**carbohydrates Glucose**

**(organic natural products)**

**General Introduction:**

Carbohydrates like sugar, starch, cellulose, etc. provide us **three** basic needs of life —

1. Food, in the form of starch containing grains,
2. Clothing, in the form of cotton, linen and rayon are literally known as cellulose, and
3. Shelter, wood used to make houses and furniture is almost cellulose.

***Ribose*** and ***deoxyribose*** (aldopentoses) are the components of ***hereditary material nucleic acid*** (). Carbohydrates are also important to the economy many countries. ***Table sugar***, for example, is one of the most important commercial commodities. In addition some commodities of daily use are ***paper***, ***photographic films***, ***plastics***, ***lacquers***, etc. derived from carbohydrate materials, as ***semisynthetic plastics***.

**Definition of Carbohydrates:**

Carbohydrates were originally defined as the compounds of with later two elements () in the ratio (water composition), having **empirical formula** , hence named as **hydrates of carbon**. For example, ***glucose*** and ***fructose***, [*i.e*. ]; ***sucrose*** [*i.e*. ], etc. However, the word carbohydrate is a misnomer, as some members do not obey above definition (*e.g*. Rhamnose , rhamnoheptose , etc.), whereas some other compounds like formaldehyde (), lactic acid (), etc. are not carbohydrates but obey empirical formula .

Structurally, carbohydrates contain only ***two*** main functional groups —

1. Carbonyl groups, and
2. Hydroxyl groups

The carbonyl group, however, does not occur in **free** from but forms ***intramolecular hemiacetal or acetal*** linkages with group(s). Further, they contain more than **one asymmetric - atoms**. Hence carbohydrates are ***defined as*** —

Carbohydrates are the ***polyhydroxy aldehydes or ketones*** or compounds which give these on ***hydrolysis*** and contain at least **one asymmetric - atom**.

The name ***carbohydrate*** is still retained because of its simplicity and historical background. They are often called ***saccharides*** (***Latin***, ***saccharum*** meaning sugar) because of the ***sweet*** taste of simple members.

**Classification of Carbohydrates**:

Carbohydrates are broadly classified (divided) into **three** main classes —

1. Monosaccharides,
2. Oligosaccharides, and
3. Polysaccharides

**Monosaccharides**: Monosaccharides are the **simplest** carbohydrates because they cannot be further hydrolyzed into simpler sugars. Depending upon whether the carbohydrates contain an ***aldehydes*** or a ***keto***- group (free or potential), they may be —

1. ***Aldoses*** or
2. ***Ketoses***

Depending upon the number of - atoms present in the monosaccharides can be further subdivided into —

1. Triose,
2. Tetrose,
3. Pentoses, or
4. Hexoses

Some representative members of each type are given below —

|  |  |  |  |
| --- | --- | --- | --- |
| ***Type*** | ***Molecular Formula*** | ***Structural Formula*** | ***Examples*** |
| **Aldoses**  Aldotriose  Aldotetrose  Aldopentose  Aldohexose  **Ketoses**  Ketotriose  Ketotetrose  Ketopentose  Ketohexose |  |  | Glyceraldehyde  Erythrose, Threose  Ribose, Xylose, Arabinose, *etc*.  Glucose, Mannose, Galactose, *etc*.  Dihydroxy acetone  Erythrulose  Ribulose, Xylulose  Fructose, Sorbose, *etc*. |

**Oligosaccharides** (***Greek***, ***oligos*** meaning few): Carbohydrates, those on hydrolysis yields **two** to **four** monosaccharide units are termed as oligosaccharides. These are classified as -, - or - saccharides depending upon the number of monosaccharide units given on their hydrolysis. ***For example***, —

**Disaccharides** : **Sucrose**, **Maltose**, **Lactose**, etc. ()

**Trisaccharides** : **Raffinose** ()

**Tetrasaccharides** : **Stachyose** ()

**Polysaccharides**: Carbohydrates, those on hydrolysis yields more than **four** (in fact hundreds or even thousands) monosaccharide units are termed as ***polysaccharides***. These are classified as , depending upon whether they give only one kind or more than one kind of monosaccharide units on hydrolysis. ***For example***,

: **Starch** and **Cellulose** — these on hydrolysis yields only one kind of monosaccharide (Glucose, ).

