

Review Article On Polymer

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Abstract :

A broad family of materials called polymers is made up of several tiny molecules. Nearly every industry uses polymers, including rubber, cotton, wool, Teflon(tm), and plastics of all kinds. The remarkable resemblance between the infrared absorption spectra of heavenly objects and cellulose indicates its existence. The uppermost layer of the film is composed of cellulose pellicle. Most materials, including the metal used in springs, are elastic because of bond distortions. Rubber's lengthy, tightly wrapped polymer chains are connected at a few locations when it is relaxed. The main goal of polymeric delivery systems is to produce regulated or prolonged pharmaceutical dispersion. It has also been possible to target medications to the colon after oral administration by utilizing polysaccharides. Future interesting new applications for polymeric materials have a huge promise. Uses for polymers are being developed in a wide range of fields.

Keyword: Polymer, Properties, Advantage Disadvantage, Drug Delivery, Mechanism, Application

Introduction :

Polymers are large molecules, often called macromolecules, made up of many repeating subunits known as monomers. Both natural and synthetic polymers possess a wide range of properties that make them indispensable and common in everyday life. Natural biopolymers, such as DNA and proteins, play vital roles in biological structures and functions.

Synthetic polymers, such as polystyrene, are also important materials widely used in various applications. Polymers are formed through the polymerization of numerous small molecules (monomers). Because of their high molecular mass compared to small-molecule compounds, polymers exhibit distinctive physical characteristics such as toughness and durability. Polymers and polymeric materials have played a crucial role in the development of new devices, paving the way for replacing

outdated materials. The 20th century witnessed an explosion of research and activity in this field, leading to the emergence of new disciplines such as molecular electronics, conducting polymers (including synthetic metals), organic semiconductors, and plastic electronics. Polymers continue to attract significant attention from the scientific and technological communities due to their wide range of applications in industrial, pharmaceutical, and medical fields [1]. Moreover, polymers exist naturally in various forms such as wood, cotton, cellulose, and starch

HISTORY:

Henri Braconnot began his groundbreaking work on derivative cellulose compounds in 1811, marking one of the first significant contributions to polymer science. Natural rubber, a naturally occurring polymer, became more durable with the development of vulcanization later in the 19th century, making it the first semi-synthetic polymer to gain widespread use. Leo Baekeland made a major breakthrough in 1907 when he reacted phenol and formaldehyde under carefully controlled temperature and pressure conditions to produce Bakelite, the first fully synthetic polymer. Bakelite was made available to the public around 1910, revolutionizing the plastics industry.

For ages, people have used natural organic polymers such as shellac and wax. The plant polymer cellulose provides structural strength to natural fibers and

ropes. By the early 1800s, natural rubber, obtained from the sap of rubber trees, was widely used for various purposes, including as a material in medical applications and other polymerbased products.

An important contribution to synthetic polymer science was made by the Italian chemist Giulio Natta and the German chemist Karl Ziegler, who were awarded the Nobel Prize in Chemistry in 1963 for the development of the Ziegler–Natta catalyst. Further recognition of the importance of polymer science came with the Nobel Prize in Chemistry in 1974, awarded to Paul Flory for his fundamental work on the physical chemistry of macromolecules.

Goodyear’s vulcanized rubber outperformed untreated natural rubber in several key areas, including greater strength, enhanced abrasion resistance, improved flexibility, reduced temperature sensitivity, better gas impermeability, and superior resistance to chemicals and electric current.

