THE PLANT CELL WALL

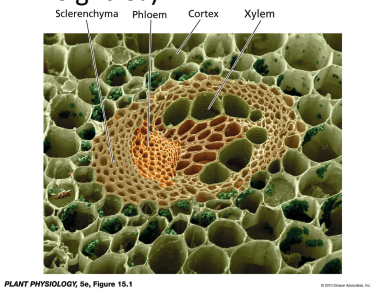
A. Introduction.

= *a tough coat of polysaccharides and proteins, which surrounds the plant cell external to the plasmalemma.*

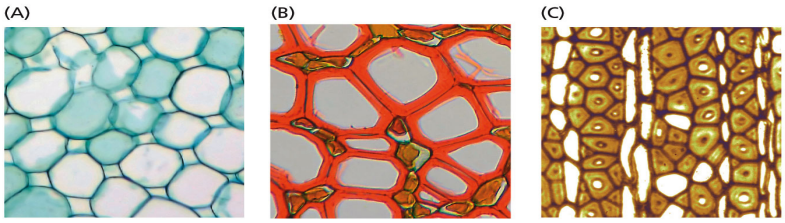
- acts as "extracellular" matrix, semi-rigid, **integral** to cell
- is a major **long-term sink of fixed carbon** in the biosphere (cellulose & lignin).
- **dynamic** structure: sensitive to environment, developmental signals, external stresses

Biological importance of the CW:

- structural support for plants (via turgor). In specialized cells, lignin further strengthens the CW
- gives plant cells shape, tied closely to cell development. [Protoplasts are cells w/o CWs, round]
- gives protection from pathogens, and acts as stress sensors to invasion and damage
- facilitates water movement between cells (capillary action of carbohydrates in CW)
- are the primary point of contact with the environment, including neighboring cells (positional signals?)



PLANT PHYSIOLOGY, 5e, Figure 15.1



PLANT PHYSIOLOGY, 5e, Figure 15.3 © 2010 Sinauer Associates, Inc.

Practical importance of the CW:

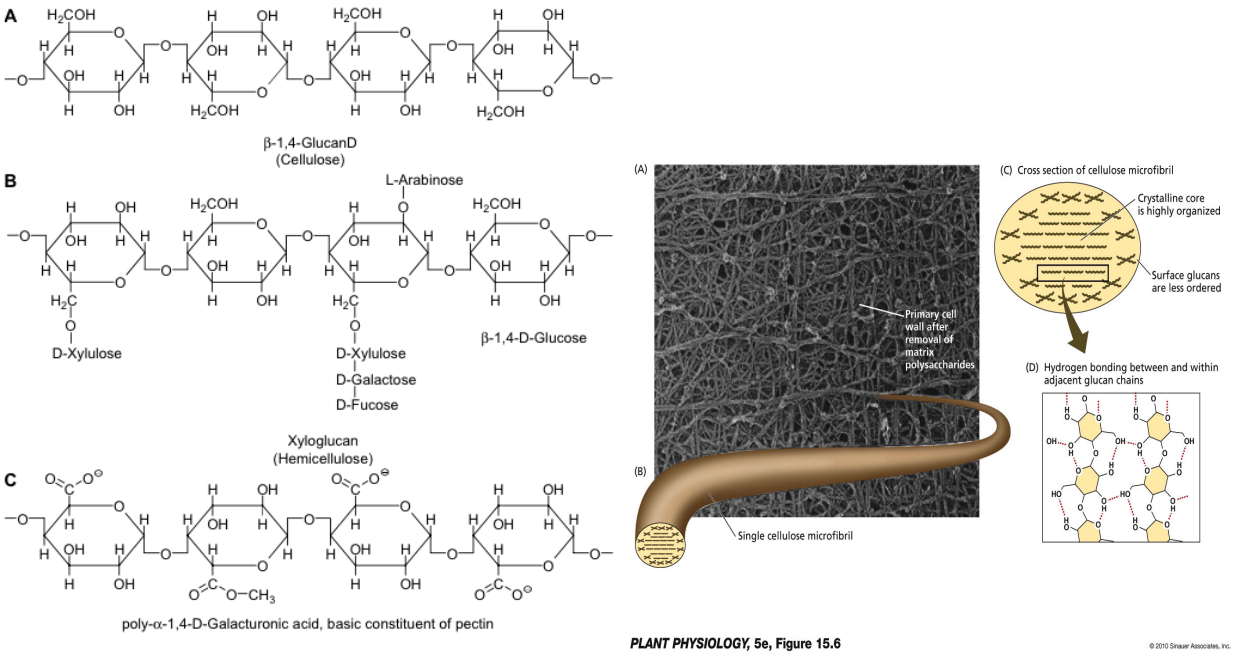
- importance of industrial fiber (cotton, flax, hemp)
- health / dietary fiber (ß-glucans in the diet postivitely affect cholesterol, insulin levels)
- source of 'solar' energy - > biofuels from cellulose?

