Carbosynth

Polysaccharide Catalogue and Handbook

Toolbox for **Polymeric sugars**

Carbosynth **Global locations**

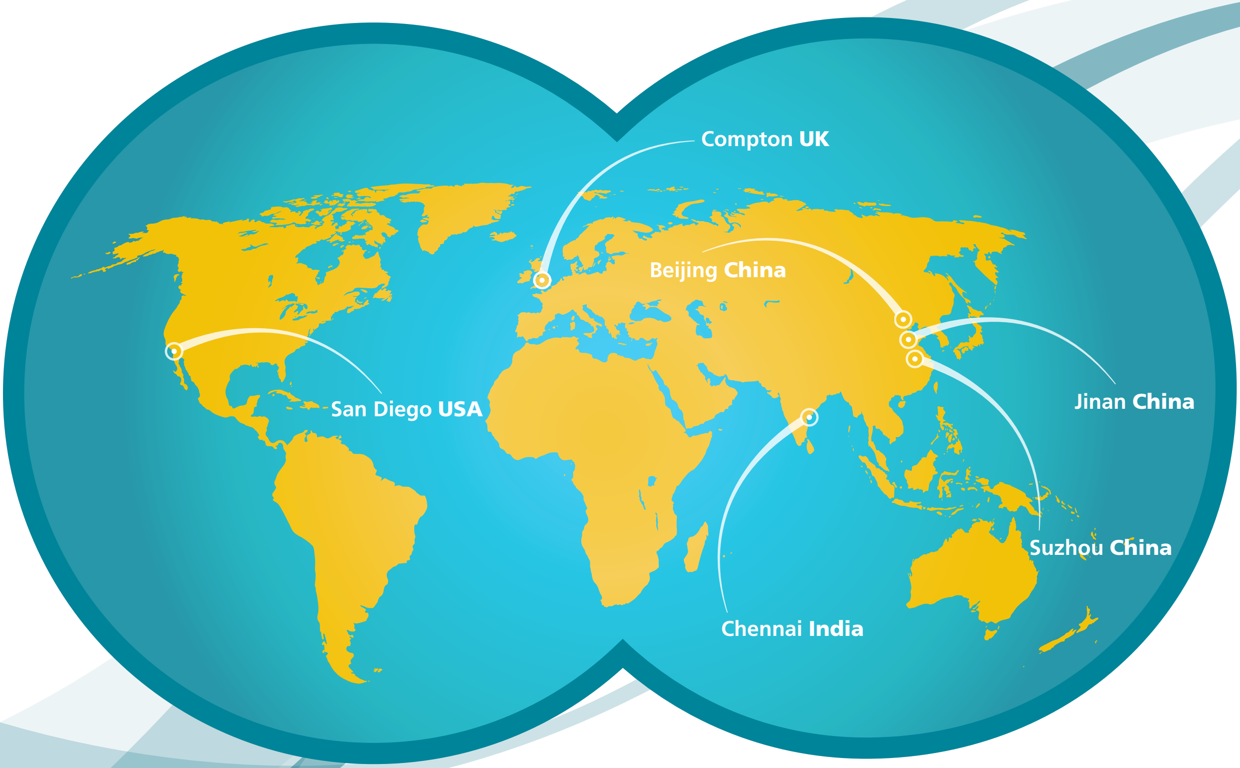


Table of contents

Section

1&2

Introduction and Classification

1 Introduction

Welcome to the Carbosynth toolbox and catalogue of polysaccharides and related biopolymers. These important products have a huge range of uses that exploit their unique functionalities across the food, pharmaceutical and industrial sectors. However, due to their complexity and diverse attributes, other laboratory suppliers have included them in general biochemical listings. In recognition of this, Carbosynth has assembled these products in a dedicated toolbox and catalogue to provide comprehensive support for your research, development and application requirements.

Carbosynth has recently acquired the speciality polysaccharide business Glycomix and the combined strengths of products, applications, analysis and process development will provide you with a fully integrated range of products and services.

This new toolbox and catalogue will guide you through the complexities of these important carbohydrates in some detail including sources, properties, applications and the relationship between their primary, secondary & tertiary structures and functionality. The most important analytical procedures for structural determination will also be discussed.

As an additional tool to provide background detail, a review section has been included covering the product range. Each polysaccharide has been examined in some detail outlining the source, covalent structure, important functionalities and key references. Finally, the catalogue section contains the comprehensive range of polysaccharides that Carbosynth now offers for research and development.

Healtang corncob feed stock

2 Classification

Polysaccharides have been recognized and exploited by man for centuries. As far as is known, they occur as energy reserves and structural materials in the tissues of all living things. In animals their structural role is performed in connective tissue, in plants in the cell walls, and in microorganisms as cell-wall materials and extracellular capsules. A large number of polysaccharides obtained from plants, animals and microorganisms including seeds, algae, fruits, plant cell walls, animal tissues, bacteria and fungi have been developed into commercially important products known collectively as industrial gums (Whistler, 1993) and, in Table 1, examples of these are listed and categorized according to source and type.

In addition, a large number of carbohydrate polymers have been developed as reaction products of the natural polysaccharides listed in Table 1. Examples of these are the ethers, esters and sulphated derivatives of cellulose, starch, dextran, chitin and curdlan. Other derivatives are the creation of fluorescent derivatives that are used as markers in medical scanning procedures.

Other products are the result of random polymerisation of sugar residues through the treatment of starch with acid under conditions of low water activity. Polydextrose is an example of this type of product.

Table 1 **Classification of polysaccharides**

Origin →	Source →	Type →	Example
Higher plants	Trees	Celluloses	Cotton
		Hemicelluloses	Xylans, arabinogalactans
		Exudate gums	Arabic, tragacanth
	Seeds	Galactomannans	Guar, locust bean gum
		Mannans	Ivory nut
		Glucomannans	Konjac
	Cereals	Amylose	Rice, wheat
		Amylopectin	Maize (waxy maize)
		Amylopectin	Oat glucan, barley glucan
	Fruits (citrus)	Pectins	Lime, sugar beet
	Tubers	Starches	Potato, yam
Algae	Red (Rhodophyceae)	Sulphated galactans	Carrageenan, porphyran
	Brown (Phaeophyceae)	Uronides, fucans	Alginates, fucoidans
	Green (Chlorophyceae)	Complex sulphated	Ulvan
Neither plant or animal	Lichens	Lichenans	Complex glucans
Microbes	Gram –ve, *(Leuconostoc)*	Branched glucan	Dextran
	Gram +ve *(Micrococcus)*	Ac., mannurono, gluco repeat	Teichuronic acid
Yeasts and fungi	Micro *(Pullularia)*	α-glucan	Pullulan
	Macro *(Schzophyllum)*	Branched β-glucan	Schizophyllan
Animals and fish	Cartilage (shark)	Glycosaminoglycan	Chondroitin sulphate
	Liver	Glycogen	Complex amylopectin lookalike
	Crustacea shells	β-Glucosamine, N-acetyl glucosamine	Chitosan, chitin

Section

3

Properties and Applications

The commercial usefulness of gums is based upon their functionality. In the food and health food industries (Table 2) they are exploited because of their ability to modify texture and as suspending agents. They do this by performing two broadly interconnected functions, namely by gelling aqueous solutions or by modifying their flow characteristics, often producing marked non-Newtonian behavior such as pseudoplasticity or thixotropy particularly at very low concentrations and in synergistic combinations (Fig 1).

Fig 1a A selection of gums in food and dietary fibre products

Fig 1b A selection of gums in food and dietary fibre products

Table 2 **Food and health food applications**
(Whistler, 1993; Blanshard, 1997)

Physical property	Gum	Application
Cold set, clear, gel formation with divalent cations	Alginate	Reformed fruit pieces
Gel formation with sucrose or acid	Pectin	Jams, jellies, dietary fibre
Slow metabolic uptake, low viscosity at high solids	Pectin, inulin	Dietary fibre
Heat reversible gel formation	Agar, gellan	Synthetic meat gels, dietetic jellies
Heat reversible gel formation in the presence of potassium ions	Kappa & iota-carrageenan	Synthetic meat gels, instant desserts, chocolate drinks
Smooth 'short' texture	Fully pregelatinised corn starch	Proprietary desserts, puddings
Cold set soft gel formation with water or milk	Pregelatinised and/or oxidized potato or tapioca starch	Instant desserts, puddings
Pseudoplastic behavior under conditions of high shear	Xanthan gum	Instant desserts, low calorie products
Synergistic binary component gel formation, high viscosity	Xanthan gum, galactomannans	Synthetic meat gels, slimming foods
Retardation of sugar crystallisation at low moisture contents	Gum arabic	In solid confectionery, soft sweets, pastilles
Complex formation with milk protein	Lambda carrageenan	Chocolate milk drinks
Stability at low pH-good viscosity	Propylene glycol alginate, xanthan gum	French dressings, salad dressings
Ice-crystal size retardation	Propylene glycol alginate	Ice creams and lollipop, popsicles
Gel formation with heat	Curdlan	Jelly sweets
Synergistic ternary component very high viscosity at low concentration	Xanthan, konjac glucomannan, alginate (polyglycoplex)	Low calorie, reduced blood glucose, reduced cholesterol products

Fig 2 Examples of polysaccharides in pharmaceuticals

In the pharmaceutical and cosmetic industries (Table 3) they perform similar functions to those used in foods but in addition, a number of polysaccharides are used directly as drugs with specific therapeutic activities (Fig 2).

Table 3 **Cosmetic and pharmaceutical applications** (Dumitriu, 1996)

Physical property	Gum	Application
Moisture retention	Hyaluronic acid	Skin creams
Blood anticoagulant	Heparin	Open heart surgery
Thermoreversible gelation	Gellan	Agar substitute in microbiology
Gel formation with calcium	Alginate	Antacid proprietory products e.g. Gaviscon
Blood anticoagulant	Fucoidan	Surgery (Heparin substitute)
High shear pseudoplasticity	Xanthan gum	High solids medicines and syrups
Stability at low pH-high viscosity	Xanthan gum	Fluoride dental gels
Anti-inflammatory properties	Chondroitin sulphate	Treatment of inflammation e.g. osteoarthritis
Protection for damaged tissues e.g. urinary tract	Pentosan polysulphate	Interstitial cystitis
Water retention	Psyllium seed gum	Laxative
Inert plasma thickener	Dextran	Blood plasma extender

Industrial (Table 4), polysaccharides have many applications in oil exploration and recovery, textile printing and building materials to name a few (Fig 3).


Fig 3a Industrial polysaccharide example


Fig 3b Polysaccharide usage in oil exploration

Table 4 **Industrial applications**
(Whistler, 1993)

Physical Property	Gum	Application
Pseudoplastic behavior under conditions of high shear	Xanthan gum	Oil drilling muds
Compatibility with reactive dyestuffs (Procion)	Sodium alginate	Cotton textile printing, carpets
Stability, high viscosity	Guar gum	Fracking
Controlled dispersion, viscosity	Na^+ carboxymethyl cellulose	Wallpaper paste
High solids compatability, viscosity	Na^+ carboxymethyl cellulose	Cement setting retardation
Film formation	Starch derivatives	Paper coating
Water soluble films	Pullulan	Water soluble seed coatings
Gel formation	Xanthan, locust bean gum	Explosive gels
Mineral suspension	Xanthan, guar	Mineral flotation aids
Metal chelation	Chitin	Heavy metal separation
Ion exchange support	DEAE dextran	Chromatography
High viscosity, non-newtonian, gel forming	Methyl cellulose	Adhesives, paints, cements
Viscous, compatability with organic solvents	Hydroxyethyl cellulose	Latex paints
Film formation	Chitosan	Textile finishing

Section

4&5

Polysaccharide Isolation, Purification and Structure Determination

4.1 Isolation Techniques

Polysaccharides occur in a wide variety of environments as exocellular bacterial slimes and capsules, plant cell wall components, covalently linked to proteins in animal tissues, as storage components in plant seeds and tubers and in the exoskeletons of crustacians and insects. Also, they often occur in mixtures as in brown algae (alginate + laminarin + fucoidan).

Thus, in an ideal world, the isolation of a polysaccharide must be approached by a consideration of all the circumstances likely to influence the production of pure and undegraded material for further study. It is very difficult to generalize and few books on the chemistry of polysaccharides cover all the available options although two older publications (Smith, 1959; Whistler, 1965) provide chapters on many of the techniques that are still relevant today. The reader who wishes to embark on the isolation and purification of representative polysaccharide material should also undertake a thorough survey of the current literature.

A selection of the techniques that are commonly used in polysaccharide isolation are:

- Homogenization of plant tissue
- Enzymatic digestion of unwanted components such as proteins and polysaccharides
- Water extraction
- Solvent extraction
- Cell wall disruption by either chemical or mechanical processes, for example with urea or by mechanical grinding
- Winnowing of seed husks
- Centrifugation to remove bacterial cells
- Precipitation with anions, cations or quaternary ammonium compounds

4.2 Purification Techniques

Commonly used purification techniques include:

- Dialysis to remove low MW materials and inorganic ions
- Lyophilization to remove water and solvents (Fig 4)
- Various forms of chromatography
- Solvent extraction
- Precipitation with solvents such as ethanol, isopropanol
- Electrophoresis
- Enzyme treatment

Fig 4 Laboratory Freeze Drier (Lyophilization)

5 Polysaccharide Structure Determination

5.1 Basic Structural Features

In describing the structure of a polysaccharide, various methods are employed to characterize (i) the basic organic and inorganic features of structure, (ii) the monomeric sugar units in the polymer and any other organic and inorganic structural features that these carry, (iii) the architecture of the polymer including the positions and relative attachment (anomeric configuration) of monomer linkages and details of chain branching, (iv) the molecular size and dispersion of the polymer chains and (v) any inter or intramolecular interaction of the polysaccharide chains or interaction with other components such as proteins and lipids.

5.1.1 Basic Structural Features

The basics of structure that are required to start with are:

(i) The moisture content which can be measured in many ways but examples include loss on drying to constant weight and Karl Fischer analysis for water content (Fig 5).

(ii) The total carbohydrate content of the material which is often determined using the phenol-sulphuric acid analysis for carbohydrates (Fig 6) (Dubois, 1956).

(iii) The protein content of the product can be determined by the Kjeldahl method.

(iv) The fat content by lipid analysis after solvent extraction.

Fig 5 Karl Fischer apparatus for moisture determination

Fig 6 Use of the phenol-sulphuric test for carbohydrates (sensitivity ~ 10 μg/ml)

5.1.2 Monomeric Structural Units and Substituents

In order to release monomeric sugars from the polysaccharide matrix, it is necessary to employ reagents that can selectively attack (protonate) the glycosidic oxygen atom between each sugar residue. The selection of suitable reagents requires a degree of insight, trial and error too involved for discussion here, but useful candidates include acids (acetic, hydrochloric, trifluoroacetic, methanolic HCl) and enzymes (hydrolases). Some polysaccharides have glycosidic bonds which are resistant to hydrolysis e.g. polyuronides (containing carboxyl groups) when much stronger conditions will be required to break these but do not destroy the sugar residues themselves (Churms, 1982).

The method used to separate and show monosaccharide components released from polysaccharides is analytical chromatography, a technique that has been used for many years (White, 1991).

The earliest methods that were developed were based on the elution of components on paper and visualization by spraying or dipping the papers in a wide variety of reagents (Fig 7).

Both analytical and preparative methods were developed using this technique but were superseded by gas chromatography, a method that was difficult due to the need for volatile derivatives, not liked by carbohydrate analysts (Fig 8 - see page 12).

Fluorophore-assisted carbohydrate electrophoresis (FACE) was also used successfully on carbohydrates often using fluorophores such as 8-aminonapthaline-1,3,6, trisulphonic acid disodium salt (ANTS) as a charged visualization agent. (Fig 9 - see page 12).

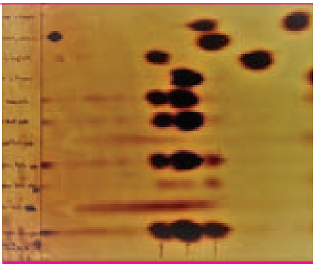


Fig 7 Paper chromatogram of monosaccharides in a polysaccharide

Monomeric Structural Units and Substituents (continued)

In recent years, high performance liquid chromatography (HPLC), a method that does not require derivatization, was developed and is now used in virtually all analytical laboratories worldwide. Methods of detection have also improved markedly and can now cope with gradient elution to enhance the separations of components.

For the analysis of mono- and oligosaccharides the chromatographic method of choice is often Dionex ion chromatography, a technique which has proved particularly successful for carbohydrates (Fig 10).

As an example of a fairly simple polysaccharide, the hydrolysis of dextran will release only glucose using either trifluoroacetic acid or the enzyme dextranase (Fig 11).

In the case of a polysaccharide mixture, for example konjac glucomannan (Fig 12), xanthan gum (Fig 13) and sodium alginate (Fig 14 - see page 13), the expected monosaccharides would be glucose and mannose (from the konjac), glucose, mannose and glucuronic acid (from the xanthan) and mannuronic acid and guluronic acid (from the alginate).

The ion chromatogram of the hydrolysis products of this mixture shown (Fig 15 - see page 13) is of both the neutral and charged monosaccharides. The difficulty is the presence of the three uronic acids (glucuronic, mannuronic, guluronic) in the mixture which requires one strength of acid to release the neutral sugars (glucose, mannose) and stronger conditions for the uronic acids.

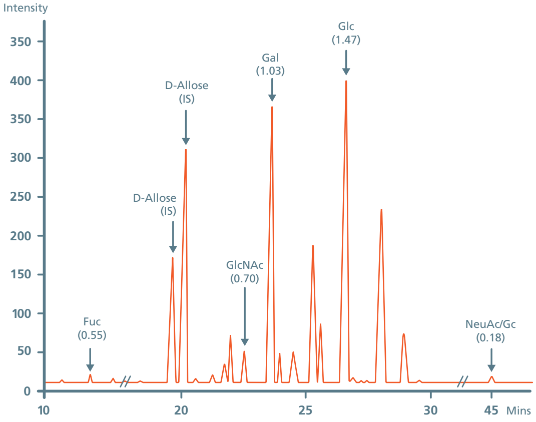


Fig 8 Gas chromatogram of monosaccharide trimethyl silyl ethers

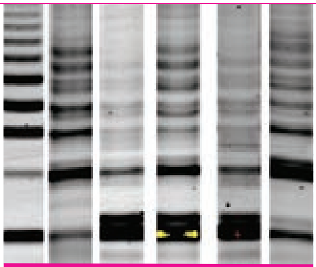


Fig 9 Electrochromatogram of glucose syrup at various stages of a beer fermentation (G4 is the tetrasaccharide marker in the ladder standard)

Fig 10 Dionex chromatography of carbohydrates

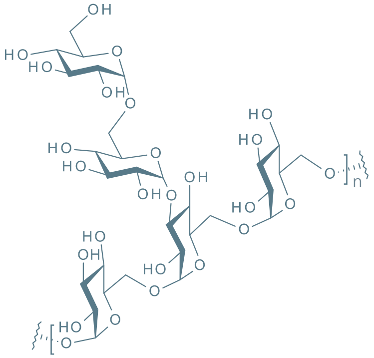


Fig 11 Dextran

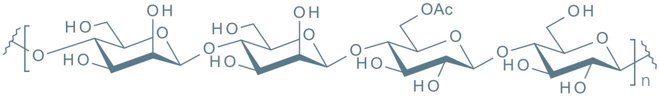


Fig 12 Konjac glucomannan

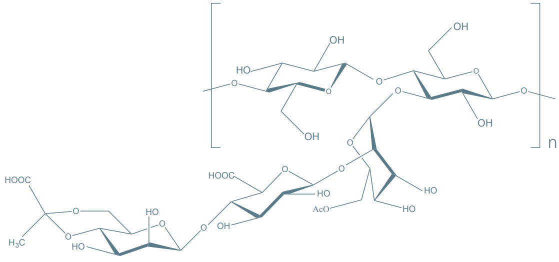


Fig 13 Xanthan gum

Monomeric Structural Units and Substituents (continued)

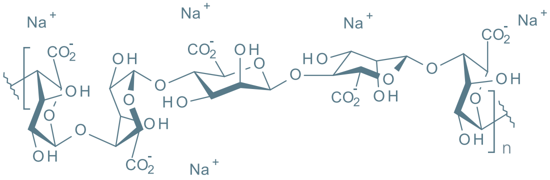


Fig 14 Sodium alginate

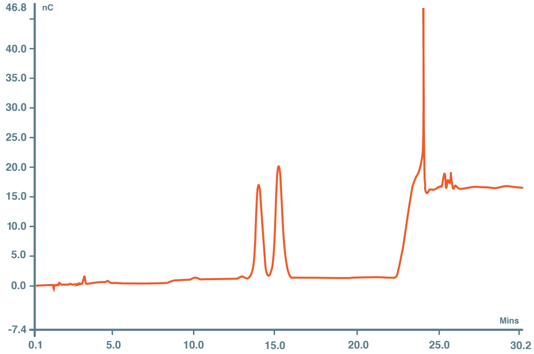
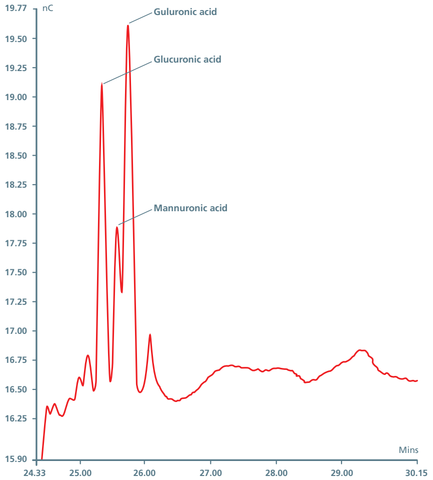


Fig 15a An example of ion chromatography in the separation of neutral monosaccharides and uronic acids



Uronic acid expansion showing glucuronic, guluronic and mannuronic acids

Fig 15b An example of ion chromatography in the separation of neutral monosaccharides and uronic acids

5.2 Linkage Positions, Branching & Anomeric Configuration

There are several ways of identifying the position and configuration of the linkages that join sugar residues and these together with their identity provide the main key to polysaccharide covalent structure. The four methodologies used most commonly are (i) methylation analysis, (ii) retro analysis based on partial degradation, (iii) methods based on spectroscopy and (iv) the use of enzymes.

It should be emphasized that the highlighted analytical techniques described will always require assistance from one or more of the others so, for example, methylation will require the use of mass spectroscopy. Analysis by nuclear magnetic resonance spectroscopy on the other hand will need careful chemical or enzymatic degradation to provide molecules small enough for analysis but large enough to be representative of the whole structure.

5.2.1 Methylation Analysis

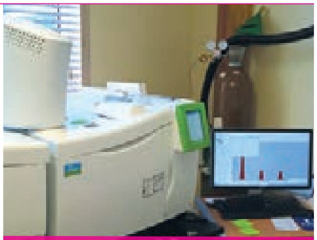


Fig 16 Mass spectroscopy

The polysaccharide is treated with reagents that selectively convert the free hydroxyl groups to methyl ethers. Methyl ethers are very stable and the methylated polysaccharide can then be hydrolyzed to release monomers that are characteristic of the original polymer, having free hydroxyl groups where the linkages had previously been in the intact polymer. In the experimental protocol the released methylated monomers are reduced to alditols and acetylated and these are characterized as partially methylated alditol acetates by a combination of gas chromatography and mass spectroscopy (GC/MS) (Fig 16).

This method has become the standard for polysaccharide linkage analysis in most laboratories throughout the world (Bouveng, 1960; Hakomori, 1964; Bjorndal, 1970).

Very briefly, as an example, in a polysaccharide having a single sugar building block (e.g. starch or dextran) linked through positions 1 and 4 then unbranched sugars in the chain would release sugars methylated at positions 2,3 and 6. A branch point at, for instance, position 3 would release sugars methylated at positions 2 and 6 and an end group sugar with position 4 free would release sugars methylated at positions 2,3,4 and 6 (Fig 17).

The drawback with methylation analysis is that it does not give information about the configuration of the anomeric link between sugar building blocks and is not very useful in providing information about non-sugar attachments in the polysaccharide such as O-acetylation, pyruvylation, succinylation etc.

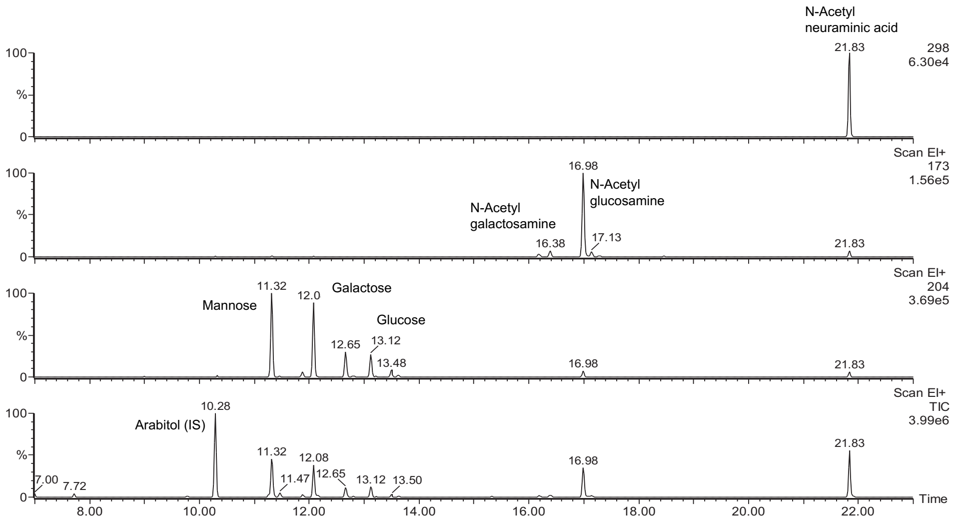


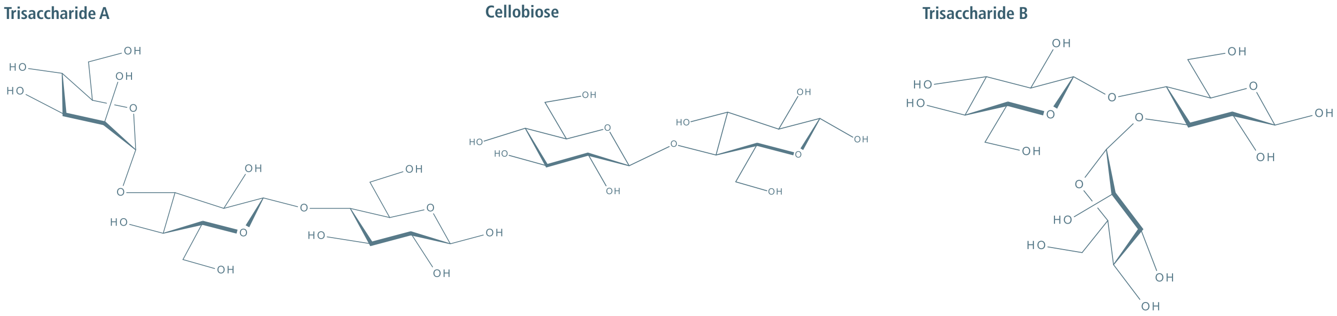
Fig 17 Mass spectrum of partially methylated alditol acetates

5.2.2 Retro Analysis by Partial Degradation

In this method, the polysaccharide is treated with reagents (Lindberg, 1975) or enzymes (McCleary, 1987) that break it down into smaller fragments that can then be characterized and reassembled into the intact polymer unit. In this procedure the chemicals that are used are normally acidic in character and examples are acetic, hydrochloric, sulphuric and trifluoroacetic acids at low concentration. Another useful reagent is methanolic hydrochloric acid. Enzymes that are employed have to be chosen with care as they will be specific to particular links in the polymer chain and so some knowledge of the polysaccharide will be important (source, monomer units etc).

Examples of the use of degradation were in (i) the analysis of xanthan gum by partial acid hydrolysis (Rees, 1976), (ii) treatment with a combination of acetic acid, sulphuric acid and acetic anhydride to produce di- and trisaccharides (Fig 18) that were recombined to form the pentasaccharide repeating residue (Lawson, 1977) and (iii) in the analysis of starch where a number of enzymes isolated and characterized by Whelan in the 1950s were elegantly employed to reveal the intricate and very different molecular architecture of the branching from starches from plants ranging through corn, potatoes, rice and tapioca (Drummond, 1970).

One technique that is very important in this method is preparative chromatography, as in order to obtain structural information it is critical to isolate, purify and identify the fragments that are released by the respective degradative methods (Hicks, 1987). The fragments so obtained can then be used to give useful information about the anomeric linkage positions of the monosaccharides using chiral enzymes (McCleary, 1987) or spectroscopic methods (section 5.2.3).



Trisaccharide A

Cellobiose

Trisaccharide B

Fig 18 Cellobiose and trisaccharides A&B from the acetolysis of xanthan gum

5.2.3 Spectroscopic Methods of Analysis

There are many methods of analysis that can be loosely classed as being based on spectroscopy, namely the use of irradiation energy of various sorts to excite structural features in the molecule of interest that will then give back useful information. These methods include infrared spectroscopy, ultraviolet spectroscopy, nuclear magnetic resonance spectroscopy, and more recently, Raman spectroscopy and mass spectroscopy.

5.2.3.1 Nuclear Magnetic Resonance (NMR)


Fig 19 NMR instrumentation

NMR spectroscopy (Fig 19) can reveal many detailed structural features in organic molecules such as how the links between the atoms in an organic molecule are organized, coupled and linked together. Couplings between atoms are used to determine the chirality of optically active molecules, a key feature in the development of drugs where one isomer can be active and another inactive or have different activity (e.g. thalidomide). A very useful feature of NMR is that substituents such as methyl, acetyl and pyruvyl groups can be identified in the NMR spectrum, something that can be difficult using other techniques (Robyt, 1998).

Figure 20 is an example of a 1H NMR spectrum of an oligosaccharide released by the partial degradation of a polysaccharide showing the anomeric and ring protons crucial to the identity of the chiral nature of the structure.

However, intact polysaccharides often produce poor spectra due to problems with increased proton relaxation times caused by the molecular weights of these large molecules. It is often necessary therefore to slightly degrade samples with care in order to obtain meaningful spectra (Fig 21).

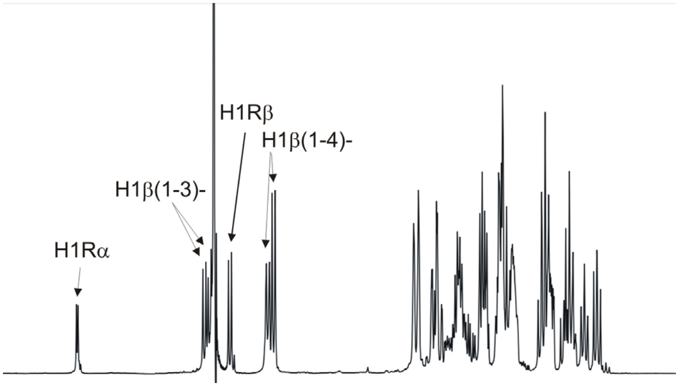


Fig 20 700 MHz 1H NMR spectrum of a tetrasaccharide produced by partial hydrolysis of a polysaccharide

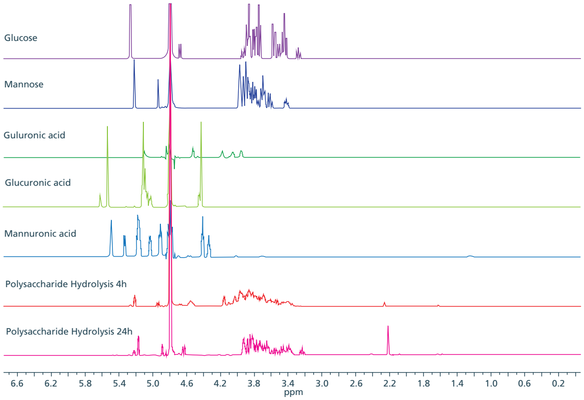


Fig 21 400 MHz ^{1}H NMR spectra of reduced polysaccharide structures

5.2.3.2 Infrared Spectroscopy

Fourier transform infrared spectroscopy (FTIR) is a very useful analytical technique which can highlight structural features not shown up using other techniques (Kacurakova, 2001). An example is the semi-quantitative analysis of the mannuronic to guluronic acid ratio in alginate by comparing the resonances at 808 & 787 cm^{-1} (Fig 22) (Mackie, 1971).

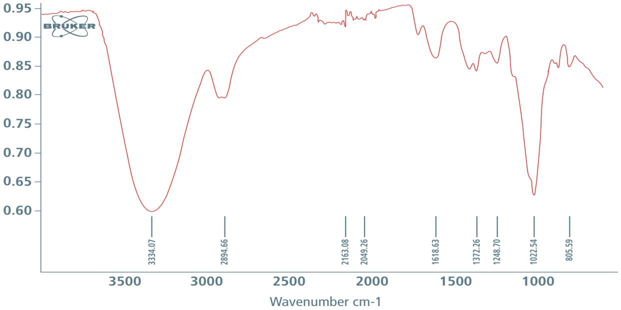


Fig 22 Infrared spectrum of sodium alginate

5.2.3.3 Raman Mapping

Raman mapping spectroscopy has rapidly gained acceptance as an invaluable tool for detecting, quantifying, and analyzing the chemical composition of materials across a broad range of industries. Raman spectroscopy, is inherently nondestructive, noninvasive, works with trace amounts of any substance in nearly any lab or field environment, and requires no sample preparation (Szymanska-Chargot, 2016).

Fig 23 shows a Raman spectrum in the fingerprint range of a mixture of xanthan gum, sodium alginate and konjac glucomannan where distinct differences can be observed between them (Szymanska-Chargot, 2016).

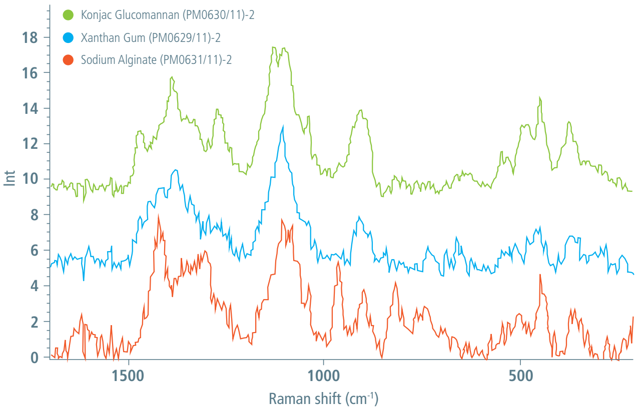


Fig 23 Raman spectrum comparing xanthan gum, sodium alginate and konjac glucomannan

5.2.3.4 Mass Spectroscopy

As has been described in section 5.2.1, mass spectroscopy is a key analytical tool in the analysis of partially methylated alditol acetates in methylation studies. However, in recent years mass spectroscopy has become an invaluable tool for analysis of large oligosaccharides and polysaccharides through the development of methods such as matrix assisted laser desorption/ionization (MALDI) techniques (Stephens 2004). Mass Spectroscopy is also a key analytical technique in the structural analysis of both N- and O- linked glycans attached to glycoproteins (North, 2009).

Methodologies have recently been developed as rapid screening and analytical tools for glucose-containing polysaccharides using a designed ‘glycome array’ in conjunction with mass spectroscopy (Palma, 2015).

5.3 Molecular Weight Determination (White, 1991)

5.3.1 Light Scattering

When a polysaccharide solution is illuminated with a beam of light at wavelength λ the polymer chains will scatter light in direct proportion to their weight-average molecular mass (MW) and the angular dependence of the scattered light at low angles can be related directly to the z-average of the ‘radius of gyration’ (Rg). This is the only technique that can be used to measure the dimensions of the molecules without any assumptions about the shape of the molecule.

Light scattering is also an absolute method for determining these molecular parameters, as opposed to viscometry and gel permeation chromatography, both of which require calibration. The method is the major technique for determining MW of polysaccharides. However, experimental difficulty in the method is the demand for high quality solutions free of dust and particulate matter (Fee, 2003; Hokputsa, 2003).

5.3.2 Size Exclusion Chromatography

Size exclusion chromatography coupled with multi-angle laser light scattering (SEC-MALS) is a valuable analytical tool for characterisation of polysaccharides (Fig 24).

Adding multi-angle light scattering (MALS) to SEC allows absolute molecular weight (MW) to be determined without the need for a reference standard. In this technique, the molecular weight of a succession of analytically separated slices is determined which then allows the molecular weight distribution to be built up. Multi-angle, static light scattering (MALS) decouples molar mass analysis from retention time and allows the determination of molar mass. In addition, with SEC-MALS, the determination of polysaccharide properties that cannot be measured using UV detection with SEC is possible (Fee, 2003; Hokputsa, 2003).

Fig 24 Size exclusion chromatography with multi-angle light scattering equipment

5.3.3 Ultracentrifugation (Harding, 2015)

Analytical ultracentrifugation is a technique widely used to characterize the sizes and shapes of polysaccharides and other carbohydrate biopolymers.

The analytical ultracentrifuge (Fig 25) works on the principle that at high rotational speeds small particles like polysaccharides in solution will move under the influence of the centrifugal field, leaving clear solvent behind. The solutions are placed in precision ultracentrifugal cells with transparent end windows. These cells contain two compartments, one for the solution and one for the reference solvent. Light rays from a laser are passed through the solution as the sedimentation process takes place - the signal is then picked up by a CCD camera and the data processed. In this way the rate of change in the concentration distribution of the dissolved macromolecule with time can be followed during the period of sedimentation (usually several hours), and from the change with time of the concentration pattern, the data is processed to yield an estimate of the distribution of sizes of polysaccharide chains in the solution, in terms of the distribution of sedimentation coefficient which gives a good idea of sample purity and heterogeneity (Harding, 2005).

Fig 25 Analytical Ultracentrifuge

The sedimentation coefficient is a function of shape as well as size (MW). At lower speeds however the sedimentation force is balanced by diffusive forces backwards and the final steady state equilibrium pattern depends only on molecular weight. Although not as resolving (because of the lower speeds), the average molecular weight (generally the weight average) can be combined with the average sedimentation coefficient from sedimentation velocity to convert the sedimentation coefficient distribution into a molecular weight distribution.

5.3.4 Viscosity

Viscosity is a molecular weight sensitive method that has been widely used because it is relatively simple to undertake and does not require expensive instrumentation. Although the measurable quantities are easy to obtain, converting them to molecular weights and comparison with other samples is not always a straightforward task, and in many cases the use of intrinsic viscosity, $[\eta]$, as a hydrodynamic property is used without conversion to molecular weights.

The basis for using viscosity as a molecular weight sensitive method is the relation between the intrinsic viscosity (limiting viscosity number) and an average of the molecular weight. The dependence of the intrinsic viscosity of a homologous series of polysaccharides on the molecular weight is classically described in terms of the Mark-Houwink equation: $[\eta]=K'M^a$ where K' and a are empirical parameters constant at a given temperature, for a specified solvent within each polysaccharide for a limited range of molecular weights. The Mark-Houwink equation forms the basis for using viscosity to determine molecular weight. From a series of calibration standards, determination of molecular weight and intrinsic viscosity yields estimates of K' and a for the given polysaccharide-solvent system (Harding, 1997).

5.4 Polysaccharide Physical Properties

In this section, the measurement of the unique physical properties of polysaccharides is explored. These range in a continuum from non-reversible hard gels, characterized by the alginates to high solids Newtonian solutions as exhibited by some of the acacia gums. Between these two extremes the carrageenans and agar form thermally reversible gels, pectins form gels with sucrose, binary combinations of xanthan and galactomannans form highly viscous quasi-gels, xanthan alone shows marked shear-dependent pseudoplastic viscosity characteristics, high molecular weight sodium alginate forms viscous solutions at low concentration and ternary mixtures of several polysaccharides (e.g. xanthan, konjac, alginate) form exceptionally high viscosities at very low concentration.

In addition to the viscosity and gelling properties described above, there are a number of lipophilic functionalities shown by polysaccharides that have been exploited. These properties include emulsion stabilization, film formation, compatibility with non-aqueous solvents, surface tension reduction and reduction of interfacial tension.

The detailed measurement and description of these fundamental characteristics is extremely complex and cannot be fully described here so the following discussion is designed to provide an insight into the key properties that have been discussed above and how they may be measured, with references for further reading.

5.4.1 Rheology

Rheology is the quantification of viscous flow and deformation of polysaccharide solutions under applied shear forces which can be applied and measured using suitable rheometers. The type of rheometer selected for measuring these properties depends on the relevant shear rates and temperatures as well as available sample size. Instruments in current use range from glass capillary viscometers (e.g. Ubbelohde), rotational viscometers (e.g. Brookfield) (Fig 26) to complex rheometers with many configurations such as cone and plate, bob and vane geometries (e.g. TA instruments, Bohlin, etc.) (Fig 27).

Fig 26 Brookfield viscometer

Fig 27 TA instruments rheometer

Rheological properties impact at all stages of polysaccharide use from formulation development and stability to processing and product performance. Examples of rheological measurements include:

- Measurement of the viscosity of non-Newtonian shear-dependant polysaccharides which can then be used to model real-life applications or processing conditions.
- The determination of viscoelastic characteristics to determine the extent of solid or liquid-like behavior.
- Optimising and assessing dispersion stability.
- Comparing polysaccharide products used in food and cosmetic products for their ability to flow, coat and suspend.
- Understanding how carbohydrate polymers can improve dispersion, coatings and emulsion stability in drug formulations.

To illustrate the value of rheological measurements, a plot of xanthan viscosity against shear rate is shown in Fig 28 . Xanthan is very shear sensitive and this depends on concentration as shown. This property is used to suspend particles, for example in food sauces, and the use of the plot is to allow the correct concentration to be calculated.

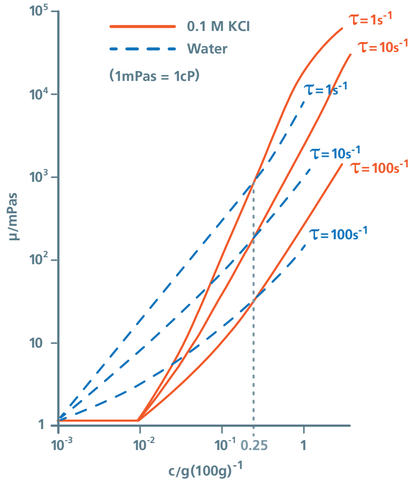


Fig 28 Relationship between xanthan viscosity, shear rate and concentration

5.4.2 Gelation (Harris, 1990; Blanshard, 1979)

Polysaccharide gels can be defined as cross-linked systems, which exhibit no flow when in a steady-state. By weight, gels are mostly water but behave like solids due to a three-dimensional cross-linked network of polysaccharide chains that give the gel its structure.

Gels can show many different physical textural attributes from a soft fruit gel dessert to a hard pharmaceutical capsule. Texture profile analysis (TPA) permits routine measurement of gel texture and for example, an Instron 4201 tester can be used for compressing the gel, with appropriate software for processing the data (Fig 29).

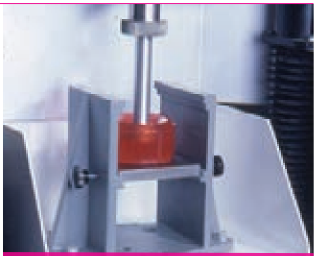


Fig 29 Instron model 4201 tensile compression tester

The textural parameters measured are shown on the idealized force-deformation curve in Fig 30.

Several criteria are used to define the gel properties namely:

- **The modulus** is the initial slope of the force-deformation curve. This is a measure of how the sample behaves when compressed a small amount. The modulus usually correlates very closely with a sensory perception of the sample's firmness.
- **Hardness** is defined as the maximum force that occurs at any time during the first cycle compression. In most cases, the hardness is correlated to the rupture strength of the material.
- **Brittleness** is the point of first fracture or cracking of the sample.
- **Elasticity** is a measure of how much the original structure of the sample was broken down by the initial compression. In sensory terms, it can be thought of as how 'rubbery' the sample will feel in the mouth.
- **Cohesiveness** is measured by taking the total work done on the sample during a second compression cycle and dividing it by the work done during the first cycle. Work is measured as the area under the respective curves. Samples that are very cohesive will have high values and will be perceived as tough and difficult to break up in the mouth.

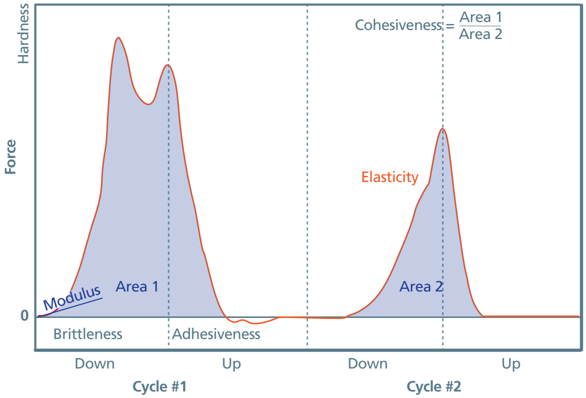


Fig 30 Idealized force-deformation curve for textural parameters

5.4.3 Surface, Emulsification and Film-Forming Properties

Unsubstituted polysaccharides such as amylose and pullulan show very little, if any lipophilic properties although they form good films. However, when the polysaccharide contains deoxy sugars such as fucose, the polysaccharide will to a greater or lesser extent show surface activity. Examples of polysaccharides with natural surface activity are Xanthan gum, a polysaccharide that acts as a secondary emulsion stabilizer. Sugar beet pectin (Dea, 1986) and Indican (Symes, 1982) have a higher degree of lipophilic substitution (methyl esterification and acetylation) and behave much more like true surfactants reducing for example, interfacial and surface tension and showing compatibility (gelling) with solvents such as glycols and alcohols In addition, a number of the synthetic polysaccharide derivatives including ethyl cellulose, ethyl (hydroxyethyl) cellulose and hydroxypropyl methyl cellulose (hypromellose) show surface properties.(Fig 31)

Techniques often used for measuring surface and interfacial tension are the Wilhelmy plate and De Nouy ring (Fig 32). Methods and instruments used for these measurements are known as tensiometers (Fig 33).

In the laboratory, the ability of polysaccharides to stabilize emulsions are tested by homogenizing the polysaccharide with an appropriate solvent (Fig 34).

Gels can also be formed with solvents as shown in (Fig 35).

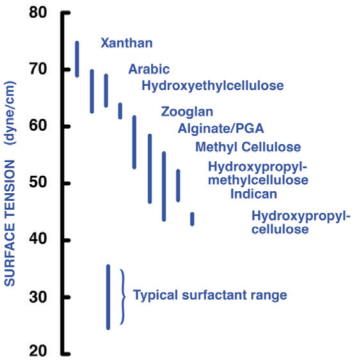


Fig 31 Comparison of surface active polysaccharides

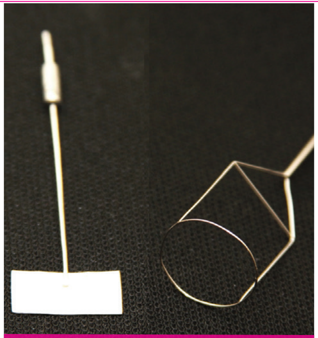


Fig 32 Wilhelmy plate & De Nouy ring

Fig 33 Kruss tensiometer

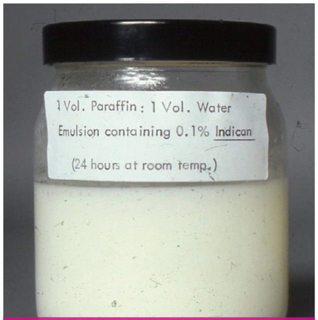


Fig 34 Polysaccharide emulsion with parrafin

Fig 35 Polysaccharide gel formed with ethylene glycol as solvent

Section

6

Secondary/Tertiary Structure and Function

6.1 Introduction

Polysaccharides have amazing physical properties and these are determined by the way in which they occupy their biological environments. Secondary structure can be defined as the general three dimensional form of a polysaccharide (e.g. open chain, helix etc) and tertiary structure as how the chains occupy three dimensional space.

They can lock up very large amounts of water in gel-like structures that appear to be solid but contain only 0.5% solid material and 99.5% water. They can form bundles called microfibrils that hold up massive trees and can occupy interstitial space between growing cells in plants and animals, forming a matrix in which organisms can grow and cells divide. These properties have been the subject of much scientific effort to work out how polysaccharides do this and in section 6.2, some of the most important structures and how they were elucidated will be discussed.

Polysaccharide primary structural information, discussed in section 4, gives very little information about the way in which the polysaccharide molecule works in three dimensional space. For this reason it has been necessary to turn to other methods of analysis to determine the secondary and tertiary structures of polysaccharides that define functionality.

A key group of biopolymers that provided insights into how the three dimensional structures of polysaccharides could be studied was found in protein chemistry where X-ray crystallography, NMR spectroscopy and electron microscopy coupled with model building (using high powered computers) allowed scientists to elucidate the structures of proteins such as lysosyme and insulin. These methods have been used to study polysaccharides.

6.2 Examples of Secondary & Tertiary Polysaccharide Structures

6.2.1 Cellulose

The polysaccharide that has attracted the most attention has been cellulose as it provides the crucial close-packed microfibrils essential to the strength of the growing plant. As can be seen in Fig 36, the glucose chains can pack together with hydrogen bonds holding them in close-packed bundles.

These bundles then arrange themselves to form the skeleton of the growing plant (Fig 37).

The secondary and tertiary structure of cellulose was determined by a combination of X-ray crystallography and electron microscopy.

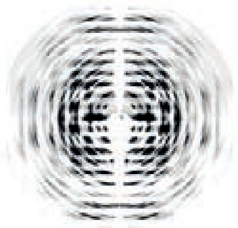


Fig 36 X-Ray diffraction diagram of cellulose

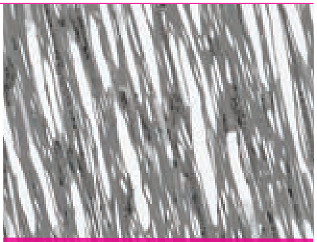


Fig 37 Electron micrograph of cellulose microfibrils

6.2.2 Carrageenan (Whistler, 1993)

Carrageenan forms thermally reversible gels and this has been exploited by the food industry in many applications such a desserts, milk drinks and for its very good freeze-thaw stability. Following extensive studies using X-ray crystallography and spectroscopy, it was found that carrageenan had a helical structure (Fig 38) and that the helices could combine in a hydrogen bonded double helix arrangement in a similar manner to DNA (Fig 39). The individual double helices then form links with other helical chains to form networks resulting in a solid gel (Fig 40). Carrageenan gels can be melted and reformed due to the breaking and reforming of the hydrogen bonds between chains (Rees, 1970) (Fig 41).

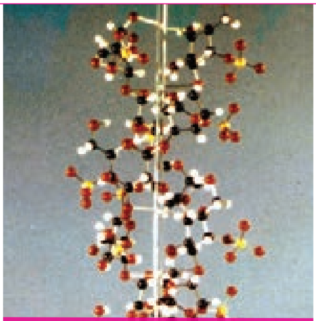


Fig 38 Ball and stick model of carrageenan helical structure

Fig 39 Space-filling model of carrageenan double helix

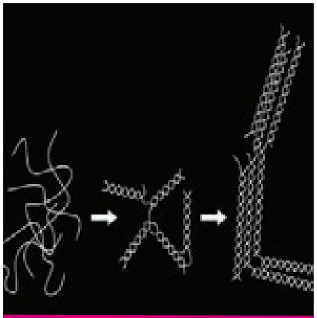


Fig 40 Representation of carrageenan gelation mechanism

Fig 41 Carrageenan gel

6.2.3 Alginate (Harris, 1990)

When sodium alginate is treated with divalent calcium ions, the calcium forms links between carboxyl groups in neighboring chains (most strongly with the guluronate residues) forming a gel matrix known as the 'egg box' due to its regular parallel arrangement (Fig 42).

These gels are not thermally reversible as the bonds are ionic in nature (Rees, 1969). Alginate gels are exploited in such applications as reformed meat and fruit pieces, glazes, dressings and to stabilize the foam on beer.

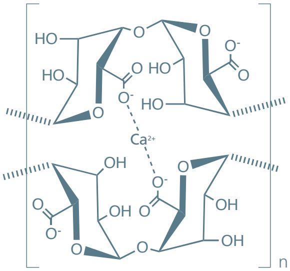


Fig 42 The alginate egg box mechanism

6.2.4 Xanthan Gum (Sandford, 1977)

Xanthan gum combines high viscosity with a remarkable ability to suspend solids under conditions of low shear. These properties arise from the ability of xanthan chains to form loosely associated double helical links with other chains that break, when sheared, and reform when shear is removed. The structural nature of these links has been the subject of much investigation and it has been concluded that the behavior of xanthan is consistent with part gel and part solution. The polymer chains form weak non-covalent bonds that break when sheared but reform when the shear is removed (Fig 43). This has found great application in oil well drilling where the lubricating polymer is required to flow under conditions of high shear but then to thicken in order to bring the drilled-out particles to the surface. Other key uses are in the food industry as a suspending agent with very good texturizing and mouthfeel properties.

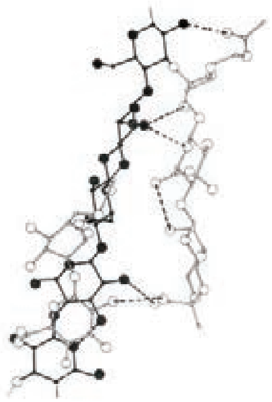


Fig 43 Xanthan gum helix with associated hydrogen bonding

6.2.5 Pectin (Whistler, 1993)

In many ways pectin is similar to alginate, being largely composed of galacturonic acid some of which is methyl esterified. Pectins that have a high level of methoxy groups (HM Pectin) form gels in the presence of sucrose and for this reason are used in jams and in combination with other fruits. Pectins with a low level of methoxy groups (LM Pectin) gel with calcium ions and are used in other food applications such as pastries and recipes designed not to be as sweet. Low methoxy pectin can be used as a fat substitute in baked goods and to stabilize acidic protein drinks such as drinking yogurt. The ‘Egg Box’ model similar to the alginate concept has also been used for Pectin (Fig 44).

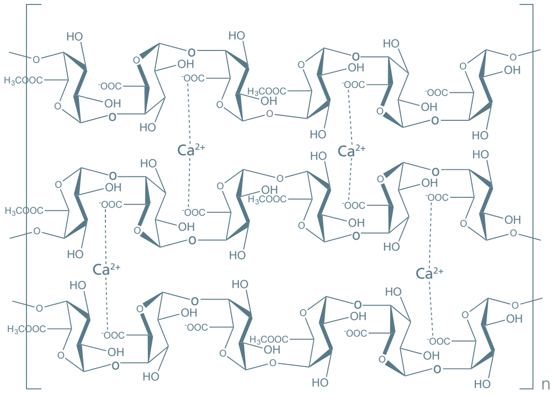


Fig 44 Pectin ‘egg box’ model of gelation

6.2.6 Konjac Glucomannan

By the use of electron microscopy and X-ray crystallography on konjac fibres, it was shown that konjac glucomannan was an extended semi-flexible linear chain without branches in the form of a double helix stabilised by hydrogen bonds. It is a traditional food in Japan where it is exploited for its ability to form stiff gels and viscous solutions. It is used in gravies, sauces, glazes, soups, stews and casseroles. It is also a thickener in pies, puddings, custards and cake fillings. Being gluten-free, it is used as a substitute in cooking and baking for flour and other wheat products (Ying-quing, 2005; Vipul, 1997).

Section

7

Binary & Ternary Interactions Between Polysaccharides

7.1 Binary Interactions (Harris, 1990)

In the 1980s scientists working on polysaccharide food ingredients at The Unilever research laboratory at Colworth House in the UK observed a new and as yet unreported phenomenon, namely that a number of binary combinations of some polysaccharides could interact in a synergistic manner (Ross-Murphy, 1995). This interaction appeared to enhance the rheological and gel-forming properties over and above those of each of the components and the property has been used in many applications where high functionality coupled with low concentration is desired.

Not all polysaccharides exhibit this behavior and the first synergistic complex formation was observed between xanthan gum and locust bean gum. Other examples were then discovered including a more general interaction between xanthan and galactomannans and glucomannans (xanthan-guar, xanthan-konjac glucomannan), carrageenan-guar and galactomannans and some starches (Dea, 1977).

Very little information has been published on the structure of these binary complexes with most studies concentrating on the rheological and gelation physical properties as will be discussed in the next chapter. The possible interaction of polymer chains has been illustrated as shown in Fig 45.

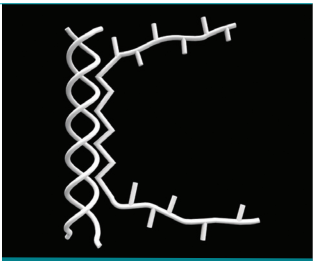


Fig 45 Postulated binary synergistic interaction between polysaccharides

7.2 Ternary Interactions

More recently, synergistic interactions between three polysaccharides have been reported. The polysaccharides in question are xanthan, konjac glucomannan and sodium alginate and the observed behavior has been an extremely high viscosity at low concentration (Harding, 2011). A published study of this phenomenon has concluded that the interactions are non-covalent and that in the ultracentrifuge a shift to a higher molecular weight from the individual components can be observed (Fig 46).

This interaction has been exploited in a product known as PGX (Polyglycoplex). When PGX is taken with meals, or added to a drink, it expands in the stomach over a 30-minute (or longer) timeframe and creates a feeling of fullness (satiety) by absorbing water and filling the stomach while slowing digestion. This keeps blood sugar from rising too high after meals thereby curbing the body's hunger cravings throughout the day (Smith 2014). Other benefits such as reducing blood sugar and cholesterol have been observed (Brand-Miller, 2010; 2012).

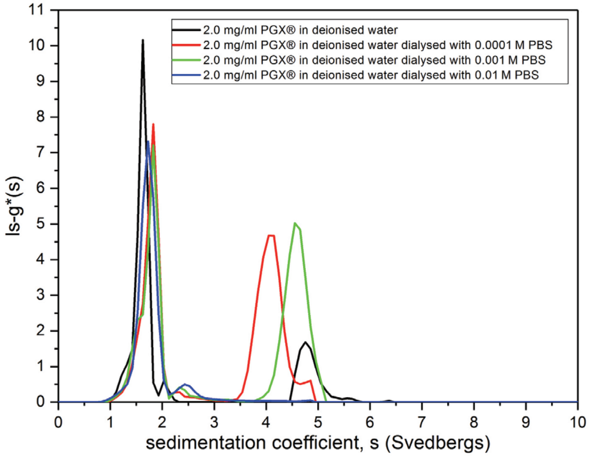


Fig 46 Shift to high MW from starting components in a ternary mixture of alginate, xanthan and konjac glucomannan

Section

8

Polysaccharide Review

8 Introduction

This review covers all the polysaccharide categories that are now offered through the combined portfolios of Glycomix and Carbosynth. We have grouped and categorized the collection with respect to origin, source and product and have included both the natural polysaccharides and the chemical derivatives that are so useful in food, pharmaceuticals and industry. Each entry contains a representation of the polysaccharide covalent structure, a description of the source and a short description of the features that are key to the functional behavior shown.

8.1 Polysaccharides from Higher Plants

8.1.1 Energy Storage Polysaccharides

8.1.1.1 Starch (Radley, 1968; Robyt, 1998; Whistler, 1993)

Starch is an energy storing polysaccharide containing only α-1,4 and α-1,6-linked glucose residues. Starch is produced by most higher plants and some algae and is the most common carbohydrate consumed by humans. It is contained in large amounts in staple foods such as potatoes, wheat, maize (corn), rice, cassava and tapioca.

Pure starch is a white, tasteless and odorless powder that is insoluble in cold water or alcohol. It consists of two types of polysaccharide: the linear and helical amylose (α-1,4-linked glucose) (Fig1R) and the branched amylopectin (α-1,4 and α-1,6-linked glucose) (Fig 2R). Depending on the plant, starch generally contains 20 to 25% amylose and 75 to 80% amylopectin by weight. Glycogen, the glucose store in animal tissues, is a more branched version of amylopectin. A variant of starch known as Waxy Maize starch contains very high levels of amylopectin.

In industry, starch is converted into glucose and glucooligosaccharides, for example by malting, and fermented to produce ethanol in the manufacture of beer, whisky and biofuel. It is processed to produce many of the sugars used in processed foods. Dissolving starch in warm water gives wheatpaste which can be used as a thickening, stiffening or gluing agent. The biggest industrial non-food use of starch is as an adhesive in the papermaking process. Starch can be applied to parts of some garments before ironing, to stiffen them. Waxy starch is used mainly in food products, but also in the textile, adhesive, corrugating and paper industry (BeMiller, 2009).

Fig 2R Amylopectin

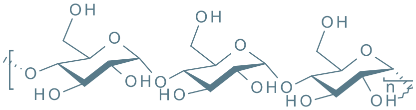


Fig 1R Amylose

8.1.1.2 Inulin

Inulin is a polysaccharide found in many vegetables such as chicory and jerusalem artichoke (Fig 3R). It is composed of β-1,2-linked fructopyranoside units with up to 60 fructose residues per chain (Fig 4R). Uses for inulin are as a diagnostic aid for kidney infections and as a low-calorie dietary fibre (Roberfroid 1993; Barclay 2010).

Fig 3R Jerusalem artichoke

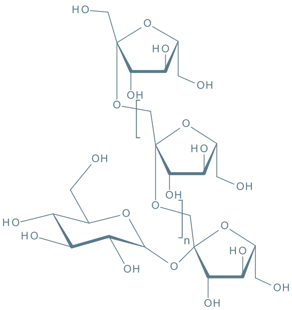


Fig 4R Inulin covalent structure

8.1.2 Structural Polysaccharides

8.1.2.1 Cellulose

Cellulose is probably the most abundant organic compound on the Earth and is the major structural component of the cell wall of higher plants. It occurs in a very pure form in the cotton boll (Fig 5R) and is also a major component of flax (80%), jute (60-70%), and wood (40-50%). Pure cellulose is also elaborated by some bacteria such as *Acetobacter xylinum* (Fig 6R) and related species (Ross, 1991).

Grasses such as papyrus and bamboo are also important sources of cellulose, and cellulosic pulps can be obtained from many agricultural by-products such as sugarcane, sorghum bagasse, corn stalks, and straws of rye, wheat, oats, and rice (Ward, 1983).

