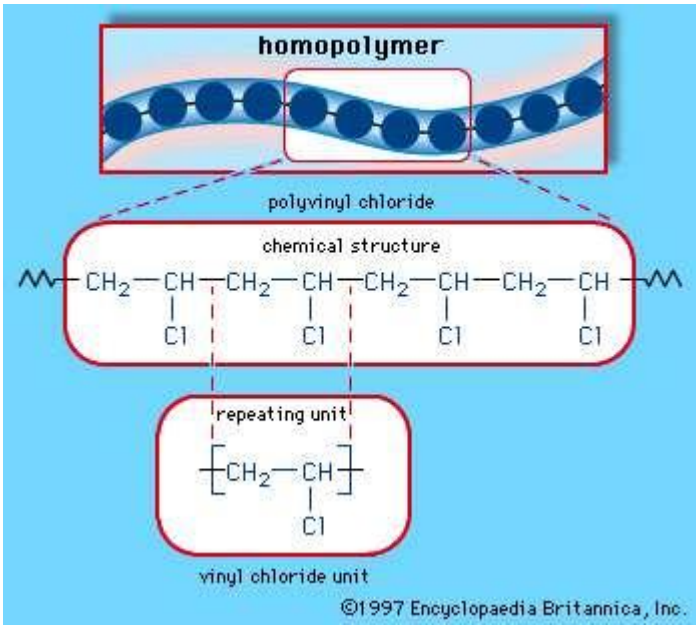
Polymer
chemistry
WRITTEN BY **The Editors of Encyclopaedia Britannica**

Polymer, any of a class of natural or synthetic substances composed of very large molecules, called macromolecules, that are multiples of simpler chemical units called monomers. Polymers make up many of the materials in living organisms, including, for example, proteins, cellulose, and nucleic acids. Moreover, they constitute the basis of such minerals as diamond, quartz, and feldspar and such man-made materials as concrete, glass, paper, plastics, and rubbers.



chemical structure of polyvinyl chloride (PVC)
Industrial polymers are synthesized from simple compounds joined together to form long chains. For example, polyvinyl chloride is an industrial homopolymer synthesized from repeating units of vinyl chloride.
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The word *polymer* designates an unspecified number of monomer units. When the number of monomers is very large, the compound is sometimes called a high polymer. Polymers are not restricted to monomers of the same chemical composition or molecular weight and structure. Some natural polymers are composed of one kind of monomer. Most natural and synthetic polymers, however, are made up of two or more different types of monomers; such polymers are known as copolymers.

Organic polymers play a crucial role in living things, providing basic structural materials and participating in vital life processes. For example, the solid parts of all plants are made up of polymers. These include cellulose, lignin, and various resins. Cellulose is a polysaccharide, a polymer that is composed of sugar molecules. Lignin consists of a complicated three-dimensional network of polymers. Wood resins are polymers of a simple hydrocarbon, isoprene. Another familiar isoprene polymer is rubber (On next page).

Other important natural polymers include the proteins, which are polymers of amino acids, and the nucleic acids, which are polymers of nucleotides—complex molecules composed of nitrogen-containing bases, sugars, and phosphoric acid. The nucleic acids carry genetic information in the cell. Starches, important sources of food energy derived from plants, are natural polymers composed of glucose.

Many inorganic polymers also are found in nature, including diamond and graphite. Both are composed of carbon. In diamond, carbon atoms are linked in a three-dimensional network that gives the material its hardness. In graphite, used as a lubricant and in pencil “leads,” the carbon atoms link in planes that can slide across one another.

natural rubber
Latex tapped from a rubber tree (*Hevea brasiliensis*) in Malaysia.
© *Stuart Taylor/Fotolia*

Synthetic polymers are produced in different types of reactions. Many simple hydrocarbons, such as ethylene and propylene, can be transformed into polymers by adding one monomer after another to the growing chain. Polyethylene, composed of repeating ethylene monomers, is an addition polymer. It may have as many as 10,000 monomers joined in long coiled chains. Polyethylene is crystalline, translucent, and thermoplastic—i.e., it softens when heated. It is used for coatings, packaging, molded parts, and the manufacture of bottles and containers. Polypropylene is also crystalline and thermoplastic but is harder than polyethylene. Its molecules may consist of from 50,000 to 200,000 monomers. This compound is used in the textile industry and to make molded objects.

Other addition polymers include polybutadiene, polyisoprene, and polychloroprene, which are all important in the manufacture of synthetic rubbers. Some polymers, such as polystyrene, are glassy and transparent at room temperature, as well as being thermoplastic. Polystyrene can be coloured any shade and is used in the manufacture of toys and other plastic objects.