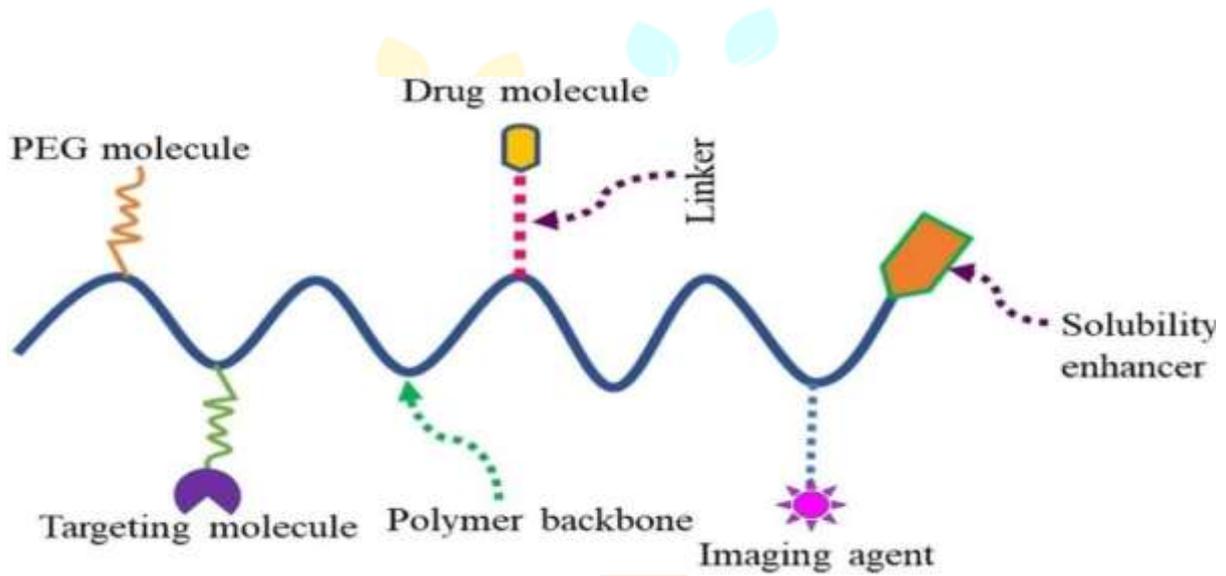
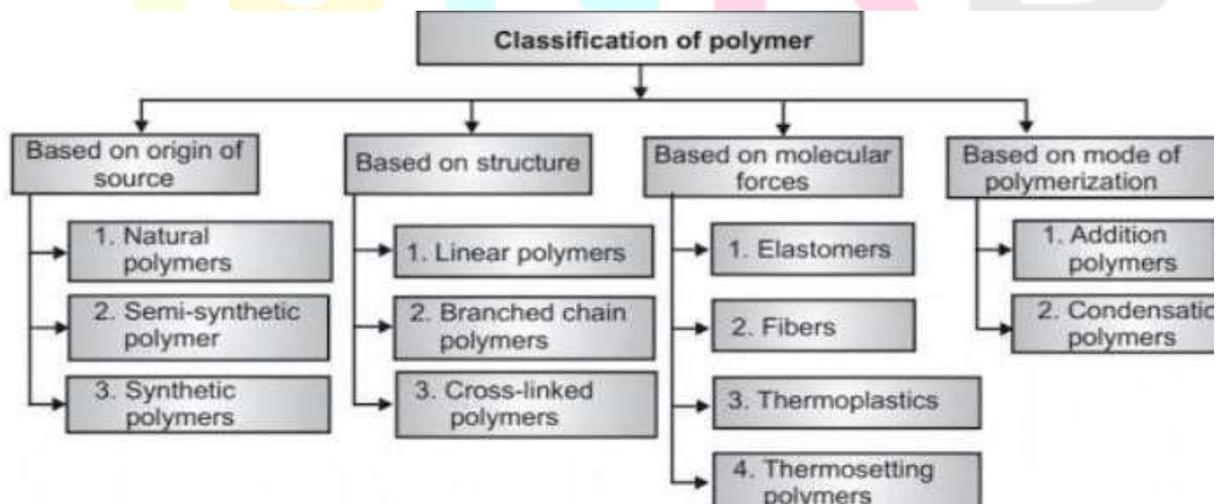


Fig 1: polymer drug conjugate

Classification of polymer :



1) Based On Source

i. Natural polymer

Natural polymers are those that are derived from living organisms such as plants or animals. Accordingly, they are often classified as plant-based polymers and animal-based polymers.

Examples:

- **Plant polymers:** Cellulose, starch, natural rubber
- **Animal polymers:** Proteins (like silk, collagen), natural fibers (like wool), and nucleic acids

ii) Semisynthetic Polymer

Semisynthetic fibers are polymers made from natural fibers that have undergone chemical processing to enhance certain physical properties, such as tensile strength and luster.

Example:

- Cupra ammonium silk , • Viscous rayon

iii) Synthetic Polymer

Synthetic fibers are man-made polymers produced in laboratories or industries through the polymerization of basic chemical components, usually derived from petroleum-based products.

Examples:

- Nylon, polyester, acrylic, and spandex are common synthetic fibers known for their durability, elasticity, and resistance to moisture

2) Based on Structure

i) Linear Polymers

In this type of polymer, monomers are interconnected to form an elongated, linear structure. These chains do not have any branches or side chains, resulting in a straight-chain polymer.

Example

- Polyester, Polyethylene

ii) Branched

Polymers

The straight long chains of molecules in these polymers are accompanied by various side chains. Due to their irregular packing, these molecules exhibit low density, tensile strength, and melting point.

Example:

- Polypropylene, Amylopectin, Glycogen

iii) Crosslinked polymers

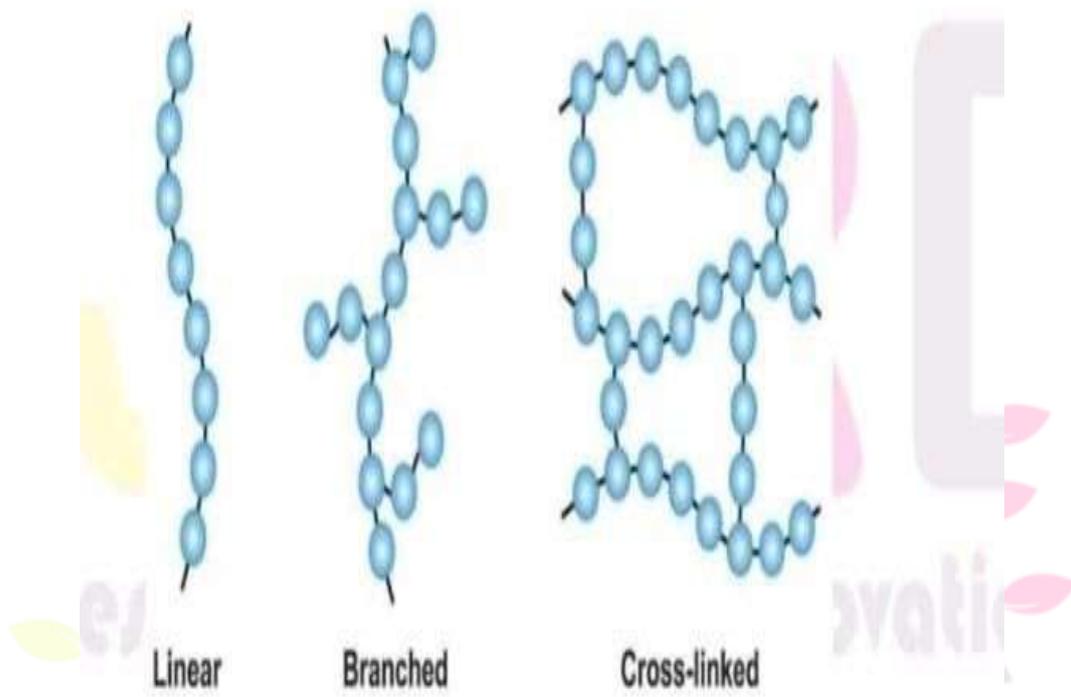
Monomer units are interconnected to form a three-dimensional network.

