2014

CSB 353
INTRODUCTION TO PLANT-MICROBE INTERACTIONS

Lecture: Thursday 3-5 pm

Prof. K.Yoshioka
(Department of Cell and Systems Biology)

- Class starts 3:10pm and will have 10 min break after the first half.

CSB
Cell & Systems Biology

U of T

II. Schedule, preparation and evaluation

Lecture 1-5	January 9th-February 6th
Mid-term Exam	February 13th (EX310 and 320)
Reading week	February 17-21st
Lecture 6-11	February 27th -April 3rd (We may have guest instructors/speakers)
Final Exam	Exam Period

TENTATIVE COURSE CONTENT

Lecture 1 General Introduction of Plant Pathogens I
- Nature of plant pathogens and their strategies -

Lecture 2 General Introduction of Plant Pathogens II
- Nature of plant pathogens and their strategies -

Lecture 3 General Plant Defense Responses I

Lecture 4 General Plant Defense Responses II

Lecture 5 Systemic Acquired Resistance

February 13th Midterm Exam (EX100)

February 20th Reading Week

Lecture 6 Recognition of Pathogen Invasion by Plants
- Gene for Gene theory and discovery of R gene -

Lecture 7 Signal Transduction of Defense Responses I
- Early events after pathogen recognition -

Lecture 8 Signal Transduction of Defense Responses II
- Identification of signalling components -

Lecture 9 Agrobacterium and Symbiosis

Lecture 10 Control of Plats Disease by Genetic Engineering

Lecture 11 TBA

II. Schedule, preparation and evaluation

Evaluation system

Mid term exam 45 points + Final exam 45 points + an essay 10 points
= Total 100 points

Mid term exam questions will be from the lecture 1-5, and the final exam questions will be from the lecture 6-11.

Both exams will be short answer format, or combination of short answer and multiple choice. The details of the essay will be announced after the mid term.

How to study

1. Attend lectures
2. Read reading materials
3. Suggested text book

- Introduction to Plant Pathology (Edited by Richard N. Strange, Wiley)
- Biochemistry & Molecular Biology of Plants (Edited by Buchanan, Gruissem and Jones) American Society of Plant Biologist

PLANT-MICROORGANISM INTERACTIONS

Introduction of “PLANT-MICROORGANISM INTERACTIONS “

I. Why study the interaction between plants and pathogenic organisms?
II. Syllabus and evaluation

I. Why study the interaction between plants and pathogenic organisms?

Why study the interaction between plants and pathogenic organisms?

1. This study should provide practical solutions for the control of plant-disease

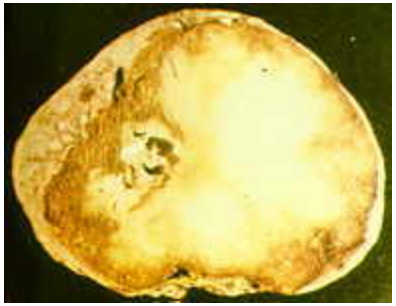
2. Scientific contribution

Introduction

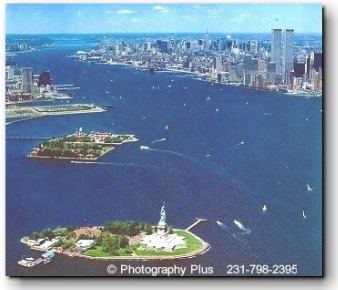
I. Why study the interaction between plants and pathogenic organisms?
- impact of plant disease in human society-

Great Irish Famine

The late blight disease in potato caused the emigration of more than one million people from Ireland to the U.S. and Canada



Late blight disease in potato caused by *Phytophthora infestans*.



Ellis island

The Discovery of the Potato Blight in Ireland, Daniel McDonald, c. 1847

Introduction

I. Why study the interaction between plants and pathogenic organisms?

1. Contribution for Agriculture

Sweet corn field with severe high plains disease (caused by High Plains virus) in south central Idaho in late July, 1993.
(Photographed by Robert Forster)

Growing monocultures of genetically uniform crop species leads to severe outbreaks of disease.

Table Comparison of natural and agricultural plant communities

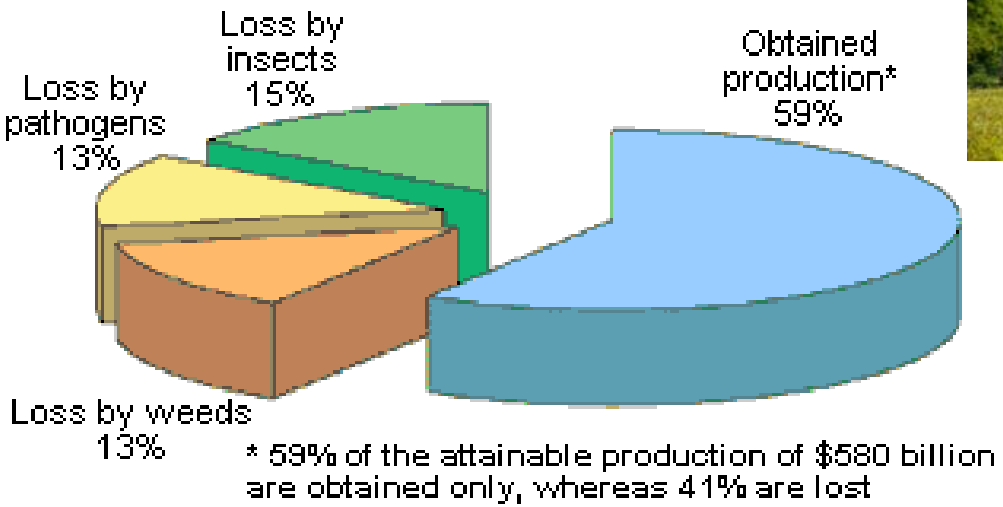
	Natural	Agriculture
Genotype	Diverse	Uniform
Age structure	Mixed	Uniform

Introduction

I. Why study the interaction between plants and pathogenic organisms?

1. Contribution for Agriculture

- Huge economical damage
- Usage of agrochemicals to control plant disease can cause serious environmental pollution.



Estimated annual crop losses worldwide by disease only approximately $220 billion

Introduction

I. Why study the interaction between plants and pathogenic organisms?

1. Contribution for Agriculture

Plant-Microbe interaction study can provide us the information for,

- Breeding pathogen resistant crop plants
- Discovery of environmentally safer agrochemicals

Introduction

I. Why study the interaction between plants and pathogenic organisms?

1. Contribution for Agriculture

In the early 90's, there is a trend to create virus resistant crops by introducing virus coat protein gene.

Delay of disease development in transgenic plants that express the tobacco mosaic virus coat protein gene.

Abel PP, Nelson RS, De B, Hoffmann N, Rogers SG, Fraley RT, Beachy RN.

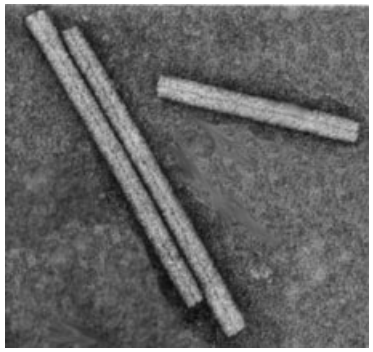
Science. 1986 May 9;232(4751):738-43.

Dr. R. Beachy
President and director of the Donald Danforth Plant Science Center, St. Louis

Introduction

I. Why study the interaction between plants and pathogenic organisms?

1. Contribution for Agriculture



Tobacco Mosaic Virus

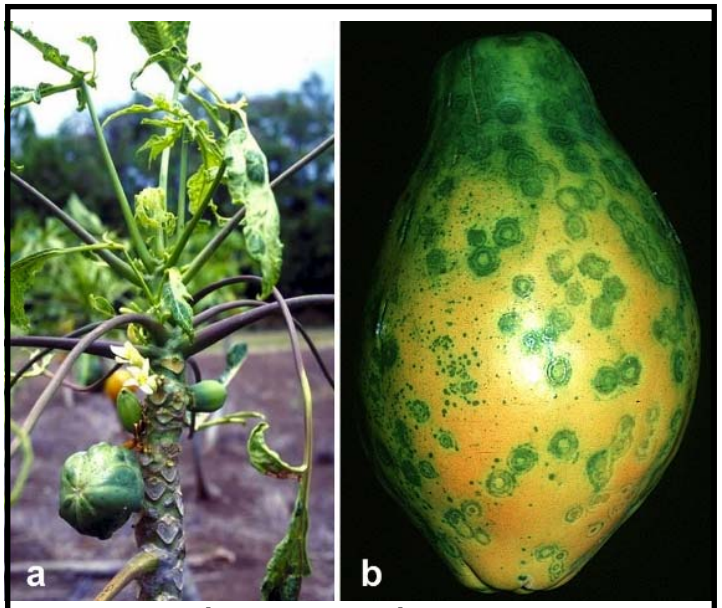
Non transgenic

Transgenic tobacco carrying the CP gene

Introduction

I. Why study the interaction between plants and pathogenic organisms?

1. Contribution for Agriculture



Papaya ringspot virus symptoms

In the 1980s, papaya ring spot virus **(**PRSV) nearly wiped out papaya production in Hawaii.

