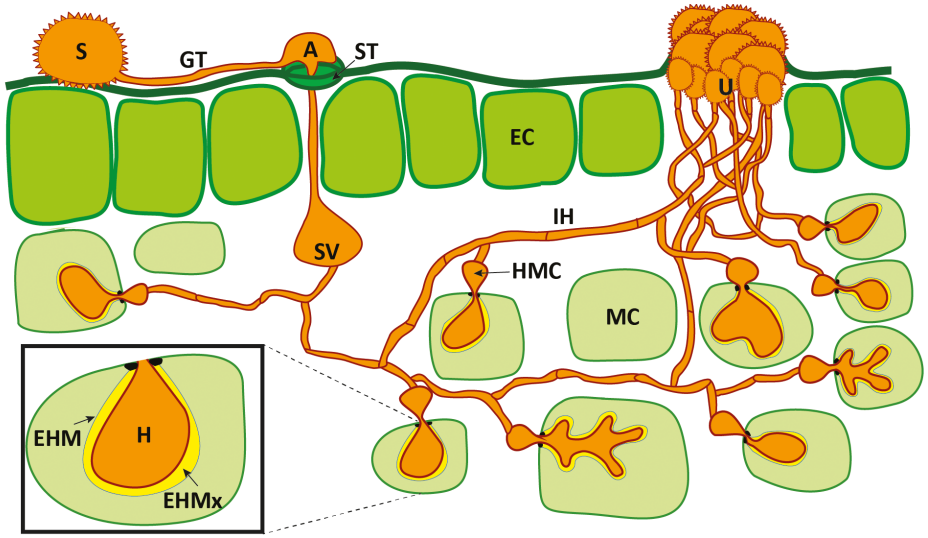
Tree defense against pathogens

Pathogens penetrate and ‘feed’ on trees differently than insects

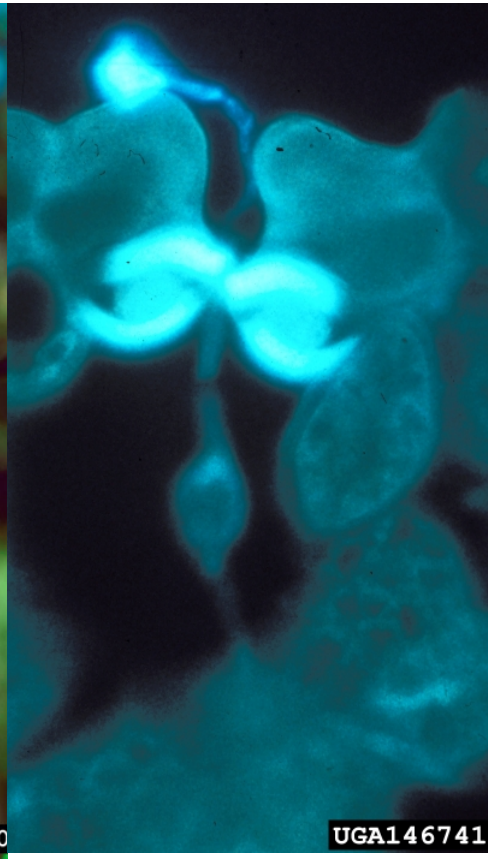
- Insects ingest tree foliage or stem tissue and digest it internally; they usually don’t invade host cells
- Pathogens generally digest their food externally by secreting enzymes and then importing the broken down products (sugars, nutrients)
- Pathogens can penetrate host cells



Garnica DP, et.al (2014) PLoS Pathog 10(9): e1004329.

Biotrophic pathogens can enter their host by using natural openings

- Biotrophic pathogens require a living host
- They can enter the host by using the natural openings in the host (the ‘sneaky’ mode of entry)
- Stomata, lenticels are natural openings that are used for gas exchanges



Necrotrophic pathogens enter their host by producing chemical compounds

- Necrotrophic pathogens produce many chemical compounds that can cause cell death
- These are secondary metabolites called phytotoxins
- Once the cells are dead, the pathogen can colonize them and feed on the substrate

