Dov Prusky

Department of Postharvest Science of Fresh Produce
The Volcani Center, Agricultural Research Organization

1st Lecture Fruit Pathology

Subjects of Study

1. Development of postharvest disease after harvest and the factors modulating their development (1.5h)
2. Different mechanism for disease resistance of fruits to postharvest diseases (2-3 h)
3. Mechanism of pathogen attack after harvest, microbiomes (3h).
4. Mycotoxins in fruits (1-2h)
5. Physical and biological factors affecting postharvest diseases (2h)
6. Disease control (4h)
7. Resistance to Fungicides (1h)
8. Biological control (1-1.5)

Objectives of Storage

- To keep the freshness of the produce
- To prevent senescence processes
- To prevent water loss
- To inhibit ripening
- To inhibit pathogen development

However as we increase the length of the storage there is a decrease in quality and increase of pathogen development

Postharvest “life” of harvested produce

The harvest indicate the end of the period of growth and the start of the period of senescence

- **Start of biochemical changes**
- **Effect on storage length**

Initiation of the pathogen colonization

What are the factors affecting the losses of harvested produce by pathogens?

Before Harvest

- Weather conditions
- Level of maturity
- Location of the fruit on the tree
- Sensitivity to wounding's
- Harvesting conditions

After harvest

- Conditions of the packing house
- Treatment at the packinghouse
- Humidity during storage
- Transport conditions

Quality decline of harvested produce: Where does it take place?

1. In the orchard: weather conditions, hot weather, ripening conditions
2. During harvest: way of harvest, time to transfer to the packing house, transport to the packing house
3. In the packing house and postharvest handling: quality of the packinghouse, cold storage, humidity
4. Transport to internationals ports: cold storage, level of oxygen, level of CO_2.

Very complicated system !!!

What are the factors affecting the losses of harvested produce?

Before Harvest

- Weather conditions
- Level of maturity
- Location of the fruit on the tree
- Sensitivity to wounding's
- Harvesting conditions

After harvest

- Conditions of the packing house
- Treatment at the packinghouse
- Humidity during storage
- Transport conditions
- Temperature of storage

Too many factors are affecting the produce quality and disease development!!!

The objective !!!
Is to improve of quality by prevention of decay development during storage

What is the source of the inoculum for host infection?

Before harvest:

1. Air (Botrytis, Penicillium)
2. Water, Humidity (Colletotrichum)
3. Soil remnants (Phytophthora)
4. Agricultural tools

Direct penetration and quiescence: Botrytis

Direct penetration + quiescent symptoms

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Green mold rot of citurs cause by *Penicillium digitatum* by wound penetration

Penicillium side peel wound penetration

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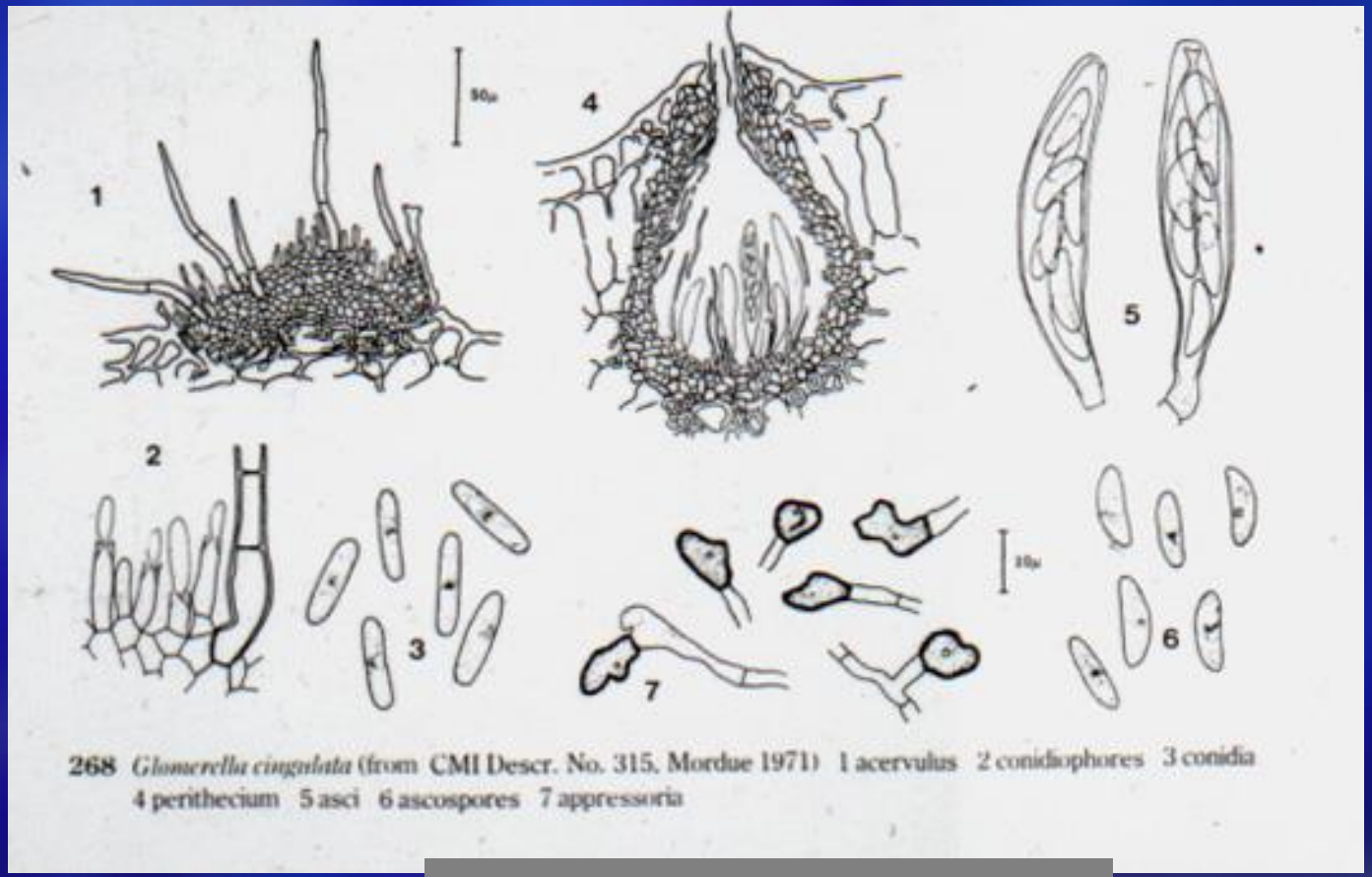
Colletotrichum the pathogen the cause Anthracnose



268 *Glomerella cingulata* (from CMI Descr. No. 315, Mordue 1971) 1 acervulus 2 conidiophores 3 conidia 4 perithecium 5 asci 6 ascospores 7 appressoria

Direct penetration + no symptoms

Humidity run off and active infections

Colletotrichum (Anthracnose) in Mango fruits

What is the source of the inoculum for host infection?

Before harvest:

1. Air (Botrytis, Penicillium)
2. Water, Humidity (Colletotrichum)
3. Soil remnants (Phytophthora)
4. Agricultural tools

Phythophtora infestans

Direct penetration + small symptoms

What is the source of the inoculum for host infection?

Before harvest:

1. Air (Botrytis, Penicillium)
2. Water, Humidity (Colletotrichum)
3. Soil remnants (Phytophthora)
4. Agricultural tools

Specificity of the host: how important?

Specificity of the colonization is dependent in several factors:

1. **Capability to breach the cuticle**
2. **Direct penetration or wound penetration**
3. **Nutritional needs**
4. **Enzyme production**
5. **Toxin accumulation**
6. **Genetic background**

Specificity of the pathogen to attack the host:

- Monophage- *Penicillium*
- Polyphage- *Alternaria, Botrytis, Rhizopus*

Penicillium side peel wound penetration

Specificity of the pathogen to attack the host:

- Monophage- *Penicillium*
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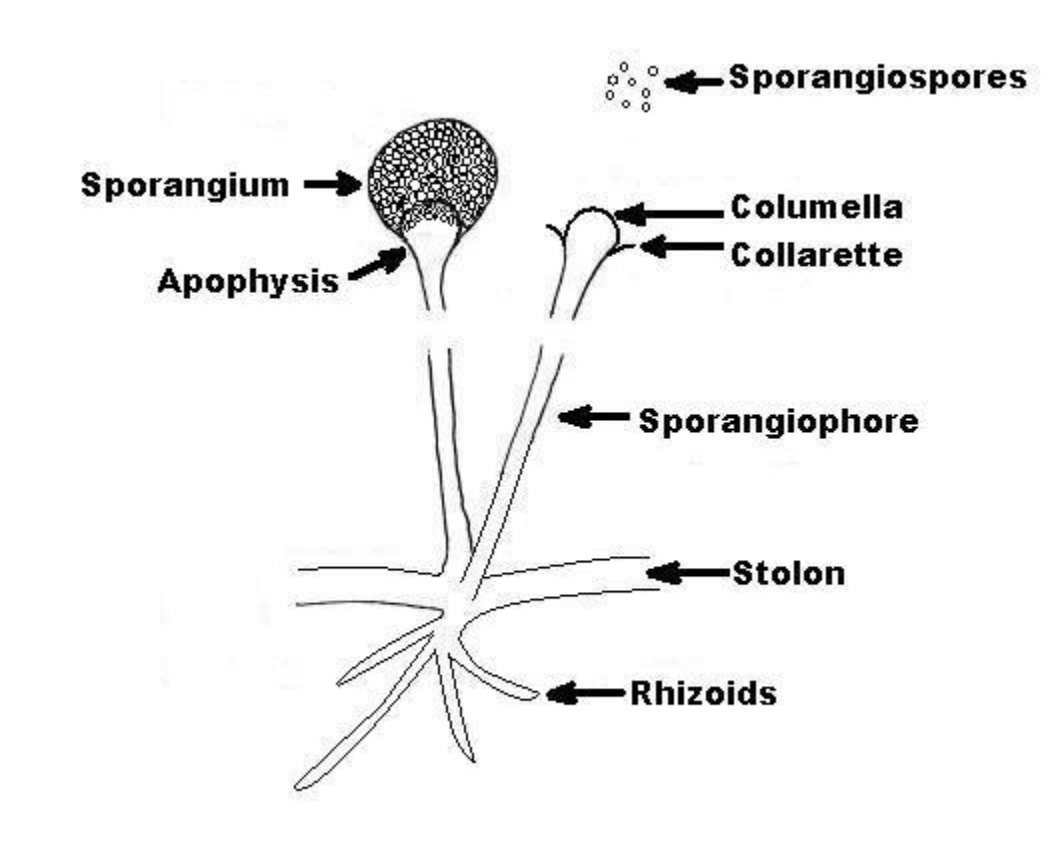
Direct penetration and quiescence: Botrytis

Direct penetration + quiescent symptoms

Alternaria alternata

Rhizopus


Sporangiospores
Sporangium
Columella
Collarette
Apophysis
Sporangiophore
Stolon
Rhizoids

Specificity of the pathogen to attack the host:

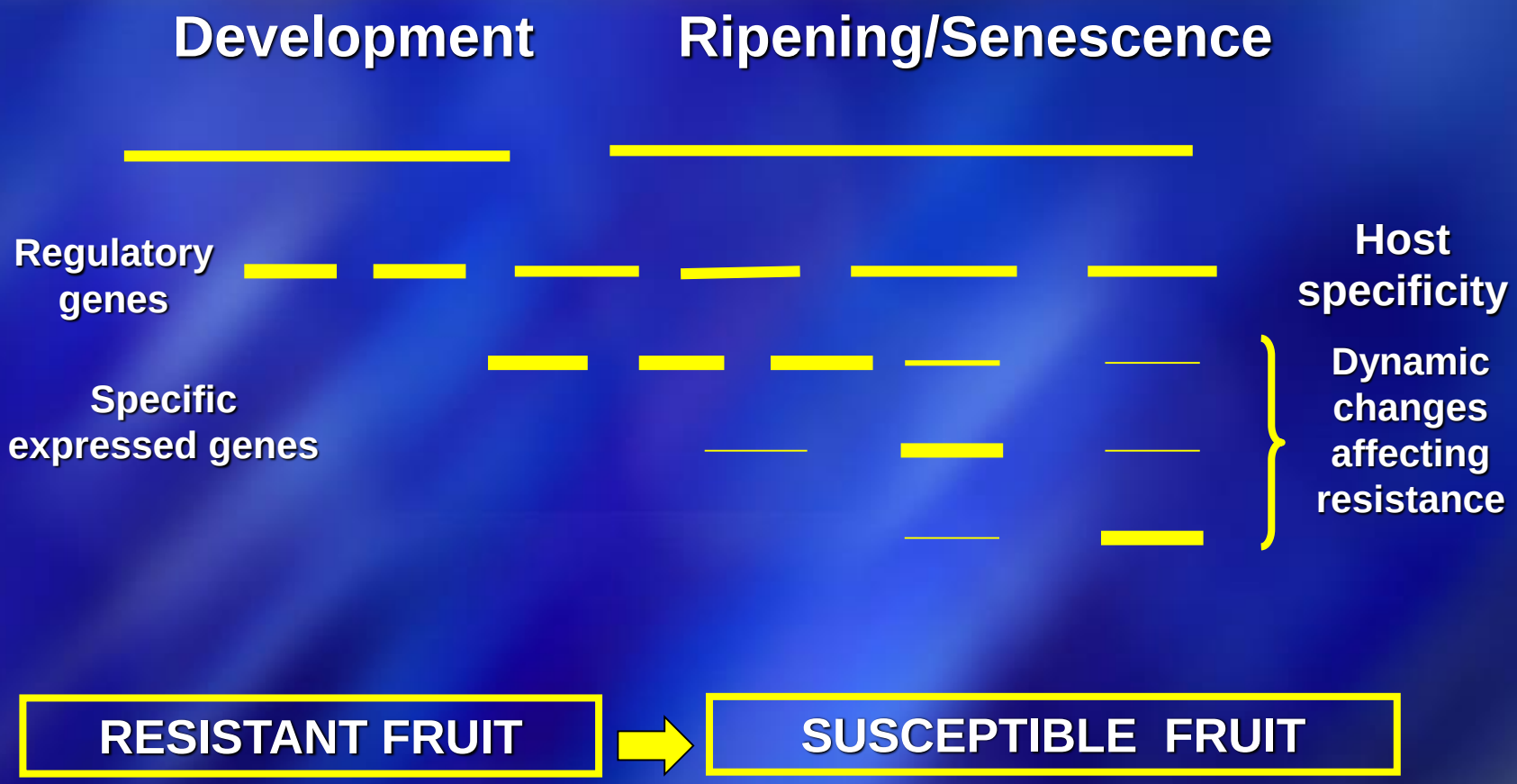
- Monophage- *Penicillium*
- Polyphage- *Alternaria, Botrytis, Rhizopus*

