

Chemistry 506: Allied Health Chemistry 2

Chapter 16: Carbohydrates

Biochemical Alcohols and Ethers

Introduction to General, Organic & Biochemistry, 5th Edition by
Bettelheim and March: Chapter 16, Pages 519-556

Outline Notes by Dr. Allen D. Hunter, YSU Department of
Chemistry, ©2000.

Outline

16A SECTION(S) 16.1 INTRODUCTION.....	2
16B SECTION(S) 16.2/3/4 ENANTIOMERS AND CHIRALITY.....	4
16C SECTION(S) 16.5 GLUCOSE.....	7
16D SECTION(S) 16.6 MONOSACCHARIDES	14
16E SECTION(S) 16.7/8 PHYSICAL AND CHEMICAL PROPERTIES OF MONOSACCHARIDES	17
16F SECTION(S) 16.10 DISACCHARIDES	19
16G SECTION(S) 16.11 POLYSACCHARIDES	20

16A Section(s) 16.1

Introduction

➤ Carbohydrates

➤ Functions

➤ Energy Storage

➤ Structure

➤ Immune Response

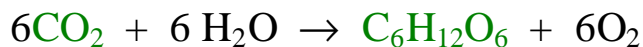
➤ Regulation of Cell Biochemistry and Physiology

➤ Typical carbohydrate formula

➤ Molecules from $n \approx 4 =$ millions

- Typical **Structural Elements of Carbohydrates**
 - Multiple **OH groups**
 - **Rings**
 - **Ether Linkages**
 - Within rings
 - Between rings (**Glycosidic Bonds**)
 - Derived from poly-OH **Aldehydes** and **Ketones**

- **Formation of Carbohydrates**



- **Photosynthesis** (plants, algae, etc.)
- **Chemosynthesis** (bacteria)
- **Biosynthesis** (all living things)

16B Section(s) 16.2/3/4 Enantiomers and Chirality**➤ Enantiomers**

➤ non-superimposable mirror images

➤ Chiral atoms

➤ for Chemistry 506: have four different groups on a central atom

➤ Exercise: Practice identifying chiral atoms in molecules

➤ **Physical Property and Chemical Property Differences**

➤ Almost all are the same

➤ **Rotation of plane of polarized light**

➤ **Polarized light**

➤ **Polarimeter**

➤ **Optical Activity**

➤ **Reactions with other chiral molecules**

➤ **Racemic Mixture**

➤ 50:50 mixture of opposite enantiomers

➤ **no net rotation of light**

➤ Fischer Projection

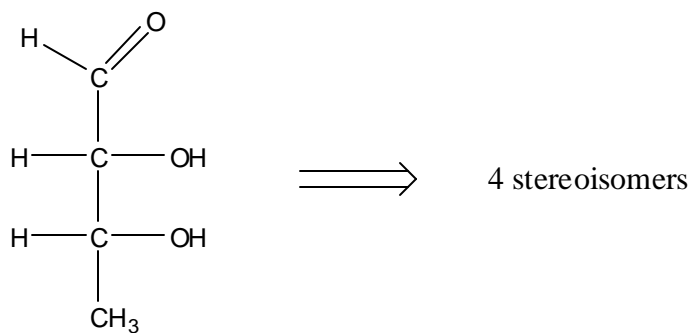
➤ “cross”



➤ Multiple Chiral Centers

➤ 2^n stereoisomers for n chiral centers

➤ examples of sugars



16C Section(s) 16.5

Glucose

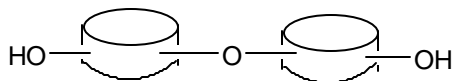
➤ Monosaccharides

- Normally 5 or 6 carbons
- Normally $C_5H_{10}O_5$ or $C_6H_{12}O_6$
- Alcohol groups and ether groups
- “cartoon picture”



➤ Glycosidic Bonds (i.e., ether linkages)

➤ Disaccharides



➤ **Trisaccharides**



➤ **Oligosaccharides**

- Common on **membrane surfaces** and **protein surfaces**
- Used for **signaling**
- Typically have **complex branched structures**

➤ **Polysaccharides**

- Used for **Structural Strength** and **Energy Storage**
- Typically have **highly repetitive structures**

