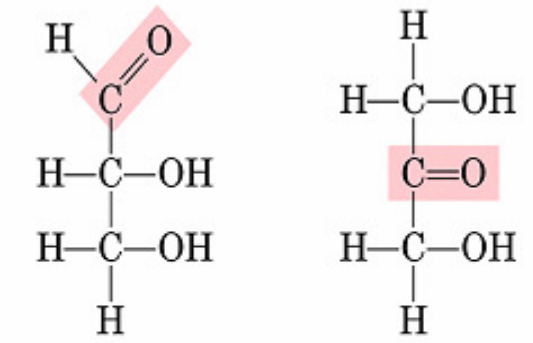
Carbohydrates and Glycobiology

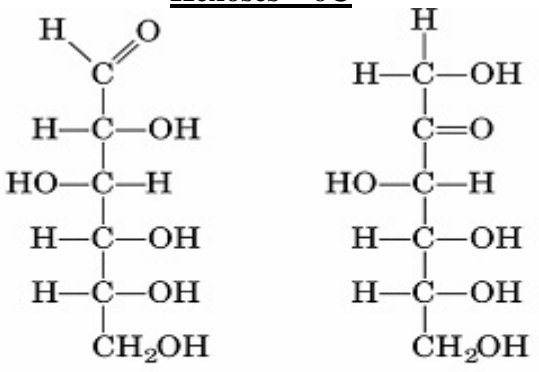
- **Monosaccharides** – consist of a simple polyhydroxy aldehyde or ketone unit
- **Disaccharide** – two monosaccharide units
- **Oligosaccharides** – consist of short chains of monosacchardies units or residues characteristic linkages called glycosidic bonds
- **Polysaccharides** – sugar polymers containing more than about 20 monosaccharide units
- **Aldose** – carbonyl group at the end of carbon chain is an aldehyde group
- **Ketose** – carbonyl group at the end of carbon chain is a ketone group

Two Trioses, an aldose and a ketose – 3C



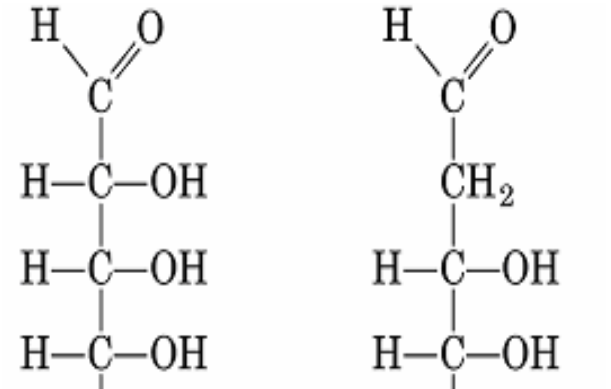
(a)

Hexoses – 6C



(b)

Pentoses - 5C



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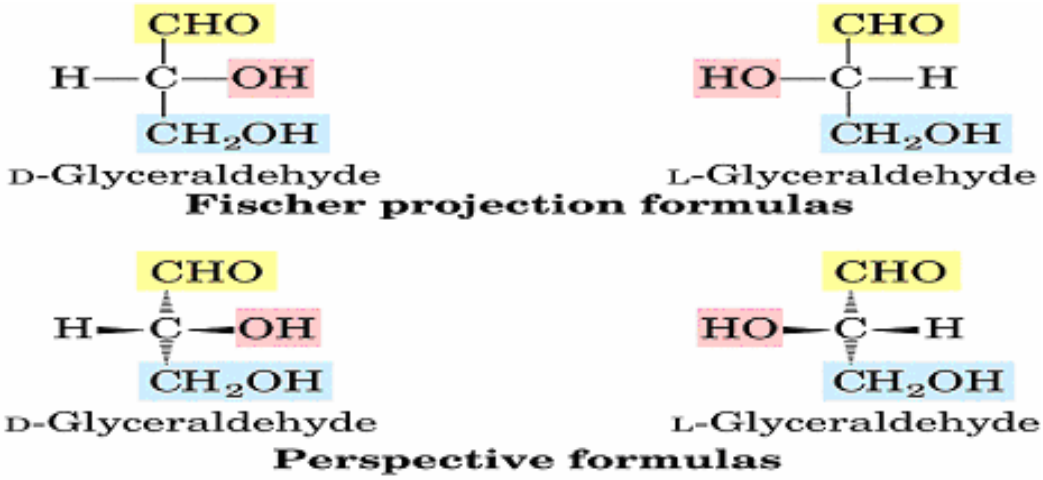
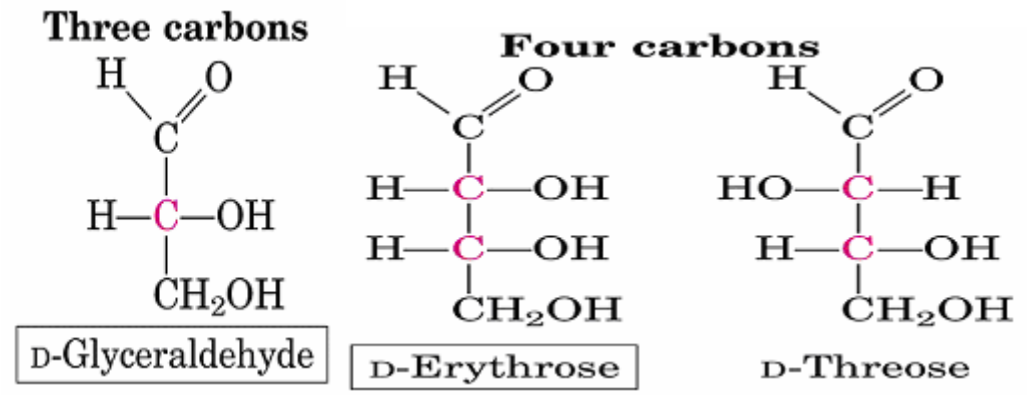
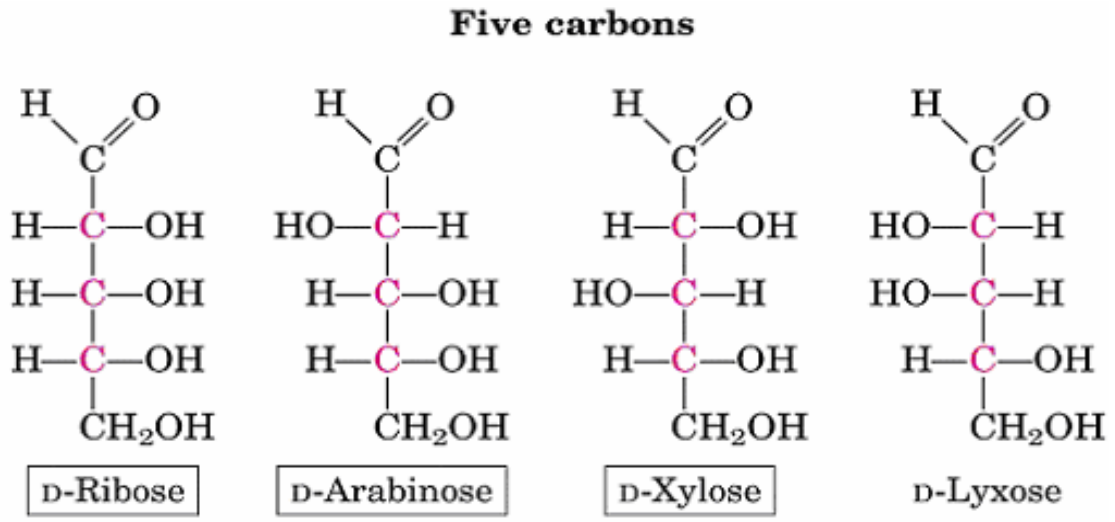
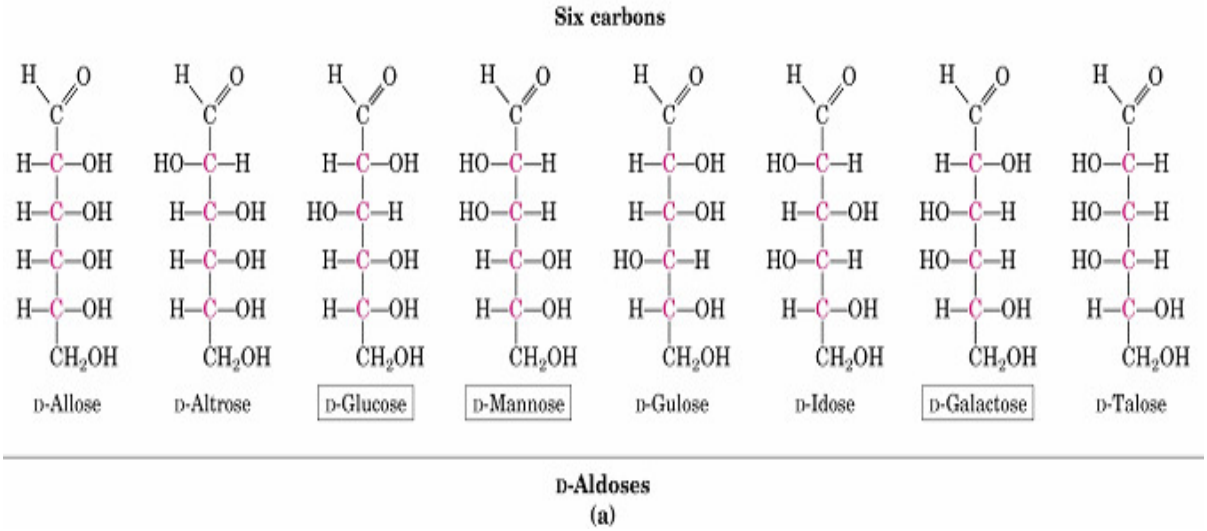