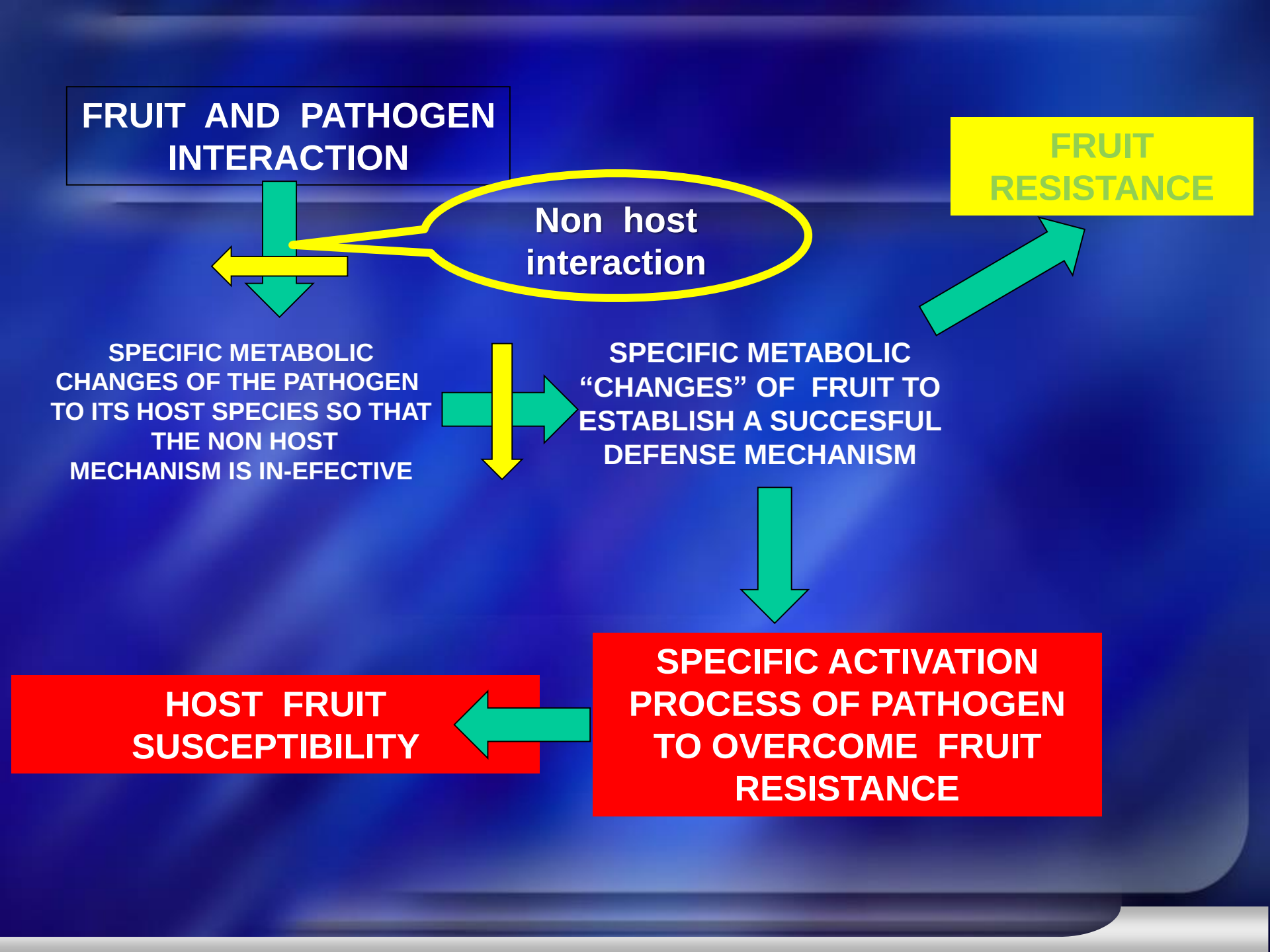
Defense or pathogencity in fruit pathogen interactions

1. Basic defense lines

2. Hierarchical response line during colonization

Mechanisms of host responses in fruit pathogen interactions




FRUIT AND PATHOGEN INTERACTION
Non host interaction
FRUIT RESISTANCE
SPECIFIC METABOLIC CHANGES OF THE PATHOGEN TO ITS HOST SPECIES SO THAT THE NON HOST MECHANISM IS IN-EFECTIVE
SPECIFIC METABOLIC "CHANGES" OF FRUIT TO ESTABLISH A SUCCESFUL DEFENSE MECHANISM
SPECIFIC ACTIVATION PROCESS OF PATHOGEN TO OVERCOME FRUIT RESISTANCE
HOST FRUIT SUSCEPTIBILITY

Fungal specificity

PATHOGEN	DISEASE	PRIMARY HOST	
Penicillium italicum	Blue mold	Citrus	Mono
Phytophthora infestans	Late Blight	Potato, tomato	Mono
Penicillium spp	Blue mold	Tomato, cucumber, melon	Poly
Phomopsis	Stem end	Citurs, mango, avocado	Poly
Rhizopus stolonifer	Soft Rot	Stone and pome fruit, grape, avocado, papaya, strawberry, raspberry, cherry, tomato, pepper, Eggplant, carrot, melon, pea, bean sweet potato	Poly

Conditions for fungal germination, pentration and colonization on horticultural crops:

- Optimal temperature 20-25 C
- Optimal relative humidity 90-95%
- Concentrations of O_2 higher that 1%
- Concentration of CO_2 lower that 15-20%
- pH range between 4-6
- Presence of nutritional factors (glucose, sucrose, fructose in the wound)
- Adhesion

Nutritional factors in sweet potato colonized by Rhizopus

Rhizopus oryzae germination and growth after supplementation with Sweet Potato Juice active Fraction (SPAF) and the whole Extract (SPJE)

Sweet potato juice extract SPJE(mg/ml).

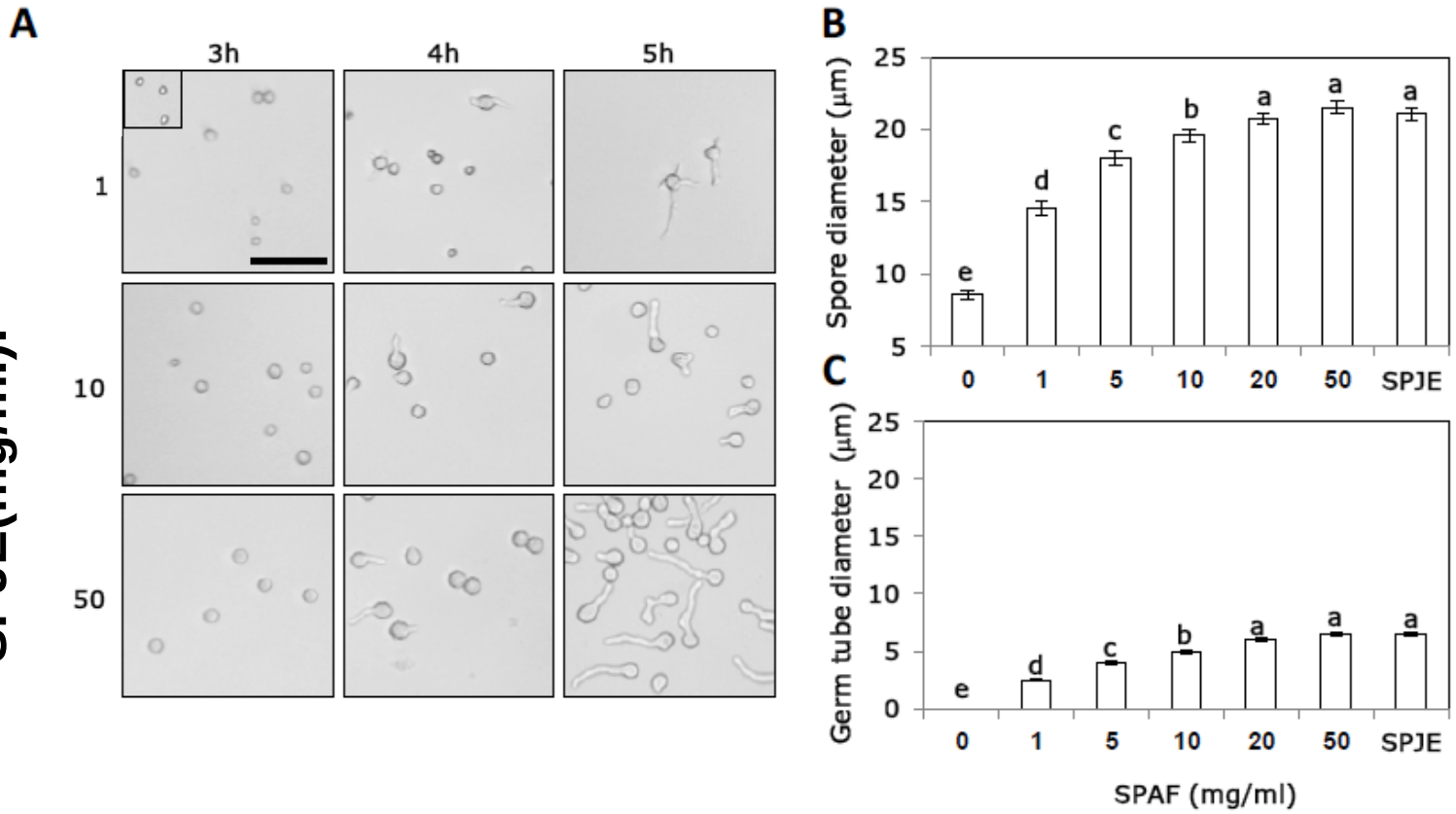
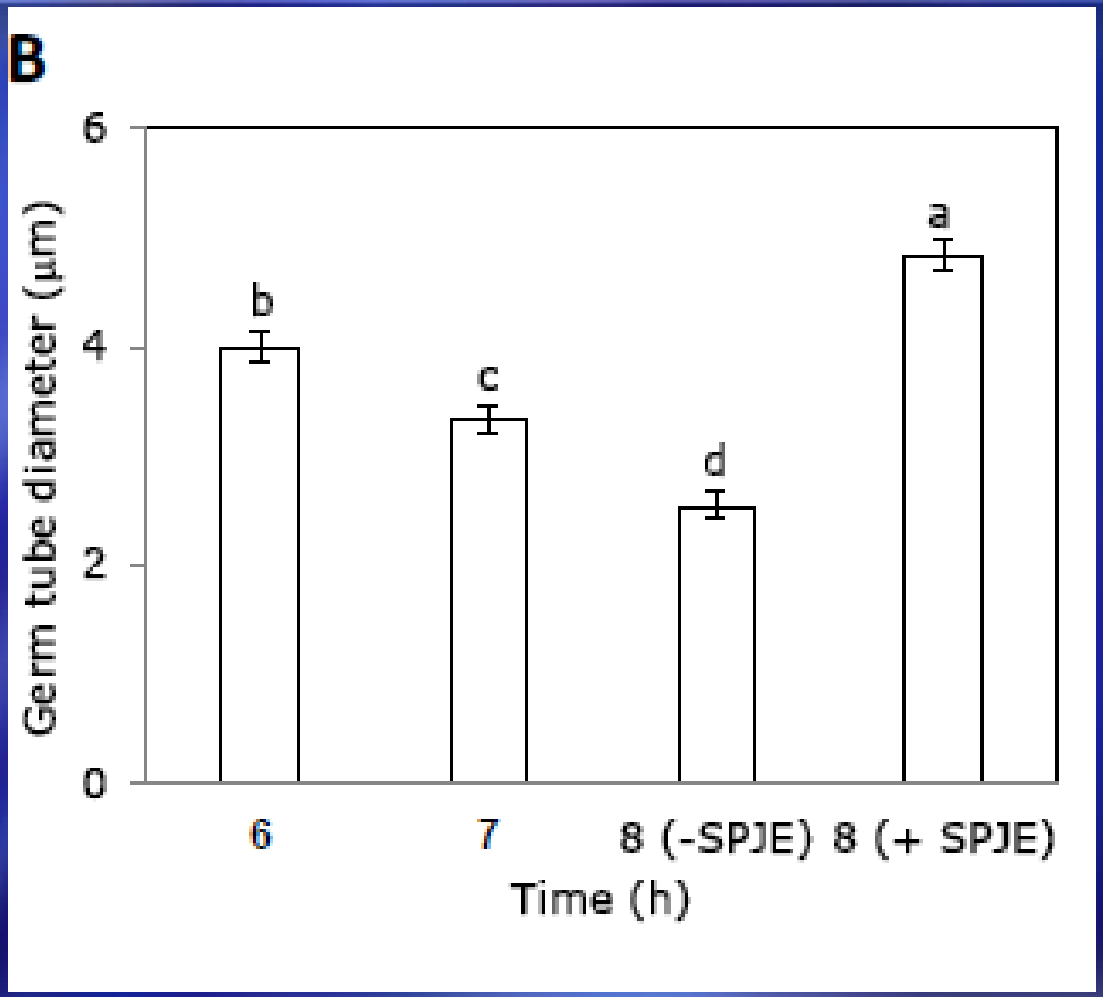


Fig. 2. Dose response of *R. oryzae* spores to sweetpotato active fraction (SPAF) as compared to sweetpotato juice extract (SPJE). A, Micrographs of spores after different incubation intervals (inset shows water-incubated spores, bar = 100 µm). B, Spore diameter after 5 h of incubation. C, Germ-tube diameter after 8 h incubation. Values are means ± SE (n = 100). Different lowercase letters above the bars denote significant differences ($P < 0.05$).

Rhizopus oryzae germ-tube shrinkage as a result of starvation and recovery after supplementation with sweetpotato juice extract (SPJE).



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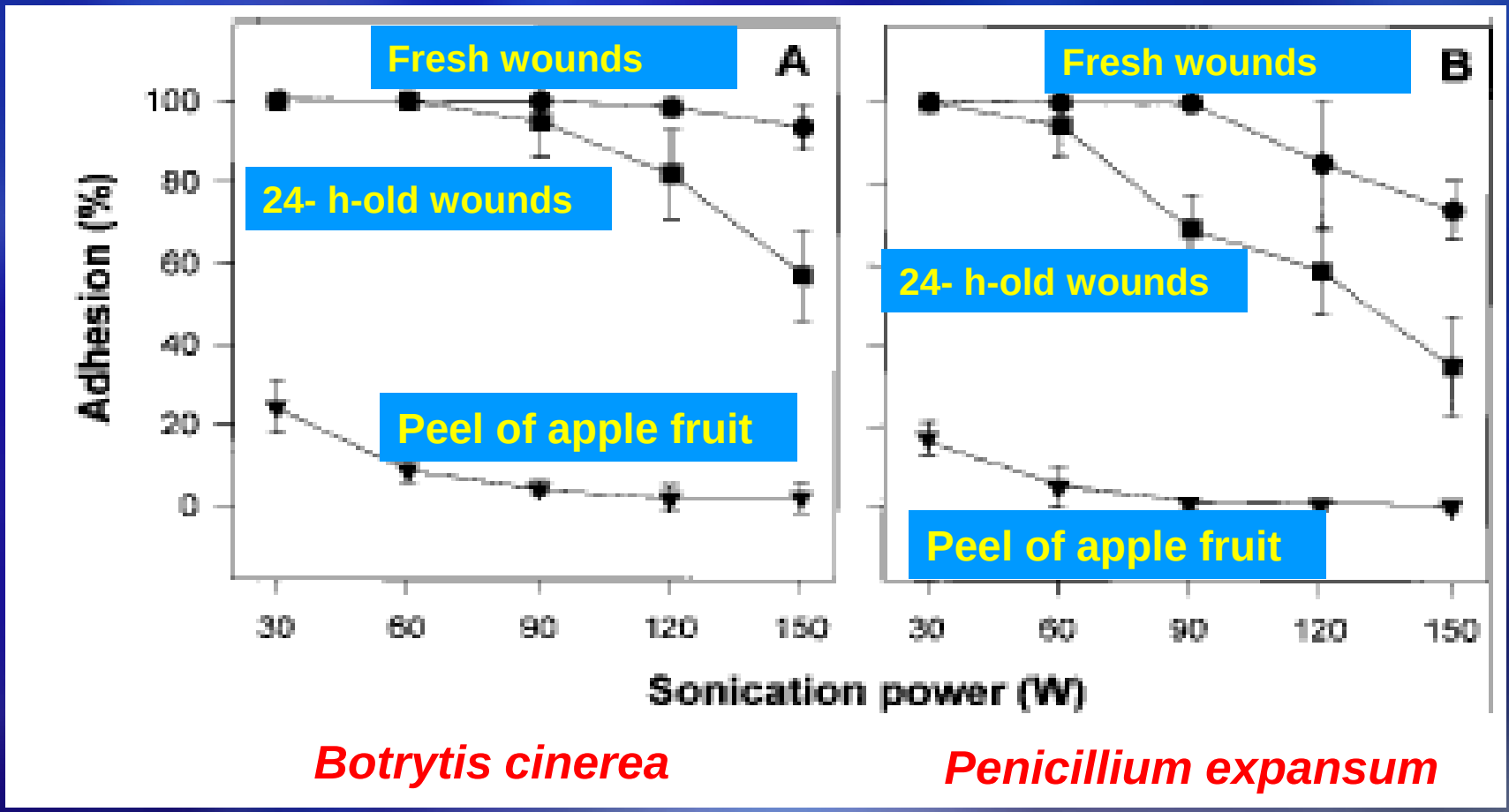
Percent adhesion of (A) *Botrytis* and (B) *Penicillium* conidia on apple fruit:



Botrytis cinerea

Penicillium expansum

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- Adhesion
- Fruit volatiles

