بسمه تعالی

کارشناسی ارشد
بیوشیمی و بیولوژی سلول

کربوهیدرات ها

ابراهیم قاسمی

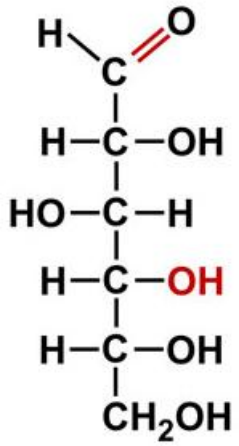
سرفصل مطالب

- بیومولکول ها
- کربوهیدرات ها
- چربی ها و اسیدهای چرب
- ساختار اسیدهای آمینه و پروتئین ها
- نقش پروتئین های ساختاری و آنزیمی
- جداسازی و خالص سازی پروتئین ها
- اسیدهای نوکلئیک
- واکنش های مربوط به تولید انرژی (گلیکولیز، تخمیر، چرخه کربس)

- سلول
- ساختمان سلول
- ریبوزوم
- سیستم و اعمال غشای سلولی
- میتوکندری و زنجیره تنفسی
- کلروپلاست و فتوسنتز
- نقش دستگاه گلژی، لیزوزوم ها و میکروبادی ها در بیولوژی سلول
- مرور مختصری بر سیستم ژنتیکی سلول

Carbohydrate

- Carbohydrates are the most abundant of all the organic compounds in nature
- In plants, energy from the Sun is used to convert carbon dioxide and water into the carbohydrate glucose
- Carbohydrates are broadly defined as polyhydroxy aldehydes or ketones and their derivatives
- Composed of carbon, hydrogen, and oxygen $(CH_2O)_n$
- Some also contain nitrogen, phosphorus, or sulfur



Glucose

Carbohydrate

- Carbohydrates make up about three fourths of the dry weight of plants.

- Less than 1% of the body weight of animals is made up of carbohydrates

Carbohydrate importance

- Store of chemical energy
  - About 65% of the foods in our diet consist of carbohydrates.
  - glucose, starch, glycogen
  - the oxidation of carbohydrates is the central energy-yielding pathway in most nonphotosynthetic cells
- Structural elements
  - cell walls of bacteria and plants
  - connective tissues of animals.
  - crustacean shells
- information carriers
  - cognition and adhesion between cells (glycoconjugates.)
- Essential components of nucleic acids (D-ribose and 2-deoxy-D-ribose)

…Classification of carbohydrates

- Number of carbohydrate units
  - Monosaccharides
  - Oligosaccharides (Disaccharides)
  - Polysaccharides
  - Complex carbohydrate

Monosaccharides

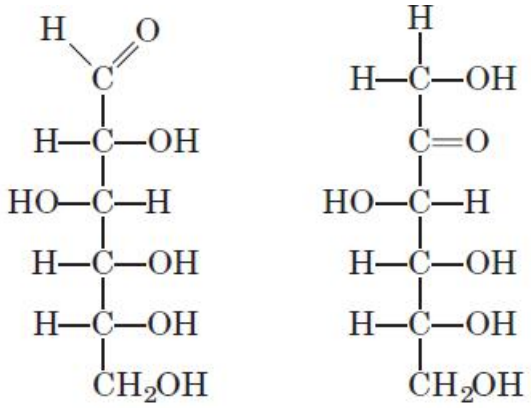
- Most have a sweet taste

- Position of carbonyl group (Aldose and Ketose)
  - at C1, carbonyl is an aldehyde: aldose
  - at any other carbon, carbonyl is a ketone: ketose
  - The four- and five-carbon ketoses are designated by inserting "ul" into the name of a corresponding aldose; D-ribulose is the ketopentose corresponding to the aldopentose D-ribose

- Number of carbons
  - three carbons: triose
  - four carbons: tetrose
  - five carbons: pentose
  - six carbons: hexose
  - seven carbons: heptose
  - etc.

Monosaccharides

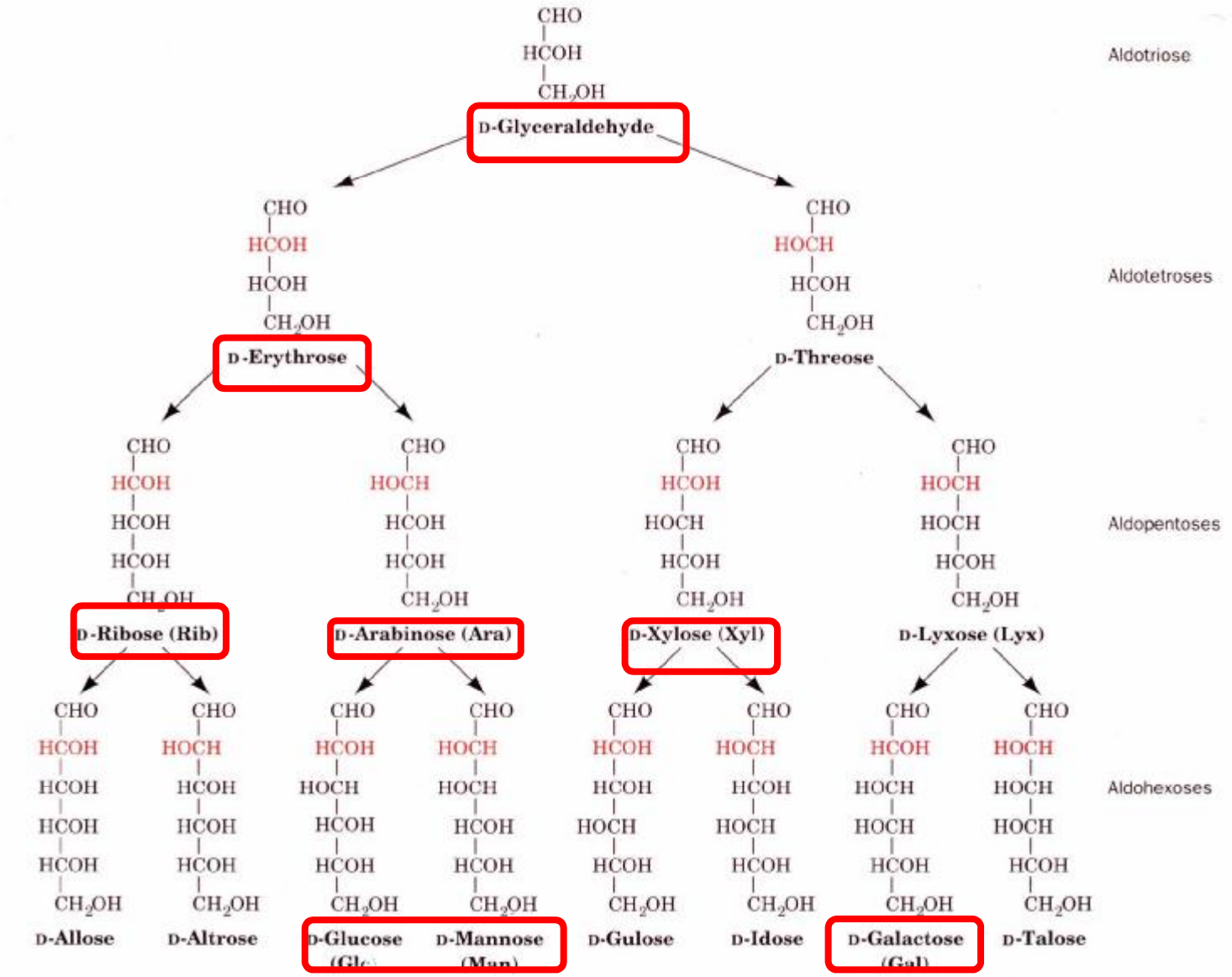
- The hexoses, which include the aldohexose D-glucose and the ketohexose D-fructose are the most common monosaccharides in nature.



