

**Lecture 19-1:**

**Biotic stress**

**Plant disease**

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**Disease**

- A big problem for all organisms.
- Infectious diseases are caused by bacteria, viruses, fungi, and nematodes.
- Diseases can also be genetic.

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**Bacteria can be...**

- **Harmless** (living on plant's surface)
- **Beneficial** (symbiotic bacteria)
- **Pathogenic**
  - Can infect animals, insects, plants, and fungi

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### Why do we study plant diseases?


- Plant diseases have a **large economic (and social) impact when they affect crop plants.**
  - Potato famine (Fungus *Phytophthora infestans*)
- **Ecological effects**
  - Chestnut Blight (fungal pathogen, *Cryphonectria parasitica*)



Starvation during the famine (1845-1849)



The orange-colored areas at the edge of the canker are where Chestnut blight is actively growing and sporulating.



Canker of Chestnut blight that has encircled and killed an American chestnut tree.

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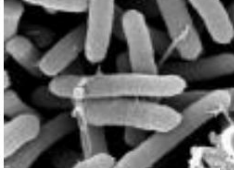
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### *Pseudomonas syringae* pv. *tomato*

- Causes bacterial speck disease in tomatoes.
- Spread by water splash and enters plants through stomates.
- Comes in a variety of **pathovars** (abbreviated pv.), which specify host plant (e.g. *Pseudomonas syringae* pv. *tomato*, *Pseudomonas syringae* pv. *phaseolicola*).
- Model system for bacterial pathogenesis and plant-pathogen interaction studies.

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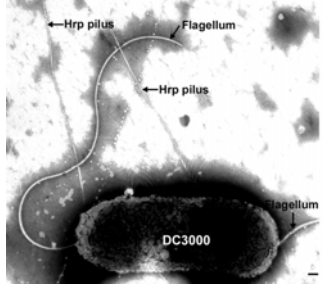
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### *Pseudomonas syringae* pv. *tomato*



Transmission electron microscope image of *Pseudomonas syringae* pv. *tomato* DC3000. DC3000 produces polar flagella (15 nm in diameter) and a few Hrp pili (8 nm in diameter). The flagella and Hrp pili are indicated with arrows. Flagella enable bacteria to swim toward or away from specific chemical stimuli. Hrp pili are involved in type III secretion of avirulence and virulence proteins.

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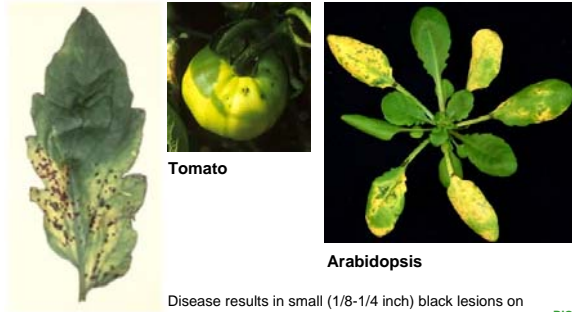
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*Pseudomonas syringae* pv. *tomato* causes **Bacterial Speck Disease** in tomato and Arabidopsis



Disease results in small (1/8-1/4 inch) black lesions on leaves and fruits. These spots usually are surrounded by a yellow halo.

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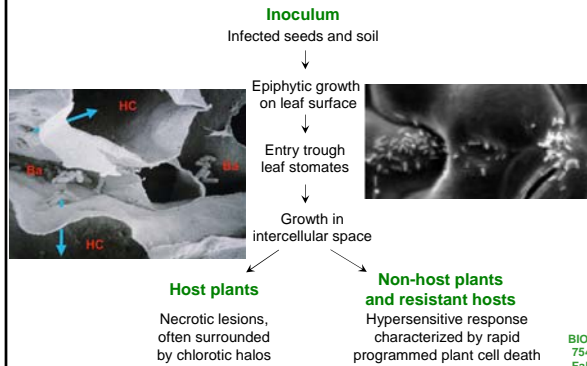
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**The *Pseudomonas syringae* pv. *tomato* infection process**



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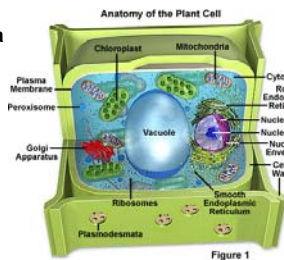
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**How do plants defend against disease?**

- Plant cell wall provides a barrier against pathogens.
- Plants do not have a circulating immune system like animals do. However, immune-like responses are being identified.



