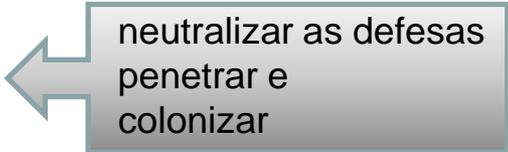


INTRODUÇÃO À FISIOLOGIA DO PARASITISMO

- **Mecanismos de ataque dos patógenos**

- ✓ Forças mecânicas

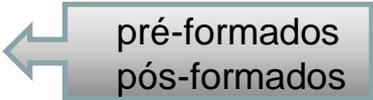
- ✓ Arsenal bioquímico



neutralizar as defesas
penetrar e
colonizar

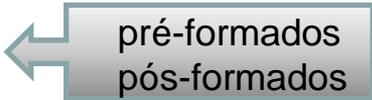
- **Mecanismos de defesa dos hospedeiros**

- ✓ Mecanismos estruturais



pré-formados
pós-formados

- ✓ Mecanismos bioquímicos



pré-formados
pós-formados

Resistência é regra

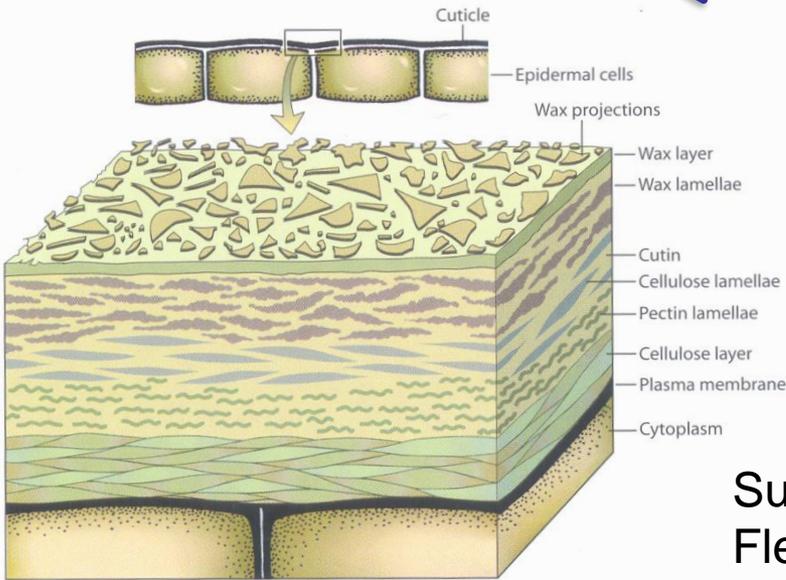
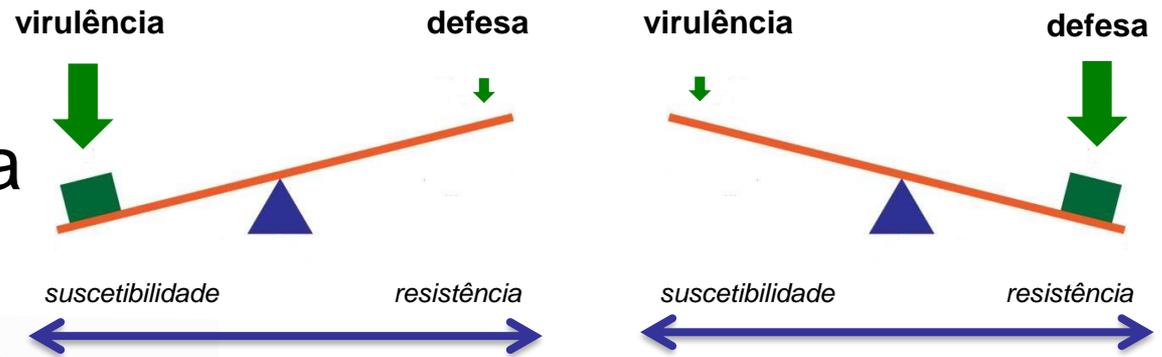
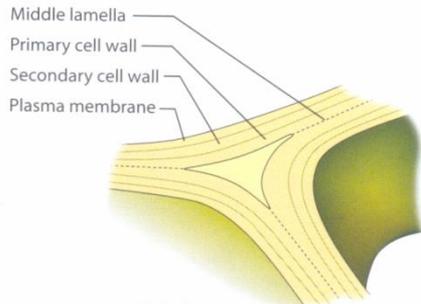


FIGURE 5-3 Schematic representation of the structure and composition of the cuticle and cell wall of foliar epidermal cells. [Adapted from Goodman *et al.* (1967).]



Barreiras extracelulares para proteção:

Insetos – quitina

Animais – queratina, escamas e pelos

Plantas – cutícula (cutina + cera)



Suficientemente rígida – resistir à infecção

Flexível – acompanhar crescimento do órgão vegetal

Barreiras inter e intracelulares em vegetais:

Lamela média

Parede celular

Produtos pré e pós formados intracelulares

Ataque do patógeno

Vencer barreiras estruturais
Neutralizar reações de defesa
Transformar compostos em produtos

Forças mecânicas bioquímicas

- ⇒ Enzimas
Cutícula e parede
- ⇒ Toxinas
Não-específicas
Específicas
- ⇒ Reguladores de crescimento
- ⇒ Polissacarídeos
Doenças vasculares
- ⇒ Outros
Efetores, peptídeos, etc.



Ataque do patógeno

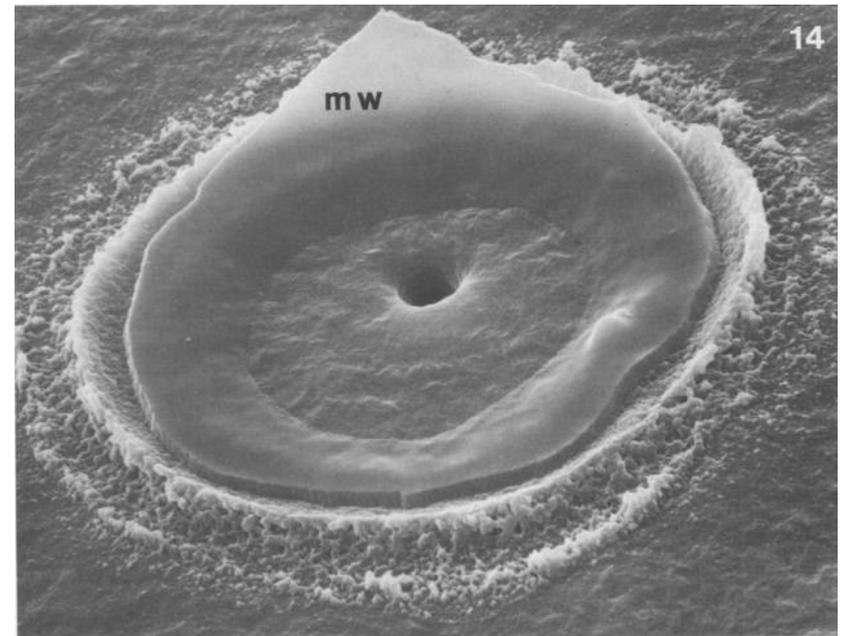
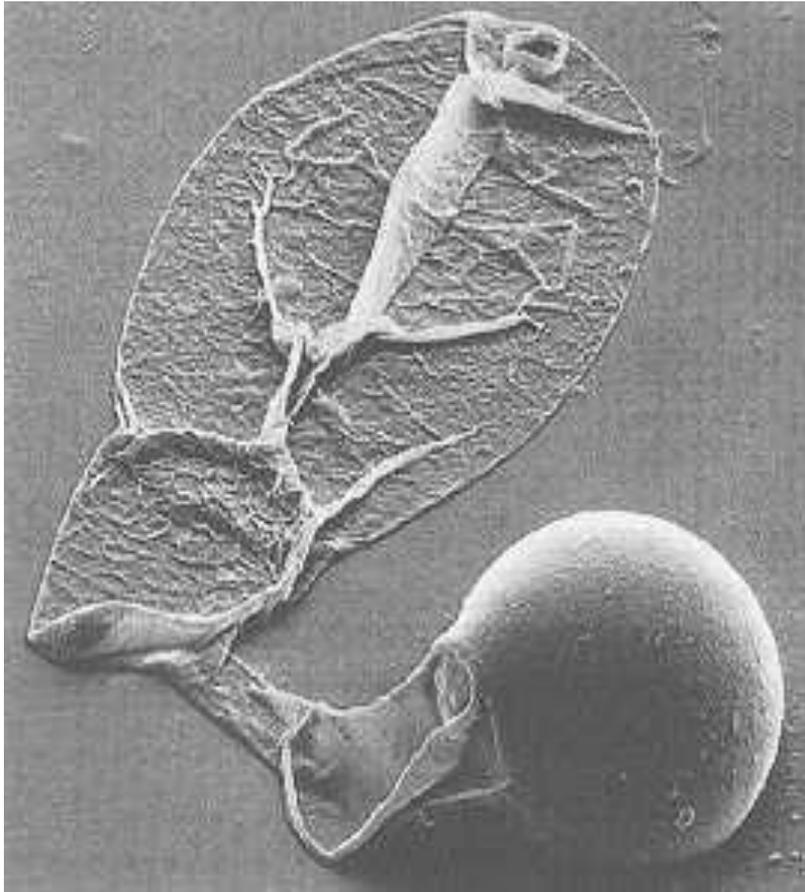
Vencer barreiras estruturais

Neutralizar reações de defesa

Transformar compostos em produtos assimiláveis (nutrição)

Forças mecânicas

Apressório de *Magnaporthe oryzae*, melanizado, preso ao conídio em colapso



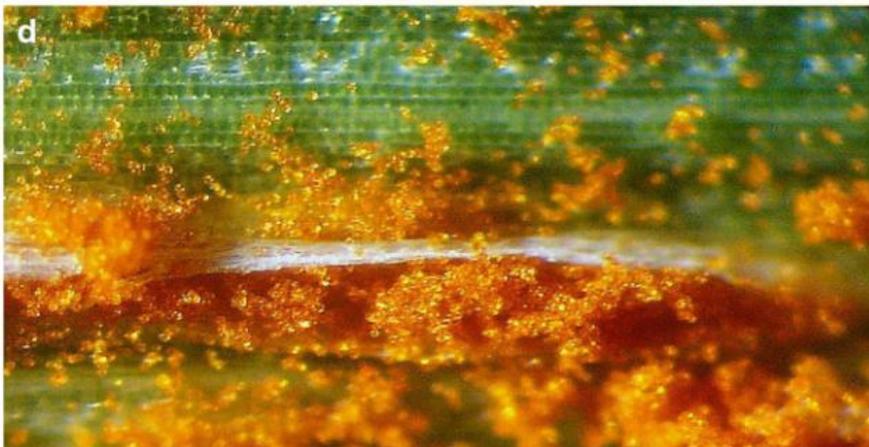
Efeito do peg de penetração em superfície de polietileno, após retirada do apressório (Braun & Howard, 1994)

Forças mecânicas

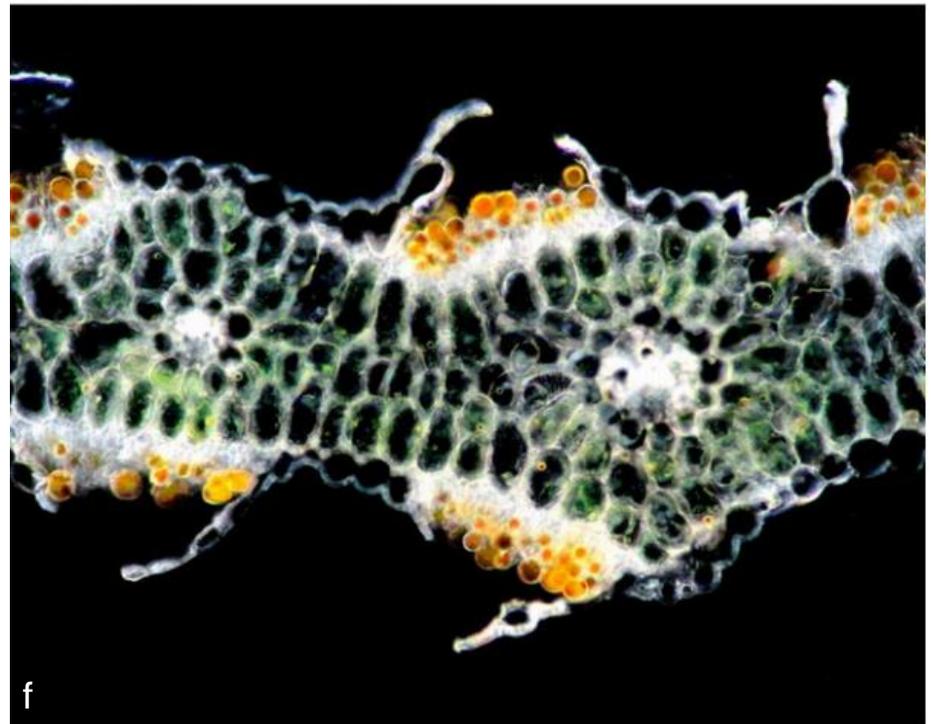
Vencer barreiras estruturais

Neutralizar reações de defesa

Transformar compostos em produtos assimiláveis (nutrição)



Ruptura mecânica da epiderme e da cutícula de folhas de trigo durante a reprodução do inóculo de *Puccinia graminis* f.sp. *tritici* (a-d) e de *Puccinia triticina* (e-f) (Chaves et al., 2013)



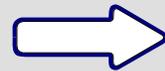
Ataque do patógeno

Vencer barreiras estruturais

Neutralizar reações de defesa

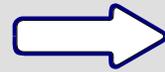
Transformar compostos em produtos assimiláveis (nutrição)

Forças mecânicas **bioquímicas**



Enzimas

Cutícula e parede



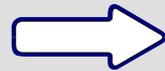
Toxinas

Não-específicas

Específicas



**Reguladores de
crescimento**



Polissacarídeos

Doenças vasculares



Outros

Efetores, peptídeos, etc.

Neutralização de reações de defesa – efetores para impedir o reconhecimento

Defesa celular

Receptores de sinais na membrana celular
percepção de sinais externos
patógenos, hormônios...

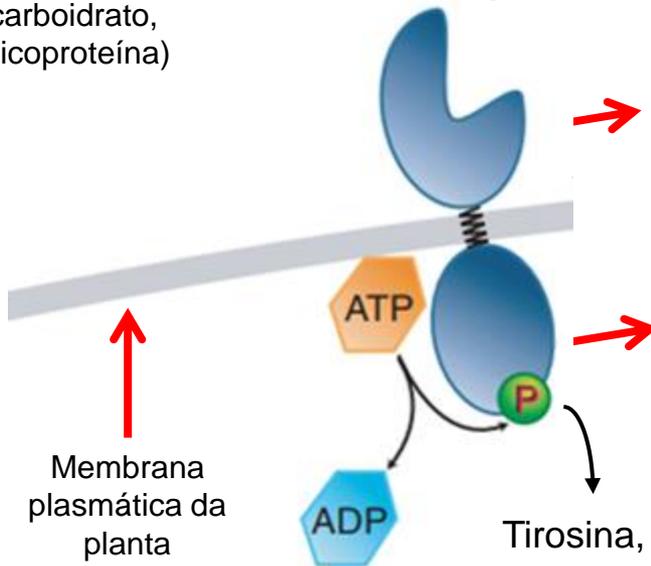


Componentes do patógeno

(proteína, peptídeo, hormônio, carboidrato, glicoproteína)

Componentes e função das quinases receptoras
Receptor-like kinases / Receptor protein kinases

COMPONENTE	FUNÇÃO
Domínio extracelular	reconhecimento de sinais
Tirosina quinases	fosforilização de resíduos de tirosina
Serina/treonina quinases	fosforilização de resíduos de serina
Histidina quinases	fosforilização de resíduos de histidina



Tirosina, etc.

