Versatile applications and types of Biodegradable polymers (Biopolymers) along with its role in drug delivery systems

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Abstract

Researchers are becoming increasingly interested in biopolymers as a cutting-edge industry. Because of their flexibility, reusability, and toughness, polymeric materials are advantageous. To create polymeric composites, these biopolymers can be combined with a variety of other natural and synthetic materials. These composite materials resemble oil-based polymers in terms of their characteristics. Biopolymers are crucial to the medicine and pharmaceutical industries as well. In this chapter, cellulose, chitin, and chitosan—three well-researched biopolymers—are briefly discussed along with common processing methods and material characterization. Biopolymers can be used for commercial objectives, such as to repair damage, provide medication together with regenerative medicine goals, and achieve minimal immunogenicity and strong pharmacological activity. Polysaccharides, in particular cellulose, chitin, and chitosan, are important biopolymers because of their large amount, wide dispersion, and affordable manufacture. This article presents a comprehensive analysis of the

usage of cellulose, chitin, and chitosan-based materials for various sorption applications. In particular, biopolymers are artificial substances created by living creatures. Compounds with monomeric units of sugars, amino acids, and nucleotides are known as biopolymers. Examples include DNA, RNA, proteins, peptides, cellulose, starch, and chitin.

Keywords: Biopolymers, Types, natural, synthetic, applications etc.

Introduction

Synthetic polymers called biopolymers are created from biological sources. These can either be chemically synthesized from organic materials or biosynthesized by living organisms. These are made up of monomeric parts that are joined covalently. These monomeric particles build larger molecules [1]. In contrast to conventional polymers, which are manufactured from petroleum, biopolymers are created from living organisms like bacteria and plants, making them a sustainable resource. Biopolymers may often be degraded. They work for a variety of companies, including those in the food industry, manufacturing, packaging, and biomedical engineering. Biopolymers are regarded as promising materials because to their abundance, biocompatibility, and unique characteristics like non-toxicity, etc. Biopolymers can naturally deteriorate [2]. Typically, they are starch polymers. Monomeric building blocks make up these. The three main types of biopolymers—polynucleotides, polypeptides, and polysaccharides-are further broken down according to the monomers used and the structure of the finished biopolymer [3].

Biopolymers are composed of monomeric components that are covalently joined to produce larger molecules. The three main classes of biopolymers are polynucleotides, polypeptides, and polysaccharides. These classes are based on the monomers used and the structure of the biopolymer produced. A polynucleotide, which includes RNA and DNA, is a long polymer made up of 13 or more nucleotide monomers [4]. Three well-known examples of polypeptides and proteins, which are polymers of amino acids, are collagen, actin, and fibrin. Polysaccharides, which are linear or branched polymeric carbohydrates, include starch, cellulose, and alginate. More examples of biopolymers are lignin (complex polyphenolic poly), suberin, and natural rubber (polymers of isoprene). Biopolymers include substances including protein, starch, cellulose, DNA, RNA, lipids, collagen, and many more things. Examples of biopolymers are protein, starch, cellulose, DNA, RNA, lipids, collagen, carbohydrates etc. [5].

Types of Biopolymers

Various scales can be used to categorise biopolymers. These divisions are made in accordance with their origin, the quantity of monomeric units, degradability, heat responsiveness, etc. (Figure 1).