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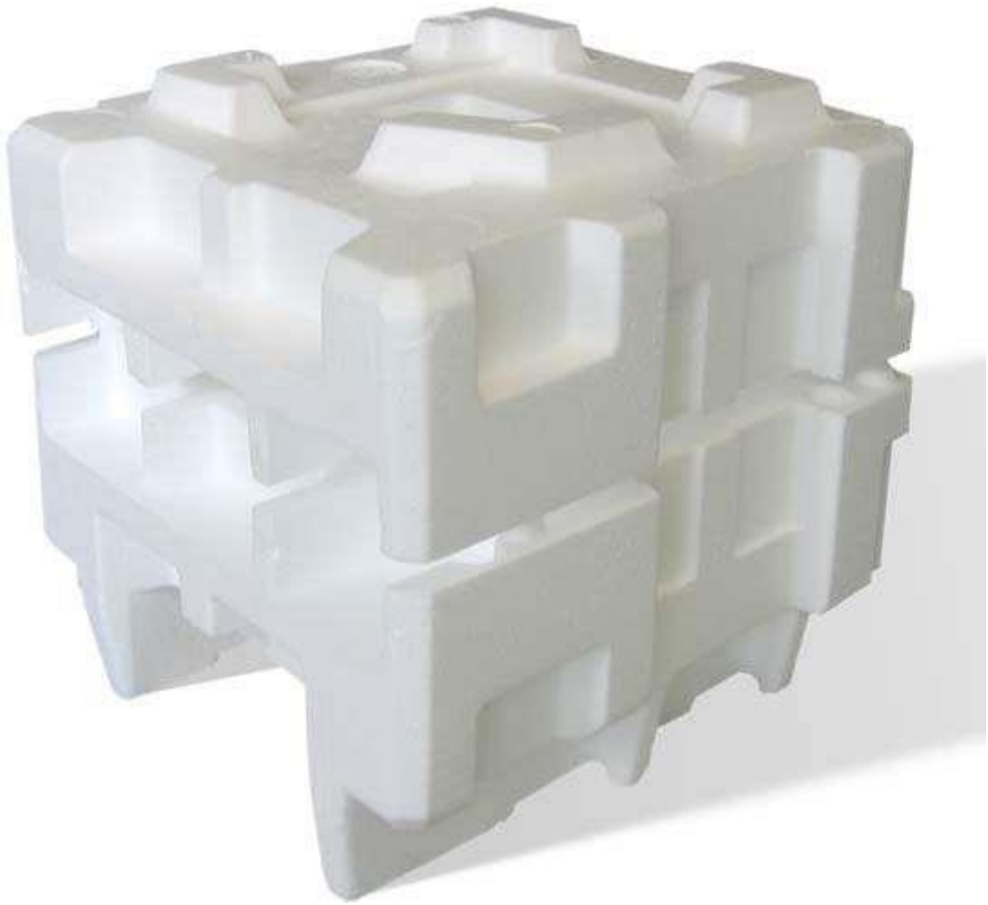
polystyrene
Polystyrene packaging.
Acdx



If one hydrogen atom in ethylene is replaced by a chlorine atom, vinyl chloride is produced. This polymerizes to polyvinyl chloride (PVC), a colourless, hard, tough, thermoplastic material that can be manufactured in a number of forms, including foams, films, and fibres. Vinyl acetate, produced by the reaction of ethylene and acetic acid, polymerizes to amorphous, soft resins used as coatings and adhesives. It copolymerizes with vinyl chloride to produce a large family of thermoplastic materials.