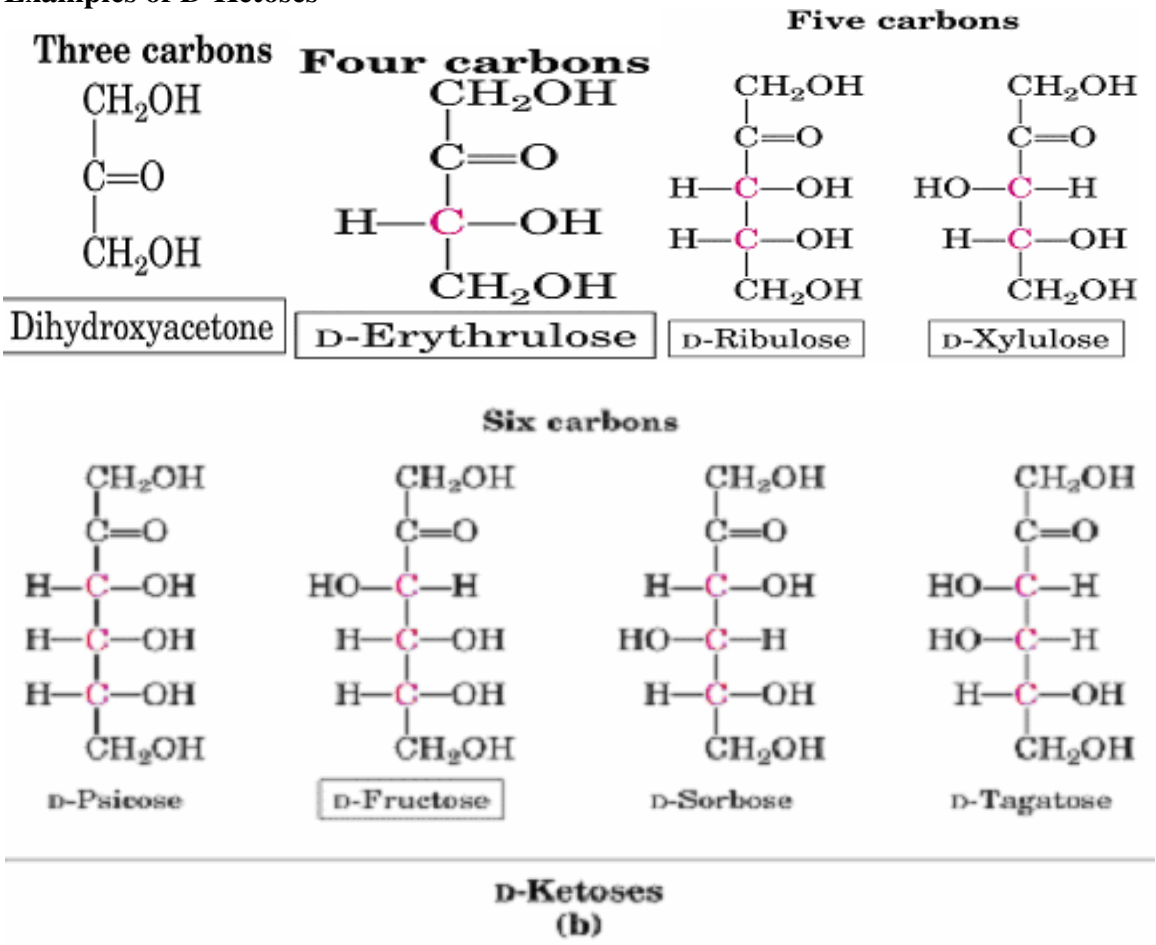
Examples of D-Aldose



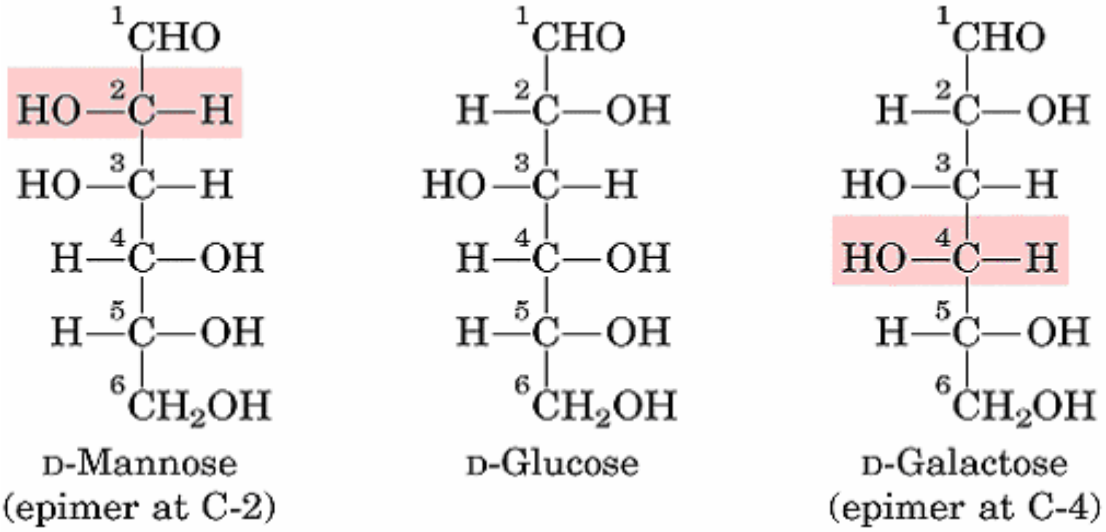




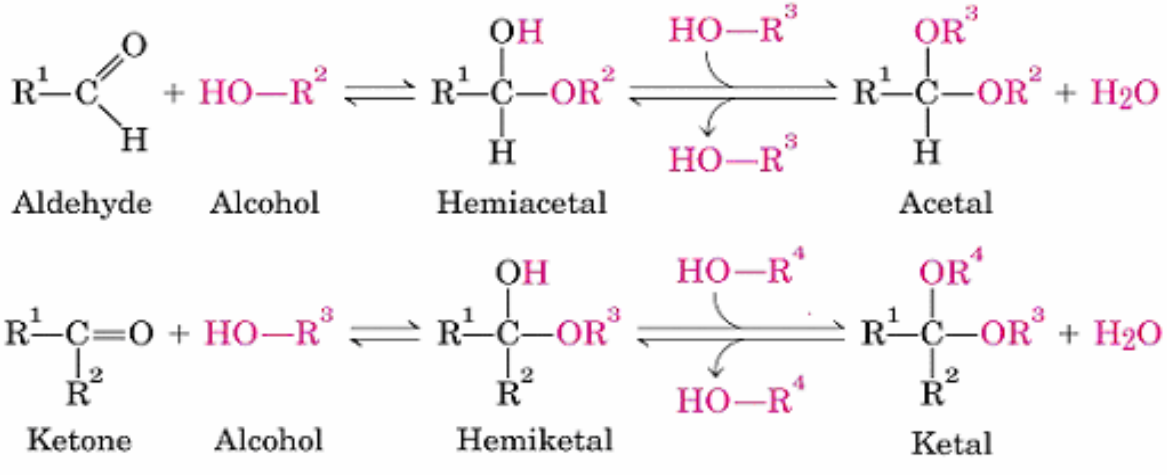
Examples of D-Ketoses



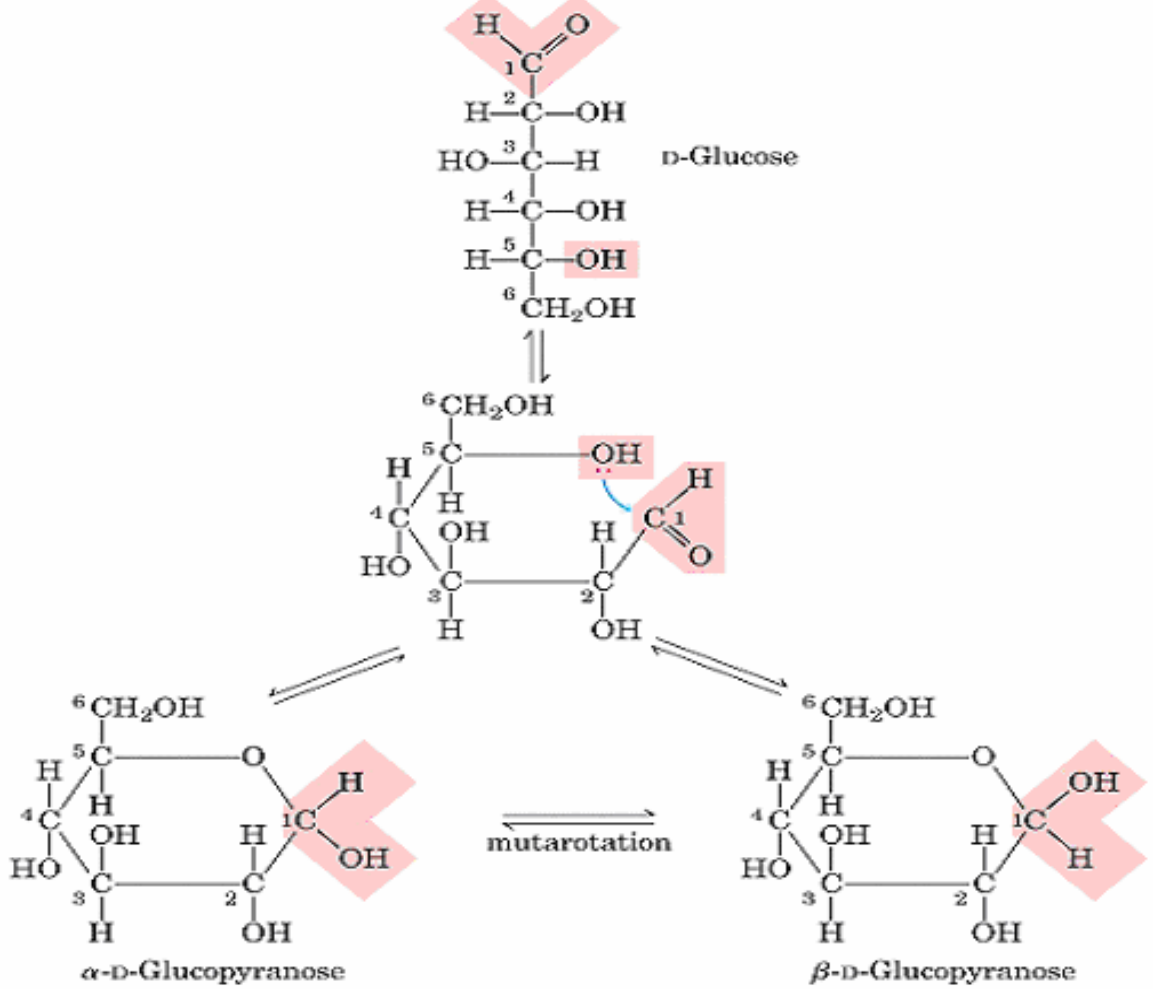
Epimers – Two sugars that differ only in the