General features:

- primary CWs can expand, found all plant cells
- secondary CWs develop:

only in specialized cells

- permeable to small molecules only, but larger molecules may go thru plasmodesmata (virus mov't)



B. Cell wall components

*- composed of cellulose **micro-** and **macro-fibrils** in a complex **matrix** of carbohydrate and protein (similar to cloth and resin of fiberglass)*

1. Microfibrils (cellulose)

- unbranched ß-(1->4) glucose polymer [the repeating unit is called 'cellobiose']
  [note ß anomers of glucose is used, unlike starch which is α-1,4 linked glucose]
- microfibrils are stabilized by H-bonds (intra-, inter-molecular)
  - 36 glucose chains make up one microfibril, many of these are coiled into macrofibrils
- arrangement of fibrils around the cell like a "slinky" permits expansion of the cell along long axis

2. Matrix (a very complex "glue", subdivided empirically by extraction methods, and can be quite variable)

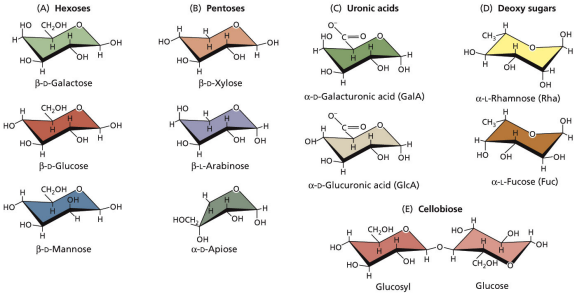
- contains pentoses, hexoses, deoxy sugars (review nomenclature and sugar structures?

Hemicellulose (**xyloglucan**- alkali or KOH extracted)

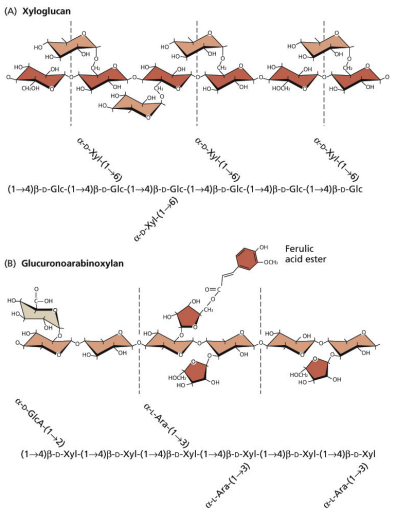
- composed of **ß(1->4) glucose** with **xylose** sidechains
- also contain many **arabinose**, **galactose**, **fucose subunits** linked to **xylose**
- xyloglucan forms "adaptors" with cellulose and crosslinks microfibrils
- hemicellulose also contains: glucuronoarabinoxylan, especially common in grasses.

Pectic polysaccharides (pectin - boiling H_2O extracted)

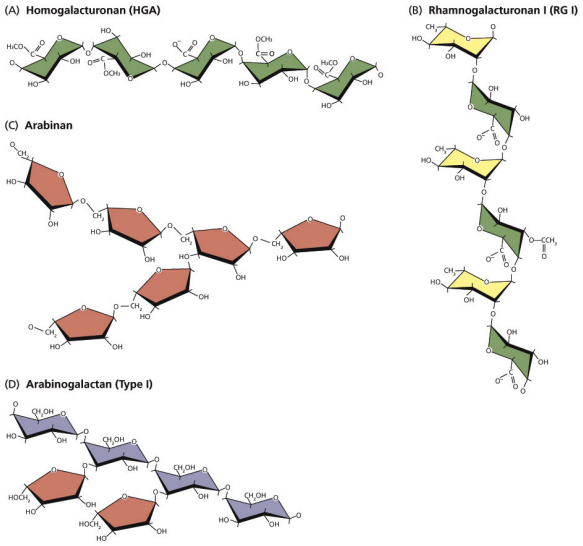
- stabilize and bind water to make a "hydrated gel"
- key component is **polygalacturonic acid**
- typcially abundant in middle lamella,
- other sugars: **arabinose**, **rhamnose** {->arabinogalactans, rhamnogalacturonan][these can link to borate]
- carboxyl interaction with Ca^{++}, pectin methylesterase remove methyl groups after export from the cell, and thus expose the charge.



