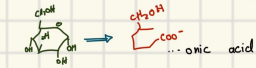


Oxidation

- Gluconate **GlcA**

Formed by oxidation of the carbon 4 [aldehyde] to form

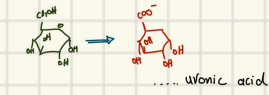
a carboxylic acid. by weak oxidizing agent



- Glucuronate **GlcUA**

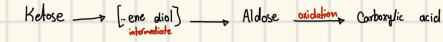
Formed by oxidation of the carbon 6 [alcohol] to form

a carboxylic acid. by enzymes



- Ketoses can't be oxidized into carboxylic acid directly, But

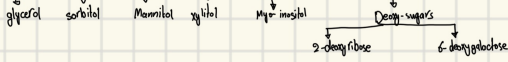
They can do so indirectly :-



Reduction

- reduce the carbonyl group $\rightarrow$ alcohol

Reduced sugars



4. Xylitol

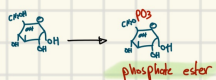
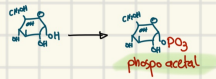
5. Myo-inositol

6. Deoxy-sugar

- a. 2-deoxyribose which is found in DNA
- b. 6-deoxygalactose [Fucose] which is found on the surface of RBCs

Esterification

• Addition of PO_4^{3-} to C_2 or C_6 of a sugar



Glycosides

- It has 3 types
 - $\rightarrow$ O-glycoside C_1OR
 - $\rightarrow$ N-glycoside $\text{C}_1\text{NR}_2 \rightarrow$ nucleotides in DNA, RNA
 - $\rightarrow$ C-glycoside C_1R

Amino sugars

- Attaching an amine $[NR_2]$ on any carbon except anomeric carbon.
- It could go under further modification
 - acetylation $\rightarrow$ [amine $\Rightarrow$ amide]

Disaccharides

- Maltose $\pm$ 2 α glucose [1-4 glycosidic bonds]
- Lactose $\pm$ α glucose + β galactose [1-galactose + 4 glucose] $\rightarrow$ reducing sugar [having a free anomeric carbon]
- Sucrose $\pm$ α glucose + β fructose [1-glucose + 2 fructose] $\rightarrow$ Non reducing sugar
- Lactulose $\pm$ isomerization of lactose
 - $\times$ leads constipation
 - $\times$ growth of health gut bacteria
 - $\times$ modulates immune system
- Sucralose $\pm$ Artificial sweetener
 - $\times$ addition of Cl atoms

Milk Problems

- Lactose intolerance $\pm$ deficiency of lactase enzyme $\rightarrow$ bacteria digest it
 - $\rightarrow$ H_2 $\Rightarrow$ digestive problems $\rightarrow$ bloating
 - $\rightarrow$ CO_2 $\rightarrow$ diarrhea
 - $\rightarrow$ organic acids
- Galactosemia $\pm$ Missing a galactose metabolizing enzyme $\rightarrow$ non-metabolized galactose accumulates $\rightarrow$ converted into hydroxy-sugar galactitol
 - $\rightarrow$ water is drawn into cells $\rightarrow$ swelling $\rightarrow$ brain [irreversible abnormality]
 - $\rightarrow$ cataract

Oligosaccharides

- Raffinose $\pm$ sucrose + α galactose at C6 of the glucose
 - Found in $\rightarrow$ 1. beans 2. cabbage 3. Kale
 - 4. sprouts 5. asparagus 6. Cauliflower
 - 7. Broccoli
- Human bodies lack α galactosidase $\rightarrow$ intestinal bacteria ferment it
 - $\rightarrow$ H_2
 - $\rightarrow$ CH_4
- Drugs
 - $\rightarrow$ streptomycin, erythromycin [antibiotics]
 - $\rightarrow$ doxorubicin [cancer chemotherapy]
 - $\rightarrow$ digoxin [cardiovascular disease]

Polysaccharides

- Storage
 - $\rightarrow$ Glycogen
 - $\rightarrow$ Starch
 - $\rightarrow$ Dextran
- Structure
 - $\rightarrow$ cellulose
 - $\rightarrow$ chitin
 - $\rightarrow$ pectin

- Glycogen $\pm$ homopolymer [glucose monomers]
 - the chain has $\approx$ 1-4 bonds
 - branching $\rightarrow$ α 1-6 bonds [branching occur about every 10 residues]
 - Found in skeletal muscles and liver animals
 - α bonds are flexible
 - $\rightarrow$ more soluble
 - $\rightarrow$ prevents crystallization
 - $\rightarrow$ glucose is accessible

- Starch $\pm$ - homopolymer in plants
 - It has 2 forms
 - $\rightarrow$ Amylose $\rightarrow$ (10-20) %
 - $\rightarrow$ Not branched
 - $\rightarrow$ Amylopectin $\rightarrow$ (80-90) %
 - $\rightarrow$ branched, but having less branching compared to glycogen
 - $\rightarrow$ The backbone is (α 1-4) bonds
 - $\rightarrow$ The branching is (α 1-6) bonds [branching occur about every 25 residues]