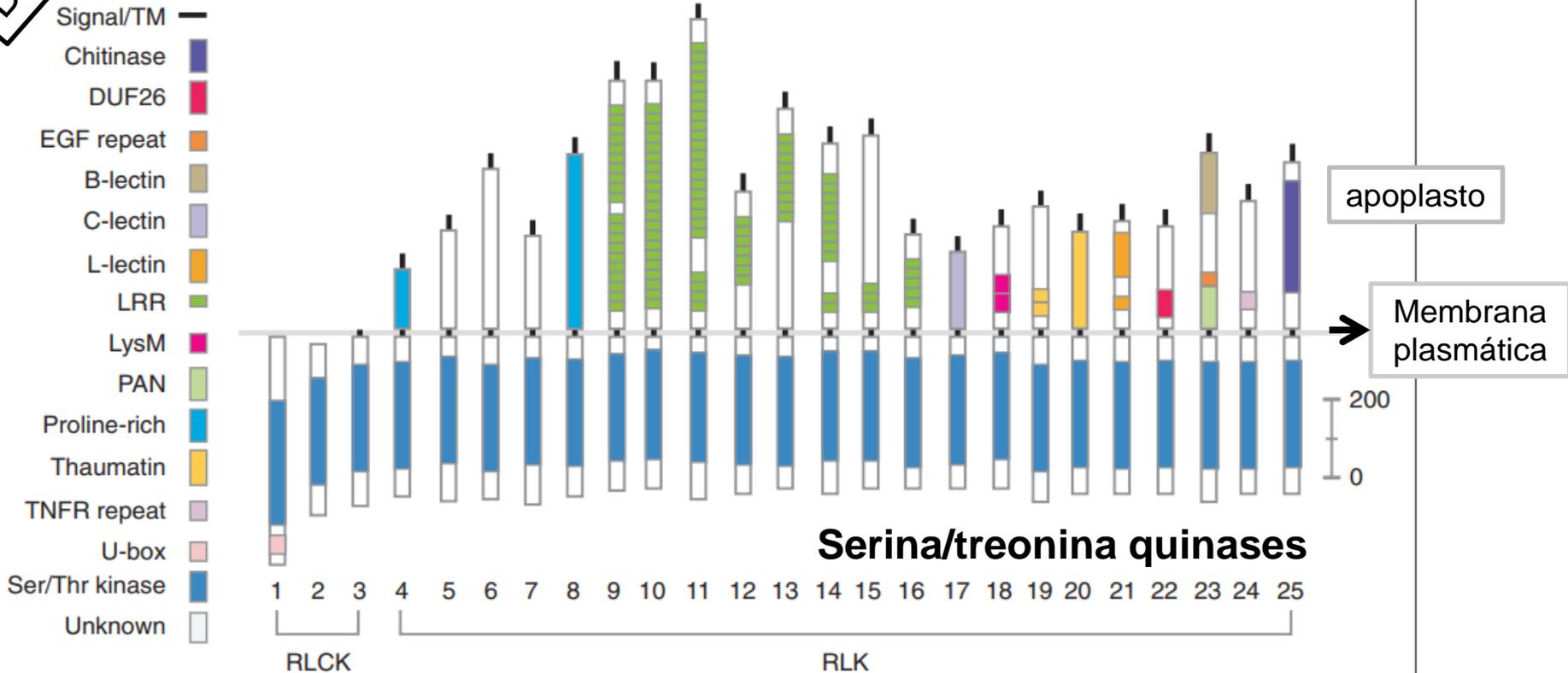
Cascata bioquímica

Neutralização de reações de defesa – efetores para impedir o reconhecimento

Membros representativos da família de quinases receptoras

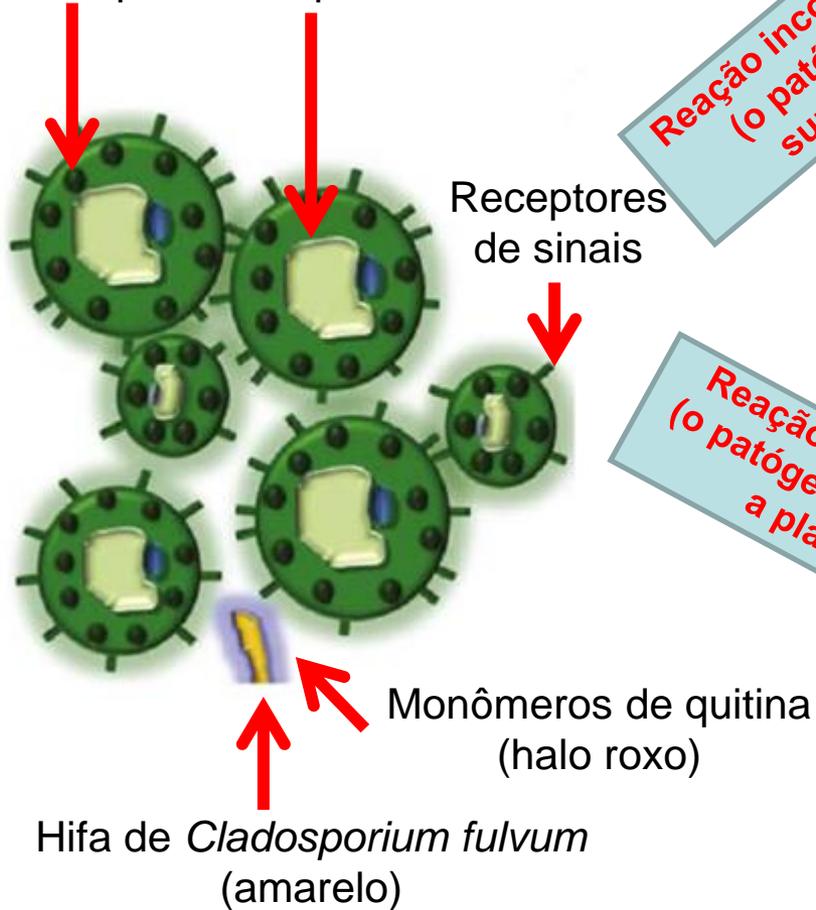
Defesa celular

Domínios extracelulares

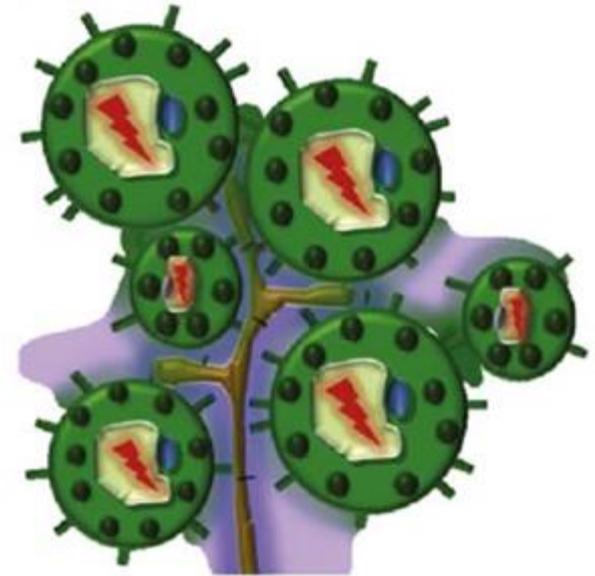


Neutralização de reações de defesa – efetores para impedir o reconhecimento

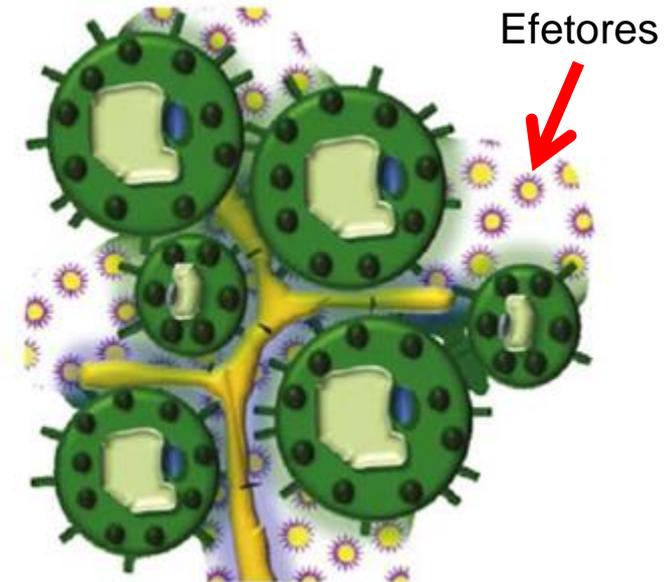
Células da planta hospedeira



Reação incompatível
(o patógeno é suprimido)



Reação compatível
(o patógeno coloniza a planta)

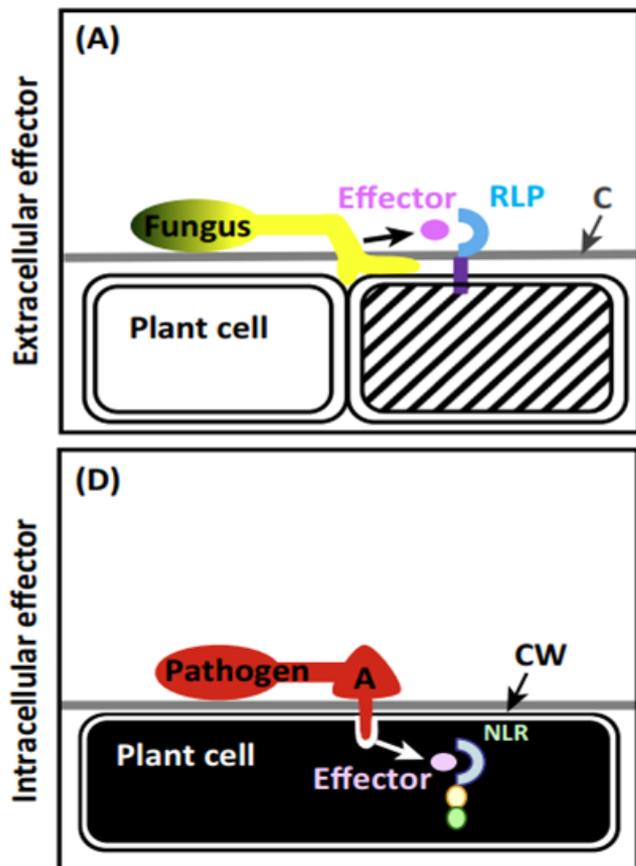


Neutralização de reações de defesa – efetores para impedir o reconhecimento

Reação incompatível



Recognition
(receptor and effector present)

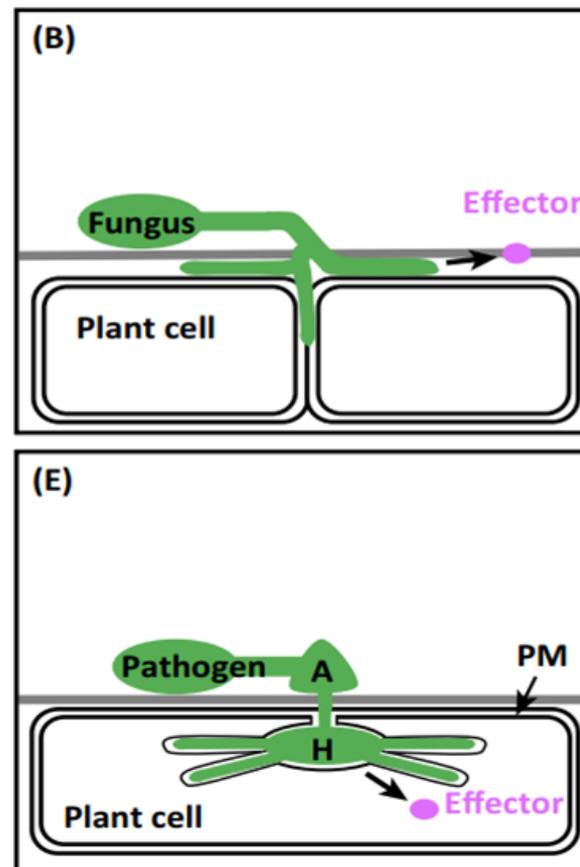


Resistência

Reação compatível



No recognition
(receptor lacking)



Suscetibilidade

Ataque do patógeno

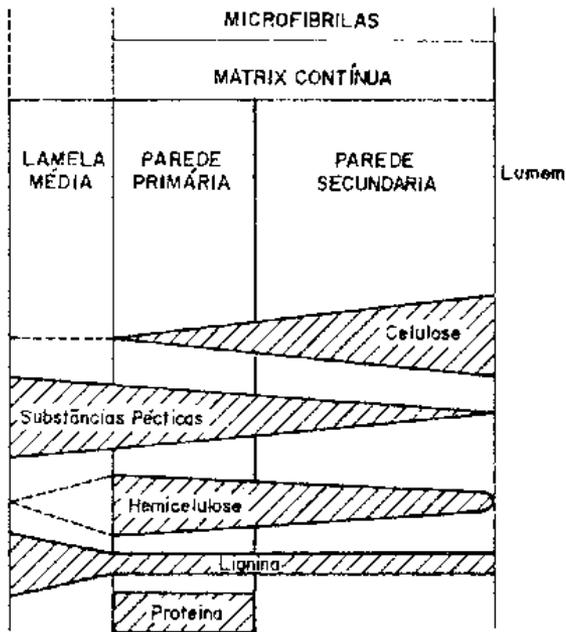
Vencer barreiras estruturais

Neutralizar reações de defesa

Transformar compostos em produtos assimiláveis

Forças **mecânicas** **bioquímicas**

- ⇒ **Enzimas**
Cutícula e parede
- ⇒ **Toxinas**
Não-específicas
Específicas
- ⇒ **Reguladores de crescimento**
- ⇒ **Polissacarídeos**
Doenças vasculares
- ⇒ **Outros**
Efetores, peptídeos, etc.



Enzimas extracelulares

Cutinase

Cutina

poliéster de ácido graxo

Enzimas Pécicas

polissacarídeo ác. galacturônico + ramnose

pectina esterases

Pectina

poligalacturonases

Pectato

pectato liases

Pectato

Hemicelulases

polímeros de xilose, arabinose, galactose...

xilanase

Xilana

arabanase

Arabana

Celulase

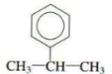
Celulose

polissacarídeo de glicose

Ligninase

Lignina

polímero de fenilpropano



Protease

Proteína

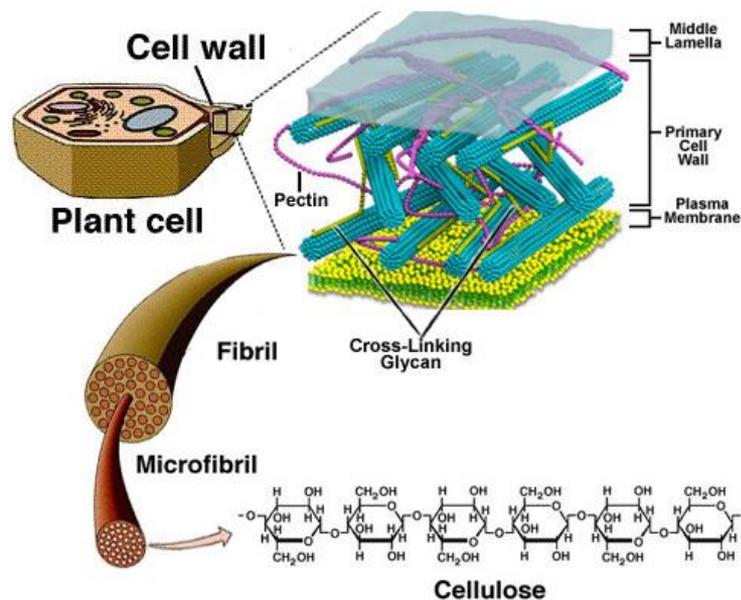
Fosfolipase

Fosfolípídeos

Amilase

Amido

polissacarídeo de glicose



Cutina - cutinases

Fungos e *Streptomyces scabies*

Cutina

Poliéster insolúvel (polímero lipídico)

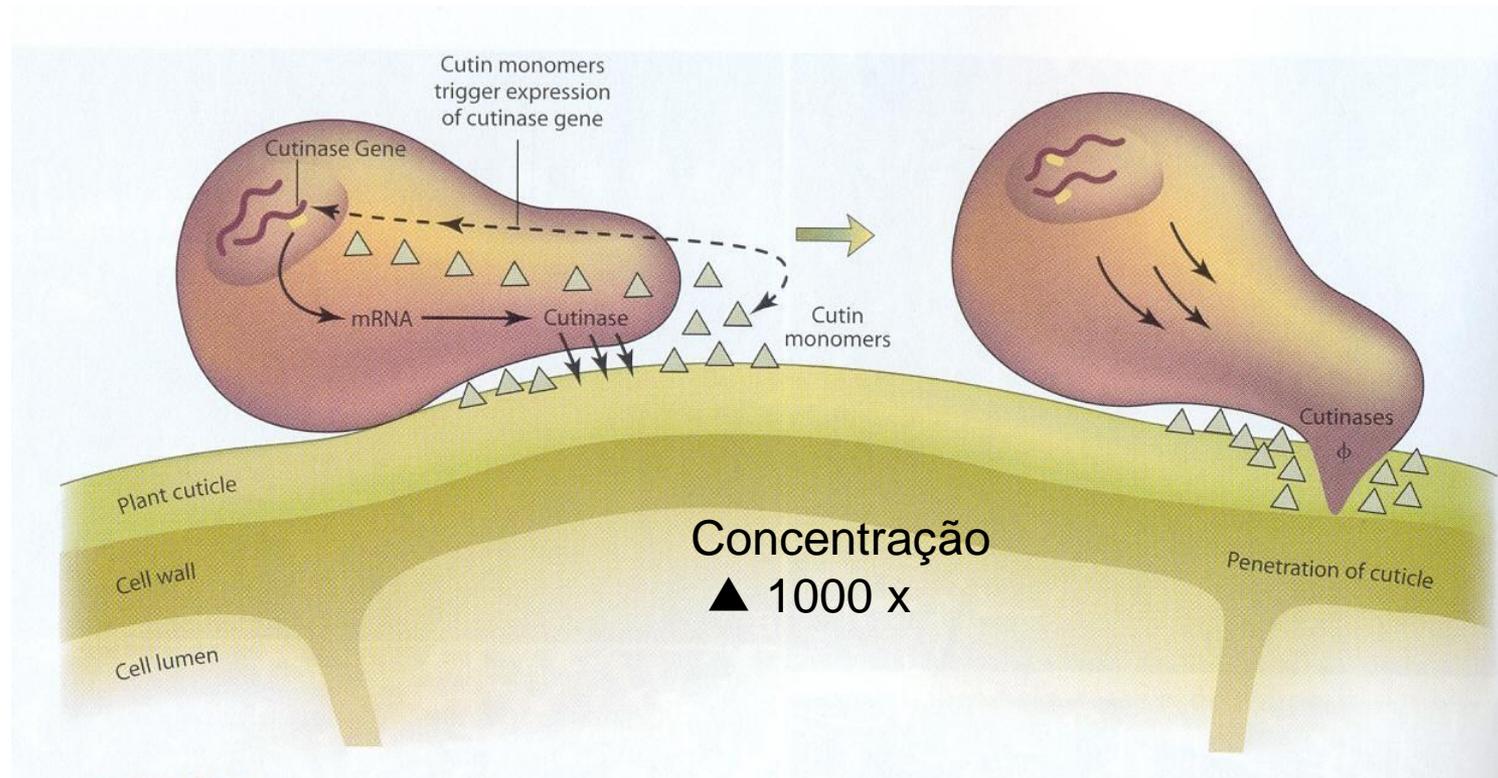
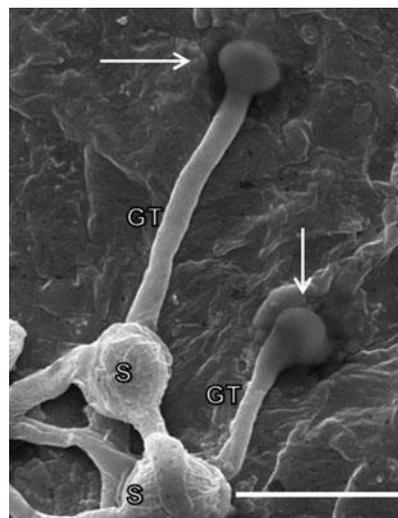


FIGURE 5-5 Diagrammatic representation of cuticle penetration by a germinating fungus spore. Constitutive cutinase releases a few cutin monomers from the plant cuticle. These trigger expression of the cutinase genes of the fungus, leading to the production of more cutinase(s), which macerates the cuticle and allows penetration by the fungus.

Desenvolvimento de podridão mole (*Rhizopus stolonifer*) em pêsegos



Germinação de aplanósporos de *R. stolonifer*



Fruto tratado com DIPF



Cutinases – 1975

Fusarium solani f. sp. *lisi* - ervilha

Isolado T-8 com múltiplos genes para cutinase

isolado 77-2-3 com 1 gene - produz 10 to 20% da cutinase de T-8

Mutante 77-102 do isolado 77-2-3 não produz cutinase

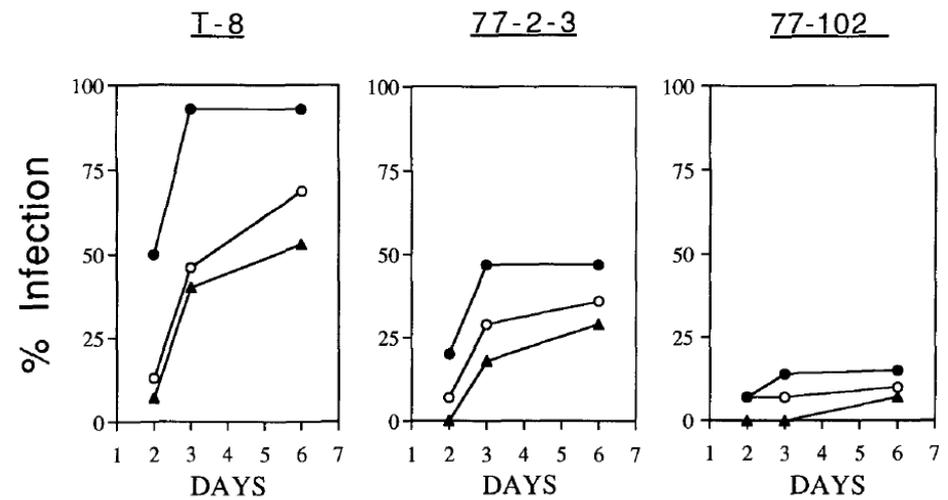


Figure 3. Time Course of Lesion Development in Pea Stem Bioassays.

