# Chapter 2: Introduction to the Chemistry of Life

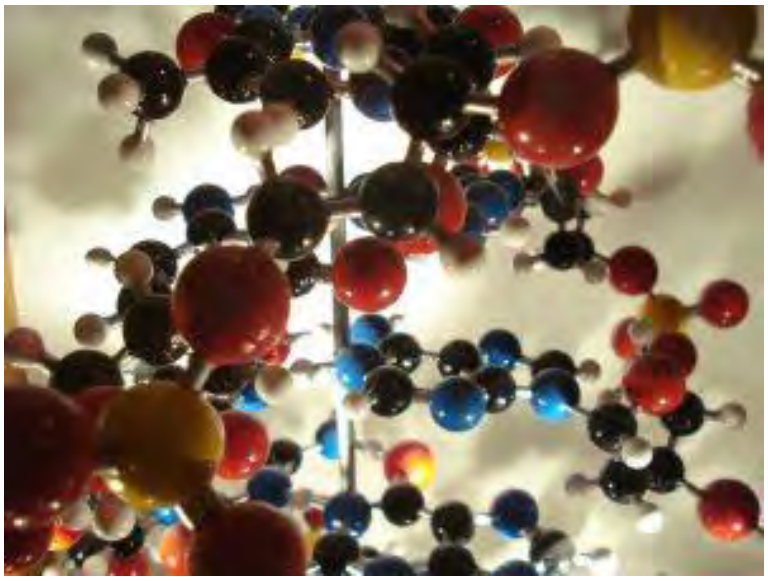


Figure 2.1 Atoms are the building blocks that come together through chemical bonding to form molecules in the universe. In this model of a molecule, the atoms of carbon (black), hydrogen (white), nitrogen (blue), oxygen (red), and sulfur (yellow) are in proportional atomic size. The silver rods indicate chemical bonds that hold the atoms together in a specific three-dimensional shape. (credit: modification of work by Christian Guthier)

The elements carbon, hydrogen, nitrogen, oxygen, sulfur, and phosphorus are the key building blocks found in all living things. Elements are unique forms of matter with specific chemical and physical properties that cannot be broken down into simpler substances by ordinary chemical processes. They form the carbohydrates, lipids, proteins, and nucleic acids which are the fundamental components of all organisms. In this chapter, we will discuss how the unique properties of atoms allow them to interact and form the molecules of life.

## 2.1 The Building Blocks of Molecules

**Learning objectives**

By the end of this section, you will be able to:

- *Describe matter, elements, and compounds*
- *Describe the interrelationship between protons, neutrons, and electrons*
- *Be able to use the number of electrons an element has to determine its reactivity*
- *Be able to define and explain all bolded terms*

At its most fundamental level, life is made up of matter. **Matter** is any substance that occupies space and has mass. **Elements** are unique forms of matter with specific chemical and physical

properties that cannot be broken down into simpler substances by ordinary chemical reactions. There are 118 elements, but only 98 occur naturally. The remaining elements are unstable and require scientists to synthesize them in laboratories.

Each element is typically designated by a single capital letter, or two letters if the first letter is already "taken" (Figure 2.2). Some elements follow the English term for the element, such as C for carbon and Ca for calcium. Other elements' chemical symbols are derived from their Latin names. For example, the symbol for sodium is Na, referring to *natrium*, the Latin word for sodium.


Figure 2.2a The element of hydrogen as designated on a periodic table (credit: Science Activist/Flickr) b. The element of helium as designated on a periodic table (credit: Science Activist/Flickr)

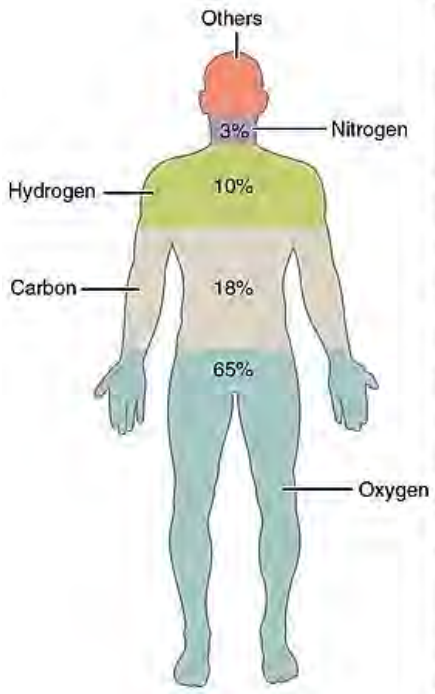
The four elements common to all living organisms are oxygen (O), carbon (C), hydrogen (H), and nitrogen (N). Some elements common to all living organisms are relatively rare on the earth as a whole, as Table 2.1 shows. For example, the atmosphere is rich in nitrogen and oxygen but contains very little carbon and hydrogen. The earth's crust contains oxygen and a small amount of hydrogen but has little nitrogen and carbon. In spite of their differences in abundance, all elements obey the same chemical and physical laws.

**Approximate Percentage of Elements in Living Organisms (Humans) Compared to the Nonliving World**

| Element | Life (Humans) | Atmosphere | Earth's Crust |
|---|---|---|---|
| Oxygen (O) | 65% | 21% | 46% |
| Carbon (C) | 18% | trace | trace |
| Hydrogen (H) | 10% | trace | 0.1% |
| Nitrogen (N) | 3% | 78% | trace |

Table 2.1 Approximate Percentage of Elements in Living Organisms (Humans) Compared to the Nonliving World (credit: Clark et al./Biology 2E OpenStax)

Organisms cannot make elements; they must come from the environment. An example of an element that humans must take in is calcium (Ca). When you consume dairy products, calcium is absorbed and used for many processes, including strengthening bones, cell division, muscle contraction, and nervous system function. The elements in the human body are shown in Figure 2.3, beginning with the most abundant: oxygen (O), carbon (C), hydrogen (H), and nitrogen (N). Trace elements are also important to the body but in much lower quantities. Iodine, which is a trace element, is required to make thyroid hormone, an important hormone that regulates body metabolism. Trace element deficiencies will lead to homeostatic imbalances within the body.




| Element | Symbol | Percentage in Body |
|---|---|---|
| Oxygen | O | 65.0 |
| Carbon | C | 18.5 |
| Hydrogen | H | 9.5 |
| Nitrogen | N | 3.2 |
| Calcium | Ca | 1.5 |
| 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 include 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), and zinc (Zn). | | less than 1.0 |

Figure 2.3 Elements of the Human Body - The main elements that compose the human body are shown from most abundant to least abundant. (credit: Betts et al./Anatomy and Physiology OpenStax)

**The Structure of the Atom**

To understand how elements come together, we must first discuss the element's smallest component or building block, the atom. An **atom** is the smallest unit of matter that retains all the chemical properties of the element. For example, one gold atom has all the properties of gold, such as being a solid metal at room temperature. A gold coin is simply a very large number of gold atoms molded into the shape of a coin and contains small amounts of other elements known as impurities. We cannot break gold atoms down into anything smaller while still retaining the properties of gold.