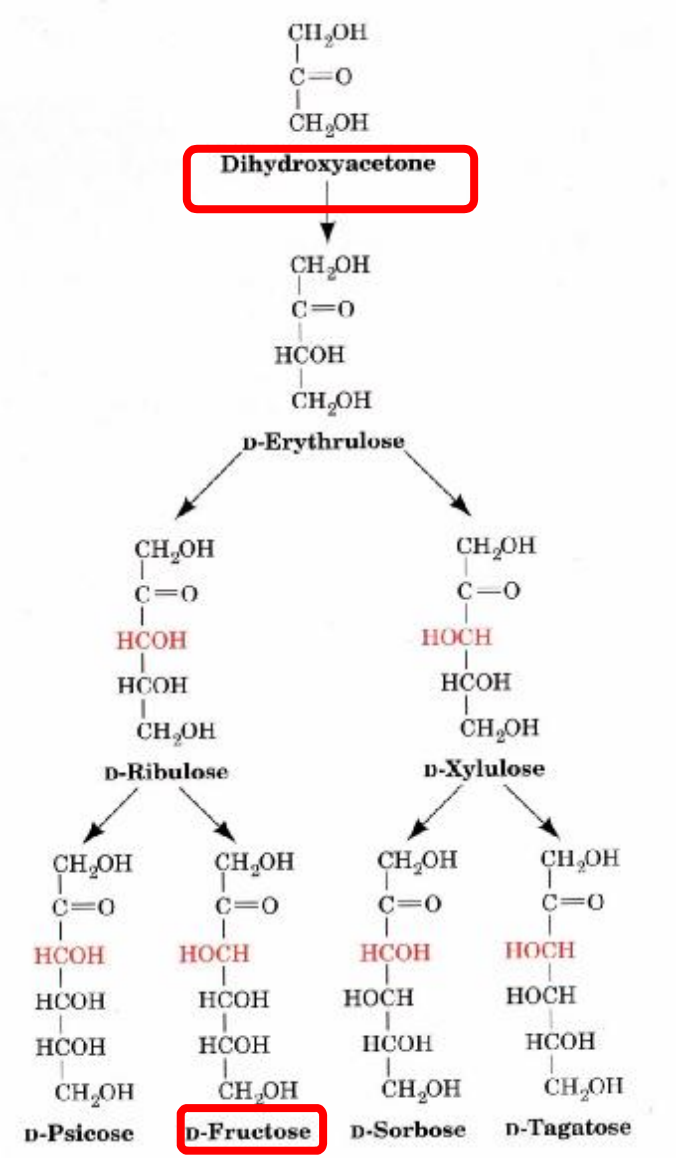
D-Glucose, an aldohexose

D-Fructose, a ketohexose

Monosaccharides (D-aldose)

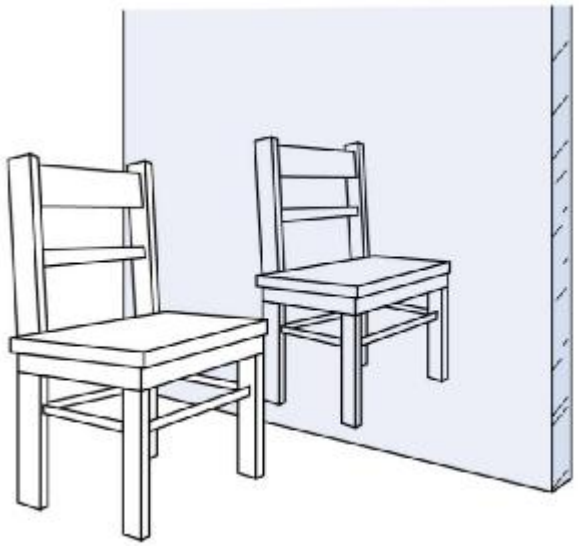


Monosaccharides (D-ketose)



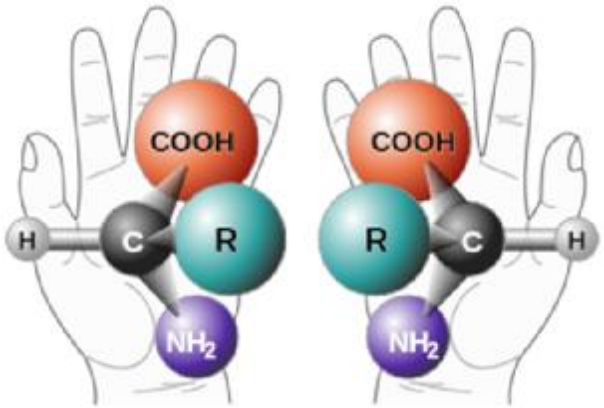
Monosaccharides

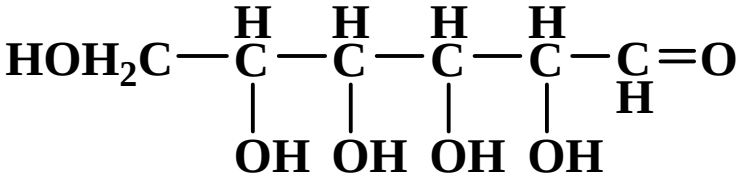
- Many molecules and objects are achiral:
  - identical to its mirror image
  - not chiral



Stereochemistry

- A carbon atom that is bonded to four different groups is chiral
- Many of the carbon atoms to which hydroxyl groups are attached are chiral centers





Aldohexoses

four asymmetric carbons

2^4 = 16 stereoisomers

Stereochemistry

- Enantiomers
  - two compounds that are nonsuperimposable mirror images of each other
  - Most of the hexoses of living organisms are D isomers.
  - Some sugars occur naturally in their L form; examples are L-arabinose

