Matter, elements, and atoms

Learn about the structure of the atom, and how atoms make up matter. An atom is the smallest unit of matter that retains all of the chemical properties of an element.

Introduction

What is your body made of? Your first thought might be that it is made up of different organs—such as your heart, lungs, and stomach—that work together to keep your body going. Or you might zoom in a level and say that your body is made up of many different types of cells. However, at the most basic level, your body—and, in fact, all of life, as well as the nonliving world—is made up of atoms, often organized into larger structures called molecules.
Atoms and molecules follow the rules of chemistry and physics, even when they're part of a complex, living, breathing being. If you learned in chemistry that some atoms tend to gain or lose electrons or form bonds with each other, those facts remain true even when the atoms or molecules are part of a living thing. In fact, simple interactions between atoms—played out many times and in many different combinations, in a single cell or a larger organism—are what make life possible. One could argue that everything you are, including your consciousness, is the byproduct of chemical and electrical interactions between a very, very large number of nonliving atoms!

So as an incredibly complex being made up of roughly 7,000,000,000,000,000,000,000,000,000 atoms, you'll probably want to know some basic chemistry as you begin to explore the world of biology, and the world in general.

Matter and elements

The term **matter** refers to anything that occupies space and has mass—in other words, the “stuff” that the universe is made of. All matter is made up of substances called elements, which have specific chemical and physical properties and cannot be broken down into other substances through ordinary chemical reactions. Gold, for instance, is an element, and so is carbon. There are 118 elements, but only 92 occur naturally. The remaining elements have only been made in laboratories and are unstable.

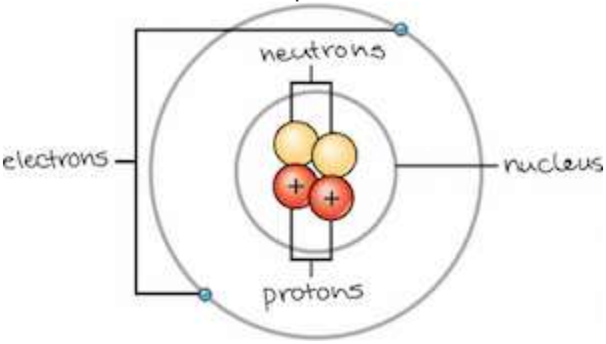
Each element is designated by its chemical symbol, which is a single capital letter or, when the first letter is already “taken” by another element, a combination of two letters. Some elements follow the English term for the element, such as C for carbon and Ca for calcium. Other elements’ chemical symbols come from their Latin names; for example, the symbol for sodium is Na, which is a short form of *natrium*, the Latin word for sodium.

The four elements common to all living organisms are oxygen (O), carbon (C), hydrogen (H), and nitrogen (N), which together make up about 96% of the human body. In the nonliving world, elements are found in different proportions, and some elements common to living organisms are relatively rare on the earth as a whole. All elements and the chemical reactions between them obey the same chemical and physical laws, regardless of whether they are a part of the living or nonliving world.

The structure of the atom

An **atom** is the smallest unit of matter that retains all of the chemical properties of an element. For example, a gold coin is simply a very large number of gold atoms molded into the shape of a coin, with small amounts of other, contaminating elements. Gold atoms cannot be broken down into anything smaller while still retaining the properties of gold. A gold atom gets its properties from the tiny subatomic particles it's made up of.

An atom consists of two regions. The first is the tiny **atomic nucleus**, which is in the center of the atom and contains positively charged particles called **protons** and neutral, uncharged, particles called **neutrons**. The second, much larger, region of the atom is a “cloud” of **electrons**, negatively charged particles that orbit around the nucleus. The attraction between the positively charged protons and negatively charged electrons holds the atom together. Most atoms contain all three of these types of **subatomic particles**—protons, electrons, and neutrons. Hydrogen (H) is an exception because it typically has one proton and one electron, but no neutrons. The number of protons in the nucleus determines which element an atom is, while the number of electrons surrounding the nucleus determines which kind of reactions the atom will undergo. The three types of subatomic particles are illustrated below for an atom of helium—which, by definition, contains two protons.



Structure of an atom. The protons (positive charge) and neutrons (neutral charge) are found together in the tiny nucleus at the center of the atom. The electrons (negative charge) occupy a large, spherical cloud surrounding the nucleus. The atom shown in this particular image is helium, with two protons, two neutrons, and two electrons.

Image credit: modified from OpenStax CNX Biology

Protons and neutrons do not have the same charge, but they do have approximately the same mass, about 1.67×10^{-24} grams. Since grams are not a very convenient unit for measuring masses that tiny, scientists chose to define an alternative measure, the **dalton** or **atomic mass unit** (amu). A single neutron or proton has a weight very close to 1 amu. Electrons are much smaller in mass than protons, only about 1/1800 of an atomic mass unit, so they do not contribute much to an element’s overall atomic mass. On the other hand, electrons do greatly affect an atom’s charge, as each electron has a negative charge equal to the positive charge of a proton. In uncharged, neutral atoms, the number of electrons orbiting the nucleus is equal to the number of protons inside the nucleus. The positive and negative charges cancel out, leading to an atom with no net charge.

Protons, neutrons, and electrons are very small, and most of the volume of an atom—greater than 99 percent—is actually empty space. With all this empty space, you might ask why so-called solid objects don’t just pass through one another. The answer is that the negatively charged electron clouds of the atoms will repel each other if they get too close together, resulting in our perception of solidity.