Macromolecules

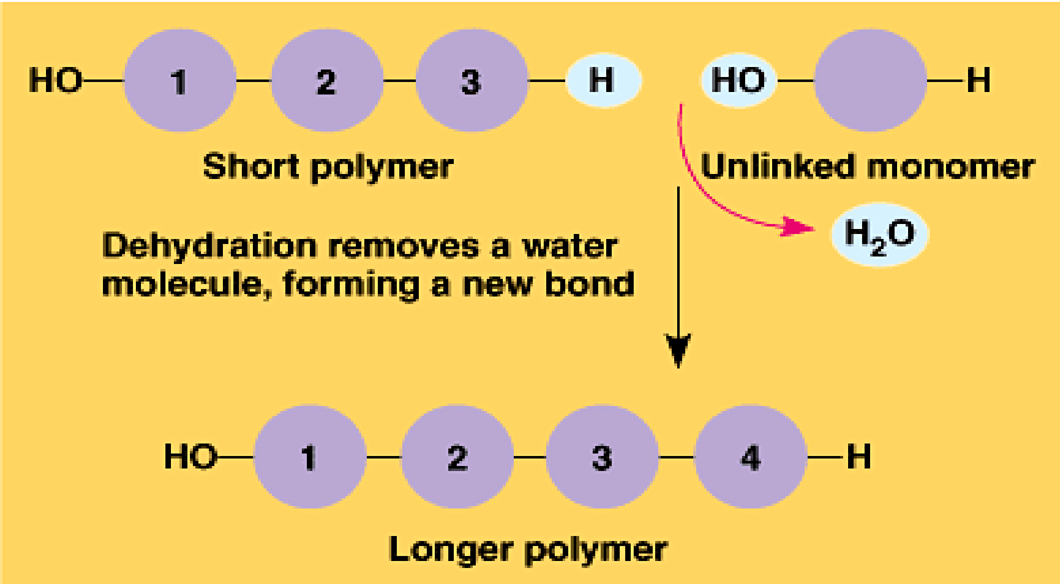
Polymerization
Carbohydrates

Metabolism

- Sum of all chemical reactions that occur in a living organism.
- Classified into 2 types:
  - Anabolism: reactions that build up molecules
  - Catabolism: reactions that breakdown molecules

Anabolism Reactions

- **Condensation** (dehydration synthesis): monomers are covalently linked to make a polymer by removing water

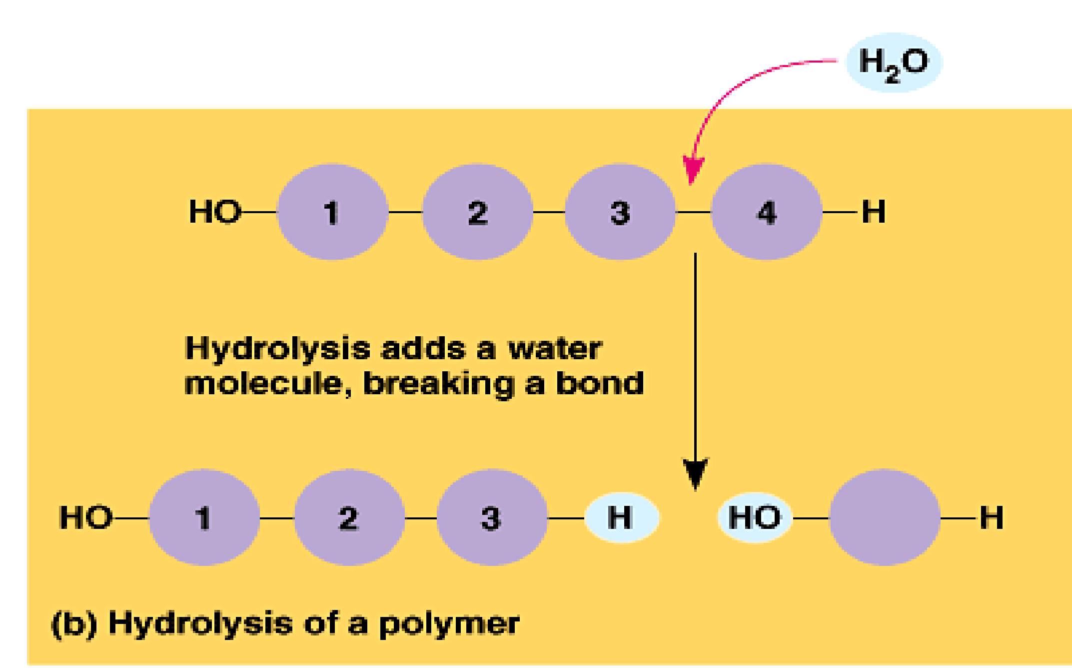


(a) Dehydration reaction in the synthesis of a polymer

Text page 63, Fig. 5.2a.

Catabolism Reactions

- Hydrolysis: covalent bonds connecting monomers in a polymer are disassembled by the addition of water



Text page 63, Fig. 5.2b.

Macromolecules

- Macro = large
- Macromolecules are built by combining a number of smaller subunits
- Monomer = smaller single subunits
- Polymer = larger unit made by covalent bonds between monomers

Macromolecules

- A large variety of polymers can be built from a few monomers
- Analogies:
  - 26 letters of the alphabet
  - 4 nitrogen bases in DNA
  - 20 amino acids.
- Cells can create many different macromolecules from a small number of starting materials by arranging them in different combinations.

Macromolecules

Four major classes are:

1. Carbohydrates
2. Lipids
3. Proteins
4. Nucleic acids

Carbohydrate

- Carbo = carbon (C)
- Hydrate = water (H_2O)
- Carbohydrates are multiples of the basic formula: CH_2O
- Example: A carbohydrate with 6 carbons
  - $CH_2O \times 6 = C_6H_{12}O_6$ = hexose (e.g. glucose)

Monosaccharides

- Mono = 1
- Saccharide = sugar
- Ranges from 3 to 7 carbons in length
- Most names for sugars end in –ose
  - Hexose: glucose, fructose

Monosaccharide Classification

A. Number of carbons in the backbone

- Triose: 3C
- Pentose: 5C
- Hexose: 6C

B. Location of the carbonyl group

- Aldose: carbonyl group at the end (aldehyde)
- Ketose: carbonyl group in the middle (ketone)