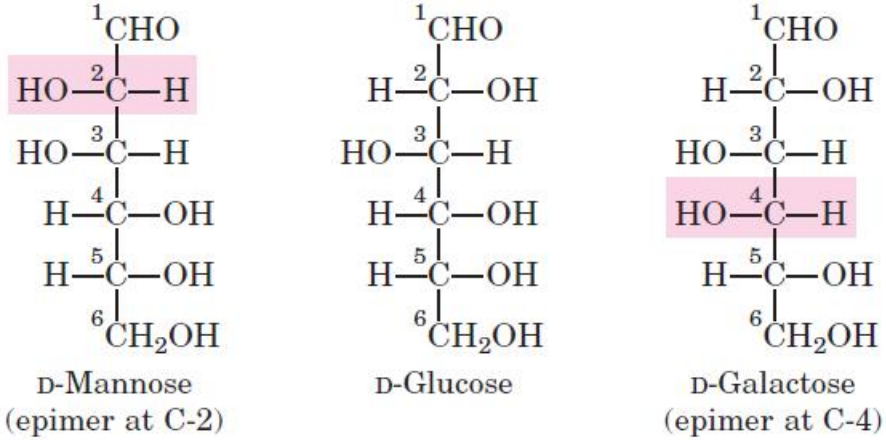
Fischer projection formulas

Stereochemistry

- Diastereomers
  - Two stereoisomers that are not mirror images of each other

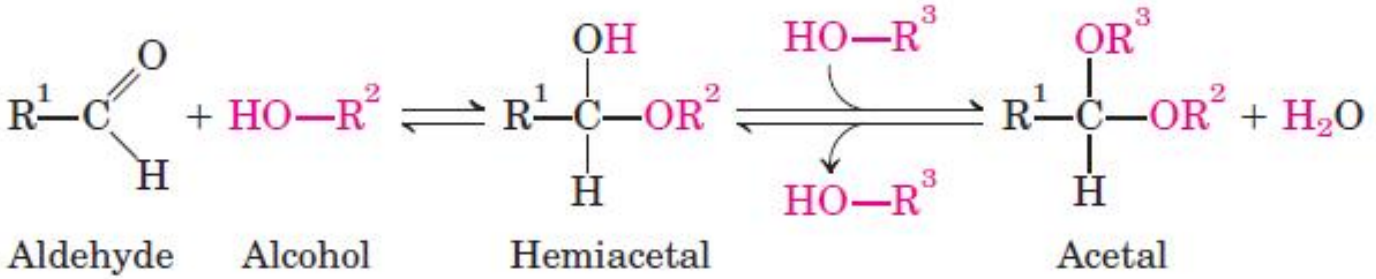
Stereochemistry

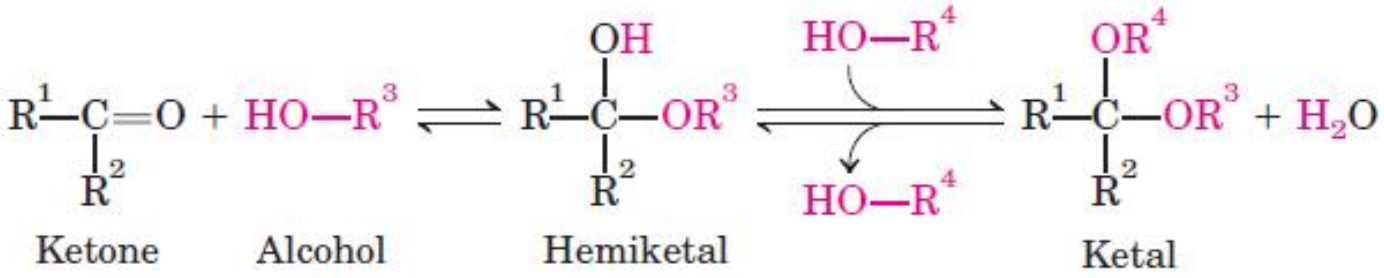
- Epimer
  - Two sugars that differ only in the configuration around one carbon atom



Hemiacetals or hemiketals

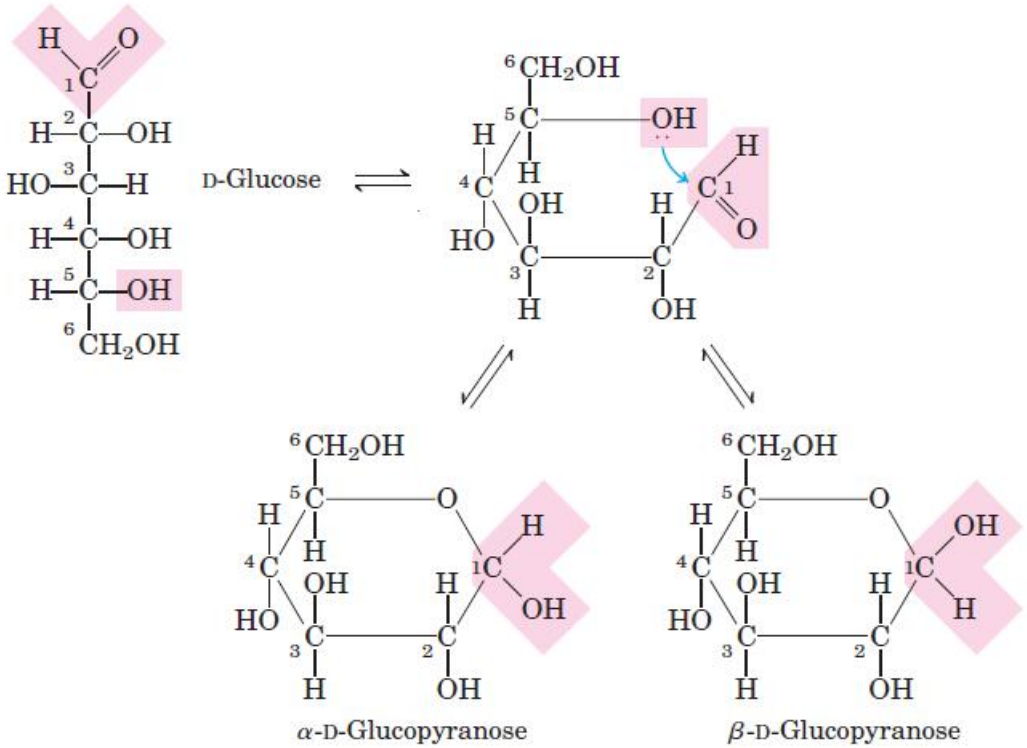
- a general reaction between alcohols and aldehydes or ketones





The Common Monosaccharides Have Cyclic Structures

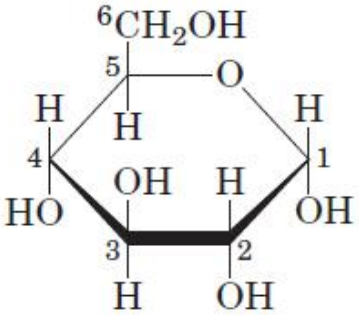
- All monosaccharides with 5 or more carbon atoms occur predominantly as cyclic (ring) structures



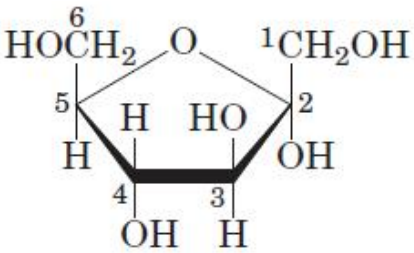
Cyclic Structures

- Producing two stereoisomers, designated **α** and **β**
- These six-membered ring compounds are called pyranoses
- Five membered ring compound are called furanoses.
- Isomeric forms of monosaccharides that differ only in their configuration about the hemiacetal or hemiketal carbon atom are called anomers
- The **α** and **β** anomers of D-glucose interconvert in aqueous solution by a process called mutarotation

