

## 5.7: Polysaccharides

### Learning Objectives

- Learn the structures and some characteristics of polysaccharides, including starches, cellulose, and chitin.

Polysaccharides are long polymers from ten to thousands of monosaccharides joined by glycosidic linkages. The most abundant polysaccharides are starch, glycogen, cellulose, and chitin. Except for chitin, all others are composed of D-glucose. Chitin is composed of a modified form of glucose. These are described next.

### Starch

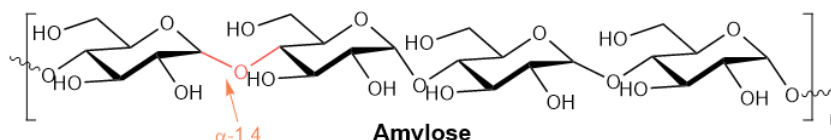
Starch is a storage form of D-glucose in plants. It is found in potatoes, beans, rice, wheat, and other grains and roots, as illustrated in Figure 5.7.1. Starch is a mixture of two forms, 20% to 25% amylose and 75 to 80% amylopectin.



Figure 5.7.1: Starch food: Sindhi Biryani is a delicious Dish of Sindh. (Copyright; Miansari66, Public domain, via Wikimedia Commons)

### Amylose

Amylose is an unbranched chain of up to 4,000 D-glucose units joined by  $\alpha$ -1,4-glycosidic linkage, as shown below.



The orientation of bonds with  $\alpha$ -1,4-glycosidic linkage makes the amylose chain exist in a helical structure, as shown in Figure 5.7.2, that allows water molecules to access and establish hydrogen bonds with  $\text{—OH}$  groups. Starch is a water-soluble polymer. It can dissolve in water due to extensive hydrogen bonding with the water molecules when mixed with water.

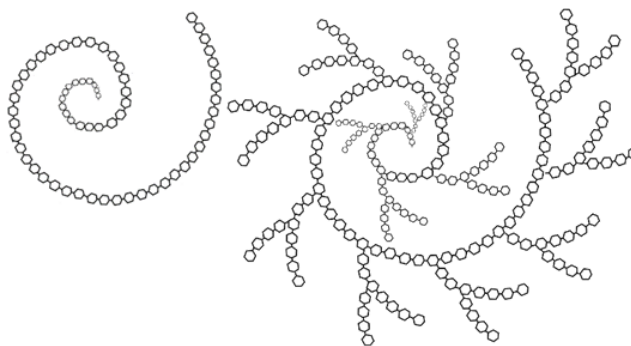
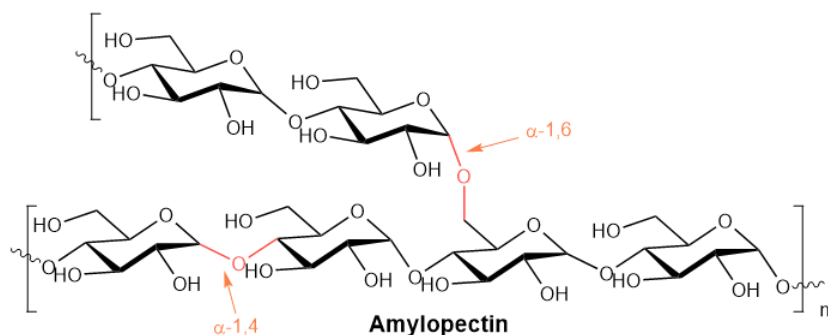


Figure 5.7.2: Illustration of a spiral structure of amylose (left) and branched helical structure of amylopectin (right). (Copyright; modified the free download from: <https://www.hiclipart.com/free-trans...lumuh/download>)

## Amylopectin

Amylopectin is a branched chain polymer of D-glucose, as shown below.



