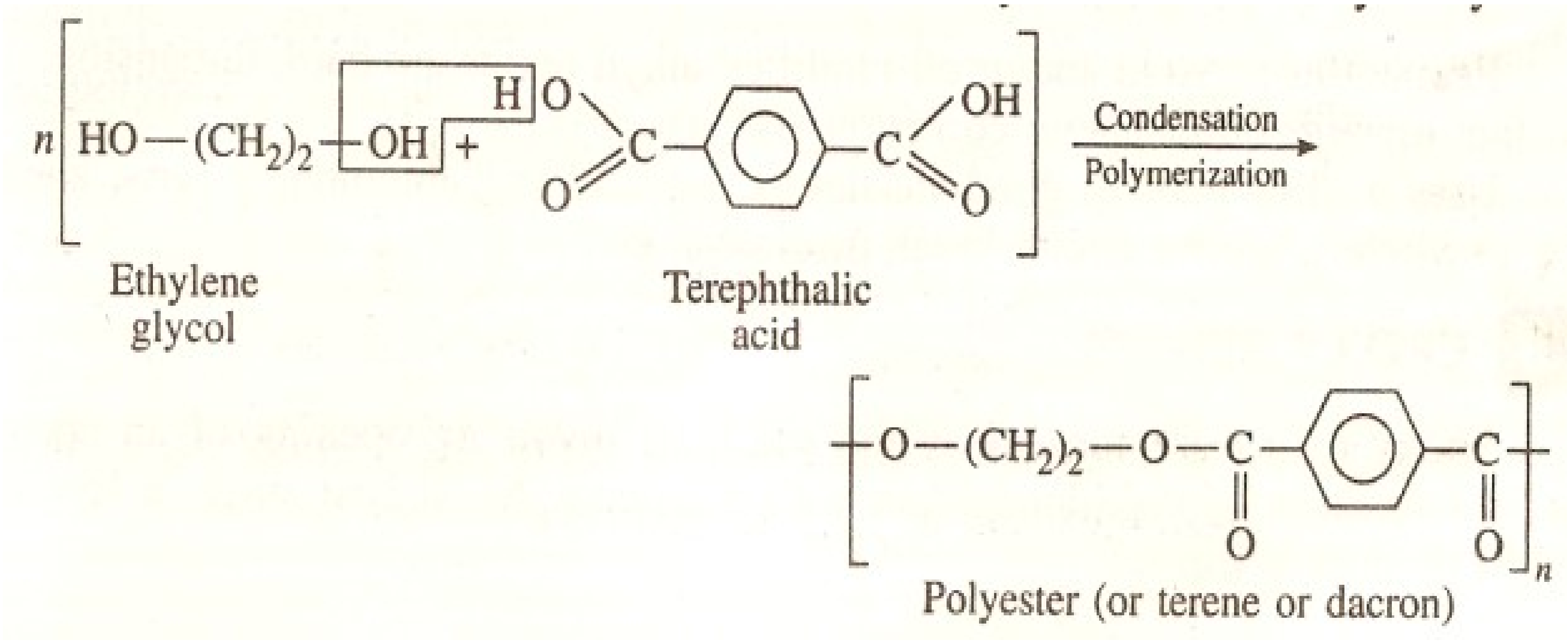
POLYMERS

Polyester : These are the condensation products of dicarboxylic acid with dihydroxy alcohols.



POLYMERS

Properties:

1. Because of its relative symmetrical structure and presence of numerous polar groups, the polyester is a good fibre-forming material and is converted into commercial fibres.
2. Such fibres have high stretch-resistance (due to high stiffness of polymer chains).
3. Polyethylene terephthalate (PET) is highly resistant to mineral and organic acids, but is less resistant to alkalis.