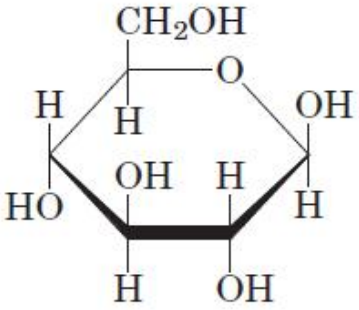
α and β



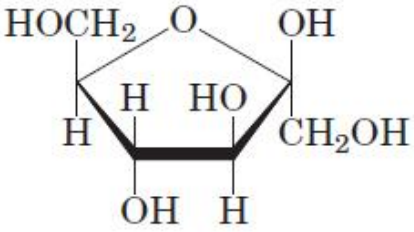
α-D-Glucopyranose



α-D-Fructofuranose

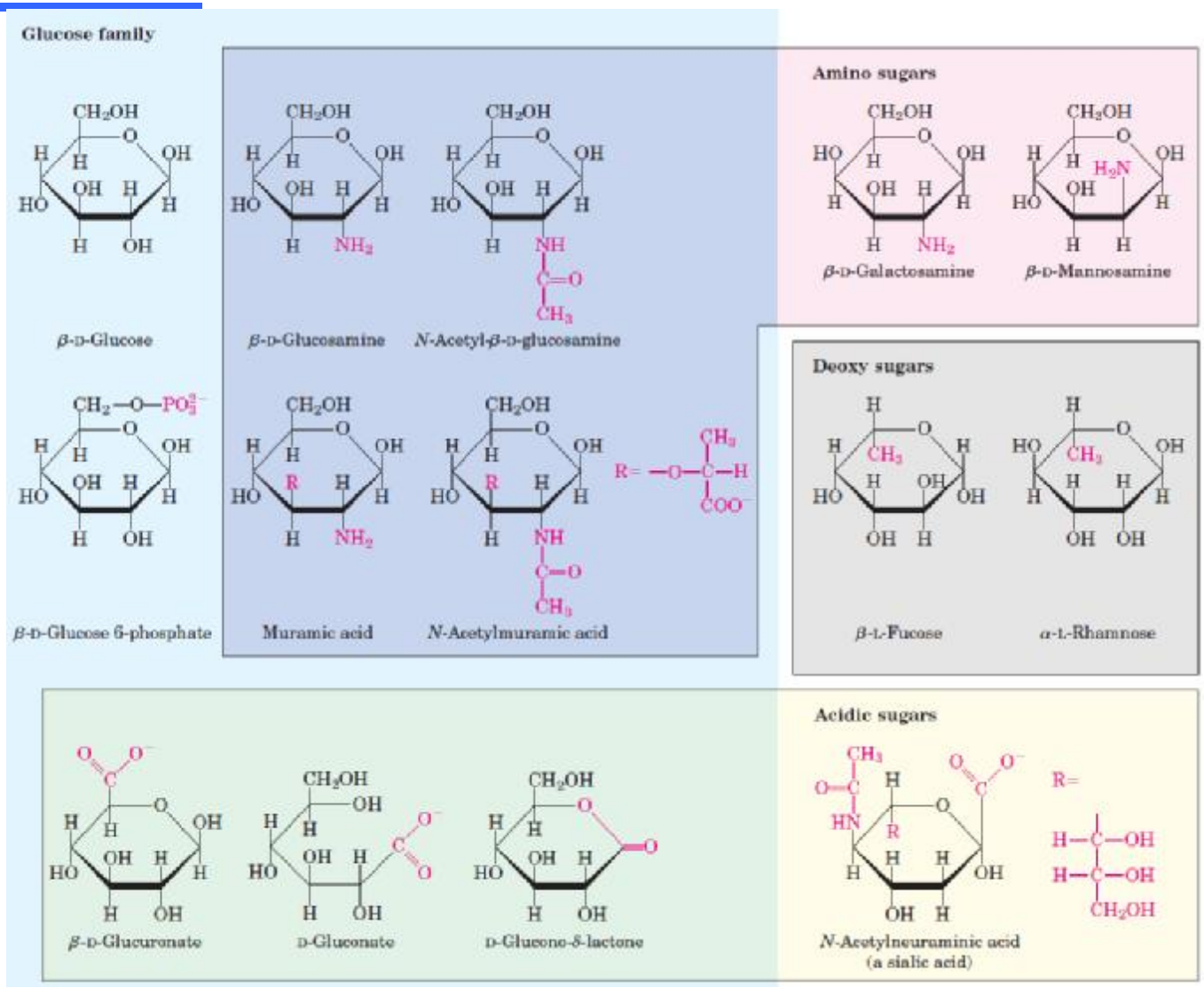


β-D-Glucopyranose



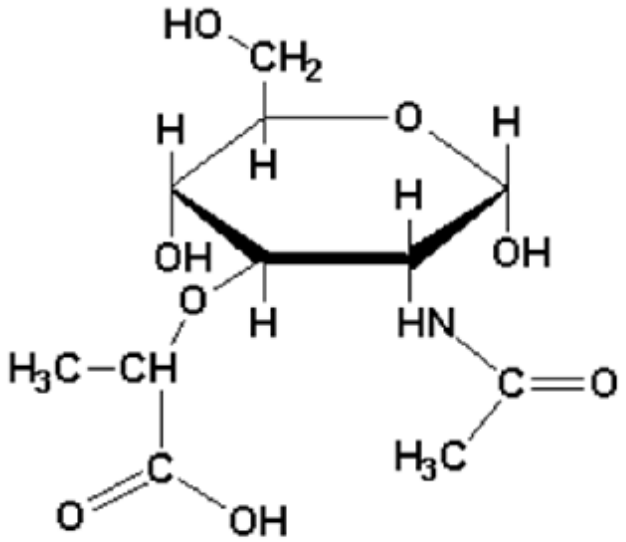
β-D-Fructofuranose

Organisms Contain a Variety of Hexose Derivatives



N-Acetylmuramic acid

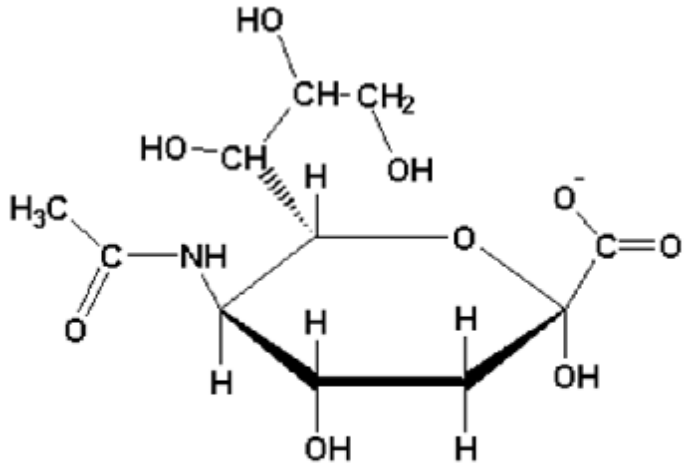
- cross-linked with oligopeptides in peptidoglycan.



N-Acetylmuramic acid

N-Acetylneuraminic acid

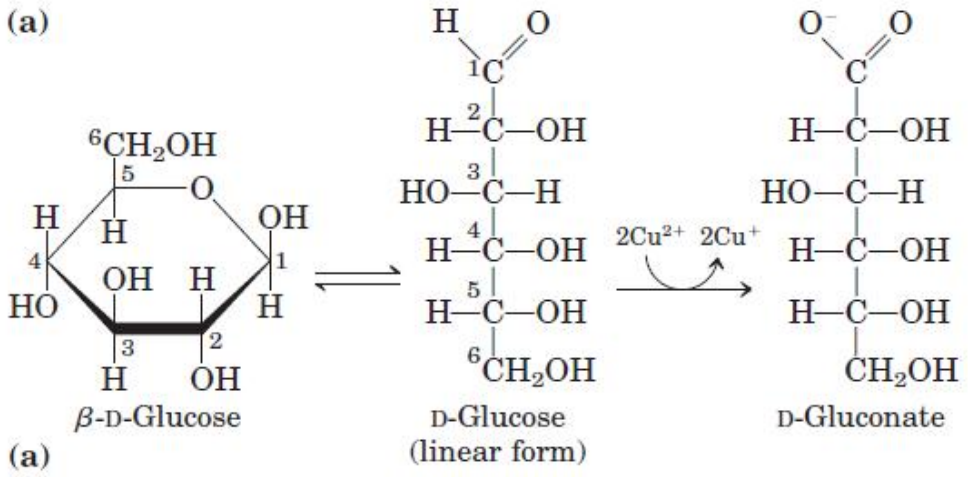
- As sialic acid
  - Acidic form of D-mannosamine + acetyl group+Glycerol
  - Mucins, glycolipids, and glycoproteins found at the cell membrane
  - Neu5Ac acts as a receptor for influenza viruses, allowing attachment to mucous cells via hemagglutinin