- **Dextran**: - Found in yeast and bacteria
 - The main chain has [α 1-6 bonds]
 - The branching could be between [C_1-C_6 C_1-C_3 , C_1-C_4]
- **Cellulose**: - It's a structural homopolysaccharide [β -glucose]
 - It is found at the cell wall of plants
 - **Cellulose + Lactulose** [Fibers] they are given to people who suffer constipation
 - They can't be digested, so they drive water to them leading to **Moisturizing the stool**
 - **Cellobiose** is a disaccharide appears from **Branching cellulose**
 - It has [β 1-4 bonds], β bonds are
 - not flexible
 - gives rigid structure
 - contribute to forming a lot of hydrogen bonds which **Stabilize the structure**.
 - unbranched
- **Chitin**: - It's a homopolysaccharide, but its monomer is a **Modified glucose**
 - The monomer is **N-acetyl- β -D-glucosamine**

 - It is found in insects' exoskeletons.
 - It has (β 1-4 bonds) so it has rigid structure for walls
 - It's **acetyl groups** increases the number of hydrogen bonds

- **Pectin**: - It is a homopolysaccharide of modified sugar [acid derived from galactose]
 - It has [α 1-4 bonds]
 
 - It can be found in **Plants, industry**

Are polysaccharides reducing?

No, the amount of the single reducing ends aren't enough to detect.
 even though they are present.  reducing end

- **Glycosaminoglycans**: - extracellular structural heteropolysaccharide
 - They contain repeated disaccharides.
 - It's rigid at water 10 bonds
 - At least one sugar of the repeating unit has **Negative charge either**
 - carboxylate group
 - sulfate group
 - It has **amino sugars**
 - glucosamine
 - amino group normally binds to C_2 of the sugar
- Causes non-covalent interactions

- **GAG**
 - **hyaluronate**
 - synovial fluid
 - lubricant fluid
 - vitreous humor
 - shock absorbing
 - ECM of loose CT
 - It has 25K subunit
 - **Chondroitin Sulfate**
 - bones
 - cartilage
 - heart valve

Most abundant GAG
 - **Heparan Sulfate**
 - basement membrane
 - component of cell surface

It has more acetylated glucosamine than heparin
 - **Heparin**
 - intracellular granules in the Mast cells
 - lining arteries of lungs, liver, skin

Natural anticoagulant [found under health as a gel structure works as immune cells]
 - **Dermatan**
 - skin
 - blood vessels
 - heart valves
 - **Keratan**
 - cornea
 - bone
 - cartilage [aggregated with chondroitin]

The only one without uronic acid

Proteoglycans

- **Proteoglycans**: - major → sugar, minor → protein
 - Function
 - lubricant [like in synovial fluid]
 - structural component in CT [like aggrecan in cartilage]
 - mediate adhesion of the cells to the ECM
 - Bind factors that stimulate cell proliferation [like the VEGF in angiogenesis]
 - ↓
 - vascular endothelial growth factor



Bacterial cell wall

- Bacterial cell wall is - repeated disaccharides
 - rigid $\rightarrow$ β bonds
 - it is formed by
 - N-acetylglucosamine
 - N-acetylmuramic acid [It has lactic acid attached to C₃]
 $\text{CH}_3 - \text{CH} - \text{COOH}$
- both of its monomers have an acetyl group attached to C₂

$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH} - \text{C} - \text{CH}_3 \\ | \\ \text{O} \end{array}$$
- between its chains it is connected to each other by oligopeptides short polypeptides

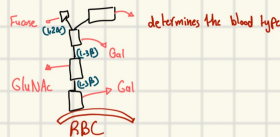
Glycoprotein

- Glycoprotein: - major $\rightarrow$ protein, minor $\rightarrow$ sugar
- The carbohydrate of the glycoprotein can be connected either by
 - N-glycosidic bond $\rightarrow$ through the amide group of asparagine (Asn)
 - from the R chain
 - O-glycosidic bond $\rightarrow$ through the hydroxyl group of
 - Serine (Ser)
 - Threonine (Thr)
 - hydroxylysine (Hlys)

Proteins linked sugars

- proteins are either
 - membrane proteins
 - soluble proteins
- What is the purpose of linking proteins to sugars
 - protein folding [forming the 3D structure]
 - protein targeting inside the cell [marking the molecules, like we studied the protein post-translational modification]
 - prolonging the protein's half life
 - cell-cell communication [MHC, recognition whether cells are "self" or "others"]
 - signaling

- Blood types: - glycoproteins on the RBC's surface determine the blood type [linked to I-antigen also]
 - O $\rightarrow$ no group
 - B $\rightarrow$ galactose [Gal]
 - A $\rightarrow$ N-acetylglucosamine [GalNAc]



- Sialic acid: - Its precursor amino sugar, neuraminic acid
 - It's called N-acetylneuraminic acid, it has 9 carbons
 - The amide is attached to C₅
 - It's the terminal residue of the oligosaccharides of glycoproteins and glycolipids
- Note: Neuraminic acid is not the same as uronic acid [oxidizing C₆]