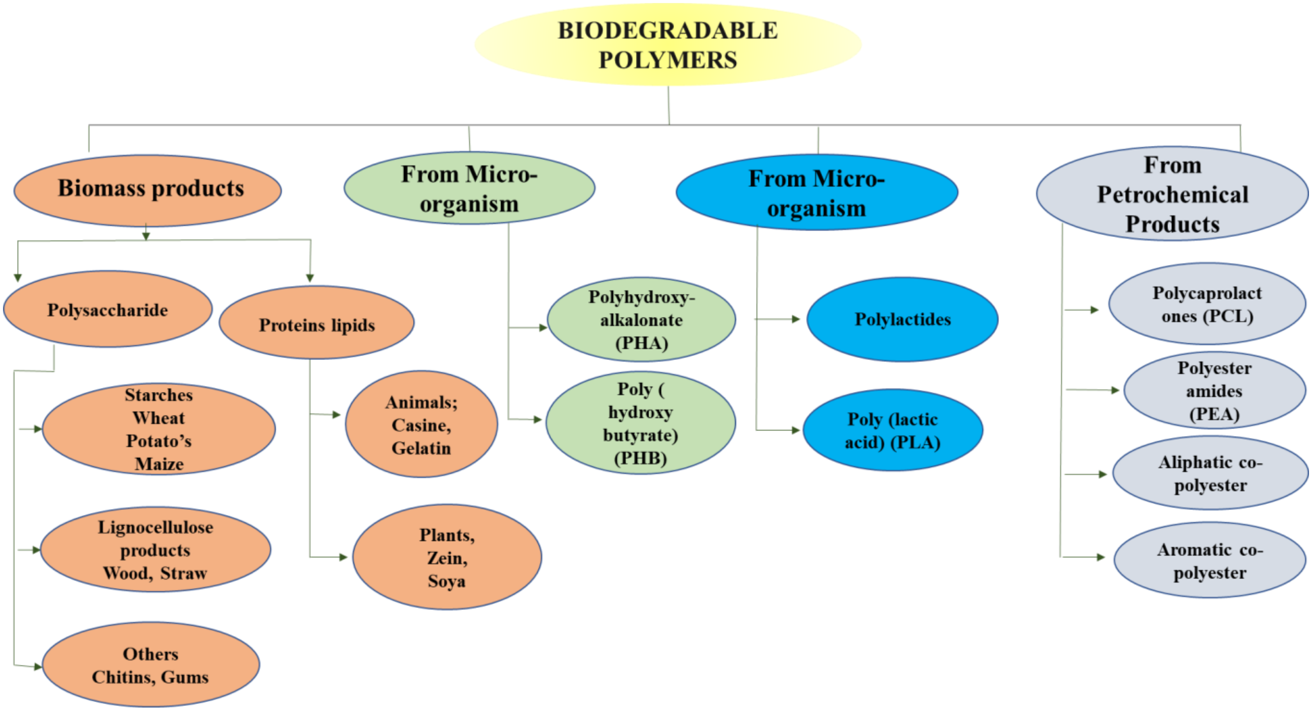

Figure 1. Classification of biopolymers

On the Basis of Type

Sugar-based polymers

Starch or sucrose are used as raw materials in production. The input for the production of lactic acid polymers is starch or sucrose, while the lactose is derived from potatoes, maise, and other sources. Lactic acid polymers are produced using potatoes, maize, and other lactose sources [6]. Starch-based polymers Starch is a naturally occurring polymer made of glucose molecules. Two recent viewpoints have increased awareness of sugar-based polymers, which are created by polymerizing vinyl sugars. One is the development of environmentally friendly materials derived from renewable resources.One class of cellulose-derived biopolymers that can be used to create a variety of materials, including coatings, films, composites, nanocomposites, etc. is the polysaccharide family. One of the most common polysaccharides in the world, cellulose, has a variety of desirable and distinctive qualities [4,7]. However, it makes sense and should be considered that cellulose can be used effectively as a packaging raw material. This chapter provides a thorough overview of the various applications for cellulose inside the packaging industry. The three main areas of cellulose application in the packaging industry are the production of composites, the development of coating materials, and the production of edible and non-edible movies Long-chain natural polymer cellulose makes a large indirect contribution to the human food cycle [8]. The veterinary food industry, the wood and paper industry, the textile and apparel industry, as well as the pharmaceutical and cosmetic industries, can all employ this polymer as an excipient. cellulose-based polymers Chitin is the second most common biopolymer in the world, closely after cellulose. The primary structural element of plants, cellulose, is a polymeric raw material that is practically infinitely abundant and has a unique structure and set of features. More than 150 years have passed since then. cellulose was used initially as a construction block Long-chain natural polymer cellulose makes a large indirect contribution to the human food cycle. The veterinary food industry, the wood and paper industry, the textile and apparel industry, as well as the pharmaceutical and cosmetic industries, can all employ this polymer as an excipient [9,10].

Starch-based polymers

Since starch is made of glucose, it functions as a natural polymer. The tissues of plants contain it. By adopting a variety of techniques like blending, derivation, and copolymerization, synthetic degradable polymeric components have been physically or chemically added to starch. Starch has been combined with a variety of polymers (mostly biodegradable), including polyesters and biopolymers, to create starch-based biodegradable plastics Many different products, including pencil sharpeners, rulers, cartridges, combs, toys, plant pots, and bones, are made from starch-based polymers [11]. It is entirely biodegradable, cheap, renewable, and has a simple chemical process. Unsurprisingly, (modified) starch-based bioplastics have drawn more interest as biodegradable substitutes for conventional petroleum-based plastics. Starch, like cellulose, is a condensation polymer because when it is hydrolyzed, glucose molecules result [12]. Starch has a rigid structure due to the cyclic nature of its molecules and strong hydrogen bonds, which result in highly organised crystalline and granular regions. High starch foods are a good source of nourishment. After being consumed, they are converted into glucose, the body's primary fuel, especially for our muscles and brain. Starchy meals contain a variety of critical minerals, including B vitamins, iron, calcium, and folate [10,11,13].

In the wet granulation process of massing and screening, a crucial stage in the creation of tablets, capsules, and other solid dosage forms, starch is frequently utilized as a binder.Starch's main nutritional purpose is to help our bodies convert glucose into energy.

The only carbohydrate that our body can utilise is glucose. Our bloodstream carries glucose, which is taken by cells and used as an energy source [14]. Food starches are commonly used as thickeners and stabilisers in foods like puddings, custards, soups, sauces, gravies, pie fillings, and salad dressings, as well as in the production of noodles and pasta. The structure of starch is made up of lengthy strands of linked sugar molecules. In plants, starch is mostly used to help in energy storage. Animal diets contain starch as a source of sugar. The amylase enzyme, which is present in saliva and the pancreas and breaks down starch for energy, is required by animals to digest starch [15].

On the Basis of Origin

Natural biopolymers

These are organic biopolymers that were produced by living things. Polysaccharides and animal-derived proteins make up natural biopolymers, which exhibit biochemical reactions to human extracellular matrix modules over and above other biopolymers in the human body (Table 1). As a result, they have no negative consequences when they come into contact. Unique interactions between natural biopolymers and the cellular domain exist. Polysaccharides and animal-derived proteins make up natural biopolymers, which exhibit biochemical responses to human extracellular module over and above other biopolymers in the human body. Natural biopolymers are appealing substitutes for petroleum-based plastics that are not biodegradable, such as starch, cellulose, chitosan, carrageenan, gelatin, and its derivatives. Due to their abundance, renewability, cost effectiveness, biocompatibility, and biodegradability, biopolymers are excellent materials for use in film production [9-12]. In order to construct nanofilms by adding unusual nanostructures, non-conventional sources (such as bacterial or fungi cellular components, soy protein, and fish skin gelatin) are constantly being studied for the isolation of biopolymers. With the development of nanotechnology, a range of intelligent bioactive nanomaterials with high microbicidal potential are being created, which can be successfully impregnated in a biopolymeric matrix to create nanocomposite coatings with antibiofilm capabilities [10,16]. In order to understand the rational fabrication of nanoparticle-embedded biopolymeric films, we present a detailed description of various biopolymers that exhibit antibiofilm activity.To assure the prevention of microbial biofilms, order various methods for chemical modification and plans for the incorporation of nanostructures. These clever polymeric films could serve as surfaces that kill germs while also limiting their interaction and attachment to surfaces [14,17]. Additionally, we hypothesise a number of passive and active mechanisms that may be at play when biofilms are inhibited or destroyed utilising nanoparticle-polymer composite films. Natural polymers have been extensively utilised in numerous applications such as pharmaceuticals, tissue regeneration scaffolds, drug delivery agents, and imaging agents. In wound care, they are used as dressings for acute or chronic wounds and as regeneration templates. There are numerous natural sources of polymers, including plants, animals, and microorganisms. Natural biomedical polymers-based scaffolds are desirable for skin repair and regeneration due to their similarity to the extracellular, mechanical tunability, high biocompatibility, and high-water holding capacity. Finding the right material for a scaffold with the right qualities for the desired type of wound poses a difficulty for researchers. In addition to providing a review of frequently employed or promising natural polymers in wound healing, this chapter will examine the desirable features of natural polymer-based acellular and cellular applications, as well as currently available scaffold for skin repair and regeneration [14-16].

Table 1. Biopolymers from animal origin and it's applications

Name ofpolymer	**Sourceoforigin**	**Physicalappearance**	**Uses/applications**	**References**
Chitosan	Shellfish and crustacean wastematerials	Pale, white and flakyand its moisturecontent was10.9%.	Cosmetics, health care, agriculture, waste management, wound healing, papermaking, food packaging, seed coating, plant growth regulator, protein waste recovery, personal hygiene products, anti-bacterial, anti-acid, drug carrier for controlled release, a flocculating agent, water purification, bioremediation of toxic phenolic compounds, promotion of osteogenesis, and fat absorbent action.	[17]
Gelatin	Cattle hides, bones, fish, pig skins, agricultural or	Water-solubletranslucent, flavourlessfood	Food wetting agent, emulsifier, stabilizing agent, thickening, texturizer, emulsifier, foaming,	[18]

	non-agricultural	ingredient,gum mywhen moistandbrittlew hendry	pharmaceutical, and medicinal uses.	
Hyaluroni cacid	The umbilical cord of a newborn kid, rooster combs, and streptococcus and other bacterial fermentation broths.	Transparent, viscousfluidorw hitepowder.	Drug delivery gel, wound healing gel, viscosity agent, filler in medicine, and antibacterial gel.	[19]
Collagen	Invertebratesinth ebodywallsandc uticles.	Hard, fibrous,insoluble , protein, andmolecules form long,thinfibrils.	In the synthesis of enzymes, solid-support microcarriers are used in the manufacture of sutures, dental composites, sausage casings, skin regeneration templates, cosmetics and biodegradable matrices.	[20]
Keratin	Scales, stratum corneum, horn, wool, feathers, hair, nails, and nails.	Insoluble in mostorganicsolv ents.	Surgical procedures, medication delivery systems, electrode materials, cosmetics, biomedical goods, and the leather and food sectors.	[21]

