Origin of Biomolecules

Six nonmetallic elements—carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur—account for more than 97% of the weight of most organisms. All these elements can form stable covalent bonds. The relative amounts of these six elements vary among organisms. Water is a major component of cells and accounts for the high percentage (by weight) of oxygen. Carbon is much more abundant in living organisms than in the rest of the universe.

On the other hand, some elements, such as silicon, aluminum, and iron, are very common in the Earth's crust but are present only in trace amounts in cells. In addition to the standard six elements (CHNOPS), there are 23 other elements commonly found in living organisms (Figure 1.1). These include five ions that are essential in all species: calcium potassium , sodium , magnesium and chloride Note that the additional 23 elements account for only 3% of the weight of living organisms.

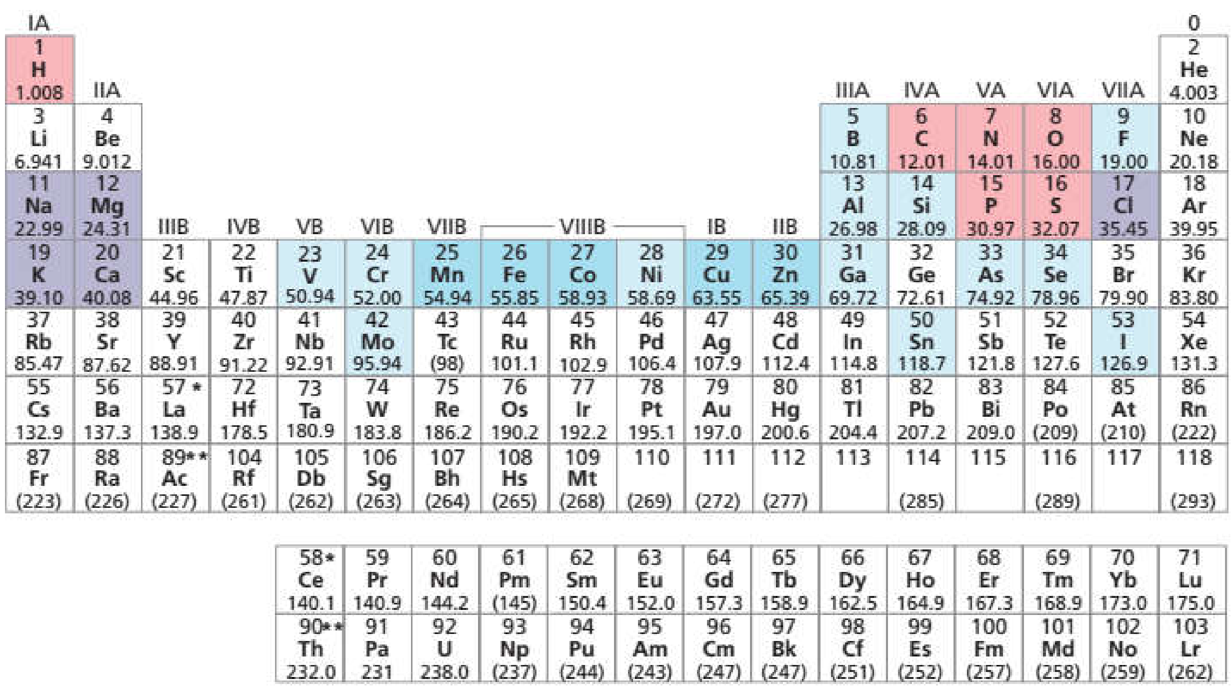

Fig 1. The 23 important elements found in living cells are shown in color.

Most of the solid material of cells consists of carbon-containing compounds. The study of such compounds falls into the domain of organic chemistry. A course in organic chemistry is helpful in understanding biochemistry because there is considerable overlap between the two disciplines. Organic chemists are more interested in reactions that take place in the laboratory, whereas biochemists would like to understand how reactions occur in living cells.

