Kirk-Othmer Encyclopedia of Chemical Technology.

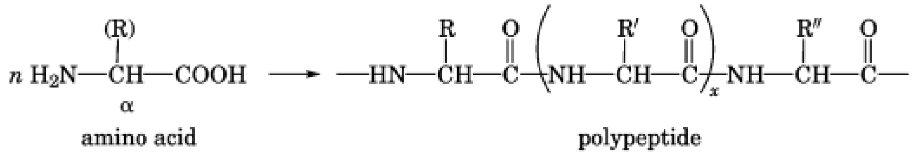
BIOPOLYMERS, SURVEY

Biopolymers are the naturally occurring macromolecular materials that are the components of all living systems. There are three principal categories of biopolymers, each of which is the topic of a separate article in the *Encyclopedia:* proteins (qv); nucleic acids (qv); and polysaccharides (see Carbohydrates; Microbial polysaccharides). Biopolymers are formed through condensation of monomeric units; ie, the corresponding monomers are amino acids (qv), nucleotides, and monosaccharides, for proteins, nucleic acids, and polysaccharides, respectively. The term biopolymers is also used to describe synthetic polymers prepared from the same or similar monomer units as are the natural molecules.

In addition to being necessary for all forms of life, biopolymers, especially enzymes (proteins), have found commercial applications in various analytical techniques (see Automated instrumentation, clinical chemistry; Automated instrumentation, hematology; Biopolymers, analytical techniques; Biosensors; Immunoassay); in synthetic processes (see Enzyme applications, industrial; Enzyme applications in organic synthesis); and in prescribed therapies (see Enzyme applications, therapeutics; Immunotherapeutic agents; Vitamins). Other naturally occurring biopolymers having significant commercial importance are the Cellulose (qv) derivatives, eg, Cotton (qv) and Wood (qv), which are complex polysaccharides.

0.1. Proteins

The most abundant and physiologically diverse natural biopolymers are proteins, which make up enzymes, hormones, and structural material such as hair, skin, and connective tissue. The monomer units of natural proteins, α-amino acids, condense to form dipeptides, tripeptides, polypeptides, and proteins.



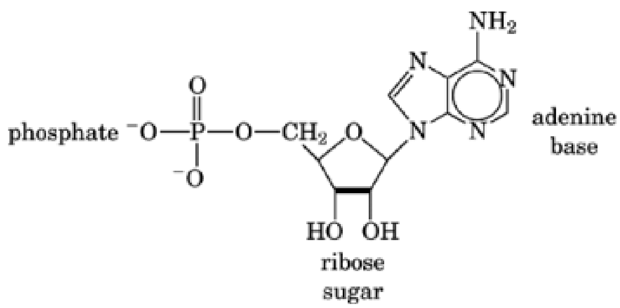
There are approximately 20 common naturally occurring amino acids, hence 20 different R groups that appear as pendents on the polyamide chain. Many other amino acids have been isolated or prepared, each representing a variation in R. The number of isomeric structures is myriad. Protein biosynthesis is mediated by other biopolymers, the nucleic acids.

The amide linkage between monomer units in a protein is called a peptide bond. Peptides and polypeptides, which often exhibit biological activity (see Antibiotics, peptides; Neuroregulators), are smaller than proteins. Although the differentiation between polypeptide and protein is somewhat arbitrary, the usual distinction is drawn around 100 monomer units. Proteins are also characterized by higher levels of structure resulting from internal interactions.

Proteins may consist exclusively of a polymeric chain of amino acids; these are the simple proteins. Quite often some other chemical component is covalently bonded to the amino acid chain. Glycoproteins and lipoproteins contain sugar and lipid components, respectively. Porphyrins are frequently associated with proteins, eg, in hemoglobin. Proteins bound to other chemical components are called conjugated proteins. Most enzymes are conjugated proteins.

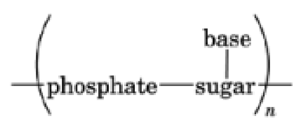
0.2. Nucleic Acids

Nucleic acids are polynucleotides; that is, they are condensation polymers of nucleotide monomers. A nucleotide is a three-component system, ie, a combination of a sugar, a phosphate, and a nitrogenous base residue. Adenosine monophosphate is an example:



A two-component sugar-base unit is called a nucleoside, eg, adenosine. Nucleosides and their derivatives are important pharmaceutically (see Antibiotics, nucleosides and nucleotides; Antiviral agents).

Polymerization of nucleotides occurs through the sugar and phosphate groups so that the polymers consist of a sugar-phosphate backbone having pendent bases.



The sugars are typically ribose (ribonucleic acids, RNA), or 2-deoxyribose (deoxyribonucleic acids, DNA). There are five common bases in nucleic acids: adenine (A); thymine (T); uracil (U); cytosine (C); and guanine (G). DNA polymers incorporate the four bases, A, T, C, and G, and RNA, the set A, U, C, and G.