Shown is the time course of lesion development when spore suspensions of *F. s. lisi* isolates T-8 and 77-2-3 and the cutinase gene-disrupted mutant were inoculated on pea stem segments for the periods indicated. Spores (10^5 [●], 10^4 [○], or 10^3 [▲]) in 5- μ L droplets were placed on each of 15 stems used for each data point.

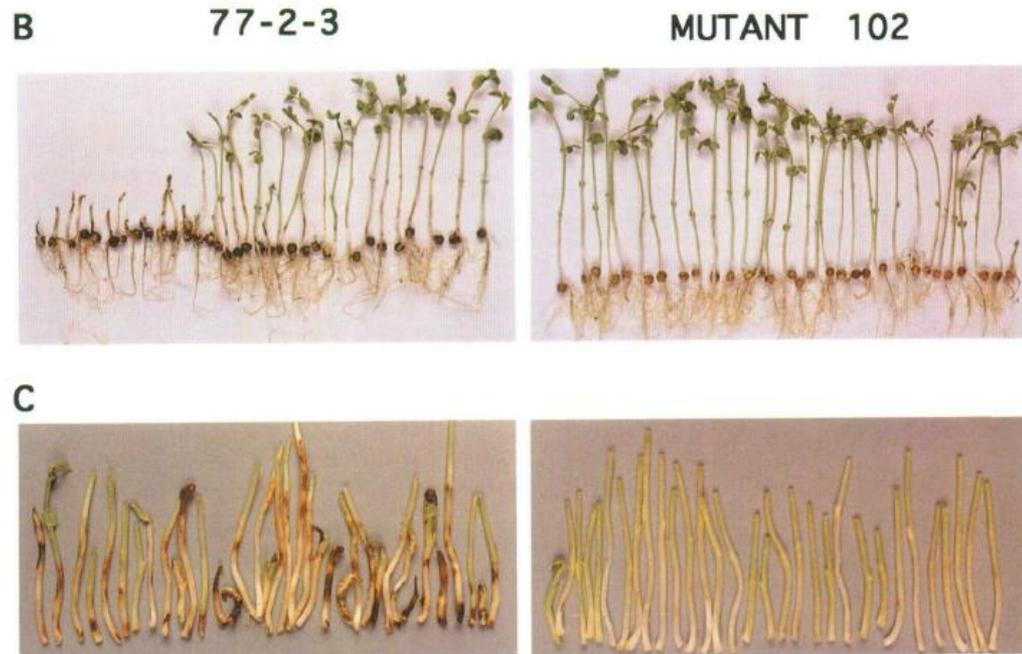
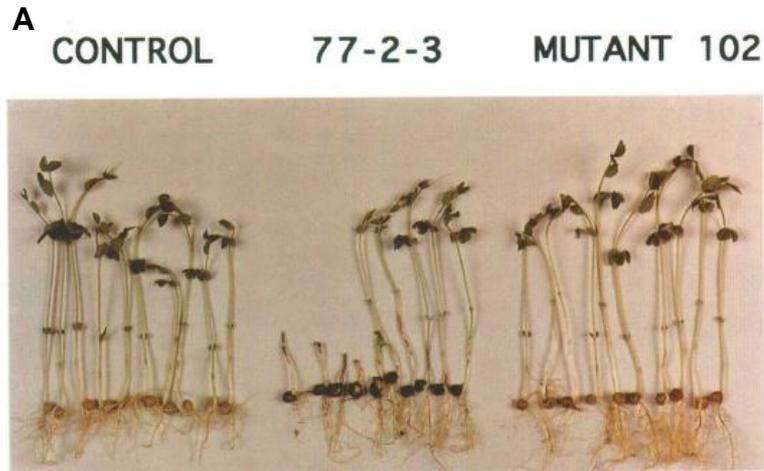
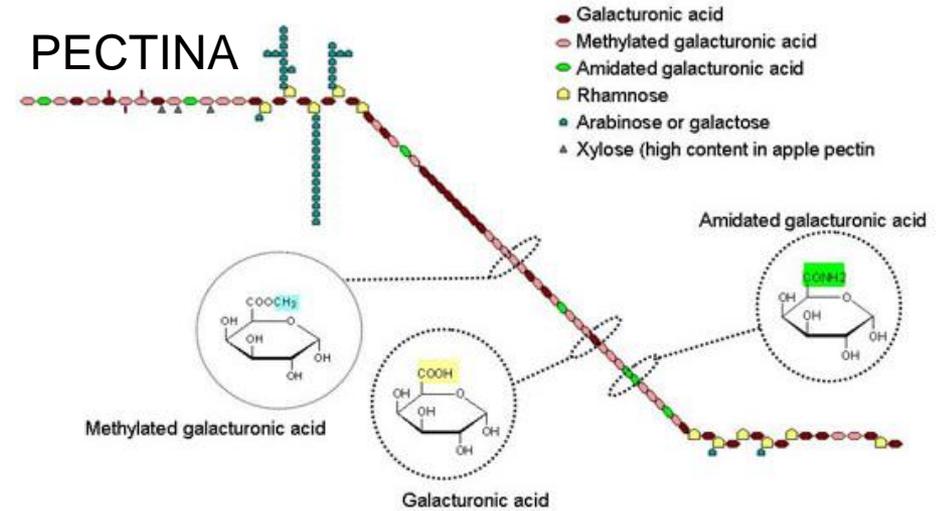


Figure 6. Infection of Pea Seedlings by *F. s. lisi* 77-2-3 and Cutinase Gene-Disrupted Mutant 77-102.

Substâncias pécticas – enzimas pectolíticas

Lamela média e parede celular
Galacturona + Rhamnose



Monilia em pêsego



Pectinases - Patógenos
causadores de podridão mole

Substâncias pécnicas – enzimas pectolíticas

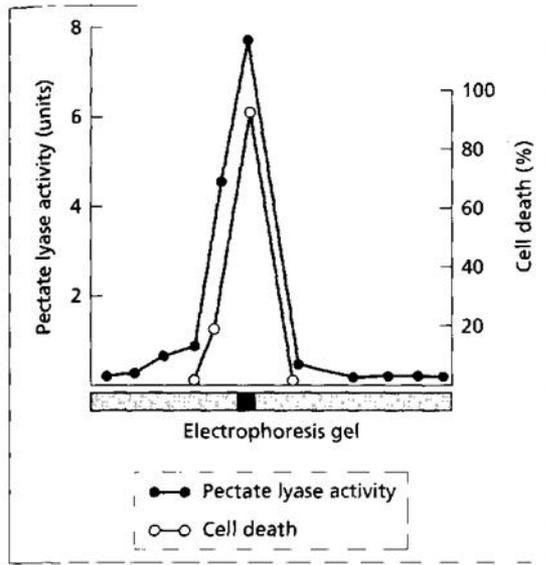


Fig. 8.3 Separation of a pectolytic enzyme (endopectate lyase) from *Erwinia* by acrylamide gel electrophoresis. The enzyme has migrated in the gel as a single band. Note that high enzyme activity coincides with greatest lethal activity towards potato cells. (Data from Basham & Bateman 1975.)

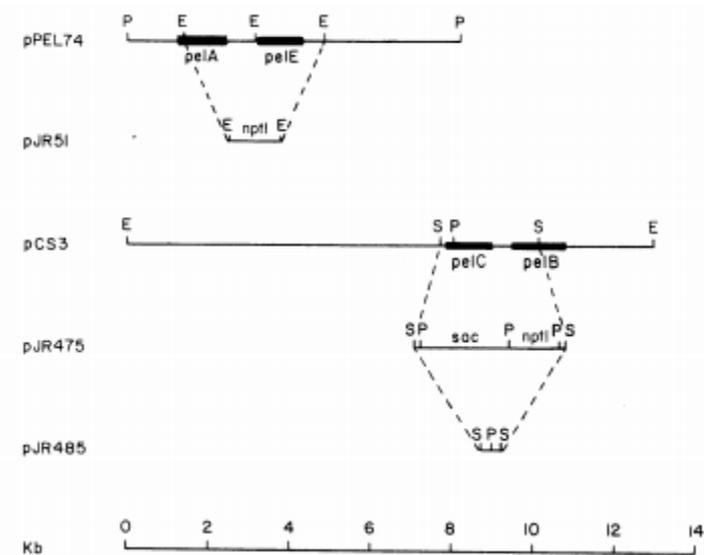


Fig. 1. Restriction map of the deletions in cloned *pel* genes used to construct *Erwinia chrysanthemi* Pel^- mutants. The cloned region of the *pel*-containing plasmids, including the location of specific *pel* genes and the relevant restriction sites, are shown for pPEL74 and pCS3. Dashed lines denote the replacement of sequences. These deletion derivatives were used

AC4150 - Isolado selvagem de *E. chrysanthemi*, com genes de enzimas pectolíticas
UM1005 – Mutante com deleções e substituições no plasmídeo que contém o gene de enzimas pectolíticas

Table 3. Maceration of potato tuber tissues by *Erwinia chrysanthemi* wild-type and Pel^- strains

Strains	Wet weight (g) of macerated tissue per inoculation site	
	Tuber slices ^a	Whole tubers ^b
AC4150	1.26 ± 0.44	0.196 ± 0.068
UM1005	0.27 ± 0.14	0.003 ± 0.006

^aBacteria were stabbed 4 mm deep into tuber slices with a toothpick. Macerated tissue was gently scraped out and weighed after 28-hr incubation. Values represent mean and SD of six slices.

^bBacterial suspensions containing 7.5×10^8 (AC4150) and 5.8×10^8 (UM1005) colony forming units in 25 μ l were injected into whole potato tubers. Macerated tissue was weighed after 68-hr anaerobic incubation. Values represent mean and SD of 11 inoculation sites.

Enzimas extracelulares

Table 1 Extracellular enzymes produced by *Erwinia chrysanthemi*

Name	Activity ^a	Strain ^b	Secretion pathway	Length amino acids ^c	Mr ^d kd	pI ^d	Substrate ^e	Products	pHopt	References
PelA	endo-Pectate lyase	EC16 3937	Out	361 + 31	44	4.2–4.6	PGA	predominant oligomers: di-to dodecamers	8.6	9, 43, 102, 130
PelB	endo-Pectate lyase	EC16 49, 57 ^f	Out	353 + 22	39	8.8	PGA	predominant oligomers: tri-tetramers	8.9–9.5	9, 66, 71, 102
PelC	endo-Pectate lyase	EC16	Out	353 + 22	39	9	PGA	predominant oligomers: tri-tetramers	8.8–9.5	9, 120, 130
PelD	endo-Pectate lyase	B374	Out	360 + 31 ^g 355 + 30	43	>10	PGA	n.d.	9	136
PelE	endo-Pectate lyase	B374 3937 EC16	Out	363 + 41 ^g	45	>10	PGA	predominant oligomers: dimers	9	9, 71, 111, 136
Exo Peh	exo-Polygalacturonase	EC16	Out	577 + 27	67	8.3	PGA	dimers		53
EGY	Cellulase	3937	? ^h	309 + 22	35	8.8	CMC	—	5.5	50
EGZ	Cellulase	3937	Out	383 + 42	43	4.3	CMC	cellobiose	6.2–7.5	8, 20, 51
Pem	Pectin methylesterase	B374 3937	Out	342 + 24	37	9.6–9.9	Pectin	Pectate	5–9	76, 99, 100
PrtA	Protease	B374 EC16	Prt	454 + 18	50		Gelatin Azocasein			34, 47
PrtB	Protease	B374	Prt	465 + 16	53		Gelatin Azocasein			36
PrtC	Protease	B374	Prt	462 + 17	55		Gelatin Azocasein			36a
PrtG	Protease	B374	Prt	460 + 15	52		Gelatin			48
PlcA	Phospholipase	EC16	? ^h	358	39		Lecithin	phosphatidyl choline		70

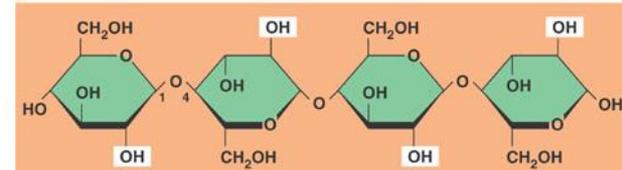
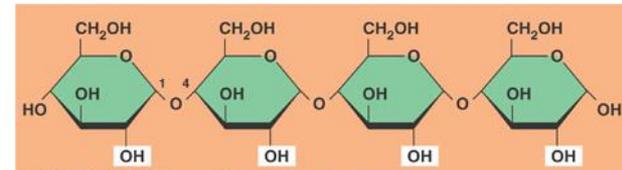
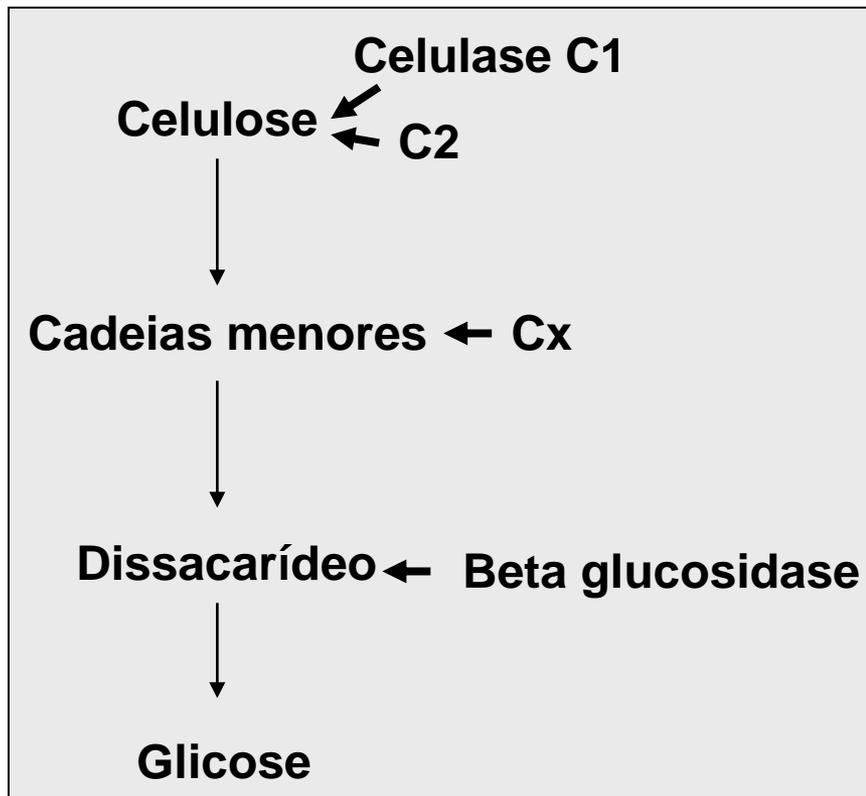
Quorum sensing

Table 2 Extracellular enzymes produced by *Erwinia carotovora*

Name	Activity	Strain ^a	Secretion pathway	Length amino acids ^b	Mr ^c kd	pI ^c	Substrate ^d	pHopt	References
PelA	endo-Pectate lyase	EC	Out	352 + 22	44	9.4	PGA	8.5	80
PelB	endo-Pectate lyase	EC	Out	352 + 22	44	9.4	PGA	8.3	78
PelC	endo-Pectate lyase	SCRI 193	Out	358 + 16	42	10.3	PGA		63
Peh	Polygalacturonase	SCRI193 SCC3193 EC ^e	Out	376 + 26	42	>10	PGA	5.5	61, 79, 120
CelS	Cellulase	SCC3193	Out	232 + 32	27	5.5	CMC	6.8	121
CelV	Cellulase	SCRI193	Out	505 + 32	50	4.5	CMC MUC	7	32
Prt1	Protease	EC14	?	347	38	4.8	Gelatin		74
PnlA	Pectin lyase	DB71 ^f	?	270	37		Pectin		24

Celulose - celulases

Parede – fibrilas
Polissacarídeo de glucose

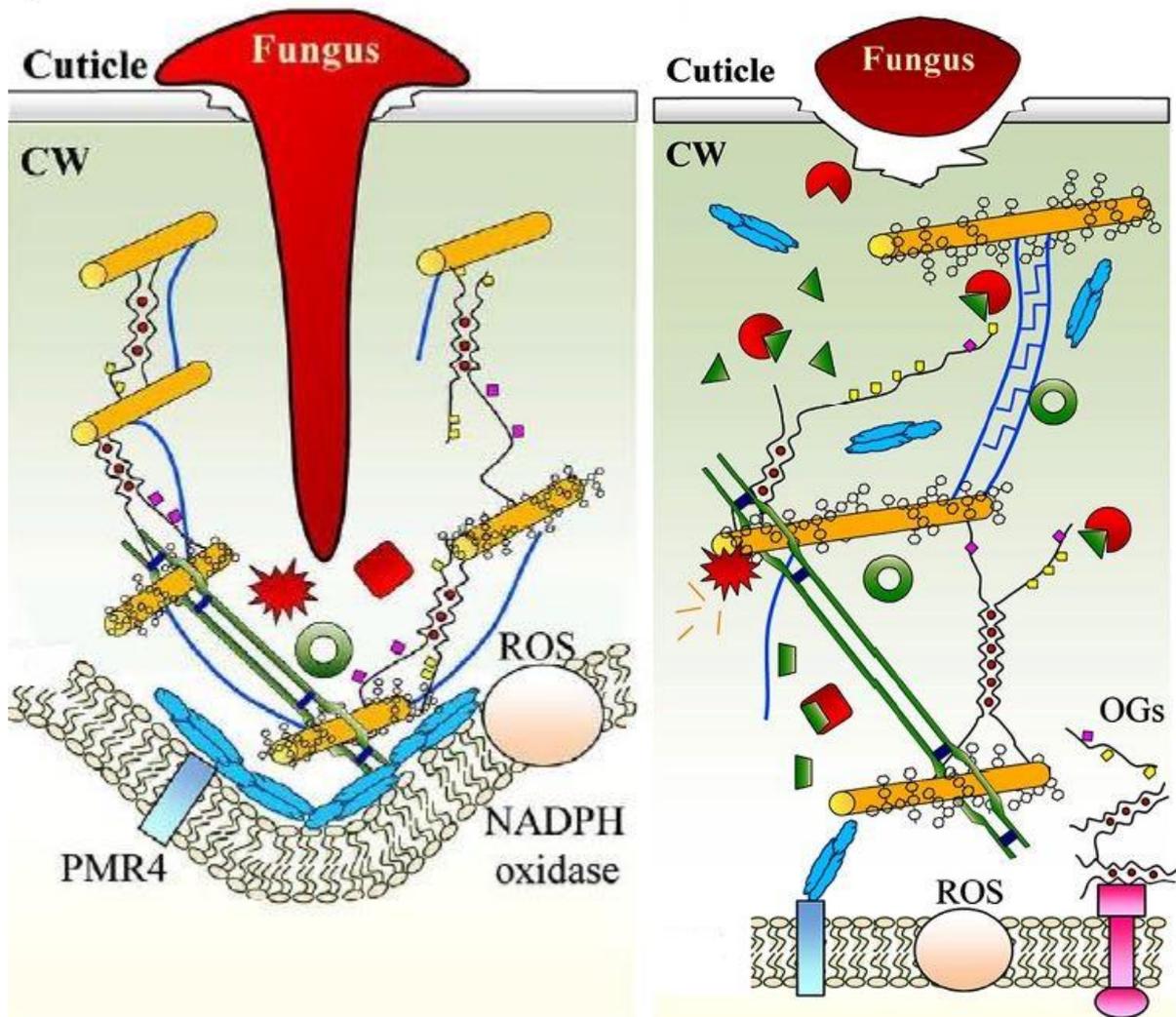


Fungos, bactérias, nematoides e plantas parasitas



Fusarium em milho

Colmo onde a celulose foi degradada
Tecidos vasculares ricos em lignina



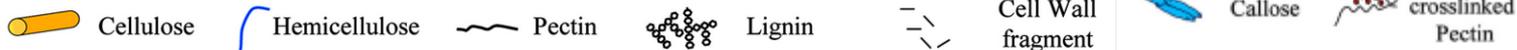
Enzimas extracelulares

Degradação da parede celular durante a invasão de patógenos biotrófico e necrotrófico

Comparativamente ao biotrófico, o fungo necrotrófico secreta maior arsenal de enzimas degradadoras da parede celular e a reação da planta é diferente.

