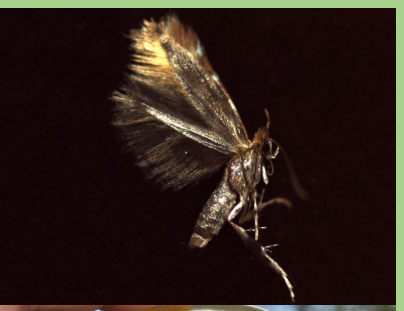
universität freiburg

FOREST PATHOLOGY



02.06.25 – 27.06.25

at the Chair of Pathology of Trees

Lecturers: Yasin Korkmaz and Kathrin Blumenstein

Defense methods and the immune system of trees

Lecture 5

https://www.spreadshirt.at/shop/design/boxender+baum+sticker-D5f4e0e875fd3e47ec539d22d?sellable=jwkrOENxJrSoozwbLvAo-1459-215

Differences in Defense Mechanisms

- mechanical / physical (barriers, deterrence)
- chemical (toxic)
- ecological (symbionts)

Defense mechanisms differ:

depending on the vitality of the host plant
→weakened / stressed = few resources available

https://www.fotocommunity.de/photo/baum-im-fels-guckrohr/32190812

available nutrients

– possibility to flexibly mobilize resources?

The provision of defense mechanisms requires large energy investments!

Defense mechanisms differ

- Type of tissue

https://myloview.de/fototapete-schnecke-mit-schneckenhaus-auf-einer-baumrinde-nr-D62E633

vs.

Fotolia.de/Dieter Hawlan

- Age / consistency of the tissue

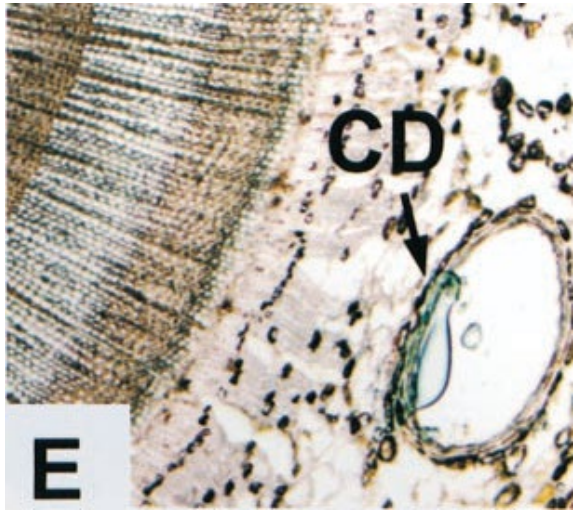
http://www.mein-garten-ratgeber.de/insekten-details/laeuse-blattlaeuse-allgemein.html

vs.

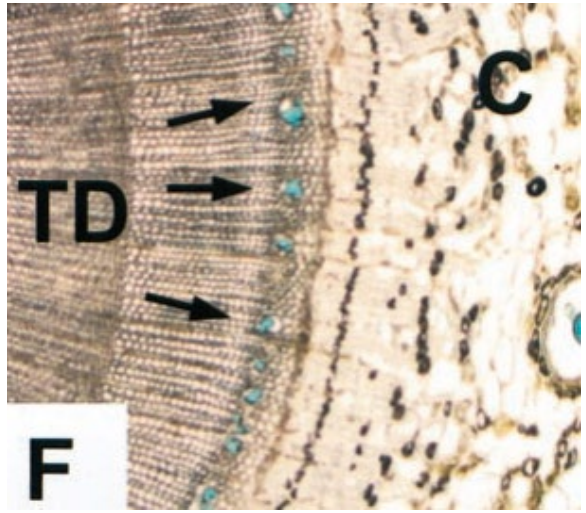
https://www.suppenhandel.de/lorbeer

Classification of Defense Mechanisms

constitutive – already present



induced – activated by damage – requires perception



Example Pine: preformed resin ducts → constitutive defense – but induced resin ducts are also possible (so-called traumatic ducts produced for bark beetle defense); Source: Martin et al. 2002

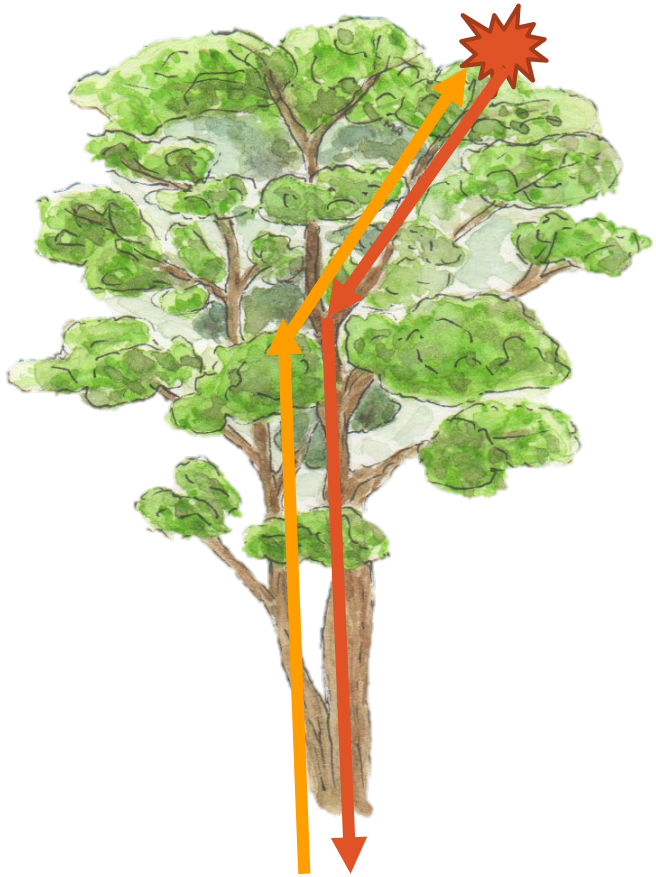
siehe Vortrag: Franziska Eberl, MPI für Chemische Ökologie Jena