Nucleic acids are the molecules of the genetic apparatus. They direct protein biosynthesis in the body and are the raw materials of genetic technology (see Genetic engineering). Most often polynucleotides are synthesized microbiologically, or at least enzymatically, but chemical synthesis is possible.

0.3. Polysaccharides

Polysaccharides, also called glycans, are the nutrient and structural materials of plants. They are a principle part of the carbohydrate portion of the biomass. The most prevalent monomeric carbohydrate is glucose. Common polysaccharides are all polymers of glucose (Fig. 1). The distinctions between these homopolymers arise from the different ways in which the monomer units are hooked together in polyacetal chains. Starch (qv), plant nutrient material, is composed of two polysaccharides: α-amylose and amylopectin. α-Amylose is linear because of exclusive α $(1 \longrightarrow 4)$ linkages, whereas amylopectin is branched because of the presence of α $(1 \longrightarrow 6)$ as well as α $(1 \longrightarrow 4)$ links. The terms linear and branched refer only to primary structure.

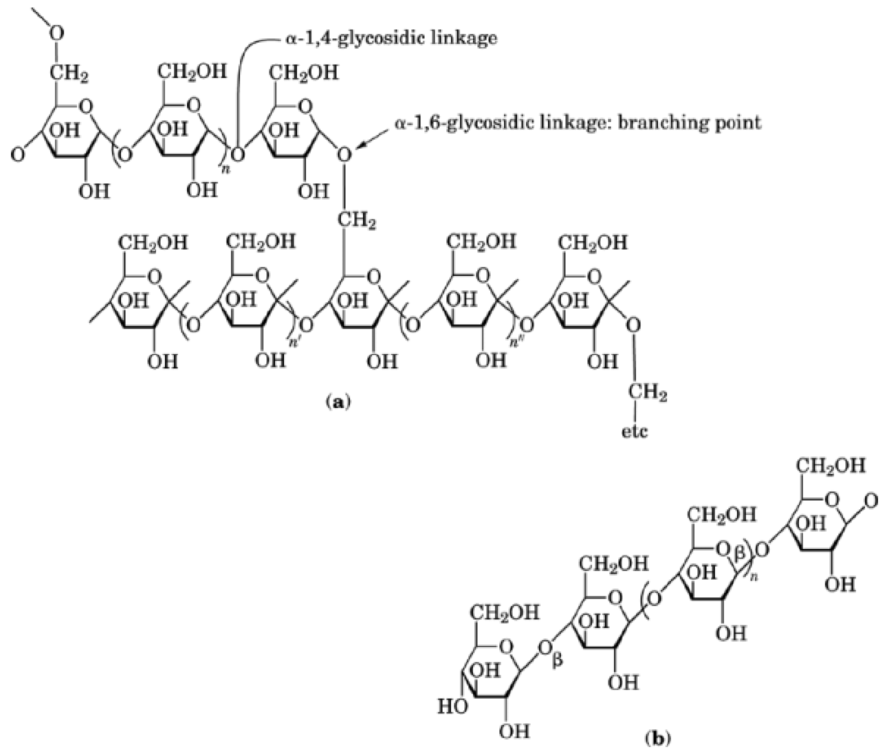


Fig. 1. Primary structures of some common polysaccharides. (**a**) Alpha-glycoside linkages characterize amylose, amylopectin, and glycogen; (**b**) cellulose has β-glycoside linkages.

Plant structural material is the polysaccharide cellulose, which is a linear β $(1 \longrightarrow 4)$ linked polymer. Some structural polysaccharides incorporate nitrogen into their molecular structure; an example is chitin, the material which comprises the hard exoskeletons of insects and crustaceans. Chitin is a cellulose derivative wherein the OH at C-2 is replaced by an acetylated amino group ($-NHCOCH_3$). Microbial polysaccharides, of which the capsular or extracellular (exopolysaccharides) are probably the most important class, show more diversity both in monomer units and the nature of their linkages.

As in the case of proteins, which may be simple or conjugated, oligosaccharides or polysaccharide chains may be covalently bonded to noncarbohydrate chemical components (see Antibiotics, oligosaccharides). For example, carbohydrate–protein combinations are called glycoproteins or proteoglycans depending on which chemical moiety predominates; the latter are also called mucopolysaccharides. Peptidoglycans and lipopolysaccharides are other complex polysaccharides. Murein, which is found in bacterial cell walls, consists of parallel polysaccharide chains cross-linked by short peptide chains. Wood (qv) is cellulose, a polysaccharide, linked to Lignin (qv).

Obviously, much more detail concerning these materials will be found in the *Encyclopedia* articles cited.

Related Articles

Peptides; Neuroregulators; Carbohydrates; Microbial polysaccharides; Genetic engineering