Celluloses from all sources are high molecular weight linear polysaccharides of D-glucopyranose residues linked β-1,4. No evidence has been found for branching (Fig 7R).

The conformation of this β-1,4-linked structure gives chains that have every other glucose residue rotated 180°, providing a high propensity to form intermolecular hydrogen bonds. This results in large aggregates of parallel cellulose chains that have crystalline properties and give X-ray diffraction patterns (Marchessault, 1983)

The tertiary structure of parallel-running intermolecular hydrogen-bonded cellulose chains further associate by hydrogen bonds and Van der Waals forces to produce three-dimensional microfibrils. The microfibrils give an X-ray diffraction pattern that indicates a regular, repeating crystalline structure interspersed by less-ordered paracrystalline regions (Brett, 2000).

Fig 5R Cotton

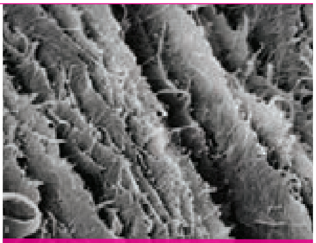


Fig 6R Electron micrograph of cellulose from *Acetobacter xylinum*

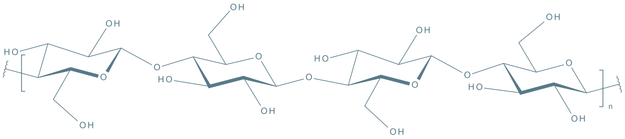


Fig 7R Cellulose

8.1.2.2 Cereal β–Glucans

Cereal β-glucans from oat, barley, wheat, and rye induce a variety of physiological effects that positively impact health. Barley and oat β-glucans (fig 8R) have been studied for their effects on blood glucose regulation in test subjects with hypercholesterolemia.

Oat and barley glucans contain both β-1,3 and β-1,4 linkages but differ in the ratio of trimer and tetramer 1,4 linkages. Barley has more 1,4 linkages with a degree of polymerization higher than 4. However, the majority of barley blocks remain trimers and tetramers. In oats, β-glucan is found mainly in the endosperm of the oat kernel, especially in the outer layers of that endosperm (Keogh, 2003). Oat β-glucans are water-soluble β-glucans (Henry, 1987) derived from the endosperm of oat kernels known for their cholesterol lowering and hypoglycemic properties, as well as their use in various cosmetic applications. Recent research has shown their potential application in immunomodulation and wound healing.

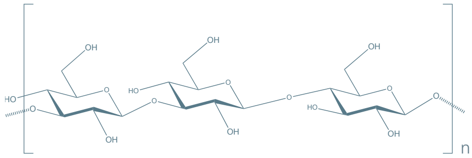


Fig 8R β-Glucan

8.1.2.3 Hemicelluloses and Related Polysaccharides

The hemicelluloses are a heterogeneous group of polysaccharides that vary from plant to plant and from one plant part to another. There are four basic types of hemicelluloses: D-xyloglucans, composed of D-xylopyranose attached to a cellulose chain; D-xylans, composed of D-xylose; O-mannans, composed of D-mannose; and D-galactans, composed of D-galactose. These polysaccharides are similar to cellulose in having their main chains linked β-1,4. Most of the hemicelluloses are, however heteropolysaccharides with one to three monosaccharide residues linked to the main monosaccharide chain.

8.1.2.3.1 Xylans

Xylan is a generic term used to describe a wide variety of highly complex polysaccharides that are found in plant cell walls and some algae (Percival, 1967).

Xylan is the most abundant noncellulosic polysaccharide present in both hardwoods and annual plants, and accounts for 20–35% of the total dry weight. In softwoods, xylans are less abundant and may comprise about 8% of the total dry weight. Xylan is found mainly in the secondary cell wall as part of the hemicellulose fraction and is considered to form an interface between lignin and other polysaccharides. It is likely that xylan sequences covalently link with lignin phenolic residues, and also interact with other polysaccharides, such as pectin and starch. In their simplest forms, xylans are linear homopolymers of β-1,4-xylose residues (Fig 9R).

In nature, they are partially substituted by acetyl, 4-O-methyl-D-glucuronosyl and α-1,3 L-arabinofuranosyl residues, forming complex heterogenous and polydispersed glycans. An example of this is in the *L-Arabino* (methyl-D-glucurono) xylan from corn cob (Fig 10R). Many structural aspects of xylans are unclear because of the difficulties associated with their isolation from the biomass complex without significant alteration or loss of the original structure (Ebringerova, 2000).

Xylans are also found in the cell walls of a number of green algae *(Embryophyta)*, especially macrophytic siphonous genera, where they replace cellulose. Similarly, they replace the inner fibrillar cell-wall layer of cellulose in some red algae *(Rhodophyta)* (Percival, 1967; Usov, 1981; Usov, 1991).

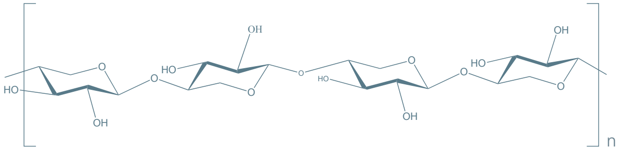


Fig 9R linear xylan

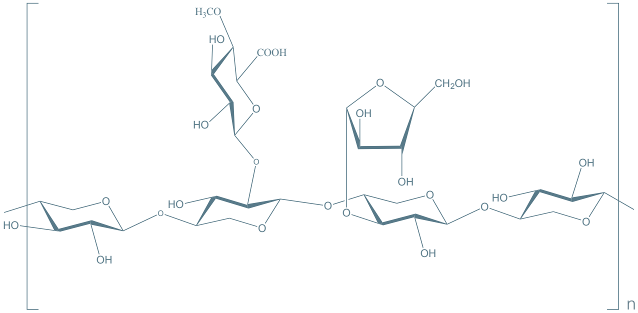


Fig 10R Corn Cob Xylan

8.1.2.3.2 Spruce Galactoglucomannan

This galactoglucomannan is a water-soluble hemicellulose consisting of galactose, glucose and mannose. Many softwood species, e.g. Norway spruce (Fig 11R) are rich in galactoglucomannans and may contain up to 10-20%. The polysaccharide is a linear backbone of randomly distributed 1,4-linked mannose and glucose with (1,6)-linked galactose units attached to the mannose residues (Fig 12R). The hydroxyl groups at C2 and C3 of the mannose residues are partially acetylated.

Fig 11R Norway spruce

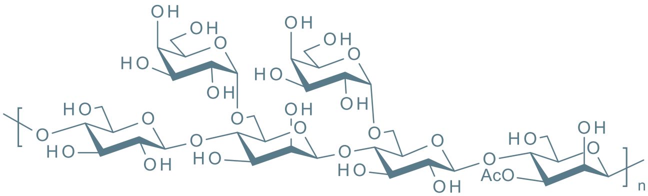


Fig 12R Spruce galactomannan

8.1.2.3.3 Larch Arabinogalactan (Whistler, 1993)

Larch arabinogalactan is extracted from the heartwood of the western larch *Larix occidentalis* (Fig 13R). These arabinogalactans have a backbone of 1,3-linked β -D-galactopyranosyl units each of which contains a side chain at position C-6. Most of these side chains are galacrobiosyl units containing α-1,6-β-D-linkages. Other side chain types that occur are monomeric L-arabinofuranose units or dimeric 3-O-(β-L-arabinopyranosyl)-α -L-arabinofuranosyl units (Fig 14R). Applications for this arabinogalactan are as emulsifiers, stabilizers and binders in the food, pharmaceutical and cosmetic industries. More recently, there has been interest in the use of this polysaccharide as a low viscosity dietary fibre and as a probiotic.

Fig 13R *Larix occidentalis* (western larch)

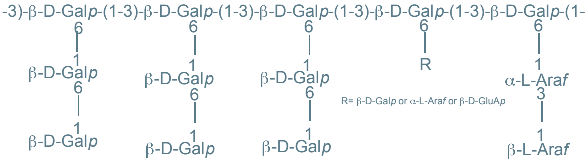


Fig 14R Covalent structure of larch arabinogalactan

8.1.2.3.4 Galactans

The characterisation of β-1,4-galactan as a distinct polysaccharide in the seeds of *Lupinus albus* was demonstrated by Hirst in 1947 (Hirst, 1947). Al-Kaisey and Wilkie (Al-Kaisey, 1992) demonstrated the presence of two types of galactans in lupin seeds namely, an α-1,3-linked galactan with some 4-linkages and an α-1,4 galactan substituted by L- arabinofuranose. Other linear β-1,4-galactans have been isolated from lemon peel (Labavitch, 1976), potato tubers (Wood, 1972), Norwegian spruce compression wood (Bouveng, 1959) and from acacia gums (Fig 15R).

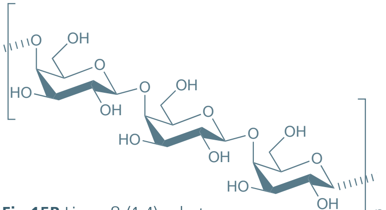


Fig 15R Linear β-(1,4) galactan

8.1.2.4 Pectin & Pectin-related Polysaccharides

Pectins are complex polysaccharides that occur in all plants, primarily in the cell wall, in low amounts of 1-5%. They are, however, particularly prevalent in fruits, where the amounts are much higher. For example, apple pulp contains 10-15% (w/w) pectin, orange, lemon and lime peel contain 20-30% (w/w). Pectins act as an intercellular cementing material that gives body to fruits and helps them keep their shape. When fruit becomes overripe, the pectin is broken down into its constituent monosaccharide sugars. As a result, the fruit becomes soft and loses its firmness.

Commercial pectins are extracted from citrus fruits such as limes and lemons and are 'stripped down' from the complex structures that exist in nature to contain a high percentage of polygalacturonic acid as described below.

The very complex structures that occur in nature have been the subject of research for many years, but are still not fully described. Later in this section, a number of the most important related polysaccharides such as apiogalacturonan, sugar beet arabinan, the pectic arabinogalactans and rhamnogalacturonans I and II will be discussed.

8.1.2.4.1 Commercial Pectin (Whistler, 1993; Harris, 1990)

Commercial pectins extracted mainly from citrus fruits are regarded as linear chains of α-1,4-linked D-galacturonic acid, a homogalacturonan (pectic acid) (Fig 16R). The polyuronide is partly methyl esterified and the free acid groups may be partly or fully neutralised with sodium, potassium or ammonium ions. In the products of commerce, the degree of methylation - termed the degree of esterification (DE) - has a vital influence on the properties of pectin, especially the solubility and gel-forming characteristics. In nature, around 80 percent of the galacturonic acid residues are methyl esterified and this proportion is decreased to a varying degree during pectin extraction but can be increased by treatment with methanol. Pectins are classified as high or low-methoxy pectins (HM- and LM-pectins) and for example in jams and marmalades that contain above 60% sugar and soluble fruit solids, high-ester pectins are used. With low-ester and amidated pectins (treatment of pectin with ammonia) less sugar is needed, so that dietetic products can be made. The mechanism for gel formation with calcium ions is known as the 'egg box' (Fig 17R).

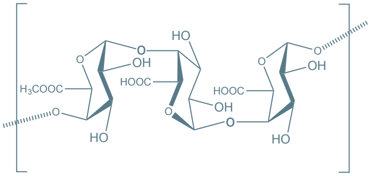


Fig 16R Covalent structure of pectic acid

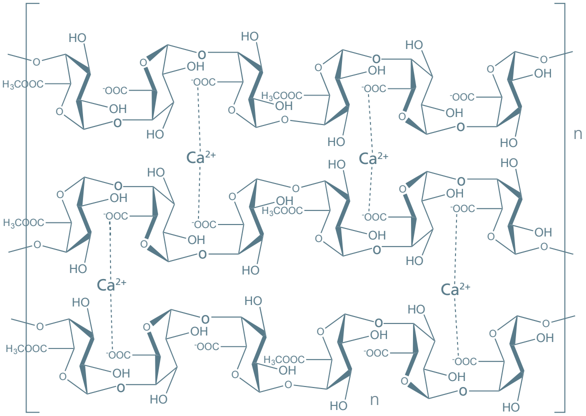


Fig 17R The 'egg box' model for pectin gelation

Commercial Pectin (continued)

Rhamnogalacturonan I

Rhamnogalacturonan I (RG-I) contains a backbone of the repeating disaccharide: 4)-α-D-galacturonic acid-(1,2)-α-L-rhamnose-(1. The galacturonic acid residues are not normally substituted, but many of the rhamnose residues carry sidechains of various neutral sugars including D-galactose, L-arabinose and D-xylose. The types and proportions of neutral sugars vary with the origin of pectin (Yapo, 2011).

Rhamnogalacturonan II

Rhamnogalacturonan (RG-II) was first described in 1978 and its structure has subsequently been shown to be conserved in the primary walls of dicotyledenous and monocotyledenous plants and gymnosperms. RG-II is also likely to be present in the walls of some lower plants (ferns, horsetails, and lycopods). RG-II is a low molecular mass (5-10 kDa) pectic polysaccharide that is solubilized by treating a cell wall with endopolygalacturonase. RG-II contains eleven different glycosyl residues.

The backbone of RG-II contains at least eight 1,4-linked α-D-GalpA residues. Two structurally distinct disaccharides (C and D) are attached to C-3 of the backbone and two structurally distinct oligosaccharides (A and B) are attached to C-2 of the backbone (Vidal, 2000; Glushka, 2003) (Fig 18R).

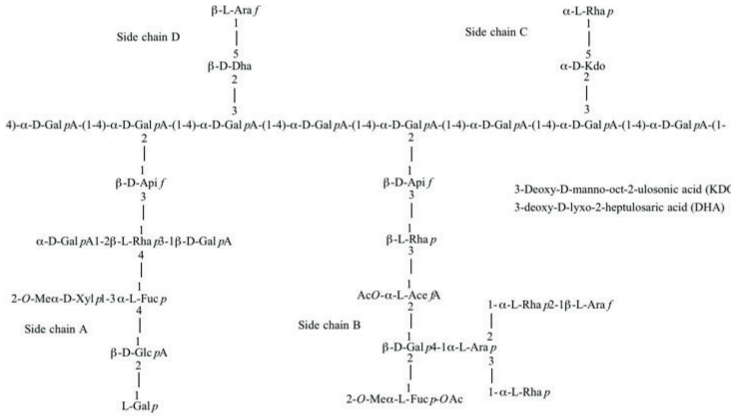


Fig 18R Rhamnogalacturonan II

8.1.2.4.2 Apiogalacturonan

Zosterin, an apiose-rich pectic-like polysaccharide which is found in the sea grass *Zostera marina* (Fig 19R), is typical of a number of similar structures occurring in higher plants. The structure consists of an α-1,4-D-galactopyranosyluronan backbone substituted by 1,2-linked apiofuranose oligosaccharides and single apiose residues (Fig 20R). The average molecular mass of the polysaccharide has been shown to be about 4100 Da with a low polydispersity (Gloaguen, 2010).

Fig 19R Zostera marina (©M.D. Guiry)

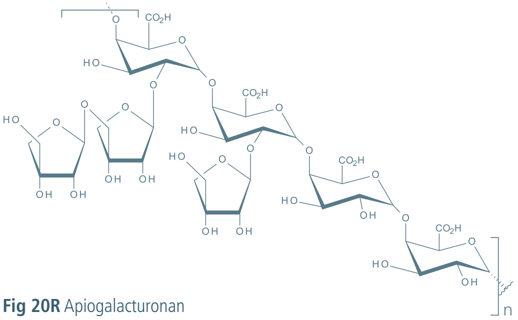


Fig 20R Apiogalacturonan

8.1.2.4.3 Arabinan (Sugar beet)

Arabinans appear in the primary cell walls of different families of plants in seeds, fruits, and roots (e.g. sugar beet) (Fig 21R), usually as pectic polysaccharide side chains or as free polymers unattached to pectic domains. Sugar beet arabinan consists of a 1,5-α-linked backbone to which 1,3-α-linked (and possibly some 1,2-α-linked) L-arabinofuranosyl residues are attached (Fig 22R). Approximately 60% of the main-chain arabinofuranosyl residues are substituted by single 1,3-linked arabinofuranosyl groups. The reducing terminal arabinosyl residue is attached through rhamnose to fragments of the rhamnogalacturonan backbone of the native pectin molecule (Wefers, 2016).

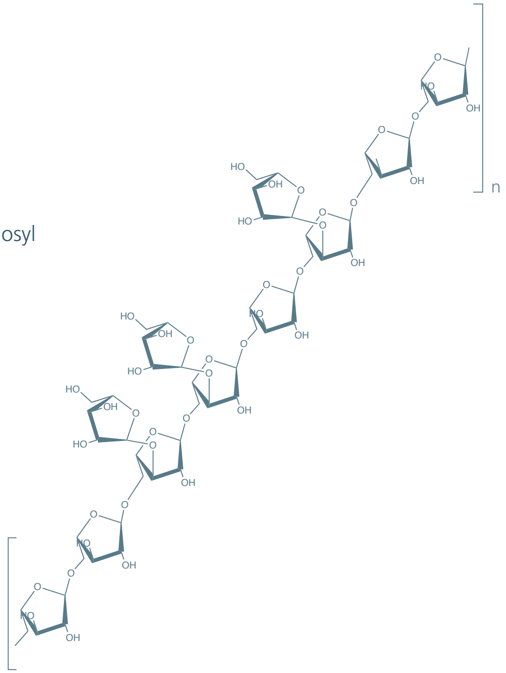


Fig 22R Arabinan

Fig 21R Sugar beet, *Beta vulgaris*

8.1.2.4.4 Pectic Arabinogalactans and Rhamnogalacturonans

Arabinogalactan I

Type I arabinogalactans (AGs) are abundant in primary walls of dicotyledonous plant tissues including many fruits (Perez, 2000). They comprise a main backbone of 1,4-linked β-D-galactose to which short side chains of α-L-arabinose are attached at the O3 position (Fig 23R). Ferulic acid has been found attached to some arabinose and galactose residues in some tissues such as sugar beet (Morris, 2010).

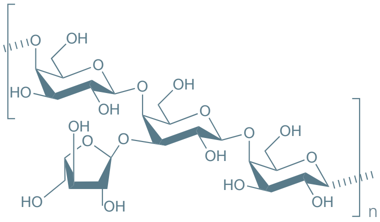


Fig 23R Arabinogalactan I

Arabinogalactan II

Type II Arabinogalactans have been extracted along with pectic polymers with which they were probably covalently linked on rhamnogalacturonan (Vincken, 2003). They exhibit highly complex structures comprising a highly branched galactan core of 1,3- and 1,6-linked β-D-galactose residues. Short side chains of 1,6-linked β-D-Galactose including between one and three residues in length are present. Galactosyl residues in these side chains are often substituted with terminal α-L-Arabinose attached at O3 or O6 (Fig 24R).

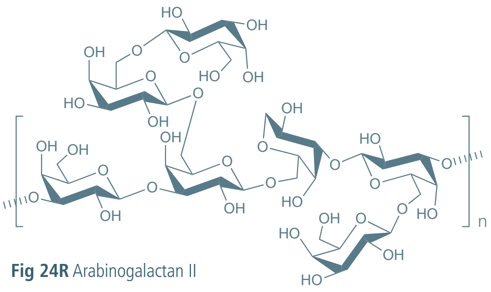


Fig 24R Arabinogalactan II

8.1.3 Polysaccharides from Seeds & Legumes

8.1.3.1 Pysillum Seed Gum (Whistler, 1993)

Psyllium seed gum comes from plants of the *Plantago* genus (Fig 25R) and is cultivated mainly in the Mediterranean and in India. Psyllium has been used for many years in medical applications and more recently the polysaccharide has attracted interest because of its increasing value as a soluble dietary fibre. The proposed structure is of a backbone of D-xylopyranosyl units linked 1,4 and 1,3 with the 4-linked units bearing side chains. The side chains consist of α-L-arabinofuranosyl units linked 1,3 and 1,2 and β-D-xylopyranosyl units linked 1,3 and 1,2 and the α-D-GalAp-1,2-α-L-Rhap aldobiuronic acid units linked 1,2 to the main chain (Fischer, 2004; Gibb, 2015) (Fig 26R).

Fig 25R *Plantago*

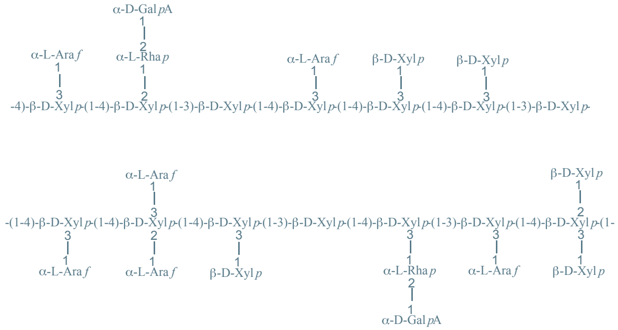


Fig 26R Covalent structure of *psyllium*

8.1.3.2 Guar Gum (Whistler, 1993)

Guar gum is obtained from the seed of the legume *Cyamopsis tetragonolobus*, (Fig 27R) an annual plant that grows mainly in semi-arid regions of India. The structure of the polysaccharide consists of a main chain of 1,4-linked β-D-mannopyranosyl units with single α-D-galactopyranosyl units linked 1,6 on average to every second main chain residue (Fig 28R). Guar has a high viscosity in aqueous solution, shows marked pseudoplastic behavior and forms synergistic gels in the presence of other gums such as carrageenan and xanthan gum. In the food industry, xanthan gum and guar gum combinations are the most frequently used gums in gluten-free recipes and gluten-free products. Industrial guar gum accounts for about 70% of the total demand. It is used mainly as a proppant (sand-based fracking fluid) in hydraulic fracturing Process.

Fig 27R Seeds of *Cyamopsis tetragonolobus*

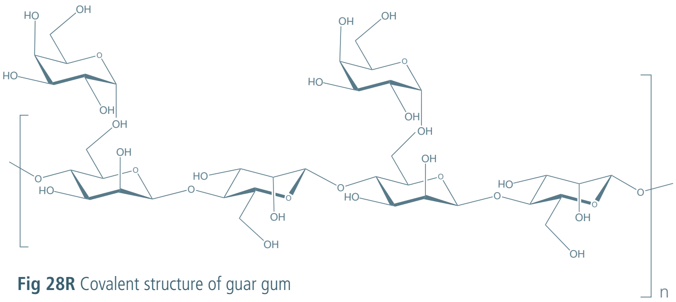


Fig 28R Covalent structure of guar gum

8.1.3.3 Ivory Nut Mannan

Fig 29R Ivory nuts

Ivory nut mannan occurs in the fruit (nuts) of members of the custard apple, ebony and palm families (ivory nut) (Fig 29R). The polysaccharide contains more than 95% mannose units linked β-1,4 with a few α-D-galactopyranosyl units linked 1-6 (Fig 30R). It is widely used in foods, pharmaceuticals paints and explosives (Timell, 1957).

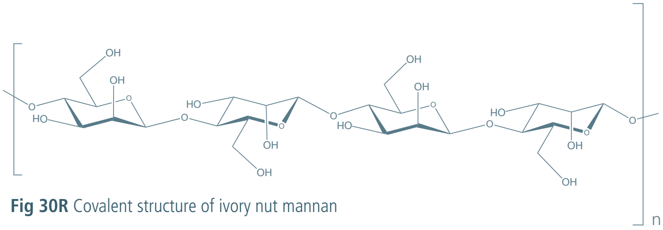


Fig 30R Covalent structure of ivory nut mannan

8.1.3.4 Locust Bean Gum (Whistler, 1993)

Fig 31R *Ceretonia siliqua* (carob tree)

Locust bean (carob) gum is the refined endosperm of the seed of the carob tree, an evergreen of the legume family (*Ceretonia siliqua*) (Fig 31R). The tree grows extensively in Spain and is cultivated in many other Mediterranean countries. Locust bean gum like guar gum is a galactomannan with a backbone of 1,4 β-D-mannopyranosyl units having branches of 1,4-linked α-D-galactopyranosyl units (Fig 32R). However, locust bean gum has substantially fewer side chains than guar gum and these are clustered in blocks leaving longer regions of unsubstituted mannosyl regions. The gum is only partially soluble in water and suspensions require heating before solubility is achieved. As with guar the polysaccharide forms gels with other gums such as carrageenan and xanthan. Applications are in the food industry to enhance texture, in paper making and in the textile industry.

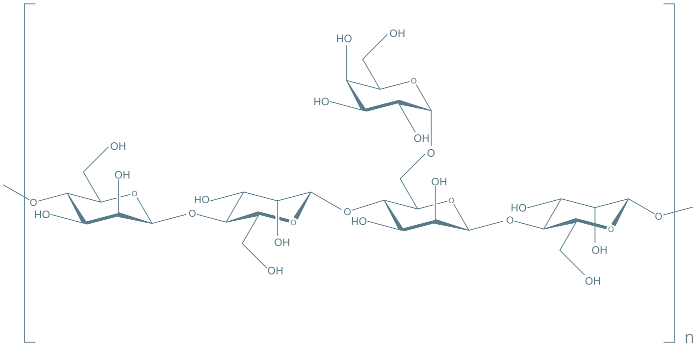


Fig 32R Covalent structure of locust bean gum

8.1.3.5 Tamarind Gum (Whistler, 1993)

Fig 33R *Tamarindus indica* (tamarind tree)

Tamarind gum comes from the seed of the tamarind tree *Tamarindus indica* (Fig 33R) and is used in the food industry as a stabiliser and an emulsifier. It has been suggested that the structure is a main chain of cellulose with frequent branching at the O-6 positions with short side chains of one or two D-xylopyranosyl capped with D-xylopyranosyl, D-galactopyranosyl or L-arabinofuranosyl units (Fig 34R). In application tamarind finds use in the sizing of jute and as a stabiliser and thickener in the food industry.

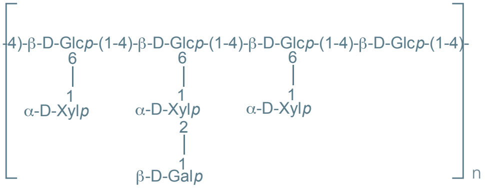


Fig 34R Covalent structure of tamarind gum

8.1.3.6 Tara Gum (Whistler, 1993)

Fig 35R *Caesalpinia spinosa* (tara shrub)

Tara gum is a galactomannan that is obtained from the seeds of the tara shrub *Caesalpinia spinosa* (Fig 35R) which is a native of the northern regions of Africa and South America. The gum is described as having a backbone of 1,4-linked β-D-mannopyranosyl units one third of which possess a single unit side chain of 1,4-linked α-D-galactopyranose (Fig 36R). The gum forms gels with carrageenan and xanthan in a similar manner to guar and locust bean gum. Currently only small quantities of tara gum are sold for use as food thickeners and stabilizers.

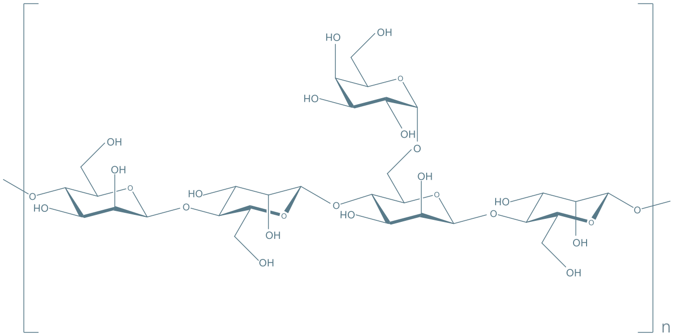


Fig 36R Covalent structure of tara gum

8.1.4 Exudate Gums

Exudate gums are polysaccharides produced by plants to seal wounds in their bark. The plant exudes an aqueous solution of polysaccharide around a break in the bark, covering the injury. The water evaporates, leaving a polysaccharide that hardens and prevents infection and desiccation of the plant.

8.1.4.1 Gum Arabic (Whistler, 1993)

Gum arabic is an exudate gum picked from *Acacia* trees growing in arid regions (typically *Acacia senegal* (Fig 37R) and *Acacia laetia*). The polysaccharide is branched with a main chain of 1,3 linked β-D-galactopyranosyl units with side chains of 1,3 β-D-galactopyranosyl units joined to it by 1,4 links. The side chains are 2-5 units in length. Both the main chain and the side chains have attached units of α-L-arabinofuranosyl, α-L-rhamnopyranosyl, β-D-glucuronopyranosyl and 4-O-methyl-β-D-glucuronopyranosyl units (Fig 38R) (Stephen, 1990).

Fig 37R *Acacia senegal*

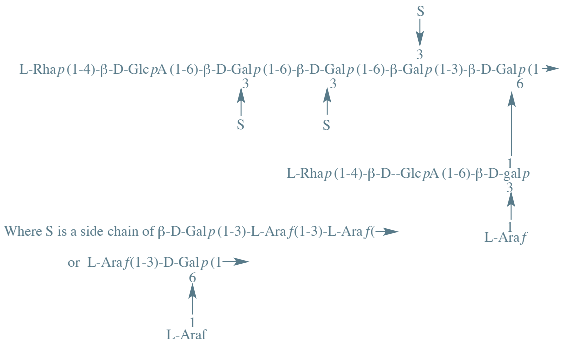


Fig 38R Gum Arabic covalent structure

8.1.4.2 Gum Ghatti (Whistler, 1993)

Gum Ghatti is an exudate gum from the tree *Anogeissus latifolia* (Fig 39R) found in India and Sri Lanka. Applications are similar to gum arabic in the food and pharmaceutical industries where it is used as an emulsifier. The polysaccharide is reported to have an extremely complex structure containing both oligosaccharides and polysaccharide elements. The polysaccharide contains Ara, Gal, Man, GlcA and Rha in a molar ratio of 61:39:6:10:6, a backbone of 1,4-linked β-D-galactopyranosyl units and side chains of L-arabinofuranose units with some 1,4-D-glucopyranosyluronic acid units, some joining 1,2-D-mannopyranosyl units. The oligosaccharides are reported to mimic the side chains and include the structures depicted below (Fig 40R).

Fig 39R *Anogeissus latifolia*

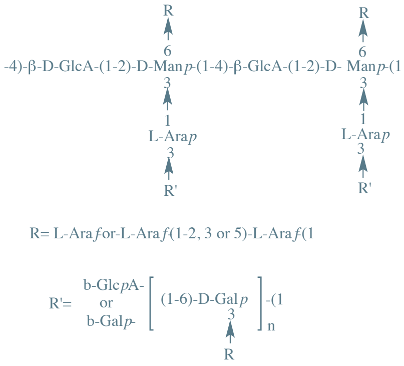


Fig 40R Partial structure of gum ghatti

8.1.4.3 Gum Karaya (Whistler, 1993)

Gum Karaya is exuded from *Sterculia urens* (Fig 41R), a bushy tree found in dry regions of North India. Due to its extensive swelling capacity in water it is used as a laxative and as a denture adhesive. The structure consists of D-galactose, D-glucuronic acid and L-rhamnose but the detailed molecular structure is still incompletely known (Fig 42R) (Aspinall, 1970).

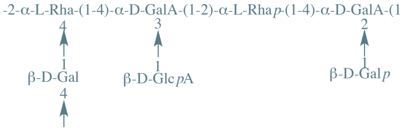


Fig 42R Covalent structure of gum karaya

Fig 41R *Sterculia urens*

8.1.4.4 Gum Tragacanth (Whistler, 1993)

Gum Tragacanth is an exudate gum from species of *Astragalus* trees (Fig 43R) mainly grown in Iran and Turkey. Tragacanth finds applications as an effective emulsifying and thickening agent in the food and pharmaceutical industries. The gum is a slightly acidic salt consisting of two fractions namely the water-soluble *tragacanthin* and the *bassorin* fraction which swells in water to form a gel. Water-soluble *tragacanthin* is reported as a branched arabiogalactan which is soluble in 70% ethanol. The acidic *bassorin* has a chain of 1,4-linked α-D-galacturonic acid units some of which are substituted at O-3 with β-D-xylopyranosyl units and some of these being terminated with galactose or fucose (Anderson, 1985) (Fig 44R).

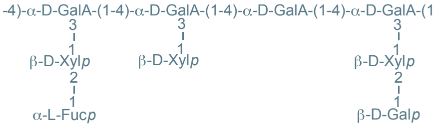


Fig 44R Covalent structure of gum tragacanth

Fig 43R Astralagus tree

8.1.5 Polysaccharides from Tubers

8.1.5.1 Konjac Glucomannan

Konjac glucomannan is an acetylated 1,4-β-D-glucomannan (Fig 45R) obtained from the tubers of *Amorphophallus konjac* (Fig 46R) or Konnyaku root. It is used in Japan in many food applications as an ingredient and due to its property of swelling in water is seen as a dietary supplement for reducing calorie intake (Vulksan, 1999; Maeda, 1980).

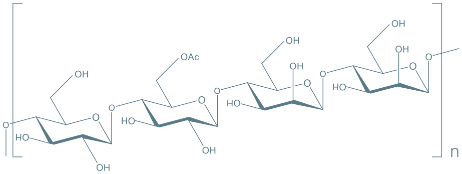


Fig 45R Covalent structure of konjac glucomannan

Fig 46R *Amorphophallus konjac*

8.2 Polysaccharides from Lichens

8.2.1 Lichenan and Isolichenan

Lichenin, also known as lichenan or moss starch, is a complex glucan occurring in certain species of lichens. It can be extracted from *Cetraria islandica* (Iceland moss) (Fig 47R). Chemically, lichenin consists of repeating glucose units linked by β-1,3 and β-1,4 glycosidic bonds (Fig 48R).

Fig 47R *Cetraria islandica*

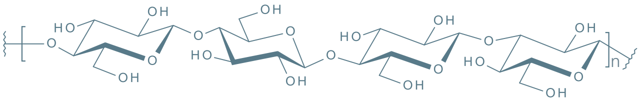


Fig 48R Lichenin

Lichenin, the poly β-D-Glucan of *Cetraria islandica* (Iceland moss), is found by enzymic degradation to differ in fine structure from the poly β-D-glucans of cereal grains. Enzymolysis was with cellulase and laminarinase, the former yielding mainly O-β-D-glucopyranosy-1,3-O-β-D-glucopyranosyl-1,4-α-D-glucose, and the latter mainly O-β-D-glucopyranosyl-1,4-O-β-D-glucopyranosyl-1,3-α-D-glucose. Di and tetra-saccharides are produced in small proportions. Thus, the basic structure of lichenin is a tetrameric unit in which two adjacent 1,4 linkages alternate with an isolated 1,3 linkage; occasionally four consecutive monomers are linked by 1,4 bonds (Perlin, 1962).

Isolichenan is a cold-water soluble 1,3-1,4-α-D-glucan also isolated from *Cetraria islandica* (Fig 47R) and reported to have MW of about 6-8 kDa (Peat, 1961b). A more recent investigation could not confirm the existence of such a small α-glucan in *Cetraria islandica*; instead, a much larger isolichenan with a linkage ratio of 2:1 according to NMR data was found (Fig 49R). The definitions "isolichenan-type" polysaccharide or sometimes only "isolichenans" have been used for α-D-glucans having 1,3-1,4-linkages in their main chain. Lichens produce isolichenan-type polysaccharides with considerable variation in linkage ratios as well as MW, even within the same species. Occasionally these α-glucans can be branched at O2, O3 or O6 (Olafsdottir, 1999). The immunomodulatory activity of isolichenan was tested in *in vitro* phagocytosis and anti-complementary assays, and proved to be active in both cases.

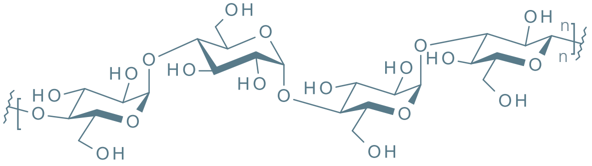


Fig 49R Isolichenin

8.2.2 Pustulan

Pustulan is a β-1,6-glucan (Fig 50R) from *Lasallia pustulata* (Fig 51R), MW (20 kDa). Pustulan is recognized by the membrane bound Dectin-1, a C-type lectin-like pattern recognition receptor. Detection of β-glucans by Dectin-1 receptor leads to the CARD9-dependent activation of NF-κB and MAP kinases. Studies have shown that pustulan can stimulate innate immune responses, inducing heat shock protein expression, eliciting phagocytosis, and the production of pro-inflammatory cytokines (Karunaratne, 2012).

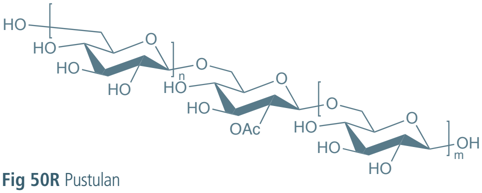


Fig 50R Pustulan

Fig 51R *Lasallia pustulata*

8.3 Polysaccharides from Algae

8.3.1 Polysaccharides from Rhodophyceae (Red algae)

8.3.1.1 Agar (Whistler, 1993)

A sulphated galactan from the red seaweeds *(Gelidium spp.)* (Fig 52R).

The major gel forming component agarose consists of a linear chain of sequences of 1,3 linked β-D-galactopyranosyl units and 1,4 linkages to 3,6-anhydro-α-L-galactopyranosyl units (Fig 53R). Gelation is via the formation of double helices as shown below (Fig 54R). Agar is primarily used as a plating gel for microbial cultures (Lahaye, 1991).

Fig 52R *Gelidium latifolium* (©M.D. Guiry)

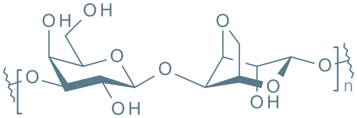


Fig 53R Covalent structure of agarose

The representation of the agarose double helix shown in Fig 54R is viewed normal and parallel to the helix axis. The small filled circles are O2 atoms of galactose and O5 of anhydrogalactose that line the inner cavity of the double helix. The large filled circles on the molecular axis are possible sites for ordered water molecules within the hydrogen-bonding distance of the oxygen atoms lining the cavity (Arnott, 1974).

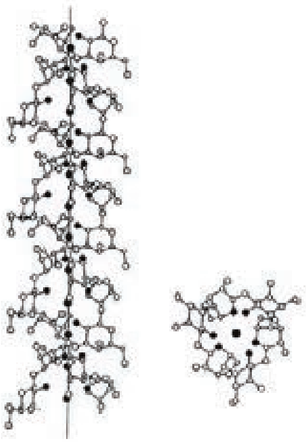


Fig 54R Agarose double helix

8.3.1.2 Carrageenan

8.3.1.2.1 λ Carrageenan (Whistler, 1993)

Lambda-Carrageenan is a non-gelling sulphated galactan extracted from red seaweed (typically *Gigartina stellata* and *Chondrus crispus)* (Fig 55R). The structure of all carrageenans consists of a strictly alternating masked repeating unit of 1,3-linked α-D-galactose and 1,4-linked β-D-galactose. λ-Carrageenan has the α-linked unit 2-6-disulphated and the β-linked unit is 2-sulphated (Lawson, 1968) (Fig 56R).

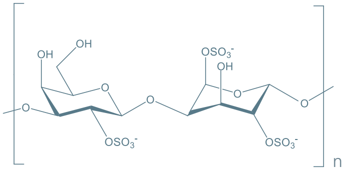


Fig 56R Covalent structure of λ carrageenan

Fig 55R *Chondrus crispus* (©M.D. Guiry)

8.3.1.2.2 κ Carrageenan (Whistler, 1993)

Kappa-Carrageenan is a gelling sulphated galactan extracted from red seaweed (typically *Mastocarpus stellata* (Fig 57R) and *Chondrus crispus*). The structure of all carrageenans consists of a strictly alternating masked repeating unit of 1,3-linked α-D-galactose and 1,4-linked β-D-galactose. The α-linked galactose occurs as α-3-6-anhydro unit and the β-linked sugar occurs as the 4-sulphate (Anderson, 1968) (Fig 58R).

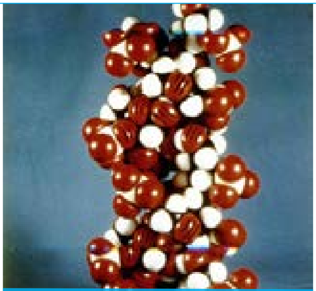


Fig 59R Space-filling model of the κ and ι double helix

Fig 57R *Mastocarpus stellata* (©M.D. Guiry)

Space-filling model of the double helix which is responsible for the gelling behavior of kappa- and iota-carrageenan (Lawson, 1970) (Fig 59R).

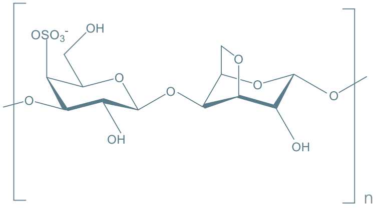


Fig 58R Covalent structure of k carrageenan

8.3.1.2.3 ι Carrageenan (Whistler, 1993)

Iota-Carageenan is a gelling sulphated galactan extracted from red algae (typically *Euchuma cottonii* and *Euchuma spinosum)* (Fig 60R). The structure of all carrageenans consists of a strictly alternating masked repeating unit of 1,3 linked α-D-galactose and 1,4 linked β-D-galactose. The α-linked galactose occurs as α-3-6-anhydro-2-sulphate unit and the β-linked sugar occurs as the 4-sulphate (Lawson, 1973) (Fig 61R).

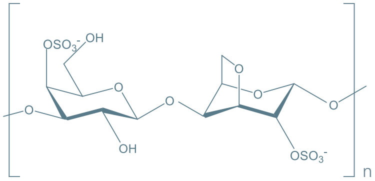


Fig 61R Covalent structure of ι carrageenann

Fig 60R *Euchuma spinosum* (©M.D. Guiry)

8.3.1.3 Porphyran


Fig 63R *Porphyra umbilicalis* (©M.D. Guiry)

Porphyran is a highly substituted agarose with a linear backbone consisting of 3 linked β-D-galactosyl units alternating with either 4-linked α-L-galactosyl 6-sulphate or 3-6-anhydro-α-L-galactosyl units. The composition includes 6-O-sulphated L-galactose, 6-O-methylated D-galactose, L-galactose, 3,6-anhydro-L-galactose, 6-O-methyl D-galactose and ester sulphate. Some of the ester is present as 1,4-linked L-galactose 6-sulphate (Rees, 1962; Peat, 1961) (Fig 62R). The precise composition of porphyran shows seasonal and environmental variations. In *Porphyra haitanensis*, the L-residues are mainly composed of alpha-L-galactosyl 6-sulphate units, and the 3,6-anhydro-galactosyl units are minor. In *Porphyra capensis*, the ratio of alpha-L-galactose-6-sulphate and the 3,6-anhydrogalactose is 1.2:1 (Zhang, 2005). Porphyran is not used commercially, but the seaweed, *Porphyra umbilicalis* (Fig 63R) is edible and is consumed in Wales (Laver). It is also made into a delicacy called Laverbread.

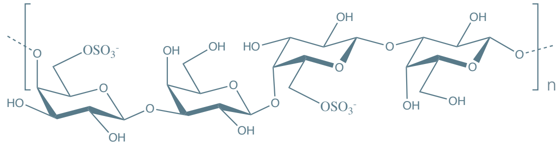


Fig 62R Covalent structure of porphyran

8.3.1.4 Furcellaran, Danish Agar


Fig 65R *Furcellaria lumbricalis* (©M.D. Guiry)

Furcellaran (Danish agar) is similar to κ-carrageenan but is less sulphated (50%) (Fig 64R). It has been extracted from *Furcellaria lumbricalis*, which is mainly harvested off the coast of Denmark (Fig 65R).

This species, which is common to most parts of Europe, occurs as a loose form and only reproduces vegetatively.

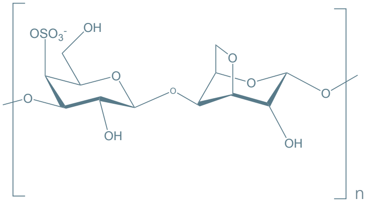


Fig 64R Furcellaran

8.3.2 Polysaccharides from Phaeophyceae (Brown algae)

8.3.2.1 Alginate (Whistler, 1993; Percival, 1967)

A linear polysaccharide obtained from the brown seaweeds (e.g. *Laminaria hyperborea, Fucus vesiculosus, Ascophyllum nodosum)* (Fig 66R). The chemical structure consists of blocks of 1,4 linked-β-D-polymannuronic acid (poly M), 1,4 linked-α-L-polyguluronic acid (poly G) and alternating blocks of the two uronic acids (poly MG) (Fig 67R). The main use for alginate is in textile printing where it is used in the printing of cottons with reactive dyes as a thickener. It is also used as a thickener in the food industry. Alginates form strong gels with divalent metal cations and the 'egg box' model has been used to describe this form of gelation (see below). The propylene glycol ester of alginate is produced by reacting it with with propylene oxide. It is mainly used as a thickener in ice creams.

Fig 66R *Ascophyllum nodosum* (©M.D. Guiry)

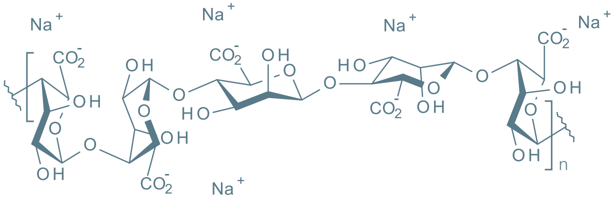


Fig 67R Alginate covalent structure

8.3.2.2 Laminaran

Laminaran is a polysaccharide that co-occurs with fucoidan and alginate in brown seaweeds such as *Laminaria digitata* (Fig 68R), *Ascophyllum nososum, Eisenia bicyclis* and *Thallus laminariae*. It is a β-1,3-linked glucan (Fig 69R) which it is claimed stimulates the immune system in mammals and fish (Nelson, 1974; Morales-Lange, 2015).

Fig 68R *Laminaria digitata* (©M.D. Guiry)

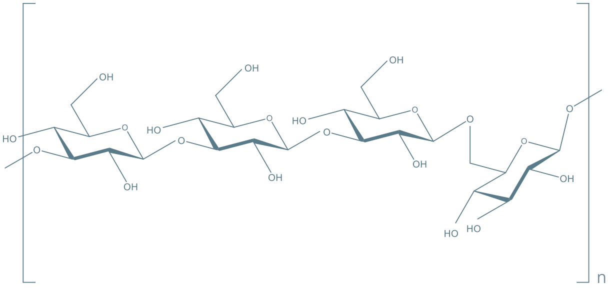


Fig 69R Covalent structure of laminaran

8.3.2.3 Fucoidan (Dumitriu, 1996)

Fucoidan is a fucan sulphate occurring in brown marine algae (*Phaeophyta*, typically *Fucus serratus* (Fig 70R), *Ascophyllum nodosum, Laminaria digitata* and *Macrocystis pyrifyra*) and has been shown to have anticoagulant activity. The main constituents are α-1,4 and α-1,2 linked L-fucose sulphates although galactose also occurs and there are many variations of the basic structure found in different species of *Phaeophyta* (Fig 71R).

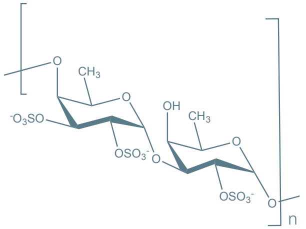


Fig 71R Covalent structure of *Ascophyllum Nodosum* fucoidan

Fig 70R *Fucus serratus* (©M.D. Guiry)

8.3.2.4 Fucogalactan

Fucogalactan (GFS) is a polysaccharide isolated and purified from the brown seaweed *Undaria pinnatifida* (Fig 72R). The polysaccharide is a sulphated galactose containing fucan (Fig 73R). GFS is currently under investigation for possible therapeutic indications including anti-inflammatory properties, immuno-modulating activities, inhibition of tumor growth, stem cell replentishment, antiviral activity, dementia and ulcer healing (Wang, 2010; Skriptsova, 2010).

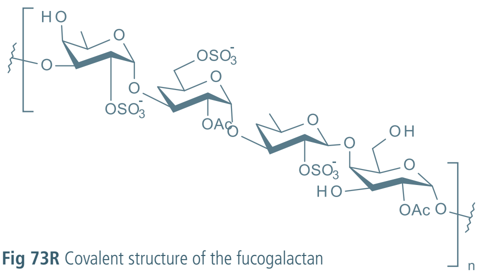


Fig 73R Covalent structure of the fucogalactan from *undaria pinnatifada*

Fig 72R *Undaria pinnatifida* (©M.D. Guiry)

8.3.3 Polysaccharides from Chlorophyceae (Green algae)

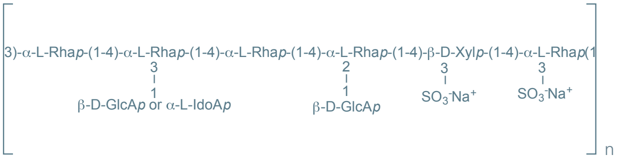
8.3.3.1 Ulvan

Ulvans are structural polysaccharides present in the cell walls of green algae such as *Ulva armoricana* (Fig 74R), *Ulva rotondata*, *Ulva rigida*, *Ulva lacterca* and *Ulva pertusa* (Ray 1995a; 1995b).

They are highly sulphated and contain rhamnose 3-sulphate, xylose, xylose 2-sulphate, glucuronic acid and iduronic acid residues (Fig 75R).

Ulvan has several potentially valuable functionalities such as gel formation for agricultural and food applications and possible anticoagulant, antioxidant, antihyperlipidemic and antitumor activities for pharmaceutical applications (Kaeffer, 1999).

Fig 74R *Ulva amoricana* (©M.D. Guiry)



$$\left[\text{3)-}\alpha\text{-L-Rha}p\text{-(1-4)-}\underset{\substack{3\\|\\1\\ \beta\text{-D-GlcA}p\text{ or }\alpha\text{-L-IdoA}p}}{\alpha\text{-L-Rha}p}\text{-(1-4)-}\alpha\text{-L-Rha}p\text{-(1-4)-}\underset{\substack{2\\|\\1\\ \beta\text{-D-GlcA}p}}{\alpha\text{-L-Rha}p}\text{-(1-4)-}\underset{\substack{3\\|\\ SO_3^-Na^+}}{\beta\text{-D-Xyl}p}\text{-(1-4)-}\underset{\substack{3\\|\\ SO_3^-Na^+}}{\alpha\text{-L-Rha}p}\text{(1}\right]_n$$

Fig 75R Ulvan from *Ulva pertusa*

8.4 Polysaccharides from Microorganisms

8.4.1 Polysaccharides from Gram-negative Bacteria

8.4.1.1 Bacterial Alginate

An alginate-like polysaccharide produced by the fermentation of *Azotobacter vinelandii* (Gorin, 1966; Deavin, 1977) (Fig 76R) or *Pseudomonas mendocina* (Hacking, 1983). The chemical structure consists of blocks of 1,4 linked-β-D-polymannuronic acid (poly M), 1,4 linked-α-L-polyguluronic acid (poly G) and alternating blocks of the two uronic acid (poly MG). Unlike the alginate from seaweed this polysaccharide is partially acetylated.

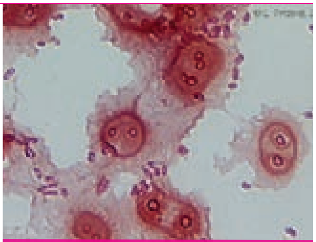


Fig 76R *Azotobacter vinelandii* showing alginate capsules

8.4.1.2 Gellan Gum (Whistler, 1993)

Gellan is a microbial polysaccharide produced by *Pseudomonas elodea* and produces gels having similar properties to agar. Gellan gum is a linear tetrasaccharide of 1,4-β-L-rhamnopyranosyl, 1,3-α-D-glucopyranosyl, 1,4-β-D-glucuronopyranosyl, 1,4-β-D-glucopyranosyl- with O2 L-glyceryl and O(6) acetyl substituents on the 3-linked glucose. Both substituents are located on the same glucose residue, and on average, there is one glycerate per repeat and one acetate per every two repeats (Fig 77R). In low acyl gellan gum, the acyl groups are removed completely. The high acyl form produces soft, elastic, non-brittle gels, whereas the low acyl form produces firm, non-elastic, brittle gels (Fig 78R).

Fig 78R High and low acyl forms of gellan gum

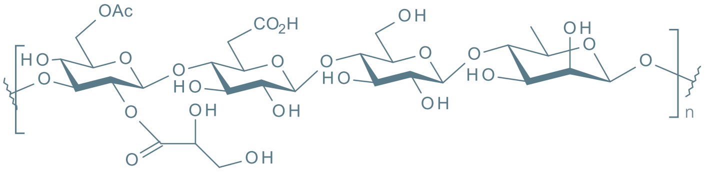


Fig 77R Covalent structure of gellan gum

8.4.1.3 Welan Gum (Whistler, 1993)

Welan gum is a microbial polysaccharide produced by a species of *Alcaligenes* and shows interesting rheological properties of use in the oil and agricultural industries. The structure is similar to gellan based on repeating glucose, rhamnose and glucuronic acid units but with a single side chain of either an α-L-rhamnopyranosyl or an α-L-mannopyranosyl unit linked 1,3 to the 4-O-substituted β-D-glucopyranosyl unit in the backbone (Fig 79R).

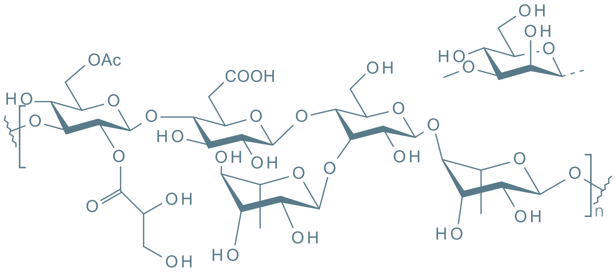


Fig 79R Covalent structure of welan gum

8.4.1.4

Xanthan Gum (Whistler, 1993; Sandford, 1977; Blanshard, 1979)

Xanthan gum is a microbial polysaccharide produced by *Xanthomonas campestris*. It was developed in the 1960s from research conducted at The Northern Regional Research Labs, Peoria, USA and has been produced commercially for many years (Fig 80R). It has unique rheological and gel forming properties and finds many applications particularly in the food and oil industries.

The structure of xanthan is based on a cellulosic backbone of β-1,4-linked glucose units which have a trisaccharide side chain of mannose-glucuronic acid-mannose linked to every second glucose unit in the main chain. Some terminal mannose units are pyruvylated and some of the inner mannose units are acetylated (Rees, 1976; Lawson, 1977) (Fig 81R).

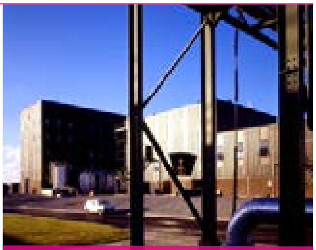


Fig 80R Fermentation plant for xanthan gum

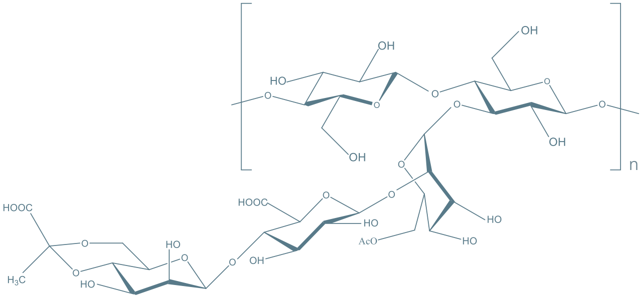


Fig 81R Covalent structure of xanthan gum

8.4.1.5

Dextran (Whistler, 1993)

Dextran is α-1,4-linked α-D-glucan with α-1,3-linked glucose branch points (Fig 82R) produced by fermentation of *Leuconostoc mesenteroides* (Fig 83R) via the action of the enzyme dextransucrase on sucrose. The main use for native dextran is as an extender in blood transfusions and products having a range of sharp cut-off molecular weights are produced commercially for this and other applications. A complex of iron with dextran known as iron dextran is used as a source of iron for baby piglets which are often anaemic at birth (Sidebotham, 1974).

Dextran is a huge problem in the cane sugar industry due to the production of dextran in sugar cane following harvesting when the cut ends are exposed and become infected with *Leuconostoc mesenteroides*. This has the result of slowing down the processing of the cane in raw sugar factories and farmers are paid according to how much dextran is detected on delivery of the cane for processing (Ravno, 2005).

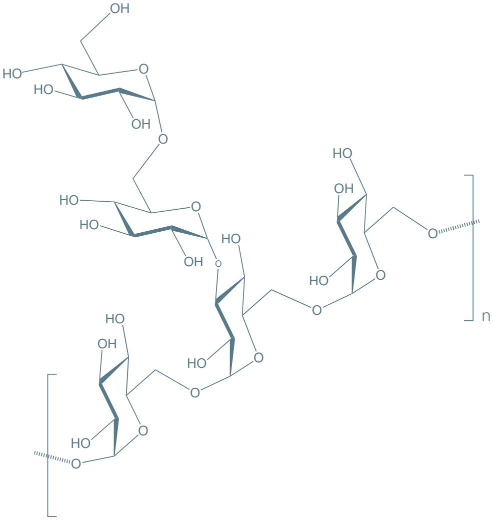


Fig 82R Covalent structure of dextran

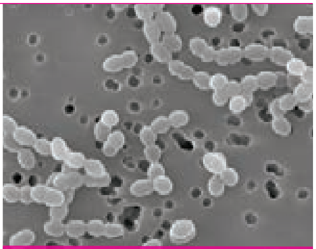


Fig 83R *Leuconostoc mesenteroides*

8.4.1.6 *Arthrobacter viscosus* NRRL 1973 Exopolysaccharide

The polysaccharide has a linear structure and consists predominantly of repeating trisaccharide units, -O-(3-D-mannuronic acid-1,4-O-(3-D-glucopyranosyl-1,4-D-galactose. 50% of the hydroxyl groups are acetylated (Sloneker, 1968) (Fig 84R).

The physical properties for both native and deacetylated forms of the polysaccharide include high viscosity in water and in the presence of chlorides, shear and pH stability, and good film forming properties.

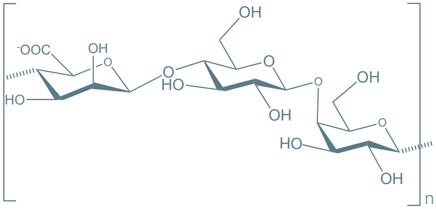


Fig 84R Covalent structure of *Arthrobacter viscosus* exopolysaccharide

8.4.1.7 *Arthrobacter stabilis* NRRL B3225 Exopolysaccharide

The extracellular polysaccharide produced by *Arthrobacter stabilis* NRRL B-3225 contains D-glucose, D-galactose, pyruvic acid, O-succinyl, and O-acetyl in the approximate molar ratio of 6:3:1:1:1.5. Succinyl is linked as its half-ester, making it readily removable. The viscosity of aqueous, salt-free solutions of both native and deacylated polymer is relatively low, but atypical of anionic polysaccharides, increases rapidly in the presence of salts, acids, or alkali (Knutson, 1979).

8.4.1.8 Indican

Indican is a polysaccharide comprising 1,3 glucose, 1,4 mannose, 1,4 rhamnose and 1,3 or 4) -0-(1-carboxyethyl) rhamnose units in a molar ratio of about 2:1:1-2:1 respectively; containing 12-15% by weight acetyl units. Indican is soluble to at least 1% by weight in methanol and in ethylene glycol, forms gels with these solvents (Fig 86R), and has an inherent viscosity of about 33.5 dl/g. It has a number of useful thixotropic properties not least being compatible with organic solvents and having surface-active properties (Fig 85R). Indican is produced by fermentation of the gram negative microbe *Beijerinkia indica* (NCIB 8712) (Lawson,1979).

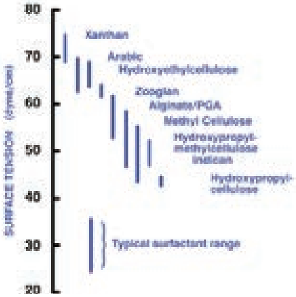


Fig 85R Comparison of Indican Surface Properties with Other Biopolymers

Fig 86R Indican gel formation in ethylene glycol

8.4.1.9 Levan from *Erwinia herbicola*

Levan is a (2,6)-linked fructan produced by Erwinia herbicola. The polysaccharide contains branches every 10-12 fructose residues linked (1,2) and is reported to have a molecular weight in excess of 103 kDa. Potential industrial applications of levan have been proposed as an emulsifier, formulation aid, stabilizer and thickener, surface-finishing agent, encapsulating agent, and carrier for flavor and fragrances. In addition, levan is promising in medicine as a plasma substitute, drug activity prolongator and antihyperlipidemic agent.

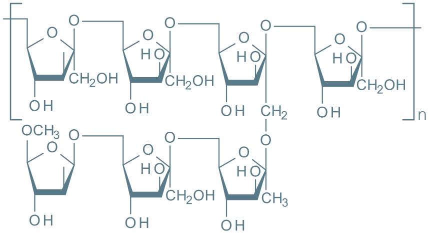


Fig 87R Levan from *Erwinia herbicola*

8.4.2 Polysaccharides from Gram-positive Bacteria

8.4.2.1 Peptidoglycan from *Staphylococcus aureus*

Peptidoglycan, also known as murein, is a polymer consisting of sugars and amino acids that forms a mesh-like layer outside the plasma membrane of most bacteria, forming the cell wall. The sugar component consists of alternating residues of β-1,4 linked N-acetylglucosamine and N-acetylmuramic acid (Fig 88R). Attached to the N-acetylmuramic acid is a peptide chain of three to five amino acids. The peptide chain can be cross-linked to the peptide chain of another strand forming the 3D mesh-like layer. Peptidoglycan serves a structural role in the bacterial cell wall, giving structural strength, as well as counteracting the osmotic pressure of the cytoplasm. In *Staphylococcus aureus*, each peptidoglycan is attached to a short (4- to 5-residue) amino acid chain, L-alanine, D-glutamine, L-lysine, and D-alanine with a 5-glycine interbridge between tetrapeptides. Peptidoglycan is one of the most important sources of D-amino acids in nature (Tipper,1970).