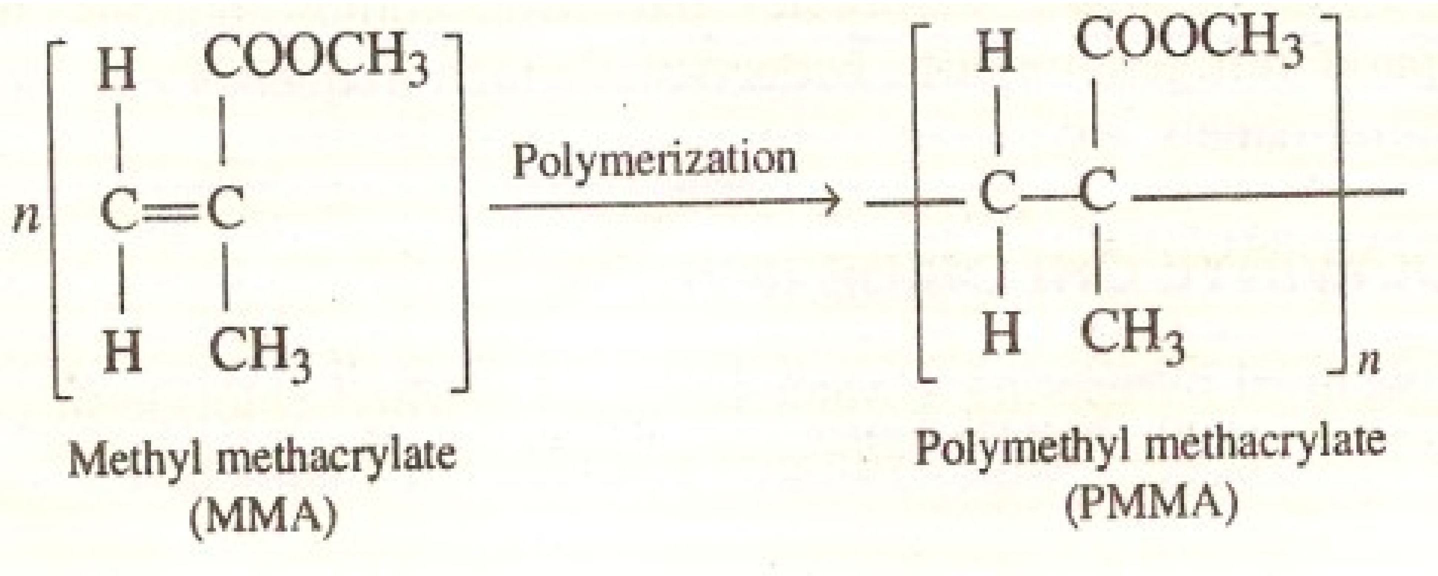
Uses : 1. It is mostly used for making synthetic fibres like terylene, dacron etc.

2. For blending with wool to provide better crease and wrinkle resistance.

3. As glass reinforcing material in safety he/ments, aircrafls ballery boxes, etc.

POLYMERS

Polymethyl Methacrylate (PMMA) or Lucite or Plexiglass : It is obtained by polymerization of methyl methacrylate (ester of methyl acrylic acid, $CH_2=C(CH_3)COOH$) in presence of acetyl peroxide or hydrogen peroxide. It is an acrylic polymer.



POLYMERS

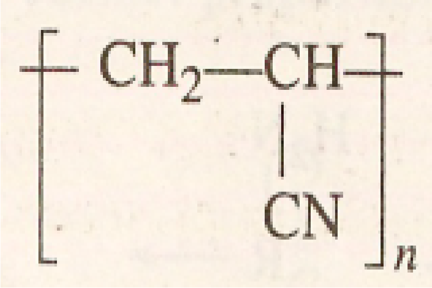
Properties:

1. Polymethyl methacrylate (PMMA) is hard, fairly rigid material with a high softening point of about 130-140°C, but it becomes rubber-like at a temperature above 65°C.
2. This relatively wide span of temperature from its rigid state to viscous consistency accounts for the outstanding shape-forming properties of polymethyl metha-crylate.
3. It has high optical-transparency, high resistance to sunlight and ability of transmitting light accurately, even in curved sections.