Synthetic biopolymers

These are biodegradable polymers made of renewable substances like polylactic acid. The synthesis of biopolymers is intrinsically tedious due to their large molecular weight. Additional difficulties may result from the native biopolymer's unique spatial arrangement, which may be crucial to its characteristics or function but is difficult to replicate in the synthetic duplicate. Despite this, it is highly desirable to use chemical methods to obtain biopolymers in order to get around problems like the target biopolymer's low abundance in nature, the need for time-consuming isolation procedures, or high batch-to-batch variability or inhomogeneity of the found naturally speciessynthetic polymers have random, straightforward structures [18]. The fact that their synthesis is controlled by a template-directed mechanism may indicate the absence of a molecular mass distribution in biopolymers. Sugar polymers can be linear or branched, and glycosidic linkages hold them together [3-5]. Synthetic biopolymers are polymers that have been chemically or naturally changed from other polymers. made from synthetic monomers in a way that allows for natural breakdown and prevents the residues from being hazardous to the environment or to living things. Because of their inherent benefits over natural polymers in terms of durability and flexibility to suit a number of applications, synthetic biopolymers have garnered a lot of attention in recent years. However, due to their biodegradable qualities and environmental safety, synthetic biopolymers are preferred over synthetic polymers. Artificial biopolymers have discovered one of its most important applications in the medical field because of some of their unique properties such as stability, controlled release, non-immunogenicity, and clearance from the body, which suits their application in human bodies [19-21].

Polymers created by humans are referred to as synthetic polymers. Monomers, which are repeated structural units, are what make up polymers. Ethene or ethylene serves as the monomer unit in polyethylene, which is one of the simplest polymers. High-density polyethylene, or HDPE, is the name of the linear polymer. Many of the polymeric materials have structures that mimic polyethylene in that they resemble chains. Plastics are sometimes used to refer to polymers; nylon and polyethylene are two examples [22]. Addition polymers, sometimes referred to as chain-growth polymers, are polymers that are created by joining monomer units without changing the original material. These are all supposedly manmade polymers. The well-known synthetic polymers, nylon and polyethylene, are referred to as "plastics" in some contexts. Addition polymers, sometimes referred to as chain-growth polymers, are polymers that are created by joining monomer units without changing the original material [23]. These are all supposedly manmade polymers. Teflon, which is used in nonstick cookware, polyvinyl chloride, and nylon are some examples of synthetic polymers that we utilise on a daily basis. Polyethylene terephthalate, a synthetic polymer, is a common component of the PET bottles we use. The tyres of cars are made from buna rubbers, and the coverings and plastic kits are made of synthetic polymers like polythene. However, the use of these synthetic polymers, such as bioplastics and those derived from petroleum, also brings about environmental problems because they are considered to be non-biodegradable. Plastic bags and film wrap both include the polymer known as polyethylene. Bottles, electrical insulation, toys, etc. all use polyethylene [23,24].

PVC is a plastic that is used for flooring, pipelines, and siding.Polystyrene, a synthetic polymer, is utilised in cabinetry and packaging.Both latex paints and adhesives include polyvinyl acetate. Biopolymers produced by microorganisms.

Microbial origin

Polyesters, polyamides, and polysaccharides are examples of microbial biopolymers that can be successfully produced from pure cultures, mutants chosen from the lab, or genetically modified organisms. Biopolymers include bioplastics and viscous fluids. The food business employs a number of biopolymers made by microorganisms. Today, a number of bacteria have been recognised as microbial biopolymer makers (Table 2). These polymers are recovered from the fermentation media or found attached to the cell surface [25]. Extracellular polymeric substances (EPS) and polyhydroxyalkanoates (PHAs), which are made by a variety of microbial taxa, are examples of microbial biopolymers that could serve as more effective alternatives to aid in the waste bioremediation process. Almost every process on Earth is strongly reliant on bacteria and their activities. Microorganisms are significant because they affect every aspect of our lives and are present in, on, and around us. focuses on all types of living things that are too tiny to see with the human eye [26]. This includes what are collectively referred to as "microbes," which are bacteria, archaea, viruses, fungus, prions, protozoa, and algae. The cycling of nutrients, biodegradation and deterioration, climate change, food spoilage, the discovery of novel therapeutics, and biotechnology all depend on these bacteria. The creation of biofuels, the removal of contaminants, and the production/processing of food and drink are just a few of the processes in which microbes are helpful. Their versatility makes this feasible. Famous microbiologists like Marshall, who found a link between the Helicobacter pylori infection and stomach ulcers, Jenner, who created a smallpox vaccine, Fleming, who discovered penicillin, and zur Hausen, who found a link between the papilloma virus and cervical cancer, have made some of the most important discoveries that have helped to sustain modern society. Microbiology research has been and will continue to be crucial in tackling the many present global objectives and difficulties, including maintaining food, water, and energy security for a healthy people on a habitable planet [27-30].

Table 2. Biopolymers from microbial origin and their applications

Name	**Sourceoforigin**	**Physicalappearance**	**Uses/applications**	**References**

ofpolymer				
Levan	*Rothisdentocariosa,Streptococcus salivarius,andOdontomycesviscosus, (Bacillus subtilis,Bacillus megaterium,Bacilluscereus,*and*Bacilluspumilus)*	Natural adhesive andsurfactant, non-viscousand water and oilsoluble.	Emulsifying agents aid in preparation, function as preservers, gelatinize surfaces, encapsulate, transport flavours and odours, aid in the filtering of gels, and increase blood volume.	[31]
Pullulan	*Aureobasidium*pullulans.	White powderdissoluble in water,uncoloured and glueyadherent solution,indissoluble insolvents such asethanol,methanoland acetone.	Low-viscosity filler that stabilizes quality and texture, fatty emulsions that are stabilized, denture glue, and medicinal coatings all work to prevent the growth of fungi.	[32]
PHA Polyhydroxyacetonoate	*Cupriavidusnecator (Ralstonia eutropha*or *Alcaligeneseutrophus*).	Pliant, adjustable, amorphous.	Shaving equipment, furniture, diapers, sanitary towels, cosmetics, shampoo bottles, bone plates, stitches, and new blood vessels.	[33]
PHB (polyhydroxybutyrates)	Microorganisms (such asthe*Cupriavidus necator*,	Biodegradablethermoplasticpolyester. Highlycrystalline(>50%), brittleandhard.	Osteosynthetic materials are biocompatible, biodegradable carriers that support cell	[34]