A gene encoding a viral coat protein was introduced into papaya. The modified plants are resistant to viral infection. This was the first commercialized transgenic fruit.

Introduction

I. Why study the interaction between plants and pathogenic organisms?

1. Contribution for Agriculture

Transgenic Papaya plants carrying papaya ring spot virus CP gene (Agbio Forum Vol. 7) developed by Dr. Gonsalves (left pannel)

Introduction

I. Why study the interaction between plants and pathogenic organisms?

1. Contribution for Agriculture

Successful Transfer of the Cucumber Mosaic Virus Coat Protein Gene

K. Yoshioka, K. Hanada, Y. Nakazaki, Y. Minobe, T. Yakuwa and K. Oosawa

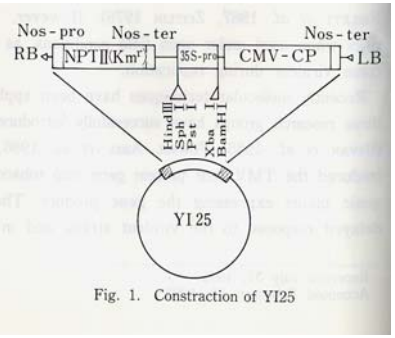


Fig. 1. Constraction of YI25

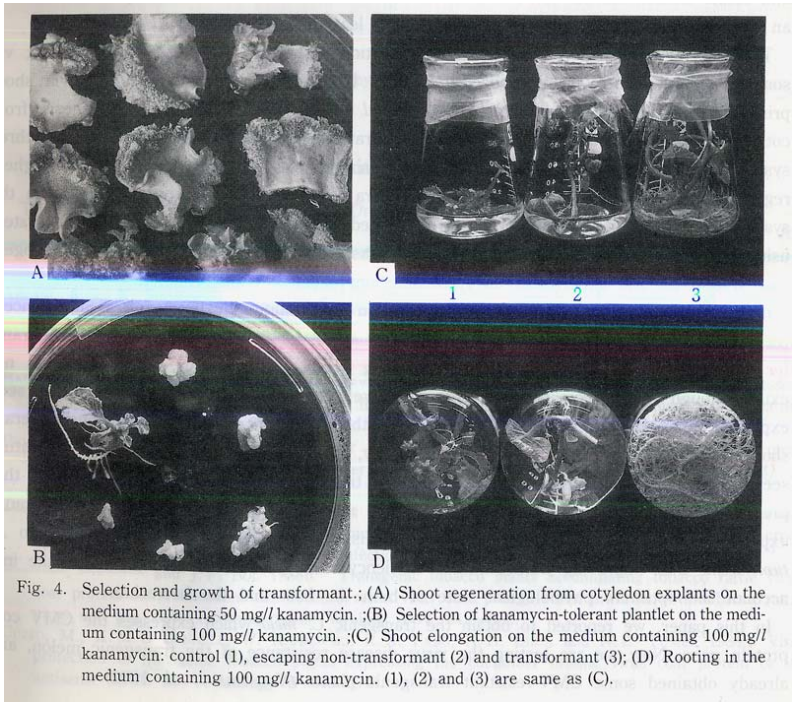


Fig. 4. Selection and growth of transformant.; (A) Shoot regeneration from cotyledon explants on the medium containing 50 mg/*l* kanamycin. ;(B) Selection of kanamycin-tolerant plantlet on the medium containing 100 mg/*l* kanamycin. ;(C) Shoot elongation on the medium containing 100 mg/*l* kanamycin: control (1), escaping non-transformant (2) and transformant (3); (D) Rooting in the medium containing 100 mg/*l* kanamycin. (1), (2) and (3) are same as (C).


Fig. 1. Symptoms after inoculation with a solution of 2 μg/ml of CMV.
Left; non-transformed plant of the same cultivar.
Right; transformed plant that expresses CMV-CP gene.

National Institute of Agrobiological Sciences

Yoshioka et al., 1992

I. Why study the interaction between plants and pathogenic organisms?

2. Scientific contribution

2. **Scientific contribution**

Immune system is essential for living organisms!

Bread with fungus

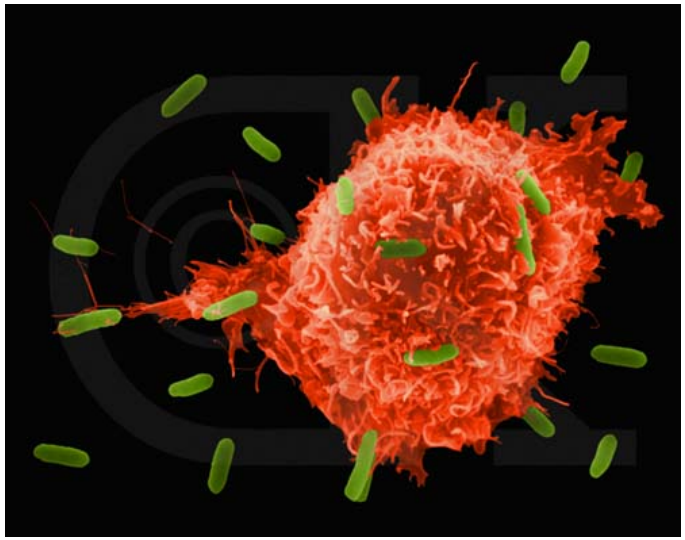
My lab member Dr. M.

A plant

But how different between animal and plant immunity?

I. Why study the interaction between plants and pathogenic organisms?

2. **Scientific contribution**



A macrophage searches bacteria
(Photo: University of South California)

- Animals have a number of ways to defend themselves by specialized cells.
- Animals also have a system to distinguish between "*self* and *non-self*".

↓

What about plants?

Introduction

I. Why study the interaction between plants and pathogenic organisms?

2. Scientific contribution

•Plant evolved a different immune system from animals.

Model plant;
Arabidopsis thaliana

- Plants are also exposed to a large number of microorganisms, viruses, fungi, bacteria and invertebrates.
- Plants can not move to change the environment.
- Plants also have a system to detect “invaders”.
- Plants must continuously defend themselves.

Two types of defense

1. Preformed (passive) defense
2. Induced (active) defense

***Basically each plants cell possess these defense capacity (not by specialized cells)**

↓

Striking contrast between plant and animal immune systems

Goal of this course

- Understand the basic molecular mechanisms of plant- (mainly pathogenic) microbe interaction and plant immune responses

INTODUCTION TO PLANT-MICROORGANISM INTERACTION

General introduction of plant pathogens
- Nature of plant pathogens and their strategies -

What are the symptoms of plant disease?