Crosslinks play a crucial role in making the structure hard, rigid, and brittle.

- **Examples:**

- Bakelite
- Formaldehyde resin
- Vulcanized rubber

- **Structure of polymer**



Polymer

3) Based on Molecular Force

- **Example: Elastomer** (rubber-like materials with elasticity)⁴

i) Elastomers

Elastomers are polymers in which polymer chains are held together by the weakest forces.

These forces allow the chains to stretch easily when a small force is applied and return to their original position when the force is removed.

They consist of randomly coiled molecular chains with very few cross-links.

Because of their elasticity, they can be stretched and then return to their shape.

ii) Fibers:

Fibers possess strong intermolecular attractive forces (similar to hydrogen bonding).

They exhibit high tensile strength, which makes them very useful in textile industries.

- **Examples:** ○ Nylon-66

- Terylene

iii) Thermoplastic Polymers

These polymers have intermolecular forces stronger than elastomers but weaker than fibers. They can be softened by heating and hardened by cooling — meaning they can be reshaped multiple times.

- They may have linear or branched molecular structures.

- **Examples:**

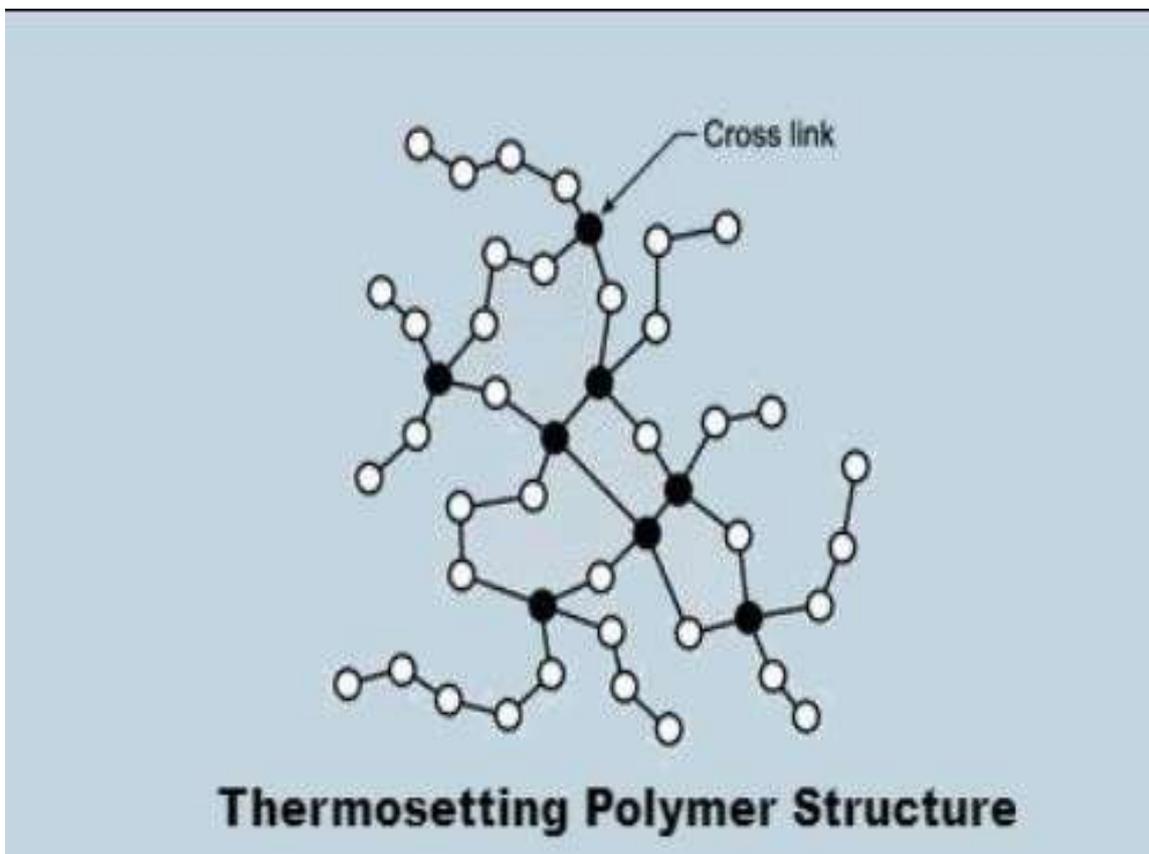
- Acrylic ○ Polypropylene ○



iv) Thermosetting Polymer:

These polymers become hard and infusible when heated.