	Methylobacterium rhodesianum or Bacillus *megaterium*).		development, direct and organise the cells, promote tissue growth, and serve as food packing.	
Curdlan	*Agrobacterium* genus,Gram-negativebacteria	White granulates,fragrance-free, non-poisonous gel, steadyat3to9 pHscale.	Stabilizers, biothickeners, materials for immobilization, texturizers, binding agents, and immunostimulators.	[35]
Bacterial Cellulose	*Achromobacter, Alcaligenes, Aerobacter,Agrobacterium,Azotobacter,Gluconacetobacte,Pseudomonas, Rhizobium,Sarcina,Dickeya,and Rhodobacter*belong to theKomagataeibactergenus	Intact membranes(fibres form or pelletsform), disassembledBC, and BCnanocrystals(BCNC).	Food packaging, transparent coverings, cell dividers, permeable materials, water research, cosmetics, biocompatible materials, ethyl alcohol production, materials that conduct electricity, magnetic materials, artificial blood vessels, and scaffolds for tissue engineering are just a few examples of the goods that fall under this category.	[36]
Dextran	*Dextran sucrase,Leuconostocmesenteroides,Saccharomyces cerevisiae,Lacto*	Dissoluble in water,dimethyl sulfoxide,formamide, ethyleneglycol, glycerol andindissoluble	Solidifying, thickening, emulsifying, soothing, palatable, loaf mass, smoothness, storage life, cryoprotectant, viscosifier, creamy,	[37]

	bacillus plantarum,or *Lactobacillussa nfrancisco*.	inmonohydric alcohols,e.g., methanol,ethanol, isopropanol,andketone s, e.g., acetone and 2-propanone	lowering synaeresis, food antioxidant, water holding capacity, moisture content raised in non-fat mass, and functional foods are some of the other terms used.	
Xanthan gum	Plant pathogen such as*Xanthomonas campestris*NRR LB-1459.	Motile, with one polar flagellum, and a cream-colored powder that is soluble in both hot and cold water.	Texture, viscosity, flavour release, appearance, and water control are all characteristics of emulsifiers and thickeners.	[38]

On the Basis of Monomeric Units

Polysaccharides

These are either branching or linear carbohydrate chains: cellulose, starch, etc. Biopolymers based on polysaccharides are excellent possibilities for creating materials that can satisfy the highly desired twin criteria of economic sustainability and environmental friendliness. Polysaccharides, which are naturally occurring polymeric carbohydrates generated from living things including plants (Table 3), algae, animals, fungus, bacteria, and/or other biological sources, are renewable, sustainable, and environmentally benign.The characteristics of natural polysaccharides such as availability, chemical/mechanical stability, biocompatibility, biodegradability, reinforcing capacity, ease of functionalization, variety of forms, cost efficiency, and non-polluting nature have led study in this field. Consequently, they have lately been studied in a variety of applications [31]. Plant, animal, algal, bacterial, fungal, and other polysaccharides are frequently employed to make sustainable biopolymers. This chapter discusses the role of various living organisms in the synthesis of a wide variety of natural biopolymers, including pullulan, elsinan, scleroglucan, xanthan gum, curdlan, dextran, and gellan. Animals, fungi, plants, and bacteria are some of the other creatures that are covered. The most prevalent natural biopolymer, polysaccharides have distinctive chemical, physical, and biological characteristics [32]. The diversity and complexity of the polysaccharides are determined by the monosaccharide building blocks and glycosidic connections that form the backbone of these polymers. Enzymatic, chemical, and chemoenzymatic methods will be discussed in order to provide access to well-defined polysaccharides. In reality, polysaccharides-based materials in a variety of forms, such as fibres, films, food casing, membranes, hydrogels, aerogels, and sponges, have been created. These materials have applications in a number of significant economic sectors, including adsorption, food, pharmaceuticals, biomedicine, electronics, and food [28-31].

Table 3. Plant origin biopolymers with their applications

Name ofpolymer	**Sourceoforigin**	**Physicalappearance**	**Uses/applications**	**References**
Carrageenan	Cell wall matrix of redseaweeds.	At normal temperature, large, flexible molecules form helical shapes and solidify.	Anticoagulantandantithrombotic activity,Antiviralactivity,textural functionalityparticularlyindairypr oducts.	[36]
Pectin	Plant cell walls, citruspeels,apple pomace.	Yellowish-white, coarse or fine-powder, odourless, with a mucilaginous taste, and completely soluble in 20 parts of water.	Reduce blood cholesterol, treat gastrointestinaldisorders, remove metals such as lead, mercuryfrom intestine and lungs, control haemorrhage,tabletformulations, antimicrobialaction,improvescoa gulation,treatment ofovereating,anti-inflammatory.	[38]
Cellulose	Plant tissue(trees, cotton etc),bacteria (*Acetobacterxyli num*).	solvents that are hydrophilic, chemical-free, odourless, and environment-friendly are insoluble in water.	Controlled Drug Delivery Devices, Wound Dressings, Regenerative Medicine Scaffolds, Cellophane Films, Thickeners, Wrappers, Adhesives, Coatings, Ligatures, Preservers, Dispersing Agents,	[34]

			Flow Controllers, Tile Sealants, Board Fixative, Indelible Inks, and Cosmetics.	
GuarGum	*Cyamopsistetragonolobus orCyamopsispsoraloides.*	90% of this granule, which is white to off-white in colourand odourless, dissolves in water.	Disintegrating, binding, film-forming, thickening, gelling, stabilising, emulsifying, bioadhesive, bulk-forming laxative, and non-toxic properties.	[39]
Xylan	Hardwood (eg-*Eucalyptus globules*etc),almondshell,ricehusk,corncobs.	Yellow gummy highlycomplexpentosan.	Low-caloriesweetener, preventive measure, textile printing, paper manufacturing, and medicine delivery method.	[40]
GumArabic	Stems and branches of*Acacia Seyal andAcaciaSenegal*tree.	Dried, gummy.whitetoyellowish white, practically withtasteless,andodourless.	Stabilizer, thickening agent, emulsifier, print photolithograph, fabric, ceramics, nephroprotectant, cosmetic items, pharmaceutical manufacturing sectors.	
Alginate	Brown algae of thegenera'*Nacrocystis, Laminaria, Ascophyllum, Alario,Ecklonia, Eisenia,nercocystis,sargassum, cystoseria,fucus*	Whitetoyellow,fibrouspowder.	Texturization of fruit, diffusion-set gels, protein ejection, prolonged shelf life of potatoes, inhibition of banana enzymes, crumbled fish patties, meat products, water-holding, ice cream stabilizers, and dispersive power.	