Physiological Mechanisms

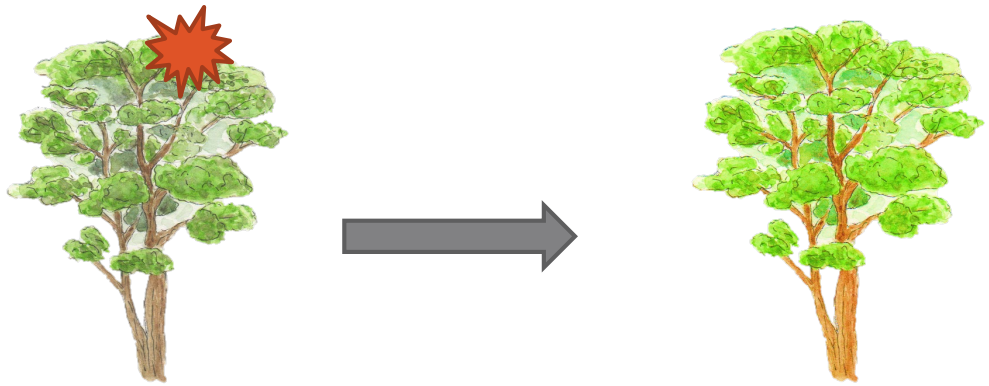
Allocation of Nutrients

- Infected tissue → storage tissue
  - deprives pathogen/herbivores of nutrients

- Storage tissue→ infected tissue
  - mobilization of resources for the formation of defense compounds