: - **Haparin** and **Hyaluronic acid** — these on hydrolysis yields more than one kind of monosaccharide.

***Sugars and Non-Sugars***: All the - and - saccharides are called **sugars** as they possesses **sweet** taste and ***soluble in water***. In contrast, **polysaccharides** are **non-sugars**, **amorphous** in nature and ***insoluble in water***.

**Reducing and Non-Reducing Sugars or Carbohydrates**:

The terms ***reducing*** and ***non-reducing*** carbohydrates/ sugars are commonly used in carbohydrate chemistry. Carbohydrates that ***can reduce Fehling solution*** or ***Tollen’s reagent*** are termed as reducing carbohydrates, while the others which do not reduce these reagents are called ***non-reducing carbohydrates***. All **monosaccharides** and most of the **disaccharides** (except ***sucrose***) are reducing carbohydrates.

**Configuration of Aldotetrose and Aldopentoses**:

Glyceraldehyde is the simplest **aldotriose** having an **asymmetric - atom** and therefore, exist in ***two optically active*** forms. One form has a specific rotation of and for the other it is . ***Emil Fischer*** gave the ***convention*** of projecting the formulae on - dimensional plane in which the aldehyde group is written at the top followed by group written ***right*** and ***left*** on a vertical line. The formula of glyceraldehyde in which  **group is in the right** to the asymmetric - atom (marked with ‘’) represents the ***dextrorotatory isomer*** and is assigned as **- configuration**. The laevorotatory isomer in which the  **group is in the left** to the asymmetric - atom (marked with ‘’) represents the ***levorotatory*** and is assigned as **- configuration**.



These forms of glyceraldehyde are very important in carbohydrate chemistry, as the more complex sugars may be considered to be originated from them. The sugars whose **bottom** structure terminate in the same configuration as **-glyceraldehyde** are designated as **- sugars** and those having ***terminal structure*** similar to **-glyceraldehyde** (***irrespective of optical rotation***) are designated as **- sugars**.

Its isomeric ***Ketotriose*** (***dihydroxy acetone***) is **optically inactive** due to the lack of **asymmetric - atom**.

The **Fischer convention** can be illustrated by assigning configurations to the following **six stereoisomeric** ***aldopentoses*** out of the ***eight*** () optically form.



**Important Note**: The designation has ***no concern*** (relation) ***with optical rotation*** as - configuration may have () or () specific rotation and it is also true for - forms. This is based only on the position (in relation to glyceraldehyde) of the ***lower group*** attached to ***bottom*** ***asymmetric carbon atom***.

**Monosaccharides** — **Glucose:**

Though monosaccharides contains - atoms, only pentoses and hexoses are the important members containing - atoms respectively.

Monosaccharides are colourless, crystalline compounds soluble in water but insoluble in organic solvents. Unlike disaccharides, monosaccharides crystallize with difficulty. When heated, they char and give characteristic smell of sugars.

Chemically, monosaccharides exhibit the reactions of **alcohols** and **aldehydes**/ **ketones**. **Glucose** and **fructose** are the representative **aldoses** and **ketoses** respectively.

**Glucose (dextrose, grape sugar, corn sugar, blood sugar), :**

() **Occurrence**:

Glucose, the most important and abundant monosaccharides, occurs free in honey, ripe grapes (hence the name ‘grape sugar’), most sweet fruits, blood and urine of animals. In the combined form, it is present in many glycosides, disaccharides and polysaccharides.

() **Manufacture**:

Glucose is manufactured from **starch** by **hydrolysis** with hot dilute mineral acids. The actual reaction is very complicated and involves the following three steps —

Starch Dextrin Maltose Glucose

The common **sources** of starch are maize, rice and potatoes.

On complete hydrolysis, product is ***neutralized*** with chalk and the mixture is filtered. The filtrate is decolourized with animal charcoal and concentrated in vaccum pans. Glucose crystallizes out and can be purified from the crude product by recrystallization from alcohol.