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**Different plants can have different responses to a pathogen**

- No response
- Resistant response
- Susceptible response

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**So how do plants defend against bacteria that enter the cell?**

- **Plants have a general response to infection**
  - anti-microbial molecules (phytoalexins)
  - strengthening of cell walls (callose synthesis)
- **Plants respond to specific infections through the Hypersensitive Response (PCD)**
  - rapid accumulation of reactive oxygen species (directly kill pathogen)
  - Induction of defense genes (pathogenesis-related proteins)

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**The Hypersensitive Response**

- **Bacteria like *Pseudomonas syringae* inject effector proteins (bacterial avirulence and virulence proteins) into plant cells using the Type-III secretion system.**
- **Plants that are resistant to the bacteria have resistance proteins that recognize the effector proteins and cause the infected cell to commit suicide (apoptosis/PCD/Hypersensitive Response).**
  - Gene-for-gene resistance
  - prevents the bacteria from infecting the rest of the plant by directly killing them and depleting nutrients

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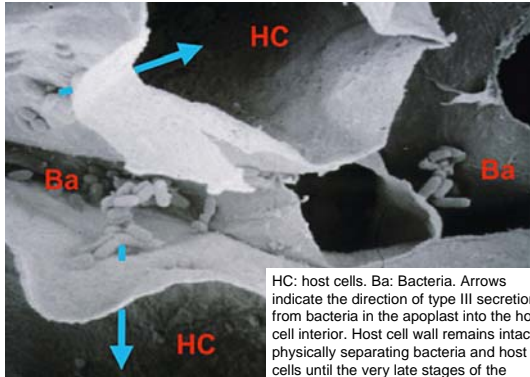
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**Infection of Arabidopsis by *Pseudomonas syringae* pv. *tomato***



HC: host cells. Ba: Bacteria. Arrows indicate the direction of type III secretion from bacteria in the apoplast into the host cell interior. Host cell wall remains intact, physically separating bacteria and host cells until the very late stages of the interaction, when host cells collapse.

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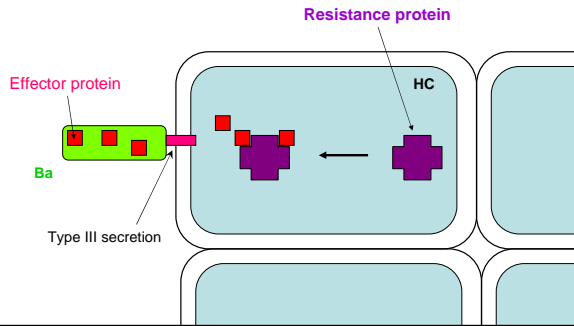
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**The Hypersensitive Response**

Ba = Bacterium  
HC = Host Cell




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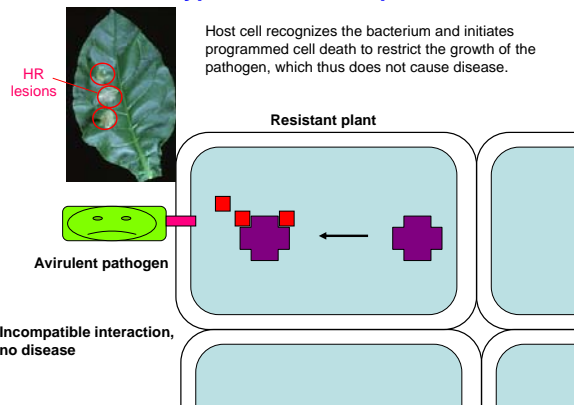
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**The Hypersensitive Response**