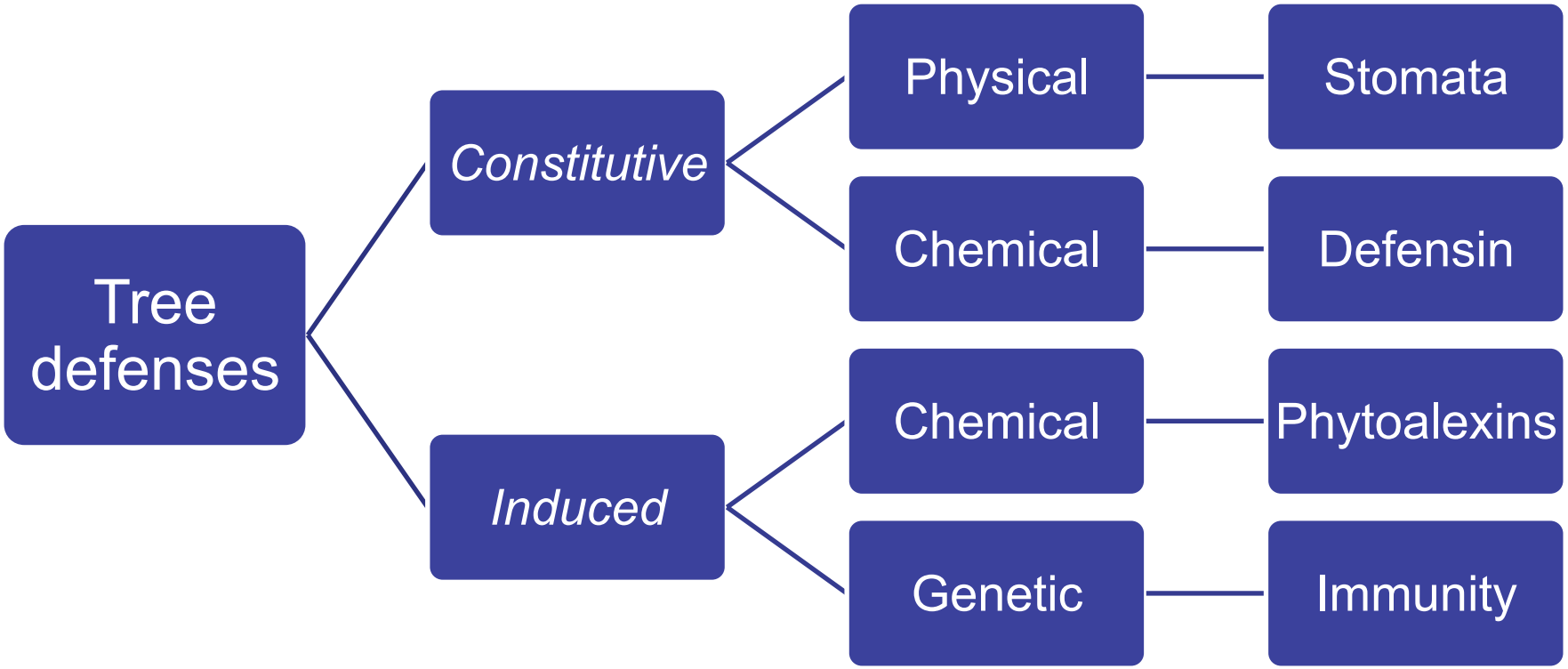
Vectored pathogens enter their host by hitchhiking on an insect

- Insects are very efficient vectors of pathogens
- The relationship can be direct and mutualistic: Dutch elm disease
- The relationship can also be loose or indirect: e.g. beech bark disease

Opportunistic pathogens can enter their host by using natural injuries

- Opportunistic pathogens or saprophytes can enter the host by using natural injuries
- These can be part of the natural tree development, such as branch stubs or wounds caused by other pathogens (e.g. Dwarf mistletoe brooms)

Trees have similar defenses against pathogens and insects

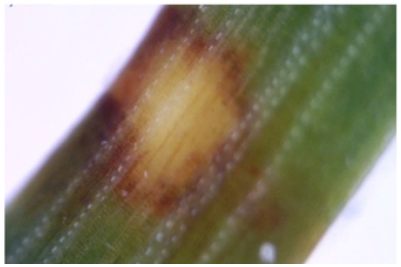


Trees possess constitutive barriers against pathogens

- Constitutive physical barriers
  - bark, wax layers, cell walls, stomata, lenticels
- Constitutive chemical barriers
  - pH, nutrient deprivation
  - suberin, defensin