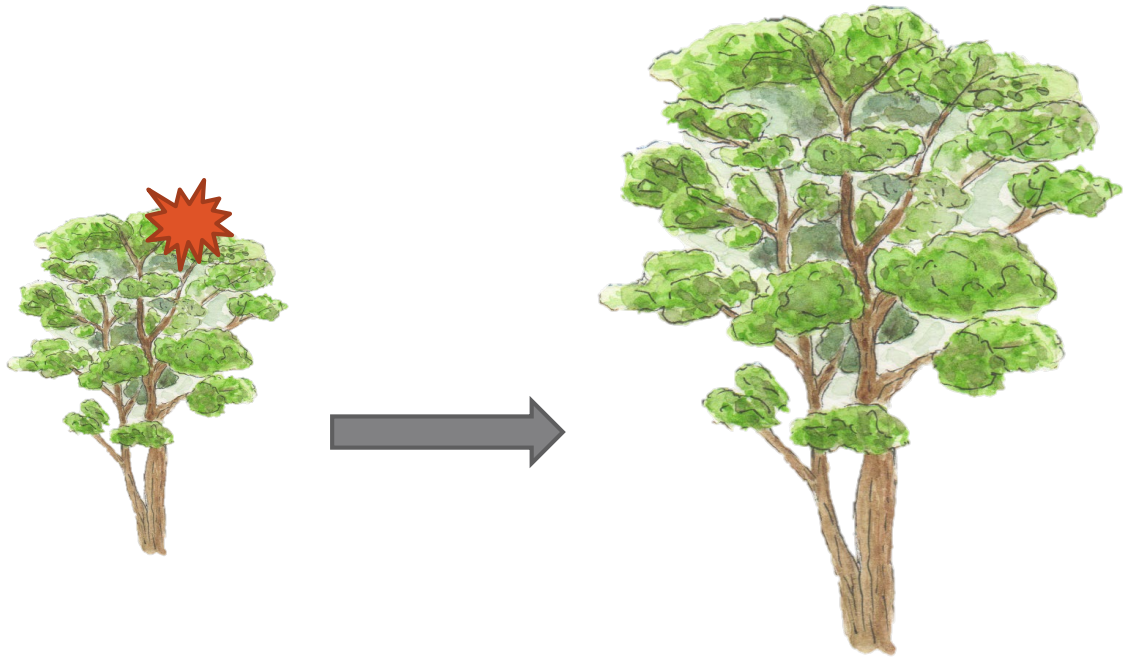
Physiological Mechanisms



Compensation

- elevated photosynthesis activity

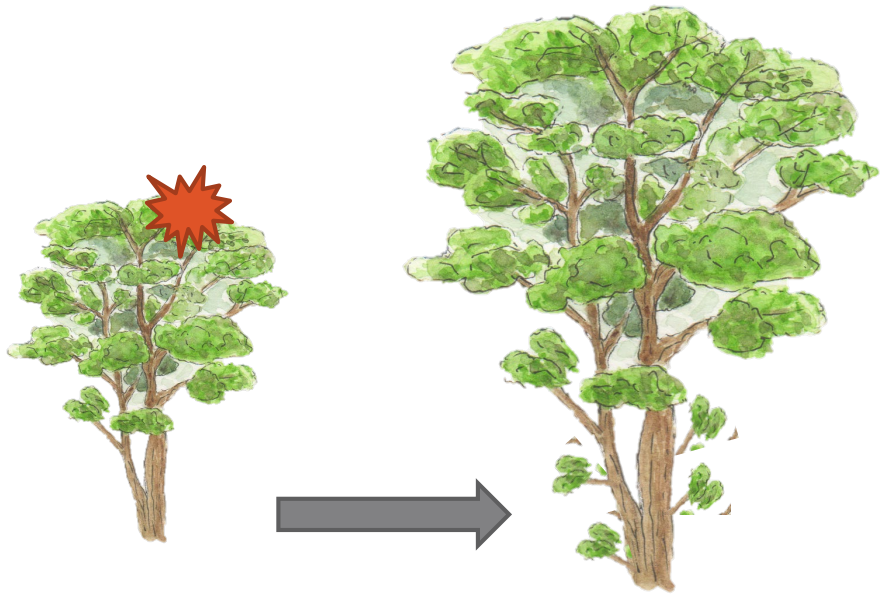
Physiological Mechanisms



Compensation

- elevated photosynthesis activity
- growth activation

Physiological Mechanisms

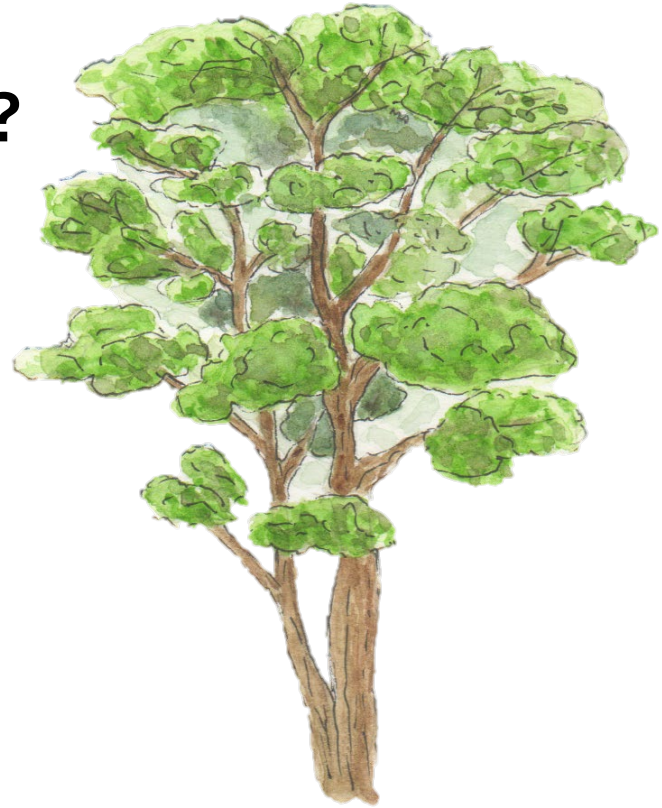


Compensation

- elevated photosynthesis activity
- growth activation
- development of new shoots

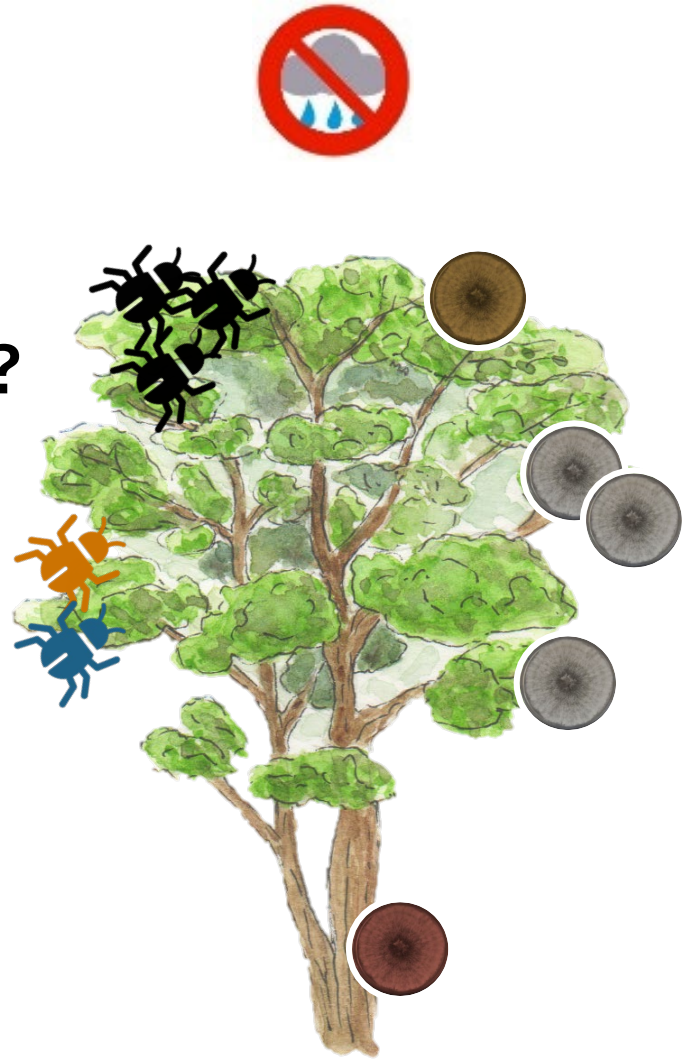
Challenges

- **Dilemma: to grow or to defend themself?**



Challenges

- **Dilemma: to grow or to defend themself?**
- Reality: multiple stressors
  - Multiple herbivores
  - Multiple pathogens
  - Herbivores + pathogens
  - Abiotic stress



