Fungal Diseases of Vegetables

Somsiri Sangchote
Department of Plant pathology
Kasetsart University
Bangkok-10900, Thailand
Email: agrsrs@ku.ac.th

Oomycota

- Sexual spore is a oospore
- Hyphae are coenocytic
- Asexual zoospores, formed within a sporangium
- Aquatic, amplibious, terrestrial habitats, obligate parasite

Oomycota

Oomycetes

- Asexual reproduction - zoospores
- Zoospores - biflagellate; 1 whiplash; 1 tinsel
- Sexual reproduction - oogamous - meiosis in gametangia
- Gametangia - oogonia; antheridia
- Sexual spore = thick-walled oospore
- Thallus - 2n; Hyphae - coenocytic
- Cell wall = β1–3 / β1–6 glucans & cellulose
- Mitochondria cristae - tubular

Primary Zoospore

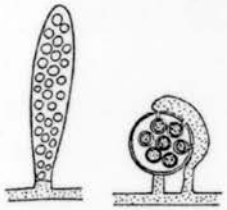
Secondary Zoospore

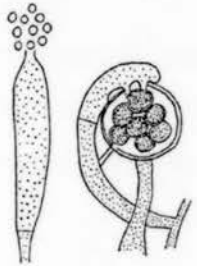
Classification

- Placed in Kingdom Stramenopila
- ~ 65 Genera; ~ 500-800 Species
- Placement...
  - Based on ultrastructure of flagella
  - Strongly supported by molecular data
- Other closely-related fungal-like phyla:
  - Labyrinthulomycota
  - Hyphochytriomycota
- Not closely related to Kingdom Fungi
- Within lineage of brown algae, diatoms

Saprolegniales

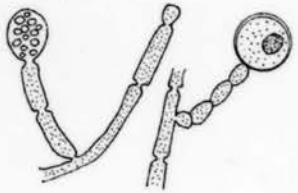
- Water Molds
- Freshwater/soil
- Saprobic - most
- Parasitic - animals
- Branched mycelium
- Zoosporangia - cylindrical
- Zoospores - diplanetic
- Sexual Reproduction
  - Oospores/oogonium = several
- *Achlya*
- *Aphanomyces*
  - Monomorphic, monoplanetic
  - Root rot of peas
- *Saprolegnia*
  - Dimorphic; diplanetic





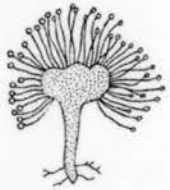
Leptomitales

- Clear freshwater/soil
- Saprobes
- Hyphae
  - Constrictions
  - Cellulin granules
- No vesicles
- Oogonia thin-walled
  - No periplasm
- *Leptomitus*
- *Plerogone*



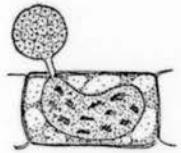
Rhipidiales

- Inhabit stagnant water
- Saprobes
- Facultative anaerobes
- Fermentative
- No mitochondria
- Vesicle maybe present
- Oogonia
  - One oospore
  - Periplasm
- *Rhipidium*
- *Sapromyces*



Lagenidiales

- Parasites - algae, rotifers, nematodes, water molds
- Thallus
  - Endobiotic/monocentric
  - Unbranched
- Gametangial copulation
- *Lagenidium*
- *Olpidiopsis*

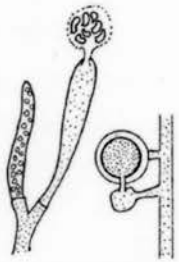


Peronosporales

- Aquatic, amphibious, terrestrial habitats
- Mycelium
  - Well-developed - branched
  - Haustoria in some species
- Asexual Reproduction
  - Zoospores - kidney-shaped (secondary)
- Sexual Reproduction
  - Oogonia - globose; oosphere
  - Fertilization tube

Pythiaceae

- Saprobes - water/soil
- Pathogens - herb./woody plants
- Mycelium well-developed
- Sporangiophore - indeter. growth
- *Pythium*
  - Damping off disease
  - Sporangial germ. - vesicle
- *Phytophthora*
  - Late blight of potatoes
  - Sporangial germ. - no vesicle

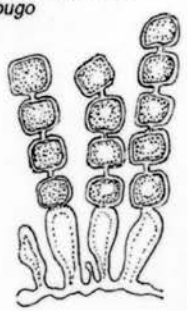


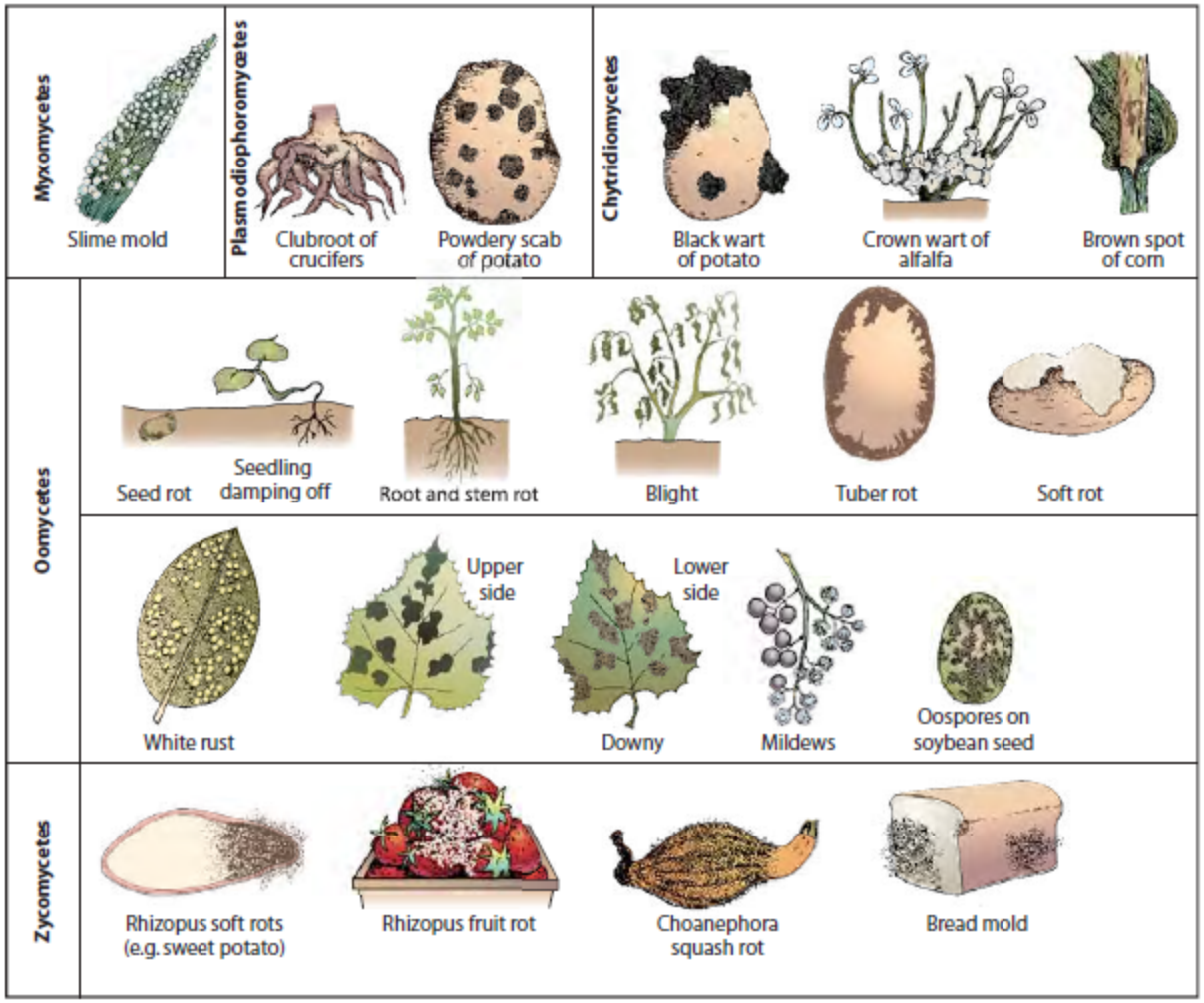
Peronosporaceae

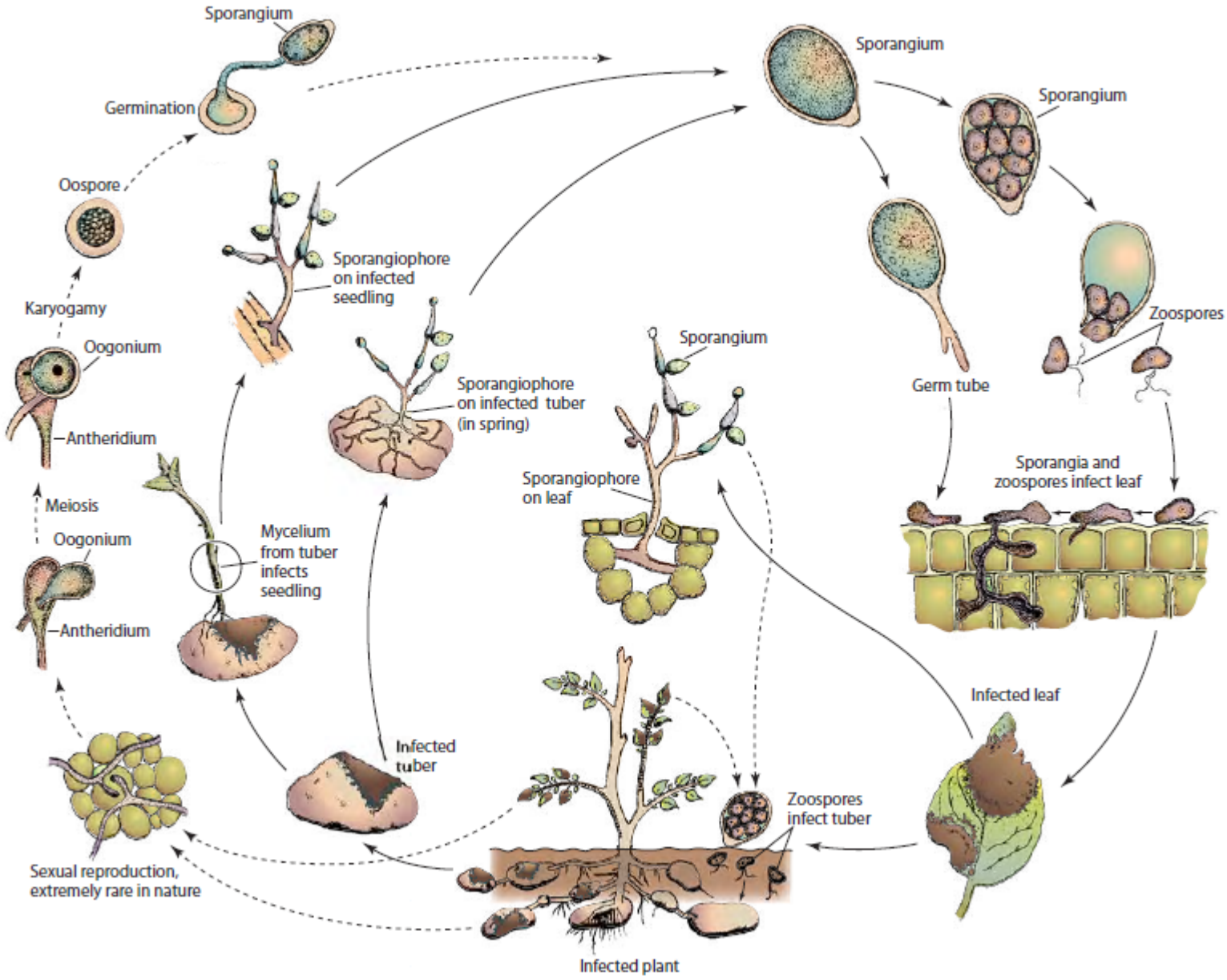
- Downy mildews
- Obligate parasites - plants
- Sporangiophore
  - Branched
  - Determinate growth
- Sporangia - wind-disseminated
- *Peronospora*
- *Bremia*
- *Sclerospora*
- *Plasmopara*

Albuginaceae

- White Rusts
- Obligate parasites - plants
- Sporangiophore
  - Unbranched
  - Club-shaped
- Sporangia - prod in chains
  - Wind-dispersed
- *Albugo*

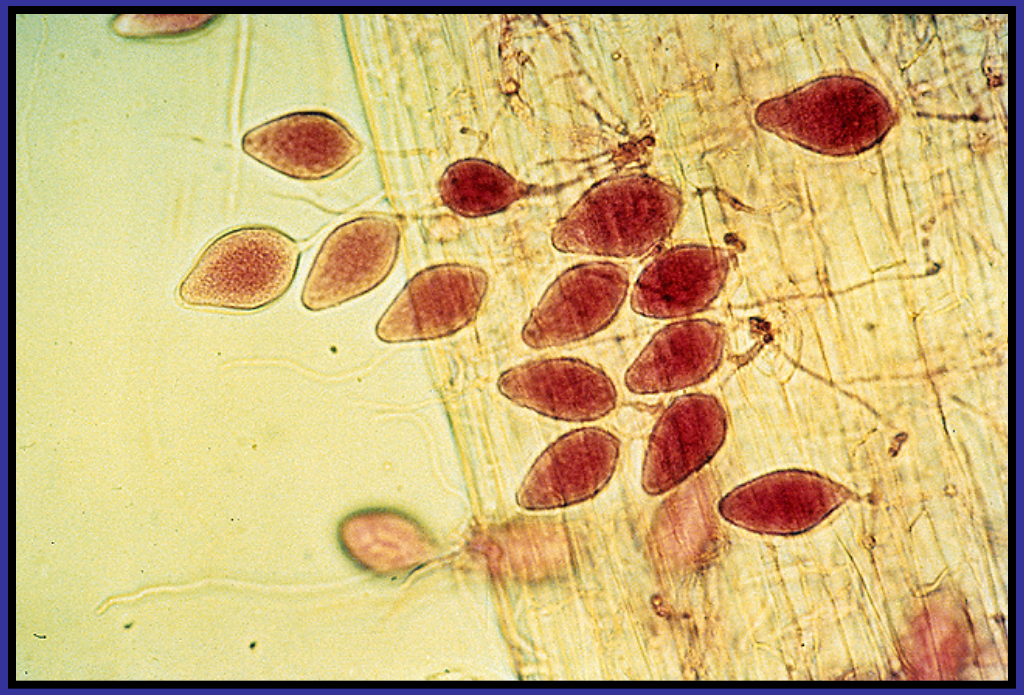



Myxomycetes
Slime mold
Plasmodiophoromycetes
Clubroot of crucifers
Powdery scab of potato
Chytridiomycetes
Black wart of potato
Crown wart of alfalfa
Brown spot of corn
Oomycetes
Seed rot
Seedling damping off
Root and stem rot
Blight
Tuber rot
Soft rot
White rust
Upper side
Lower side
Downy
Mildews
Oospores on soybean seed
Zygomycetes
Rhizopus soft rots (e.g. sweet potato)
Rhizopus fruit rot
Choanephora squash rot
Bread mold


Sporangium
Germination
Oospore
Karyogamy
Oogonium
Antheridium
Meiosis
Oogonium
Antheridium
Sexual reproduction, extremely rare in nature
Mycelium from tuber infects seedling
Sporangiophore on infected seedling
Sporangiophore on infected tuber (in spring)
Infected tuber
Sporangium
Sporangiophore on leaf
Infected plant
Zoospores infect tuber
Sporangium
Sporangium
Germ tube
Zoospores
Sporangia and zoospores infect leaf
Infected leaf

Asexual Reproductive Structures of Oomycetes

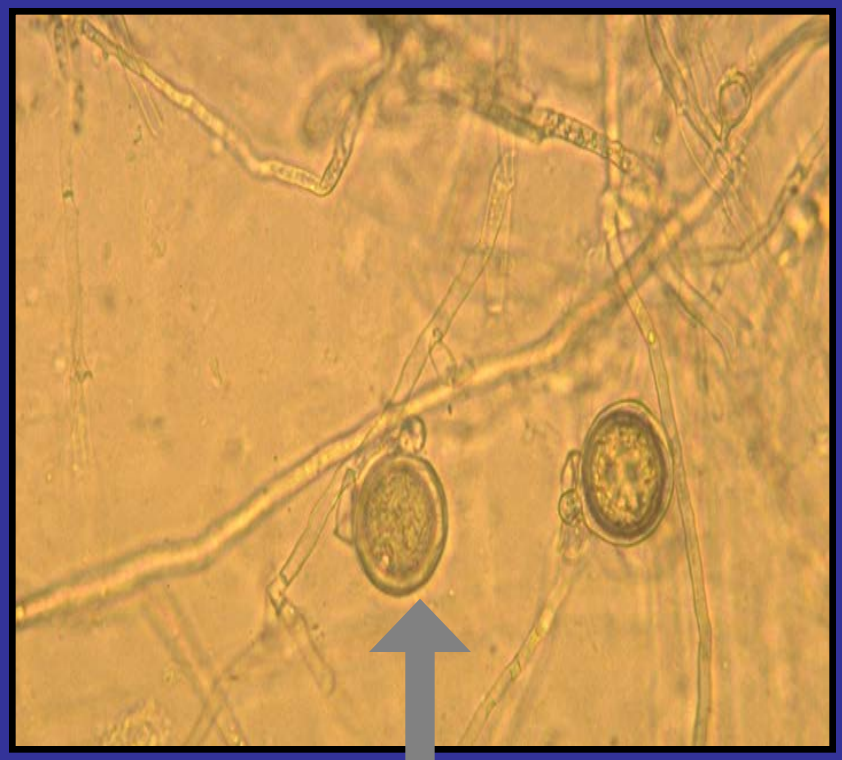
- Sporangium borne on a sporangiophore



Hyphae of Oomycetes

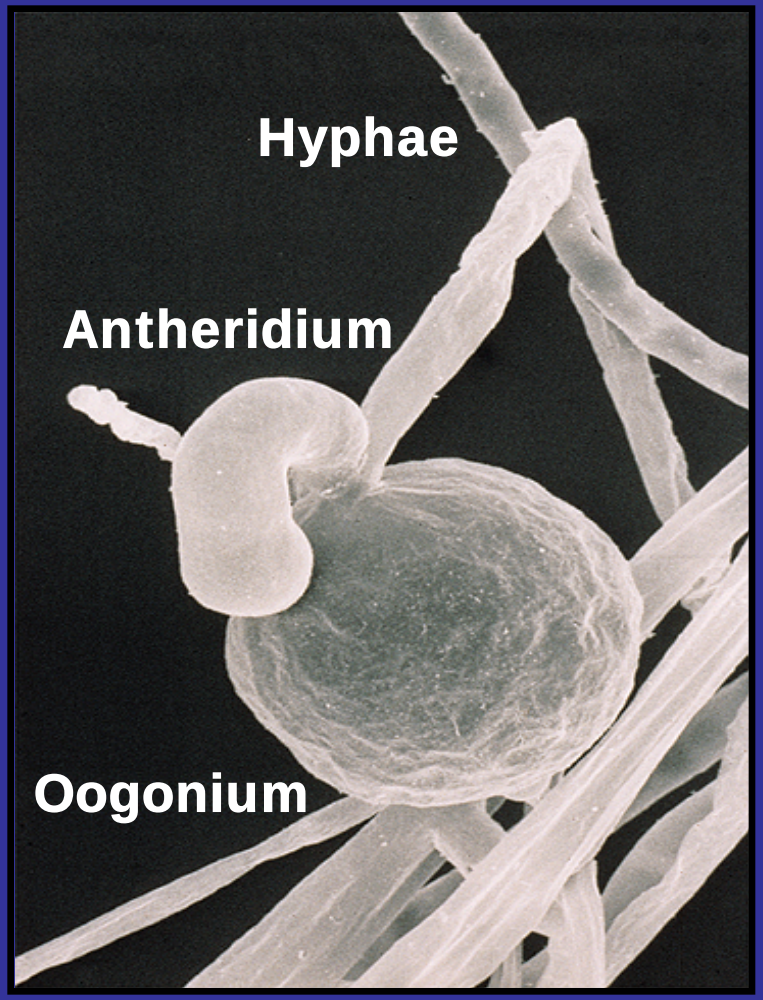
Hyphae of Oomycetes

- **Nuclei = 2N**
- **Few cell walls (septa)**
- **Coenocytic hyphae**
- **Fungus hyphae have many cell walls – septate hyphae**
- **Composed primarily of cellulose**
- **Cell walls of fungi mostly chitin**



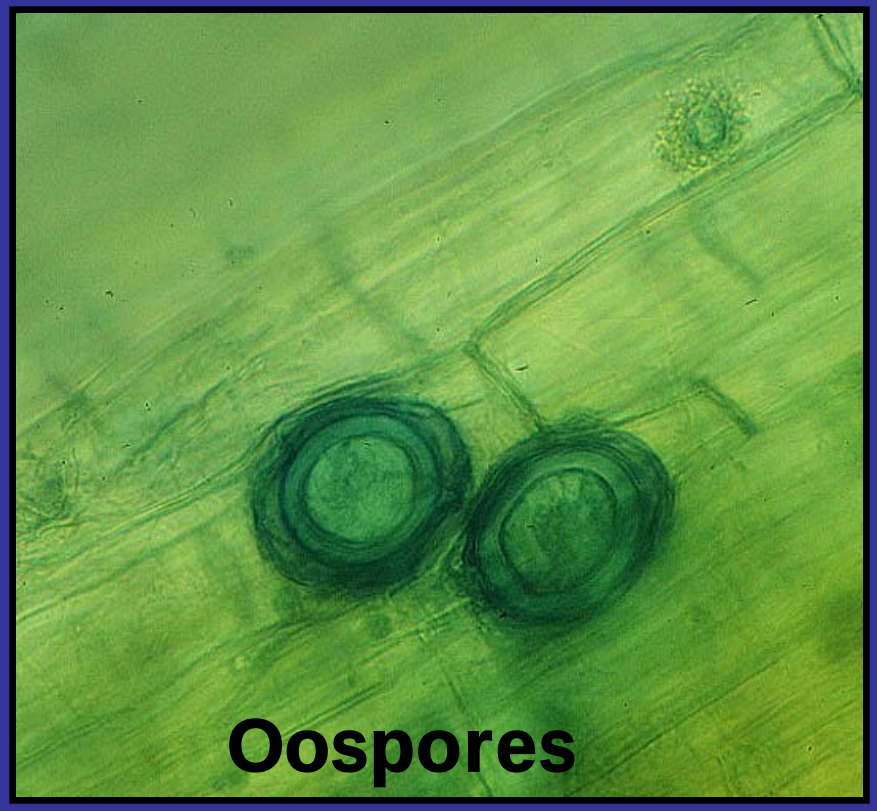
Antheridium and Oogonium of an Oomycete

- Meiosis; 2N to 1N
- Migration of 1N nuclei from antheridium into oogonium
- Nuclei fuse to reestablish 2N nuclear condition (diploid)



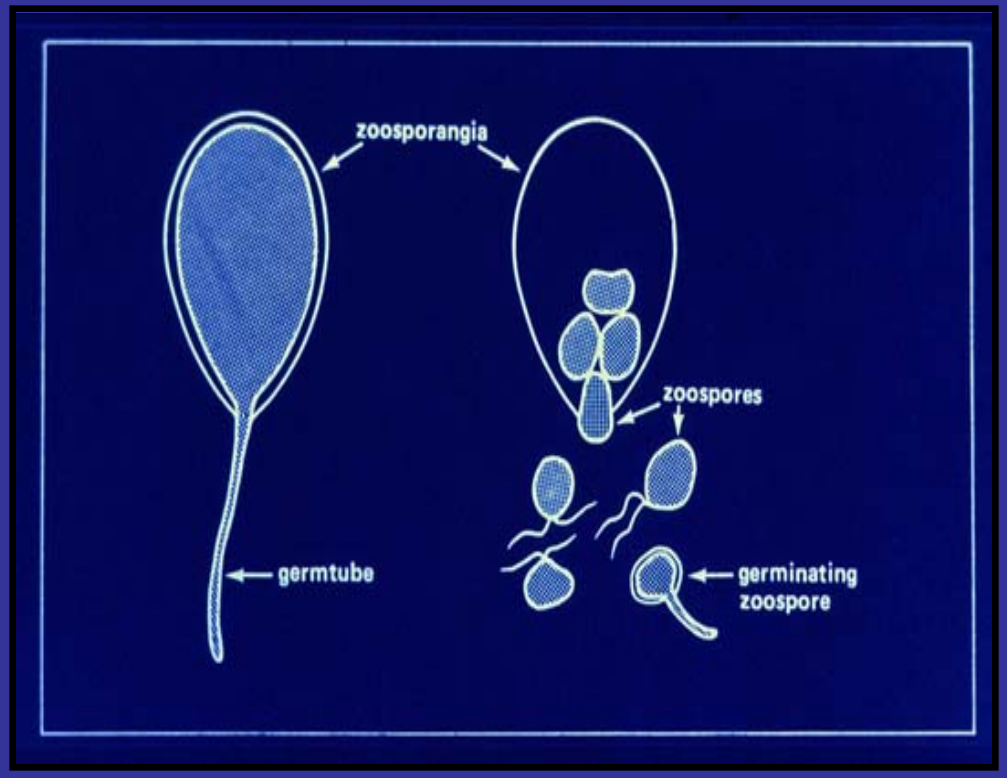
Spore Type of Oomycetes Oospore

- Thick cell walls
- Site of genetic recombination
- Survival
- Embedded in plant tissue
- Free in soil
- Surface of seed



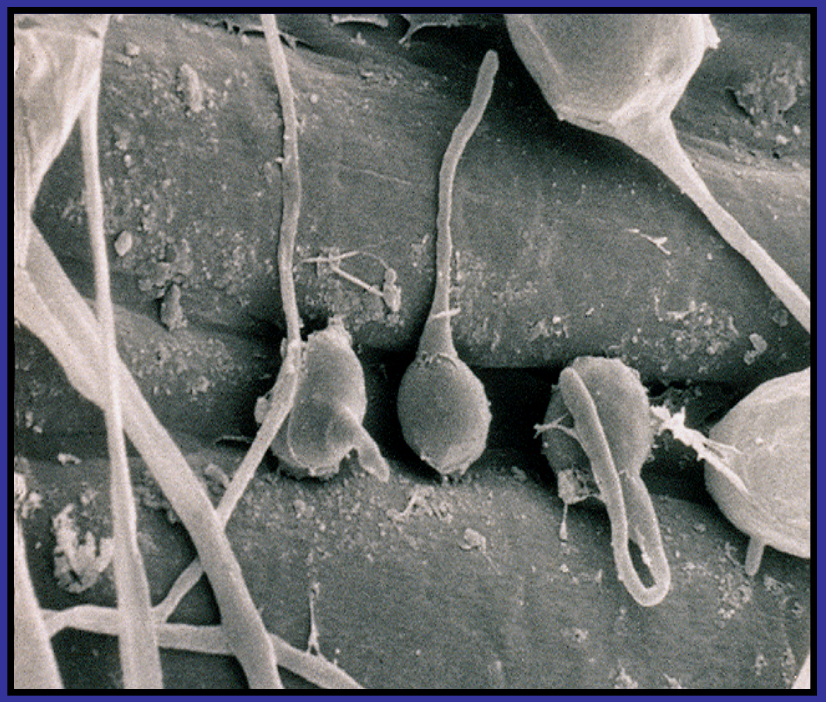
Germination of Sporangium

- Sporangia germinate directly – germ tube
- Germinate by releasing zoospores



Germination of Zoospores

Motile after release from sporangium
move to infection court
cease motility and germinate
germ tube penetrates host

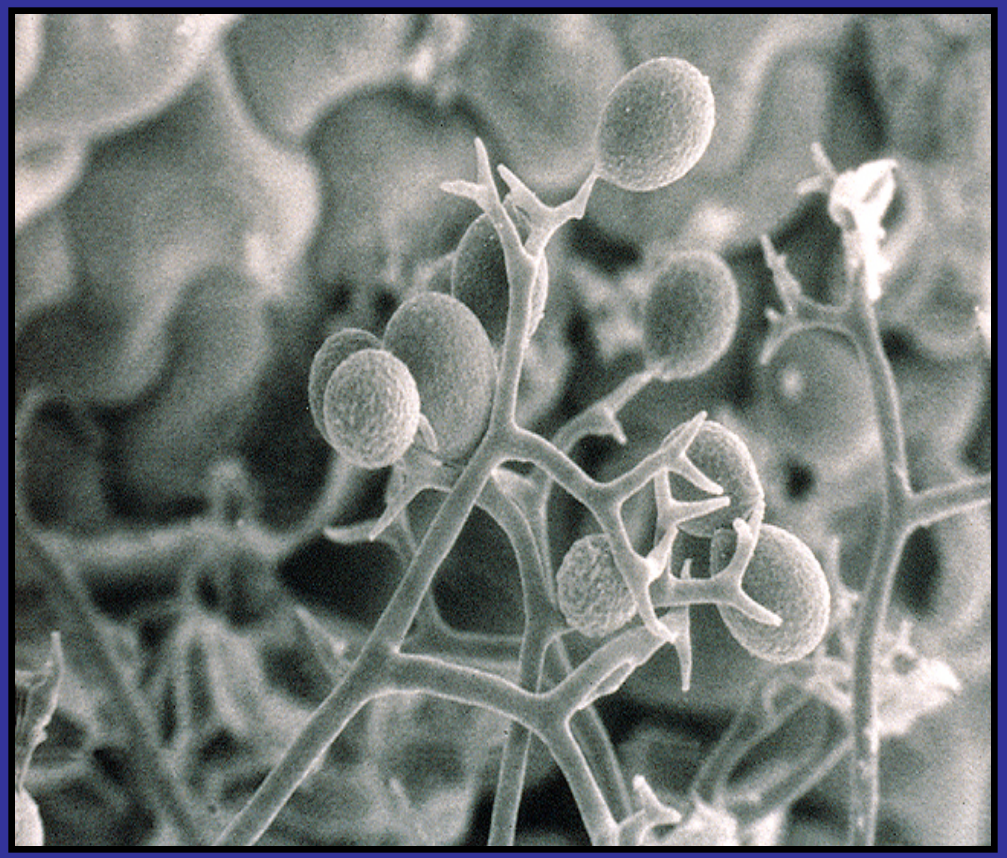


Plant Pathogenic Oomycetes

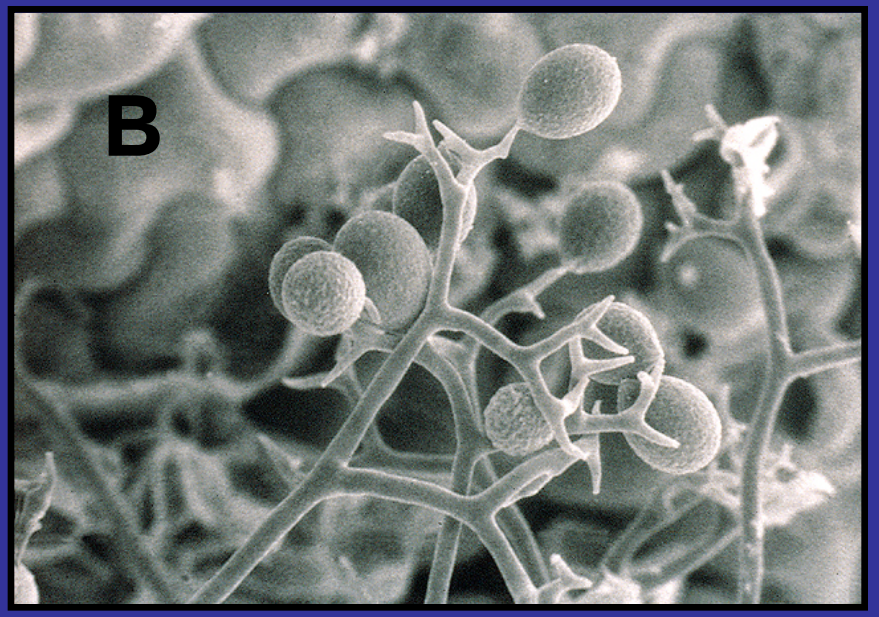
- **Multiple species within genera of:**
  - *Phytophthora*
  - *Pythium*
  - *Peronospora*
  - *Plasmopsora*
  - *Bremia*
  - *Aphanomyces*

Sporangia of Downy Mildew Fungi

- **Sporangiophores are branched**
- **Many sporangia borne on one sporangiophore**
- ***Peronospora* is common cause of downy mildew**