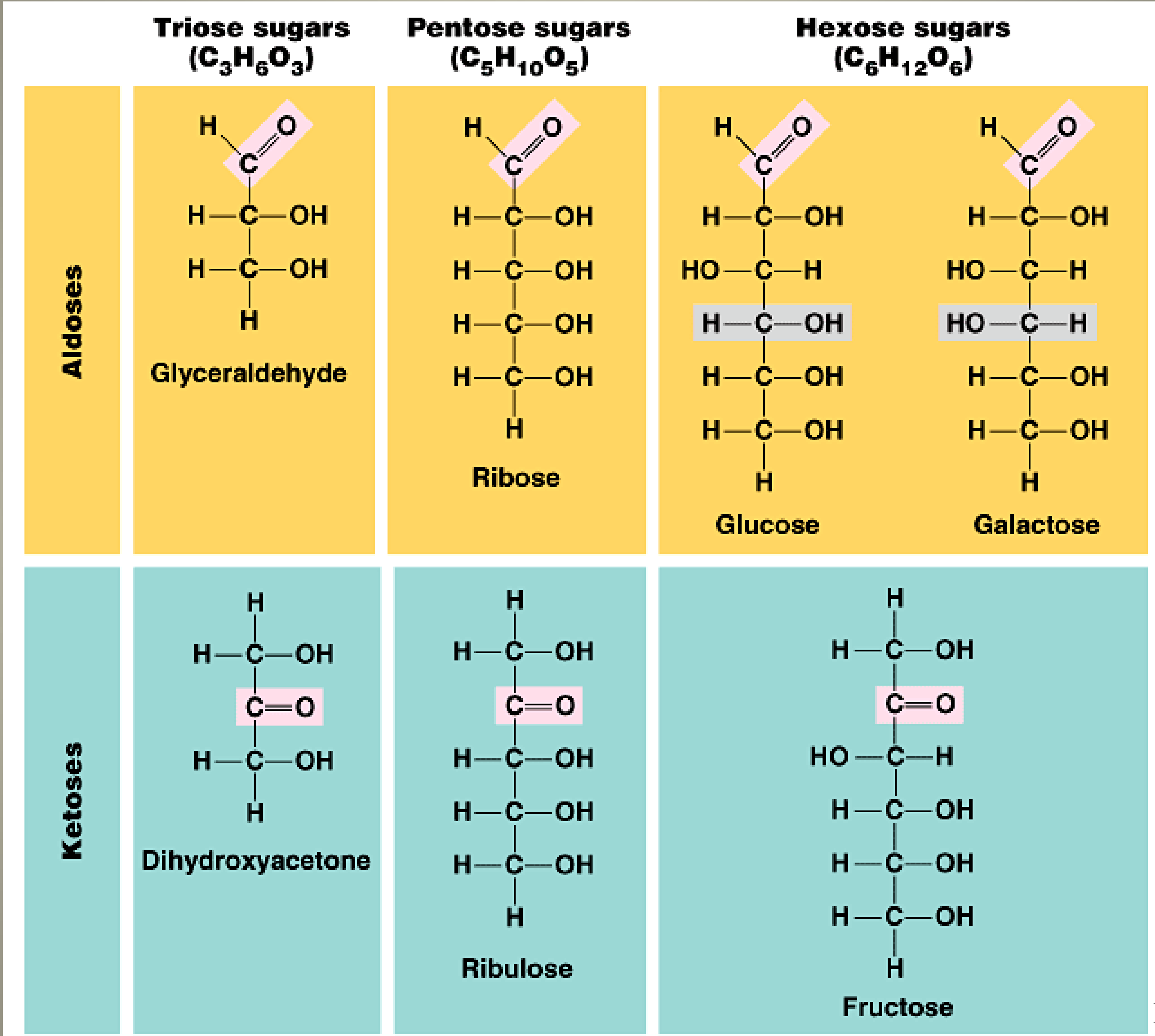
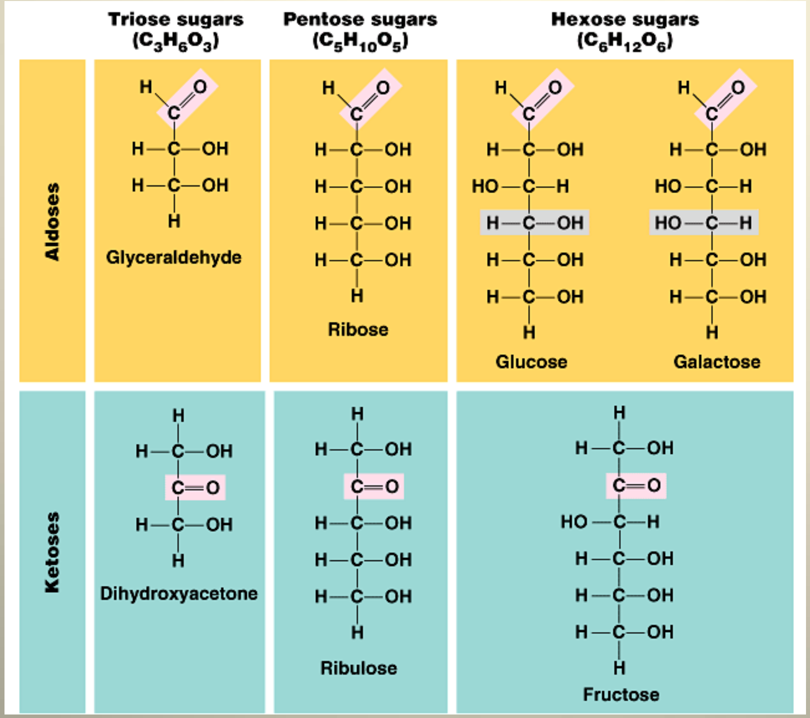

Triose sugars ($C_3H_6O_3$)
Pentose sugars ($C_5H_{10}O_5$)
Hexose sugars ($C_6H_{12}O_6$)
Aldoses
Glyceraldehyde
Ribose
Glucose
Galactose
Ketoses
Dihydroxyacetone
Ribulose
Fructose

Fig. 5.3

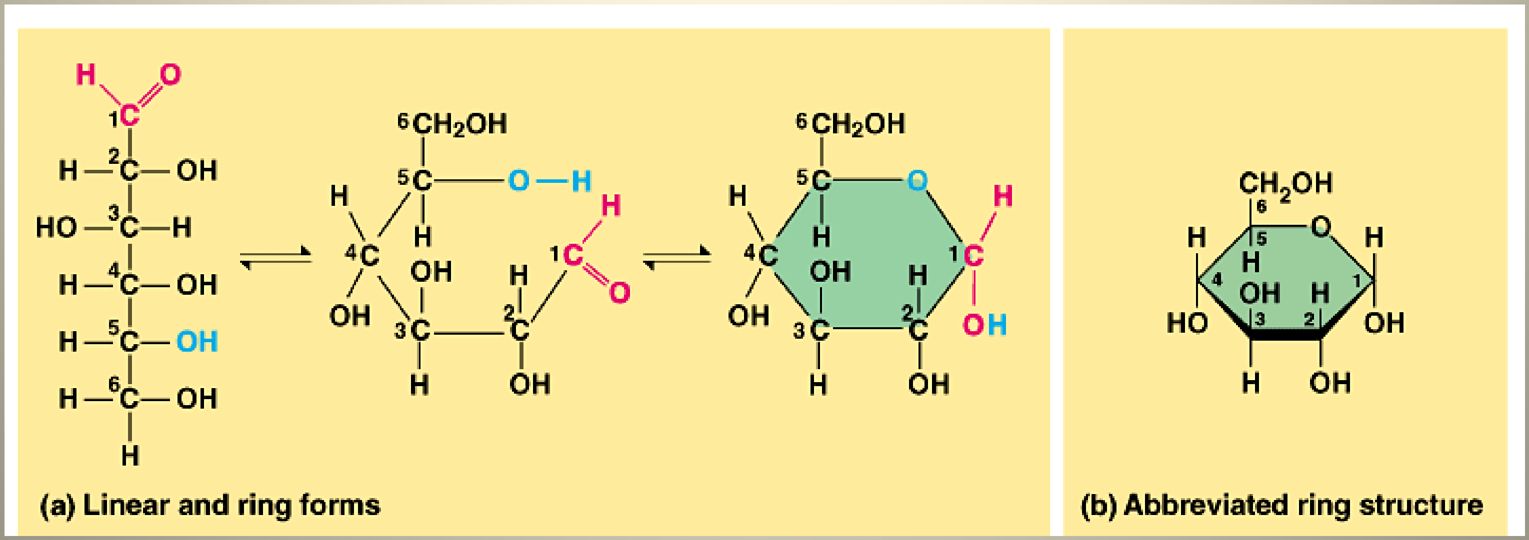
Anomeric Carbon

- The C of the C=O group
  What number is the anomeric carbon in each molecule? Explain how the choice was made



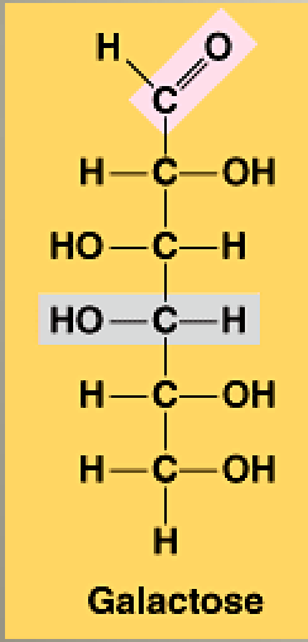
Linear and Ring forms

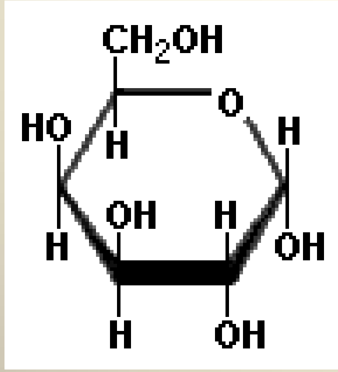
- In aqueous solutions, hexose sugars form rings
- Anomeric carbon (C=O group) will react with the OH group to form a stable 5 or 6 sided ring structure
- Count the number of C, H, O in the ring structure. Are any atoms lost?