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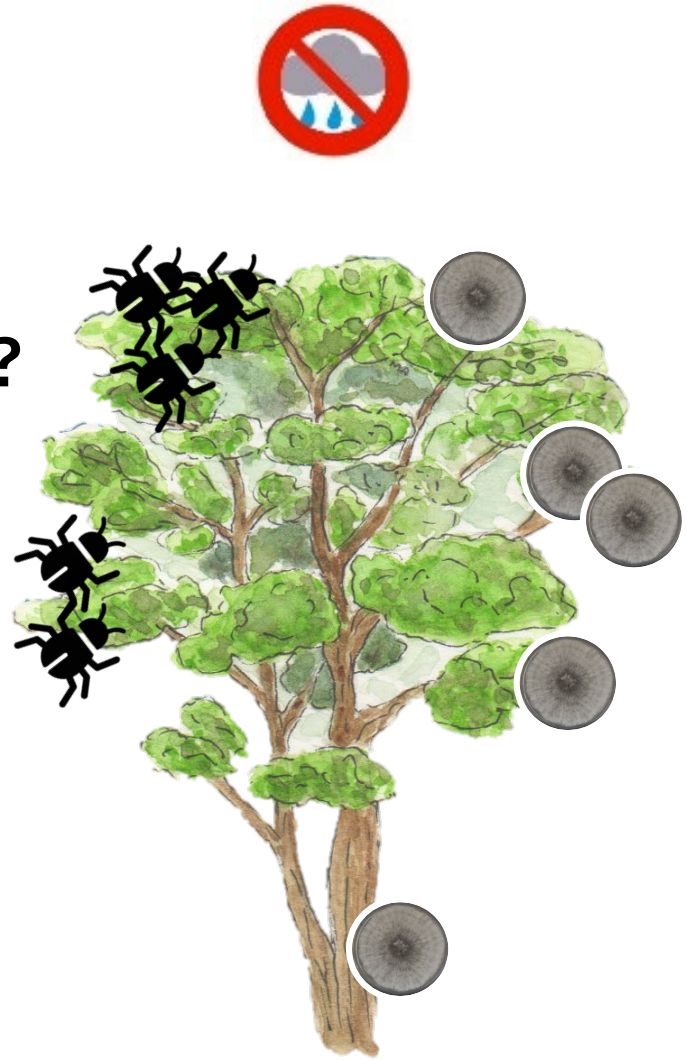


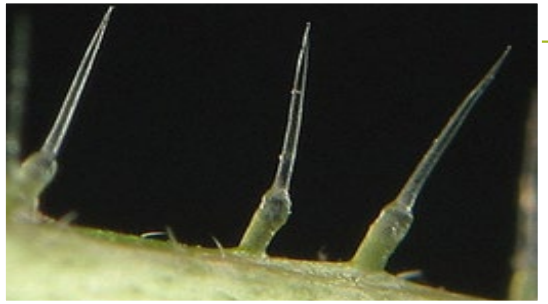
- Prioritization of resistance mechanisms
- Signal processing at the molecular level
- Allocation of resources ("trade-off")
- Influence of antagonists on each other

Mechanical / Physical

mechanical

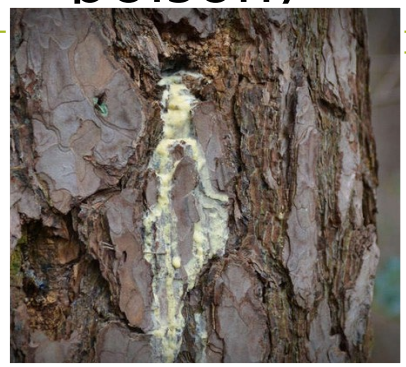
bark

wax layer on needles or leaves (cuticula)



Trichomes = hairs on leaves (especially stinging hairs with poison)

leaves or branches transformed into thorns



Resin – helpful for injuries and pest defense (it traps them)

https://naturdetektive.bfn.de/lexikon/zum-lesen/pflanzen/brennnesselalarm.html; https://www.mein-schoener-garten.de/lifestyle/natur-tiere/baumrinde-39262; https://www.baumportal.de/nadelbaeume-fuer-die-jaegerpruefung; https://www.meinbezirk.at/imst/c-lokales/die-robinie-ist-sehr-giftig_a4181433#gallery=default&pid=24211638

Natural protection against decay fungi: heartwood

- Which tree species have heartwood?

Natural protection against decay fungi: heartwood

- Pine (*Pinus* spp.)
- Oak (*Quercus* spp.)
- Sweet Chestnut (*Castanea sativa*)
- Larch (*Larix* spp.)
- Black locust (*Robinia pseudoacacia*)
- Elm (*Ulmus* spp.)
- Walnut (*Juglans* spp.)
- Douglas fir (*Pseudotsuga menziesii*)