The main chain comprises 10,000 D-glucose units joined by  $\alpha$ -1,4-glycosidic linkage. The main chain exists in the form of a helix. Branches originate at every 24 to 30 unit intervals on the main chain connected to the main chain by a ( $\alpha$ )-1,6-glycosidic linkage, as shown in Figure 5.7.2. This helix with branches going outwards makes amylopectin more accessible to water for hydrogen bonding and easier to digest.

## Glycogen

Glycogen is an energy-storage polysaccharide in animals with the same structure as amylopectin. It has up to  $10^6$  D-glucose units joined by  $\alpha$ -1,4-glycosidic linkages and branching through ( $\alpha$ )-1,6-glycosidic linkages. The main difference from amylopectin is that glycogen has more frequent branching at 10 to 15 D-glucose units interval, as illustrated in Figure 5.7.3. More branching makes it more soluble in water and easier to hydrolyze multiple D-glucose units when the body needs D-glucose.

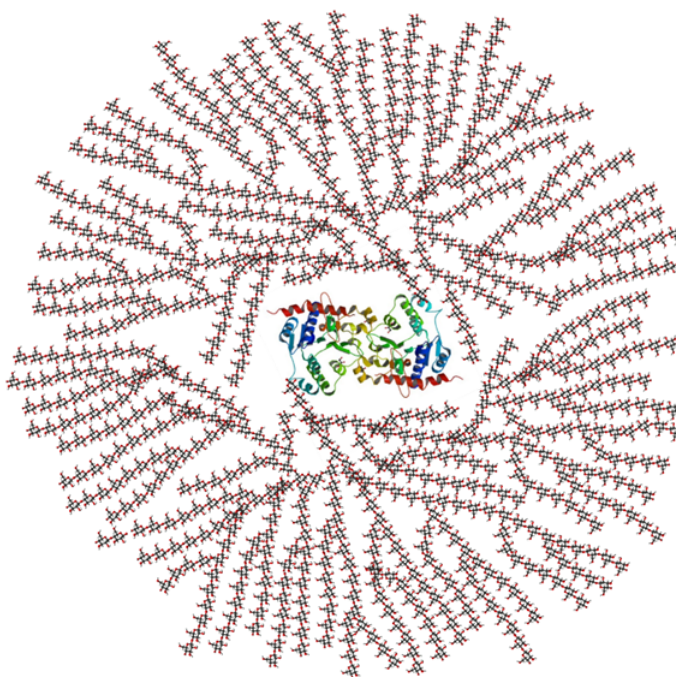


Figure 5.7.3: A 2-D cross-sectional view of glycogen -A core glycogenin protein surrounded by branches of glucose units. (Copyright; Mikael Häggström. Public domain, via Wikimedia Commons)

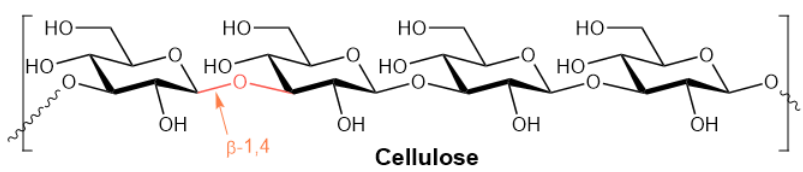
## Cellulose

Cellulose is the most abundant polysaccharide in nature that makes up about 50% of the cell wall of plant cells. Cotton, shown in Figure 5.7.4, is almost pure cellulose.



Figure 5.7.4: Cellulose: Cotton is almost pure cellulose. (Copyright; United States Department of Agriculture, Public domain via Wikimedia Common)

Cellulose is a linear polysaccharide of about 2200 D-glucose units joined by  $\beta$ -1,4-glycosidic linkage, as shown below.



The  $\beta$ -1,4-glycosidic linkage allows glucose units to adopt a linear structure with intra-molecule hydrogen bonding. The linear polymer packs nicely with inter-molecular hydrogen bonding and the London-dispersion forces, as shown in Figure 5.7.5. It gives cellulose its mechanical strength and makes it insoluble in water. Due to the extensive inter- and intra-molecular hydrogen bonding within cellulose, water can not establish enough hydrogen-bonds to dissolve it.

