Stereogenicity, Chirotopicity and Pseudoasymmetry (Local Symmetry)

Much of the confusion that can be generated with the terms given above was eliminated with the introduction of the stereogenic center (or, equivalently, stereocenter) as an organizing principle in stereochemistry. An atom, or a grouping of atoms, is considered to be a stereogenic center if the interchange of two ligands attached to it can produce a new stereoisomer. Not all interchanges have to give a new stereoisomer, but if one does, then the center is stereogenic. The center therefore ‘‘generates’’ stereochemistry. A non-stereogenic center is one in which exchange of any pair of ligands does not produce a stereoisomer. The term ‘‘stereogenic center’’ is, in a sense, broader than the term ‘‘chiral center’’. It implies nothing about the molecule being chiral, only that stereoisomerism is possible. The structures in Figure below show several stereogenic centers. Note that in more complex geometries, such as pentacoordinate or hexacoordinate atoms, we do not need all the ligands to be inequivalent in order to have a stereogenic center. Given these new terms, we strongly encourage students to abandon the term ‘‘chiral center’’ and to reserve ‘‘optically active’’ as a description of an experimental measurement.

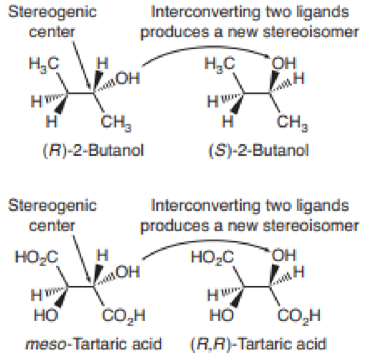
A. **Stereogenic atom or centre**: The term stereogenic atom or centrehas been introduce to generalize the system of naming stereoisomers. The term is defined as follows:

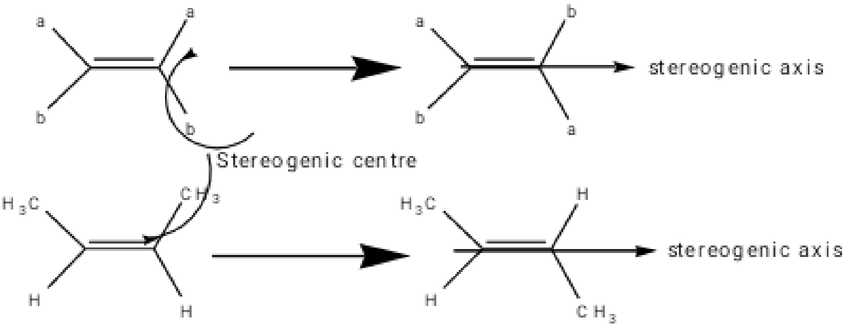
   i. An atom of such nature and bearing of atom(s) and/group(s) of such nature that it can have two non equivalent configurations.

   ii. An atom bearing several atom(s) and or group(s) of such nature that mutual exchange of two atom and or group will generate a new stereoisomer.

For example a molecule of Cabcd, C atom is stereogenic it satisfy the above condition

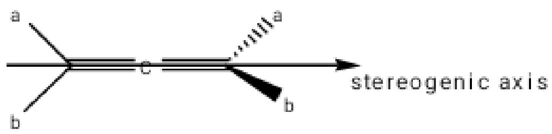
two non equivalent configuration of Cabcd

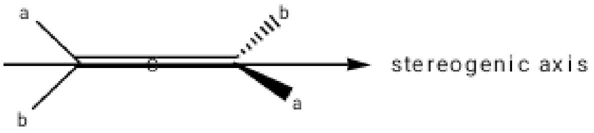




Interestingly, stereogenicity is also associated with double bonds. If you have this compound, this is what is called *cis*-2-obutene. Now no look at this carbon, that is the sp^2 carbon. If you interchange the position of methyl and hydrogen, what will happen? You will get what is called the *trans*-2-butene, Then what is the relationship between these forms? They are stereoisomers but they are not mirror images. So they are Diastereomers.

In case of alkenes like Cab=Cab or Cab=Cac or Cab=Ccd, the axis joining two carbon atoms is called stereogenic axis, because stereoisomerism generate through this axis. In case of allene same process will be applied,





So that is what is what are called stereogenic centre and molecules possessing stereogenic centre with the phenomena is called stereogenicity. This phenomena involving interchanging groups giving Diastereomers, or Enantiomers or in general stereoisomers, is what is called stereogenicity.

