Chemical bounds

Some Types of Chemical Bonds close to 99% of the weight of a living cell is composed of just four elements: carbon (C), hydrogen (H), nitrogen (N), and oxygen (O). Almost 50% of the atoms are hydrogen atoms; about 25% are carbon, and 25% oxygen. Apart from water (about 70% of the weight of the cell) almost all components are carbon compounds. Carbon, a small atom with four electrons in its outer shell, can form four strong covalent bonds withotheratoms.But most importantly,carbon atoms can combine with each other to build chains and rings, and thus large complex molecules with specific biological properties.

A. Compounds of hydrogen (H), oxygen (O), and carbon (C)

Four simple combinations of these atoms occur frequently in biologically important molecules: hydroxyl (–OH; alcohols), methyl ($–CH_3$), carboxyl (–COOH), and carbonyl (C=O; aldehydes and ketones) groups. They impart to the molecules characteristic chemical properties, including possibilities to form compounds.

B. Acids and esters

Many biological substances contain a carbon– oxygen bond with weak acidic or basic (alkaline) properties. The degree of acidity is expressed by the pH value, which indicates the concentration of H^+ ions in a solution, ranging from 10^{-1} mol/L (pH 1, strongly acidic) to 10^{-14} mol/L (pH 14, strongly alkaline). Pure water contains 10^{-7} moles H^+ per liter (pH 7.0). An ester is formed when an acid reacts with an alcohol. Esters are frequently found in lipids and phosphate compounds.

C. Carbon–nitrogen bonds (C–N)

C–N bonds occur in many biologically important molecules: in amino groups, amines, and amides, especially in proteins. Of paramount significance are the amino acids, which are the subunits of proteins. All proteins have a specific role in the functioning of an organism.

D. Phosphate compounds

Ionized phosphate compounds play an essential biological role. HPO 4 2– is a stable inorganic phosphate ion from ionized phosphoric acid. A phosphate ion and a free hydroxyl group can form a phosphate ester. Phosphate compounds playan important role in energy-rich molecules and numerous macromolecules because they can store energy.

E. Sulfur compounds

Sulfur often serves to bind biological molecules together, especially when two sulfhydryl groups(–SH)reacttoformadisulfidebridge(– S–S–). Sulfur is a component of two amino acids (cysteine and methionine) and of some polysaccharides and sugars. Disulfide bridges play an important role in many complex molecules, serving to stabilize and maintain particular three-dimensional structures.

[The Cell and Its Components]

Cells are the smallest organized structural units able to maintain an individual, albeit limited, life span while carrying out a wide variety of functions. Cells have evolved on earth during the past 3.5 billion years, presumably orginating from suitable early molecular aggregations. Each cell originates from another living cell as postulatedbyR.Virchowin1855(“omniscellula ecellula”).Thelivingworldconsistsoftwobasic types of cells: prokaryotic cells, which carry their functional information in a circular genome without a nucleus, and eukaryotic cells, which contain their genome in individual chromosomes in a nucleus and have a well-organized internal structure. Cells communicate with each other by means of a broad repertoire of molecular signals. Great progress has been made since 1839, when cells were first recognized as the “elementary particles of organisms” by M. Schleiden and T. Schwann. Today we understand most of the biological processes of cells at the molecular level.

Eukaryotic cells

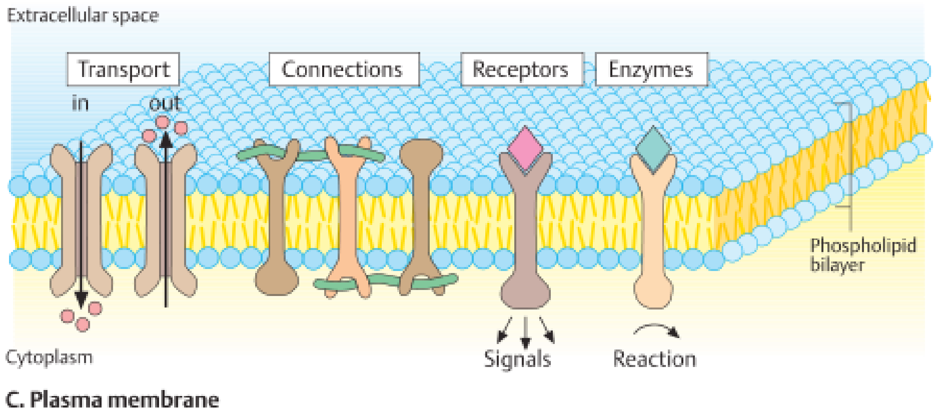
A eukaryotic cell consists of cytoplasm and a nucleus. It is enclosed by a plasma membrane. The cytoplasm contains a complex system of inner membranes that form cellular structures (organelles). The main organelles are the mitochondria (in which important energy–delivering chemical reactions take place), the endoplasmic reticulum (consisting of a series of membranes in which glycoproteins and lipids are formed), the Golgi apparatus (for certain transport functions), and peroxisomes (for the formation or degradation of certain substances). Eukaryotic cells contain lysosomes, in which numerous proteins, nucleic acids, and lipids are broken down. Centrioles, small cylindrical particles made up of microtubules, play an essential role in cell division. Ribosomes are the sites of protein synthesis.