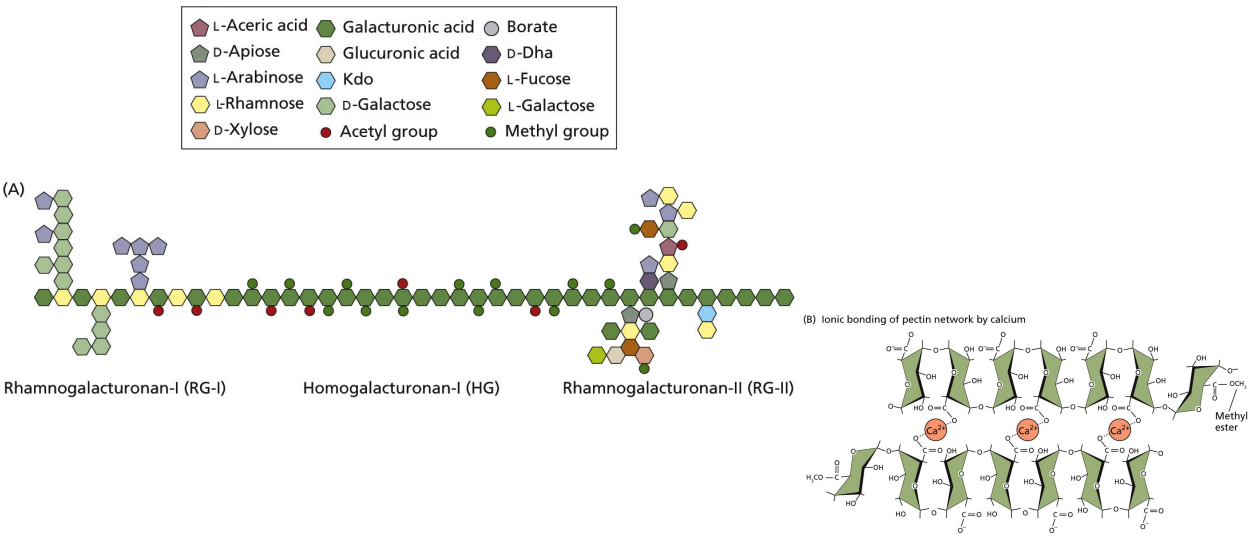
***PLANT PHYSIOLOGY*, 5e, Figure 15.5**



***PLANT PHYSIOLOGY*, 5e, Figure 15.10**



***PLANT PHYSIOLOGY*, 5e, Figure 15.11**



***PLANT PHYSIOLOGY*, 5e, Figure 15.13 (Part 1)**

***PLANT PHYSIOLOGY*, 5e, Figure 15.13 (Part 2)**

3. CW Proteins [structural & enzymes]**:**

Structural Proteins in CW:

- usually heavily glycosylated, linked to polysaccharides
- typcially contain simple, repeated sequences of amino acids

Common structural CW proteins

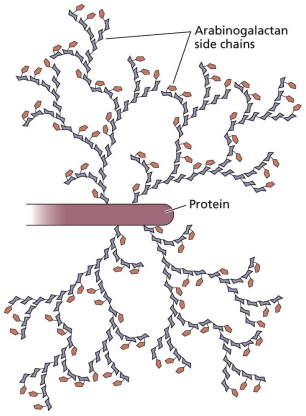
- Hydroxyproline-rich glycoproteins (HRGPs, (extensin)