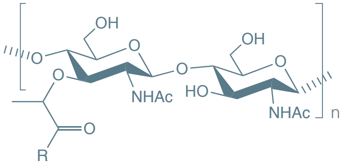


Fig 88R Peptidoglycan from *Staphylococcus aureus*

8.4.2.2 Teichuronic Acid

Teichuronic acid isolated from the cell walls of *Micrococcus luteus* has been examined by natural-abundance 13C NMR spectroscopy. Proton-decoupled and proton-coupled spectra were obtained for native teichuronic acid and also after the teichuronic acid had been oxidized with periodate and reduced with borohydride. The spectra are consistent with the structure [ManNAcUAp-β-1,6-Glcp-α-1,4]n (Fig 89R). Teichuronic acid synthesized *in vitro* from suitable substrates by the particulate enzyme fraction obtained from *Micrococcus luteus* yielded a 13C NMR spectrum which is indistinguishable from that of the native teichuronic acid, indicating a structural identity of the teichuronic acid synthesized *in vitro* with that isolated from cell walls (Johnson, 1981).

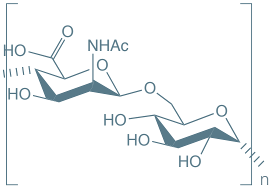


Fig 89R Teichuronic acid from *Micrococcus luteus*

8.5 Polysaccharides from Yeasts & Fungi

8.5.1 Beta Glucans

In addition to the β-glucans from cereals, another group of β-glucans are found in the cell walls of yeast (*Saccharomyces cerevisiae*), bacteria and fungi, with significantly differing physicochemical properties dependent on source. Typically these β-glucans form a linear backbone with 1,3 β-glycosidic bonds but vary with respect to molecular mass, solubility, viscosity, branching structure, and gelation properties, causing diverse physiological effects in animals (Manners, 1973) (Fig 90R).

The yeast and fungal β-glucans have been investigated for their ability to modulate the immune system. They are also used in various nutraceutical and cosmetic products, as texturing agents, and as fibre supplements. Their detailed molecular structures are key to the physical properties that they exhibit, such as water solubility, viscosity, gelation properties and physiological functions (Izydorczyk, 2008).

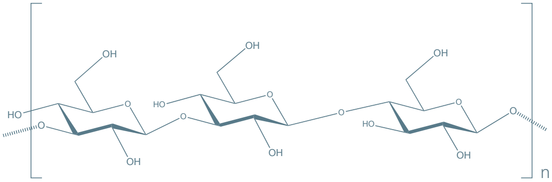


Fig 90R Covalent structure of β-glucan from *Saccharomyces cerevisiae*

8.5.2 Mannan from *Saccharomyces cerevisiae*

The main cell-wall components of baker's yeast (*Saccharomyces cerevisiae*) as well as β-glucan (Manners, 1973) are mannans with an α-1,6 mannose backbone and α-1,2 and α-1,3 mannose branches (Ballou, 1974) (Fig 91R).

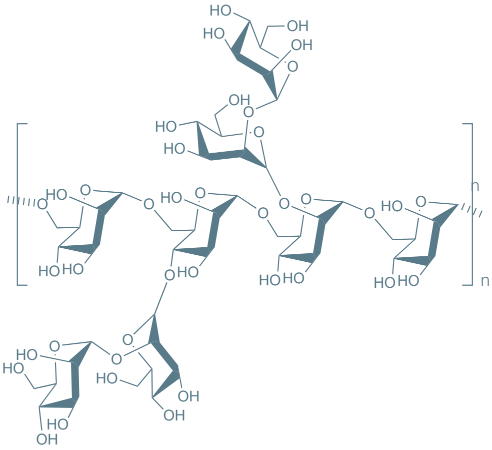


Fig 91R Mannan from *Saccharomyces cerevisiae*

8.5.3 Curdlan (Whistler, 1993)

Curdlan is a microbial polysaccharide produced by a mutant strain of *Alcaligenes faecalis var. myxogenes* which was first shown to produce succinoglucan prior to mutation. Curdlan is a β-1,3 glucan (Fig 93R) forming clear solutions at about 55 °C which then gels ("low-set") when cooled. Suspensions of curdlan at higher temperatures form firm resilient gels ("high set") that melt at 140 - 160 °C (Fig 92R).

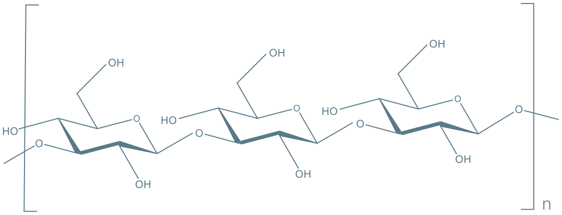


Fig 92R Covalent structure of curdlan

Fig 93R Curdlan gel

8.5.4 Pullulan (Whistler, 1993)

Pullulan is a glucan elaborated by the fungus *Aureobasidium pullulans* (Fig 94R). The chemical structure is essentially repeating units of maltotriose joined by α-1,6 linkages (Fig 95R). Pullulan dissolves readily in water to form stable, viscous solutions that do not gel. The polysaccharide can be moulded, made into fibres and forms clear soluble films. Applications are in foods as a low calorie ingredient and the polysaccharide forms water soluble films that have been used as seed coatings and to coat fruit. Pullulan can also be used in industrial applications as a binder, film former and in pharmaceutical applications (Catley, 1971).

Fig 94R *Aureobasidium pullulans*

Fig 95R Covalent structure of pullulan

8.5.5 Schizophyllan

Schizophyllan is a neutral extracellular polysaccharide produced by the fungus *Schyizophyllum commune* (Fig 96R). Schizophyllan is a β-1,3 beta glucan with β-1,6 branches (Fig 97R) and a molecular weight of around 450 kDa. It is reported that this polysaccharide can stimulate the immune system, chelate metals, act as an adjuvant in delivering drugs and aid in the production of nanofibres (Saito, 1979).

Fig 96R *Schizophyllum commune*

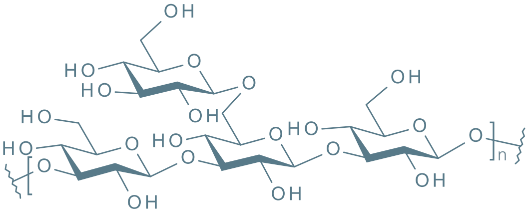


Fig 97R Covalent structure of schizophyllan

8.5.6 Scleroglucan (Whistler, 1993)

Scleroglucan is produced by the fermentation of the fungus *Sclerotium rolfsii* (Fig 98R). It is a glucan with a main chain of 1,3-linked β-D-glucopyranosyl units with every third unit having a single β-D-glucopyranosyl unit linked 1,6 (Fig 99R). Scleroglucan powders disperse in water and give very viscous shear thinning solutions. Applications are in the oil industry in enhanced oil recovery, in agriculture in sprays and in the food and pharmaceutical industries.

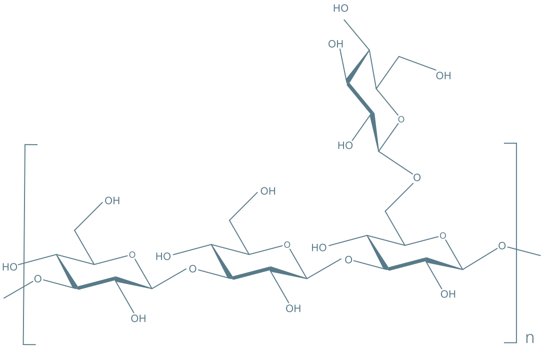


Fig 99R Covalent structure of scleroglucan

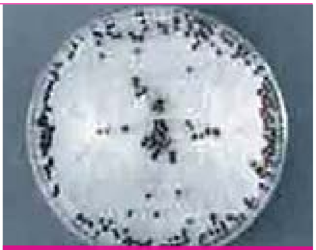


Fig 98R *Sclerotium rolfsii*

8.5.7 Glucuronoxylomannan from *Cyptococcus neoformans*

The cell envelope of *Cryptococcus neoformans* is composed of a rigid cell wall, composed mainly of glucans and a capsular polysaccharide, glucuronoxylomannan, consisting of mannose, xylose, glucuronic acid, and O-acetyl (Fig 100R). Glucuronoxylomannan is a viscous polysaccharide that constitutes about 88 % of the capsule mass. Glucuronoxylomannan, the antigenic basis for serotype specificity is a set of structurally related capsular polysaccharides (Cherniak, 1994).

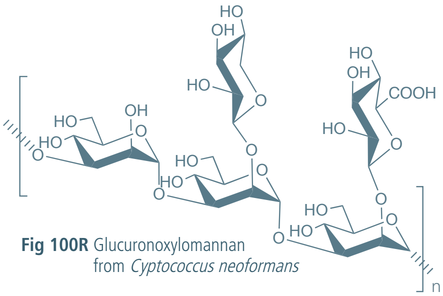


Fig 100R Glucuronoxylomannan from *Cyptococcus neoformans*

8.5.8 Nigeran

Nigeran is a polysaccharide found in the cell wall of lower fungi. In certain *Aspergillus* and *Penicillium* spp., nigeran was first isolated from *Penicillium expansum* and *Aspergillus niger* (Tung, 1967), and has been shown to be synthesized by only a few species of *Aspergillus* and *Penicillium*. The polysaccharide contains unbranched α-D-glucopyranose residues linked 1,3 and 1,4 (Fig 101R) (Barker, 1957).

Nigeran is part of the hyphal cell wall, where it can contribute up to 40 % of the cell dry weight. The polysaccharide occupies several domains or location on the hyphal wal and is highly crystalline *in vivo*. Deposition of nigeran is primarily at the outer surface of the hyphal wall.

Little information is available in the literature on the possible uses of nigeran.

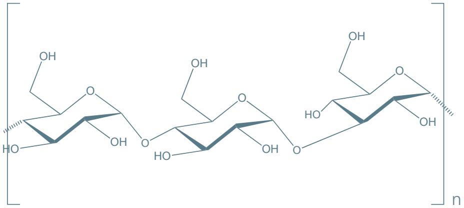


Fig 101R Nigeran

8.6 Polysaccharides from Animal or Fish Tissues

8.6.1 Energy Storage Polysaccharides

8.6.1.1 Glycogen

Glycogen is a highly branched polysaccharide of glucose that serves as a form of energy storage in animals and fungi. It is the main storage form of glucose in the body. In humans, glycogen is made and stored primarily in liver and muscle cells and functions as the second most important energy storage molecule to fat, which is held in adipose tissue. Glycogen is analogous to starch and has a structure similar to amylopectin (Fig 102R), but is more extensively branched and compact than starch (Manners, 1991). It occurs as granules in the cytosol/cytoplasm in many cell types, and plays an important role in the glucose cycle (Geddes, 1985).

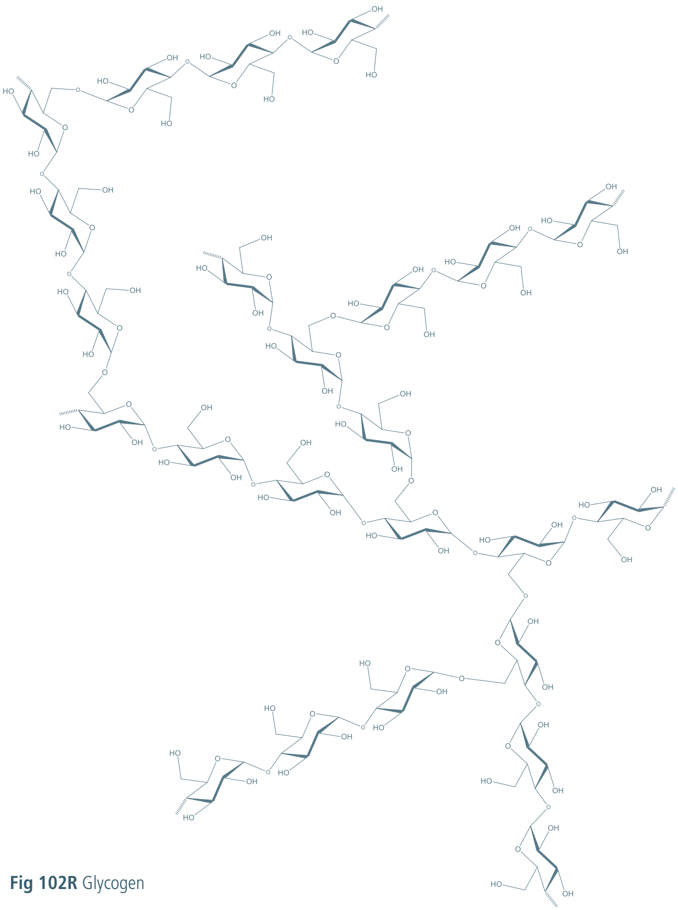


Fig 102R Glycogen

8.6.2 Structural Polysaccharides

8.6.2.1 Chondroitin Sulphate

Chondroitin sulphate is the most abundant glycosaminoglycan in mammalian tissues and occurs both in skeletal and soft connective tissue (typical source-shark cartilage) (Fig 103R). The disaccharide repeat unit consists of N-acetyl galactosamine sulphate linked β-1,4 to glucuronic acid (Zhang, 2009) (Fig 104R). Each monosaccharide may be left unsulphated, sulphated once, or sulphated twice. The most common pattern has the hydroxyls of the 4 and 6 positions of the N-acetyl-galactosamine sulphated, with some chains having the position 2 of the glucuronic acid sulphated.

Fig 103R Shark cartilage

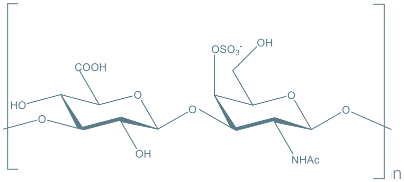


Fig 104R Covalent structure of chondroitin sulphate

8.6.2.2 Fucosylated Chondroitin Sulphate

A polysaccharide, isolated from the body wall of the sea cucumber *Ludwigothurea grisea* (Fig 105R), has a backbone like that of mammalian chondroitin sulphate: [4-β-D-GlcA-1,3-β-D-GalNAc-1]n but substituted at the 3-position of the β-D-glucuronic acid residues with sulphated α-L-fucopyranosyl branches (Fig 106R). These sulphated α-L-fucose branches confer anticoagulant activity on the polysaccharide and the specific activity of fucosylated chondroitin sulphate in the activated partial thromboplastin time assay is greater than that of a linear homopolymeric α-L-fucan with about the same level of sulfation (Vieira, 1991).

The antimalarial capacity of heparin-like sulphated polysaccharides (anticoagulant) from the sea cucumbers *Ludwigothurea grisea* and *Isostichopus badionotus*, from the red alga *Botryocladia occidentalis*, and from the marine sponge *Desmapsamma anchorata* has been explored. *In vitro* experiments demonstrated that for most compounds, significant inhibition of *Plasmodium falciparum* growth ocurred at low-anticoagulant concentrations. It was suggested that the retarded invasion mediated by sulphated polysaccharides, and the ensuing prolonged exposure of *Plasmodium* to the immune system, might be explored for the design of new therapeutic approaches against malaria where heparin-related polysaccharides of low anticoagulating activity could play a dual role as drugs and as potentiators of immune responses (Mourao, 1996).

Fig 105R Sea Urchin, *Ludwigothurea grisea*

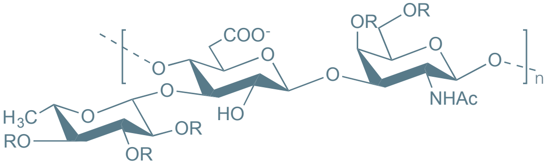


Fig 106R Partial structures of fucosylated chondroitin sulphate

8.6.2.3 Dermatan Sulphate

Dermatan sulphate is a glycosaminoglycan found in skin, blood vessels, heart valves, tendons, aorta, spleen and brain and is usually isolated from pig skin or beef lung tissue. The disaccharide repeat unit is composed of L-iduronic acid and N-acetyl-galactosamine-4-sulphate linked β-1,3 and β-1,4. There are also small amounts of D-glucuronic acid (Zhang, 2009) (Fig 107R).

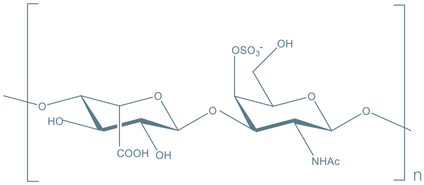


Fig 107R Covalent structure of dermatan sulphate

8.6.2.4

Hyaluronic Acid

Hyaluronic acid is a glycosaminoglycan found in many organs where it functions as a joint lubricant and shock absorber. It is obtained principally from synovial fluid, vitreous humor of the eye, umbilical tissue and cocks comb. The chemical structure of hyaluronic acid is a disaccharide repeat of β-1,3 glucuronic acid and β-1,4 N-acetyl glucosamine (Casu, 1985) (Fig 108R).

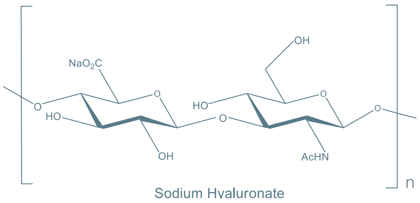


Fig 108R Covalent structure of sodium hyaluronate

8.6.2.5

Chitin (Whistler, 1993)

Chitin is a polysaccharide found widely in nature where it functions in a manner similar to collagen in chordates. It forms the tough fibrous exoskeletons of insects, crustaceans (Fig 109R) and other arthropods, and, in addition to its presence in some fungi it occurs in at least one alga. The structure of chitin is similar to that of cellulose but with glucose replaced with N-acetyl-D-glucosaminyl units linked β-D-1,4 in a linear chain (Fig 110R). It is normally produced from the shells of lobster, crab or shrimp.

Fig 109R Crustaceans

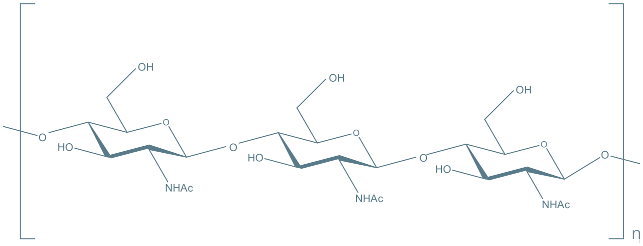


Fig 110R Covalent structure of chitin

8.6.2.6

Chitosan (Dumitriu, 2005)

Chitosan is the deacetylated form of chitin. The polysaccharide is deacetylated in order to render it soluble at pH values of less than 7 (Fig 111R). This then allows the material to be used in a number of industrial applications as a binder and film former. Chitosan has a number of commercial and biomedical uses. It can be used in agriculture as a seed treatment and biopesticide, helping plants to fight off fungal infections. In winemaking it can be used as a fining agent, also helping to prevent spoilage. In industry, it can be used in self-curing polyurethane paint coatings. In medicine, it may be useful in bandages to reduce bleeding and as an antibacterial agent; it can also be used to help deliver drugs through the skin.

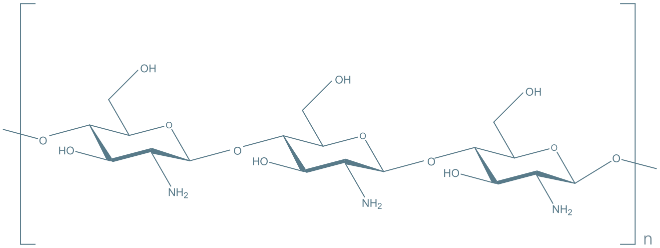


Fig 111R Covalent structure of chitosan

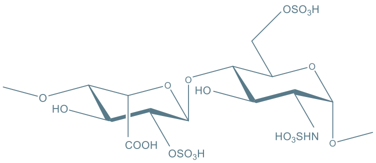
8.6.3 Polysaccharides with Key Physiological Functions

8.6.3.1 Heparin

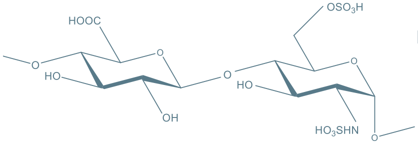
Heparin is a glycosaminoglycan which occurs in many mammalian tissues, particularly mast cells and has important anticoagulant and thrombolytic properties. The chemical structure is complex and is composed mainly of two disaccharide repeating units A & B. A is L-iduronic acid 2-suplhate linked α-1,4 to 2-deoxy-2-sulfamido-D-galactose 6-sulphate while B is D-glucuronic acid β-1,4 linked to 2-deoxy-2-sulfamido-D-glucose 6-sulphate (Fig 113R).

The three-dimensional structure of heparin is complicated by the fact that iduronic acid may be present in either of two low-energy conformations when internally positioned within an oligosaccharide (Fig 112R) (Casu, 1985).

It has been shown that N-acetyl heparin (Fig 114R) (a derivative of heparin devoid of anticoagulant effects) can protect the heart from injury associated with global ischemia and reperfusion. It was found that N-acetyl heparin protects the heart from subsequent myocardial dysfunction secondary to ischemia/reperfusion (Friedrichs, 1994).



Heparin A



Heparin B

Fig 112R The two disaccharide repeats A&B of heparin

Fig 113R Three dimensional structure of heparin

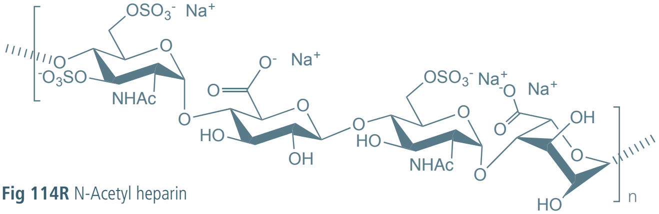


Fig 114R N-Acetyl heparin

8.6.3.2 Heparan Sulphates

Heparan sulphates are linear, anionic polysaccharides in which the basic polymer structure is made up of repeating amino sugar–uronic acid disaccharide units that are commonly modified by sulphation. With the exception of hyaluronic acid, these glycosaminoglycans are normally present in tissues in the form of proteoglycans, the polymer chains being in covalent linkage to various types of protein core that determine the glycosaminoglycan composition and the cellular/extracellular matrix location of the proteoglycan. The protein cores also play active roles in many spheres of cell regulation, particularly in the key areas of cell growth and cell adhesion (Gallagher, 2015).

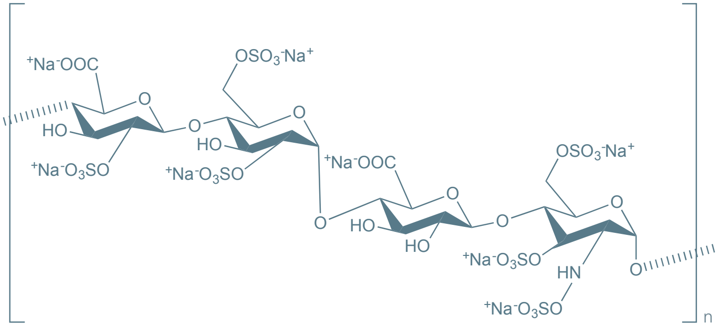


Fig 115R Heparan sulphate

Heparan Sulphates (continued)

The repeating disaccharide unit in heparan sulphate consists of an α-/β-1,4-linked N-acetyl glucosamine or N-sulphoglucosamine and uronic acid (glucuronic acid, or its C5 epimer iduronic acid) with chain lengths ranging in size from about 50 to 200 disaccharide residues (Fig 115R). The formation of heparan sulphate begins in the cis-Golgi where an heparan sulphate co-polymerase complex synthesizes a De N-sulphated N-acetylated polymer composed of repeating units of -4-β-GlcA 1,4 α-GlcNAc-1 (Fig 116R) (Gallagher, 2015).

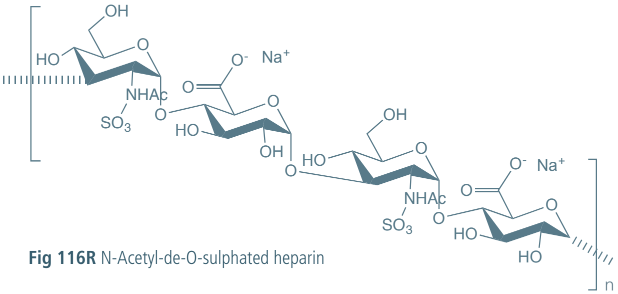


Fig 116R N-Acetyl-de-O-sulphated heparin

8.6.3.3 Colominic Acid or Polysialic Acid

Polysialic acid is an unusual post translational modification carbohydrate that is widely expressed in nature in bacterial capsules, fish, sea urchin eggs, embryonic tissues, amphibians, animal and human brains, and in a variety of cancers. The major carrier of polysialic acids in mammals is the neural cell adhesion molecule (a glycoprotein that belongs to the immunoglobulin superfamily). It is a linear small polysaccharide containing α-2,8-linked sialic acid residues with (n = 8 to >100) of sialic acid residues (Fig 117R). These cell surface glycans are highly expressed during embryonic brain development and modulate cell-cell interactions (mainly during embryonic growth), neural plasticity, and tumor metastasis. This unusual carbohydrate was identified almost three decades ago and has since attracted much interest from biochemists, cell biologists, and neurobiologists. This is not surprising, because the study of polysialic acid has provided key insights into how unusual glycans are synthesized, how carbohydrate conjugation of proteins can be so specific, and how these modifications then function in developmental processes.

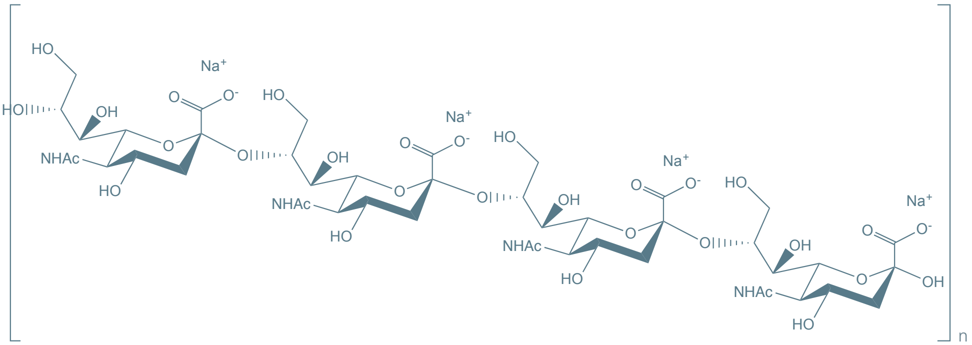


Fig 117R Polysialic acid

The biological roles of polysialylation in the nervous system have been studied almost exclusively in relationship to its major known target, the neuronal cell adhesion molecule (NCAM). The high negativity of colominic acid modifies the surface charge and binding ability of NCAMs. Within the synapse, this negative polysialylation restricts the ability of NCAM to bind to NCAMs on adjacent membranes (Schauer, 2009).

Colominic acid is now available in significant quantities via the metabolic engineering of *E. coli* and has been investigated for the controlled release of drugs and scaffolds in biomedical applications. Polysialic acid has been proposed as the next generation of scaffolds for bioavailable products, augmenting the wide use of polyethylene glycol (Chen, 2015).

8.7.1 Methyl and Ethyl Cellulose (Whistler, 1993)

Methylcellulose is a water-soluble polymer used as a binder or thickener in pharmaceutical, food, and ceramic processing applications. The methylation of a number of the polysaccharide hydroxyl groups causes hydrogen bond disruption and methylcellulose becomes water-soluble (Fig 118R).

Methylcellulose has an unusual lower critical solution temperature (LCST) between 40 °C and 50 °C. At temperatures below the LCST, it is readily soluble in water; above the LCST it is not soluble, which has a paradoxical effect that heating a saturated solution of methylcellulose will turn it solid, because methylcellulose will precipitate out. The temperature at which this occurs depends on DS-value, with higher DS-values giving lower solubility and lower precipitation temperatures because the polar hydroxyl groups are masked (Kobayashi, 1999).

Ethyl cellulose is similar in structure to methyl cellulose with ethyl replacing the methyl groups. It is approved for use in regulated markets such as food and pharmaceuticals. In pharmaceuticals, it can mask the taste of bitter actives, enhance the strength and appearance of tablets and capsules, and enable controlled release formulations. In food products, it functions as a binder, film former and flavor fixative.

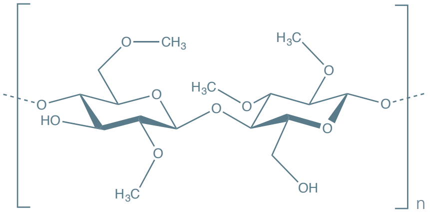


Fig 118R Covalent structure of methyl (or ethyl) cellulose

8.7.2 Hydroxypropyl Cellulose, Hydroxyethyl Cellulose and Ethyl Hydroxyethyl Cellulose (Whistler, 1993)

Hydroxypropylcellulose (HPC) is an ether of cellulose in which some of the hydroxyl groups have been hydroxypropylated with propylene oxide. Complete substitution would provide a DS of 3 but because each substituted hydroxypropyl group contains a hydroxyl group, these can also be etherified. When this occurs, the number of moles of hydroxypropyl groups per glucose ring (MS), can be higher than 3 (Fig 119R).

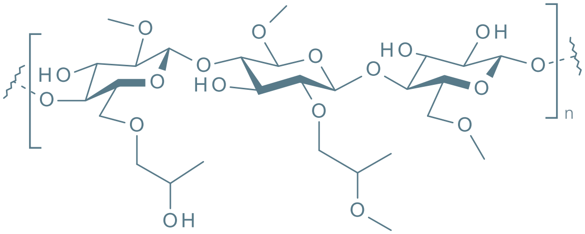


Fig 119R Covalent structure of hydroxypropyl cellulose

Because cellulose is very crystalline, hydroxypropylcellulose must have a DS of about 4 for good water solubility. In water, hydroxypropyl cellulose forms liquid crystals with many mesophases depending on concentration. These mesophases include isotropic, anisotropic, nematic and cholesteric, the latter resulting in many colors such as violet, green and red.

Pharmaceutical applications include treatments for medical conditions such as dry eye syndrome (*keratoconjunctivitis sicca*), recurrent corneal erosions, decreased corneal sensitivity, exposure and *neuroparalytic keratitis*. It is also used as a binder in tablets.

Hydroxypropyl Cellulose, Hydroxyethyl Cellulose and Ethyl Hydroxyethyl Cellulose (Whistler, 1993) (continued)

Hydroxypropylcellulose is also used as a thickener, a binder and emulsion stabiliser in foods with E number E463. HPC is used as a support matrix for DNA separations by capillary and microchip electrophoresis.

Hydroxyethyl cellulose is useful as a water thickener, rheological control additive, protective colloid, binder, stabilizer, suspending agent and film former. It is used in many industrial applications including latex paints, emulsion polymerization, petroleum, paper, pharmaceuticals, cosmetics and many other applications.

Ethyl (hydroxyethyl) cellulose (EHEC) is a nonionic, water-soluble cellulose derivative produced by introduction of ethyl and ethylene oxide groups to the hydroxyl groups of the cellulose backbone (Fig 120R/121R). It is an important industrial product used mainly in water-based paints and building products as thickener, emulsifier, and dispersing agent (Carlsson, 1986). It is also used as a laxative and has surface active properties.

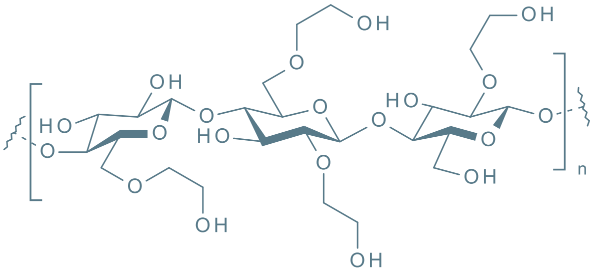


Fig 120R Hydroxyethyl cellulose

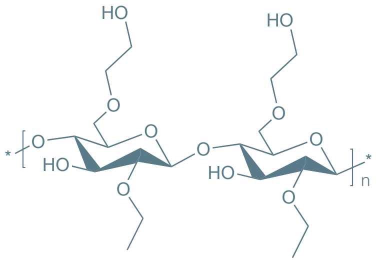


Fig 121R Ethyl hydroxyethyl cellulose

8.7.3 Hydroxypropyl Methyl Cellulose (Whistler, 1993)

Hydroxypropyl methylcellulose (HPMC or Hypromellose) (Fig 122R) is a semisynthetic, inert, viscoelastic polymer used as eye drops, as a semisynthetic substitute for tear-film. When applied, a hypromellose solution acts to swell and absorb water, by increasing the thickness of the tear-film, which results in decreased eye irritation. In addition to its use in ophthalmic liquids, hypromellose has been used as an excipient in oral tablet and capsule formulations, where, depending on the grade, it functions as controlled release agent. It is also used as a binder and as a component of tablet coatings.

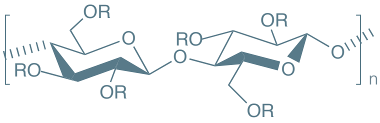


Fig 122R Hydroxypropyl methylcellulose

Hypromellose in aqueous solution, unlike methylcellulose, exhibits thermal gelation properties. Thus, when solutions are heated to the critical temperature, they form a loose gel-like mass. Critical temperatures are inversely related to both the solution concentration of HPMC and the degree of methoxy substitution, ie, the higher the methoxyl concentration, the lower the critical temperature. Also, the texture of the semi-flexible mass is directly related to the degree of methoxyl substitution.

HPMC is approved as a food additive as an emulsifier, thickening and suspending agent, and an alternative to animal gelatin (Codex Alimentarius code (E number) is E464). HPMC has been investigated as a substitute for gluten in making all-oat and other grain breads.

8.7.4 Hydroxypropyl Methylcellulose Phthalate (Whistler, 1993)

Hypromellose phthalate (hydroxypropyl methylcellulose phthalate, or HPMCP) is a phthalic acid ester of hydroxypropyl methylcellulose (Fig 123R). Hypromellose phthalate was introduced in 1971 as a cellulose derivative for enteric coatings, used to protect drugs from degradation by gastric acid or to prevent them from causing side effects in the stomach. HPMCP is also used in sustained-release preparations, in binders and as microcapsule bases (Weiβ, 1995).

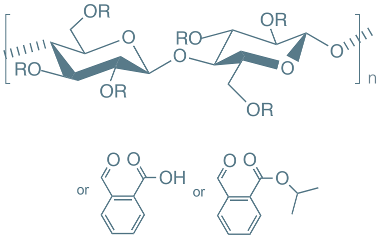


Fig 123R Hydroxypropyl methylcellulose phthalate

8.7.5 Sodium Carboxymethyl Cellulose (Whistler, 1993)

Carboxymethylcellulose (CMC) is synthesized by the alkali-catalyzed reaction of cellulose with chloroacetic acid. The polar carboxyl groups render the cellulose soluble and chemically reactive.

The functional properties of CMC depend on the degree of substitution of the cellulose, the chain length of the cellulose backbone structure and the degree of clustering of the carboxymethyl substituents (Fig 124R).

Carboxymethyl cellulose is used in food under the E number E466 as a viscosity modifier or thickener, and to stabilize emulsions in various products including ice cream. It is also a constituent of many non-food products, such as toothpaste, laxatives, diet pills, water-based paints, detergents, textile sizing, and various paper products. Carboxymethyl cellulose is used extensively in gluten free and reduced fat food products.

In laundry detergents, it is used as a soil suspension polymer designed to deposit onto cotton and other cellulosic fabrics, creating a negatively charged barrier to soils in the wash solution.

CMC is also used in pharmaceuticals as a thickening agent, for example as the lubricant in lubricating eye drops, and in the oil-drilling industry as an ingredient of drilling mud, where it acts as a viscosity modifier and water retention agent.

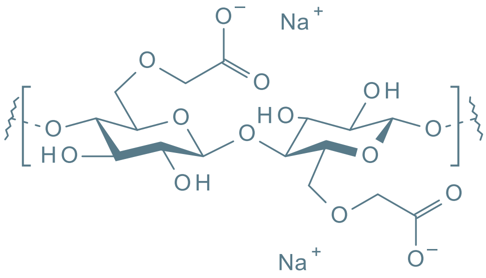


Fig 124R Covalent structure of sodium carboxymethyl cellulose

8.7.6 Cellouronic Acid

The oxidation of the primary hydroxyl groups of cellulose to yield the 6-carboxycellulose derivative, known as cellouronic acid (β-1,4 glucuronide) (Fig 125R), is attracting a substantial interest. As the sodium salt, this water-soluble derivative presents excellent rheological and gel-forming properties and when cast as films, exhibit superior gas barrier properties (Kato, 2005). In addition to these physical characteristics, cellouronic acid is biodegradable (Kato, 2002) and has shown promise in a number of biological and medical applications ranging from wound healing (Dimitrijevich, 1990), to bioabsorbable hemostatic properties (Kato, 2005). Cellouronic acid has also demonstrated activity as a bioactive elicitor for defense response in plants (Lienart, 2001).

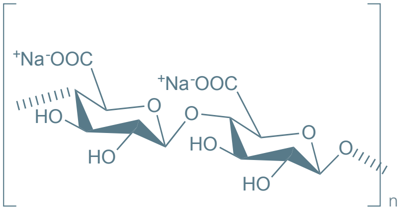


Fig 125R Cellouronic acid

8.7.7 Cellulose Acetate Hydrogen Phthalate

Cellulose acetate phthalate (CAP) (Fig 126R) finds appliction in the formulation of pharmaceuticals, such as the enteric coating of tablets or capsules and for controlled release formulations. It contains about 50 % acetate and 25 % as the phthalate ester with the rest as free hydroxyl groups.
The main use of CAP is in pharmaceutical enteric formulations where it is often used with other coating agents such as ethyl cellulose. CAP is commonly plasticized with diethyl phthalate, a hydrophobic compound, or triethyl citrate, a hydrophilic compound; other compatible plasticizers are various other phthalates, triacetin, dibutyl tartrate, glycerol, propylene glycol, tripropionin, triacetin citrate, acetylated monoglycerides, etc.

Enteric coatings based on CAP are resistant to acidic gastric fluids, but easily soluble in the mildly basic medium of the intestine. The pH sensitive solubility of CAP is mainly determined (as are other properties of this mixed ester) by the degree of substitution and by the molar ratio (acetyl and phthaloyl groups) (Delgado, 1998).

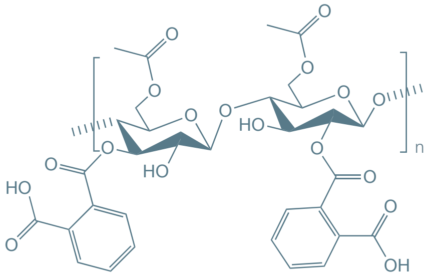


Fig 126R Cellulose acetate hydrogen phthalate

8.7.8 Celluose Acetate

The acetate ester of cellulose, cellulose acetate (Fig 127R) is probably the oldest of the polysaccharide chemical derivatives and was first prepared in 1865. Cellulose acetate is still used as a film base in photography, as a component in some coatings, and as a frame material for eyeglasses. It is also used as a synthetic fiber in the manufacture of cigarette filters and playing cards. In photographic film, cellulose acetate replaced nitrate film in the 1950s, being far less flammable and cheaper to produce but in recent years has been rendered obsolete by the advent of digital cameras.

Cellulose acetate fiber is one of the earliest synthetic fibers and is based on cotton or tree pulp cellulose. These "cellulosic fibers" have been replaced in many applications by cheaper petro-based fibers (nylon and polyester) in recent decades. Acetate shares many similarities with rayon, and was formerly considered as the same textile. Acetate differs from rayon in the employment of acetic acid in production.

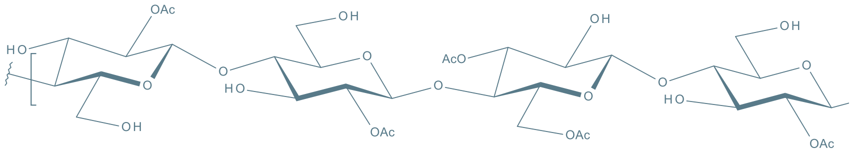


Fig 127R Cellulose acetate

8.7.9 Carboxymethyl Chitosan

Carboxymethyl chitosan (Fig 128R) has good solubility in water and also unique chemical, physical and biological properties such as high viscosity, large hydrodynamic volume, low toxicity, biocompatibility and good ability to form films, fibres and hydrogels (Muzzarelli, 1988; Chen, 2005). For this reason, it has been extensively used in many biomedical fields such as a moisture-retention agent, a bactericide, wound dressing agent, artificial bone and skin, blood anticoagulant and as a component in different drug delivery matrices (Farag, 2013). Thus, the reactive ligands COOH and NH_2 groups are available for metal chelation and dye binding.

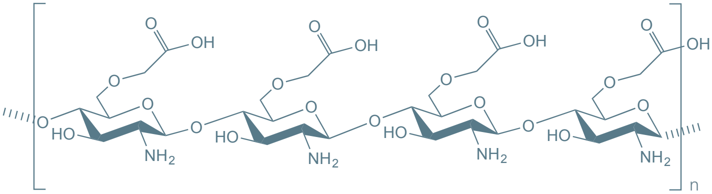


Fig 128R Carboxymethyl chitosan

8.7.10 Glycol Chitosan

Chitosan, a copolymer of β-1,4-linked D-glucosamine derived by deacetylation of natural chitin, is chemically modified to produce glycol chitosan by introducing ethylene glycol groups mostly at position 6, which yields a hydrophilic polymer that is soluble in water and culture media at neutral pH (Fig 129R). Glycol chitosan is non-cytotoxic and biocompatible and stimulates the growth of chondrocytes at low concentration. Glycol chitosan and a number of derivatives such as by adding cholesterol or folic acid to glycol chitosan, yields self-assemblies that contain a hydrophobic core and a hydrophilic shell and these can be used for targeted drug delivery (Yu, 2013).

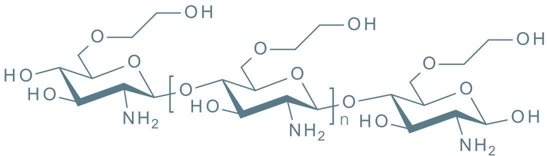


Fig 129R Glycol chitosan

8.7.11 Hyaluronate Fluorescein

Hyaluronic acid, a polysaccharide with alternating β-1,3 glucuronide and β-1,4 glucosamine residues-derived from *Streptococcus equi*, was labelled with 5-amino-fluorescein giving a yellow fibrous product, soluble in both water and electrolytes (de Belder, 1975) (Fig 130R). The degree of substitution was between 0.001 and 0.008 and the molecular weight determined by gel chromatography system gave a MW of 6.0 x 10^6.

Fluorescein-labelled hyaluronic acid may be used as a probe to follow the fate of hyaluronan *in vitro*. A FITC-labelled hyaluronic preparation greatly enhanced the visualization of the permeation of the substrate through skin (Yang, 2012). Other applications of fluorescein-labelled hyaluronic acid have been reported in cancer research (Cheng, 2014)

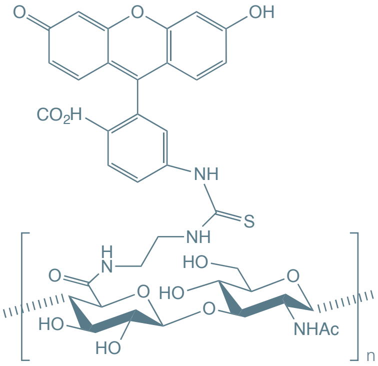


Fig 130R Hyaluronate fluorescein

8.7.12 Dextran Biotin and Rhodamine

Dextrans are widely used as both anterograde and retrograde tracers in neurons (Ferguson, 2001) and for numerous other applications. They are biologically rather inert as they have α-1,6 -linked glucose residues, which are resistant to cleavage by most endogenous cellular glycosidases. They usually have low immunogenicity.

These properties make dextrans effective water-soluble carriers for dyes (Fig 131R), indicators, and reactive groups in a wide variety of applications. Therefore, dextran conjugates make ideal long-term tracers for live cells. Fluorescent dextrans (Fig 132R) also serve as valuable markers for cell loading of macromolecules by micro- injection, vesicular fusion, and electroporation, as well as for the uptake and internal processing of exogenous materials by phagocytotic and endocytic pathways (Ansorge, 1988).

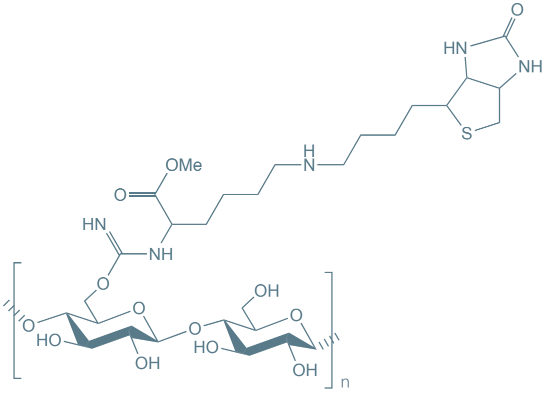


Fig 131R Dextran biotin

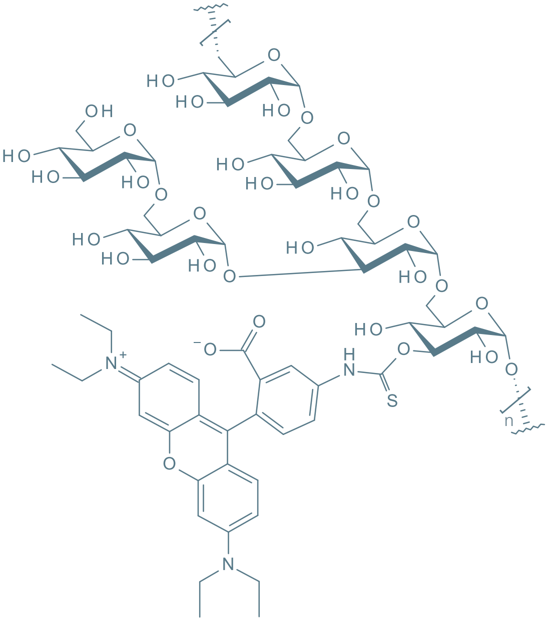


Fig 132R Dextran rhodamine

8.7.13 Dextran Sulphate

Dextran sulphate (Fig 133R) is a dextran derivative whose ulcer causing properties were first reported in hamsters (Ohkusa, 1985) and extrapolated a few years later to mice (Okayasu, 1990) and rats. The exact mechanisms through which dextran sulphate induces intestinal inflammation are unclear but may be the result of direct damage of the monolayer of epithelial cells in the colon, leading to the crossing of intestinal contents (e.g., commensal bacteria and their products) into underlying tissue and therefore induction of inflammation.

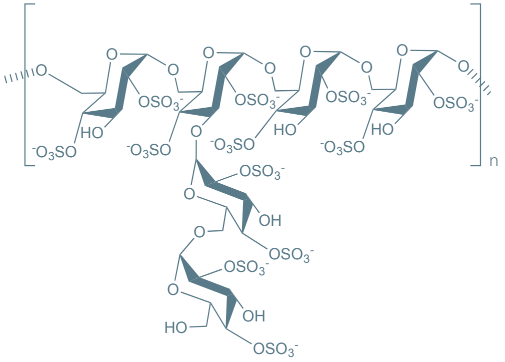


Fig 133R Dextran sulphate

8.7.14 Carboxymethyl Dextran

Carboxymethyl dextran (CM-dextran) is a white, odorless and tasteless powder which is freely soluble in water or electrolyte solutions. The product has a pronounced polyanionic character due to the high degree of carboxyl substitution (Fig 134R). The solution properties of CM-dextran are described in several publications (Gekko, 1979; 1981). Applications that have been described for CM-dextran include carriers of paramagnetic contrast agents (Rongved, 1991), preparation of conjugates of pharmacologically active compounds (Baudys, 1998; Ma, 2011) and CM-dextrans in biosensors (Situ, 2008). A number of other uses in cosmetics, agriculture, foods, paints and textiles have been the subject of patent applications.

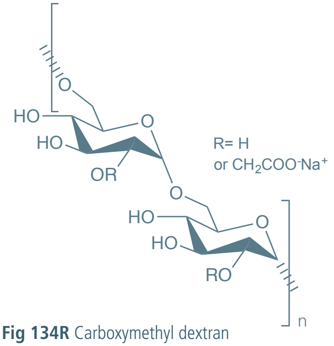


Fig 134R Carboxymethyl dextran

8.7.15 Diethylaminoethyl Dextran

DEAE-Dextran (Fig 135R) (DEAE-D) is a positively charged dextran derivative that can be used for vaccine production, gene therapy, protein stabilisation, dyslipidemia prevention, flocculating agents, and many other applications. DEAE-D is also used for transfecting animal cells with foreign DNA. DEAE-Sepharose, DEAE-650 and DEAE-Sephadex are commonly used in chromatography for the separation of biological molecules such as proteins and carbohydrates (de Belder, 1996).

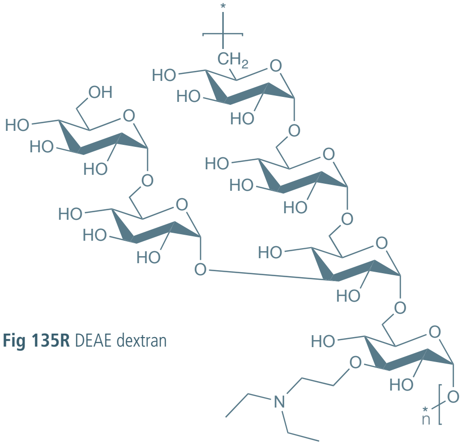


Fig 135R DEAE dextran

8.7.16 Fluorescein Isothiocyanate Dextran

Fluorescein isothiocyanate dextran (Fig 136R) is primarily used for studying permeability and transport in cells and tissues. An added benefit is that measurements of the fluorescence provide quantitative data on the permeability of healthy and diseased tissues. Such studies can be performed in real time by intravital fluorescence microscopy. The technique offers high sensitivity and concentrations down to 1µg/ml can be detected in tissue fluids. FITC-dextrans have also been used as a pH probe in cells (Geisow, 1981; Ohkuma, 1978). It may also be noted from polarisation experiments that the rotational freedom of fluorescein conjugated to dextran remains high and fluorescent lifetime of the excited state is similar to that before conjugation (Geisow, 1981).

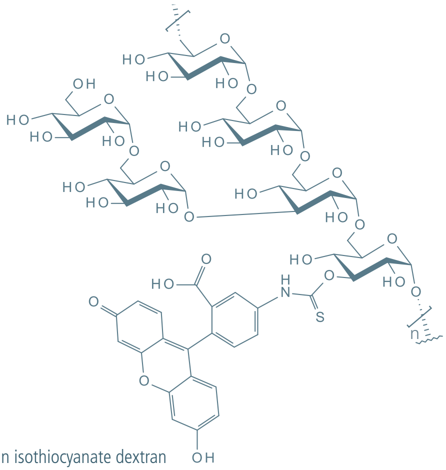


Fig 136R Fluorescein isothiocyanate dextran

8.7.17 Carboxymethyl Curdlan

Carboxymethyl curdlan (CMC) (Fig 137R) is widely used in the preparation of nanoparticles for biomedical applications. In a recent study, following the synthesis of superparamagnetic iron oxide nanoparticles capped with CMC for use in cellular and *in vivo* imaging applications, the stability and dispersibility of SPIN in water were greatly improved with the introduction of the CMC moiety (Lee, 2009). More recently, a green and simple route was proposed to synthesize Ag nanoparticles using carboxymethylcurdlan under UV irradiation (Wu, 2012).

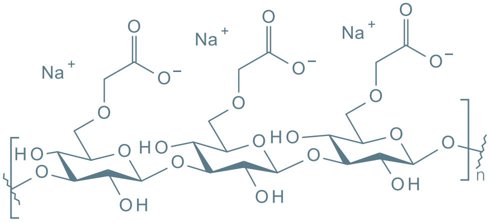


Fig 137R Carboxymethyl curdlan

8.7.18 Propylene Glycol Alginate

Propylene glycol alginate (Fig 138R) is a reaction product of propylene oxide and alginic acid (Steiner, 1951). At the 49th JECFA meeting (1997) it was resolved that the total dietary propylene glycol intake from all sources should be allocated an ADI of 0-25 mg/kg. Applications include as a stabiliser in beer foam due to electrostatic interaction between carboxyl groups on the glycol alginate molecules and amino groups on the peptides in the bubble wall (Jackson, 1980) and in ice cream by emulsifying the fat (Finney, 1972).

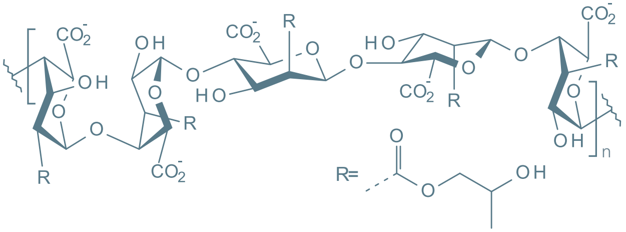


Fig 138R Propylene glycol alginate

8.8 Formulated Polysaccharides

8.8.1 Danaparoid

Danaparoid sodium (the active pharmaceutical ingredient in Orgaran; Merck Sharp and Dohme) is a biopolymeric non-heparin drug used as an anticoagulant and antithrombotic agent approved for the prophylaxis of postoperative deep-vein thrombosis. It consists of a mixture of three glycosaminoglycans: heparan sulphate, dermatan sulphate, and chondroitin sulphate (Üstün, 2011). Danaparoid has well established antithrombotic activity. The drug has a high antifactor Xa to antifactor IIa (thrombin) activity ratio, a low tendency to cause bleeding and minimal effects on the fibrinolytic system (Ibbotson, 2002).

8.8.2 Polyglycoplex

PolyGlycopleX, (α-L-glucurono-α-D-manno-β-D-manno-β-D-gluco), (α-L-gulurono-β-D- mannurono), (β-D-gluco-β-D-mannan (PGX)) is produced from a mixture containing proprietary proportions of three polysaccharides, konjac glucomannan, xanthan gum and sodium alginate. It has been subjected to a proprietary process (EnviroSimplex) including heat input after mixing the solid components. Recent hydrodynamic, rheological and analytical studies (Abdelhameed, 2010; Harding, 2011) have shown that the unexpectedly high viscosity of solutions of PGX is consistent with an interaction between a konjac glucomannan, xanthan gum complex and sodium alginate to form a new, ternary complex in solution. Human and animal feeding studies have shown that PGX can be used to control weight, lower the glycaemic index of foods and postprandial glycaemia (Brand-Miller, 2010; 2012). A monograph on the identification of PolyGlycoplex has recently been published (FCC, 2013).

8.9 Artificial Polysaccharides

8.9.1 Polydextrose

Polydextrose is a synthetic polymer of glucose. It is a food ingredient classified as soluble fibre by the U.S. Food and Drug Administration (FDA) as well as Health Canada, as of April 2013. It is frequently used to increase the non-dietary fibre content of food, to replace sugar, and to reduce calories and fat content. It is a multi-purpose food ingredient synthesized from dextrose (glucose), plus about 10 percent sorbitol and 1 percent citric acid. Its E number is E1200. It was approved by FDA in 1981.

Polydextrose is described in its Foods Chemicals Codex (FCC) Monograph as a randomly bonded (the 1,6-glycosidic linkage predominates) condensation polymer of D-glucose, sorbitol, and citric acid (Fig 139R). Commercial polydextrose also contains small amounts of free glucose, sorbitol, citric acid, and 1,6 anhydro-D-glucose (levoglucosan). Polydextrose has a broad molecular weight range (162 to 20,000) with 90 % of the molecules being between 504 and 5,000 MW. The average degree of polymerisation is 12: average molecular weight of approximately 2000. It is 0.1 times as sweet as sugar.

Polydextrose is commonly used as a replacement for sugar, starch, and fat in commercial beverages, cakes, candies, dessert mixes, breakfast cereals, gelatins, frozen desserts, puddings, and salad dressings. Polydextrose is frequently used as an ingredient in low-carb, sugar-free, and diabetic cooking recipes. It is also used as a humectant, stabiliser, and thickening agent.

Polydextrose is a form of soluble fibre and has shown healthful prebiotic benefits when tested in animals. It contains only 1 kcal per gram and, therefore, is able to help reduce calories (Rennhard, 1973).

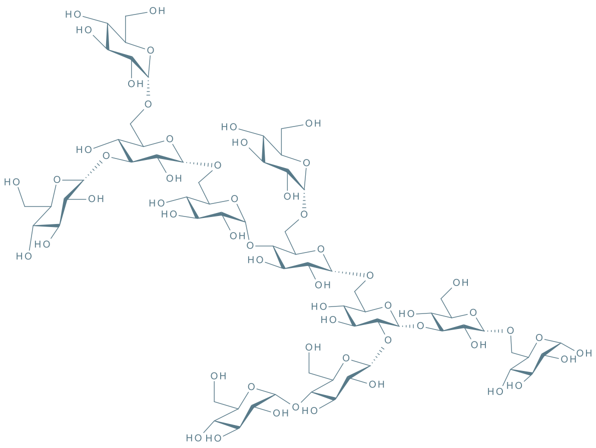


Fig 139R Polydextrose

Section

9

References

References

Abdelhameed, A. S., Ang, S., Morris, G. A., Smith, I., Lawson, C., Gahler, R., et al., An analytical ultracentrifuge study on ternary mixtures of konjac glucomannan supplemented with sodium alginate and xanthan gum. *Carbohydrate Polymers*, **81**, 145–148, (2010)

Al-Kaisey, M.T., Wilkie, C.B., The polysaccharides of agricultural lupin seeds. *Carbohyd. Res.*, **227**, 147-161, (1992)

Anderson D. M. W. and Bridgeman M. M. E., The composition of the proteinaceous polysaccharides exuded by a*stragalus microcephalus, A. gummifer and A. kurdicus*-the sources of turkish gum tragacanth, *Phytochemistry*, **24**, 2301,2304, (1985)

Anderson, N.S., Dolan, T.C.S., Lawson C.J. and Rees D.A., The Masked Repeating Structures of ι and Κ-Carrageenans. *Carbohydrate Research*, **7**, 368-473, (1968)

Ansorge W., Pepperkok R., Performance of an automated system for capillary microinjection into living cells, *Journal of Biochemical and Biophysical Methods,* **16(4)**, 283-292, (1988)

Arnott S., Fulmer A., Scott W. E., Dea I. C. M., Moorhouse R. and Rees D. A., The agarose double helix and its function in agarose gel structure, *J Mol Biol*, **90**, 269, (1974)

Aspinall G. O. and Sanderson G. R., Plant gums of the genus *Sterculia*. Part V. Degradation of carboxyl reduced *Sterculia urens gum, J Chem. Soc*., 2259, (1970)

Ballou, C. E. (1974). Some aspects of the structure, biosynthesis and genetic control of yeast mannans. In *Advances in Enzymology*, **40**, 239-270, Ed. A. Meister. New York, Wiley (1974).