DISEASE: Early blight
PATHOGEN: *Alternaria solani*
HOSTS: : Tomato, Potato

Fungal pathogen

DISEASE: Tobacco mosaic
PATHOGEN: *Tobacco mosaic virus*
HOSTS: Tobacco, tomato, and other solanaceous plants

Viral pathogen

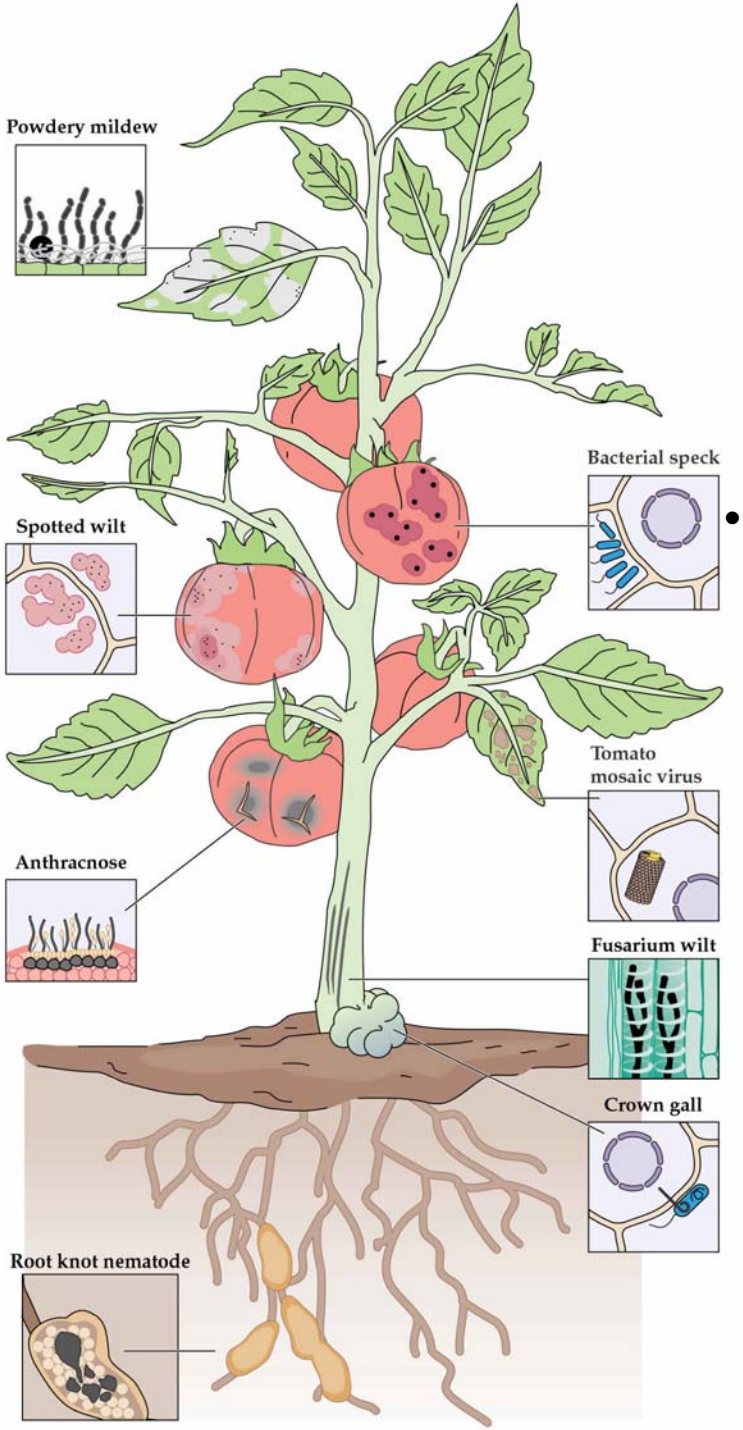
What are the symptoms of plant disease?

DISEASE: Stem rust (black rust)
PATHOGEN: *Puccinia graminis* f.sp. *tritici*
HOSTS: wheat and barley,

Fungal pathogen

DISEASE: Bacterial spot
PATHOGEN: *Xanthomonas axonopodis, Xanthomonas vesicatoria, Xanthomonas gardneri*
HOSTS: pepper and tomato

Bacterial pathogen



PLANT-MICROORGANISM INTERACTION

General introduction of plant pathogens

- Plants are exposed to a large number of microorganisms

Pathogens are phylogenetically diverse

Main types of pathogens

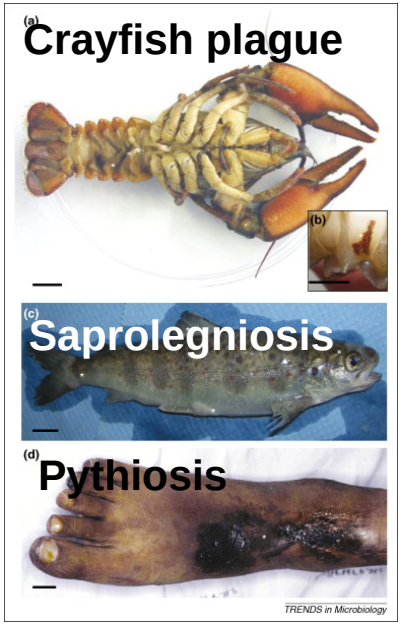
- Fungi
- Oomycetes
- Bacteria
- Viruses
- (Insect)
- (Nematodes)

General introduction of plant pathogens

Microbe types that cause disease are the same as those infecting animals.

A deadly aquatic fungus called Batrachochytrium dendrobatidis has killed more than 200 amphibian species around the world since 2004 when the fungus epidemic began.

Fungus- Athlete's foot etc.
Bacteria- bubonic plague, gonorrhea etc.
Virus- HIV, flu etc.



Disease symptoms as a result of some important animal pathogenic oomycetes.

PLANT-MICROORGANISM INTERACTION

Model plant; *Arabidopsis thaliana*

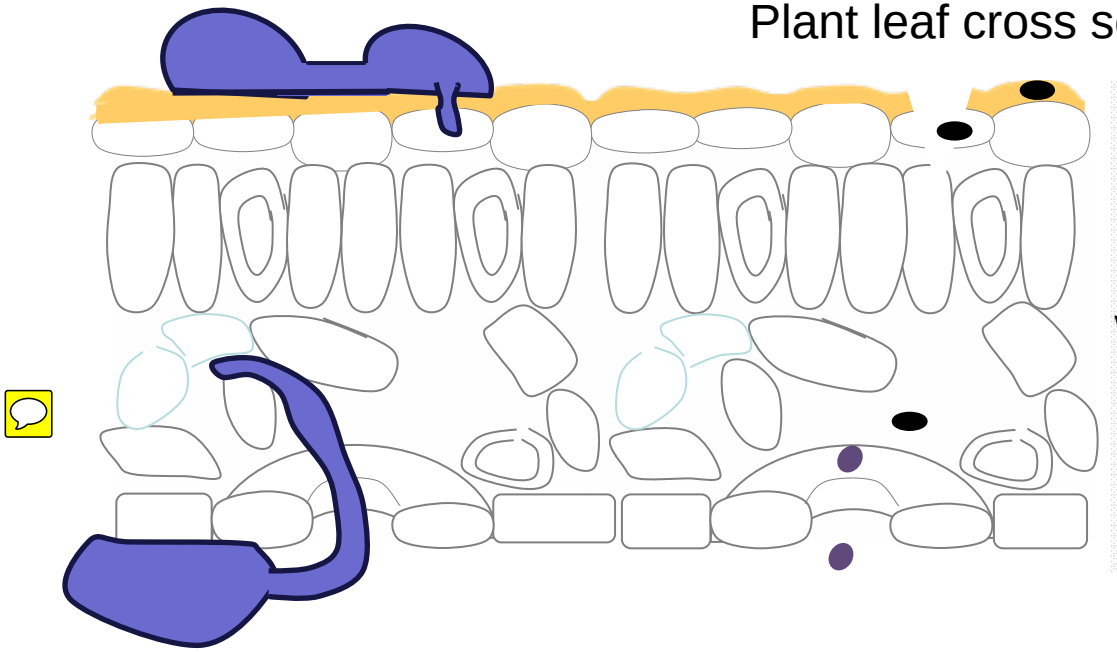
However,
Very few pathogens can cause **Disease.**

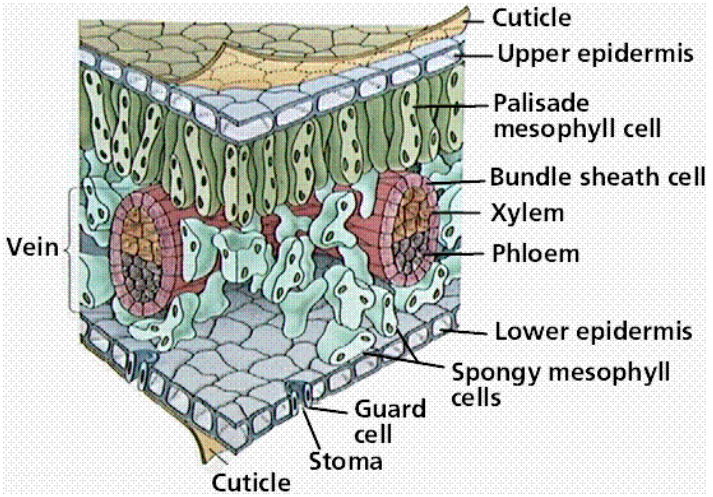
For example there are more than 100 thousands fungus in this world, but only **less than 2%** of these can infect to plants and causes disease.