Trees have developed unique induced defenses against pathogens

- Induced defenses: chemical
  - phytoalexins: plant toxins that specific inhibit a pathogen
- Induced defenses: genetic
  - plant immune response
  - hypersensitive reaction



Constitutive physical barriers: controlling stomata

- Stomata are natural openings that allow gas exchange
- The number and density of stomata can vary, directly affecting the likelihood of entry by a pathogen
- Plants can actively close their stomata in response to environmental stimuli and to pathogen attacks

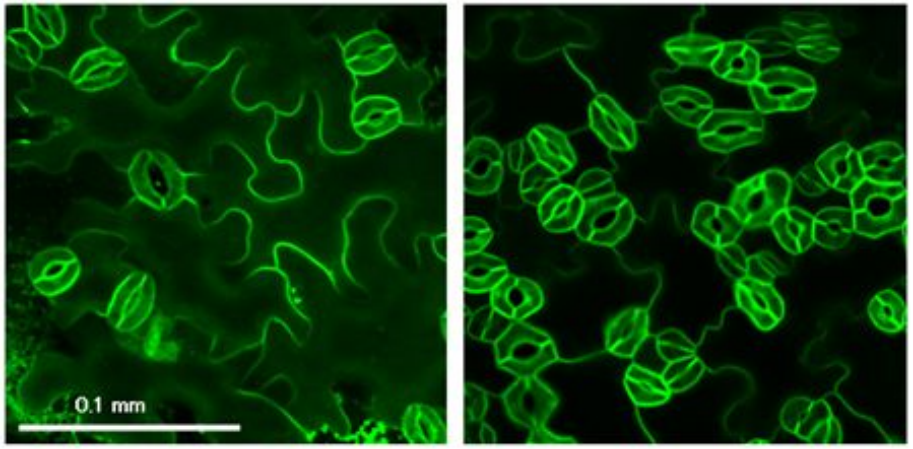
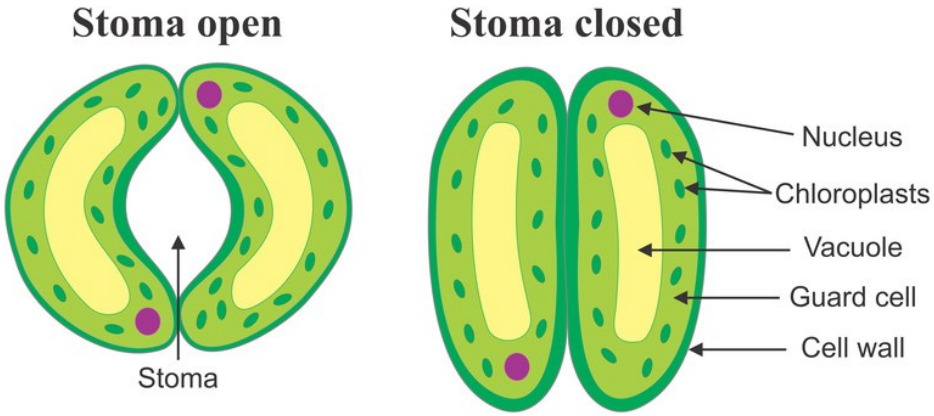


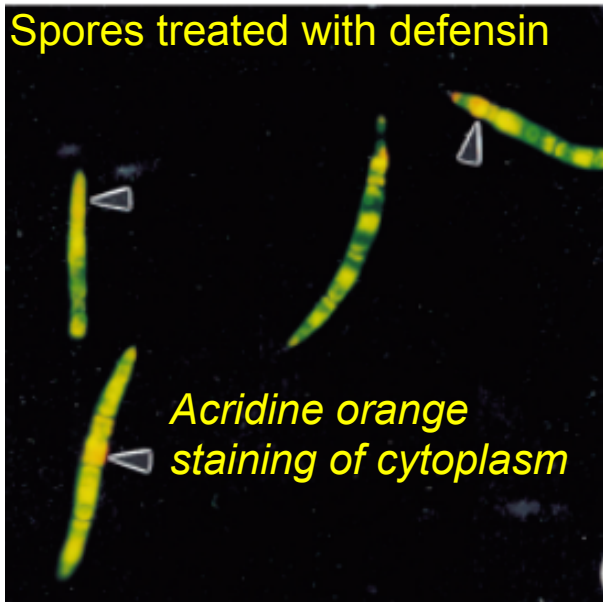
Photo Kyoto University



Drawing biology champs

Constitutive chemical barriers: defensins

- Defensins are peptides (short proteins) produced by plants that inhibit the growth of fungi, bacteria and viruses
- They are not induced but instead are produced constitutively
- Interfere with pathogen nutrition, delay their development, or cause structural changes to cell walls