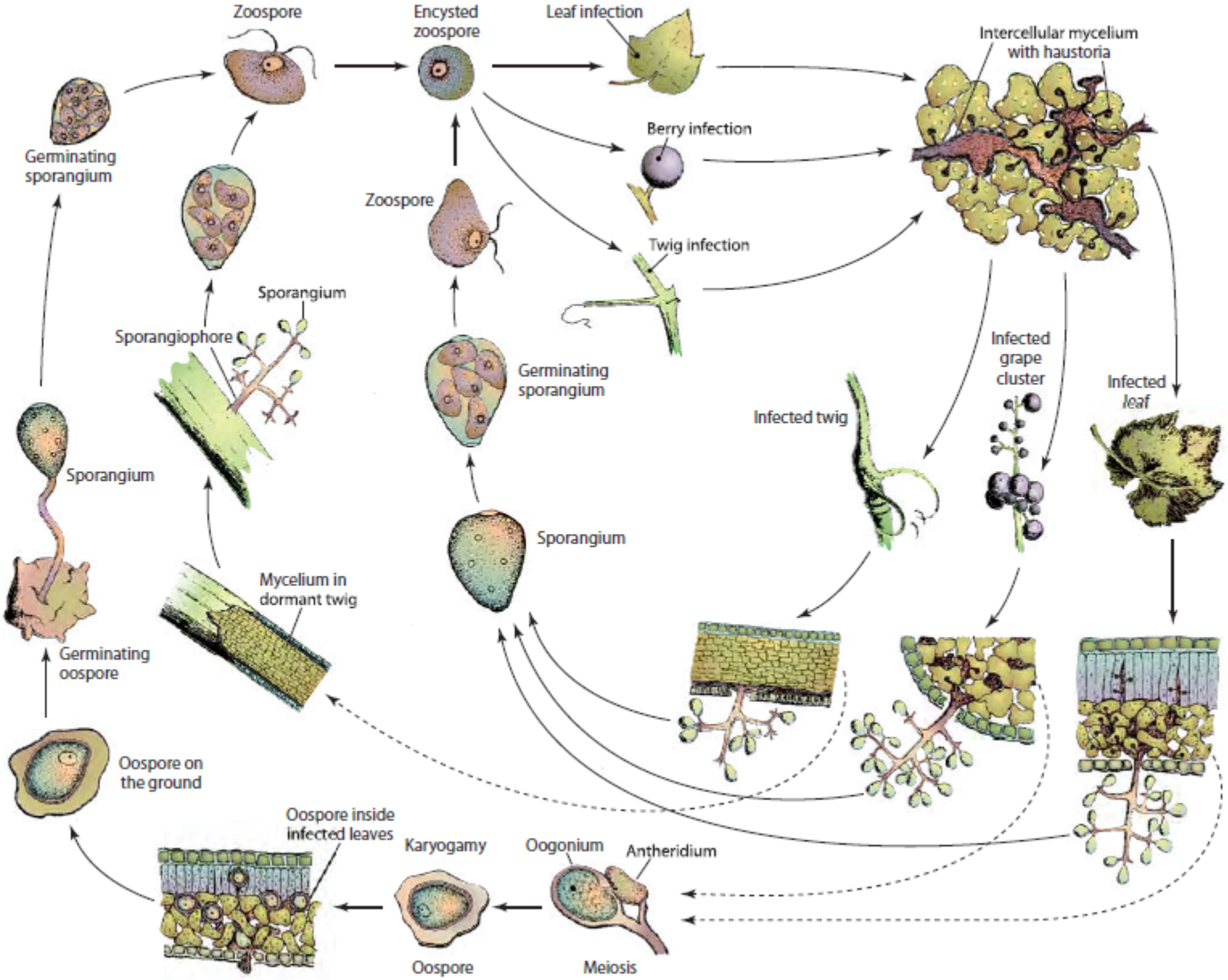


Phytophthora compared to Downy Mildew Fungi



A = Phytophthora

B = Downy mildew fungus


Zoospore
Encysted zoospore
Leaf infection
Intercellular mycelium with haustoria
Germinating sporangium
Berry infection
Zoospore
Twig infection
Sporangium
Sporangiophore
Germinating sporangium
Infected grape cluster
Infected leaf
Infected twig
Sporangium
Sporangium
Mycelium in dormant twig
Germinating oospore
Oospore on the ground
Oospore inside infected leaves
Karyogamy
Oogonium
Antheridium
Oospore
Meiosis


Downy mildew of kale


Downy mildew of cucurbit


Downy mildew of cucurbit

Pseudoperonospora cubensis
Sporangiophore & sporangium

Trophic Types within Oomycetes

- **Biotrophic**
  - **Obligate parasites**
    - **Downy mildew pathogens**
  - **Facultative parasites**
    - *Phytophthora infestans*
- **Necrotrophic**
  - **Facultative parasites**
    - *Pythium species*
    - *Phytophthora species*
    - *Aphanomyces species*

Diseases Caused by Oomycetes

Seed, stems and roots

- *Pythium*
  - **Damping off**
  - **Root rots**
- *Phytophthora*
  - **Root and stem rots**
- *Aphanomyces*
  - **Root rots**

Foliage and fruits

- **Late blight**
  - *Phytophthora infestans*
- **Downy mildew**
  - *Peronospora*
  - *Plasmopora*
  - *Bremia*
- **Blight of turfgrass**
  - *Pythium*

Diseases caused by Oomycetes
Seed rots and Seedling Damping-off

- **Pre-emergence damping-off**
- **Wet soil conditions**
- *Pythium*
- *Phytophthora*
- *Aphanomyces*
- **Seed rot and seedling necrosis**
- **Monocyclic disease cycle**

Diseases caused by Oomycetes Damping-off

- **Post-emergence damping-off**
- **Wet soil conditions**
- *Pythium*
- *Phytophthora*
- *Aphanomyces*
- **Seedling necrosis**

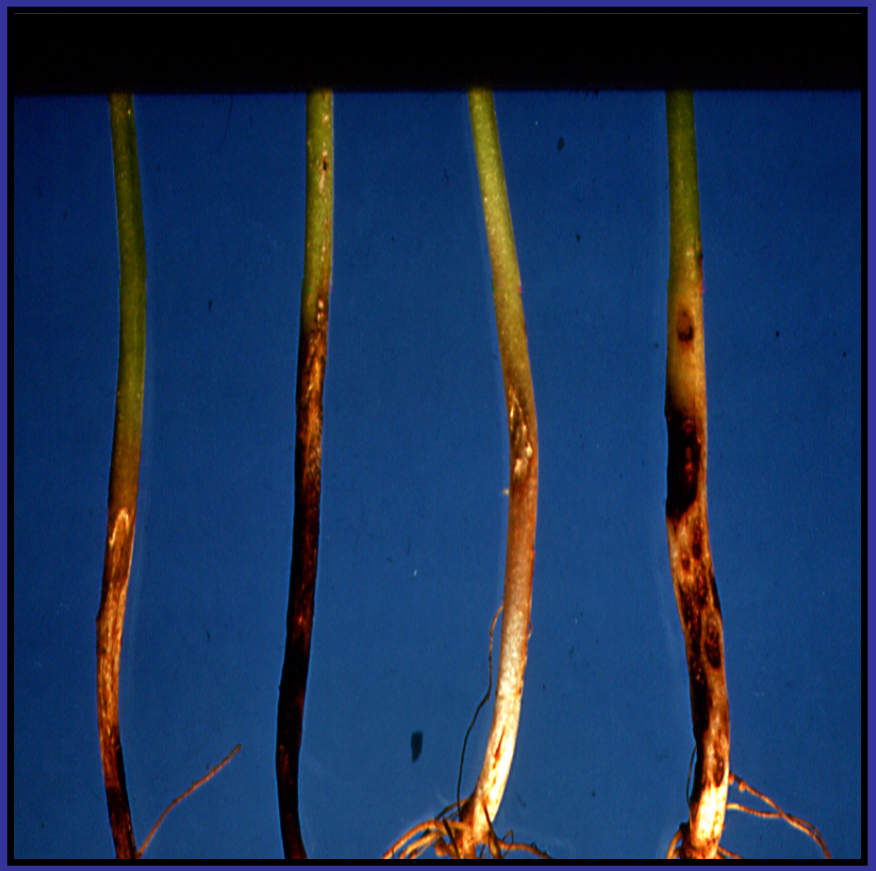
Oomycetes: *Pythium*, *Phytophthora* & *Aphanomyces*

- Nectrophic pathogens
- Cause seedling and root rot diseases
- Dormant inoculum: oospores
- Primary inoculum: zoospores
- Source: soil, hose nozzles, used plastic pots

Damping-off

- Term related to seed rot or seedling death
- Relates to disease caused by Pythium species
- Pythium most active in water saturated soils or potting media
- Pre- or Post- are prefixes related to status of seedling emergence

Diseases Caused by Oomycetes Concept of Primary & Secondary Symptoms



Oomycetes: *Peronospora*, *Plasmopora*, *Phytophthora infestans*

- **Obligate Biotrophs:**
  - *Peronospora*
  - *Plasmopora*
- **Facultative Biotrophs:**
  - *Phytophthora infestans*
- **Cause leaf blights**

Oomycetes: Leaf pathogens that also infect fruit or other forms of harvested product

Diseases Caused by Oomycetes
Root rots

Root rots

- **Wet soil favors disease**
- **Monocyclic disease cycle**
- *Phytophthora*
- *Pythium*
- *Aphanomyces*
- **Resistant cultivars**

Diseases Caused by Oomycetes
Stem rots

- *Phytophthora sojae*
- **Stem Lesion is common symptom**
- **Numerous resistance genes to pathogen**
- **Many races of pathogen**

Diseases Caused by Oomycetes
Durian Root and Crown Rot


Phytophthora palmivora
Sporagium & zoospore

Diseases Caused by Oomycetes
Diseases of leaves, stems & fruits

Late Blight

- *Phytophthora infestans*
- **Potato & tomato**
- **Facultative biotroph**
- **Polycylic disease cycle**
- **Infect leaves, stems and tubers/fruit**

Downy Mildews

- *Peronospora*
- *Plasmopara*
- **Obligate biotrophs**
- **Polycyclic disease cycles**
- **Infect leaves and fruit**

Zygomycota

- Sexual spore is a zygospore
- Hyphae are coenocytic
- Asexual sporangiospores, formed within a sporangium
- Trend is from many-spored to monospored sporangia
- Fast-growing saprophytes, some insect and plant pathogens

Zygomycota

- Mycelium/ hyphae - coenocytic
- Produce resting/sexual spores = zygospores that develop within zygosporangium
- Cell walls - chitin, chitosan, polygalacturonic acid

Zygomycetes

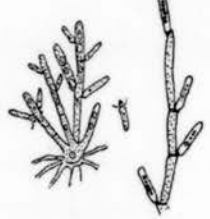
- Common saprobes of soil, dung, litter
- Asexual spores
  - Sporangiospores (Ss) borne in sporangia on sporangiophores
  - Conidia

Trichomycetes

- Obligate symbionts of arthropods
- Attached by holdfast to host's
  - lining of foregut/midgut/hindgut
  - exoskeleton
- Thallus - simple/branched
- Asexual reproduction
  - Sporangiospores (Ss)
  - Trichospores (Ts)
  - Arthrospores
  - Amoeboid cells/cytospores (Cs)
- Sexual = zygospores in some

Harpellales

- Ts prod. exogenously w/basal appendages
- Gut lining - aquatic insect larvae
- Zygospores - biconical
- *Harpella* · *Smittium*



Asellariales

- Thallus branched/septate
- Arthrospores
- Sexual repro - unknown
- *Asellaria*

Eccrinales

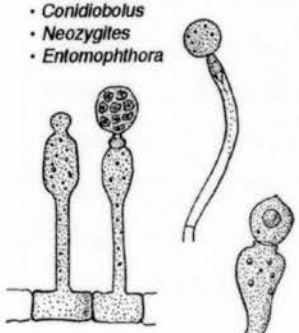
- Thallus coenocytic
  - Unbranched at base
- Ss prod. basipetally
- *Enterobryus*

Amoebidales

- Thallus unbranched/coenocytic
- Thallus converts to sporangium
- Protoplast prod amoeboid cells/Ss
- Amoeboid cells encyst form Cs
- Cell walls - no chitin
- *Amoebidium*

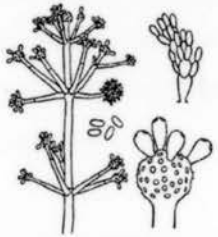
Entomophthorales

- Insect pathogens
- Saprobes - soil, dung
- Parasites of algae, ferns, invertebrates, mammals
- Mycelium not extensive
- Asexual structures
  - Undifferentiated
  - Spores = conidia
- Forcible spore discharge
- Distinguished by cell charac.
  - Nuclei size
  - Condensed chromatin
- *Ballocephala*
- *Completoria*
- *Conidiobolus*
- *Neozygites*
- *Entomophthora*



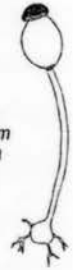
Dimargaritales

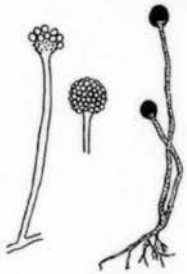
- Haustorial mycoparasites
- 2-spored merosporangia
- Septate hyphae - perforate
- *Spinalia*
- *Dimargaris*



Mucorales

- Saprobes & parasites
- Soil, dung, plants, litter
- Human/plant pathogens
- Mycoparasites
- Extensive mycelium
- Dimorphism common
- Rhizoids & stolons
- Heterothallism
- Storage rot - Peaches & tomatoes
- *Mucor*
- *Rhizomucor*
- *Pilobolus*
- *Rhizopus*
- *Phycomyces*
- *Gilbertella*
- *Mycotypha*
- *Syncephalastrum*
- *Cunninghamella*





Endogonales

- Ectomycorrhizae
- Saprobes - soil, peat, wood
- Sporocarps - zygospores
- Sporangia - unknown
- *Endogone*
- *Sclerogone*

Glomales

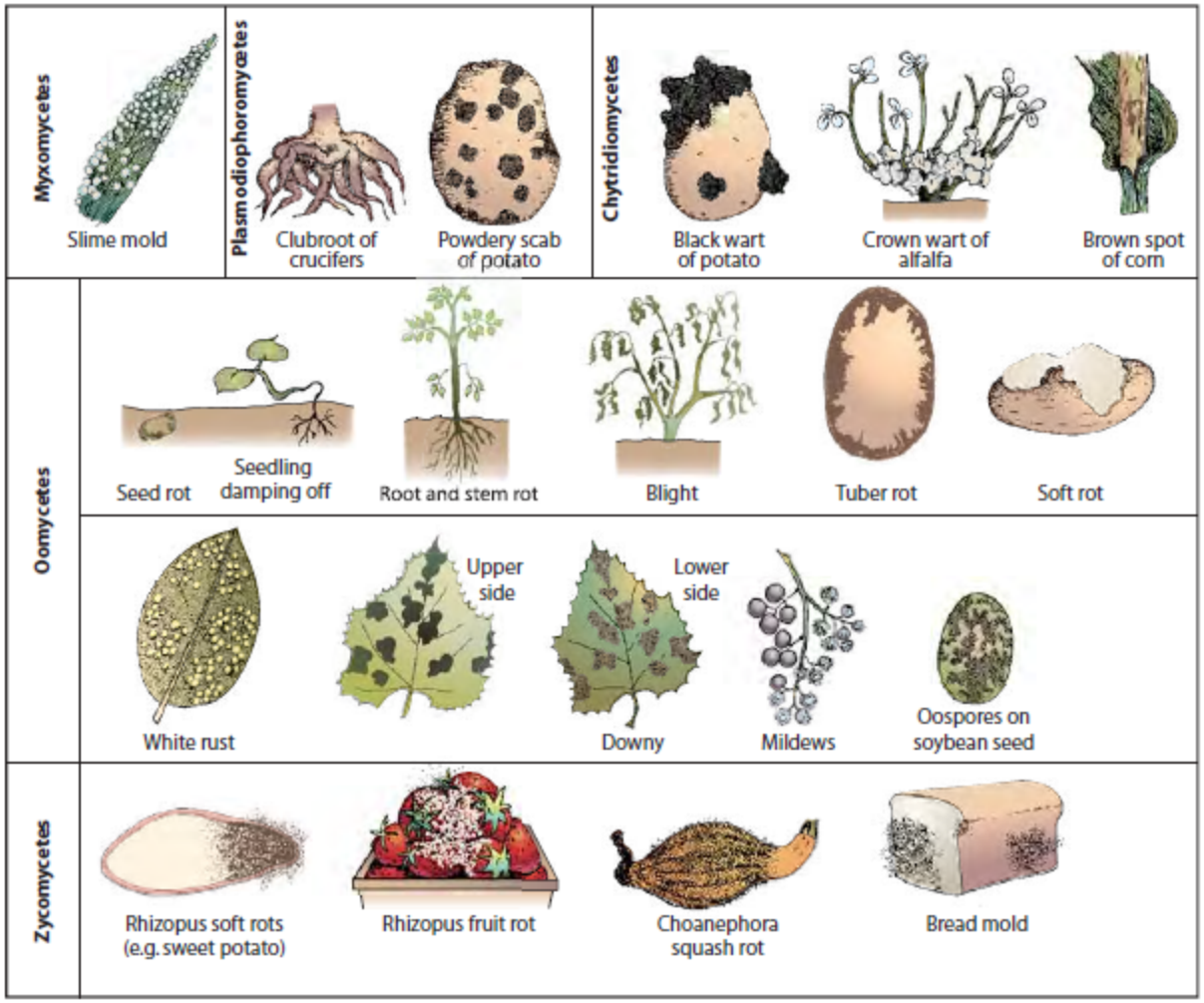
- Arbuscular mycorrhizae
- Form arbuscules
- Some form vesicles (VAM)
- Asexual spores only
- *Glomus*
- *Sclerocystis*
- *Acaulospora*
- *Entrophospora*
- *Gigaspora*
- *Scutellospora*

Kickxellales

- Saprobes soil, dung
- Mycoparasites
- Extensive hyphae
- Septal plug - perforate
- Sporocladia
- 1-spored merosporangia
- *Kickxella*
- *Coemansia*

Zoopagales

- Nematode-trappers
- Parasites/haustorial predators of
  - Amoebae · Nematodes
  - Rotifers · Fungi
- Animal symbionts
- *Amoebaphilus*
- *Cochlonema*
- *Helicocephalum*
- *Zoophagus*
- *Stylopage*
- *Piptocephalis*
- *Syncephalis*


Myxomycetes
Slime mold
Plasmodiophoromycetes
Clubroot of crucifers
Powdery scab of potato
Chytridiomycetes
Black wart of potato
Crown wart of alfalfa
Brown spot of corn
Oomycetes
Seed rot
Seedling damping off
Root and stem rot
Blight
Tuber rot
Soft rot
White rust
Upper side
Lower side
Downy
Mildews
Oospores on soybean seed
Zygomycetes
Rhizopus soft rots (e.g. sweet potato)
Rhizopus fruit rot
Choanephora squash rot
Bread mold

Zygomycetes

Zygomycetes

- *Choanephora spp*
  - Soft rot of squash, pepper, okra
- *Rhizopus spp.* and *Mucor spp.*
  - Soft rot fruits, vegies, bulbs, corms
- Weak parasites
- Sexual resting spore = zygospore
- Sporangiospores = infectious spore, produced in sporangium

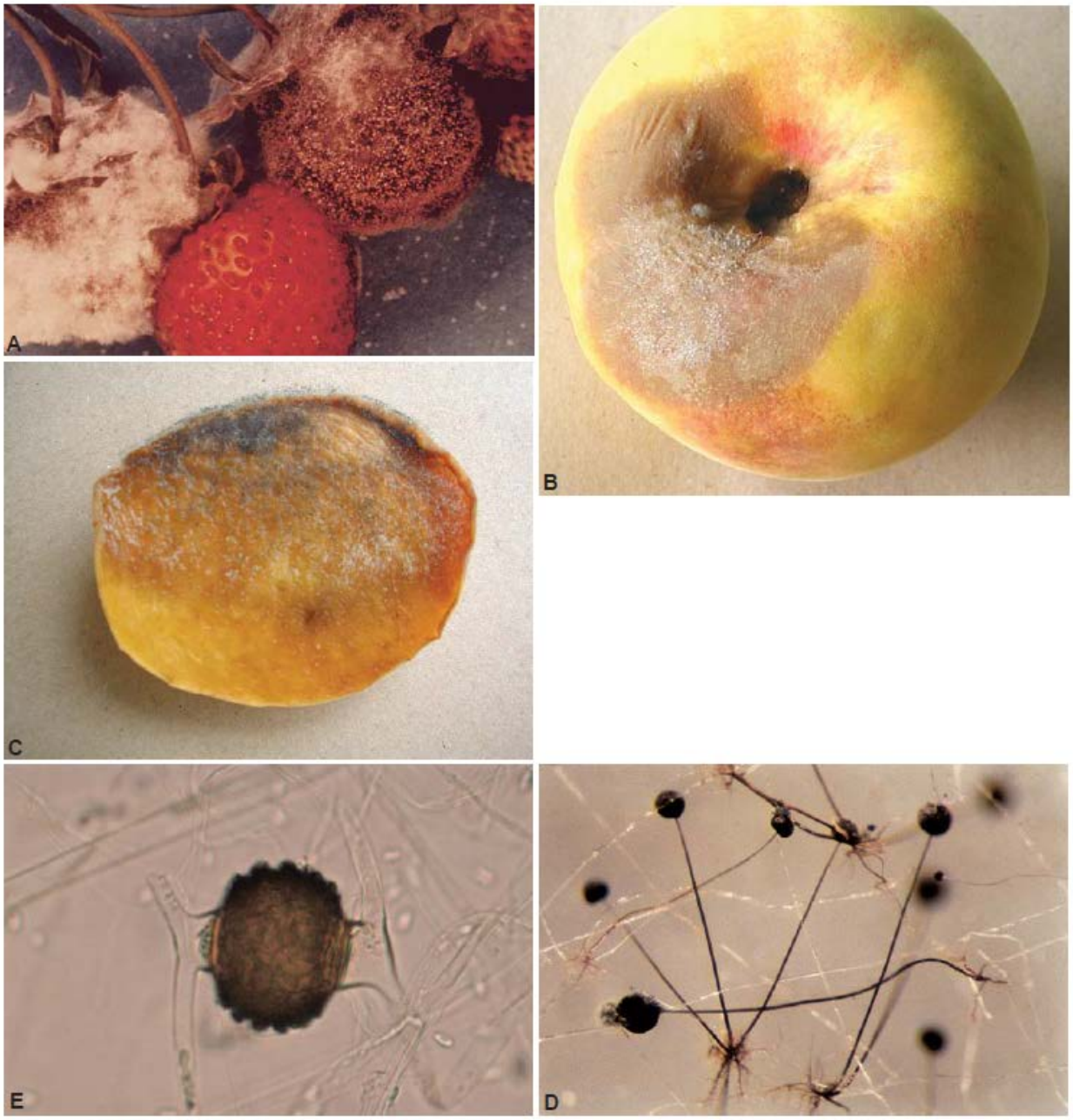


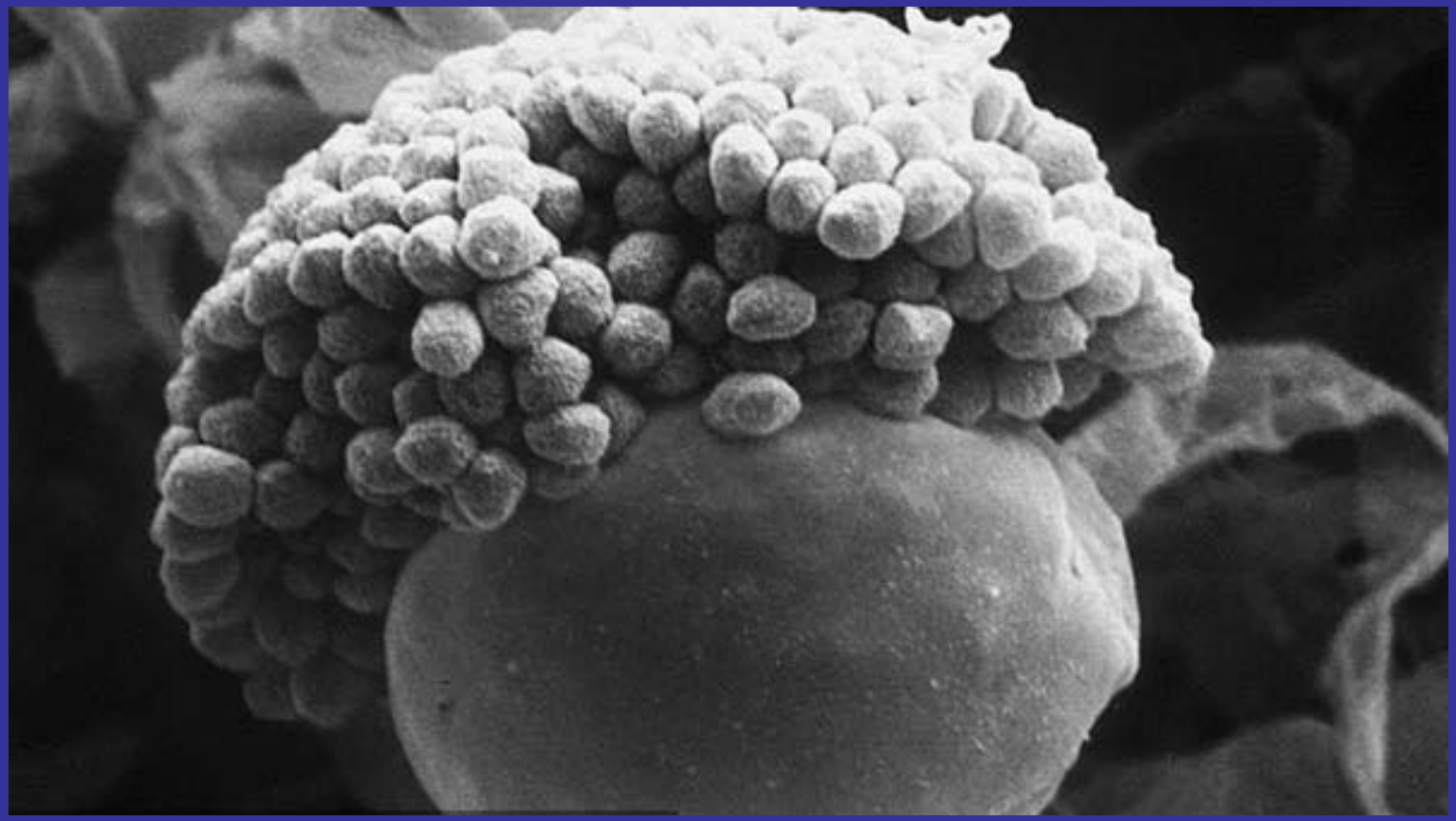
FIGURE 11-36 Rhizopus rot of strawberries (A), of peach externally (B), and of peach in cross section (C). Sporangiophores with sporangia (D) and zygospore (E) of *Rhizopus* sp. [Photographs courtesy of (A, D, and E) Plant Pathology Department, University of Florida.]

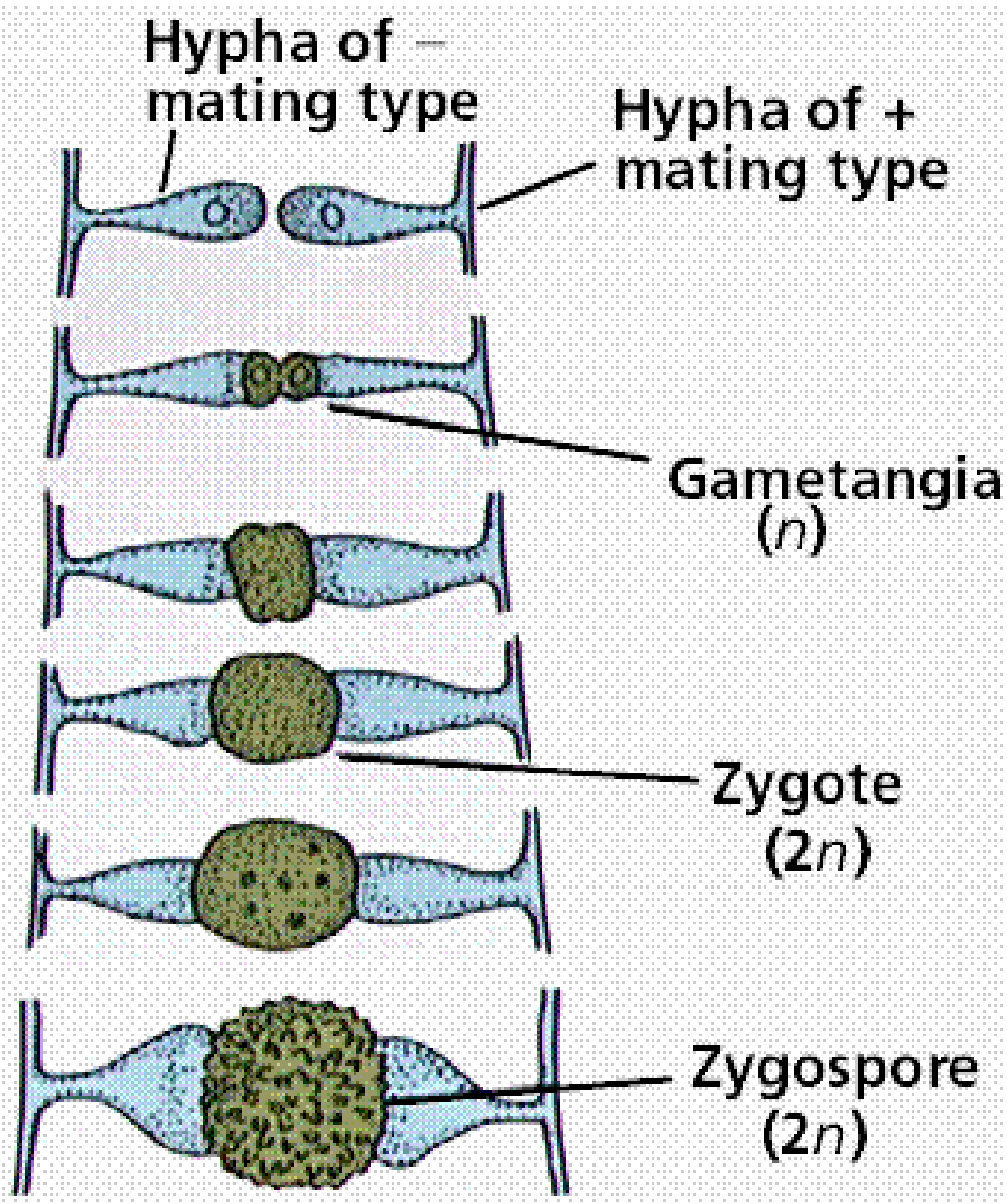
Rhizopus spp.

Rhizopus rot of strawberry

Sporangia

Sporangium with Sporangiospores

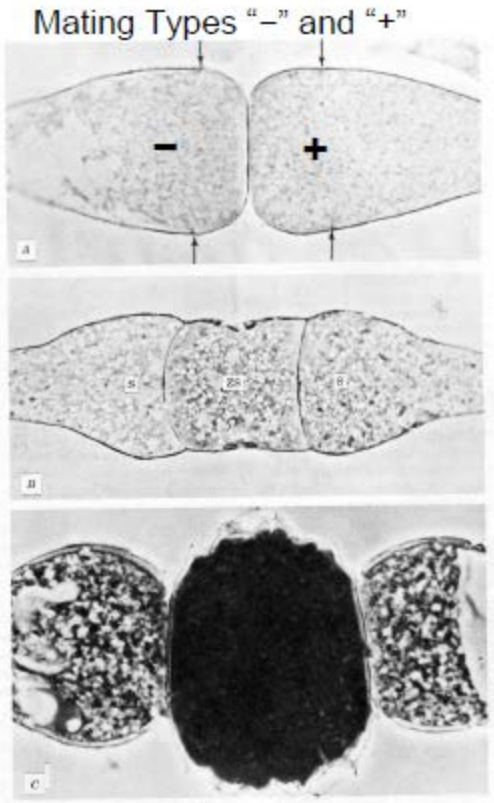



Hypha of – mating type
Hypha of + mating type
Gametangia (n)
Zygote (2n)
Zygospore (2n)

True Fungi – Meiospores
Zygomycetes

Zygosporangium between suspensors

- Common cause of fruit storage rots
- Bread molds



Zygospore = zygosporangium

Zygosporangium containing zygospore

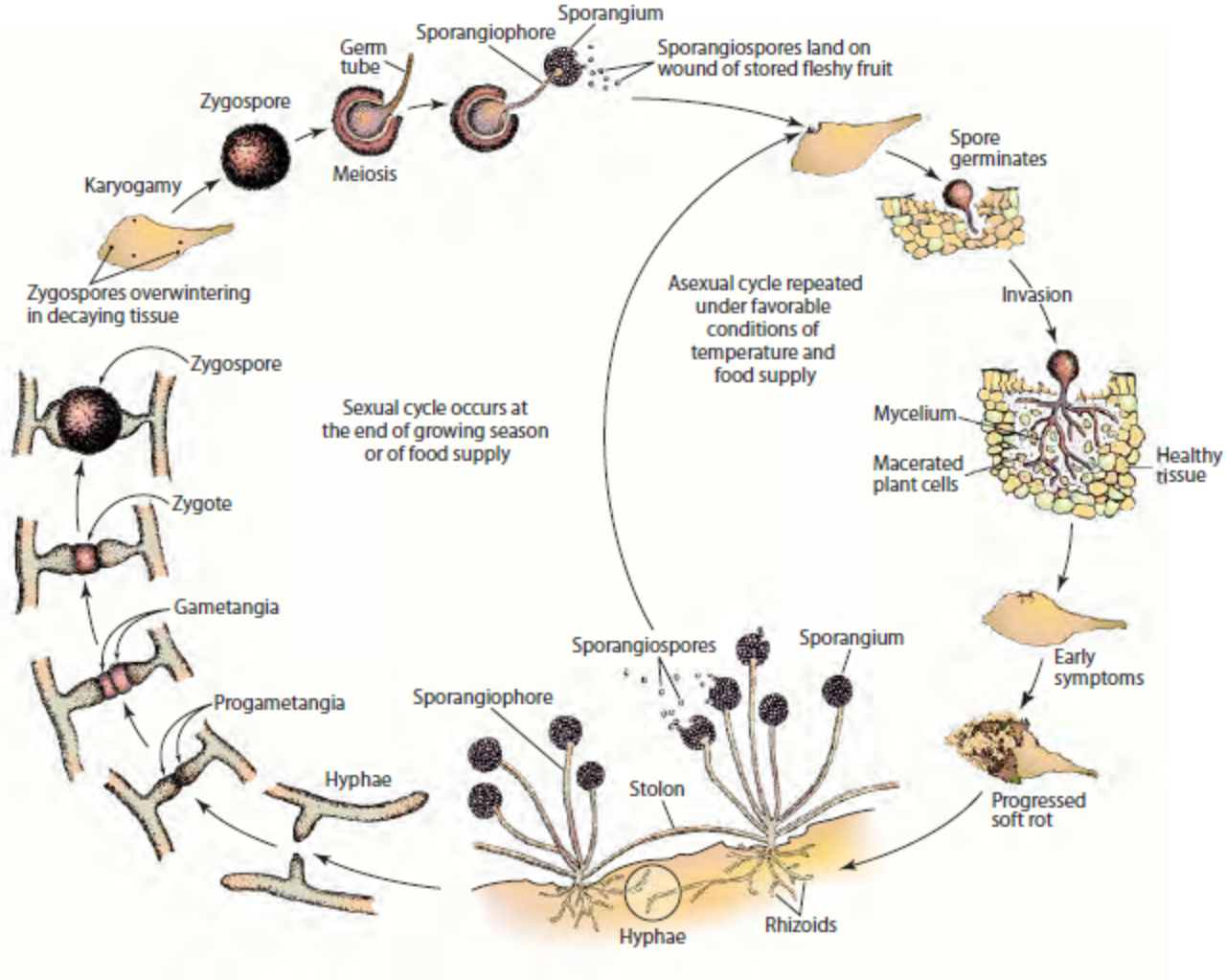


FIGURE 11-37 Disease cycle of soft rot of fruits and vegetables caused by *Rhizopus* spp.