Arms race of plant and pathogens

Entry routes for plant pathogens

Plant leaf cross section

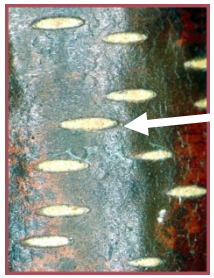




Wounds

TMV
Agrobacterium
Soft rot fungi
etc.

Natural openings



- Lenticels
- stomata

Rust fungi
Pseudomonas
etc.

Direct penetration

Powdery mildews
Rice Blast
etc.

General introduction of plant pathogens

Important characteristics of plant pathogen

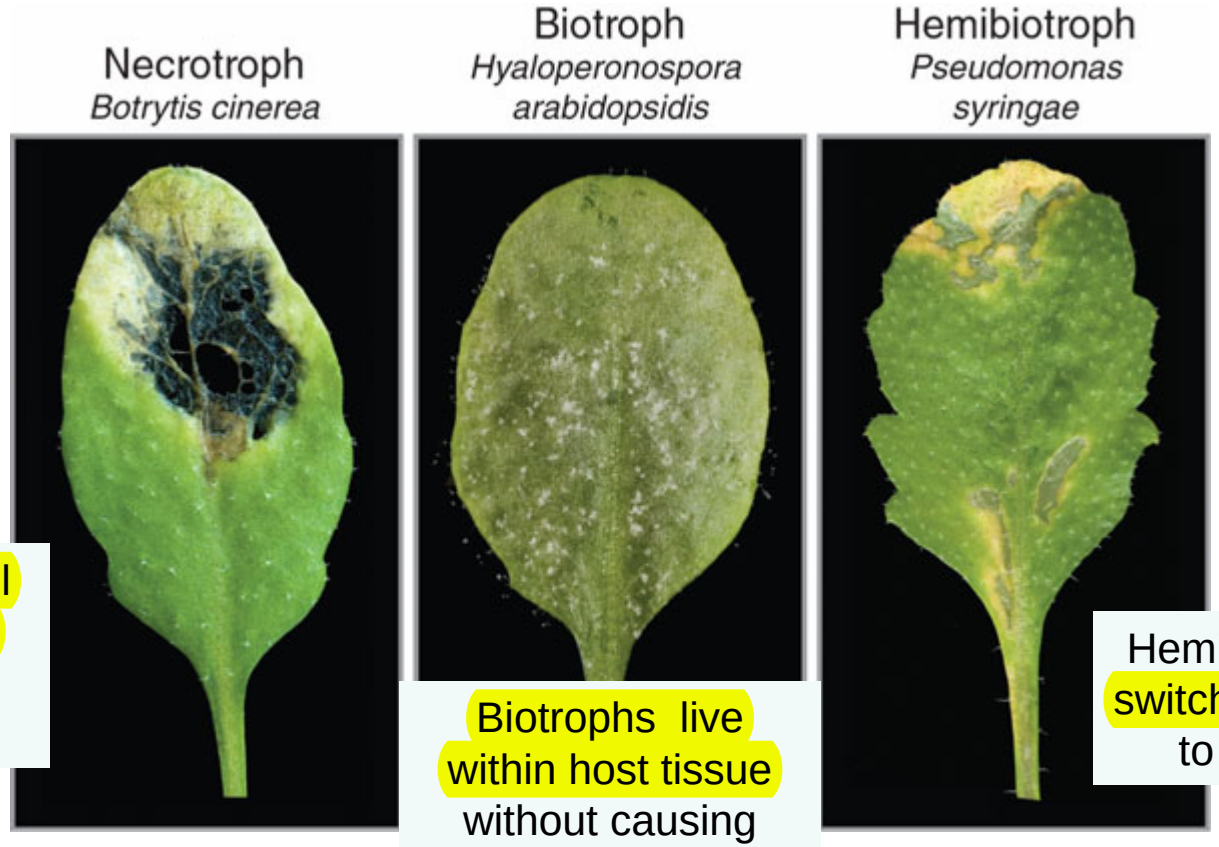
- Necrotrophs (⟷ saprotrophs)
- Biotrophs
- Hemi-biotrophs

Strategies utilized by plant pathogens

	Necrotrophic	**Biotrophics**	**Hemi-biotrophics**
Attack Strategy	Secreted cell wall-degrading enzymes, host toxins	Intimate intercellular contact with plant cells	Initial biotrophic phase, then necrotrophic phase
Specific features of interaction	Plant tissue is killed and colonized by pathogen	Plant cells remain alive	Plant cells alive only in the initial stages of the infection
Example	Rotting bacteria and fungi	Fungal mildews and rust viruses	Phytophthora infestans Pseudomonas

PLANT-MICROORGANISM INTERACTION

General introduction of plant pathogens



Necrotrophs kill cells and then consume the contents

Biotrophs live within host tissue without causing death

Hemibiotrophs can switch from biotroph to necrotroph

1. Fungi as plant pathogens

General introduction of plant pathogens

1. Fungi as plant pathogens

Fungi; A group of organisms traditionally included among the plants, but now considered so distinct as to constitute a separate kingdom of their own. They live by absorptive nutrition.

Although viruses and bacteria cause diseases in plants. **Fungi are the number one cause of crop losses worldwide.**

Most notorious disease of humans and animals are caused by bacteria and viruses.

This can be explained partly **on the basis of several differences between plants and animals as habitats for microbial growth.**

General introduction of plant pathogens

1. Fungi as plant pathogens

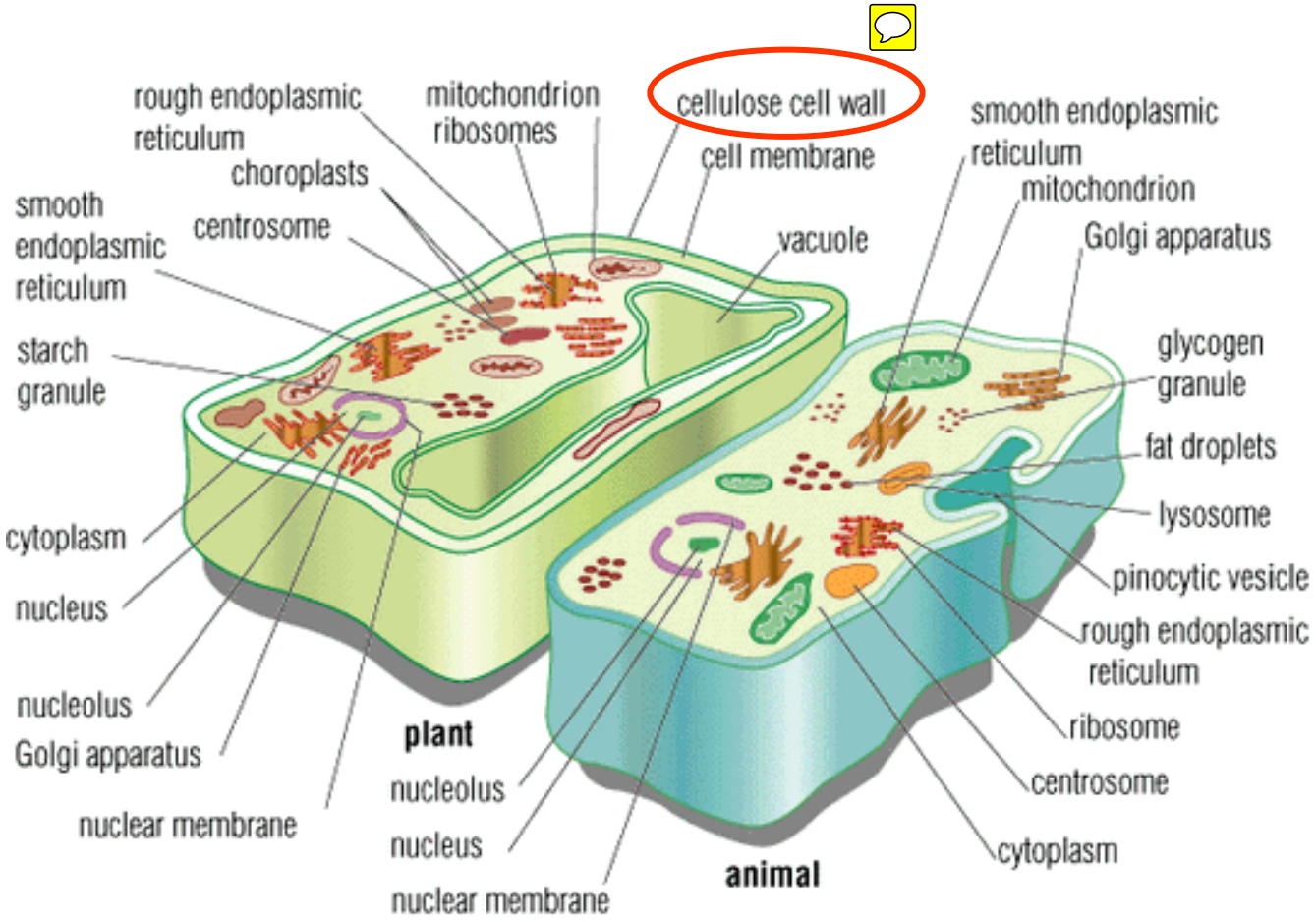
Comparison of higher plants and animals as hosts