- They do not soften upon heating or under pressure. ○ Once set, they cannot be remolded or reshaped, hence they are non-recyclable.
- Their cross-linked structure gives them high hardness and rigidity.
- **Examples:** ○ Melamine ○ Silicone ○ Polyurea



4) Based on Polymerization

i) Addition polymer:

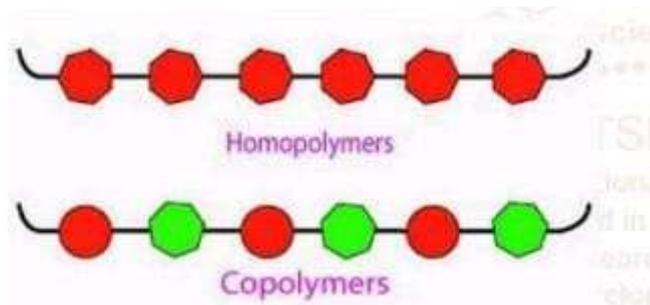
Addition polymers are formed by the repeated addition of monomers without the elimination of any by-products.

As a result, the polymer contains all the atoms of the monomers, making it an exact multiple of the monomer unit.

- **Examples:** ○ Orion ○ Teflon

Types of Addition Polymers:

1. **Homopolymer**
 - a. Formed by polymerization of a single type of monomer.
 - b. Example: Polyethylene (from ethene monomers).
2. **Copolymer**
 - a. Formed by polymerization of two or more different monomers.
 - b. **Example:** Buna-S rubber (from styrene and butadiene).



ii) Condensation Polymer

Condensation polymers are formed by the combination of two monomers with the elimination of small molecules such as water (H_2O), ammonia (NH_3), or alcohol.

- They often contain ester or amide linkages in their structure.
- The molecular mass of these polymers does not correspond to an integral multiple of the monomer units.
- **Examples:**
 - Polyamide
 - Polyurethane

Properties of Polymers:

Polymer characteristics are classified into groups depending on the level at which the property is determined — chemical, physical, or structural.

- The type of monomer and organization of monomer units in the chain define the polymer's fundamental characteristics.
- Microstructure refers to the detailed arrangement of monomers within a single polymer chain.

1) Chemical Property

- The chemical properties of polymers are greatly affected by the intermolecular attractive forces between chains.
- Due to the long chain length, these interchain forces are stronger compared to attractions in small molecules.
- These forces can be influenced by the presence of dipoles or polar groups in monomer units.

2) Physical Properties

I) Tensile Strength

- As the chain length and cross-linking in polymers increase, the tensile strength of the polymer also increases.
- Longer chains and stronger cross-links make the material tougher and more durable.

II) Melting Behavior

- Polymers generally do not melt completely like small molecules.
- Instead, they change their state from crystalline to semi-crystalline when heated.

3)Optical Properties

- Polymers like PMMA and HEMA: MMA are used in lasers for applications in spectroscopy and analytical applications.
- This use is due to their ability to change their refractive index with temperature.

4) Transport properties

The diffusivity of molecule within a polymer matrix is crucial for various application involving film and membranes.

In the context of polymer the term melting point signifies a shift from a crystalline or semicrystalline phase to a solid amorphous phase rather than a solid liquid phase transition.

5)Mechanical properties

The bulk properties of a polymer are those most often of end-use interest. These are the properties that dictate how the polymer actually behaves on a macroscopic scale. The tensile strength of a material quantifies how much stress the material will endure before suffering permanent deformation

Types of Polymer: ○ Natural Polymers

Natural polymers, often called **biopolymers**, are synthesized by living organisms and are fundamental to biological structure and function. They generally fall into three main biochemical families:

1. Polysaccharides (Carbohydrates)

These are polymers formed from repeating units of monosaccharides (simple sugars) like glucose. They primarily serve as energy storage or structural support.

- **Cellulose:** The example you provided. It is the most abundant organic polymer on Earth. ○ **Function:** Provides the structural integrity in the cell walls of plants (wood, cotton, paper).
 - **Monomer:** D-Glucose (connected by β -1,4 glycosidic linkages).
- **Starch:** The energy storage polymer in plants (potatoes, grains).
 - **Monomer:** D-Glucose (connected by α -1,4 linkages), comprising Amylose (linear) and Amylopectin (branched).
- **Chitin:** A structural polysaccharide found in the exoskeletons of insects and crustaceans, and the cell walls of fungi.

2. Proteins (Polypeptides)

These are polymers formed from repeating units of amino acids connected by peptide bonds. They are involved in nearly every biological process.

- **Structure/Function:** Their function is defined by their complex 3D structure (primary, secondary, tertiary, and quaternary).
- **Examples:**
 - **Collagen:** A structural protein and the most abundant protein in mammals, providing strength to skin, tendons, and bones.
 - **Keratin:** A structural protein found in hair, wool, nails, and horns.
 - **Enzymes (e.g., Amylase):** Proteins that catalyze specific biochemical reactions.
 - **Silk and Wool:** Natural protein fibers.

3. Nucleic Acids (Polynucleotides)

These are polymers formed from repeating units of **nucleotides**. They store and transmit genetic information.

- **Examples:**

- **DNA (Deoxyribonucleic Acid):** Stores genetic instructions.
- **RNA (Ribonucleic Acid):** Involved in protein synthesis.

4. Natural Rubber



- **Monomer : Isoprene** (2-methyl-1,3-butadiene).
- **Source:** Harvested as latex from rubber trees.

- Major Families of Synthetic Polymers

Synthetic polymers are human-made materials derived primarily from petroleum-based monomers. They are classified based on their structure, application, or reaction type.