Barclay T., Ginic-Markovic M., Cooper P. and Petrovsky N., Inulin-a versatile polysaccharide with multiple pharmaceutical and food uses, *J Excipients and Food Chem*., **1(3)**, 28-50, (2010)

Barker S. A., Bourne E. J., O'Mant D. M. and Stacey M., Studies of *Aspergillus niger*. Part VI. The separation and structures of oligosaccharides from Nigeran, *J. Chem. Soc*., 2448-2454 (1957)

Baudys M., Letourneur D., et al., Extending insulin action in vivo by conjugation to carboxymethyl dextran, *Bioconj. Chem*., **9**,176-183 (1998)

BeMiller J., Whistler R. L., (eds), Starch Chemistry and Technology, *Food Science and Technology International Series*, Academic Press, 3rd Edition, (ISBN 978-0-12-746275-2), (2009)

Bjorndal H., Hellerquist C. G., Lindberg B. and Svensson S., Gas-Liquid Chromatography and Mass Spectroscopy in Methylation Analysis of Polysaccharides, *Angew. Chem. Internat. Ed*., **9**, 610-619, (1970)

Blake J. D., Clarke M. L., Jansson P. E., and McNeil K. E., Fructan from *Erwinia herbicola, Journal of Bacteriology*, **151(3)**, 1595-1597, (1982)

Blanshard J. M. V. and Mitchell J. R., eds., *Polysaccharides in Food*, Butterworths, (1979)

Bouveng, H.O., Meier, H., Galactan from Norwegian spruce compression wood. *Acta Chem. Scand*., **22**, 1884-1889, (1959)

Bouveng H. and Lindberg B., Methods in Structural Polysaccharide Chemistry, *Adv. Carbohydr. Chem*., **15**, 58-68, (1960)

Brand-Miller J. C., Atkinson F. S., Gahler R. J., Kacinik V., Lyon M. R. and Wood S., Effects of PGX, a novel functional fibre, on acute and delayed post-prandial glycaemia, *European Journal of Clinical Nutrition*, **64**, 1488-1493, (2010)

Brand-Miller J. C., Atkinson F. S., Gahler R. J., Kacinik V., Lyon M. R. and Wood S., Effects of added PGX, a novel functional fibre, on the glycaemic index of starchy foods, *British Journal of Nutrition*, **108**, 245-248, (2012)

Brett C. T., Cellulose microfibrils in plants: biosynthesis, deposition, and integration into the cell wall, *Int Rev Cytol*., **199**, 161-99, (2000)

Carlsson, A., Lindman, B., Nilsson, P.-G., Karlsson, *G. Polymer*, **27**, 431, (1986) Casu B., Structure and biological activity of heparin, *Advances in Carbohydrate Chemistry and biochemistry*, **43**, 51-134, (1985)

Catley B. J. and Whelan W. J., Obsevations on the structure of pullulan, *Arch. Biochem. Biophys*., **143**, 138-142, (1971)

Chen F., Tao Y., Jin C., Xu Y., Lin B–X., Enhanced production of polysialic acid by metabolic engineering of *Escherichia coli, Applied Microbiology and Biotechnology,* **99(6)**, 2603–2611, (2015)

Chen L., Du Y., Tian Z. and Sun L., Effect of the degree of deacetylation and the substitution ofcarboxymethyl chitosan on its aggregation behavior, *J. Polym. Sci. Polym. Phys*., **43**, 296–305, (2005)

Cheng D., Han W., Song K., et al., One-step facile synthesis of hylauronic acid functionalized fluorescent gold nanoprobes sensitive to hyaluronidase in urine specimens from bladder cancer patients, *Talanta*, **130**, 408-414, (2014)

Churms S. C., ed., *CRC Handbook of Chromatography*, Carbohydrates Volume I, CRC Press, (1982)

Dea I. C. M. and Madden J. K., Acetylated Pectic Polysaccharides of Sugar Beet, *Food Hydrocolloids*, **1 (1)**, 71-88, (1986)

Dea I. C. M., Morris E. R., Rees D. A., Welsh E. J., Barnes H. A. and Price J., Association of like and unlike polysaccharides: mechanism and specificity ion galactomannans, interacting bacterial polysaccharides, and related systems, *Carbohydr. Res*., **57**, 249-272, (1977)

Deavin L., Jarman T.J., Lawson C.J., Righelato R.C., Slocombe S., The Production of Alginic Acid by *Azotobacter vinelandii* in Batch and Continuous Culture. *ACS Symp. Ser*., **45**, 14-26, (1977)

de Belder A. N., Wik K. O., Preparation and properties of fluorescein-labelled hyaluronate, *Carbohyd. Res*., **44(2)**, 251-257, (1975)

De Belder A. N., Medical Applications of Dextran and its Derivatives, *Polysaccharides, Medical Applications*, *Marcel Dekker,* ed Dumitriu S., 505-523, (1996)

Delgado J. N., William A. *in Wilson and Gisvold's textbook of organic medicinal and pharmaceutical chemistry*. Lippincott-Raven Publishers, Wickford (1998)

Dimitrijevich S.D., Tatarko M., Gracy R.W., Linsky C.B. and Olsen C., Biodegradation of oxidized regenerated cellulose. *Carbohydr. Res*., **195**, 247–256, (1990)

Drummond G.S., Smith E.E. and Whelan W. J., On The Specificity of Starch Debranching Enzymes, *Febs Letters*, **9(3)**, 136-140, (1970)

Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., and Smith., F., Colorimetric method for determination of sugars and related substances, *Anal Chem*., **28**, 350, (1956)

Dumitriu S., ed., *Polysaccharides in Medicinal Applications*, Marcel Dekker, Second Edition, (1996)

Dumitriu S., ed., *Polysaccharides, Structural Diversity and Functional Versatility*, Marcel Dekker, Second Edition, (2005)

Ebringerova A., Heinze T., Xylan and Xylan derivatives-biopolymers with valuable properties 1, Naturaly occurring Xylans structures, isolation procedures and properties, *Macromol. Rapid Commun*., **21**, 542-556, (2000)

Farag R. K., and Mohamed R. R., Synthesis and Characterization of Carboxymethyl Chitosan Nanogels for Swelling Studies and Antimicrobial Activity, *Molecules*, **18**, 190-203, (2013)

FCC, Alginate-Konjac-Xanthan Polysaccharide Complex, Second Supplement to *FCC 8th Edition*, 1743, (2013)

Fee M., Errington N., Illum K. J. L., Smith A. and Harding S. E., Correlation of SEC/MALLS with ultracentrifuge and viscometric data for chitosan, *Eur. Biophys*. J., **32**, 457-464, (2003)

Ferguson I. A., Xian C., Barati E., Rush R. A., Comparison of wheat germ agglutinin–horseradish peroxidase and biotinylated dextran for anterograde tracing of corticospinal tract following spinal cord injury, *Journal of Neuroscience Methods*, **109(2)**, 81–89, (2001)

References (continued)

Finney D. J., Ravenhill J. R. and Tait M. J., Ice Cream, *US Patent 3914441* to Lever Brothers (1972)

Fischer M. H., Yu N., Gray G. R., Ralph J., Anderson L. and Marlett J. A., The gel-forming polysaccharide of psyllium husk (*Plantago ovata forsk*), *Carbohydr. Res.*, **339(11)**, 2009-2017, (2004)

Friedrichs G. S., Kilgore K. S., Manley P. J., Gralinski M. R., Lucchesi B. R., Effects of heparin and *N*-acetyl heparin on ischemia/reperfusion-induced alterations in myocardial function in the rabbit isolated heart, *Circulation Research*, **75**, 701-710 (1994)

Geddes R., in *The Polysaccharides*, **3**, 316 (1985)

Geisow M. J., D'Arcy Hart P. and Young M. R., Temporal changes of lysosome and phagosome pH during phagolysosome formation in macrophages; studies by fluorescence spectroscopy, *J. Cell. Biol.*, **89**, 645-652, (1981)

Gekko K., Solution properties of dextran and its ionic derivatives, *ACS Symposium Series*, **150**, 415-438, (1981)

Gekko K. and Noguchi H., Selective interaction of calcium and magnesium ions with ionic dextran derivatives, *Carbohyd. Res.*, **69**, 323-326, (1979)

Gibb R. D., Johnson W. McR. Jr., Russell D A., Hasselblad V. and Alessio D. A D., Psyllium fibre improves glycemic control proportional to loss of glycemic control, *Am. J. Clin. Nutr.*, **102 (6)**, 1604-1614, (2015)

Gloaguen V., Brudieux V., Closs B., Barbat A., Krausz P., Sainte-Catherine O., Kraemer M., Maes E. and Guerardel Y., Structural Characterization and Cytotoxic Properties of an Apiose-Rich Pectic Polysaccharide Obtained from the Cell Wall of the Marine Phanerogam Zostera marina, *J. Nat. Prod.*, **73(6)**, 1087–1092, (2010)

Glushka J.N., Terrell M., York W. S., O'Neill M.A., Gucwa A., Darvill A.G., Albersheim P., Prestegard J.H., Primary structure of the 2-O-methyl α-L-fucose-containing
side chain of the pectic polysaccharide, rhamnogalacturonan II. *Carbohydr. Res.*, 338, 341,352, (2003)

Gorin P. A. J. and Spencer J.F.T., Exocellular alginate from Azotobacter vinelandii, *Canad. J. Chem.*, **44**, 993-998, (1966)

Hacking A. J., Taylor I. W. F., Jarman T. R. and Govan J. R. W., Alginate biosynthesis by *Pseudomonas mendocina, Journal of General Microbiology*, **129**, 3473-3480, (1983)

Hakomori S., A rapid permethylation of glycolipid, and polysaccharide catalyzed by methylsulfinyl carbanion in dimethyl sulfoxide, *J. Biochem.*, **55**, 205-208, (1964)

Harding S. E., Challenges for the modern analytical ultracentrifuge analysis of polysaccharides, *Carbohydr. Res.*, **340(5)**, 811-826 (2005)

Harding S. E., The Intrinsic viscosity of biological macromolecules, progress in measurement, interpretation and application to structure in dilute solution, *Progress in Biophysics and Molecular Biology*, **68**, 207-262, (1997)

Harding S.E., Smith I.H., Lawson C.J., Gahler R J. and Wood S., Studies on macromolecular interaction in ternary mixtures of konjac glucomannan, xanthan gum and sodium alginate, *Carbohydrate Polymers*, **83(2)** 329-338, (2011)

Harding S.E., Adams G.G., Almutairi F., Alzahrani Q., Erten T., Kok M.S. and Gillis R.B., Ultracentrifuge methods for the analysis of polysaccharides, glycoconjugates, and lignins. *Methods in Enzymology.* **562**, 391-439 (2015)

Harris P., ed., *Food Gels*, Elsevier Applied Science, (1990)

Henry R.J., Pentosan and 1,3,1,4)-β-Glucan concentrations in endosperm and wholegrain of wheat, barley, oats and rye, *Journal of Cereal Science*, **6(3)**, 253–258, (1987)

Hicks K.B., Scott M. and Doner L.W., Preparative chromatography of carbohydrates, uronic acids and related derivatives, *Carbohydr. Res.*, **168 (1)**, 33-45, (1987)

Hirst, E.L., Jons, J.K.N., Walder, W.O., Pectic substances. Part 7: the constitution of the galactan from *Lupinus albus. J. Chem. Soc.*, 1225-1229, (1947)

Hokputsa., Alexander K. J. C. and Harding S. E., A comparison of molecular mass determination of hyaluronic acid using SEC/MALLS and sedimentation equilibrium, *Eur. Biophys. J.*, **32**, 450-456, (2003) Ibbotson T., Perry C. M., Danaparoid, A Review of its Use in Thromboembolic and Coagulation Disorders, *Drugs*, **62 (15)**, 2283–2314, (2002)

Izydorczyk M. S and Dexter J. E., Barley β-glucans and arabinoxylans: molecular structure, physical properties, and uses in food products-a review, *Food Research International,* **41**, 850-868, (2008)

Jackson G., Roberts R. T. and Wainwright T., Mechanism of Beer Foam Stabilisation by Propylene Glycol Alginate, *J. Inst. Brew*., **86**, 34-37 (1980)

Johnson S.D., Lacher K.P. and Anderson J.S., Carbon-13 nuclear magnetic resonance spectroscopic study of teichuronic acid from *Micrococcus luteus* cell walls. Comparison of the polysaccharide isolated from cells with that synthesized in vitro, *Biochemistry*, **20(16)**, 4781,4785, (1981)

Kacurakova M. and Wilson R. H., Developments in mid-infrared FT-IR spectroscopy of selected carbohydrates, *Carbohydrate Polymers*, **44(4)**, 291,303, (2001)

Kaeffer B., Bénard C., Lahaye M., Blottière H. M., Cherbut C., Biological Properties of Ulvan, a New Source of Green Seaweed Sulphated Polysaccharides, on Cultured Normal and Cancerous Colonic Epithelial Cells, *Planta Med*., **65(6)**, 527-531, (1999)

Karunaratne D. N., Jayalal R. G. U. and Karunaratne V., Lichen Polysaccharides in *The Complex World of Polysaccharides*, Chapter 8, Intech (Open Science), 215-226, (2012)

Kato Y., Habu N., Yamaguchi J., Kobayashi Y., Shibata I., Isogai A. and Samejima M., Biodegradation of -1,4-linked polyglucuronic acid (cellouronic acid), *Cellulose*, **9(1)**, 75–81, (2002)

Kato Y., Kaminaga J., Matsuo R. and Isogai A., Oxygen permeability and biodegradability of polyuronic acids prepared from polysaccharides by TEMPO-mediated oxidation, *J. Polym. Environ*., **13(3)**, 261–266, (2005)

Keogh, G.F., Cooper G.J., Mulvey T.B., McArdle B.H., Coles G.D., Monro J.A., Poppitt S.D., Randomized controlled crossover study of the effect of a highly beta-glucan-enriched barley on cardiovascular disease risk factors in mildly hypercholesterolemic men, *The American Journal of Clinical Nutrition*, **78(4)**, 711–718, (2003)

Kishimoto S., Kobayashi H., Shimizu S et al., Changes of colonic vasoactive intestinal peptide and cholinergic activity in rats with chemical colitis, *Dig. Dis. Sci*., **37**, 1729–1737, (1992)

Knutson C. A., Pittsley J. E., Jeanes A., Composition and properties of the extracellular polysaccharide produced by *Arthrobacter stabilis* NRRL B-3225, *Carbohydr. Res.*, **73(1)**, 159-168 (1979)

Kobayashi K., Huang Ci. and Lodge T. P., Thermoreversible gelation of aqueous methylcellulose solutions, *Macromolecules*, **32**, 7070-7077, (1999)

Labavitch J.H., Freeman L.E., Albersheim P., Purification and characterisation of β-1,4-galactanase which degrades a structural component of the primary cell wall of dicots., *J. Biol. Chem*., **251**, 5904-5910, (1976)

Lahaye M. and Rochas C., Chemical structure and physico-chemical properties of agar, *Hydrobiologia*, **221**, 137-148, (1991)

Lawson C.J. and Rees D.A., Reinvestigation of the Acetolysis Products of Carrageenan, Revision of the structure of α-1,3-Galactotriose and a Further Example of the Reverse Specificities of Glycoside Hydrolysis and Acetolysis. *J. Chem. Soc*, 1301, (1968)

Lawson C.J. and Rees D.A., An Enzyme for the Metabolic Control of Polysaccharide Conformation and Function, *Nature* (London), 227, (1970)

Lawson C.J., Rees D.A., Stancioff D.J. and Stanley N.F., Repeating Structures of Galactan Sulphates from *Furcellaria, Gigartina, Ahnfeltia, Gymnogongrus, Euchuma. J. Chem. Soc. Perkin Trans*. 1, **19**, 2177-2182, (1973)

Lawson, C.J., Symes, K.C., Oligosaccharides produced by partial acetolysis of xanthan gum, *Carbohydr. Res*., **58**, 433, (1977)

Lawson C. J. and Symes K. C, Suspensions and gels of indican and their uses, US Patent, US 4372785 A, (1979)

References (continued)

Lindberg B., Longren J., Svensson S., Specific Degradation of Polysaccharides, *Advances in carbohydrate Chemistry & Biochemistry*, **31**, 185-240, (1975)

Lee C.M., Jeong H.J., Kim E.M., Cheong S.J., Park E.H., Kim D.W., Lim S.T. and Sohn M.H., Synthesis and characterization of iron oxide nanoparticles decorated with carboxymethyl curdlan, *Macromolecular Research*, **17**, 133-136, (2009)

Lienart Y., Heyraud A. and Sevenou O., β-1,4-D-glucuronane polymers and related polysaccharide and oligosaccharide pesticides and fertilizers. WO 2001000025, (2001)

Ma H., Li X. et al., High antimetastatic efficacy of MEN4901/T-0128, a novel campothecin carboxymethyldextran conjugate, *J. Surg. Res.*, **171(2)**, 684-690, (2011)

Mackie W., Semi-quantitative estimation of the composition of alginates by infra-red spectroscopy, *Carbohydr. Res.*, **20(2)**, 413-415, (1971)

Maeda M., Shimahara H. and Sugiyama N., Detailed examination of the branched structure of konjac glucomannan, *Agric. Biol. Chem.*, **44(2)**, 245-252, (1980)

Manners D. J., Massan A. J. and Patterson J. C., The structure of a β-1,3 glucan from yeast cell walls, *Biochem. J.*, **135**, 19-30, (1973)

Manners D J., Recent developments in our understanding of glycogen structure, *Carbohydrate Polymers*, **16(1)**, 37-82, (1991)

Marchessault R. H. and Sundararajan P. R., in *The Polysaccharides*, (Aspinall G. O., ed.), Academic Press, New York, **2**, 25-65, (1983)

Mazeau K., Hervé du Penhoat C., Pérez S., Pectic Arabinogalactans & Rhamnogalacturonans, *Plant Physiology and Biochemistry*, **38(1–2)**, 37–55, (2000)

McCleary B.V. and Matheson N.K., Enzymic Analysis of Polysaccharide Structure, *Advances in Carbohydrate Chemistry & Biochemistry*, **44**, 147-276, (1987)

Meena D. K., Das P., Kumar S., Mandal S. C., Prusty A. K., Singh S. K., Akhtar M. S., Behera B. K., Kumar K., Pal A. K. and Mukhergee S. C., Beta-glucan an ideal immunostimulant in aquaculture, *Fish Physiology and Biochemistry*, **39 (3)**, 431,457, (2013)

Morales-Lange B., Bethke J., Schmitt P. and Mercado L., Phenotypical parameters as a tool to evaluate the immunostimulatory effects of laminarin in *Oncorhnchus mykiss, Aquaculture Research*, **46(11)**, 2707-2715, (2015)

Morris G.A., Ralet M-C., Bonnina E., Thibault J-F and Harding S. E., Physical characterisation of the rhamnogalacturonan and homogalacturonan fractions of sugar beet (*Beta vulgaris*) pectin, *Carbohydrate Polymers*, **82**, 1161–1167, (2010)

Mourão P. A. S., Pereira M. S., Pavão M. S. G., Mulloy B., Tollefsen D. M., Mowinckel M-C. and Abildgaard U., Structure and Anticoagulant Activity of a Fucosylated Chondroitin Sulphate from Echinoderm, Sulphated Fucose Branches on The Polysaccharide Account For Its High Anticoagulant Action, *J. Biol. Chem.*, **271**, 23973-23984, (1996)

Muzzarelli, R.A.A., Carboxymethylated chitins and chitosans, *Carbohyd. Polym.*, **8**, 1–21, (1988).

Nelson T. E. and Lewis B. A., Separation and characterisation of the soluble and insoluble components of insoluble laminaran, *Carbohydr. Res.*, **33**, 63-74, (1974)

North S. J., Hitchen P. G., Haslam S. M., and Dell A., Mass spectrometry in the analysis of N- and O-linked glycans, *Curr Opin Struct Biol.*, **19(5)**, 498–506, (2009)

Ohkuma S. and Poole B., Fluorescence probe measurement of the intralysosomal pH in living cells and the perturbation of pH of by various agents, *Proc. Natl. Acad. Sci. USA,* **75**, 3327-3331, (1978)

Ohkusa T., Production of experimental ulcerative colitis in hamsters by Dextran Sulphate Sodium and changes in intestinal microflora, *Nihon Shokakibyo Gakkai Zasshi*, **82(5)**, 1327-36, (1985).

Okayasu I., Hatakeyama S., Yamada M. et al., A novel method in the induction of reliable experimental acute and chronic ulcerative colitis in mice, *Gastroenterology*, **98**, 694–702, (1990)

Olafsdottir E. S., Ingolfsdottir K., Barsett H., Paulsen S. B., Jurcic K., Wagner H., Immunologically active 1,3-1,4)-α-D-Glucan from *Cetraria islandica, Phytomedicine*, **6(1)**, 33-39, (1999) Palma A. S., Liu Y., Zhang H., Zhang Y., McCleary B. V., Yu G., Huang Q., Guidolin L. S., Ciocchini A. E., Torosantucci A., Wang D., Carvalho A. L., Fontes C. M. G. A., Mulloy B., Childs R A., Feizi T and Chai W., Unravelling Glucan Recognition Systems by Glycome Microarrays Using the Designer Approach and Mass Spectrometry, *Molecular & Cellular Proteomics*, **14**, 974-988, (2015)

Peat S., Turvey J. R. and Rees D. A., Carbohydrates of the red alga, *Porphyra umbilicalis, J. Chem. Soc.*, 1590-1595, (1961)

Peat S., Whelan W. J., Turvey J. R., Morgan K., The structure of isolichenin, *J. Chem*. Soc., 623-9, (1961b)

Percival E. and McDowell R. H., *The Chemistry and Enzymology of Marine Algal Polysaccharides*, Academic Press, (1967)

Pérez S., Mazeau K., Hervé du Penhoat C., The three-dimensional structures of the pectic polysaccharides, *Plant Physiol. Biochem*., **38(1/2)**, 37–55, (2000)

Perlin A. S., Suzuki S., The Structure of Lichenin: Selective Enzymological Studies, *Canadian Journal of Chemistry*, **40(1)**, 50-56, (1962)

Radley J. A., Starch and its Derivatives, 4th Edition, Chapman and Hall, (1968)

Ravno A. B. and Purchase B. S., Dealing with Dextran in the South African Sugar Industry, *Proc. S. Afr. Sug. Technol. Ass*., **79**, 28, (2005)

Ray B. and Lahaye M., Cell-wall polysaccharides from the marine green algae *Ulva 'rigida'* (*Ulvales, Chlorophyta*) — 1 Extraction and chemical composition, *Carbohydr. Res*., **274**, 251–261, (1995a)

Ray B. and Lahaye M., Cell-wall polysaccharides from the marine green algae *Ulva 'rigida'* (*Ulvales, Chlorophyta*) — 2 Chemical structure of ulvan. *Carbohydr. Res*., **274**, 313–318, (1995b)

Rees D. A., *The Shapes of Molecules, Carbohydrate Polymers*, Oliver & Boyd, (1967)

Rees D. A. and Conway E., The structure and biosynthesis of *Porphyran*, a comparison of some samples, *Biochem J*., **84**, 411,416, (1962)

Rees D. A., A double helix structure in food, *Science Journal*, **6(12)**, 47-51, (1970)

Rees D. A., Structure conformation and mechanism in the formation of polysaccharide gels and networks, In *Advances in Carbohydrate Chemistry and Biochemistry*, eds. Wolfrom M.L. and Tipson R. S., **24**, 267, (1969)

Rees D.A. et al, Covalent structure of the extracellular polysaccharide from Xanthomonas campestris: evidence from partial hydrolysis studies, *Carbohydr. Res*., **46**, (1976)

Rees D. A., *Polysaccharide Shapes*, Chapman and Hall, (1977)

Rennhard H., Polysaccharides and their preparation, US Patent, US 3766165 A (1973)

Roberfroid M., Dietary fibre, inulin and oligofructose: a review comparing their physiological effects, *Critical Reviews in Food Science and Nutrition*, **33(2)**, 103-148, (1993)

Robyt J.F., *Essentials of Carbohydrate Chemistry*, Springer Advanced Texts in Chemistry, (1998)

Rongved P. and Klaveness J., Water soluble polysaccharides as carriers of paramagnetic contrast reagents for magnetic resonance imaging; Synthesis and relaxation properties, *Carbohyd.Res*., **214**, 315-323, (1991)

Ross-Murphy S. B., Structure-property relationships in food biopolymer gels and solutions, *J. Rheol.*, **39**, 1451-1463, (1995)

Ross P., Mayer R. and Benziman M., Cellulose Biosynthesis and Function in Bacteria, *Microbiological Reviews*, **55(1)**, 35-58, (1991)

References (continued)

Saito H., Ohki T. and Sasaki T., A ^{13}C-nuclear magnetic resonance study of polysacchaccharide gels. Molecular architecture in the gels consisting of fungal, branched 1,3)-β-D-glucans (lentinan) and (schizophyllan), *Carbohydr. Res*., **74(1)**, 227-240, (1979)

Sandford P.A. and Laskin A., *Extracellular Microbial polysaccharides*, eds., ACS Symposium Series **45**, (1977)

Schauer R., Sialic acids as regulators of molecular and cellular interactions, *Current Opinion in Structural Biology*, **19 (5)**, 507–514, (2009)

Sidebotham R. L., Dextrans, *Advances in Carbohydrate Chemistry and Biochemistry*, **30**, 371,444, (1974)

Situ C., Wylie A.R.G., Douglas A., et al., Reduction of severe bovine serum associated matrix effects on carboxymethylated dextran coated biosensor surfaces, *Talanta*, **76**, 832-836, (2008)

Skriptsova A. V., Shevchenko N. M., Zvagintseva T. N. and Imbs T. I., Monthly changes in the content and monosaccharide composition of fucoidan from Undaria Pinnatifida, *J. Appl*. Phycol., **22**, 79-86, (2010)

Smith I. H., Lawson C. J., Harding S. E., Gahler R. J. and Wood S., Viscosity development during aqueous dispersion and dissolution: A comparison of PGX with other dietary supplements and individual polysaccharides, *Food Hydrocolloids*, **38**, 152-162, (2014)

Smith F. and Montgomery R., The Chemistry of Plant Gums and Mucilages, Reinhold, New York, 1959

Steiner A. B., McNeely W. H., Organic Derivatives of Alginic Acid, *Ind. Eng. Chem*., **43(9)**, 2073–2077, (1951)

Stephen A. M., Churms S. C. and Vogt D. C., Exudate Gums, *in Methods in Plant Biochemistry*, **2**, 484-522, (1990)

Stephens E., Maslen S. L., Green L. G., and Williams D. H., Fragmentation Characteristics of Neutral N-Linked Glycans Using a MALDI-TOF/TOF Tandem Mass Spectrometer, *Anal. Chem*., **76 (8)**, 2343–2354 (2004)

Symes K. C., Lipophilic Polysaccharides, *Carbohydr. Polymers*., **2**, 276-281, (1982)

Szymanska-Chargot M., Chylinska M., Pieczywek P. M., Rosch P., Schmitt M., Popp J., Zdunek A., Raman imaging of changes in the polysaccharides distribution in the cell wall during apple fruit development and senescence, *Planta*, **243**, 935-945, (2016)

Timell T. E., Vegetable ivory as a source of a mannan polysaccharide, *Canad. J. Chem*., **35**, 333-338, (1957)

Tipper D. J., Structure and Function of Peptidoglycans, *International Journal of Systematic Bacteriology*, **20(4)**, 361,377, (1970)

Tomulescu C., Stoica R., Sevcenco C., Casarica A., Moscoviki M., Vamanu A., Levan - A Mini Review, *Scientific Bulletin. Series F. Biotechnologies*, **20**, 309-317, (2016)

Tung K. K., Nordin J. H., Evidence for a buried location of Nigeran in the cell wall of Aspergillus niger, *Biochem. Biophys. Res. Commun*., **28(4)**, 518-524, (1967)

Usov A. I., Yarotskii S. V., Esteves M. L., Algal polysaccharides. XXXII. Polysaccharides of the red algae *Galaxaura squalida kjellm., Bioorganicheskaya Khimiya*, **7(8)**, 1261-70, (1981)

Usov A. I., Dobkina I. M., Polysaccharides of algae. 43. Neutral xylan and sulphated xylomannan from the red seaweed *Liagora valida., Bioorganicheskaya Khimiya*, **17(8)**, 1051-8, (1991)

Üstün B., Sanders K. B., Dani P. and Kellenbach E. R., Quantification of chondroitin sulphate and dermatan sulphate in danaparoid sodium by ^{1}H NMR spectroscopy and PLS regression, *Analytical and Bioanalytical Chemistry*, **399(2)**, 629–634, (2011)

Vidal S., Doco T., Williams P., Patrice Pellerin P., York W. S., O'Neill M.A., Glushka J., Darvill A.G., Albersheim P., Structural characterization of the pectic polysaccharide rhamnogalacturonan II: evidence for the backbone location of the aceric acid-containing oligoglycosyl side chain. *Carbohydr. Res*., **326**, 277-294, (2000) Vieira R. P., Mulloy B. and Mourão P. A. S., Structure of a fucose-branched chondroitin sulphate from sea cucumber. Evidence for the presence of 3-O-sulpho-beta-D-glucuronosyl residues, *J. Biol. Chem*., **266**, 13530-13536, (1991)

Vincken J-P., Schols H. A., Ronald J.F.J., Oomen R. J. F. J., McCann M. C., Ulvskov P., Voragen A. G. J., and Visser R. G. F., If Homogalacturonan Were a Side Chain of Rhamnogalacturonan I. Implications for Cell Wall Architecture1, *Plant Physiology*, **132(4)**, 1781-1789, (2003)

Vipul D. and McCarthy S.P., Review of Konjac Glucomannan, *Journal of Environmental Polymer Degradation*, **5**, 237-241, (1997)

Vuksan V. et al., Konjac-mannan (glucomannan) improves glycemia and other associated risk factors for coronary heart disease in type 2 diabetes. A randomized controlled metabolic trial, *Diabetes Care*, **22(6)**, 913-919, (1999)

Wang J., Zhang Q., Zhang Z., Zhang H. and Niu X., Structural studies on a novel fucogalactan sulphate extracted from the brown seaweed Lamonaria japonica, *International Journal of Biological Macromolecules*, **47(2)**, 126-131, (2010)

Ward K. and Seib P. A., in *The Carbohydrates*, 2nd edn., (Pigman W., Horton D. and Herp A., eds.) Academic Press, New York, **2A**, 413-415, (1983)

Wefers D. and Bunzel M., Arabinan and Galactan Oligosaccharide Profiling by High-Performance Anion-Exchange Chromatography with Pulsed Amperometric Detection (HPAEC-PAD), *J. Agric. Food Chem*., **64(22)**, 4656–4664, (2016)

Weiβ G., Knochc A., Laichera A., Stanislausa F. and Daniels R., Simple coacervation of hydroxypropyl methylcellulose phthalate (HPMCP) II. Microencapsulation of ibuprofen, *International Journal of Pharmaceutics*, **124(1)**, 97–105, (1995)

Whistler R. L., ed., *Methods in Carbohydrate Chemistry, General Polysaccharides*, Academic Press, Volume V, (1965)

Whistler R. L. and BeMiller J. N., eds., *Industrial Gums, Polysaccharides and Their Derivatives*, Academic Press, Third Edition, (1993)

White C. A., ed., Advances in *Carbohydrate Analysis*, JAI Press, Volume I, (1991)

Willför S., Sundberg K., Tenkanen M., Holmbom B., Spruce-derived mannans, a potential raw material for hydrocolloids and novel advanced natural materials, *Carbohydrate Polymers*. **72(2)**, 197–210, (2008)

Wood P.J., Siddiqui I.R., Isolation and structural studies of a water-soluble galactan from potato (*Solanum tuberosum*) tubers, Carbohyd. Res., **22**, 212-220, (1972)

Wu J., Zhang F. and Zhang H., Facile synthesis of carboxymethyl curdlan-capped silver nanoparticles and their application in surface enhanced Raman spectroscopy, *Carbohydrate Polymers*, **90(1)**, 261–269, (2012)

Yang J-E., E-S. KimE-S., Kwon J. H., et al., Transdermal delivery of hyaluronic acid–human growth hormone, *Biomaterials*, **33**, 5947-5954, (2012)

Yapo B. M., Rhamnogalacturonan-I: A Structurally Puzzling and Functionally Versatile Polysaccharide from Plant Cell Walls and Mucilages, *Polymer Reviews*, **51** (4), 391-413, (2011)

Ying-qing Z., Xie Bi-jun., Gan X., Advance in the application of konjac glucomannan and it's derivatives, *Carbohydrate Polymers*, **60**, 27-31, (2005)

Yu J., Xie X., Wu J., Liu Y., Liu P. and Xu X., Folic acid conjugated glycol chitosan micelles for targeted delivery of doxorubicin: preparation and preliminary evaluation in vitro, *Journal of Biomaterials Science, Polymer Edition*, **24**, 606-620, (2013),

Zhang F., Zhang Z. and Linhardt R., *Glycosaminoglycans, in Handbook of Glycomics*, eds. Cummings R. D. and Pierce J. M., 59-80, (2009)

Zhang Q., Zhao T. et al., Chemical characteristics of a polysaccharide from *Porphyra capensis, Carbohydr. Res*., **340**, 2447-2450, (2005)

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10&11

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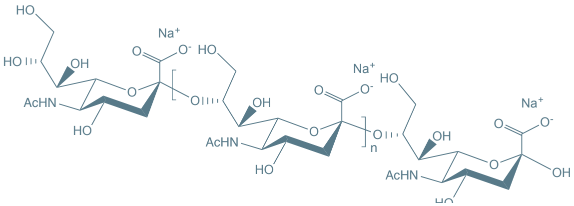

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Prices

All prices are on an EXW basis in US Dollars ($) and are subject to alteration at any time. Actual transport costs vary and depend on weight, hazard class and destination. Any transport costs and hazardous surcharges are indicated on our invoices and we endeavour to minimise these. A guide to our transport and hazard charge is given below and we will advise you if the costs are higher than those in the table, prior to delivery.

Destination	Gross weight	Transport charge	Hazard charge
Europe*, USA & Canada	< 0.5 kg	$35	$75
	0.5 - 2.5 kg	$50	$75
	2.5 - 5 kg	$65	$75
UK	< 0.5 kg	$20	$75
	0.5 - 2.5 kg	$20	$75
	2.5 - 5 kg	$25	$75
China, Australia, New Zealand, Russia & Ukraine	< 0.5 kg	$60	$150
	0.5 - 2.5 kg	$75	$150
	2.5 - 5 kg	$90	$150
India**	< 0.5 kg	$45	$90
	0.5 - 2.5 kg	$60	$90
	2.5 - 5 kg	$80	$90
Rest of World***	< 0.5 kg	$60	$90
	0.5 - 2.5 kg	$75	$90
	2.5 - 5 kg	$90	$90

* Additional costs apply to hazardous shipments to Greece, Norway, Poland, Romania and some regions in Spain

** Hazardous shipments are to the following airports only: Mumbai, Hyderabad, Bangalore and New Delhi. An additional cost of $100 applies to hazardous shipments to Hyderabad airport

*** Some restrictions apply and some additional costs apply to some territories. These will be advised on request

Different carriers have different restrictions on the hazardous classes and territories they serve. Our preferred carrier is FedEx, although the actual carrier will depend on the hazard class and the final destination. If you wish to have products shipped by your chosen carrier, please include your carrier's name and account number on your purchase order. We reserve the right to alter the method of shipment if we deem that it does not comply with regulations or that the product will not be delivered in good order.

If you wish to purchase in pounds (£) or euros (€) please enquire or visit our website.

Section

10

Listing by Origin

10. Listing by Origin

10.1 Polysaccharides from Higher Plants

10.1.1 Energy Storage Polysaccharides

10.1.1.1 Starch

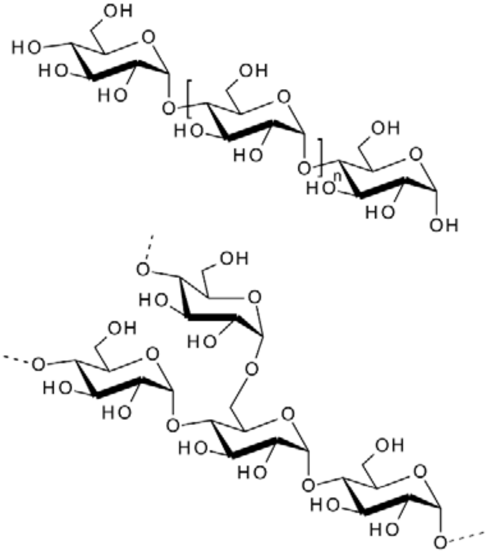
Corn starch

- Starch - from maize

[9005-25-8]

YC35117

1Kg	$100.00
2Kg	$160.00
5Kg	$320.00



Starch from potato

[9005-25-8]

YS164195

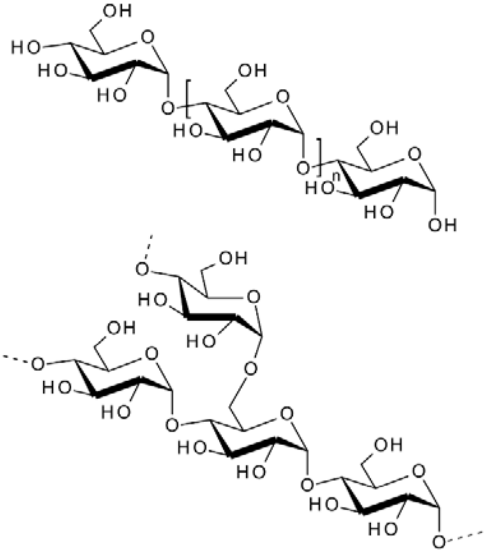
500g	$45.00
1Kg	$100.00
2Kg	$170.00

Wheat starch

[9005-25-8]

YW32318

250g	$52.50
500g	$85.00
1kg	$126.00

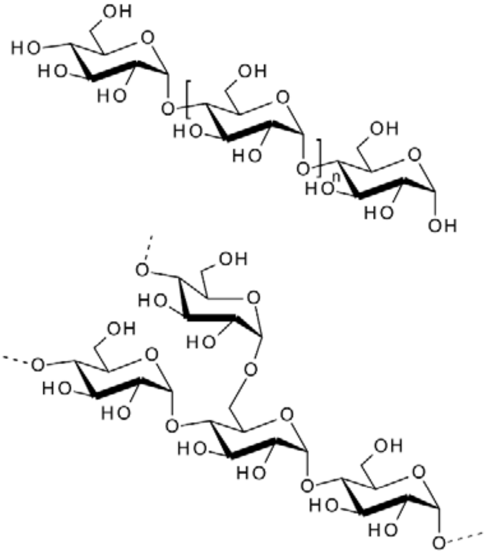


Pregelatinized starch

[9005-25-8]

YP35111

Price on Application

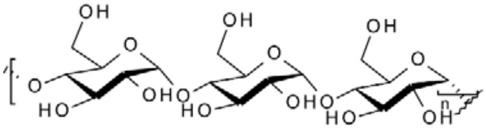


Amylose

[9005-82-7]

YA10257

10g	$85.00
25g	$150.00
50g	$250.00

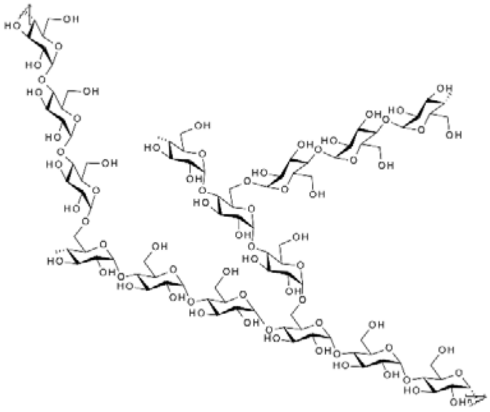


Amylopectin - from maize

[9037-22-3]

YA39745

100g	$45.00
250g	$70.00
500g	$110.00

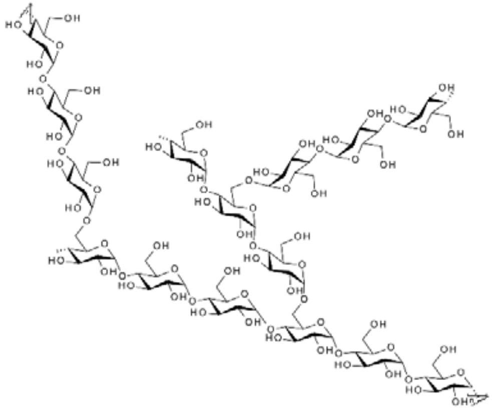


Amylopectin - from potato starch

[9037-22-3]

YA164124

1g	$65.00
2g	$96.00
5g	$180.00



10.1.1.2 Inulin and Levan

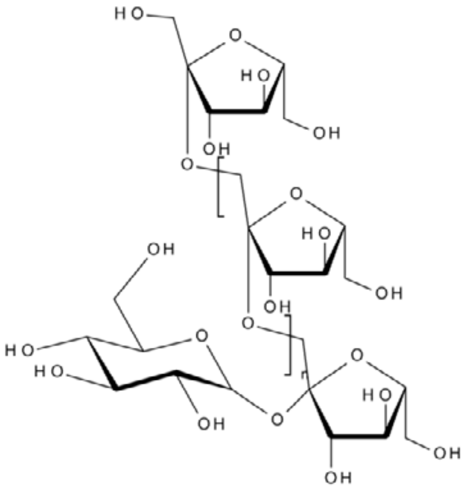
Inulin - from chicory

- Poly-b-(2-1)-fructofuranose

[9005-80-5]

YI01274

500g	$50.00
1kg	$85.00
2kg	$160.00

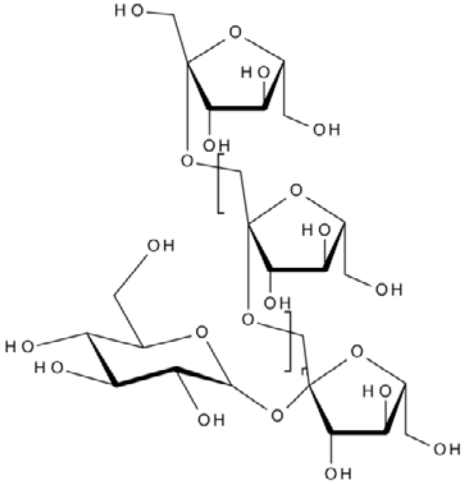


Inulin - from Jerusalem artichoke

[9005-80-5]

YL75175

1g	$50.00
2g	$80.00
5g	$175.00



10.1.2 Structural Polysaccharides

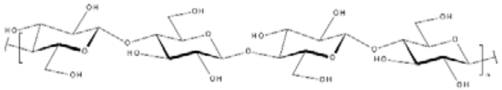
10.1.2.1 The Celluloses

Cellulose - Arbocel

[9004-34-6]

YC145383

100g	$75.00
250g	$150.00
500g	$250.00

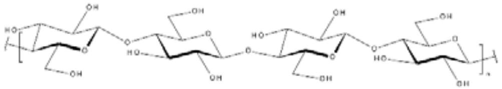


Cellulose - Microcystalline USP

[9004-34-6]

YC05773

50mg	$50.00
100mg	$80.00
250mg	$130.00



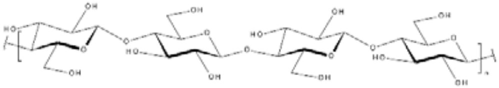
Cellulose - Particle Size approx 50 um

- Cellulose microcrystalline

[9004-34-6]

YC31812

500g	$75.00
1kg	$125.00
2kg	$210.00

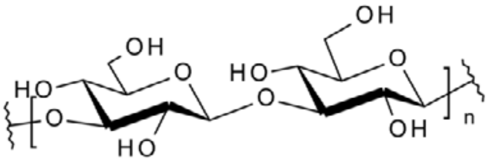


10.1.2.2 Cereal β Glucans

Oat b-D-glucan

YO32420

1g	$125.00
2g	$190.00
5g	$395.00



10.1.2.3 Hemicelluloses and Related Polysaccharides

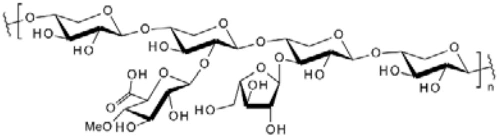
Corncob xylan

- L-Arabino (Methyl-D-glucurono) xylan

[9014-63-5]

YC165265

Price on Application



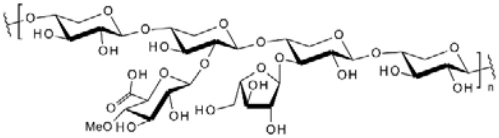
Xylan - from corncob, MW 300-900

- Poly[b-(1,4)-D-xylopyranose]

[9014-63-5]

YC05381

50g	$65.00
100g	$100.00
250g	$175.00

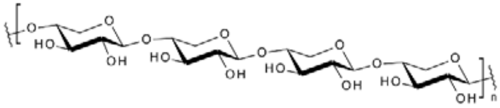


Xylan - from beechwood

[9014-63-5]

YX45751

10g	$70.00
25g	$125.00
50g	$195.00

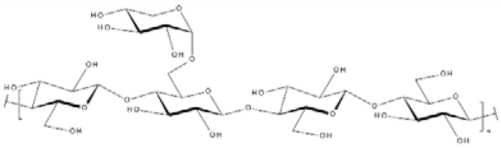


Xyloglucan

[37294-28-3]

YX11685

1g	$95.00
2g	$170.00
5g	$400.00

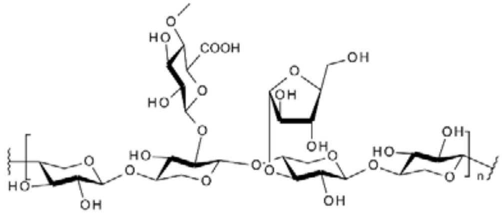


Arabinoxylan

[9040-27-1]

YA29478

1g	$95.00
2g	$150.00
5g	$275.00

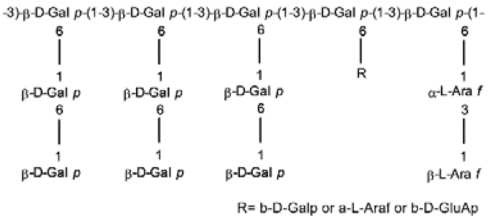


Larch arabinogalactan

[9036-66-2]

YL29121

25g	$65.00
50g	$110.00
100g	$180.00

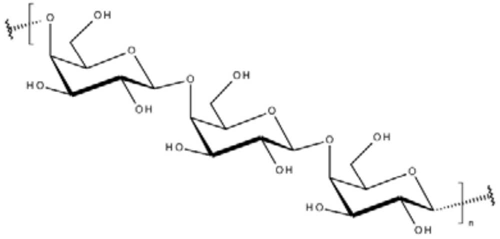


Galactan - from gum arabic

[39300-87-3]

YG08091

100mg	$95.00
250mg	$160.00
500mg	$285.00

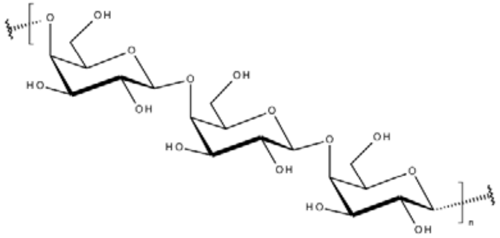


Galactan - from potato

[39300-87-3]

YG71532

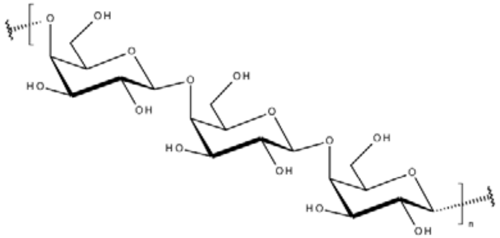
250mg	$85.00
500mg	$130.00
1g	$206.00



Compression wood galactan

YC165863

Price on Application



10.1.2.4 Pectin & pectin-related polysaccharides

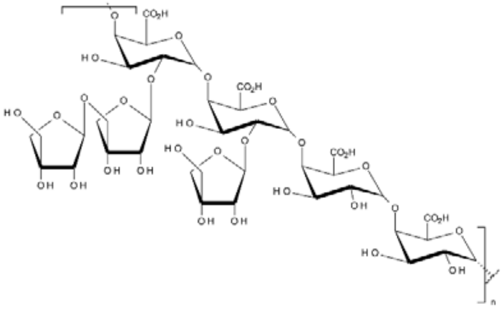
Apiogalacturonan

- Galacturonoapian

[9039-03-6]

YA09575

10mg	$200.00
25mg	$450.00
50mg	$800.00

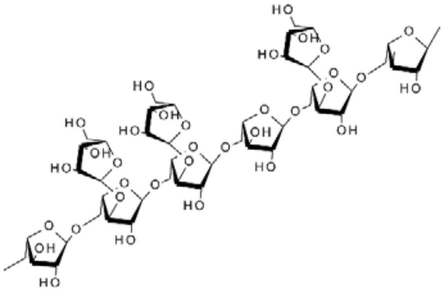


Arabinan

[11078-27-6]

YA46077

1g	$55.00
2g	$84.00
5g	$175.00

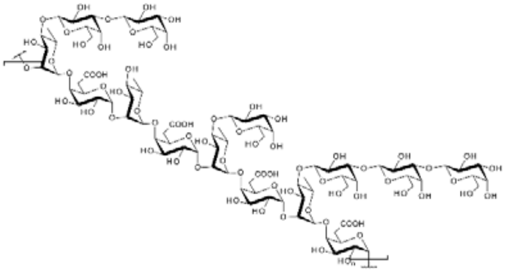


Rhamnogalacturonan - from potato

[39280-21-2]

YR59706

1g	$150.00
2g	$260.00
5g	$550.00

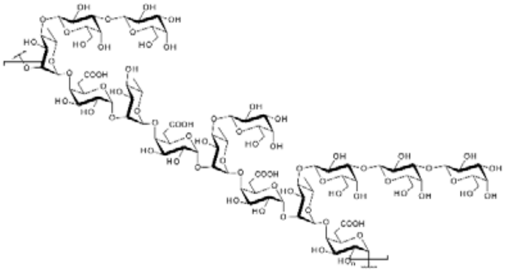


Rhamnogalacturonan - from soy bean

[39280-21-2]

YR158311

1g	$95.00
2g	$150.00
5g	$275.00



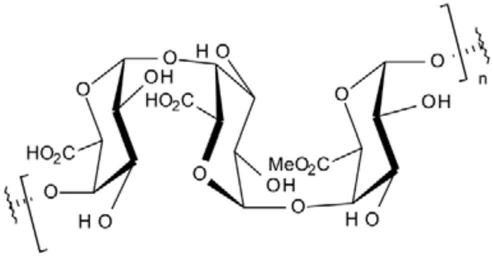
LM Pectin

- Low methoxy pectin

[9000-69-5]

YL158537

100g	$59.00
250g	$130.00
500g	$235.00



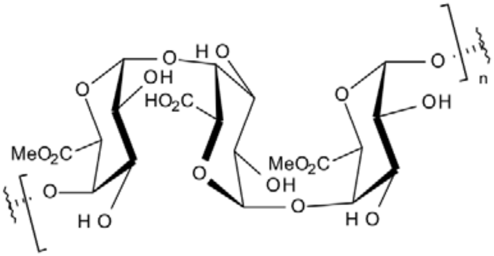
HM Pectin

- High methoxy pectin

[9000-69-5]

YH158538

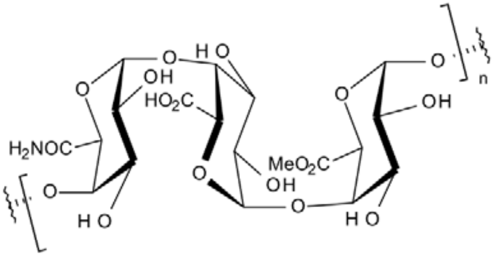
100g	$59.00
250g	$130.00
500g	$235.00



Amidated Pectin

YA158357

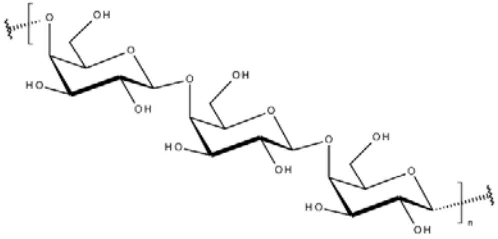
50g	$50.00
100g	$90.00
250g	$175.00



Pectic galactan - From lupin

YP158924

1g	$125.00
2g	$190.00

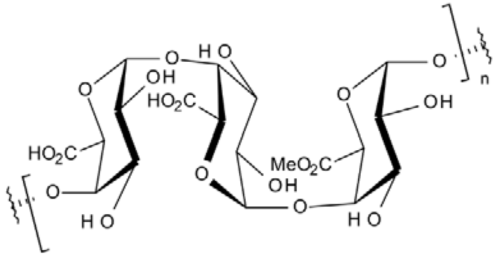


Pectic acid

[9046-40-6]

YP33892

25g	$150.00
50g	$200.00
100g	$300.00



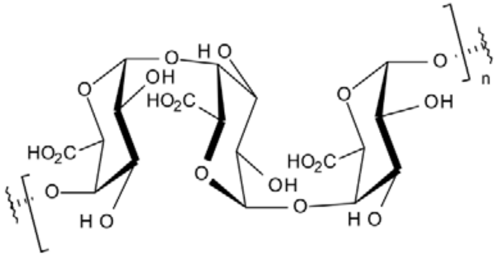
Polygalacturonic acid

- Pectic Acid

[25990-10-7]

FP31687

5g	$35.00
10g	$40.00
25g	$50.00



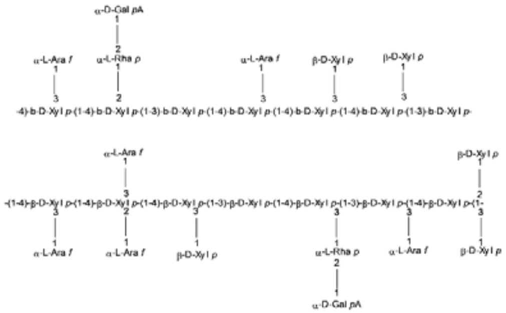
10.1.3 Polysaccharides from Seeds & Legumes

Psyllium seed gum

[8063-16-9]

YP58645

100g	$75.00
250g	$150.00
500g	$275.00



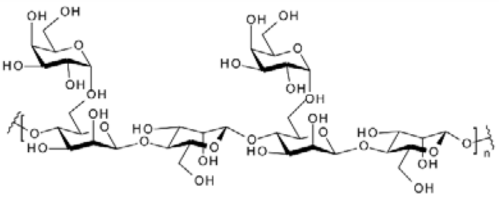
Guar gum

- Galactomannan

[9000-30-0]

YG11700

100g	$75.00
250g	$140.00
500g	$250.00

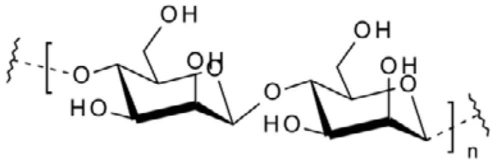


Ivory nut mannan

[37251-47-1]

YI45754

1g	$65.00
2g	$110.00
5g	$250.00



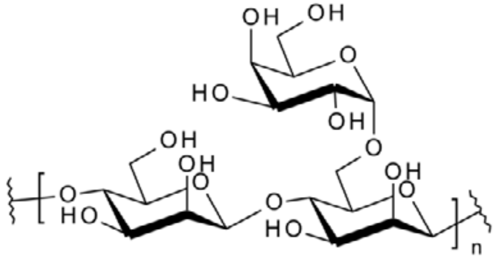
D-Galacto-D-mannan - from carob

- Galactomannan from Ceratonia Siliqua

[11078-30-1]

YG08098

1g	$75.00
2g	$120.00
5g	$240.00



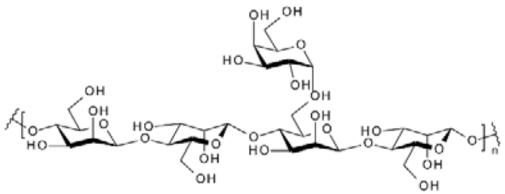
Locust bean gum

- Galactomannnan

[9000-40-2]

YL58654

50g	$60.00
100g	$95.00
250g	$175.00

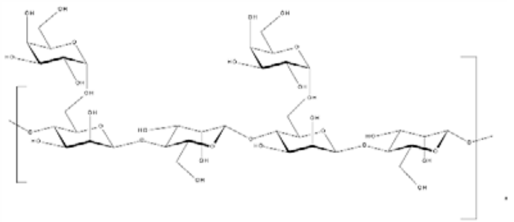


Gum cassia tora

[51434-18-5]

OG157266

Price on Application

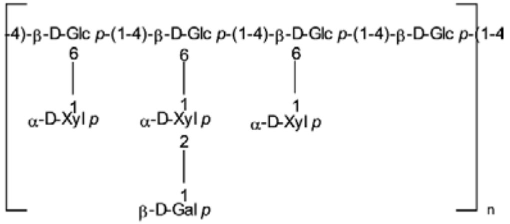


Tamarind gum

[39386-78-2]

YT58655

50g	$65.00
100g	$110.00
250g	$190.00

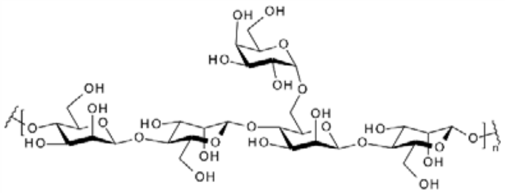


Tara gum

[39300-88-4]

YT58656

100g	$100.00
250g	$175.00
500g	$300.00



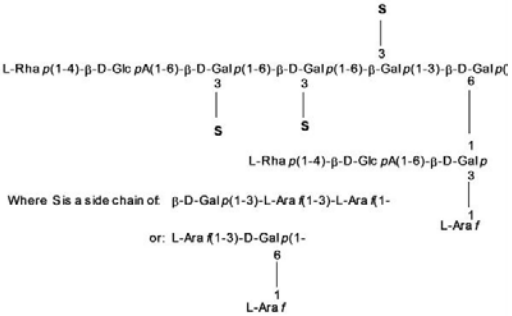
10.1.4 Exudate gums

Gum arabic

[9000-01-5]

YG58641

500g	$60.00
1Kg	$100.00
2Kg	$160.00

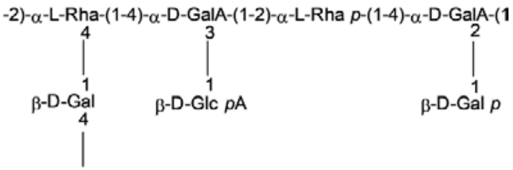


Gum karaya

[9000-36-6]

YG58642

50g	$55.00
100g	$95.00
250g	$175.00

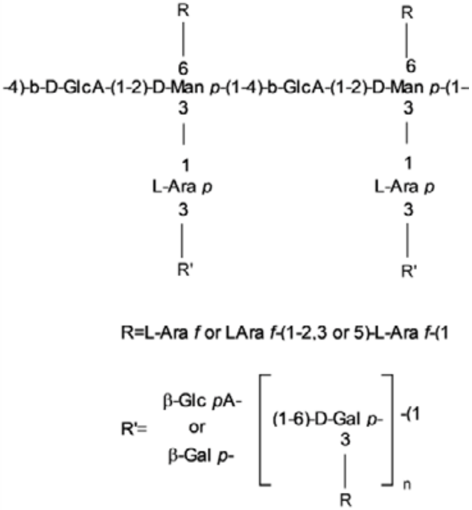


Ghatti gum

[9000-28-6]

YG35531

1kg	$60.00
2kg	$100.00
5kg	$200.00



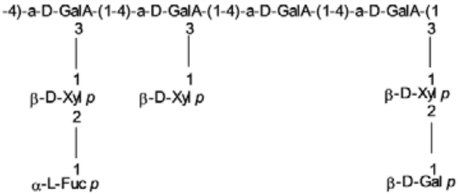
Tragacanth gum

- Tragacanth

[9000-65-1]

YT31961

250g	$50.00
500g	$80.00
1kg	$157.50



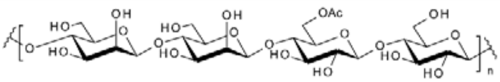
10.1.5 Polysaccharides from Tubers

Konjac glucomannan

[37220-17-0]

YK10336

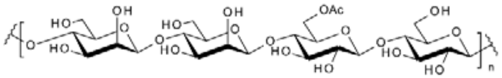
50g	$60.00
100g	$90.00
250g	$150.00



Glucomannan oligosaccharides - from Konjac MW <10KDa

OG63199

5mg	$85.00
10mg	$150.00
25mg	$275.00



10.2 Polysaccharides from Lichens

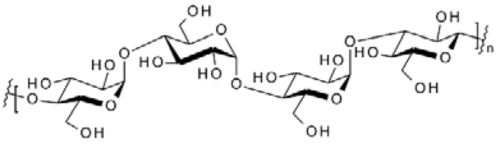
Isolichenan

- (1-3)&(1-4) a-D-glucan

[53025-03-9]

YI11686

100mg	$155.00
250mg	$300.00
500mg	$500.00



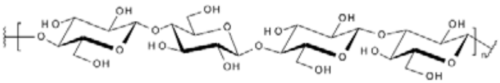
Lichenan - from Cetraria islandica

- Lichenin
- 1,3:1,4-b-D-Glucan

[1402-10-4]

YL11687

1g	$125.00
2g	$190.00
5g	$375.00

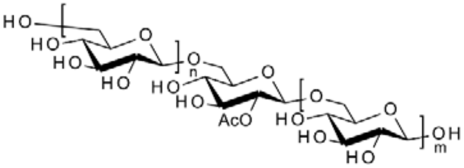


Pustulan

[37331-28-5]

YP15423

100mg	$115.00
250mg	$205.00
500mg	$340.00



10.3 Polysaccharides from Algae

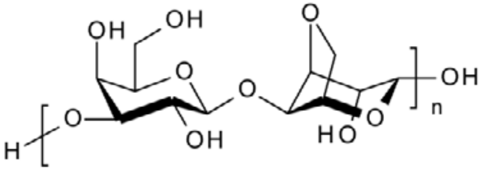
10.3.1 Polysaccharides from Rhodophyceae (Red algae)

Agar

[9002-18-0]

OA39737

250g	$85.00
500g	$150.00
1Kg	$275.00

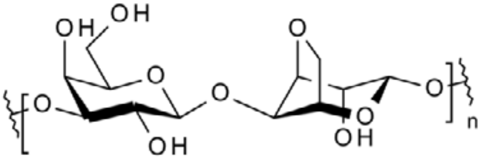


Agarose

[9012-36-6]

YA34896

25g	$47.00
50g	$75.00
100g	$118.00



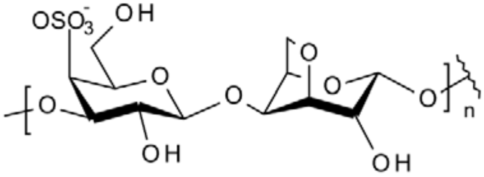
kappa-Carrageenan

- k-Carrageenan

[11114-20-8]

YC30039

100g	$50.00
250g	$75.00
500g	$125.00



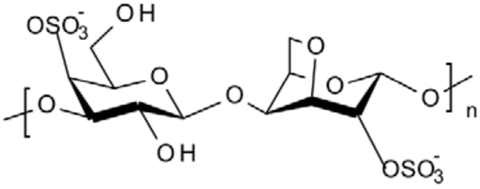
iota-Carrageenan

- i-Carrageenan

[9062-07-1]

YC30038

100g	$75.00
250g	$125.00
500g	$200.00



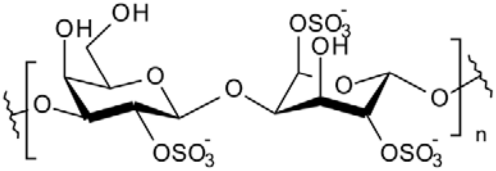
lambda-Carrageenan

- lambda-Carrageenan

[9064-57-7]

YC41782

5g	$50.00
10g	$80.00
25g	$150.00



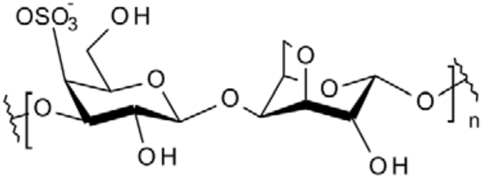
Furcellaran

- Danish agar

[9000-21-9]

YF44604

5Kg	$375.00
10Kg	$600.00
20Kg	$1000.00

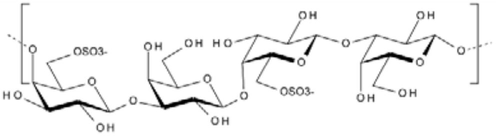


Porphyran

[11016-36-7]

YP157502

25mg	$50.00
50mg	$90.00
100mg	$150.00



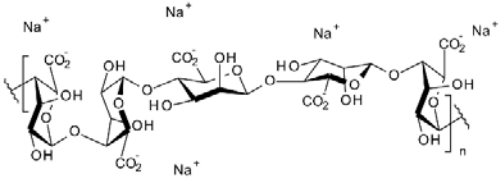
10.3.2 Polysaccharides from Phaeophyceae (brown algae)

Sodium alginate - low viscosity

[9005-38-3]

YS31736

500g	$65.00
1kg	$100.00
2kg	$180.00

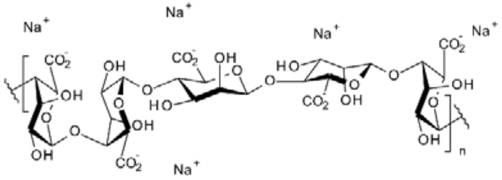


Sodium alginate - high vicosity

[9005-38-3]

YS165508

500g	$75.00
1Kg	$125.00
2Kg	$200.00

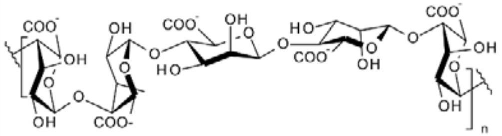


Alginic acid

[9005-32-7]