Wet rot
Choanephora


Wet rot
Choanephora


Choanephora cucurbitacae

Ascomycota

- Sexual spores (ascospores) formed within an ascus
- Dikaryon restricted to ascoma
- Vegetative nuclei haploid, cells heterokaryotic
- Over 40,000 named species

Ascomycota

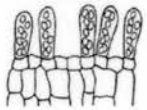
- Sexual spores borne in an ascus
- Single-celled, mycelial, or dimorphic
- Septate hyphae
- Simple septal pores
- Cell walls mostly chitin
- Heterothallic mating system - unifactorial

No ascocarps/ Lack ascogenous hyphae

Archiascomycetes

Taphrinales

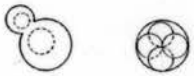
- Ascus arises from ascogenous cell
- Obligate plant parasites
- Dimorphic
- Saprobic haploid yeast
- Parasitic mycelium w/simple septal pores
- *Taphrina* - Peach leaf curl
- *Protomyces*



Ascomycetous Yeasts

Saccharomycetales

- Ascus = transformed vegtative cell
- Yeast phase only or dimorphic
- Asci- thin-walled
- CW = β-1,3 glucans/mannans/chitin
- No dikaryotic phase
- Budding, conidia, arthrospores
- Live in sugar-rich habitats
- Human pathogen - *Candida*
- Baking, brewing, distilling
- *Saccharomyces, Pichia*
- *Cephaloascus, Debaryomyces*



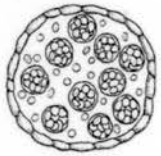
Filamentous
Ascocarps & Ascogenous hyphae

Plectomycetes

- Ascocarp = cleistothecium
- No hymenium
- Evanescent asci
- Ascospores unicellular
- Distinguished by conidial types

Eurotiales

- Ascocarps small
- Peridium - thin
- *Eupenicillium*
- *Eurotium*
- *Emericella*
- *Thermoascus*



Onygenales

- Peridium - solid, often w/appendages
- Ascospores -globose, small often ornamented
- Saprobes - soil/dung
- Keratinophilic, cellulolytic
- Dimorphic animal pathogens
- Histoplasmosis, blastomycosis
- *Onygena, Ajellomyces*
- *Coccidioides*

Erysiphales

- Powdery mildews
- Obligate biotrophs on plants
- Enclosed ascocarp oft w/ appendages
- Asci in basal layer - bitunicate
- *Erysiphe, Uncinula, Phyllactinia*

Laboulbeniales

- Obligate parasites - arthropods
- Lack true mycelium
- Perithecium
- No hamathecia
- *Herpomyces*

Pyrenomycetes

- Ascocarps = perithecium
- Hymenium w/unitunicate asci
- Hamathecia w/sterile hyphae
- Pseudoparenchyma
- Parasites, symbionts, saprobes

Sordariales

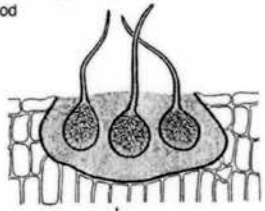
- Lack stroma
- Perithecia/cleistothecia leathery/membranous
- Periphysate
- Ascospores 1-2 celled w/apical ring
- *Sordaria, Neurospora Podospora*

Xylariales

- Dark, black perithecia
- Asci - I^+ w/ apical ring
- Ascospores pigmented often w/ pores/slits
- Paraphyses; periphyses
- Saprobes, parasites bark/wood
- *Xylaria, Daldinia*
- *Hypoxylon, Diatrype*

Diaporthales

- Perithecia in stroma
- Pseudoparenchyma
- Chestnut blight
- *Diaporthe, Magnaporthe*
- *Cryphonectria*



Discomycetes

- Ascocarp = apothecium
- Asci - unitunicate
- Hymenium - exposed at maturity

Inoperculate — Operculate — Lecanoralean

Rhytismatales

- Ascocarp stromatic
- Saprobes, lichens, endophytes, pathogens
- Tar spots
- Needle-cast disease
- *Rhytisma*

Pezizales

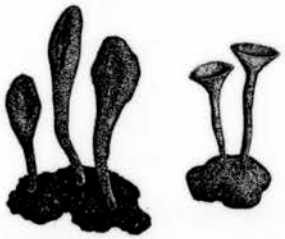
- Apothecia open
- Spherical Woronin bodies
- *Morchella, Sarcoscypha*
- *Ascobolus, Pyronema*
- *Helvella, Gyromitra*
- Hypogeous forms
- *Tuber, Elaphomyces*

Lecanorales

- Lichen-forming; lichenicolous
- Rostrate dehiscence
- Gymnocarpous devel.
- *Parmelia, Cladonia, Usnea*

Helotiales

- Lack stroma
- Asci - small/thin-walled
- *Sclerotinia, Moniliia*
- *Geoglossum, Helotium*



Loculoascomycetes

- Bitunicate asci
- Ascostroma
- Asci dev. within locules
- Many lichen-forming

Myriangiales

- One ascus/locule
- Asci - globose
- *Myriangium, Elsinoe*

Dothideales

- Asci in bundles
- Many asci/locule
- Leaf spots
- *Mycosphaerella*

Pleosporales

- Pseudoparaphyses - septate; grow down
- *Venturia* - apple scab
- *Cochliobolus*

Microascales

- Lack stroma
- Perithecia/cleistothecia
- Plant/animal parasites
- Saprobes
- Assoc. w/insects
- Blue stain, oak wilt
- *Ceratocystis*

Hypocreales

- Perithecia single or soft, brightly-colored stroma
- Asci w/apical pore
- *Nectria, Hypomyces*
- *Claviceps, Cordyceps*
- *Epichloe, Balansia*

Melanosporales

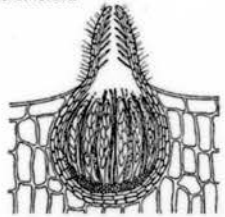
- Lack stroma
- Perithecia -long-necked
- Pseudoparenchyma
- Paraphyses absent
- Periphyses present
- Ascospores w/pores
- *Melanospora*

Ophiostomales

- Lack stroma
- Perithecia long-necked
- No paraphyses
- No periphyses
- Asci formed in chains
- Assoc. w/beetles
- Dutch elm disease
- *Ophiostoma*

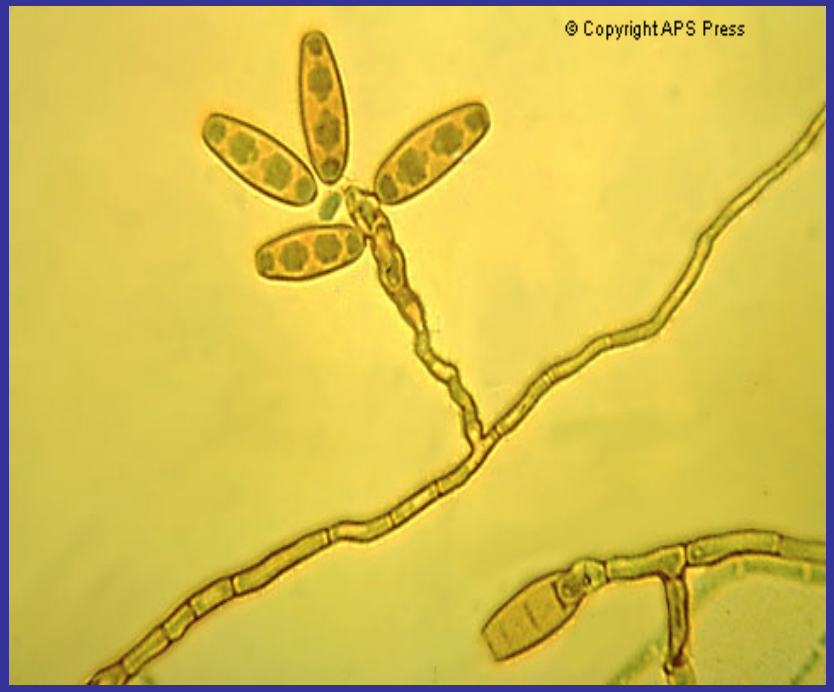
Phyllachorales

- Perithecia in stroma
- Paraphyses deliquesce
- Ostiole w/periphyses
- *Glomerella*



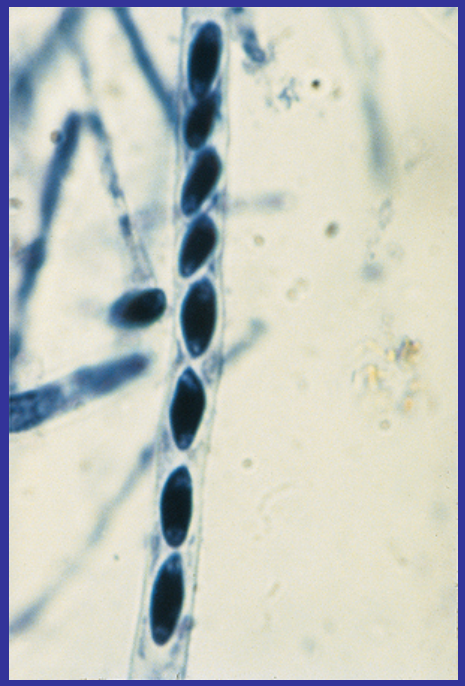
Ascomycete Spores

- Asexual Spores



- Conidia

- Sexual Spores



- Ascospore

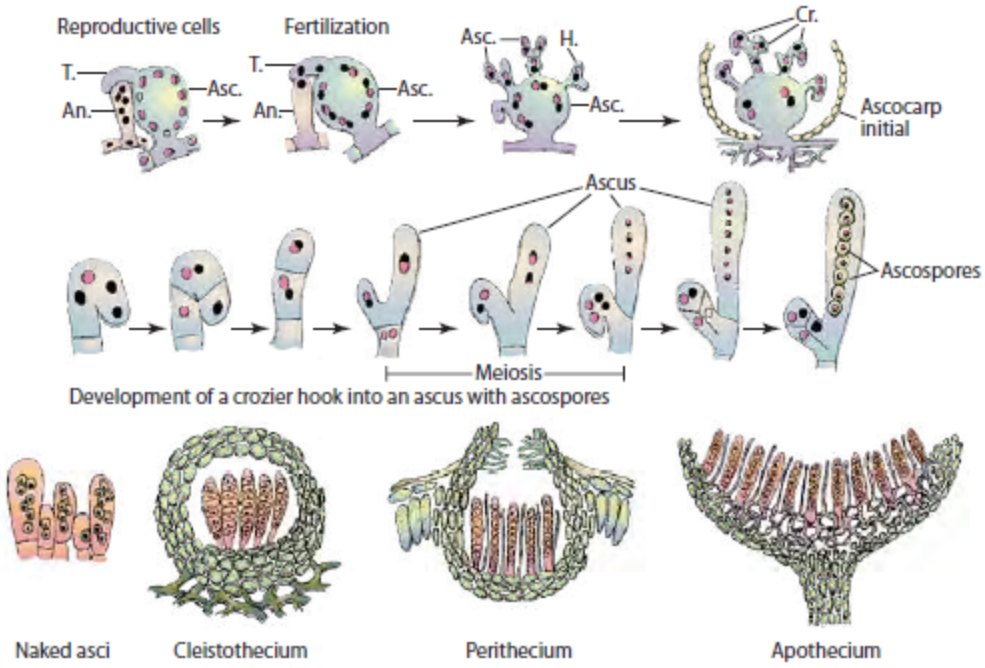
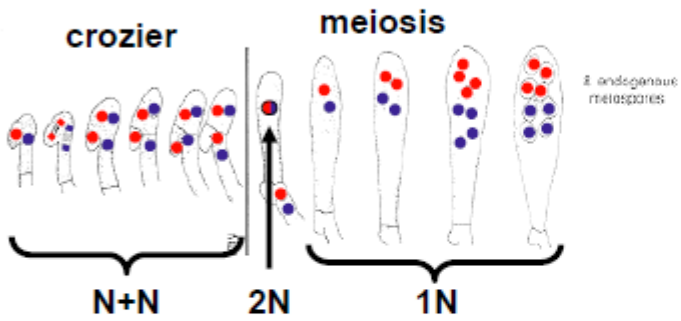
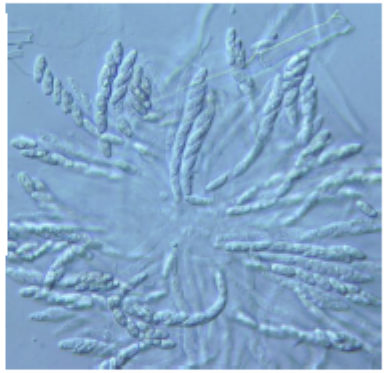


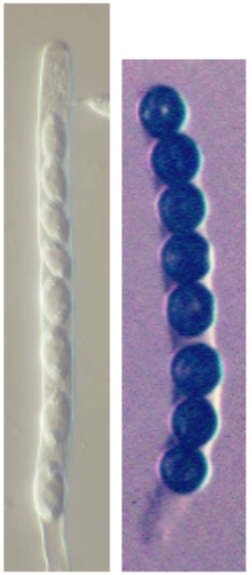
FIGURE 11-38 General scheme of sexual reproduction, ascus development, and types of ascocarps in Ascomycetes. An, antheridium; Asc, ascogonium; T, trichogyne; Asc H, Ascogenous hyphae; Cr, crozier.

True Fungi – Meiospores
Ascomycetes

Ascus development

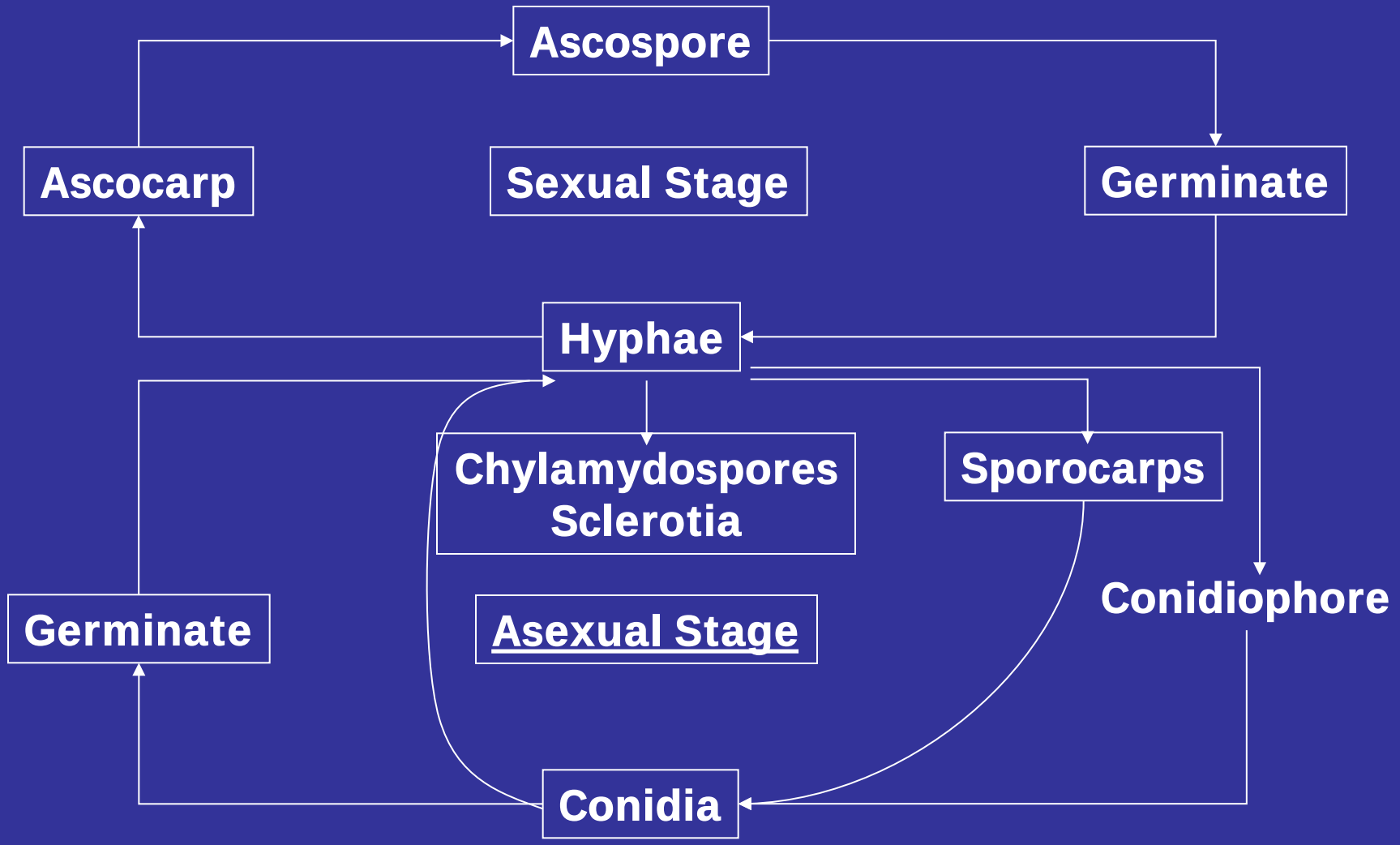






- Ascospores borne in ascus (“sac”)
  - Usually 8 ascospores per ascus
  - Or multiples of 8: 4, 8, 16, 32…
- Asci are borne in characteristic ascomata (fruiting structures)

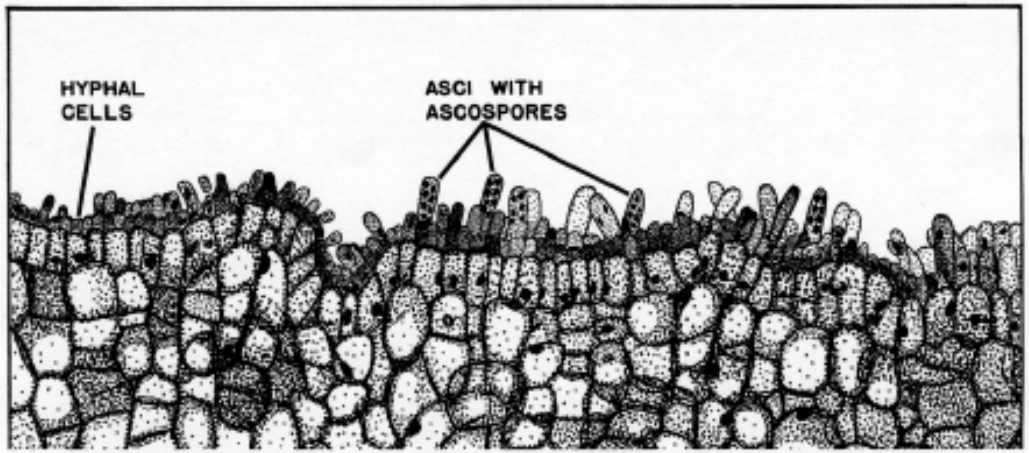
Life Cycles of Ascomycete Fungi

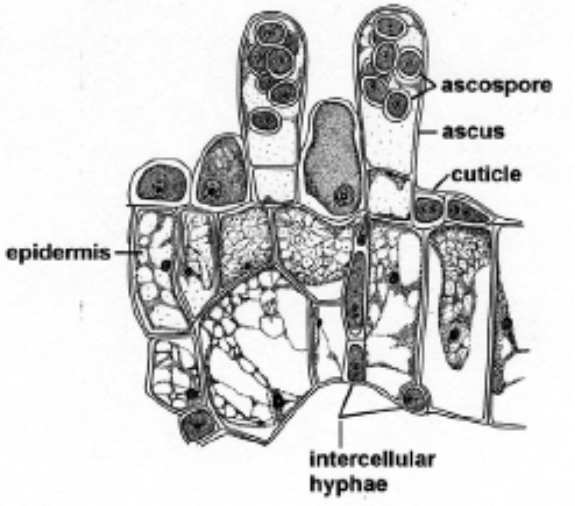


Ascomata

- Naked asci
- Cleistothecia
- Perithecia
- Pseudothecia
- Apothecia

Ascomycetes: 'Hemiascomycetes' asci not borne in ascomata



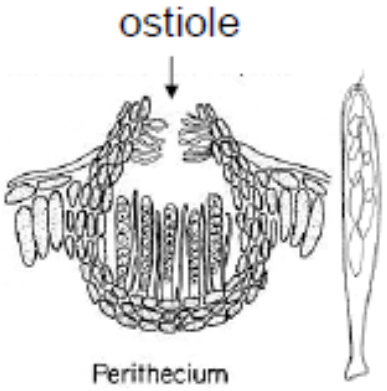


Naked Asci
contain ascospores
on leaf surface
e.g. Taphrina deformans
"The Yeasts"
Saccharomycotina,
Taphrinomycetes, etc.

Ascomycetes: Four Ascomata

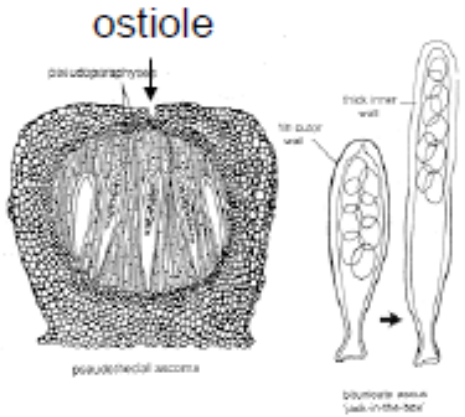
Cleistothecia
- closed
- "cracks" open

'Plectomycetes'
Powdery Mildews



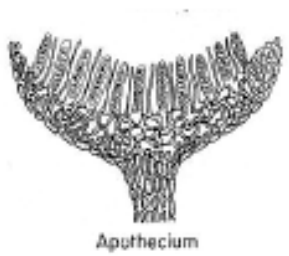
Perithecia
- ostiole
- periphyses

Unitunicate asci
'Pyrenomycetes'



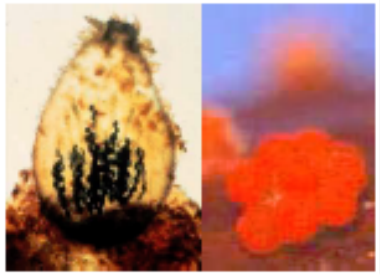
Pseudothecia
- locule immersed
- stroma

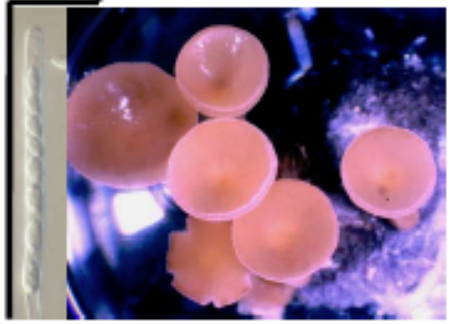
Bitunicate asci
'Loculoascomycetes'



Apothecia
- hymenium
- paraphyses

Unitunicate asci
'Discomycetes'





Diseases Caused by Ascomycetes

- Powdery mildew
  - Host specific
- Leaf spots & blights
  - Fruit-grain rots
- Cankers
  - Usually woody hosts
- Anthracnose
  - *Colletotrichum*
- Root & stem rots
- Vascular wilts
  - Host specific pathogens
- Fruit – grain rots
  - Field problems
- Post harvest diseases
  - Transit to storage
  - In storage

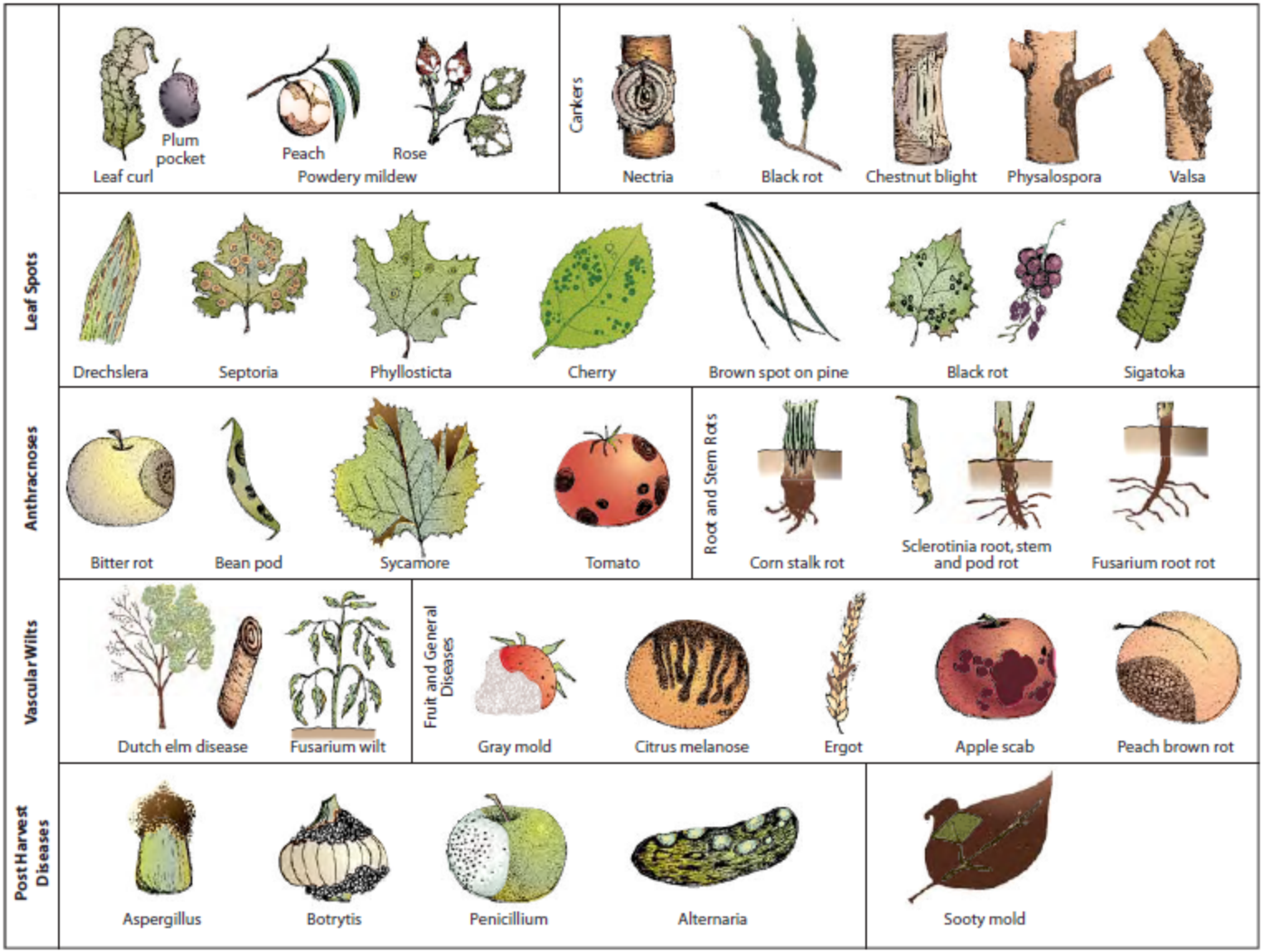


FIGURE 11-44 Common symptoms caused by some important Ascomycetes and mitosporic fungi.

Powdery Mildews

- **Pathogens: Species within the genera *Uncinula, Phyllactinia, Sphaerotheca, Erysiphe (Blumeria), Podosphaera* and *Microsphaera*.**
- **Host Range: Cereals and Grasses: Barley, wheat, bluegrass**
- **Vegetables: Pea, cucumber, squash, "melons"**
- **Fruit: Apple, Grape, Peaches, Cherries**
- **Ornamentals: Roses, Crepe Myrtle, Zinnia, Rudebeckia, Lilac, Phlox, Viburum**
- **Trees: Oaks, elms, willows**

Powdery Mildews

- **Obligate biotrophs (parasites):**

Haustorium (a): specialized structure of fungus which penetrates epidermal cells and absorbs nutrients

Effect on Host: Reduces photosynthesis; infected cells act as "nutrient sink" – organic and inorganic compounds rerouted to infected cells – translocation patterns of plant disrupted.

Physiological changes in host: reduced photosynthesis, increased respiration and transpiration

Powdery Mildews

- Powdery mildew pathogens cause polycylic diseases
  - conidia
- Conidia germinate in absence of free water
- Cleistothecia form towards end of season
  - Overwinter stage