Plants	**Animals**
Anatomical features	
Rigid cell walls	No cell wall
No circulatory system*	Circulatory system
Internal environment	
Acidic pH	Alkaline pH
No temperature regulation	Temperature regulation

*** Bacteria generally prefer warm, alkaline conditions with high nitrogen levels.**
*** Virus is too small to penetrate plant cell wall by themselves.**

General introduction of plant pathogens

1. Fungi as plant pathogens

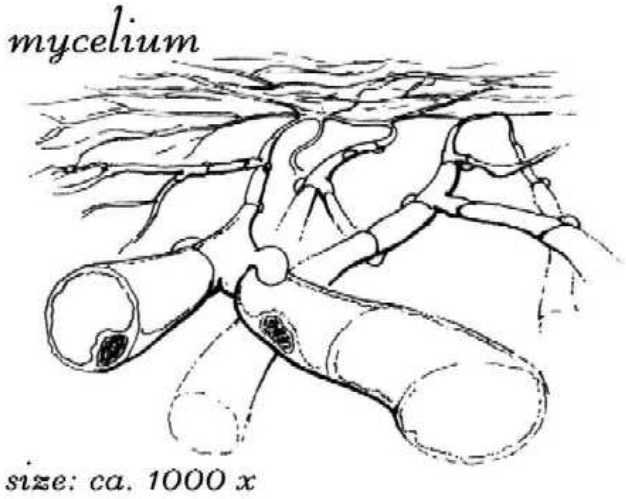


General introduction of plant pathogens

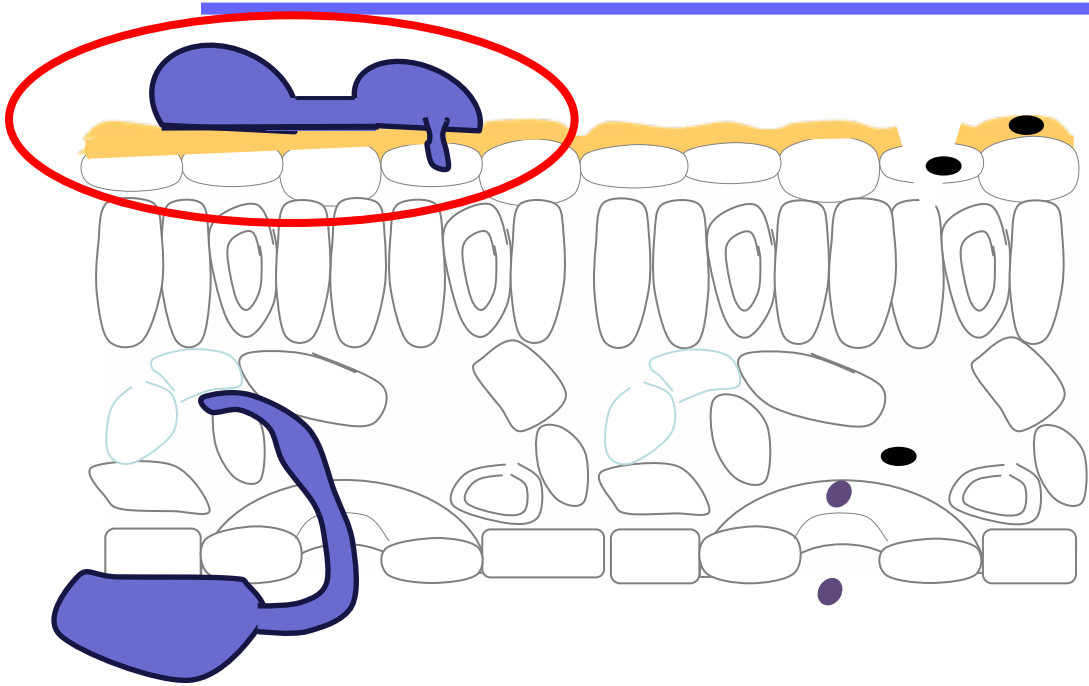
1. Fungi as plant pathogens

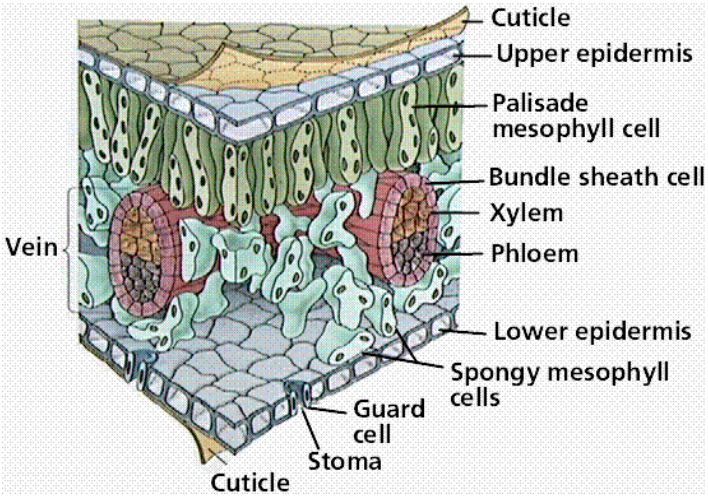
Morphology:

- Cell walls contain mainly chitin.
- When fungal spoors germinate, they develop into microscopical, cylindric, elongated structures with cross walls: the **hyphae (singular: hypha)**.
- In most cases the hyphae join up and form very fine filaments, the **mycelium**, a kind of felt-like web of varying density.
- Hyphae are distributed within the substrate, i.e. soil, organic litter or wood, and are able to extract nutrients and carbohydrates from this substrate.



Entry routes for plant pathogens



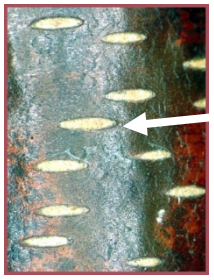


Wounds

Natural openings

Direct penetration

TMV
Agrobacterium
Soft rot fungi
etc.



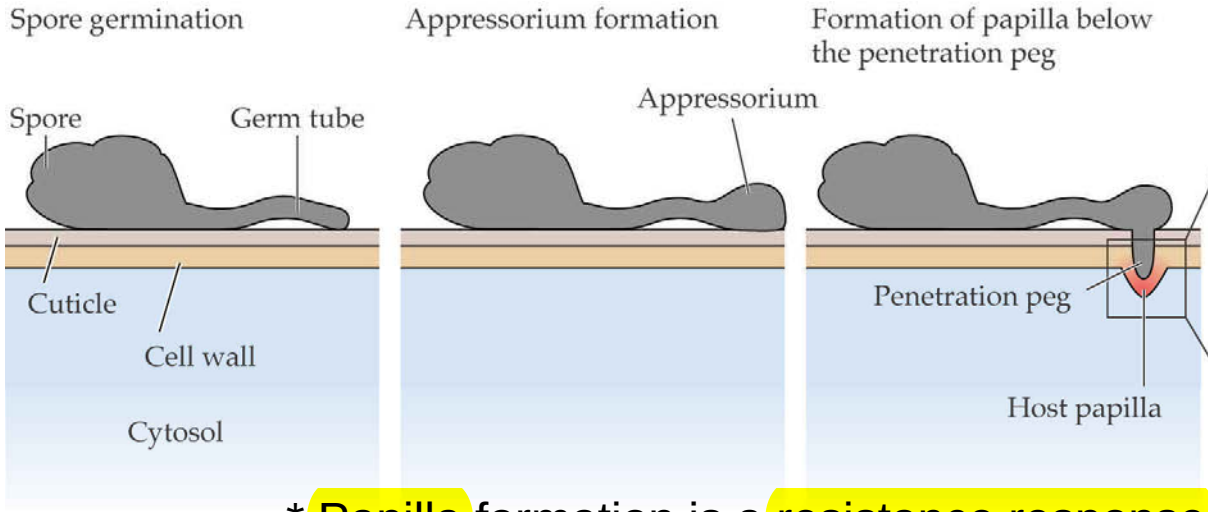
- Lenticels
- stomata

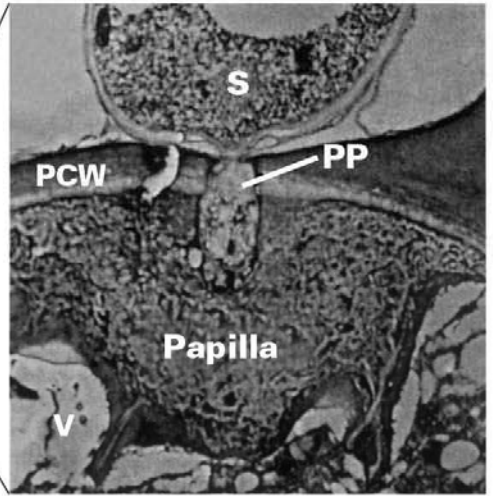
Rust fungi
Pseudomonas
etc.