configuration around one carbon atom eg D-Mannose vs D-Glucose or D-glucose vs D-Galactose



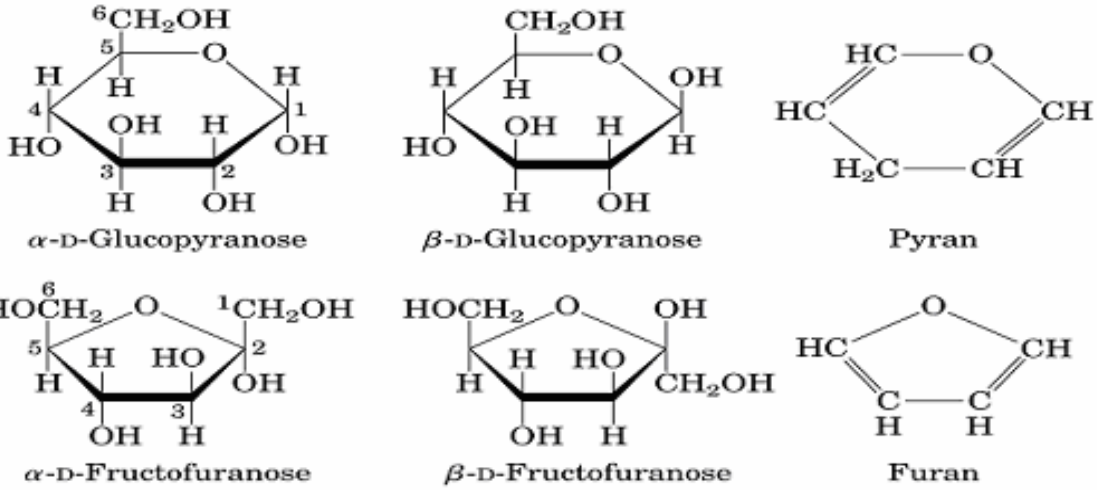
Formation of hemiacetals and hemiketals



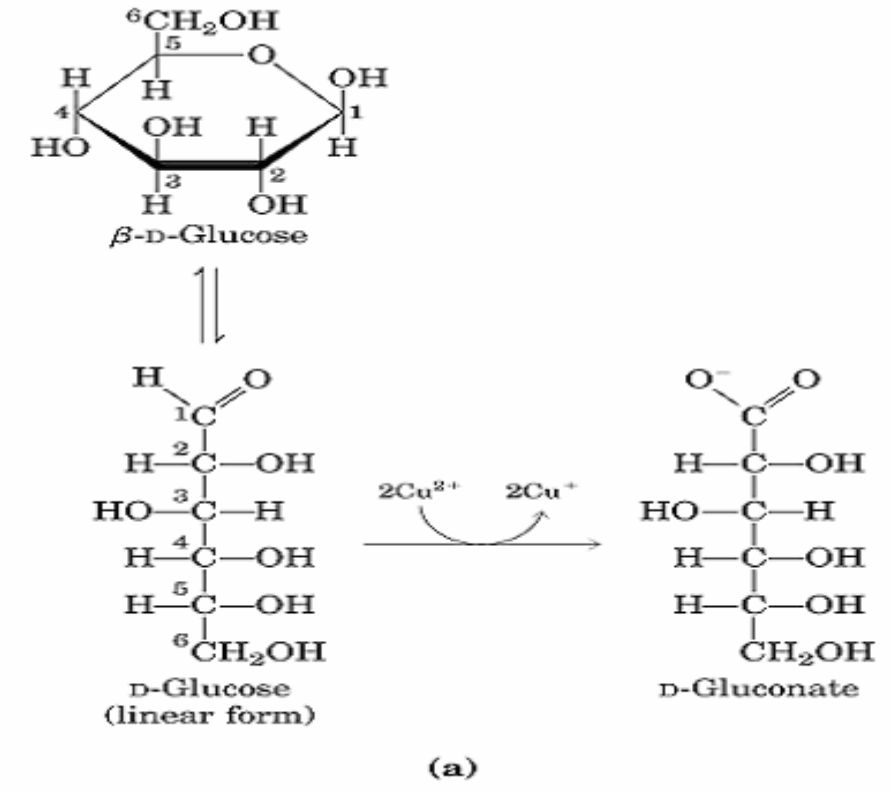
Formation of the two cyclic forms of D-glucose