Powdery Mildew
Rose

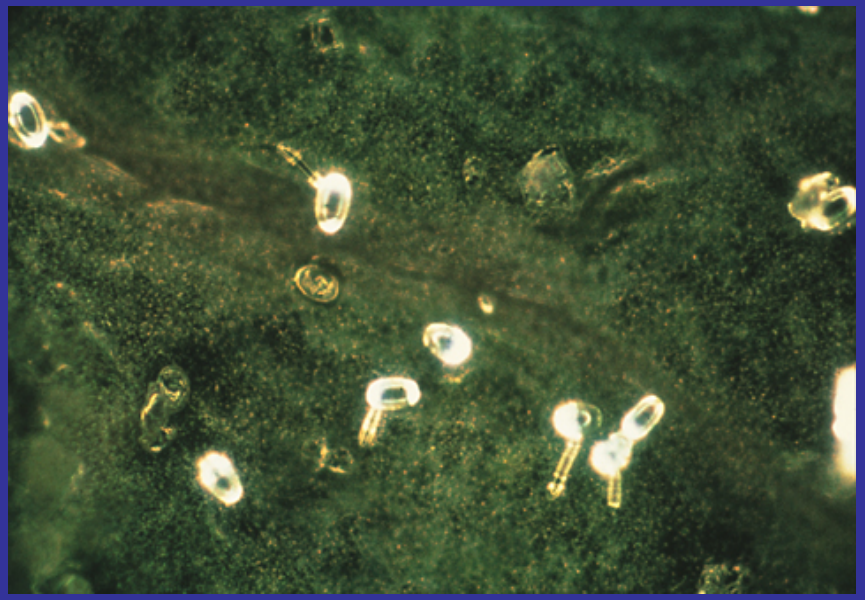
- **Cause:** ***Sphaerotheca pannosa***

Powdery Mildew
Rose

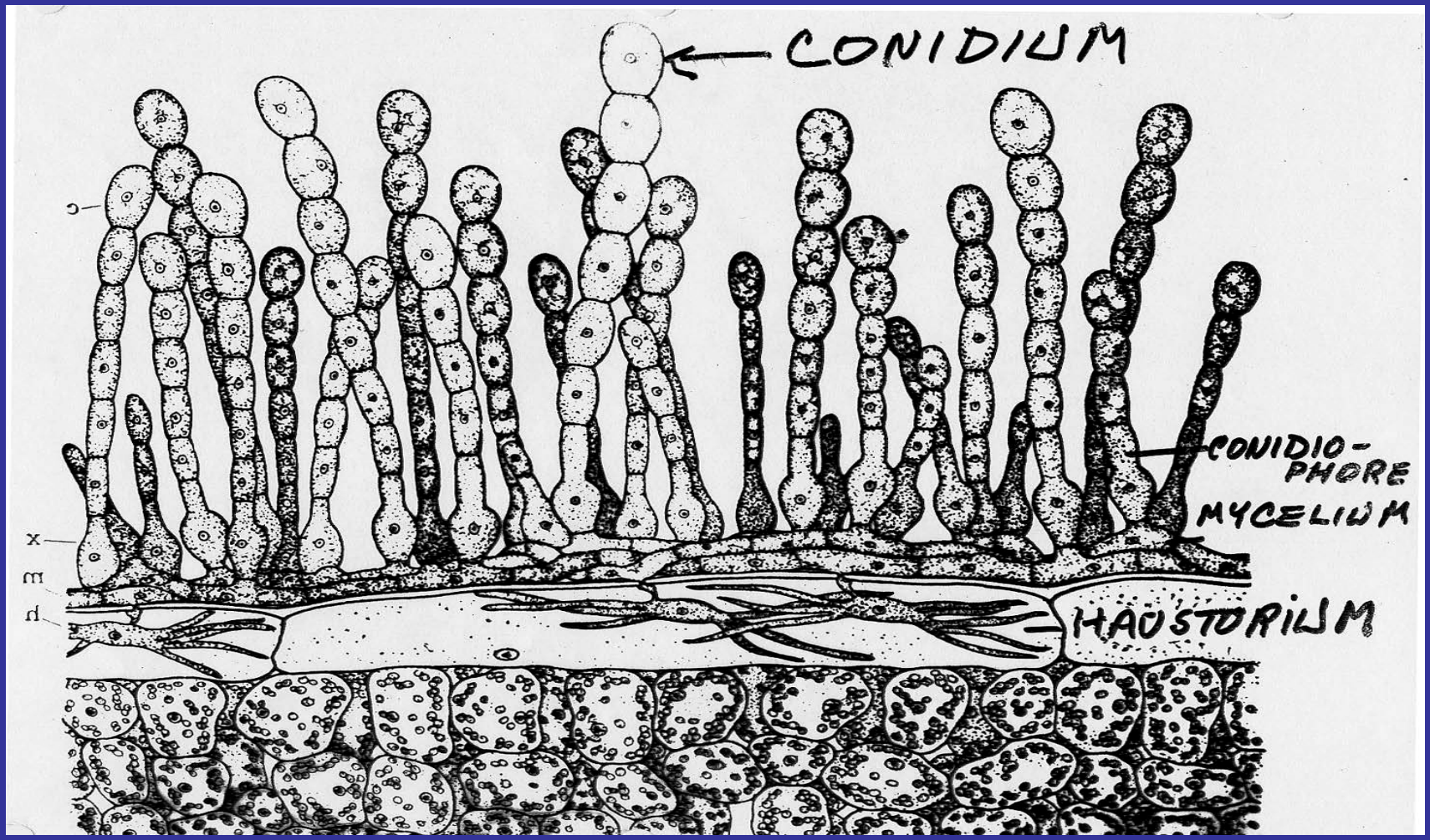
- **Signs of pathogen on stem**

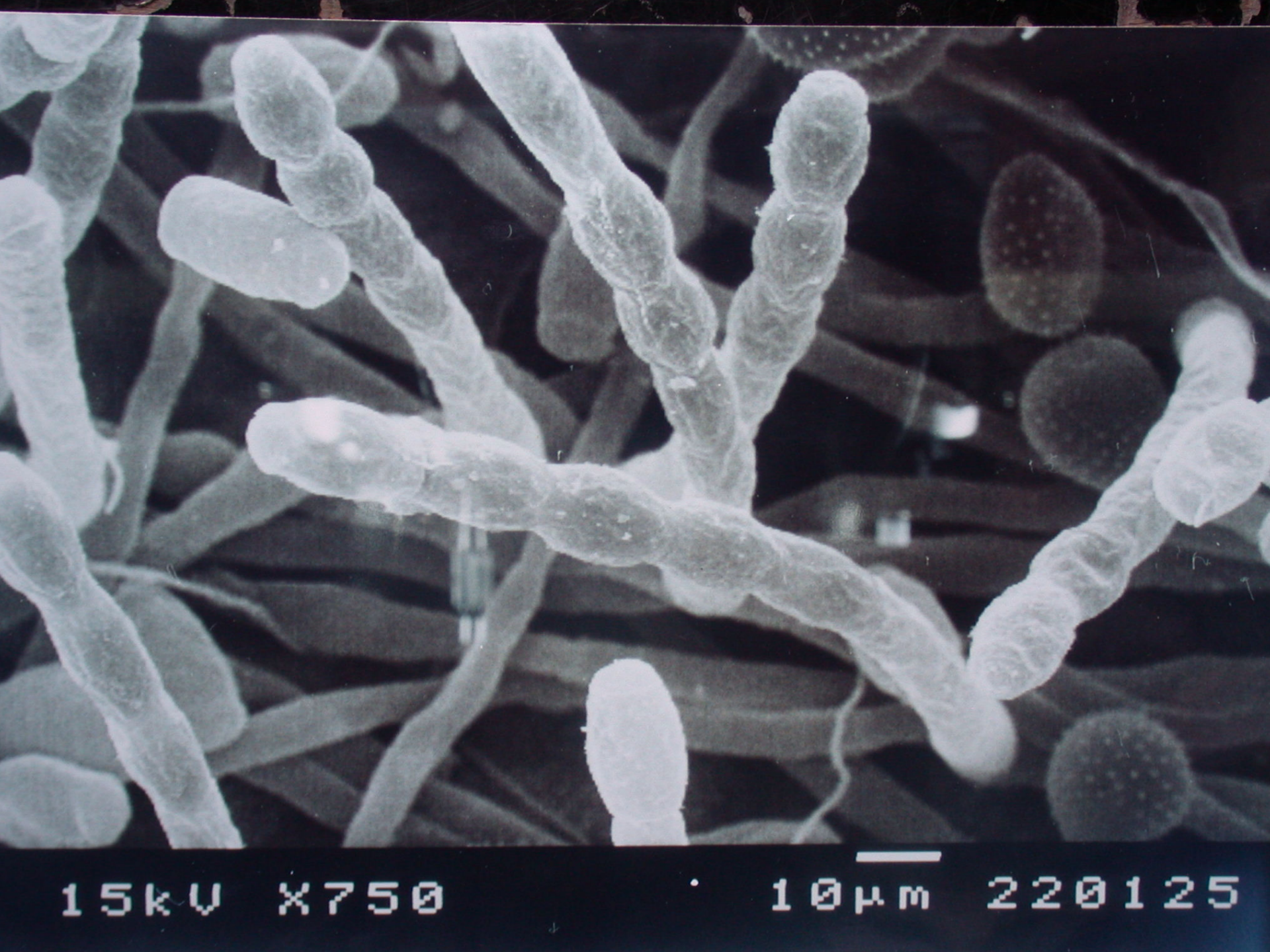
Powdery Mildew
Rose

- Conidia of pathogen on leaf surface
- Note germ tubes emerging from conidia

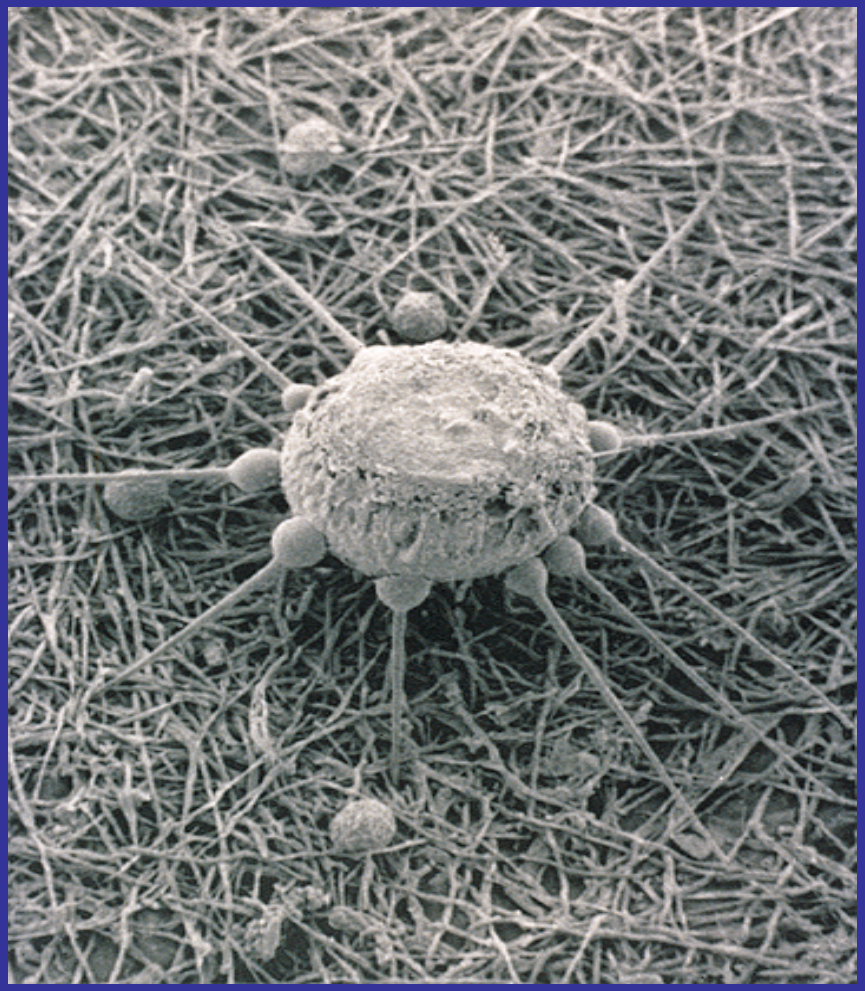


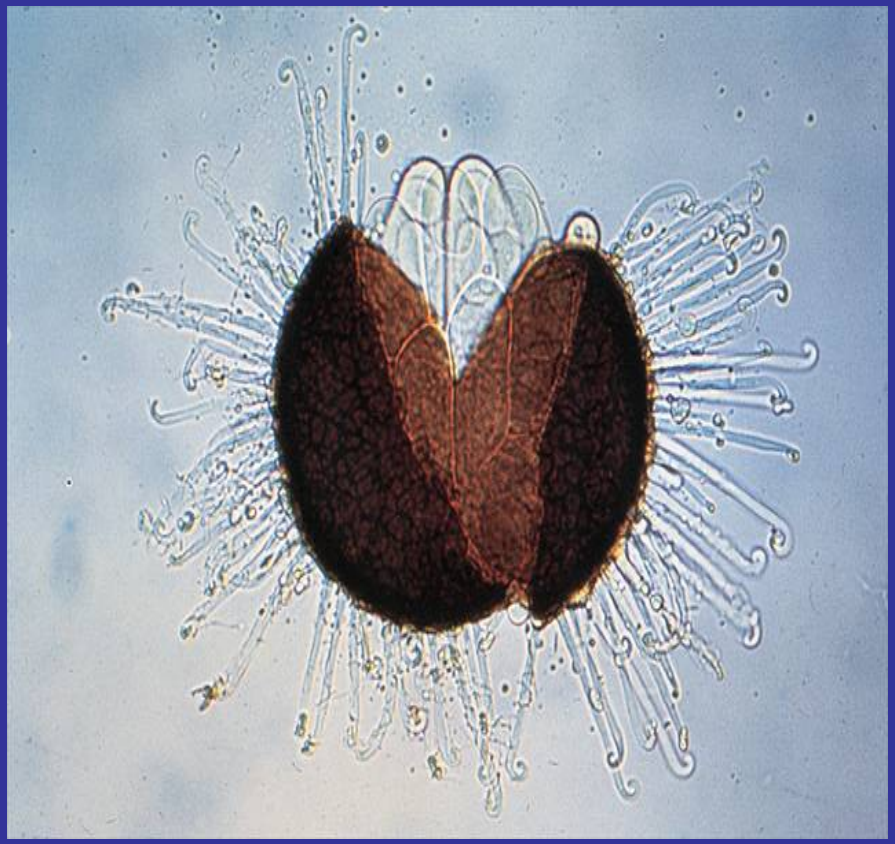
Powdery Mildew Fungi




15kV X750
10µm 220125

Cleistothecia of Powdery Mildews





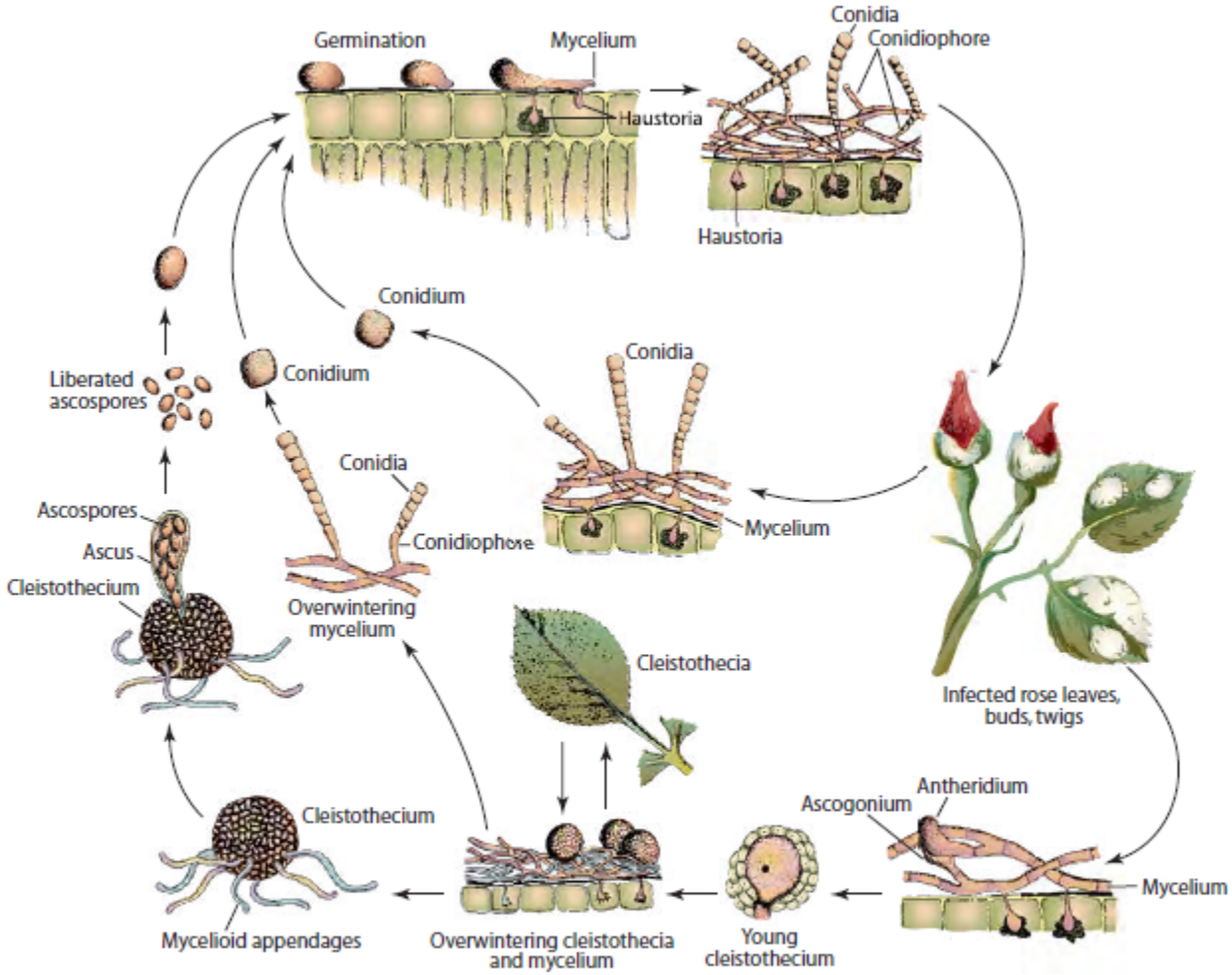


FIGURE 11-50 Disease cycle of powdery mildew of roses caused by *Sphaerotheca pannosa* f. sp. *rosae*.

White Mold
Sclerotinia sclerotiorum

- *Sclerotinia sclerotiorum*
  - Wide host range
- White Mold
  - Monocyclic disease
- Environmental factors
  - High humidity
  - Moderate air temperatures
- Host factors
  - Dense crop canopy

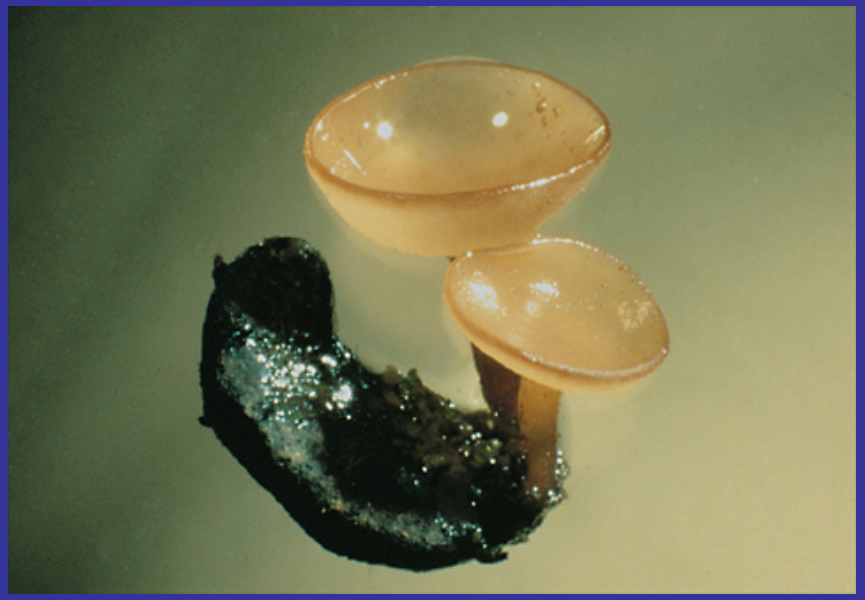
Source of Apothecia

- Frequently formed from sclerotia
- Sclerotia
  - Composed of hyphae
  - Hard pigmented cover = rind
  - Hyphae inside and protected by rind
  - Overwinter well

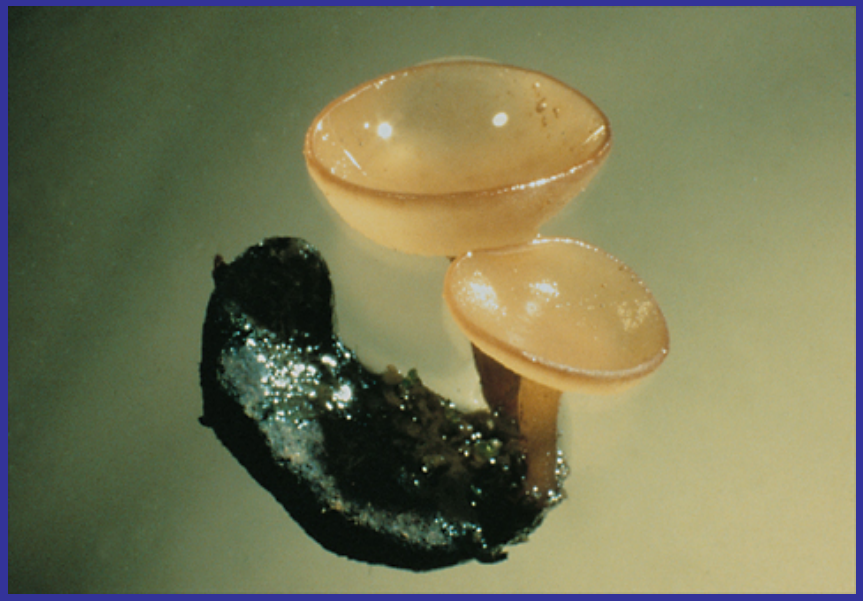
White Mold
Sclerotinia sclerotiorum

Factors that affect germination of sclerotia

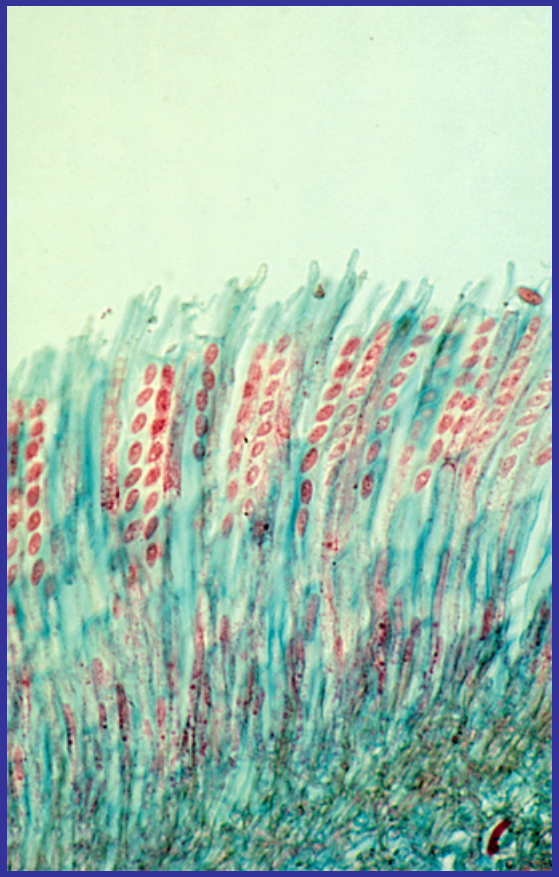
- **Water, temperature and light**
- **Crop canopy important**
- **Germinate by:**
  - **Apothecia**
  - **Mycelium**

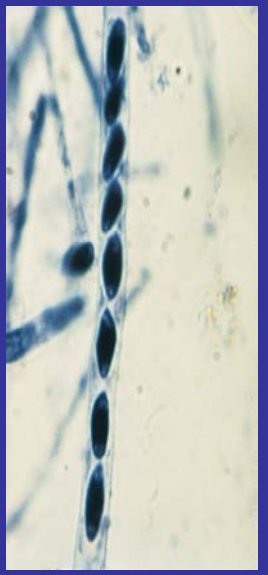


Apothecium
Sclerotinia sclerotiorum



2 apothecia emerging from a sclerotium





Asci with ascospores

White Mold
Sclerotinia sclerotiorum

- **Rapid changes in pressure within asci**
- **Ascospores are ejected from ascus**
- **Wind currents carry ascospores to host**

Cloud of ascospores

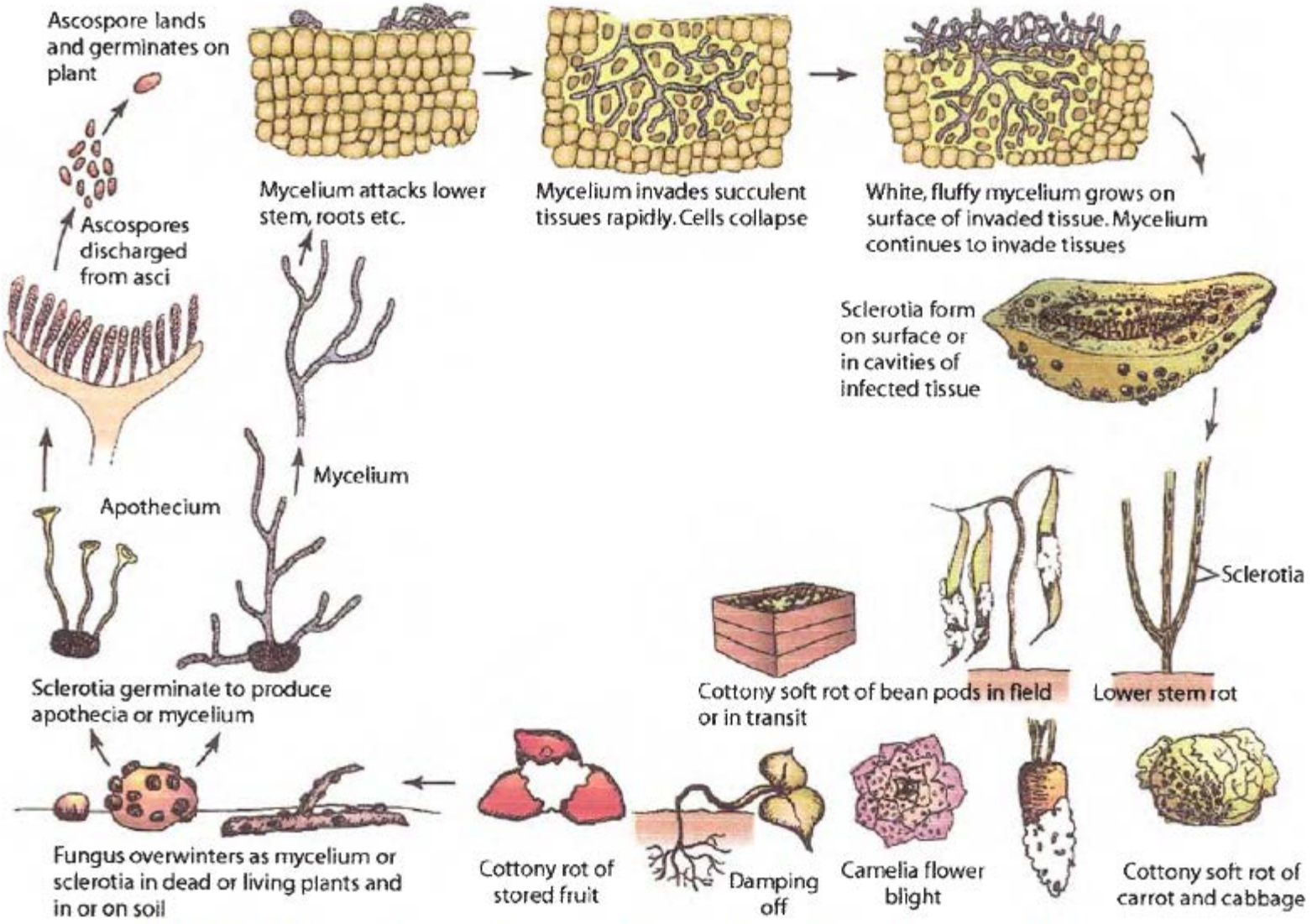
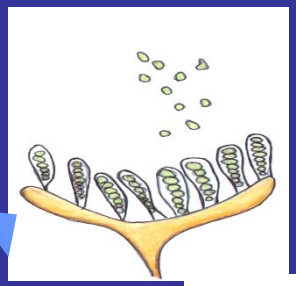


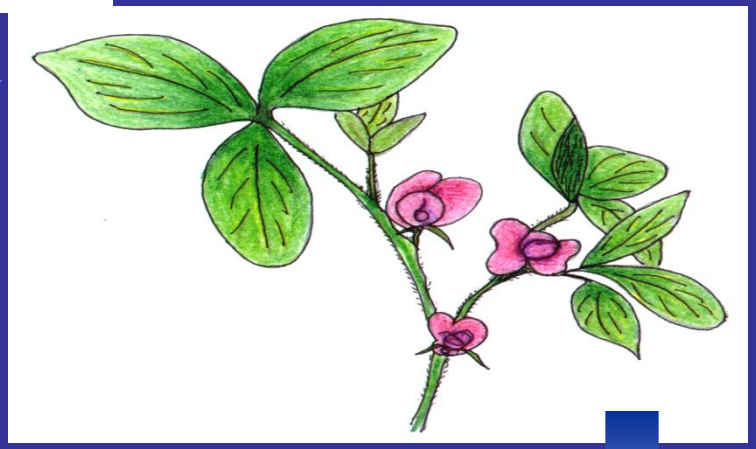
FIGURE 11-123 Development and symptoms of diseases of vegetables and flowers caused by *Sclerotinia sclerotiorum*.

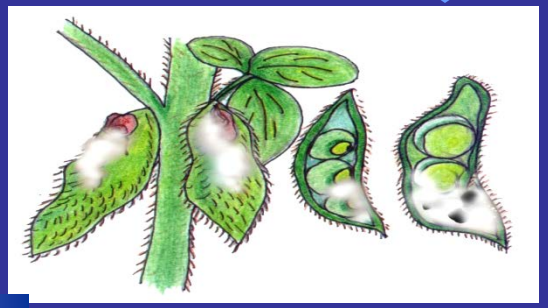
White Mold on Soybean
Sclerotinia sclerotiorum

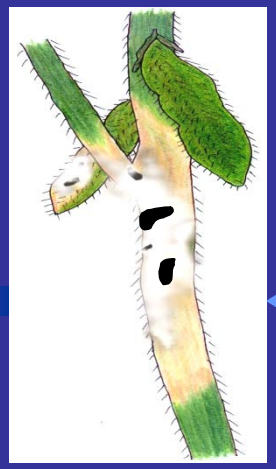
- **Symptoms**
  - **Necrosis**
  - **Wilt**
  - **Chlorosis**
- **Signs**
  - **Mycelium**
  - **Sclerotia**

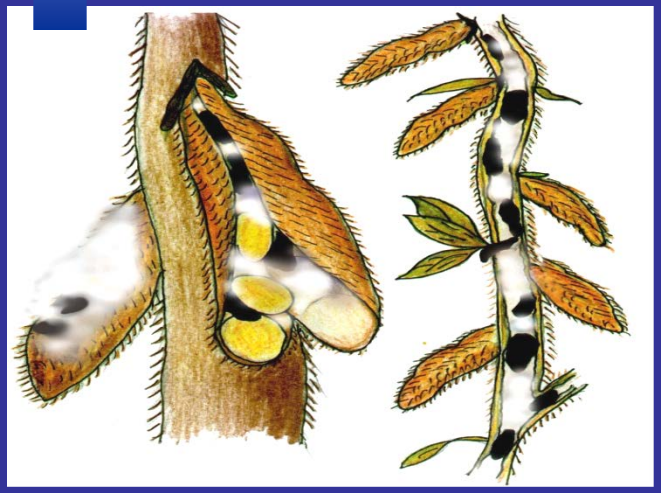
White Mold on soybeans







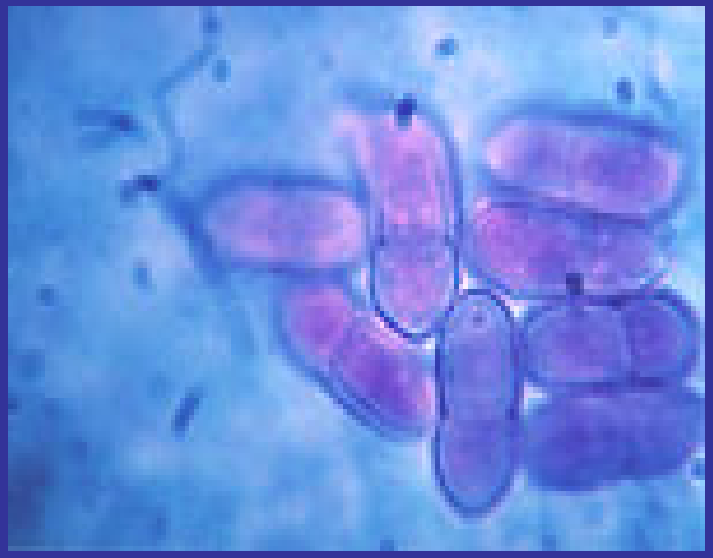




Apple Scab

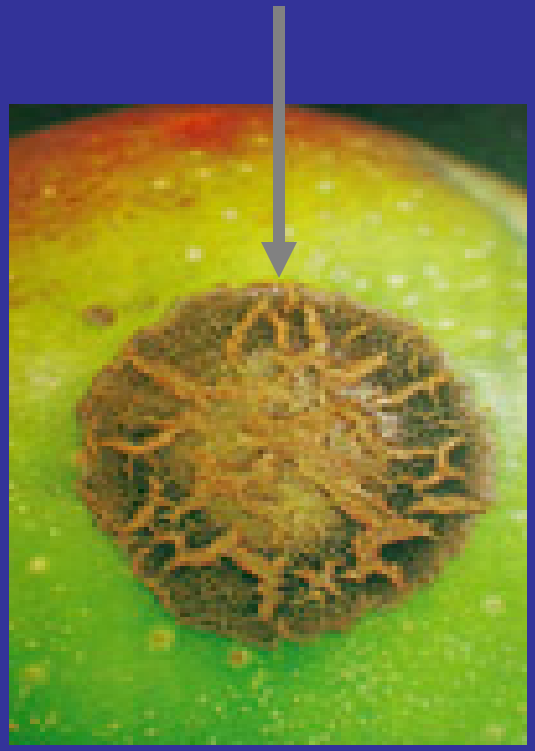
Apple Scab

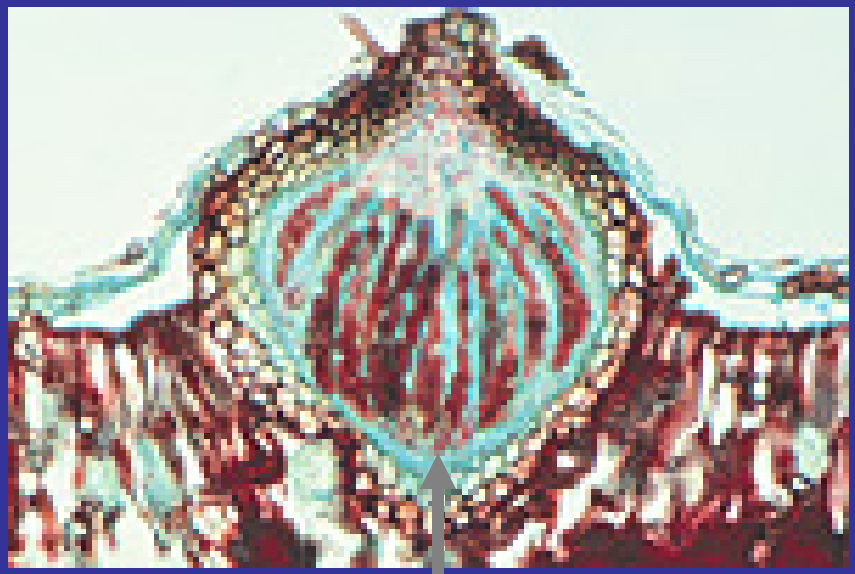
Venturia inaequalis (Spilocaea pomi **syn**. *spilocaea dendriticum)*



- **asexual spore**
- **sexual spore**

•Sub-cuticular growth of hyphae





•Pseudothecium (specialized perithecium)

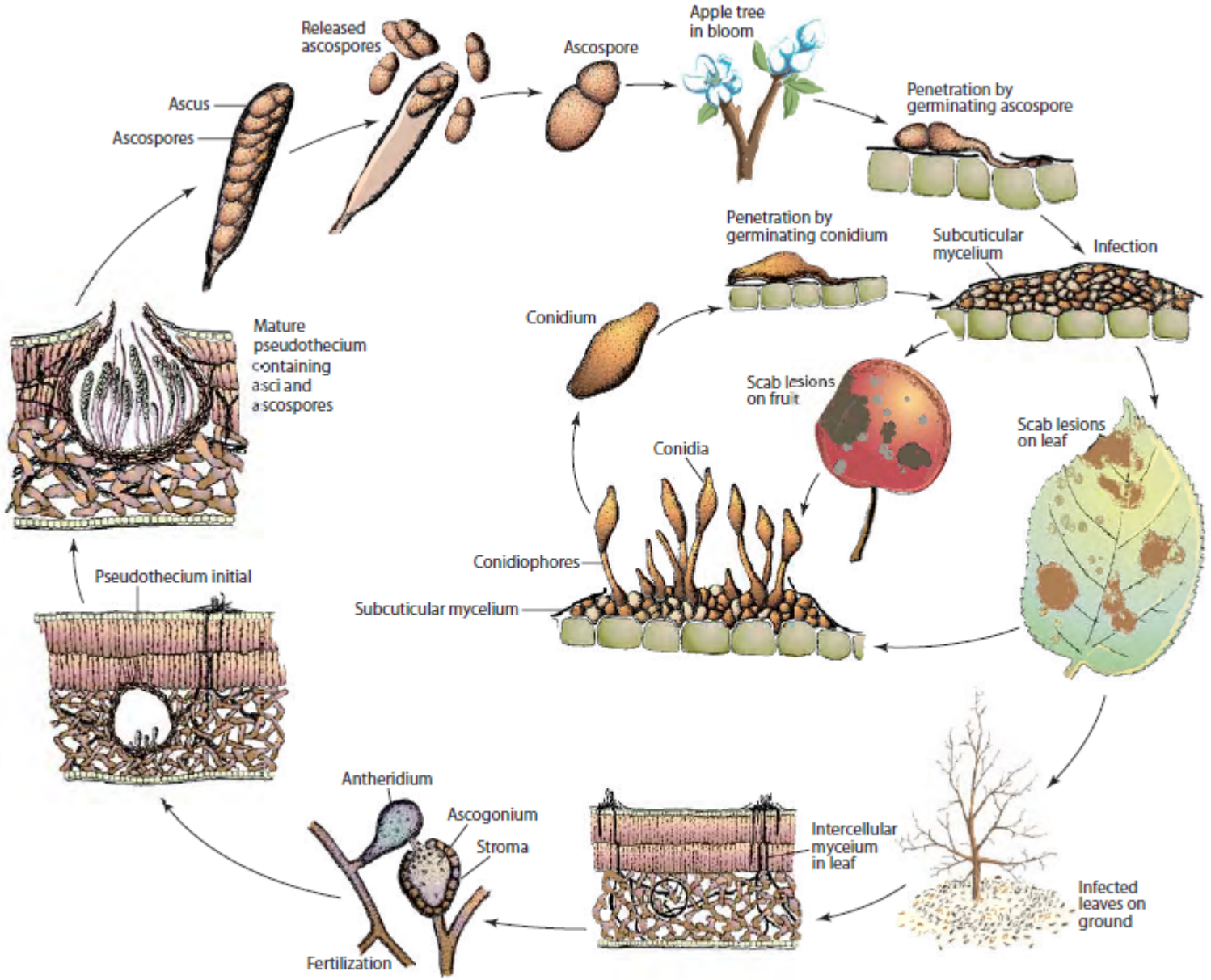


FIGURE 11-90 Disease cycle of apple scab caused by *Venturia inaequalis*.