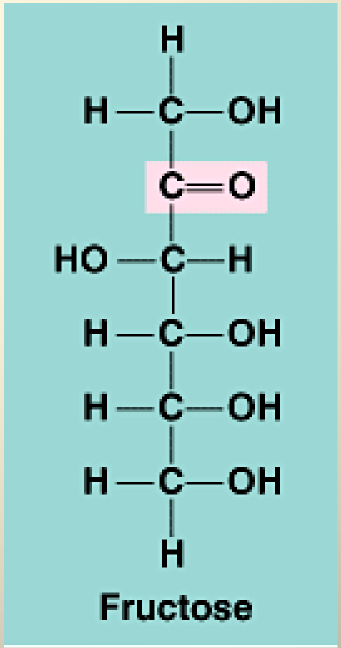


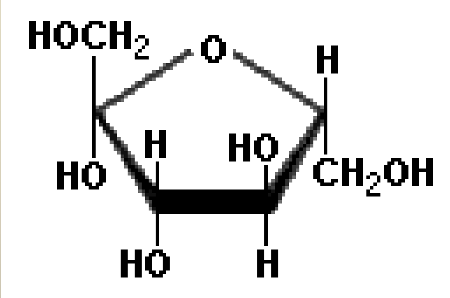
Forming Ring Structures

- Use an arrow to show which 2 atoms in the linear structure below connect to form the ring structures
- hint: it must employ the functional group



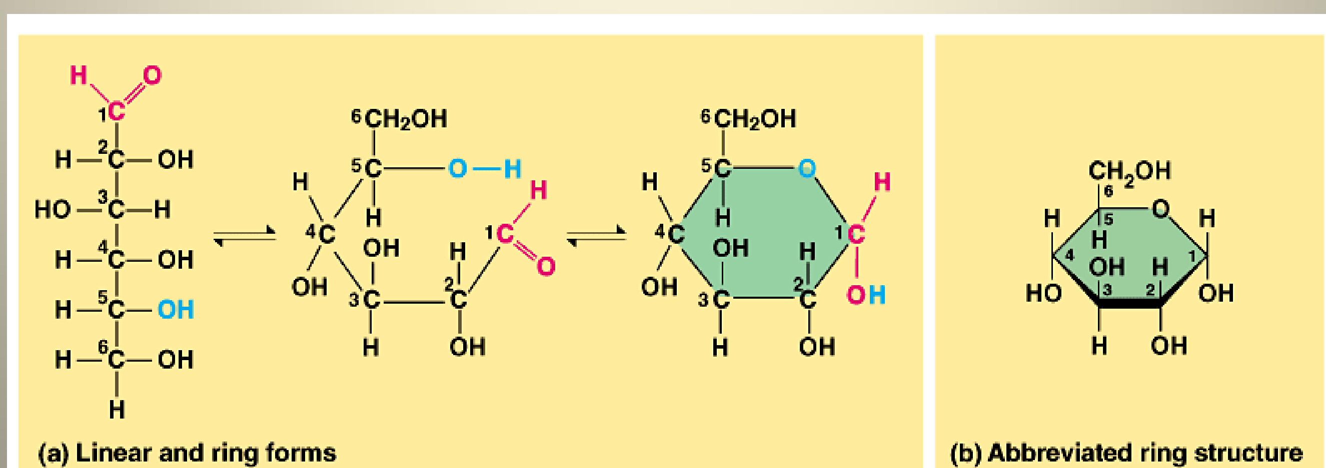






Ring formation summary

- Which carbon is always involved in the ring formation?
- What functional group does the double bonded oxygen become?
- Name the original functional group that the oxygen in the ring originates from.

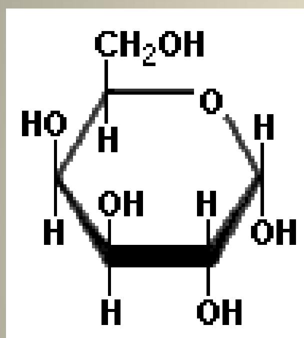


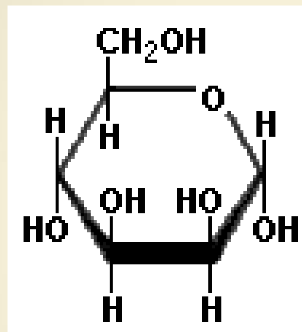
(a) Linear and ring forms

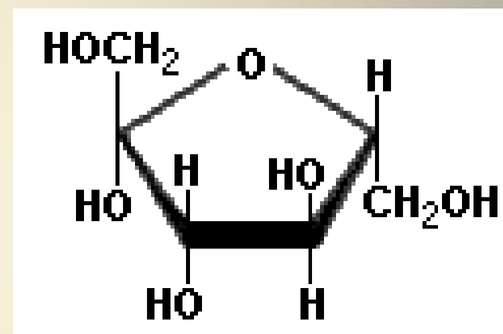
(b) Abbreviated ring structure

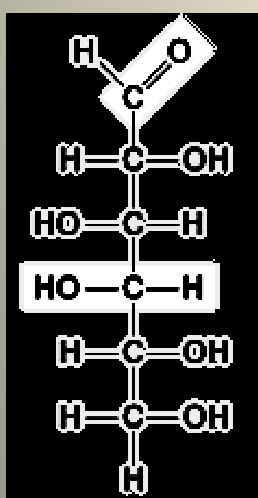
Practice Numbering

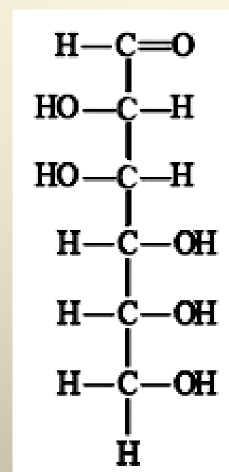
- Number these cyclic monosaccharides

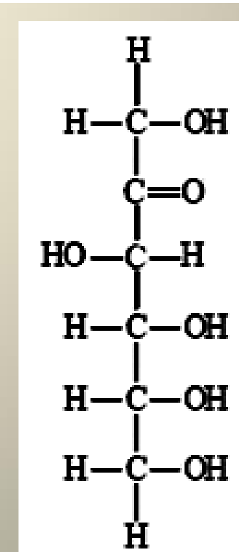




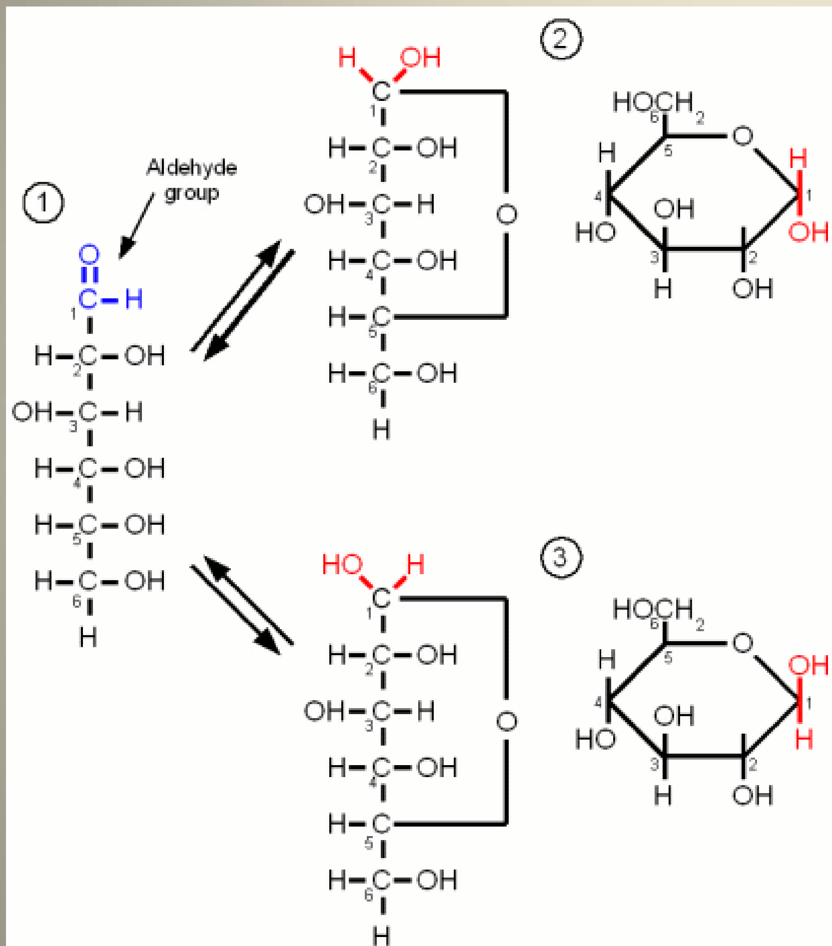








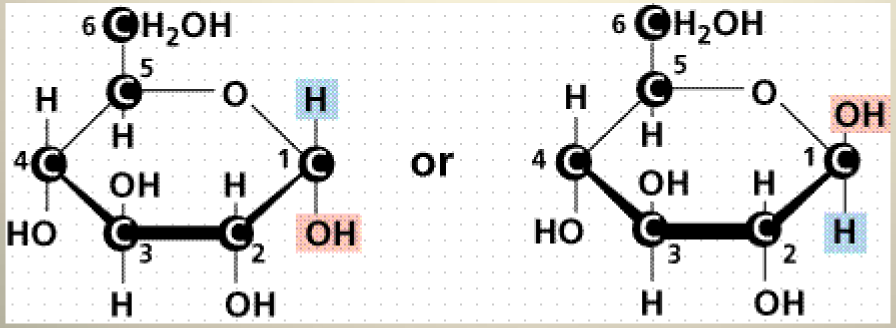
Alpha Beta Orientation



Depending if the OH group attaches from the top or bottom, a different ring structure is formed.