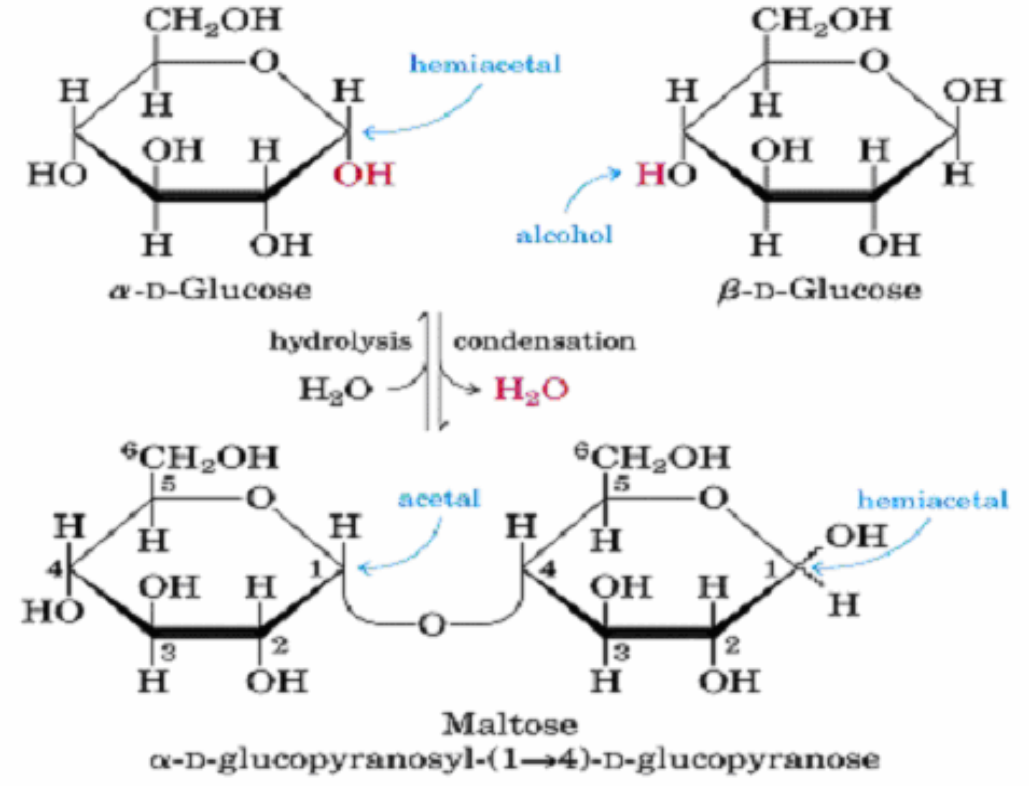
Pyranoses and Furanoses

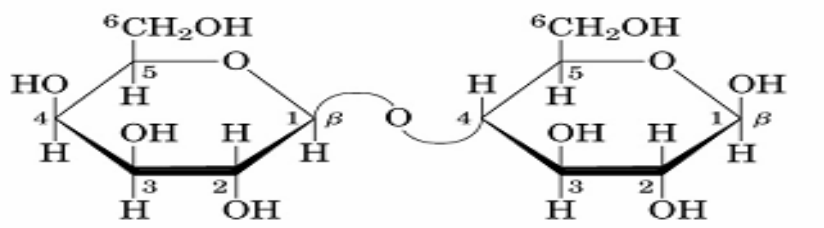


Sugars as reducing agents

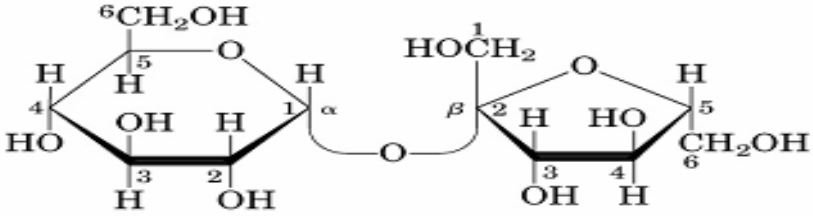


Formation of maltose – O-glycocidic bond

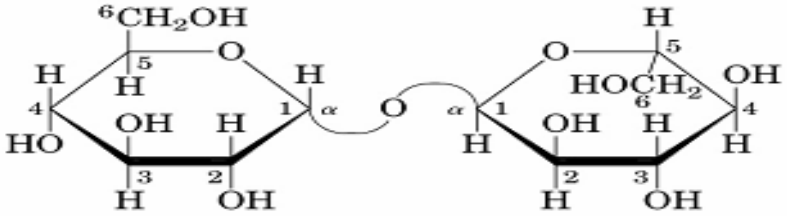




Lactose (β form)
β-D-galactopyranosyl-(1→4)-β-D-glucopyranose
Gal(β1→4)Glc

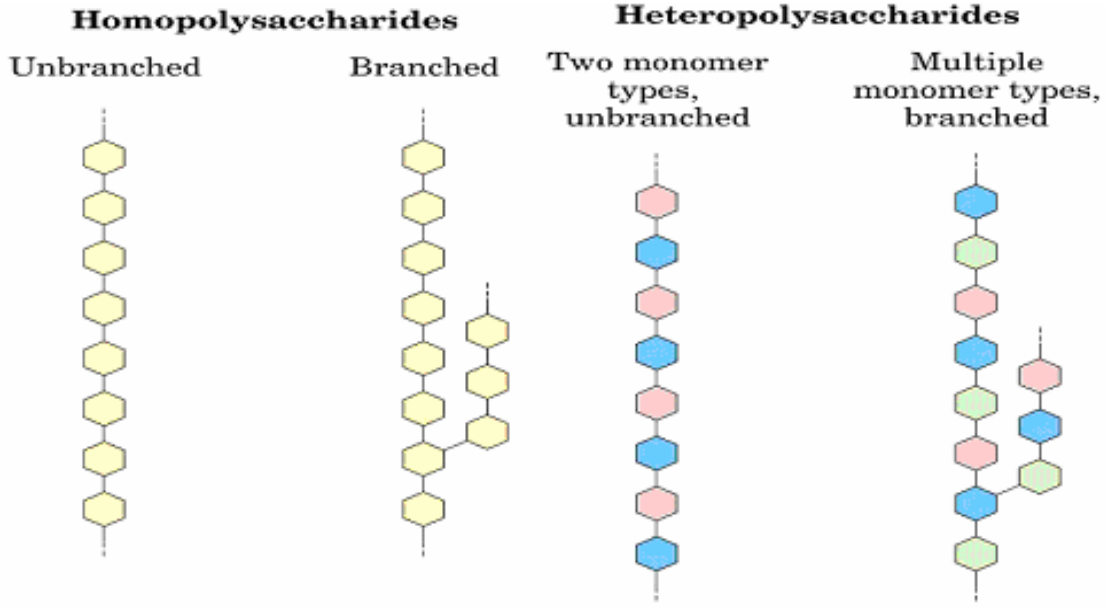


Sucrose
β-D-fructofuranosyl α-D-glucopyranoside
Fru(β2↔1α)Glc

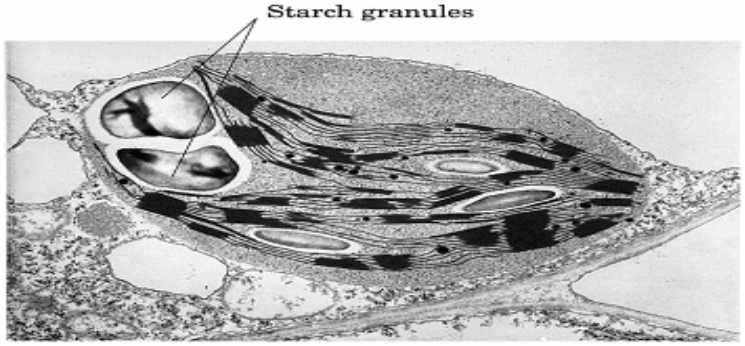


Trehalose
α-D-glucopyranosyl α-D-glucopyranoside
Glc(α1↔1α)Glc

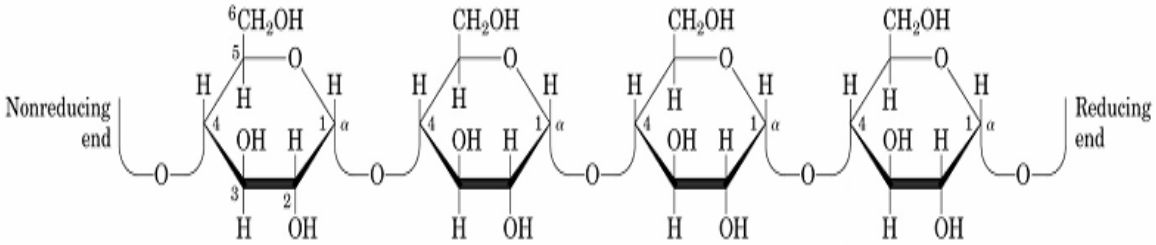
Polysaccharides



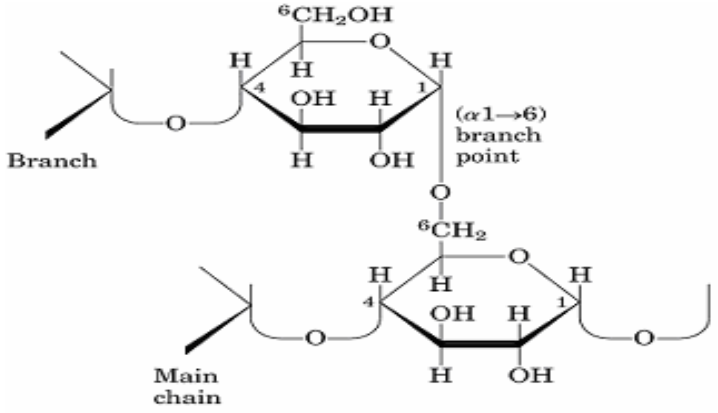
Stored fuel



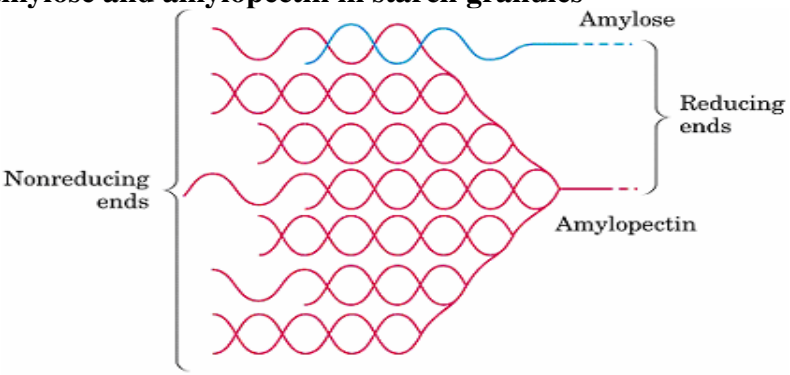
Amylose and amylopectin, the polysaccharides of starch