Uses: For making lenses, aircraft light fixtares, transparent models of compljcated machines, bone splints, artificial eyes, dentares, emulsions, paints, adhesives, automotive appliances, jewellery, wind screens, T. V. Screens, guards etc.

POLYMERS

POLYACRYLONITRILE (PAN) : It is also known as polyvinyl cyanide and obtained from acrylonitrile.

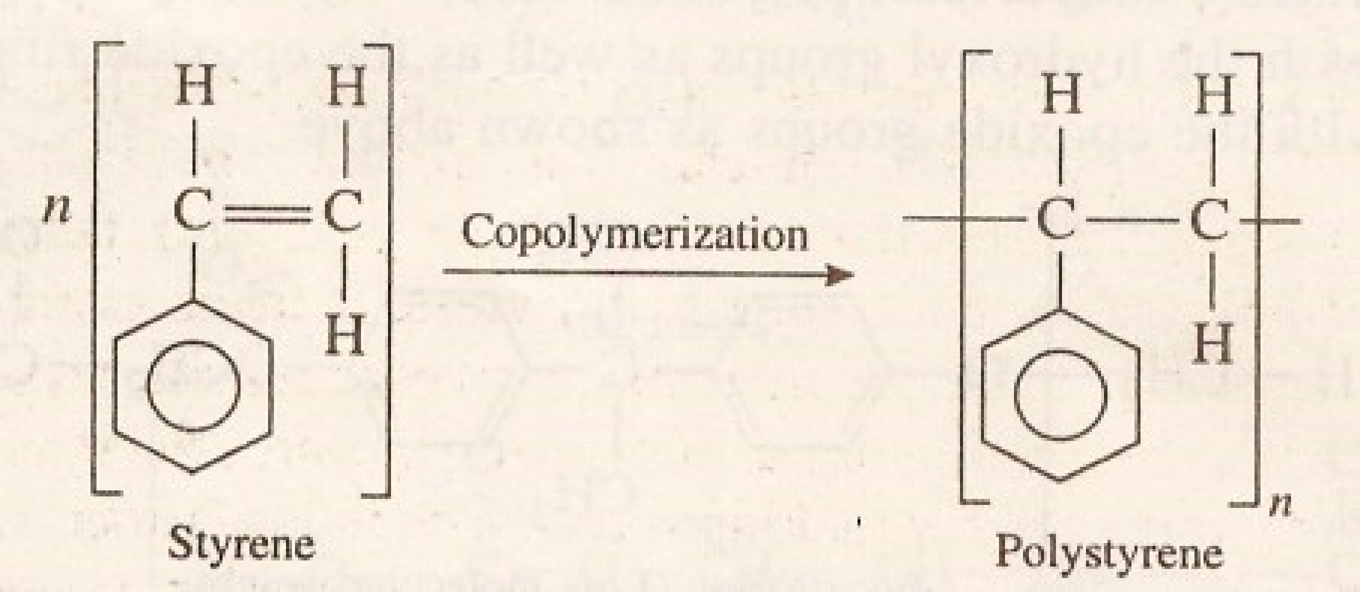


Properties : It is quite hard, horny material of high melting point.

Uses : It is used for cloth, carpets and blankets.

POLYMERS

POLYSTYRENE : It is prepared by polymerization of styrene (dissolved in ethyl benzene) in presence of peroxide catalyst.