Powdery mildews
Rice Blast
etc.

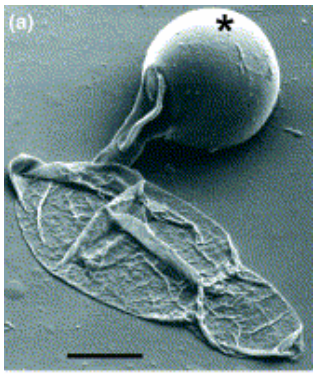
General introduction of plant pathogens

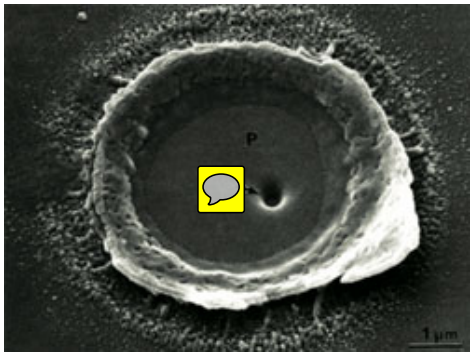
- Powdery mildew: spore germination and penetration





* Papilla formation is a resistance response.





Rice Blast fungus

S: spore
PCW: Plant cell wall
PP: Penetration peg
Papilla: In plant pathology, papilla refers to the accumulation of material (protein, lignin etc.) between the host plant's cell wall and cell membrane at the point of fungal penetration.

General introduction of plant pathogens

Important characteristics of plant pathogen

- Necrotrophs (⟷ saprotrophs)
- Biotrophs
- Hemi-biotrophs

Strategies utilized by plant pathogens

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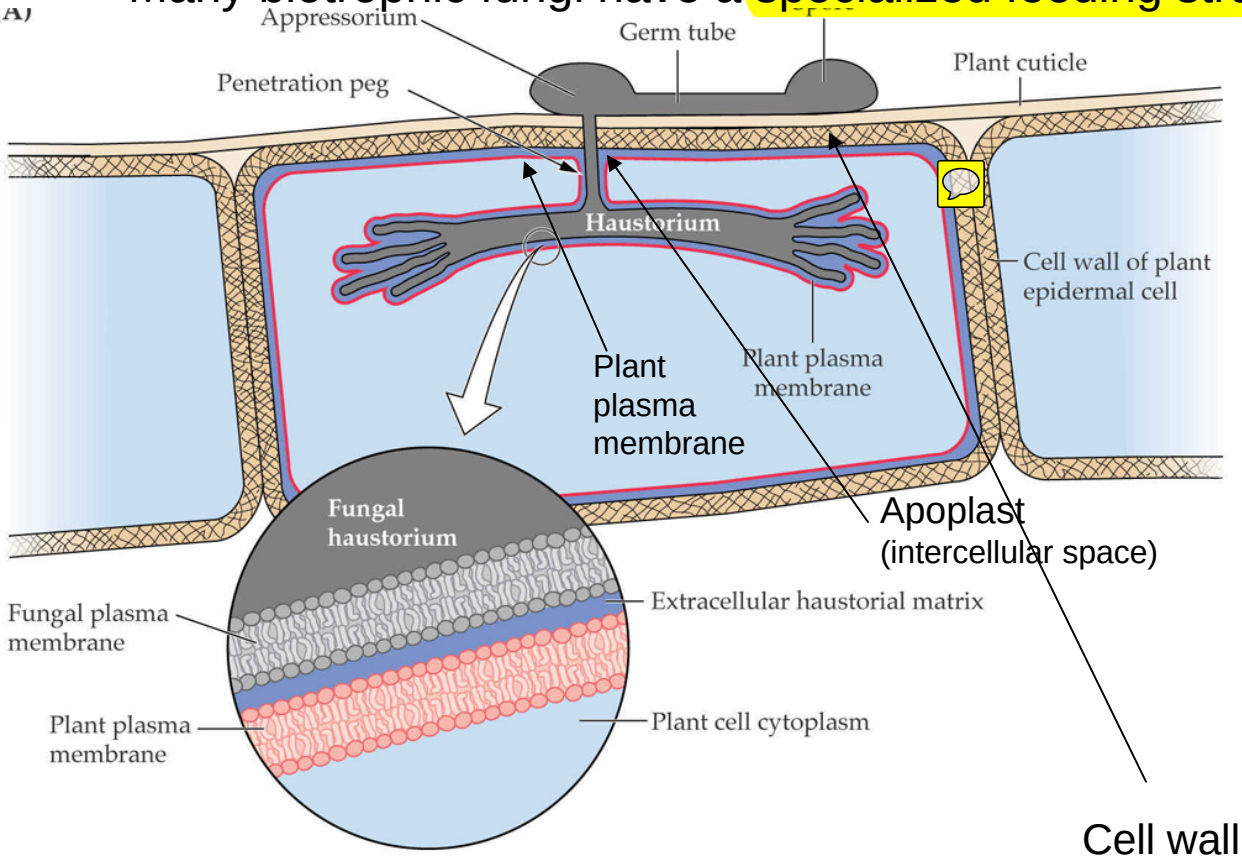
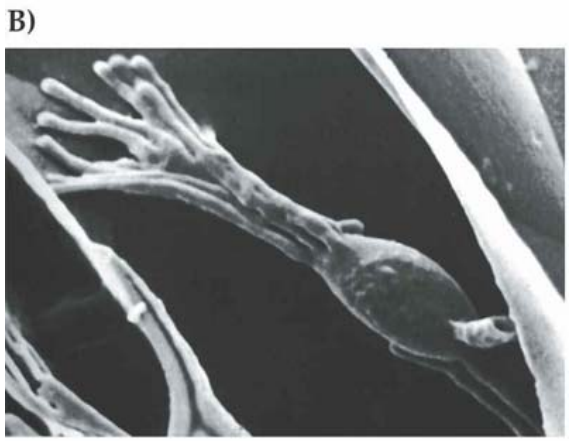
Example	Rotting bacteria and fungi	Fungal mildews and rust viruses	Phytophthora infestans Pseudomonas

General introduction of plant pathogens

1. Fungi as plant pathogens

- Many biotrophic fungi have a specialized feeding structure, the **haustorium**.





* Extracellular matrix of haustorium contains products of both fungal and plant origin

General introduction of plant pathogens

1. Fungi as plant pathogens

“Green islands”
in senescing leave

•Frequently this type of biotrophic fungus suppresses natural senescence of plants and causes “ green islands” in infected leaves.

General introduction of plant pathogens

1. Fungi as plant pathogens

Chemical weapons of fungi

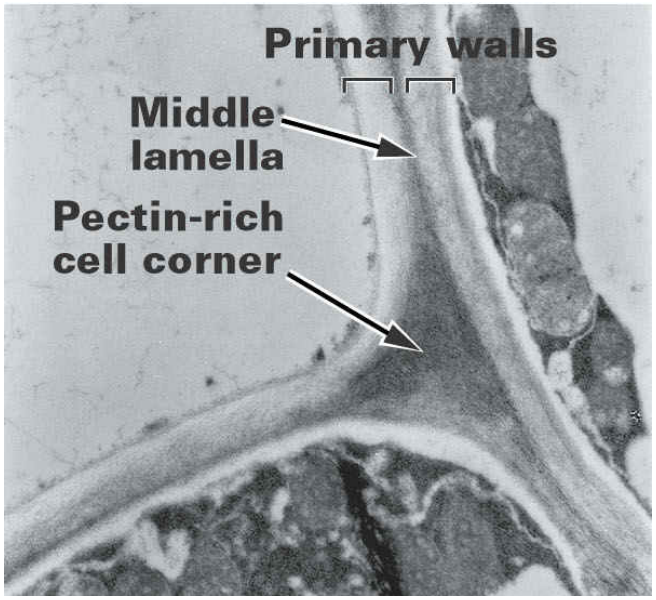
1. Enzymes

- Phytopathogenic fungi (some bacteria, too) produce different sets of degrading enzymes.
- These enzymes play important roles during penetration and disease developmental stages.