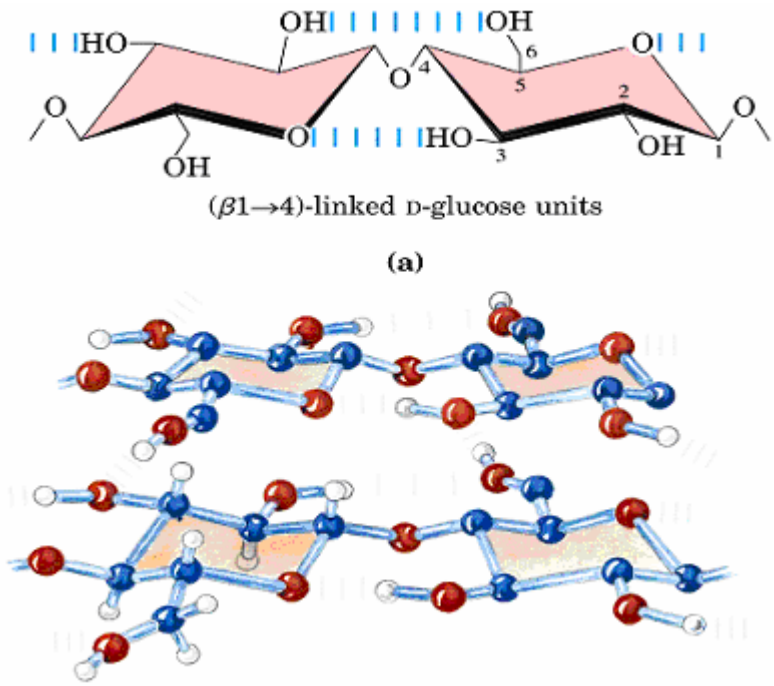
Amylopectin

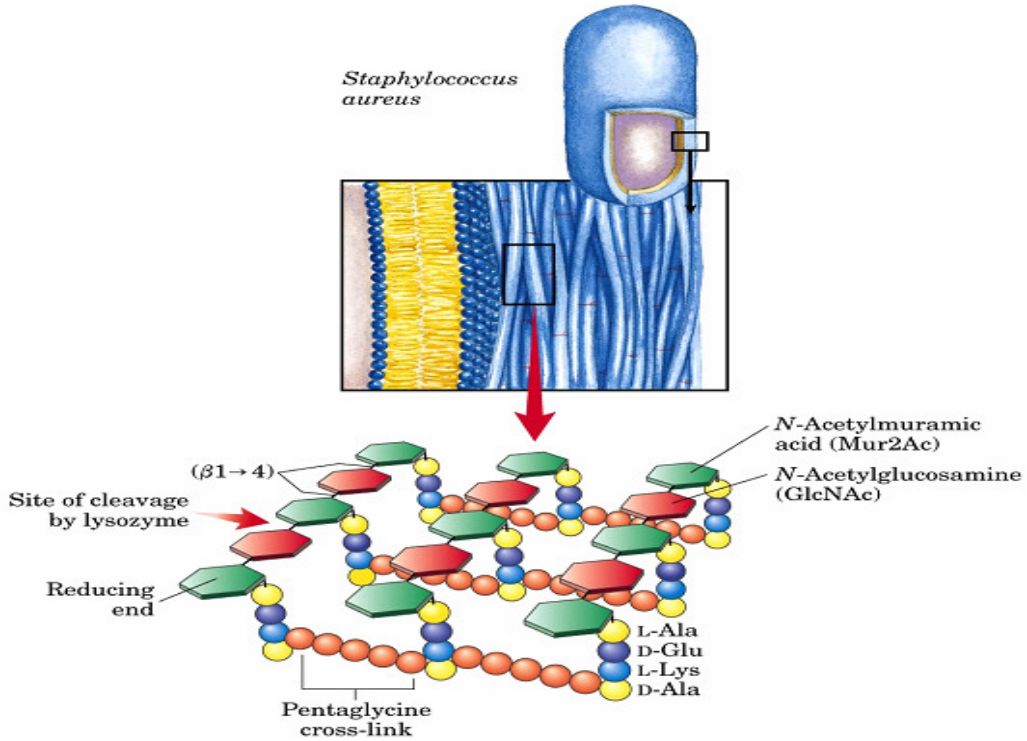


A cluster of amylose and amylopectin in starch granules

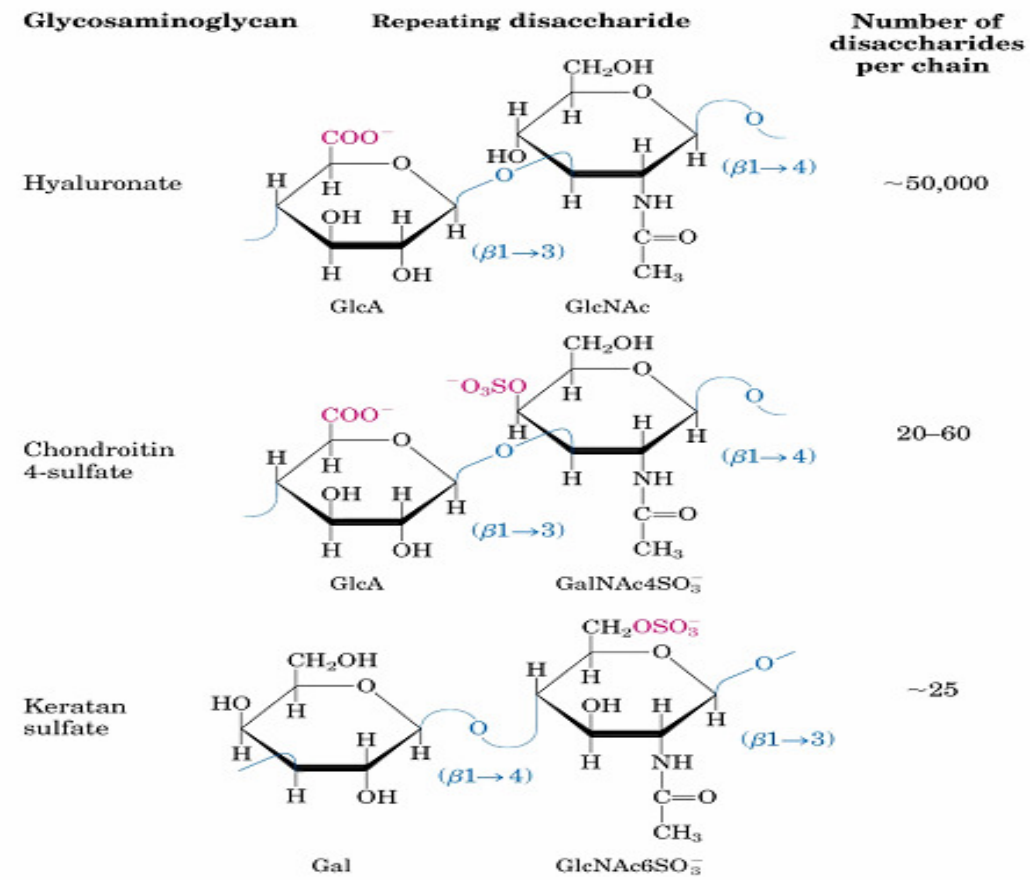


Cellulose – structural homopolysaccharides





Glycosaminoglycans are components of the ECM



Structures and Roles of Some Polysaccharides

Polymer	Type*	Repeating unit†	Size (number of monosaccharide units)	Roles
Starch				Energy storage: in plants
Amylose	Homo-	(α1→4)Glc, linear	50–5,000	
Amylopectin	Homo-	(α1→4)Glc, with (α1→6)Glc branches every 24 to 30 residues	Up to 10^6	
Glycogen	Homo-	(α1→4)Glc, with (α1→6)Glc branches every 8 to 12 residues	Up to 50,000	Energy storage: in bacteria and animal cells
Cellulose	Homo-	(β1→4)Glc	Up to 15,000	Structural: in plants, gives rigidity and strength to cell walls
Chitin	Homo-	(β1→4)GlcNAc	Very large	Structural: in insects, spiders, crustaceans, gives rigidity and strength to exoskeletons
Peptidoglycan	Hetero-; peptides attached	4)Mur2Ac(β1→4) GlcNAc(β1	Very large	Structural: in bacteria, gives rigidity and strength to cell envelope
Hyaluronate (a glycosamino-glycan)	Hetero-; acidic	4)GlcA(β1→3) GlcNAc(β1	Up to 100,000	Structural: in vertebrates, extracellular matrix of skin and connective tissue; viscosity and lubrication in joints