POLYMERS

Properties:

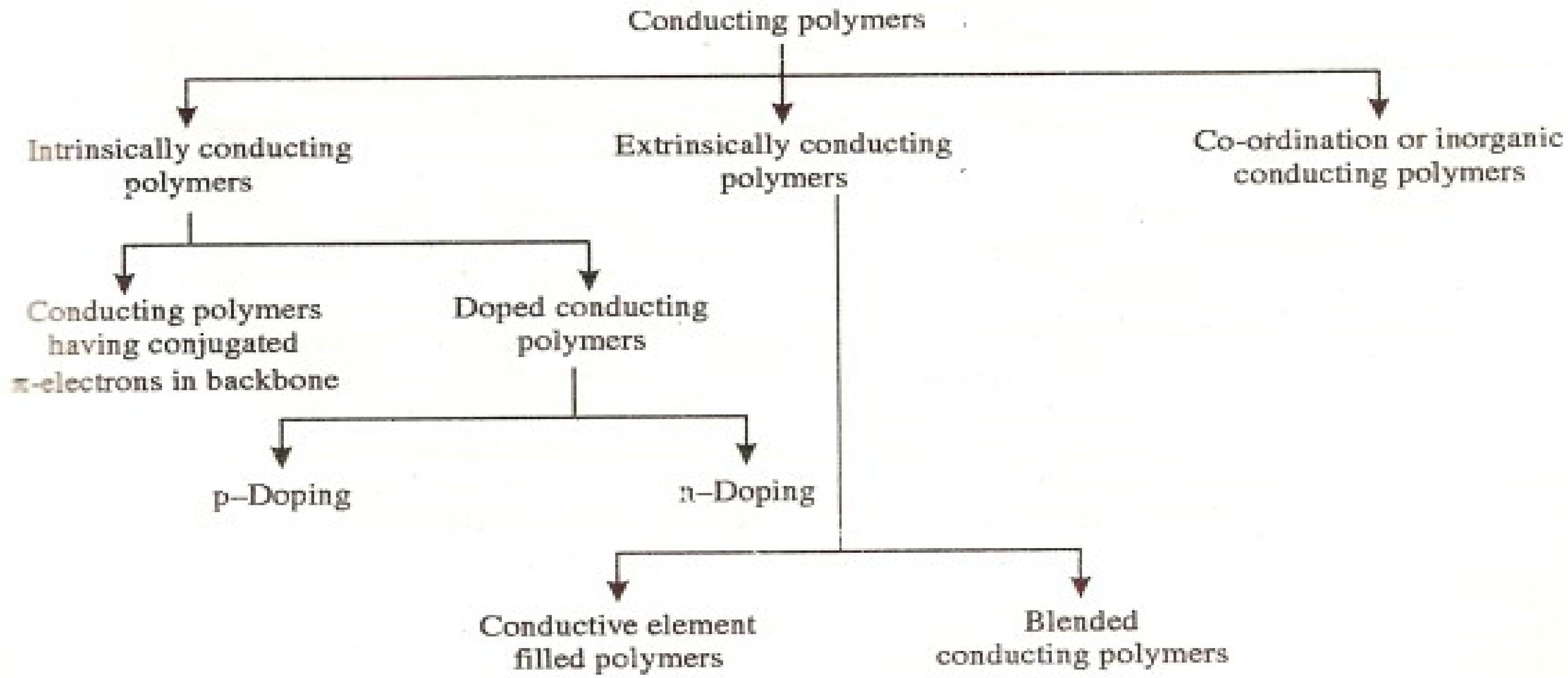
1. Polystyrene is a transparent, light, good light-stable, excellent moisture-resistant.
2. It can be nitrated by fuming nitricacid and sulphonated by conc. H_2S0_4. At about lOO°C, it yields water-soluble emulsion.
3. It is highly electric insulating, highly resistant to acids and good chemical-resistant.
4. It has the unique property of transmitting light through curved sections.

Uses: In moulding of articles like toys, combs, buttons, buckles, radio and television parts, refrigerator parts, battery cases, high frequency electric insulators, lenses, indoor lighting-panels, etc.

POLYMERS

CONDUCTING POLYMERS : Polymers which can conduct electricity are called conducting polymers. Ordinary polymers obtained by usual methods are nearly insulators. However, some specific polymers may act as conductors.