Proteins

Because enzymes are involved in the manufacture and breakdown of all biopolymers, proteins in particular must be able to interact with other polymers. However, there are several documented instances of connections between nonenzymic proteins and other proteins, polysaccharides, or nucleic acids. Large biomolecules and macromolecules called proteins are made up of one or more extended chains of amino acid residues [33]. Among the many tasks that proteins carry out in living things include catalyzing metabolic processes, replicating DNA, reacting to stimuli, giving cells and organisms shape, and transferring chemicals from one place to another. The primary way that proteins differ from one another is in the order of their amino acids, which is determined by the nucleotide sequence of their genes and often causes a protein to fold into a certain 3D shape that controls its function. A polypeptide is an ordered sequence of amino acid residues. At least one lengthy polypeptide is present in every protein [19,23,33]. Less than 20–30 residue polypeptides are frequently referred to as peptides or even oligopeptides and are rarely thought of as proteins. The individual amino acid residues are bonded together by peptide bonds and adjacent amino acid residues. The sequence of a gene, which is encoded in the genetic code, determines the arrangement of amino acid residues in a protein [34]. The genetic code typically only defines the 20 conventional amino acids, but in certain species it may also include selenocysteine and—in some archaea—pyrrolysine. The residues in a protein are frequently chemically altered by post-translational modification shortly after or even during synthesis, which modifies the physical and chemical characteristics, folding, stability, activity, and ultimately the function of the proteins. Non-peptide groups, often known as cofactors or prosthetic groups, are sometimes added to proteins. Additionally, proteins may cooperate to carry out certain tasks, and they frequently join forces to create stable protein complexes [35].Protein turnover is the process through which the machinery of the cell breaks down and recycles proteins that have already been created after a finite amount of time. The half-life of a protein is a broad measure of a protein's lifetime. In mammalian cells, they have an average lifetime of 1-2 days but can live for minutes or years. Proteins that are abnormal or misfolded degrade more quickly either because they are targets for apoptosis or because they are unstable. Proteins play a crucial role in nearly every cellular activity and are fundamental components of organisms, just like other biological macromolecules like polysaccharides and nucleic acids. Many proteins are enzymes, which are essential to metabolism and catalyze biological events [29].Actin and myosin in muscle and the proteins in the cytoskeleton, which constitute a system of scaffolding that preserves cell shape, are examples of proteins that also have structural or mechanical roles. Other proteins have crucial roles in the cell cycle, immunological responses, cell adhesion, and cell signalling. Animals require proteins in their diets in order to supply the necessary amino acids that cannot be synthesised. The proteins are broken down during digestion for usage by the body. Using a variety of procedures such ultracentrifugation, precipitation, electrophoresis, and chromatography [36], proteins may be separated from other biological constituents; the development of genetic engineering has made a number of ways for purification available. Site-directed mutagenesis, X-ray crystallography, nuclear magnetic resonance, mass spectrometry, and immunohistochemistry are examples of techniques frequently used to examine protein structure and function [34,36]. Nucleic acids are lengthy polymer chains made up of 13 or more monomeric units, or polynucleotides. RNA, DNA, etc. The human body need protein for both development and upkeep. Proteins are the most prevalent type of molecule in the body after water. All of the body's cells, particularly muscle cells, are made mostly of protein, which can be found in every cell.Large, intricate molecules known as proteins serve a variety of vital functions in the body. They are crucial for the construction, operation, and control of the body's tissues and organs and carry out the majority of their job inside cells. Numerous thousands of amino acids, which are smaller building blocks of proteins, are linked together in lengthy chains to form proteins. Proteins are created by combining 20 distinct kinds of amino acids. Each protein has a distinct three-dimensional structure and function based on the amino acid sequence. Combinations of three DNA nucleotides, which make up nucleic acids, are used to code for amino acids, and the order of genes determines these combinations [37-40].

Polynucleotides

Long polymer chains made up of 13 or more monomeric units make up nucleic acids. RNA, DNA, etc. Important models for DNA have been researched using polynucleotides, which are made up of a high-molecular-weight polymeric chain of identical base-sugar-phosphate subunits. single-stranded form of the polynucleotides makes a simplification to the study of DNA damage, although strand aggregation can be induced under certain pH conditions. Poly(C) and poly(A), for instance, become double stranded at pH 5–6. A double-stranded complex can also be created by joining two polynucleotides that naturally base pair, such as poly(A) and poly(U) [39]. In comparison to reactions using free bases, the rate constant for hydrated electron processes involving polynucleotides is at least a factor of orders of magnitude lower. Both the stronger repelling forces of the negatively charged polymer and the polymer's lower encounter frequency with the electron may be to blame for this. The reactivity of the uncharged OH radical is only around 5 times reduced from a single nucleotide to a polynucleotide. Several nucleotide monomers are linked by covalent bonds to form a polynucleotide [28]. At least 14 nucleotide monomers are assembled in a chain to form a single polynucleotide molecule. Ribonucleic acid (RNA) and deoxyribonucleic acid are two examples of polynucleotides (DNA). DNA is made up of two spiral chains of polynucleotides that are arranged in a helical manner, as opposed to RNA, which is a single-stranded molecule. Huge molecules known as polynucleotides are the building blocks of life. The polynucleotide is a polymer molecule composed of nucleotide monomers. Nucleic acids, also known as polynucleotides, are found in nature in two main types [29,32]. RNA and DRA are the two types of nucleic acids that make up life (DNA). Every live cell's genetic building block is DNA. Unique chemical, structural, and biological characteristics are shared by DNA and RNA. Ribonucleic acid (RNA) and DNA are examples of polynucleotides (amino acid). DNA is made up of two spiral chains of polynucleotides that are arranged in a helical manner, as opposed to RNA, which is a single-stranded molecule. Huge molecules known as polynucleotides are the building blocks of life. The polynucleotide is a polymer molecule composed of nucleotide monomers. There are two primary forms of nucleic acids, sometimes referred to as polynucleotides, in nature. The following is a list of key DNA structural characteristics: Both DNA strands have based that face inward toward the core of the helix and sugar-phosphate backbones that are at the outside of the helix (like steps of the circular staircase) [17-22].

Through hydrogen bonds formed between base pairs that complement one another, both strands communicate with one another.Both strands are held together by the base pairing of purines and pyrimidines. Through two hydrogen bonds, adenine is always paired with thymine in the opposing strand and vice versa. Similar to this, hydrogen bonding between guanine and cytosine in opposing strands is permitted. Three hydrogen bonds allow guanine and cytosine to interact. A polymer made up of numerous nucleotides joined together is called a polynucleotide. The polynucleotide molecules found in the cell include DNA and RNA [36]. Every sugar molecule in a polynucleotide chain has a nitrogen base linked to it, giving the chain its sugar-phosphate backbone. A double helix-shaped structure made up of complementary pairs of extremely long polynucleotides makes up an organism's genome. Other functions played by polynucleotides in organisms are diverse. In biological tests like DNA sequencing or the polymerase chain reaction (PCR), polynucleotides are employed. Polynucleotide. Two polynucleotides with different biological purposes are DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). The prefix "poly" is derived from the Greek letter "O" (polys, many DNA is made up of two chains of polynucleotides, each of which is shaped like a helical spiral [26-29].