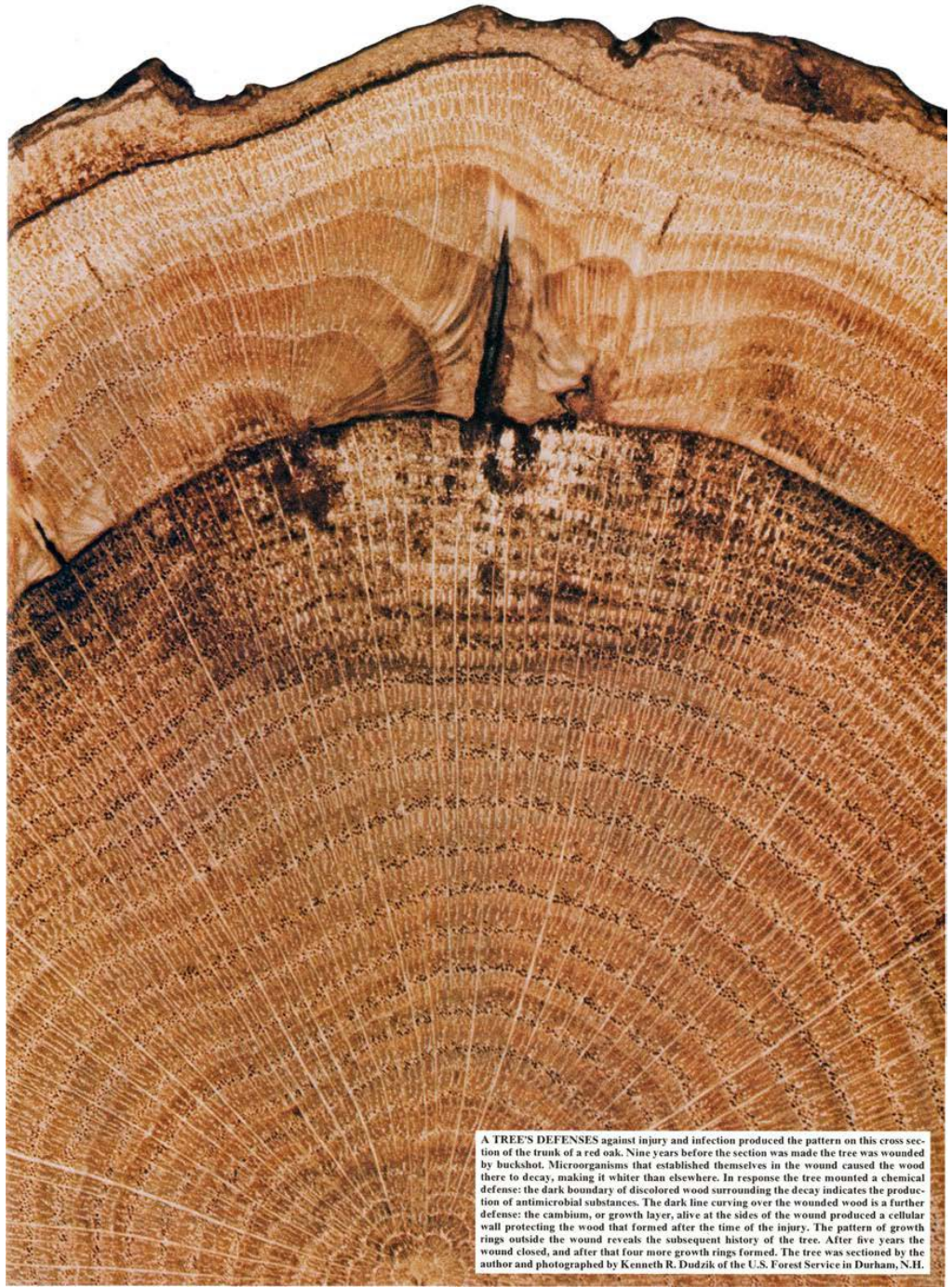
- **Dead cells in the center of the trunk contain strong phenols**
- **Difficult for fungi to decompose these cells**
- **Slower process of heartwood decay – better structural stability**

The CODIT Model

- CODIT = Compartmentalization Of Damage In Trees

→After injury, trees respond to the intrusion of air by activating their defense system (keyword: air embolism).

- Concept: The tree is a compartmentalized organism that seals off areas sequentially.



A TREE'S DEFENSES against injury and infection produced the pattern on this cross section of the trunk of a red oak. Nine years before the section was made the tree was wounded by buckshot. Microorganisms that established themselves in the wound caused the wood there to decay, making it whiter than elsewhere. In response the tree mounted a chemical defense: the dark boundary of discolored wood surrounding the decay indicates the production of antimicrobial substances. The dark line curving over the wounded wood is a further defense: the cambium, or growth layer, alive at the sides of the wound produced a cellular wall protecting the wood that formed after the time of the injury. The pattern of growth rings outside the wound reveals the subsequent history of the tree. After five years the wound closed, and after that four more growth rings formed. The tree was sectioned by the author and photographed by Kenneth R. Dudzik of the U.S. Forest Service in Durham, N.H.

4 Walls of the CODIT Model

First phase: Air gets in - Wall 1: axial

The tree forms a chemical barrier to inhibit the inward spread of pathogens through the vertical xylem vessels.

Deciduous Trees:

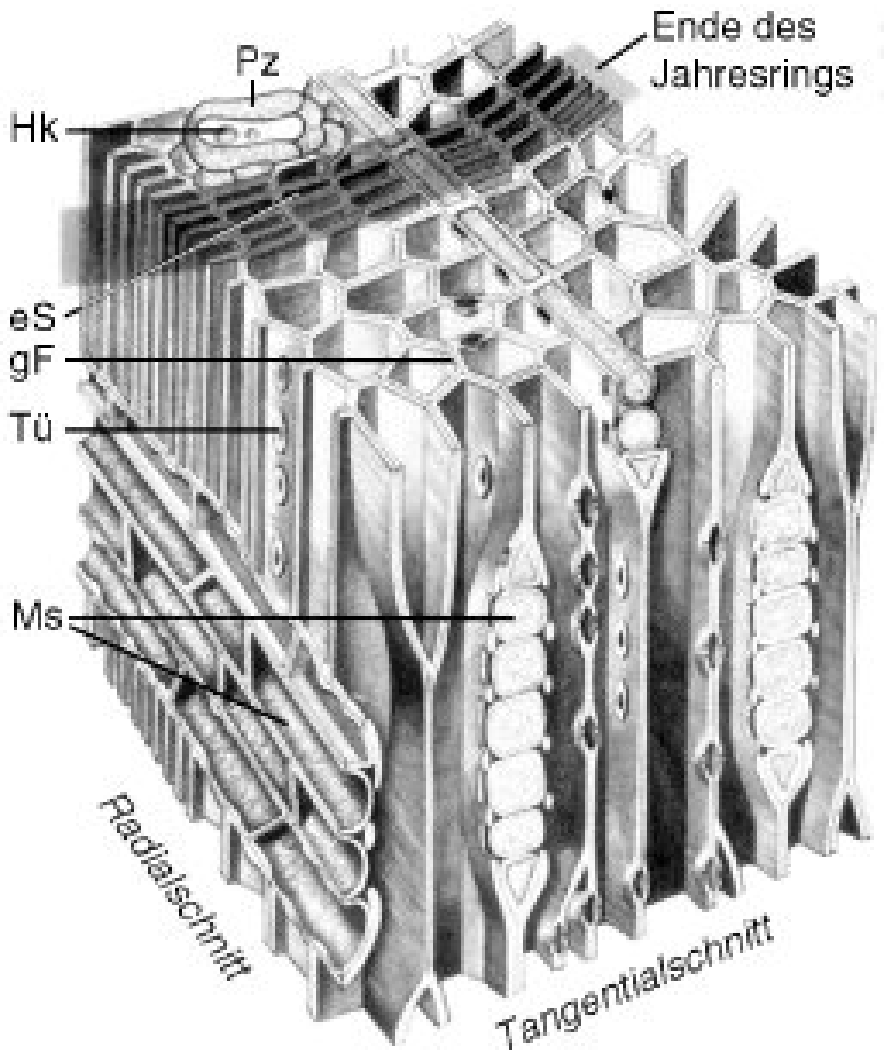
- Formation of tyloses (transforming parenchyma cells)
- Suberin (cork) is produced, which fungi have difficulty decomposing.