Effect of volatiles

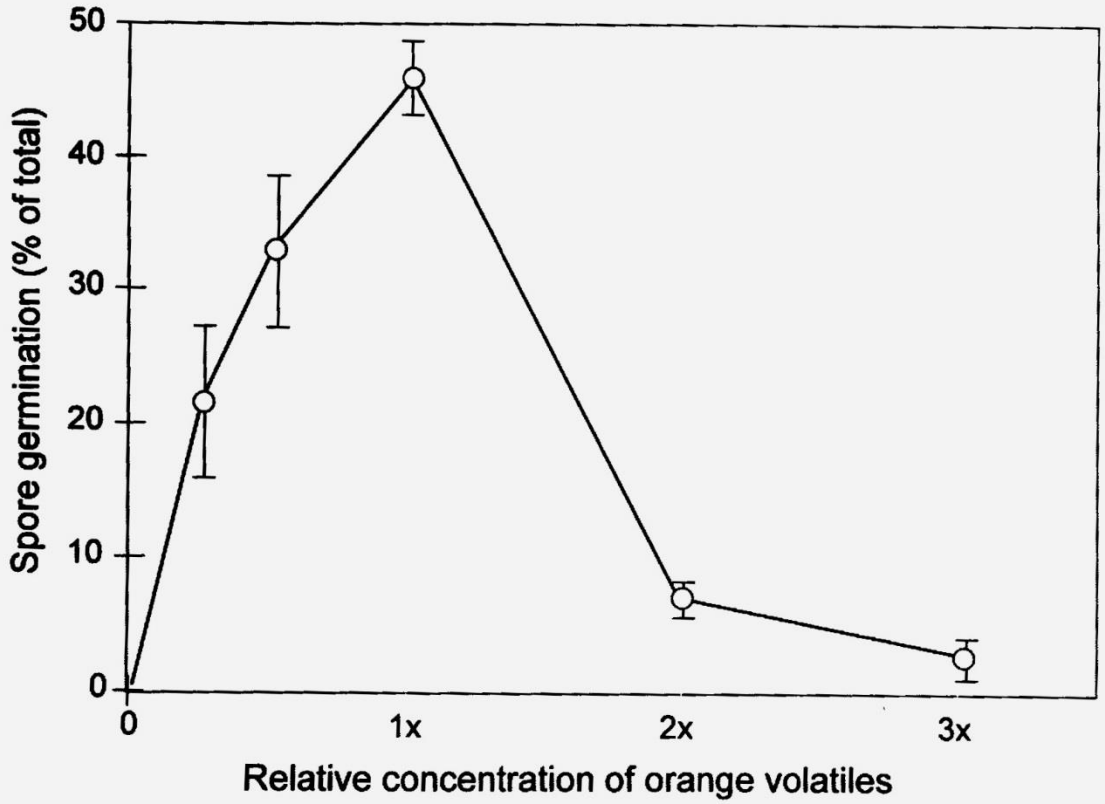
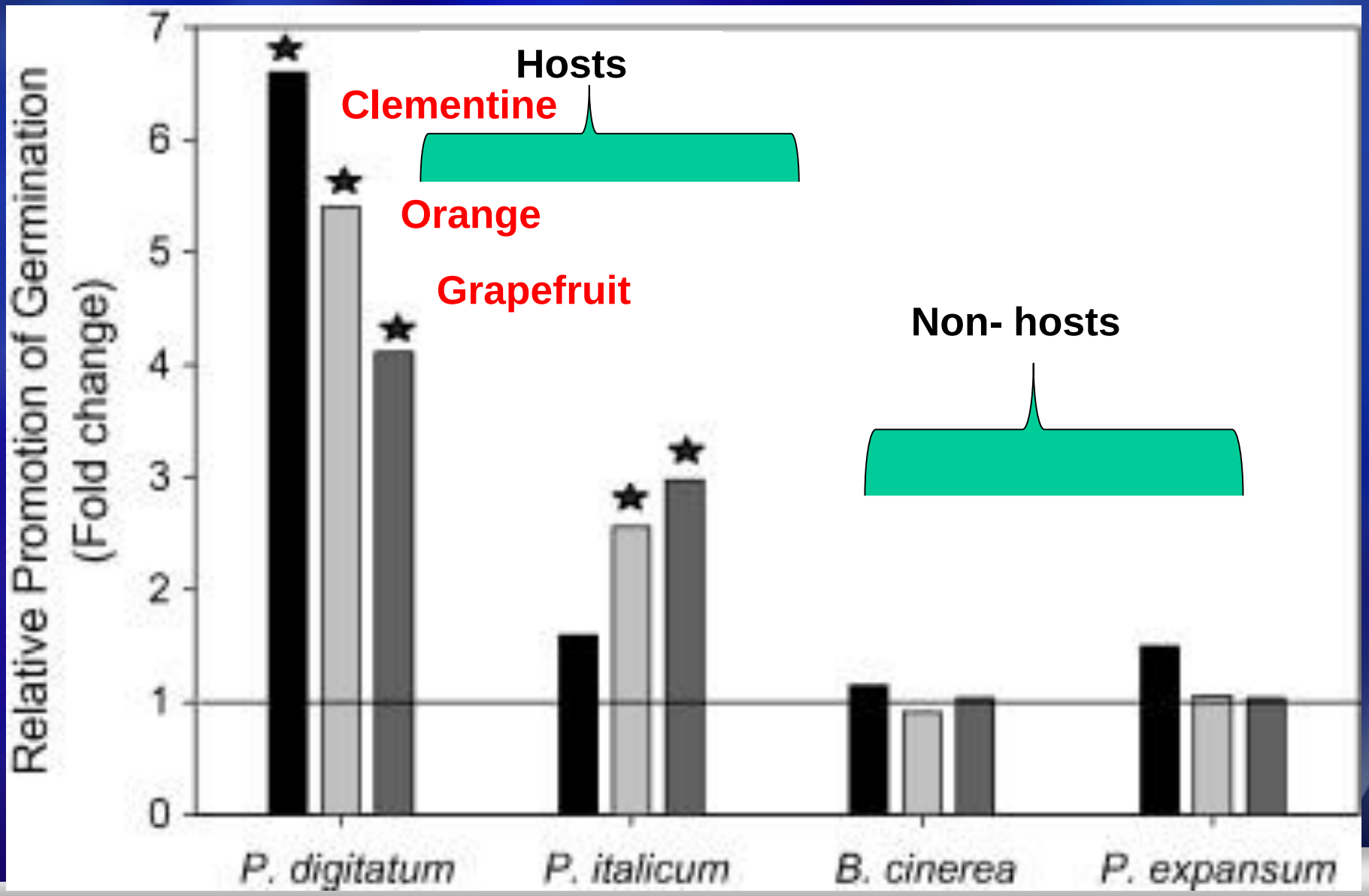
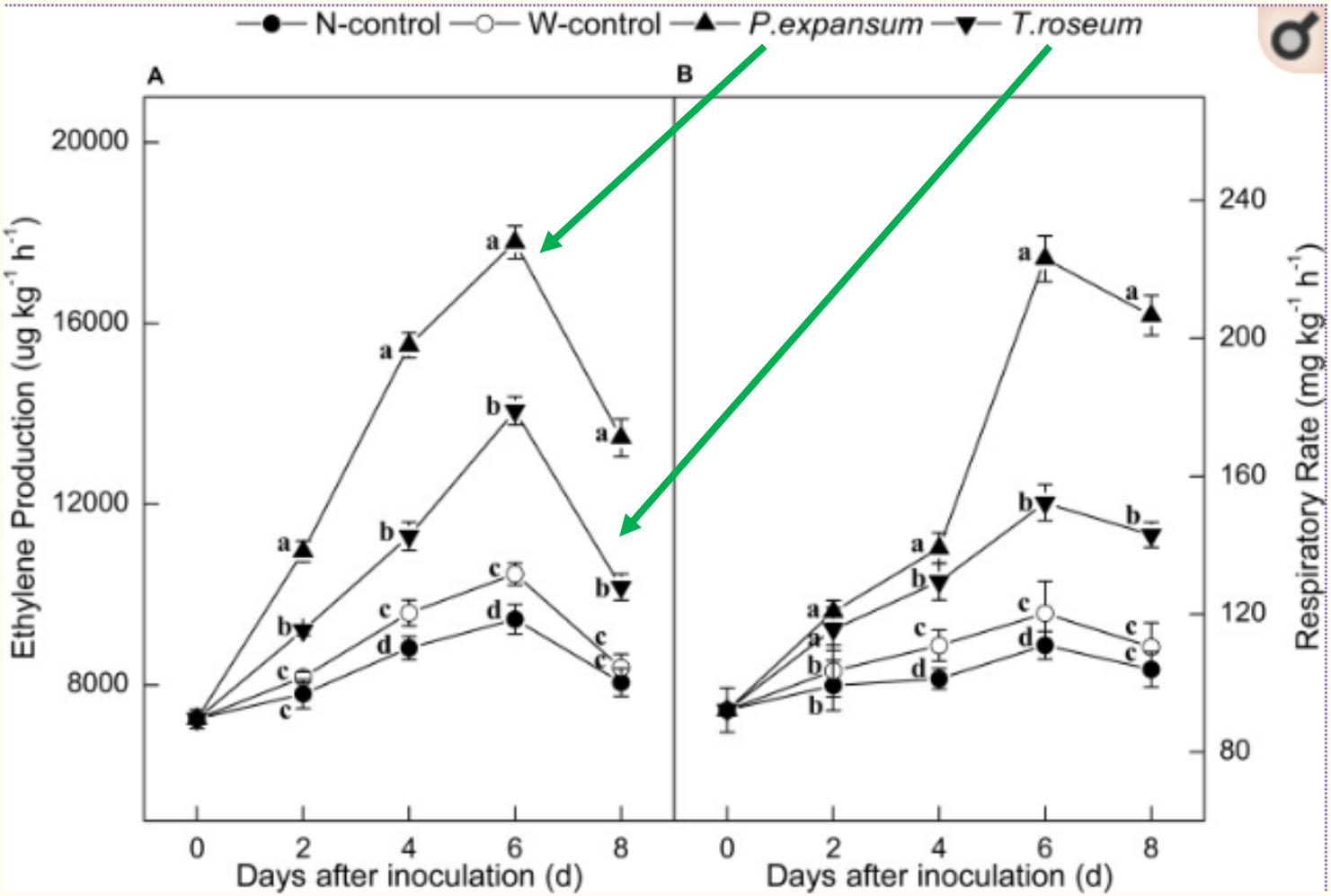


Fig. 3. Effect of concentration of the synthetic mixture of volatile compounds on the germination of *Penicillium digitatum* spores. 1x is the concentration typical of the natural mixture measured surrounding wounded oranges. Bars indicate standard errors. (Reproduced from Eckert and Ratnayake,1994 with permission of the American Phytopathological Society).

The effect of volatiles released from peel discs of clementine, orange and grapefruit germination of *P. digitatum*, *P. italicum*, *B. cinerea* and *P. expansum*



Effect of *Penicillium expansum* and *Trichothecium roseum* on ethylene production and respiration of apple fruit storage



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Penetration of postharvest pathogens

Spread of spores

- Air movement
- Water, water splash, humidity run off
- Mechanical wounds
- Direct contact

- **Direct penetration**
- **Penetration through wounds**

Penetration of postharvest pathogens

Direct penetration :

Showing no Symptoms- Quiescent infections by producing appressoria for penetration

- *Botrytis cinerea*
- *Colletotrichum gloeosporioides*

Showing small initial symptoms:

- Phytophthora infestans in potato
- Phytophthora citrophthora in citrus

Direct penetration and quiescence: Botrytis

Direct penetration + quiescent symptoms

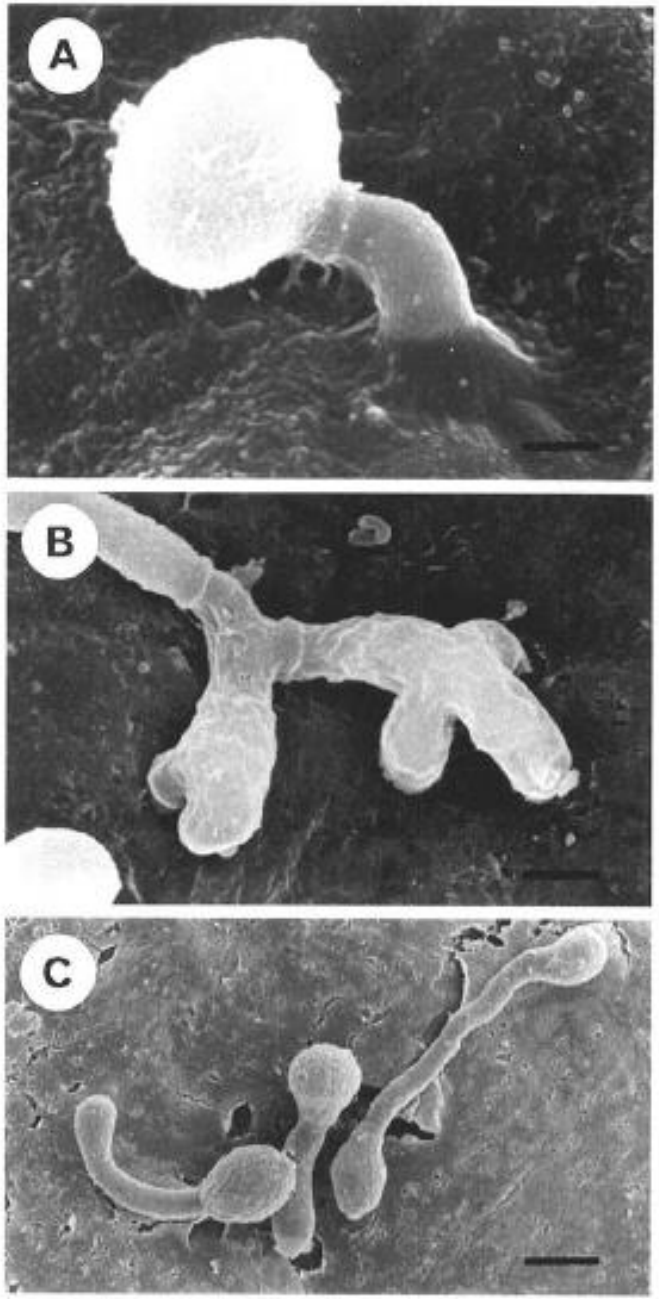


Fig. 1. Scanning electron microscope micrograph of appressoria formed by *Botrytis cinerea* on plum and nectarine fruit. **A**, Protoappressorium on plum 9 h after inoculation. Scale bar = 3.3 μm. **B**, Lobate appressoria on nectarine 48 h after inoculation. Scale bar = 4 μm. **C**, Simple, hyaline appressoria on nectarine 24 h after inoculation. Scale bar = 9 μm.

Direct pentration of Botrytis penetrating plum and nectarine fuits

Quiescent infection defined by Prusky (1996), is :

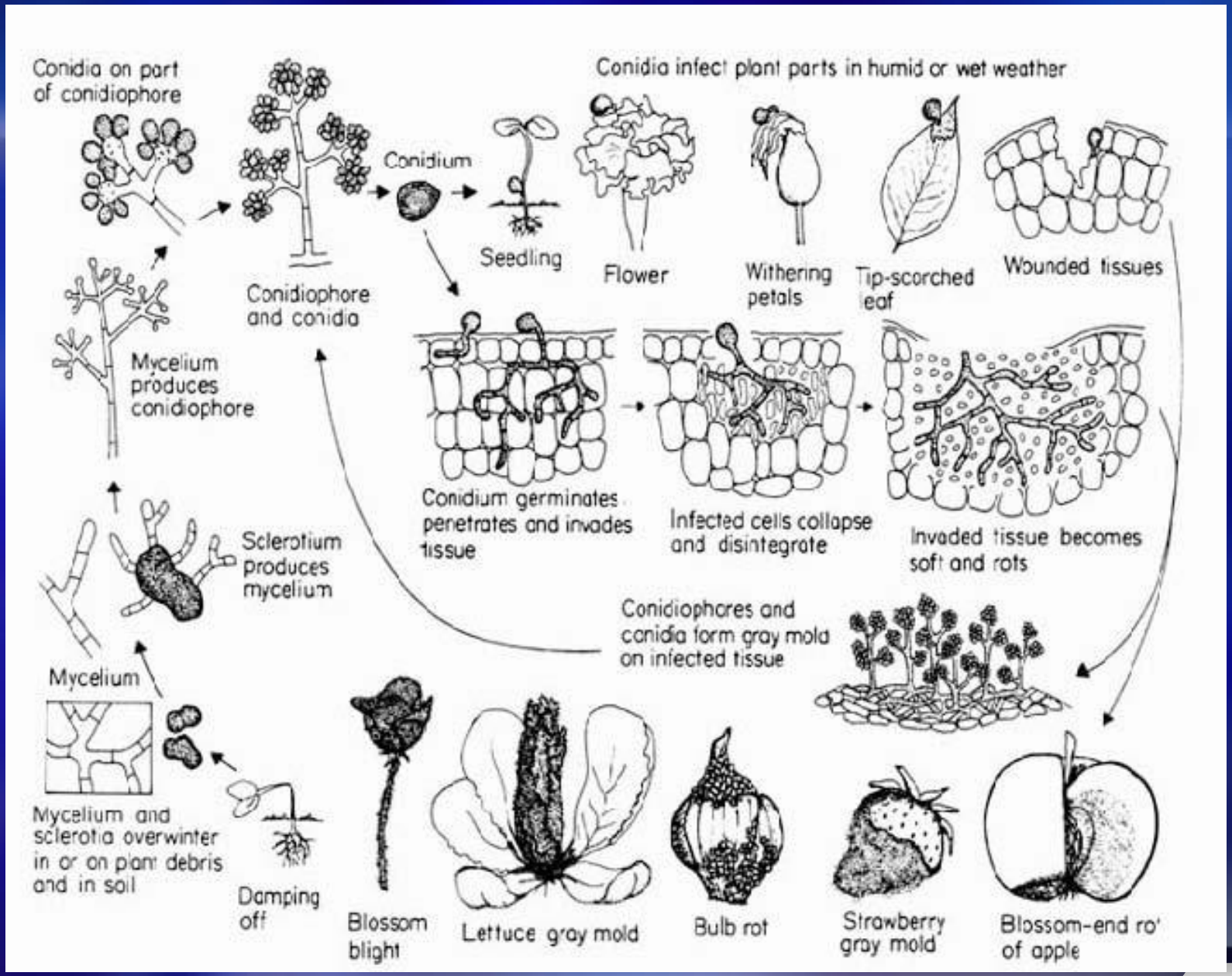
A latent, or dormant parasitic relationship in which the pathogen spends long periods during the host's life in a quiescent stage until, under specific circumstances, it becomes active.