(Bellincampi et al., 2014)

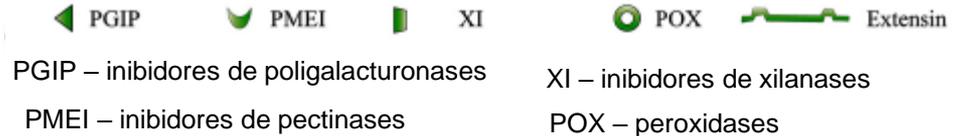
CELL WALL COMPONENTS AND CROSSLINKS



FUNGAL ENZYMES



PLANT DEFENCE PROTEINS



Ataque do patógeno

Forças mecânicas e bioquímicas



Toxinas

- produtos de microrganismos patogênicos
- causam danos nos tecidos Protoplasto
- envolvidos na patogênese
- baixo peso molecular
- ativas em conc. fisiológicas

NÃO

- características enzimáticas
- características hormonais
- características de ácido nucléico

Toxinas



Toxina T
em
milho
(Agris,
2005)

Seletivas (específicas)

Componentes primários de patogenicidade

Produzem sintomas característicos da doença

Não seletivas (inespecíficas)

Componentes secundários de patogenicidade

Incrementam a severidade da doença



Cercosporina em milho (Agris, 2005)

Toxinas

135 toxinas em fungos fitopatogênicos (maioria não seletiva)

Sintomas de *Mycosphaerella graminicola* em folhas de *Triticum durum* (trigo duro)



Septorina

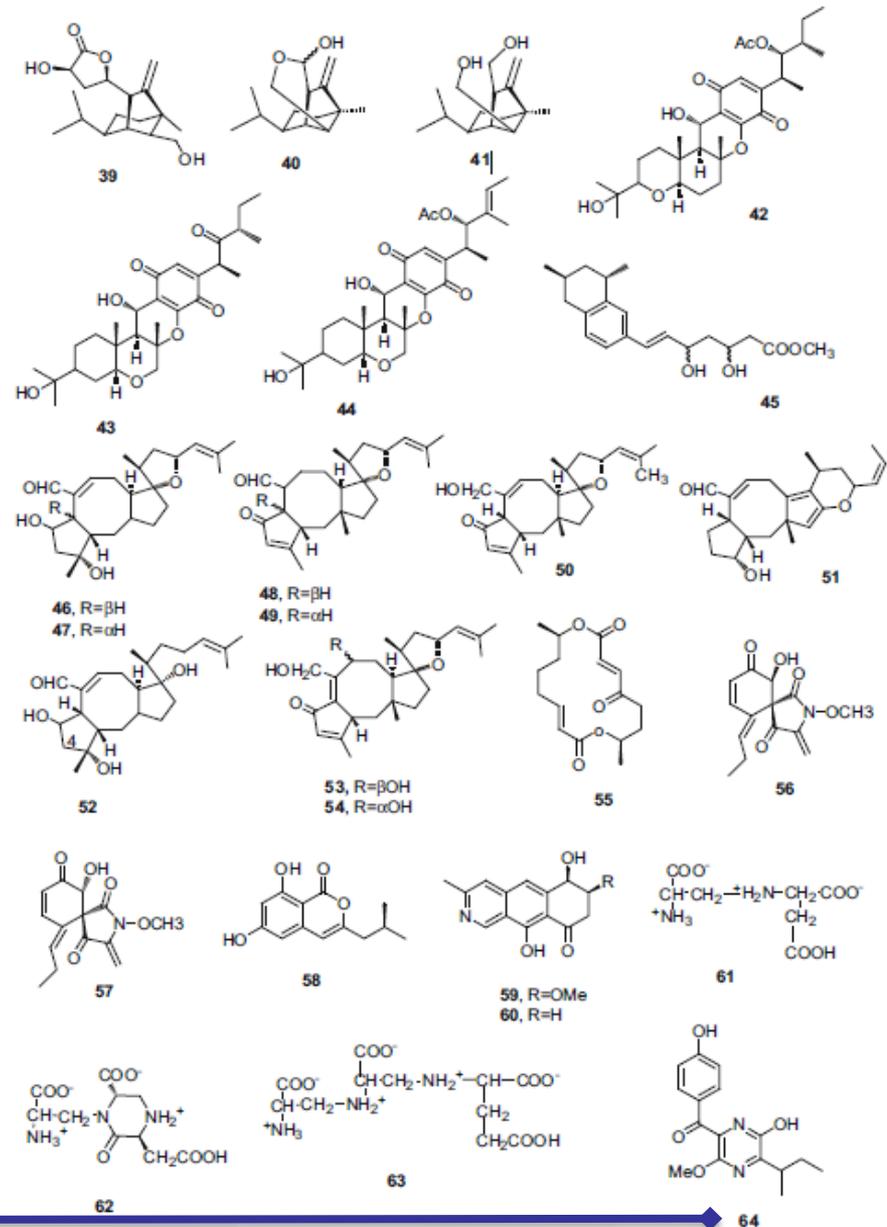
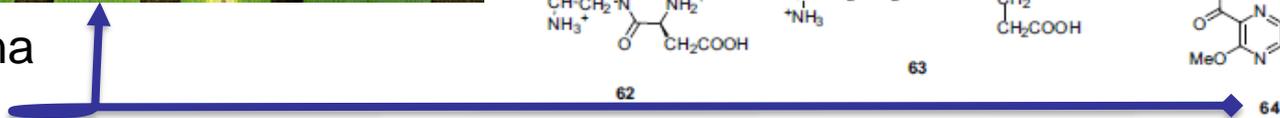


Fig. 2 Phytotoxins produced by fungi pathogenic on cereals

(Evidente et al., 2019)

Toxinas

Seletivas (específicas)

Toxina HV (victorina)

Helminthosporium victoriae

Cochliobolus victoriae

específica de aveia com gene *Vb*
(resistência à ferrugem)

Permeabilidade das membranas
morte da planta

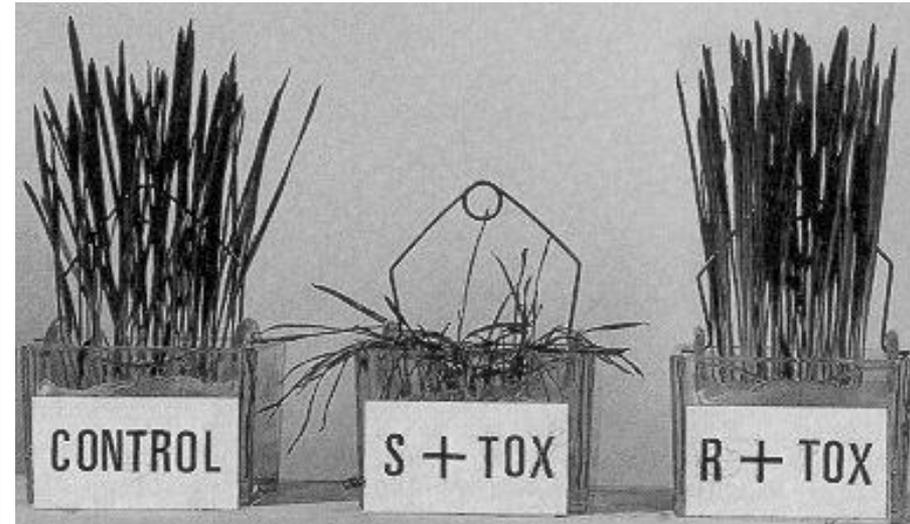
Toxina HmT ou T

Helminthosporium maydis

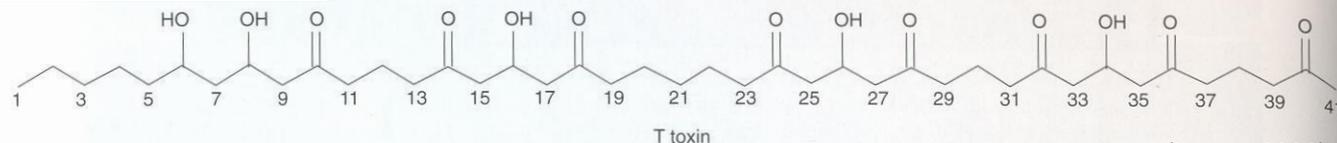
Cochliobolus heterotrophus

específica de milho com macho
esterilidade citoplasmática

membrana mitocondrial



Victorina adicionada à solução nutritiva aplicada em seedlings de aveia, 3 dias antes da foto. Controle = cv. victoria sem toxina, S+tox = cultivar victoria com toxina e R + tox = cv. resistente com toxina.



(Lucas, 1998)

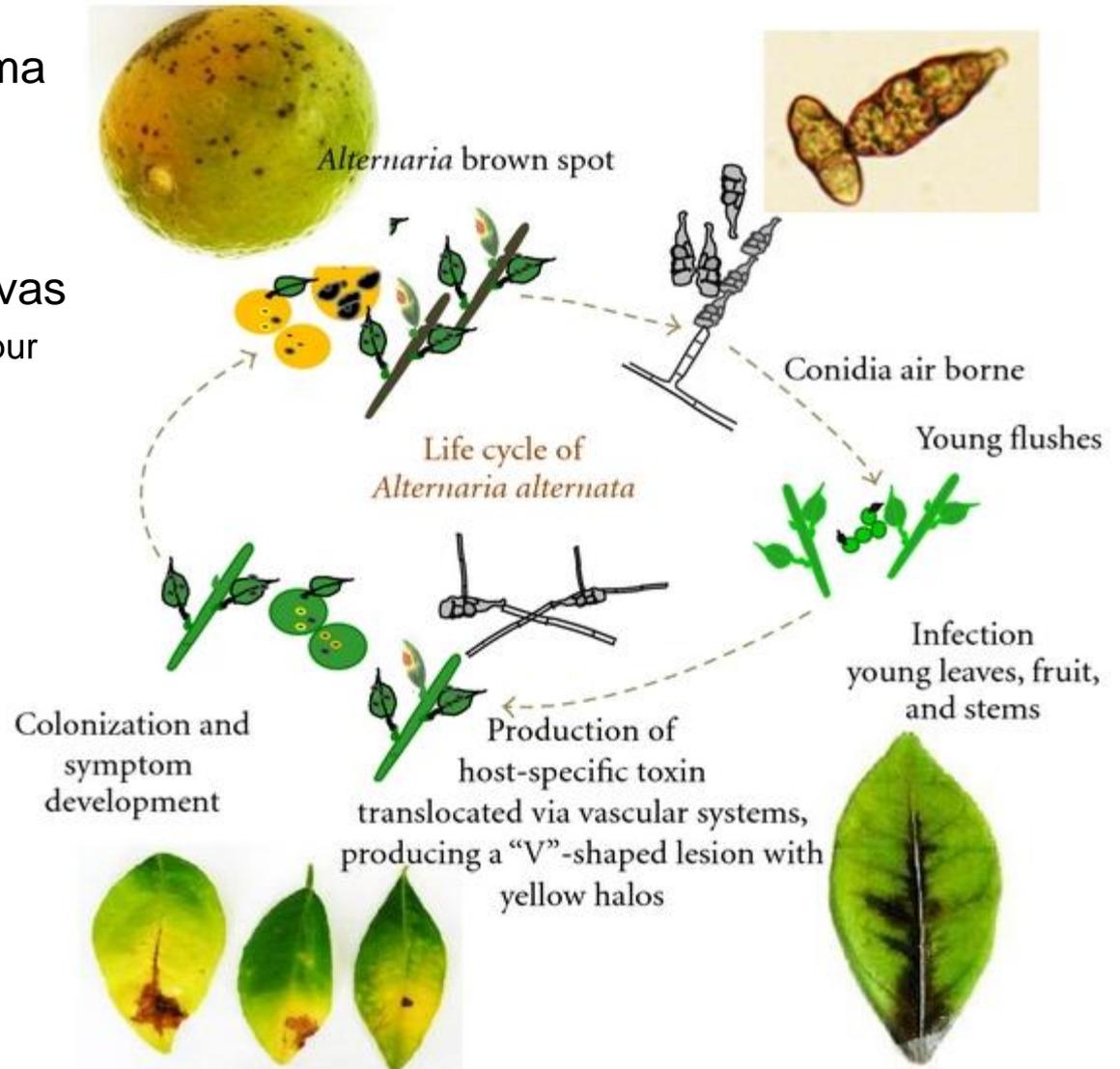
Toxinas

Mancha marrom de *Alternaria* em tangerina

Alternaria spp. - ampla gama de toxinas seletivas e não seletivas.

A. alternata – toxinas seletivas
ACRL – Limão Cravo (Rangpur lime)
ACT – Tangerinas

Figure 1: Life cycle of *Alternaria alternata*, the causal agent of citrus brown spot. ACT toxin produced by the tangerine pathotype of *A. alternata* is transported via the vascular system and formation of necrotic lesions on a detached calamondin leaf (bottom right).



Toxinas

Não seletivas (inespecíficas)

Tabtoxina

Pseudomonas syringae pv. *tabaci*

Dipeptídeo tóxico após hidrólise na planta

Atua nas tilacoides - necrose com halo

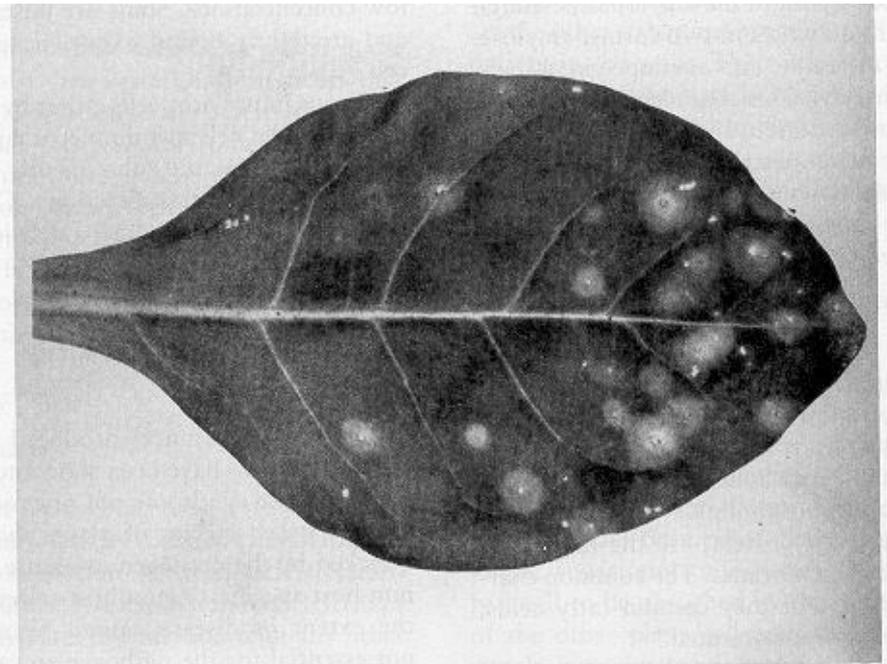
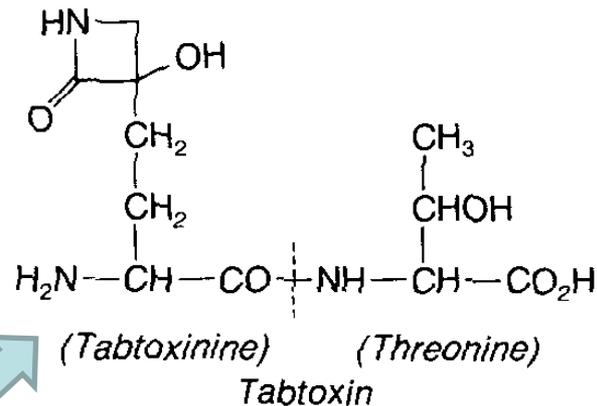


FIGURE 3-9 Young tobacco leaf showing spots caused by the bacterium *Pseudomonas syringae* pv. *tabaci*. The chlorotic halos surrounding the necrotic white spots are caused by the tabtoxin produced by the bacterium.