Non sexual spore Ascomycotina

- Most are Ascomycotina that lost sexual stage
- Various mechanisms generate genetic diversity
- Rely on conidia for dispersal
- Anamorph Class Hyphomycetes have exposed conidiophores
- Anamorph Class Coelomycetes have enclosed conidiophores

Saccardoan System

Based primarily on:
- Conidiophore position - free, or within pycnidia or acervuli
- Conidium and conidiophore pigmentation and morphology

Non sexual spore Ascomycotina

- Imperfect fungi
- Hyphae -- well-developed & septate
- Asexual spore = conidium
- Mostly anamorphs of Ascomycota

Due to its artficial nature, the formal taxonomic hierarchy shown below has been discontinued. It is included here because of its presence in the literature and it remains an effective way to organize and learn these fungi.

Conidiophore superficial
Conidiomata not produced

Conidia produced within asexual fruit bodies

Hyphomycetes

Mycelia Sterilia

- No conidia produced
- Sclerotia may be formed
- Root rot, crown rot diseases
- *Rhizoctonia* (Basidiomycota anamorph)
- *Sclerotium*

Moniliales

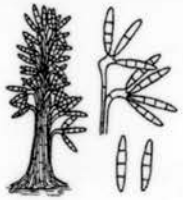
- Conidia free and produced either:
  - directly on mycelium
  - on distinct conidiophores
  - on separate conidiogenous cells

Conidiophores:
- mostly single
- separate/loose clusters

Conidiophores grouped/clustered

Stilbaceae

- Conidiophores = Synnemata
- Dutch elm disease
- *Stilbum*
- *Graphium*
- *Pesotum*
- *Arthrosporium*

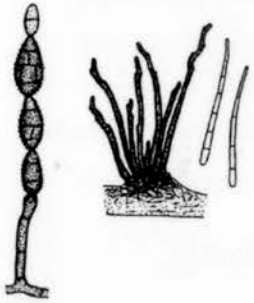


Tuberculariaceae

- Conidiophores = Sporodochia
- Canker, wilt diseases
- *Strumella*
- *Fusarium*

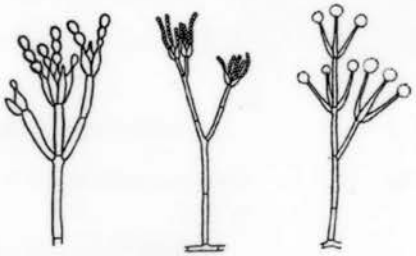
Dematiaceae

- Conidia or mycelium - pigmented
- Leaf spots, blight, root rot diseases
- *Aureosporium*
- *Cercospora*
- *Leptographium*
- *Cladosporium*
- *Drechslera, Bipolaris*
- *Alternaria*



Moniliaceae

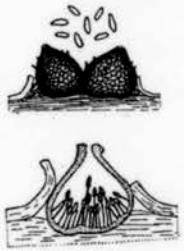
- Conidia - hyaline
- Gray mold, wilt, root rot, blight rot of stored seed, canker diseases
- *Aspergillus*
- *Botrytis*
- *Fusarium*
- *Paecilomyces*
- *Cylindrocladium*
- *Penicillium*
- *Candida*
- *Verticillium*
- *Trichoderma*
- *Sporobolomyces*



Coelomycetes

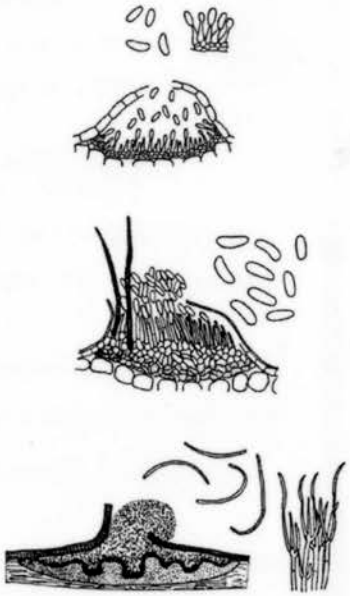
Sphaeropsidales

- Asexual fuit body = Pycnidium
- Blight, canker, leaf spot diseases
- *Phomopsis*
- *Cytospora*
- *Ascochyta*
- *Diplodia*
- *Dothistroma*
- *Septoria*



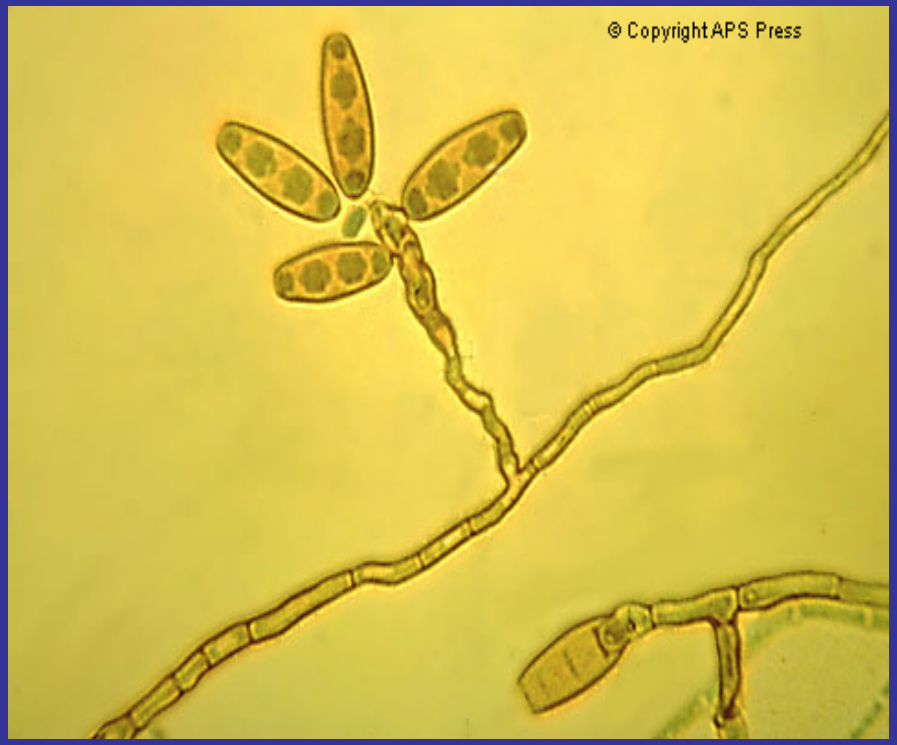
Melanconiales

- Asexual fruit body = Acervulus
- Anthracnose, leaf spots, blight diseases
- *Colletotrichum*
- *Melanconium*
- *Phragmotrichum*
- *Pestalotia*
- *Gleosporium*



Non sexual spore Ascomycotina

- Asexual spores - mitosis
- Spores = conidia (singular = conidium)
- Borne on conidiophores
- Naked on hyphae
- Sporocarps (Sporodochium, acervulus, pycnidium)

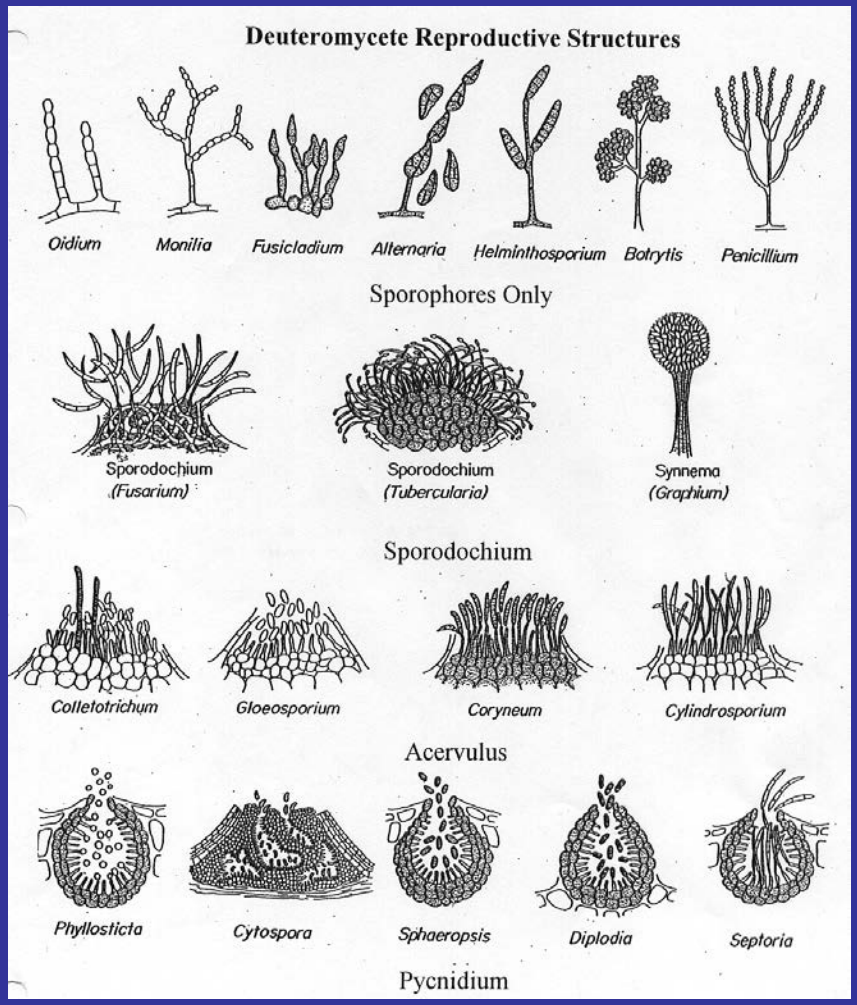


Non sexual spore Ascomycetes- Conidia

- **Conidia borne on conidiophore**
- ***Bipolaris spp.***
- **Pathogens of corn**

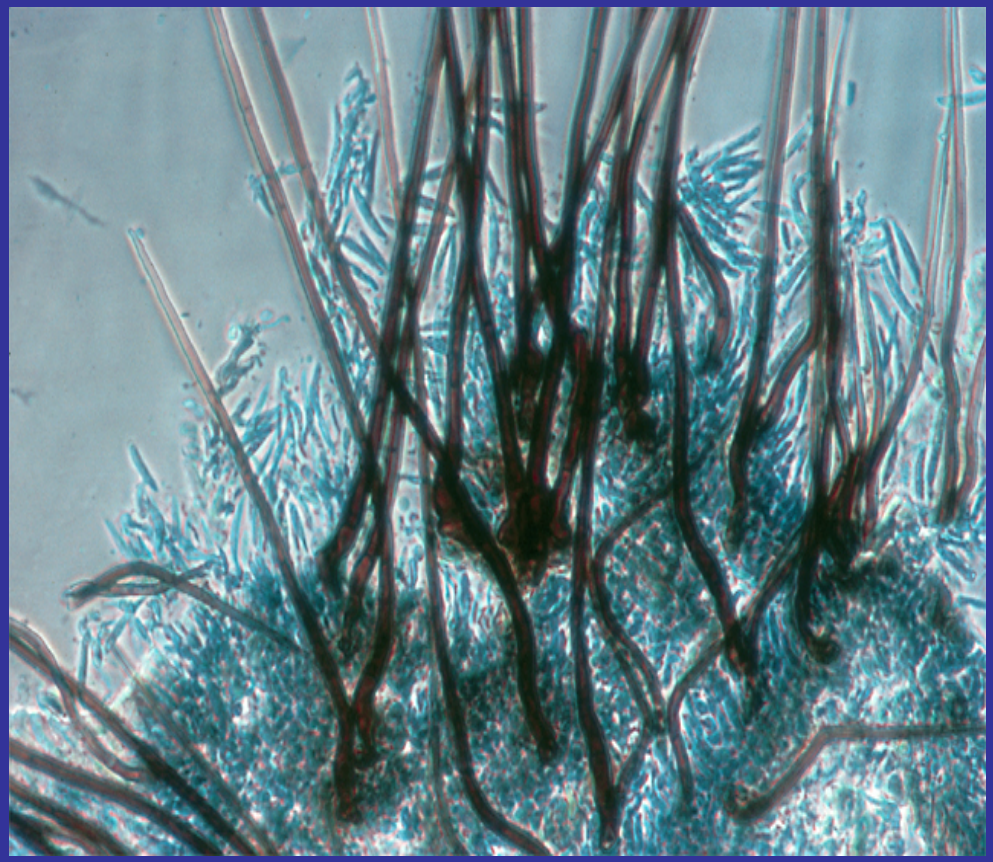
Reproductive Structures of non sexual spore Ascomycetes

- Conidia on conidiophores
- Sporodochium
- Synemma
- Acervulus
- Pycnidium

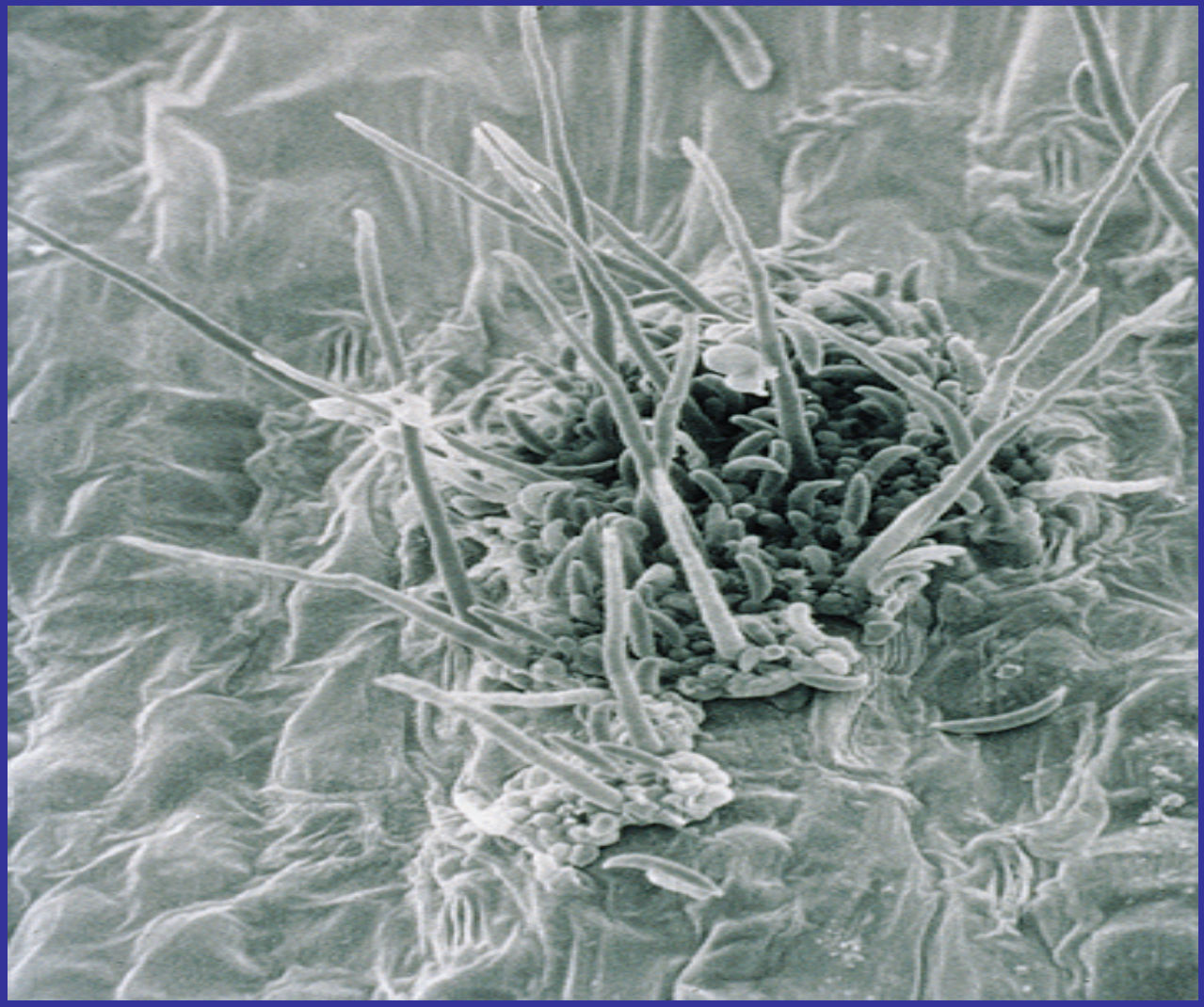


Acervulus

- **Open sporocarp**
- **Contains conidia**
- **Sterile hyphae - setae**
- ***Colletotrichum***

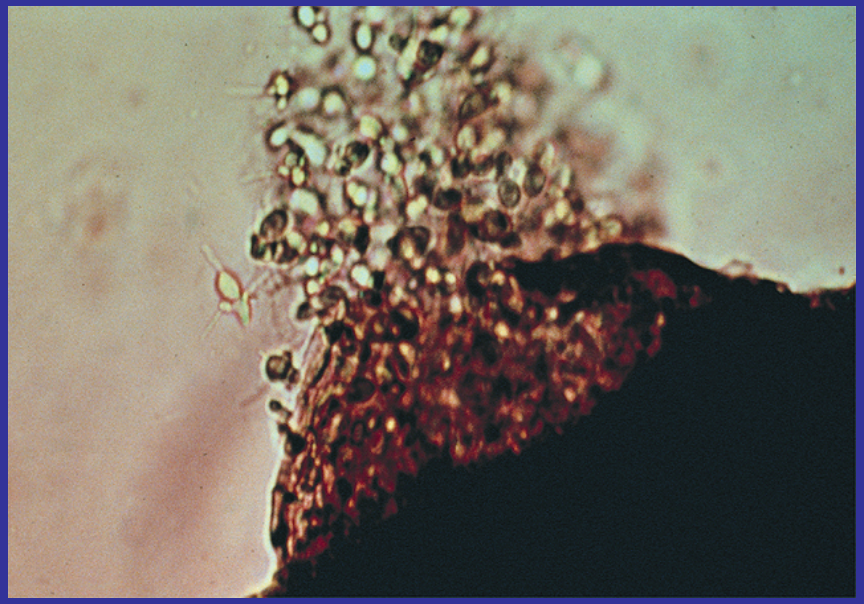


Acervulus



Pycnidium

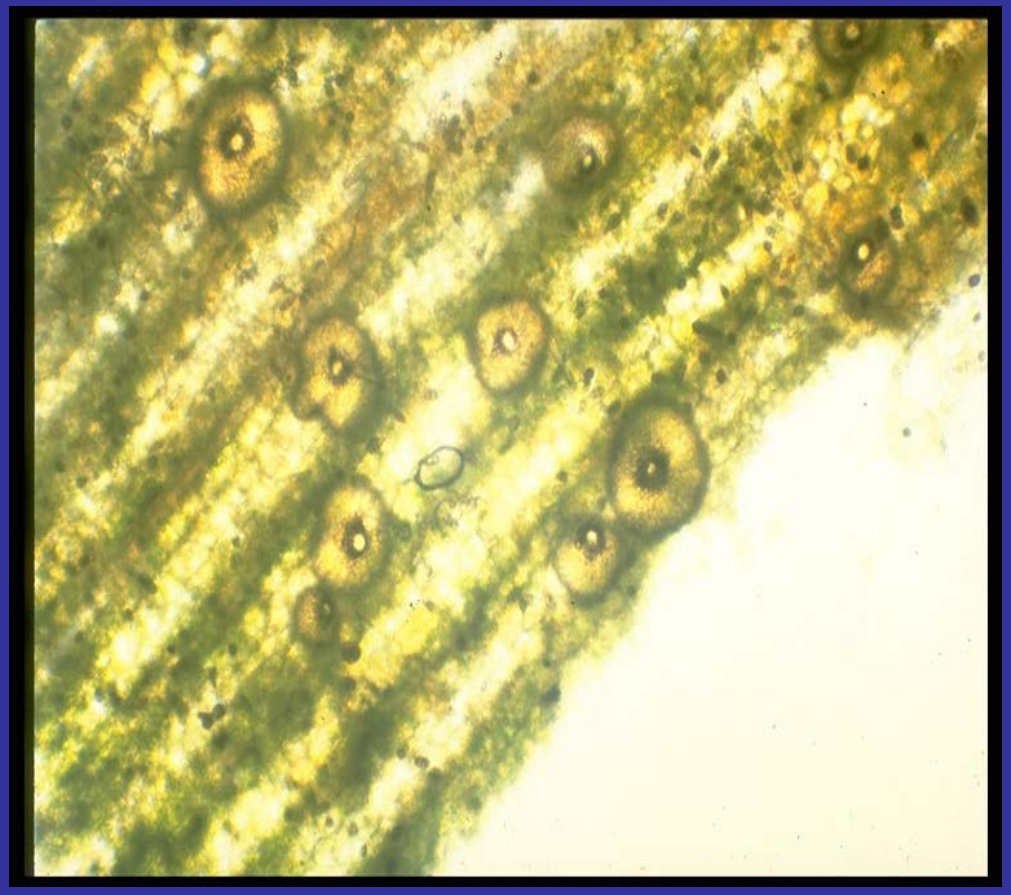
- Closed sporocarp
- Contains conidia
- Flask shaped

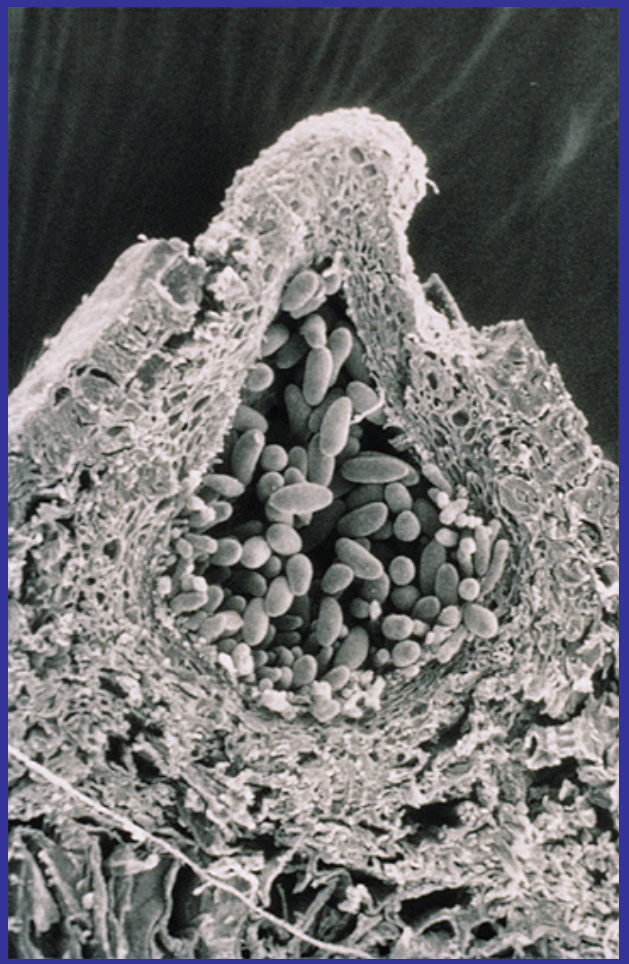


Pycnidium

- **Pycnidia of *Septoria* embedded in lesion**
- **Septoria species are common pathogens of vegetables**

Pycnidium





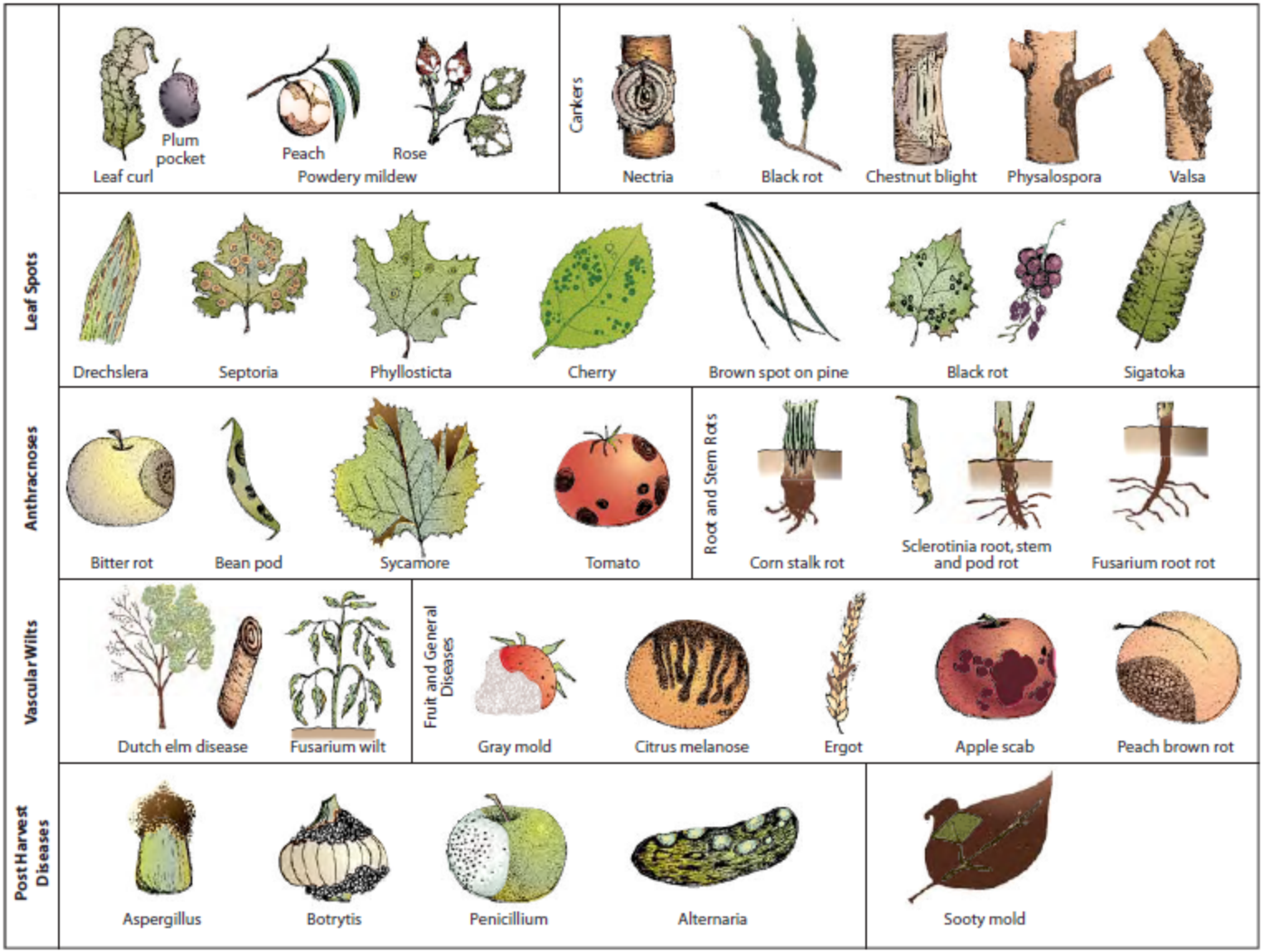
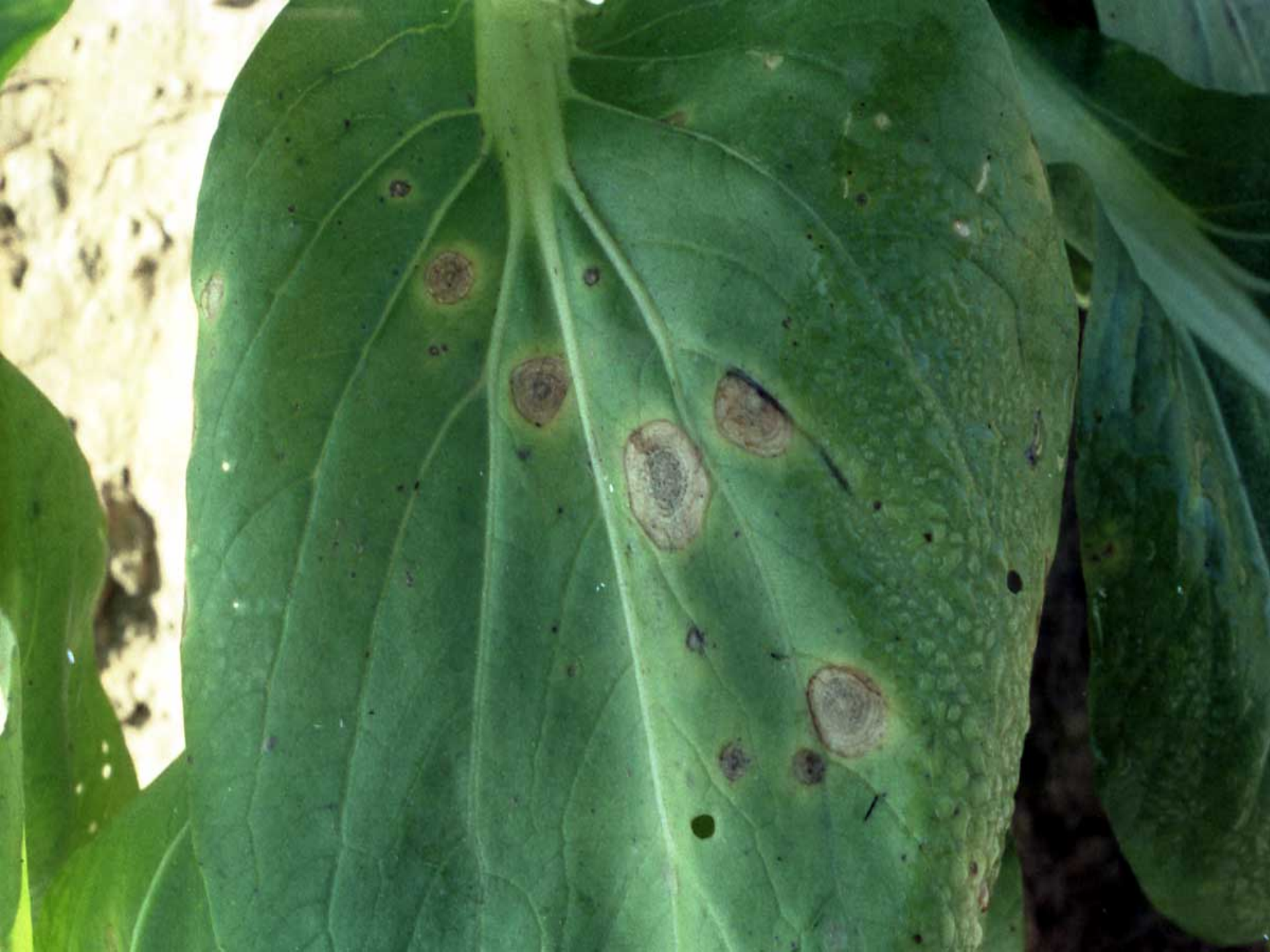


FIGURE 11-44 Common symptoms caused by some important Ascomycetes and mitosporic fungi.