Swinburne (1995) proposed the term "period of quiescence" to differentiate the quiescent parasitic relationship from the latent period.

Air distribution and direct infection

Botrytis quiescent (latent infections)

Botrytis life cycle



Botrytis

Quiescent infections of Botrytis in grapes

Direct penetration and colonization:

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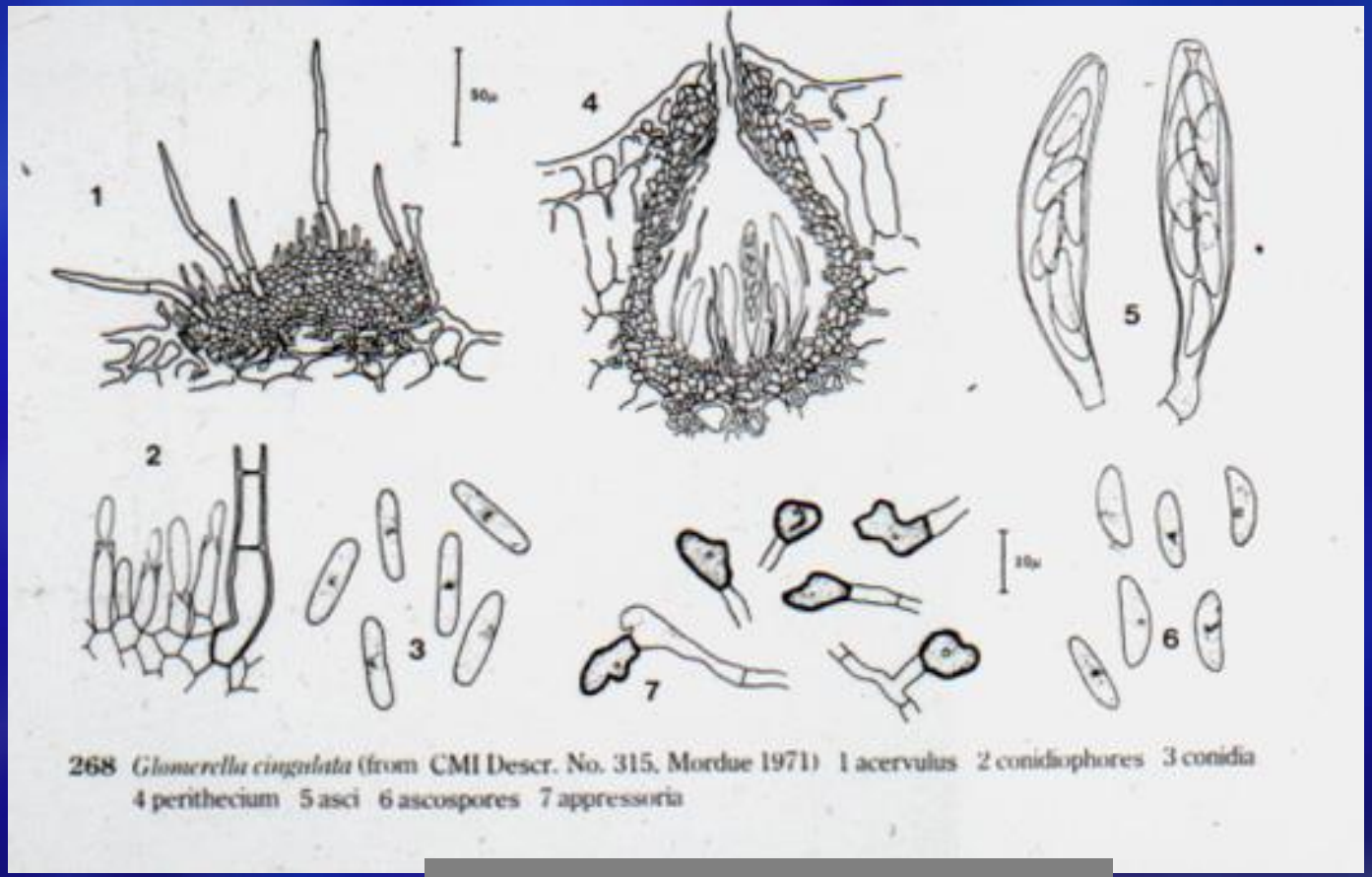
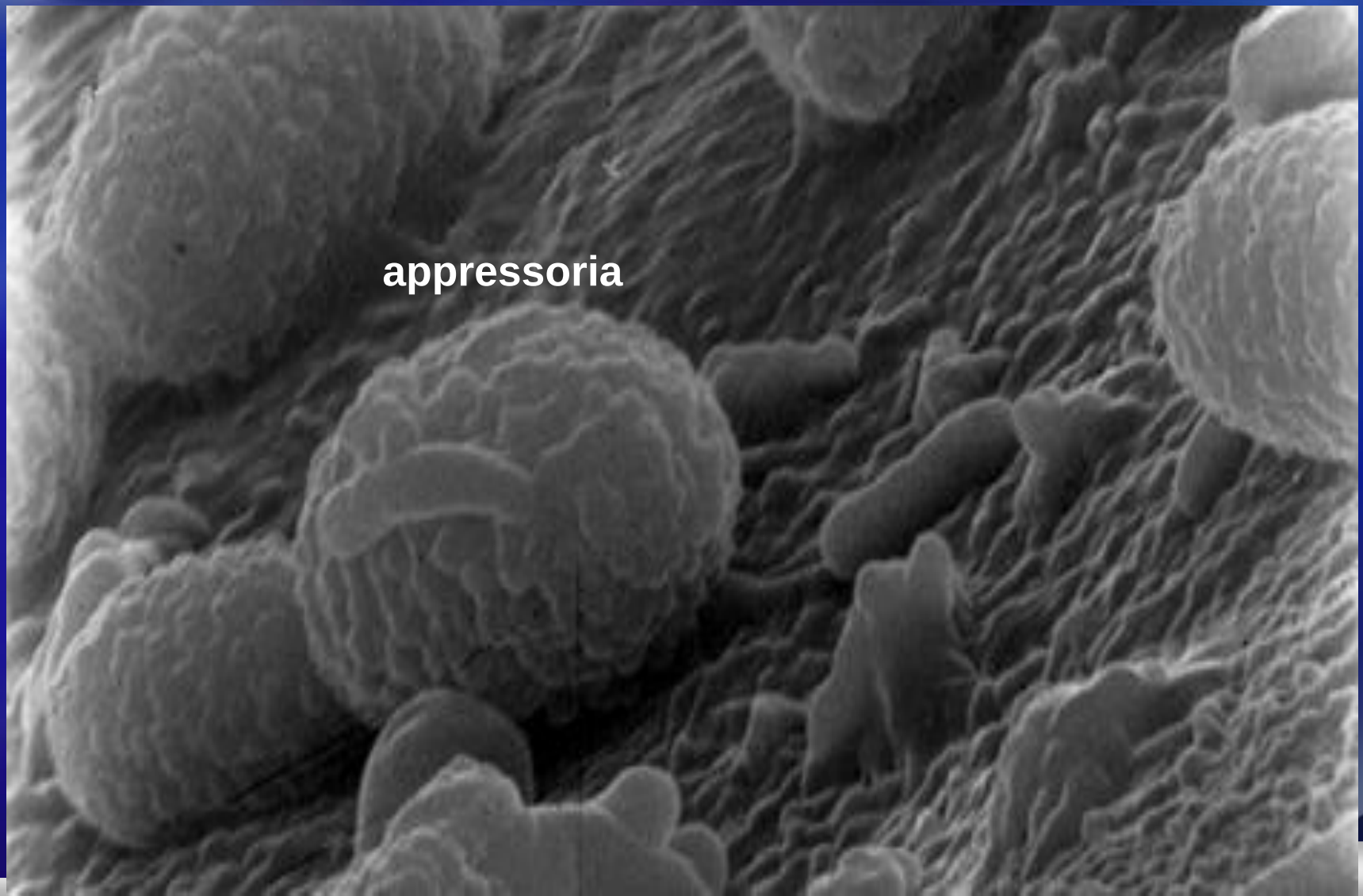
Colletotrichum the pathogen the cause Anthracnose



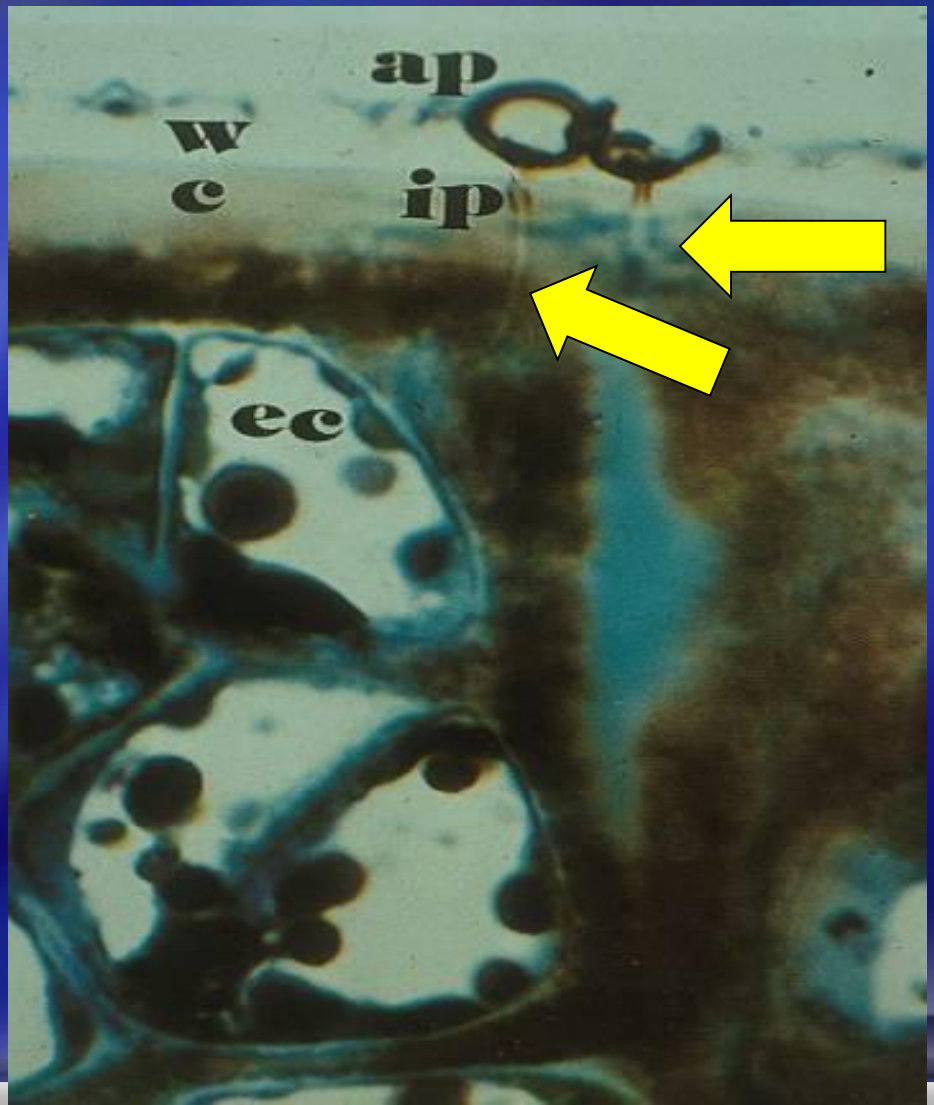
268 *Glomerella cingulata* (from CMI Descr. No. 315, Mordue 1971) 1 acervulus 2 conidiophores 3 conidia 4 perithecium 5 asci 6 ascospores 7 appressoria

Direct penetration + no symptoms

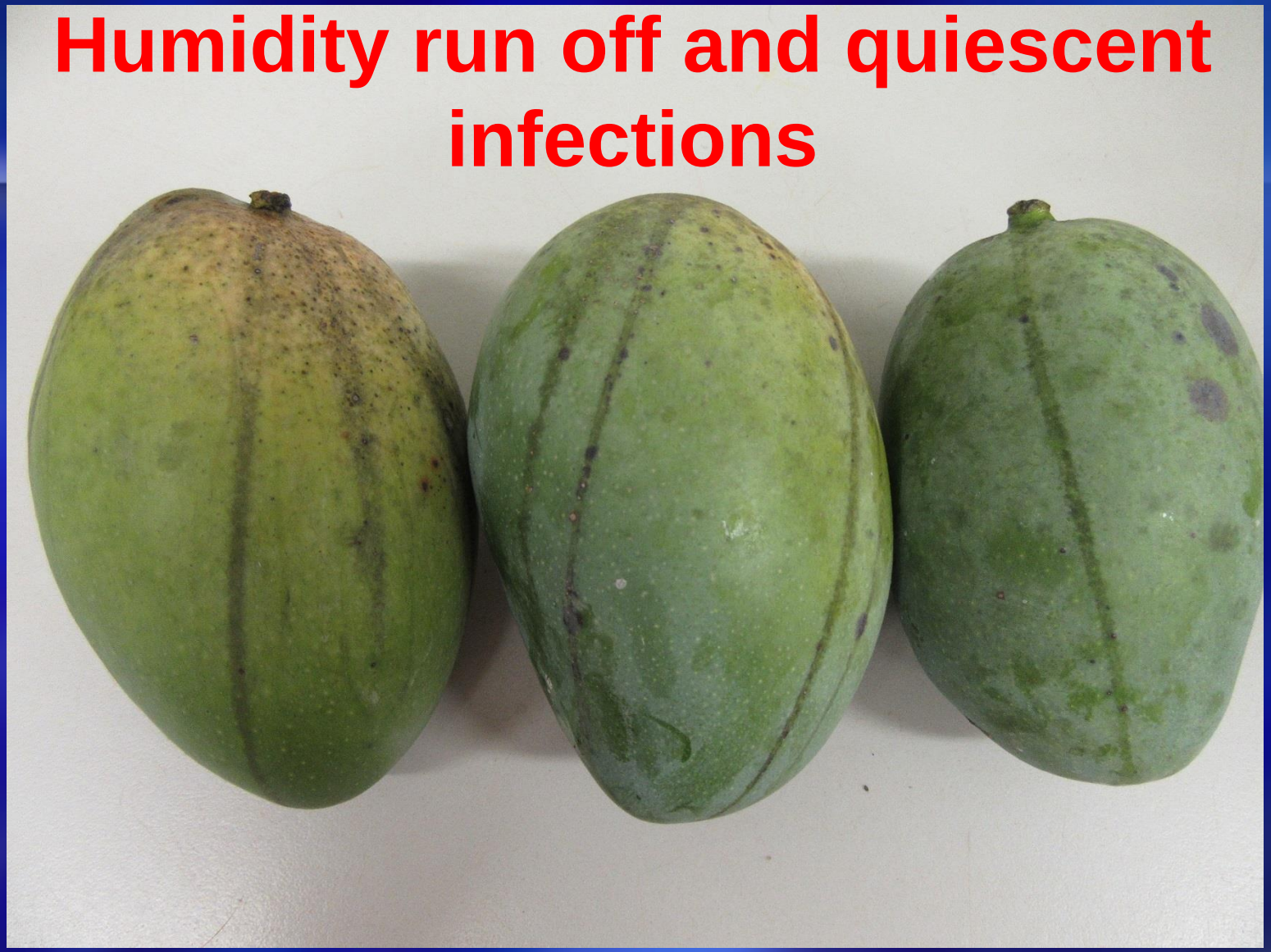
Colletotrichum gloeosporioides germination