Nucleus

The eukaryotic cell nucleus contains the genetic information.

It is enclosed by an inner and an outer membrane, which contain pores for the transport of substances between the nucleus and the cytoplasm. The nucleus contains a nucleolus and a fibrous matrix with different DNA–protein complexes.

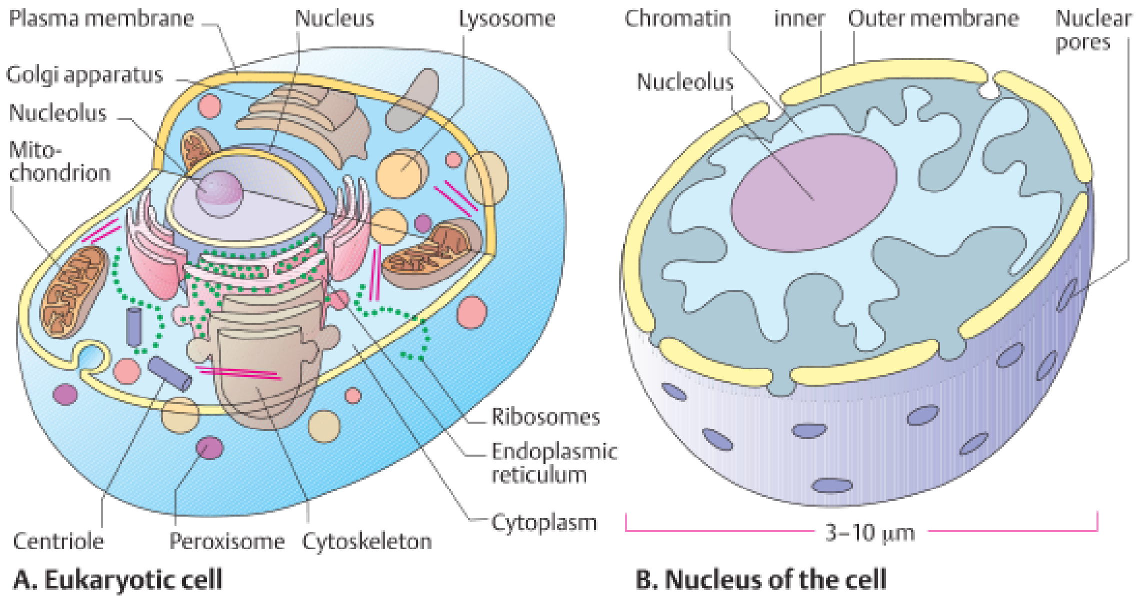
Plasma membrane of the cell



Plasma membrane of the cell

The environment of cells, whether blood or other body fluids, is water-based, and the chemical processes inside a cell involve water soluble molecules.In order to maintain their integrity, cells must prevent water and other molecules from flowing in or out uncontrolled. This is accomplished by a water-resistant membrane composed of bipartite molecules of fatty acids, the plasma membrane. These molecules are phospholipids arranged in a double layer (bilayer) with a fatty interior. The plasma membrane itself contains numerous molecules that traverse the lipid bilayer once or many times to perform special functions. Different types of membrane proteins can be distinguished: (i) transmembrane proteins used as channels for transport of molecules into or out of the cell, (ii) proteins connected with each other to provide stability, (iii) receptor molecules involved in signal transduction, and (iv) molecules with enzyme function to catalyze internal chemical reactions in response to an external signal. (Figure redrawn from Alberts et al., 1998.)

Comparison of animal and plant cells



Eukartotic cell and neucleus

Plant and animal cells have many similar characteristics. One fundamental difference is that plant cells contain chloroplasts for photosynthesis. In addition, plant cells are surrounded by a rigid wall of cellulose and other polymeric molecules and contain vacuoles for water, ions, sugar, nitrogen–containing compounds,orwasteproducts.Vacuolesarepermeable to water but not to the other substances enclosed in the vacuoles. (Figures in A, B and D adapted from de Duve, 1984.) <fn>Alberts,B.etal.:EssentialCellBiology.An Introduction to the Molecular Biology of the Cell. Garland Publishing Co., New York, 1998.</fn> <fn>deDuve,C.:A Guided Tour of the Living Cell.Vol. I and II. Scientific American Books, Inc., New York, 1984.</fn> <fn>Lodish, H. et al.: Molecular Cell Biology (with an animatedCD-ROM).4thed.W.H.Freeman&Co., New York, 2000.</fn>