Early Blight of Potato
Alternaria solani

- Target like lesions
- Causes premature decline of foliage
- Tubers infected
- Reason for multiple applications of fungicides

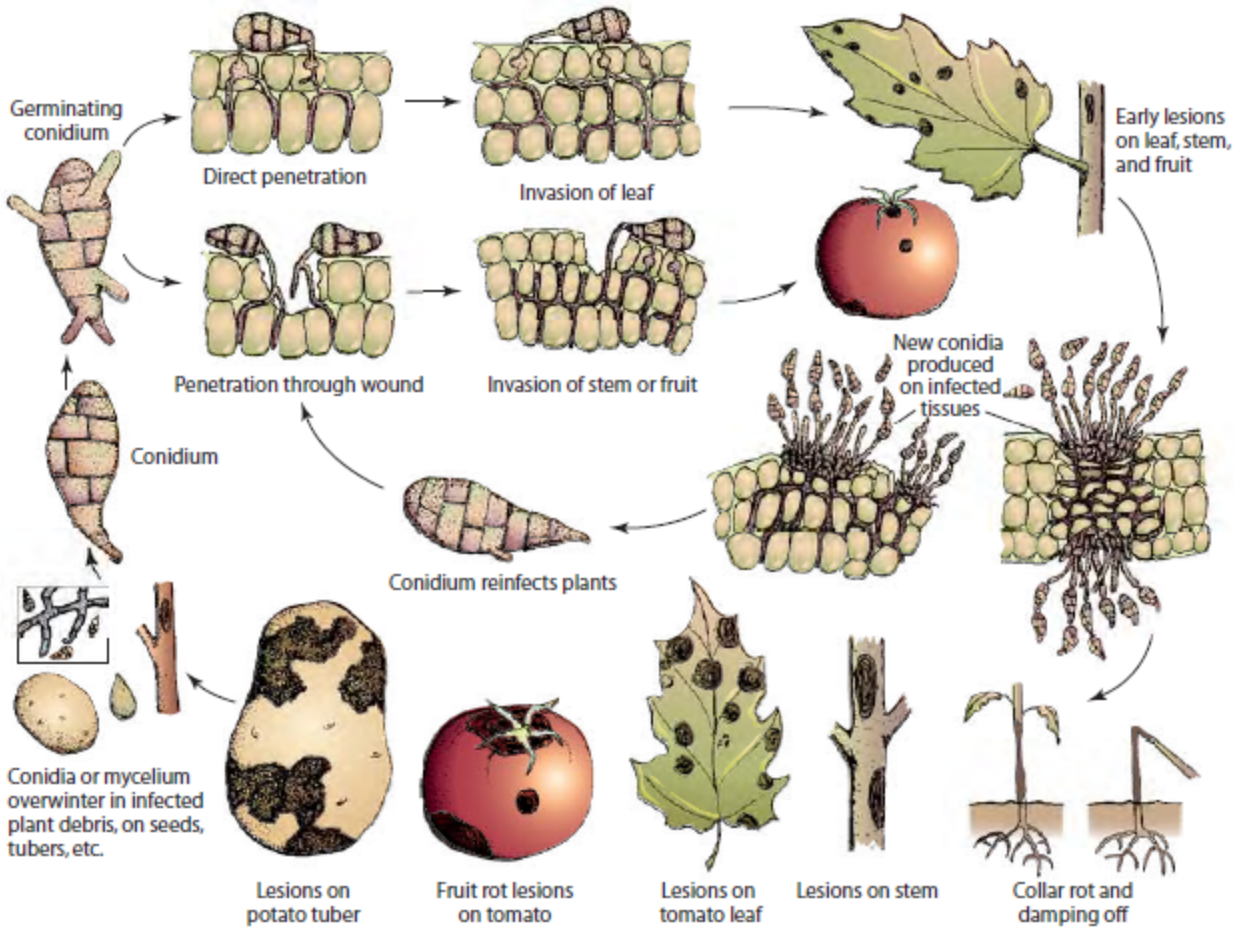
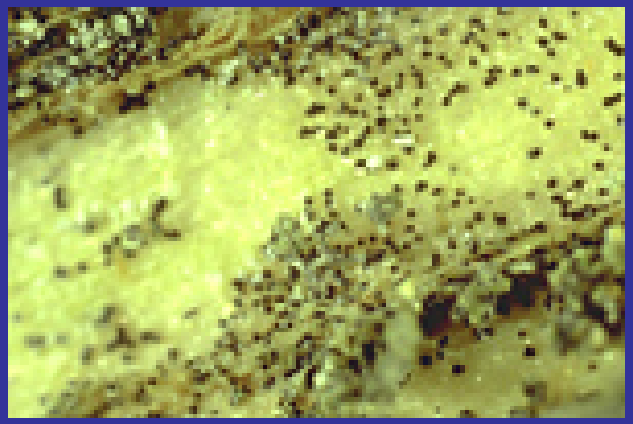
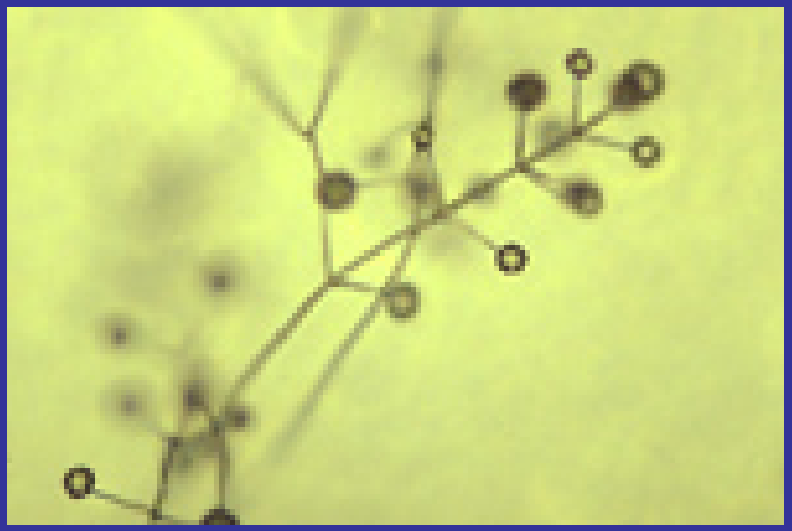


FIGURE 11-53 Development and symptoms of diseases caused by *Alternaria*.

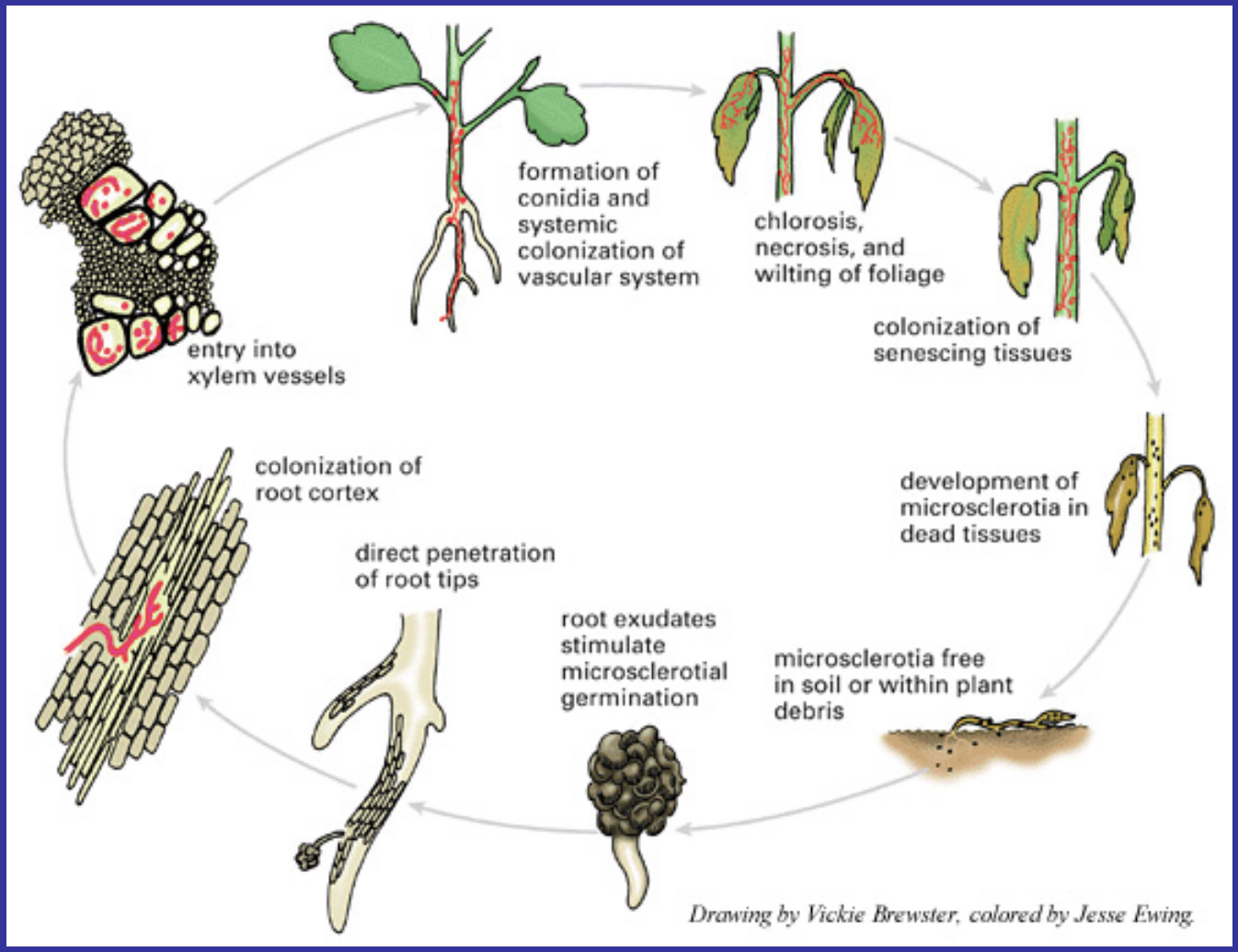
Verticillium wilt

Verticillium dahliae





Verticillium wilt

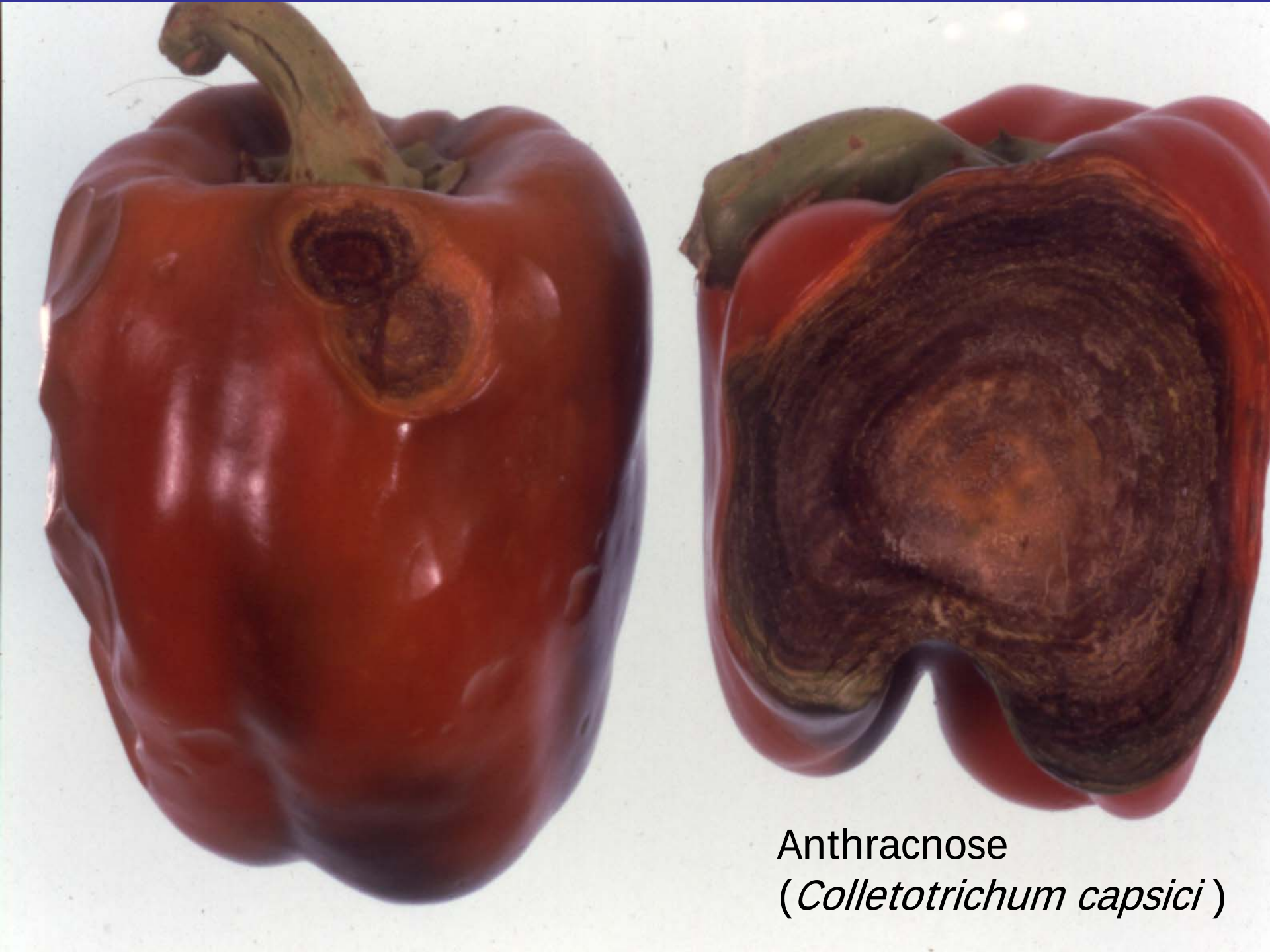


Anthracnose of Vegetable soybean (*Colletotrichum truncatum*)

Chilli anthracnose (*Colletotrichum capsici*)

ANTHRACNOSE
(*Colletotrichum circinans*)


Anthracnose
(*Colletotrichum gloeosporioides*)



Anthracnose
(*Colletotrichum capsici*)

Anthracnose
(*Colletotrichum truncatum*)

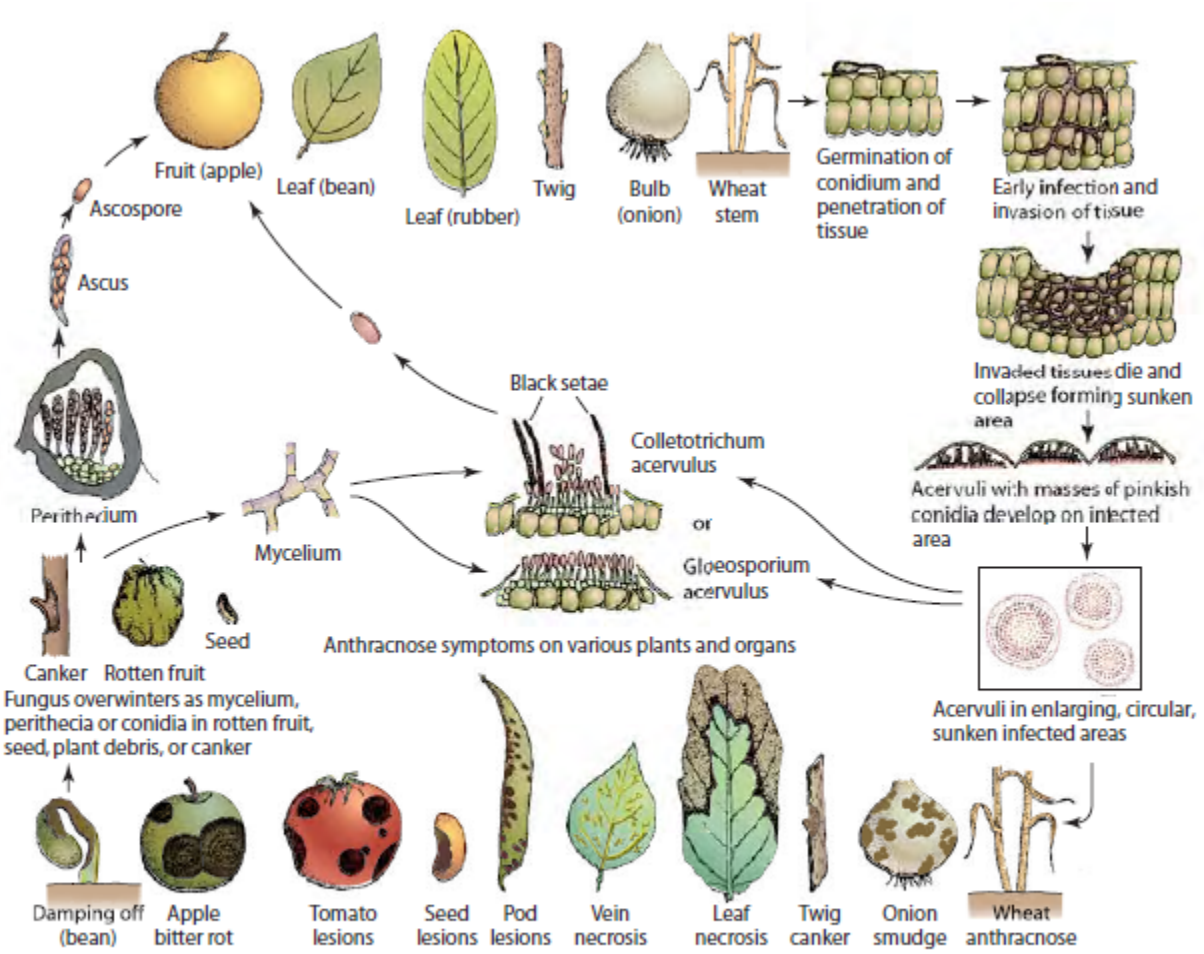


FIGURE 11-84 Disease cycle of anthracnose diseases caused by *Glomerella cingulata* and *Colletotrichum* or *Gloeosporium* sp.


Root rot of chilli
(*Sclerotium rolfsii)*


Root rot of tomato
(*Sclerotium rolfsii)*

Basidiomycotina

- Sexual spore (basidiospore) formed on the basidium
- Vegetative nuclei are haploid, cells are dikaryotic
- Classification based on structure of the basidium:
  - septate or non-septate

Basidiomycetes

- **Sexual spores**
  - **Basidiospores, produced on the outside of a specialized, microscopic, spore-producing structure called the basidium**
- **Asexual spores**
  - **Various types of asexual spores formed by some basidiomycetes**
  - **Sometimes called conidia**

Basidiomycota

- Sexual spores = basidiospores (Bspores = spores)
- Bspores prod. on basidium (Bsdm)
- Sexual fruit body = basidiocarp (Bcrp)
- Septate hyphae often w/clamps
- Simple or dolipore septa

Hymenomycetes

Basidia in a layer = hymenium

Agaricales

- Mushrooms - pileus/stipe
- Holobasidia - chiastobasidial type
- Hymenium lines gills or tubes
- Asexual phase gen. lacking
- Uni-, bi-factorial heterothallism

Tubes

Boletaceae
- Boletes
- Ectomycorrhizal
- Hymenium lines tubes
- *Boletus* • *Suillus*

Gills; White or Pink Spores

Russulaceae
- Ornamented bspores
- *Russula* • *Lactarius*

Tricholomataceae
- Attached gills
- *Flammulina* • *Clitocybe*
- *Marasmius* • *Armillaria*
- *Tricholoma* • *Laccaria*

Amanitaceae
- Free gills/annulus/volva
- *Amanita*

Hygrophoraceae
- Thick, waxy gills
- *Hygrophorus*

Pluteaceae
- Smooth, pink spores
- *Pluteus* • *Volvariella*

Gills; Brown/Black Spores

Coprinaceae
- Inky caps - black spores
- *Coprinus* • *Panaeolus*

Strophariaceae
- Purple-brown spores
- *Stropharia* • *Psilocybe*

Cortinariaceae
- Cortina
- *Cortinarius* • *Inocybe*
- *Galerina* • *Pholiota*

Agaricaceae
- Annulus/no volva
- *Agaricus*

Dacrymycetales

- Brown-rotter
- Bcrp - gelatinous, waxy yellow-orange
- Bsdm -tuning fork
- *Dacrymyces*

Auriculariales

- Saprobes on wood
- Parasites on fungi/plants
- Elongate metabasidia divided tranv. - 4 cells
- *Auricularia* • *Exidia*

Tulasnellales

- Saprobes on wood
- Parasites - plants
- Mycorrhizal-orchids
- Balloon-like sterigmata
- Bcrp-flattened -filmy crust, web-like
- *Tulasnella*

Tremellales

- Saprobes on wood/soil
- Bcrp - gelatinous brightly-colored
- Phragmobasidium
- Metabasidia divided longitudinally -- 4 cells
- Yeast stages in l.cycle
- *Tremella*

Ceratobasidiales

- Mycorrhizal - orchids
- Parasites - plants
- Holobasidia - deeply div.
- Septal pore caps/perf.
- *Ceratobasidium*
- *Thanatephorus*

Uredinomycetes

Uredinales

- Rust fungi
- Plant parasites/obligate biotrophs
- No basidiocarp
- Pleomorphic - up to 5 spore stages
- Teliospores
- Simple septa/No septal pore cap
- Mating system - unifactorial
- *Puccinia* • *Gymnosporangium*
- *Uromyces* • *Melampsora*
- *Coleosporium* • *Cronartium*

Septobasidiales

- Obligate w/scale insects
- Bcrp - dry, crust, spongy
- Basidia - transv. septate
- Clamps/dolipore absent
- Teliospores
- *Septobasidium*
- *Uredinella*

Sporidinales

- Basidiomycetous yeasts
- Simple septa
- Teliospores
- *Rhodosporidium*
- *Sporidiobolus*

Ustilaginomycetes

Ustilaginales

- Smut fungi
- Plant parasites - angiosperms
- No septal pore cap
- Saprobic phase
- Teliospores = resting spore
- *Ustilago* • *Tilletia*

Exobasidiales

- No basidiocarp
- Holobasidia - 1-celled
- Simple septa
- Parasites of Ericaceae
- Intracellular hyphae
- Produce gall-like growths
- *Exobasidium*

Aphyllophorales

- Wood-decay; plant pathogens
- Bcrp - variable texture, not soft
- Lack gills, gymnocarpous
- Holobasidia
- Heterothallic; bifactorial mating

Corticiaceae
- Resupinate/lignicolous
- *Corticium* • *Botrybasidium*

Hericiaceae
- Saprobes - tree wounds
- Gloeoplerous hyphae
- Hymenium on teeth
- *Hericium*

Coniophoraceae
- Saprobes on building wood
- Hymenium - smooth or toothed
- Rhizomorphs
- *Serpula*

Ganodermaceae
- Delignifiers/clamps
- Poroid, ovoid, gold bspores
- *Ganoderma*

Schizophyllaceae
- White-rotter/split-gills
- *Schizophyllum*

Stereaceae
- Bcrp - leathery/corky/woody
- Hymenium - smooth
- *Stereum* • *Veluticeps*

Clavariaceae
- Coral/Club fungi
- Saprobes - soil, wood
- *Clavaria*

Thelephoraceae
- Lignicolous, mycorrhizal
- Smooth, toothed, poroid
- *Thelephora*

Cantharellaceae
- Chanterelles
- Hymenium on ridges
- *Cantharellus* • *Craterellus*

Hydnaceae
- Bcrp - fleshy, stalked
- Hymenium - toothed
- *Hydnum*

Hymenochaetaceae
- White-rotters/clamps absent
- Poroid, smooth, hyaline bspores
- *Phellinus* • *Inonotus*

Polyporaceae
- White/brown-rotters
- Poroid, smooth hyaline bspores
- *Polyporus* • *Trametes* • *Fomes*

Gastromycetes

- Polyphyletic
- Bspores mature within Bcrp

Lycoperdales

- Common puffballs, earthstars
- Saprobes - soil, litter, wood
- Peridium - exo-, endo-
- Gleba = true hymenium
- *Calvatia* • *Lycoperdon*
- *Geastrum*

Sclerodermatales

- Hard puffballs, earthballs
- Saprobes/ectomycorrhizal
- Peridium - thick, hard, 1-layered
- Gleba - dark/ no ostiole
- *Scleroderma* • *Psilolithus*

Tulostomales

- Stalked puffballs
- Xeric habitats
- *Tulostoma* • *Calostoma*

Phallales

- Stinkhorns
- Saprobes
- Peridium - 3-layered
- Gleba = true hymenium
- Bspores - insect dispersed
- *Phallus* • *Pseudocolus*
- *Dictyophora*

Nidulariales

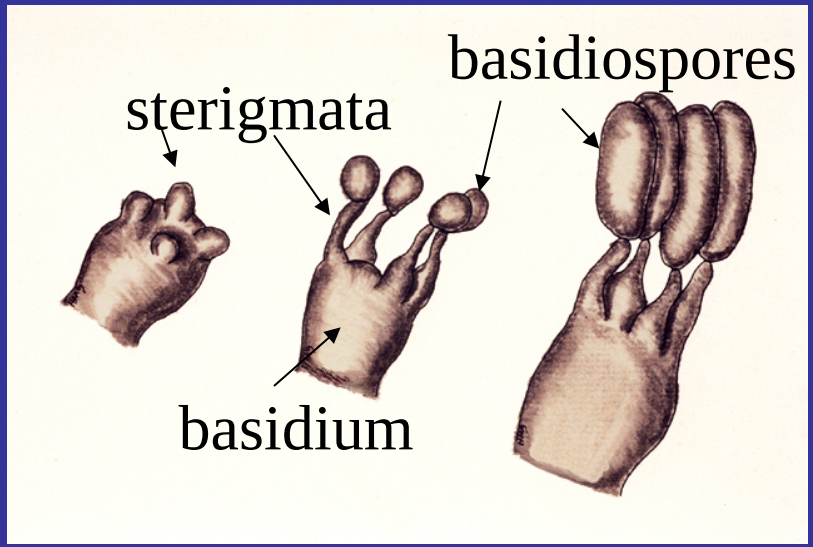
- Bird's nest, cannonball fungi
- Splash cup, explosive dispersal
- Bspores in peridioles
- *Sphaerobolus* • *Cyathus*
- *Crucibulum*

Hymenogastrales

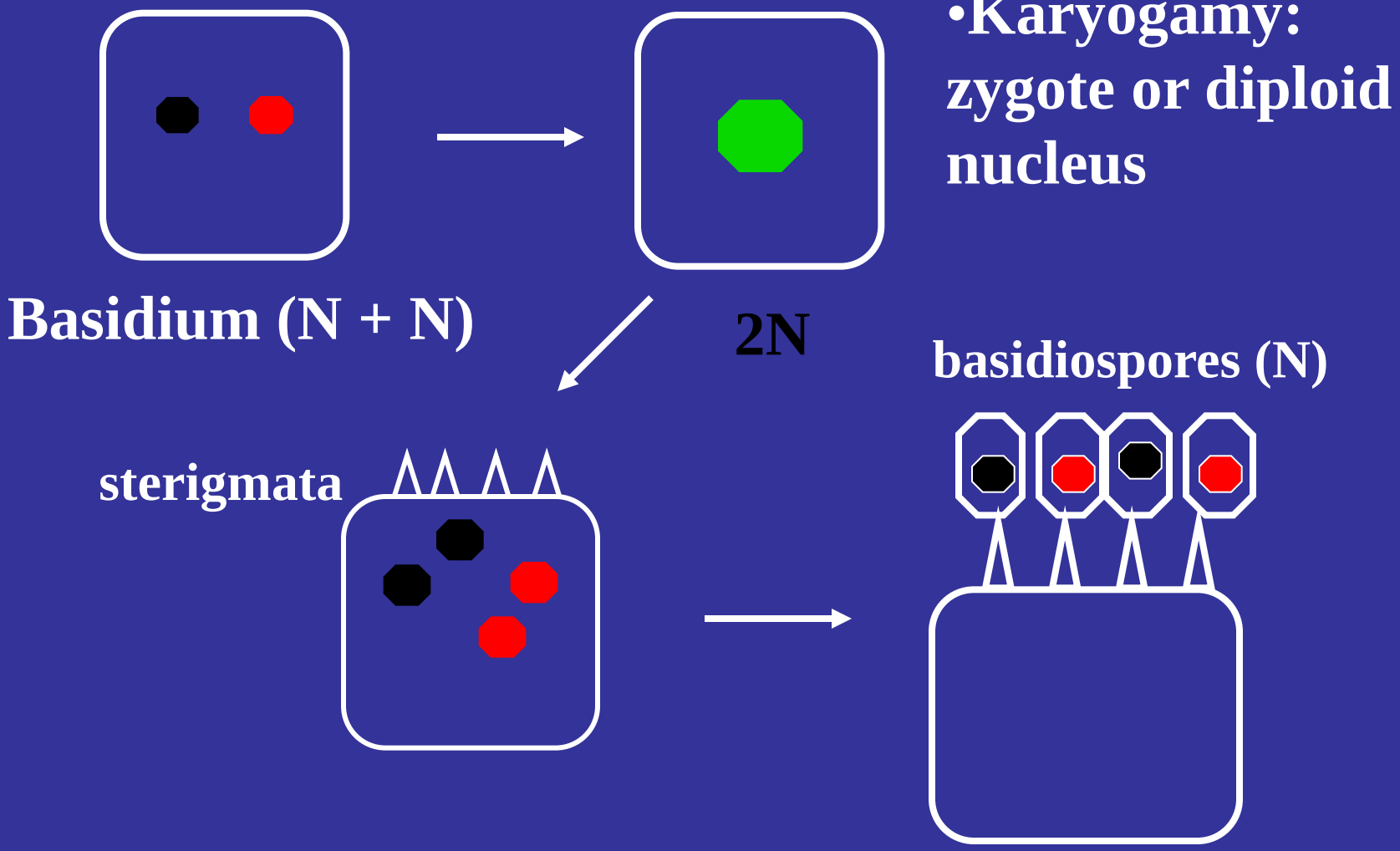
- False truffles
- Hypogeous/animal-dispersed
- Chambered hymenium
- *Rhizopogon* • *Hymenogaster*

Sexual Spore = Basidiospore

- Product of meiosis
- Spores formed on sterigmata
- Sterigmata arise from basidium



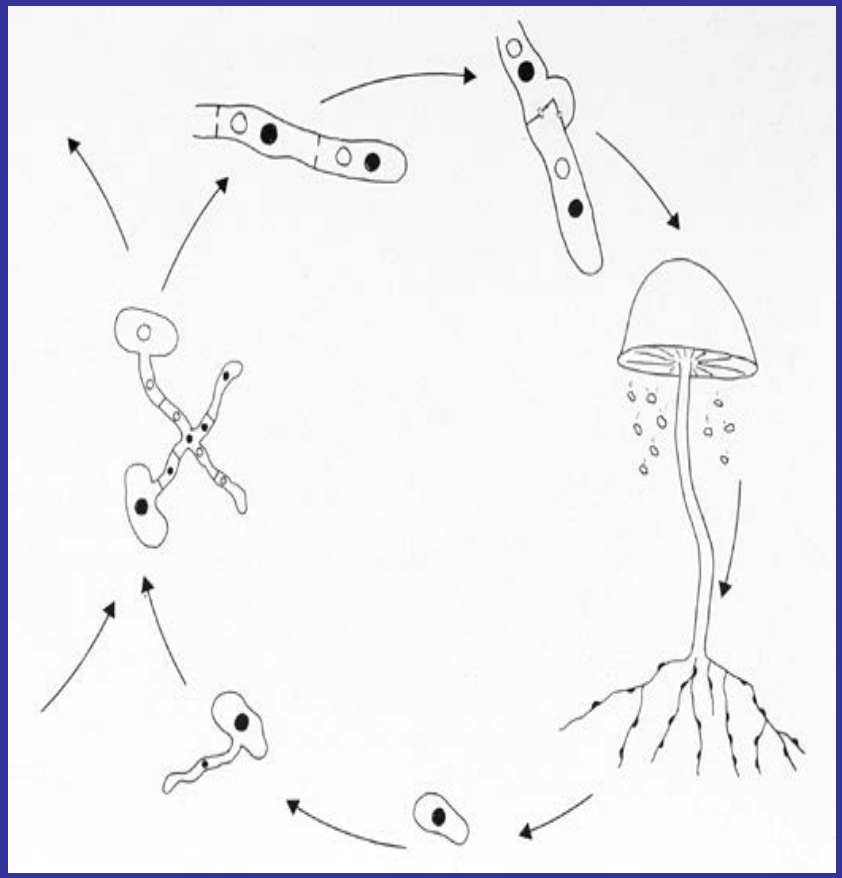
Haploidization (N)



- **Karyogamy: zygote or diploid nucleus**

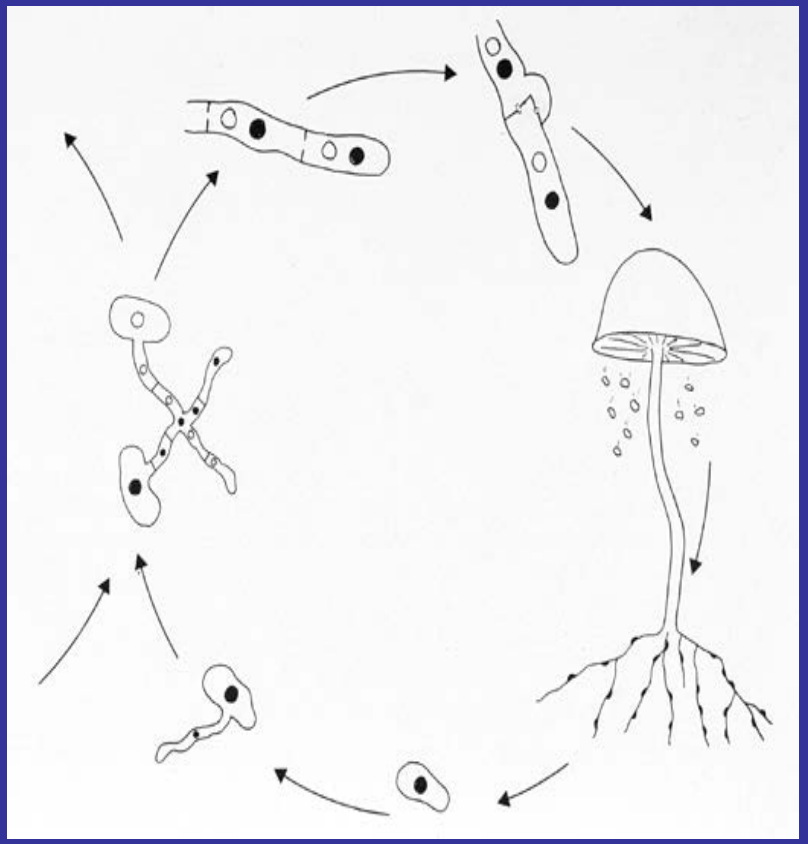
Basidiomycetes: reestablish the dikaryotic condition (N + N)

- Life cycle of a basidiomycete
- Dikaryon reestablished by fusion of (N) hyphae and migration of nuclei
- **Anastomosis** = fusion of hyphae



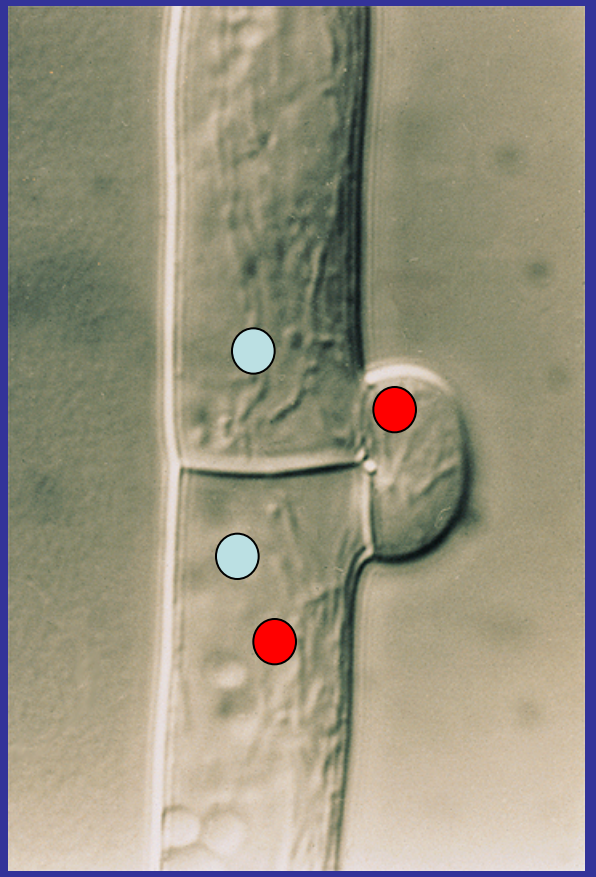
Dikaryon Formation

- Frequently identical N genotypes will not form dikaryon
- **Mating types** = genes control whether two hyphae will anastomose
- Ensures outcrossing



How do Basidiomycetes maintain dikaryotic (N+N) status?