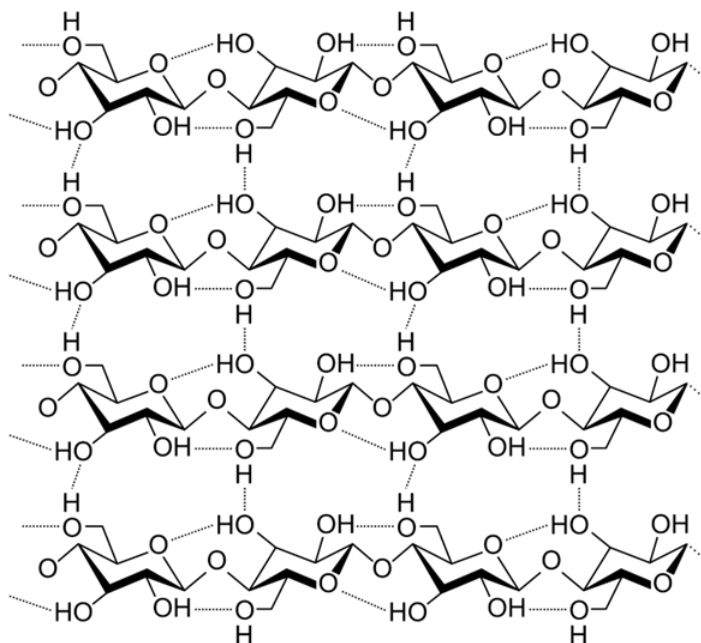


Figure 5.7.5: Illustration of linear chains of cellulose polymer with intra- and inter-molecular hydrogen bonding shown by dotted lines. (Copyright; Laghi.l, CC BY-SA 3.0, via Wikimedia Commons)

Animals have  $\alpha$ -glucosidase enzymes that allow them to hydrolyze starch and glycogen to D-glucose, but they do not have  $\beta$ -glucosidase enzymes needed to hydrolyze cellulose. Grazing animals and termite hose bacteria in their stomach that have the  $\beta$ -glucosidase enzymes. Therefore, grazing animals and termites can digest cellulose.

## Chitin

Chitin is the second most abundant polysaccharide, second only to cellulose. It is found in the exoskeleton of crustaceans and insects, as shown in Figure 5.7.6.



Figure 5.7.6: Blue crab, an example of chitin in the exoskeleton of crustaceans and insects. (Copyright; Blue Crab. USEPA Environmental-Protection-Agency, Public domain, via Wikimedia Commons)

Chitin has the same structure as cellulose except that it is composed of N-acetylglucosamine, an amide derivative of D-glucose, in place of D-glucose in cellulose, as illustrated below Figure 5.7.7.

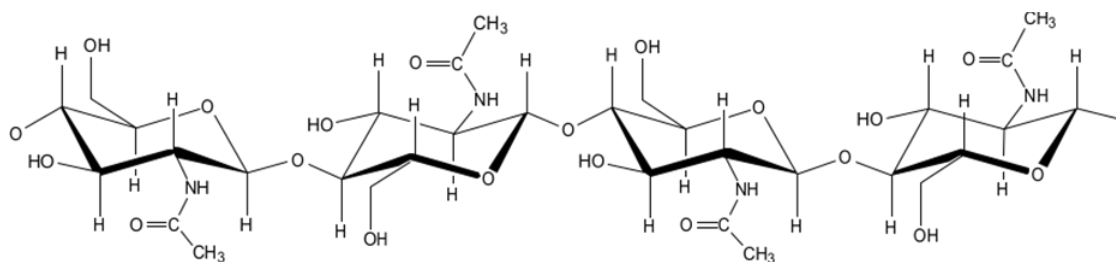


Figure 5.7.7: Structure of chitin. (Copyright; Ronny Flores, Public domain, via Wikimedia Commons)

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