4 Walls of the CODIT Model

First phase: Air gets in - Wall 1: axial

Conifers:

- Wood fibers are connected by pits and can become lignified.



Block diagram of gymnosperm wood (pine):
eS narrow-lumened latewood,
gF wide-lumened earlywood,
Hk resin canal,
Ms pith or wood rays,
Pz parenchyma cell,
Tü pits

https://www.spektrum.de/lexikon/biologie/holz/32298

4 Walls of the CODIT Model

First phase: Air gets in - Wall 1: axial

Conifers:

= Formation of a wound periderm starting from the bark and callus formation starting from the cambium

→ Result: despite the intrusion of air, the negative pressure is maintained

- Due to lignification, the cells die superficially.
- Formation of traumatic resin ducts for sealing.

4 Walls of the CODIT Model

Second phase: The damaging organism penetrates up to the barrier zone

- Wall 2: radially inward

- Cells of the latewood are thick-walled
- can accumulate lignin to stop the spread on a radial level

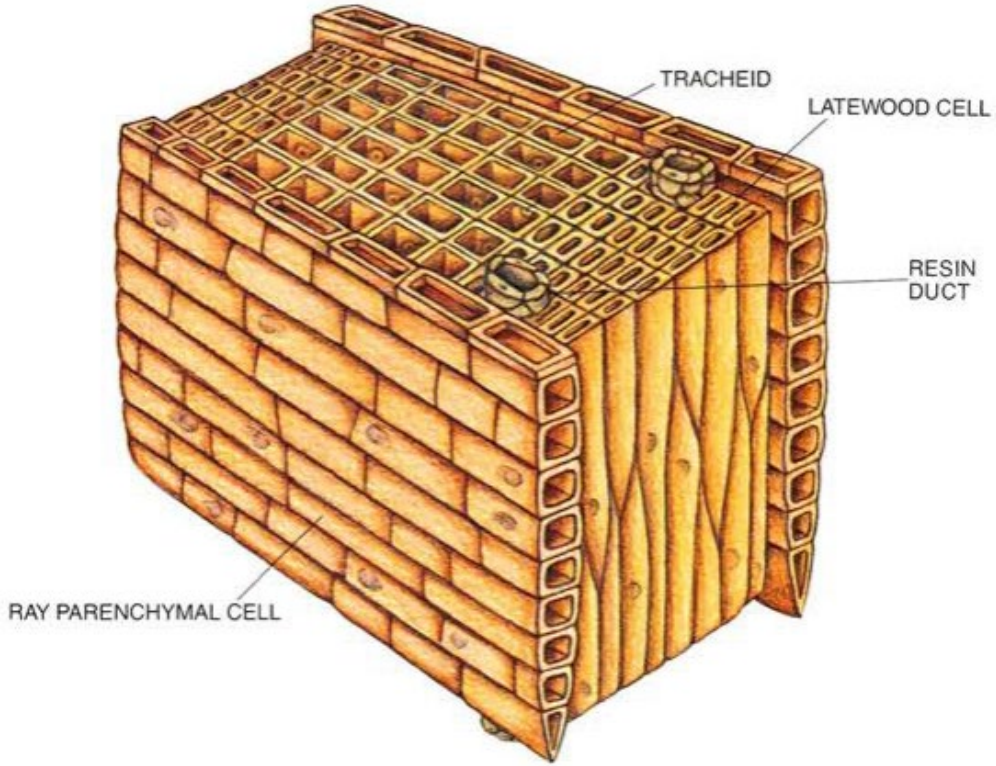
https://cdn.duden.de/_media_/full/S/Spaetholz-201020595185.jpg

4 Walls of the CODIT Model

<u>Third phase: Spread of the pathogen</u>

<u>- Wall 3: tangentially</u>

- Wood ray cells (vary in their orientation and size)
- The pathogen remains alive
- can delay infestation for a long time