- **Clamp connections**: formed during the conjugate division of the nuclei in the tip of a growing hypha
  - Regulate movement of nuclei from cell to cell
- **Dolipore septum** prevents movement of nuclei from cell to cell

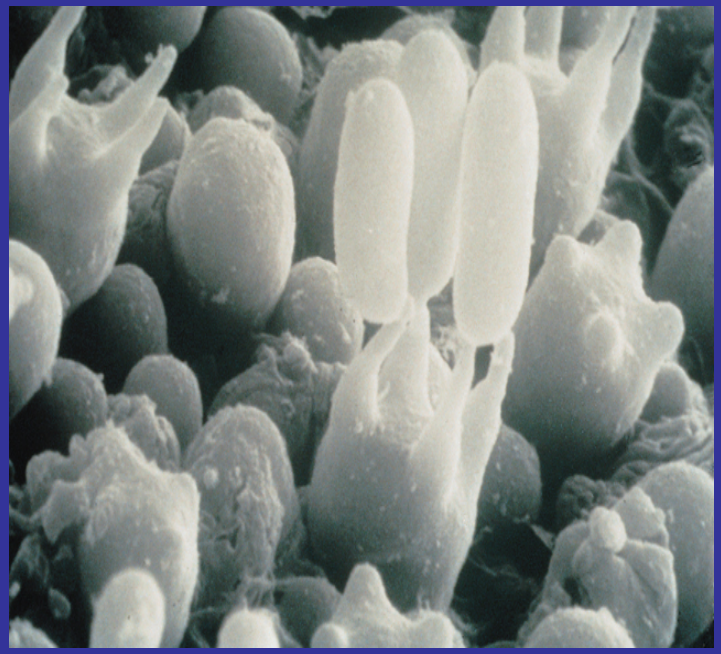


Members of Basidiomycetes

"Mushrooms"

Basidiocarps: fruiting bodies that bear the basidia

Basidiospores can be seen from gills of mushrooms



Fairy Rings

Basidiomycetes: diverse group of fungi and diseases

- **Rusts**
- **Smuts**
- **Seed and seedling rots**
- **Leaf blights**
- **Root and stem rots**
- **Wood rots**

Rusts

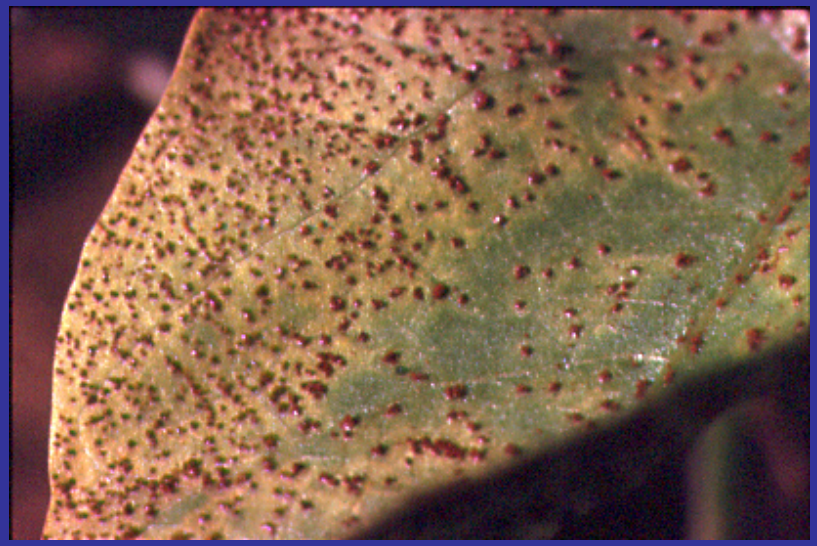
- Order: Uredinales
- ~ 5000 species
- Obligate parasites
- Destructive, esp. grain crops
- Historical famines
- Robigus and Robigalia: Roman Empire

Economic Impact of Rusts

- Millions of dollars per year in crop loss
- Important pathogens:
  - *Cronartium ribicola*
    - white pine blister rust
  - *Endocronartium harknessii*
    - western gall rust
  - *Melampsora larici-populina*
    - poplar leaf rust
  - *Puccinia striiformis*
    - yellow rust
  - *Puccinia graminis* f. sp. *tritici*
    - black stem rust of wheat
  - *Hemelia vastatrix*
    - coffee rust
  - *Phakopsora pachyrizi*
    - soybean rust
    - Australia
  - *Puccinia pittieriana*
    - potato rust
    - potential problem

Signs/Symptoms

- Attack stems and leafs
- Leaf spots
- Numerous lesions
  - blisters or pustules
  - spores rupture epidermis



Rust Reproduction

- Up to five spore types
- All five = **macrocyclic** rust
- Less than five = **microcyclic** rust
- Macrocyclic
  - One host = **autoecious**
  - Two hosts = **heteroecious**

Rust Reproduction

- Spore stages
  - Stage 0 = Spermatia(-um) / Spermogonia(-um)
  - Stage I = Aeciospore(s) / Aecia(-um)
  - Stage II = Uredospores / Uredia(-um)
  - Stage III = Teliospores / Telia (-um)
  - Stage IV = Basidiospores* / Basidia(-um)

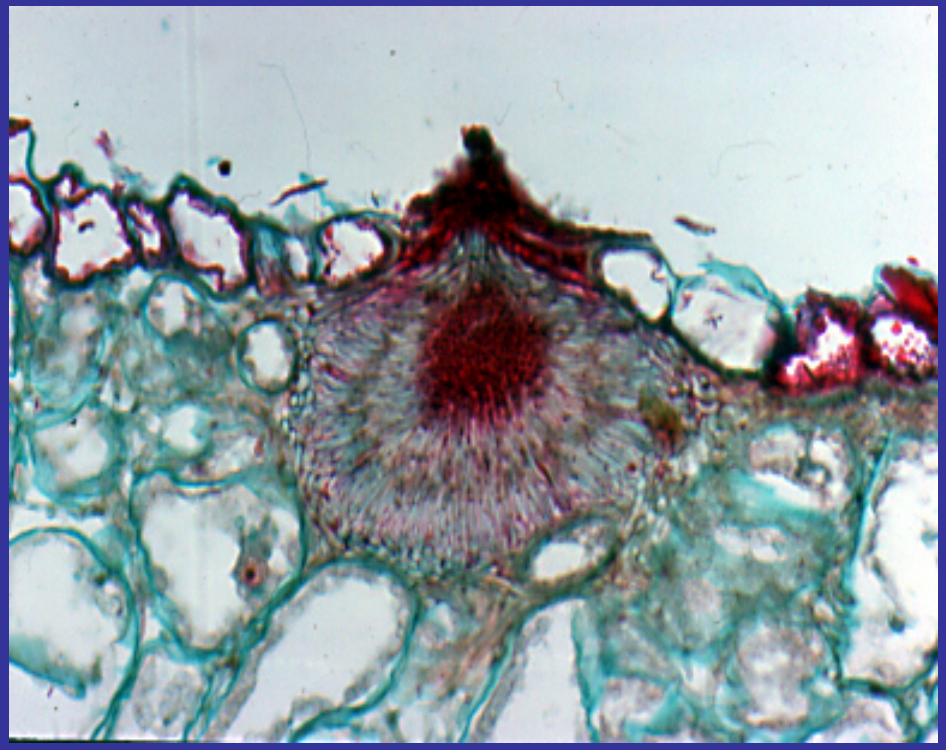
*formerly pycniospores

Rust Reproduction

- Up to five spore types
- All five = macrocyclic rust
- Less than five = microcyclic rust
- Macrocyclic
  - One host = autoecious
  - Two hosts = heteroecious
    - primary (telial) host = one host for stages II, III, IV
    - alternate (aecial) host = host for stages 0 and I

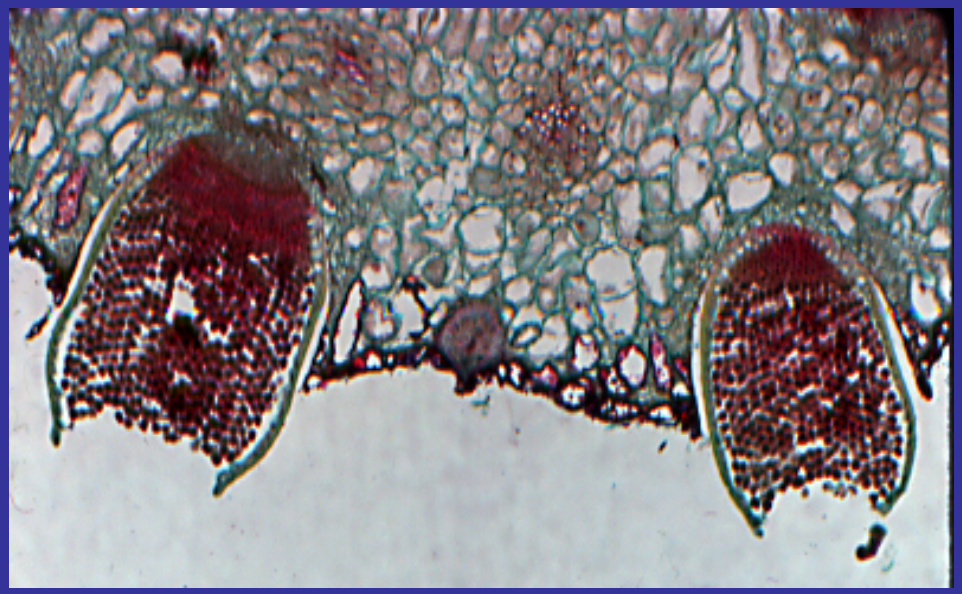
Stage 0: Spermogonium

- Spermogonium formed from infection by basidiospore (N)
- Spermatia formed
- Receptive hyphae formed
- Spermatia fuse with receptive hyphae of opposite type
- Dikaryon reestablished (N + N)

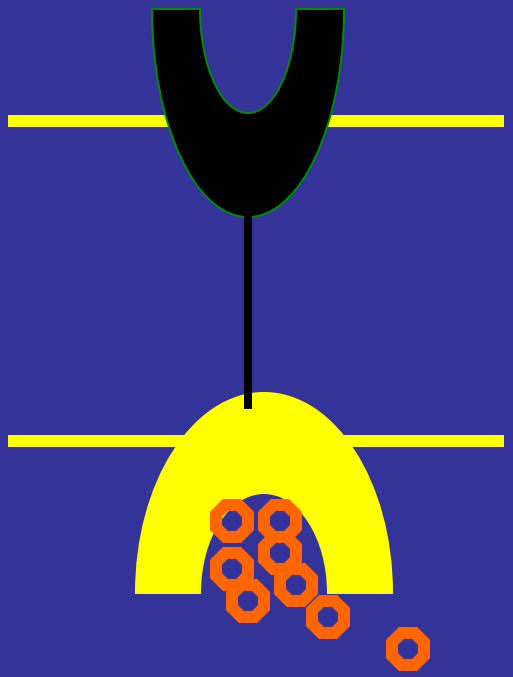


Stage I: Aecium

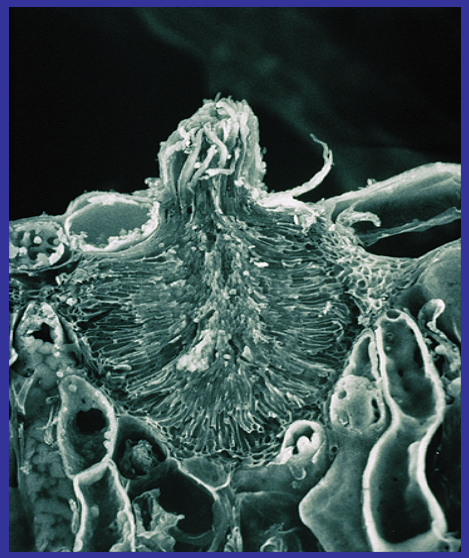
- Dikaryon hyphae from spermogonium migrate to tissue below to form aecium
- Aecia form on bottom leaf
- Aeciospores formed
- Disseminated to alternative host if heteroecious rust

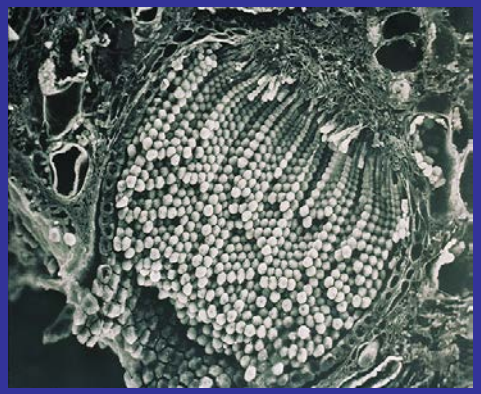


Top of leaf:
spermogonium



Bottom of leaf:
aecium





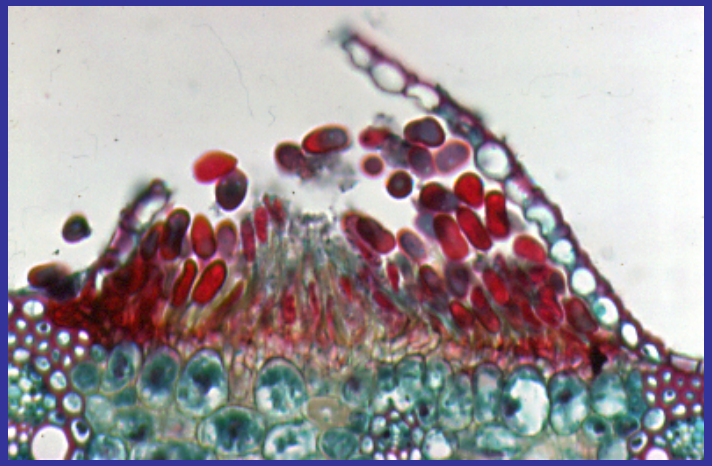
Aecium & Aeciospore Biological and Pathological Significance

- Captures dikaryotic state in a spore - aeciospore
- Aeciospores wind disseminated
- Disperse old and new genotypes of rust fungus
- Aeciospores serve as **primary inoculum**

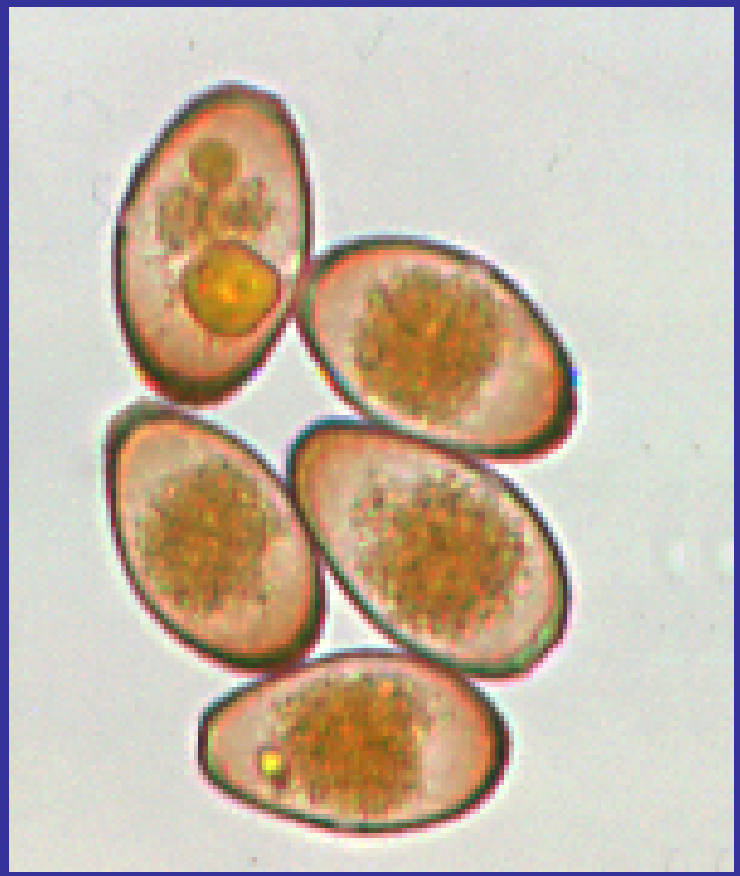
Stage II: Uredium

- Arises from dikaryotic mycelium from germinated aeciospores or urediospores
- Urediospores form in uredium
- Disseminated to same host: repeating stage
- Secondary inoculum
- Associated with polycyclic diseases

Stage II: Uredium

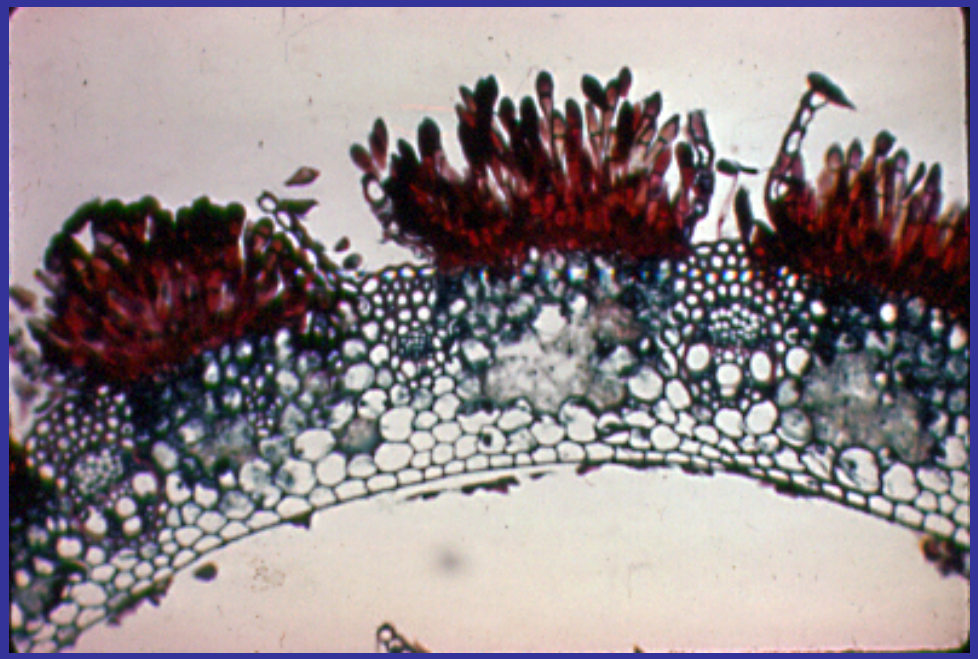


- Rupture of epidermis
- Repeating spore
- Rust color



Stage III: Telium

- Teliospores formed within telium
- Frequently uredium converts to telium
- Common to observe urediospores and teliospores in same pustule
- Teliospores form when host is near end of life cycle : **overwintering spores**

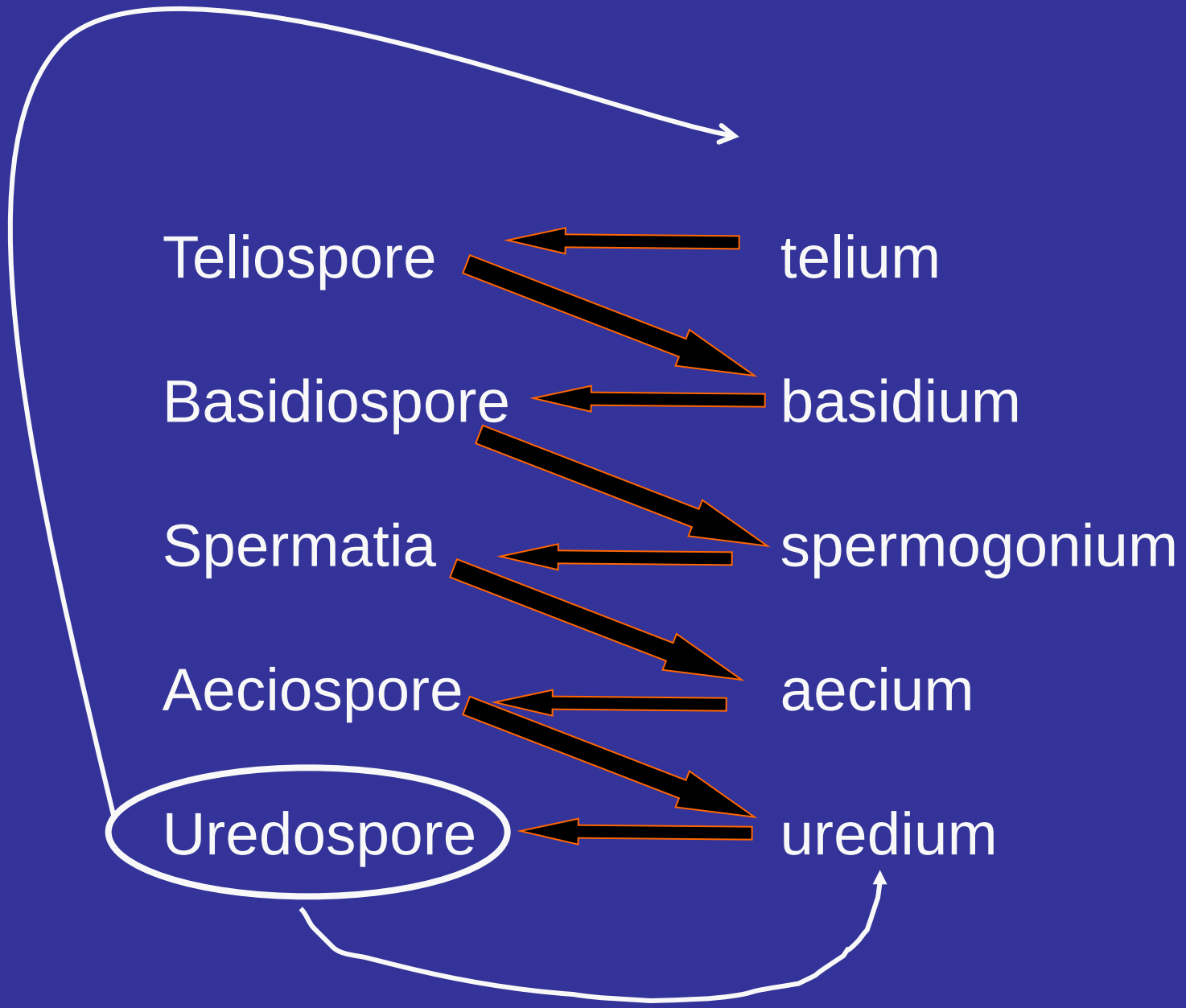


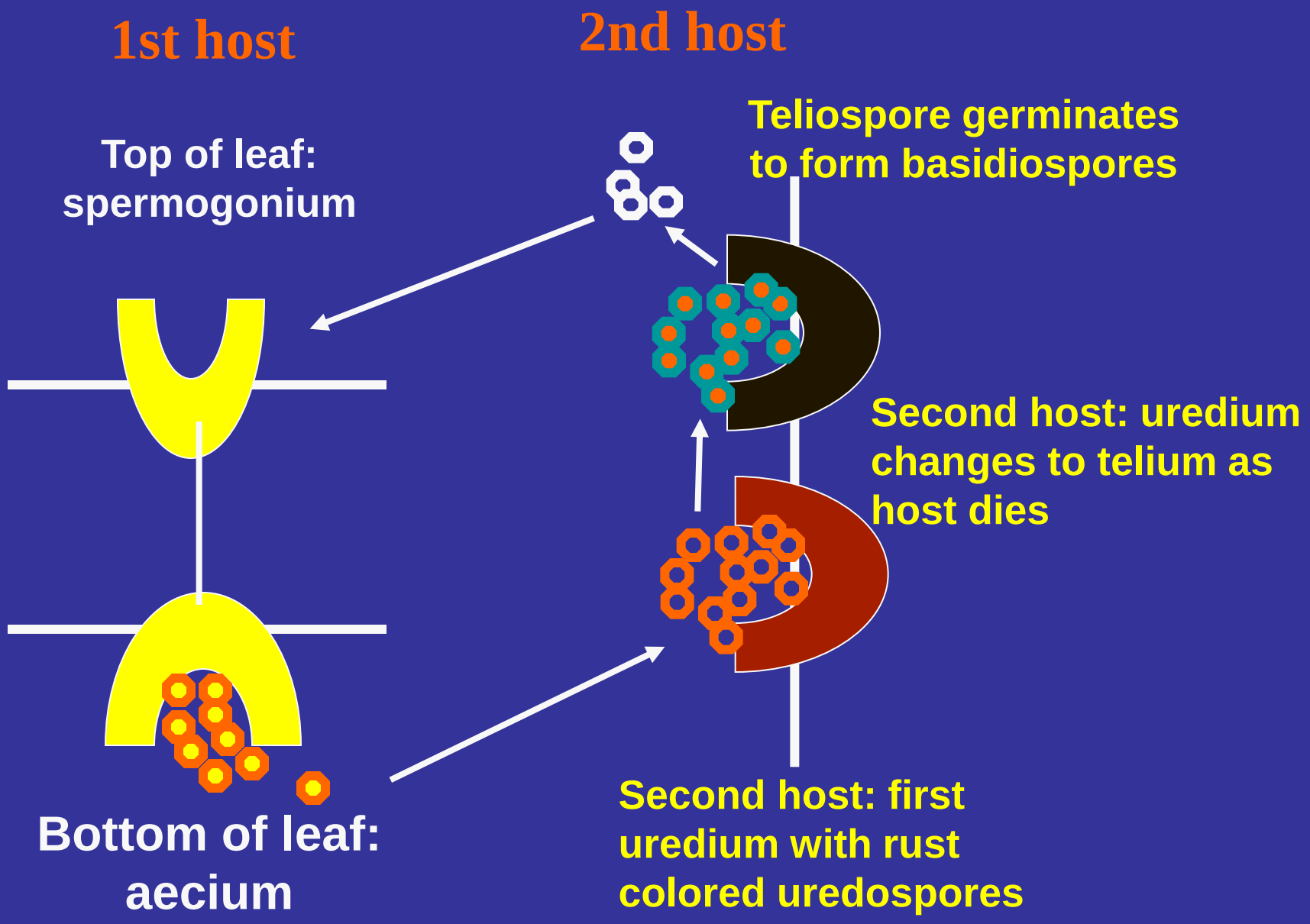
Stage III: Telium

- Survival structure
- Site of nuclear fusion
- (N+N) to 2N
- Meiosis
- Teliospores can not infect but germinate to form basidiospores (N)

Stage IV: Basidium

- Basidium emerges from germinating teliospore
- Four haploid (N) basidiospores formed on basidium
- Basidiospores wind dispersed
- Disseminated to alternative host if heteroecious rust


Teliospore
telium
Basidiospore
basidium
Spermatia
spermogonium
Aeciospore
aecium
Uredospore
uredium


1st host
2nd host
Top of leaf: spermogonium
Teliospore germinates to form basidiospores
Second host: uredium changes to telium as host dies
Bottom of leaf: aecium
Second host: first uredium with rust colored uredospores

Rust Reproductive Structures

Spore	Sorus	Infect Host
Teliospore	telium	no
Basidiospore	basidium	yes
Spermatia*	spermogonium	no
Aeciospore	aecium	yes
Uredospore	uredium	yes

Genus: *Puccinia*

- largest genus
- 3000 - 4000 species
- angiosperms
- heteroecious forms often have grasses as primary (uredinial/telial) hosts
- teliospores = 2 - celled
- *P. graminis* = stem rust
- *P. coronata* = crown rust of oats
- *P. sorghi* = common maize rust
- *P. polysora* = tropical maize rust
- *P. helianthi* = sunflower rust
- *P. antirrhini* = snapdragon rust
- *P. arachidis* = peanut rust

Puccinia graminis f. sp. tritici

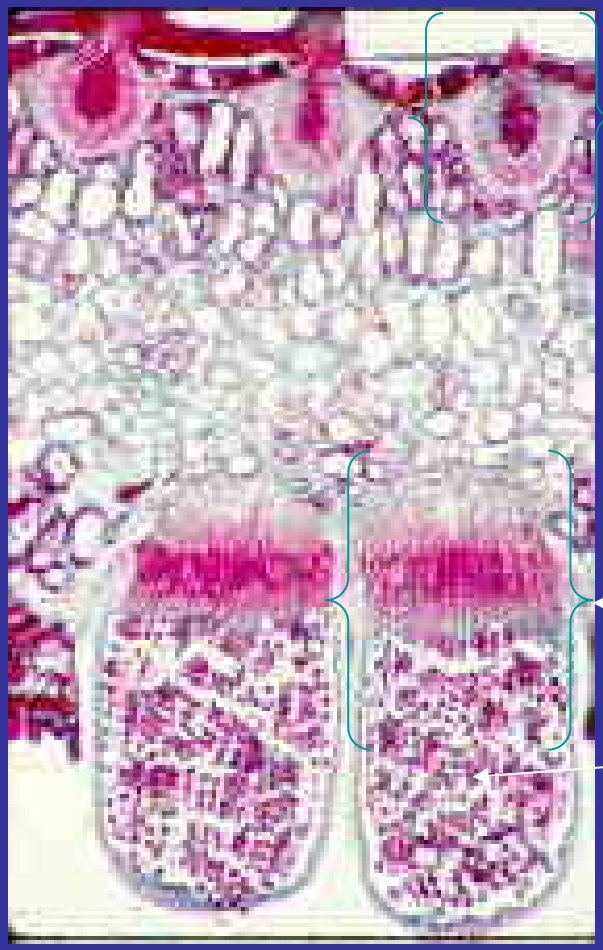
- **Stem rust of small grains**
- **2 hosts**
- **Uredium on grass**
- **Aecium on barberry**
- ***Puccinia graminis f.sp. hordei* (barley)**

Barberry (*Berberis* spp.): Alternate Host to *Puccinia graminis*

- Barberry
- Common shrub
- Introduced from Europe
- Rust reproduction
  - Spermogonium
  - Aecium

Barberry Infection

Cross secction of leaf



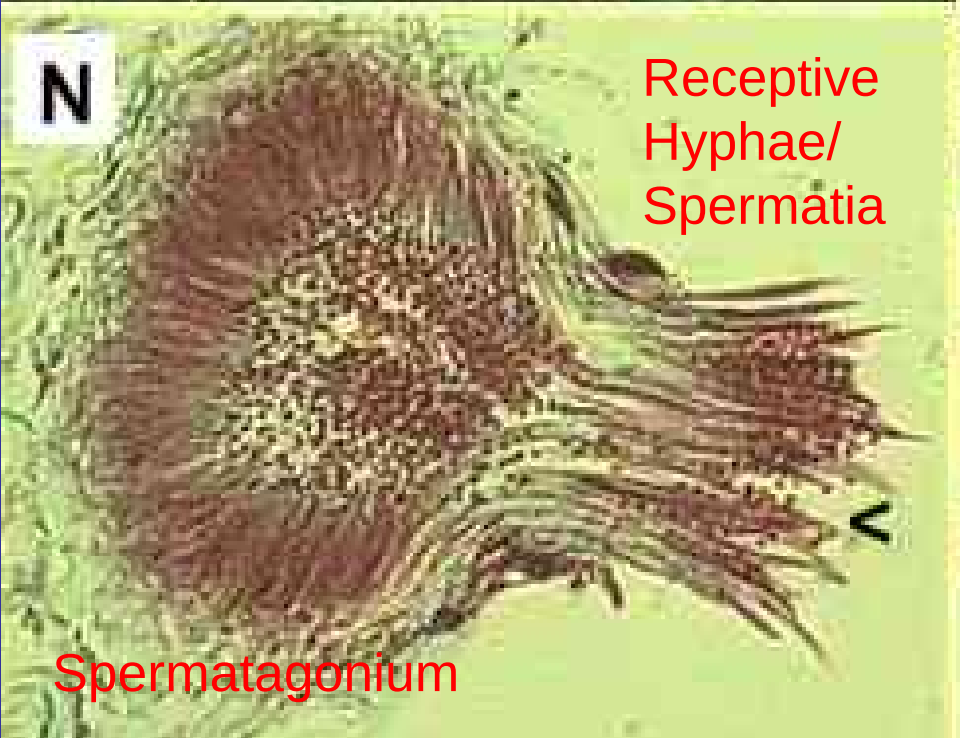
Spermogonium

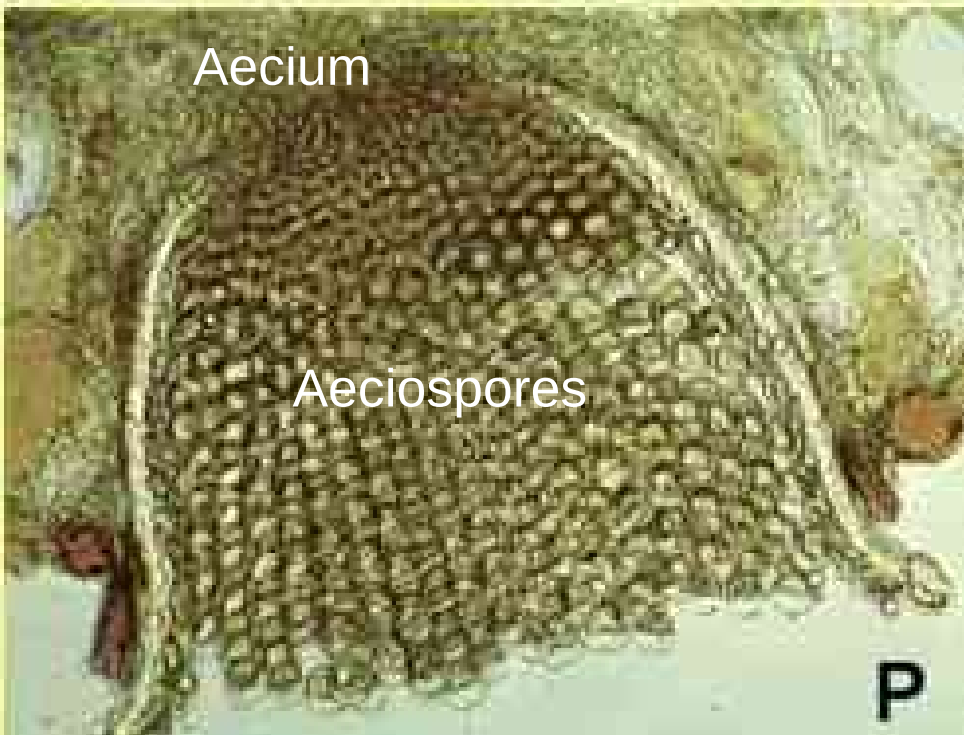
Aecium

Aeciospores (n + n)