Classification: Conducting polymers may be classified as



POLYMERS

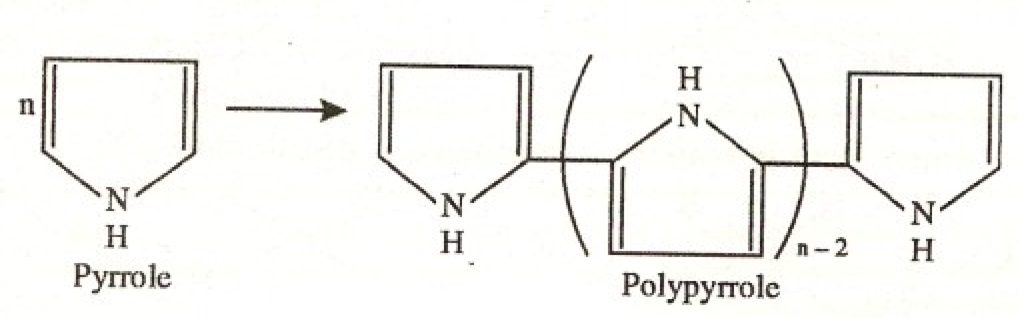
1. Intrinsically conducting polymers :

These types of polymers have a solid backbone made up of extensive conjugated system, which is responsible for conductance. They may be of two types:

(i) **Conducting polymers having conjugated π-electrons in the backbone :** These polymers essentially contain a conjugated π-electron backbone responsible for electrical charge. Under the influence of electrical field conjugated π -electrons of the polymer get excited, which can then be transported through the solid polymer. Fulther, overlapping of orbitals of conjugated π -electrons over the entire backbone results in the formation of valence bands as well as conduction bands, which extend over the complete polymer molecule. The presence of conjugated π -electrons in polymers increases its conductivity, *e.g.,*

POLYMERS

Polypyrrole



POLYMERS

(ii) Doped conducting polymers: The conducting polymers obtained by exposing the polymer to a charged transfer agent in either gas phase or in solution are called *doped conducting polymers.*

Doping is the process by which conductivity of the polymers may be increased by creating negative or positive charge on the polymer backbone by oxidation or reduction.

Doping may be of two types:

(A) p-Doping : It is done by oxidation process. In this process, the conducting polymer is treated with a Lewis acid.

$$\underset{\text{Polyacetylene}}{(CH)_x} + \underset{\text{Lewis acid}}{A} \rightleftharpoons \underset{p\text{-Doped polyacetylene}}{(CH)_x^+ A^-}$$

POLYMERS

(B) n-Doping : It is done by reduction process. In this process, the conducting polymer is treated with a Lewis base.

$$\underset{\text{Polyacetylene}}{(CH)_x} + \underset{\text{Lewis base}}{B} \rightleftharpoons \underset{\text{n-Doped polyacetylene}}{(CH)^-_x B^+}$$

Advantages of intrinsically conducting polymers :

(i) Their conductivity

(ii) Their ability to store a charge.

(iii) Their ability to undergo ion exchange.

(iv) They can absorb visible light to give coloured products.

(v) They are transparent to X-rays.

POLYMERS

Limitations of intrinsically conducting polymers:

(i) Their conductivities are poorer than metals.

(ii) Their improcessability.

(iii) Their poor mechanical strength.

(iv) They are less stable at high temperatures.

(v) On storage they lead to loss in their conductivity.

POLYMERS

2. Extrinsically conducting polymers :

Those conducting polymers which owe their conductivity due to the presence of externally added ingredients in them are called *extrinsically conducting polymers.* They are of two types :

(i) Conductive element filled polymers : In this type, polymer acts as a binder to hold the conducting elements together in solid entity.

The minimum concentration of the conductive filler, which is added to let the polymer start conducting is called the *percolation threshold.*

Important characteristics of these polymers are : (a) They possess good bulk conductivity.

(b) They are cheaper.

(c) They are light in weight.

(d) They are mechanically durable and strong.

(e) They are easily processable in different forms, shapes and sizes.