N-Acetyl-Neuraminic Acid

Monosaccharides Are Reducing Agents

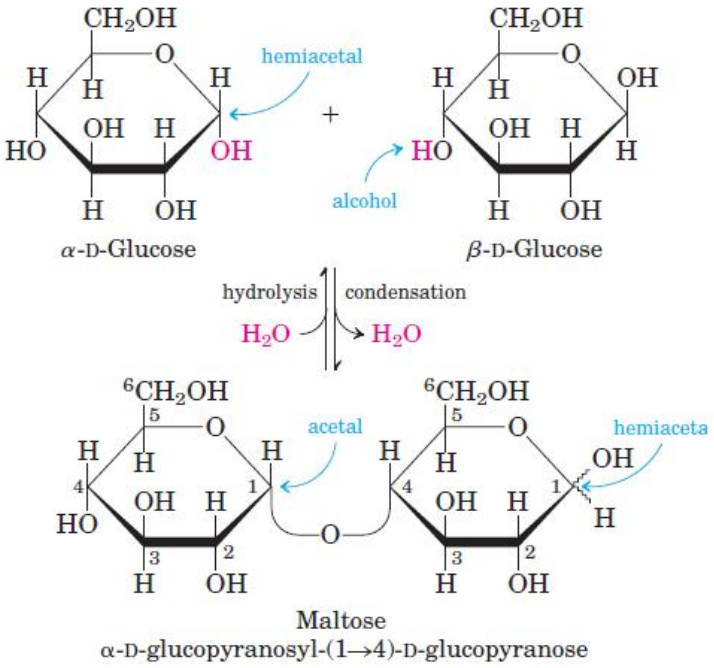
- The carbonyl carbon is oxidized to a carboxyl group.
- Reducing sugars



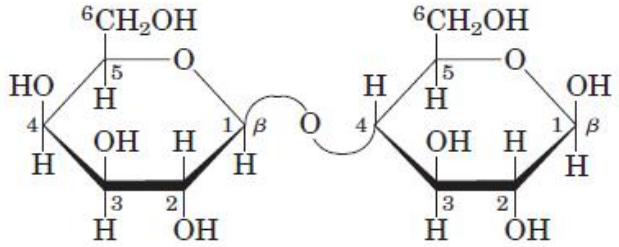
(b) D-Glucose + O_2 $\xrightarrow{\text{glucose oxidase}}$ D-Glucono-δ-lactone + H_2O_2

Oligosaccharides

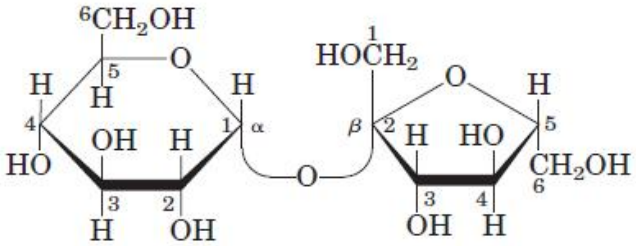
- glycosidic bond
  - O-glycosidic: formation of an acetal from a hemiacetal (such as glucopyranose) and an alcohol (a hydroxyl group of the second sugar molecule): Disaccharides
  - Glycosidic bonds are readily hydrolyzed by acid but resist cleavage by base.



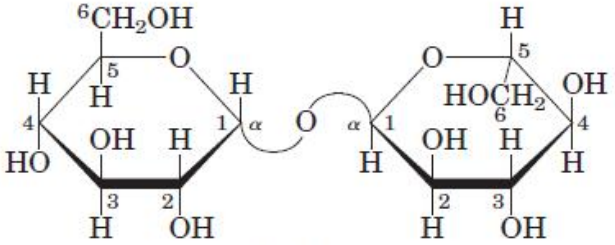
Some common disaccharides



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



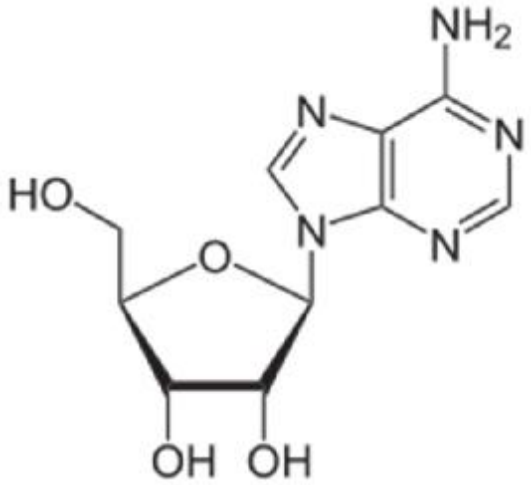
Sucrose
α-D-glucopyranosyl β-D-fructofuranoside
Glc(α1↔2β)Fru



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

N- glycosidic bond

- join the anomeric carbon of a sugar to a nitrogen atom in glycoproteins

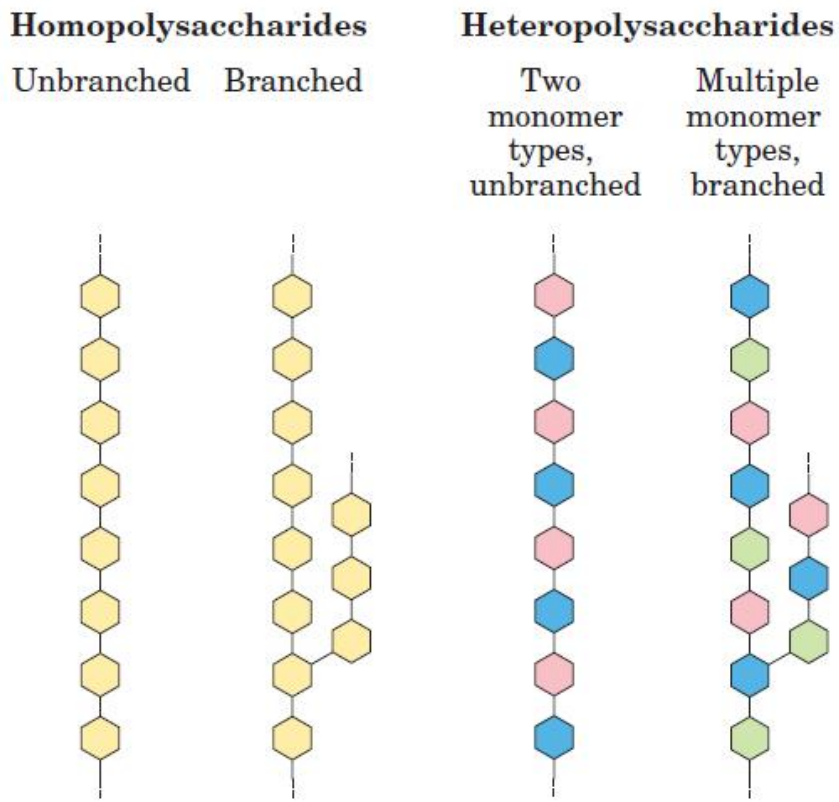


…Oligosaccharides

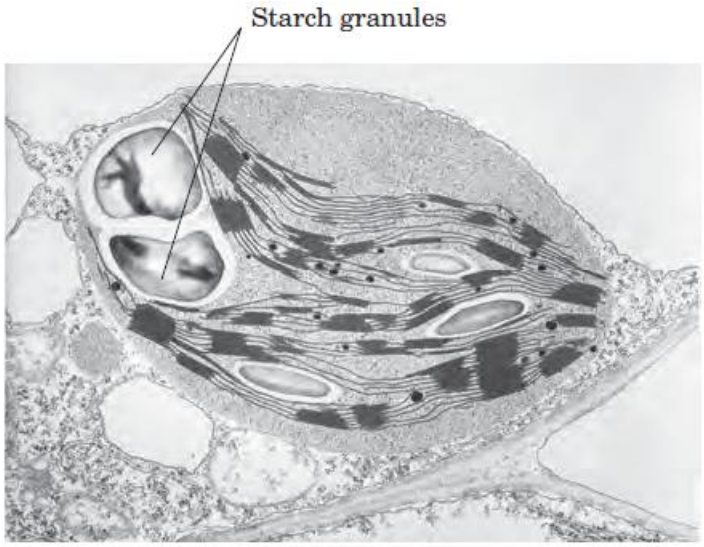
- Fructo-oligosaccharides (FOS), which are found in banana and garlic, consist of short chains of fructose and glucose molecules (3-5 monosaccharide units).
- As part of glycoconjugates

