Johns Hopkins Engineering

Molecular Biology

Richard S. Potember, Ph.D.
Potember@jhu.edu

Module 2 / Lecture 3

Polysaccharides

Polysaccharides

Unlike proteins and nucleic acids, **polysaccharides** play **no known informational** role in the cell.

Polysaccharides, in higher organisms, are the storage polysaccharides **starch** and **glycogen** and the structural polysaccharide **cellulose**.

Each of these polymers contains the six-carbon sugar **glucose** as its single repeating unit, but they differ in both the nature of the bond between successive glucose units and the presence and extent of side branches on the chains.

The Monomers are Monosaccharides

The repeating units of polysaccharides are simple sugars called **monosaccharides.**

A sugar can be an **aldehyde** or **ketone** that has two or more hydroxyl groups.

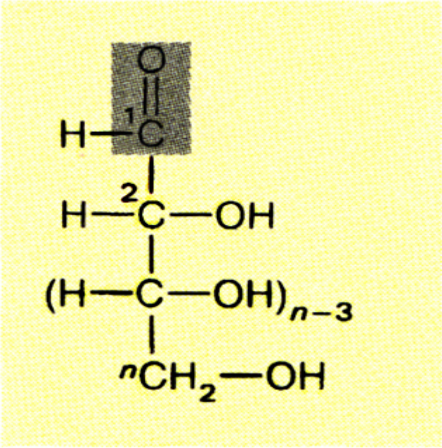
There are two categories of sugars: the ***aldosugars***, with a terminal carbonyl group; and the ***ketosugars***, *with an internal carbonyl group.*

Most sugars have between three and seven carbon atoms and are therefore classified as a triose (three carbons), a *tetrose* (four carbons), a *pentose* (five carbons), a *hexose* (six carbons), or a *heptose* (seven carbons).

The single most common monosaccharide in the biological world is the aldohexose D-glucose.

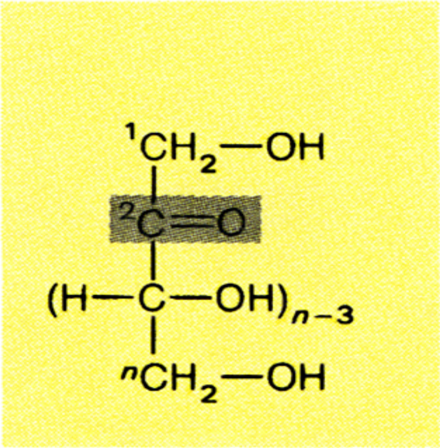
It is represented by the formula $C_6H_{12}0_6$.

Structures of Monosaccharides



Aldosugar

(a)



Ketosugar

(b)