POLYMERS

(ii) Blended conducting polymers: These types of polymers are obtained by blending a conventional polymer with a conducting polymer either physically or chemically. Such polymers can be easily processed and possess better physical, chemical and mechanical properties.

3. Coordination or inorganic conducting polymers :

These polymers contain charge transfer complexes and are obtained by combining metal atoms with polydentate ligands.

POLYMERS

Applications of conducting polymers: Conducting polymers are widely used :

1. In rechargable batteries.
2. In making analytical sensors for pH, O_2, SO_2, NH_3, glucose, etc.
3. In the preparation of ion exchangers.
4. In controlled release of drugs.
5. In optical filters.
6. In photo voltaic devices.
7. In telecommunication systems.
8. In micro-electronic devices.
9. In bio-medical applications.

BIODEGRADABLE POLYMERS

Biodegradation is the breakdown of polymer by microbial organisms (such as bacteria, fungi etc.) into smaller compounds. The microbial organisms degrade the polymer through metabolic or enzymatic processes. The biodegradability of a given polymeric material is defined by the chemical structure of the polymer. Photodegradation is often subsequently followed by microbial or biodegradation. Natural products which are susceptible to biological attack are: starch, cellulose etc. Biodegradation of any organic material under controlled aerobic and anaerobic conditions produce **compost**. The process is termed as **composting**. Hence, a plastic that undergoes degradation by microbial action during composting to yield CO_2, H_2O and inorganic compounds, leaving no toxic residue is termed as **compostable plastic**. Ideal conditions for micro organism growth are obtained during the composting process.

Environmental Degradable Polymers

A variety of natural, synthetic, and biosynthetic polymers are bio- and environmentally degradable. **A polymer based on the C-C backbone tends to be nonbiodegradable, whereas heteroatom-containing polymer backbones confer biodegradability**. Biodegradability can therefore be engineered into polymer by the judicious addition of chemical linkages such as anhydride, ester, or amide bonds, among others.

Many polymers that are claimed to be 'biodegradable' are in fact 'bioerodable', 'hydrobiodegradable' or 'photo-biodegradable'. These different polymer classes all come under the broader category of '*environmentally degradable polymers*'.

Thus the classes of biodegradable plastics considered, in terms of the degradation mechanism, are:

1. Biodegradable
2. Compostable
3. Hydro-biodegradable
4. Photo-biodegradable
5. Bioerodable

Biodegradable: American society of Testing and Materials (ASTM) defines 'biodegradable' as: "*capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, or biomass in which the predominant mechanism is the enzymatic action of microorganisms, that can be measured by standardized tests, in a specified period of time, reflecting available disposal condition.*"

In simple words, biodegradation is the degradation caused by biological activity, particularly by enzyme action leading to significant changes in the material's chemical structure. In essence, biodegradable plastics should break down cleanly, in a defined time period, to simple molecules found in the environment such as carbon dioxide and water.

Compostable: Compostable plastics are a subset of biodegradable plastics. Compostable biodegradable plastics must biodegrade and disintegrate in a compost system during the composting process (typically around 12 weeks at temperatures over 50°C). The compost must meet quality criteria such as heavy metal content, ecotoxicity, and no obvious distinguishable residues caused by the breakdown of the polymers.

Hydro-biodegradable and Photo-biodegradable: Two closely linked mechanisms of degradation that are frequently confused with biodegradation are Hydro-degradation (degradation via hydrolysis) and Photo-degradation (degradation via photolysis). Since both mechanisms are often subsequently followed by microbial degradation, confusion of definition frequently occurs. Hydro-biodegradable and photo-biodegradable polymers are broken down in a **two-step** process - an initial hydrolysis or photo-degradation stage, followed by further biodegradation. Single degradation phase 'water- soluble' and 'photodegradable' polymer also exist.