YA39739

100g	$50.00
250g	$85.00
500g	$150.00



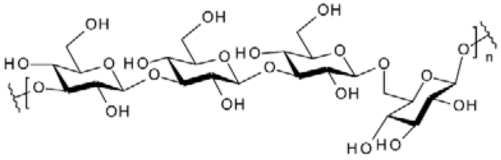
Laminaran - from Laminaria cloustoni

- Laminarin

[9008-22-4]

YL165861

Price on Application



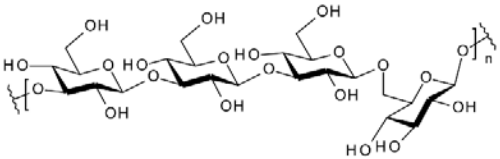
Laminaran - from Laminaria digitata

- Laminarin

[9008-22-4]

YL09900

100mg	$69.00
250mg	$132.50
500mg	$210.00



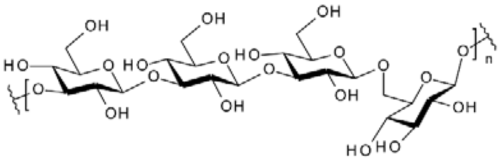
Laminaran - from Eisenia bicyclis

- Laminarin

[9008-22-4]

YL02421

2g	$52.50
5g	$89.30
10g	$136.50



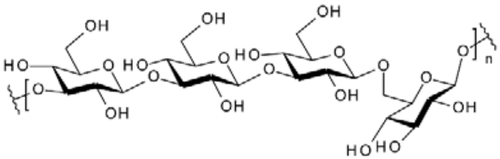
Laminaran - from Thallus laminariae

- Laminarin

[9008-22-4]

YL76431

2g	$52.50
5g	$89.30
10g	$136.50



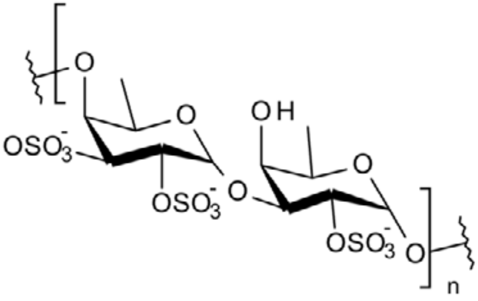
Fucoidan - Ascophyllum nodosum

- Sulfated L-fucan

[9072-19-9]

YF09363

5g	$75.00
10g	$130.00
25g	$250.00

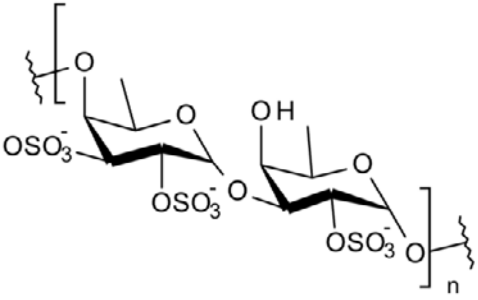


Fucoidan - Ascophyllum nodosum, analytical grade

[9072-19-9]

YF153483

50mg	$90.00
100mg	$150.00
250mg	$250.00



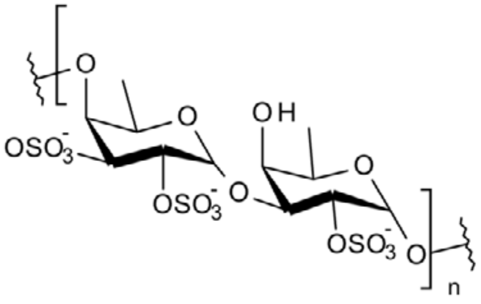
Fucoidan - Fucus serratus

- Sulfated L-fucan

[9072-19-9]

YF09360

10g	$76.00
25g	$152.50
50g	$244.00



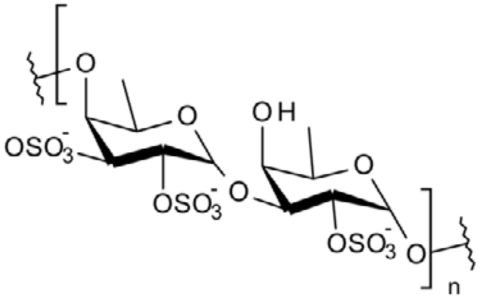
Fucoidan - Fucus vesiculosus

- Sulfated L-fucan

[9072-19-9]

YF57714

50mg	$65.00
100mg	$118.00
250mg	$237.50



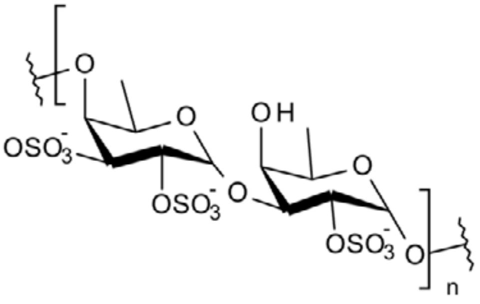
Fucoidan - Laminaria digitata

- Sulfated L-fucan

[9072-19-9]

YF09361

100mg	$60.00
250mg	$95.00
500mg	$150.00

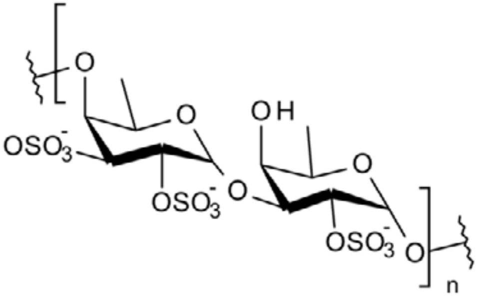


Fucoidan - Laminaria japonicia

[9072-19-9]

YF01606

10g	$50.00
25g	$80.00
50g	$121.00



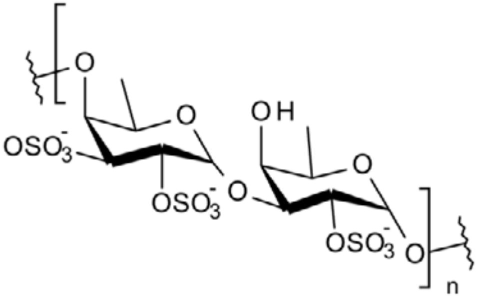
Fucoidan - Pelvetia canaliculata

- Sulfated L-fucan

[9072-19-9]

YF09362

Price on Application



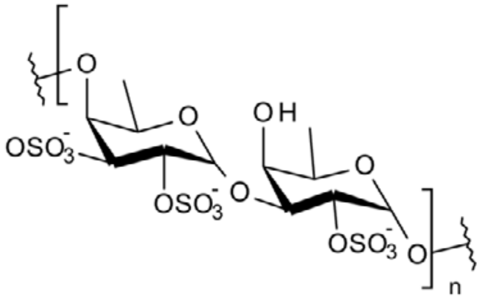
Fucoidan - Macrocystis pyrifera

- Sulfated L-fucan

[9072-19-9]

YF145109

500mg	$50.00
1g	$90.00
2g	$120.00

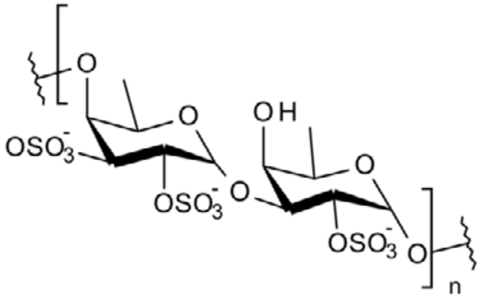


Fucoidan - Alaria

[9072-19-9]

YF157138

10mg	$90.00
25mg	$200.00
50mg	$350.00

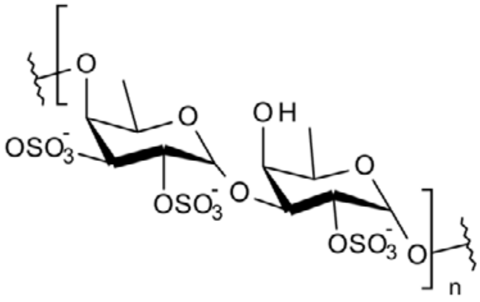


Fucoidan - Cladosiphon

[9072-19-9]

YF146834

10mg	$90.00
25mg	$200.00
50mg	$350.00

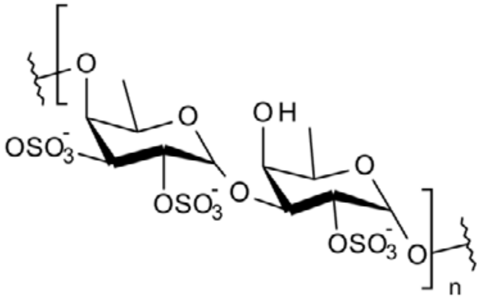


Fucoidan - Durvillea

[9072-19-9]

YF157165

10mg	$90.00
25mg	$200.00
50mg	$350.00

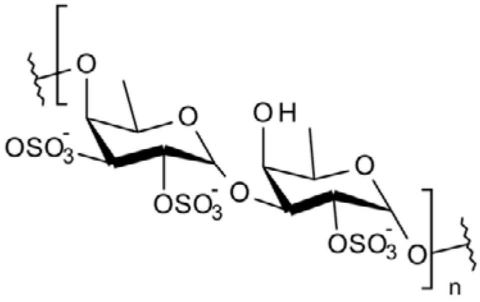


Fucoidan - Ecklonia

[9072-19-9]

YF157166

10mg	$90.00
25mg	$200.00
50mg	$350.00

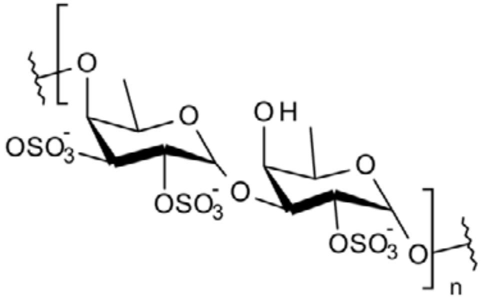


Fucoidan - Lessonia nigrescens

[9072-19-9]

YF146833

10mg	$90.00
25mg	$200.00
50mg	$350.00



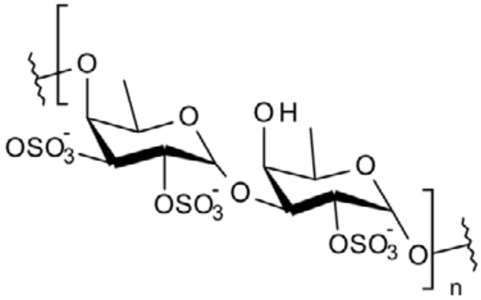
Fucoidan - Sargassum

- Sulfated L-fucan

[9072-19-9]

YF157167

10mg	$90.00
25mg	$200.00
50mg	$350.00

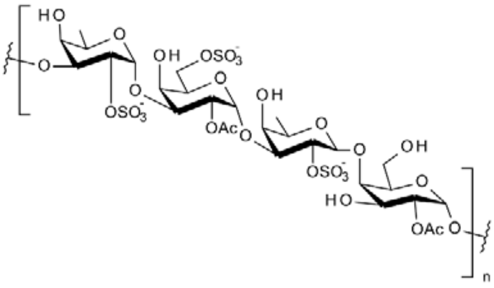


Fucogalactan - from Undaria pinnatifida

[9061-39-6]

YF58639

5g	$60.00
10g	$100.00
25g	$175.00

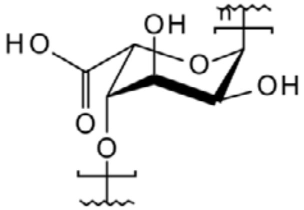


Polyguluronic acid

[36562-70-6]

YP03135

1g	$60.00
2g	$90.00
5g	$175.00

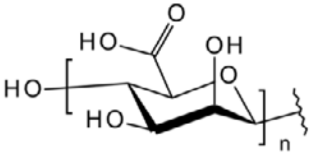


Polymannuronic acid - Average MW < 5000 Da

[29894-36-8]

YP03136

50mg	$100.00
100mg	$150.00
250mg	$250.00

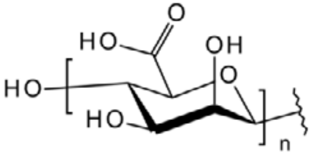


Polymannuronic acid - Average MW > 5000 Da

[29894-36-8]

YP31737

1g	$50.00
2g	$80.00
5g	$140.00



10.3.3 Polysaccharides from Chlorophyceae (green algae)

Ulvan

[164252-34-0]

YU11689

50mg	$60.00
100mg	$100.00
250mg	$150.00

Ulvan - Ulva armoricana-winter-heavy

- Sulfated xylorhamnoglucuronan
- Ulvan MW: 90000 - 980000 (80%)

[164252-34-0]

YU09364

100mg	$85.00
250mg	$155.00
500mg	$265.00

Ulvan - Ulva armoricana-winter-light

- Sulfated xylorhamnoglucuronan
- Ulvan MW: 100000 - 660000 (90%)

[164252-34-0]

YU09365 Price on Application

Ulvan - Ulva rotondata-Autumn

- Sulfated xylorhamnoglycuronan
- Ulvan MW: 87000 - 630000 (80%)

[164252-34-0]

YU09366

500mg	$265.00
1g	$450.00
2g	$850.00

Ulvan - Ulva rotondata-Summer

- Sulfated xylorhamnoglycuronan
- Ulvan MW: 140000 - 1050000 (78%)

[164252-34-0]

YU09367

500mg	$265.00
1g	$450.00
2g	$850.00

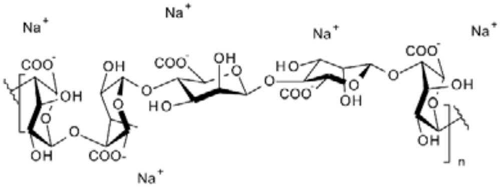
10.4 Polysaccharides from Microorganisms

10.4.1 Polysaccharides from gram negative bacteria

Bacterial alginate - from fermentation of Azotobacter vinelandii or Pseudomonas mendocina

YB58638

1g	$175.00
2g	$320.00
5g	$625.00

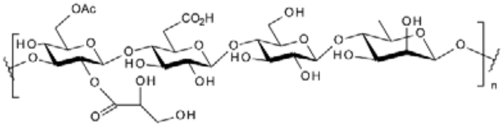


Gellan gum

[71010-52-1]

YG153497

500g	$60.00
1Kg	$100.00
2Kg	$180.00



Kephir gum

- Kefiran

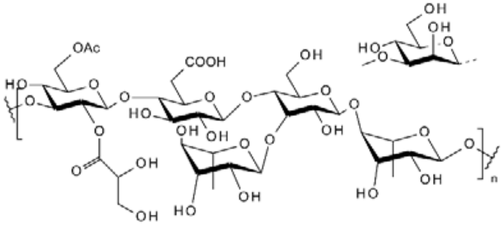
YK165865 Price on Application

Welan gum

[96949-22-3]

YW58646

500mg	$65.00
1g	$110.00
2g	$150.00

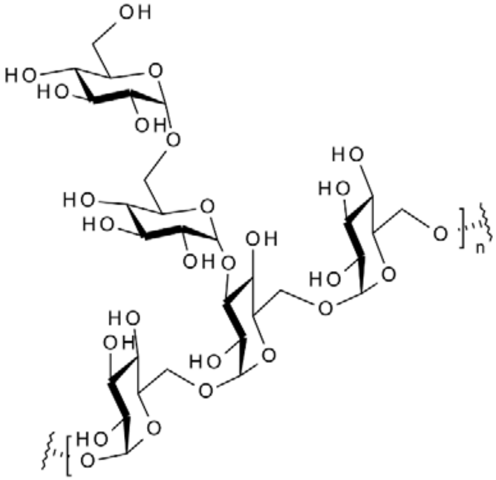


Dextran 3 - MW 2500 - 4000

[9004-54-0]

YD00049

25g	$50.00
50g	$79.00
100g	$140.00

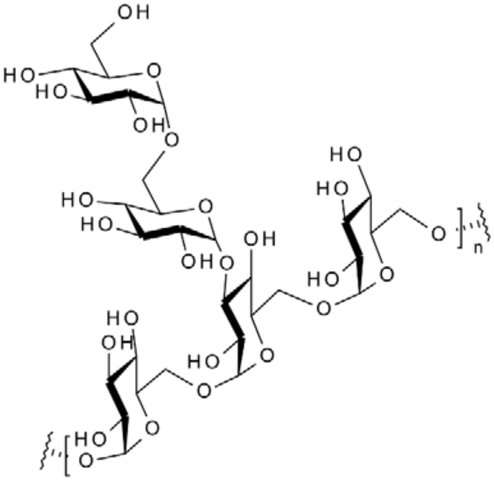


Dextran 6 - MW 5,500 to 7,500

[9004-54-0]

YD35507

50g	$70.00
100g	$110.00
250g	$215.00

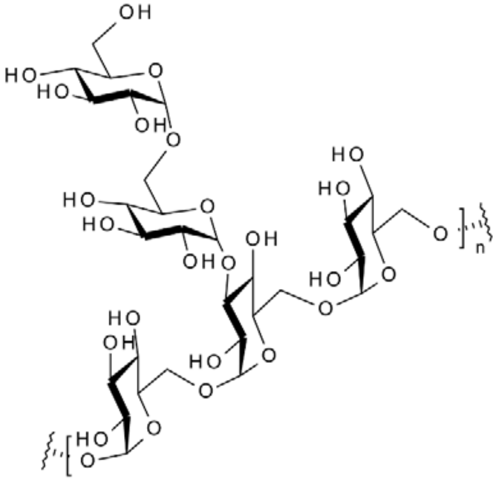


Dextran 5 - MW 4,000 to 6,000

[9004-54-0]

YD44759

100g	$95.00
250g	$175.00
500g	$300.00

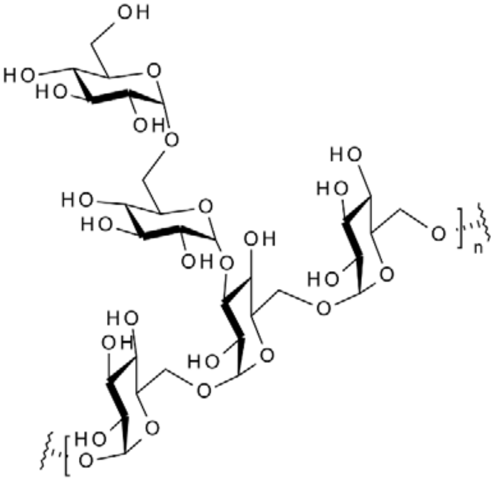


Dextran 10 - MW 9,000 to 11,000

[9004-54-0]

YD32417

50g	$40.00
100g	$56.00
250g	$107.50

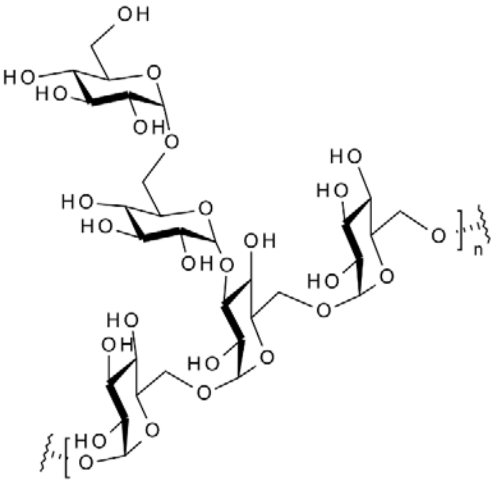


Dextran 40 - MW 35,000 to 45,000

[9004-54-0]

YD01481

50g	$60.00
100g	$98.00
250g	$195.00

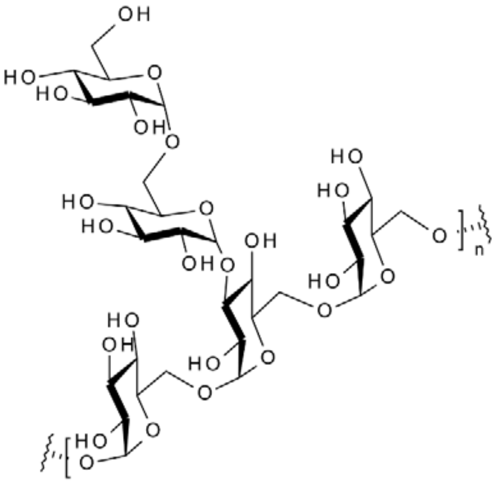


Dextran 500 - MW 450,000 to 550,000

[9004-54-0]

YD34755

50g	$85.00
100g	$130.00
250g	$275.00

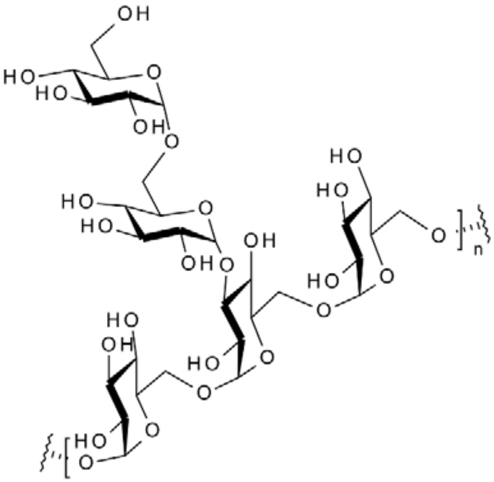


Dextran 70 - MW 64,000 to 76,000

[9004-54-0]

YD30645

50g	$60.00
100g	$100.00
250g	$200.00

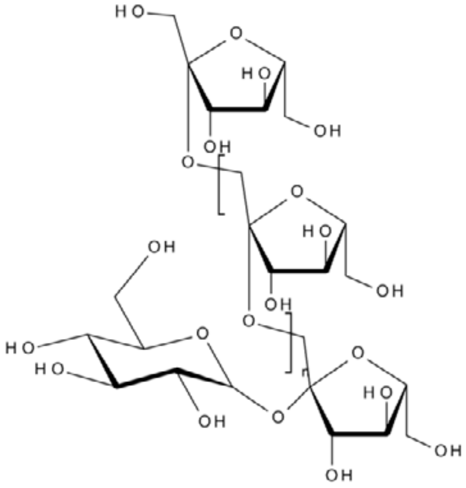


Levan - from Erwinia herbicola

[9013-95-0]

YL76657

100mg	$60.00
250mg	$112.50
500mg	$175.00

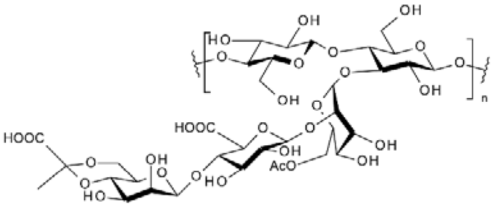


Xanthan gum

[11138-66-2]

YX29708

50g	$52.50
100g	$84.00
250g	$157.50



Arthrobacter stabilis exopolysaccharide

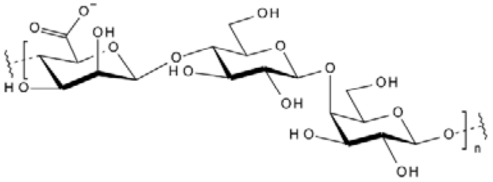
YA157504

5mg	$175.00
10mg	$290.00
25mg	$425.00

Arthrobacter viscosus exopolysaccharide

YA157503

50mg	$120.00
100mg	$190.00
250mg	$375.00



Exopolysaccharide - from Bacillus polymixa

YE165867 Price on Application

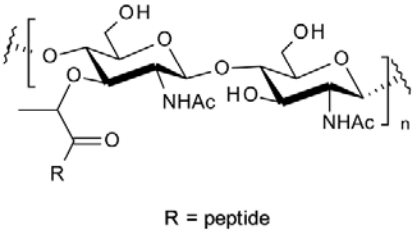
10.4.2 Polysaccharides from gram positive bacteria

Peptidoglycan - from Staphylococcus aureus

- PGN

YP57750

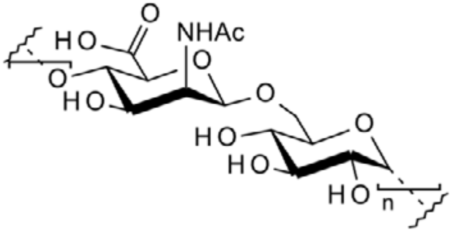
2mg	$90.00
5mg	$150.00
10mg	$250.00



Teichuronic acid

[37251-79-9]

YT30835 Price on Application



10.5 Polysaccharides from Yeasts & Fungi

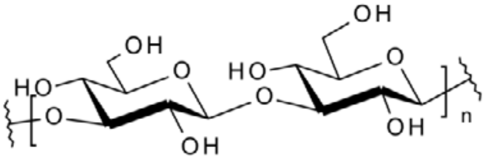
b-D-Glucan - from Yeast (Saccharomyces Cerevisiae)

- 1,3-b-D-Glucan

[9012-72-0][9051-97-2]

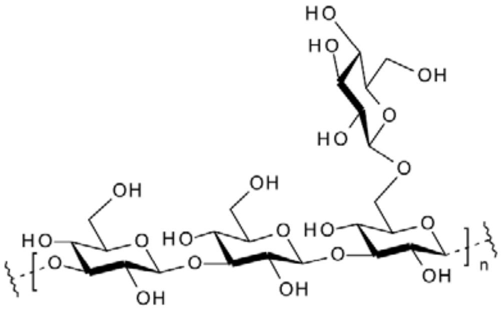
YG30829

250g	$80.00
500g	$135.00
1kg	$250.00



Glucan - from Piptoporus betulinus

YG165864 Price on Application

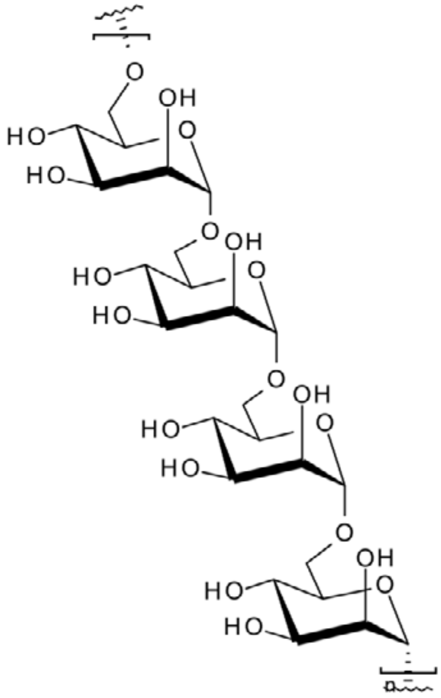


Mannan - from Saccharomyces cerevisiae

[9036-88-8]

YM63069

250mg	$65.00
500mg	$100.00
1g	$180.00



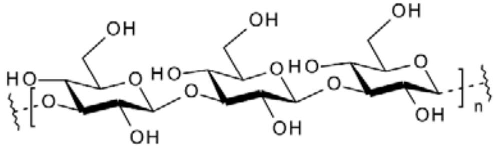
Curdlan

• b-1,3-Glucan

[54724-00-4]

YC46078

1g	$75.00
2g	$130.00
5g	$220.00



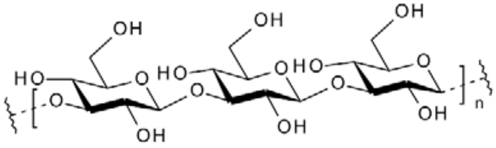
Pachyman - from Poria cocos

• b-D-Glucan

[9037-88-1]

YG158923

1g	$85.00
2g	$150.00
5g	$275.00

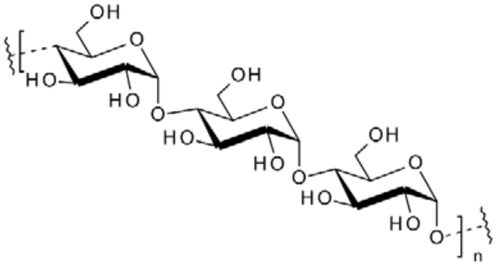


Nigeran

[31799-84-5]

YN157505

100mg	$190.00
250mg	$350.00
500mg	$550.00

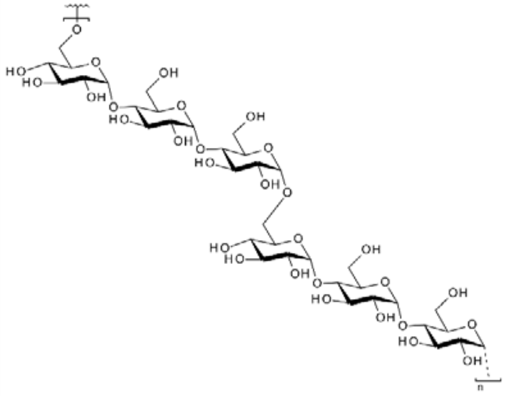


Pullulan

[9057-02-7]

YP07957

100g	$40.00
250g	$75.00
500g	$100.00

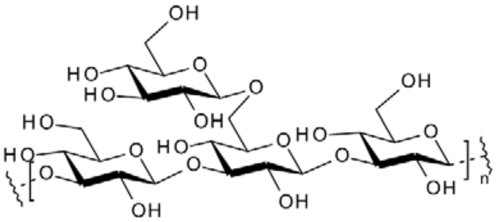


Schizophyllan

- Sonifilan
- Sizofiran

[9050-67-3]

YS46139 Price on Application

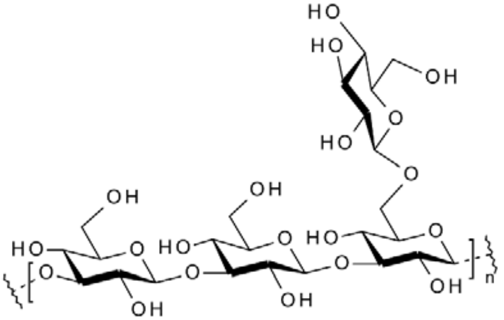


Scleroglucan

[39464-87-4]

YS09784

2g	$60.00
5g	$105.00
10g	$175.00

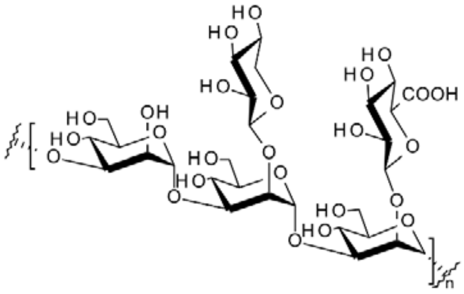


Glucurono-xylomannan - from Cryptococcus neoformans

[76082-65-0]

YG11701

2mg	$60.00
5mg	$110.00
10mg	$157.50



Galactooligosaccharides

- GOS

OG32134

100g	$70.00
250g	$125.00
500g	$230.00

10.6 Polysaccharides from Animal or Fish Tissues

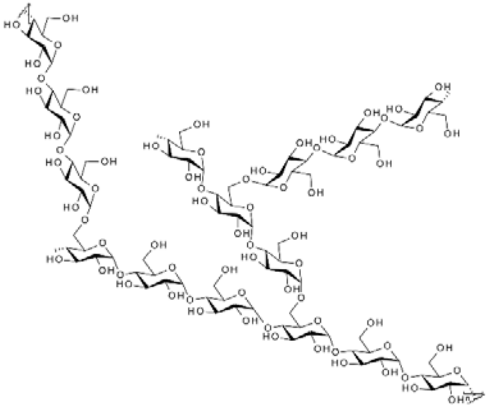
10.6.1 Energy Storage Polysaccharides

Glycogen - from bovine liver

[9005-79-2]

YG162526

50mg	$50.00
100mg	$90.00
250mg	$200.00

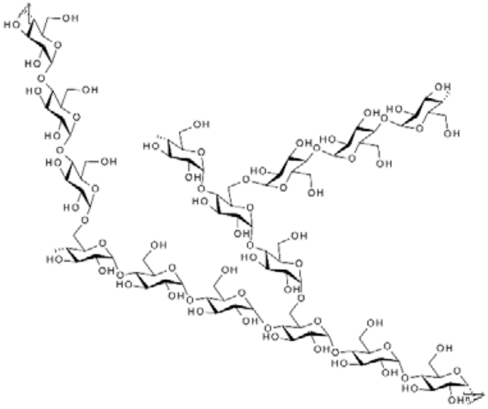


Glycogen - from oyster

[9005-79-2]

YG40133

10g	$250.00
25g	$450.00
50g	$800.00

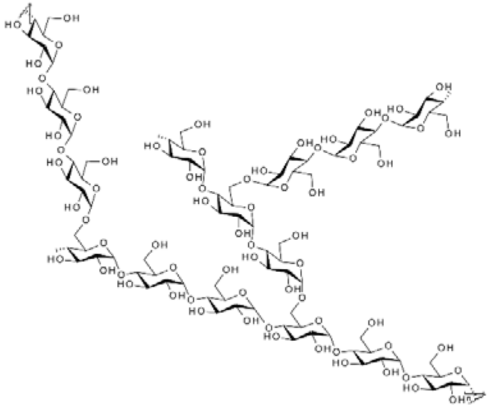


Glycogen - from oyster for molecular biology

[9005-79-2]

YG164194

10g	$490.00

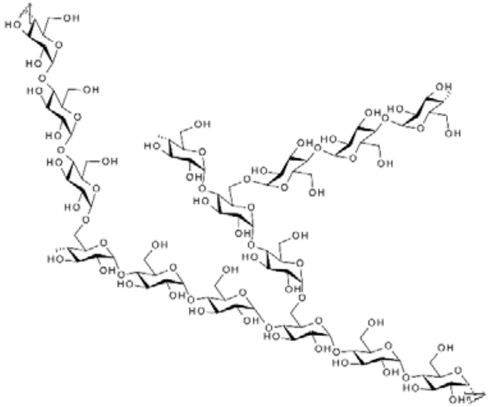


Glycogen - from rabbit liver

[9005-79-2]

YG71459

250mg	$80.00
500mg	$150.00
1g	$270.00



10.6.2 Structural Polysaccharides

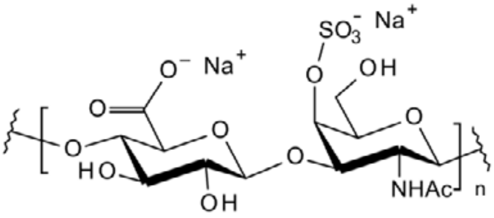
Chondroitin sulfate sodium salt

- Sulfated glycosaminoglycan

[9082-07-9]

YC04273

50g	$50.00
100g	$90.00
250g	$167.50

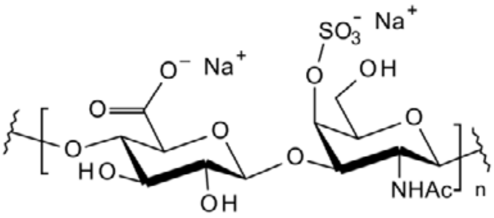


Chondroitin sulfate A sodium salt - Average MW 10,000 - 30,000

[39455-18-0]

YC15288

100g	$68.00
250g	$125.00
500g	$190.00



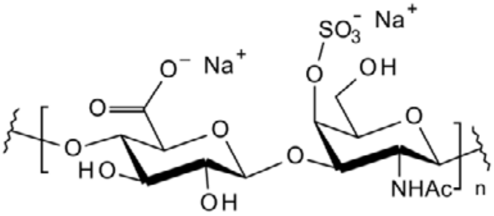
Chondroitin sulfate A sodium salt - Average MW 20,000 - 30,000

- Chondroitin 4-sulfate sodium salt

[39455-18-0]

YC31416

100g	$60.00
250g	$120.00
500g	$200.00

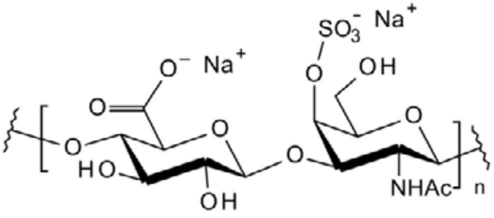


Chondroitin sulfate A sodium salt - Average MW 100,000

- Chondroitin 4-sulfate sodium salt

[39455-18-0]

YC31419 Price on Application



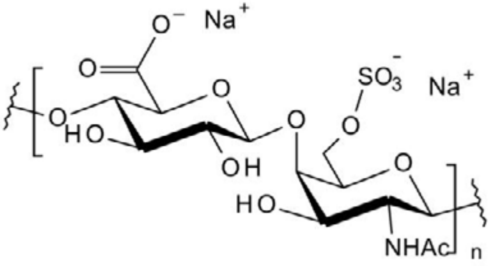
Chondroitin sulfate C sodium salt

- Chondroitin 6-sulfate sodium salt

[12678-07-8]

YC31458

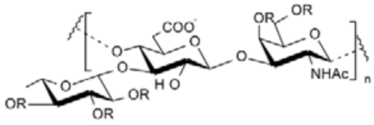
10g	$40.00
25g	$80.00
50g	$125.00



Fucosylated chondroitin sulfate

- FucCS

YF76156 Price on Application



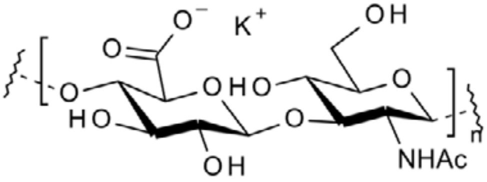
R=OH or SO_3^-

Hyaluronic acid potassium salt - from Cockscomb

[31799-91-4]

FH71608

50mg	$50.00
100mg	$80.00
250mg	$160.00

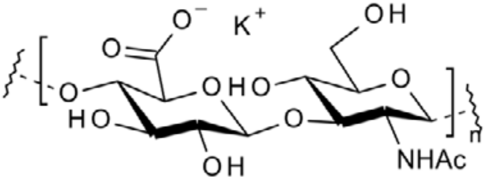


Hyaluronic acid potassium salt - from human umbilical cord

- Potassium hyaluronate

[31799-91-4]

FH146394 Price on Application

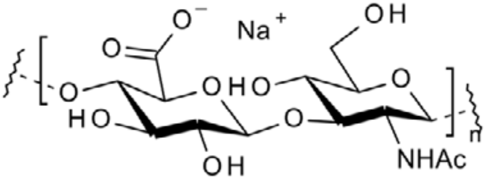


Hyaluronic acid sodium salt - Average MW 0.6 - 1.0 million Da

[9067-32-7]

FH71634

25g	$60.00
50g	$100.00
100g	$150.00



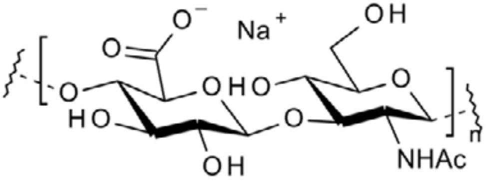
Hyaluronic acid sodium salt - Average MW 1.0 - 2.0 million Da

- Poly(b-glucuronic acid-[1→3]-b-N-acetylglucosamine-[1→4])

[9067-32-7]

YH05852

25g	$65.00
50g	$95.00
100g	$150.00

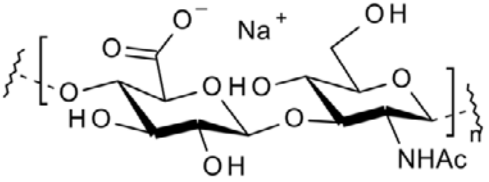


Hyaluronic acid sodium salt - Average MW 1.5 - 2.5 million Da

- Poly(b-glucuronic acid-[1→3]-b-N-acetylglucosamine-[1→4])

[9067-32-7]

YH141813 Price on Application

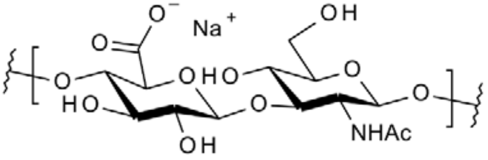


Hyaluronic acid sodium salt - Average MW 1.8 - 2.5 million Da

[9067-32-7]

FH145201

25g	$195.00
50g	$300.00
100g	$400.00

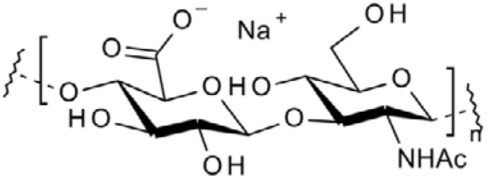


Hyaluronic acid sodium salt - Average MW 2.0 - 2.5 million Da

[9067-32-7]

FH139153

2g	$48.00
5g	$90.00
10g	$140.00

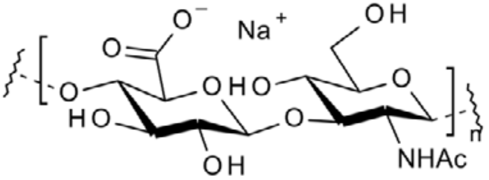


Hyaluronic acid sodium salt - Average MW 70,000-80,000

[9067-32-7]

FH159379

10g	$40.00
25g	$78.25
50g	$125.00

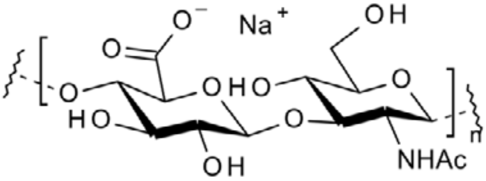


Hyaluronic acid sodium salt - Low molecular weight 10,000 - 50,000

[9067-32-7]

FH76335

25g	$60.00
50g	$100.00
100g	$156.00

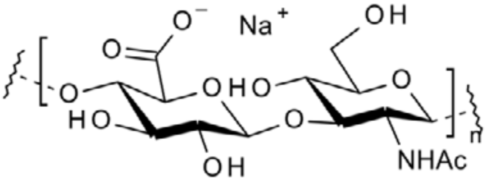


Hyaluronic acid sodium salt - Low molecular weight 40,000 - 50,000

[9067-32-7]

FH01773

25g	$65.00
50g	$107.00
100g	$178.00

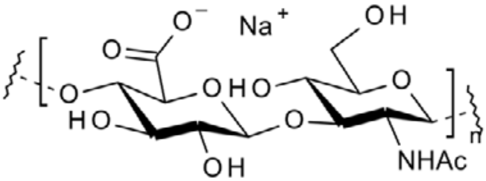


Hyaluronic acid sodium salt - Low molecular weight 80,000 - 100,000

[9067-32-7]

FH63427

25g	$70.00
50g	$110.00
100g	$180.00

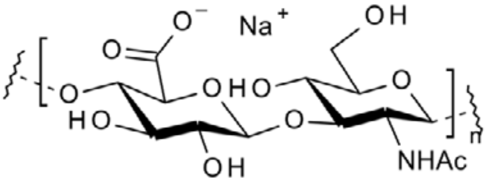


Hyaluronic acid sodium salt - Extra low molecular weight 8,000-15,000

[9067-32-7]

FH63426

10g	$60.00
25g	$100.00
50g	$150.00



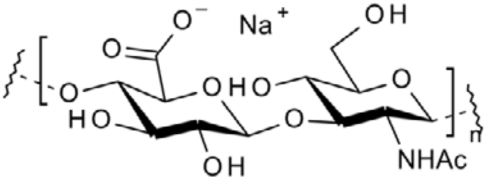
Hyaluronic acid sodium salt - EP7, Average MW 0.2-0.5 million Daltons

- Poly(b-glucuronic acid-[1→3]-b-N-acetylglucosamine-[1→4])

[9067-32-7]

YH72470

5g	$75.00
10g	$125.00
25g	$200.00

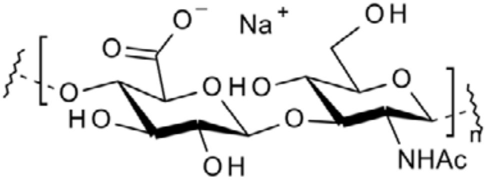


Hyaluronic acid sodium salt - EP7, Average MW 0.6-2.5 million Daltons

[9067-32-7]

FH76752

Price on Application



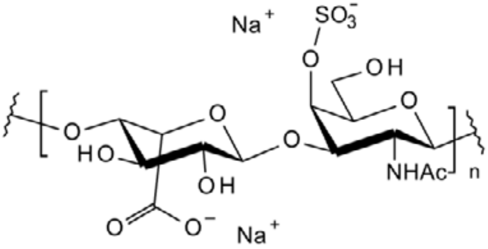
Dermatan sulphate sodium salt

- Chondroitin sulfate B sodium salt
- b-Heparin

[54328-33-5]

YD30120

10mg	$52.00
25mg	$95.00
50mg	$150.00



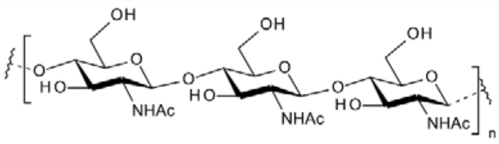
Chitin

- (1-4)-2-acetamido-2-deoxy-b-D-glucan

[1398-61-4]

YC04085

250g	$50.00
500g	$85.00
1kg	$150.00

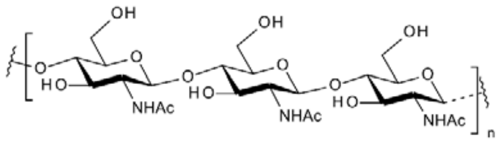


Colloidal Chitin

[1398-61-4]

YC159471

1g	$170.00



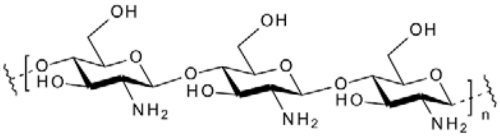
Chitosan

- (1,4)-2-amino-2-deoxy-b-D-glucan
- Deacetylated chitin

[9012-76-4]

YC06764

250g	$50.00
500g	$95.00
1kg	$154.00

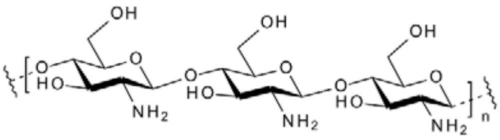


Chitosan - Water soluble

[9012-76-4]

YC58325

50g	$92.50
100g	$139.00
250g	$280.00

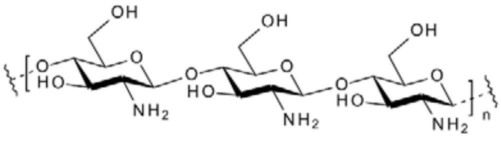


Chitosan - Molecular weight 50,000-190,000

[9012-76-4]

YC158300

100g	$60.00
250g	$100.00
500g	$150.00

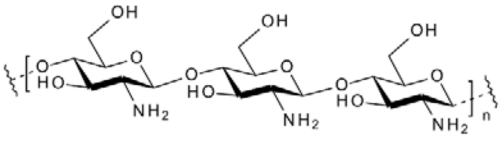


Chitosan - Molecular weight 190,000-310,000

[9012-76-4]

YC158299

250g	$50.00
500g	$90.00
1Kg	$160.00

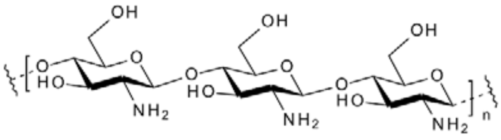


Chitosan - Molecular weight 310,000-375,000

[9012-76-4]

YC158301

100g	$50.00
250g	$100.00
500g	$160.00



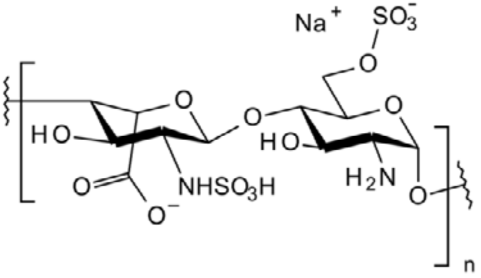
10.6.3 Polysaccharides with Key Physiological Functions

De-N-sulfated heparin sodium salt

[61932-66-9]

YD58544

10mg	$65.00
25mg	$115.00
50mg	$180.00

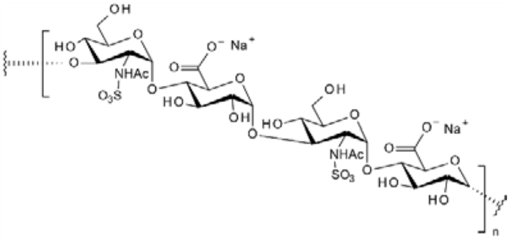


N-Acetyl-de-O-sulfated heparin sodium salt

[133686-69-8]

YA58545

5mg	$153.00
10mg	$235.00
25mg	$375.00

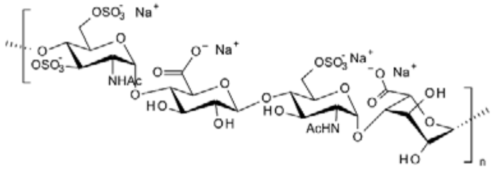


N-Acetyl-heparin

[134498-62-7]

YA58546

10mg	$67.40
25mg	$123.75
50mg	$198.00

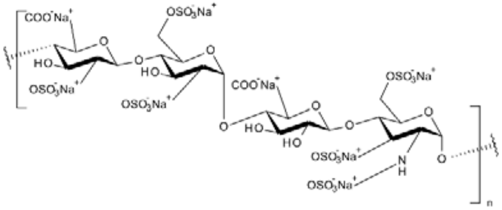


Heparan sulphate sodium salt

[57459-72-0]

YH30121

1mg	$250.00
2mg	$390.00
5mg	$750.00

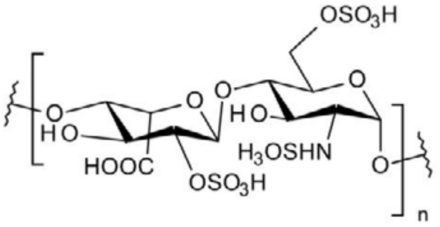


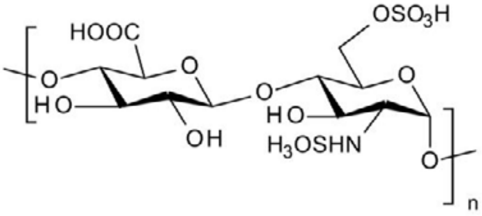
Heparin sodium salt

[9041-08-1]

YH09354

1g	$50.00
2g	$80.00
5g	$175.00



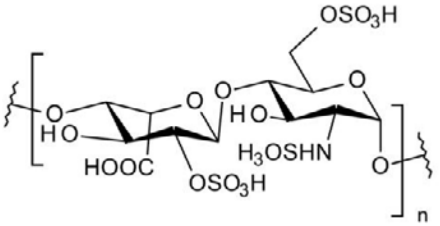


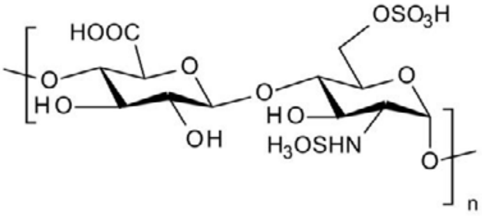
Heparin

[9005-49-6]

YH03833

Price on Application

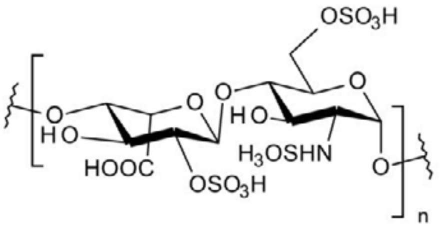


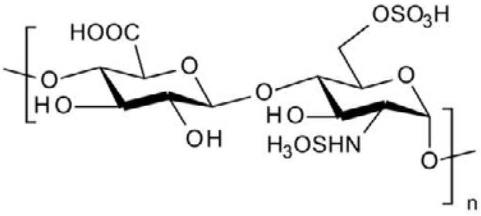


Low calcium heparin

[9005-49-6]

YL30119 100mg $342.00



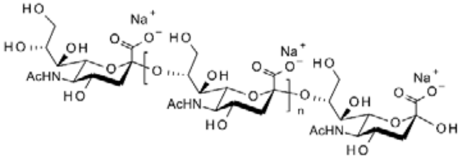


Colominic acid sodium salt - Average MW 30,000

- Poly[2,8-(N-acetylneuraminic acid sodium salt)]

[70431-34-4]

YC11298 Price on Application



10.7 Functionally Modified Polysaccharides

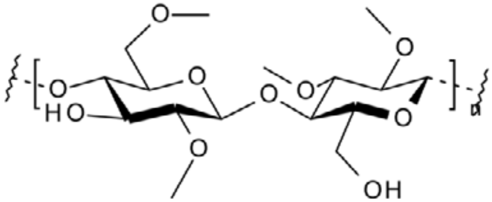
10.7.1 Methyl and Ethyl Cellulose

Methyl cellulose - About 15cP

[9004-67-5]

YM30635

250g	$50.00
500g	$100.00
1kg	$150.00

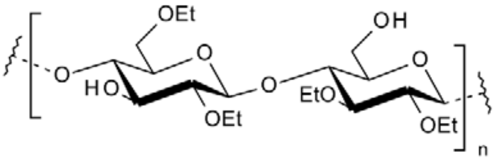


Ethyl cellulose

[9004-57-3]

YE43907

1Kg	$150.00
2Kg	$250.00
5Kg	$475.00



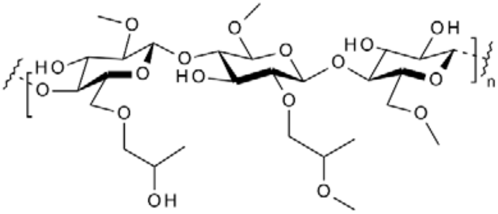
10.7.2 Hydroxypropyl, Hydroxyethyl and Ethyl Hydroxyethyl Cellulose

Hydroxypropyl cellulose - Average MW 80,000

[9004-64-2]

YH63490

50g	$125.00
100g	$190.00
250g	$375.00

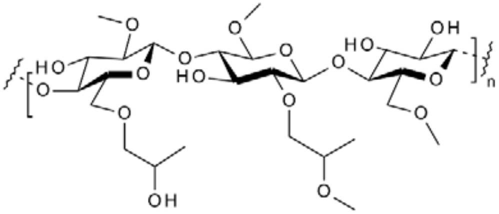


Hydroxypropyl cellulose - Average MW 100,000

[9004-64-2]

YH63491

100g	$95.00
250g	$150.00
500g	$185.00

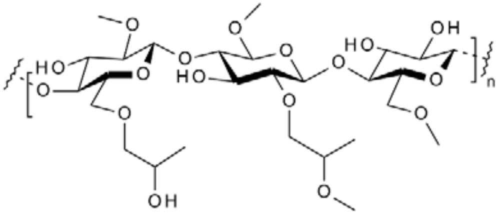


Hydroxypropyl cellulose - Average MW 150,000

[9004-64-2]

YH158877

100g	$130.00
250g	$225.00
500g	$350.00

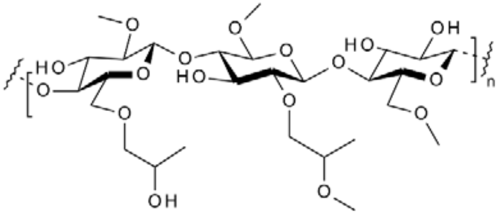


Hydroxypropyl cellulose - Average MW 200,000

[9004-64-2]

YH158878

Price on Application

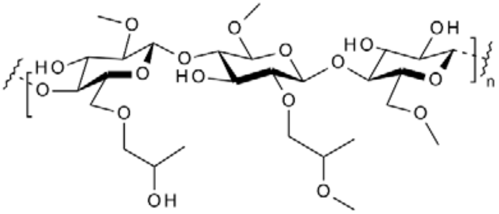


Hydroxypropyl cellulose - Average MW 370,000

[9004-64-2]

YH63492

250g	$375.00
500g	$600.00
1Kg	$950.00

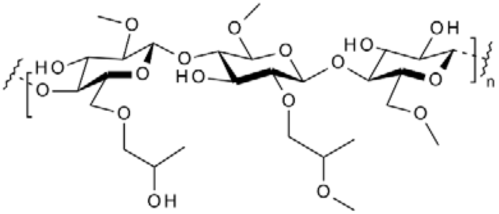


Hydroxypropyl cellulose - Average MW 1,000,000

[9004-64-2]

OH63493

100g	$190.00
250g	$350.00
500g	$600.00

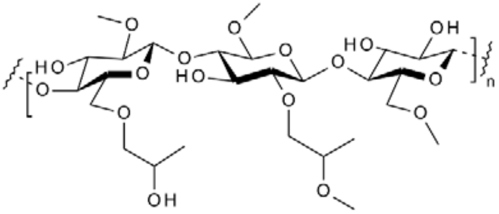


Hydroxypropyl cellulose - Average MW 50,000 - 1250,000

[9004-64-2]

YH16040

250g	$65.00
500g	$95.00
1kg	$150.00

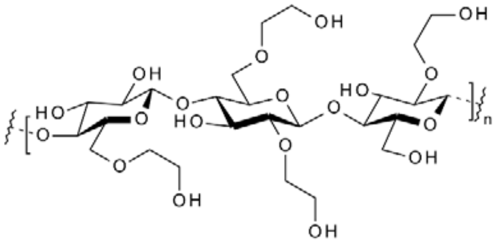


Hydroxyethyl cellulose

[9004-62-0]

YH30634

250g	$70.00
500g	$105.00
1kg	$180.00



10.7.3 Hydroxypropyl Methyl Cellulose

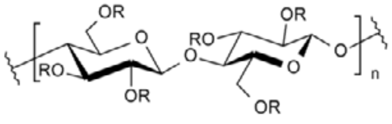
(Hydroxypropyl)methyl cellulose - Viscocity 3000-5600 cP

- Hypromellose

[9004-65-3]

YH59732

500g	$60.00
1Kg	$100.00
2Kg	$170.00



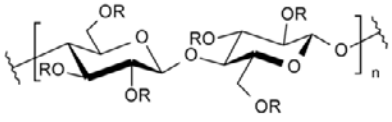
R = -H, $-CH_3$ or $-CH_2CHOHCH_3$

(Hydroxypropyl)methyl cellulose - USP39, Viscocity 3000-5600 cP

[9004-65-3]

YH160972

Price on Application



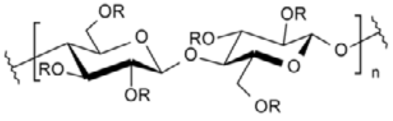
R = -H, $-CH_3$ or $-CH_2CHOHCH_3$

(Hydroxypropyl)methyl cellulose - Viscocity 40-60 cP, 2 % in H2O (20 °C)

[9004-65-3]

YH158082

250g	$65.00
500g	$115.00
1Kg	$195.00



R = -H, $-CH_3$ or $-CH_2CHOHCH_3$

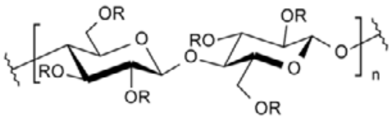
(Hydroxypropyl)methyl cellulose - Viscocity 80-120 cP, 2 % in H2O (20 °C)

- Hypromellose

[9004-65-3]

YH32865

500g	$70.00
1kg	$100.00
2kg	$160.00



R = -H, $-CH_3$ or $-CH_2CHOHCH_3$

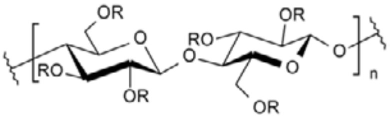
(Hydroxypropyl)methyl cellulose - USP39, Viscocity 80-120 cP, 2 % in H2O (20 °C)

- Hypromellose

[9004-65-3]

YH160970

Price on Application



R = -H, $-CH_3$ or $-CH_2CHOHCH_3$

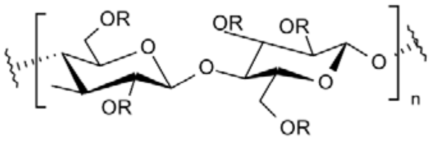
10.7.4 Hydroxypropyl Methyl Cellulose Phthalate

(Hydroxypropyl)methyl cellulose phthalate

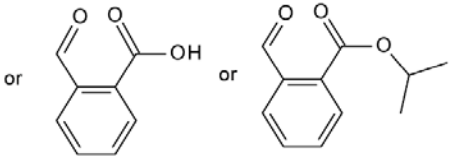
[9050-31-1]

YH44175

100g	$60.00
250g	$90.00
500g	$140.00



R= -H, $-CH_3$ or $-CH_2\text{-}CHOH\text{-}CH_3$



10.7.5 Sodium Carboxymethyl Cellulose

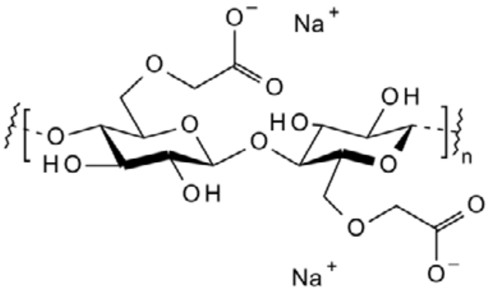
Carboxymethyl cellulose sodium - Viscosity 1000 - 1300 mPa·s

- CM Cellulose
- Carmellose

[9004-32-4]

YC44523

500g	$60.00
1kg	$100.00
2kg	$160.00

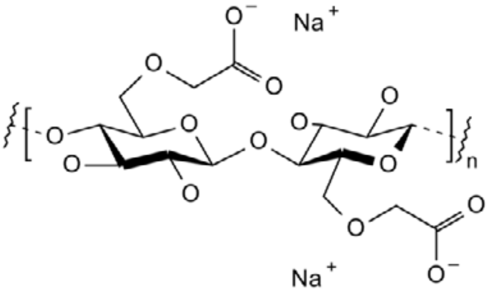


Carboxymethyl cellulose

[9000-11-7]

YC158179

50g	$40.00
100g	$65.00
250g	$100.00

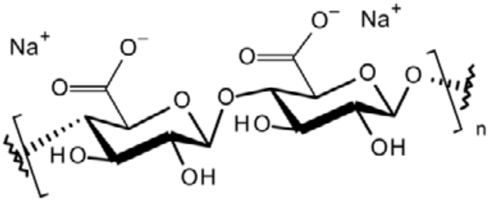


10.7.6 Celluronic Acid

Cellouronic acid sodium salt

YC59633

Price on Application



10.7.7 Cellulose Acetate Hydrogen Phthalate

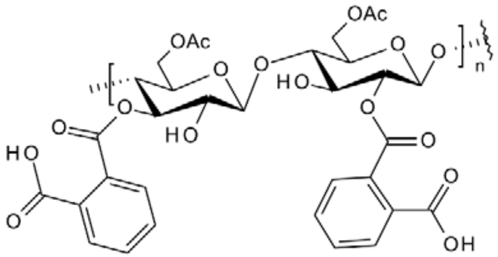
Cellulose acetate hydrogen phthalate

- Cellacefate

[9004-38-0]