B. Chirotopic and achirotopic centre:

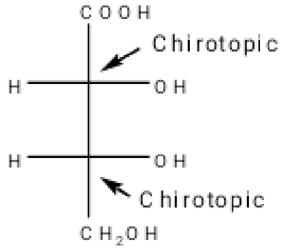
Now as I said that chirality is an all pervasive property. That means when you take a chiral molecule, every point in the molecule is chiral. You cannot say that there is a chiral centre in the molecule. You see, the concept is very important. If you say there is a chiral centre in the molecule that means other centres are not chiral. That is the meaning of your statement.

But that is not true. In a chiral molecule, every point in the molecule is chiral. Then Mislow Segal, introduced another concept which is called Chirotopic or Chirotopicity.

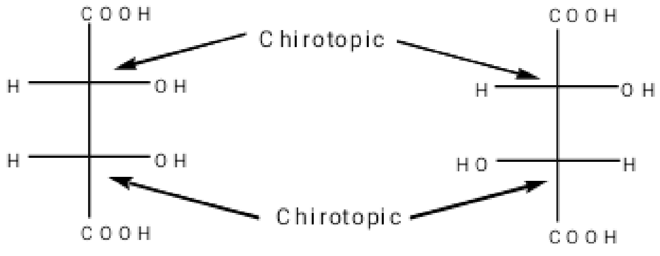
Molecular models built from atoms properly represent symmetry elements of molecules but provide incomplete information of local or site symmetry, i.e., symmetry point group of every atom or set of atoms within the molecule.

The site symmetry of atoms in molecules falls into two classes, chiral and achiral. It should be remembered that main classification of chirality and achirality is a function of geometric shape. *An atom within a molecular framework is said to be chirotopic if its site symmetry is chiral*, i.e., the atom resides in a chiral environment. The molecule(s) bearing chirotopic centre need not be as a whole chiral. *An atom within a molecular framework is said to be achirotopic if its site symmetry is achiral*, i.e., a point or atom located on a plane of symmetry or a centre of symmetry or at the point where an alternating axis of symmetry interacts in reflection plane is achirotopic. So in a chiral molecule, every point is chiral or that belongs to a chiral environment and that point is called a chirotopic point.

For example, in lactic acid, $CH_3CH(OH)CO_2H$, all ligands are chirotopic but in propanoicacid, $CH_3CH_2CO_2H$, ligands are acirotopic, i.e., they do not reside in chiral site symmetry. Other examples are shown below:



Chiral Molecule

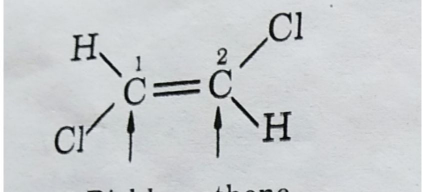


Achiral Molecule(i)

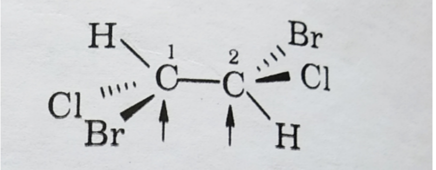
Chiral Molecule

Difference between stereogenicity and chirotopicity

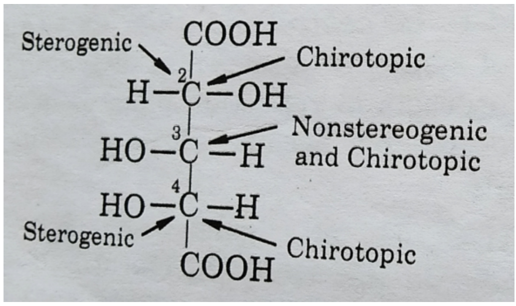
In a molecule Cabcd, a‡ b‡ c‡ d, the carbon centre is chirotopic as well as stereogenic. But in some cases, both the carbon centre in trans-1,2-dichloroethene are stereogenic but acirotopic. Carbon atoms in 1,2-dibromo-1,2-dichloroethane are stereogenic as well as chirotopic, similarly there are some other examples:

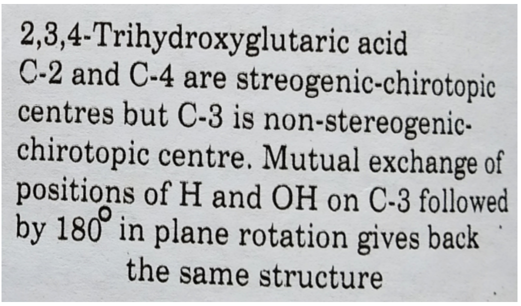


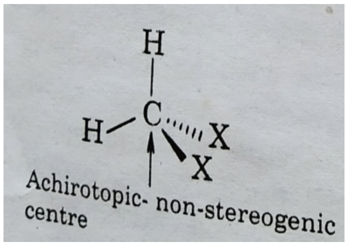
1,2-Dichloroethene
C-1 and C-2 are achirotopic and stereogenic centre



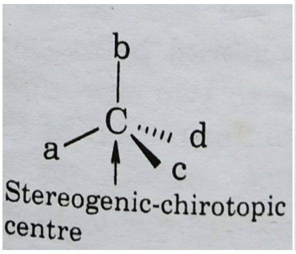
1,2-Dibromo-1,2-dichloroethane
C-1 and C-2 are chiritopic and stereogenic centres



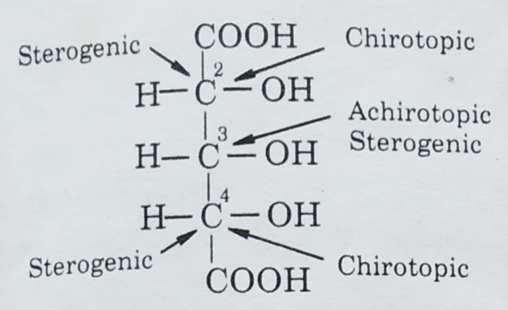

2,3,4-Trihydroxyglutaric acid
C-2 and C-4 are streogenic-chirotopic centres but C-3 is non-stereogenic-chirotopic centre. Mutual exchange of positions of H and OH on C-3 followed by 180° in plane rotation gives back the same structure



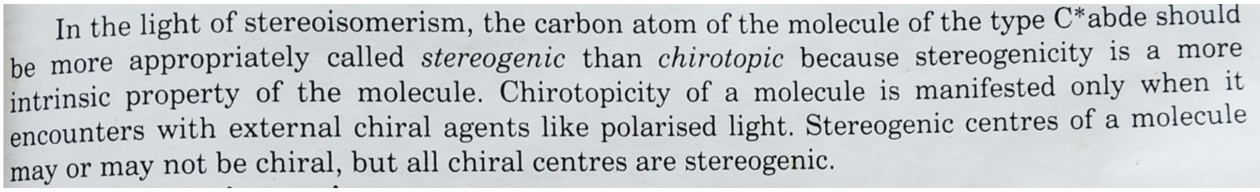
Achirotopic- non-stereogenic centre



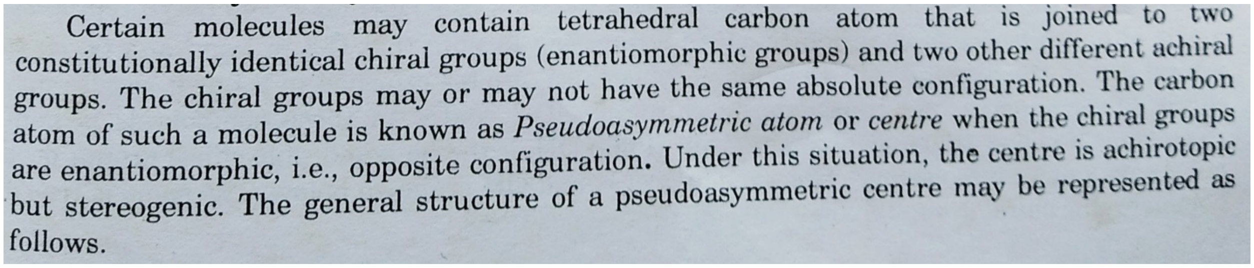
Stereogenic-chirotopic centre

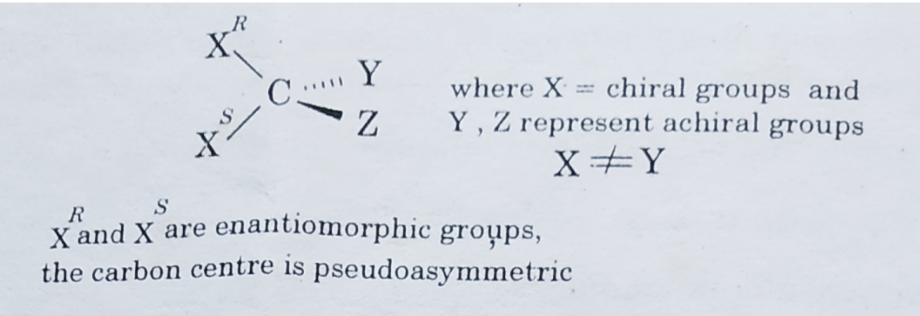


Therefore it is evident that chirotopicy and stereogenicity of a centre can be delinked and each term indicates a definite stereochemical aspect of an atom in a molecule.


