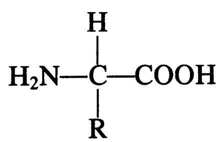
cells. For example, a typical bacterial cell wall contains polysaccharides, proteins, and lipids; cell cytoplasm contains proteins mostly in the form of enzymes; in eucaryotes, the cell nucleus contains nucleic acids mostly in the form of DNA. In addition to these biopolymers, cells contain other metabolites in the form of inorganic salts (e.g., NH_4^+, PO_4^{3-}, K^+, Ca^{2+}, Na^+, SO_4^{2-}), metabolic intermediates (e.g., pyruvate, acetate), and vitamins. The elemental composition of a typical bacterial cell is 50% carbon, 20% oxygen, 14% nitrogen, 8% hydrogen, 3% phosphorus, and 1% sulfur, with small amounts of K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, and vitamins.

The cellular macromolecules are functional only when in the proper three-dimensional configuration. The interaction among them is very complicated. Each macromolecule is part of an intracellular organelle and functions in its unique microenvironment. Information transfer from one organelle to another (e.g., from nucleus to ribosomes) is mediated by special molecules (e.g., messenger RNA). Most of the enzymes and metabolic intermediates are present in cytoplasm. However, other organelles, such as mitochondria, contain enzymes and other metabolites. A living cell can be visualized as a very complex reactor in which more than 2000 reactions take place. These reactions (metabolic pathways) are interrelated and are controlled in a complicated fashion.

Despite all their complexity, an understanding of biological systems can be simplified by analyzing the system at several different levels: molecular level (molecular biology, biochemistry); cellular level (cell biology, microbiology); population level (microbiology, ecology); and production level (bioprocess engineering). This section is devoted mainly to the structure and function of biological molecules.

2.2.2. Amino Acids and Proteins

Proteins are the most abundant organic molecules in living cells, constituting 40% to 70% of their dry weight. Proteins are polymers built from amino acid monomers. Proteins typically have molecular weights of 6000 to several hundred thousand. The α-amino acids are the building blocks of proteins and contain at least one carboxyl group and one α-amino group, but they differ from each other in the structure of their R groups or side chains.



L-amino acid

Although the sequence of amino acids determines a protein's *primary* structure, the *secondary* and *tertiary* structure are determined by the weak interactions among the various side groups. The ultimate three-dimensional structure is critical to the biological activity of the protein. Two major types of protein conformation are (1) fibrous proteins and (2) globular proteins. Figure 2.9 depicts examples of fibrous and globular proteins. Proteins have diverse biological functions, which can be classified in five major categories:

1. Structural proteins: glycoproteins, collagen, keratin
2. Catalytic proteins: enzymes