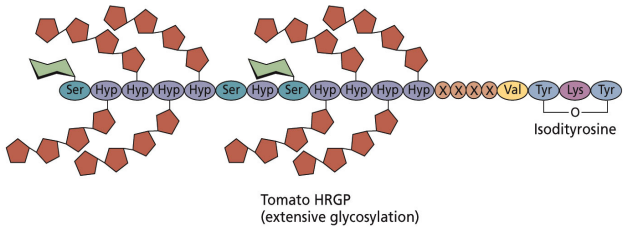
[...-ser-hyp-hyp-hyp-hyp-ser etc...tyr-lys-tyr] - glycosylated

- Glycine-rich proteins (GRPs) [...-gly-gly-X-...]
- Proline-rich proteins (PRPs) [pro, hyp]
- Arabinogalactan-proteins (AGPs) : typically 90% carbohydrate!

Enzymes - [see dynamic nature of CW, later]:

- ß-glucanase, polygalacturonase -
- xyloglucan endotransglycosylase (XET) -
- expansins - proteins which loosen H-bonds in CW





Tomato HRGP
(extensive glycosylation)

PLANT PHYSIOLOGY, 5e, Figure 15.15

© 2010 Sinauer Associates, Inc.

PLANT PHYSIOLOGY, 5e, Figure 15.14

© 2010 Sinauer Associates, Inc.

PLA

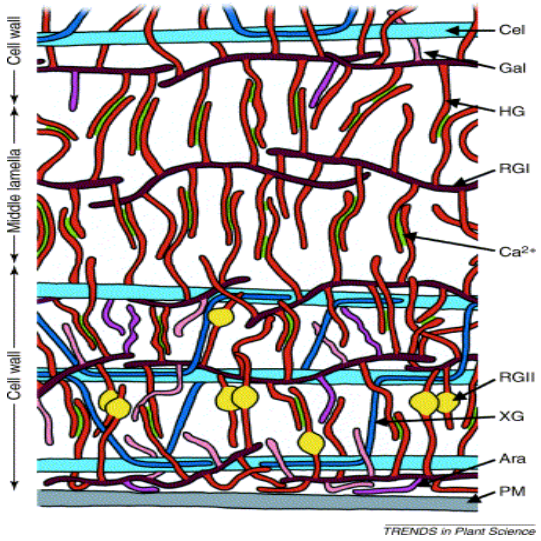
10 Sinauer Associates, Inc.

PLANT PHYSIOLOGY, 5e, Figure 15.14

© 2010 Sinauer Associates, Inc.

4. Model of polysaccharides in primary CW

- xyloglucans H-bond to microfibrils (MFs), crosslink MFs
- pectins make connections between MF's via xyloglucans, which act like 'adaptors'
  - pectins also connect to CW proteins, act as hydrophilic filler



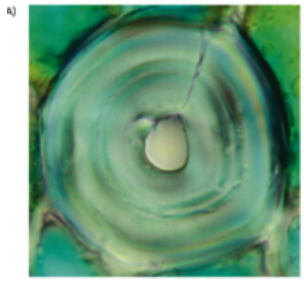
5. Secondary CW

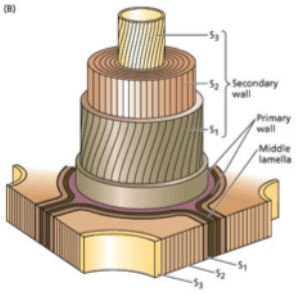
- more xylan and less xyloglucan, making polymers less branched, tighter fibrils
- lots of **glucomannose**
- secondary CW is formed in **tracheids/xylem**, **fibers**, **sclereid** cells (mechanical support)

6. Lignin:

= high MW polymer, in matrix, derived from phenylalanine (see later lectures)

- predominantly in xylem (i.e., wood), where it makes up 30% DW
- resists crushing forces, important because xylems is dead at maturity.





C. Summary of CW & Biosynthesis

- primary CW:

cellulose	20-30%
hemicellulose (xyloglucan)	25 %
pectic substances	30%
proteins	5-10%

- secondary CW: up to 90 % cellulose
- wood: 40 % cellulose, 30 %hemi-cellulose, 30 % lignin
- there are both homo- and hetero-polymers

Biosynthesis of cellulose and CW

Components all get exported NB: Assembly in situ

i) cellulose: - **cellulose synthase** is organized into **rosettes** (hexamer), visible by electron microscopy.