Polymer Family (by Structure/Application)	Monomer Typical Type	Key Properties	Common Examples
Plastics (Thermoplastics)	Alkenes (e.g., Ethylene, Propylene)	Meltable/reformable upon heating; flexible or rigid.	Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC).
Fibers	Diacids/Diamines (for Polyamides); Diols/Diacids (for Polyesters)	High tensile strength; good elasticity; linear chains.	Nylon (Polyamide), Polyester (e.g., PET), Rayon (Semi-Synthetic Cellulose derivative).
Elastomers (Rubbers)	Dienes (e.g., Butadiene, Isoprene)	Amorphous; highly flexible and elastic (can be greatly deformed and recover).	Styrene-Butadiene Rubber (SBR), Neoprene.
Thermosets	Phenol/Formaldehyde, Epoxy compounds	Hard and rigid; permanently set after curing (cannot be melted or reformed).	Bakelite, Epoxy Resins, Melamine Resins.

Conjugated Polymers	Thiophenes, Anilines (with π -bonds)	Semiconducting or electrically conductive after doping; used in electronics.	Polythiophene, Polyaniline.
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Natural Polymers

1. Starches (Polysaccharide Family)

- **Structure:** Consist of alpha glucose polymers (meaning the glucose monomers are linked by α -glycosidic bonds).
- **Function in Plants:** Primarily used for energy storage in a water-stable form.
- **Weaknesses:** Naturally exhibit poor strength and thermal stability.
- **Industrial Use (Feedstock):** Can be converted into monomers for bio-sourced synthetic polymers:
 - Directly into Polylactic Acid (PLA).
 - Fermented into industrial alcohol (ethanol), which is used to manufacture Polyvinyl Alcohol (PVA).

2. Silk (Protein/Polypeptide Family)

- **Composition:** Made from proteins: Sericin (the sticky outer layer) and Fibroin (the core structural fiber).
- **Spider Silk:** Similar protein structure, primarily composed of alanine and glycine monomers.
- **Key Property:** Known for being an exceptionally strong material.
- **Future Potential:** The synthetic development of similar materials from plant sources suggests a potential path for bulk polymers applicable to single-use plastics.
 - Synthetic Polymers

1. Nylon (Polyamide Family)



- **Structure:** Polymer chains constructed from **polyamide** repeating units
- **Properties:** Tough, chemically resilient engineering polymer with a slippery, low energy surface.
- **Applications:** Mainly manufactured as fibers for clothing, ropes, and webbing.

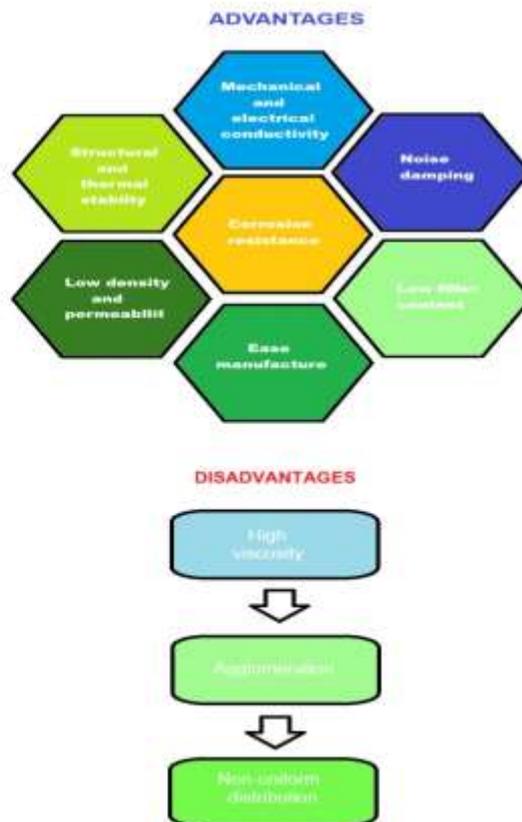
2. Polyethylene (Thermoplastic/Polyolefin Family)

- **Monomer:** Ethylene gas only.
- **Differentiation:** Grades are distinguished by molecular weight and the degree and complexity of side branching.
 - Ranges from low density (soft) material to Ultra High Molecular Weight (UHMW) engineering grades.

- **Applications:** Food containers, pipes, and general engineering parts.

3. Silicone (Elastomer/Thermoset Family)

- **Structure:** Mostly made as a two-part thermoset polymer that requires a catalytic reaction to cure.
- **Properties:** Generally elastomers (flexible rubbery materials) with high compressive strength and excellent high-temperature resistance.
- **Weakness:** Low to moderate tear resilience
- Advantages and Disadvantages of polymer



○ Role of polymers in drug delivery:-

1. Immediate release dosage forms Tablets:

Polymers including polyvinyl-pyrrolidone and hydroxypropyl methylcellulose (HPMC) find uses as binders that aid the formation of granules that improve the flow and compaction properties of tablet formulations prior to tableting.

• Capsules:

Many of the polymeric excipients used to "bulk out" capsule fills are the same as those used in immediate release tablets. Gelatine has been used almost exclusively as a shell material for hard (two-piece) and soft (one-piece) capsules HPMC has recently been developed and accepted as an alternative material for the manufacture of hard (two-piece) capsules.

2.Modified-release dosage form

To achieve gastro retention mucoadhesive and low-density polymers have been evaluated, with little success so far, for their ability to extend gastric residence time by bonding to the mucus lining of the stomach and floating on top of the gastric contents respectively.