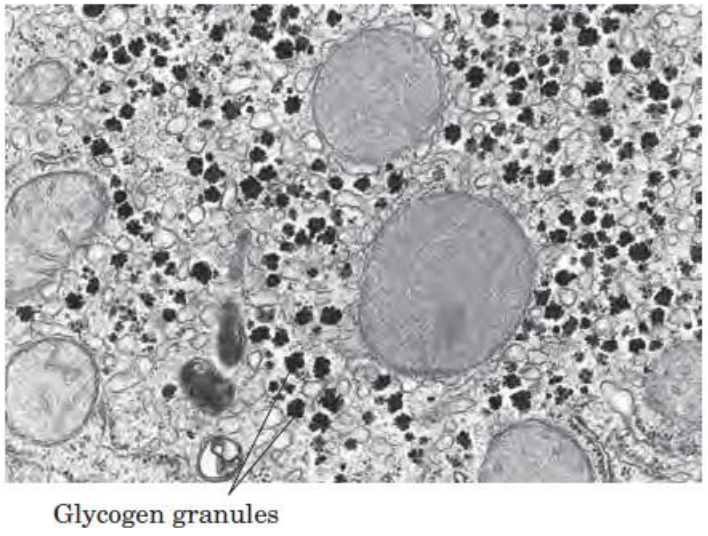
Polysaccharides

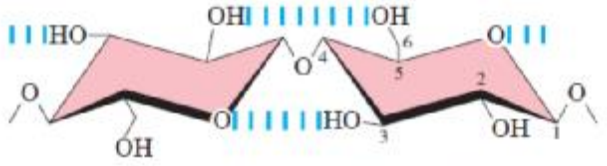
- Polysaccharides, also called glycans
  - Homopolysaccharides
    - fuels
    - structural elements
  - Heteropolysaccharides
    - extracellular support

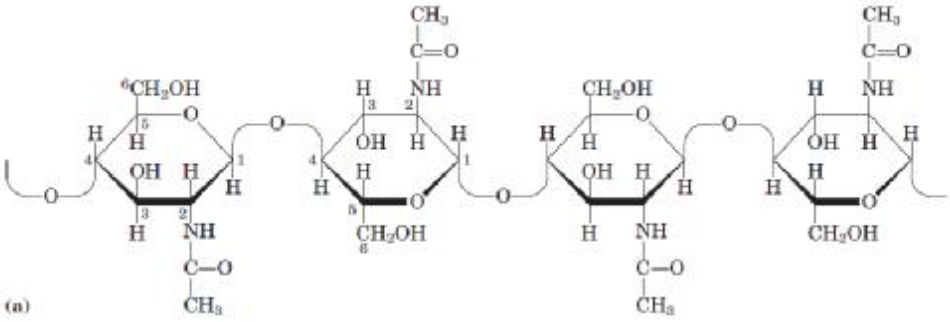


Homopolysaccharide



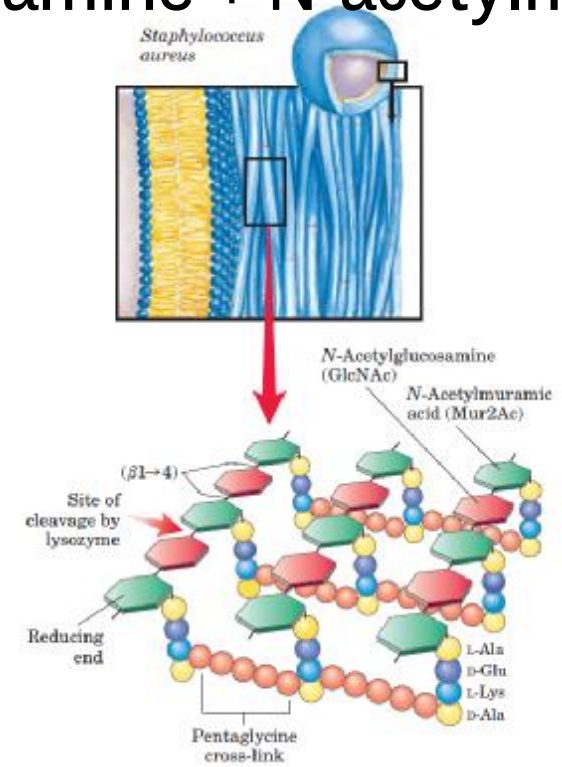






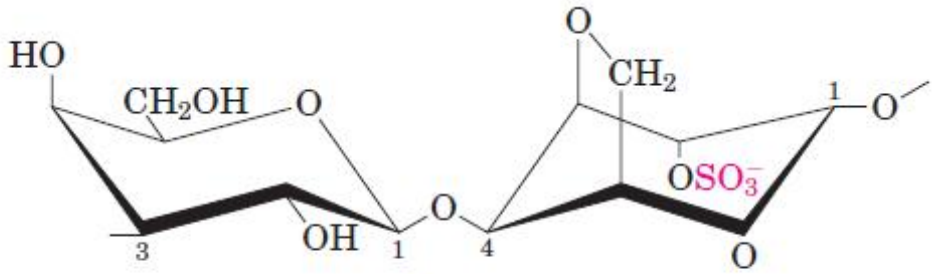
Peptidoglycan

- Peptide + Heteropolysaccharides
- Bacterial and Algal Cell Walls
- N-acetylglucosamine + N-acetylmuramic acid



Agar

- sulfated heteropolysaccharides
- D-galactose +L-galactose derivative



Agarose

3)D-Gal(β1→4)3,6-anhydro-L-Gal2S(α1 repeats

Glycosaminoglycans

- Heteropolysaccharides
- Extracellular space in the tissues in animals
- Interlocking meshwork of heteropolysaccharides and fibrous proteins such as collagen, elastin, fibronectin, and laminin.
  - holds the cells together

glycosaminoglycans

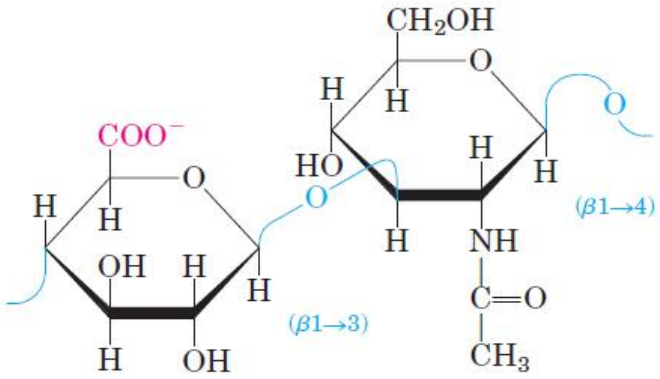
- polymers of repeating disaccharide units

- One is always either N-acetylglucosamine or N-acetylgalactosamine; the other is in most cases a uronic acid, usually D-glucuronic or L-iduronic acid.