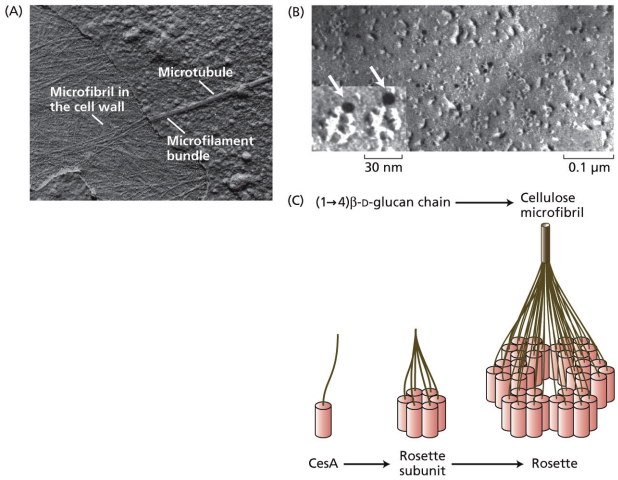
= "sugar nucleotide polysaccharide glycosyl transferase"

- encoded by **CesA gene**s. This is a large family, with 10 CesA genes in Arabidopsis, and a large number of CesA-like genes that encode other glucosyltransferases for CW synthesis

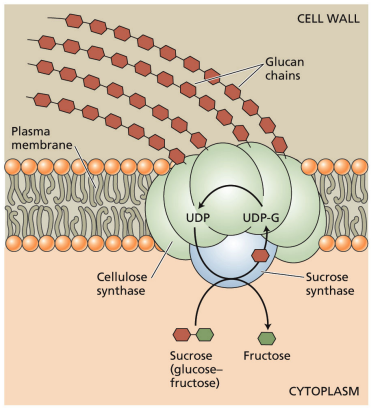
- embedded guided by microtubules of cytoskeleton (see double-labele experiment
  - Sucrose synthase (associated) provides **UDP-glucose**, which is the immediate substrate

ii) xyloglucans and pectic substances: secretory pathway and Golgi, assembly in CW space

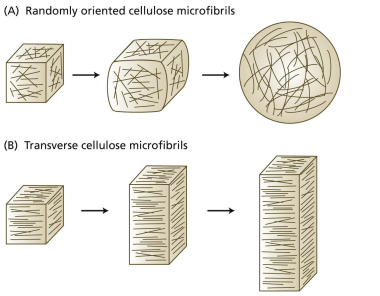
iii) proteins - secreted via Golgi, and then attached to matrix in the CW space



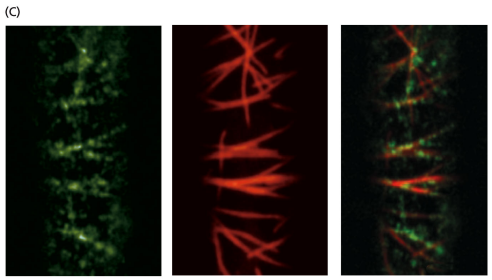
PLANT PHYSIOLOGY, 5e, Figure 15.7



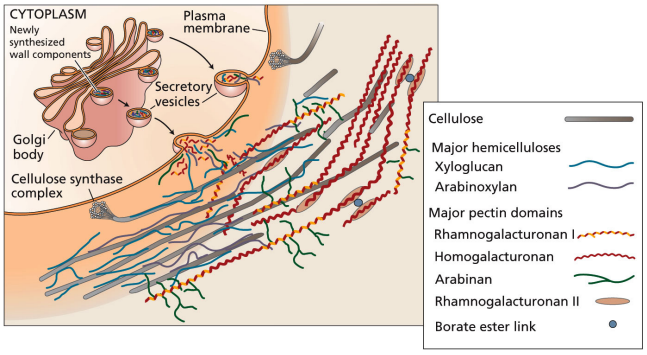
PLANT PHYSIOLOGY, 5e, Figure 15.8



PLANT PHYSIOLOGY, 5e, Figure 15.20



PLANT PHYSIOLOGY, 5e, Figure 15.23 (Part 2)



PLANT PHYSIOLOGY, 5e, Figure 15.4