Inibe enzimas no fumo e acúmulo de amônia

Hormônios

Doenças cujos sintomas podem ser correlacionados com alterações no metabolismo hormonal (Dallo e Pascholati, 2018)



Doença	Agente causal	Principais hormônios envolvidos
“Bakanae”	<i>Giberella fujikuroi</i>	Giberelinas / auxinas
Carvão do milho	<i>Ustilago maydis</i>	Auxinas
Crespeira do pessegueiro	<i>Taphrina deformans</i>	Auxinas / citocininas
Fasciação	<i>Corynebacterium fascians</i>	Citocininas
Ferrugem branca	<i>Albugo candida</i>	Auxinas
Ferrugem	<i>Uromyces</i> sp.	Auxinas
Galha da coroa	<i>Agrobacterium tumefaciens</i>	Auxinas / citocininas
Galha das raízes	<i>Meloidogyne</i> sp.	Auxinas
Hérnia das crucíferas	<i>Plasmodiophora brassicae</i>	Auxinas
Murcha de Fusarium	<i>Fusarium oxysporum</i>	Etileno / auxinas
Murcha de Verticillium	<i>Verticillium albo-atrum</i>	Ácido abscísico
Murchas bacterianas	<i>Pseudomonas solanacearum</i>	Auxinas / etileno
Requeima da batata	<i>Phytophthora infestans</i>	Auxinas
Superalongamento da mandioca	<i>Sphaceloma manihoticola</i>	Giberelinas
Superbrotamento da mandioca	Fitoplasma	Citocininas

Hormônios

Agrobacterium tumefaciens

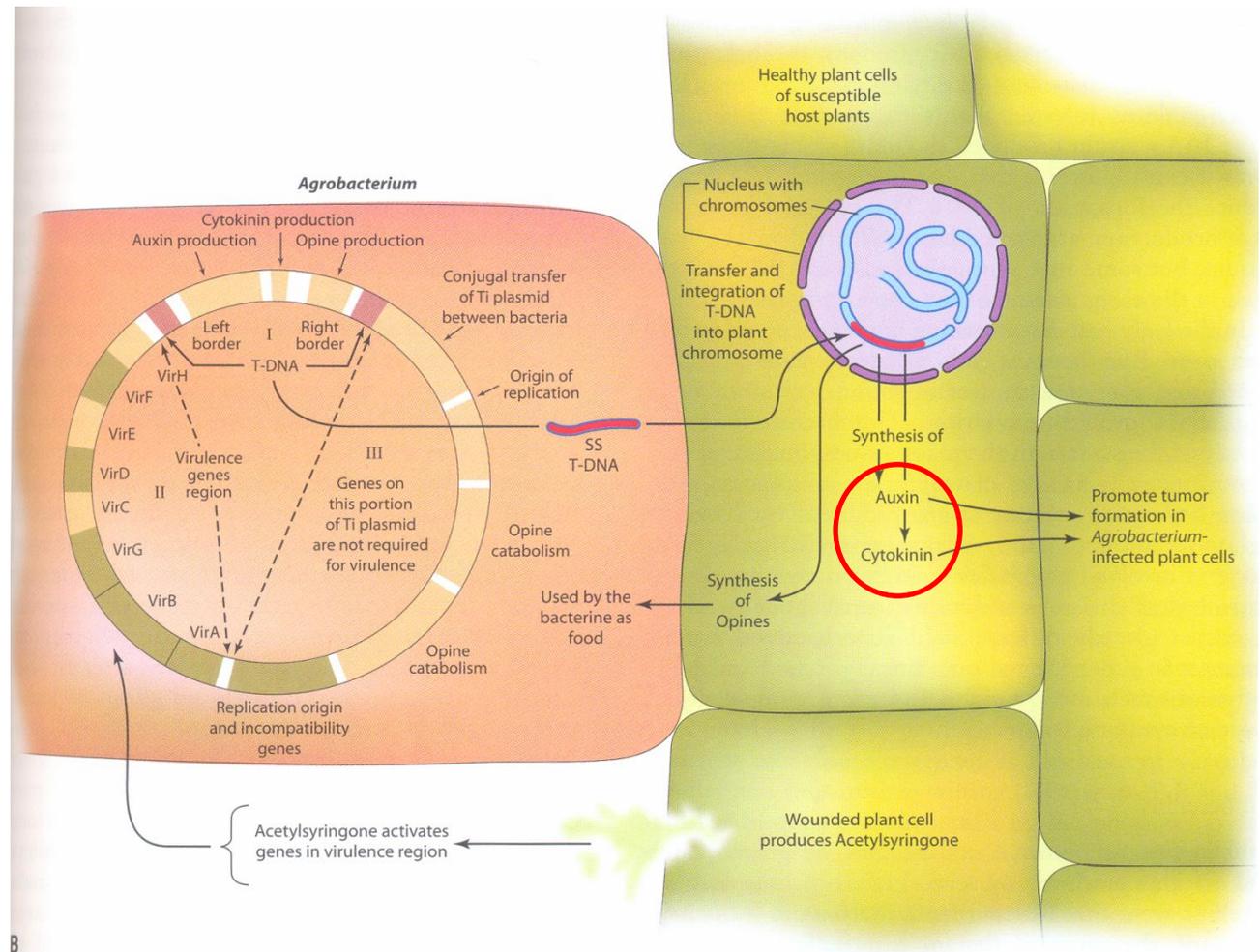


FIGURE 5-17 (A) External and cross-sectional view of crown gall on a rose stem caused by the bacterium *Agrobacterium tumefaciens*. (B) Schematic representation of the structure of Ti plasmid of the bacterium and of the transfer, integration, and expression of T-DNA in an infected plant that results in the production of crown gall tumors. Genes A, B, D, and G are needed for tumor formation on any susceptible plant species. Genes C, E, F, and H affect the host plant range and/or the size of tumors caused by the bacterium. The functions of the proteins of virulence genes are as follows: A, receptor of wound signal; B, codes for proteins that form membrane pores; C, enhances transfer of T-DNA; D, codes for proteins that nick T-DNA at its borders, help transport T-DNA across membranes, and carry signal compounds to the nucleus; E, protects T-DNA from nuclease enzymes and also carries nuclear localization signals; F, may increase host range of tumor induction; G, activates other virulence genes; H, protects the bacterium from toxic plant compounds. The entire diagram presents a simplified scheme of interaction of gene products of host cells and T-DNA that lead to the production of a gall. [Photograph (A) courtesy of Oregon State University.]

Como as plantas se defendem?

Mecanismos estruturais bioquímicos



Pré-formados

Estômatos, tricomas...

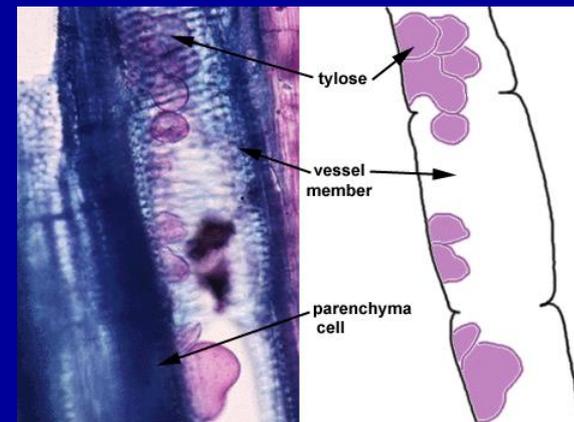
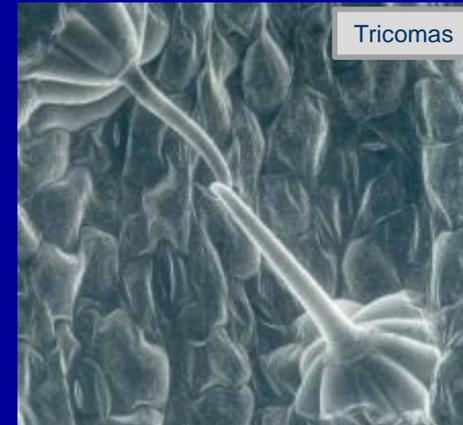
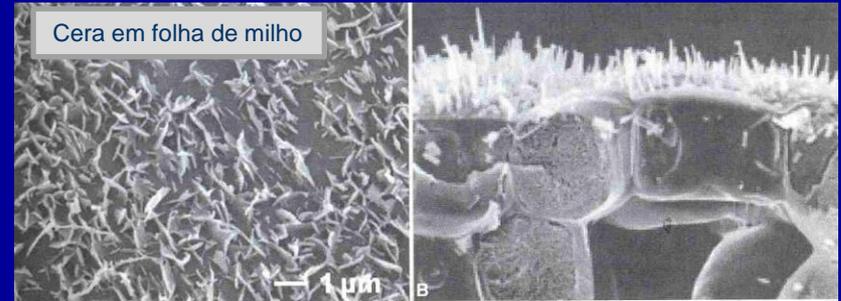
Fenóis, alcalóides...



Pós-formados

Tiloses, camadas de cortiça...

PR proteínas, fitoalexinas...



Xilema de tomate colonizado por *Verticillium*

(Agrios. 2005)

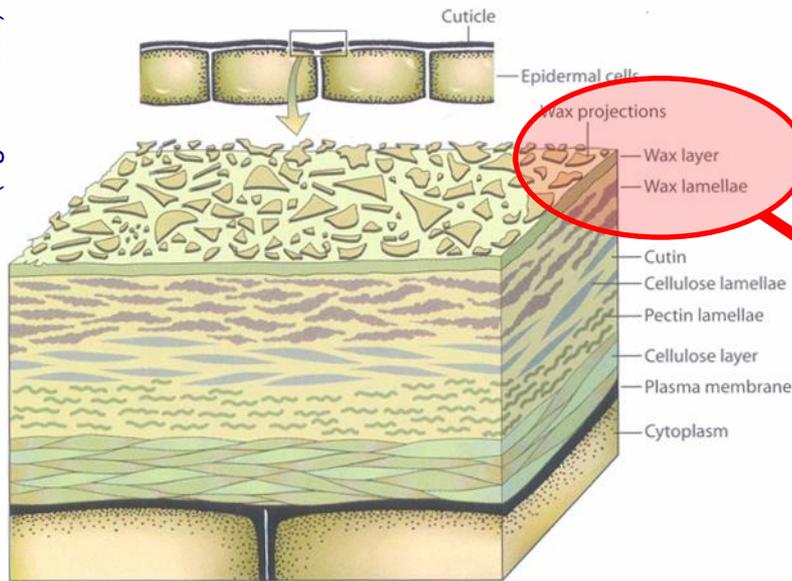
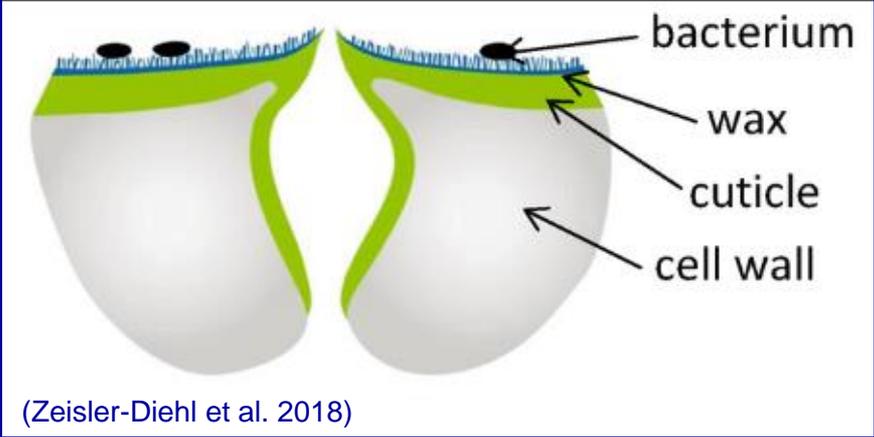


FIGURE 5-3 Schematic representation of the structure and composition of the cuticle and cell wall of foliar epidermal cells. [Adapted from Goodman *et al.* (1967).]

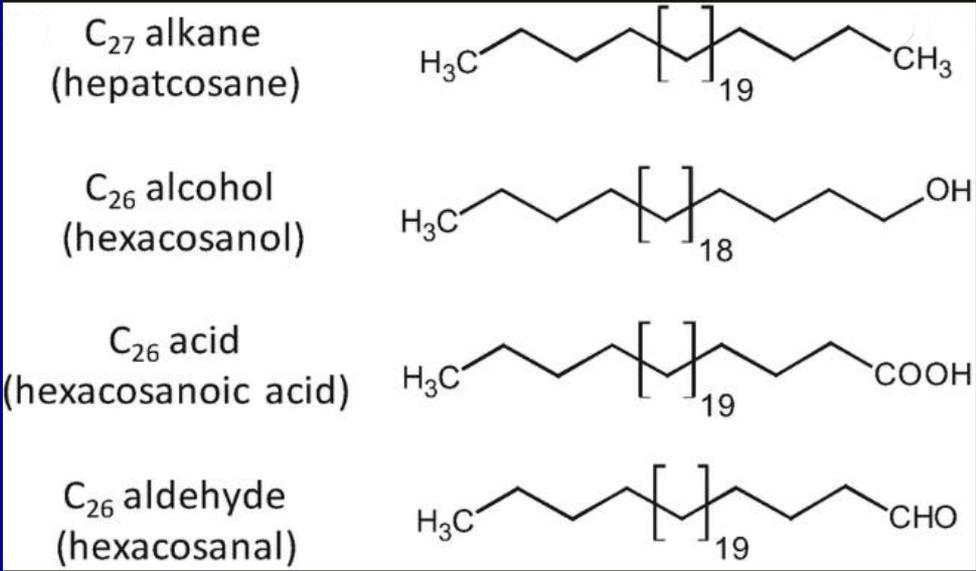
Como as plantas se defendem?

Mecanismos pré-formados

- Cera epicuticular



(Zeisler-Diehl et al. 2018)



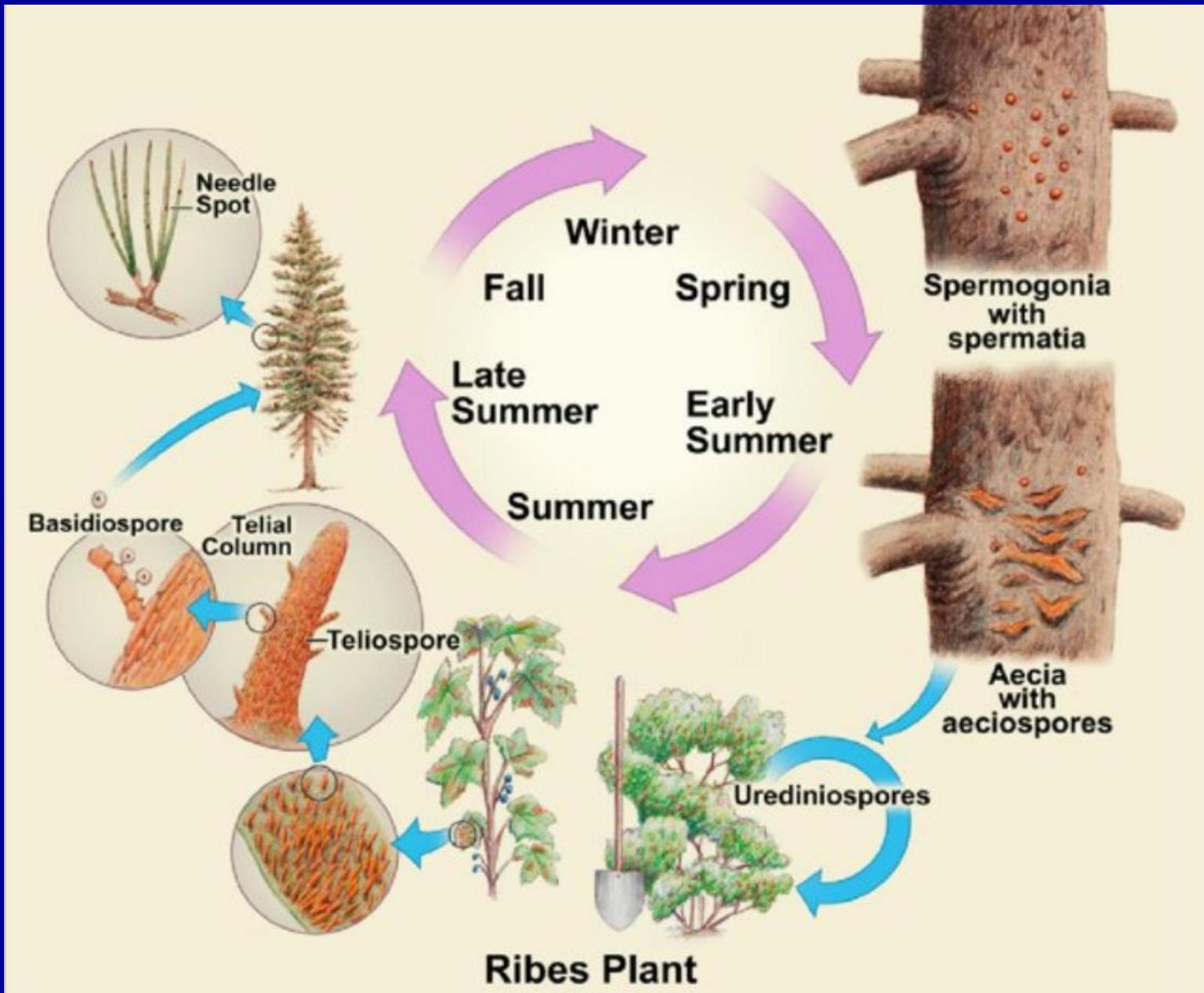
(Zeisler-Diehl et al. 2018)

Epicuticular Wax and White Pine Blister Rust Resistance in Resistant and Susceptible Selections of Eastern White Pine (*Pinus strobus*)

Jason A. Smith, Robert A. Blanchette, Todd A. Burnes, Jeffrey H. Gillman, and Andrew J. David



Ferrugem do pinheiro – *Cronartium ribicola*



Comparação de seleções de *Pinus* suscetíveis (H111 - A) e resistentes (P327 - B) à ferrugem branca (*Cronartium ribicola*)

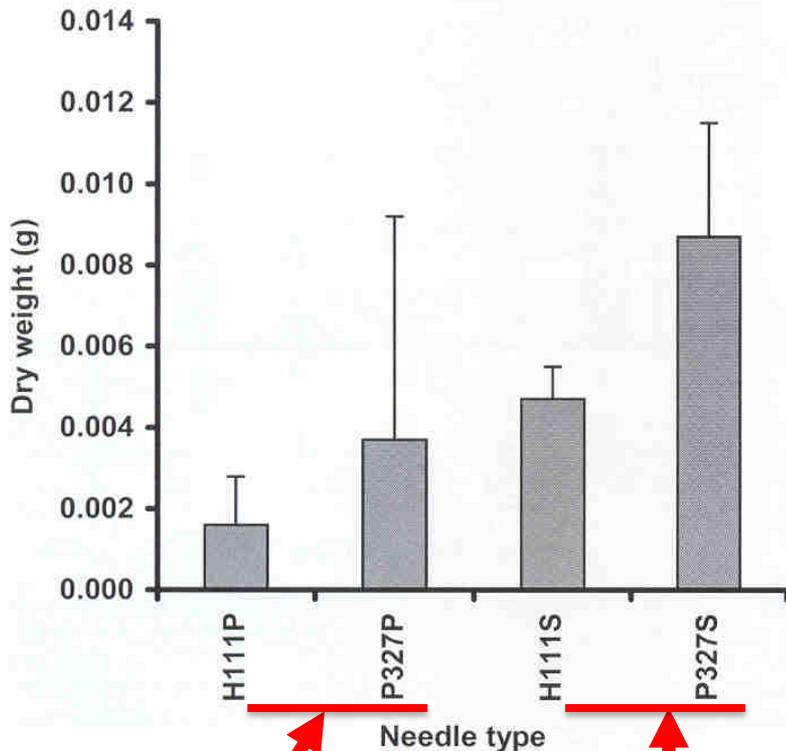


Fig. 1. Mean dry weight measurements (g) of needle wax removed from 1 g of primary (P) and secondary (S) needles from seedlings of selfed crosses of white pine blister rust-susceptible and -resistant *Pinus strobus* selections H111 and P327, respectively. Error bars represent standard deviation for each group.

