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Mnemonic of Carbohydrates Structure with Proper Stereochemistry

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Abstract

There are sixteen structures possible for aldohexose since it contains four unlike chiral centres ($2^4 = 16$). Thus, eight pairs of enantiomers are possible, all of which are optically active. If the bottom chiral centre (C-5) is taken as naturally occurring D-isomer, still eight isomers are possible. So, it is a very difficult task for the students to remember the names of all the naturally occurring aldohexoses as well as their structures with appropriate stereochemistry. Most of the students lost their interest in organic chemistry while memorising the names and structures of these enormous numbers of molecules. Thus, writing the structure of aldohexoses on paper within a short period of time with proper stereochemistry is a challenging task for all the students. Currently, the students are memorising the structures of hexoses by starting from the structure of tetroses and pentoses. Also, the calculation by this process needs a very long time. Moreover, these memorised structures are very quickly lost after a few days of the evaluation since they are not using a proper mnemonic. Instead of directly memorising the structure of a complex molecule, mnemonics has been recognised to be much more effective in long- term memorisation. In this chapter a new and simple mnemonic will be described to write the structure of all the D-aldohexoses in Fischer projection formula within a few seconds. The mnemonic will be extended for the naturally occurring aldopentose as well.

Keywords: *Aldohexose; Carbohydrates; Fischer Projection; Mnemonic; Stereochemistry*

Introduction

Most students find enormous difficulties when they try to memorise the name and structure of larger organic molecules. It has been found that a vast majority of students lost their interest in organic chemistry during memorising the names and, in some cases, the stereochemistry of a huge number of biomolecules. But anyhow, if they memorise it, all their effort goes to vain after a few days since the memorised names and stereochemistry are quickly forgotten. In this case, mnemonics offer great help to the student since these tools help students to memorise complex organic structures with proper stereochemistry for a much longer time (Levin & Levin, 1990). Mezl (2001) demonstrated how a rhyme can be used to aid in memorising the structural properties of amino acids. Sailakshmi et al. (2013) showed that the phrase 'Oh My Such Good Apple Pie' (OMSGAP) helps us to remember the name and structure of dicarboxylic acids. If the molecule contains multiple chiral centres, writing the structure with proper stereochemistry becomes a nightmare for a large section of students. In this connection it is to be noted that the structure of different carbohydrate molecules plays an important role in the biological system (Su, Hendrikse & Meijer, 2022; Scherbinina & Toukach, 2020; Morgan & Baraban, 2024). For that type of molecule, some tricks need to be adopted to write on paper with proper stereochemistry. E.g., Leary (1955) reported that the name and the structures of the monosaccharides can be memorised by numbering the carbons and also remembering the position of the hydroxyl group on the right and left sides in the Fischer projection formula. In this process a lot of numbers need to be remembered, which limits the goal of the tools.

Another version for the nomenclature of the carbohydrates is done by binary numbering, which needs a lot of calculations to find a carbohydrate structure with stereochemistry (Klein, 1980). Ronald Starkey (2000) has shown how a student can remember the absolute configuration of all the chiral centres of glucose from the term SOS (Same–Opposite–Same), where 'S' denotes same configuration, 'O' denotes opposite configuration and again 'S' denotes same configuration of the chiral centres from C-2 to C-4 carbon, respectively, to the reference chiral centre C-5, which may be 'D' or 'L' configuration. The major drawback of this process is that the stereochemistry of the chiral centres of only glucose molecules can be memorised. Belhomme, Castex and Haudrechy (2019) recently reported a complex process of sugar mapping to find out the stereochemical relationship among the carbohydrates. Writing the structures of eight naturally occurring D-aldohexoses with proper stereochemistry is a huge challenge for undergraduate and postgraduate students because they need to remember the structure and stereochemistry of the pentoses first. Then, with the help of the structure of pentose, the student can write a structure of hexose after doing some calculations. For the whole process, the student needs a very long time, which sometimes becomes very difficult to manage, especially in the comparative examination. Here, an easy trick has been developed by which the structure of any aldohexose can be written directly within a few seconds without taking any help from the structure of pentoses.

Discussion

First, the popular phrase 'All Altruists Gladly Make Gum In Gallon Tanks' is used to know the name of eight aldohexose Allose, Altrose, Glucose, Mannose, Gulose, Idose and Galactose respectively (Parish, 1961). Thus, four pairs of hexoses are obtained in the category of naturally occurring aldohexose. Now, for a given aldohexose, the position of it is found out using this phrase. In every pair, the first member is termed as A, and second member is termed as B. So, the numbering of the molecules will be as follows (Figure 1).