() **Physical Properties of Glucose**:

Important and representative physical properties of glucose are —

1. Glucose forms colourless crystals, ,
2. It also forms monohydrate, ,
3. It is readily soluble in water, sparingly soluble in alcohol but insoluble in ether,
4. It is optically active,
5. Freshly prepared solution of glucose is dextrorotatory, (since, the optical rotation is , hence the name ***dextrose***), and
6. It is about three-forth as sweet as cane-sugar (sucrose). //

() **Uses of Glucose**:

Glucose has many potential uses, some of these are —

1. As **food** for children and individuals,
2. As **reducing agent** in silvering of mirrors,
3. In the manufacture of confectionary, in syrups, candies, jams, wine, beer, etc.,
4. As the starting material for the manufacture of ascorbic acid (Vitamin C), and
5. For the treatment of tobacco. //

() **Structure/ Constitution of Glucose**:

Two different structures were proposed for glucose —

1. Open Chain structure and
2. Ring structure

Both the structures were elucidated from the various established chemical analysis.

() **Open chain Structure for Glucose**:

The open chain structure for glucose () was given by Baeyer form the following observations —



() **Molecular formula**: On the basis of elemental analysis and molecular weight determination data, the molecular formula established for glucose is

() **Presence of Straight Chain**: Glucose on vigorous reduction with gives - hexane, indicating that the - atoms of glucose are in a straight chain.

() **Presence of Aldehyde Group**: Glucose reacts with —

1. **Hydroxylamine** to form a **mono-oxime**, and
2. **Hydrogen cyanide** () to form a **cyanohydrine**

These shows the presence of **one carbonyl group** in the glucose, so the partial structure for glucose is .

Mild oxidation of glucose with bromine water or sodium hypobromite gives a monobasic acid, **gluconic acid**, , containing the same number of - atoms as in glucose. Therefore, the **carbonyl group present in glucose must be an aldehyde group**. The **nature** of the carbonyl group as an aldehyde also follows from the formation of **heptanoic acid** by the hydrolysis of the **cyanohydrine** of glucose followed by **vigorous reduction** with **hydroiodic acid**. Thus, the partial structure for glucose can be written as .

() **Presence of Groups**: Glucose forms **penta-acetate** [], with **acetic anhydride**, indicating the presence of five groups in it. Thus, all - atoms in glucose have been accounted for and it can be formulated as .

This assignment is confirmed by the **catalytic reduction** of glucose to **hexahydric alcohol**, **sorbitol** (), which gives **hexa-acetate with acetic anhydride**.

() **Presence of Terminal Group**: Oxidation of **gluconic acid** with gives a dicarboxylic acid (**glucaric acid** or **saccharic acid**, ), containing the same number of - atoms. As glucose contains only one group, the **2nd carbonyl group** must have originated from the oxidation of a ***primary alcoholic group*** (). Hence, the formula of glucose becomes

The arrangement of the - atoms in glucose has been shown to be in a straight chain. The group must be in the **terminal position**. One of the groups is present as group, and this should be in a **terminal position**.

() **Open Chain Structure**: The disposition of the remaining four - atoms and four groups follows from the fact that the glucose **does not dehydrate easily**, to fulfil this criteria, glucose must not contain groups and a corresponding additional number of groups. On the basis of these observations, **Baeyer in 1870** proposed the following open chain formula for glucose.



This open chain structure satisfactorily explains all the above **reactions** as shown below —



The **open-chain structure of glucose** as an ***aldohexose*** is further confirmed by the fact that glucose consumes of periodic acid () to form of formaldehyde and of formic acid. Thus, —

Glucose Periodic acid Formaldehyde Iodic acid

This oxidative cleavage by for vicinal groups can explain the open chain structure for glucose as follows —



() **Stereochemistry**: There are four **different asymmetric - atoms** () in the open-chain structure () of glucose. Therefore, the **possible stereoisomeric** structures would be , i.e. - **pairs of enantiomers**. There would be **no**  **compounds** because two ends are dissimilar.



The naturally occurring dextrorotatory glucose, better represented as () - glucose, is only one of the - stereoisomers. **E. Fischer**, assigned **configuration** (), usually shown as - glucose, or () – glucose, as the bottom structure (shown in screen box) resembles to **- configuration** of glyceraldehyde.



() **Limitations of Open chain Structure of Glucose**: The open chain structure (II) for glucose can explain most of the reactions of glucose, but failed to explain the following properties —

() **Reaction of Aldehydic Group**: It failed to give some reactions of ***aldehydes*** like formation of ***adduct with sodium bisulphite*** and does not give pink colour with ***Schiff’s reagent***.