Active chemical defense: phytoalexins

- Phytoalexins are antimicrobial compounds produced by plants
- They are synthesized *de novo* and accumulate rapidly at areas of pathogen infection
- Phytoalexins may puncture cell walls, delay maturation, disrupt metabolism or prevent pathogen reproduction

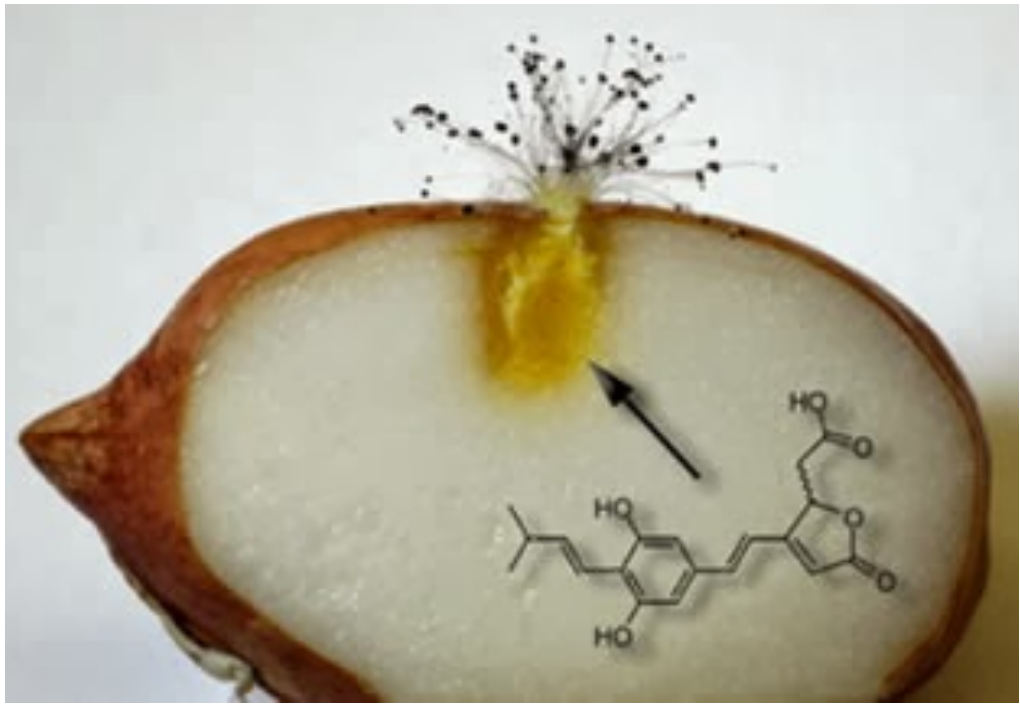
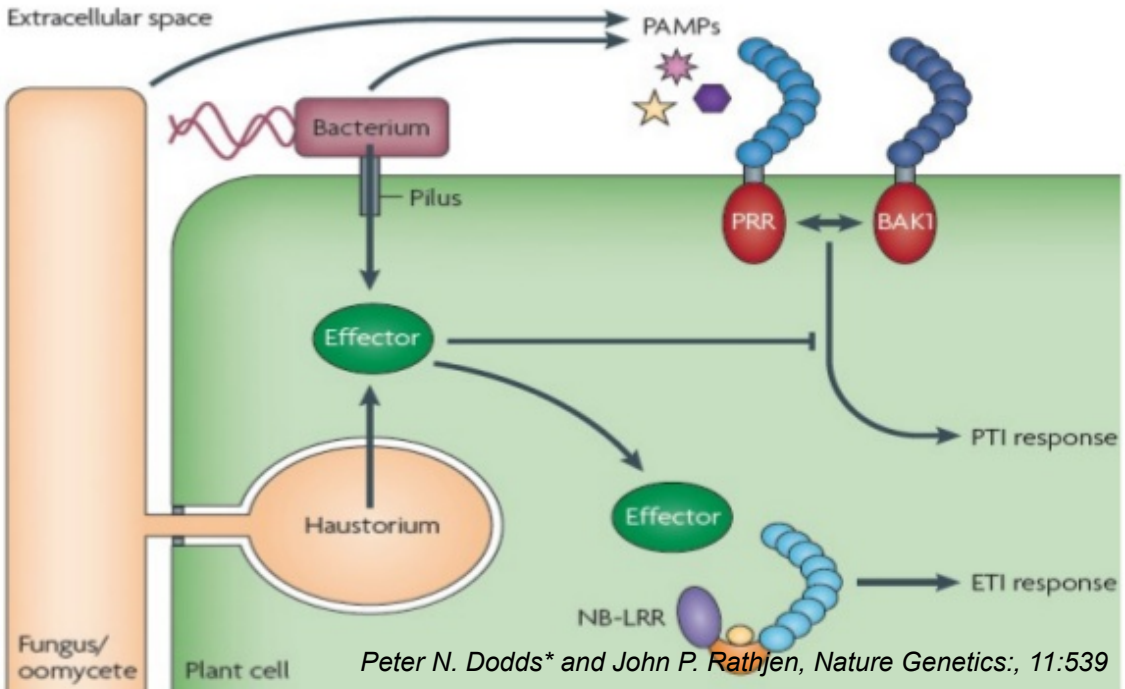


