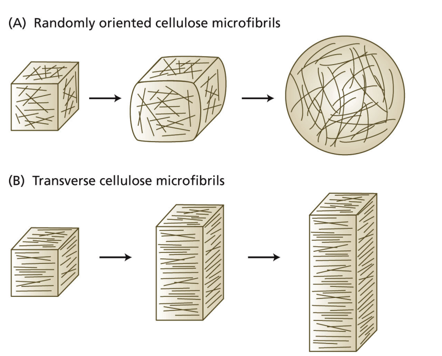
The Dynamic Nature of the Cell Wall

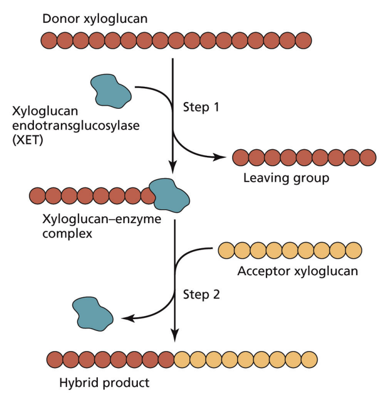
Introduction: The cell wall is a dynamic structure that allows the plant cell to grow and to adapt to external stresses.

Example 1: Cell wall loosening during cell expansion

- growth is "plastic, not elastic", and is diffuse (not at the end but along the whole cell)
- the arrangement of microfibrils (slinky, or hoops around a barrel) is critical to facilitate growth as the microfibrils slide against each other
- enzymes to loosen matrix, turgor expands CW
  - i) **ß(1->4) endoglucanase** (hydrolyses xyloglucan or non-crystalline cellulose)
  - ii) **xyloglucan endotransglycosylase (XET)** - breaks glycosidic bonds of **xyloglucan backbone**, and transfers polysaccharide chains to new acceptor xyloglucans
  - iii) **expansin** - proteins that l**oosen xyloglucan/cellulose H-bond**s via pH activation (see the "acid growth" hypothesis. Can be assayed by hypocotyl and filter paper experiments.
    - after expansion (final cell size), CW is 'locked' into final shape by **HRGP crosslinks** & **desterification** of pectins.



PLANT PHYSIOLOGY, 5e, Figure 15.20



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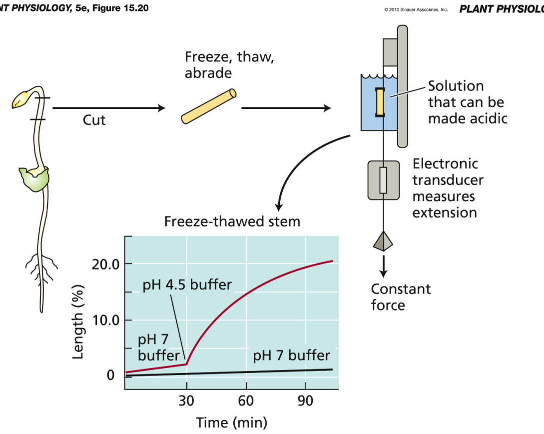
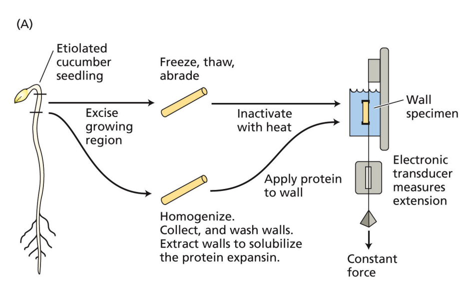
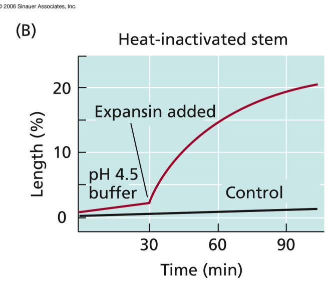


PLANT PHYSIOLOGY, Fourth Edition, Figure 15.26





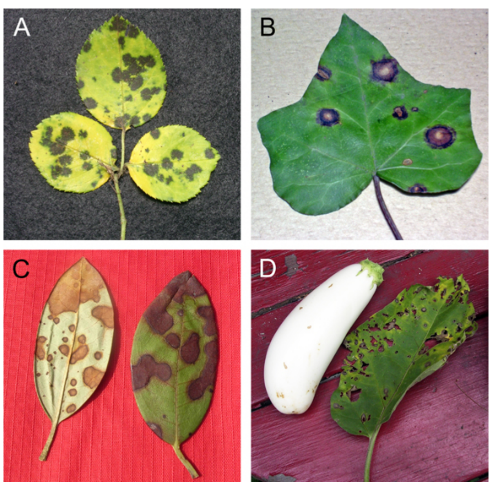
Example 2: **Defense against plant pathogens:** CW as a **barrier** to entry and a p**athogen sensor**
- CW is a physical barrier to pathogen, needs to be broken or breached. [there are also other defenses, such as defense proteins and toxins called phytoalexins, see below.]