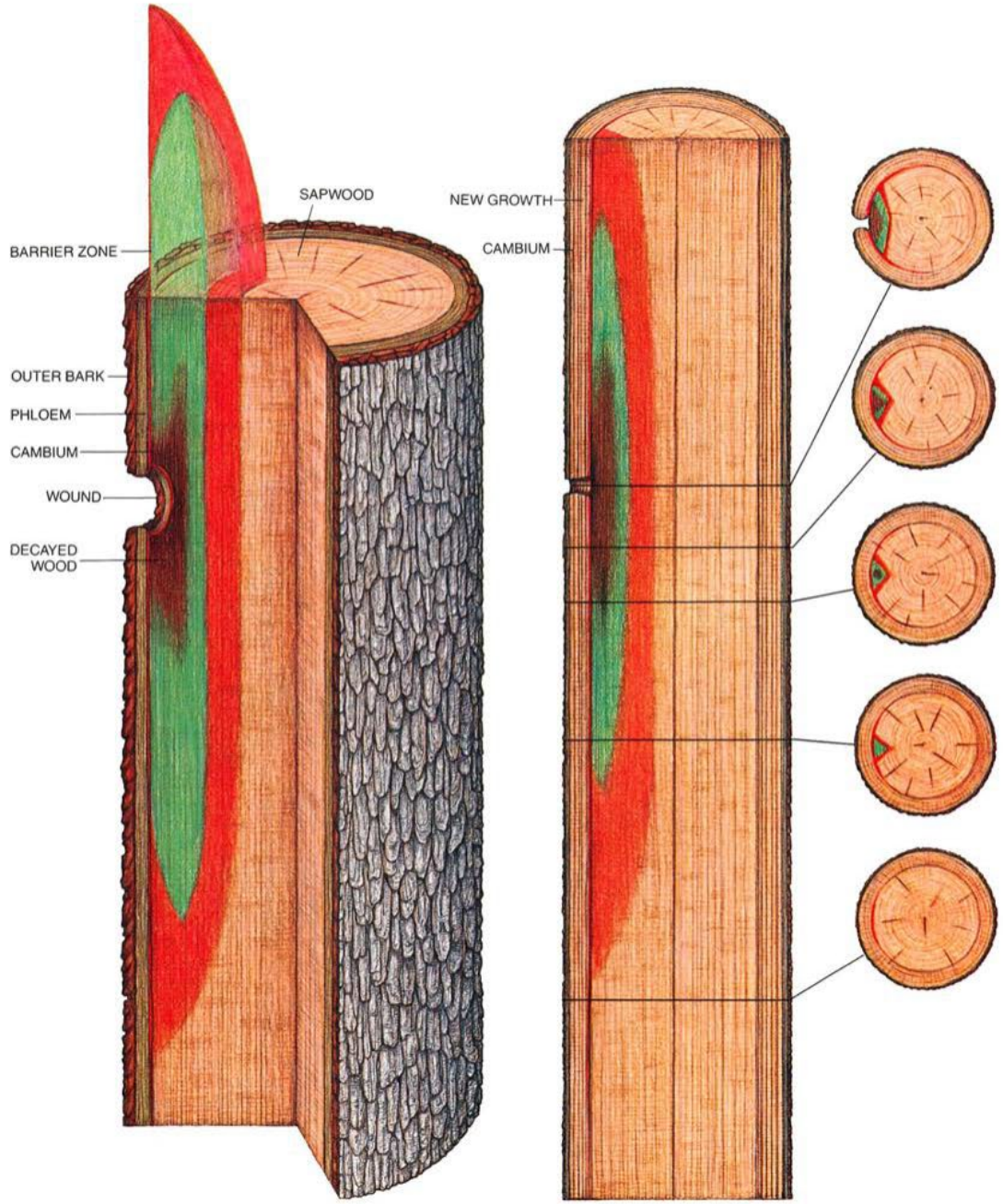
4 Walls of the CODIT Model

Fourth phase: Encapsulation of the pathogen

- Wall 4: radially outward

- Ideally, the wound callus (wound xylem from specialized wood tissue) encapsulates the pathogen from all sides.

- Due to a lack of oxygen, wood-decomposing fungi die off.


SAPWOOD
BARRIER ZONE
OUTER BARK
PHLOEM
CAMBIUM
WOUND
DECAYED WOOD
NEW GROWTH
CAMBIUM

chemical

chemical

- Production of harmful substances
  - So-called secondary metabolites = specialized metabolites
- Poisons or bitter substances are released upon contact with the plant or stored in the tissue
  - Terpenes
  - Phenols
  - Cyanogenic glycosides
  - Alkaloids
- Pest infestation – increase in tannin or phenol content
- Communication via scents – sending out warnings
  - Some toxins exist as activatable precursors → they are then activated

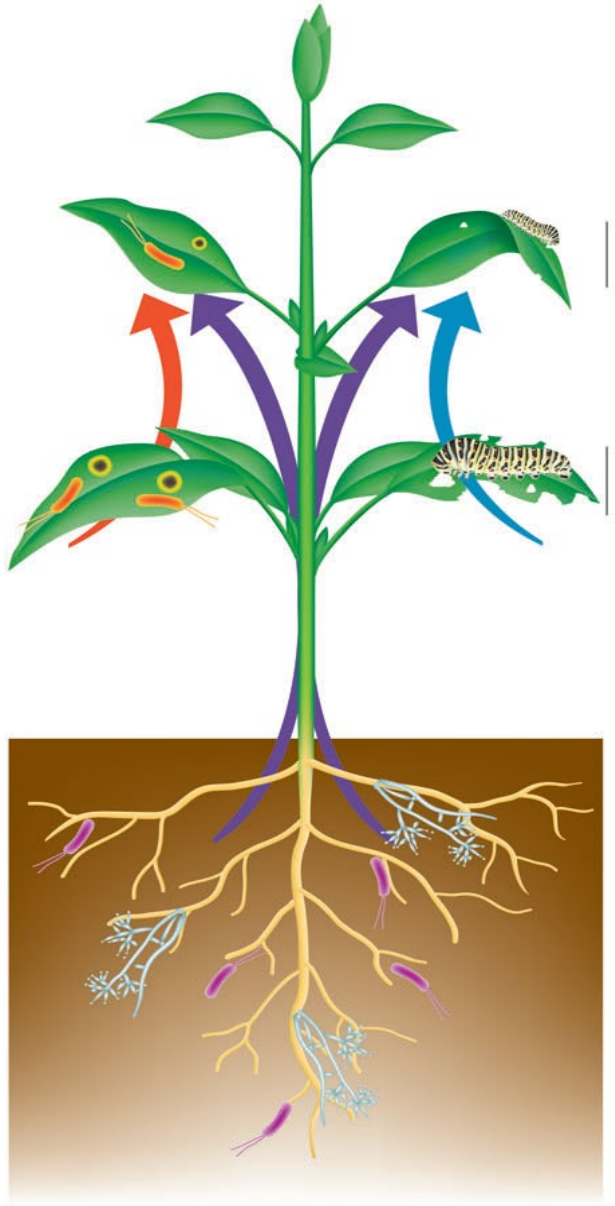
Induction of defense responses

ISR = Induced Systemic Resistance

- Plant growth-promoting bacteria and fungi in the rhizosphere strengthen the host plant against a wide variety of pathogens and herbivores.
  - Examples: *Pseudomonads*, *Bacillus*, *Trichoderma*, and mycorrhizal fungi

- Induced resistance involves long-distance signals (vascular or volatile – jasmonic acid and ethylene)

- Defense response is significantly stronger during the second infection compared to the first.