Alpha Beta Orientation

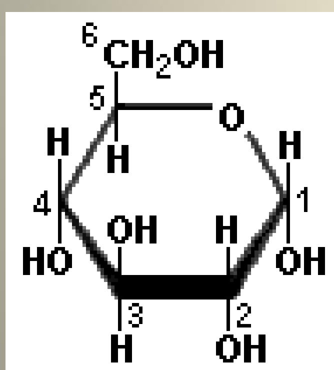
- The different orientation of the resulting OH group have different names
- Alpha (α) = OH group below ring / on the opposite side to the –CH2OH group
- Beta (β) = OH group above ring / on the same side as the –CH2OH group

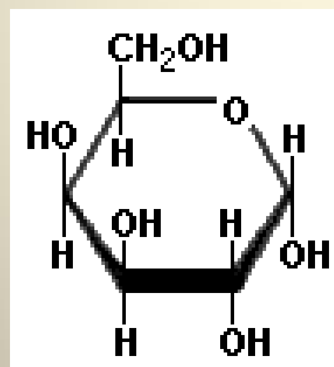


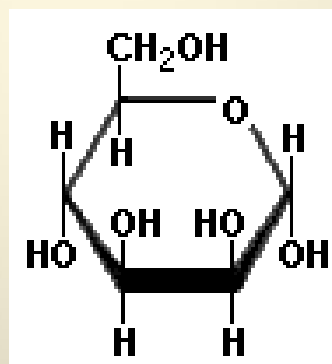
Ring forms of hexose sugars

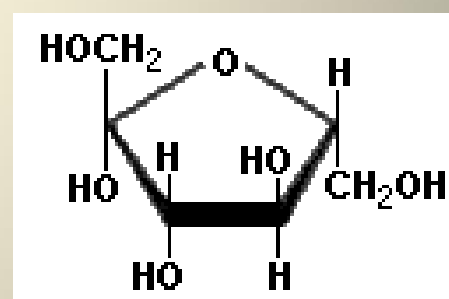
- Question: How do you distinguish galactose, mannose and fructose from glucose?

Glucose Galactose Mannose Fructose

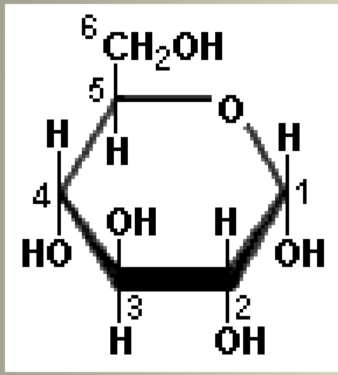
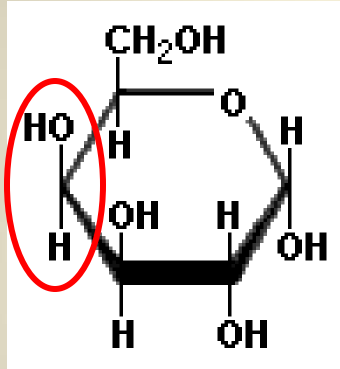
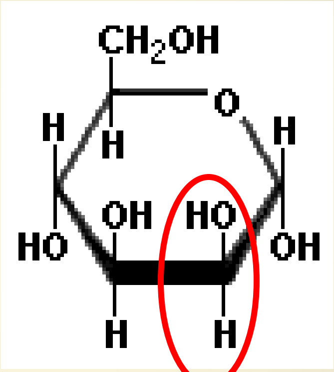
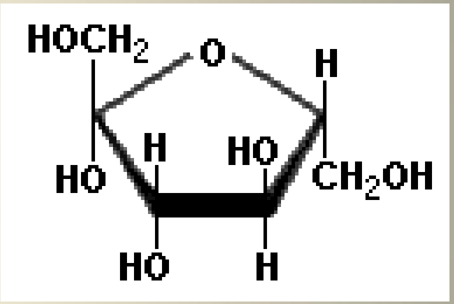






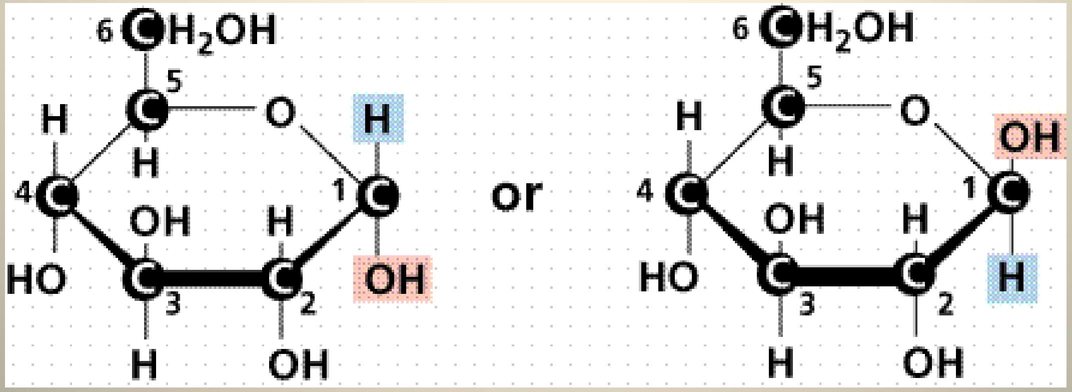


Ring forms of hexose sugars

Glucose	Galactose	Mannose	Fructose
			
	Carbon 4 – OH is up	Carbon 2 – OH is up	5 sided ring

α and β ring forms of glucose

- OH group on carbon **1** can end up above or below the plane of the ring
- Alpha (α) = OH group below ring
- Beta (β) = OH group above ring



Monosaccharide: Property

- Polar: Due to all the hydroxyl groups
- Hydrophilic:

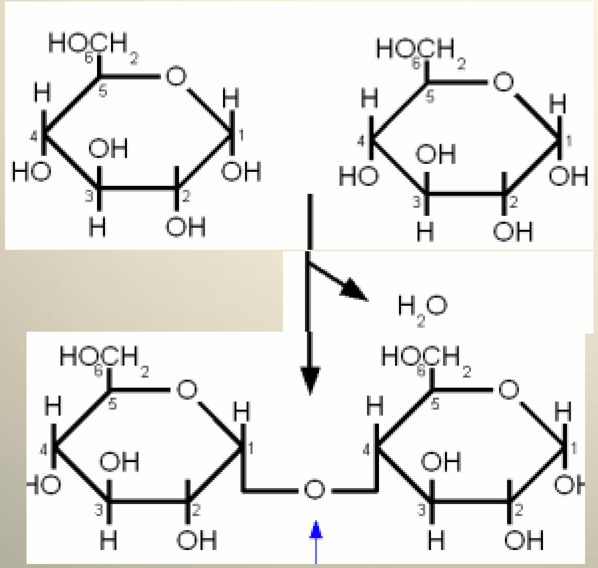
- Soluble in water
- Sweet taste of monosaccharides require it to dissolve in water

Function of Carbohydrates

- Monosaccharides: fuel
- Dissaccharides: fuel
- Polysaccharides: structural support and storage

Saccharide Condensation Reactions

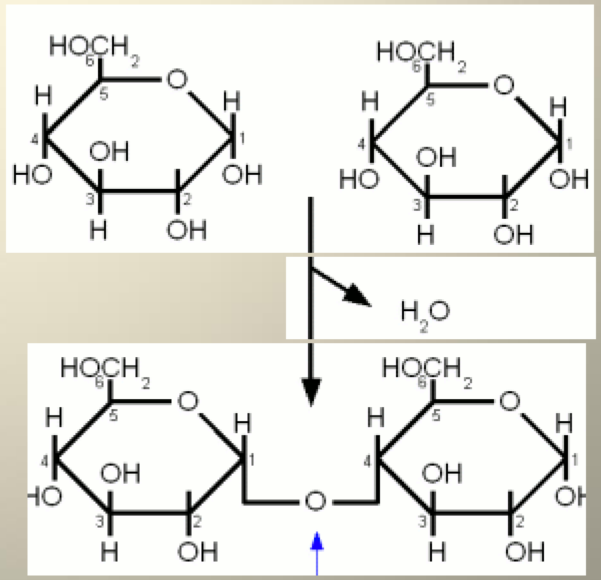
- Which functional group(s) participates in this reaction?
- What is the name of the new functional group formed?