All	Altruists	Gladly	Make	Gum	In	Gallon	Tanks
1A	1B	2A	2B	3A	3B	4A	4B
Pair 1		Pair 2		Pair 3		Pair 4	

Figure 1: Division of Eight Aldohexose into Four Pairs

Since all are aldohexoses, the top carbon will remain as -CHO and the bottom carbon as -CH_2OH. Also, in the bottom chiral centre (C5), the -OH group remains at the right-hand side in the Fischer projection formula since all are D-aldohexoses. Therefore, the common structure of all the D-aldohexoses is as follows (Figure 2).

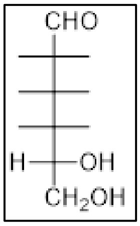

Figure 2: Common Fischer Projection Structural Formula of D-hexose

Now, all the -OH groups on the right-hand side in the Fischer projection formula are assumed to be the standard structure, i.e., the structure of allose is the standard structure, and changes come from the pair number and A, B. In every pair, A and B denote the orientation of the -OH group at the top chiral centre. A means the -OH group at the top chiral centre remains at the right-hand side, and B means the -OH group at the top chiral centre remains at the left-hand side in the Fischer projection formula. For the first pair of hexoses, the changes come only at the top chiral centre. For the second pair of hexoses, keeping the -OH group of the second chiral centre at the left-hand side, the top chiral centre will be changed according to A and B.

Similarly, for the third pair of hexoses, keeping the -OH group of the third chiral centre at the left-hand side, the top chiral centre will be changed according to A and B. For the fourth pair of hexose, keeping the -OH group of both the second and third chiral centres on the left-hand side, the top chiral centre will be changed according to A and B. For the fourth pair, since the -OH group of the fourth chiral centre cannot be changed, both the second and third chiral centres need to be changed. Now every individual structure can be written within a few seconds by following this instruction without taking any help from the structure of pentoses. E.g., if someone has been asked to write the structure of D-Gulose, first, the position of gulose in the phrase 'All Altruists Gladly Make Gum In Gallon Tanks' is found out. It is observed to be 3A (third pair first compound).

Therefore, during writing on paper, the -OH group of the third chiral centre will go to the left-hand side, and at the top chiral centre, the -OH group will go to the right- hand side since it is A. There will be no change in the position of the second chiral centre, i.e., it remains on the right-hand side like allose. So, the structure of Gulose will be as follows (Figure 3). Similarly, the Fischer projection of D-Idose can easily be drawn.

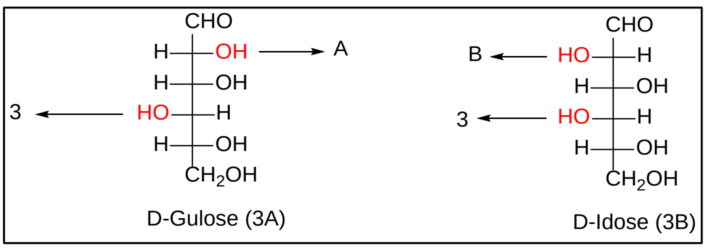

Figure 3: Fischer Projection Structural Formula of D-gulose and D- Idose

Similarly, if someone is asked to write the structure of D-mannose, within a few seconds it is found first that mannose is positioned 2B (second pair, second compound) in the aforementioned phrase. Therefore, during writing on paper, the -OH group of the second chiral centre will go at the left-hand side, and at the top chiral centre, the -OH group will also go at the left-hand side since it is B. So, the structure of mannose will be as follows (Figure 4). Similarly, the Fischer projection of D-glucose can easily be drawn.

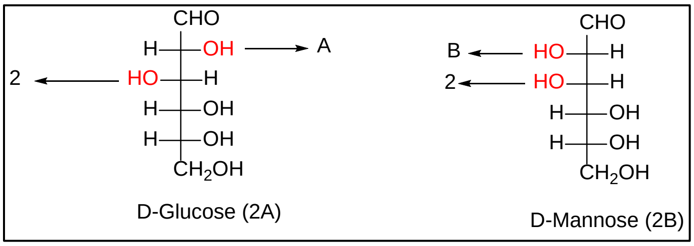

Figure 4: Fischer Projection Structural Formula of D-Glucose and D-mannose

Again, if the structure of galactose is asked to be written in Fischer projection formula, first the position of galactose is found to be 4A (fourth pair first compound) in the aforementioned phrase. Therefore, during writing on paper, the -OH group of both the second and third chiral centres will go to the left-hand side, and at the top chiral centre, the -OH group will go to the right-hand side since it is A. So, the structure of galactose will be as follows (Figure 5). Similarly, the Fischer projection of D-talose can easily be drawn.