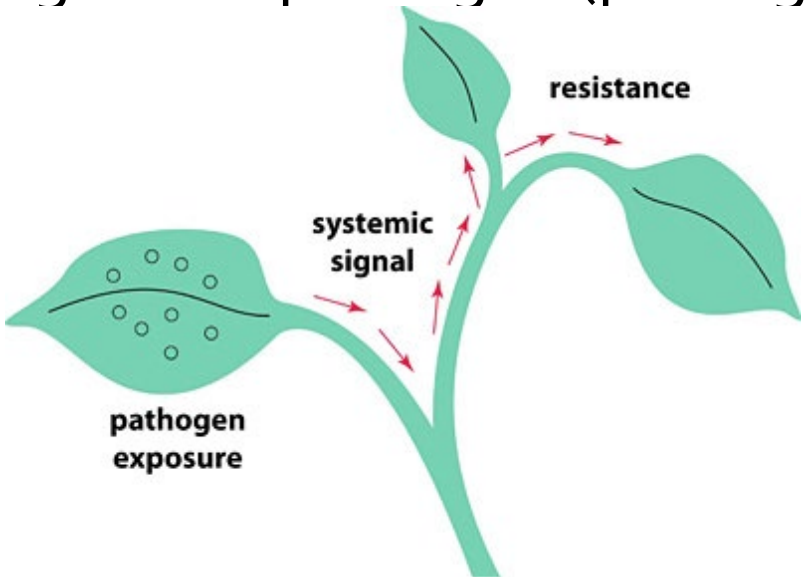


10.1146/annurev-phyto-082712-102340

SAR = Systemic Acquired Resistance

- Defense response of a plant against a pathogen (pathogen, bacterium, virus)
- Plant immune system

Plant confronted with a pathogen – at the site of infection, a response is triggered that affects the entire plant (protecting it from subsequent attacks).

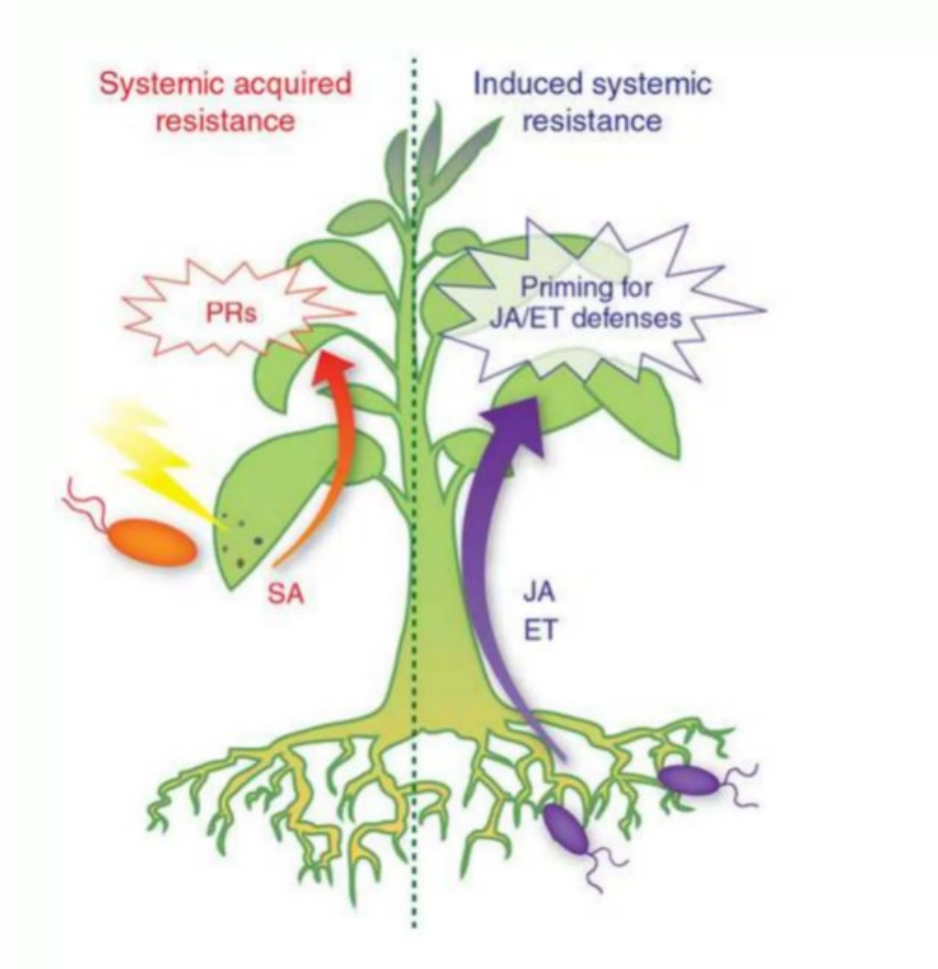


At the site of infection, salicylic acid (SA) is produced.

Signal in the plant through the phloem.

Production of specific enzymes (PR = pathogen-related proteins)

SAR vs. ISR


Systemic acquired resistance
Induced systemic resistance
PRs
Priming for JA/ET defenses
SA
JA
ET

https://www.imago-images.de/st/0084854964