Figure 2a shows the basic types of organic compounds commonly encountered in biochemistry. Biochemical reactions involve specific chemical bonds or parts of molecules called functional groups (Figure 2b). We will encounter several common linkages in biochemistry (Figure 2c). Note that all these linkages consist of several different atoms and individual bonds between atoms. We will learn more about these compounds, functional groups, and linkages throughout this book. Ester and ether linkages are common in fatty acids and lipids. Amide linkages are found in proteins. Phosphate ester and phosphoanhydride linkages occur in nucleotides.

An important theme of biochemistry is that the chemical reactions occurring inside cells are the same kinds of reactions that take place in a chemistry laboratory. The most important difference is that almost all reactions in living cells are catalyzed by enzymes and thus proceed at very high rates. The catalytic efficiency of enzymes can be observed even when the enzymes and reactants are isolated in a test tube. Researchers often find it useful to distinguish between biochemical reactions that take place in an organism (in vivo) and those that occur under laboratory conditions (in vitro).

Many Important Macromolecules Are Polymers

In addition to numerous small molecules, much of biochemistry deals with very large molecules that we refer to as macromolecules. Biological macromolecules are usually a form of polymer created by joining many smaller organic molecules, or monomers, via condensation (removal of the elements of water). In some cases, such as certain carbohydrates, a single monomer is repeated many times; in other cases, such as proteins and nucleic acids, a variety of different monomers is connected in a particular order. Each monomer of a given polymer is added by repeating the same enzyme-catalyzed reaction.