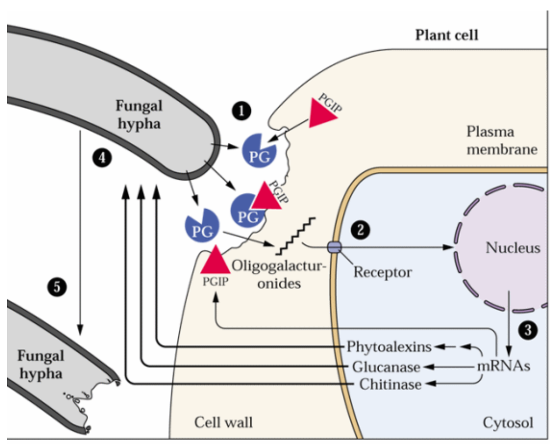
Some background on Plant Pathogens

i) **phytopathogenic bacteria:**
- cannot enter cells.
-remain extracellular, and thus kill plant cells 'from the outside', but absorb nutrients
- secrete toxins and CW-degrading enzymes (i.e., *pectate lyase*) into the plant

ii) **fungal pathogens** are classified as:

Necrotrophs - also kill cells first, then absorb nutrients that are release (require dead cells for nutrition)
- often secrete polygalacturonases which attack the plant CW (**=arms race**)
---> to defend themselves, plants can secrete **polygalacturonase inhibitory proteins** (PGIPs), as well as **chitinases** and **ß-glucanases**

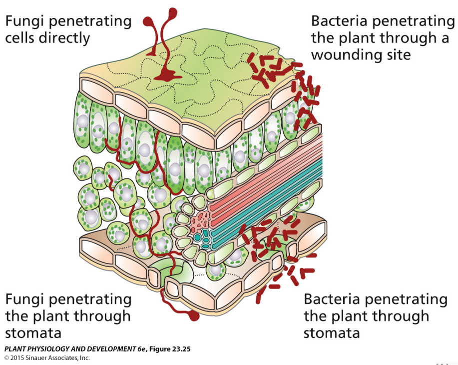


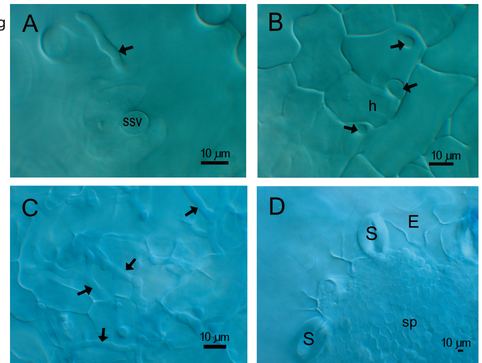


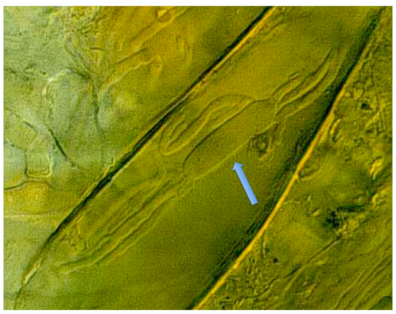
Biotrophs - require living cells and tissues to grow and reproduce (cannot be grown in culture)
- use **haustorium** to absorb nutrients (note special absorptive membrane)
- need a **penetration peg** to 'drill' into the cell and establish internal hyphae and haustoria
- to be successful, they must actively suppress plant defense responses - very sneaky

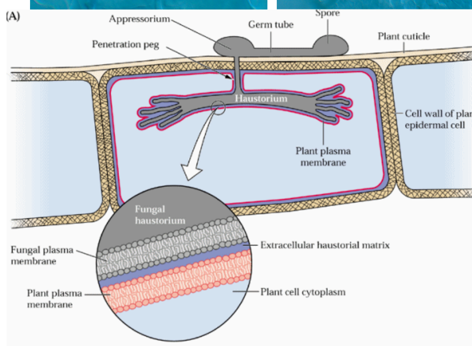
See example of poplar rust fungus *Melampsora medusae* - super sneaky pathogen that stays well below the plant's radar!