➤ D-Glucose

➤ Most abundant molecular fragment in biosphere

➤ Aldohexose

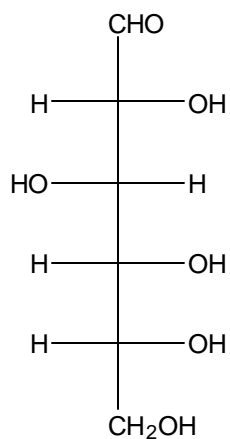
➤ $C_6H_{12}O_6$

➤ Exists in 3 **interconverting forms**

➤ Favored form depends on solvent, temperature, etc.

➤ **D-Glucose, α -D-Glucose, and β -D-Glucose**

➤ Fischer Projection of D-Glucose



➤ Cf. L-Glucose

➤ Wedges and hatches

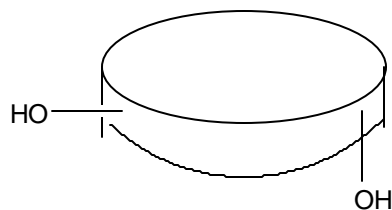
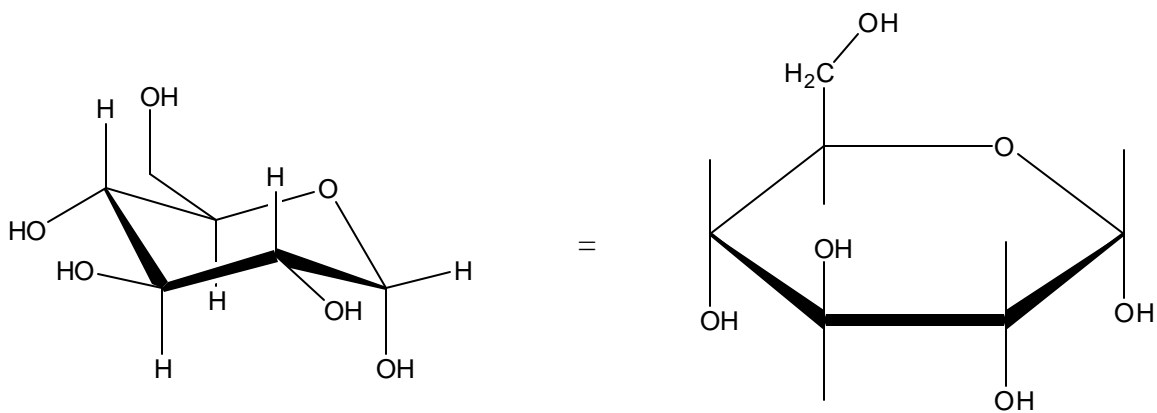
➤ C1 is Anomeric Carbon

➤ Ring Formation via intramolecular attack by OH #5

➤ Cyclization

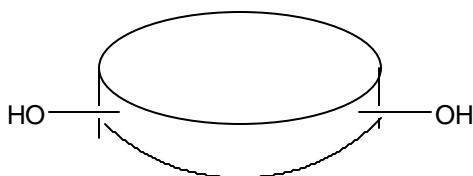
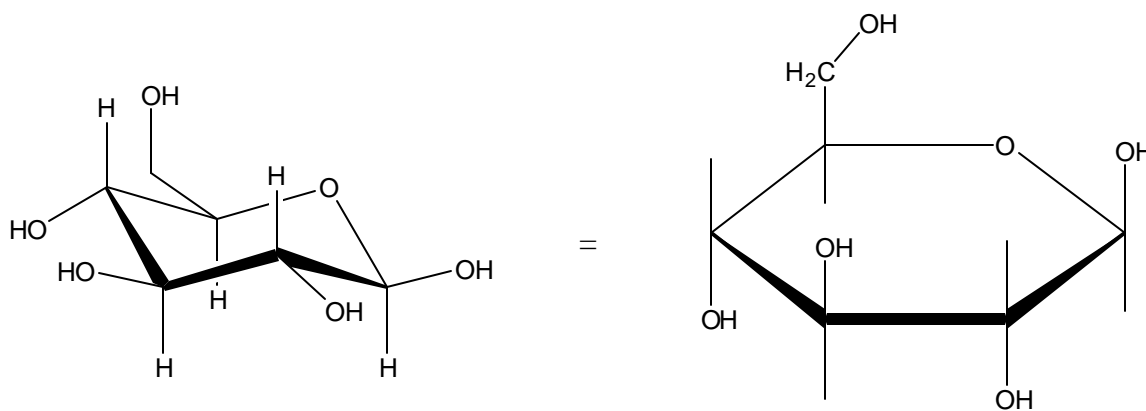
➤ Structure of α -D-Glucose