Appressoria penetration and quiescence by Colletotrichum



Humidity run off and quiescent infections



Colletotrichum (Anthracnose) direct penetration and quiescent infections in Mango fruits

Humidity run off and active infections

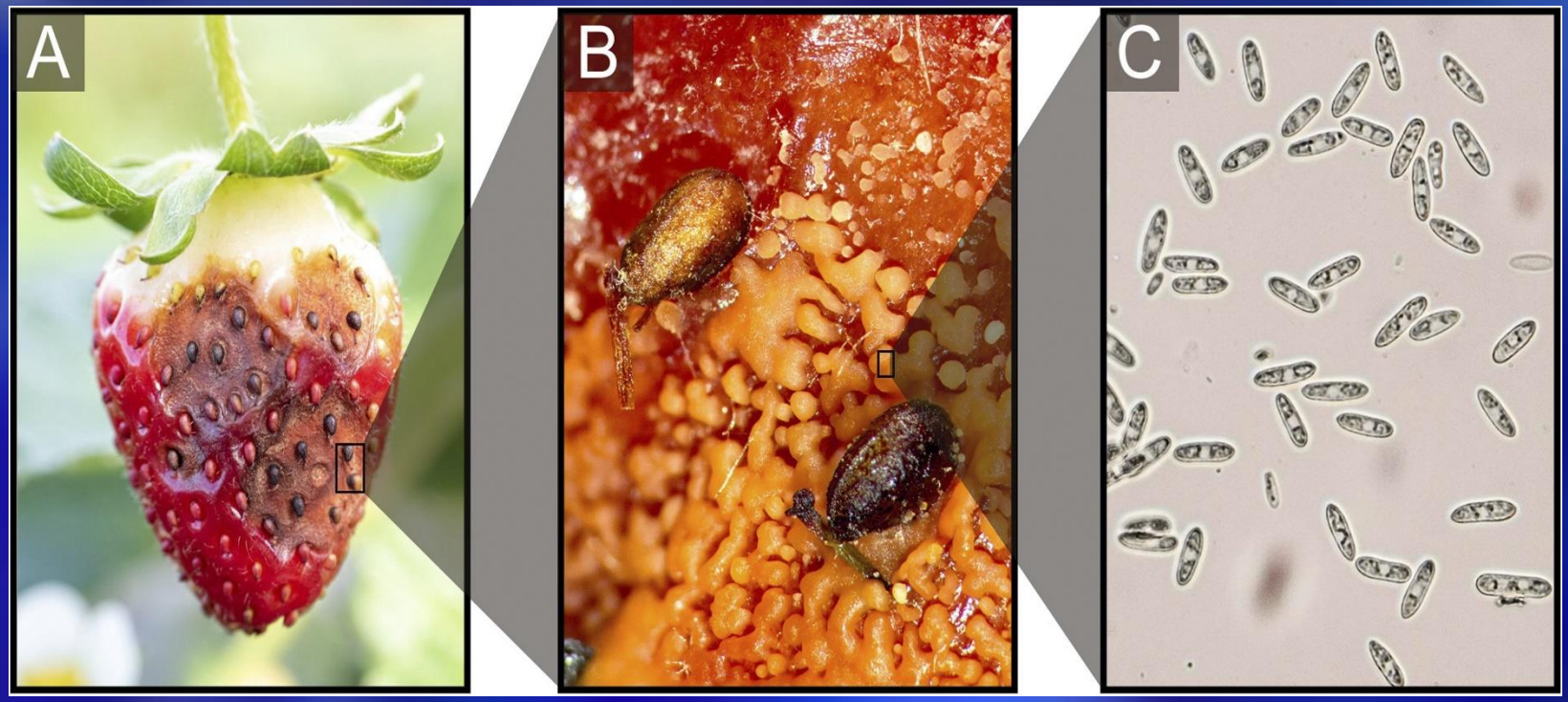
Colletotrichum (Anthracnose) in Mango fruits


Colletotrichum in Mango fruits

Symptoms of diseases caused by *Colletotrichum* spp. on representative temperate fruits: peach, apple, grape, and strawberry.

Published in: Madeline Dowling; Natalia Peres; Sara Villani; Guido Schnabel; *Plant Disease* 2020, 104, 2301-2316.
 • DOI: 10.1094/PDIS-11-19-2378-FE

Symptoms and signs of *Colletotrichum* spp. causing anthracnose fruit rot on strawberry: **A,** ripening strawberry infected by *C. acutatum*; **B,** microscopic image of *C. acutatum* sticky spore masses on anthracnose lesion; **C,** microscopic image of *C. acutatum* spores.



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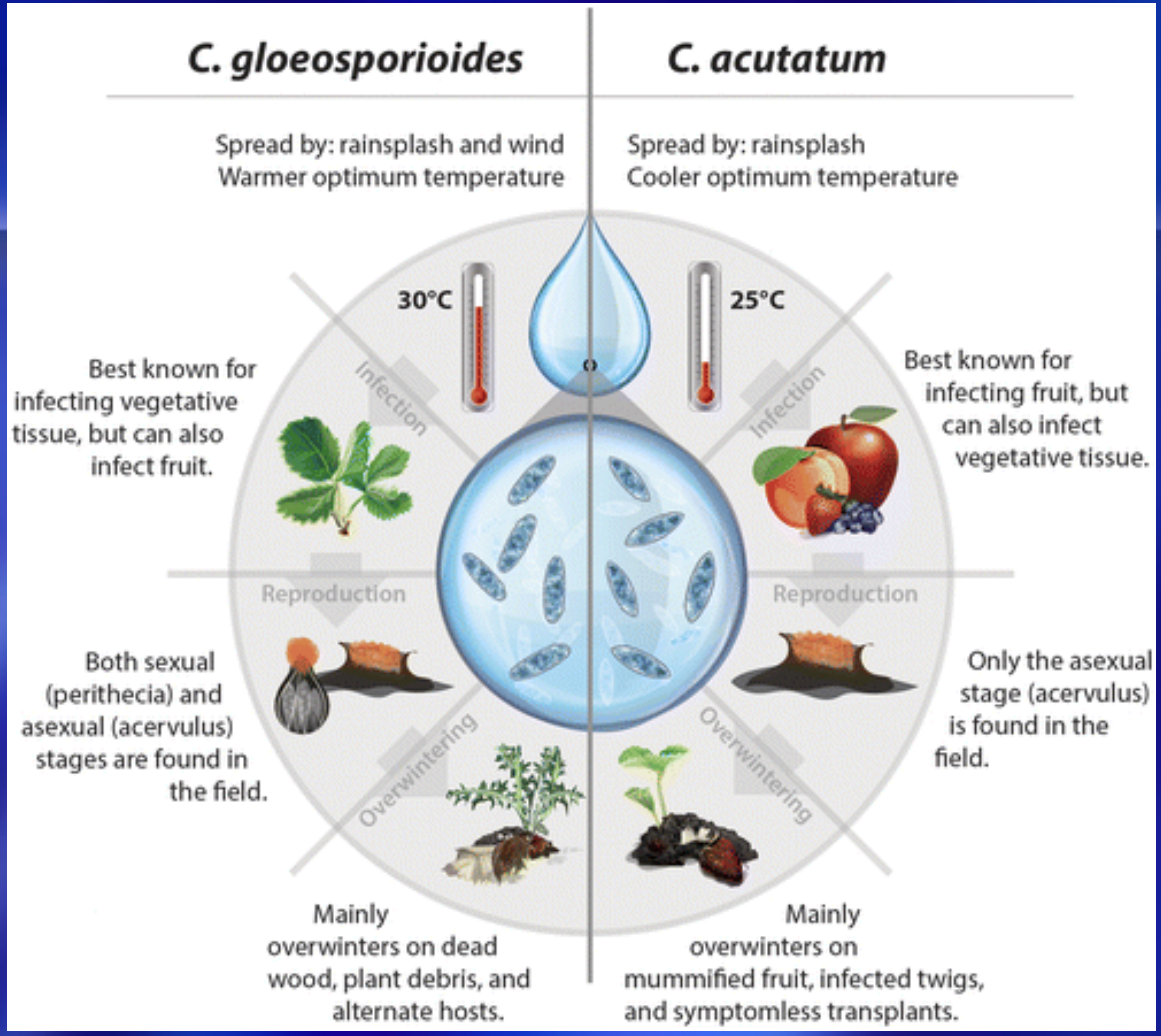
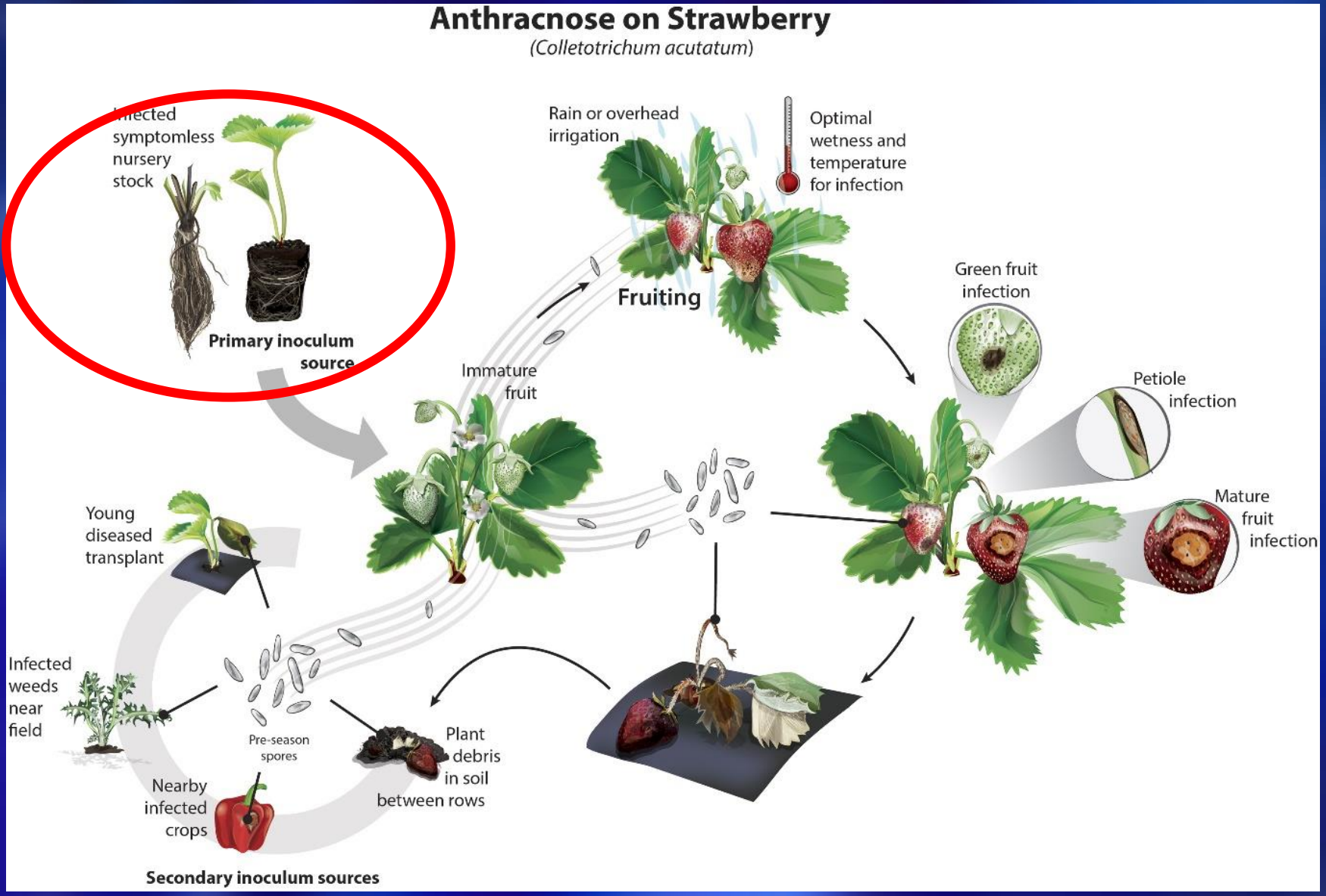
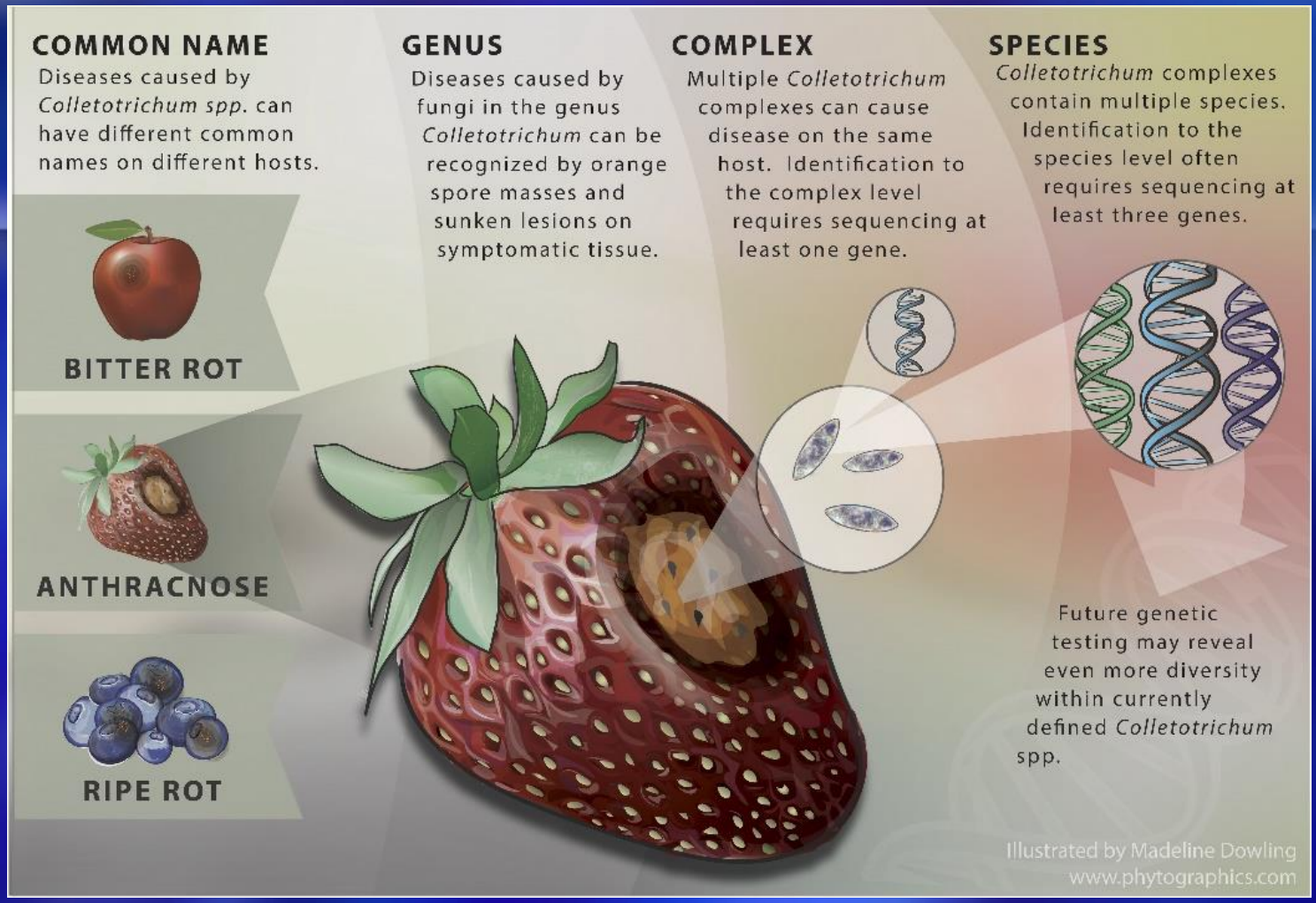


A comparison of *Colletotrichum acutatum* and *C. gloeosporioides* on temperate fruit crops.



. **Representative *Colletotrichum* disease cycle: disease cycle of anthracnose on strawberry caused by *C. acutatum*.**



Levels of complexity in distinguishing *Colletotrichum* spp.