YC43910

25g	$75.00
50g	$125.00
100g	$200.00



10.7.8 Cellulose Acetates

Cellulose acetate - MW 30,000

- Acetylcellulose

[9004-35-7]

YC44453

25g	$60.00
50g	$75.00
100g	$95.00

10.7.9 Carboxymethyl Chitosan

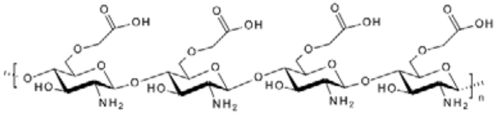
Carboxymethyl chitosan

- N-Carboxymethyl chitosan

[83512-85-0]

YC29683

5g	$60.00
10g	$100.00
25g	$150.00



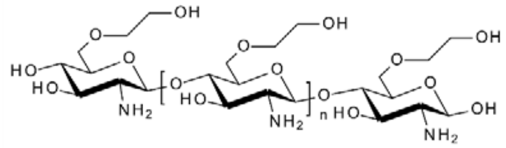
10.7.10 Glycol Chitosan

Glycol chitosan

[123938-86-3]

OG45753

250mg	$77.50
500mg	$125.00
1g	$180.00



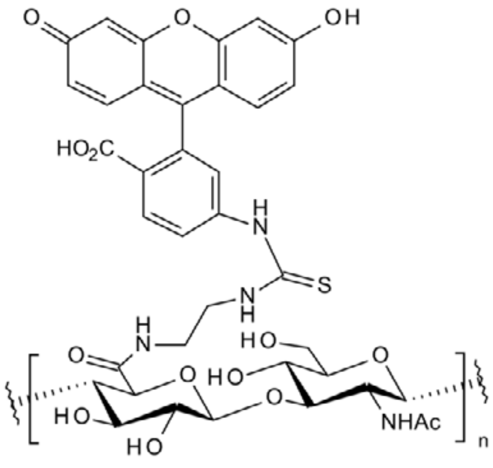
10.7.11 Hyaluronate fluorescein

Hyaluronate fluorescein - MW - 800kDa

- Fluorescein hyaluronic acid

YH45321

1mg	$70.00
2mg	$120.00
5mg	$210.00

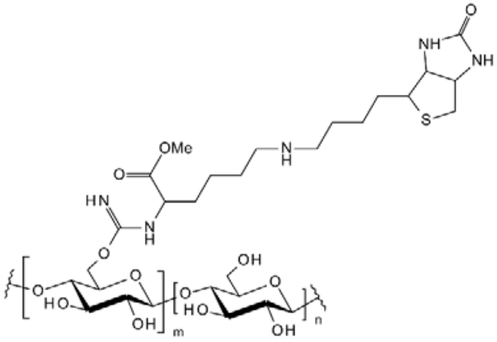


10.7.12 Dextran Biotin, Rhodamine

Biotin-dextran MW 10000

YB34651

5mg	$131.30
10mg	$210.00
25mg	$472.50

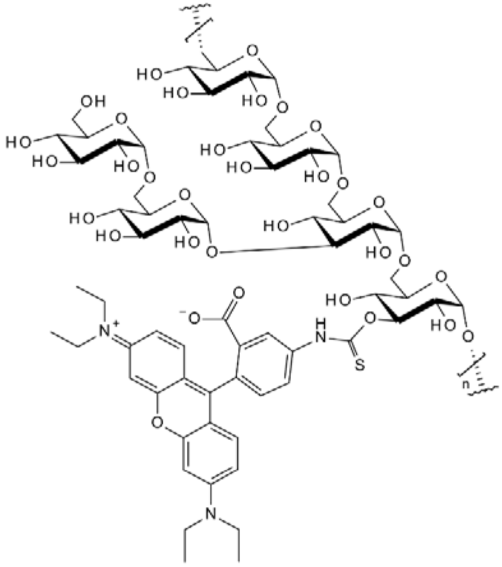


Rhodamine B isothiocyanate-dextran - Average MW 10,000

- Dextran rhodamine

YD58701

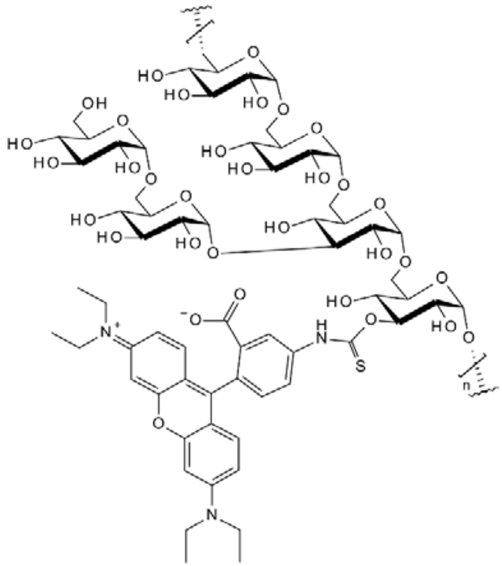
25mg	$90.00
50mg	$150.00
100mg	$250.00



Rhodamine B isothiocyanate-dextran - Average MW 70,000

YR166142

100mg	$250.00
250mg	$475.00
500mg	$750.00



10.7.13 Dyed polysaccharides

Azo-Xyloglucan

YA158177

1g	$195.00
2g	$300.00
5g	$475.00

Azo-fructan

YA165862

Price on Application

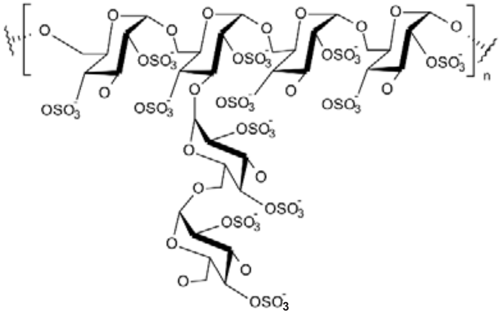
10.7.14 Dextran Sulphate

Dextran sulfate sodium salt - MW 5,000-8,000

[9011-18-1]

YD31801

25g	$75.00
50g	$140.00
100g	$220.00

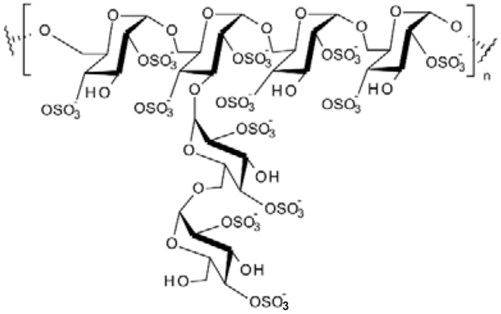


Dextran sulfate sodium salt - MW 6,000-10,000

[9011-18-1]

YD31802

50g	$250.00
100g	$350.00
250g	$550.00

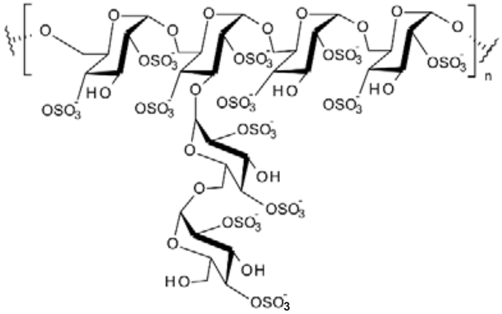


Dextran sulfate sodium salt - MW 4500-5500

[9011-18-1]

YD158380

25g	$150.00
50g	$200.00
100g	$320.00

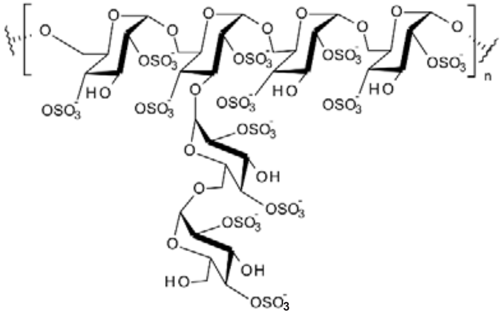


Dextran sulfate sodium salt - MW 8,000

[9011-18-1]

YD59550

50g	$150.00
100g	$250.00
250g	$500.00

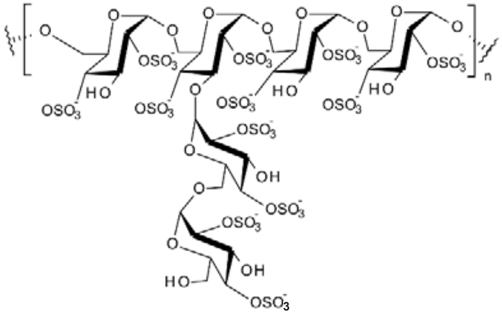


Dextran sulfate sodium salt - MW 9,000-11,000 - from Leuconostoc spp

[9011-18-1]

YD45147

500g	$390.00
1Kg	$500.00
2Kg	$900.00

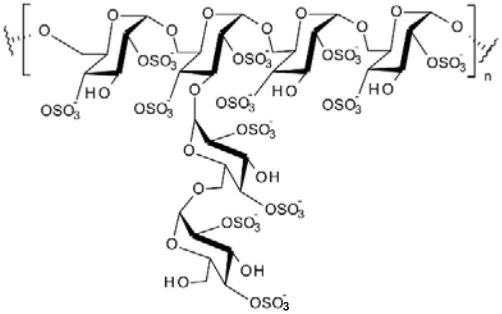


Dextran sulfate sodium salt - MW 20,000

[9011-18-1]

YD31803

500g	$390.00
1Kg	$500.00
2Kg	$900.00

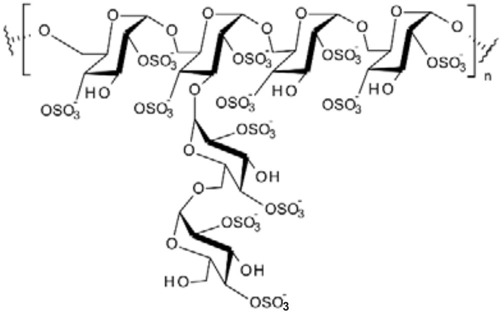


Dextran sulfate sodium salt - MW 40,000

[9011-18-1]

YD31804

10g	$60.00
25g	$95.00
50g	$140.00

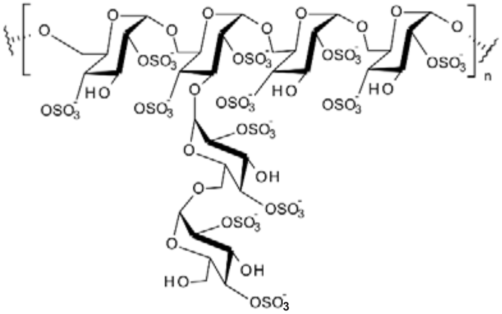


Dextran sulfate sodium salt - MW 50,000

[9011-18-1]

YD59741

25g	$170.00
50g	$225.00
100g	$385.00

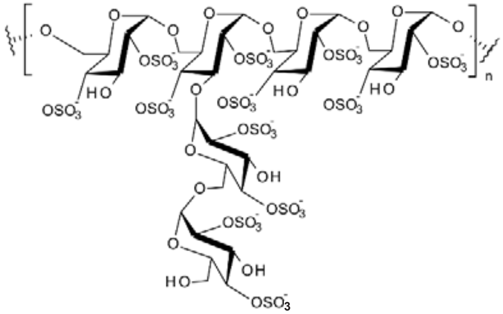


Dextran sulfate sodium salt - MW 100,000

[9011-18-1]

YD59549

5g	$190.00
10g	$295.00
25g	$500.00

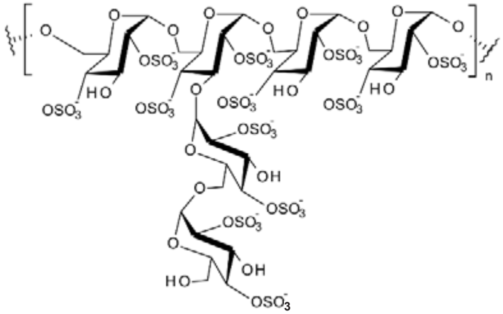


Dextran sulfate sodium salt - MW 500,000

[9011-18-1]

YD32562

10g	$45.00
25g	$80.00
50g	$135.00

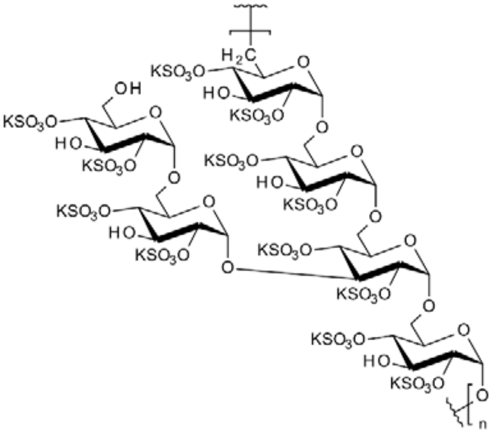


Dextran sulfate potassium salt

[39422-86-1]

YD31035

1g	$55.00
2g	$94.50
5g	$152.30



10.7.15 Carboxymethyl Dextran

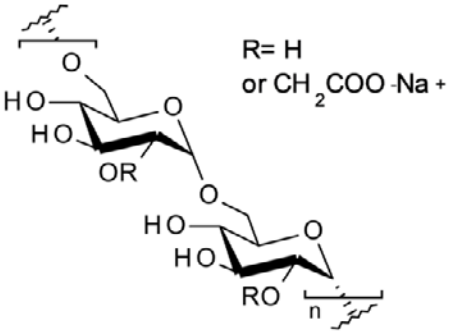
Carboxymethyl-dextran sodium salt - Average MW 4,000

- CMD4
- Carboxymethyl-dextran 4

[39422-83-8]

YC64857

5g	$125.00
10g	$200.00



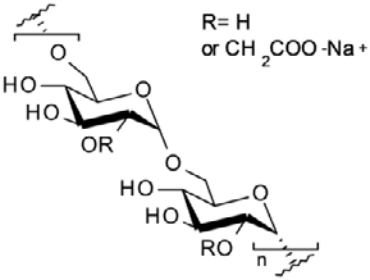
Carboxymethyl-dextran sodium salt - Average MW 10,000 - 20,000Da

- CM-Dextran sodium salt

[39422-83-8]

YC58709

5g	$75.00
10g	$125.00
25g	$262.50



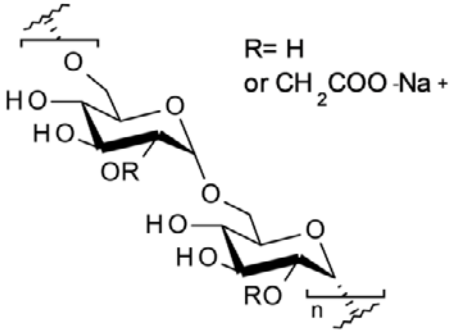
Carboxymethyl-dextran sodium salt - Average MW 20,000

- Carboxymethyl-dextran 20

[39422-83-8]

YC64858

5g	$125.00
10g	$190.00
25g	$400.00



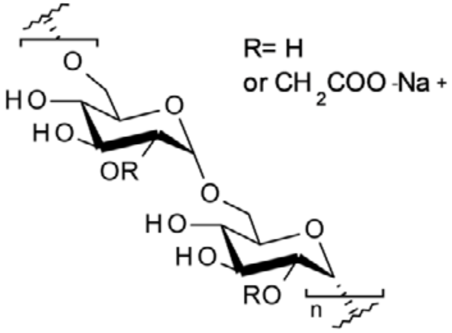
Carboxymethyl-dextran sodium salt - Average MW 40,000

- CMD40
- Carboxymethyl-dextran 40

[39422-83-8]

YC64859

10g	$250.00
25g	$550.00
50g	$850.00



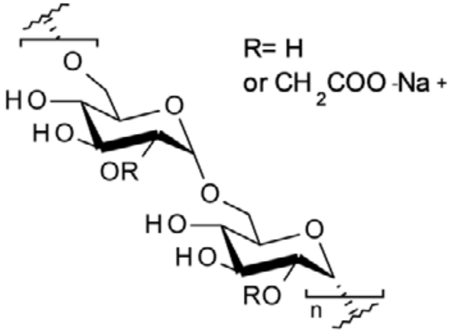
Carboxymethyl-dextran sodium salt - Average MW 70,000

- CMD70
- Carboxymethyl-dextran 70

[39422-83-8]

YC64860

10g	$190.00
25g	$400.00
50g	$600.00



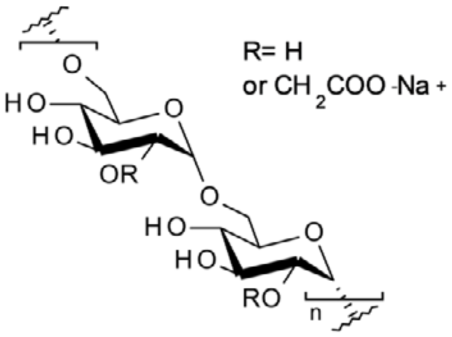
Carboxymethyl-dextran sodium salt - Average MW 150,000

- CMD150
- Carboxymethyl-dextran 150

[39422-83-8]

YC64861

2g	$60.00
5g	$110.00
10g	$190.00



10.7.16 Diethylaminoethyl Dextran

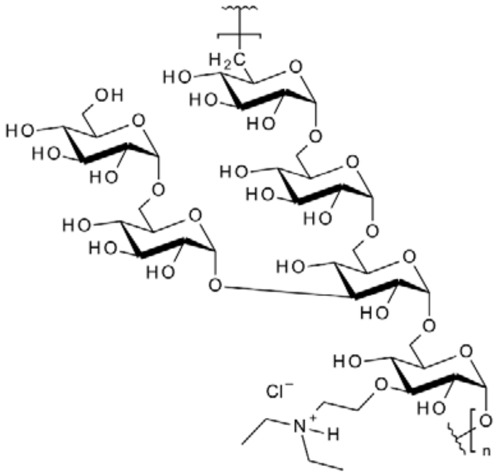
Diethylaminoethyl-dextran HCl

- DEAE-Dextran hydrochloride

[9064-91-9]

YD58710

10g	$95.00
25g	$175.00
50g	$300.00



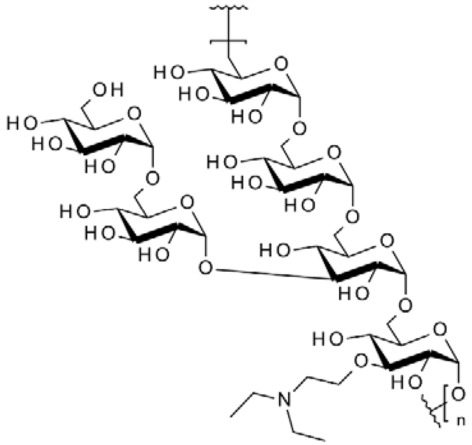
Diethylaminoethyl-dextran

- DEAE-Dextran

[9015-73-0]

YD58711

250g	$425.00
500g	$600.00
1Kg	$900.00



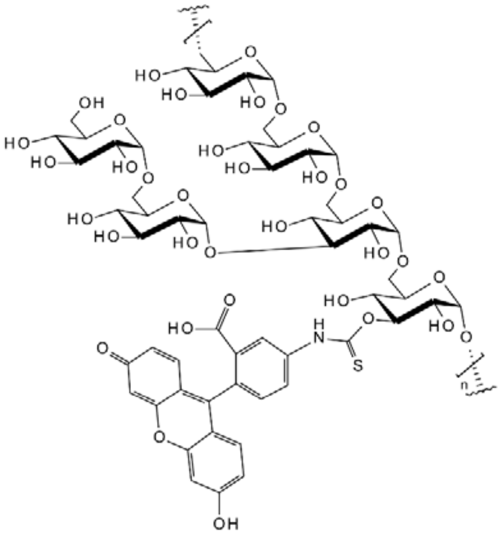
10.7.17 Fluorescein Isothiocyanate Dextran

Fluorescein isothiocyanate-dextran - Average MW 3,000-5,000

[60842-46-8]

YF45636

50mg	$90.00
100mg	$150.00
250mg	$300.00



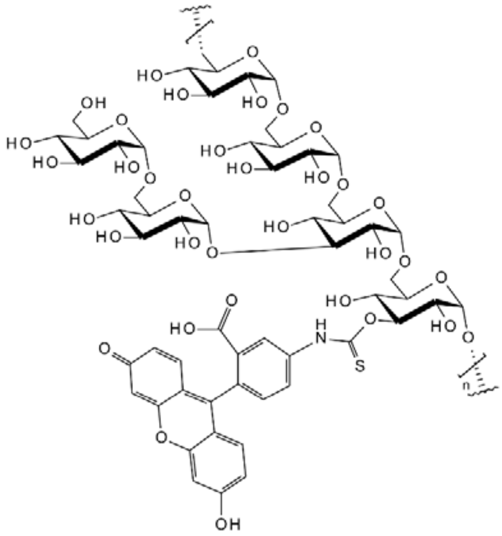
Fluorescein isothiocyanate-dextran - Average MW 10,000

- Fluorescein-labeled Dextran

[60842-46-8]

YD58708

100mg	$120.00
250mg	$250.00
500mg	$375.00

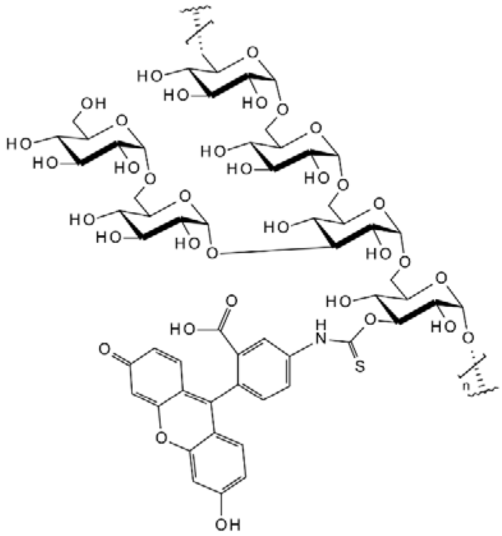


Fluorescein isothiocyanate-dextran - Average MW 20,000

[60842-46-8]

YF166140

100mg	$190.00
250mg	$375.00
500mg	$600.00



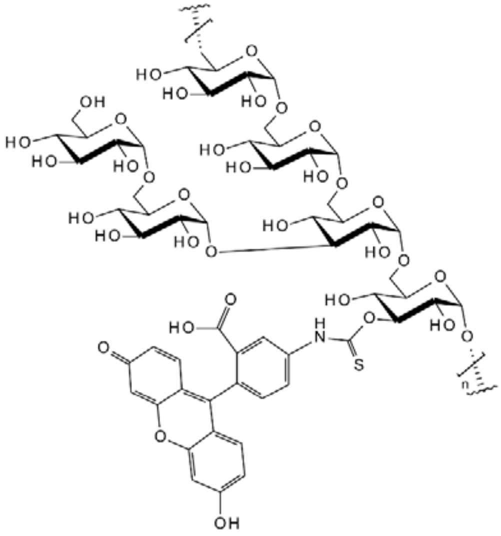
Fluorescein isothiocyanate-dextran - Average MW 70,000

- FITC–Dextran
- Dextran Fluorescein

[60842-46-8]

YF166141

100mg	$175.00
250mg	$325.00
500mg	$500.00

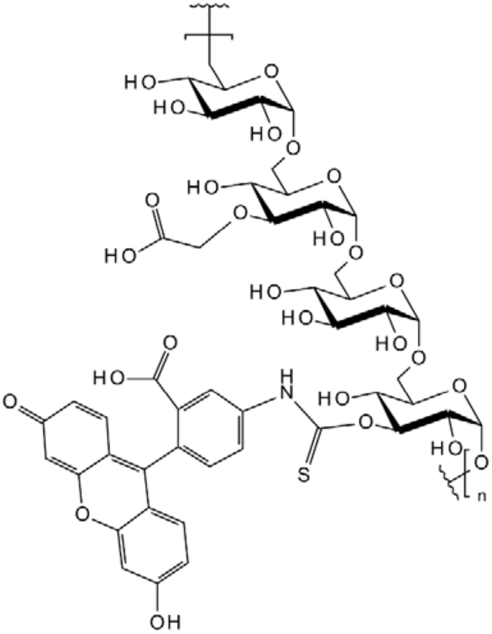


Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 4,000

- FITC-CM-Dextran

YF58321

100mg	$75.00
250mg	$145.00
500mg	$275.00

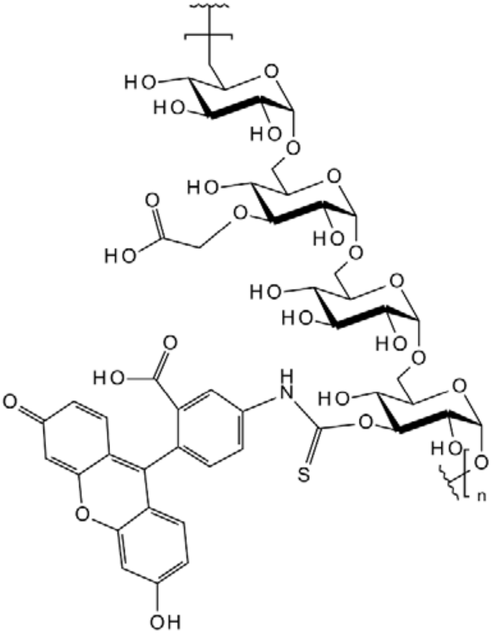


Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 20,000

- FITC-CM-Dextran

YF63888

100mg	$75.00
250mg	$145.00
500mg	$215.00

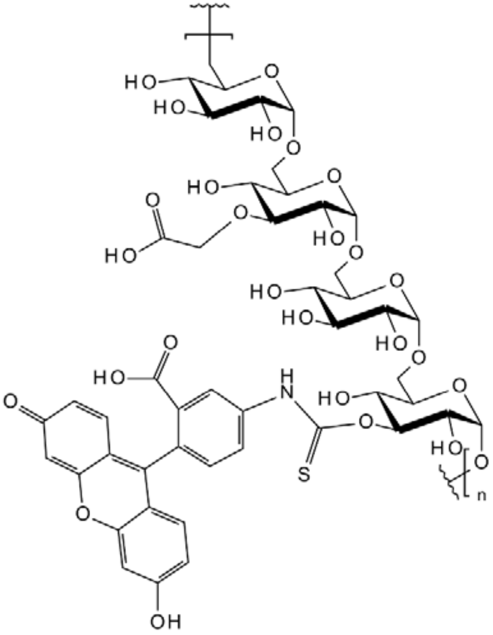


Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 40,000

- FITC-CM-Dextran

YF58322

100mg	$75.00
250mg	$145.00
500mg	$215.00

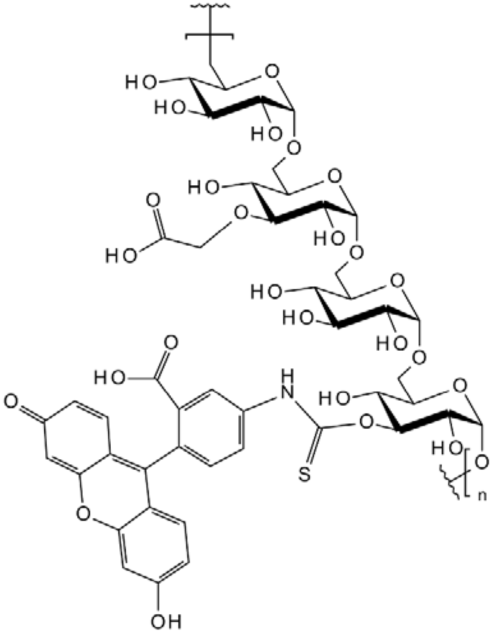


Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 70,000

- FITC-CM-Dextran

YF58323

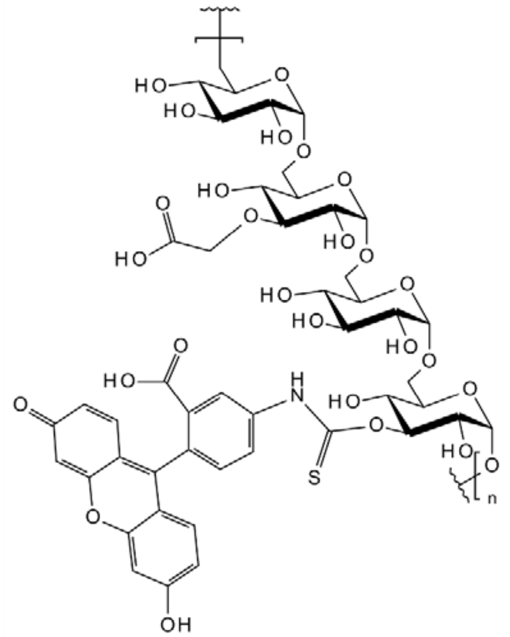
100mg	$75.00
250mg	$145.00
500mg	$215.00



Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 150,000
- FITC-CM-Dextran
- CM-Dextran fluorescein

YF58320

100mg	$72.00
250mg	$115.00
500mg	$180.00



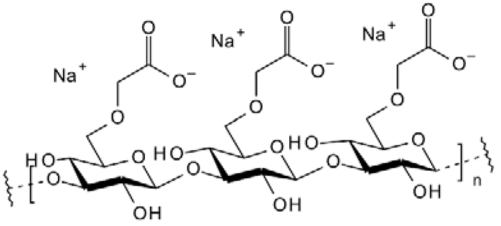
10.7.18 Carboxymethyl Curdlan

Carboxymethyl curdlan
- CM-curdlan

[114732-86-4]

YC46079

250mg	$50.00
500mg	$80.00
1g	$145.00



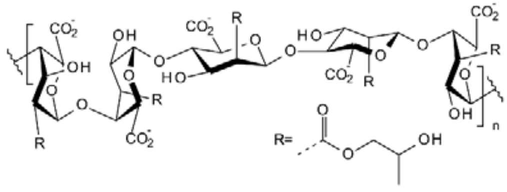
10.7.19 Propylene Glycol Alginate

Propylene glycol alginate
- E405
- Hydroxypropyl alginate

[9005-37-2]

YP58644

2g	$70.00
5g	$125.00
10g	$200.00



10.7.20 Inulin Lauryl Carbamate

Inulin lauryl carbamate - 25% in glycerol
- Lauryl inulin carbamate
- Inulin dodecylcarbamate

[478483-27-1]

OI146251

10g	$50.00
25g	$100.00
50g	$150.00

10.8 Formulated Polysaccharides

Danaparoid sodium - mixture of dermatan sulfate, heparan sulfate and chondroitin sulfate

[54328-33-5][24967-94-0]

YD58324

2mg	$95.00
5mg	$150.00
10mg	$225.00

Polyglycoplex
- PGX
- (a-L-Glucurono-a-D-Manno-b-D-Manno-b-D-Gluco), (a-L-Gulurono-b-D-Mannurono), b-D-Gluco-b-D-Mannan

YP157506 Price on Application

10.9 Artificial Polysaccharides

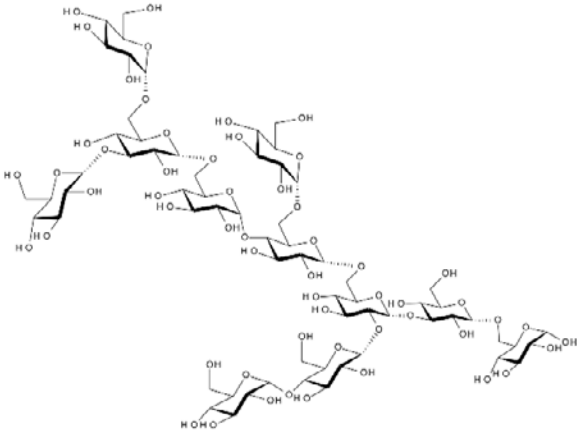
Polydextrose

- Poly-D-glucose

[68424-04-4]

YP29207

25g	$50.00
50g	$85.00
100g	$140.00



Section

11

Alphabetical Listing

(1-4)-2-acetamido-2-deoxy-b-D-glucan

see Chitin, YC04085 on page 132

Acetylcellulose

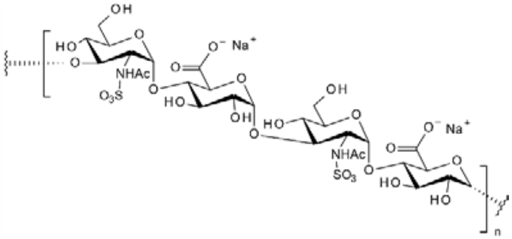
see Cellulose acetate - MW 30,000, YC44453 on page 132

N-Acetyl-de-O-sulfated heparin sodium salt

[133686-69-8]

YA58545

5mg	$153.00
10mg	$235.00
25mg	$375.00

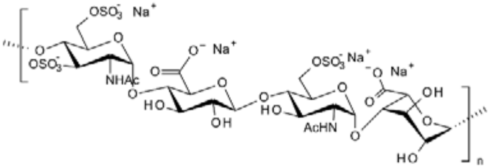


N-Acetyl-heparin

[134498-62-7]

YA58546

10mg	$67.40
25mg	$123.75
50mg	$198.00

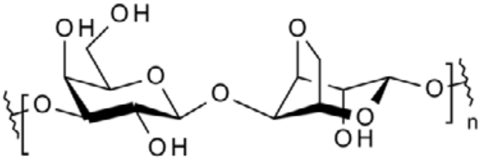


Agarose

[9012-36-6]

YA34896

25g	$47.00
50g	$75.00
100g	$118.00

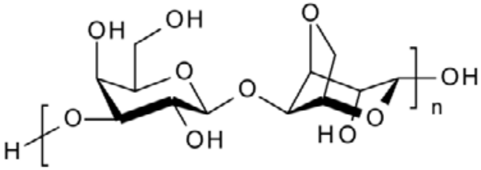


Agar

[9002-18-0]

OA39737

250g	$85.00
500g	$150.00
1Kg	$275.00



(1-3)&(1-4) a-D-glucan

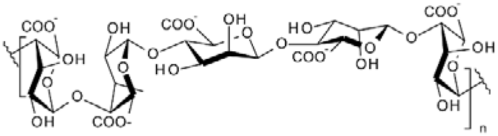
see Isolichenan, YI11686 on page 158

Alginic acid

[9005-32-7]

YA39739

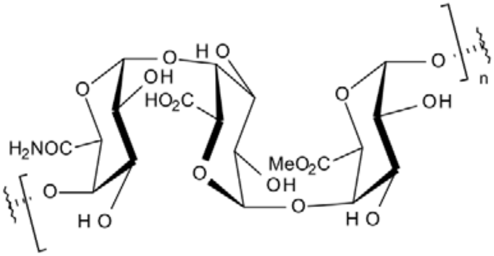
100g	$50.00
250g	$85.00
500g	$150.00



Amidated Pectin

YA158357

50g	$50.00
100g	$90.00
250g	$175.00



(1,4)-2-amino-2-deoxy-b-D-glucan

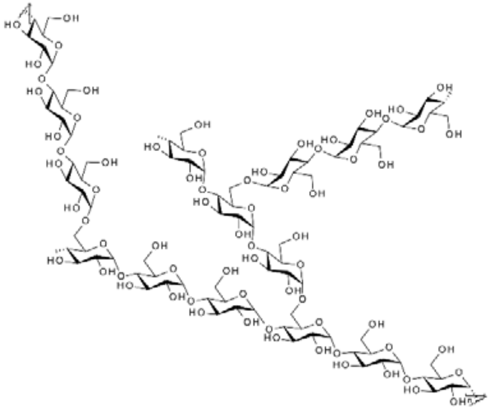
see Chitosan, YC06764 on page 132

Amylopectin - from maize

[9037-22-3]

YA39745

100g	$45.00
250g	$70.00
500g	$110.00

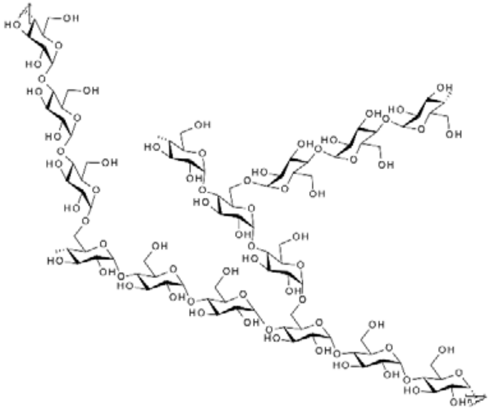


Amylopectin - from potato starch

[9037-22-3]

YA164124

1g	$65.00
2g	$96.00
5g	$180.00

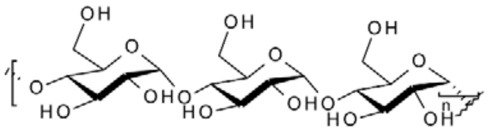


Amylose

[9005-82-7]

YA10257

10g	$85.00
25g	$150.00
50g	$250.00



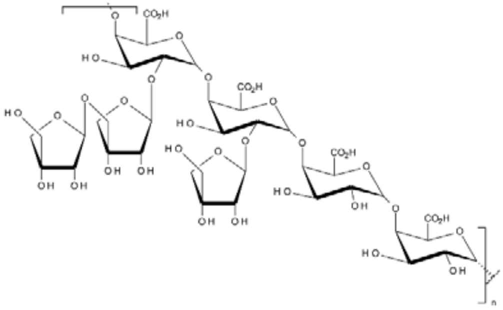
Apiogalacturonan

- Galacturonoapian

[9039-03-6]

YA09575

10mg	$200.00
25mg	$450.00
50mg	$800.00

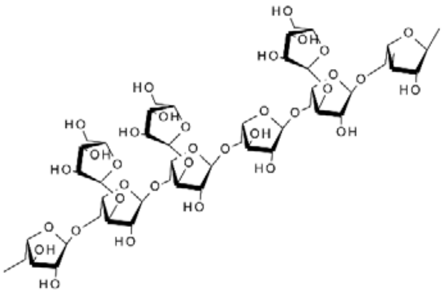


Arabinan

[11078-27-6]

YA46077

1g	$55.00
2g	$84.00
5g	$175.00



L-Arabino (Methyl-D-glucurono) xylan

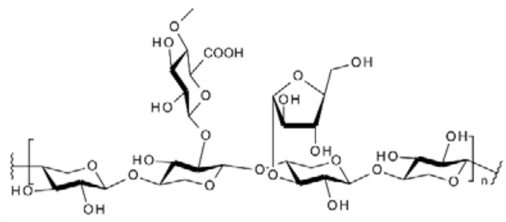
see Corncob xylan, YC165265 on page 135

Arabinoxylan

[9040-27-1]

YA29478

1g	$95.00
2g	$150.00
5g	$275.00



Arthrobacter stabilis exopolysaccharide

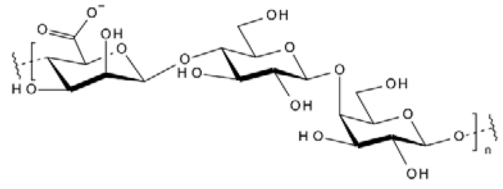
YA157504

5mg	$175.00
10mg	$290.00
25mg	$425.00

Arthrobacter viscosus exopolysaccharide

YA157503

50mg	$120.00
100mg	$190.00
250mg	$375.00



Azo-fructan

YA165862

Price on Application

Azo-Xyloglucan

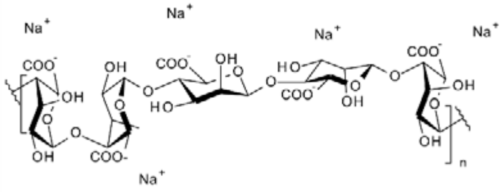
YA158177

1g	$195.00
2g	$300.00
5g	$475.00

Bacterial alginate - from fermentation of Azotobacter vinelandii or Pseudomonas mendocina

YB58638

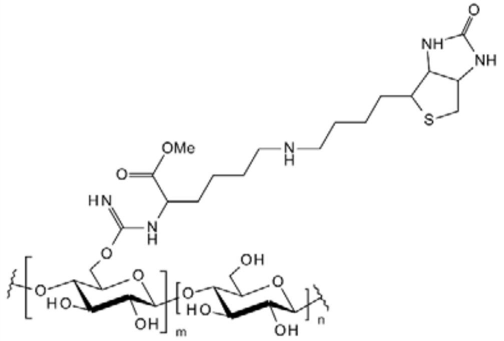
1g	$175.00
2g	$320.00
5g	$625.00



Biotin-dextran MW 10000

YB34651

5mg	$131.30
10mg	$210.00
25mg	$472.50



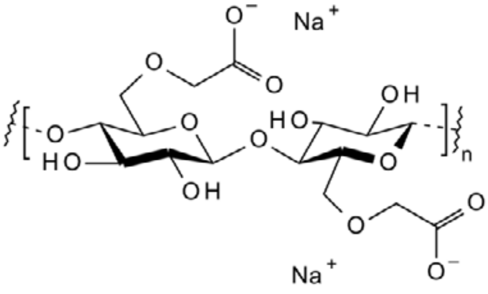
Carboxymethyl cellulose sodium - Viscosity 1000 - 1300 mPa·s

- CM Cellulose
- Carmellose

[9004-32-4]

YC44523

500g	$60.00
1kg	$100.00
2kg	$160.00

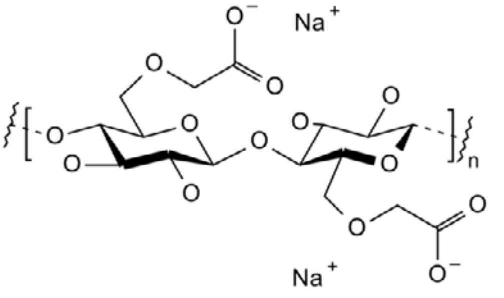


Carboxymethyl cellulose

[9000-11-7]

YC158179

50g	$40.00
100g	$65.00
250g	$100.00



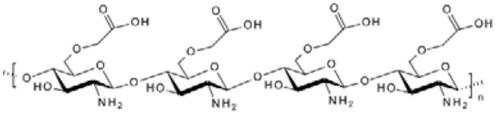
Carboxymethyl chitosan

- N-Carboxymethyl chitosan

[83512-85-0]

YC29683

5g	$60.00
10g	$100.00
25g	$150.00



N-Carboxymethyl chitosan

see Carboxymethyl chitosan, YC29683 on page 129

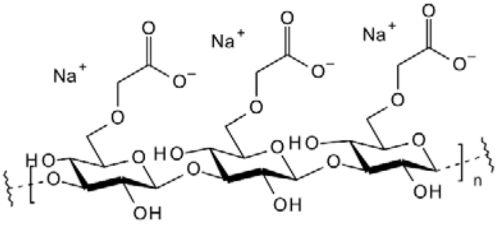
Carboxymethyl curdlan

- CM-curdlan

[114732-86-4]

YC46079

250mg	$50.00
500mg	$80.00
1g	$145.00



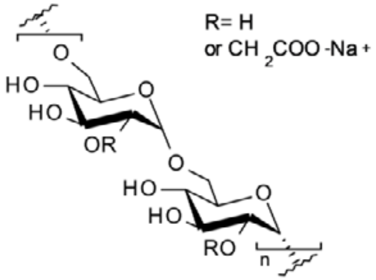
Carboxymethyl-dextran sodium salt - Average MW 10,000 - 20,000Da

- CM-Dextran sodium salt

[39422-83-8]

YC58709

5g	$75.00
10g	$125.00
25g	$262.50



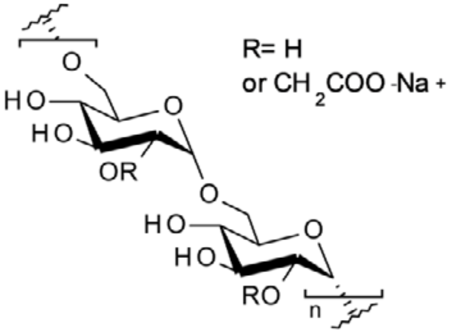
Carboxymethyl-dextran sodium salt - Average MW 150,000

- CMD150
- Carboxymethyl-dextran 150

[39422-83-8]

YC64861

2g	$60.00
5g	$110.00
10g	$190.00



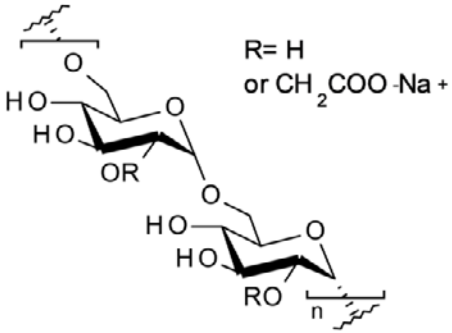
Carboxymethyl-dextran sodium salt - Average MW 20,000

- Carboxymethyl-dextran 20

[39422-83-8]

YC64858

5g	$125.00
10g	$190.00
25g	$400.00



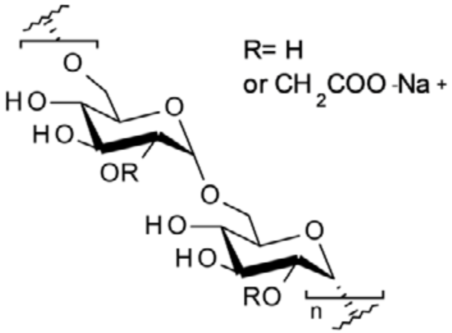
Carboxymethyl-dextran sodium salt - Average MW 4,000

- CMD4
- Carboxymethyl-dextran 4

[39422-83-8]

YC64857

5g	$125.00
10g	$200.00



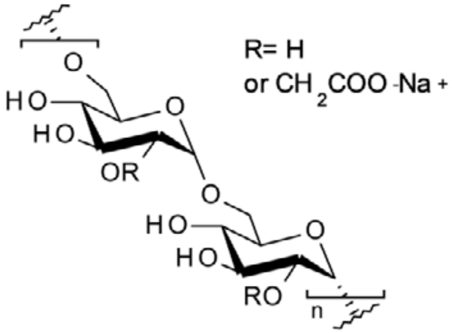
Carboxymethyl-dextran sodium salt - Average MW 40,000

- CMD40
- Carboxymethyl-dextran 40

[39422-83-8]

YC64859

10g	$250.00
25g	$550.00
50g	$850.00



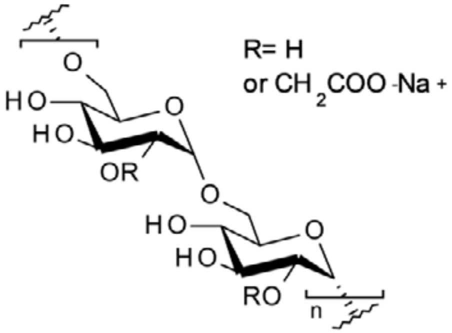
Carboxymethyl-dextran sodium salt - Average MW 70,000

- CMD70
- Carboxymethyl-dextran 70

[39422-83-8]

YC64860

10g	$190.00
25g	$400.00
50g	$600.00



Carboxymethyl-dextran 150

see Carboxymethyl-dextran sodium salt - Average MW 150,000, YC64861 on page 129

Carboxymethyl-dextran 20

see Carboxymethyl-dextran sodium salt - Average MW 20,000, YC64858 on page 130

Carboxymethyl-dextran 4

see Carboxymethyl-dextran sodium salt - Average MW 4,000, YC64857 on page 130

Carboxymethyl-dextran 40

see Carboxymethyl-dextran sodium salt - Average MW 40,000, YC64859 on page 130

Carboxymethyl-dextran 70

see Carboxymethyl-dextran sodium salt - Average MW 70,000, YC64860 on page 130

Carmellose

see Carboxymethyl cellulose sodium - Viscosity 1000 - 1300 mPa·s, YC44523 on page 128

Carrageenan

[9000-07-1]

FC166779 Price on Application

i-Carrageenan

see iota-Carrageenan, YC30038 on page 131

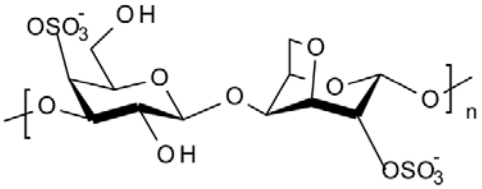
iota-Carrageenan

- i-Carrageenan

[9062-07-1]

YC30038

100g	$75.00
250g	$125.00
500g	$200.00



k-Carrageenan

see kappa-Carrageenan, YC30039 on page 131

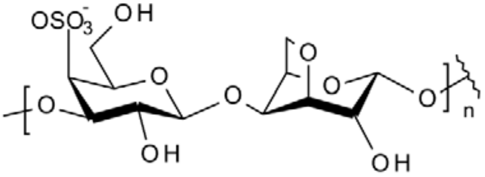
kappa-Carrageenan

- k-Carrageenan

[11114-20-8]

YC30039

100g	$50.00
250g	$75.00
500g	$125.00



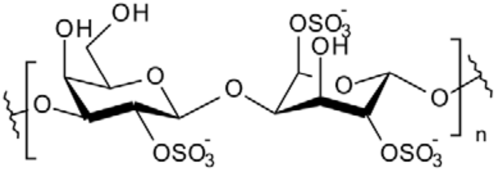
lambda-Carrageenan

- lambda-Carrageenan

[9064-57-7]

YC41782

5g	$50.00
10g	$80.00
25g	$150.00

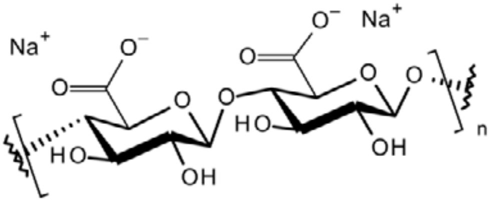


Cellacefate

see Cellulose acetate hydrogen phthalate, YC43910 on page 132

Cellouronic acid sodium salt

YC59633 Price on Application



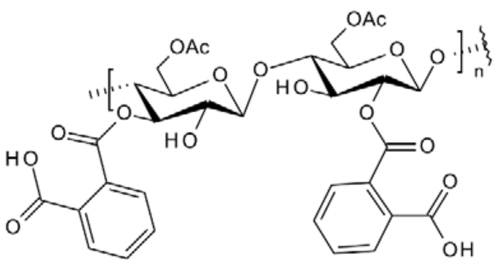
Cellulose acetate hydrogen phthalate

- Cellacefate

[9004-38-0]

YC43910

25g	$75.00
50g	$125.00
100g	$200.00



Cellulose acetate - MW 30,000

- Acetylcellulose

[9004-35-7]

YC44453

25g	$60.00
50g	$75.00
100g	$95.00

Cellulose microcrystalline

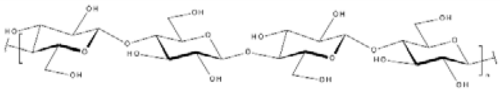
see Cellulose - Particle Size approx 50 um, YC31812 on page 132

Cellulose - Arbocel

[9004-34-6]

YC145383

100g	$75.00
250g	$150.00
500g	$250.00

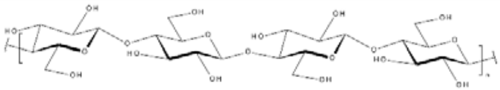


Cellulose - Microcrystalline USP

[9004-34-6]

YC05773

50mg	$50.00
100mg	$80.00
250mg	$130.00



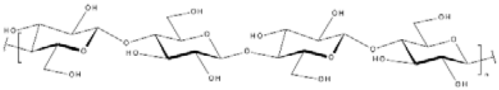
Cellulose - Particle Size approx 50 um

- Cellulose microcrystalline

[9004-34-6]

YC31812

500g	$75.00
1kg	$125.00
2kg	$210.00



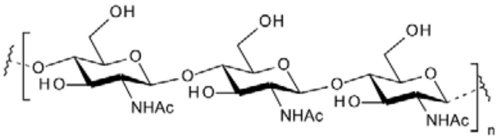
Chitin

- (1-4)-2-acetamido-2-deoxy-b-D-glucan

[1398-61-4]

YC04085

250g	$50.00
500g	$85.00
1kg	$150.00



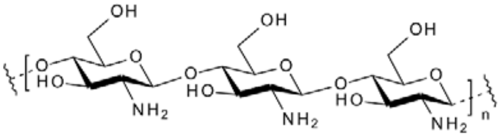
Chitosan

- (1,4)-2-amino-2-deoxy-b-D-glucan
- Deacetylated chitin

[9012-76-4]

YC06764

250g	$50.00
500g	$95.00
1kg	$154.00

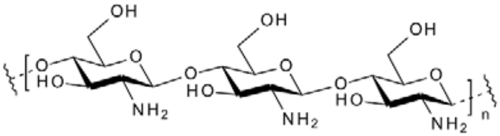


Chitosan - Molecular weight 190,000-310,000

[9012-76-4]

YC158299

250g	$50.00
500g	$90.00
1Kg	$160.00

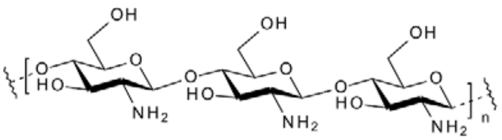


Chitosan - Molecular weight 310,000-375,000

[9012-76-4]

YC158301

100g	$50.00
250g	$100.00
500g	$160.00

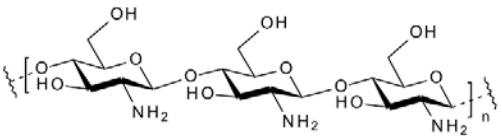


Chitosan - Molecular weight 50,000-190,000

[9012-76-4]

YC158300

100g	$60.00
250g	$100.00
500g	$150.00

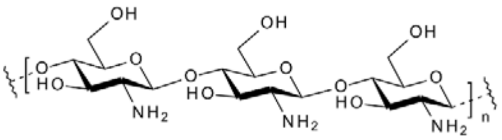


Chitosan - Water soluble

[9012-76-4]

YC58325

50g	$92.50
100g	$139.00
250g	$280.00

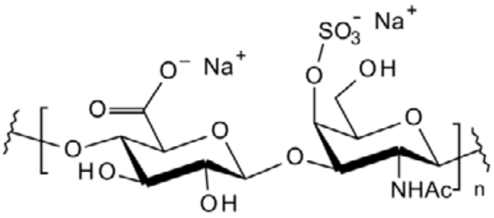


Chondroitin sulfate A sodium salt - 90%, from Bovine Cartilage

[39455-18-0]

YC165869

50g	$65.00
100g	$100.00
250g	$160.00



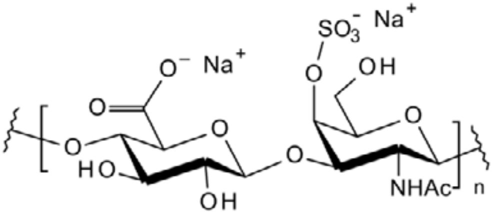
Chondroitin sulfate A sodium salt - Average MW 100,000

- Chondroitin 4-sulfate sodium salt

[39455-18-0]

YC31419

Price on Application

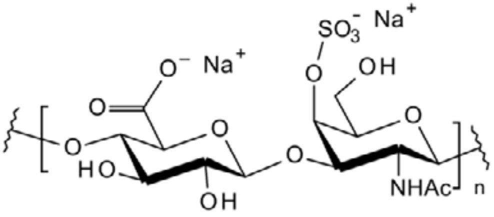


Chondroitin sulfate A sodium salt - Average MW 10,000 - 30,000

[39455-18-0]

YC15288

100g	$68.00
250g	$125.00
500g	$190.00



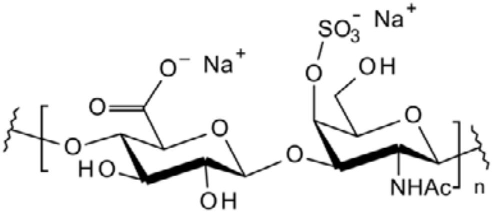
Chondroitin sulfate A sodium salt - Average MW 20,000 - 30,000

- Chondroitin 4-sulfate sodium salt

[39455-18-0]

YC31416

100g	$60.00
250g	$120.00
500g	$200.00



Chondroitin sulfate B sodium salt

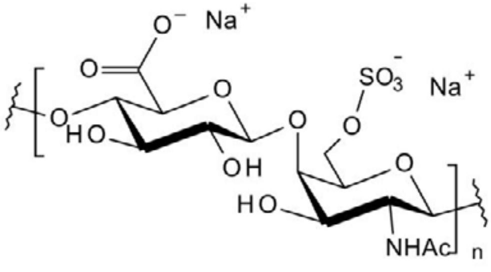
see Dermatan sulphate sodium salt, YD30120 on page 135

Chondroitin sulfate C sodium salt

- Chondroitin 6-sulfate sodium salt

[12678-07-8]

YC31458		
	10g	$40.00
	25g	$80.00
	50g	$125.00



Chondroitin 4-sulfate sodium salt

see Chondroitin sulfate A sodium salt - Average MW 100,000, YC31419 on page 133

Chondroitin 4-sulfate sodium salt

see Chondroitin sulfate A sodium salt - Average MW 20,000 - 30,000, YC31416 on page 133

Chondroitin 6-sulfate sodium salt

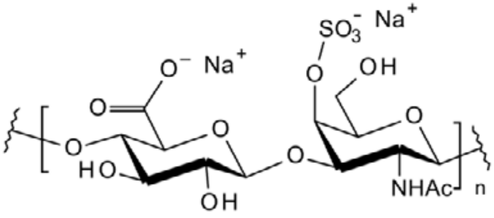
see Chondroitin sulfate C sodium salt, YC31458 on page 134

Chondroitin sulfate sodium salt

- Sulfated glycosaminoglycan

[9082-07-9]

YC04273		
	50g	$50.00
	100g	$90.00
	250g	$167.50



CM Cellulose

see Carboxymethyl cellulose sodium - Viscosity 1000 - 1300 mPa·s, YC44523 on page 128

CM-curdlan

see Carboxymethyl curdlan, YC46079 on page 129

CM-Dextran fluorescein

see Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 150,000, YF58320 on page 141

CM-Dextran sodium salt

see Carboxymethyl-dextran sodium salt - Average MW 10,000 - 20,000Da, YC58709 on page 129

CMD150

see Carboxymethyl-dextran sodium salt - Average MW 150,000, YC64861 on page 129

CMD4

see Carboxymethyl-dextran sodium salt - Average MW 4,000, YC64857 on page 130

CMD40

see Carboxymethyl-dextran sodium salt - Average MW 40,000, YC64859 on page 130

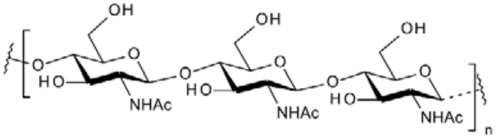
CMD70

see Carboxymethyl-dextran sodium salt - Average MW 70,000, YC64860 on page 130

Colloidal Chitin

[1398-61-4]

YC159471		
	1g	$170.00

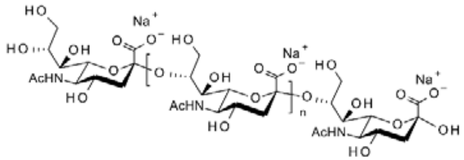


Colominic acid sodium salt - Average MW 30,000

- Poly[2,8-(N-acetylneuraminic acid sodium salt)]

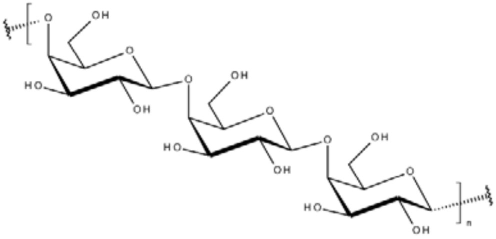
[70431-34-4]

YC11298	Price on Application



Compression wood galactan

YC165863	Price on Application

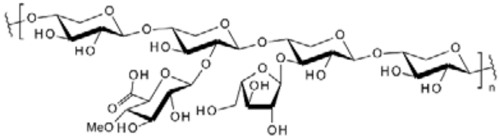


Corncob xylan

- L-Arabino (Methyl-D-glucurono) xylan

[9014-63-5]

YC165265 Price on Application



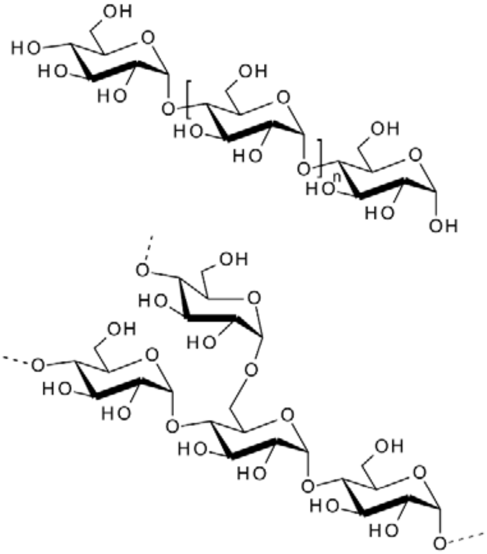
Corn starch

- Starch - from maize

[9005-25-8]

YC35117

1Kg	$100.00
2Kg	$160.00
5Kg	$320.00



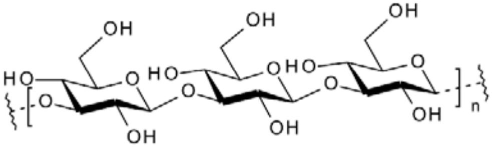
Curdlan

- b-1,3-Glucan

[54724-00-4]

YC46078

1g	$75.00
2g	$130.00
5g	$220.00



Danaparoid sodium - mixture of dermatan sulfate, heparan sulfate and chondroitin sulfate

[54328-33-5][24967-94-0]

YD58324

2mg	$95.00
5mg	$150.00
10mg	$225.00

Danish agar

see Furcellaran, YF44604 on page 148

Deacetylated chitin

see Chitosan, YC06764 on page 132

DEAE-Dextran hydrochloride

see Diethylaminoethyl-dextran HCl, YD58710 on page 140

DEAE-Dextran

see Diethylaminoethyl-dextran, YD58711 on page 140

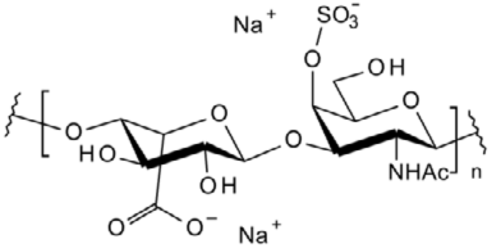
Dermatan sulphate sodium salt

- Chondroitin sulfate B sodium salt
- b-Heparin

[54328-33-5]