() **Isomeric forms**: Glucose exists in **two** stereoisomeric forms (- and -). The ordinary glucose (- form) obtained by crystallization from alcohol water has and in fresh aqueous solution. On the other hand, when glucose is crystallized from pyridine solution a new form - glucose is obtained which has and

() **Mutarotation**: It has been observed that the specific rotation of an aqueous solution of **-- glucose** gradually **falls** from, whereas in **-- glucose** gradually increases from. Thus, - and - glucose gives an equilibrium mixture with a constant specific rotation. Such change in specific rotation to give equilibrium value is known as mutarotation.

**-- Glucose** Equilibrium Mixture **-- Glucose**

() **Formation of Glycosides (ethers)**: **-- Glucose** when treated with equimolar amounts of methanol and anhydrous gives two forms of methyl glucosides *viz*. methyl-**-- glucoside** () and methyl-**-- glucoside** (). The methyl glucosides behave as acetals (formed by the interaction of ***alcohol*** and ***aldehyde group***). These ***glucosides do not reduce Fehling’s or Tollen’s reagent*** and ***do not undergo mutarotation***.



() **Ring Structure for Glucose (- Glucose)**:

From the above mentioned limitations of the open-chain structure for glucose [-], it is inferred that the aldehyde group is not free in glucose. Thus, a **hemiacetal ring structure** formed from open chain structure by the mutual **intramolecular** interaction of **aldehyde group** and  **group** of **position-** was proposed. This cyclic hemiacetal structure () generates a new **chiral** centre at **-**. This can give **two possible structures**; one with at **right** is termed as **-- glucose** () and other with at **left** () is **-- glucose**. This **pair of diastereomers** which **differ in configuration** at **-** only are known as ***anomers*** and the carbon **-** is known as ***anomeric*** carbon.



Structures explain the formation of **glycosides** (cyclic ethers) and **resistance to undergo addition reaction** with **sodium bisulphite**. The phenomenon of ***mutarotation*** given by anomers (**- and - forms**) can also be explained, as each anomer is a ***hemiacetal*** (hemiacetal is formed by the reaction of group with ) and readily hydrolyzed to give the open chain structure.

Thus, an **equilibrium mixture** contains both ***anomers*** () and small amount of open chain structure. This phenomenon is known as ***Mutarotation***.



**Mechanism of Mutarotation**: **Lowry in 1925** suggested that since water is an amphiprotic solvent (acts as an acid as well as a base), it helps in simultaneous addition and elimination of proton. The following concerted mechanism, showing 3rd order kinetics is believed to take place.



The presence of **small amount** of the **open-chain aldehyde** form in the equilibrium mixture of the two anomers can explain the reactions like **osazone** formation, reaction of **Fehling’s solution** and **Tollen’s reagents**. As the equilibrium is disturbed by conversion of the open-chain form into these derivatives, therefore, more of the open-chain forms in the equilibrium mixture will results to push the reactions. The aldehyde reactions like **Schiff’s test, bisulphite addition**, etc. are easily **reversible** and the concentration of the **open-chain structure** in the **equilibrium mixture** is too law (less than ) for satisfactory results. Therefore, it **does not** give ***Schiff’s test, bisulphite addition***.

The two **methyl - glucosides** are also **anomers**. These are **stable** in aqueous solution and **do not undergo mutarotation**. These are stable to alkali and do not hydrolyse to open chain form by the alkali present in Fehling’s or Tollen’s reagents. Hence, these are ***non-reducing***.

() **Ring Size**: We have assumed that the ring structures of **- glucose** is to be **six – membered** oxygen heterocycles pyran (hence, the name **pyranose** structure also) involving - 1 and - carbon atoms. The cyclization at - 1 and - carbon atoms gives a **- membered** **furanose** ring structure, and it has to be considered, because it has the same order of stability as that of - membered ring (**pyranose**) in accordance to Baeyer strain theory.

The following experimental facts have established the **six – membered pyranose ring structure for - glucose rather than - membered** **furanose** **ring structure for - glucose**.