Photo Dr. Art Ayers

Active genetic defense: the plant immune system

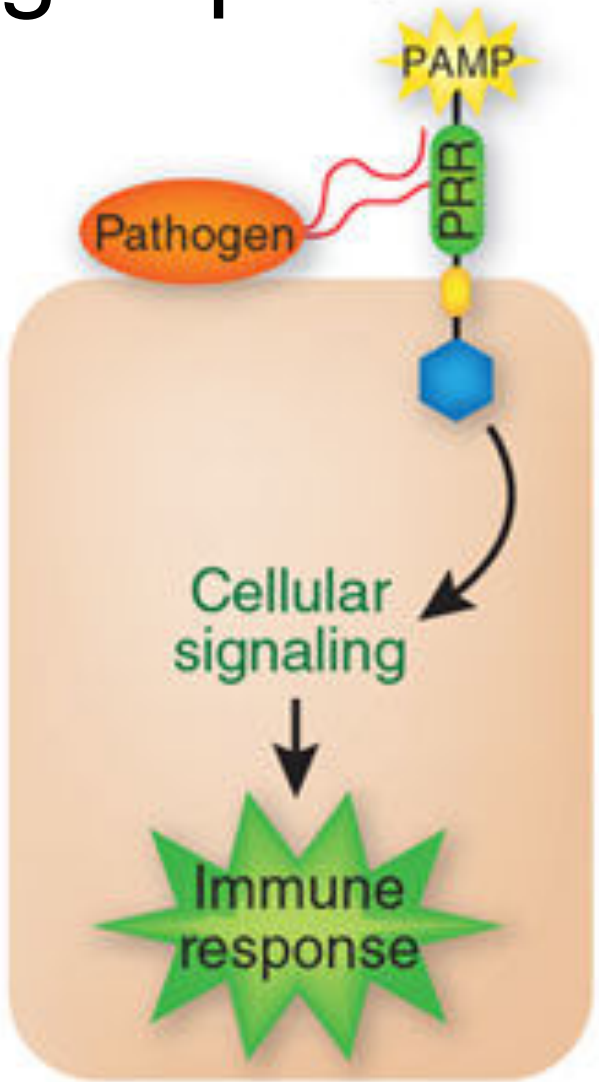
- The plant immune system carries two types of receptors: one type senses molecules outside and the other one senses molecules inside the cell
- Both systems detect intruders and respond by activating antimicrobial defenses in the infected cell and neighboring cells