Linkage Naming

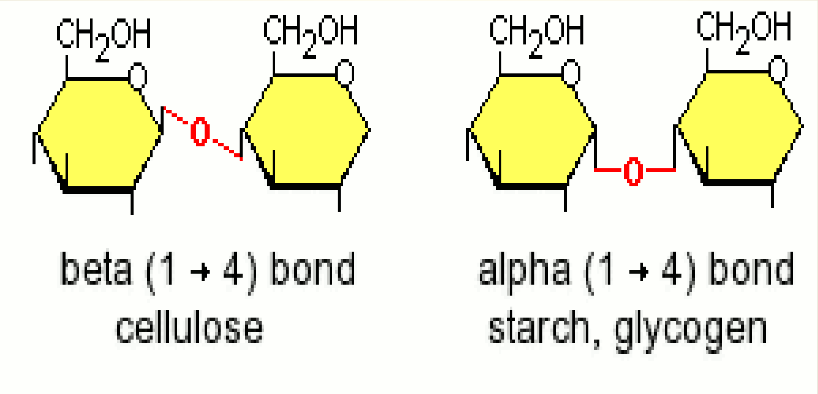
To name the linkage:

- Identify whether the anomeric carbon in the link is α or β
- Number the carbons and determine which two carbons are involved in the linkage
- Example: α-1,4 linkage



Linkage: Anomeric Carbon

α and β orientation of the anomeric carbon result in the formation of different types of bonds in polymers



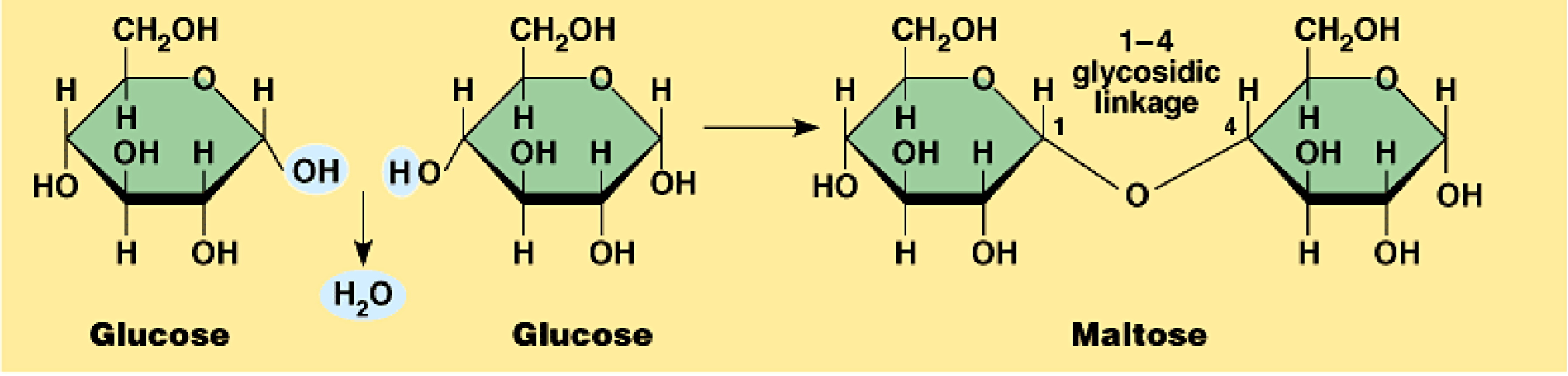
non-digestible digestible

Dissaccharide

- Di = two
- Condensation reaction of 2 monosaccharides forming an **ether** bond known in carbohydrates as a **glycosidic** bond
- 3 dissaccharides that all involve glucose:
  - Maltose = glucose + glucose
  - Lactose = glucose + galactose
  - Sucrose = glucose + fructose

Dissaccharide

- Glucose + Glucose = Maltose + H_2O
- Produced in malted products (e.g. beer)

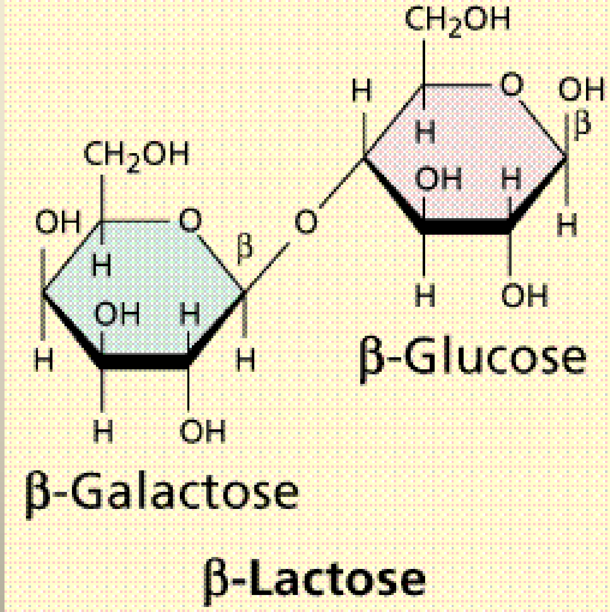


(a) Dehydration synthesis of maltose

Fig. 5.5a

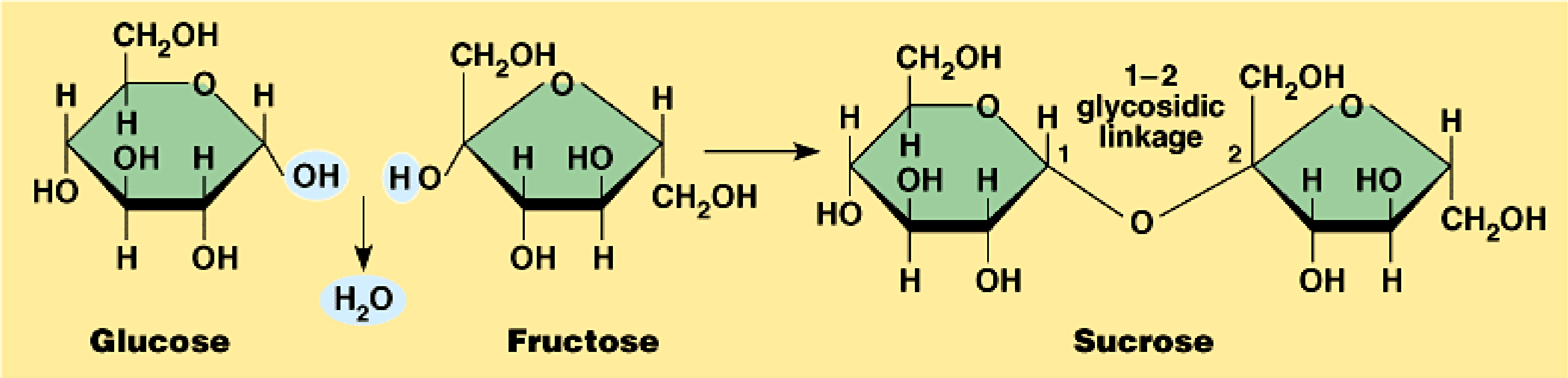
Dissaccharide

- Glucose + Galactose = Lactose + H2O
- Lactose:
  - the major form of sugar in milk
  - People with lactose intolerance lack the enzyme needed to break down lactose



Dissaccharide

- Glucose + Fructose = Sucrose + H2O
- Sucrose:
  - table sugar
  - the major transport form of sugars in plants

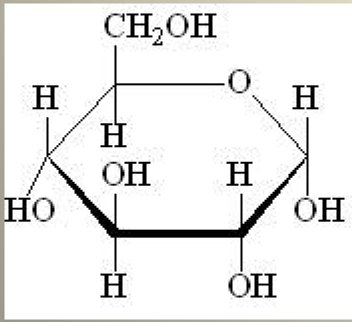


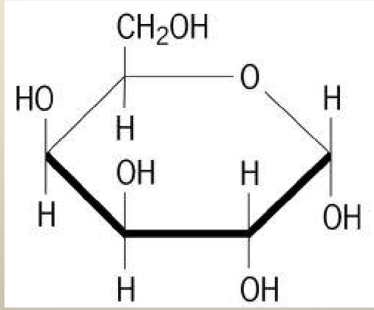
(b) Dehydration synthesis of sucrose

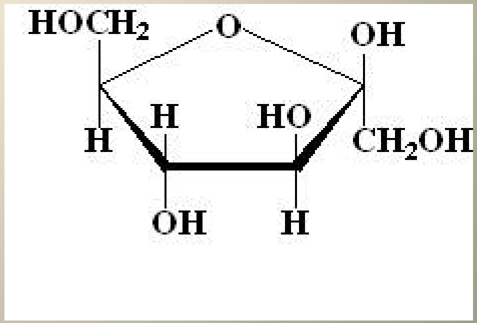
Fig. 5.5b

Reducing Sugars

- In a chemical reaction, when the **anomeric carbon has an OH group**, it is considered a reducing sugar.
- All monosaccharides are reducing sugars
- Practice: Identify the anomeric carbon in each molecule





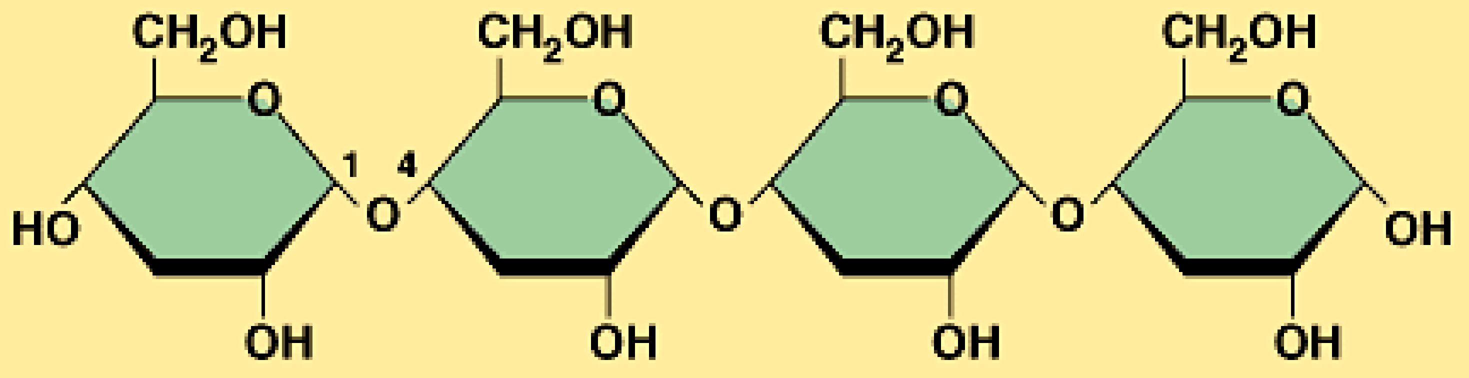


Polysaccharide

- Polysaccharides: polymers of monosaccharide (glucose) joined by **glycosidic** linkages.
- Two types of function:
  - Storage: Energy storage macromolecule that is hydrolyzed as needed.
  - Structural support: Building materials for the cell.