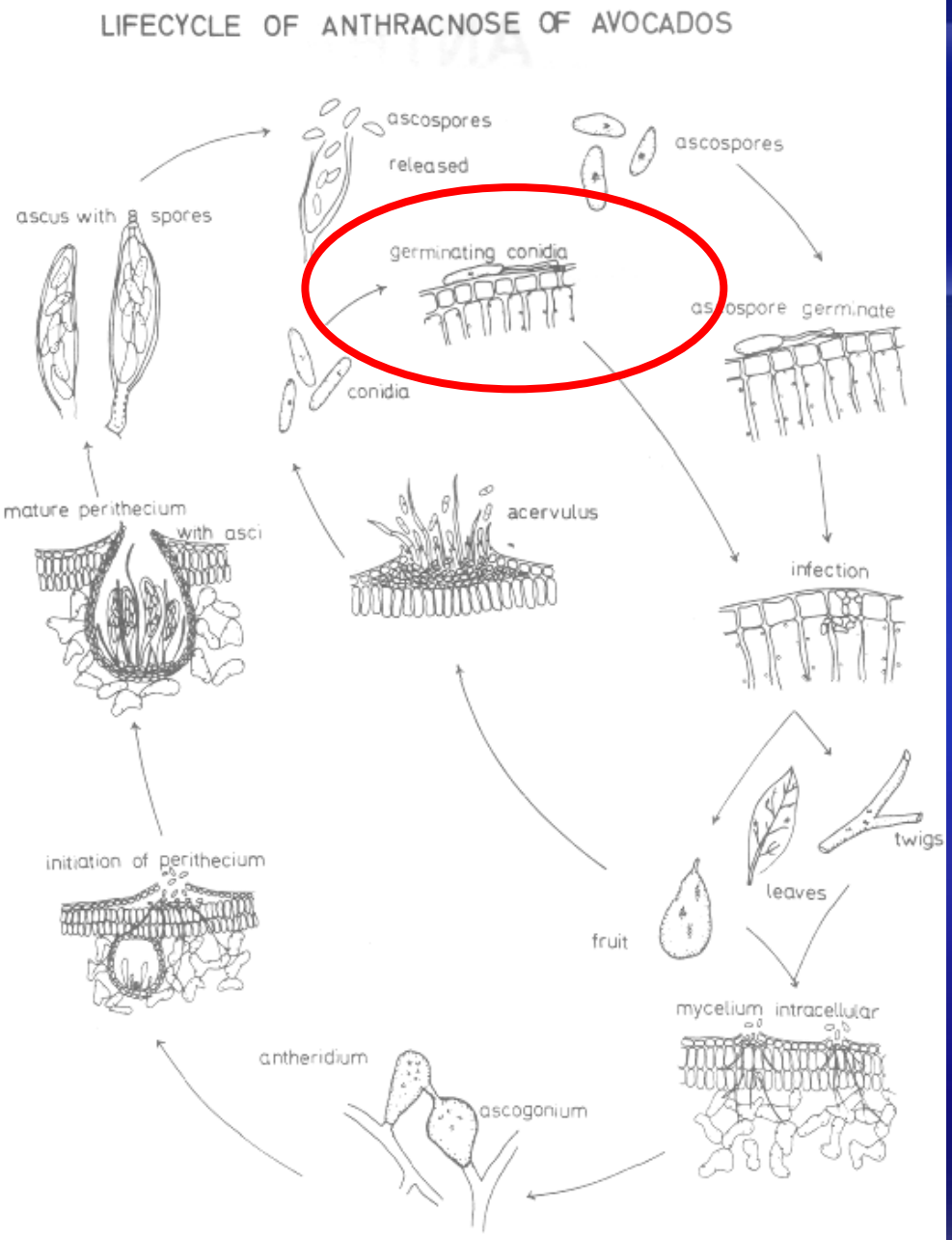
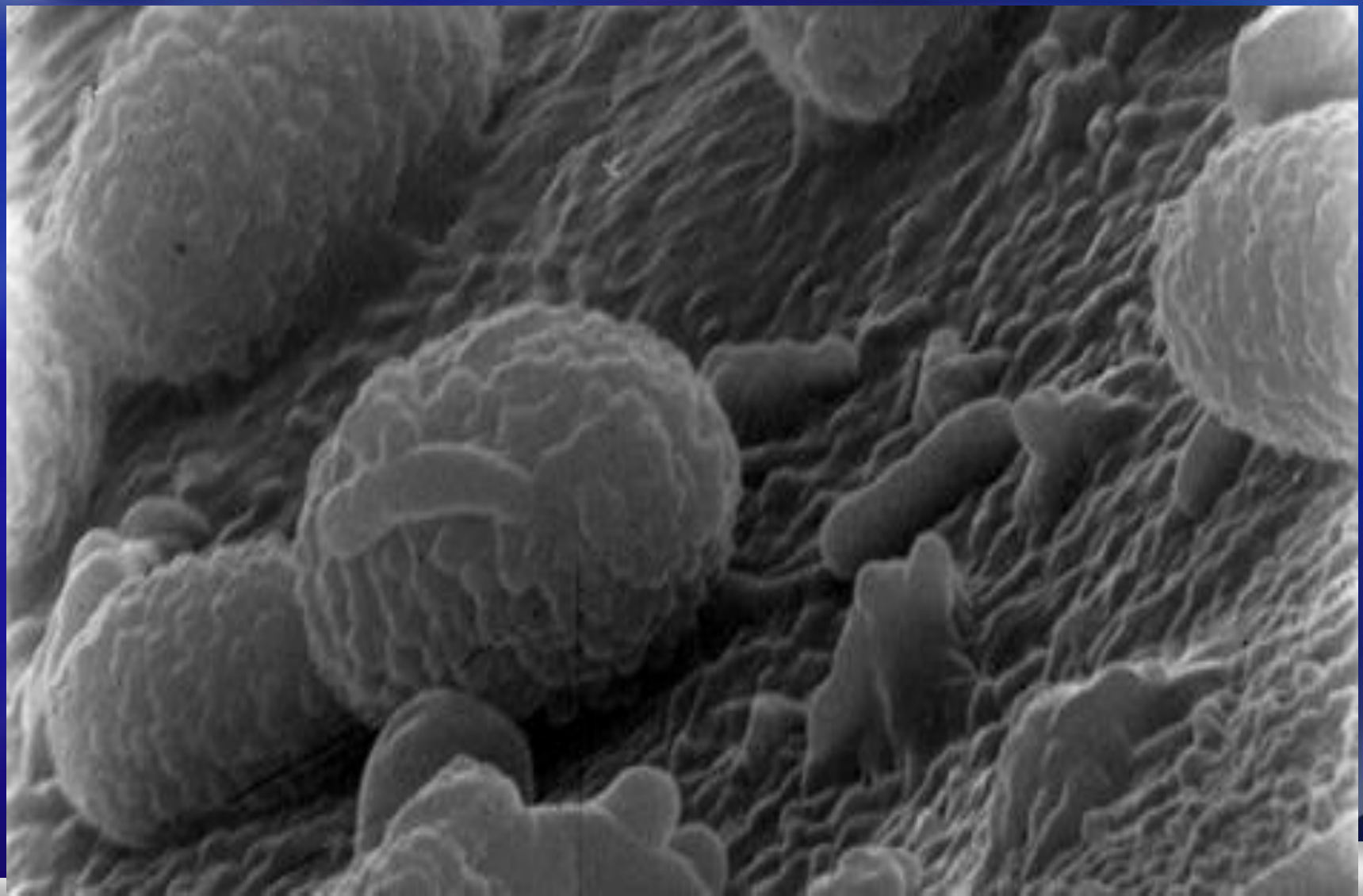
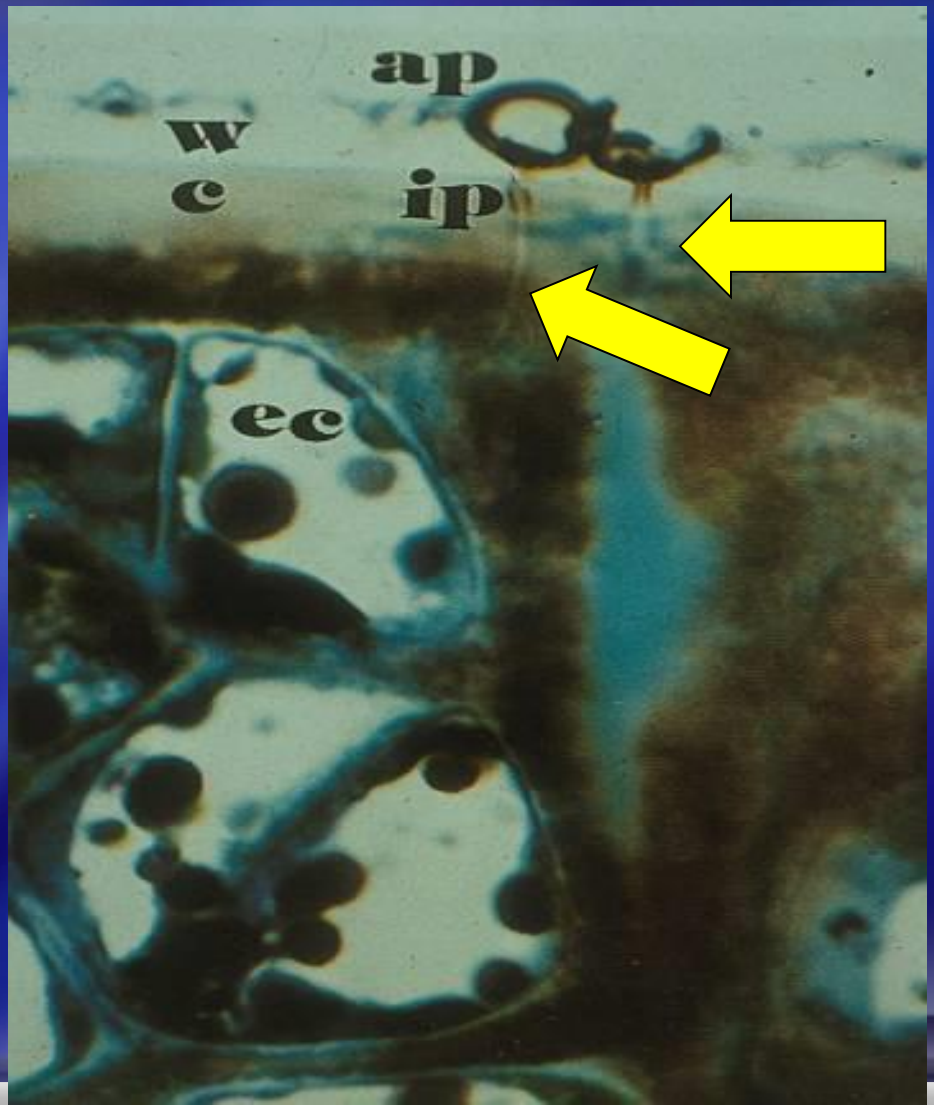


FIG. 3: Schematic presentation of the life cycle of *Colletotrichum gloeosporioides* on avocados

Colletotrichum gloeosporioides germination



Appressoria penetration and quiescence by Colletotrichum



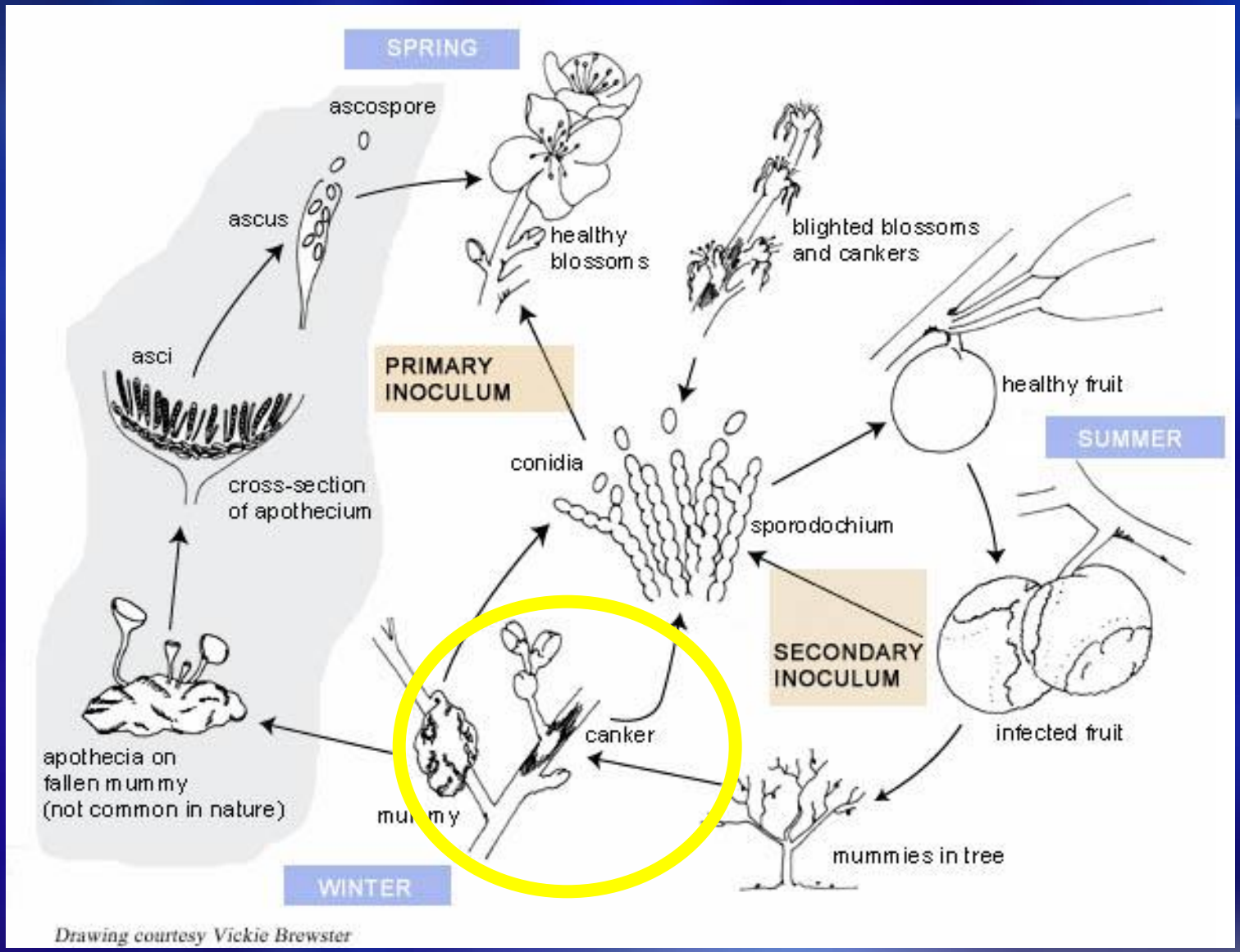
Colletotrichum (Anthracnose) in ripe avocado

Colletotrichum (Anthracnose) in ripe avocado

Anthracnose in Chilli

Anthracnose in banana

Monilinia fructicola



Wound penetration as a result of direct penetration and wound caused by wind insects insects

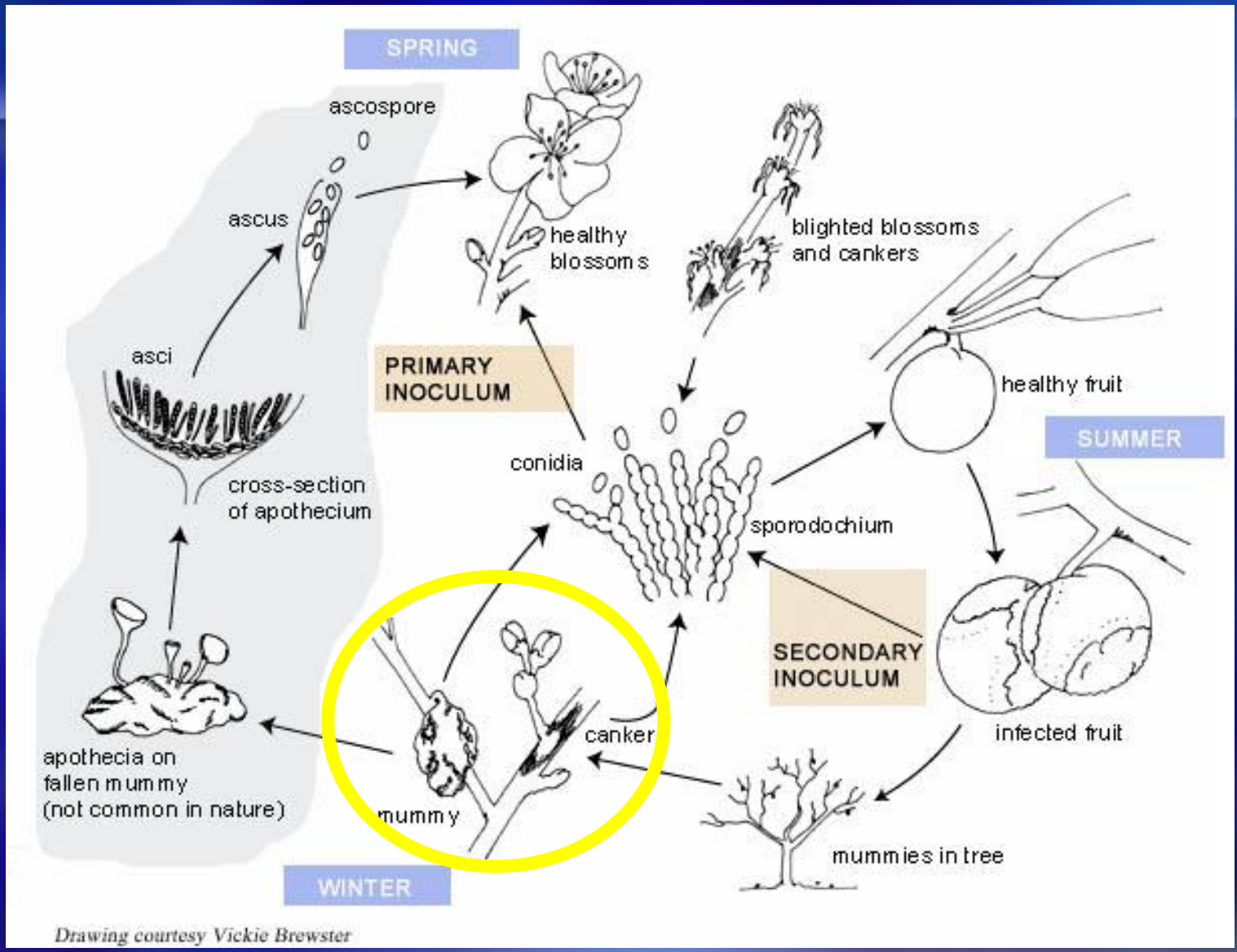
Mummy from last year fruit

Monilinia sp sporulating on mummified fruit left from last year infects new cherry flowers resulting in blossom blight.