3. Extended release dosage forms

Extended and sustained release dosage forms prolong the time that systemic drug levels are within the therapeutic range and thus reduce the number of doses the patient must take to maintain therapeutic effect thereby increasing compliance. The most commonly used waterinsoluble polymers for extended-release applications are the ammonium methacrylate copolymers (Eudragit RS and RL), cellulose derivatives ethylcellulose, and cellulose acetate, and polyvinyl derivative, polyvinyl acetate.

4. Gastroretentive Dosage Forms

Gastroretentive dosage forms offer an alternative strategy for achieving extended release profile, in which the formulation will remain in the stomach for prolonged periods, releasing the drug in situ, which will then dissolve in the liquid contents and slowly pass into the small intestine.

1. Mechanism of Polymer Chain Movement: Reptation

Primary Mechanisms of Drug Release from Polymers

1. Diffusion

This mechanism is based on the movement of the drug molecule through the polymer structure into the surrounding biological fluid.

- **Process:** The drug or active agent passes through the polymer that forms the controlled release device (e.g., a membrane or matrix). The movement is driven by the concentration gradient: from the high concentration within the polymer to the low concentration in the external environment.

- **Release Kinetics:** The release rate normally decreases over time.

- **Reason:** As the drug near the surface is released, the remaining drug has a progressively longer distance to travel (a longer diffusion path) through the polymer, which increases the required diffusion time.

- **Polymer Requirement:** The polymer matrix and drug combination must allow the drug to diffuse through the polymer's pores or macromolecular structure without the polymer itself undergoing any structural change (i.e., the polymer is non-degrading and nonswelling).

2. Degradation (Erosion)

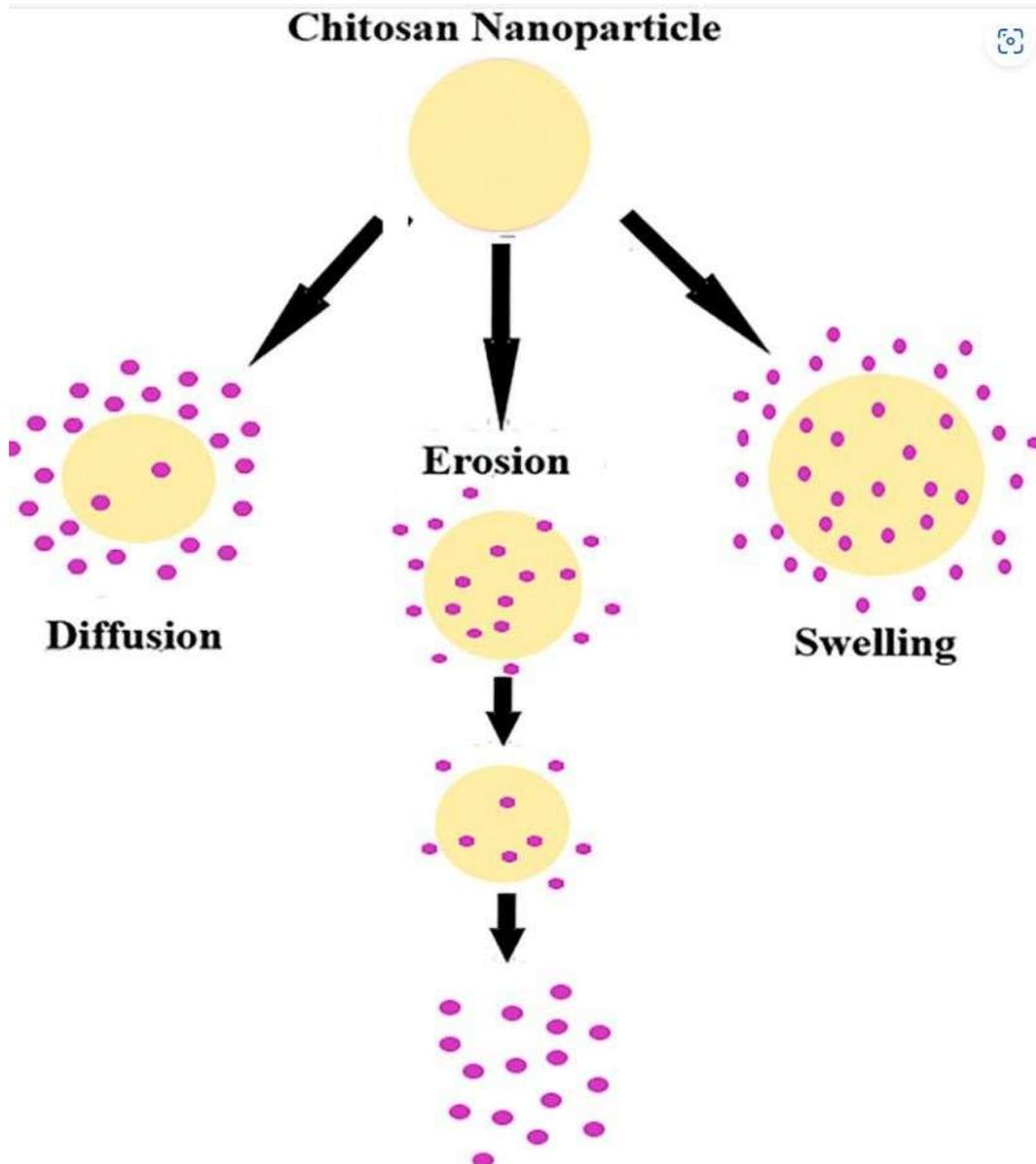
This mechanism relies on the polymer breaking down within the body to release the encapsulated drug.