Starch

- glucose monomers joined by α1-4 linkages



(b) Starch: 1–4 linkage of α glucose monomers

Fig. 5.7

Starch

- Is made up of two forms that have a helical structure
- Amylose: unbranched form
- Amylopectin: branched form

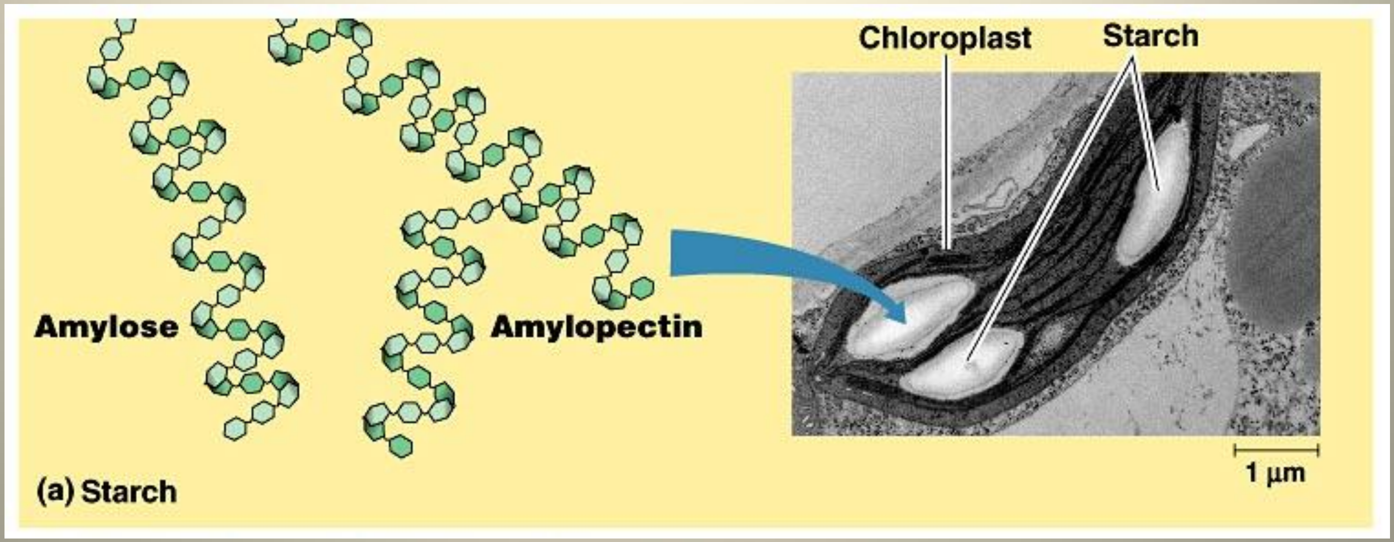


Fig. 5.6a

Starch

- Found in plants
- stored within chloroplasts
- a way to store surplus glucose
- Animals can eat plants containing starch and derive energy from it

Glycogen

- Storage in liver and muscle cells of animals
- Glucose polymer with extensive branching
- Helical structure

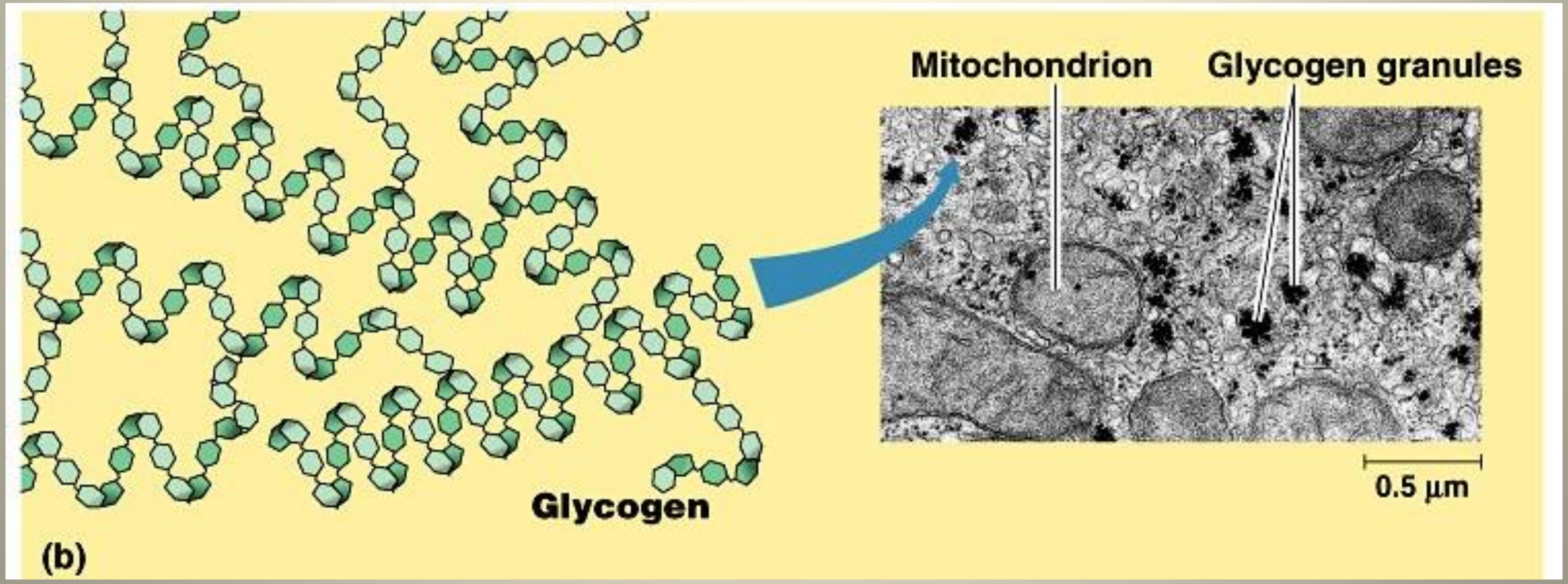
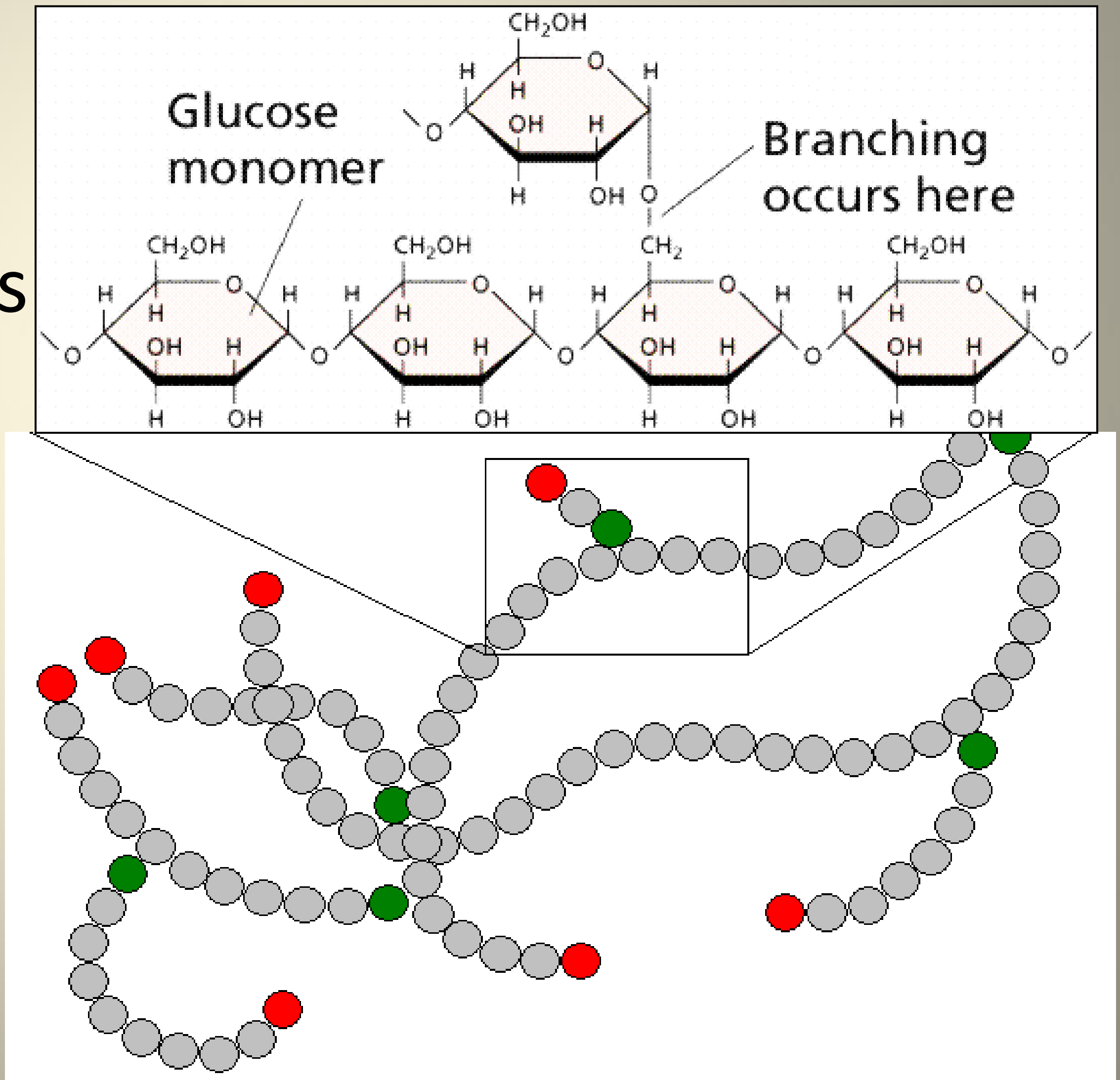