Peter N. Dodds and John P. Rathjen, Nature Genetics:, 11:539*

The plant immune system: recognition of pathogen pattern

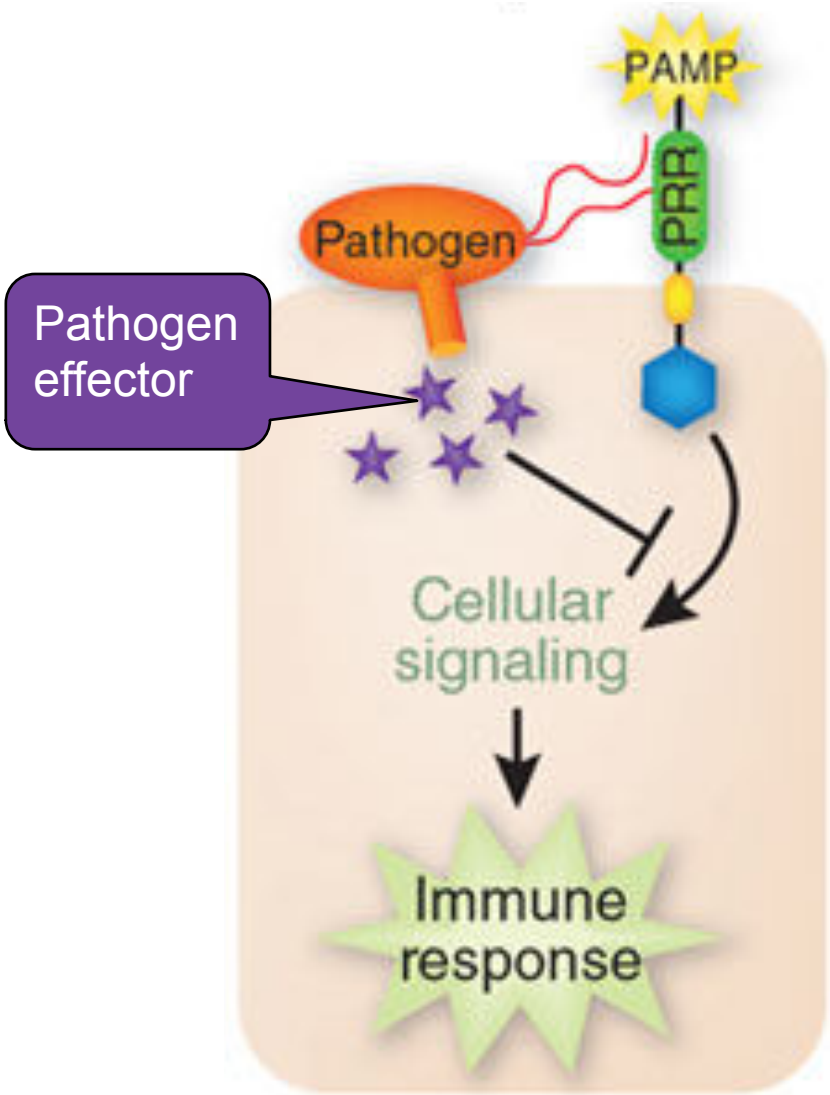
- First tier of the plant immune system based on the recognition of common pathogen components (it's called Pathogen Associated Molecular Patterns; PAMP)
- Usually essential to the pathogen and do not exist in host; e.g. chitin, the major component of the fungal cell wall, is a PAMP



*Corné M J Pieterse, Antonio Leon-Reyes, Sjoerd Van der Ent & Saskia C M Van Wees Nature Chemical Biology **5**, 308 - 316 (2009) Published online: 17 April 2009*