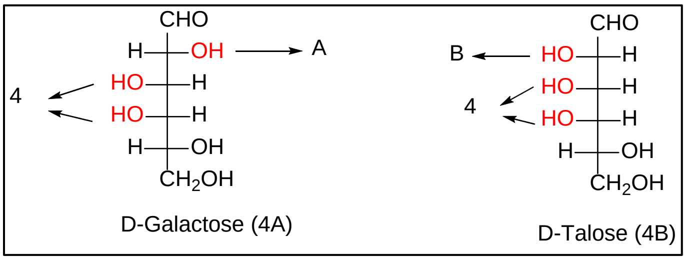

Figure 5: Fischer Projection Structural Formula of D-galactose and D-Talose

The name and structure of an aldopentose with proper stereochemistry can also be found out by the similar concept. The name of the pentose sugar can be memorised by the phrase 'Ring All Xylophones Loudly', where the words in the phrase stand for Ribose, Arabinose, Xylose and Lyxose, respectively. Now, for a given aldopentose, the position in the phrase was found out. In every pair, the first member is considered as A and the second member is B. So, the numbering of the molecules will be as follows (Figure 6).

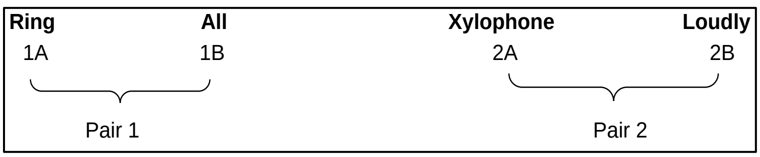

Figure 6: Division of Four Aldopentose into Two Pairs

All aldopentoses contain -CHO and -CH2OH groups at the top and bottom positions, respectively. Also, in the Fischer projection formula, the -OH group at the bottom chiral centre (C-4) remains at the right-hand side since all are D-aldopentose. Therefore, the common structure of all the D-aldopentoses is as follows (Figure 7).

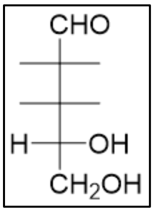

Figure 7: Common Fischer Projection Structural Formula of D-pentose

In the standard structure, all the -OH groups are taken at the right-hand side in the Fischer projection formula. i.e., the structure of Ribose is the standard structure, and changes in the structure come from the pair number and A, B. In every pair, A means the -OH group at the top chiral centre remains at the right-hand side, and B means the -OH group at the top chiral centre remains at the left-hand side in the Fischer projection formula. In the first pair of pentose (1A and 1B), the changes come only at the top chiral centre. The numbering of the second pair of pentose comes as 2A and 2B.

Thus, keeping the -OH group of the second chiral centre at the left-hand side, the top chiral centre will be changed according to A and B. For example, if the structure of Xylose is asked to be drawn, first, the position of Xylose in the phrase 'Ring All Xylophone Loudly' is found to be 2A (second pair first compound). Therefore, during writing on paper, the -OH group of the second chiral centre from the top will go to the left-hand side, and at the top chiral centre, the -OH group will go to the right-hand side since it is A. So, the structure of Xylose will be as follows (Figure 8). Similarly, the Fischer projection of D-Lyxose can be drawn based on the structure of molecule 2B.

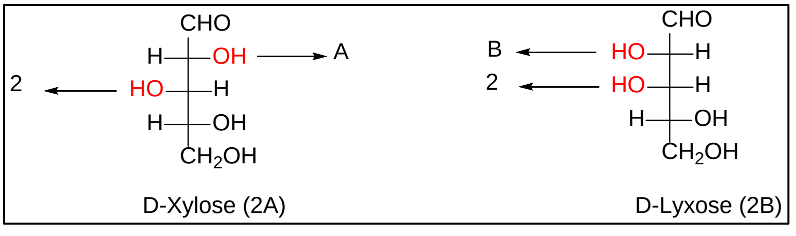

Figure 8: Fischer Projection Structural Formula of D-Xylose and D-Lyxose

Conclusion

An efficient way has been described by which a student can write the structure of any aldohexose and aldopentose with proper stereochemistry within a few seconds. The students do not need to memorise the structure of any aldoses. Therefore, the students will benefit enormously if they use this simple mnemonic.

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