➤ “bent”



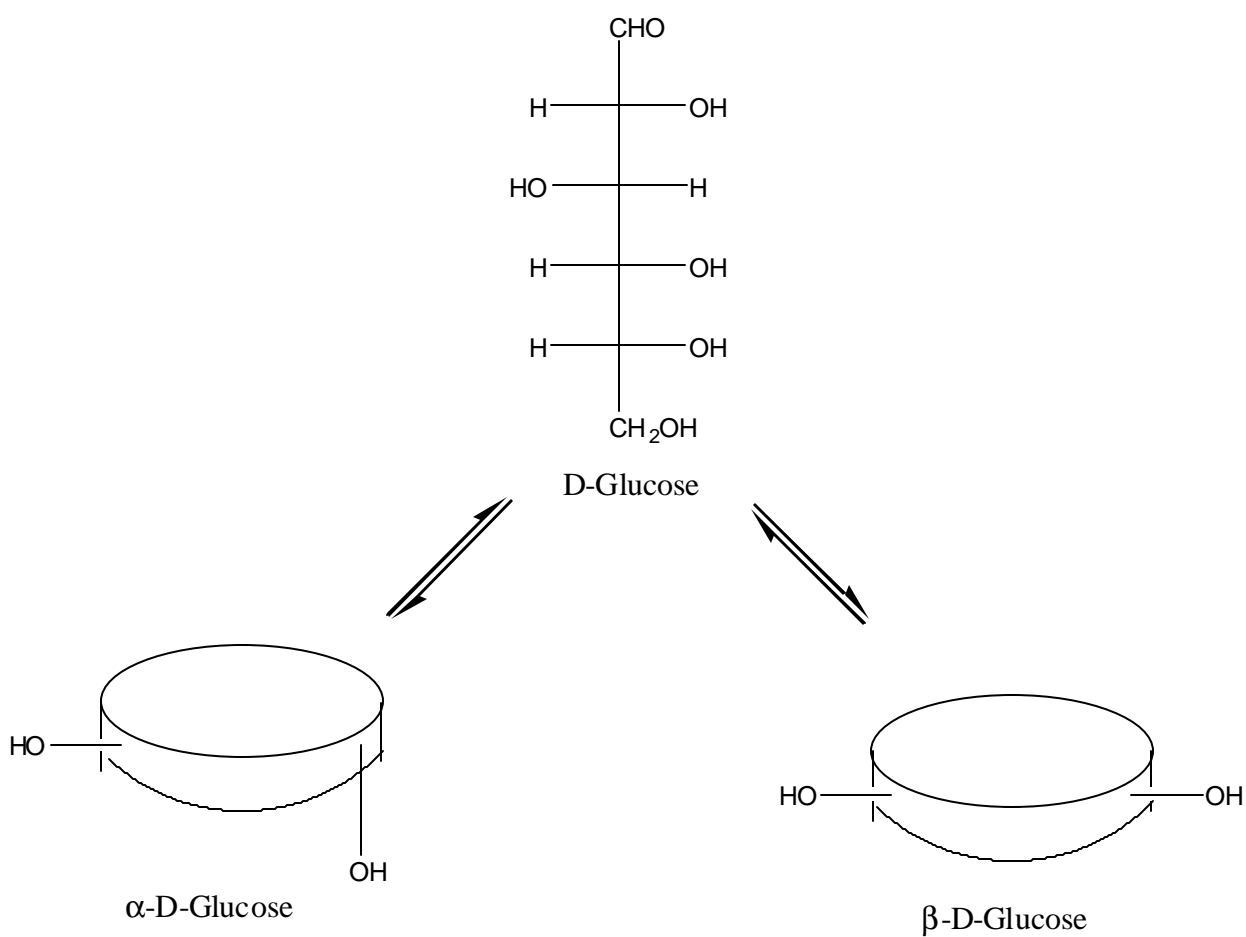
➤ Structure of β -D-Glucose

➤ “flat”