Monilinia fructicola

Direct penetration + no symptoms

Monilinia fructicola



Direct penetration and colonization:

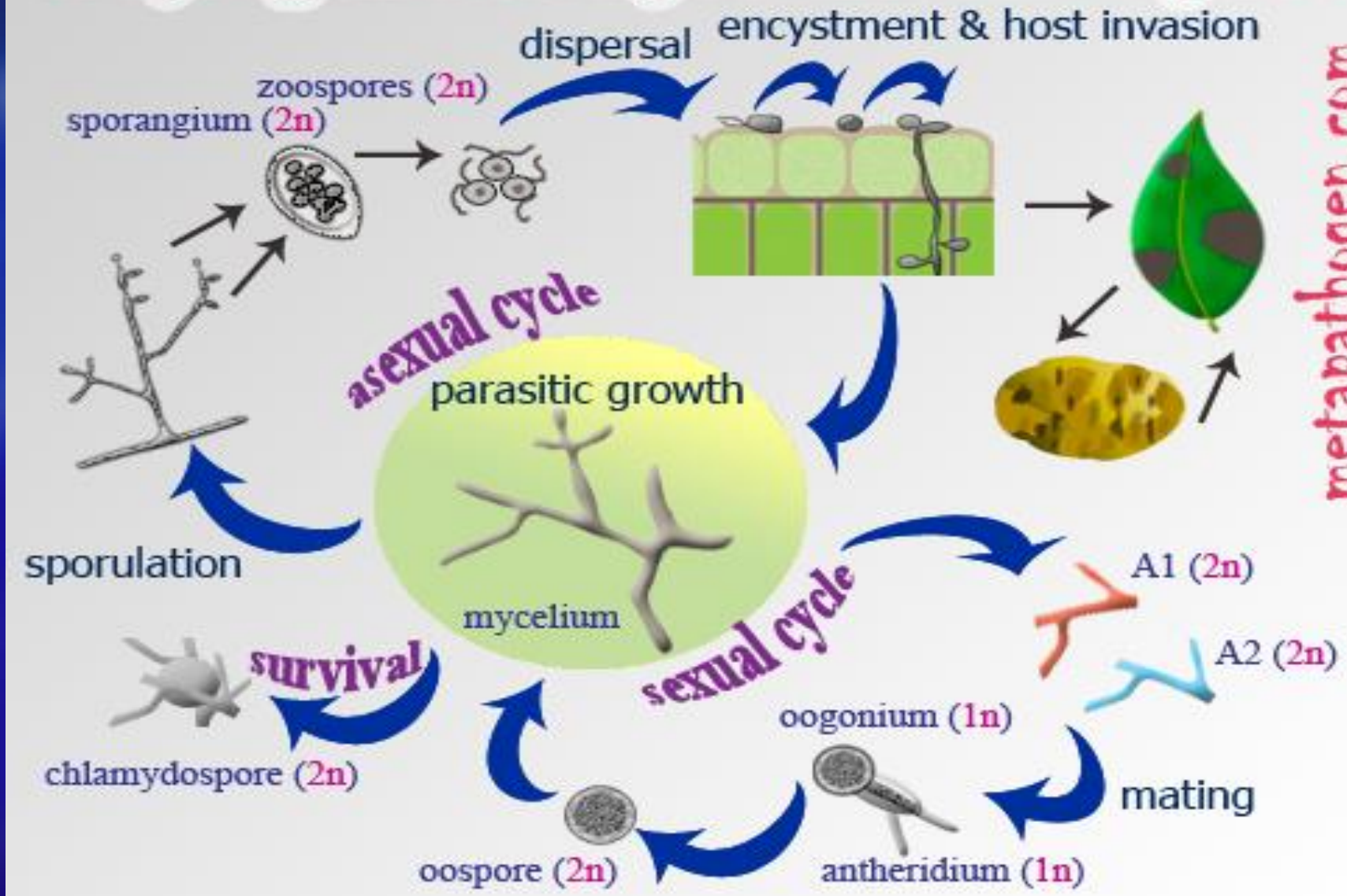
Showing no Symptoms- Quiescent infections by producing appressoria for penetration

- *Botrytis cinerea*
- *Colletotrichum gloeosporioides*
- *Monilinia fructicola*

Showing small initial symptoms:

- Phytophthora infestans in potato
- Phytophthora citrophthora in citrus

Phytophtora infestans life cycle



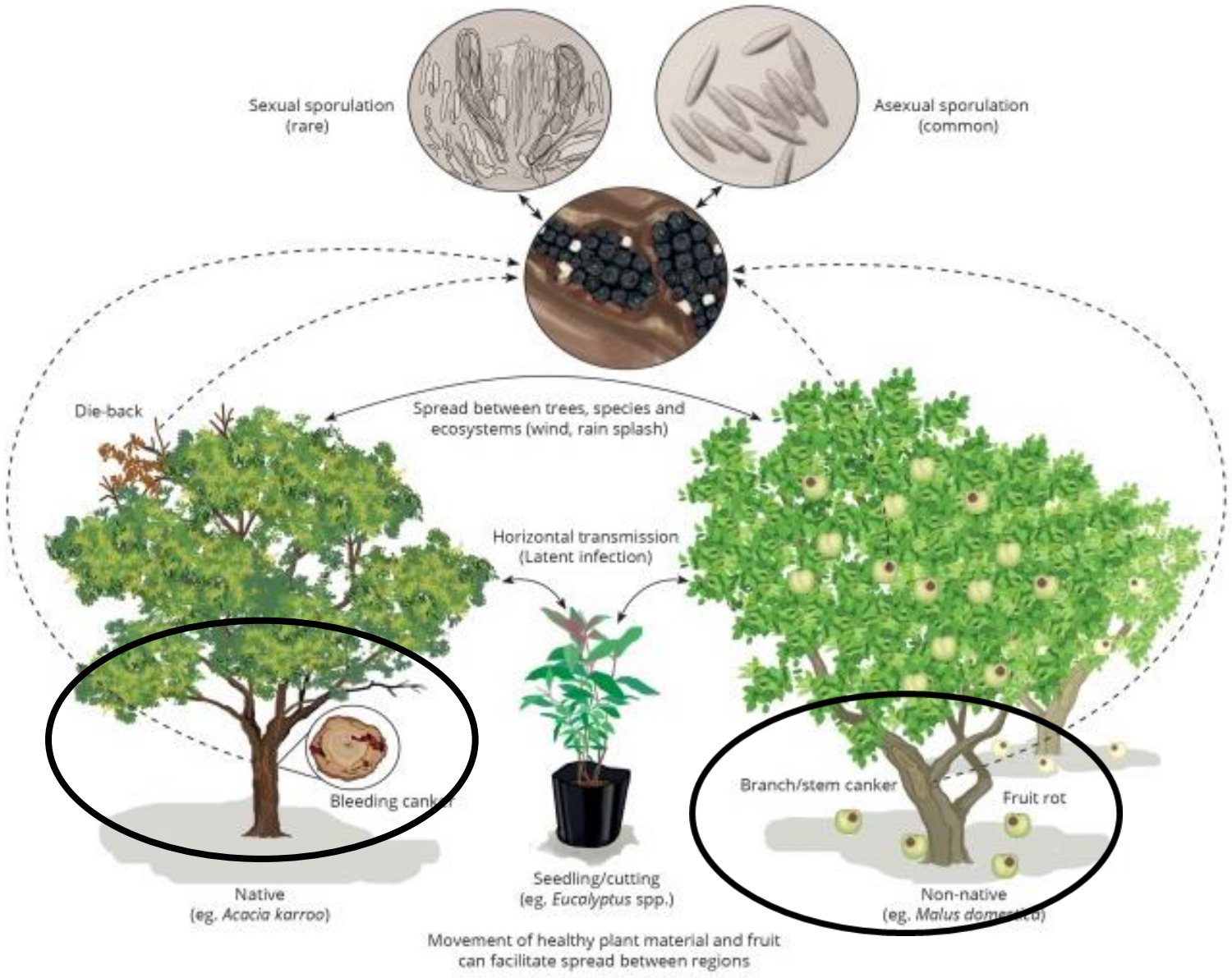
Phythophtora infestans

Direct penetration + small symptoms

Phythophtora infestans

Infected tubers

An example of the changes in disease incidence: a field disease that become and postharvest disease: *Botryosphaeria dothidea*.



The illustration represents infection of the fungus on three hosts, as observed in South Africa, including native (*Acacia karroo*) and non-native (*Eucalyptus* and *Malus domestica*) hosts.

Typical disease symptoms include dieback, cankers and fruit rot. Fruiting structures containing sexual and/or asexual spores are often found associated with the disease symptoms and these are dispersed through wind or rain splash.

Movement of latent or endophytically infected plant material to new regions poses a threat to quarantine systems. Given the broad host range and geographical distribution of *B. dothidea*, all three hosts could be replaced by various others, as could the geographical setting.

Penetration through wounds

- Small wounds
- Lenticels
- Stem wounds
- Wounds caused by hands
- Wounds caused by pruning
- Wounds cause by nails
- Wounds caused by birds
- Wounds caused by insects
- Wound caused by storage conditions

Penetrations by wounds

- *Penicillium sp.*
- *Colletotrichum*
- *Lasiodiplodia theobromae*
- *Rhizopus stolonifer*
- *Alternaria alternate*
- *Botrytis cinerea*

Classification of wound penetration according to period of penetration of the fungus

1. Before harvest
2. During harvest
3. After harvest

Classification of way of disease penetration according to period of penetration of the fungus

Before harvest

Phytophthora infestans
Phytophthora citrophtora
Botrytis cinerea
Alternaria alternata

During harvest

Penicillium italicum
Penicllium expansum
Lasiodiplodia theobromae
Colletotrichum

After harvest

Monilinia
Rhizopus stolonifer
Botrytis cinerea

Classification of way of disease penetration according to period of penetration of the fungus

Before harvest

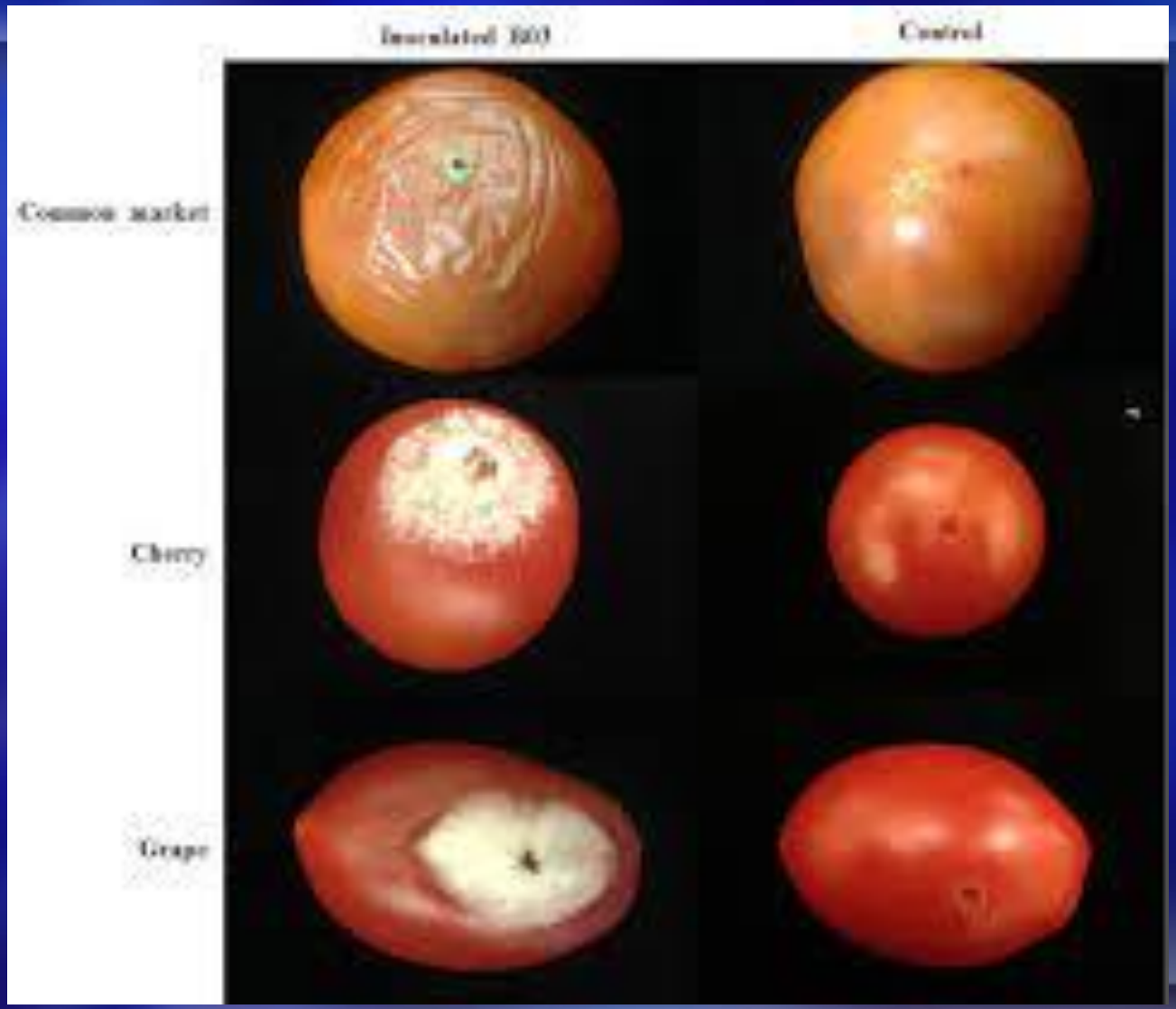
Phytophthora infestans

Phytophthora citrophtora

Botrytis cinerea

Alternaria alternata

Botrytis



Cracks as a result of growth

Classification of way of disease penetration according to period of penetration of the fungus

