Understanding Biomass: Plant Cell Walls

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1 Switchgrass

A potential bioenergy crop

2 Overview of plant cell walls

Optimizing plant biomass for more efficient processing requires a better understanding of plant cell-wall structure and function. Plants can have two types of cell walls, primary and secondary. Primary cell walls contain cellulose consisting of hydrogen-bonded chains of thousands of glucose molecules,* in addition to hemicellulose and other materials all woven into a network. Certain types of cells, such as those in vascular tissues, develop secondary walls inside the primary wall after the cell has stopped growing. These cell-wall structures also contain lignin, which provides rigidity and resistance to compression. The area formed by two adjacent plant cells, the middle lamella, typically is enriched with pectin.

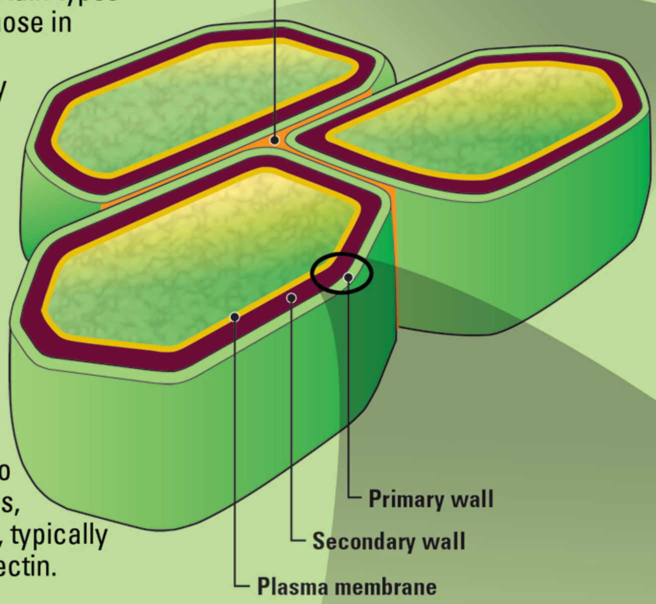


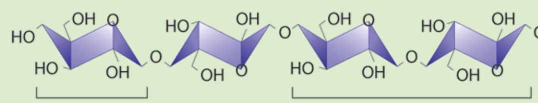
Figure adapted from L. Taiz and E. Zeiger, *Plant Physiology* (1991).

Questions Remain

- *How is cellulose synthesis regulated?*
- *How is hemicellulose synthesized and regulated?*
- *How can we alter cell-wall structure (e.g., increase cellulose and hemicellulose, decrease lignin) for easier breakdown into component sugars?*

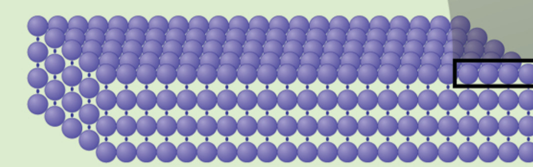
See reverse for explanation of processes to pretreat and breakdown cellulosic biomass and convert the resulting sugars to bioethanol.

7 Fragment of a cellulose molecule



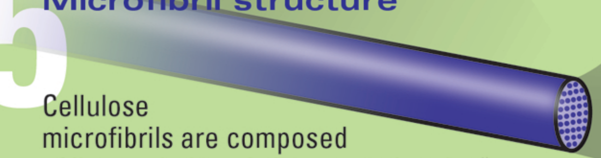
Alternating glucose residues are in an inverted orientation. Cellobiose is the repeating structural unit consisting of two glucose residues.

6 Crystalline cellulose



The glucan chains contain thousands of glucose residues.

5 Microfibril structure

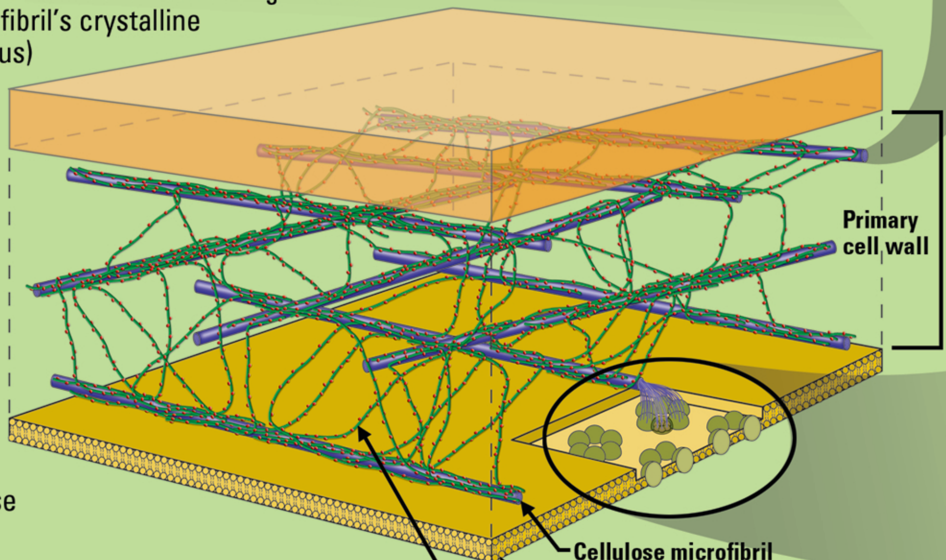


Cellulose microfibrils are composed of linear chains of glucose molecules* that hydrogen bond to form the microfibrils.

3 Simplified model of a primary cell wall

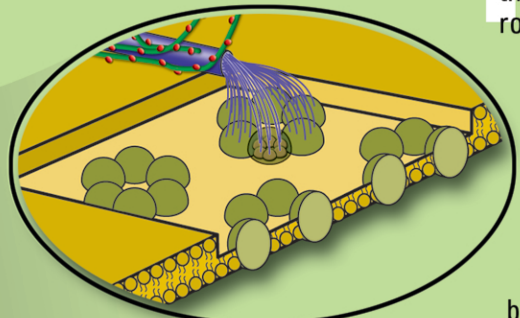
Cellulose in higher plants is organized into microfibrils, each measuring about 3 to 6 nm in diameter and containing up to 36 glucan chains having thousands of glucose residues. Like steel girders stabilizing a skyscraper's structure, the primary cell wall's mechanical strength is due mainly to the microfibril scaffold. A microfibril's crystalline (see No. 6) and paracrystalline (amorphous) cellulose core is surrounded by hemicellulose, a branched polymer composed of pentose (5-carbon) and hexose (6-carbon) sugars. In addition to cross-linking individual microfibrils, hemicellulose in secondary cell walls (not shown) forms covalent associations with lignin, a rigidaromatic polymer whose structure and organization within the cell wall are poorly understood. The crystallinity of cellulose and its association with hemicellulose and lignin are two key challenges preventing efficient cellulose breakdown into glucose molecules convertible to ethanol.

Figure source: C. Somerville (Stanford University)



4 Cellulose synthesis

Many enzymes involved in cell-wall synthesis or modification are thought to be located in complexes. Within the plasma membrane are rosettes composed of the enzyme cellulose synthase; these protein complexes move through the membrane during the synthesis of glucan chains (36 per rosette) that aggregate to form cellulose microfibrils. Cellulose synthase interacts with the cytoskeleton in a poorly characterized way impacting cellulose fibrilorientation and perhaps length. Understanding the function of these complexes and their interactions with sugar-producing metabolic pathways will be important for eventually controlling cell-wall composition. A number of cellulose synthase genes have been cloned for a variety of plants.



Cellulose synthase complexes

* Containing β-1,4-linkages

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