YD30120

10mg	$52.00
25mg	$95.00
50mg	$150.00

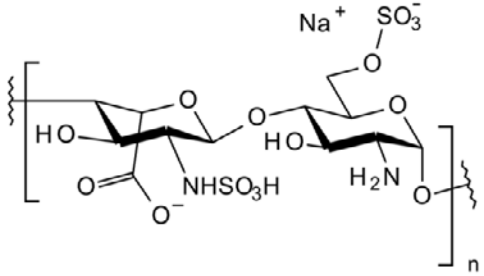


De-N-sulfated heparin sodium salt

[61932-66-9]

YD58544

10mg	$65.00
25mg	$115.00
50mg	$180.00



Dextran Fluorescein

see Fluorescein isothiocyanate-dextran - Average MW 70,000, YF166141 on page 144

Dextran rhodamine

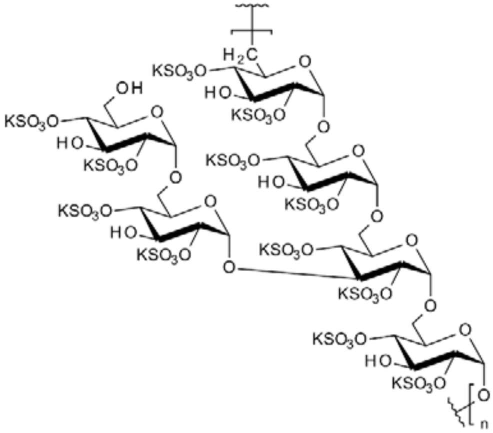
see Rhodamine B isothiocyanate-dextran - Average MW 10,000, YD58701 on page 165

Dextran sulfate potassium salt

[39422-86-1]

YD31035

1g	$55.00
2g	$94.50
5g	$152.30

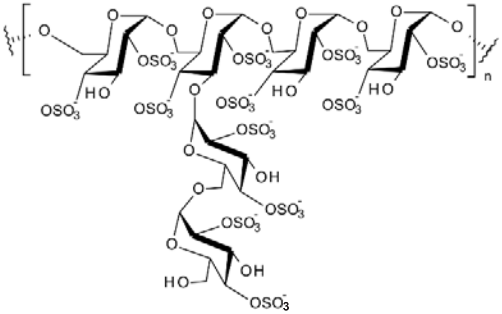


Dextran sulfate sodium salt - MW 100,000

[9011-18-1]

YD59549

5g	$190.00
10g	$295.00
25g	$500.00

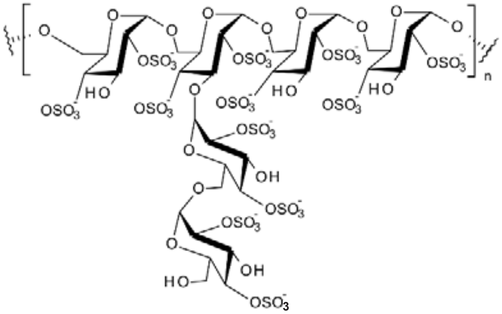


Dextran sulfate sodium salt - MW 20,000

[9011-18-1]

YD31803

500g	$390.00
1Kg	$500.00
2Kg	$900.00

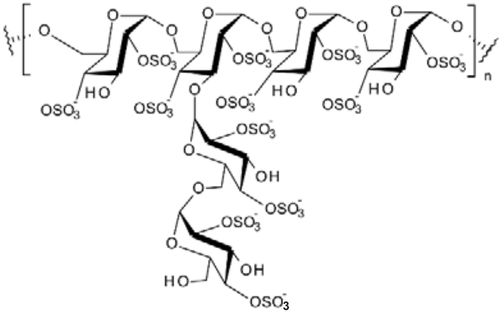


Dextran sulfate sodium salt - MW 40,000

[9011-18-1]

YD31804

10g	$60.00
25g	$95.00
50g	$140.00

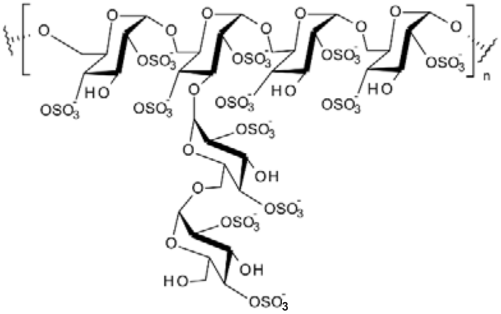


Dextran sulfate sodium salt - MW 4500-5500

[9011-18-1]

YD158380

25g	$150.00
50g	$200.00
100g	$320.00

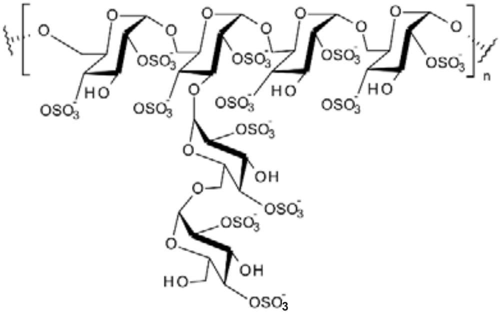


Dextran sulfate sodium salt - MW 500,000

[9011-18-1]

YD32562

10g	$45.00
25g	$80.00
50g	$135.00

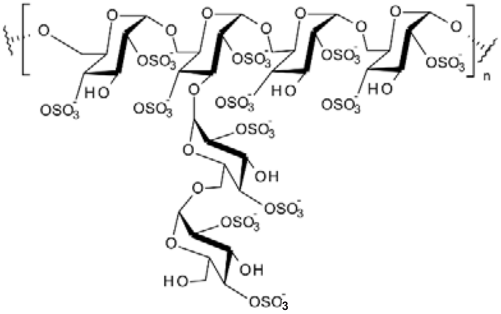


Dextran sulfate sodium salt - MW 50,000

[9011-18-1]

YD59741

25g	$170.00
50g	$225.00
100g	$385.00

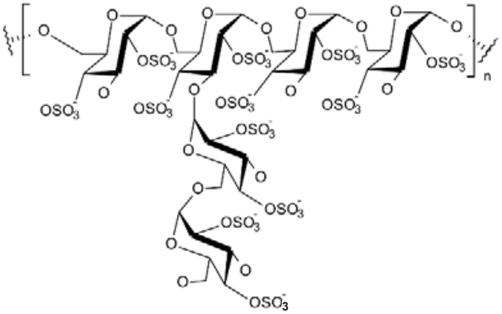


Dextran sulfate sodium salt - MW 5,000-8,000

[9011-18-1]

YD31801

25g	$75.00
50g	$140.00
100g	$220.00

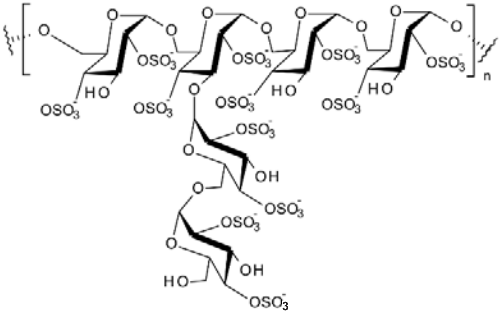


Dextran sulfate sodium salt - MW 6,000-10,000

[9011-18-1]

YD31802

50g	$250.00
100g	$350.00
250g	$550.00

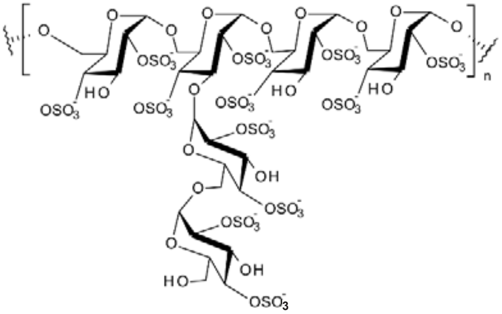


Dextran sulfate sodium salt - MW 8,000

[9011-18-1]

YD59550

50g	$150.00
100g	$250.00
250g	$500.00

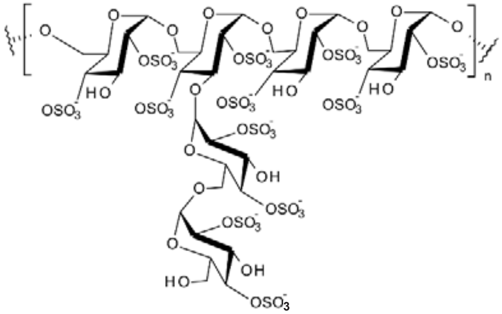


Dextran sulfate sodium salt - MW 9,000-11,000 - from Leuconostoc spp

[9011-18-1]

YD45147

500g	$390.00
1Kg	$500.00
2Kg	$900.00

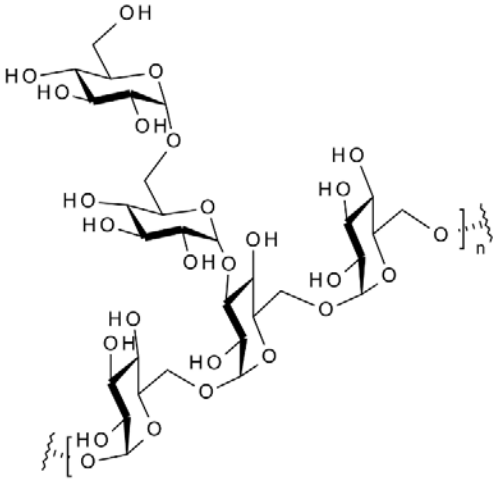


Dextran 10 - MW 9,000 to 11,000

[9004-54-0]

YD32417

50g	$40.00
100g	$56.00
250g	$107.50

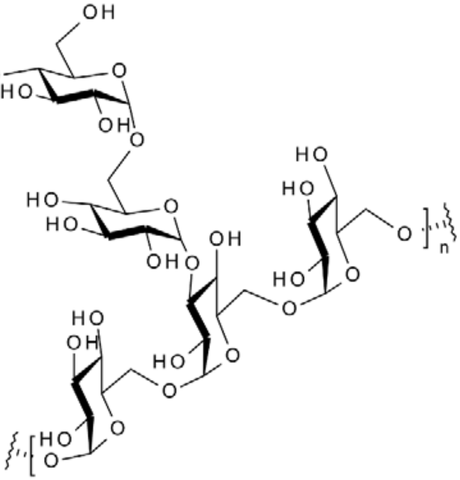


Dextran 3 - MW 2500 - 4000

[9004-54-0]

YD00049

25g	$50.00
50g	$79.00
100g	$140.00

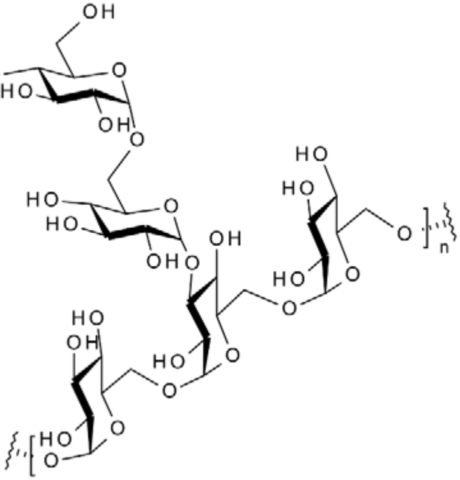


Dextran 40 - MW 35,000 to 45,000

[9004-54-0]

YD01481

50g	$60.00
100g	$98.00
250g	$195.00

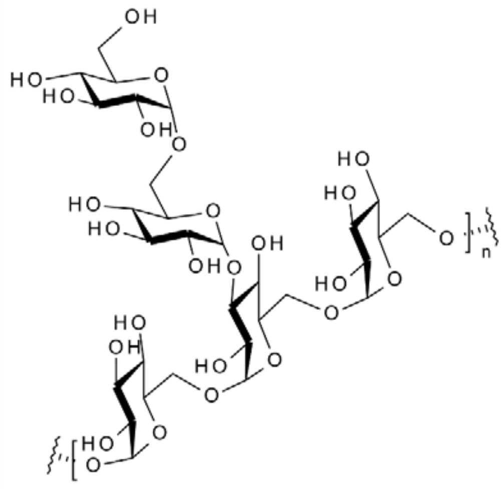


Dextran 5 - MW 4,000 to 6,000

[9004-54-0]

YD44759

100g	$95.00
250g	$175.00
500g	$300.00

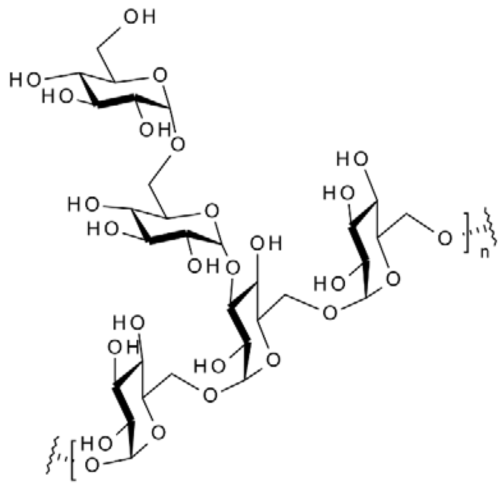


Dextran 6 - MW 5,500 to 7,500

[9004-54-0]

YD35507

50g	$70.00
100g	$110.00
250g	$215.00

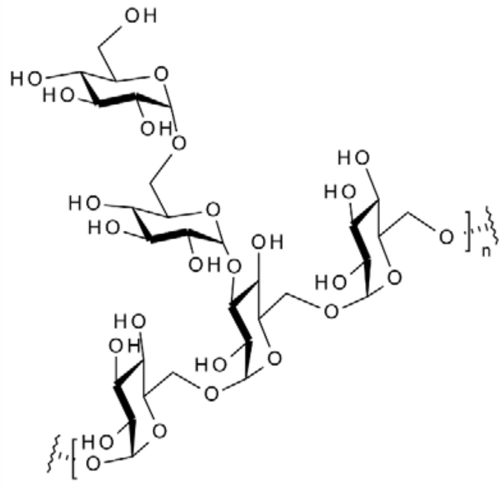


Dextran 500 - MW 450,000 to 550,000

[9004-54-0]

YD34755

50g	$85.00
100g	$130.00
250g	$275.00

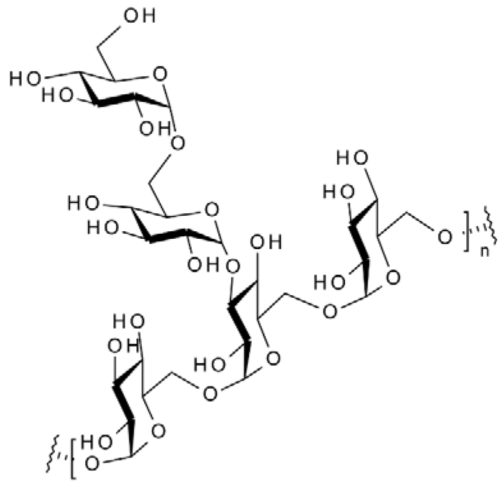


Dextran 70 - MW 64,000 to 76,000

[9004-54-0]

YD30645

50g	$60.00
100g	$100.00
250g	$200.00



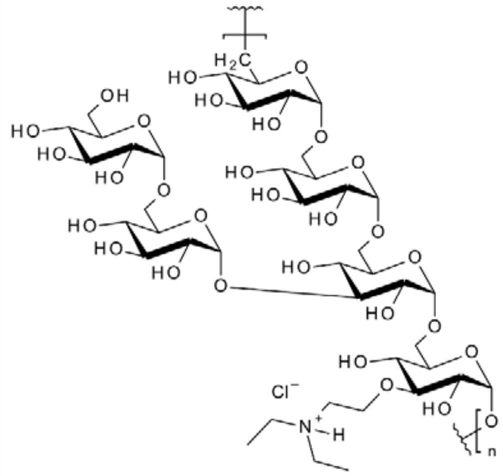
Diethylaminoethyl-dextran HCl

- DEAE-Dextran hydrochloride

[9064-91-9]

YD58710

10g	$95.00
25g	$175.00
50g	$300.00



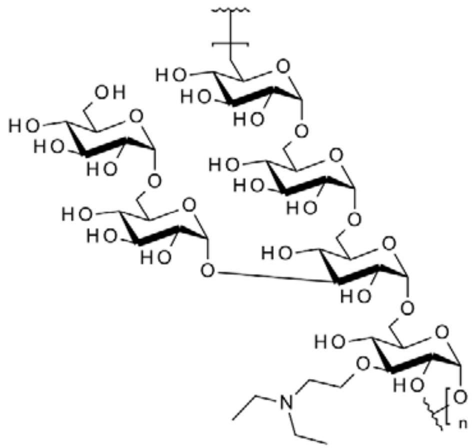
Diethylaminoethyl-dextran

- DEAE-Dextran

[9015-73-0]

YD58711

250g	$425.00
500g	$600.00
1Kg	$900.00

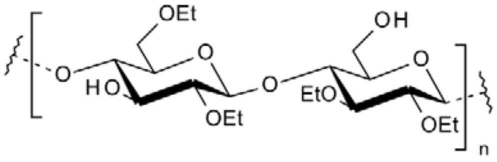


Ethyl cellulose

[9004-57-3]

YE43907

1Kg	$150.00
2Kg	$250.00
5Kg	$475.00



Exopolysaccharide - from Bacillus polymixa

YE165867

Price on Application

Exopolysaccharide - from Flavobacterium

YE165866

Price on Application

FITC-CM-Dextran

see Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 150,000, YF58320 on page 141

FITC-CM-Dextran

see Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 20,000, YF63888 on page 141

FITC-CM-Dextran

see Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 40,000, YF58322 on page 142

FITC-CM-Dextran

see Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 4,000, YF58321 on page 142

FITC-CM-Dextran

see Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 70,000, YF58323 on page 143

FITC–Dextran

see Fluorescein isothiocyanate-dextran - Average MW 70,000, YF166141 on page 144

Fluorescein hyaluronic acid

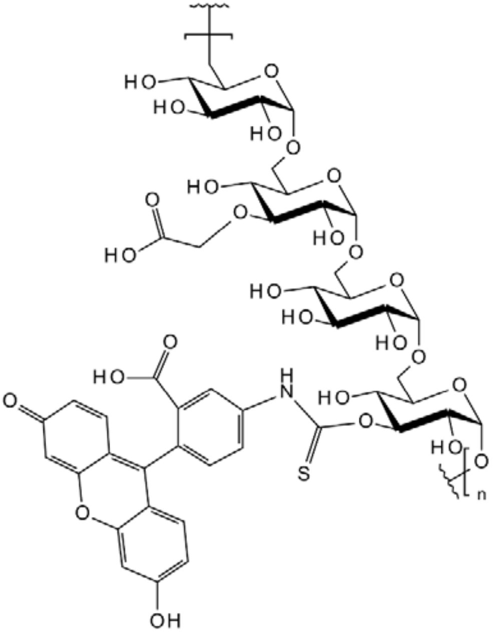
see Hyaluronate fluorescein - MW - 800kDa, YH45321 on page 153

Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 150,000

- FITC-CM-Dextran
- CM-Dextran fluorescein

YF58320

100mg	$72.00
250mg	$115.00
500mg	$180.00

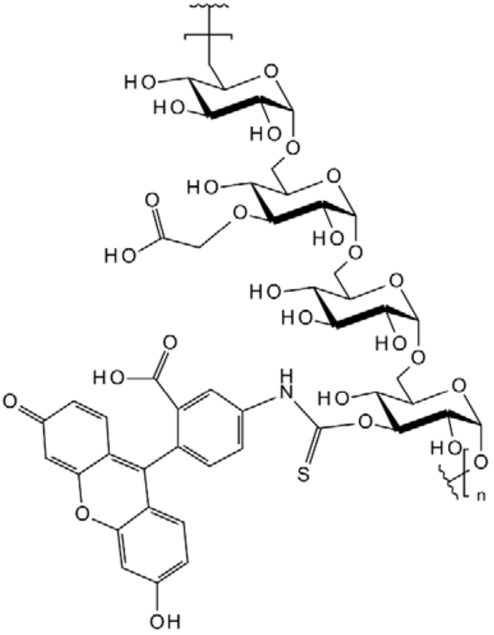


Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 20,000

- FITC-CM-Dextran

YF63888

100mg	$75.00
250mg	$145.00
500mg	$215.00

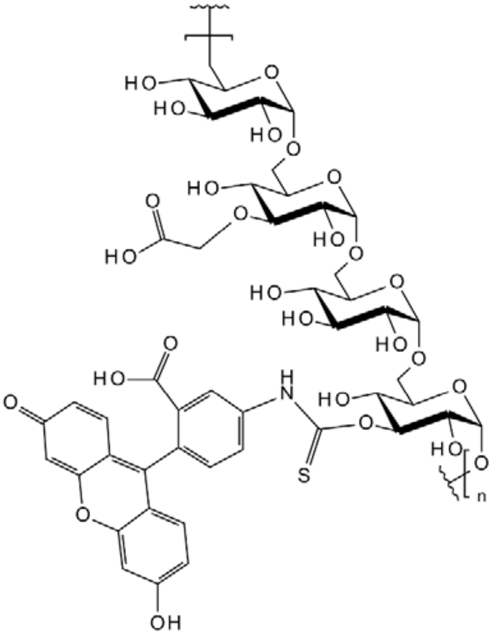


Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 40,000

- FITC-CM-Dextran

YF58322

100mg	$75.00
250mg	$145.00
500mg	$215.00

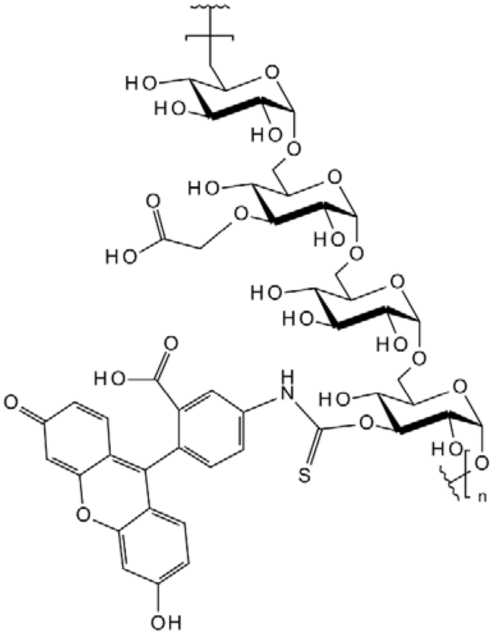


Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 4,000

- FITC-CM-Dextran

YF58321

100mg	$75.00
250mg	$145.00
500mg	$275.00

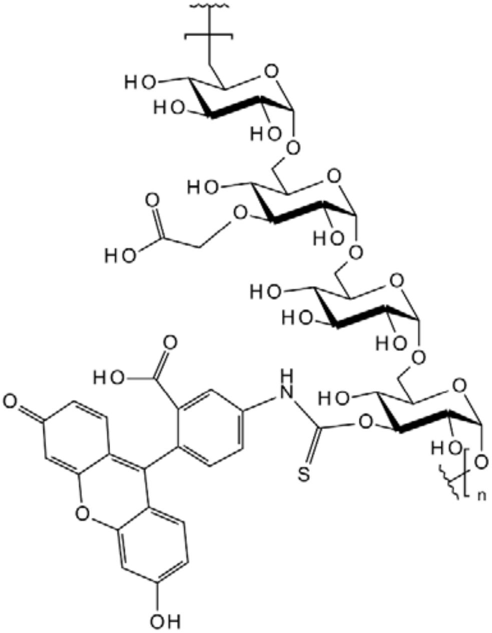


Fluorescein isothiocyanate-carboxymethyl-dextran - Average MW 70,000

- FITC-CM-Dextran

YF58323

100mg	$75.00
250mg	$145.00
500mg	$215.00



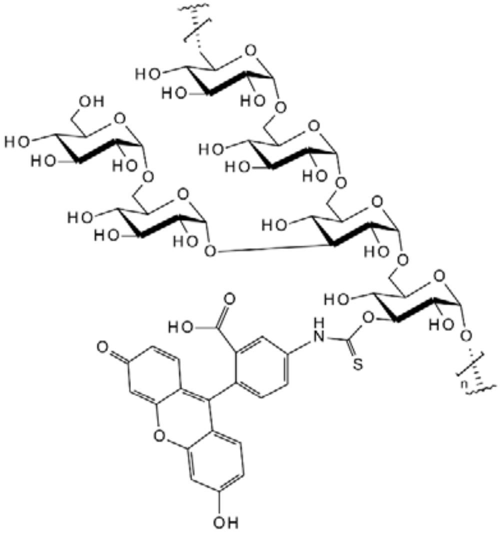
Fluorescein isothiocyanate-dextran - Average MW 10,000

- Fluorescein-labeled Dextran

[60842-46-8]

YD58708

100mg	$120.00
250mg	$250.00
500mg	$375.00

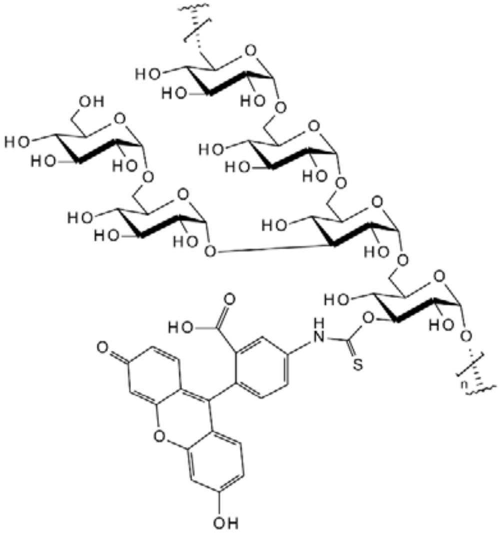


Fluorescein isothiocyanate-dextran - Average MW 20,000

[60842-46-8]

YF166140

100mg	$190.00
250mg	$375.00
500mg	$600.00

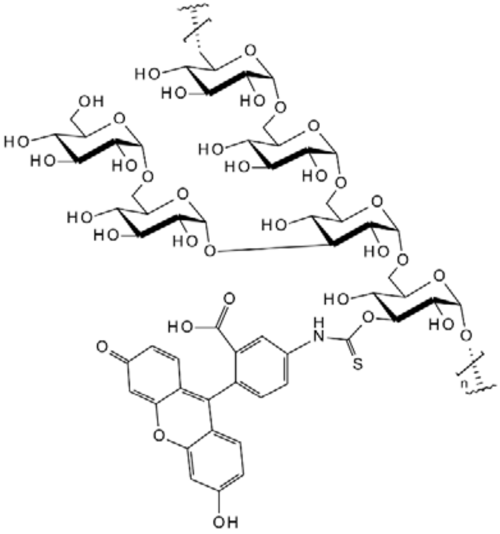


Fluorescein isothiocyanate-dextran - Average MW 3,000-5,000

[60842-46-8]

YF45636

50mg	$90.00
100mg	$150.00
250mg	$300.00



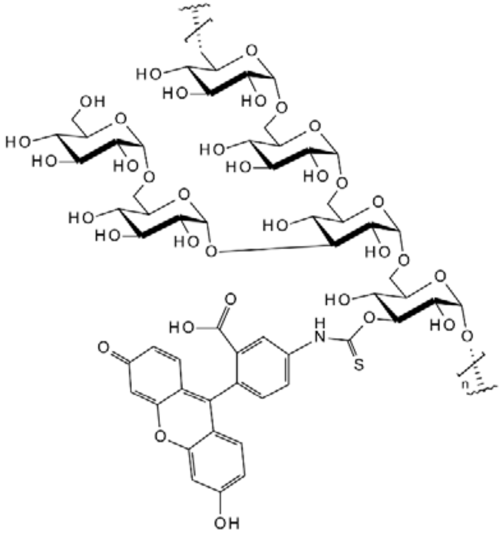
Fluorescein isothiocyanate-dextran - Average MW 70,000

- FITC–Dextran
- Dextran Fluorescein

[60842-46-8]

YF166141

100mg	$175.00
250mg	$325.00
500mg	$500.00



Fluorescein-labeled Dextran

see Fluorescein isothiocyanate-dextran - Average MW 10,000, YD58708 on page 143

FucCS

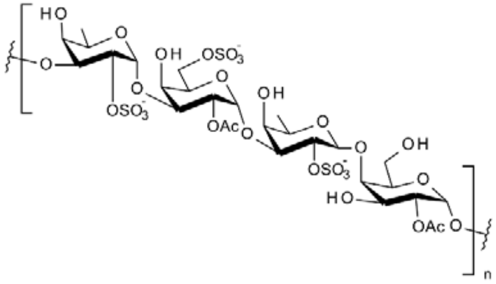
see Fucosylated chondroitin sulfate, YF76156 on page 148

Fucogalactan - from Undaria pinnatifida

[9061-39-6]

YF58639

5g	$60.00
10g	$100.00
25g	$175.00

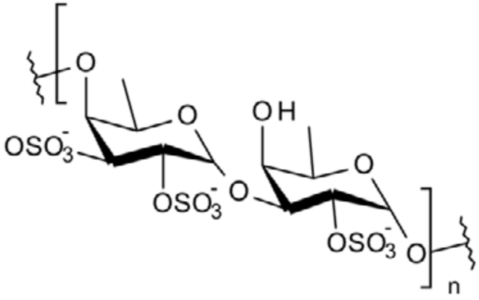


Fucoidan - Alaria

[9072-19-9]

YF157138

10mg	$90.00
25mg	$200.00
50mg	$350.00



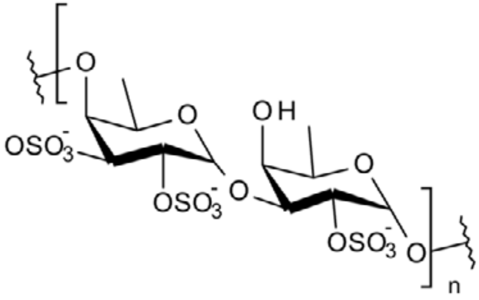
Fucoidan - Ascophyllum nodosum

• Sulfated L-fucan

[9072-19-9]

YF09363

5g	$75.00
10g	$130.00
25g	$250.00

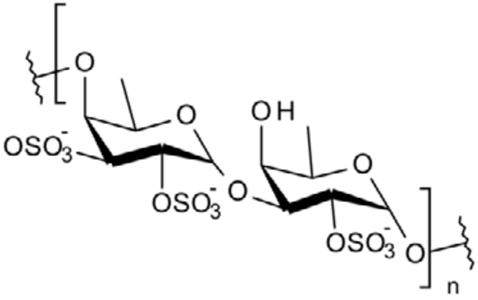


Fucoidan - Ascophyllum nodosum, analytical grade

[9072-19-9]

YF153483

50mg	$90.00
100mg	$150.00
250mg	$250.00

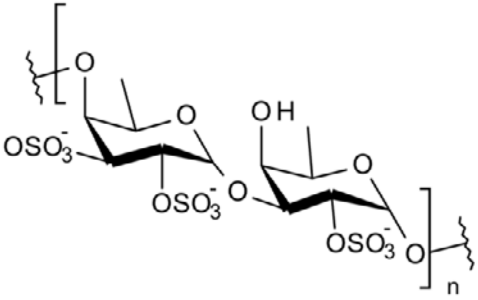


Fucoidan - Cladosiphon

[9072-19-9]

YF146834

10mg	$90.00
25mg	$200.00
50mg	$350.00

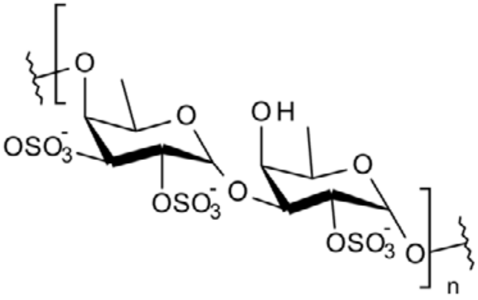


Fucoidan - Durvillea

[9072-19-9]

YF157165

10mg	$90.00
25mg	$200.00
50mg	$350.00

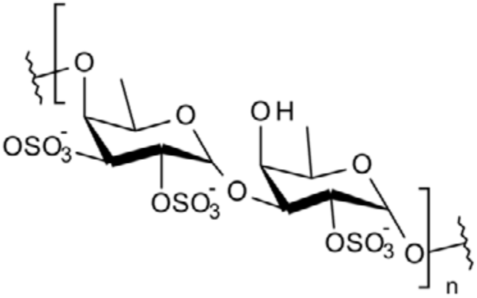


Fucoidan - Ecklonia

[9072-19-9]

YF157166

10mg	$90.00
25mg	$200.00
50mg	$350.00



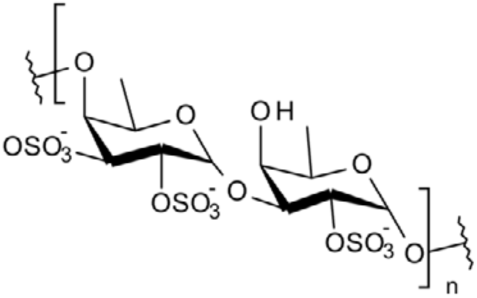
Fucoidan - Fucus serratus

- Sulfated L-fucan

[9072-19-9]

YF09360

10g	$76.00
25g	$152.50
50g	$244.00



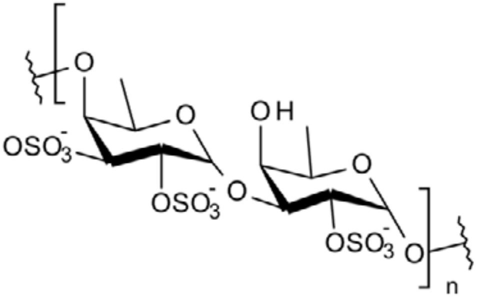
Fucoidan - Fucus vesiculosus

- Sulfated L-fucan

[9072-19-9]

YF57714

50mg	$65.00
100mg	$118.00
250mg	$237.50



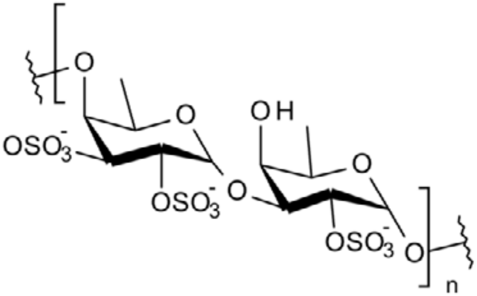
Fucoidan - Laminaria digitata

- Sulfated L-fucan

[9072-19-9]

YF09361

100mg	$60.00
250mg	$95.00
500mg	$150.00

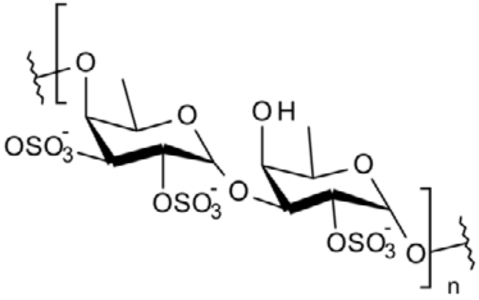


Fucoidan - Laminaria japonicia

[9072-19-9]

YF01606

10g	$50.00
25g	$80.00
50g	$121.00

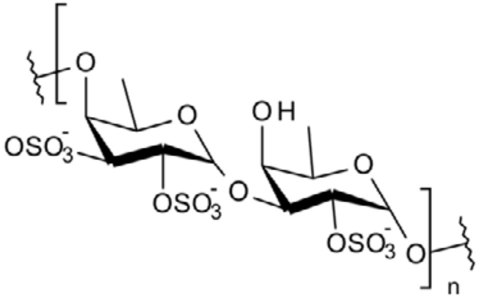


Fucoidan - Lessonia nigrescens

[9072-19-9]

YF146833

10mg	$90.00
25mg	$200.00
50mg	$350.00



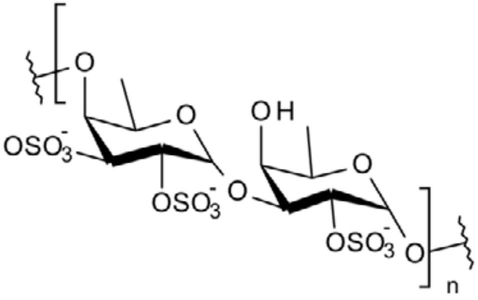
Fucoidan - Macrocystis pyrifera

- Sulfated L-fucan

[9072-19-9]

YF145109

500mg	$50.00
1g	$90.00
2g	$120.00



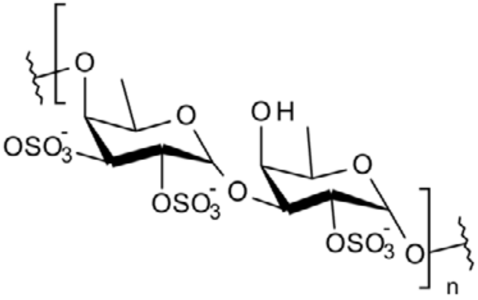
Fucoidan - Pelvetia canaliculata

- Sulfated L-fucan

[9072-19-9]

YF09362

Price on Application



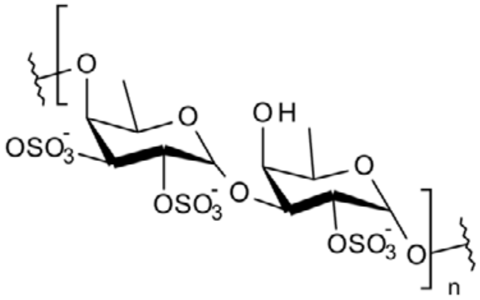
Fucoidan - Sargassum

- Sulfated L-fucan

[9072-19-9]

YF157167

10mg	$90.00
25mg	$200.00
50mg	$350.00

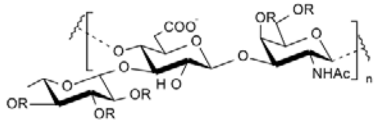


Fucosylated chondroitin sulfate

- FucCS

YF76156

Price on Application


R=OH or SO_3 -

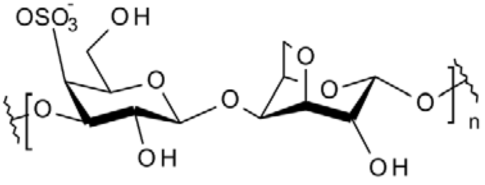
Furcellaran

- Danish agar

[9000-21-9]

YF44604

5Kg	$375.00
10Kg	$600.00
20Kg	$1000.00

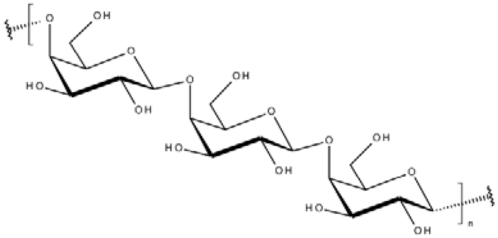


Galactan - from gum arabic

[39300-87-3]

YG08091

100mg	$95.00
250mg	$160.00
500mg	$285.00

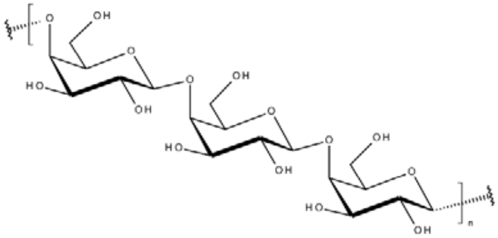


Galactan - from potato

[39300-87-3]

YG71532

250mg	$85.00
500mg	$130.00
1g	$206.00



Galactomannan from Ceratonia Siliqua

see D-Galacto-D-mannan - from carob, YG08098 on page 148

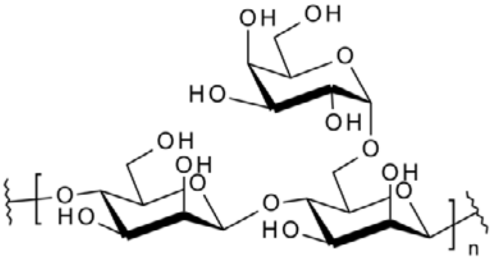
D-Galacto-D-mannan - from carob

- Galactomannan from Ceratonia Siliqua

[11078-30-1]

YG08098

1g	$75.00
2g	$120.00
5g	$240.00



Galactomannan

see Guar gum, YG11700 on page 151

Galactomannnan

see Locust bean gum, YL58654 on page 160

Galactooligosaccharides

- GOS

OG32134

100g	$70.00
250g	$125.00
500g	$230.00

Galacturonoapian

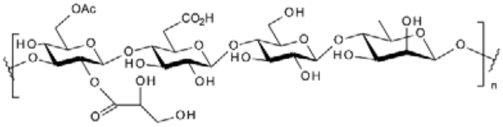
see Apiogalacturonan, YA09575 on page 127

Gellan gum

[71010-52-1]

YG153497

500g	$60.00
1Kg	$100.00
2Kg	$180.00

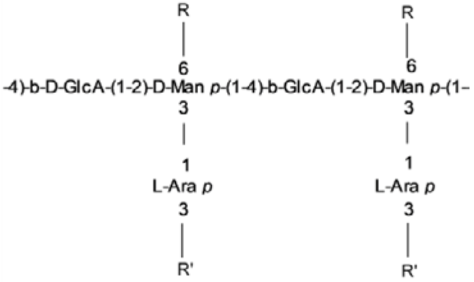


Ghatti gum

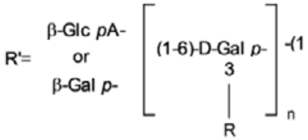
[9000-28-6]

YG35531

1kg	$60.00
2kg	$100.00
5kg	$200.00



R=L-Ara *f* or LAra *f*-(1-2,3 or 5)-L-Ara *f*-(1



1,3-b-D-Glucan

see b-D-Glucan - from Yeast (Saccharomyces Cerevisiae), YG30829 on page 149

1,3:1,4-b-D-Glucan

see Lichenan - from Cetraria islandica, YL11687 on page 159

b-1,3-Glucan

see Curdlan, YC46078 on page 135

b-D-Glucan

see Pachyman - from Poria cocos, YG158923 on page 162

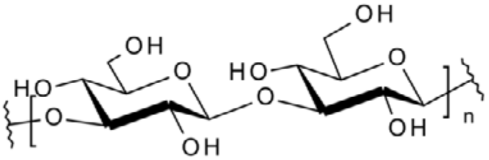
b-D-Glucan - from Yeast (Saccharomyces Cerevisiae)

- 1,3-b-D-Glucan

[9012-72-0][9051-97-2]

YG30829

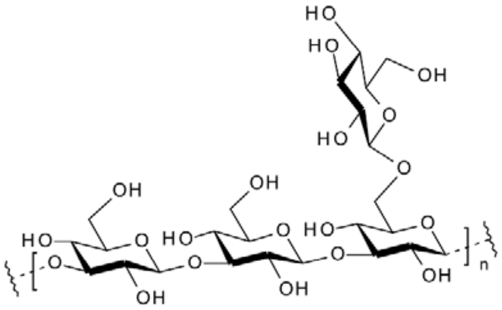
250g	$80.00
500g	$135.00
1kg	$250.00



Glucan - from Piptoporus betulinus

YG165864

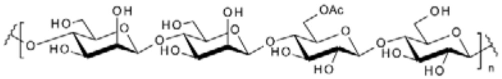
Price on Application



Glucomannan oligosaccharides - from Konjac MW <10KDa

OG63199

5mg	$85.00
10mg	$150.00
25mg	$275.00



(a-L-Glucurono-a-D-Manno-b-D-Manno-b-D-Gluco), (a-L-Gulurono-b-D-Mannurono), b-D-Gluco-b-D-Mannan

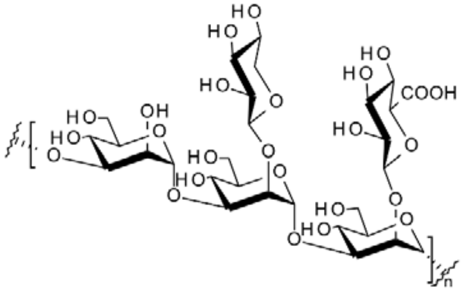
see Polyglycoplex, YP157506 on page 163

Glucurono-xylomannan - from Cryptococcus neoformans

[76082-65-0]

YG11701

2mg	$60.00
5mg	$110.00
10mg	$157.50

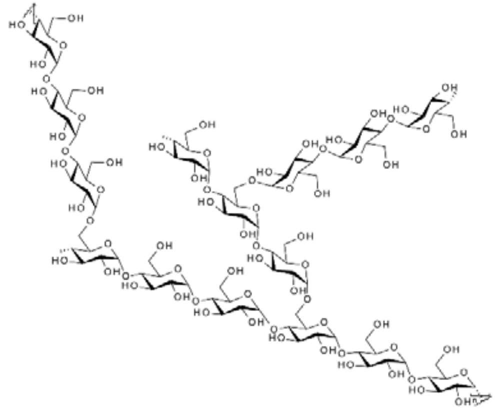


Glycogen - from bovine liver

[9005-79-2]

YG162526

50mg	$50.00
100mg	$90.00
250mg	$200.00

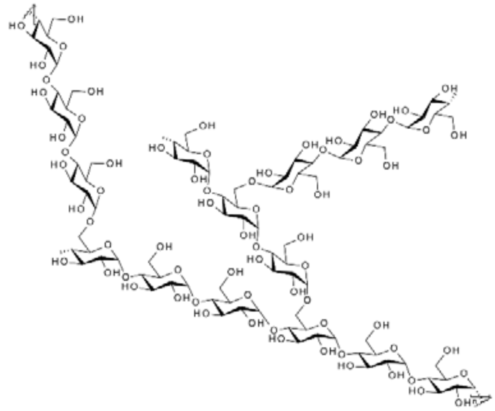


Glycogen - from oyster

[9005-79-2]

YG40133

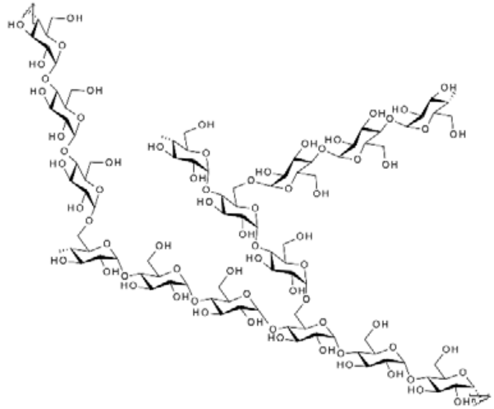
10g	$250.00
25g	$450.00
50g	$800.00



Glycogen - from oyster for molecular biology

[9005-79-2]

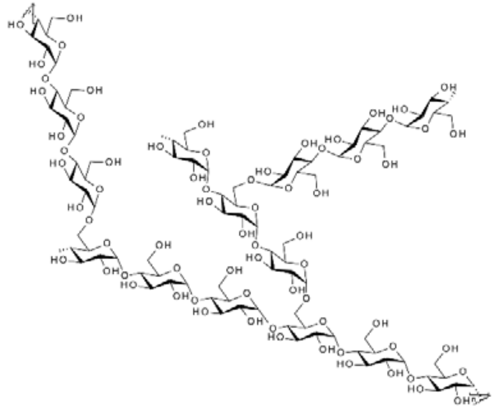
YG164194	10g	$490.00



Glycogen - from rabbit liver

[9005-79-2]

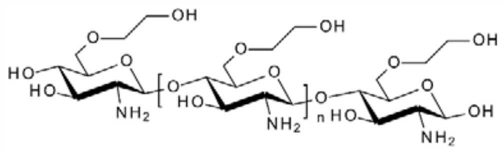
YG71459	250mg	$80.00
	500mg	$150.00
	1g	$270.00



Glycol chitosan

[123938-86-3]

OG45753	250mg	$77.50
	500mg	$125.00
	1g	$180.00



GOS

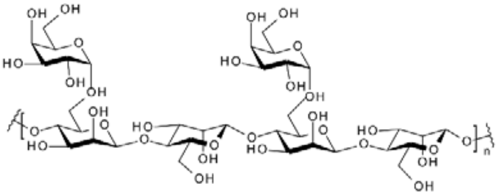
see Galactooligosaccharides, OG32134 on page 149

Guar gum

- Galactomannan

[9000-30-0]

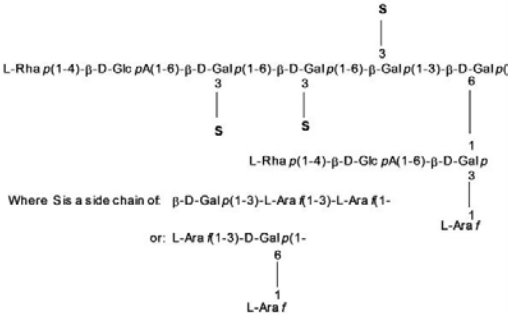
YG11700	100g	$75.00
	250g	$140.00
	500g	$250.00



Gum arabic

[9000-01-5]

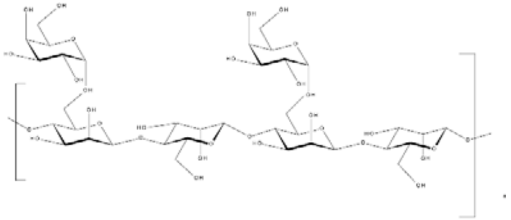
YG58641	500g	$60.00
	1Kg	$100.00
	2Kg	$160.00



Gum cassia tora

[51434-18-5]

OG157266	Price on Application

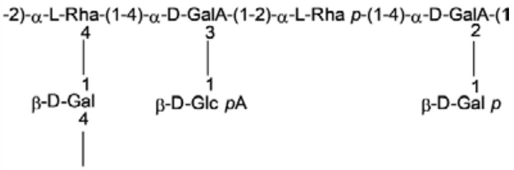


Gum karaya

[9000-36-6]

YG58642

50g	$55.00
100g	$95.00
250g	$175.00

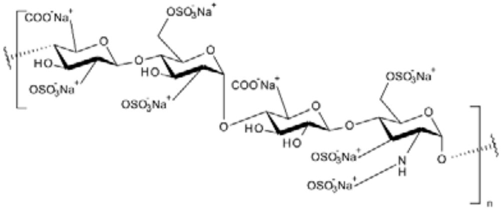


Heparan sulphate sodium salt

[57459-72-0]

YH30121

1mg	$250.00
2mg	$390.00
5mg	$750.00

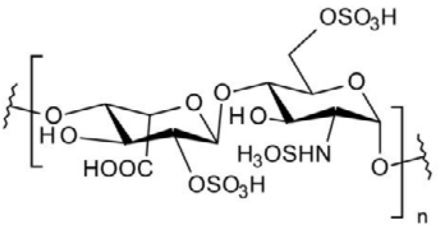


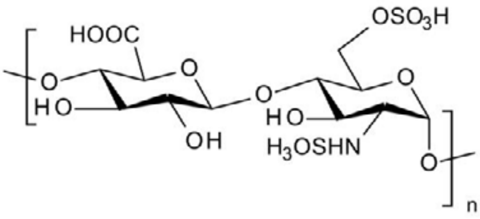
Heparin sodium salt

[9041-08-1]

YH09354

1g	$50.00
2g	$80.00
5g	$175.00





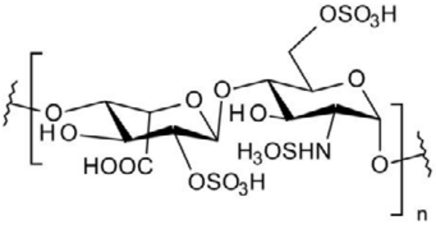
b-Heparin

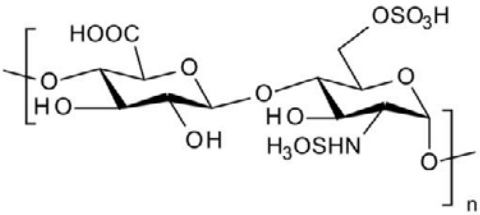
see Dermatan sulphate sodium salt, YD30120 on page 135

Heparin

[9005-49-6]

YH03833 Price on Application





High methoxy pectin

see HM Pectin, YH158538 on page 152

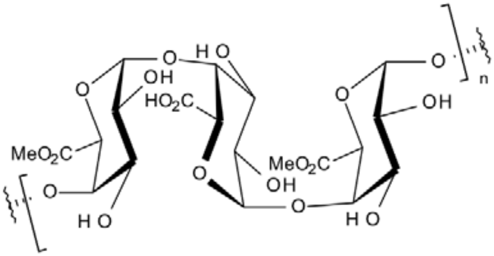
HM Pectin

- High methoxy pectin

[9000-69-5]

YH158538

100g	$59.00
250g	$130.00
500g	$235.00

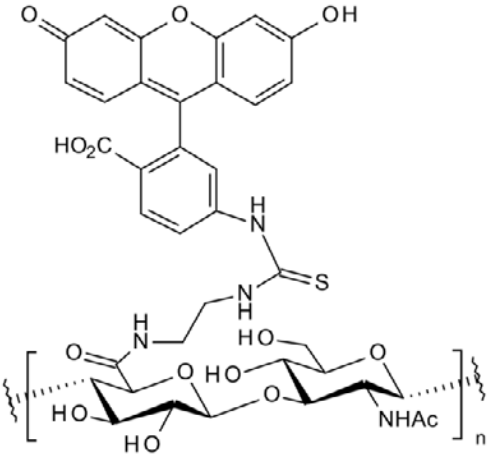


Hyaluronate fluorescein - MW - 800kDa

- Fluorescein hyaluronic acid

YH45321

1mg	$70.00
2mg	$120.00
5mg	$210.00

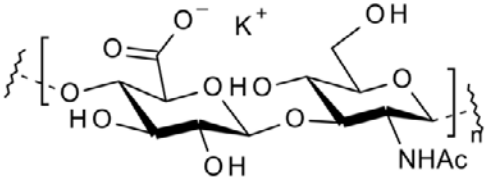


Hyaluronic acid potassium salt - from Cockscomb

[31799-91-4]

FH71608

50mg	$50.00
100mg	$80.00
250mg	$160.00

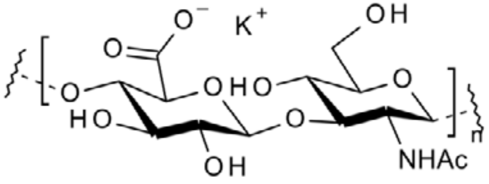


Hyaluronic acid potassium salt - from human umbilical cord

- Potassium hyaluronate

[31799-91-4]

FH146394 Price on Application

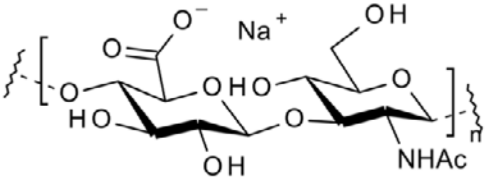


Hyaluronic acid sodium salt - Average MW 0.6 - 1.0 million Da

[9067-32-7]

FH71634

25g	$60.00
50g	$100.00
100g	$150.00



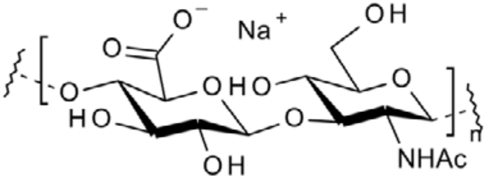
Hyaluronic acid sodium salt - Average MW 1.0 - 2.0 million Da

- Poly(b-glucuronic acid-[1→3]-b-N-acetylglucosamine-[1→4])

[9067-32-7]

YH05852

25g	$65.00
50g	$95.00
100g	$150.00

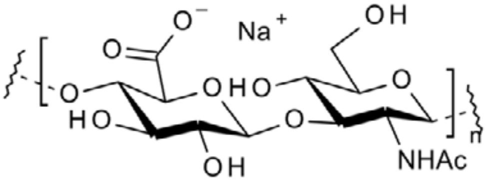


Hyaluronic acid sodium salt - Average MW 1.5 - 2.5 million Da

- Poly(b-glucuronic acid-[1→3]-b-N-acetylglucosamine-[1→4])

[9067-32-7]

YH141813 Price on Application

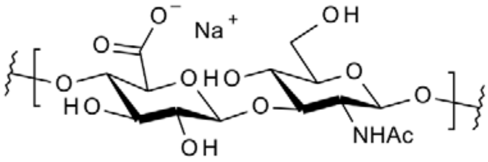


Hyaluronic acid sodium salt - Average MW 1.8 - 2.5 million Da

[9067-32-7]

FH145201

25g	$195.00
50g	$300.00
100g	$400.00

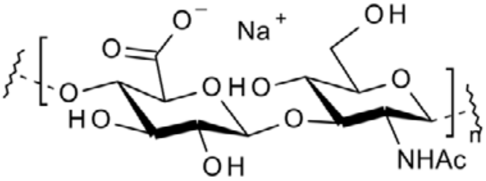


Hyaluronic acid sodium salt - Average MW 2.0 - 2.5 million Da

[9067-32-7]

FH139153

2g	$48.00
5g	$90.00
10g	$140.00

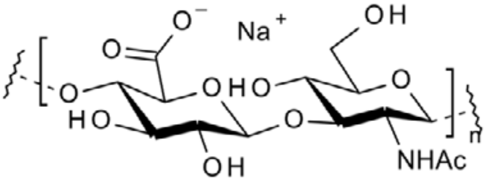


Hyaluronic acid sodium salt - Average MW 70,000-80,000

[9067-32-7]

FH159379

10g	$40.00
25g	$78.25
50g	$125.00



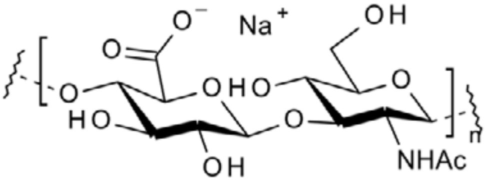
Hyaluronic acid sodium salt - EP7, Average MW 0.2-0.5 million Daltons

- Poly(b-glucuronic acid-[1→3]-b-N-acetylglucosamine-[1→4])

[9067-32-7]

YH72470

5g	$75.00
10g	$125.00
25g	$200.00

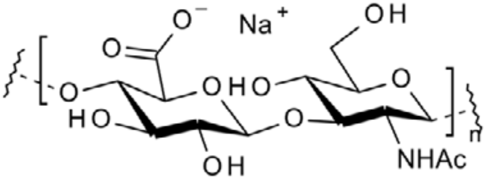


Hyaluronic acid sodium salt - EP7, Average MW 0.6-2.5 million Daltons

[9067-32-7]

FH76752

Price on Application

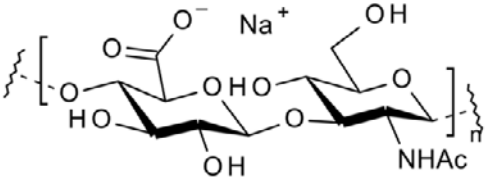


Hyaluronic acid sodium salt - Extra low molecular weight 8,000-15,000

[9067-32-7]

FH63426

10g	$60.00
25g	$100.00
50g	$150.00

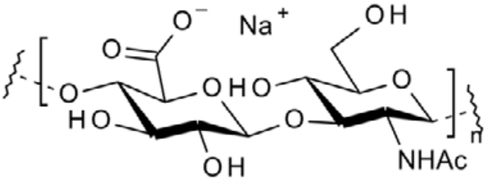


Hyaluronic acid sodium salt - Low molecular weight 10,000 - 50,000

[9067-32-7]

FH76335

25g	$60.00
50g	$100.00
100g	$156.00

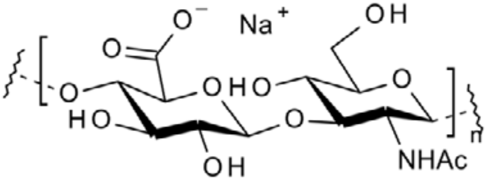


Hyaluronic acid sodium salt - Low molecular weight 40,000 - 50,000

[9067-32-7]

FH01773

25g	$65.00
50g	$107.00
100g	$178.00

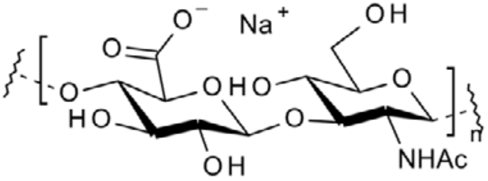


Hyaluronic acid sodium salt - Low molecular weight 80,000 - 100,000

[9067-32-7]

FH63427

25g	$70.00
50g	$110.00
100g	$180.00

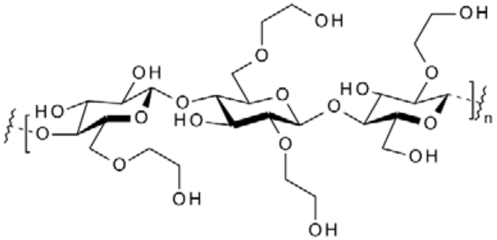


Hydroxyethyl cellulose

[9004-62-0]

YH30634

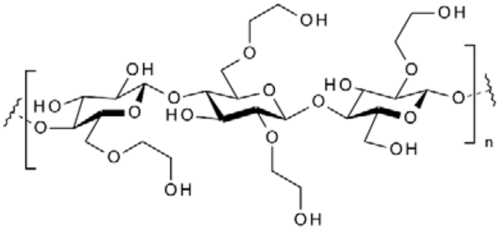
250g	$70.00
500g	$105.00
1kg	$180.00



Hydroxyethyl cellulose - Viscocity 4500-6500mPa·s

YH167268

250g	$70.00
500g	$120.00



E405

see Propylene glycol alginate, YP58644 on page 164

Hydroxypropyl alginate

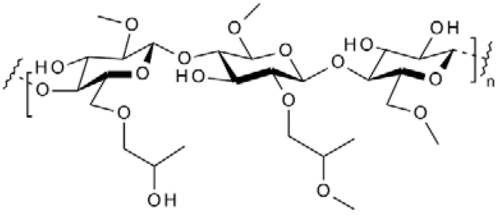
see Propylene glycol alginate, YP58644 on page 164

Hydroxypropyl cellulose - Average MW 100,000

[9004-64-2]

YH63491

100g	$95.00
250g	$150.00
500g	$185.00

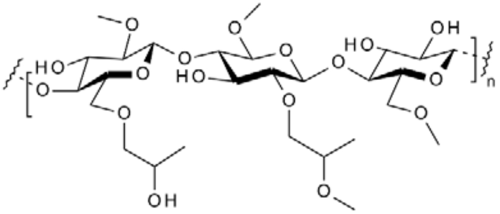


Hydroxypropyl cellulose - Average MW 150,000

[9004-64-2]