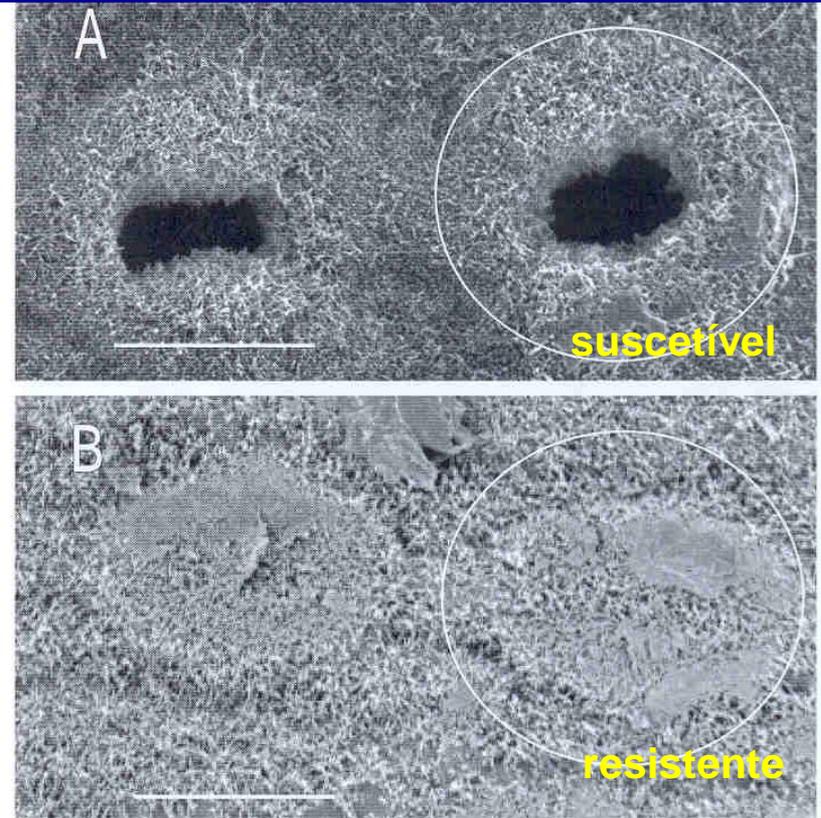
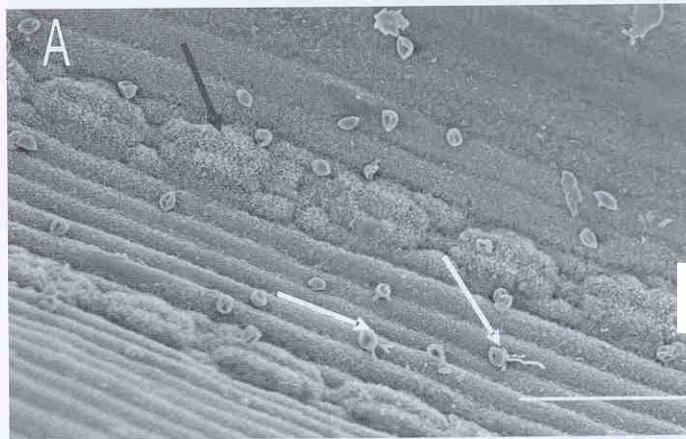


Fig. 2. Environmental scanning electron microscopy image of stomata of secondary needles of **A**, susceptible clone H111 (bar = 60 μ m) and **B**, resistant clone P327 (bar = 60 μ m). Notice the large opening to stomatal chamber and lack of wax occlusion in **A** and the complete wax occlusion of stomata in **B**. White circles provide outline of a stoma.

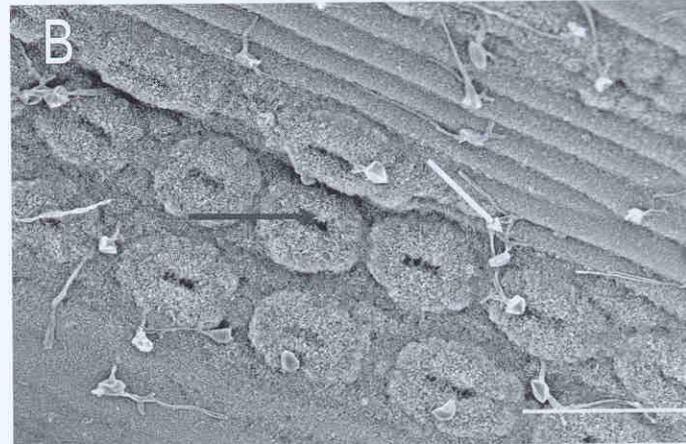
Acículas velhas

Acículas jovens

Comparação de seleções de *Pinus* suscetíveis (H111 - B) e resistentes (P327 - A) à ferrugem branca



resistente



suscetível

Fig. 6. Environmental scanning electron microscopy image of germinating basidiospores of *Cronartium ribicola* on primary needles from seedlings of **A**, resistant P327 × P327 (bar = 100 μm) and **B**, susceptible H111 × H111 (bar = 100 μm). Notice the few germinating spores with short germ tubes (white arrow) and the wax-occluded stomata (black arrow) in **A** and the numerous germinating spores with longer germ tubes (white arrow) and lack of wax occlusion of stomata (black arrow).

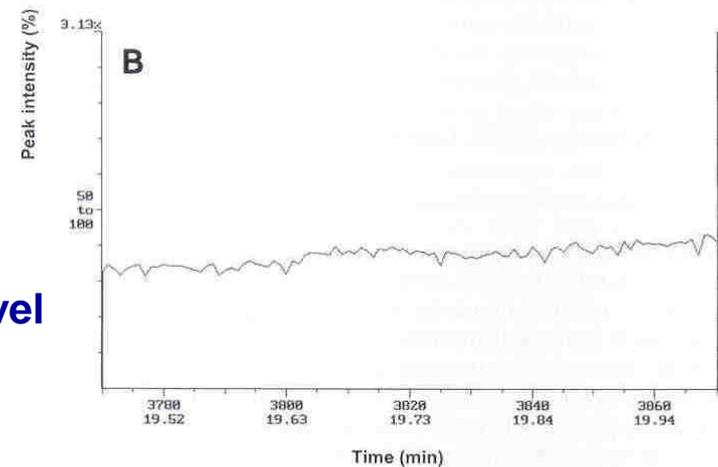
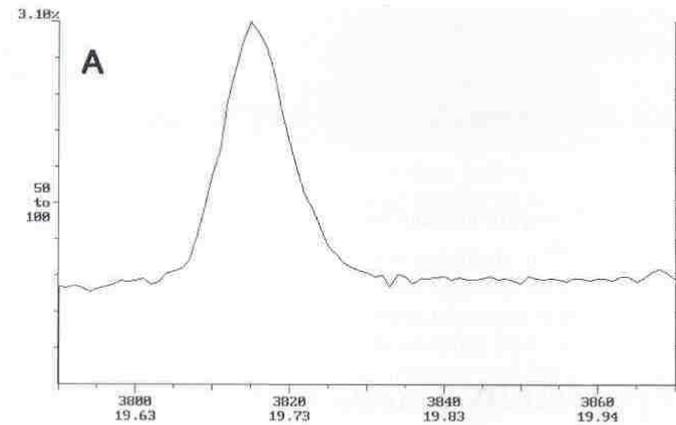


Fig. 9. Gas chromatography/mass spectrometry (GC/MS) chromatograms showing peak of a compound found in epidermal wax extracted from primary needles of **A**, resistant family P327, but not found in extracted wax from primary needles from **B**, susceptible family H111. GC/MS chromatograms using secondary needles provided similar results. x axis = time (minutes) and y axis = peak intensity.

**Resistência estrutural pré-formada
em gemas de cana-de-açúcar**

NA56-79

X

SP70-1143



Resistência estrutural pré-formada em gemas de cana-de-açúcar

Sporisorium scitamineum

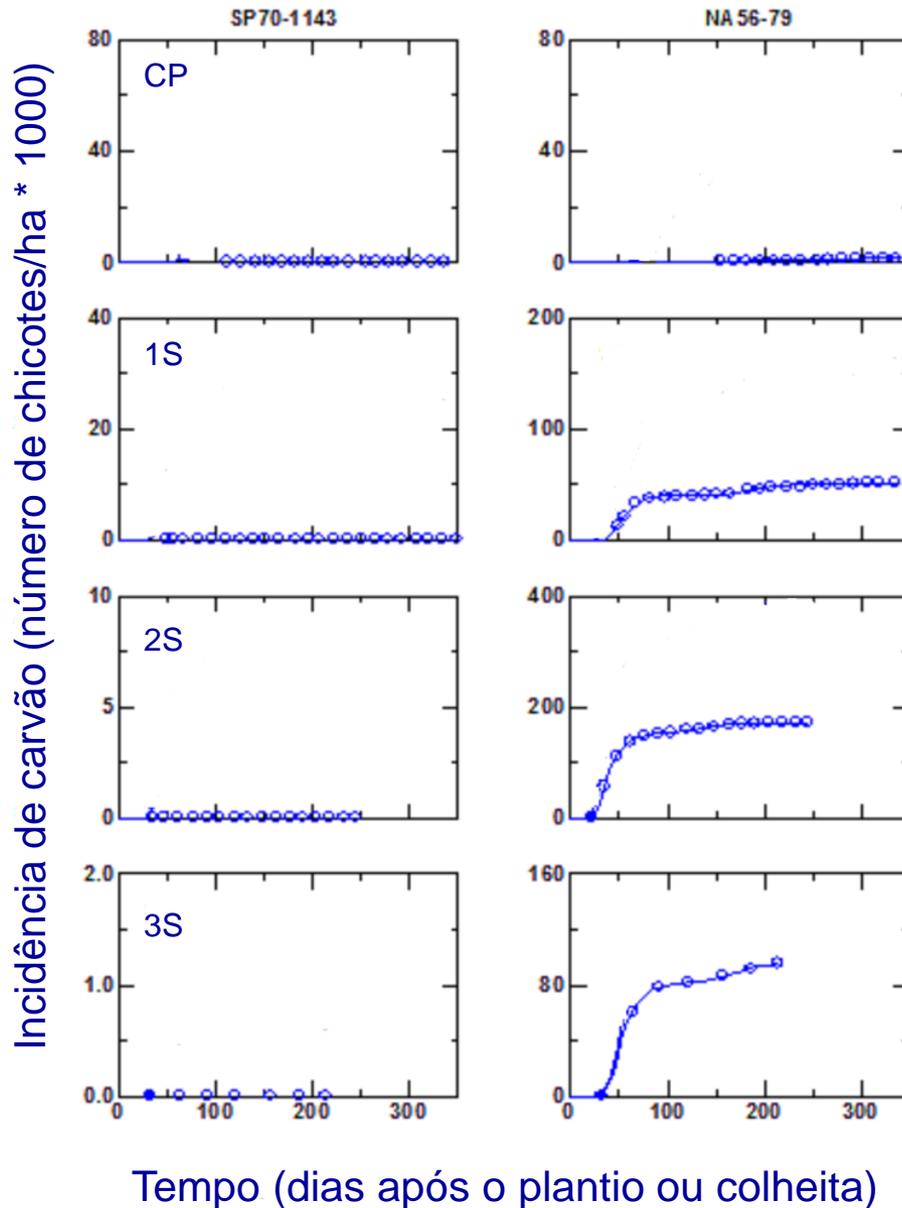


Como as plantas se defendem?

Mecanismos pré-formados

SP70-1143 e
NA56-79
inoculadas com
suspensão de
teliósporos sem
ferimentos nas
gemas

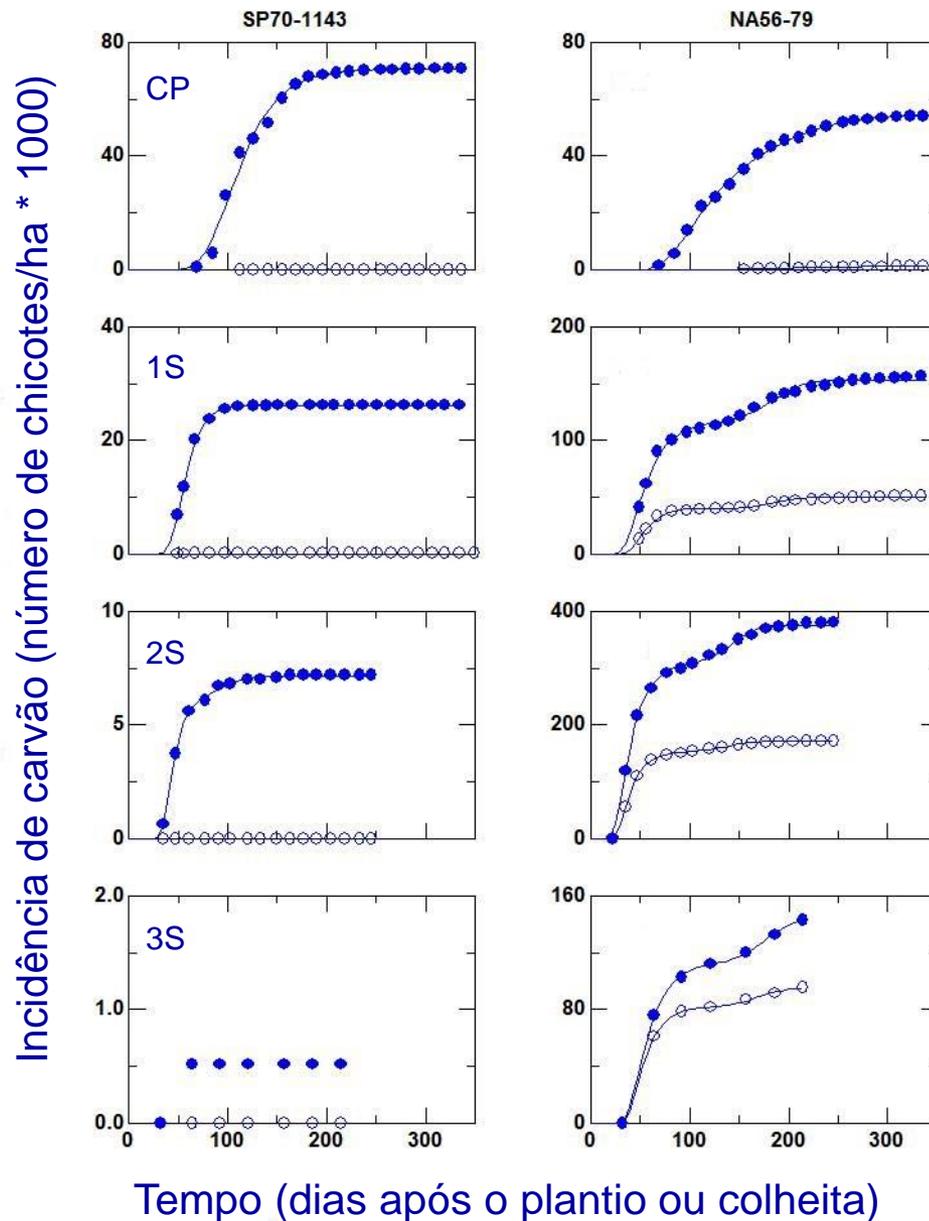
(CP = cana planta; 1S = primeira soca; 2S = segunda soca; 3S = terceira soca)



Como as plantas se defendem?

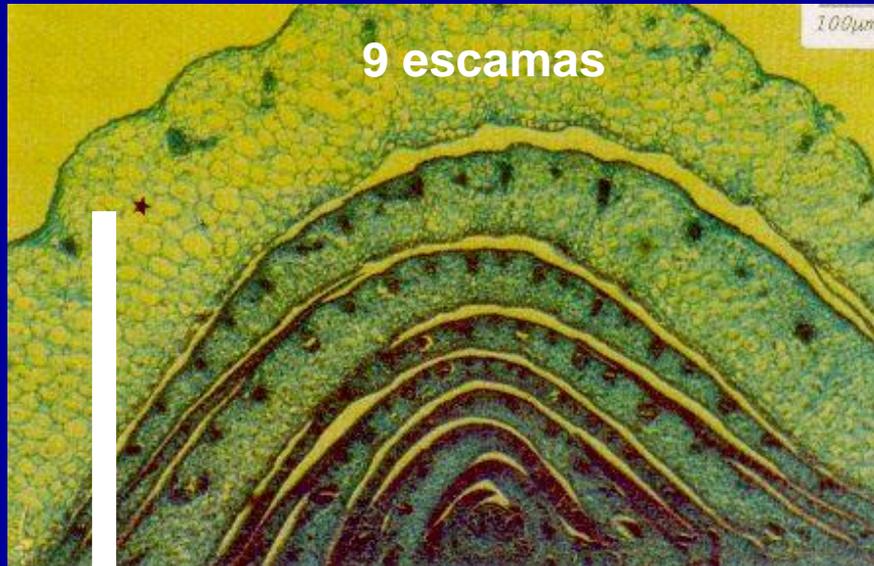
Mecanismos pré-formados

SP70-1143 e NA56-79 inoculadas com suspensão de teliósporos sem fermentos nas gemas (círculos vazios) ou após (círculos cheios) fermentos nas gemas



(CP = cana planta; 1S = primeira soca; 2S = segunda soca; 3S = terceira soca)

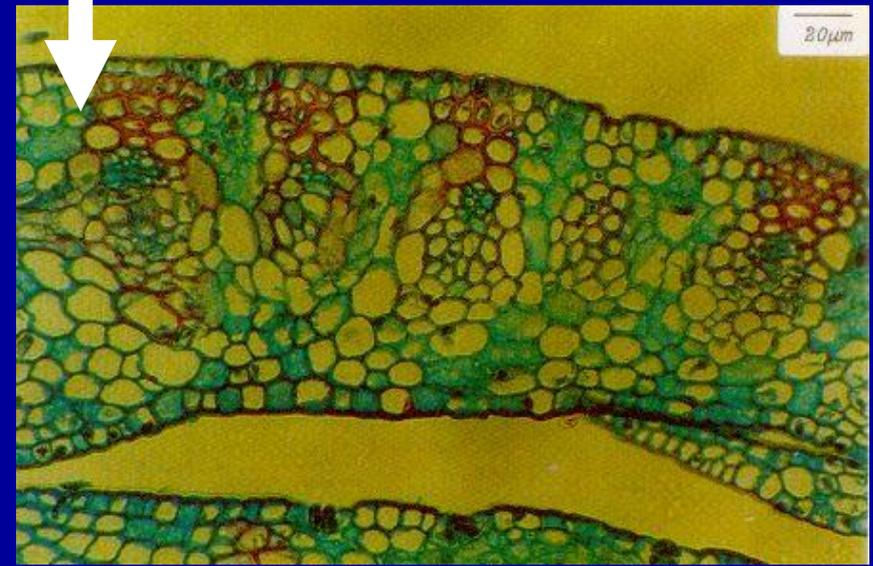
Mecanismos de defesa pré-formados



SP70-1143

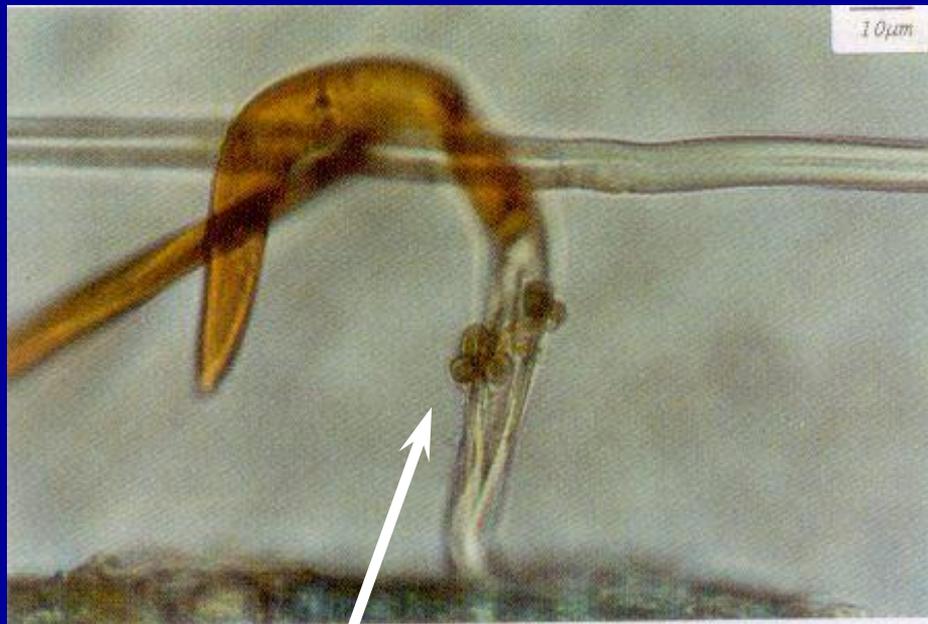


NA56-79



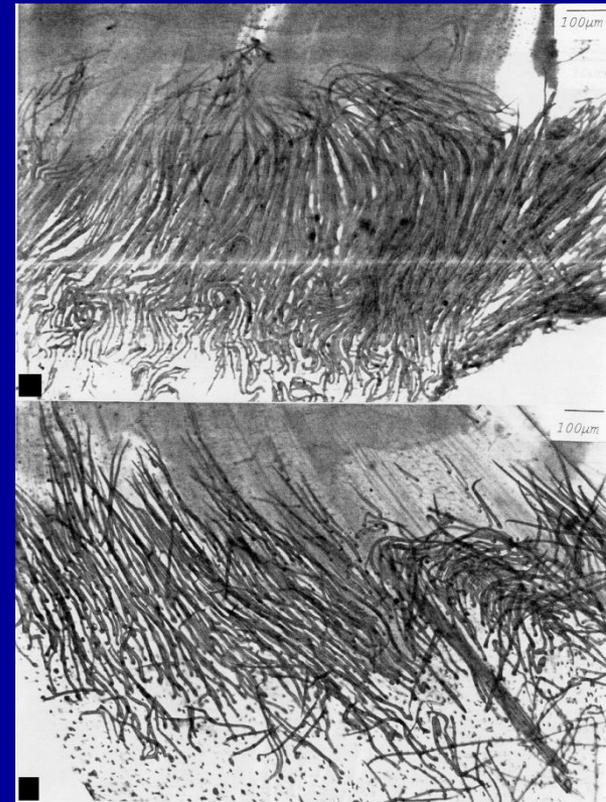
Mecanismos pré-formados

Tricomas



teliósporos de *Sporisorium scitamineum* (*Ustilago scitaminea*) aderidos a tricoma da gema na variedade SP70-1143