In the light of stereoisomerism, the carbon atom of the molecule of the type C*abde should be more appropriately called *stereogenic* than *chirotopic* because stereogenicity is a more intrinsic property of the molecule. Chirotopicity of a molecule is manifested only when it encounters with external chiral agents like polarised light. Stereogenic centres of a molecule may or may not be chiral, but all chiral centres are stereogenic.

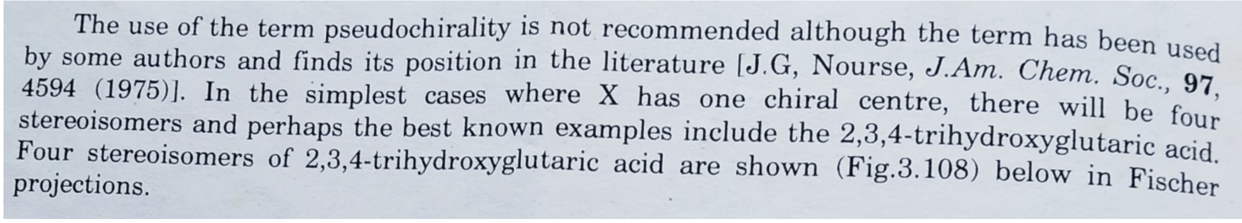
C. Pseudoasymmetry:


Certain molecules may contain tetrahedral carbon atom that is joined to two constitutionally identical chiral groups (enantiomorphic groups) and two other different achiral groups. The chiral groups may or may not have the same absolute configuration. The carbon atom of such a molecule is known as *Pseudoasymmetric atom* or *centre* when the chiral groups are enantiomorphic, i.e., opposite configuration. Under this situation, the centre is achirotopic but stereogenic. The general structure of a pseudoasymmetric centre may be represented as follows.

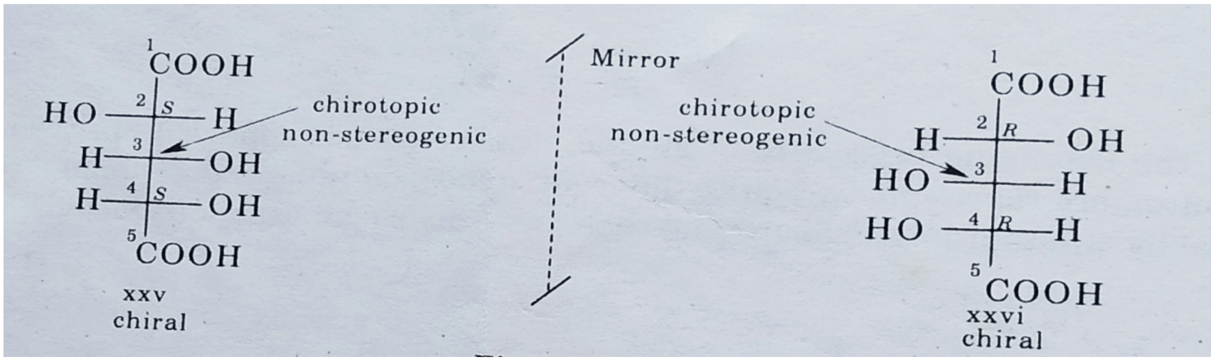


where X = chiral groups and
Y , Z represent achiral groups
X ≠ Y

X^R and X^S are enantiomorphic groups,
the carbon centre is pseudoasymmetric

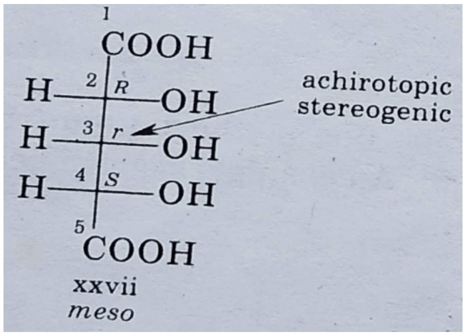


The use of the term pseudochirality is not recommended although the term has been used by some authors and finds its position in the literature [J.G, Nourse, *J.Am. Chem. Soc.*, **97**, 4594 (1975)]. In the simplest cases where X has one chiral centre, there will be four stereoisomers and perhaps the best known examples include the 2,3,4-trihydroxyglutaric acid. Four stereoisomers of 2,3,4-trihydroxyglutaric acid are shown (Fig.3.108) below in Fischer projections.