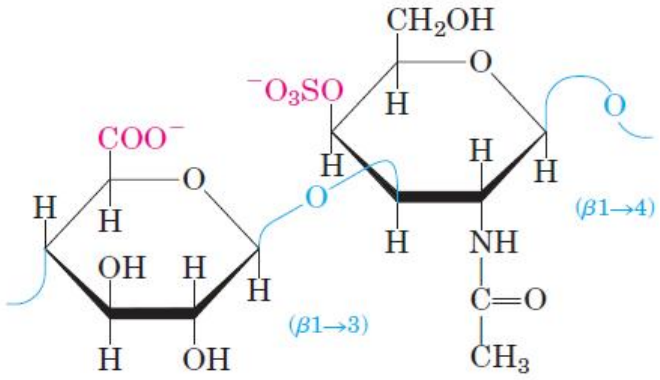
glycosaminoglycans

Glycosaminoglycan — **Number of disaccharides per chain** — **Repeating disaccharide**

Hyaluronate
~50,000

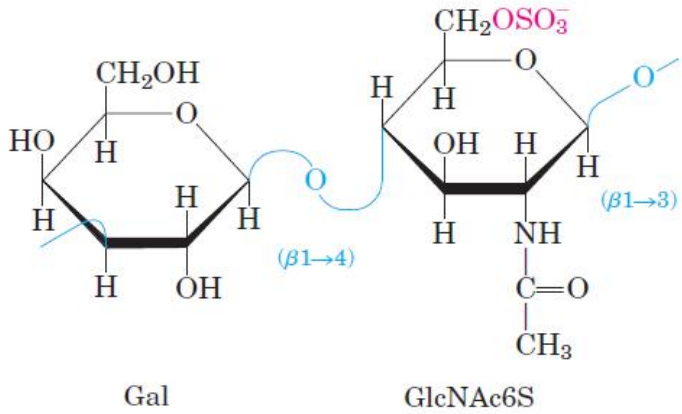


Chondroitin 4-sulfate
20–60

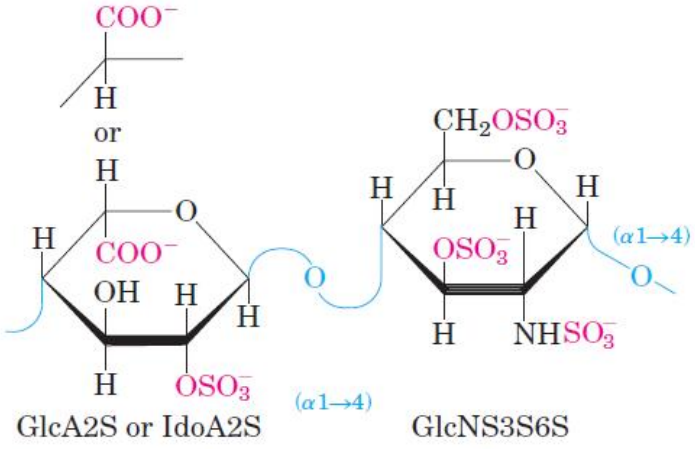


Glycosaminoglycan — **Number of disaccharides per chain** — **Repeating disaccharide**

Keratan sulfate
~25



Heparin
15–90



glycosaminoglycans

- Hyaluronates
  - have molecular weights greater than 1 million;
  - they form clear, highly viscous as lubricants in the synovial fluid of joints
  - give the vitreous humor of the vertebrate eye
  - essential component of the extracellular matrix of cartilage and tendons

- Chondroitin sulfate
  - contributes to the tensile strength of cartilage, tendons, ligaments, and the walls of the aorta

glycosaminoglycans

- Dermatan sulfate
  - contributes to the pliability of skin and is also present in blood vessels and heart valves
- Keratan sulfates
  - are present in cornea, cartilage, bone, and a variety of horny structures formed of dead cells: horn, hair, hoofs, nails, and claws
- Heparin
  - is a natural anticoagulant made in mast cells (a type of leukocyte) and released into the blood, where it inhibits blood coagulation by binding to the protein antithrombin.

TABLE 7–2 Structures and Roles of Some Polysaccharides

Polymer	*Type**	*Repeating unit*[†]	*Size (number of monosaccharide units)*	*Roles/significance*
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 24–30 residues	Up to 10^6	
Glycogen	Homo-	(α1→4)Glc, with (α1→6)Glc branches every 8–12 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
Dextran	Homo-	(α1→6)Glc, with (α1→3) branches	Wide range	Structural: in bacteria, extracellular adhesive
Peptidoglycan	Hetero-; peptides attached	4)Mur2Ac(β1→4) GlcNAc(β1	Very large	Structural: in bacteria, gives rigidity and strength to cell envelope
Agarose	Hetero-	3)D-Gal(β1→4)3,6-anhydro-L-Gal(α1	1,000	Structural: in algae, cell wall material
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

Glycoconjugates

- Proteoglycans, Glycoproteins, Glycolipids

- information carriers (labels)
  - cell-cell recognition and adhesion
  - cell migration during development
  - the immune response

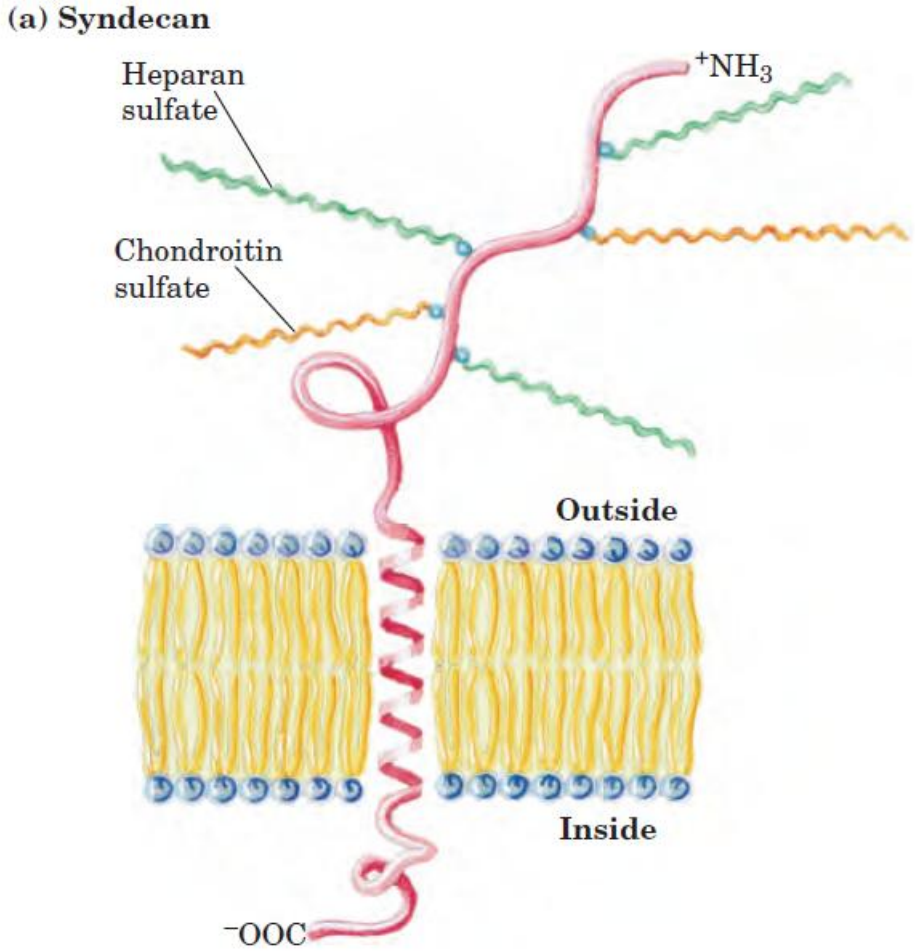
- informational carbohydrate is covalently joined to a protein or a lipid to form a glycoconjugate