The Structure of Glucose

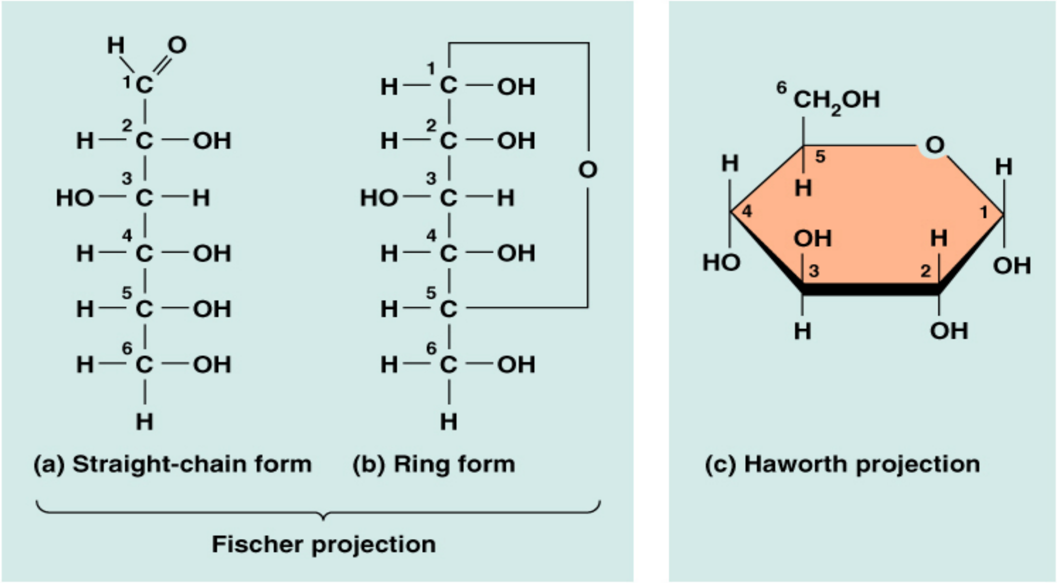
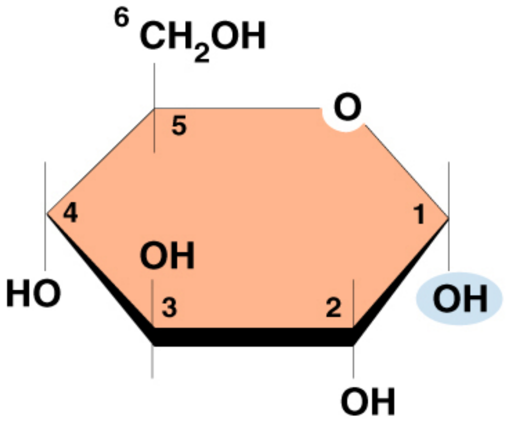
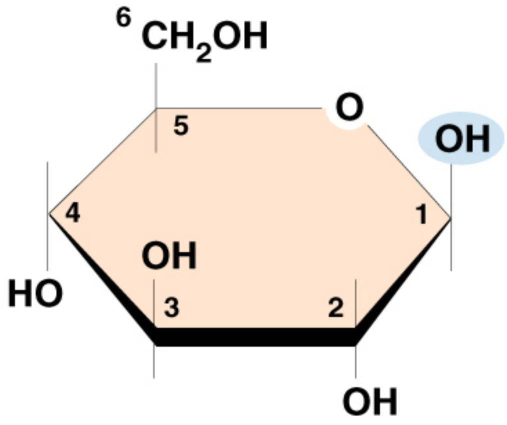


Figure 3-21 The Structure of Glucose. The glucose molecule can be represented by Fischer projections of (a) the straight-chain form or (b) the ring form of the molecule, as well as by (c) the Haworth projection of the ring form. In the Fischer projections, the JH and JOH groups are intended to be projecting slightly out of the plane of the paper. In the Haworth projection, carbon atoms 2 and 3 are intended to be jutting out of the plane of the paper, and carbon atoms 5 and 6 are behind the plane of the paper. The JH and JOH groups then project upward or downward, as indicated. Notice that the carbon atoms are numbered from the more oxidized end of the molecule.

Ring Forms of D-Glucose



α-D-glucose, the repeating unit of starch and glycogen



β-D-glucose, the repeating unit of cellulose

Figure 3-22 The Ring Forms of D-Glucose. The hydroxyl group on carbon atom 1 points downward in the alpha form and upward in the beta form.

Polysaccharides

In addition to free monosaccharide and long-chain polysaccharides, glucose also occurs in **disaccharides,** which consist of 2 monosaccharide units linked covalently.

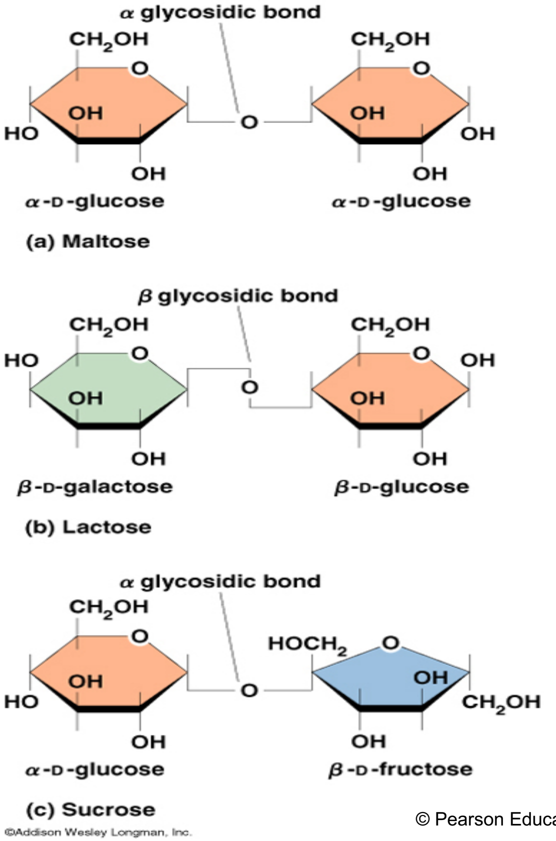
Three common disaccharides. ***Maltose*** (malt sugar) consists of two glucose units linked together, whereas ***lactose*** (milk sugar) contains a glucose linked to a galactose and **sucrose** (common table sugar) has a glucose linked to a fructose.