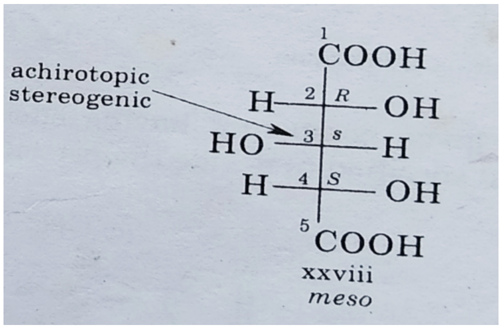


xxv
chiral

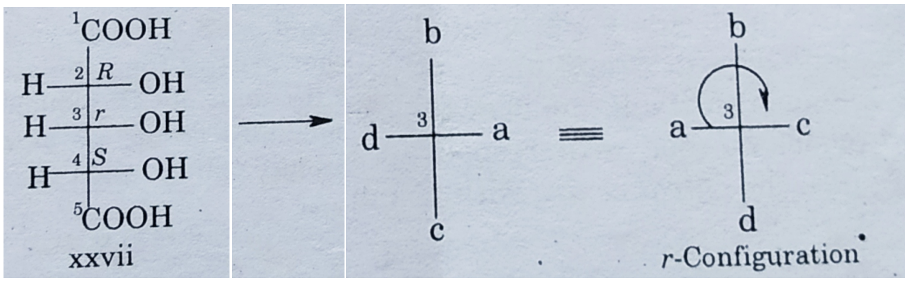
xxvi
chiral



xxvii
meso

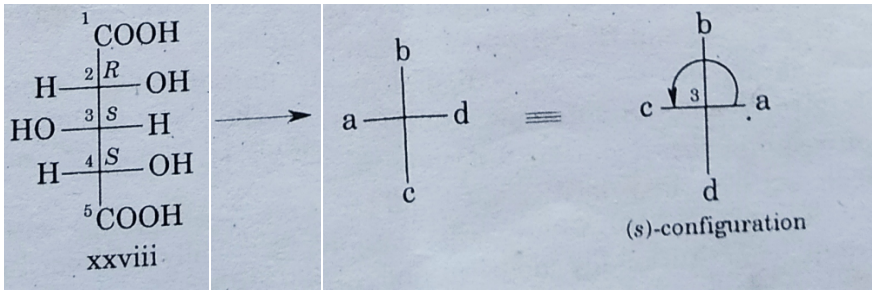


xxviii
meso



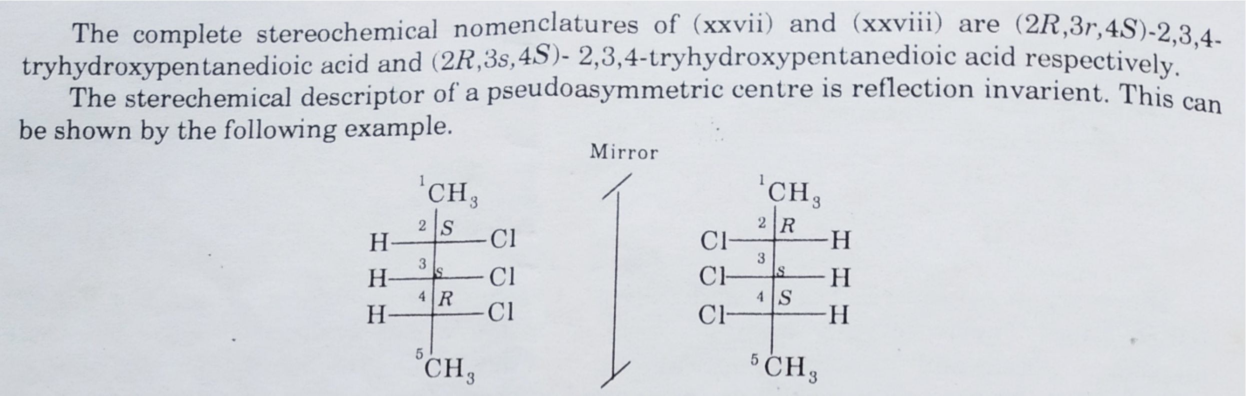
xxvii

r-Configuration



xxviii

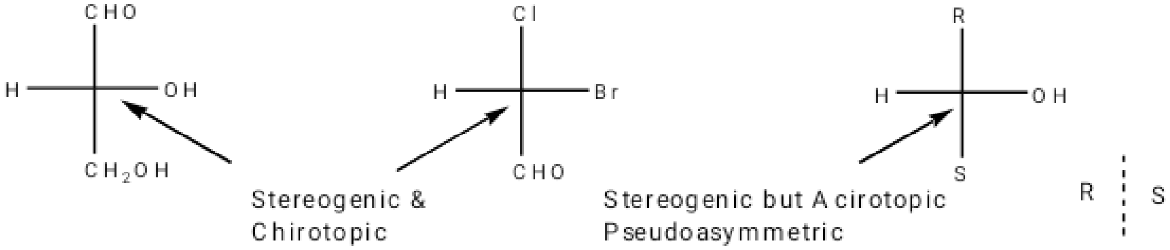
(*s*)-configuration

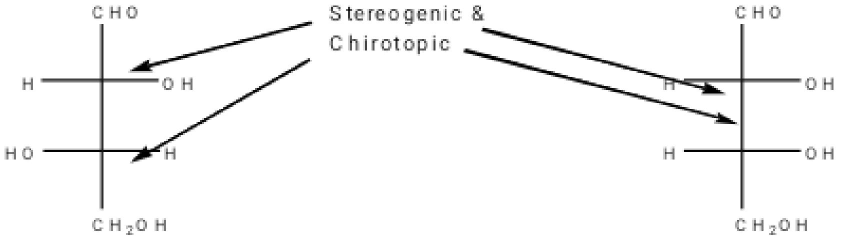


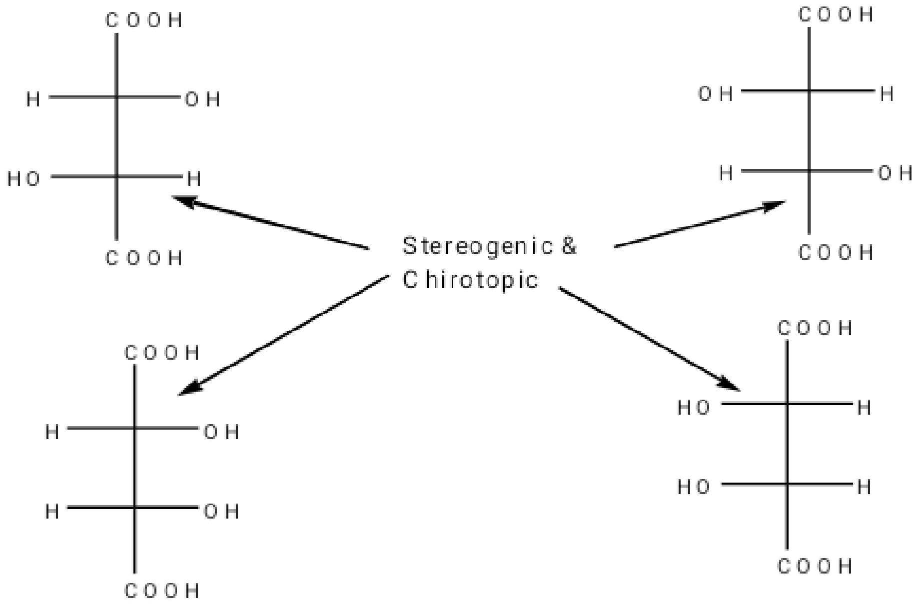
The complete stereochemical nomenclatures of (xxvii) and (xxviii) are (2*R*,3*r*,4*S*)-2,3,4-tryhydroxypentanedioic acid and (2*R*,3*s*,4*S*)- 2,3,4-tryhydroxypentanedioic acid respectively.

The sterechemical descriptor of a pseudoasymmetric centre is reflection invarient. This can be shown by the following example.

Examples:






COOH
H
OH
HO
H
COOH
COOH
OH
H
H
OH
COOH
Stereogenic &
Chirotopic
COOH
H
OH
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OH
COOH
COOH
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