➤ Interconversion of D-Glucoses

- each form has different physical properties and chemical properties
- α forms and β forms give different saccharide products



16D Section(s) 16.6

Monosaccharides

➤ Structures: Figure 16.9, p532

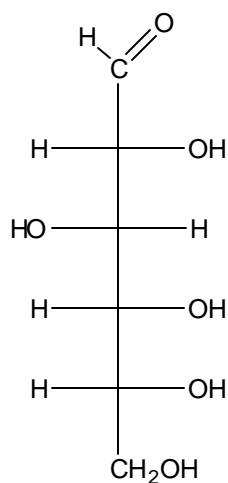
➤ **Aldohexoses**

➤ 6 carbon **aldehydes**

➤ 4 **chiral centers** \Rightarrow 16 **stereoisomers**

➤ only the 8 "D" forms common in nature

➤ **D-Glucose** most common



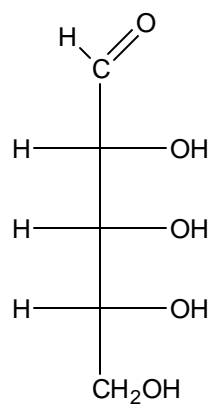
➤ Aldopentoses

➤ 5 carbon aldehydes

➤ 3 chiral centers \Rightarrow 8 stereoisomers

➤ only the 4 "D" forms common

➤ Example is D-Ribose (in RNA)

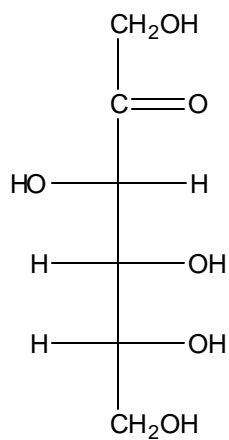


➤ **Ketohexoses**

➤ 6 carbon **ketones**

➤ 3 **chiral centers** \Rightarrow 8 **stereoisomers**

➤ Only **D-Fructose** is important



➤ Other **Aldo*oses** and **Keto*oses**

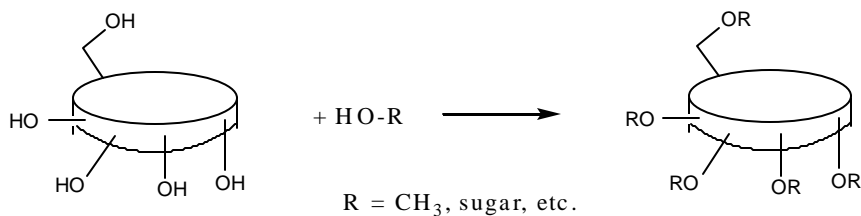
➤ Don't need to memorize

16E Section(s) 16.7/8 Physical and Chemical Properties of**Monosaccharides**

- Sweetness
- Solubility
 - Bond polarity
 - Hydrogen bonding
- Optical Activity
 - Multiple chiral centers
- Solvent and temperature dependent equilibria
- Predominantly cyclic rather than linear Aldo or Keto forms in solution

➤ Glycosidic Bond Formation

- ether linkages from carbohydrate OH groups



- Highly specific in biological systems
- Often get mixtures in chemical syntheses

16.9 Skip

16F Section(s) 16.10 Disaccharides

- Sucrose
 - Beet Sugar and Cane Sugar
 - α -D-Glucose and β -D-Fructose

- Maltose
 - Malt Sugar

- Lactose
 - Milk Sugar

16G Section(s) 16.11 Polysaccharides

- **Starch**
 - Energy storage molecule
 - Referred to as **Glycogen** in mammals
 - Poly(α -D-Glucose), 1,4-Glycosidic Linkages
 - Primary structure is **Kinked chain**
 - Easy to break/digest
 - Water soluble