Six membered, methyl- - - glucoside, on methylation with methyl sulphate in the presence of an alkali followed by hydrolysis with dilute gave - - tetra- - methyl- - glucose. This was oxidised by to give a mixture of trimethoxy glutaric acid and dimethoxy succinic acid, which can be given only by the oxidative cleavage of the intermediate “Keto acid” on either side of -. The keto group in the intermediate keto acid must be situated at -. The free group in tetra- - methyl- - glucose would obviously be at - that is the point of linkage of hemiacetal ring in - - glucoside. These sequence of reactions are shown below —



If - hydroxy group is involved in the formation of hemiacetal ring of - - glucoside, then, we will have - membered furanose ring structure, then **trimethyl glutaric acid could not be formed** which is actually been obtained in the experimental (as illustrated above). Further, - membered ring is expected to give **methoxymalonic acid**, which is ***not found to be formed*** actually. Hence, **- membered furanose ring** structure for **glucose is ruled out**.



Hence, the **- membered pyranose ring** structure is the common ring for **- - glucoside** and **- - glucose** which can account for the formation of both final products of oxidative cleavage.

() **Haworth Projection formulae to represent isomeric Glucose**: OR

**Representation of - and - - Glucose**:

Instead of vertical presentation (Fischer Projection Formula) for two cyclic forms of glucose and their glucosides, these can be represented by the **Haworth projection formula** , in which ***hexagonal pyran ring*** is considered to be situated in the plane of the paper. In this structure next to oxygen is the **chiral carbon -**  followed by **- , - , - and -**  arranged in a ***clockwise*** direction. The are situated at right angles to the plane of the ring. The lines projecting ***upwards are above the plane*** and lines projecting ***downwards are below the plane***. Intersection of lines carries - atom.



() **Chair Conformation of Glucose**: **Haworth planer projection formula** for - - and - - glucose (**)** can be best represented by a ***strain free chair conformation*** (). This is believed to be **most stable conformation** as all the **bulky substituents** () occupy the **equatorial positions**, except group at - in - - glucose. It is obvious that **- anomer** of **- glucose** is **more stable** as all the **bulky substituents occupy equatorial position**, and hence, it is [- anomer of - glucose, i.e. - - glucose] more dominating anomer (). These structures have been **confirmed by - ray analysis**.



These two chair conformational structures have ***pyranose ring*** structures, and hence glucose is also known as ***glucopyranose***. When the - atom of group of - is replaced by **methyl** group, it gives corresponding **- and - methyl glucoside** or methyl ***glucopyranoside***.

() **Chemical Properties of Glucose**: —

Glucose is an **aldohexose**, and it will exhibit the properties of glucose as well as an aldohexose i.e. reactions corresponding to an aldehyde group. Representative reactions are —

() ***Reaction with Phenylhydrazine***: With limited amounts of phenylhydrazine, glucose forms the corresponding phenylhydrazone. Thus, —

Glucose Glucose phenylhydrazone

With **excess** phenylhydrazine, the reaction is somewhat more complicated. ***Three moles*** of ***phenylhydrazine*** are consumed for each mole of the glucose to form ***glucosazone***, a yellow crystalline solid containing two phenylhydrazine residues per molecule. ***For example***, —



**[Important** —

**Osazone Formation**: Osazone formation is a **general reaction** given by all **- hydroxycarbonyl** (aldehydes or ketone) compounds (which may not be a carbohydrate). ***Thus***, —



**Mechanism** **of the reaction of Phenylhydrazone with Glucose**:

It was suggested that the 2nd molecule of phenylhydrazine oxidise the **- alcoholic group** adjacent to the **aldehyde to a keto group** that reacts with the **3rd molecule** of phenylhydrazine. It is not clear how phenylhydrazine (a **strong reducing agent**) acts as an **oxidising agent**. It is believed that that, this reaction involves **rearrangement** of **phenylhydrazone** to a - bonded intermediate known as ***Amadori rearrangement***. This intermediate loses a molecule of aniline to give an imino ketone which react further with phenylhydrazine to give the final product glucosazone.



***Epimer and Epimerisation***: ***Conversion of Glucose to Mannose***

During **osazone formation**, it has been observed that **() - glucose** has ***destroyed configuration*** only at one of the four asymmetric carbons, i.e. at **-** . Obviously, a diastereomeric aldohexose which differ from () - glucose only in configuration at - should give the **same glucosazone**. Actually, **() - mannose**, a diastereomer of glucose gives the same osazone as () – glucose. Therefore, () – glucose and () – mannose should be a pair of diastereomeric aldohexoses, differ in the configuration at - only. Such diastereomers which ***differ in configuration at one- asymmetric carbon atom are called epimers***. The process used to change the configuration at one of the asymmetric carbon atoms (in compounds containing more than one- asymmetric carbon atoms) without altering any change in the remaining part is called ***epimerization***.