Each of these disaccharides is formed by a condensation reaction in which two monosaccharides are linked together by the elimination of water.

The resulting **glycosidic bond** is characteristic of linkages between sugars.

Some Common Disaccharides

Figure 3-23 Some Common Disaccharides (a) Maltose (malt sugar) consists of two molecules of alpha-D-glucose linked by an a glycosidic bond (b) Lactose (milk sugar) consists of a molecule of beta-D-galactose linked to a molecule of beta-D-glucose by a beta glycosidic bond (c) Sucrose (table sugar) consists of a molecule of alpha-D-glucose linked to a molecule of a-D-fructose by an alpha glycosidic bond.



Polysaccharide Polymers are Storage and Structural

Polysaccharides perform either storage or structural functions in cells. The most familiar *storage polysaccharides* are the starch of plant cells and the glycogen of animal cells. Both of these polymers consist of alpha-d-glucose units linked together by a glycosidic bonds.

Storage polysaccharides can be branched or unbranched polymers, depending on the presence or absence of alpha (1 -> 6) linkages.

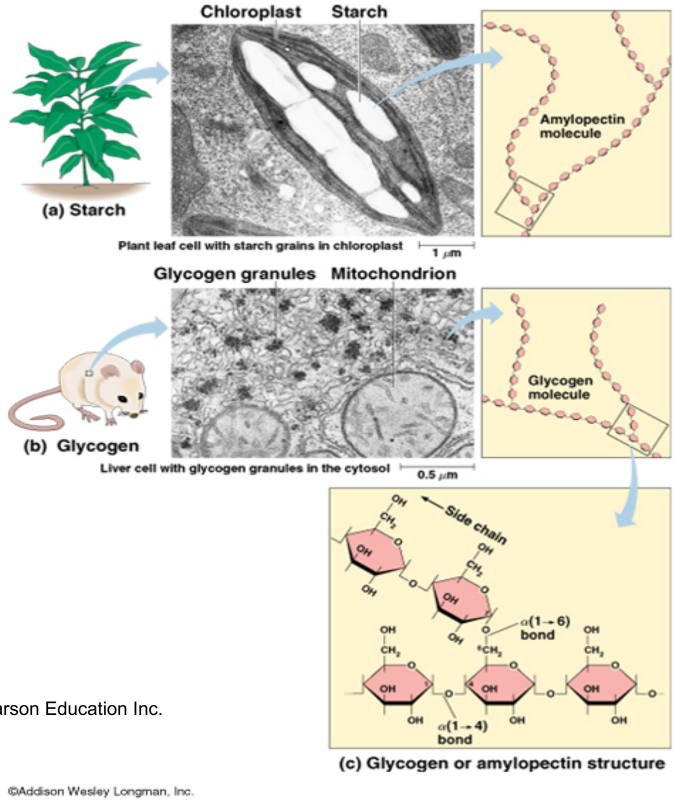
Glycogen is highly branched, with linkages occurring every 8 to 10 glucose units along the backbone and giving rise to short side chains of about 8 to 12 glucose units.

Glycogen is stored mainly in the liver and in muscle tissue.

In the **liver** it is used as a source of glucose to maintain blood sugar levels, whereas in **muscle** it serves as a **fuel source** to generate the ATP needed for muscle contraction.

The Structure of Starch and Glycogen

Figure 3-24 The Structure of Starch and Glycogen (a) The starch found in plant cells and (b) the glycogen found in animal cells are both storage polysaccharides composed of linear chains of a-D-glucose units, with or without occasional branch points (TEMs). Starch occurs in two forms: branched amylopectin, as shown in part a, and unbranched amylose (not shown). Glycogen occurs only as the branched form shown in part b. (c) The straight-chain portion of all three kinds of molecules consists of a-D-glucose units linked by a(1D4) glycosidic bonds. In the case of amylopectin and glycogen, branch chains originate at a(1D6) glycosidic bonds.



Polysaccharides Polymers are Storage and Structural

Starch occurs both as un-branched **amylose** and as branched **amylopectin.**

Like glycogen, **amylopectin** has a (1 -> 6) branches, but these occur less frequently along the backbone (once every 12 to 25 glucose units) and give rise to longer side chains (lengths of 20 to 25 glucose units are common).

