**Chapter 2**

**Are We Alone in the Universe?  
Water, Biochemistry, and Cells**

**What Does Life Require?**

**A Definition of Life**

* There is no simple definition of life. Instead there is a list of characteristics.
  + Growth
  + Movement
  + Reproduction
  + Response to external environmental stimuli
  + Metabolism
  + But, all Earth organisms…
    - have a common set of biological molecules
    - Are composed of cells
    - can maintain **homeostasis**
    - can evolve
    - require liquid **water**

**The Properties of Water**

* **Elements:** fundamental forms of matter
* **Atoms:** the smallest units of an element
* Atoms are composed of
  + **Protons (positive charge)** and **neutrons** in the **nucleus** of the atom
  + **Electrons (negative charge)** are found in an “electron cloud”
* **Ions** are atoms with an electrical charge.
* **Atomic number** is determined by the number of protons in the nucleus
* **Molecule:** two or more atoms held together by **chemical bonds**
* Water molecule: two hydrogen atoms bonded to one oxygen atom
* Water is a good **solvent** (helps chemical reactions).
  + **Solute:** what is being dissolved in the solvent
  + **Solution:** solutes added to a solvent
* Water is a **polar** molecule:
  + Oxygen side is   
    slightly negative
    - Because it is more   
      **electronegative** than hydrogen
  + Hydrogen side is slightly positive
* When molecules have no charges, they are **nonpolar.**
* **Hydrogen bond:** the weak attraction between the hydrogen atom of one water molecule and the oxygen atom of another
* Water can dissolve salts and **hydrophilic** (water–loving) molecules   
  because it is polar.
* Nonpolar molecules such as oil are **hydrophobic** (water-fearing) and do not easily dissolve in water
* Water facilitates chemical reactions
* Solutes in the mixture are called **reactants**
* End result of the chemical reaction are called **products**
* Water molecules tend to stick together: **cohesion**
* Water moderates temperature
* Water can dissolve **acids** and **bases**.
* The **pH scale** is a measure of the relative amounts of acids and bases in a solution.
  + pH greater than 7 = basic
  + pH lower than 7 = acidic
  + Pure water = 7 – neutral

**Organic Chemistry**

* All life on Earth is based on **organic chemistry**: the chemistry of the complex carbon containing molecules.
* Carbon makes up most of the mass of living organisms.
  + Carbon: a molecular TinkerToy
  + Can bond to 4 different atoms at once
  + Carbon can make **hydrocarbons**
    - Simple organic molecules
  + Carbon can make **macromolecules**
* Chemical bonds are dependent on the atom’s electron configuration.
* Electrons are arranged in energy levels or **electron shells**
  + 1st electron shell holds up to 2 electrons
  + 2nd and 3rd electron shells holds up to 8 electrons each
  + The outer shell that holds electrons is called the **valence shell**
  + **Covalent bonds:** strong bonds from sharing electrons
  + Single bonds indicate sharing of one pair of electrons
  + Double bonds share two pairs of electrons
  + **Ionic bonds:** occurs when there is a transfer of electrons between atoms.

**Structure and Function of Macromolecules**

* + **Carbohydrates:** molecules of carbon, oxygen, and hydrogen
    - Major source of energy for cells
    - Monosaccharides or simple sugars are building blocks for carbohydrates
    - Disaccharides are composed of two monosaccharides
    - Polysaccharides are composed of many monosaccharides
  + **Proteins:** polymers of **amino acids;** joined by **peptide bonds**
    - Proteins are made up of carbon, oxygen, hydrogen, and nitrogen.
    - There are 20 different amino acids, with different chemical properties.
    - Different combinations of amino acids give proteins different properties.
  + Lipids: hydrophobic; composed mostly of carbon and hydrogen
    - Three types:
      * **Fat** is composed of a glycerol molecule joined with 3 fatty acid tails
      * **Steroids** are a four carbon ring structure such as cholesterol, estrogen and testosterone
      * **Phospholipids** are composed of a glycerol molecule, 2 fatty acid tails and a phosphate group
  + Nucleic acids: polymers of nucleotides
    - Nucleotide: sugar + a phosphate + a nitrogenous base
    - Nucleotides are of two types: **RNA** and **DNA**, depending on the sugar.
    - DNA is the hereditary material in nearly all organisms.
    - The structure of a DNA molecule is a double helix.
    - Bonding between bases on opposite strands follows strict **base-pairing rules:**
      * **A with T**
      * **G with C**
      * Each strand consists of a **sugar-phosphate backbone**

**Prokaryotic and Eukaryotic Cells**

* + A **cell** is the fundamental structural unit of life
  + All cells on Earth are either **prokaryotic** or **eukaryotic**.
  + Prokaryotic cells are smaller and simpler in structure.
  + Prokaryotic cells probably resemble the earliest cells to arise on Earth.
  + Some structures in the Martian meteorite resemble prokaryotic cells.
  + Prokaryotes do not have a true nucleus.
  + Prokaryotes do have cell wall
  + Eukaryotic cells are much more complex.
    - Have a true nucleus surrounded by a membrane
    - Also have membrane-bound **organelles** with specialized jobs

**Cell Structure**

* + All cells are surrounded by a **plasma membrane**.
    - Made of a **phospholipids bilayer**: hydrophobic tails orient inside the membrane, away from water
    - **Fluid mosaic**: lipids and proteins can move about within the membrane
    - **Semipermeable**: some molecules can cross and some can’t
  + **Nucleus:** surrounded by a double nuclear membrane which houses DNA
  + **Ribosomes:** assembly proteins can be attached to membranes or free floating
  + **Cytosol:** watery substances that surrounds the nucleus and organelles
  + **Mitochondria**: provide energy for the cell, using oxygen
  + **Chloroplasts**: sites of photosynthesis in plant cells
  + **Lysosomes:** contain digestive enzymes to break down substances
  + **Rough Endoplasmic reticulum**: involved in protein synthesis and has ribosomes attached to its membrane
  + **Smooth Endoplasmic reticulum**: involved in lipid synthesis and lacks ribosomes
  + **Golgi apparatus**: modifies and sorts proteins and packages them into vesicles
  + **Centrioles**: moves genetic material during cell division
  + **Cytoskeleton**: maintains cell shape
  + **Central vacuole:** found in plant cells and stores water, starch and pigments

**The Tree of Life and Evolutionary Theory**

* All Earth organisms share many similarities:
  + Same basic biochemistry, with same types of macromolecules
  + All organisms consist of cells
  + Cells always have phospholipids bilayer plasma membrane
  + Eukaryotes share most of the same organelles
  + These ideas are known as the **theory of evolution**
  + Natural selection is based on the variations in organisms that may increase or decrease survival
  + This **unity of life** is best explained by a **tree of life**, with modern   
    species having evolved from **common ancestors**.