Before harvest

Phytophthora infestans

Phytophthora citrophtora

Botrytis cinerea

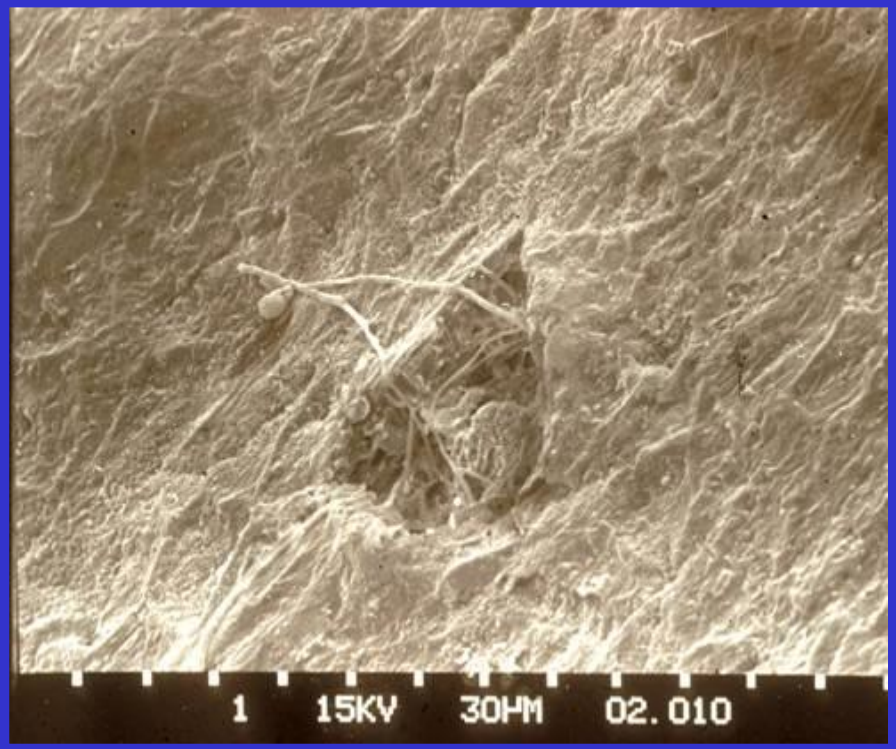
Alternaria alternata

Alternaria alternata

Alternaria rot of tomatoes, peppers ad eggplants cuased by Alternaria alternata wound penetration

Mode of infection of Alternaria in mango fruit: natural openings

a. Lenticel penetration



b. Initial symptoms

Alternaria penetration through lenticels in Mango fruits

Alternaria alternata symptoms

Classification of way of disease penetration according to period of penetration of the fungus

Before harvest

Phytophthora infestans
Phytophthora citrophtora
Botrytis cinerea
Alternaria alternata

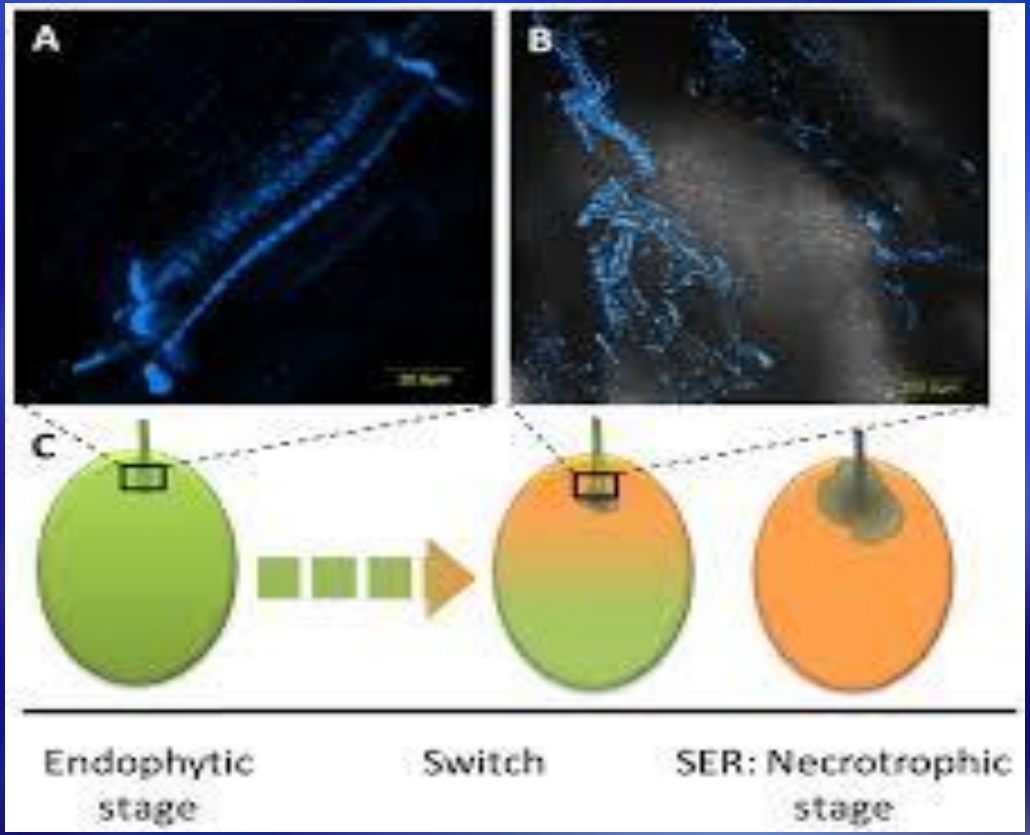
During harvest

Penicillium italicum
Penicllium expansum
Lasiodiplodia theobromae
Colletotrichum

Lasiodiplodia theobromae stem end penetration

Part of the group of Botryiospheria

Stem end infected by penetrating pathogens



Alkan et al. 2015

Lasiodiplodia, penetration through the stem end

Lasiodiplodia, penetration through the stem end

Colletotrichum stem end penetration of avocado

Classification of way of disease penetration according to period of penetration of the fungus

Before harvest

Phytophthora infestans

Phytophthora citrophtora

Botrytis cinerea

Alternaria alternata

During harvest

Penicillium digitatum and italicum

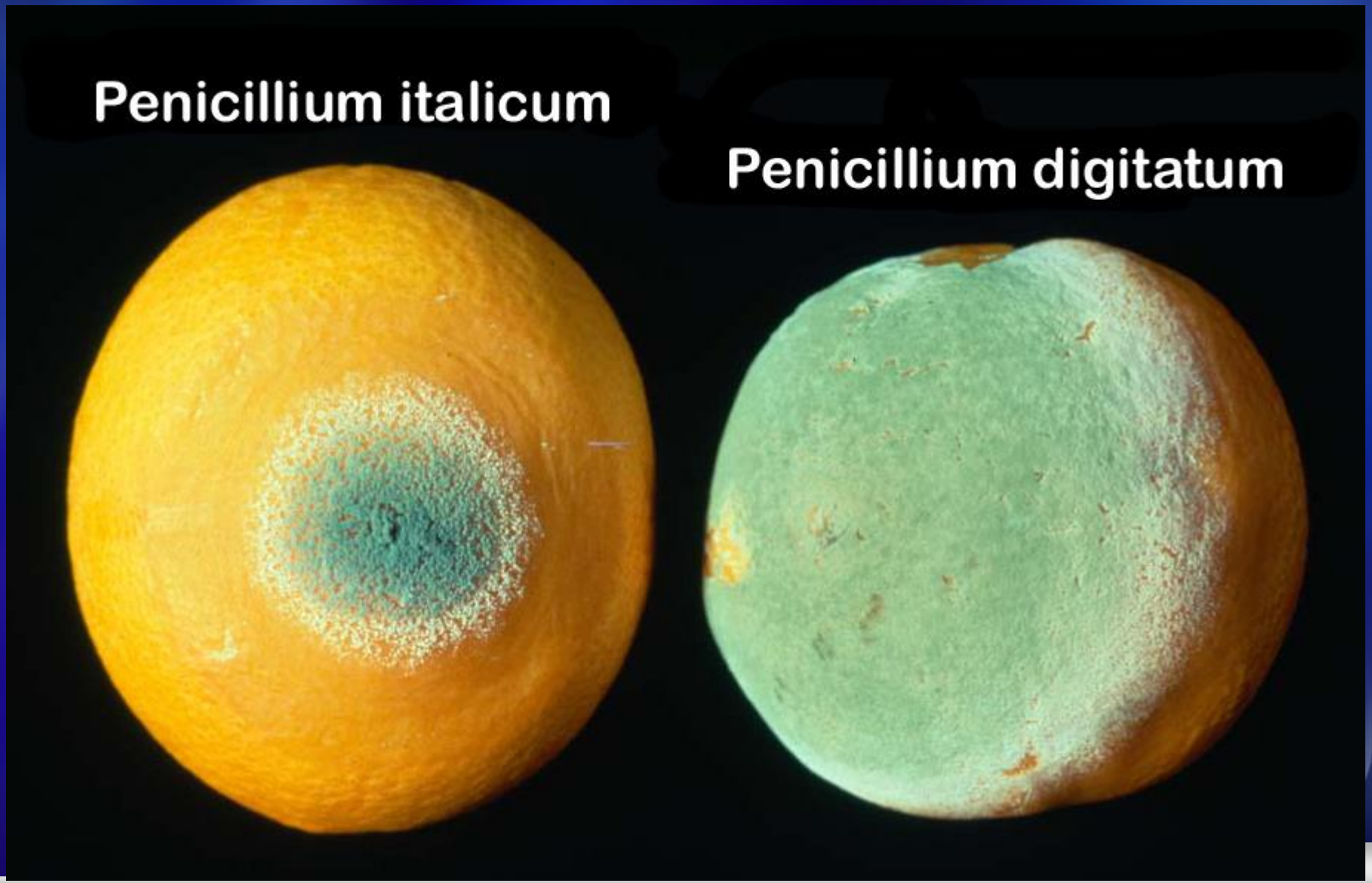
Penicllium expansum

Lasiodiplodia theobromae

Colletotrichum gloesporioides

Green mold rot of citurs cause by *Penicillium digitatum* by wound penetration

Blue mold rot of citrus cause by *Penicillium italicum* wound penetration



Penicillium expansum wound penetration

Classification of way of disease penetration according to period of penetration of the fungus

Before harvest

Phytophthora infestans
Phytophthora citrophtora
Botrytis cinerea
Alternaria alternata

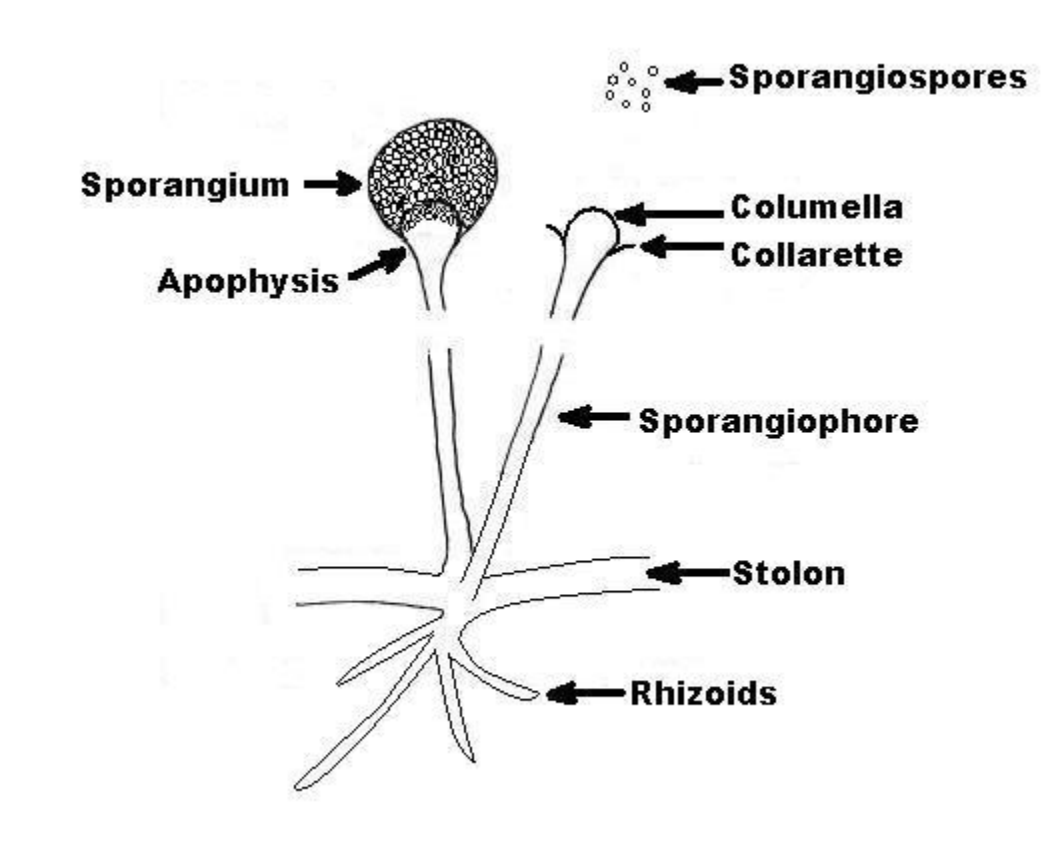
During harvest

Penicillium italicum
Penicllium expansum
Lasiodiplodia theobromae
Colletotrichum

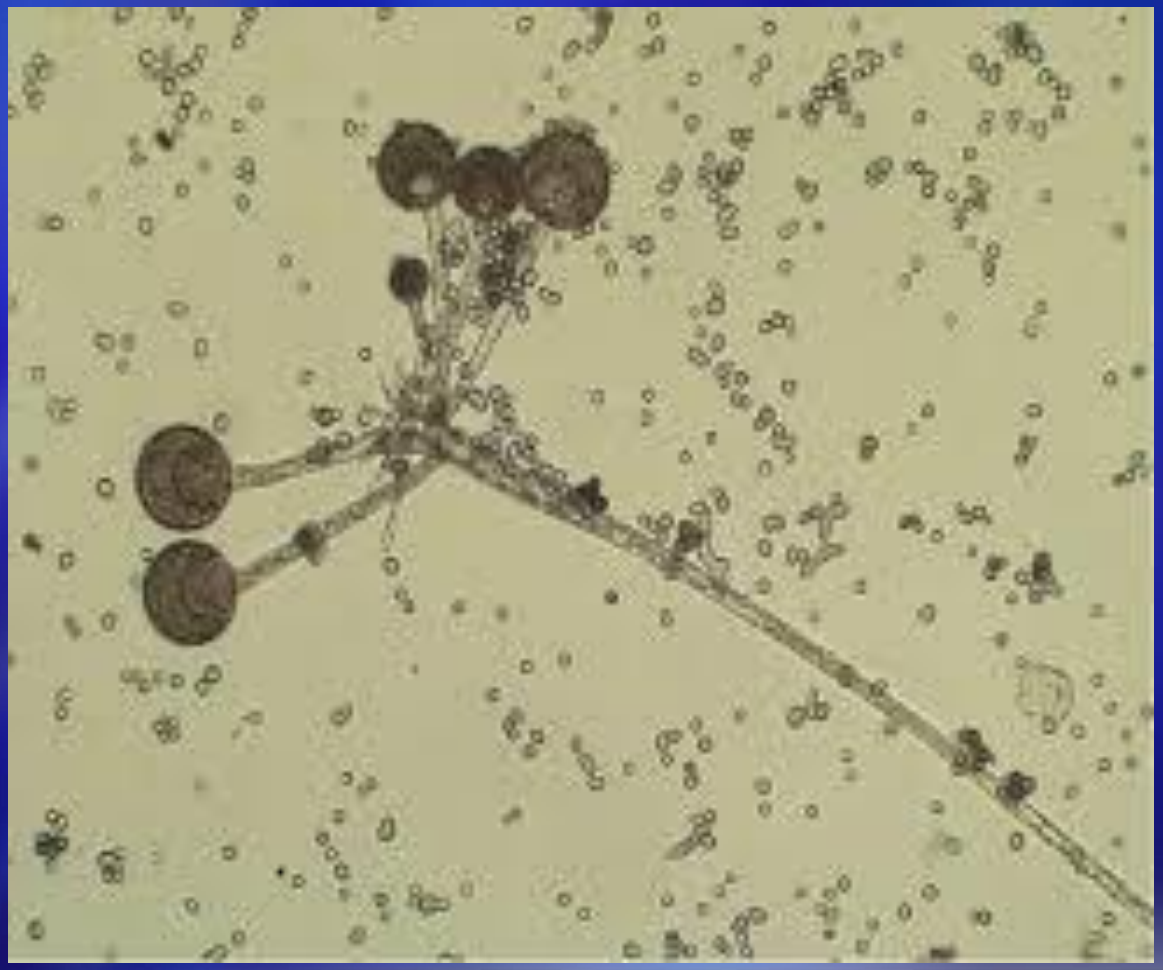
After harvest

Monilinia
Rhizopus stolonifer
Botrytis cinerea

Rhizopus


Sporangiospores
Sporangium
Columella
Collarette
Apophysis
Sporangiophore
Stolon
Rhizoids

Spores of Rhizopus in water solutions of decayed fruits



Rhizopus wound penetration in stored fruit

Summary

Penetration of postharvest pathogens

Spread of spores

- Air movement
- Water, water splash, humidity run off
- Mechanical wounds
- Direct contact

- **Direct penetration**
- **Penetration through wounds**

Classification of way of disease penetration according to period of penetration of the fungus

Before harvest

Phytophthora infestans
Phytophthora citrophtora
Botrytis cinerea
Alternaria alternata

During harvest

Penicillium italicum
Penicllium expansum
Lasiodiplodia theobromae
Colletotrichum

After harvest

Monilinia
Rhizopus stolonifer
Botrytis cinerea