For example, conversion of glucose into mannose is an example of ***epimerization***. Hence, **mannose** is an **epimer of glucose**.



The **Stereochemical significance** of this reaction has been used in determining the stereochemistry of **- () - fructose**.

() ***Action of Alkalies* (*Lobry de Bruyn and Alberda Van Ekenstein Rearrangement*)**:

Concentrated alkalis convert **glucose into brown resins**. Dilute alkalis, however, bring ***extensive isomerisation*** and even decomposition, presumably *via* monosaccharide with an ***enediol*** structure. ***Thus***, —



It is possibly due to this reversible isomerisation that ketoses (***e.g***. **fructose**) give **positive tests** with alkaline oxidising agents like ***Fehling, Benedict and Tollen’s*** reagents although they contain a **keto** group rather than an **aldehyde** group (***simple ketones do not respond to these tests***).

() ***Action of Acids***: Dilute acids have particularly no effect on glucose, but hot strong acids leads to complex reactions involving ***dihydro-cyclization***, etc. ***- Hydroxymethyl furfural***, initially formed, transformed by hot acids into ***laevulinic acid*** and large amount of dark, insoluble condensation product known as ***humins*** is formed. Thus, —



These furfurals give characteristic colour reactions with polyhydric phenols like ***resorcinol***, ***phloroglucinol***, *etc*. This reaction is used to **distinguish hexoses** from **pentoses**.

() ***Action of Oxidising agents***: Different oxidation products are obtained, depending on the nature of the oxidising agent the experimental conditions used. ***For example*** —

() **Fehling solution** () and **Tollen’s reagent** () are **reduced** (blue Fehling solution to red cuprous oxide and Tollen’s reagent to metallic silver) and the **aldehyde group** of glucose is **oxidised** to group. The resulting acid formed is the ***gluconic acid***.

() **Bromine water** () **oxidises** glucose to ***gluconic acid***.



**Mechanism of Oxidation**: Monosaccharides (*e.g*. glucose) exist in the hemicyclic acetal form. The cyclic form is in equilibrium with the free aldehyde form, and therefore, susceptible to oxidation by above solutions. Hence, ***all monosaccharides are reducing sugars***.



**Important Note**: **Glycosides** of monosaccharides are however **non-reducing sugars**, due to the **hemiacetal ring** which is **unaffected by alkaline solution** used to test ***reducing sugars***. Glycoside rings do not open into ***free aldehyde form***.

() **Nitric acid** (), being a **vigorous oxidising** agent, **oxidises both**  groups glucose to  **groups**. The **dicarboxylic acid** so formed is called ***glucaric acid*** (or ***saccharic acid***).

Glucose Glucaric acid

() **Oxidative Cleavage of Glucose**: Glucose, being an **- hydroxy carbonyl** compound (aldehyde) containing a number of **- hydroxyl groups**, it undergoes o***xidative cleavage*** with specific oxidising agents like **periodic acid** (***Malaprade reagent***) and **lead tetra-acetate**. ***Thus***, —

Glucose Periodic acid Formaldehyde Formic acid Iodic acid

**Application**: This reaction has a great potential for **structure determination** of glycols and in carbohydrate research for structure determination of groups present.

() ***Reaction of Glucose with Hydroxy Compounds***:

Glucose reacts with **methyl alcohol** in **presence** of **anhydrous**  to form ***methyl glucoside*** which exists in **two** stereoisomeric forms viz. **- and** - [This reaction has already been discussed in the ring structure of glucose under the heading transformation of the hemiacetal form of glucose into an acetal].

The general reaction of aldohexoses in which methyl alcohol can be replaced by other alcohols or hydroxy compounds can be written as —



() ***Fermentation of Glucose***: Glucose, in the presence of the enzyme ***zymase*** (*e.g*. ***yeast***) undergoes fermentation to form ***ethyl alcohol*** and release carbon dioxide. ***Thus***, —

Glucose Ethyl alcohol

This reaction forms the basis of the manufacture of ethyl alcohol from molasses.

***Structures of some important Aldopentoses and Aldohexoses***: JS 990

**The End**