**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**.