* Each polymer is classified as a homopolysaccharide (homo-) or heteropolysaccharide (hetero-).

†The abbreviated names for the peptidoglycan and hyaluronate repeating units indicate that the polymer contains repeats of this disaccharide unit, with the GlcNAc of one disaccharide unit linked β(1→4) to the first residue of the next disaccharide unit.

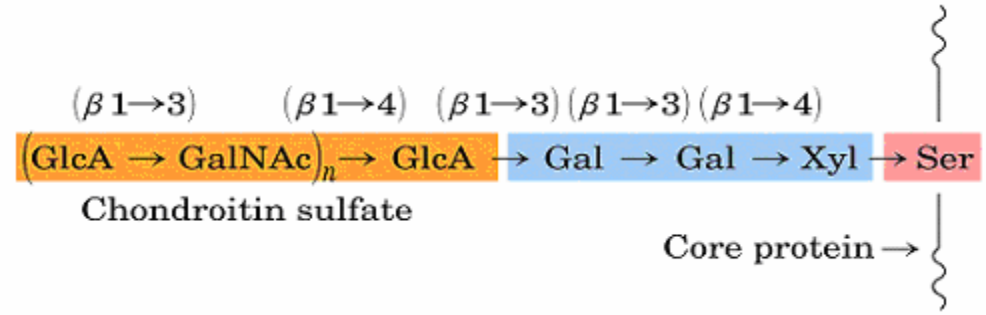
Glycoconjugates: Proteoglycans, Glycoproteins and Glycolipids

- **Proteoglycans** – are macromolecules of the cell surface or ECM in which one or more glycosaminoglycan chains are covalently to a membrane protein or a secreted protein

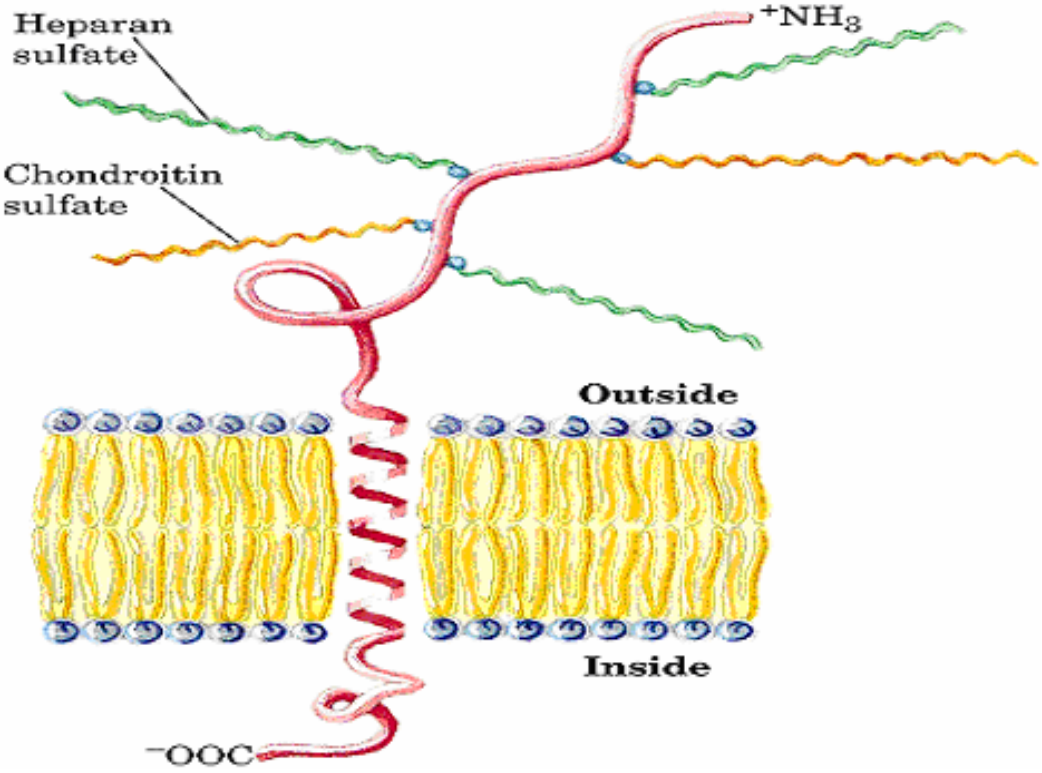
- **Glycoproteins** – have one or several oligosaccharides of varying complexity joined covalently to a protein

- **Glycolipids** – are membrane lipids in which the hydrophobilic head groups are oligosaccharides, which as in glycoproteins, act as specific sites for recognition by carbohydrate-binding proteins.

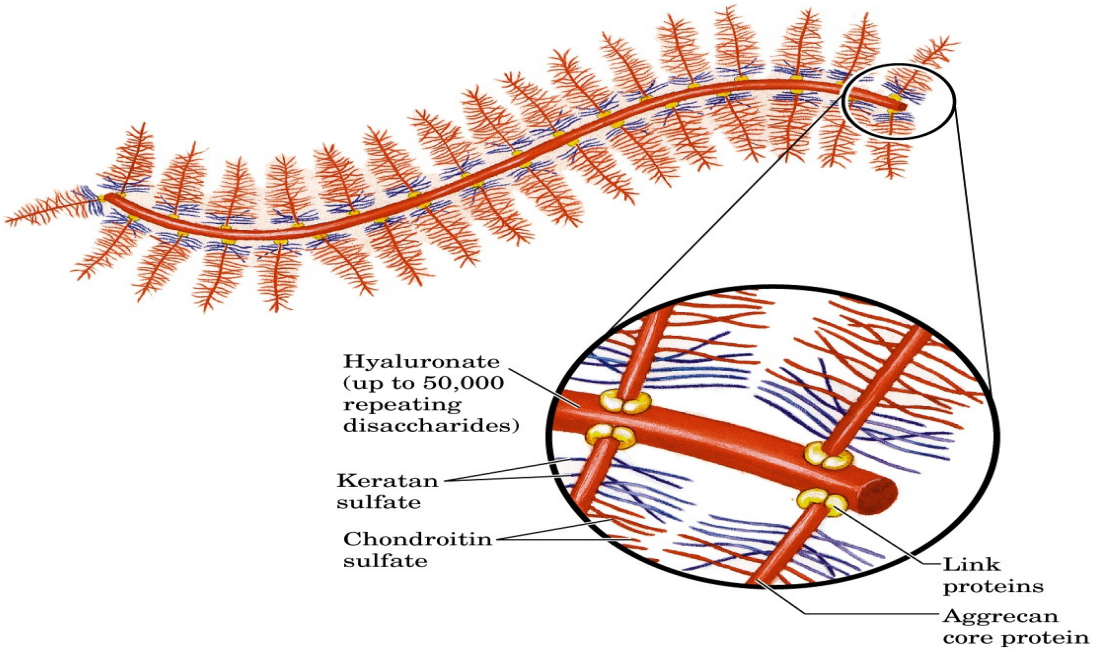
Proteoglycan structure, showing the trisaccharide bridge (blue)



