Section B: Carbohydrates - Fuel and Building Material

1. Sugars, the smallest carbohydrates, serve as fuel and carbon sources
2. Polysaccharides, the polymers of sugars, have storage and structural roles
Introduction

- **Carbohydrates** include both sugars and polymers.
- The simplest carbohydrates are monosaccharides or simple sugars.
- Disaccharides, double sugars, consist of two monosaccharides joined by a condensation reaction.
- Polysaccharides are polymers of monosaccharides.
1. Sugars, the smallest carbohydrates serve as a source of fuel and carbon sources

- Monosaccharides generally have molecular formulas that are some multiple of CH\(_2\)O.
  - For example, glucose has the formula C\(_6\)H\(_{12}\)O\(_6\).
  - Most names for sugars end in -ose.
- Monosaccharides have a carbonyl group and multiple hydroxyl groups.
  - If the carbonly group is at the end, the sugar is an aldose, if not, the sugars is a ketose.
  - Glucose, an aldose, and fructose, a ketose, are structural isomers.
Monosaccharides are also classified by the number of carbons in the backbone.

- Glucose and other six carbon sugars are hexoses.
- Five carbon backbones are pentoses and three carbon sugars are trioses.

Monosaccharides may also exist as enantiomers.

For example, glucose and galactose, both six-carbon aldoses, differ in the spatial arrangement around asymmetrical carbons.
Fig. 5.3

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• Monosaccharides, particularly glucose, are a major fuel for cellular work.

• They also function as the raw material for the synthesis of other monomers, including those of amino acids and fatty acids.

Fig. 5.4

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• Two monosaccharides can join with a **glycosidic linkage** to form a **dissaccharide** via dehydration.

• Maltose, malt sugar, is formed by joining two glucose molecules.

• Sucrose, table sugar, is formed by joining glucose and fructose and is the major transport form of sugars in plants.

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**Fig. 5.5a**

(a) Dehydration synthesis of maltose

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• While often drawn as a linear skeleton, in aqueous solutions monosaccharides form rings.

(b) Dehydration synthesis of sucrose

Fig. 5.5
2. Polysaccharides, the polymers of sugars, have storage and structural roles

- **Polysaccharides** are polymers of hundreds to thousands of monosaccharides joined by glycosidic linkages.

- One function of polysaccharides is as an energy storage macromolecule that is hydrolyzed as needed.

- Other polysaccharides serve as building materials for the cell or whole organism.
• **Starch** is a storage polysaccharide composed entirely of glucose monomers.
  
  • Most monomers are joined by 1-4 linkages between the glucose molecules.
  
  • One unbranched form of starch, amylose, forms a helix.
  
  • Branched forms, like amylopectin, are more complex.
• Plants store starch within plastids, including chloroplasts.

• Plants can store surplus glucose in starch and withdraw it when needed for energy or carbon.

• Animals that feed on plants, especially parts rich in starch, can also access this starch to support their own metabolism.
• Animals also store glucose in a polysaccharide called **glycogen**.
  
  • Glycogen is highly branched, like amylopectin.
  
  • Humans and other vertebrates store glycogen in the liver and muscles but only have about a one day supply.

Fig. 5.6b
• While polysaccharides can be built from a variety of monosaccharides, glucose is the primary monomer used in polysaccharides.

• One key difference among polysaccharides develops from 2 possible ring structure of glucose.
  • These two ring forms differ in whether the hydroxyl group attached to the number 1 carbon is fixed above (beta glucose) or below (alpha glucose) the ring plane.

Fig. 5.7a  (a) α and β glucose ring structures
• Starch is a polysaccharide of alpha glucose monomers.
• Structural polysaccharides form strong building materials.

• **Cellulose** is a major component of the tough wall of plant cells.
  
  • Cellulose is also a polymer of glucose monomers, but using beta rings.

![Diagram of cellulose structure](image)

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

Fig. 5.7c
• While polymers built with alpha glucose form helical structures, polymers built with beta glucose form straight structures.

• This allows H atoms on one strand to form hydrogen bonds with OH groups on other strands.
  • Groups of polymers form strong strands, microfibrils, that are basic building material for plants (and humans).
• The enzymes that digest starch cannot hydrolyze the beta linkages in cellulose.
  • Cellulose in our food passes through the digestive tract and is eliminated in feces as “insoluble fiber”.
  • As it travels through the digestive tract, it abrades the intestinal walls and stimulates the secretion of mucus.
• Some microbes can digest cellulose to its glucose monomers through the use of cellulase enzymes.
• Many eukaryotic herbivores, like cows and termites, have symbiotic relationships with cellulolytic microbes, allowing them access to this rich source of energy.
Another important structural polysaccharide is **chitin**, used in the exoskeletons of arthropods (including insects, spiders, and crustaceans).

- Chitin is similar to cellulose, except that it contains a nitrogen-containing appendage on each glucose.
- Pure chitin is leathery, but the addition of calcium carbonate hardens the chitin.

Chitin also forms the structural support for the cell walls of many fungi.

Fig. 5.9