Fig. 5.6b

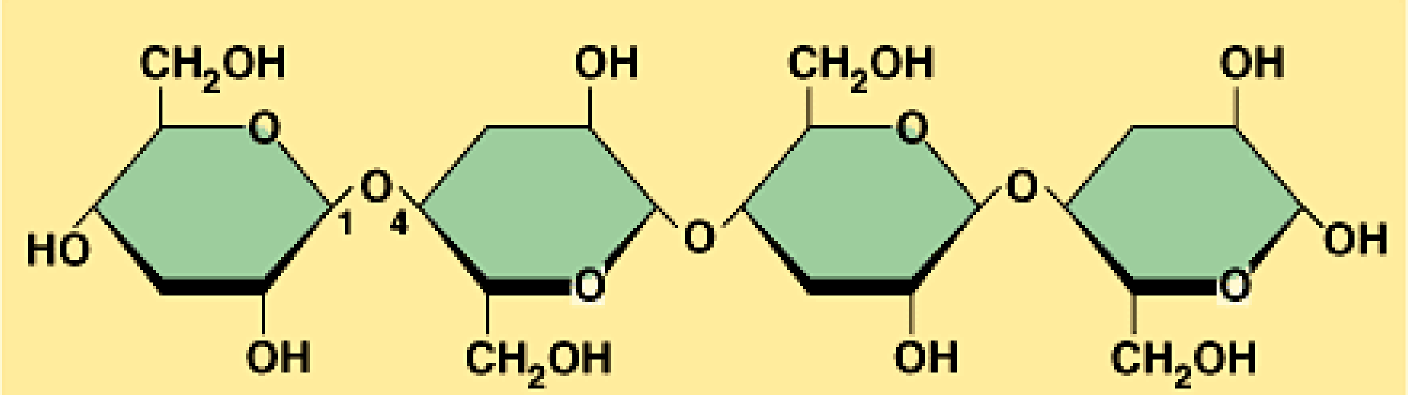
Glycogen

Function of branching: allows enzyme easy access to breakdown the more loosely packed molecule into glucose



Cellulose

- glucose monomers joined by β1-4 linkages
- has no branching
- this linkage makes **every other glucose molecule face upside down** resulting in a straight chain (non-helical) 3D structure



(c) Cellulose: 1–4 linkage of β glucose monomers

Fig. 5.7c

Cellulose

- Make up the plant cell wall
- Strength of cellulose from **crosslinks**:
  - hydrogen bonds between parallel strands of cellulose
  - H atoms of OH groups on one strand form H-bonds with OH groups on other strands.
- **Microfibrils**: 80 cellulose polymers grouped and held together by crosslinks

Cellulose

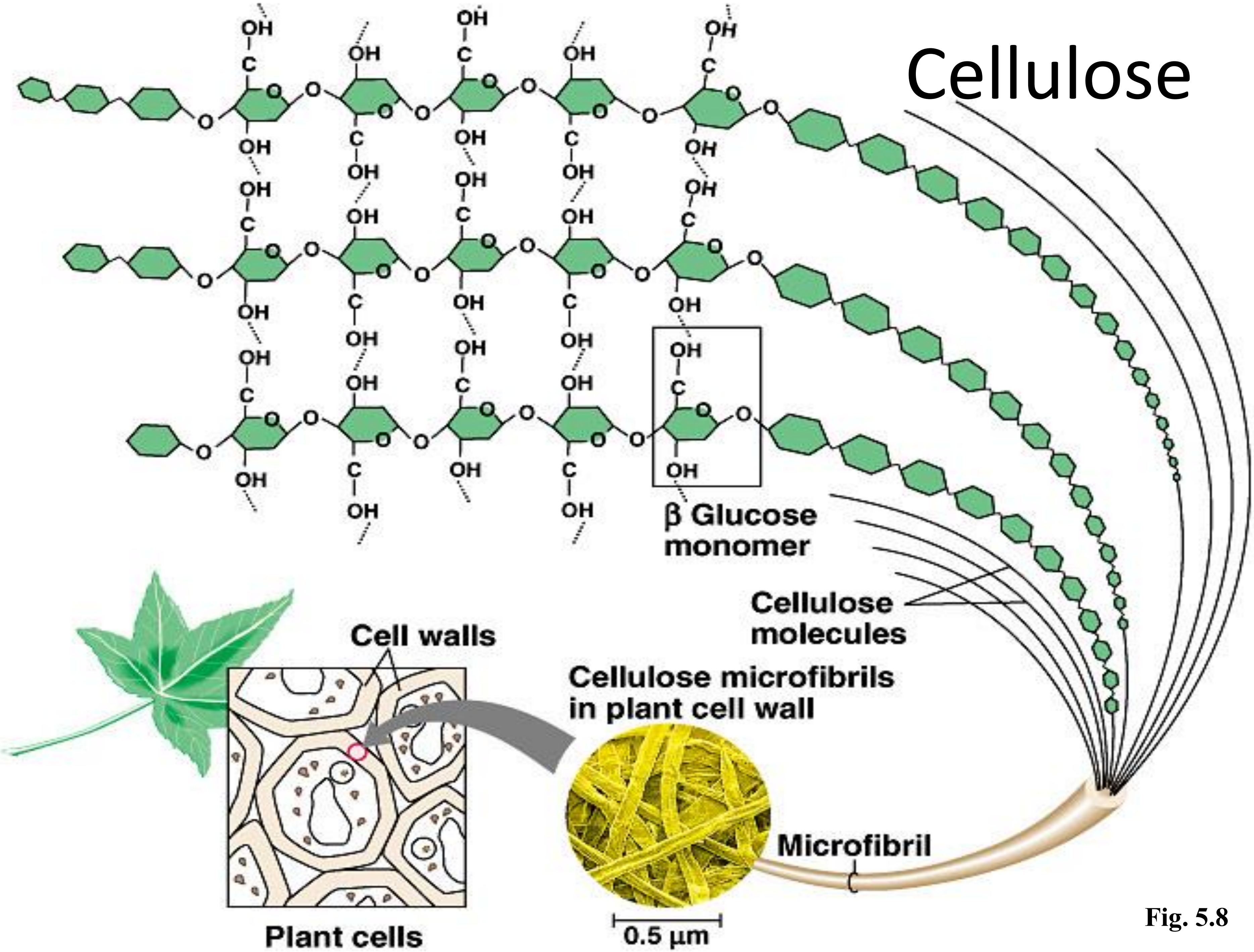
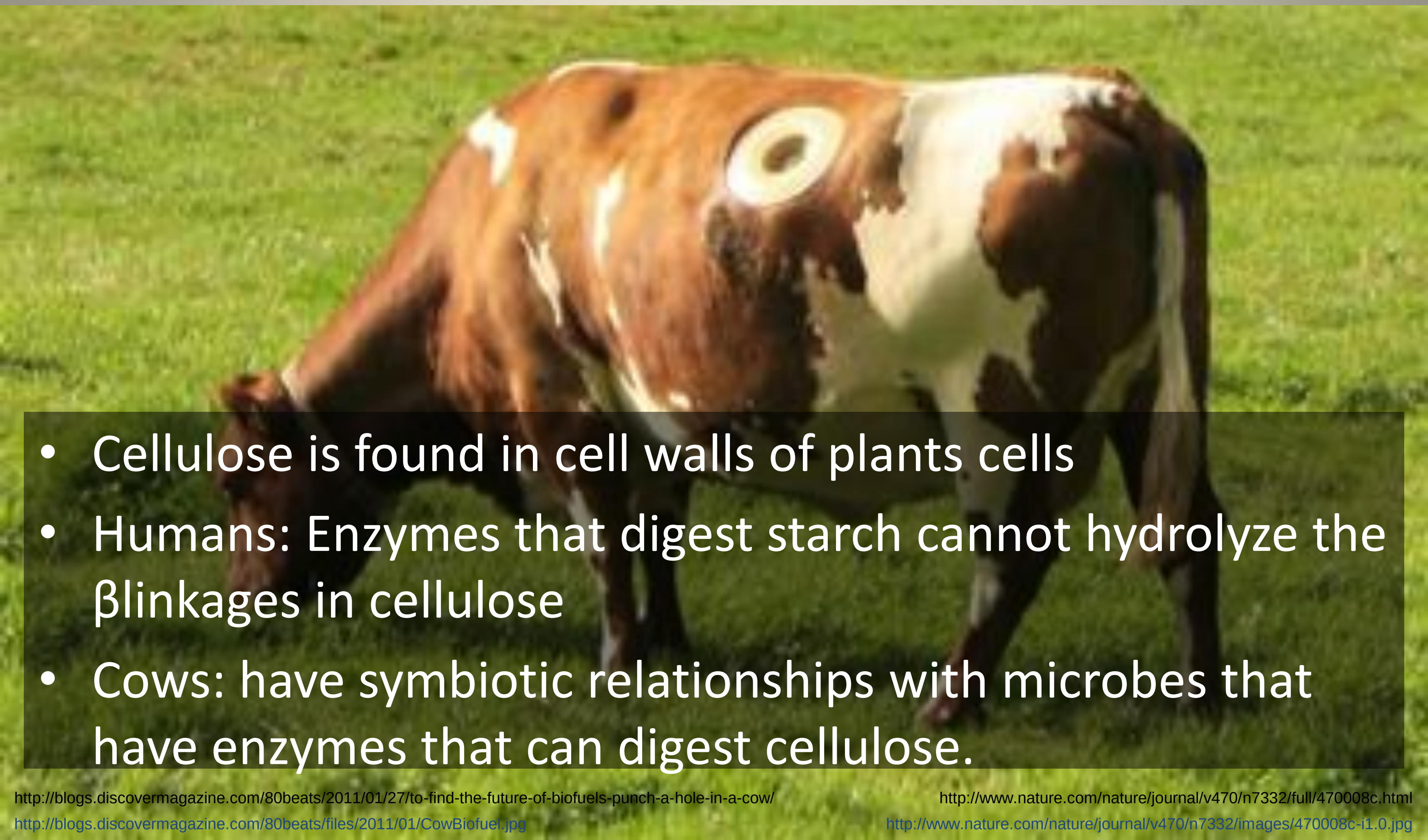