General introduction of plant pathogens

1. Fungi as plant pathogens

• Cell wall degrading enzymes produced by plant pathogens include cutinases, pectinases, cellulases, glucanases, proteinase, ligninases etc.



• Many of the necrotrophic pathogens which attack herbaceous tissues produce pectolytic enzymes.

• Some tree pathogens secrete cellulase and ligninases.

Structure of the plant cell wall

Cuticle, pectin, cellulose, hemicellulose, lignin and cell wall proteins.

Middle lamella is a thin layer of pectic substance.

Chemical weapons of fungi

2. Microbial Toxins

In phytopathology, “toxin” is reserved for toxic chemicals able to cause effects similar to those of disease symptoms induced by microorganisms.

Two types of microbial toxins

- Host specific (selective) toxins
- Non host specific (selective) toxins

General introduction of plant pathogens

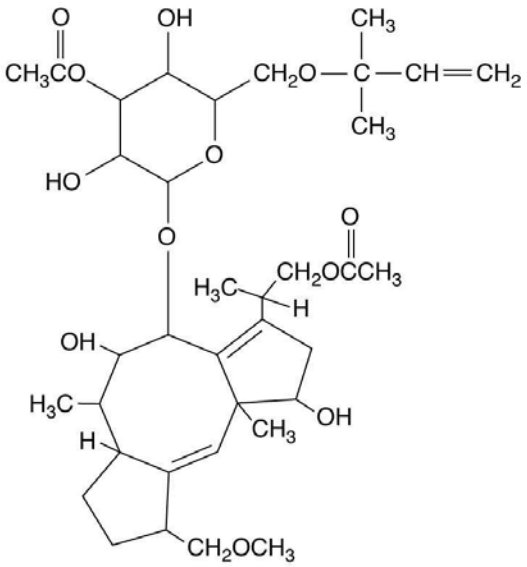
1. Fungi as plant pathogens

Non-host specific (selective) toxins

Toxins produced by phytopathogenic microbes.

This type of toxins are active not only in host plants but also in the non-host plants.

Non-host specific toxins are not primary determinants of host range.



Fusicoccin

Fusicoccin is produced by *Fusicoccum amygdali*

Disease symptoms

Common name “ Canker”

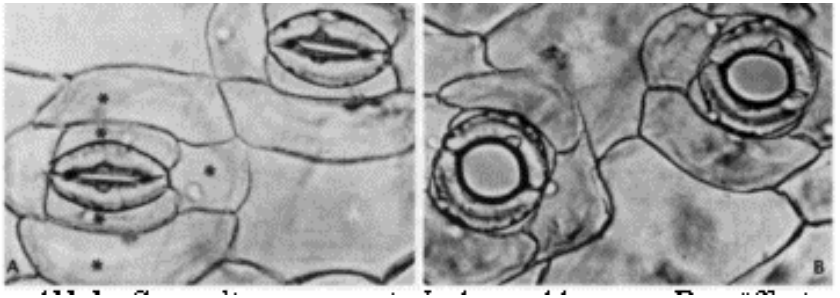
Host range-The range of host species or cell types which a particular virus, bacteria, or parasite is able to infect or parasitise.

General introduction of plant pathogens

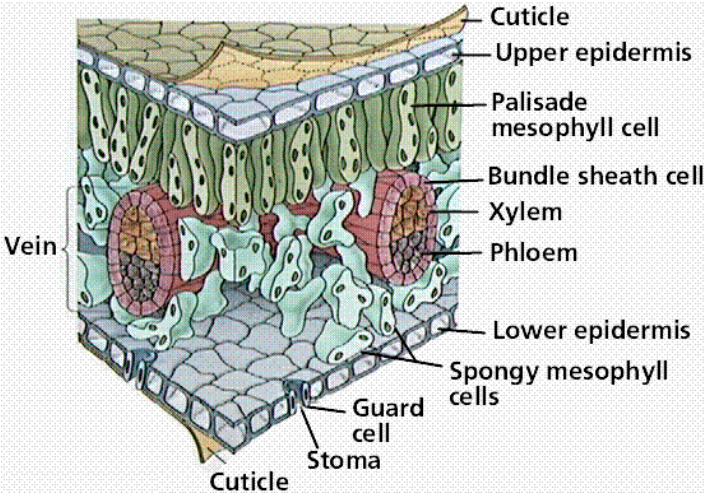
1. Fungi as plant pathogens

Disease symptoms
Common name " Canker"
•The toxin stimulates
the **H^+-ATPases** of the **guard cells**

Stomata opening by FC

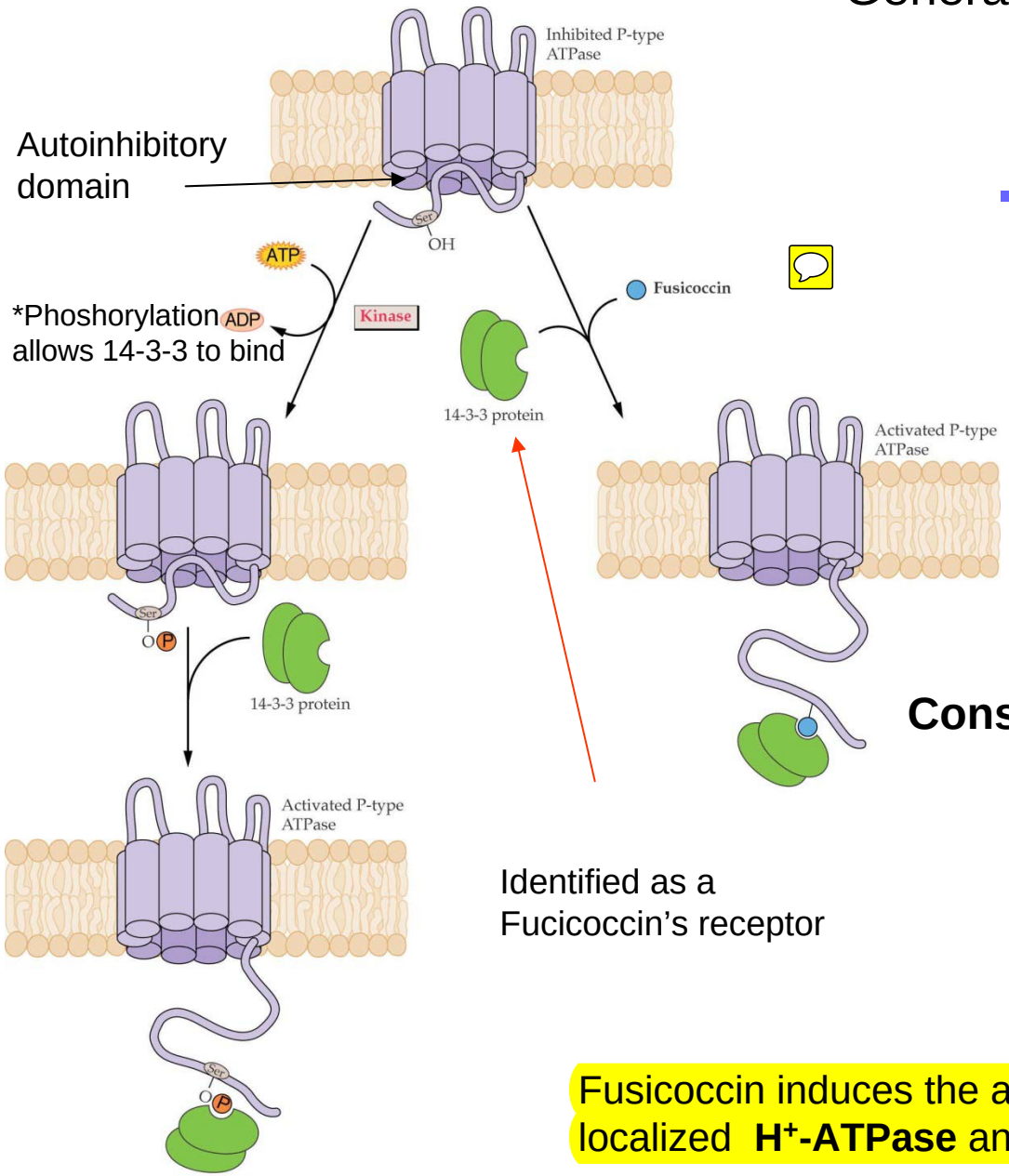


•A rapid (10 to 30 seconds) hyperpolarization of the plasma membrane occurs and open stomata