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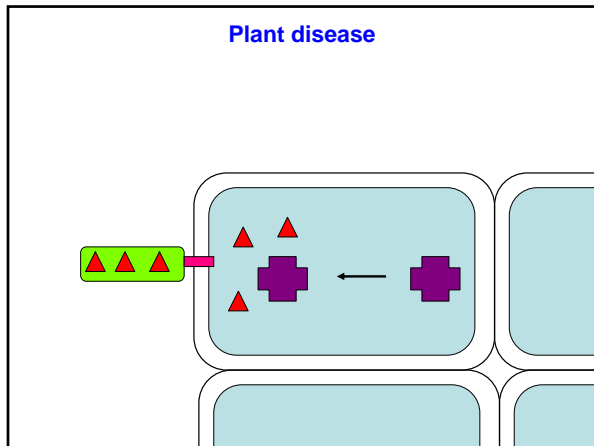
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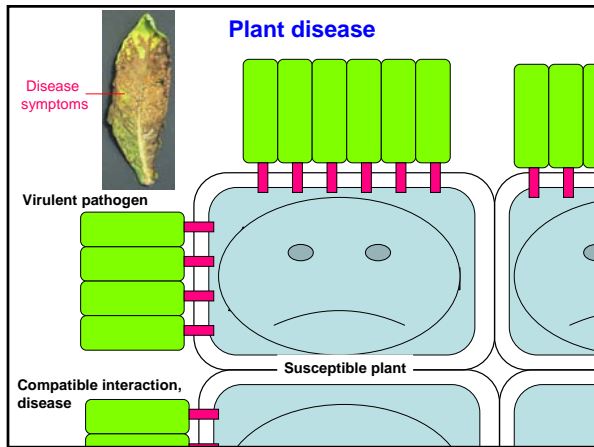
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**Terminology in gene-for-gene resistance**

Interaction	Pathogen	Plant Host
Compatible ↓ Disease	Virulent (No <i>avr</i> )	Susceptible ( <i>r/r</i> )
Incompatible ↓ HR	Avirulent ( <i>avr</i> ) <i>avrPto</i>	Resistant ( <i>R/R</i> or <i>R/r</i> ) <i>Pto</i> , Ser/Thr kinase

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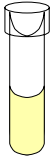
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## The Hypersensitive Response – An experiment




1. Grow up bacteria and dilute to desired OD



2. Infiltrate bacteria into leaves



3. Look for disease symptoms/HR



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## The Hypersensitive Response – An experiment: Hypotheses

Infection with	Tomato	Tobacco	Bean
<i>Pseudomonas syringae</i> pv. <i>tomato</i>	Disease	HR	HR
<i>Pseudomonas syringae</i> pv. <i>phaseolicola</i>	HR	HR	Disease
Water	No response	No response	No response

Do you think you would see HR in nature?

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## Susceptible vs. resistant plant

	Susceptible Plant	Resistant plant
What happens when <i>P. syringae</i> infects a...?	<i>P. syringae</i> can infect these plants and cause disease. It injects effector proteins into the plant that cause disease.	<i>P. syringae</i> cannot infect these plants. The plant is resistant due to the HR defense. The plant turns on HR because it has resistance proteins that recognize the bacterial effector proteins. This recognition signals the plant it is being 'invaded' and that it should 'arm' itself.

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### Other bacteria that use the Type III Secretion System

- The type III secretion system is found in a variety of otherwise distantly-related bacteria.
  - This is because bacteria are able to exchange genetic information between different species (horizontal transfer)
- One bacterium that uses the type III secretion system, *Yersinia pestis*, causes disease in humans.
  - What disease does it cause?

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### The Black Death (aka. The Bubonic Plague)



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### The Bubonic Plague

- Symptoms include fever, chills, headache, and extreme exhaustion.
- The lymph glands swell to form egg-shaped lumps under the skin called bubos.



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### The Bubonic Plague

- Is caused by the bacteria *Yersinia pestis*.
- *Y. pestis* uses the type III secretion system like *Pseudomonas syringae*.
- The natural hosts of *Y. pestis* are actually rats and fleas. Fleas are forced to infect humans once a large amount of rats succumb to the disease.

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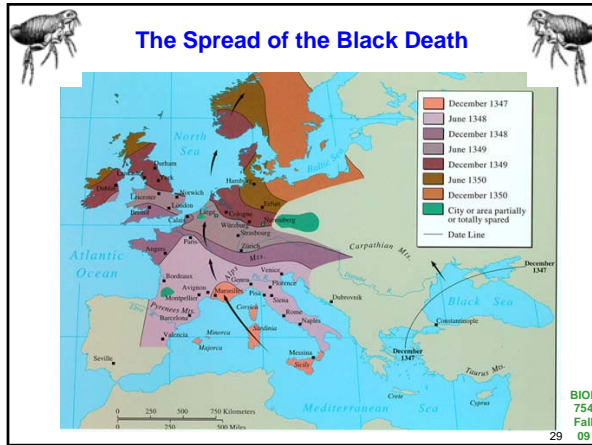
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