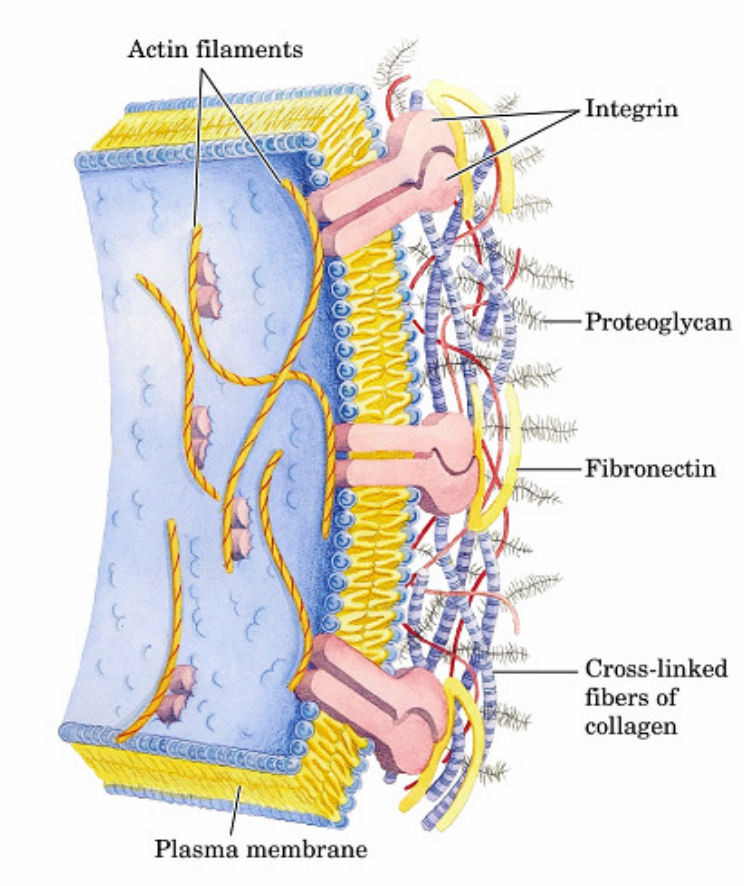
Proteoglycan structure of an integral membrane protein – syndecan (a core protein of the plasma membrane)



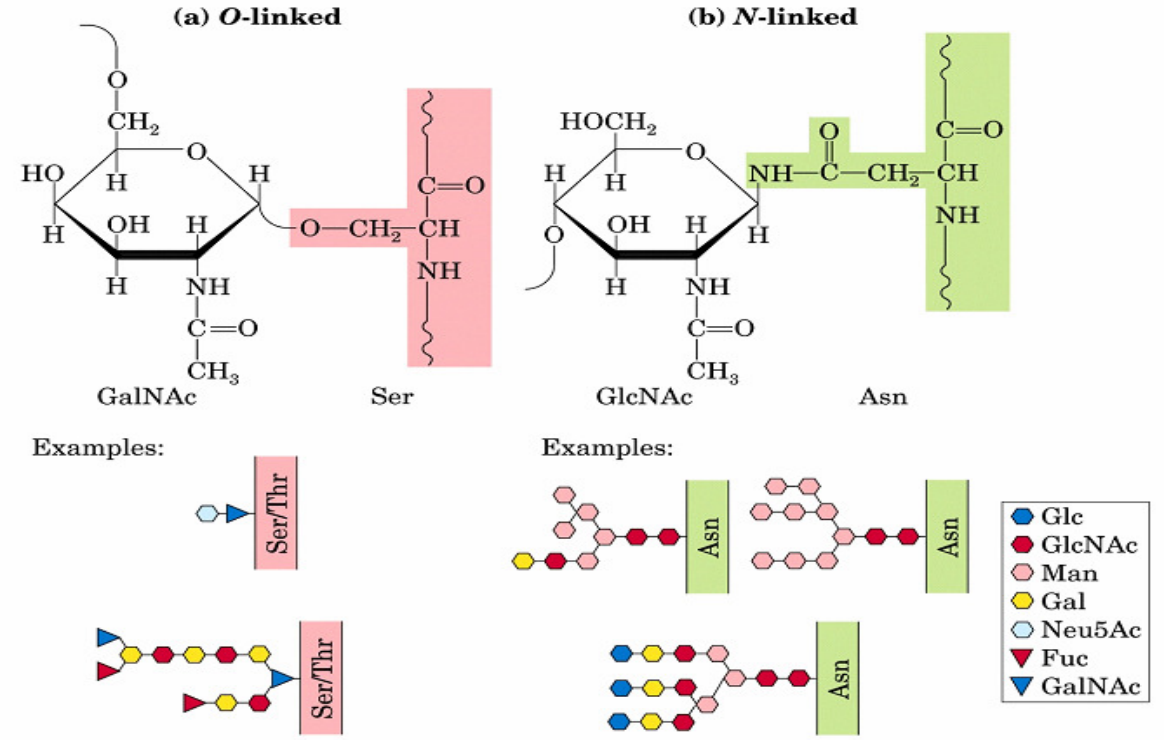
A proteoglycan aggregate of the extracellular matrix



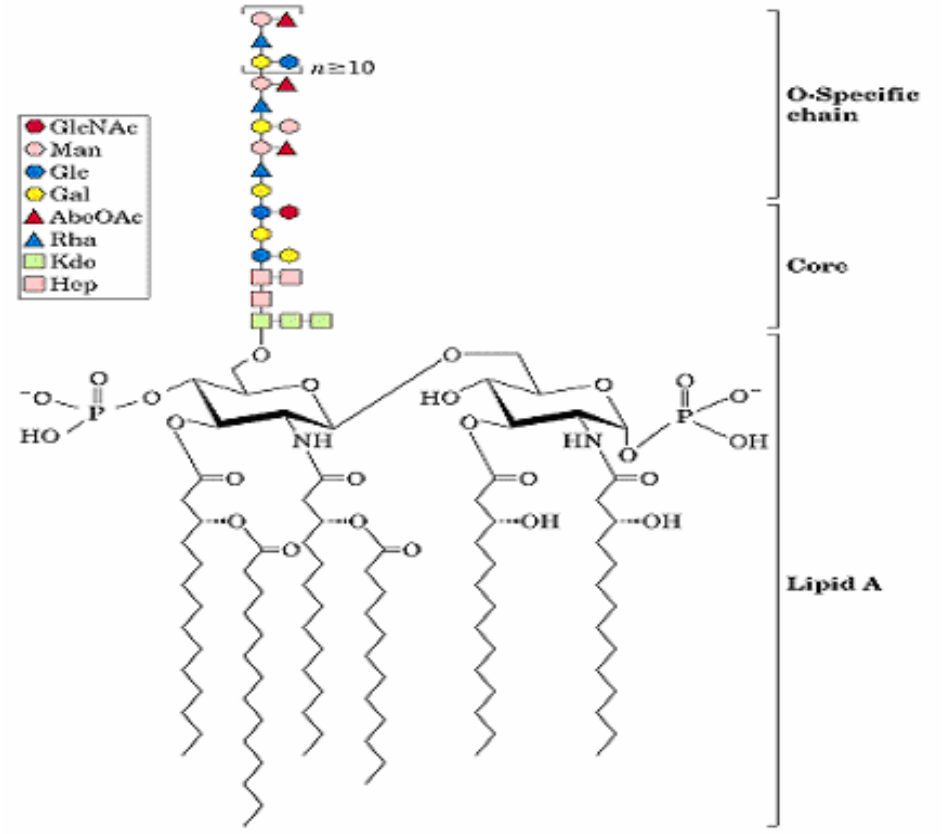
Interactions between cells and extracellular matrix