- **Process:** The drug is released as the biodegradable polymer degrades due to natural biological processes (like hydrolysis).
- **Key Advantage:** This mechanism eliminates the need to surgically remove the drug delivery system (e.g., an implant) once the drug release is complete.
- **Chemistry:** Most biodegradable polymers are designed to degrade via hydrolysis of the polymer chains into progressively smaller, biologically acceptable compounds.
- **Surface vs. Bulk Degradation:**
 - **Surface Degradation:** (e.g., in polyanhydrides and polyorthoesters) Degradation occurs only at the surface of the device. This results in a release rate that is proportional to the surface area of the system, often leading to a desirable **zero-order release** (constant rate).
 - **Bulk Degradation:** (More common, e.g., in PLGA) Degradation occurs uniformly throughout the entire volume of the device.

3. Swelling

This mechanism combines polymer deformation with diffusion to achieve release.

- **Process:** The polymer is initially dry. When placed in the body, it absorbs water or other body fluids and swells.
- **Effect on Drug Release:**
 - **Increased Solvent Content:** Swelling increases the aqueous solvent content within the formulation
 - **Increased Mesh Size:** Swelling increases the polymer mesh size (the space between the polymer chains).
- **Result:** The combination of increased solvent and larger mesh size enables the drug to diffuse through the swollen network into the external environment.



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Research Through Innovation

Application of Polymer:

1. Application of natural polymer in drug delivery system

○ Colon delivery

Microorganisms in the human colon can break down the coating material used for drug delivery to the colon. Therefore, the coating material must possess excellent film-forming and mucoadhesive properties. Microspheres have been created for efficient drug delivery to the colon. Ciofani et al (2008) designed an alginate-based drug delivery system for neurological purposes, focusing on neural regeneration and neuroprotection.

○ Topical delivery

Carrageenans, derived from red marine algae, are a group of sulfated polysaccharides commonly used in various industries due to their ability to create firm and thermally reversible gels,

Ocular delivery

Chitosan's exceptional film-forming ability renders it highly suitable for the advancement of ocular bondage lenses.

○ Mucosal delivery.

In an acidic solution, the natural polymer becomes protonated, allowing it to effectively bind to the negatively charged cell surface and thus proving beneficial in the development of bio adhesive dosage forms.

○ Transdermal drug delivery

Various experiments have been conducted to investigate the delivery systems of propranolol hydrochloride. These studies have focused on utilizing different natural polymers with varying crosslink densities as membranes to control the release of the drug. Additionally, chitosan gel has been employed as the drug reservoir in these experiments.

○ Gene delivery

A natural polymer, commonly extracted from shrimp shells, possesses the capability to interact with DNA and condense it into nanoparticles. These nanoparticles are more easily absorbed by cells."

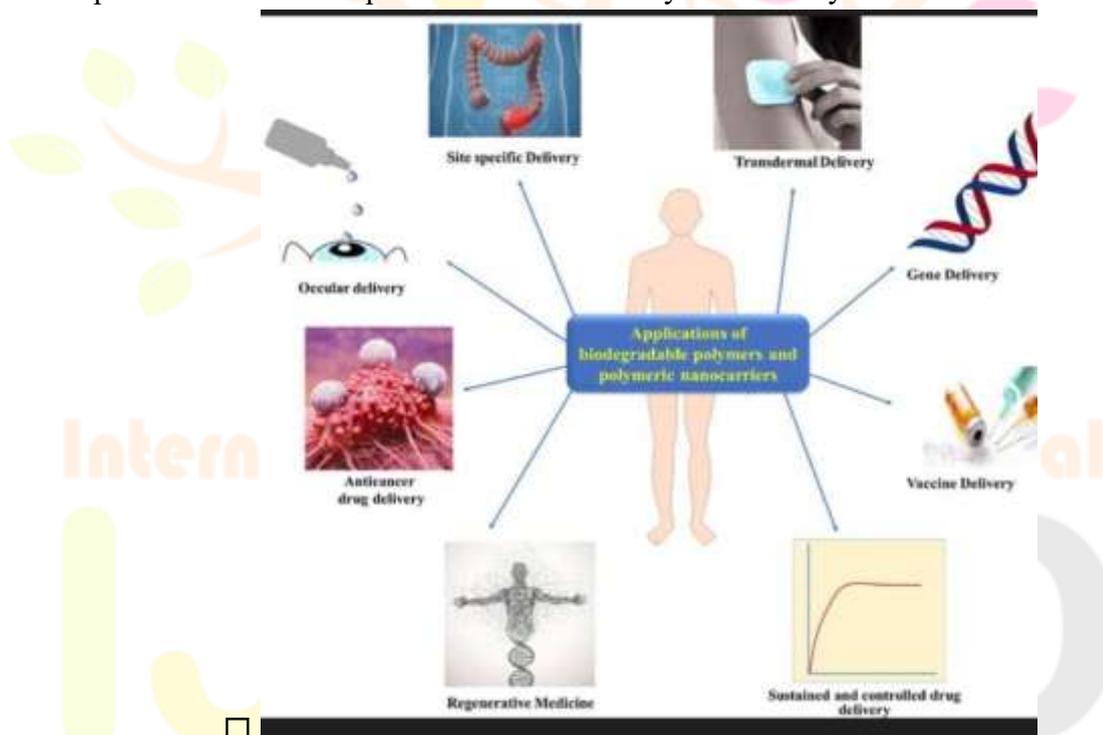


Fig: drug delivery system

2. Industrial Application

A. Uses of Guar Gum

Guar gum for pharmaceutical industries

- Guar gum powder finds application in the pharmaceutical industry for viscosity, gelling and thickening purposes. It is utilized for stabilization, suspension, preservation, emulsification, water retention, binding, water phase control, and process aid in various pharmaceutical applications.