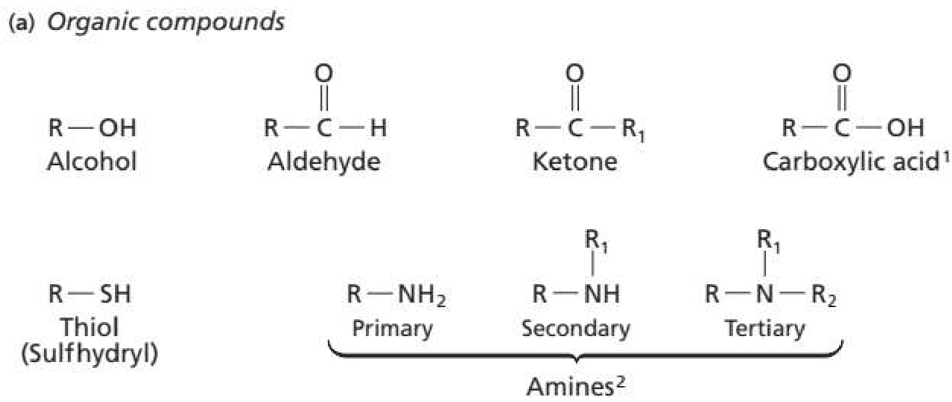

Fig 2a. General formulas of different organic compounds

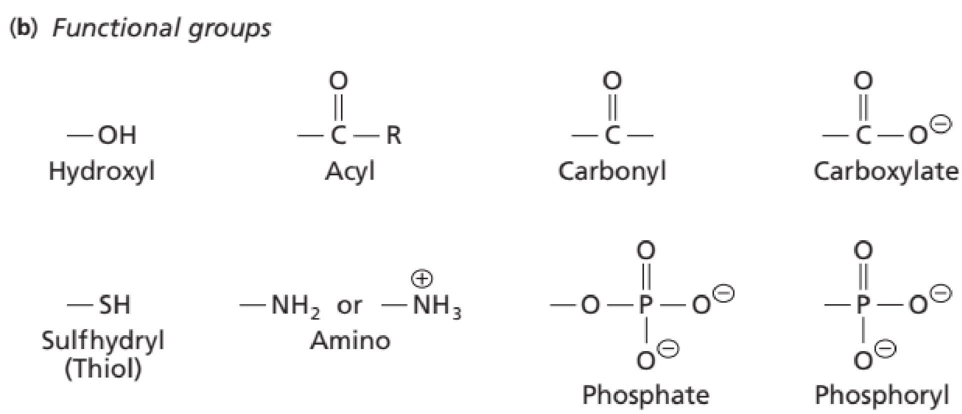

Fig 2b. General formulas of different functional groups

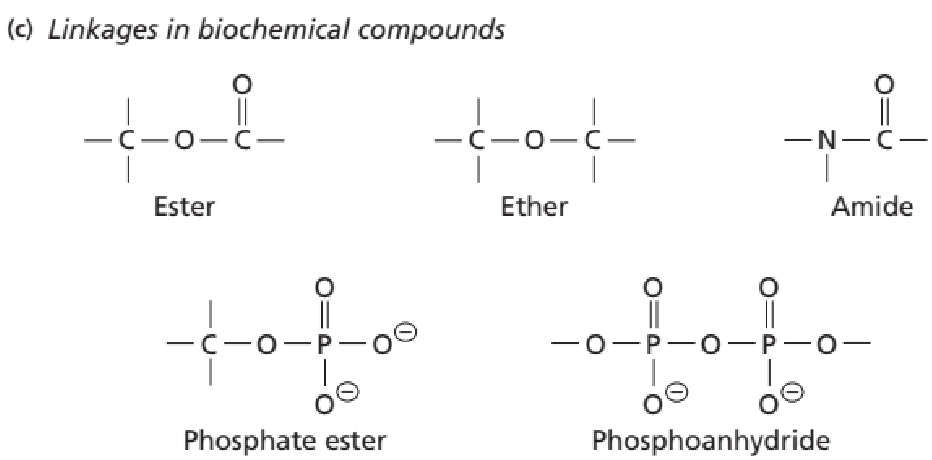

Fig 2c. General formulas of linkages common in biochemistry.

R represents an alkyl group $(CH_3 \neg (CH_2)_n \neg$

Thus, all of the monomers, or residues, in a macromolecule are aligned in the same direction and the ends of the macromolecule are chemically distinct. Macromolecules have properties that are very different from those of their constituent monomers. For example, starch is a polymer of the sugar glucose but it is not soluble in water and does not taste sweet. Observations such as this have led to the general principle of the hierarchical organization of life. Each new level of organization results in properties that cannot be predicted solely from those of the previous level. The levels of complexity, in increasing order, are: atoms, molecules, macromolecules, organelles, cells, tissues, organs, and whole organisms. (Note that many species lack one or more of these levels of complexity. Single-celled organisms, for example, do not have tissues and organs.) The following sections briefly describe the principal types of macromolecules and how their sequences of residues or three-dimensional shapes grant them unique properties.

In discussing molecules and macromolecules we will often refer to the molecular weight of a compound. A more precise term for molecular weight is relative molecular mass (abbreviated M_r). It is the mass of a molecule relative to one-twelfth (1/12) the mass of an atom of the carbon isotope 12C. (The atomic weight of this isotope has been defined as exactly 12 atomic mass units. Note that the atomic weight of carbon shown in the Periodic Table represents the average of several different isotopes, including 13C and 14C.) Because M_r is a relative quantity, it is dimensionless and has no units associated with its value.

The relative molecular mass of a typical protein, for example, is 38,000 The absolute molecular mass of a compound has the same magnitude as the molecular weight except that it is expressed in units called daltons (mass unit *Da*). The molecular mass is also called the molar mass because it represents the mass (measured in grams) of 1 mole, or molecules. The molecular mass of a typical protein is 38,000 daltons, which means that 1 mole weighs 38 kilograms. The main source of confusion is that the term “molecular weight” has become common jargon in biochemistry although it refers to relative molecular mass and not to weight. It is a common error to give a molecular weight in daltons (D*a*) when it should be dimensionless. In most cases, this isn't a very important mistake but you should know the correct terminology.