Properties of biopolymers

The primary goal of biopolymers is to replace several common objects made of petroleum-based materials. In order to be suitable for the many uses that they will be subjected to, they must therefore possess comparable, if not superior, qualities to the materials they replace. Due to variables including the degree of polymerization, the kind and quantity of additives, and the presence of reinforcement materials, a large portion of the property measurements of biopolymers vary [29,37]. Although there hasn't been as much research into the physical, mechanical, and thermal properties of biopolymers as there has been for standard polymers, knowledge about their characteristics is nevertheless quite substantial. The harmful effects of environmental pollution from fossil fuels and waste from petrochemical industries are causing significant concern. Many studies have been conducted to investigate different alternatives to petroleum-based goods that would be renewable and biodegradable and so pose less of a damage to the environment [4,18,38]. Being largely biodegradable materials made from renewable basic resources, biopolymers are one such potential answer to the issue. It should be emphasised, nonetheless, that not all biopolymers are biodegradable polymers. As one might anticipate, there are difficulties with biopolymers, including their low rate of production, high cost, and suitability of their properties. Rubber, linoleum, celluloid, and cellophane are a few of the earliest contemporary biomaterials made from natural biopolymers. The latter two are created from cellulose, which makes up a third of all plant matter and is both the most prevalent organic material and the most naturally occurring biopolymer on Earth. Since the middle of the 20th century, petrochemical-based materials have largely replaced these man-made biopolymers [39].

Properties of biopolymers [36-38]

Physical Properties:The tensile strength of the polymer increases with chain length and cross-linking. Instead of melting, polymers transition from a crystalline to a semi-crystalline state.

Chemical Properties:The polymer is enabled with hydrogen bonding and ionic bonding, resulting in a better cross-linking strength than conventional molecules with various side molecules. The polymer's high flexibility is made possible by the side chains' dipole-dipole bonding. Although known to be weak, polymers containing Van der Waals forces connecting chains also have a low melting point.

Optical Properties:They are used in lasers for spectroscopy and analytical purposes on biopolymers because they can change their refractive index with temperature, as PMMA and HEMA:MMA do.

Applications of biopolymers

In addition to being utilised in cosmetics, pharmaceuticals, and food packaging, biopolymers have numerous industrial applications. In many applications, they can take the place of conventional petroleum-based polymers (Figure 2). Some biopolymers have also been used for particular purposes for which other plastics would not be appropriate, such as the production of synthetic tissue. For these applications, materials that are sensitive to pH changes, physicochemical changes, and thermal fluctuations may need to be biocompatible and biodegradable. In comparison to synthetic polymers, biopolymers typically have poor tensile characteristics, chemical resistance, and processability. They can be supplemented with fillers, which significantly enhance their qualities, to make them more appropriate for particular applications. Biopolymer composites are biopolymers that have undergone this type of reinforcement [5,8,14,35]. A list of several popular biopolymer composites, their characteristics, and the sectors in which they are already in use are provided in the figure 2.

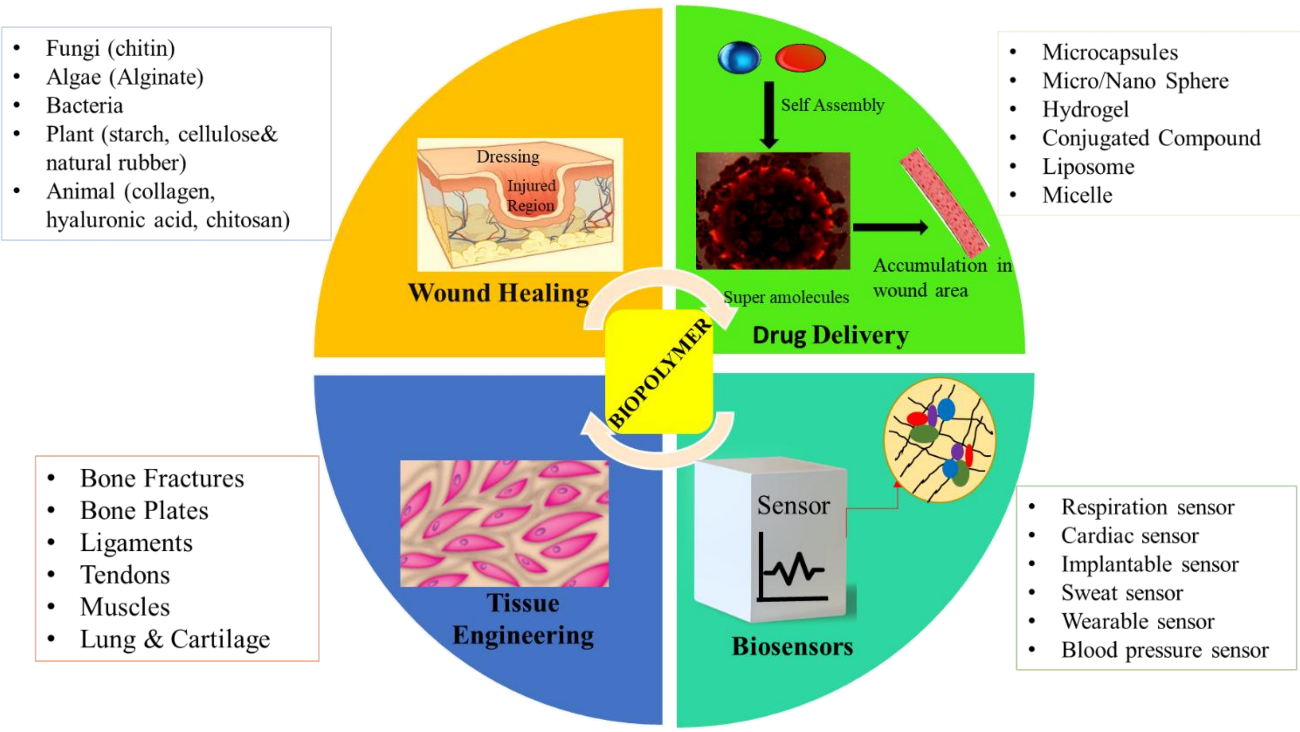

Figure 2. Versatile applications in biopolymers in different areas

Biomedical applications

Due to qualities like degradability and non-toxicity, they are used in tissue engineering, the pharmaceutical sector, pharmaceuticals, drug delivery, and other applications. Due to their low cost and accessibility, polypeptides are used in a wide range of biomedical goods.

pharma delivery systems Medicine delivery techniques use biopolymers like collagen and chitosan to target the drug and enhance medication absorption [34]. Collagen sponges are frequently used to treat burn burns. Collagen and chitosan are both used in tissue engineering. Since they are so permeable, wounds can heal quickly. The usage of biopolymers in the biomedical industry is fairly widespread. They are employed in tissue engineering, the pharmaceutical industry, medications, drug delivery, and other fields due to their attributes including degradability and non-toxicity. Polypeptides are widely used in biological materials because they are affordable and accessible [29,32].

Industrial applications

Due to their distinctive qualities, biopolymers are used as standard materials in the industry. To strengthen the qualities of these biopolymers and increase their desired properties and useful applications, they are combined with some materials [9].These are widely used in packaging; PHA, polylactic acid and starch being inexpensive and readily available are perfect for this task. They also have barrier characteristics which are not available in other polymers, like these are water-resistant. Biopolymers are used in the automotive industry to make interior and exterior parts, electrical components, engine, exhaust, steering wheels etc. Biopolymers are added to cement during concrete preparation to increase the desired properties. They are used in the construction industry of interior decoration.Chitosan has properties that remove metals from the water which makes it usable for water purification. Due to its antimicrobial properties, it is also used at places to stop microorganism growth. These are widely used in packaging; PHA, polylactic acid and starch being inexpensive and readily available are perfect for this task [16]. They also have barrier characteristics which are not available in other polymers, like these are water-resistant.Biopolymers are used in the automotive industry to make interior and exterior parts, electrical components, engine, exhaust, steering wheels etc. Biopolymers are added to cement during concrete preparation to increase the desired properties. They are used in the construction industry of interior decoration. Chitosan has properties that remove metals from the water which makes it usable for water purification. Due to its antimicrobial properties, it is also used at places to stop microorganism growth [33,37,39].