Oligosaccharide linkages in glycoproteins



Bacterial lipo-polysaccharides



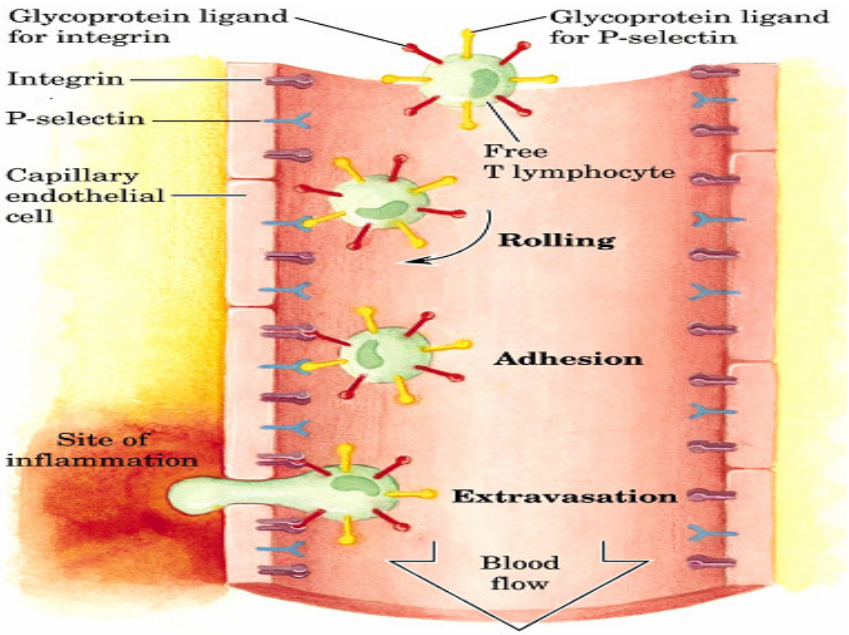
Oligosaccharide-Lectin interaction mediate biological process

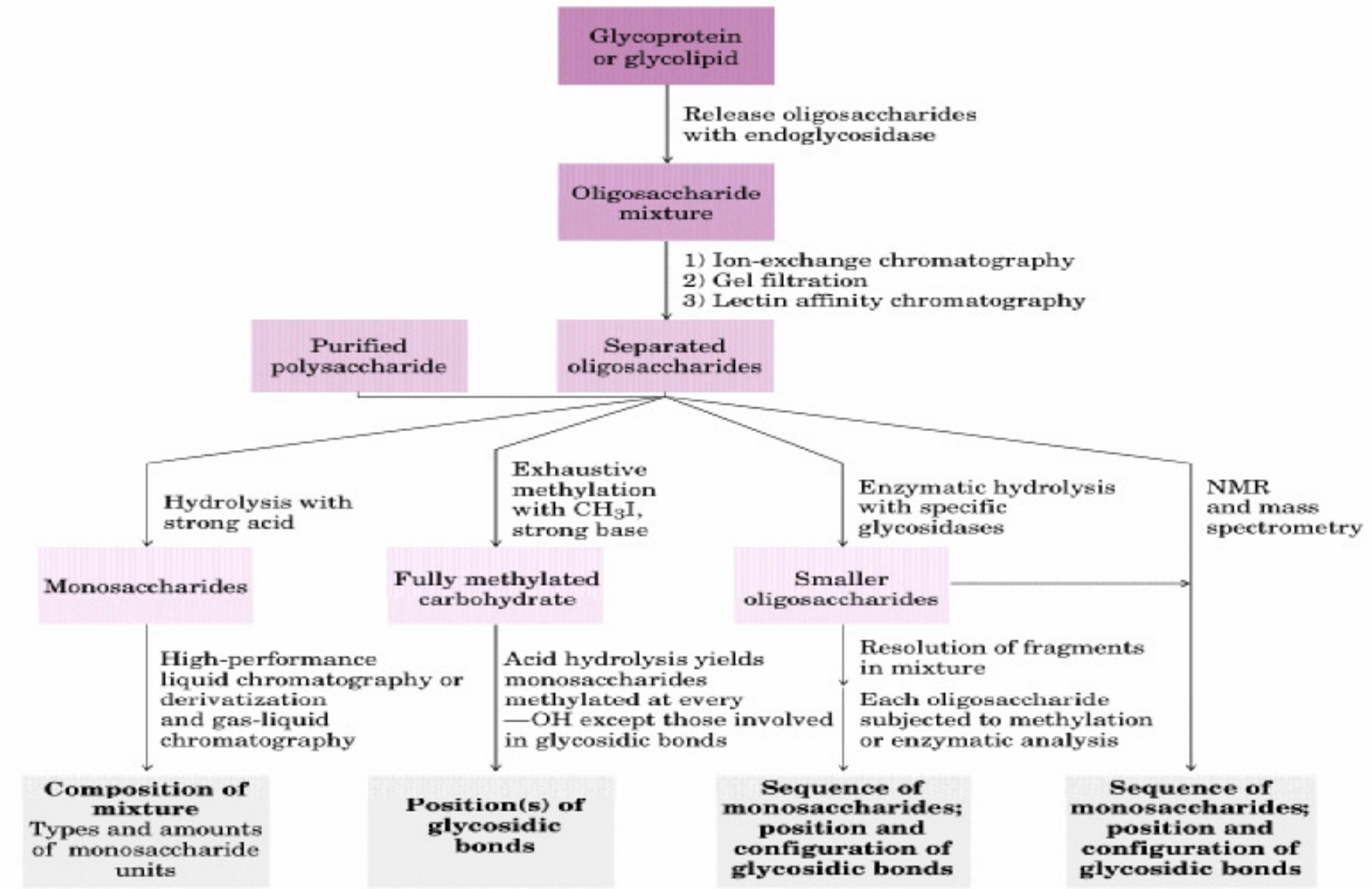
- **Lectin –** found in all organisms, are proteins that bind carbodydrates with high affinity and specificity
- **Selectins –** are family of lectins, found in plasma membranes, that mediate cell-cell recognition and adhesion in a wide range of cellular processes

Lectins and the Oligosaccharide Ligands That They Bind

Lectin family and lectin	Abbreviation	Ligand(s)
Plant		
Concanavalin A	ConA	Manα1—OCH_3
Griffonia simplicifolia lectin 4	GS4	Lewis b (Le^b) tetrasaccharide
Wheat germ agglutinin	WGA	Neu5Ac(α2→3)Gal(β1→4)Glc GlcNAc(β1→4)GlcNAc
Ricin		Gal(β1→4)Glc
Animal		
Galectin-1		Gal(β1→4)Glc
Mannose-binding protein A	MBP-A	High-mannose octasaccharide
Viral		
Influenza virus hemagglutinin	HA	Neu5Ac(α2→6)Gal(β1→4)Glc
Polyoma virus protein 1	VP1	Neu5Ac(α2→3)Gal(β1→4)Glc
Bacterial		
Enterotoxin	LT	Gal
Cholera toxin	CT	GM1 pentasaccharide

Role of lectin-ligand interactions in lymphocyte movement to the site of an infection or injury




Glycoprotein or glycolipid
Release oligosaccharides with endoglycosidase
Oligosaccharide mixture
1) Ion-exchange chromatography
2) Gel filtration
3) Lectin affinity chromatography
Purified polysaccharide
Separated oligosaccharides
Hydrolysis with strong acid
Exhaustive methylation with CH_3I, strong base
Enzymatic hydrolysis with specific glycosidases
NMR and mass spectrometry
Monosaccharides
Fully methylated carbohydrate
Smaller oligosaccharides
High-performance liquid chromatography or derivatization and gas-liquid chromatography
Acid hydrolysis yields monosaccharides methylated at every —OH except those involved in glycosidic bonds
Resolution of fragments in mixture
Each oligosaccharide subjected to methylation or enzymatic analysis
Composition of mixture
Types and amounts of monosaccharide units
Position(s) of glycosidic bonds
Sequence of monosaccharides; position and configuration of glycosidic bonds
Sequence of monosaccharides; position and configuration of glycosidic bonds