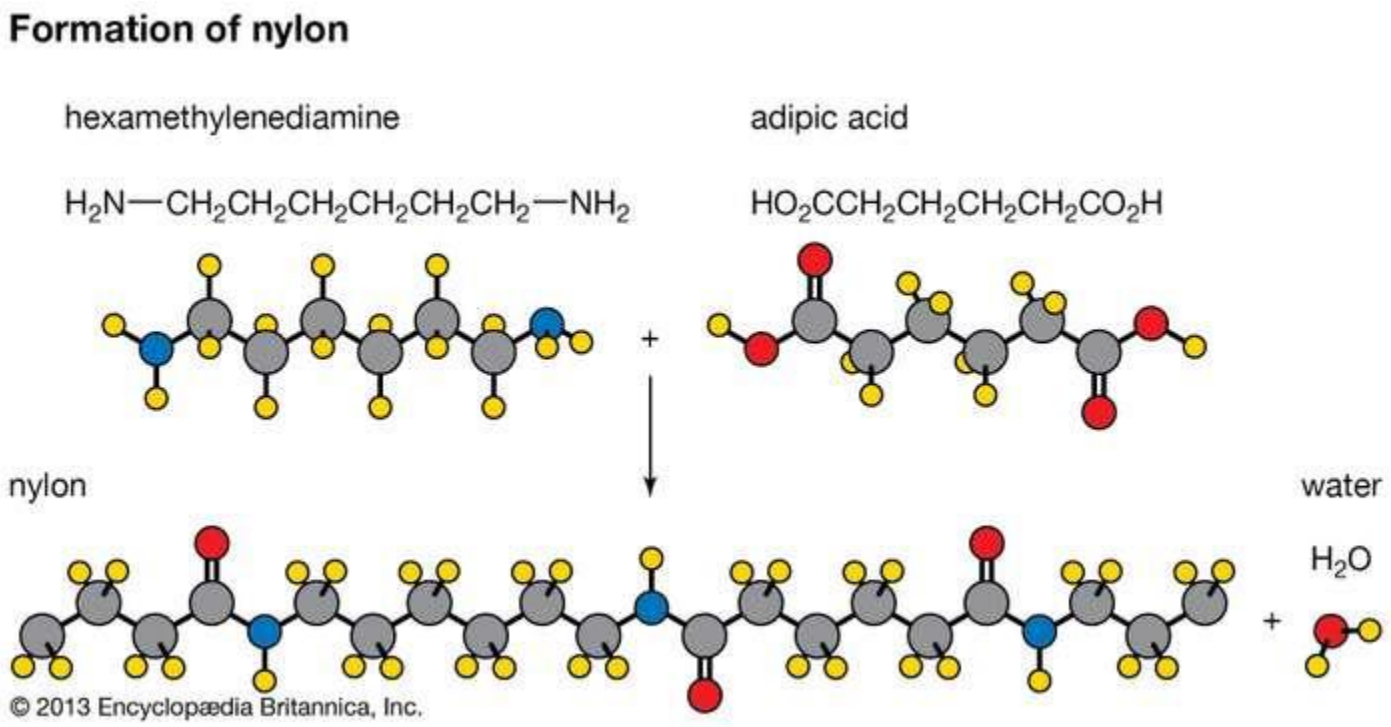
PVC piping
Polyvinyl chloride (PVC) pipes.
AdstockRF

Many important polymers have oxygen or nitrogen atoms, along with those of carbon, in the backbone chain. Among such macromolecular materials with oxygen atoms are polyacetals. The simplest polyacetal is polyformaldehyde. It has a high melting point and is crystalline and resistant to abrasion and the action of solvents. Acetal resins are more like metal than are any other plastics and are used in the manufacture of machine parts such as gears and bearings.

A linear polymer characterized by a repetition of ester groups along the backbone chain is called a polyester. Open-

chain polyesters are colourless, crystalline, thermoplastic materials. Those with high molecular weights (10,000 to 15,000 molecules) are employed in the manufacture of films, molded objects, and fibres such as Dacron.

The polyamides include the naturally occurring proteins casein, found in milk, and zein, found in corn (maize), from which plastics, fibres, adhesives, and coatings are made. Among the synthetic polyamides are the urea-formaldehyde resins, which are thermosetting. They are used to produce molded objects and as adhesives and coatings for textiles and paper. Also important are the polyamide resins known as nylons. They are strong, resistant to heat and abrasion, noncombustible, and nontoxic, and they can be coloured. Their best-known use is as textile fibres, but they have many other applications.



nylon
The formation of nylon, a polymer.
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Another important family of synthetic organic polymers is formed of linear repetitions of the urethane group. Polyurethanes are employed in making elastomeric fibres known as spandex and in the production of coating bases and soft and rigid foams.

A different class of polymers are the mixed organic-inorganic compounds. The most important representatives of this polymer family are the silicones. Their backbone consists of alternating silicon and oxygen atoms with organic groups attached to each of the silicon atoms. Silicones with low molecular weight are oils and greases. Higher-molecular-weight species are versatile elastic materials that remain soft and rubbery at very low temperatures. They are also relatively stable at high temperatures.

caulk
Silicone caulk being dispensed from a caulking gun.
Achim Hering

Fluorocarbon-containing polymers, known as fluoropolymers, are made up of carbon–fluorine bonds, which are highly stable and render the compound resistant to solvents. The nature of carbon–fluorine bonding further imparts a nonstick quality to fluoropolymers; this is most widely evident in the polytetrafluoroethylene (PFTE) Teflon.

The Editors of Encyclopaedia Britannica This article was most recently revised and updated by Kara Rogers, Senior Editor.

QUICK FACTS

KEY PEOPLE

- Karl Ziegler
- J. Fraser Stoddart
- Herman Francis Mark
- Carl Shipp Marvel
- Werner Kuhn
- Stephanie Kwolek
- Hermann Staudinger
- Pierre-Gilles de Gennes
- Giulio Natta