The automotive industry uses biopolymers to create interior and exterior components, electrical parts, engine, exhaust, steering wheels, etc. In order to increase the desired qualities, biopolymers are added to cement during the manufacture of concrete. They are employed in the field of interior design and building. In addition to being utilised in cosmetics, pharmaceuticals, and food packaging, biopolymers have numerous industrial applications. In many applications, they can take the place of conventional petroleum-based polymers. Some biopolymers have also been used for particular purposes for which other plastics would not be appropriate, such as the production of synthetic tissue [17,21].

Bioplastics

In the food business, biopolymers are utilised for coating foods, edible encapsulation films, and packaging. The clear colour and water resilience of polylactic acid (PLA) make it a particularly popular ingredient in the food sector. But because most polymers are hydrophilic, they begin to break down when they come into contact with moistureSome bioplastics are made by processing naturally occurring polysaccharides (such as starch, cellulose, chitosan, and alginate) and proteins (such as soy protein, gluten, and gelatin). Others are made chemically from lipids (such as lactic acid) and lipid derivatives (such as sugars, such as sugars), which can come from either plants or animals. Contrarily, conventional plastics like fossil-fuel plastics, often known as petro-based polymers, are made from natural gas or petroleum. A moldable plastic substance known as bioplastic is composed of chemical compounds that are produced or synthesised by microorganisms like bacteria or plants that have undergone genetic engineering. Bioplastics are made from renewable resources, as opposed to conventional plastics, which are made from petroleum. Some bioplastics are also biodegradable [8,14,34,38].

Biopapers

Recyclable papers can go by the name of natural papers. These papers are recycled and natural. Here, we conserve more than 80% of our water resources and wood resources by using natural papers. The ability to recycle and reuse natural papers positively benefits our environment. The paper is used for numerous things, including post cards, greeting cards, and letterhead. Modern times have seen a significant resurgence of natural paper. Natural paper offers a novel option that is straightforward, rustic, and fashionable at a time when more and more people are concerned about chemicals, poisons, and pollution. Raw plant-based fibres like cotton, linen, hemp, wood, or grass stalks are used to make natural paper. It is renowned for having many creative textures [26]. Natural paper uses fewer synthetic chemicals because it isn't bleached. Flowers and natural colouring can be used to add style. The majority of factory-white standard paper has historically been made from wood pulp [28]. However, natural paper is typically produced from recycled organic material or fibre materials from non-wood plants. Raw plant-based fibres like cotton, linen, hemp, wood, or grass stalks are used to make natural paper.It is renowned for having many creative textures. Natural paper uses fewer synthetic chemicals because it isn't bleached. Flowers and natural colouring can be used to add style. In addition to being better for the environment, it feels and looks better overall. Natural resources can be used to creat natural paper (Figure 3) [35].

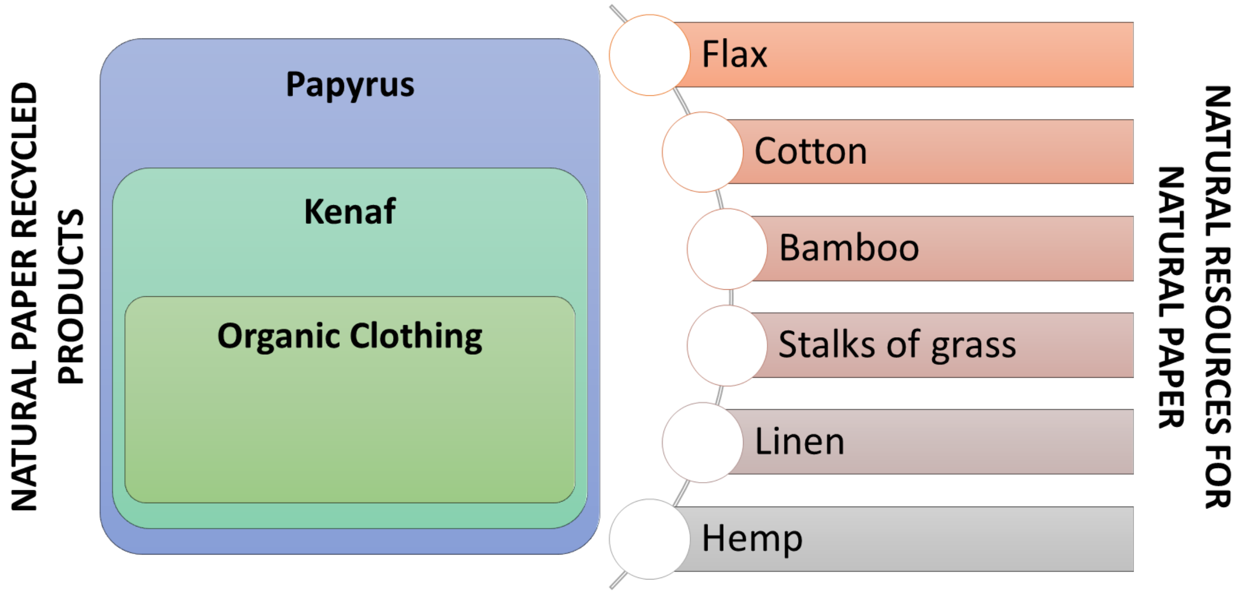

Figure 3. Natural resources and recycled product of natural paper

Natural fibers

Natural resources, such as plants or animals, are used to make natural fibres. Our natural resource has a lot of fibres to offer. Finally, these fibres are turning into woven knitted fibre, ropes, and treads. The most notable natural fibre is cotton. Our skin feels nice on it because of its wearing quality and silky texture [23-26]. The phrase "natural fibre" is used to describe fibres that come from (or are produced by) plants and animals. These fibres can be used in a variety of ways to create composite materials. Different layers of natural fibres can be matted into sheets to create paper and felt (a type of textile material). Plant fibres and animal fibres are the two broad categories into which natural fibresfallIn this subsection, examples for both plant and animal fibres have been given. Natural fibres come in a range of textures and are effective sweat absorbents. For instance, cotton fabrics created from cotton fibres have a pleasant touch, are lightweight, and come in a variety of sizes and colours. People who live in hot, humid conditions frequently prefer natural textiles like cotton over synthetic fibres for their apparel [31-35].

Plant Fibres Seed fibres:The fibres obtained from the seeds of different types of plants.

Leaf fibres:The natural fibres that can be collected from the leaves of certain plants. Examples include pineapple and banana leaf fibres.

Fruit fibres:The plant's fruit is used to produce natural fibers.