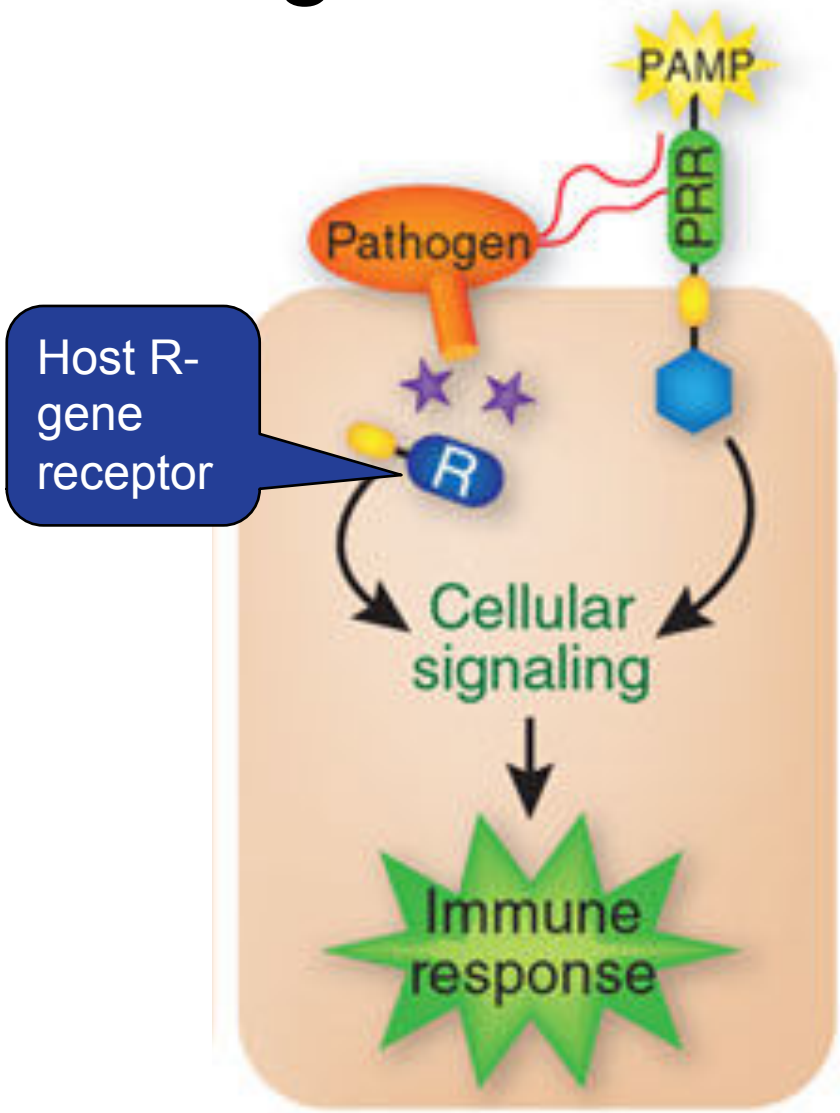
The plant immune system: the pathogen fights back with effectors

- Pathogen effectors are proteins that are delivered inside the host
- Effectors manipulate the host to facilitate development of disease
- Effectors can block the host response to PAMPs and make it possible for the pathogen to invade host cells



The plant immune system: the host responds with R-genes

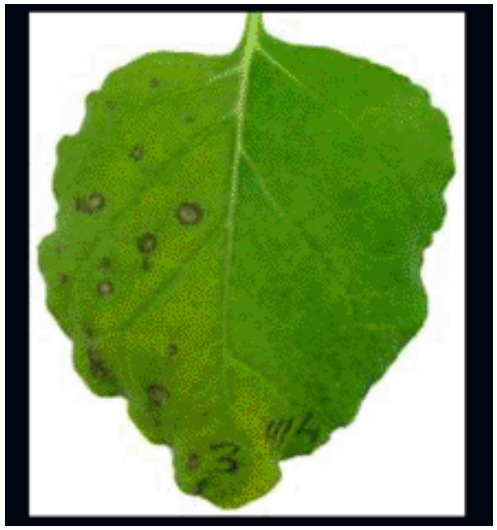
- Plants have developed receptors that are activated by effectors (commonly called resistance genes or R-genes)
- R-gene products are proteins that recognize specific pathogen effectors, can directly bind to the effector and activate the immune response



The plant immune system: hypersensitive response

- Following recognition of a pathogen and/or of effector, the plant triggers a hypersensitive response (HR)
- HR causes the rapid death of the host cells in the local region surrounding an infection
- The HR restricts the growth and spread of pathogens to other parts of the plant

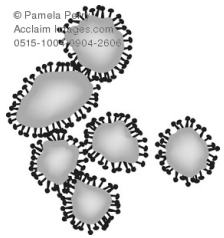
No hypersensitive response



Hypersensitive response

Recapitulation of tree defense

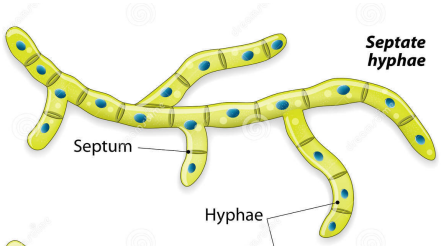
Constitutive defense



Host penetration: openings, injuries, vectors

Bark, stomata closing, defensins

Induced defense



PAMP: e.g. chitin

PAMP triggered immunity

Secrete effectors

Effector receptor leading to immunity, HR