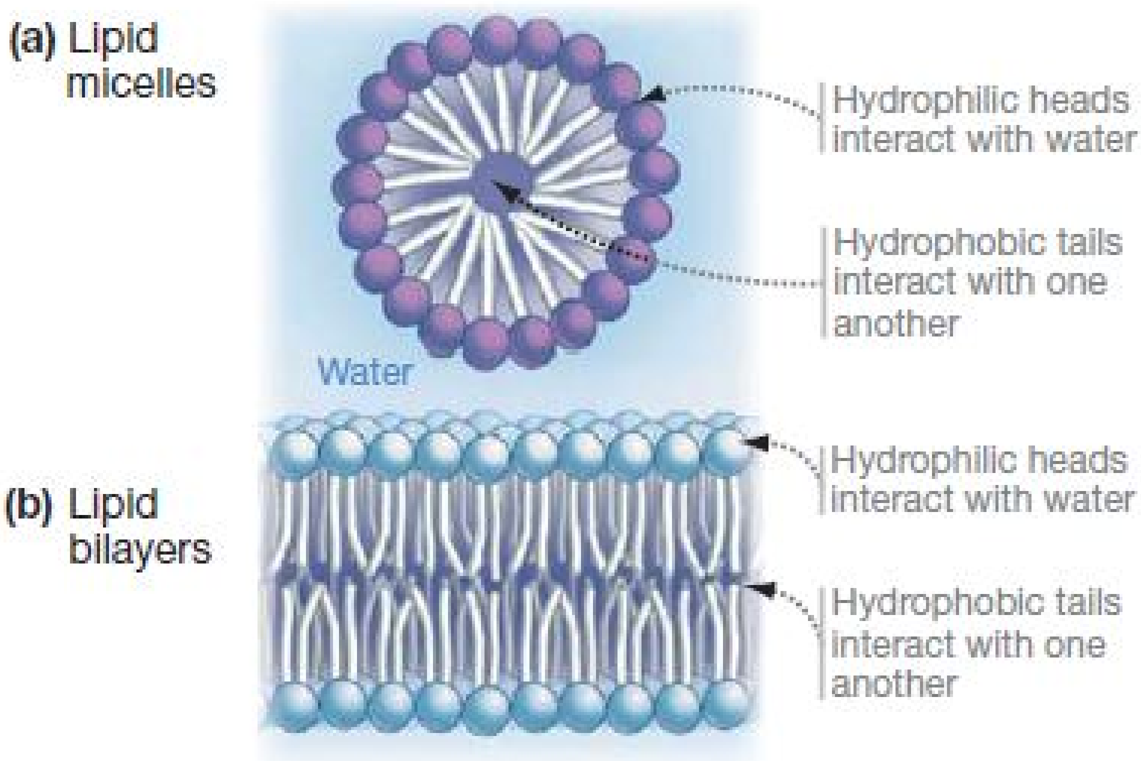


Bond saturation affects physical state of the lipids. High saturated fats are solid at room temperature (for example butter), where unsaturated lipids are liquid.

- **Fats** - are non-polar molecules composed of three fatty acids that are linked to a three-carbon molecule called glycerol. Due to this, fats are also called **triacylglycerols or triglycerides**. Primary role is energy storage.
- **Oils** - Polysaturated fatty acids, liquid triglycerides.
- **Steroids** - Family of lipids, distinguished by the bulky, four-ring structure and hydroxyl group.
- **Phospholipids** - They are crucial components of the plasma membrane. consist of a glycerol that is linked to a phosphate group and two hydrocarbon chains of either isoprenoids or fatty acids. The phosphate group is also bonded to a small organic molecule that is charged or polar.
- **Amphipathic** - Are compounds that contain both hydrophilic and hydrophobic parts (i.e. Phospholipids) Membrane-forming lipids have a polar, hydrophilic region—in addition to the non-polar, hydrophobic region found in all lipids.


(a) A steroid
Schematic
Space-filling
Polar
(hydrophilic)
OH
Nonpolar
(hydrophobic)
Steroid rings
Isoprenoid
(b) A phospholipid
Polar head
(hydrophilic)
Polar or charged group
Phosphate
Glycerol
Nonpolar tail
(hydrophobic)
Fatty acid
Fatty acid

- **Amphipathic layers** - Amphipathic lipids do not dissolve when they are placed in water. Their hydrophilic heads interact with water, but their hydrophobic tails do not. Instead of dissolving in water, then, amphipathic lipids assume one of two types of structures: micelles or lipid bilayers.
  - **Micelles** - are tiny droplets created when the hydrophilic heads of a set of lipids face the water and form hydrogen bonds, while the hydrophobic tails interact with each other in the interior, away from the water (Van der Waals forces).
  - **lipid bilayer** - is created when two sheets of lipid molecules align. The hydrophilic heads in each layer face the surrounding solution while the hydrophobic tails face one another inside the bilayer. In this way, the hydrophilic heads interact with water while the hydrophobic tails interact with one another.



Micelles tend to form from fatty acids or other simple amphipathic hydrocarbon chains. Bilayers tend to form from phospholipids that contain two hydrocarbon tails. For this reason, bilayers are often called phospholipid bilayers.