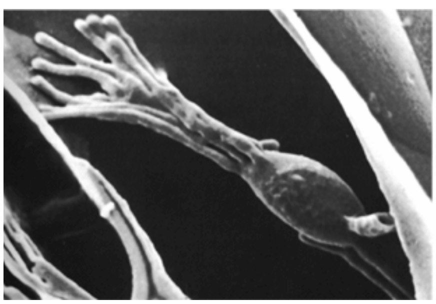
Plant defense against biotrophs can take many forms.:
- increased **HRGP** synthesis to reinforce the CW.
- crosslinking of **PRPs** (=disappearance from extracts), reinforce CW
- **papillae** formation to block penetration (**callose: ß1,3 glucose**), CW proteins.
- ultimately, the cells can trigger **hypersensitive response** (cell death), depriving pathogen of nutrients
- this is typically an active process, involving gene expression and protein synthesis

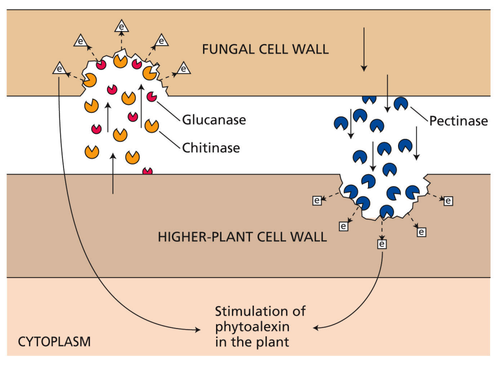












How do plants know they are being invaded? What triggers these active defenses?

-> pathogen-derived elicitors: molecules that are recognized by the plant and stimulate defense mechanisms

i) peptides, ie systemin or flag22, derived from bacterial flagellin fragment

ii) **plant-derived CW fragments**:

- xyloglucan nonasaccharide
- oligogalacturonide (n=11-14)

ii) **pathogen-derived CW** fragments:

- hepta ß-glucoside
- oligochitin (oligo N-acetyl glucosamine)

Note high degree of specificity! (***Group Discussion/Assignment***).

Pathogen signals are sometimes referred to as **MAMPs** (microbe associated molecular patterns), as well as **DAMPs** (damage-associated molecular patterns)

The Plant CW is potentially huge source of biofuels

- there is a large amount of biomass in plant CWs (polysaccharide that make up the polymeric structures)
- but, it is difficult to get the energy stored in these polymers as they cannot be broken up or digested easily (takes lots of energy and harsh chemical treatments)
- thus we we need to understand CW structure, to be able to modify or select the best source

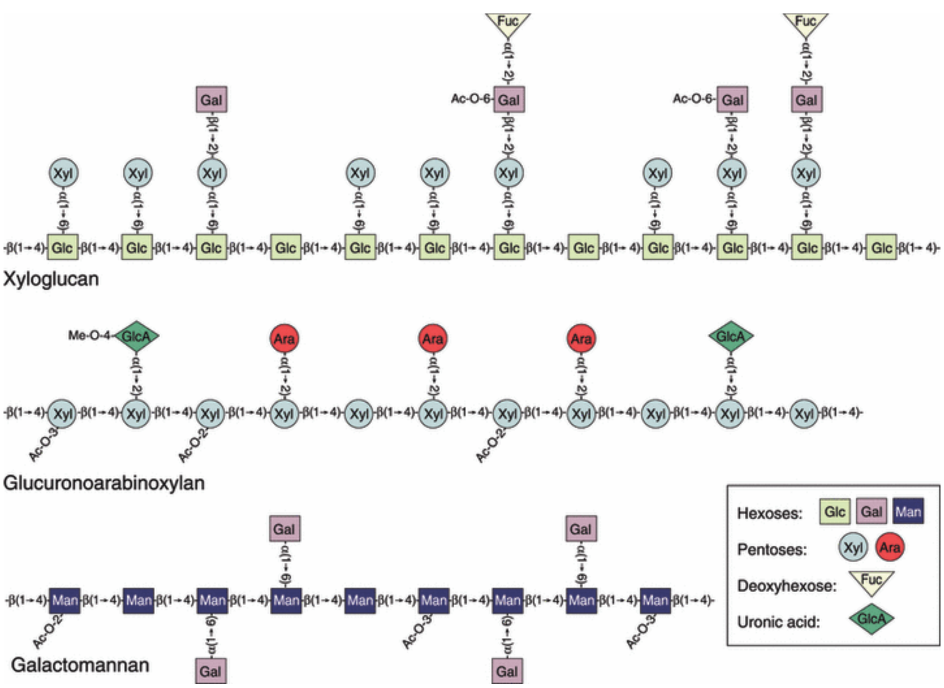
1. Biofuels problem: need a transportable form of energy

2. CW sugars can be fermented to ethanol by microbes

3. Where are the bottlenecks?
    - ironically, the CW evolved in part to resist microbial attack
    - the sugars are not easily accessible to microbial enzymes (especially crystalline cellulose)
    - hemicelluloses are very variable in composition

4. Attempts to modify the CW for cellulosic biofuels
    i) decrease crystalline cellulose
    ii) reduce H-bonding of xyloglucan, modify the structure
    iii) less pentoses (arabinose, xylose), more hexose (mannose, glucose)
    iv) reduce lignin content

[Can these by modified and still have a viable plant?]



Pauly and Keegstra (2008) Plant J. 54, 559-568