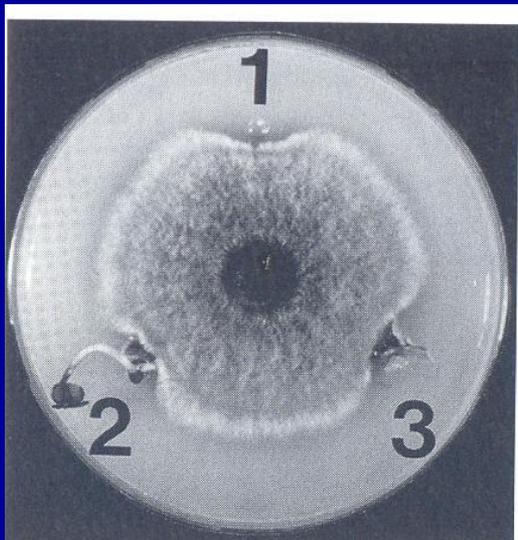
SP70-1143
resistente ao carvão
316,6 tricomas/cm



NA56-79
suscetível ao carvão
250,0 tricomas/cm

Mecanismos de defesa bioquímicos pré-formados

Compostos fenólicos
Taninos
Saponinas
Exsudatos fungitóxicos
Proteínas / peptídeos



Inibição do crescimento micelial por exsudatos de sementes (3) e de plântulas de rabanete (2) e pela proteína isolada a partir desses exsudatos (1).

(Lucas, 1998)

(Agris. 2005)

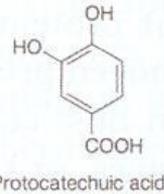
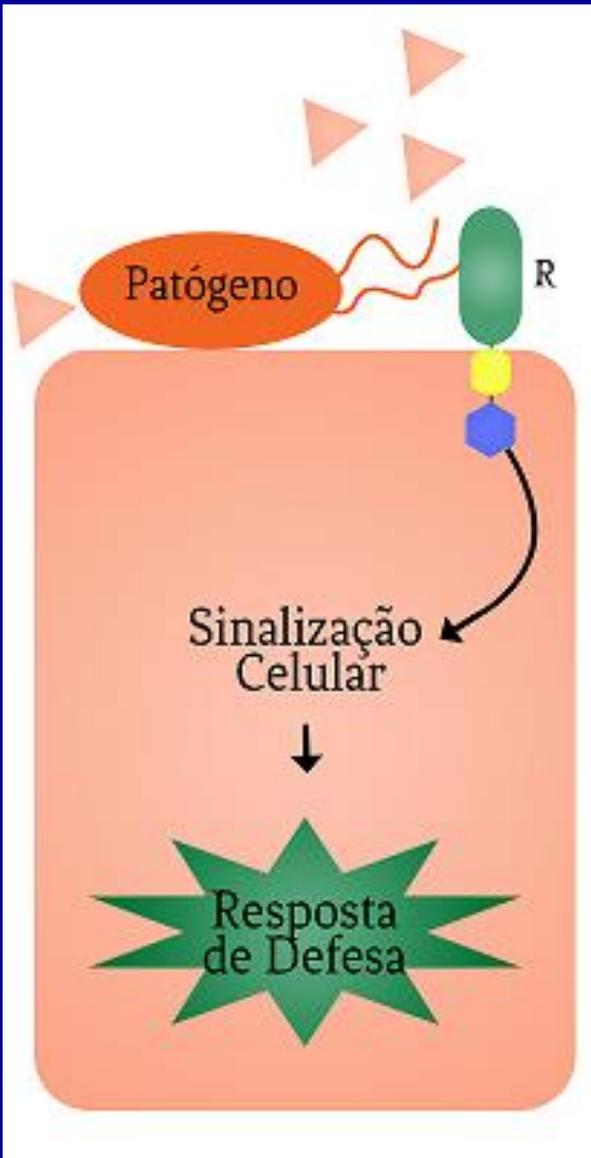


FIGURE 6-2 Onion smudge, caused by the fungus *Colletotrichum circinans*, develops on white onions but not on colored ones, which, in addition to the red or yellow pigment, also contain the phenolics protocatechuic acid and catechol, both of which are toxic to the fungus. (Photograph courtesy of G. W. Simone.)

Mecanismos de defesa pós-formados



RECONHECIMENTO

- **PATÓGENO**

PAMP – *Pathogen Associated Molecular Pattern*
MAMP – *Microbe Associated Molecular Pattern*

flagelina em bactérias
quitina em fungos
glucanas em oomicetos

- **HOSPEDEIRO**

monômeros de cutina
oligômeros de polissacarídeos

RECEPTORES

PRR – *Pattern-Recognition Receptor*
PAMP-Recognition Receptor

Mecanismos de defesa pós-formados

CELULAR { Papilas (lignina, fenóis, silício, celulose)
Lignificação (polímero tridimensional)

Papilas

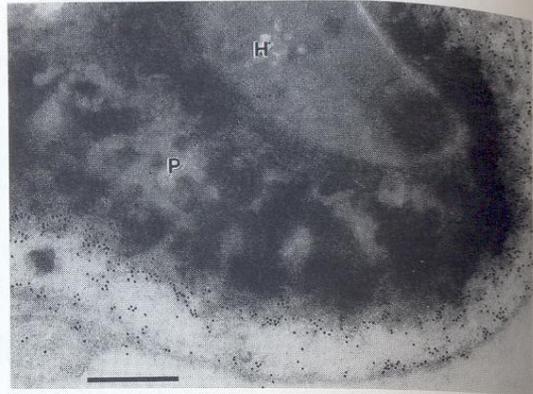
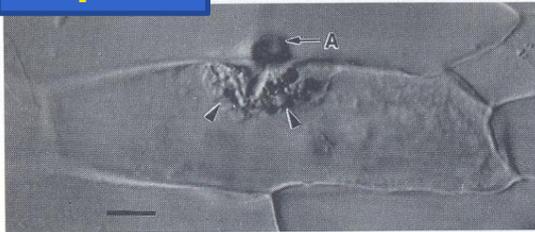
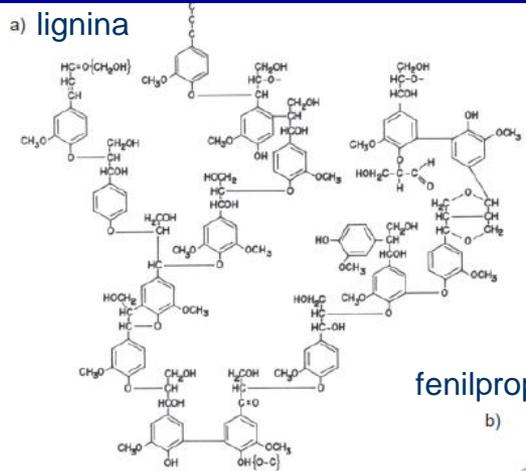


Fig. 9.16 Penetration of epidermal cell of bean by the fungus *Colletotrichum lindemuthianum*. (a) Light micrograph showing papilla (arrow heads) formed beneath fungal appressorium (A). Scale bar = 10 μ m. (b) Electron micrograph of section through penetrated cell showing cell wall (CW) and a small infection hypha (H) encased by a papilla (P). Scale bar = 1 μ m. (c) High-power view of penetrating hypha (H) and surrounding papilla (P) labelled with a gold-conjugated antibody specific for hydroxyproline-rich glycoproteins. Small black particles locate the protein mainly in the outer layers of the papilla. Scale bar = 0.5 μ m. (All parts courtesy of Richard O'Connell.)

a) lignina



fenilpropano



Lignificação

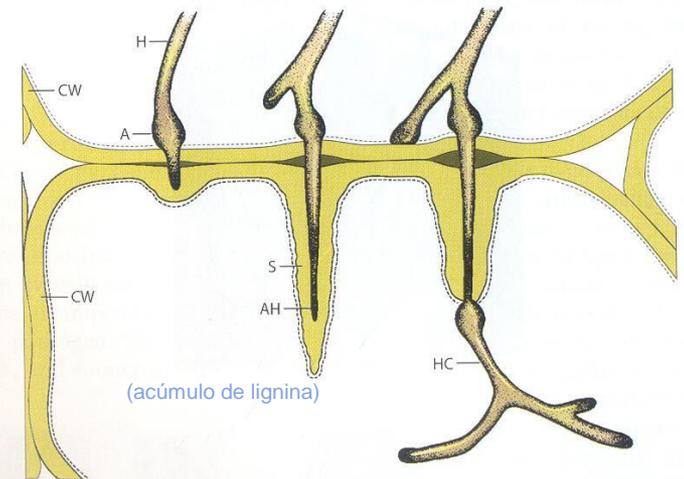
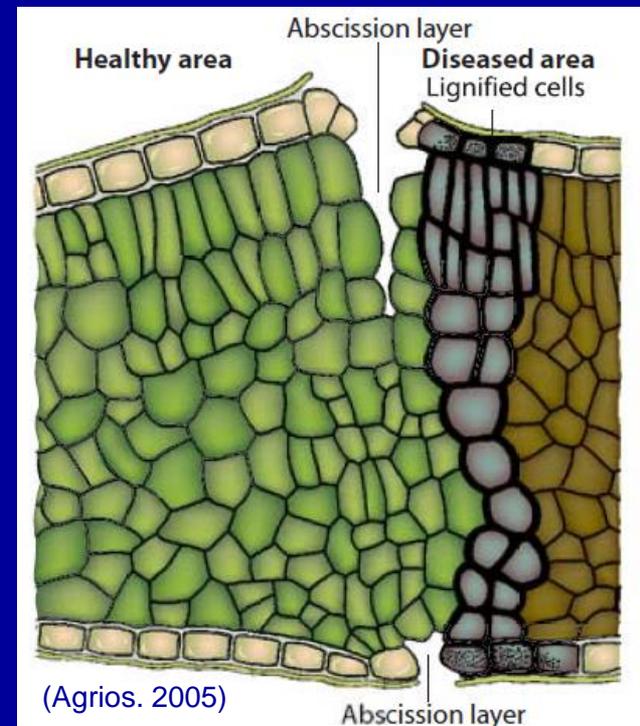


FIGURE 6-4 Formation of a sheath around a hypha (H) penetrating a cell wall (CW). A, appressorium; AH, advancing hypha still enclosed in sheath; HC, hypha in cytoplasm; S, sheath. (Agrios. 2005)

Mecanismos de defesa pós-formados

HISTOLÓGICO { Cortiça
Abcisão
Tilose



(Agris. 2005)

Cortiça

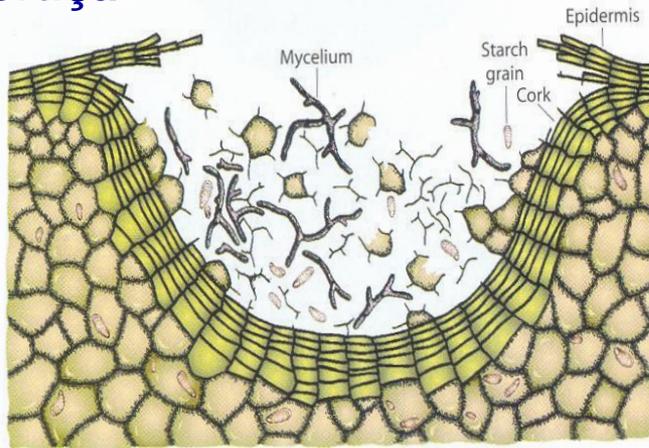
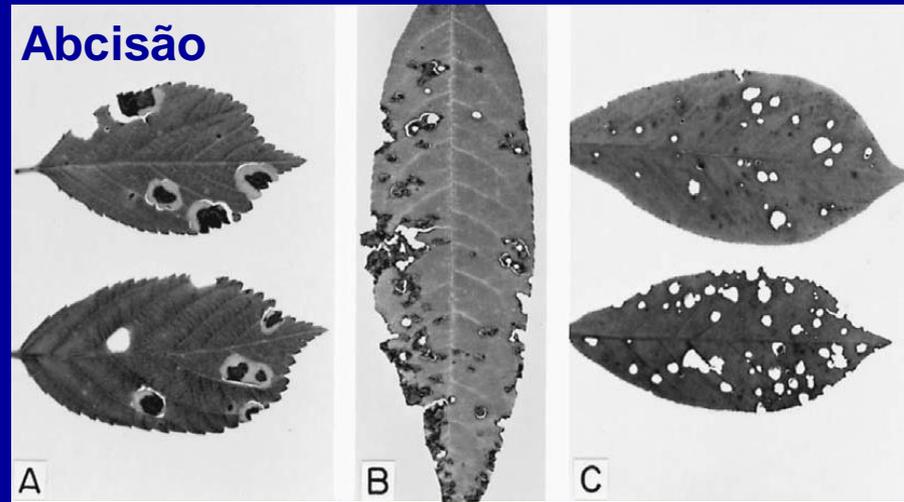


FIGURE 6-6 Formation of a cork layer on a potato tuber following infection with *Rhizoctonia*. [After Ramsey (1917). *J. Agric. Res.* 9, 421-426.]

(Agris. 2005)

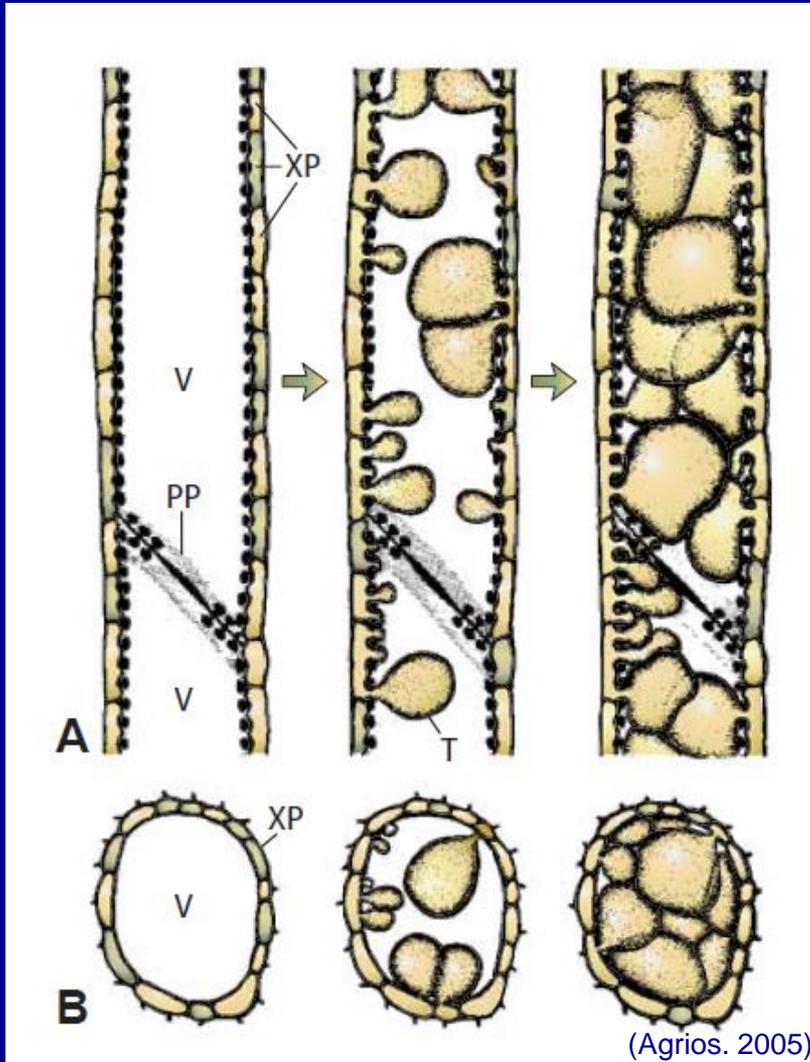
Abcisão



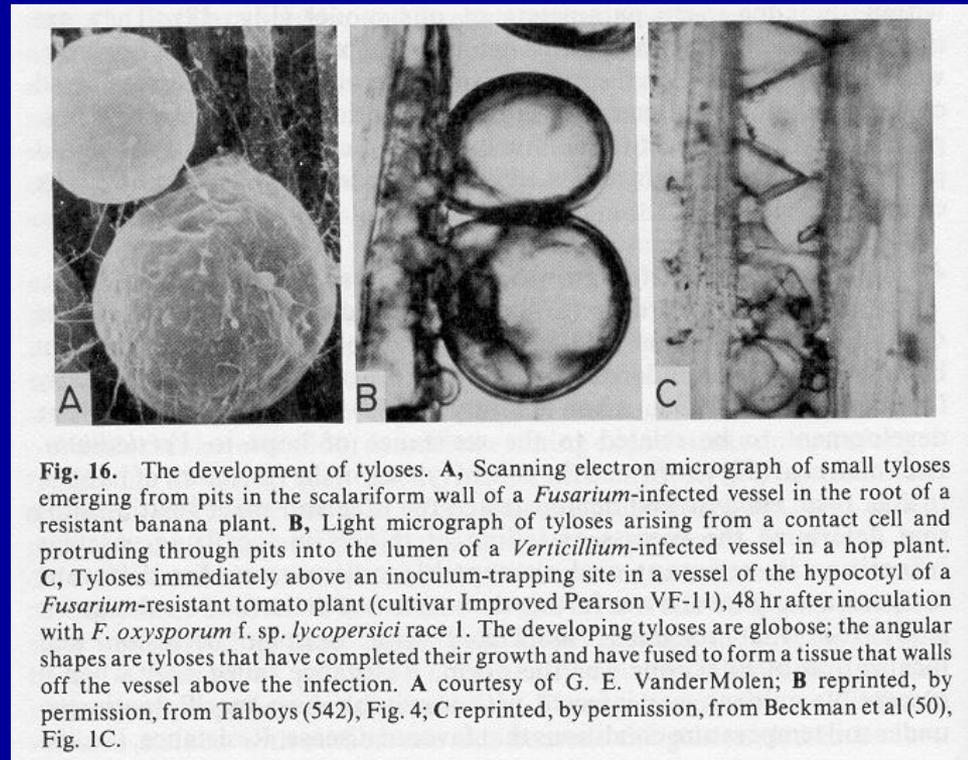
Sintomas de mancha bacteriana (*Xanthomonas arboricola* pv. *pruni*) em folhas de cerejeira (A), pessegueiro (B) e ameixeira (C)