Starch deposits are usually about 10-30% **amylose** and 70-90% **amylopectin**.

The Polymers Are Storage and Structural – Polysaccharides

The best-known example of a ***structural polysaccharide*** is **cellulose** found in plant cell walls.

Cellulose is an important polymer quantitatively; more than half of the carbon in higher plants is present in cellulose.

Like starch and glycogen, **cellulose** is also a polymer of glucose, but the repeating monomer is *beta*-d-glucose and the linkage is therefore beta (1 --> 4).

Polysaccharide Structure Depends on Glycosidic Bonds

Cellulose forms rigid, linear rods. These aggregate laterally into *microfibrils*.

Microfibrils are about 25 nm in diameter and are composed of about 2000 cellulose chains.

Plant and fungal cell walls consist of these rigid microfibrils of cellulose embedded in a *noncellulosic matrix* containing a rather variable mixture of several other polymers.

The Structure of Cellulose

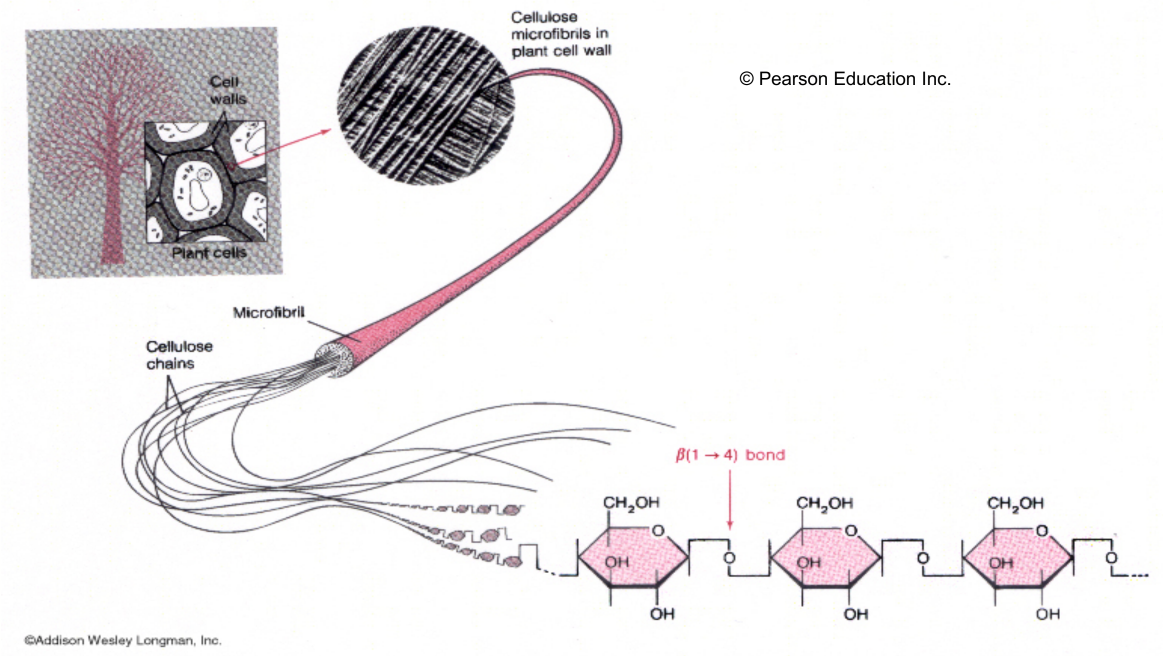


Figure 3-25 The Structure of Cellulose. Cellulose consists of long, unbranched chains of beta-D-glucose units linked together by beta(1 to 4) glycosidic bonds. Many such chains associate laterally to form microfibrils. Individual microfibrils can be seen in the micrograph of a primary plant cell wall shown here (TEM). The beta(1 to 4) glycosidic bonds cannot be hydrolyzed by most higher animals.

Polymers Are Storage and Structural – Polysaccharides

Mammals do not possess an enzyme that **utilize cellulose as food**.

Humans can digest potatoes (starch) but not grass (cellulose).

Animals such as cows and sheep might seem to be exceptions because they do eat grass and similar plant products.

But they cannot cleave beta glycosidic bonds either; they depend on the population of bacteria and protozoa in their rumen (part of their compound stomach) to do this for them.

The microorganisms digest the cellulose, and the host animal then obtains the end-products of microbial digestion, now in a form the animal can use.

JOHNS HOPKINS

WHITING SCHOOL *of* ENGINEERING