1. Fungi as plant pathogens

Models for the activation of plasma membrane H+ ATPase



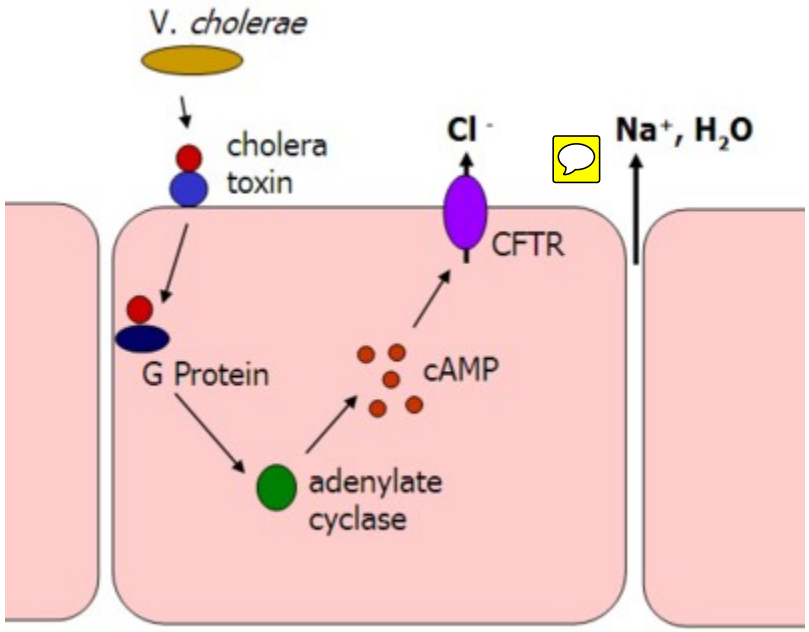
Constitutive active

Identified as a Fucicoccin's receptor

Fusicoccin induces the activation of the plasma membrane localized **H^+-ATPase** and leads to stomata opening.

1. Fungi as plant pathogens

Similarity to the effect of cholera toxin from *Vibrio cholerae* for the intestinal epithelium.



High concentration of cAMP courses constitutive activeness of the chloride channel CFTR.

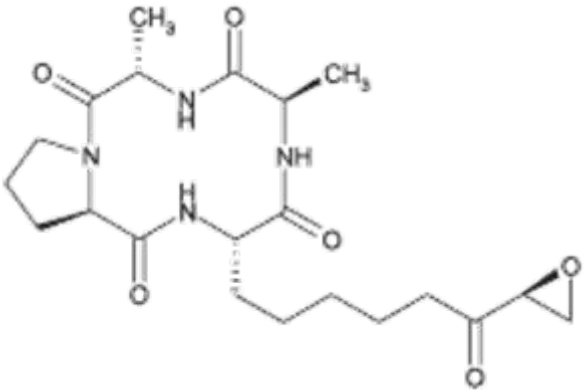
General introduction of plant pathogens

1. Fungi as plant pathogens

• Host-specific (selective) toxins

A host-specific toxin is a substance produced by a pathogenic microbe that, at physiological concentrations, is toxic to the hosts of that pathogen and shows little or no toxicity against non-host plants.

In general, HSTs must be present for the producing microorganism to be able to cause disease.

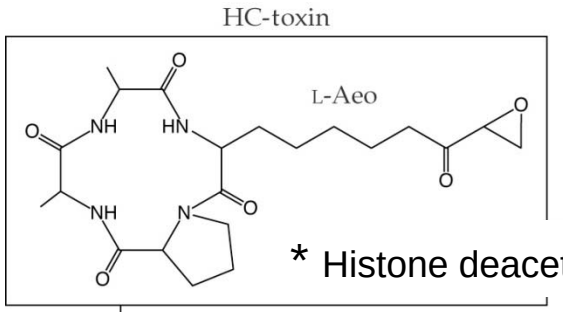


HC-toxin produced by *Cochliobolus carbonum.*

General introduction of plant pathogens

1. Fungi as plant pathogens

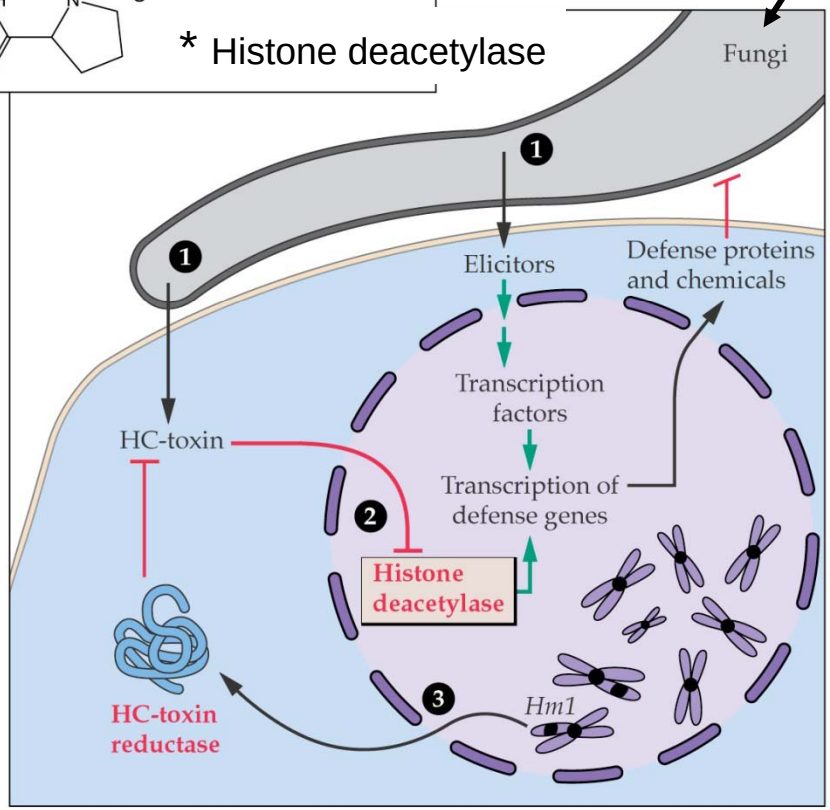
- Pathogens fight against plant defense system and plants fight back

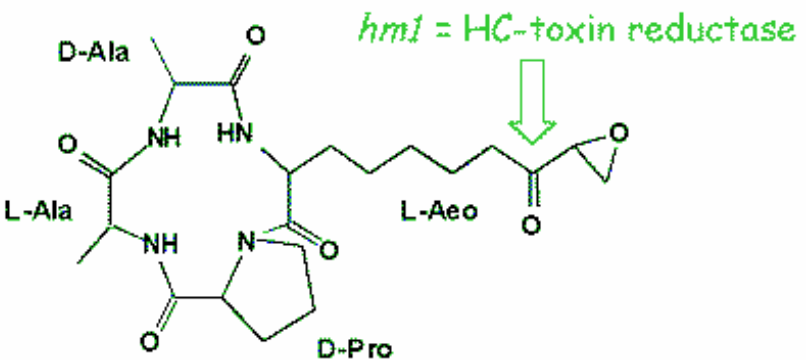


* Histone deacetylase

maize (corn) fungal pathogen

Cochliobolus carbonum.





* *Hm1* encodes HC-toxin reductase (HCTR)

*Elicitors: substances of biotic origin which induce a defense response

From Biochemistry and Molecular Biology of Plants

2. Oomycetes as plant pathogens

General introduction of plant pathogens

2. Oomycetes as plant pathogens

Oomycetes

- They are colloquially regarded as "fungi," but ultra-structure and DNA sequence argues against their inclusion in the kingdom Mycota (kingdom Fungi). (They bear closer relationship to a group of algae, and the kingdom Chromista has been proposed)
- Cell walls contain mainly β-1,3-glucans and perhaps cellulose, but not chitin.

- *Phytophthora infestans* on potato