Mecanismos de defesa pós-formados

HISTOLÓGICO {
Cortiça
Abcisão
Tilose



Tilose



XP=parênquima do xilema e PP=perfurações nas placas

Mecanismos bioquímicos de defesa pós-formados

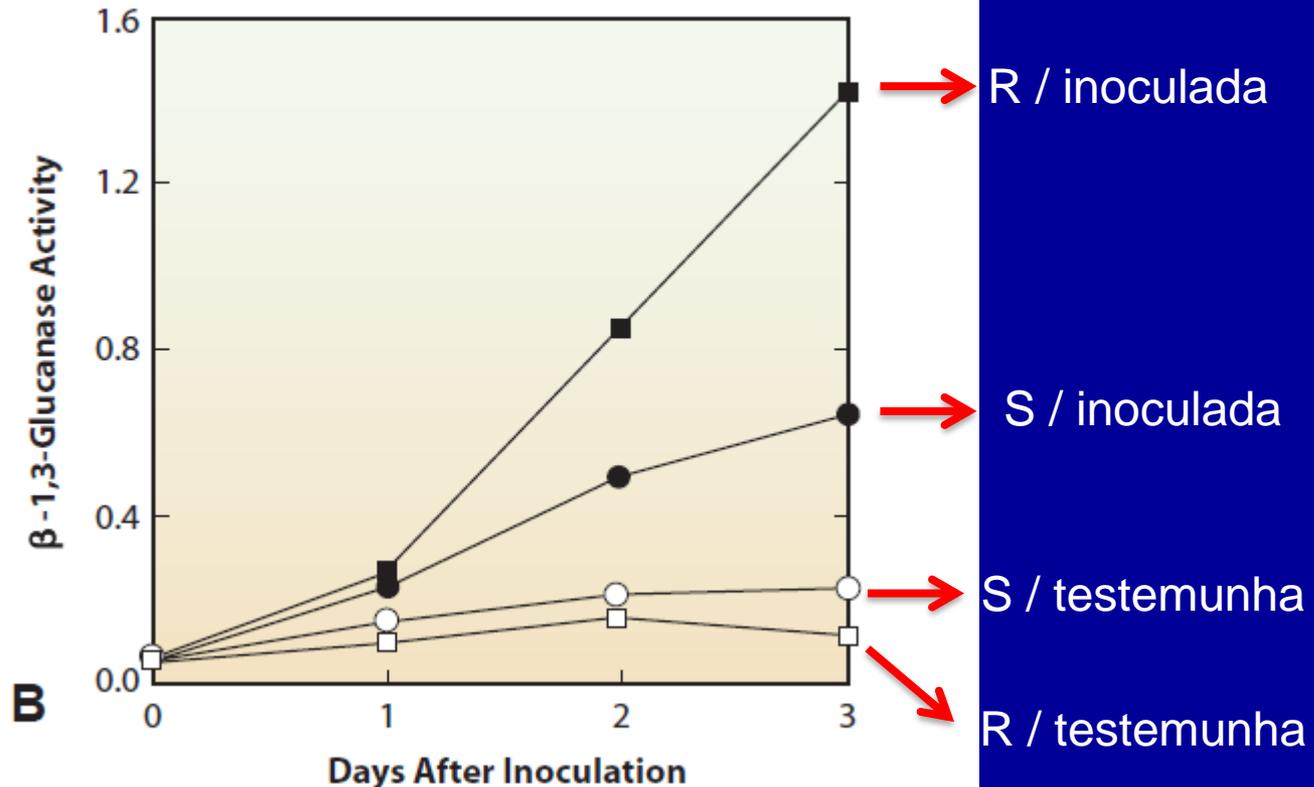
PROTEÍNAS RP – Proteínas relacionadas à patogênese

Presentes na parede celular (baixa concentração)

Produzidas após estímulo

Quitinase, beta 1-3 glucanase, proteinase, etc.

Oídio da cevada (*Erisiphe graminis* f.sp. *hordei*)



Mecanismos bioquímicos de defesa pós-formados

Fitoalexinas - compostos antimicrobianos de baixa massa molecular, sintetizados e acumulados nas células vegetais em resposta à infecção microbiana

- 350 já identificadas
- Composição química diversa
- Produzidas por 40 famílias botânicas
- Induzidas por agentes bióticos ou abióticos
- Produzidas por diferentes vias metabólicas
- Ação na membrana plasmática e metabolismo respiratório amplo espectro

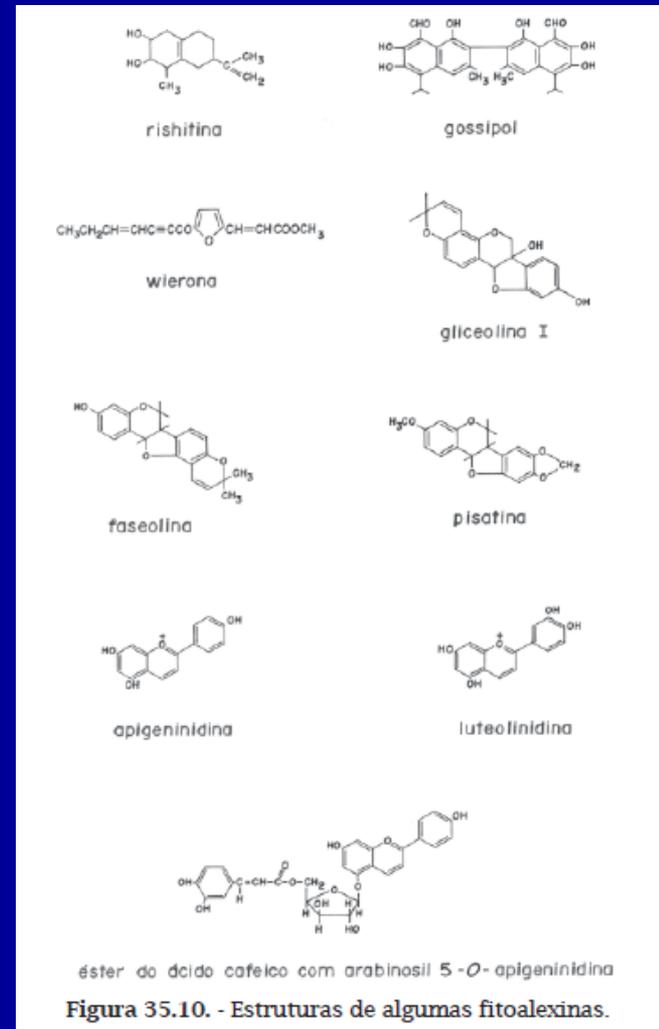
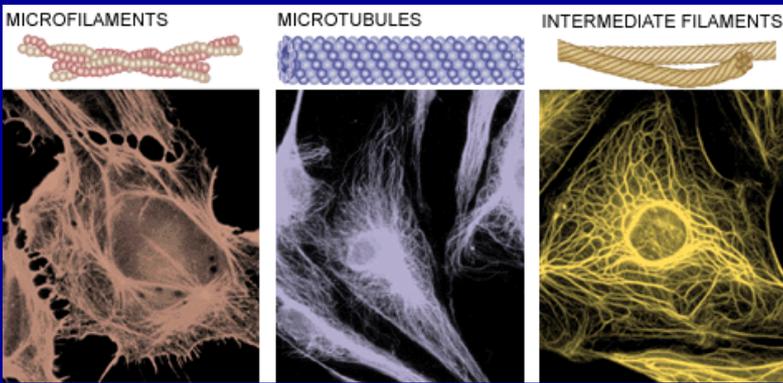


Figura 35.10. - Estruturas de algumas fitoalexinas.



Suicídio celular, resposta de hipersensibilidade ou morte celular programada - biotróficos

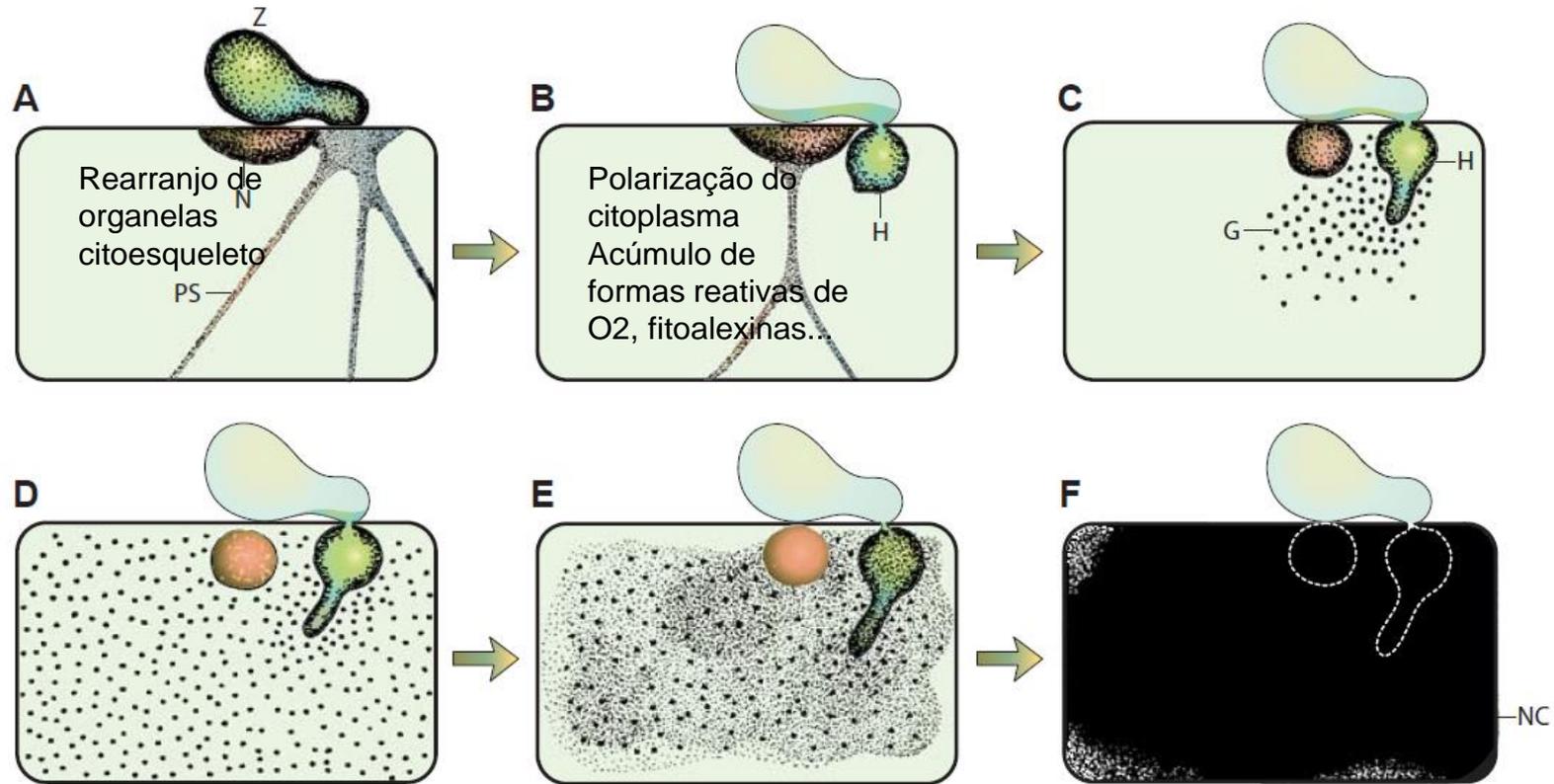
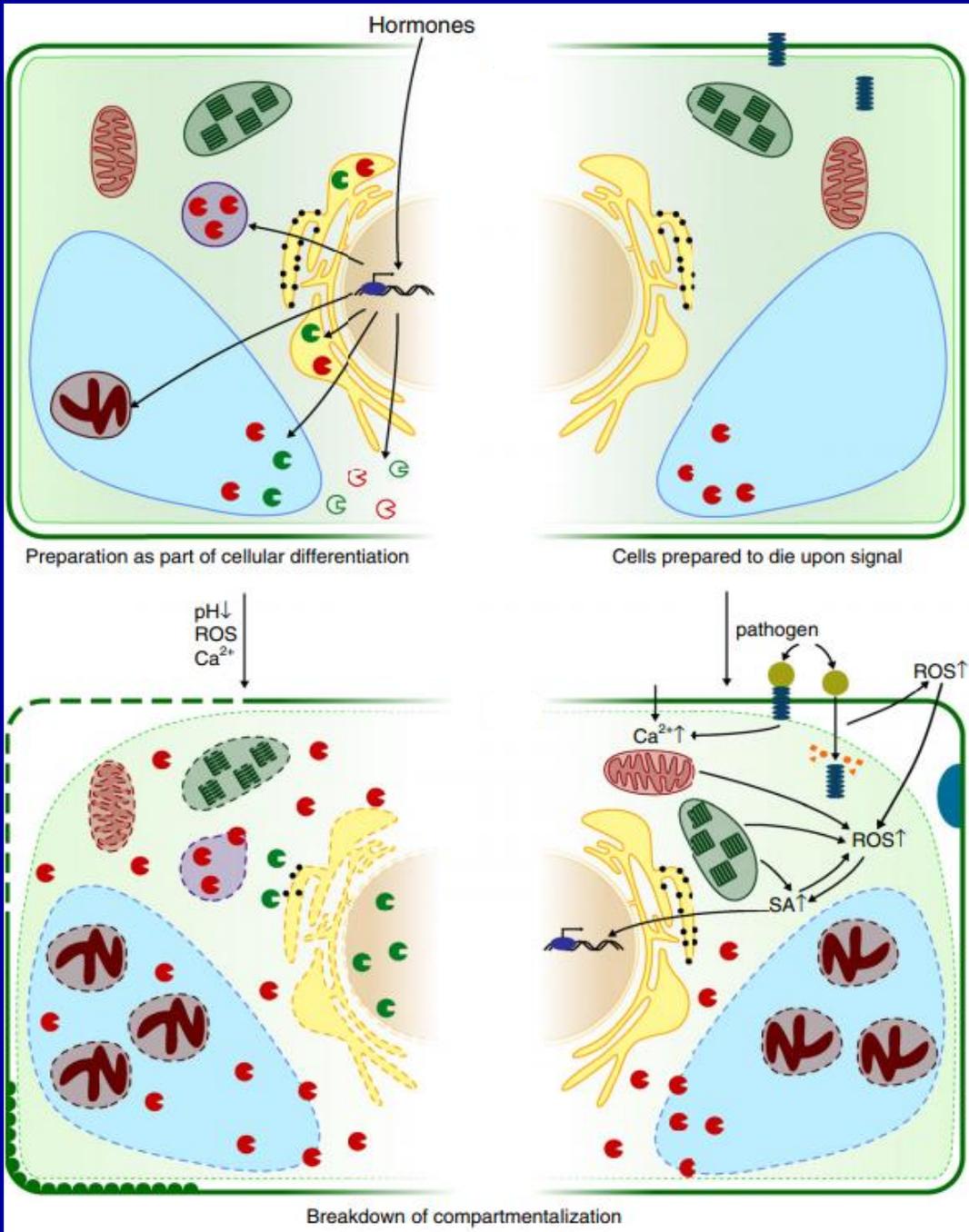


FIGURE 6-9 Stages in the development of the necrotic defense reaction in a cell of a very resistant potato variety infected by *Phytophthora infestans*. N, nucleus; PS, protoplasmic strands; Z, zoospore; H, hypha; G, granular material; NC, necrotic cell. [After Tomiyama (1956). *Ann. Phytopathol. Soc. Jpn.* 21, 54-62.]

Morte celular programada controlada pelo desenvolvimento

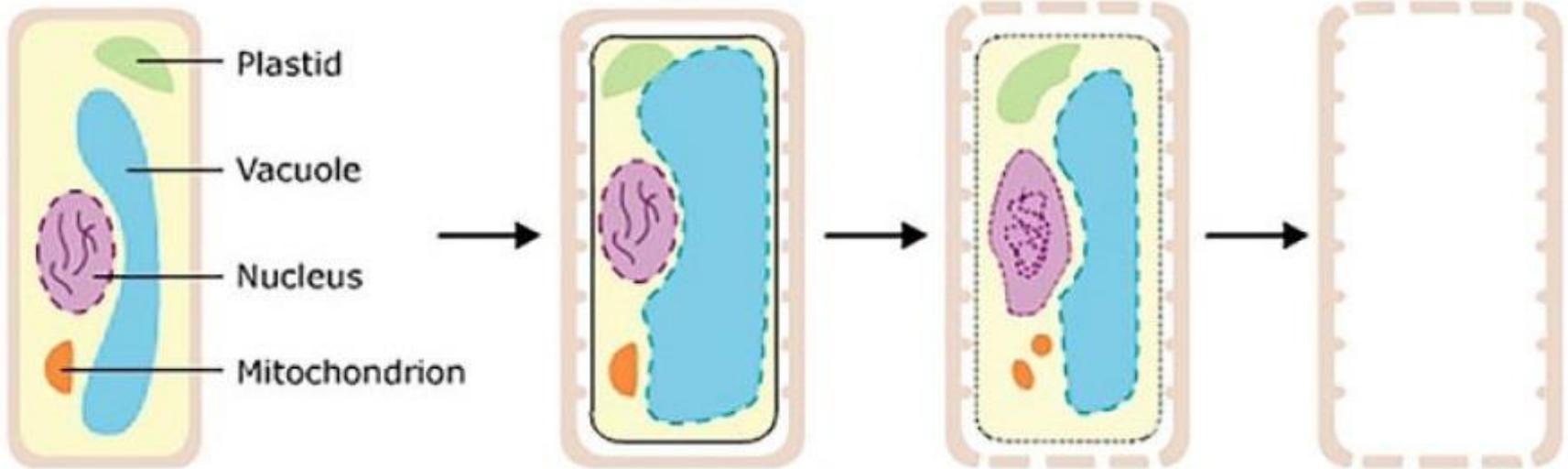


Morte celular programada induzida por patógenos

Morte celular programada

	protease inativa
	protease ativa
	nuclease inativa
	nuclease ativa
	ribossomo
	ricinossomo
	autofagossomo
	ativação transcricional
	modificação na parede
	calose
	patógeno
	sinais do patógeno
	PRR

(A) Morte celular programada controlada *pelo desenvolvimento*



(B) Morte celular programada *induzida por patógenos*