YH158877

100g	$130.00
250g	$225.00
500g	$350.00

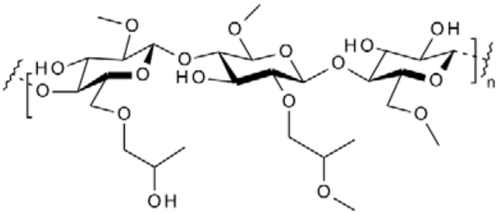


Hydroxypropyl cellulose - Average MW 1,000,000

[9004-64-2]

OH63493

100g	$190.00
250g	$350.00
500g	$600.00

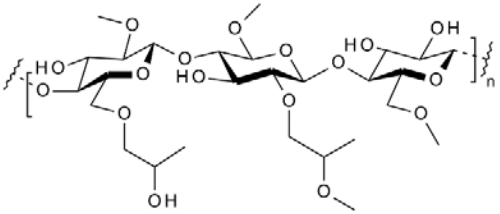


Hydroxypropyl cellulose - Average MW 200,000

[9004-64-2]

YH158878

Price on Application

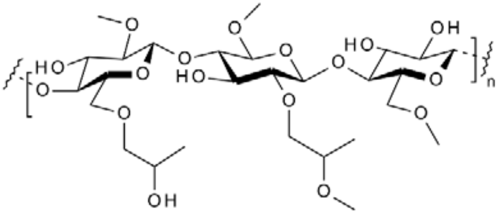


Hydroxypropyl cellulose - Average MW 370,000

[9004-64-2]

YH63492

250g	$375.00
500g	$600.00
1Kg	$950.00

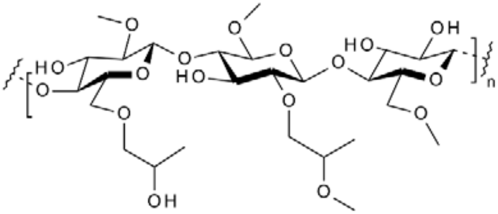


Hydroxypropyl cellulose - Average MW 50,000 - 1250,000

[9004-64-2]

YH16040

250g	$65.00
500g	$95.00
1kg	$150.00

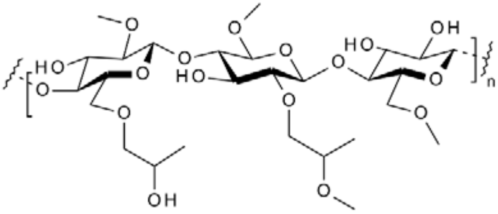


Hydroxypropyl cellulose - Average MW 80,000

[9004-64-2]

YH63490

50g	$125.00
100g	$190.00
250g	$375.00

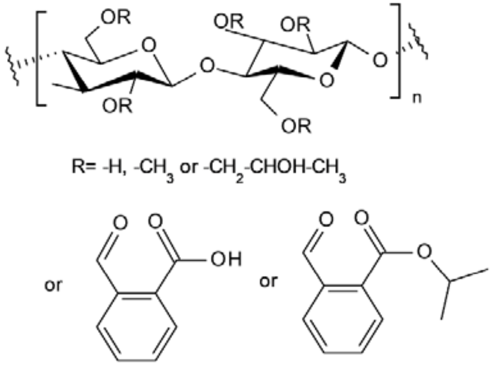


(Hydroxypropyl)methyl cellulose phthalate

[9050-31-1]

YH44175

100g	$60.00
250g	$90.00
500g	$140.00



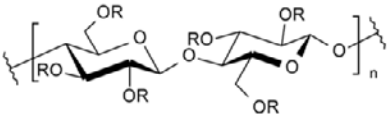
R= -H, $-CH_3$ or $-CH_2$-CHOH-CH_3

(Hydroxypropyl)methyl cellulose - USP39, Viscocity 3000-5600 cP

[9004-65-3]

YH160972

Price on Application



R = -H, $-CH_3$ or $-CH_2CHOHCH_3$

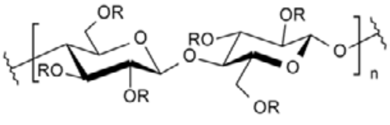
(Hydroxypropyl)methyl cellulose - USP39, Viscocity 80-120 cP, 2 % in H2O (20 °C)

- Hypromellose

[9004-65-3]

YH160970

Price on Application



R = -H, $-CH_3$ or $-CH_2CHOHCH_3$

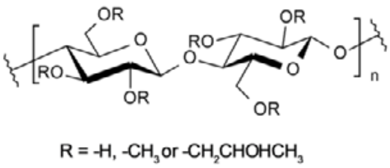
(Hydroxypropyl)methyl cellulose - Viscocity 3000-5600 cP

- Hypromellose

[9004-65-3]

YH59732

500g	$60.00
1Kg	$100.00
2Kg	$170.00

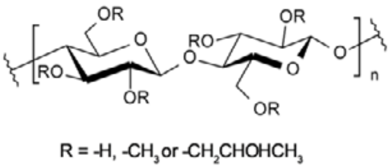


(Hydroxypropyl)methyl cellulose - Viscocity 40-60 cP, 2 % in H2O (20 °C)

[9004-65-3]

YH158082

250g	$65.00
500g	$115.00
1Kg	$195.00



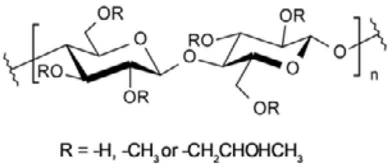
(Hydroxypropyl)methyl cellulose - Viscocity 80-120 cP, 2 % in H2O (20 °C)

- Hypromellose

[9004-65-3]

YH32865

500g	$70.00
1kg	$100.00
2kg	$160.00



Hypromellose

see (Hydroxypropyl)methyl cellulose - USP39, Viscocity 80-120 cP, 2 % in H2O (20 °C), YH160970 on page 156

Hypromellose

see (Hydroxypropyl)methyl cellulose - Viscocity 3000-5600 cP, YH59732 on page 157

Hypromellose

see (Hydroxypropyl)methyl cellulose - Viscocity 80-120 cP, 2 % in H2O (20 °C), YH32865 on page 157

Inulin dodecylcarbamate

see Inulin lauryl carbamate - 25% in glycerol, OI146251 on page 157

Inulin lauryl carbamate - 25% in glycerol

- Lauryl inulin carbamate
- Inulin dodecylcarbamate

[478483-27-1]

OI146251

10g	$50.00
25g	$100.00
50g	$150.00

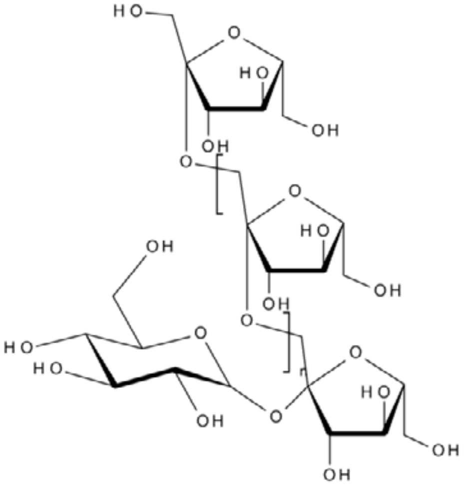
Inulin - from chicory

- Poly-b-(2-1)-fructofuranose

[9005-80-5]

YI01274

500g	$50.00
1kg	$85.00
2kg	$160.00

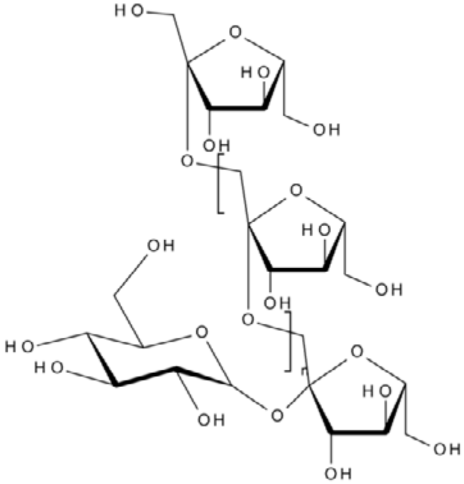


Inulin - from Jerusalem artichoke

[9005-80-5]

YL75175

1g	$50.00
2g	$80.00
5g	$175.00



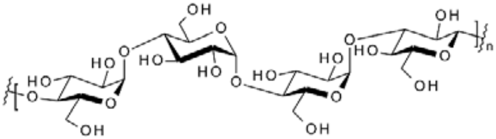
Isolichenan

- (1-3)&(1-4) a-D-glucan

[53025-03-9]

YI11686

100mg	$155.00
250mg	$300.00
500mg	$500.00

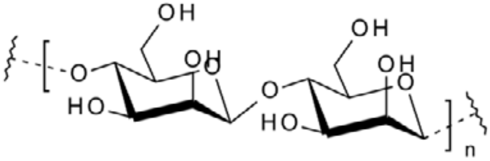


Ivory nut mannan

[37251-47-1]

YI45754

1g	$65.00
2g	$110.00
5g	$250.00



Kefiran

see Kephir gum, YK165865 on page 158

Kephir gum

- Kefiran

YK165865

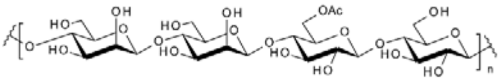
Price on Application

Konjac glucomannan

[37220-17-0]

YK10336

50g	$60.00
100g	$90.00
250g	$150.00



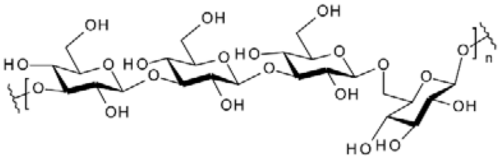
Laminaran - from Eisenia bicyclis

- Laminarin

[9008-22-4]

YL02421

2g	$52.50
5g	$89.30
10g	$136.50



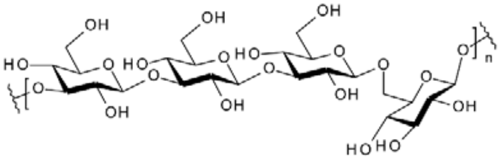
Laminaran - from Laminaria cloustoni

- Laminarin

[9008-22-4]

YL165861

Price on Application



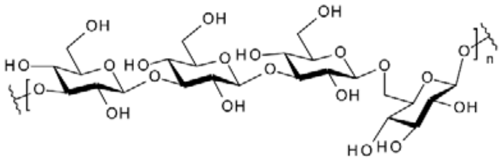
Laminaran - from Laminaria digitata

- Laminarin

[9008-22-4]

YL09900

100mg	$69.00
250mg	$132.50
500mg	$210.00



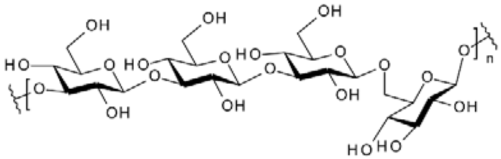
Laminaran - from Thallus laminariae

- Laminarin

[9008-22-4]

YL76431

2g	$52.50
5g	$89.30
10g	$136.50



Laminarin

see Laminaran - from Eisenia bicyclis, YL02421 on page 158

Laminarin

see Laminaran - from Laminaria cloustoni, YL165861 on page 158

Laminarin

see Laminaran - from Laminaria digitata, YL09900 on page 159

Laminarin

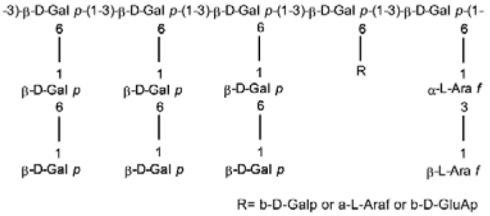
see Laminaran - from Thallus laminariae, YL76431 on page 159

Larch arabinogalactan

[9036-66-2]

YL29121

25g	$65.00
50g	$110.00
100g	$180.00



Lauryl inulin carbamate

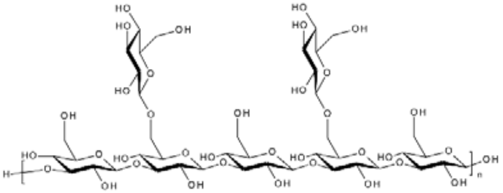
see Inulin lauryl carbamate - 25% in glycerol, OI146251 on page 157

Lentinan

[37339-90-5]

FL33321

5g	$50.00
10g	$80.00
25g	$162.50

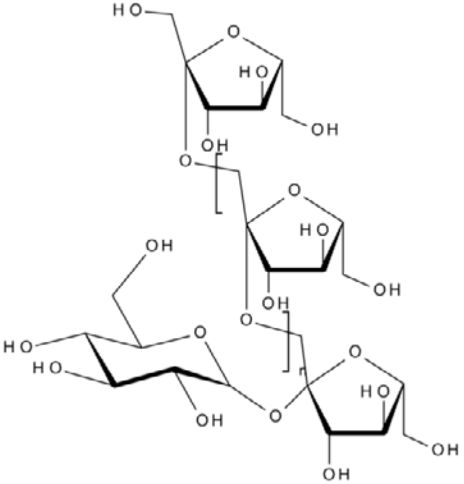


Levan - from Erwinia herbicola

[9013-95-0]

YL76657

100mg	$60.00
250mg	$112.50
500mg	$175.00



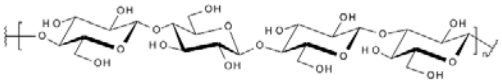
Lichenan - from Cetraria islandica

- Lichenin
- 1,3:1,4-b-D-Glucan

[1402-10-4]

YL11687

1g	$125.00
2g	$190.00
5g	$375.00



Lichenin

see Lichenan - from Cetraria islandica, YL11687 on page 159

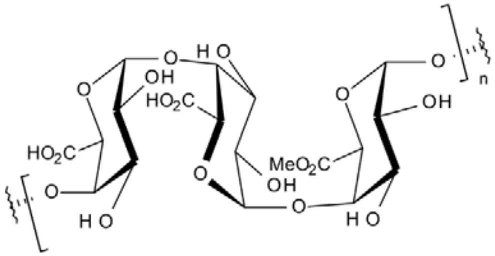
LM Pectin

- Low methoxy pectin

[9000-69-5]

YL158537

100g	$59.00
250g	$130.00
500g	$235.00



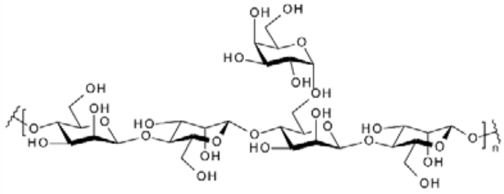
Locust bean gum

- Galactomannnan

[9000-40-2]

YL58654

50g	$60.00
100g	$95.00
250g	$175.00

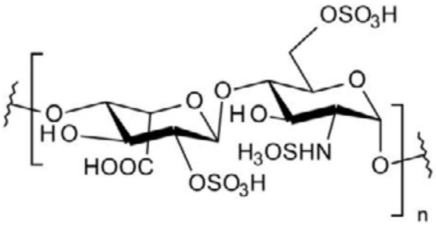


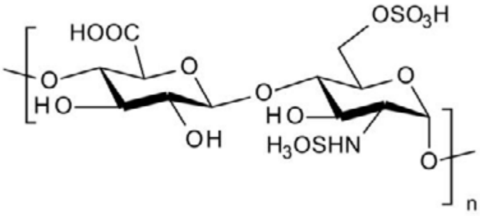
Low calcium heparin

[9005-49-6]

YL30119

100mg	$342.00





Low methoxy pectin

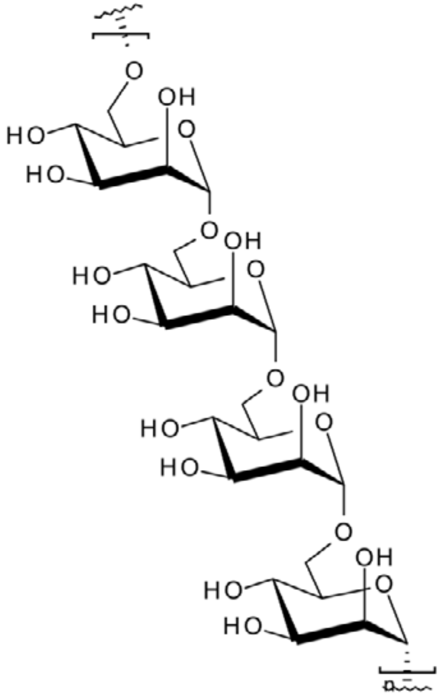
see LM Pectin, YL158537 on page 160

Mannan - from Saccharomyces cerevisiae

[9036-88-8]

YM63069

250mg	$65.00
500mg	$100.00
1g	$180.00

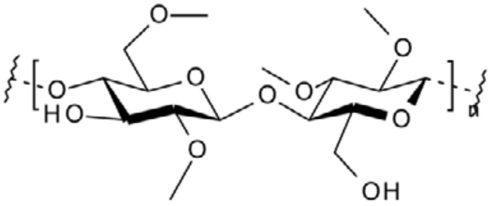


Methyl cellulose - About 15cP

[9004-67-5]

YM30635

250g	$50.00
500g	$100.00
1kg	$150.00

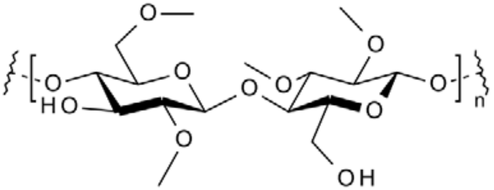


Methyl cellulose - Viscosity 40000 cPs

[9004-67-5]

OM143934

100g	$65.00
250g	$100.00
500g	$160.00

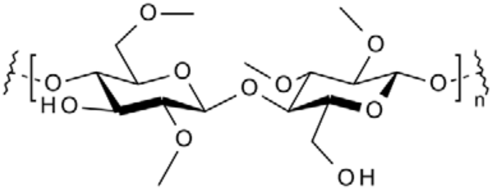


Methyl cellulose - viscosity: 400 cP

[9004-67-5]

OM166726

Price on Application

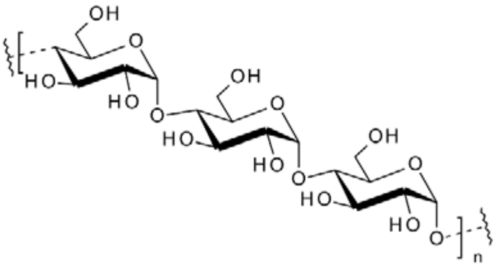


Nigeran

[31799-84-5]

YN157505

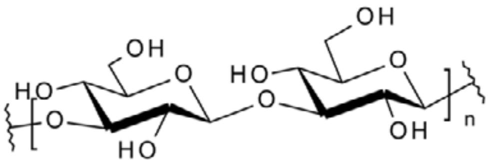
100mg	$190.00
250mg	$350.00
500mg	$550.00



Oat b-D-glucan

YO32420

1g	$125.00
2g	$190.00
5g	$395.00



Octyl-agarose

[68652-09-5]

YO167206

25g	$200.00
50g	$300.00
100g	$500.00

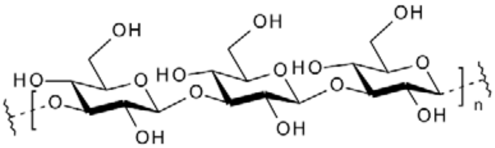
Pachyman - from Poria cocos

- b-D-Glucan

[9037-88-1]

YG158923

1g	$85.00
2g	$150.00
5g	$275.00

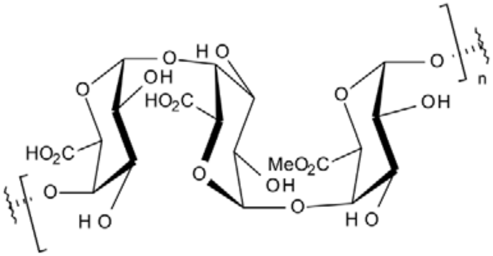


Pectic acid

[9046-40-6]

YP33892

25g	$150.00
50g	$200.00
100g	$300.00



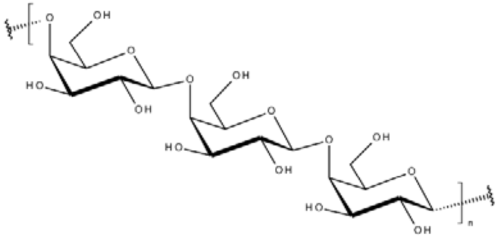
Pectic Acid

see Polygalacturonic acid, FP31687 on page 163

Pectic galactan - From lupin

YP158924

1g	$125.00
2g	$190.00

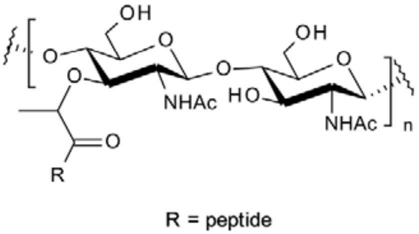


Peptidoglycan - from Staphylococcus aureus

- PGN

YP57750

2mg	$90.00
5mg	$150.00
10mg	$250.00



PGN

see Peptidoglycan - from Staphylococcus aureus, YP57750 on page 162

PGX

see Polyglycoplex, YP157506 on page 163

Poly[2,8-(N-acetylneuraminic acid sodium salt)]

see Colominic acid sodium salt - Average MW 30,000, YC11298 on page 134

Polyanhydrogalacturonic acid

see Sodium pectate, YG10332 on page 167

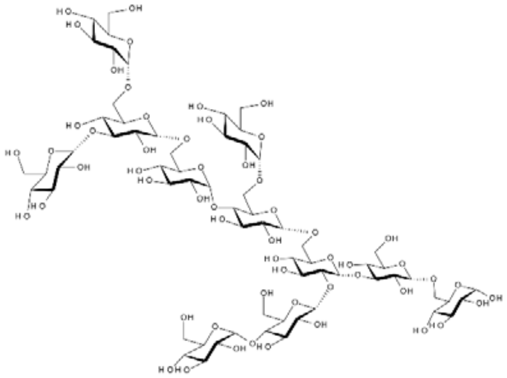
Polydextrose

- Poly-D-glucose

[68424-04-4]

YP29207

25g	$50.00
50g	$85.00
100g	$140.00



Poly-b-(2-1)-fructofuranose

see Inulin - from chicory, YI01274 on page 157

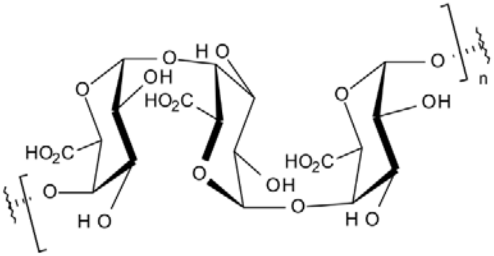
Polygalacturonic acid

- Pectic Acid

[25990-10-7]

FP31687

5g	$35.00
10g	$40.00
25g	$50.00



Poly-D-glucose

see Polydextrose, YP29207 on page 163

Poly(b-glucuronic acid-[1→3]-b-N-acetylglucosamine-[1→4])

see Hyaluronic acid sodium salt - Average MW 1.0 - 2.0 million Da, YH05852 on page 153

Poly(b-glucuronic acid-[1→3]-b-N-acetylglucosamine-[1→4])

see Hyaluronic acid sodium salt - EP7, Average MW 0.2-0.5 million Daltons, YH72470 on page 154

Poly(b-glucuronic acid-[1→3]-b-N-acetylglucosamine-[1→4])

see Hyaluronic acid sodium salt - Average MW 1.5 - 2.5 million Da, YH141813 on page 153

Polyglycoplex

- PGX
- (a-L-Glucurono-a-D-Manno-b-D-Manno-b-D-Gluco), (a-L-Gulurono-b-D-Mannurono), b-D-Gluco-b-D-Mannan

YP157506

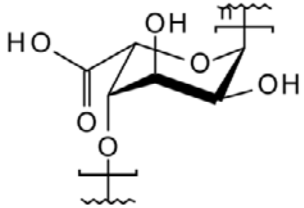
Price on Application

Polyguluronic acid

[36562-70-6]

YP03135

1g	$60.00
2g	$90.00
5g	$175.00

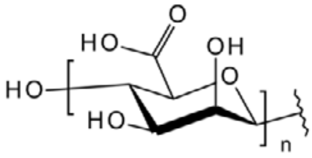


Polymannuronic acid - Average MW < 5000 Da

[29894-36-8]

YP03136

50mg	$100.00
100mg	$150.00
250mg	$250.00

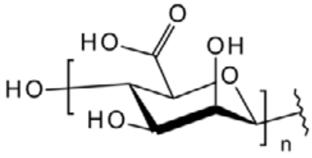


Polymannuronic acid - Average MW > 5000 Da

[29894-36-8]

YP31737

1g	$50.00
2g	$80.00
5g	$140.00



Poly[b-(1,4)-D-xylopyranose]

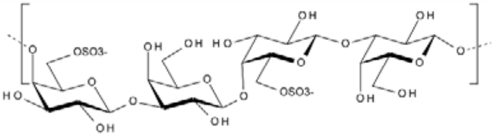
see Xylan - from corncob, MW 300-900, YC05381 on page 169

Porphyran

[11016-36-7]

YP157502

25mg	$50.00
50mg	$90.00
100mg	$150.00



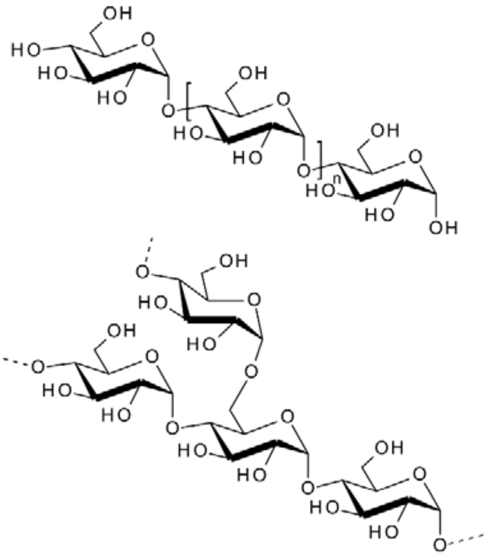
Potassium hyaluronate

see Hyaluronic acid potassium salt - from human umbilical cord, FH146394 on page 153

Pregelatinized starch

[9005-25-8]

YP35111 Price on Application



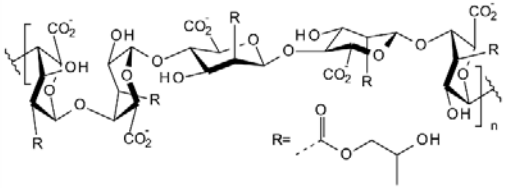
Propylene glycol alginate

- E405
- Hydroxypropyl alginate

[9005-37-2]

YP58644

2g	$70.00
5g	$125.00
10g	$200.00



Psyllium seed gum

[8063-16-9]

YP58645

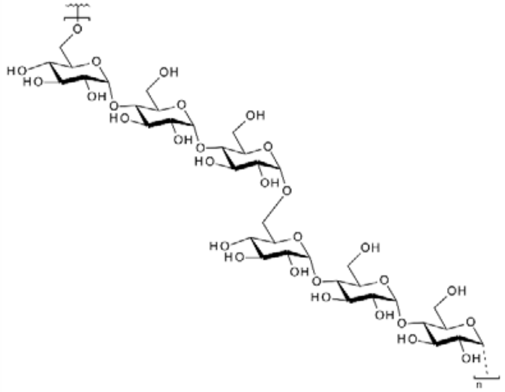
100g	$75.00
250g	$150.00
500g	$275.00

Pullulan

[9057-02-7]

YP07957

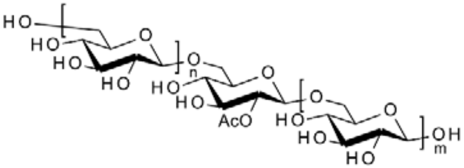
100g	$40.00
250g	$75.00
500g	$100.00



Pustulan

[37331-28-5]

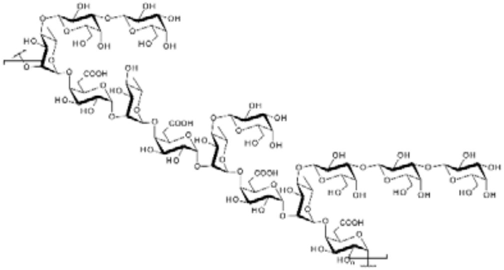
YP15423		
	100mg	$115.00
	250mg	$205.00
	500mg	$340.00



Rhamnogalacturonan - from potato

[39280-21-2]

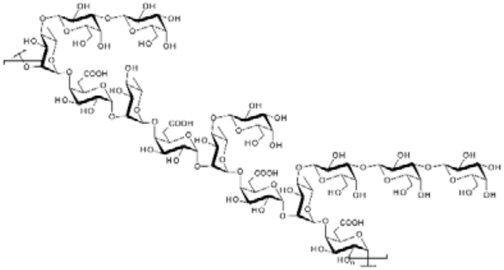
YR59706		
	1g	$150.00
	2g	$260.00
	5g	$550.00



Rhamnogalacturonan - from soy bean

[39280-21-2]

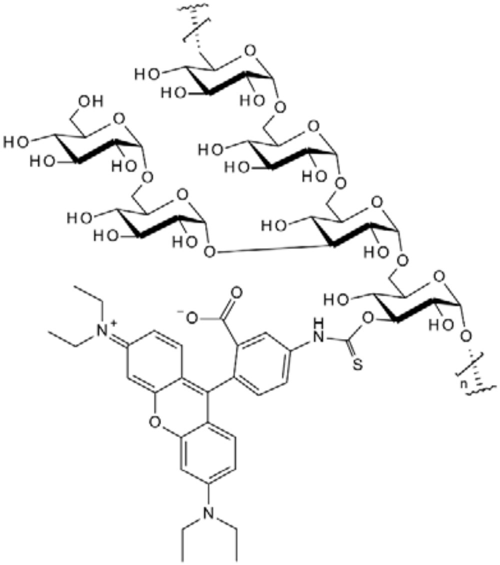
YR158311		
	1g	$95.00
	2g	$150.00
	5g	$275.00



Rhodamine B isothiocyanate-dextran - Average MW 10,000

- Dextran rhodamine

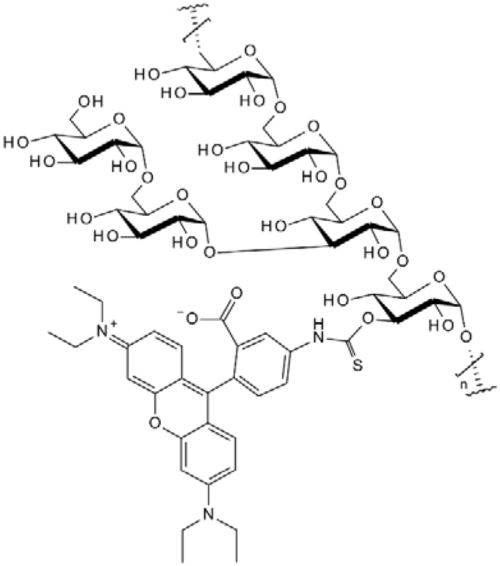
YD58701		
	25mg	$90.00
	50mg	$150.00
	100mg	$250.00



Rhodamine B isothiocyanate-dextran - Average MW 70,000

YR166142

100mg	$250.00
250mg	$475.00
500mg	$750.00

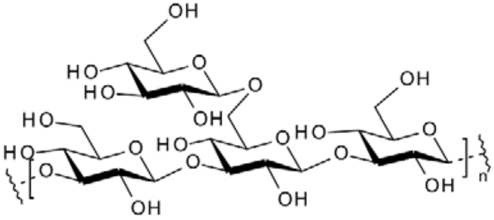


Schizophyllan

- Sonifilan
- Sizofiran

[9050-67-3]

YS46139 Price on Application

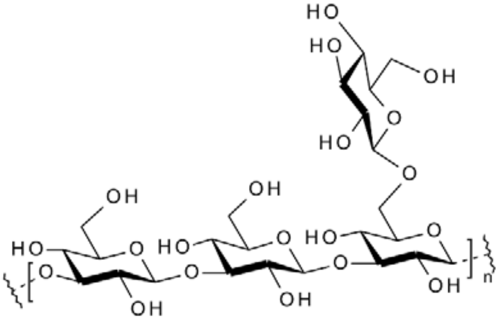


Scleroglucan

[39464-87-4]

YS09784

2g	$60.00
5g	$105.00
10g	$175.00



Sizofiran

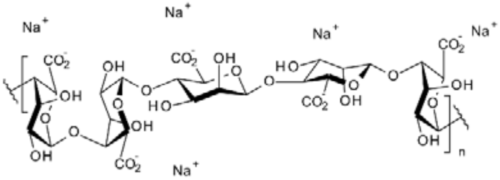
see Schizophyllan, YS46139 on page 166

Sodium alginate - high vicosity

[9005-38-3]

YS165508

500g	$75.00
1Kg	$125.00
2Kg	$200.00

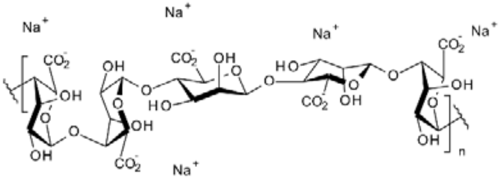


Sodium alginate - low viscosity

[9005-38-3]

YS31736

500g	$65.00
1kg	$100.00
2kg	$180.00

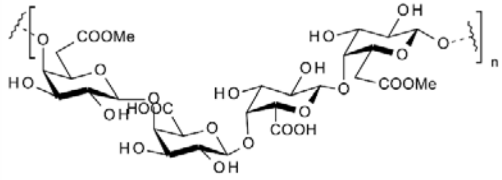


Sodium pectate
- Sodium polypectate
- Polyanhydrogalacturonic acid

[9049-37-0]

YG10332

5g	$75.00
10g	$120.00
25g	$225.00



Sodium polypectate
see Sodium pectate, YG10332 on page 167

Sonifilan
see Schizophyllan, YS46139 on page 166

Starch - from maize
see Corn starch, YC35117 on page 135

Starch from potato
[9005-25-8]

YS164195

500g	$45.00
1Kg	$100.00
2Kg	$170.00

Sulfated glycosaminoglycan
see Chondroitin sulfate sodium salt, YC04273 on page 134

Sulfated L-fucan
see Fucoidan - Ascophyllum nodosum, YF09363 on page 145

Sulfated L-fucan
see Fucoidan - Fucus serratus, YF09360 on page 146

Sulfated L-fucan
see Fucoidan - Fucus vesiculosus, YF57714 on page 146

Sulfated L-fucan
see Fucoidan - Laminaria digitata, YF09361 on page 146

Sulfated L-fucan
see Fucoidan - Macrocystis pyrifera, YF145109 on page 147

Sulfated L-fucan
see Fucoidan - Pelvetia canaliculata, YF09362 on page 147

Sulfated L-fucan
see Fucoidan - Sargassum, YF157167 on page 148

Sulfated xylorhamnoglucuronan
see Ulvan - Ulva armoricana-winter-heavy, YU09364 on page 168

Sulfated xylorhamnoglucuronan
see Ulvan - Ulva armoricana-winter-light, YU09365 on page 168

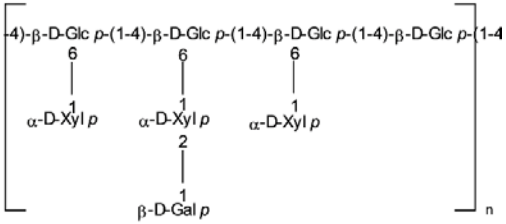
Sulfated xylorhamnoglycuronan
see Ulvan - Ulva rotondata-Autumn, YU09366 on page 168

Sulfated xylorhamnoglycuronan
see Ulvan - Ulva rotondata-Summer, YU09367 on page 169

Tamarind gum
[39386-78-2]

YT58655

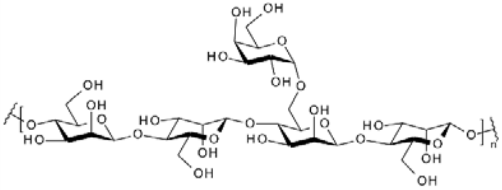
50g	$65.00
100g	$110.00
250g	$190.00



Tara gum
[39300-88-4]

YT58656

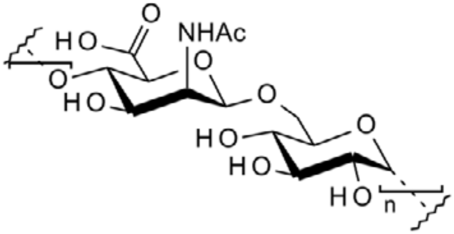
100g	$100.00
250g	$175.00
500g	$300.00



Teichuronic acid

[37251-79-9]

YT30835 Price on Application



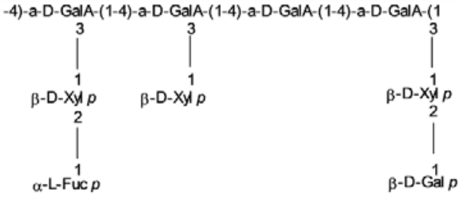
Tragacanth gum

- Tragacanth

[9000-65-1]

YT31961

250g	$50.00
500g	$80.00
1kg	$157.50



Tragacanth

see Tragacanth gum, YT31961 on page 168

Ulvan MW: 100000 - 660000 (90%)

see Ulvan - Ulva armoricana-winter-light, YU09365 on page 168

Ulvan MW: 140000 - 1050000 (78%)

see Ulvan - Ulva rotondata-Summer, YU09367 on page 169

Ulvan MW: 87000 - 630000 (80%)

see Ulvan - Ulva rotondata-Autumn, YU09366 on page 168

Ulvan MW: 90000 - 980000 (80%)

see Ulvan - Ulva armoricana-winter-heavy, YU09364 on page 168

Ulvan

[164252-34-0]

YU11689

50mg	$60.00
100mg	$100.00
250mg	$150.00

Ulvan - Ulva armoricana-winter-heavy

- Sulfated xylorhamnoglucuronan
- Ulvan MW: 90000 - 980000 (80%)

[164252-34-0]

YU09364

100mg	$85.00
250mg	$155.00
500mg	$265.00

Ulvan - Ulva armoricana-winter-light

- Sulfated xylorhamnoglucuronan
- Ulvan MW: 100000 - 660000 (90%)

[164252-34-0]

YU09365 Price on Application

Ulvan - Ulva rotondata-Autumn

- Sulfated xylorhamnoglycuronan
- Ulvan MW: 87000 - 630000 (80%)

[164252-34-0]

YU09366

500mg	$265.00
1g	$450.00
2g	$850.00

Ulvan - Ulva rotondata-Summer

- Sulfated xylorhamnoglycuronan
- Ulvan MW: 140000 - 1050000 (78%)

[164252-34-0]

YU09367

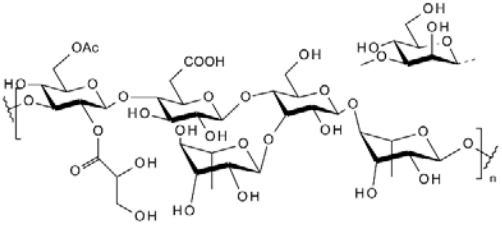
500mg	$265.00
1g	$450.00
2g	$850.00

Welan gum

[96949-22-3]

YW58646

500mg	$65.00
1g	$110.00
2g	$150.00

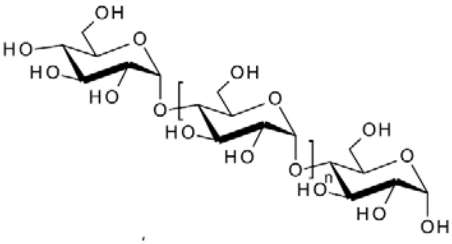


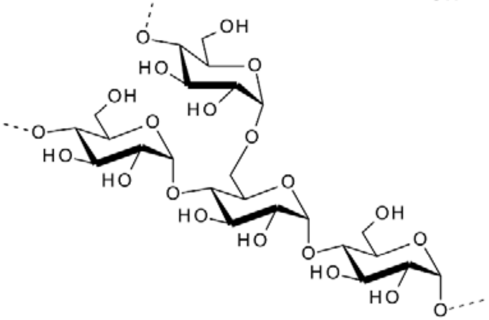
Wheat starch

[9005-25-8]

YW32318

250g	$52.50
500g	$85.00
1kg	$126.00



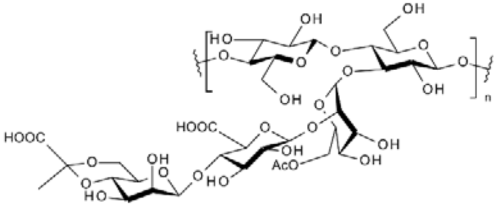


Xanthan gum

[11138-66-2]

YX29708

50g	$52.50
100g	$84.00
250g	$157.50

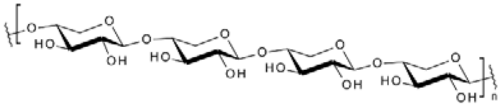


Xylan - from beechwood

[9014-63-5]

YX45751

10g	$70.00
25g	$125.00
50g	$195.00



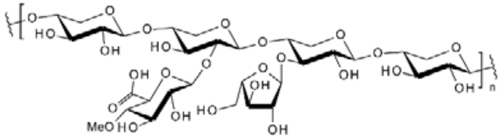
Xylan - from corncob, MW 300-900

- Poly[b-(1,4)-D-xylopyranose]

[9014-63-5]

YC05381

50g	$65.00
100g	$100.00
250g	$175.00

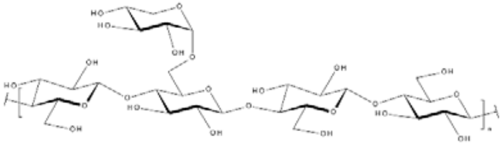


Xyloglucan

[37294-28-3]

YX11685

1g	$95.00
2g	$170.00
5g	$400.00



ZymosanA

Z **Zymosan A**

[58856-93-2]

OZ139261

1g	$125.00
2g	$190.00
5g	$300.00

Section

12

Indices

Listing by Origin CAS Index

Listing by Origin Product Code Index

Alphabetical Listing CAS Index

Alphabetical Listing Product Code Index

Custom Synthesis

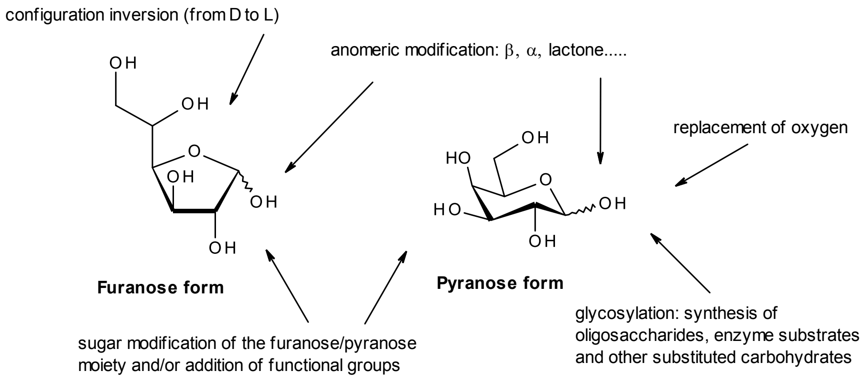
Carbosynth custom synthesis laboratories operate from a modern well equipped facility near Oxford, UK. Our scientists are chemistry-focused and skilled in design and synthesis of complex multi-step reaction schemes. We handle from mg to 100g scale and are able to transfer technology to our bulk manufacturing plant.

We specialise in:

- Functionalised building blocks
- Nucleosides, dinucleotides and analogues
- Small scale automated purification
- Synthetic route development
- High purity complex products
- Natural product synthesis
- Heterocyclic chemistry
- Oligosaccharide synthesis
- Conjugates
- Impurities and metabolites

Carbosynth welcomes custom synthesis and development projects which utilise our core expertise in carbohydrate and nucleic acid chemistries as well as niche fine chemical requirements. We operate under strict confidentiality.

- State of the art synthetic labs:
  - Biotage and Companion purification
  - Preparative HPLC
  - Size exclusion chromatography
  - Buchi MPLC
  - CEM Microwave synthesis system
  - Genevac evaporation
  - Lyophillisation
- Full in-house analytical support
  - LC-MS, HPLC, GC, optical rotation, Dionex, UPLC, ICP and NMR (1H, 13C, 19F and 31P)
- Experienced Group Leaders/Senior Chemists/Chemists
  - PhDs in carbohydrate and oligosaccharide synthesis
  - > 40 years combined experience
  - Scale up



Catalogue Abbreviations

$	United States Dollars
£	United Kingdom Pounds
€	Euros
a	Alpha
Ac	Acetyl
AdNJ	2-Acetamido-1,2-dideoxynojirimycin
ADR	European Agreement concerning the International Carriage of Dangerous goods by Road
Alt	Altrose
APD	Acetylphenylenediamine
APE	Aminophenylethyl
API	Active Pharmaceutical Ingredient
Ara	Arabinose
ATP	Adenosine 5'-triphosphate
AZT	Azidothymidine
b	Beta
Bn	Benzyl
Boc	tert-Butoxycarbonyl
BSA	Bovine serum albumin
Bz	Benzoyl
ca.	approximately
CAP	Cellulose acetate phthalate
CAS	Chemical Abstracts Service (Registry Number)
CMC	Carboxymethyl cellulose
CM-Dextran	Carboxymethyl dextran
CUG	Carboxyumbelliferyl galactopyranoside
DEAE-Dextran	Diethylaminoethyl dextran
DIC	1,3-Diisopropylcarbodiimide
DMF	Dimethylaminomethylidine
DMT	Dimethoxytrityl
E	trans
EC	European Commission
ECe	Ethyl cellulose
EHC	Ethyl hydroxyethyl cellulose
EINECS	European Inventory of Existing Commercial Chemical Substances
ELINCS	European List of Notified Chemical Substances
Et	Ethyl group
Et3N	Triethyl amine
EUR	Euros
EXW	Ex works
Fmoc	Fluorenylmethoxycarbonyl
Fru	Fructose
Fuc	Fucose
FucN	Fucosamine
FucNac	N-Acetyl-fucosamine
FW	Formula weight calculated using C mass 12.0107 and including hydrates if known
G	Gram
GAG	Glycosaminoglycan
Gal	Galactose
GalA	Galacturonic acid
GalNAc	N-Acetylgalactosamine
GDP	Guanosine 5'-diphosphate
Glc	Glucose
GicA	Glucuronic acid
GlcN	Glucosamine
GlcNAc	N-Acetylglucosamine
Gul	Gulose
GulA	Guluronic acid
HEC	Hydroxyethyl cellulose
HM	High methoxy
HPC	Hydroxypropyl cellulose
HPLC	High-performance liquid chromatography
HPMC	Hydroxypropylmethyl cellulose
HPMCP	Hydroxypropylmethyl cellulose phthalate
HSA	Human serum albumin
i	Iota
Ido	Idose
IdoA	Iduronic acid
Ino	Inositol
IPTG	Isopropyl b-D-1-thiogalactopyranoside
k	Kappa
Kg	Kilogram
KLH	Keyhole limpet hemocyanin
l	Lambda
LacNAc	N-Acetyl-lactosamine
LM	Low methoxy
LogNAc	2-Acetamido-2-deoxy-D glucohydroximo-1,5-lactone
Lyx	Lyxose
Man	Mannose
ManA	Mannurinic acid
ManN	Mannosamine
ManNAc	N-Acetyl-mannosamine
MCe	Methyl cellulose
Me	Methyl group
Mel	Methiodide
mg	Milligram
ug	Microgram
MMT	Monomethoxytrityl
Ms	Methanesulfonyl
MTS	Methanethiosulfonyl
MU	Methylumbelliferyl
n	Normal
NAG	N-Acetyl-glucosamine
NANA	N-Acetyl neuraminic acid
NAO	Non-animal origin
Neu	Neuraminic acid
Neu5Ac	N-Acetyl neuraminic acid
ONP	2-Nitrophenyl
ONPG	2-Nitrophenyl-b-D-galactopyranoside
Ots	p-Toluenesulfonyl
PAP	p-Aminophenyl
PGX	Polyglycoplex
PMB	Anisoyl
PNP	4-Nitrophenyl
PugNAc	0-(2-Acetamido-2-deoxy-D-glucopyranosylidene)amine N-phenyl carbamate
Rha	Rhamnose
Rib	Ribose
ROW	Rest of World
Sol	Solution
Sor	Sorbose
Tag	Tagatose
Tal	Talose
TBDMS	tert-Butyldimethyl silyl
t-Bu	tert-Butyl
Tol	Tolyl
Tr	Trityl
UDP	Uridine 5'-diphosphate
UN Number	United Nations Substance Identification Number
WSC	Water-soluble carbodiimide
Xyl	Xylose
Z	cis

Terms of Sale

Application

These terms and conditions apply to all sales of goods by the Seller to any Purchaser (Buyer) and shall prevail over and apply to the exclusion of any terms or conditions contained or referred to in the Buyer's order or in correspondence or elsewhere or implied by trade custom or dealing unless specifically agreed to in writing by a director or other authorised representative of the Seller and any purported provisions to the contrary are hereby excluded or extinguished.

Definitions

"Seller" means Carbosynth Limited (registration number 5771788)

"Products" "Goods" means the items described in the orders to be supplied by Carbosynth to the Buyer pursuant to this Agreement

"Buyer" "Purchaser" means the other party to this agreement

Quotations

A quotation by the Seller does not constitute an offer and may be withdrawn or revised at any time prior to the Seller's acceptance of the Buyer's order.

Prices

(A) The prices payable for the goods shall be those contained in the Seller's list prices that is current at the time of despatch. The Seller shall have the right at any time to withdraw any discount from its normal prices and/or to revise prices to take into account increases in costs including without limitation costs of any goods, materials, carriage, labour or overheads, the increase or imposition of any tax, duty or other levy and any variation in exchange rates.

(B) Unless otherwise specified VAT and any other tax or duties payable by the Buyer shall be added to the price.

Terms of Payment

(A) Payment of invoices, unless subject to the terms and conditions under "Export Sales", shall unless otherwise agreed in writing be made in full without any deduction or set-off within 30 days of the date of invoice.

(B) Any extension of credit allowed to the Buyer may be changed or withdrawn at any time

(C) Interest shall be payable on overdue accounts at the rate of 3% over Royal Bank of Scotland Plc base rate to run from the due date for payment thereof until receipt by the Seller of the full amount whether or not after judgement.

Delivery

(A) Delivery dates mentioned in any quotation, acknowledgement of order or elsewhere are approximate only and not of any contractual effect and the Seller shall not be under any liability to the Buyer in respect of any failure to deliver on any particular date or dates.

(B) Delivery shall be at the Buyer's premises unless otherwise stipulated or agreed by the Seller. The Seller may charge for delivery other than at its premises.

(C) If the Buyer refuses or fails to take delivery of goods tendered in accordance with the contract the Seller shall be entitled to immediate payment in full for the goods so tendered. The Seller shall be entitled to store at the risk of the Buyer any goods of which the Buyer refuses or fails to take delivery and the Buyer shall in addition to the purchase price pay all costs of such storage and any additional costs incurred as a result of such refusal or failure. The Seller shall be entitled after the expiration of 3 months from the date upon which the price became payable to dispose of the goods in such manner as the Seller may determine.

Divisibility

Each delivery made hereunder shall be deemed to arise from a separate contract and shall be invoiced separately; any invoice for a delivery shall be payable in full in accordance with the terms of payment provided for herein, without reference to and notwithstanding any defect of default in delivery of any other instalment.

Risk

Subject (where appropriate) to the terms and conditions under "Export Sales" shall pass on delivery.

Export Sales

(A) In the case where the goods are sold CIF or FOB or on the basis of other international trade term the meaning of such term contained in incoterms as revised from time to time shall apply except where inconsistent with any of the provisions contained in these Conditions.

(B) Unless otherwise agreed the price of the goods shall be secured by an irrevocable Letter of Credit satisfactory to the Seller established by the Buyer in favour of the Seller immediately upon receipt of the Seller's acknowledgement of order and confirmed by a United Kingdom bank acceptable to the Seller. The letter of credit shall be for the contract price inclusive of any tax or duty payable by the Buyer and shall be valid for at least 6 months or such longer period as shall have been estimated by the Seller for delivery. The Seller shall be entitled to payment on presentation to such United Kingdom bank of the documents specified by the Seller or as herein stipulated.

(C) Should the Buyer fail when requested by the Seller and within the time specified by the Seller to take any action necessary on its part for delivery and/or shipment of the goods then (i) The Seller shall be entitled by way of delivery to store the goods in a warehouse at the expense and risk of the Buyer (ii) The price shall become immediately payable (iii) If payment is secured by a Letter of Credit the Seller shall be entitled to payment on

Terms of Sale

presentation of the copy sales invoice and the warehouse receipt and (iv) The Seller shall be entitled after the expiration of 3 months from the date upon which the price became payable to dispose of the goods in such manner as the Seller may determine without accounting to the Buyer therefore:

(D) Section 32(2) of the Sale of Goods Act 1979 shall not apply. The Seller shall not be required to give the Buyer the notice specified in Section 32(3) of that Act.

Title

(A) Title to the goods shall not pass to the Buyer until the earlier of: payment in full of the price or the goods ceasing to be identifiable by virtue of their utilisation or consumption in the production of other items or materials. Until such payment, utilisation or consumption the Buyer shall have possession of the goods as bailee for the Seller and shall store the goods in such a way as to enable them to be identifiable as the property of the Seller provided that if the Buyer is purchasing the goods for resale the Buyer may in the ordinary course of its business sell and deliver the goods to a third party on condition that until such payment as aforesaid the Buyer shall hold all proceeds of such sale in trust for the Seller and in a separate account. The Buyer hereby undertakes forthwith upon being so requested by the Seller to assign to the Seller all rights and claims which the Buyer may have against its customers arising from such sales until payment is made in full as aforesaid.

(B) The Seller reserves the right to repossess any identifiable goods in respect of which payment is overdue and thereafter to re-sell the same and for this purpose the Buyer grants an irrevocable right and licence to the Seller's servants and agents to enter upon all or any of its premises with or without vehicles during normal business hours. This right shall continue to subsist notwithstanding the termination of the contract for any reason and is without prejudice to any accrued rights of the Seller there under or otherwise.

Variation

The Seller shall be determined to have fulfilled its contractual obligations in respect of any delivery though the quantity may be up to 10% more or less than the quantity specified in the contract and in such event the Buyer shall pay for the actual quantity delivered.

Third Party Rights

(A) The Buyer shall indemnify the Seller against any and all liabilities, claims and costs incurred by or made against the Seller as a direct or indirect result of the carrying out of any work required to be done on or to the goods in accordance with the requirements or specifications of the Buyer involving any infringement or alleged infringement of any rights of any third party.

(B) The Seller shall have no liability to the Buyer in the event of the goods infringing or being alleged to infringe the rights of any third party. In the event that the goods are or may be the subject of patent, copyright, registered design, trade mark or other rights of any third party the Seller shall be obliged to transfer to the Buyer only such title as the Seller may have.

Specifications

Unless expressly agreed in writing by the Seller all data sheets, specifications and particulars of physical properties submitted by the Seller are approximate only and the Seller shall have no liability in respect of any deviation therefrom. The Seller accepts no responsibility for any errors, omissions or other defects in any data sheets, specifications or particulars of physical properties not prepared by the Seller and the Seller shall be indemnified by the Buyer against any and all liabilities and expenses incurred by the Seller arising therefrom.

Liability

(A) The Seller shall not be liable to the Buyer (i) For shortages in quantity delivered unless the Buyer notifies the Seller of any claim of short delivery within 7 days of receipt of goods (ii) Where goods are carried by the Seller's own transport or by a carrier on behalf of the Seller for damage in transit to the goods apparent upon a reasonable inspection or loss in transit of the goods or any part thereof unless the Buyer shall notify the Seller of any such claim within 14 daysof receipt of the goods or the scheduled date of delivery whichever shall be the earlier (iii) For defects in the goods caused by any act, neglect or default of the Buyer or of any third party. (iv) For other defects in the goods unless notified to the Seller within 14 days of receipt of the goods by the Buyer or where the defect would not be apparent on reasonable inspection within 3 months of delivery.

(B) The Seller may at its option make good any shortage or non-delivery and/or as appropriate replace any goods found to be damaged or defective.

(C) The Seller's aggregate liability to the Buyer whether for negligence, breach of contract, misrepresentation or otherwise shall in no circumstances exceed the cost of the defective damaged or under delivered goods determined by net price invoiced to the Buyer in respect of any occurrence or series of occurrences.

(D) The Seller's prices are determined on the basis of the limits of liability set out in this Condition. The Buyer may by written notice to the Seller request the Seller to agree a higher limit of liability provided insurance cover can be obtained therefore. The Seller shall effect insurance up to such limit and the Buyer shall pay upon demand the amount of any and all premiums. The Buyer shall disclose such information as the insurer shall require. In no case shall the Buyer be entitled to recover from the Seller more than the amount received from the insurers.

(E) Without prejudice to any other provisions herein where a shelf life is specified for the goods (in any relevant data sheet or other document available to the Buyer) the Seller shall have no liability for any degradation to the goods after the expiry of such shelf life and for any resulting loss to the Buyer and any other person, firm or company

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Terms of Sale

(F) Subject to the foregoing all conditions, warranties and representations expressed or implied by statute, common law or otherwise in relation to the goods are hereby excluded and the Seller shall be under no liability to the Buyer for any loss, damage or injury direct or indirect resulting from defective material, faulty workmanship or otherwise howsoever arising and whether or not caused by the negligence of the Seller, its employees or agents SAVE THAT the Seller shall accept liability for death or personal injury caused by the negligence of the Seller.

Packaging

(A) The Buyer shall meet the cost of any special packaging requested by the Buyer for any packaging rendered necessary by delivery by any means other than the Seller's normal means of delivery.

(B) The Seller shall be entitled to invoice the Buyer for the cost of all pallets and other returnable packaging materials unless the same are returned to the Seller in good condition carriage paid within 30 days of the date of delivery.

Licences and Consents

If any licence or consent of any government or other authority shall be required for the acquisition, carriage or use of the goods by the Buyer the Buyer shall obtain the same at its own expense and if necessary produce evidence of the same to the Seller on demand. Failure to do so shall not entitle the Buyer to withhold or delay payment of the price. Any additional expenses or charges incurred by the Seller resulting from such failure shall be for the Buyer's account.

Force Majeure

(A) The Seller shall not be liable to the Buyer for any loss or damage which may be suffered by the Buyer as a direct or indirect result of the supply of goods by the Seller being prevented, hindered, delayed or rendered uneconomic by reason of circumstances or events beyond the Seller's reasonable control including but not limited to act of God, war, riot, strike, lock-out, trade dispute or labour disturbance, accident, breakdown of plant or machinery, fire, flood, storm, difficulty or increased expense in obtaining workmen, materials or transport or other circumstances affecting the supply of the goods or of raw materials therefore by the Seller's normal source of supply or the manufacture of the goods by the Seller's normal means or the delivery of the goods by the Seller's normal route or means of delivery

(B) If due to such events or circumstances the Seller has insufficient stocks to meet all its commitments the Seller may apportion available stocks between its customers at its sole discretion.

Insolvency and Default

If the Buyer makes any voluntary arrangement with its creditors or becomes subject to an administration order or permits an act of bankruptcy or compounds with his creditors or if a receiving order is made against him or if (being a company) an order is made or a resolution is passed for the winding up of the Buyer (otherwise than for the purpose of amalgamation or reconstruction) or if a receiver is appointed of any of the Buyer's assets or undertaking or if circumstances arise which entitle the court or a creditor to appoint a receiver or manager or which entitle the court to make a winding up order or if the Buyer takes or suffers any similar or analogous action in consequence of debt or commits any breach of this or any other contract between the Seller and the Buyer the Seller may without prejudice to any of its other rights stop any goods in transit and/or suspend further deliveries and/or determine the rights of the Buyer under condition 8 and/or by notice in writing to the Buyer determine the contract.

Waiver

Failure by the Seller to exercise or enforce any rights hereunder shall not be deemed to be a waiver of any such right nor operate so as to bar the exercise or enforcement thereof at any time or times thereafter.

Notices

Any notice hereunder shall be deemed to have been duly given if sent by registered post, personal delivery, telex, fax or e-mail to the party concerned at its last known address. Notices sent by registered post shall be deemed to have been given 7 days after despatch and notices sent by telex, fax or e-mail shall be deemed to have been given on the date of despatch. Notices given by personal delivery shall be deemed to be given on delivery.

Governing Law

This contract shall be governed by and construed in all respects in accordance with the laws of England and the parties hereby submit to the jurisdiction of the English court.

Health and Safety

The Seller provides Material Safety Data Sheets on request, in accordance with current legislation; the goods supplied are for supply to qualified personnel only. The goods should be used in facilities designed for chemical, biological and allied research only and not for human or animal consumption. Goods should be stored in accordance with details provided on the Material Safety Data Sheet and labels. Precautions should be taken to ensure that contact between goods and skin, eyes or other mucous membranes is avoided using where necessary protective clothing and air extraction.

Section

13

Acknowledgements

13 Acknowledgements

The review section was compiled and written by Dr Chris Lawson (Scientific Director of Biopolymers, Carbosynth Limited) who has had an expansive industry career working with a wide variety of polysaccharides, their analysis and applications. We wish to acknowledge the contributions from Dr. Ian Smith (Ian Smith Scientific Solutions Ltd) and Prof. Stephen Harding (Professor of Hydrodynamics, University of Nottingham) and Dr Maitland McLean (Grampian Enzymes) who read the draft providing useful and helpful comments. Prof Ten Feizi and Prof Barbara Mulloy (Imperial College, London) helped with useful discussions, references and images. Our thanks also to Dr. Andrew Reason (CEO Biopharmaspec Ltd) and Dr. Mike Guiry (Emeritus Professor of Botany, NUI, Galway) who generously provided images and photographs for inclusion in the catalogue and to Ewan Lawson who produced a number of the graphics.

Available catalogues

Impurity and Metabolite Catalogue

Polysaccharide Catalogue and Handbook

Monosaccharide Catalogue

Enzyme Substrate and Detergent Catalogue

Nucleoside Catalogue

Oligosaccharide Catalogue

Fine Chemicals Catalogue

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