Fig. 5.8

Cellulose



- Cellulose is found in cell walls of plants cells
- Humans: Enzymes that digest starch cannot hydrolyze the βlinkages in cellulose
- Cows: have symbiotic relationships with microbes that have enzymes that can digest cellulose.

http://blogs.discovermagazine.com/80beats/2011/01/27/to-find-the-future-of-biofuels-punch-a-hole-in-a-cow/
http://blogs.discovermagazine.com/80beats/files/2011/01/CowBiofuel.jpg

http://www.nature.com/nature/journal/v470/n7332/full/470008c.html
http://www.nature.com/nature/journal/v470/n7332/images/470008c-i1.0.jpg

Chitin

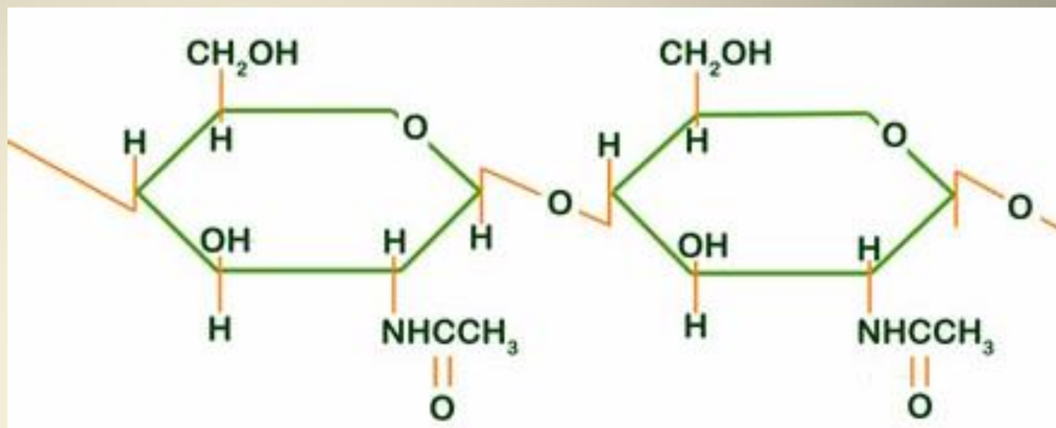
Found in:

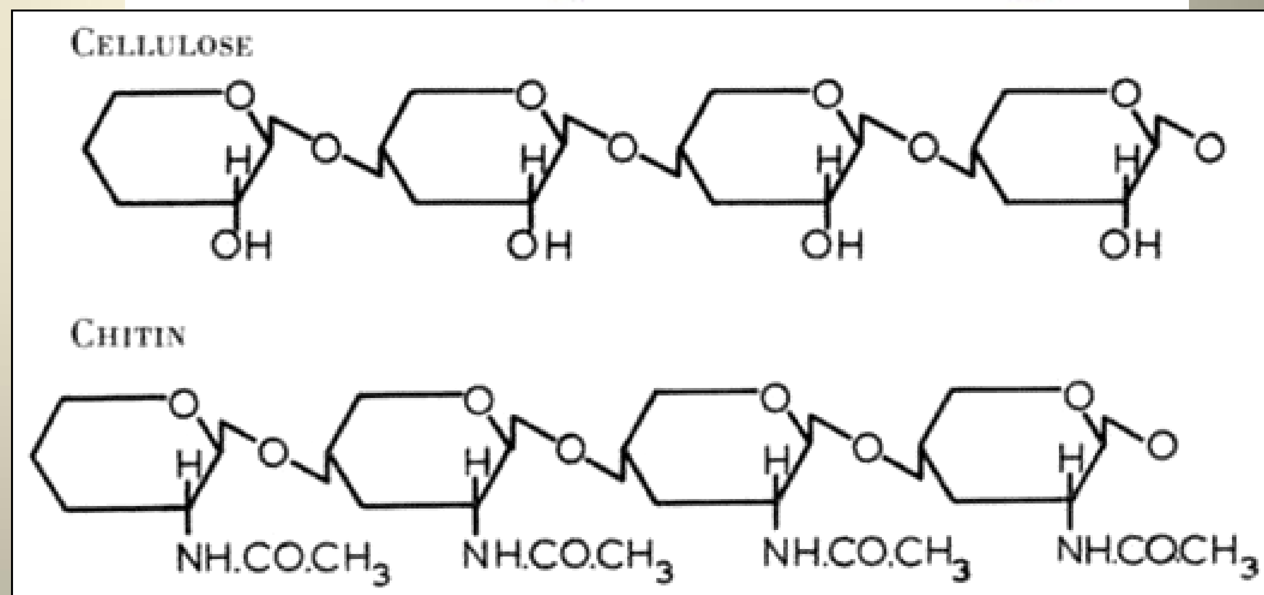
- cell walls of many fungi
- exoskeletons of arthropods (insects, spiders, and crustaceans such as crabs, lobsters and shrimp).

http://academic.brooklyn.cuny.edu/biology/bio4fv/page/chitin.html

Chitin

- Similar in structure to cellulose, except that it contains nitrogen





http://www.ceoe.udel.edu/horseshoecrab/research/images/Chitin_molecule2_flat.jpg

http://www.nzetc.org/etexts/Bio14Tuat01/Bio14Tuat01_038a.jpg

Polysaccharide Summary

Function	Structure	Animals	Plants
Fuel	helical & mostly branched	Glycogen	Starch
Support	straight, unbranched	Chitin (fungi & arthropods)	Cellulose