- **Cellulose**
 - Plant structural molecule
 - Single most common polymer/material in nature
 - **Wood** is formed from **Cellulose** and **Lignin**
 - Poly(β -D-Glucose)
 - Primary structure is **Strait chain**
 - Hard to break/digest (bacteria can)
 - **Wettable** but not water soluble

➤ **Structural Variations in Polysaccharides**

➤ **Chain Length**

➤ **Branching**

➤ **Crosslinking**

Skip 16.12/13

Questions: 16.1 to 16.31 and 16.36 to 16.41

Index of Topics and Vocabulary

A	
Alcohol groups.....	7
aldehydes.....	14, 15
Aldehydes	3
Aldo.....	17
Aldo*oses.....	16
Aldohexose.....	9
Aldohexoses	14
Aldopentoses.....	15
algae.....	3
Anomeric Carbon	10
B	
bacteria	3, 20
Beet Sugar	19
biological systems.....	18
Biosynthesis	3
Bond polarity	17
Branching.....	21
C	
$C_5H_{10}O_5$	7
$C_6H_{12}O_6$	3, 7, 9
Cane Sugar	19
carbohydrate OH groups.....	18
Carbohydrates	2
Cellulose.....	20
Chain Length.....	21
chemical properties	13
Chemical Property	5
chemical syntheses.....	18
Chemosynthesis	3
Chiral atoms	4
chiral centers	14, 15, 16, 17
$C_nH_{2n}O_n$	2
CO_2	3
cross	6
Crosslinking.....	21
cyclic	17
Cyclization.....	10
D	
D-Fructose.....	16
D-Glucose.....	9, 10, 14
digest.....	20
Disaccharides	7, 19
D-Ribose.....	15
E	
Enantiomers.....	4
Enantiomers and Chirality	4
Energy Storage	2, 8
Energy storage molecule	20
equilibria.....	17
ether groups.....	7
ether linkages.....	7, 18
Ether Linkages.....	3
F	
Fischer Projection.....	6, 10
Formation of Carbohydrates	3
G	
Glucose.....	7
Glycogen	20
Glycosidic Bond Formation.....	18
Glycosidic Bonds.....	3, 7
Glycosidic Linkages	20
H	
hatches.....	10
highly repetitive structures	8
Hydrogen bonding.....	17
I	
Immune Response.....	2
Interconversion of D-Glucoses	13
interconverting forms	9
intramolecular attack by OH.....	10
Introduction.....	2
K	
Keto.....	17
Keto*oses	16
Ketohexoses	16
ketones	16
Ketones	3
Kinked chain.....	20
L	
L-Glucose.....	10
Lignin	20
M	
Malt Sugar.....	19
Maltose.....	19
mammals	20
membrane surfaces	8
Milk Sugar.....	19
mirror images	4
Monosaccharides	7, 14
Multiple Chiral Centers.....	6
N	
net rotation of light.....	5
non-superimposable	4
O	
OH groups.....	3
Oligosaccharides	8
Optical Activity	5, 17

P

Photosynthesis	3
Physical and Chemical Properties of Monosaccharides	17
physical properties	13
Physical Property	5
Physiology	2
plants.....	3
Polarimeter	5
Polarized light	5
Poly(α -D-Glucose)	20
Poly(β -D-Glucose).....	20
polymer	20
Polysaccharides	8, 20, 21
protein surfaces	8

Q

Questions	21
-----------------	----

R

Racemic Mixture	5
Reactions with other chiral molecules	5
Ring Formation	10
Rings	3
RNA	15
Rotation of plane of polarized light	5

S

saccharide products.....	13
signaling.....	8
Solubility.....	17

Starch.....	20
stereoisomers.....	6, 14, 15, 16
Strait chain.....	20
Structural Elements of Carbohydrates	3
structural molecule	20
Structural Strength.....	8
Structural Variations	21
Sucrose.....	19
Sweetness	17

T

temperature	17
Trisaccharides.....	8

W

water soluble	20
Water soluble.....	20
Wedges	10
Wettable	20
Wood.....	20

α

α forms.....	13
α -D-Glucose.....	9, 11, 19

β

β forms	13
β -D-Fructose.....	19
β -D-Glucose.....	9, 12