Proteoglycans

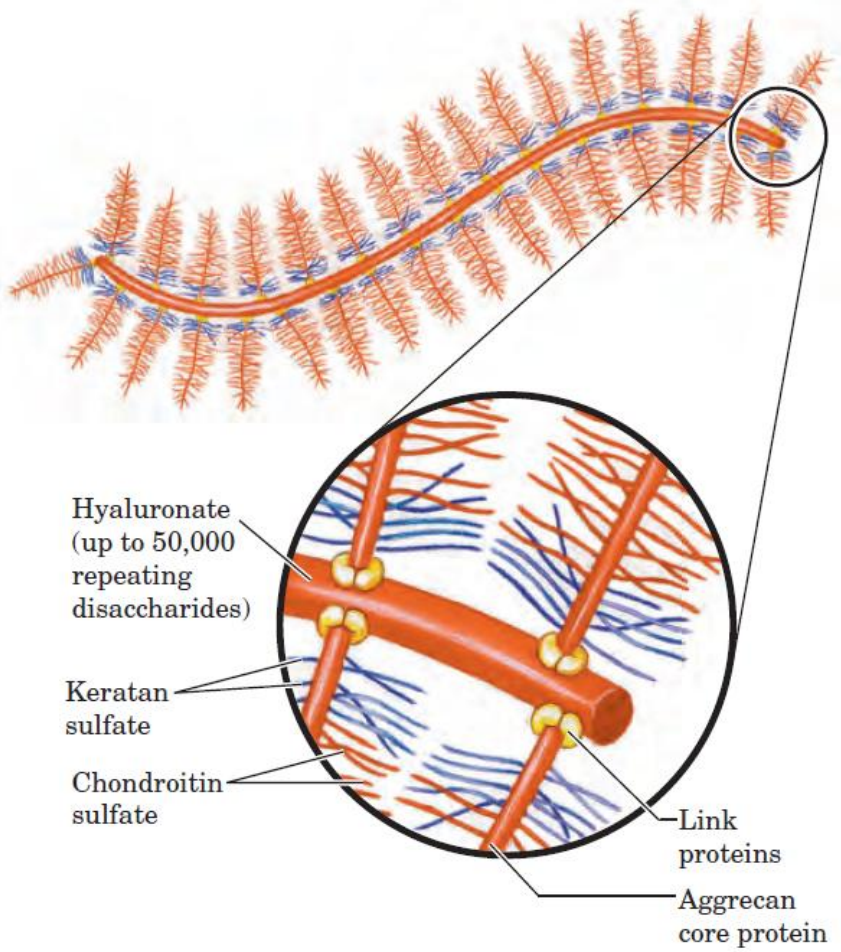
- Glycosaminoglycans are attached to extracellular proteins to form proteoglycans
- Are glycosaminoglycan-containing macromolecules of the cell surface and extracellular matrix
- Tissues strength and resilience
- Many proteoglycans are secreted into the extracellular matrix, but some are integral membrane proteins
- syndecan core protein

Proteoglycan

Proteoglycan structure of an integral membrane protein

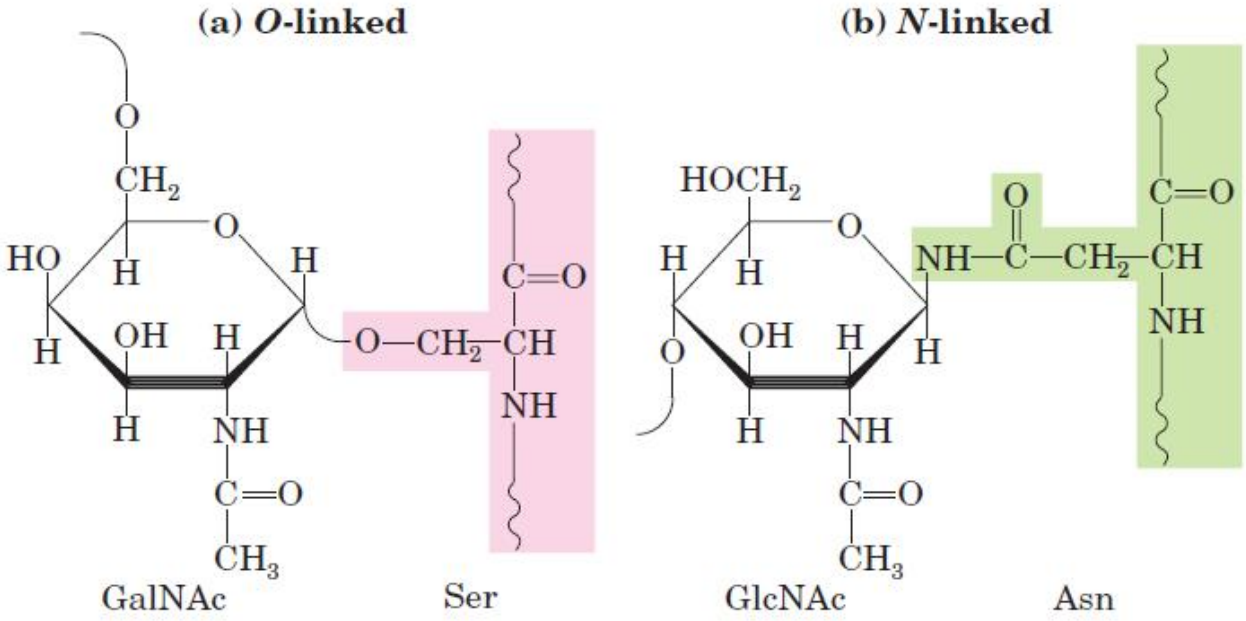


extracellular matrix



Glycoproteins

- have one or several oligosaccharides of varying complexity joined covalently to a protein
  - The carbohydrate is link to the OOH of a Ser or Thr residue (O-linked), or through an N-glycosyl link to Asn residue (N-linked)



Glycoproteins

- Outer face of the plasma membrane, in the extracellular matrix, and in the blood
- Golgi complexes, secretory granules, and lysosomes
- the carbohydrate moieties are smaller
- Many of the proteins secreted (immunoglobulins and certain hormones, such as follicle-stimulating hormone, luteinizing hormone, and thyroid-stimulating hormone)
- Many milk proteins, including lactalbumin, and some of the proteins secreted by the pancreas (such as ribonuclease) are glycosylated

Glycolipids

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

- Gangliosides

- Some of the oligosaccharide moieties of gangliosides, such as those that determine human blood groups

Lectins

- Are Proteins That Read the Sugar Code and Mediate Many Biological Processes
  - Selectins are a family of plasma membrane lectins that mediate cell-cell recognition and adhesion in a wide range of cellular processes. One such process is the movement of immune cells (T lymphocytes) through the capillary wall, from blood to tissues
  - Lectins serve in a wide variety of cell-cell recognition, signaling, and adhesion processes
  - Some peptide hormones
  - A similar mechanism is apparently responsible for removing old erythrocytes from the mammalian bloodstream.
  - Several animal viruses, including the influenza virus, attach to their host cells through interactions with oligosaccharides displayed on the host cell
  - Some microbial pathogens have lectins that mediate bacterial adhesion to host cells

TABLE 7-3 Some Lectins and the Oligosaccharide Ligands They Bind

Lectin source 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