Bio-erodable: Many polymers that claimed to be 'biodegradable' are in fact 'bioerodable' and degrade without the action of micro-organisms - at least initially in the first step. This is also known as abiotic disintegration, and may include process such as dissolution in water, 'oxidative embrittlement' (heat ageing) or 'photolytic embrittlement' (UV ageing).

Some Biodegradable Polymers:

- Starch based products including thermoplastic starch.
- Polyester blends and Polyvinyl alcohol (PVOH) blends.
- Naturally produced polyesters including polyhydroxybutyrate (PHB).
- Renewable resource polyesters such as polylactic acid (PLA).
- Synthetic aliphatic polyesters including polycaprolactone (PCL) and polybutylene succinate (PBS).
- Aliphatic-aromatic (AAC) copolyesters.
- Hydro-biodegradable polyester such as modified PET.
- Water soluble polymer such as polyvinyl alcohol and ethylene vinyl alcohol.
- Photo-biodegradable plastics.
- Controlled degradation additive masterbatches.

Biopolymers and Bioplastics

Biopolymers are polymers which are present in, or created by, living organisms. These include polymers from renewable resources that can be polymerized to create bioplastics.Carbohydrates and proteins, for example, are biopolymers. Many biopolymers are already being produced commercially on large scales, although they usually are not used for the production of plastics.

Bioplastics are plastics manufactured using biopolymers, and are biodegradable.These are also called green plastics. Green plastics are the focus of an emerging industry focused on making convenient living consistent with environmental stability.

Biopolymers and bioplastics are the main components in creating a sustainable plastics industry. These products reduce the dependence on non-renewable fossil fuels, and are easily biodegradable. Also, being biodegradable make bioplastics more acceptable for long term use by society.

Biopolymers

Types of Biopolymers: There are two main types of biopolymers:

(i) those that come from living organisms; and
(ii) those which need to be polymerized but come from renewable resources.

Both types are used in the production of bioplastics.

(i) Biopolymers From Living Organisms

These biopolymers are present in, or created by, living organisms. These include carbohydrates, and proteins. These can be used in the production of plastic for commercial purposes. Examples are listed in the table below.

Biopolymer	Source	Remarks
Cellulose	In plants cellulose is synthesized from glucose. It is the main component of plant cell walls Examples include wood, cotton, corn, wheat, and others	• Cellulose is the most plentiful carbohydrate in the world; 40 percent of all organic matter is cellulose • It has β glucose as the repeat unit. • Cellulose is insoluble in most of the solvents and hence it is converted to its derivatives to make it process able.
Soy protein	Soy protein and zein (from corn) are abundant plant proteins.	• They are used for making adhesives and coatings for paper and cardboard.
Starch	Starch is found in corn (maize), potatoes, wheat, tapioca (cassava), and some other plants.	• Starch is also made up of glucose units and is stored in plant tissues. It is not found in animal tissues. • It has β glucose as the repeat unit • Annual world production of starch is well over 70 billion pounds, with much of it being used for non-food purposes, like making paper, cardboard, textile sizing, and adhesives.
Polyesters	Polyesters are produced by bacteria, and can be made commercially on large scales through fermentation processes. Commercially produced mainly from cow's skimmed milk	• These polyesters are created through naturally occurring chemical reactions that are carried out by certain types of bacteria. • They are now being used in biomedical applications
Casein		• Casein is used in adhesives, binders, protective coatings, and other products

(ii) Polymerizable Molecules

These molecules come from renewable natural resources, and can be polymerized to be used in the manufacture of biodegradable plastics.Some of these are listed in the table below:

Biopolymer	Natural Source	Remarks
Lactic Acid	Beets, corn, potatoes, and others	• Produced through fermentation of sugar feed-stocks, such as beets, and by converting starch in corn, potatoes, or other starch sources. • It is polymerized to produce polylactic acid — a polymer that is used to produce plastic.
Triglycerides	Vegetable oils mainly from soybean, flax, and rapeseed.	• Triglycerides are another promising raw material for producing plastics.