- Guar gum for cosmetic industries
 - Utilized as a viscosity enhancer and a safeguarding agent in skincare formulations, creams, and lotions.
 - Furthermore, it finds application in toothpaste and shaving cream to facilitate effortless dispensing from the container.
- Industrial grade guar gum powder
 - Guar gum powder is an incredibly versatile product in industrial applications, serving various purposes such as thickening, sizing, enhancing wet-end strength, acting as a gelling agent and water barrier, aiding in flocculation for waste water treatment, and functioning as an emulsifier and binder.
- Guar gum for paper industry
 - Guar Gum offers superior characteristics in comparison to alternative options, resulting in a more compact surface for printing paper.
- Guar gum for textile industry
 - Guar Gum offers exceptional film-forming and thickening characteristics when applied in textile sizing, finishing, and printing processes. It helps minimize warp breakage, decreases dusting during sizing, and enhances production efficiency.
- Guar gum in oil field application
 - Industrial grade Guar gum powder is utilized in various applications such as oil well fracturing, oil well stimulation, mud drilling, and industrial preparations. It serves as a stabilizer, thickener, and suspending agent in these processes.
 - This particular guar gum powder is a natural and highly hydrating substance that can easily disperse in water. Additionally, it has the unique property of being able to form a slurry with diesel



3. Pharmaceutical Application

□ Water-soluble synthetic polymer

- Poly (acrylic acid) cosmetic, pharmaceuticals, immobilization of cationic drug, base for Carbopol polymers.
- Poly (ethylene oxide) coagulant, flocculent, very high molecular weight up to a few millions, swelling agent.
- Poly (ethylene glycol) MW <10,000; liquid (MW<1000) and wax (MW >10,00), plasticizer, base for suppositories.
- Poly (vinyl pyrrolidone) used to make betadine (iodine complex of PVP) with less toxicity than iodine , plasma replacement, tablet granulation

□ Cellulose-Based Polymers

- Ethyl cellulose insoluble but dispersible in water, aqueous coating system for sustained release application
- Carboxymethyl cellulose super disintegrant, emulsion stabilizer.
- Hydroxyethyl and hydroxypropyl cellulose soluble in water and in alcohol for tablet coating.
- Hydroxypropyl methyl cellulose binder for tablet matrix and tablet coating gelatin alternative as capsule material

□ Hydrocolloids

- Alginic acid oral and topical pharmaceutical products; thickening and suspending agent in a variety of pastes, cream, and gels, as well as a stabilizing agent for oil-in-water emulsions; binder and disintegrants
- Carrageenan modified release, viscosifier

□ Water-insoluble Biodegradable polymer

- (Lactide-co-glycolide) polymer microparticle-nanoparticle for protein delivery.

□ Plastics and Rubbers

- Polyurethane transdermal patch backing , blood pump, artificial heart, and vascular graft , foam in biomedical and industrial products.
- Polyisobutylene pressure sensitive adhesives for transdermal delivery.
- Polycyanoacrylate Biodegradable tissue adhesives in surgery , a drug carrier in nano-and microparticles

- Polyethylene Transdermal patch backing for drug in adhesive design , wrap, packaging, containers



○ **Ideal properties of biomedical polymers:**

- i) They should be easy to manufacture.
- ii) They must be recyclable.
- iii) They should have low molecular weights.
- iv) They must be available in a wide variety.
- v) Biocompatibility and biodegradability
- vi) They should possess minimum levels of toxicity to the organism or the environment
- vii) They should be stable at the physiological PH of the organism

CONCLUSION:

we have seen that polymer is not a single compound, it has a large variety . All the different form comes under one one umbrella. Form a simple polyethylene to a complex composite , all comes under the heading of polymers. Polymer have been around us in the natural world since the very beginning (e.g., cellulose, starch, and natural rubber). An-made polymeric material has been studied since the middle of the nineteenth century.

Polymer have become indispensable in various sectors and have brought about a significant transformation in the field of material science , continuous exploration and advancement in polymer technology are crucial in trackling worldwide issue and promoting sustainable methodologies through the utilization of polymers distinctive characteristics, we the persistently develop groundbreaking remedies that contribute to the betterment of both socirty and the natural world . Natural hase utilized biological polymers as the perferred material , and similarly , human eill opt for polymeric material as their material of choice . Advancing from the stone age of polymer synthetic polymer have become and will continue to be the fovored material . The increasing application of polymeric material have led to a significant demand for individuals with specialized training in polymer science and engineering . Those who pursue a carrer in this field can anticipate both financial gain and personal satisfication.

Polymer- based pharmaceuticals are becoming recognized as essential components in the treatment of various life- threatening disease like cancer or hepatitis that impact a large number of individuals . While excipients have traditionally been added to formulations as inactive substance to praimarily increase volume and aid in the manufacturing process . They are now being incorporated into dosage forms to serve specific functions for enhanced drug delivery due to

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