Stalk fibres:The natural fibres that can be extracted from certain plant species' stalks. Examples include straw, bamboo fibres, rice and barley plant stalk fibres, as well as wheat straws.

Bast fibres:The natural fibres that are derived from the cells in the stem's outer layer. Jute, flax, vine, hemp-based commercial fibres, kenaf, rattan, and ramie fibres are a few examples of bast fibres. Due to their durability, it should be mentioned that these fibres are frequently employed in fabric and packaging.

Animal Fibres:These fibres are often composed of many protein types. The two most well-known types of animal fibres are silk and wool. It is crucial to remember that animal fibres from various animals typically have distinct characteristics. Animal fibres are natural fibres that typically include proteins like collagen, fibroin, and keratin. Natural fibres made mostly of particular proteins are known as animal fibres. Silk, hair/fur (including wool), and feathers are among examples [26-31]. Domestic sheep's wool and silk are the two types of animal fibre that are most frequently utilised in production and by hand spinners. Alpaca fibre and mohair from Angora goats are both in high demand. There are other unusual fibres, such Angora wool from rabbits and Chiengora from dogs, although these are rarely employed in large-scale manufacturing. Even within a species, animal fibres vary in their characteristics from one another. Cotswold wool is coarser than Merino wool, despite the fact that both sheep breeds produce wool, both of which are very soft and fine. The diameter and structure of the fibre can be compared on a microscopic scale to continue this comparison. Individual animal fibres and natural fibres in general have a distinctive appearance, but all synthetic fibres have a uniform appearance. This makes it simple to distinguish between synthetic and natural fibres under a microscope [25-27].

Silk

The silkworm produces one type of animal fibre called silk. A fabric with a shimmering appearance, silk is strong, light, and silky. Animal fibres from silk moth cocoons are used to make silk. Two proteins—sericin and fibroin—make up the fibre of silk. These proteins impart a lovely sheen to the fiber [22].We will learn everything there is to know about silk, an animal fibre, and the sericulture process of breeding silk moths to extract the silk. fibres from animals that are produced by silkworms (different species produce different types of silk). The silk moth, Bombyx mori, produces the finest silk in its cocoons. The mulberry tree's leaves serve as food for its caterpillar. The mountainous regions of Northern India and China both grow this particular kind of silk moth [25]. Tassar, a type of wild silk, is produced by silk moths that consume oak leaves. In India and China, oak trees proliferate profusely.Munga silk is produced in the Brahmaputra Valley by a different species of wild silk moth [31].

A Moth's Life Cycle The fibres are made from a variety of insects, and the majority of the silk is made from butterfly larvae, mulberry silk (Bombyx mori), silkworm, and spider dragline silk (Nephila). The Bombyx mori larvae and their cocoons are displayed. China is where silk was first developed. The first silk reel, according to legend, was created by Xi-Chung-Shih, the bride of the Chinese Emperor Hunang Di, around 3,000 BC. For many centuries, it was kept a closely guarded secret. India first learned how to make silk around the year 300 AD thanks to traders and travellers. Silk moths were also exported to European nations, but the cold prevented them from surviving. However, Italy developed became a major silk producer for western European nations. China is one of the world's top producers of silk. Japan, India, and Italy are additional major producers of silk [35-39].

Wool

Shearing off the fur of specific sheep breeds produces animal fibre. Wool is a textile fibre that can be obtained from sheep and some other animals, such as goats for cashmere and mohair, muskoxen for qiviut, rabbits for angora, and camelids for other kinds of wool. Small cells found in the skin called follicles make wool. These follicles are situated in the epidermis, the top layer of skin, and when the wool fibres develop, they push down into the dermis, the second layer of skin. Primary or secondary follicles are the two categories within which follicles fall. Kemp, medullated fibres, and genuine wool fibres are the three forms of fibre that primary follicles create. Only real wool fibres are produced by secondary follicles. Medullated fibres are long and almost identical to hair in appearance, but they lack crimp and elasticity. Kemp fibres shed out and are very coarse [24-27].

The term "wool crimp" describes the distinct natural wave that each fibre of wool exhibits when it is worn by an animal. The crimp of wool and, to a lesser extent, scales help the individual fibres connect to one another so they stay together, making it simpler to spin the fleece. Wool fabrics are bulkier than other textiles due to the crimp, which also helps the fabric hold air and retain heat. Wool restricts heat transfer because it has a high specific thermal resistance. Due to the fact that Bedouins and Tuaregs wear wool clothing for insulation, this impact has helped desert dwellers [31]. The minute barbs on the surface of the wool fibres link together when hammered or subjected to other mechanical agitation, causing felting of the wool. Wet felting or dry felting are the two primary categories of felting. Wet felting is the process of agitating wool with water and a lubricant (particularly an alkali, like soap), causing the fibres to mingle and join together [33]. The felting process is accentuated by temperature shock while damp or wet. On an animal's back, some natural felting may take place. The fineness of the wool fibres is correlated with the quantity of crimp. When compared to coarser wools like karakul, fine wools like Merino can contain up to 40 crimps per centimetre (100 crimps per inch) (one or two crimps per inch) [35,37]. In contrast, hair has little to no crimp, minimal capacity to bind into yarn, and little to no scale. Kemp is the name for the hairy portion of a sheep's fleece. Some fleeces are more desirable for spinning, felting, or carding into batts for quilts or other insulating products, including the well-known tweed cloth of Scotland, because the relative amounts of kemp to wool vary from breed to breed. Wool burns more readily than cotton and other synthetic fabrics at higher temperatures. In comparison to other flooring materials, it contributes less to harmful gases and smoke when used in carpets. It has a lower rate of flame spread, a lower rate of heat release, a lower heat of combustion, does not melt, and does not drip. For high-security areas like trains and aeroplanes, wool rugs are required. Clothing for firefighters, soldiers, and other professions where exposure to fire risk is a possibility typically calls for wool. Sweaters are woven using wool. Carpets have been made using wool in the past [38-40].

Conclusion

Certain polymers have been developed into a few materials with uses in healthcare, pharmaceuticals, agriculture, nutrition and beverages, toiletries, beautifiers, materials, and other cutting-edge, local, and person-focused things. The scale has also highlighted some common polymers as starch, cellulose, chitosan, alginate, and gelatin. Then, there are several common polymers that today's civilization needs to survive, such as starch, wood, and common elastic that is used for particular purposes like transportation, papermaking, nutrient production, and transportation. These are the world's most important products provided, and they are prominent sustainable characteristic polymer sources used in our daily lives.

A deeper knowledge of the molecular mechanisms underlying how biopolymers work in food emulsions will be beneficial for the creation of new foods and food processing techniques. Natural biopolymers make intriguing structural assembles at the micro- and nanoscale. Polysaccharide- and protein-based biopolymers are being used more often in a wide range of sectors, including food, material science, chemical, pharmaceutical, medical, and nanotechnology, due to their availability and sustainability. In the food processing industries, these biopolymers can interact with food to maintain texture, produce gels, freeze, make film coatings, and package food components. The development of food items and processes is influenced by the physicochemical and thermodynamic characteristics of biopolymers, which may have an impact on the transport process and unit operations.

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