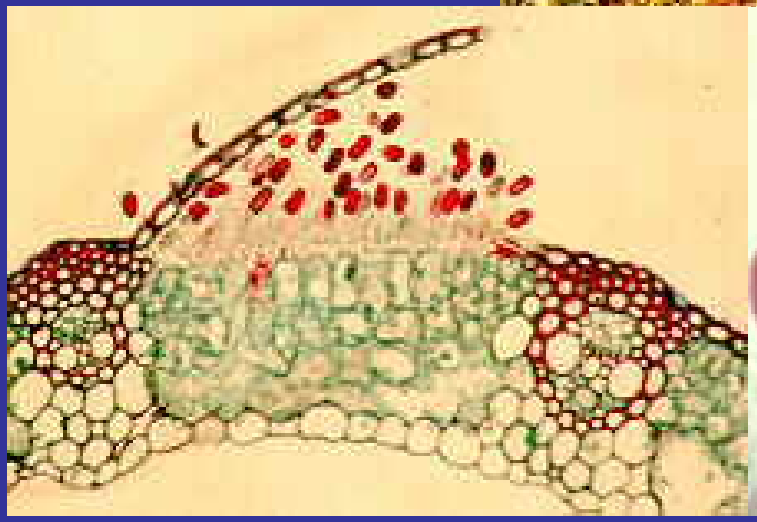

M
Barberry


O
Spermatagonia


N
Receptive
Hyphae/
Spermatia
Spermatagonium

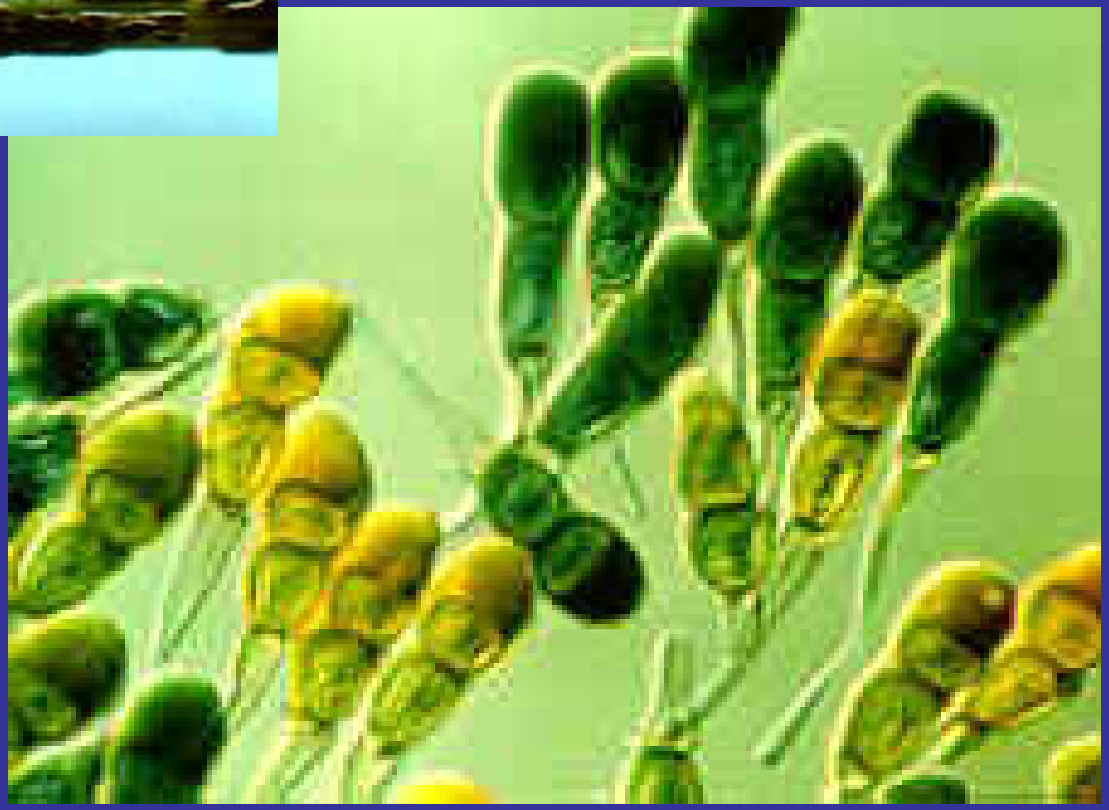

Aecium
Aeciospores
P

Uredia/Urediospores of *Puccinia graminis*



From: The Fifth Kingdom Online

Telia/2 - celled Teliospores of *Puccinia graminis*



From: The Fifth Kingdom Online

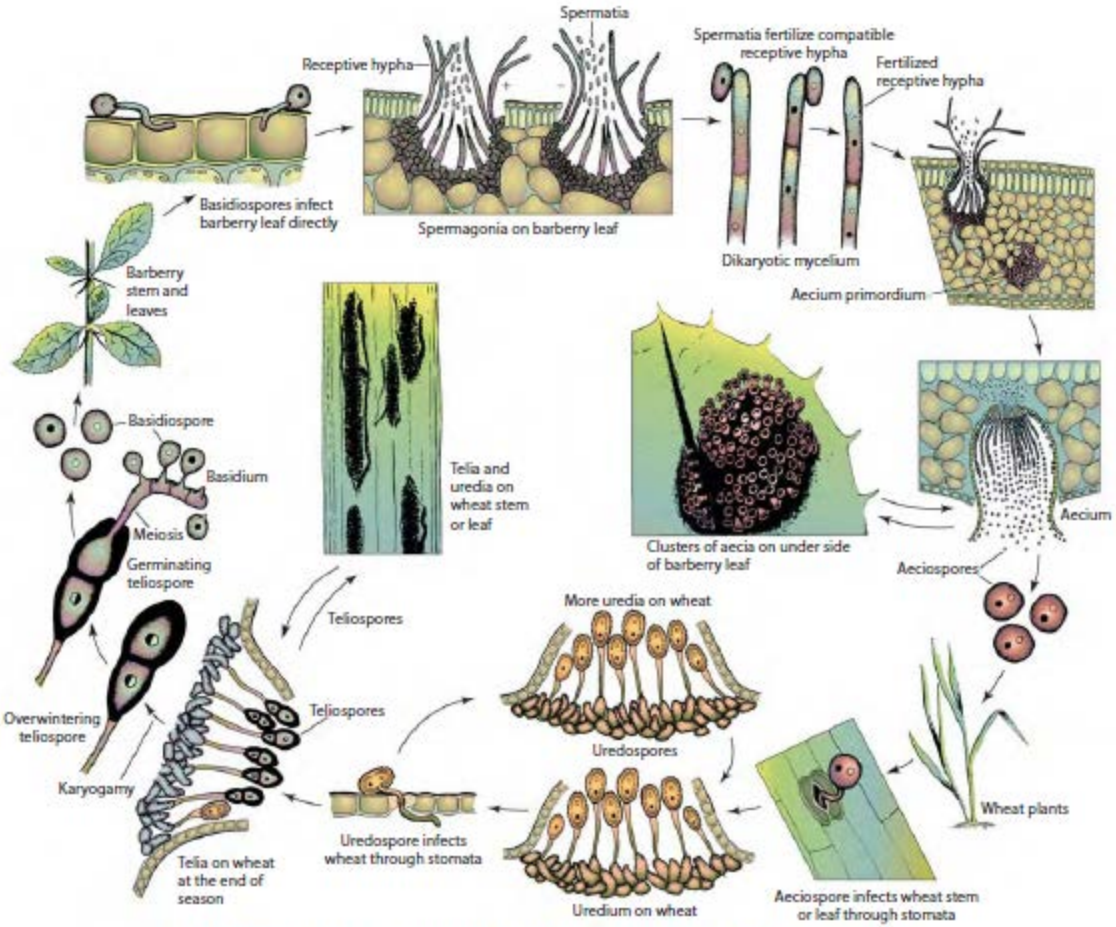


FIGURE 11-134 Disease cycle of stem rust of wheat caused by *Puccinia graminis tritici*.

Other Rusts

Snapdragon rust

Puccinia antirrhini

Coffee rust

Hemelia vastatrix

Other Rusts

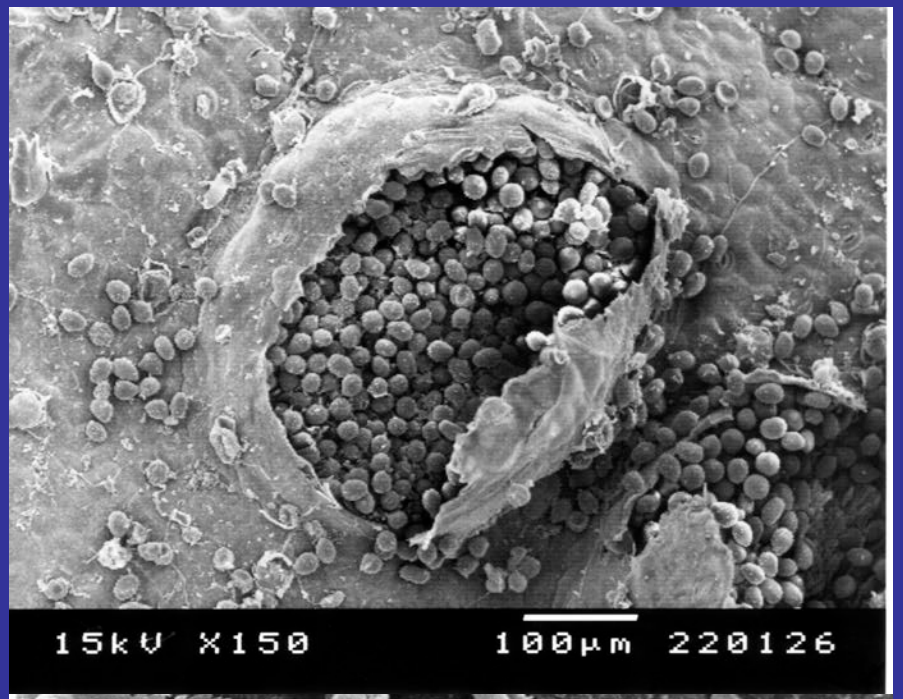
Cedar apple rust

Gymnosporangium juniperi-virginianae

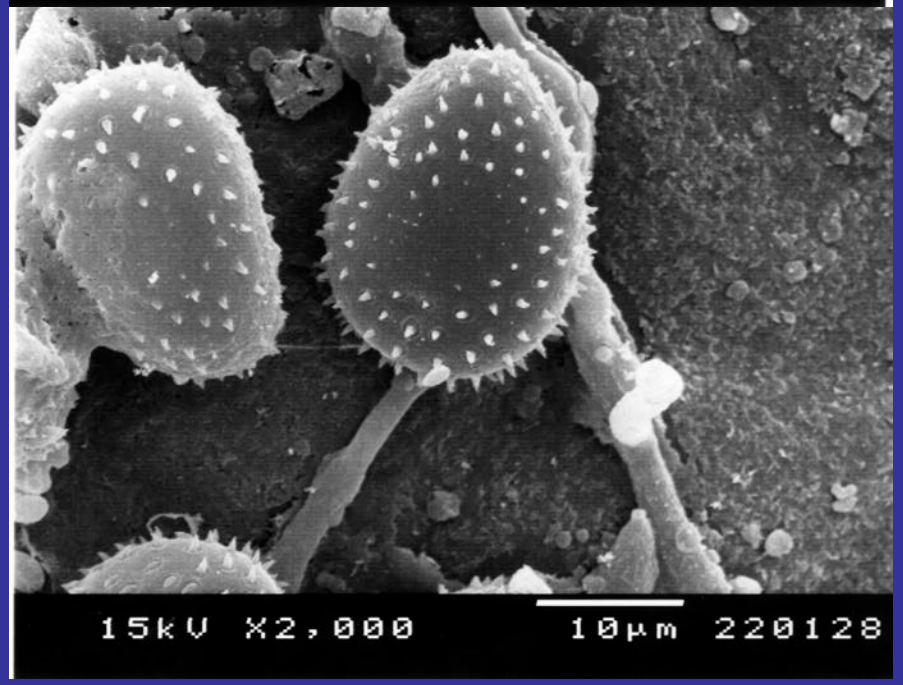
Bean rust

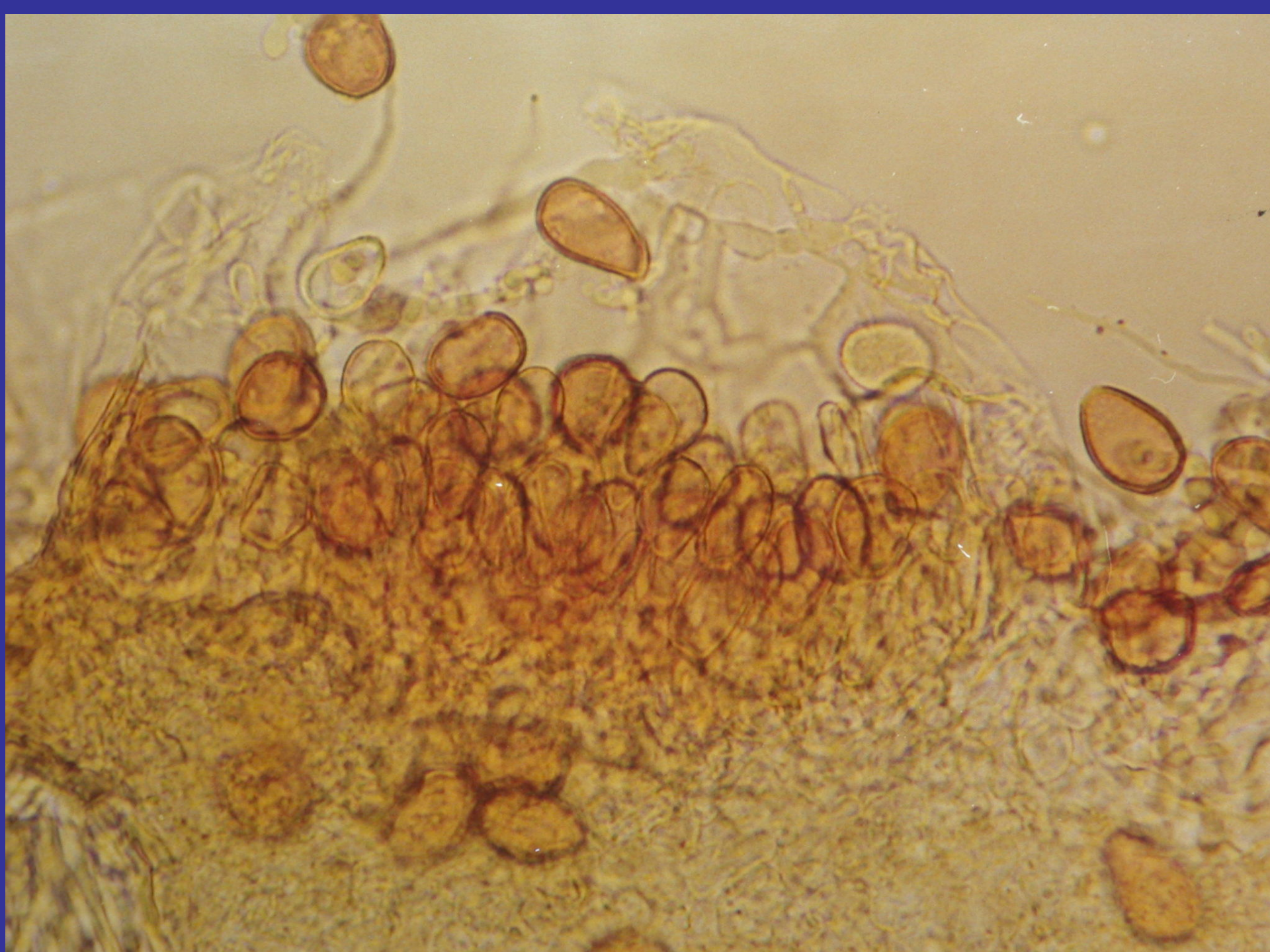
Uromyces appendiculatus

Pastule of
Uromyces sp.



Urediospore





Smut Fungi

- “Smut” from dark, dusty masses of teliospores produced in host tissue
- Economically important pathogens include:
  - *Ustilago maydis* (corn smut)
  - *Ustilago avenae* (loose smut of oats)
  - *Tilletia controversa* (dwarf bunt of wheat)
  - *Tillieta tritici* and *T. laevis* (common bunt)
  - *Tilletia indica* (Karnal bunt of wheat)
  - *Urocystis cepulae* (onion smut)
  - *Urocystis agropyri* (flag smut)

- 1200 species, 50 genera, infect > 4000 species of plants in 75 families of angiosperms
- Experimental organisms:
  - *Ustilago maydis*
  - *Microbotryum violaceum*

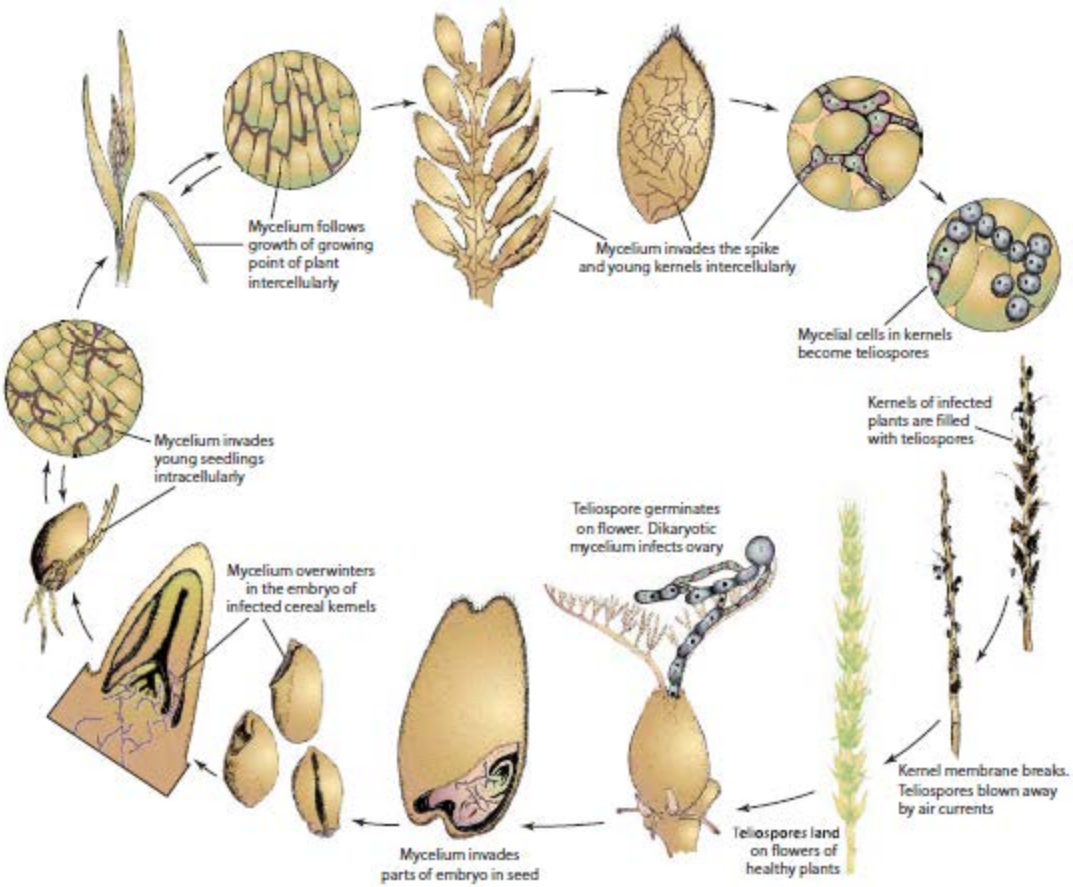
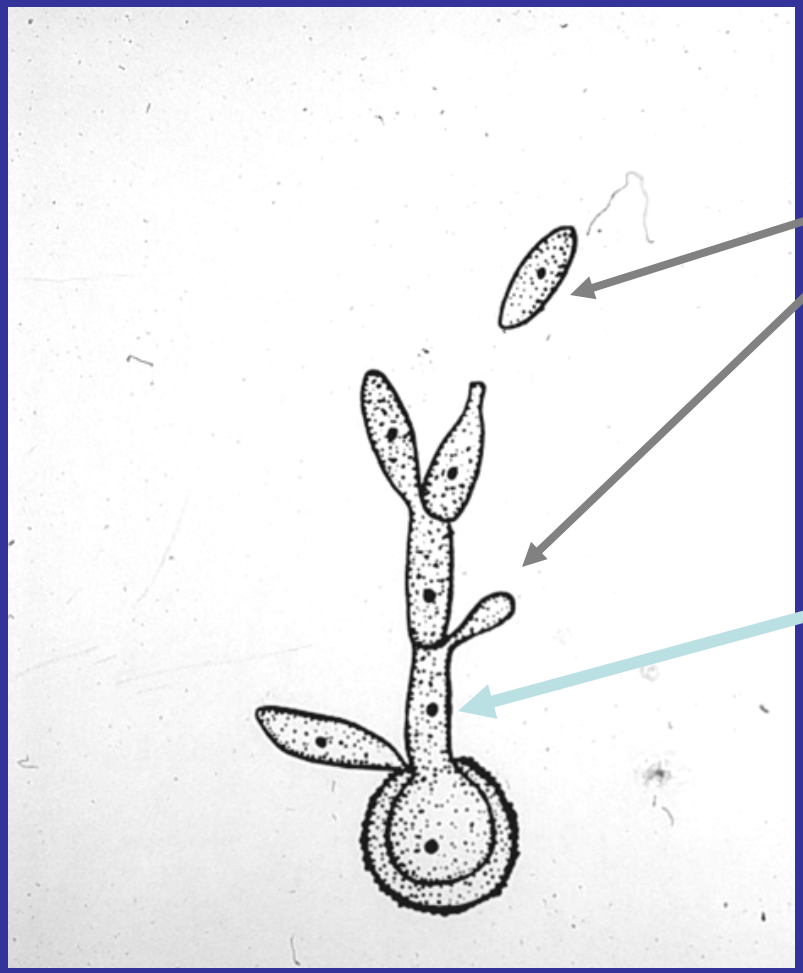
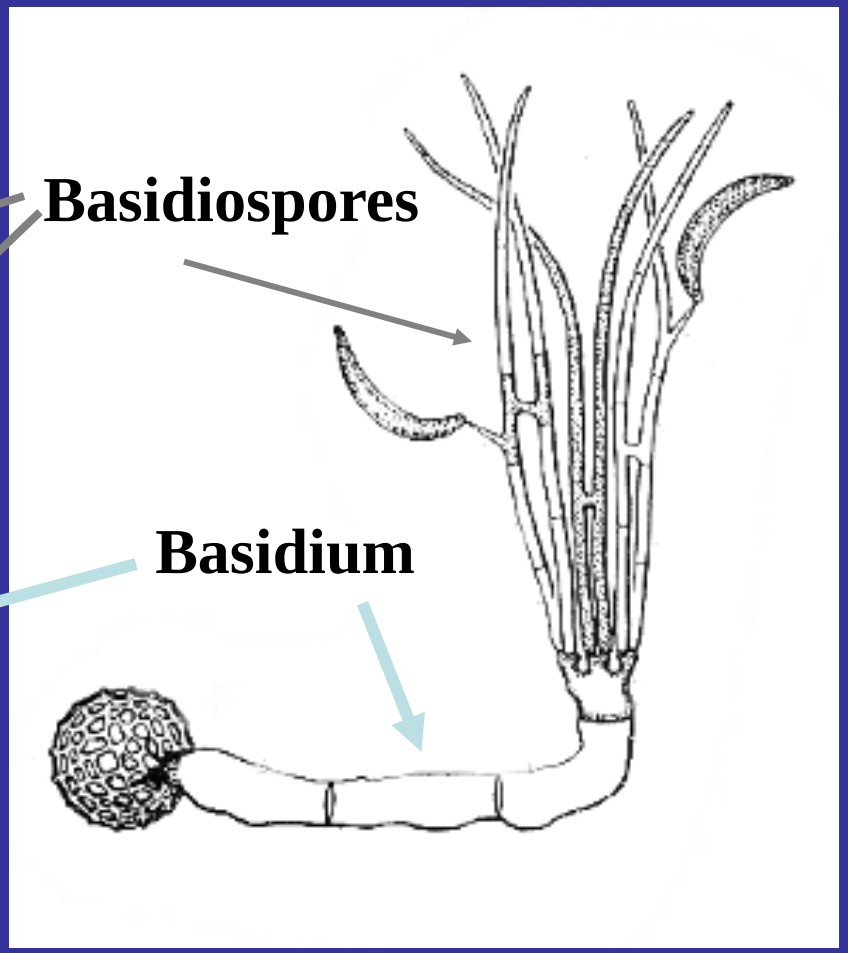


FIGURE 11-147 Disease cycle of loose smuts of barley and wheat caused by *Ustilago nuda* and *U. tritici*.

Teliospore germination



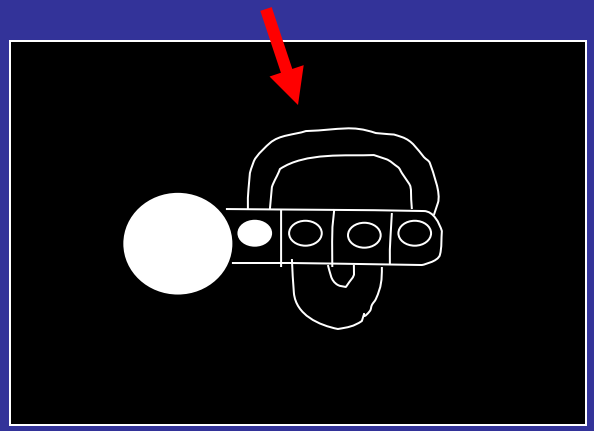
Ustilago-type

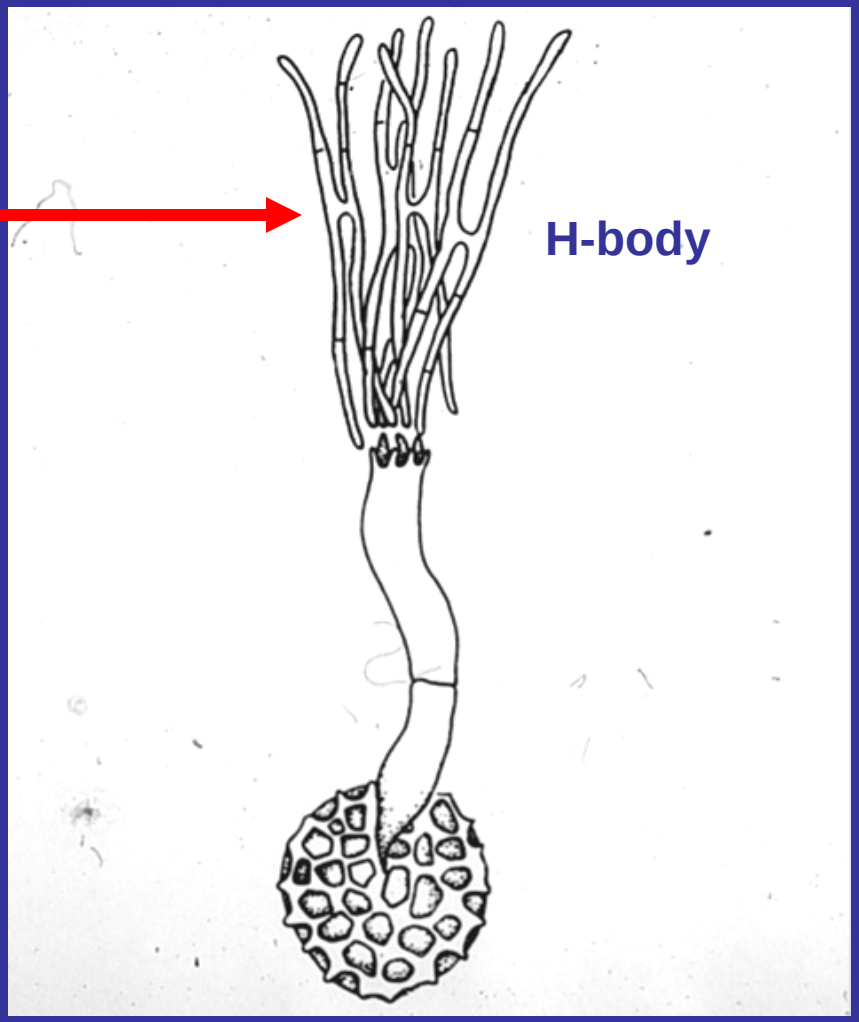


Tilletia-type

Dikaryon formation

- Conjugation of primary or secondary basidiospores
- Conjugation of basidium cells





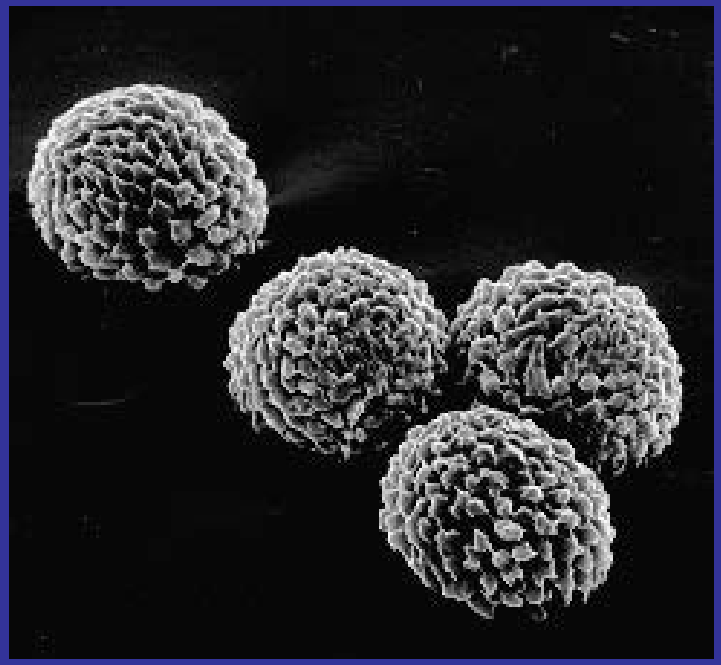
Sori

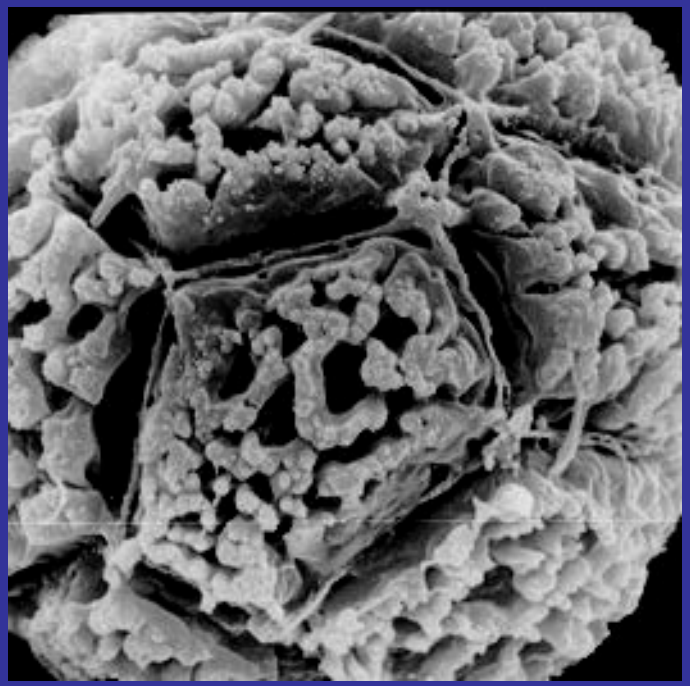
- Composed of host and fungal tissues
- Teliospores are formed in sori
- Formed in host ovaries, stems, leaves, or roots depending on the smut taxon
- Characters of taxonomic importance include:
  - Thread-like structures (fungal)
  - Sterile cells
  - Columella (host)
  - Peridium (host or fungus)
    - Persistent = covered smut
    - Thin, breaking down to expose spores = loose smut

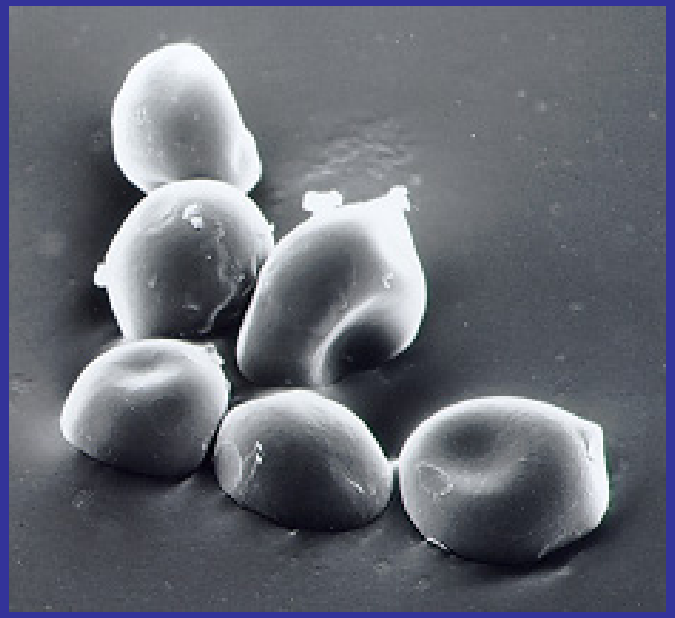

JUN 21 2002

Teliospores

- Formed singly or in spore balls
- Mostly globose, pigmented, with thick, ornamented walls
- Size ranges from 3.5 to 60 microns diam.
- Teliospore mass is usually dark
- Resistant structures, in some species can survive up to 10 years in soil, and 25 years or more under optimal conditions







Smut Diseases

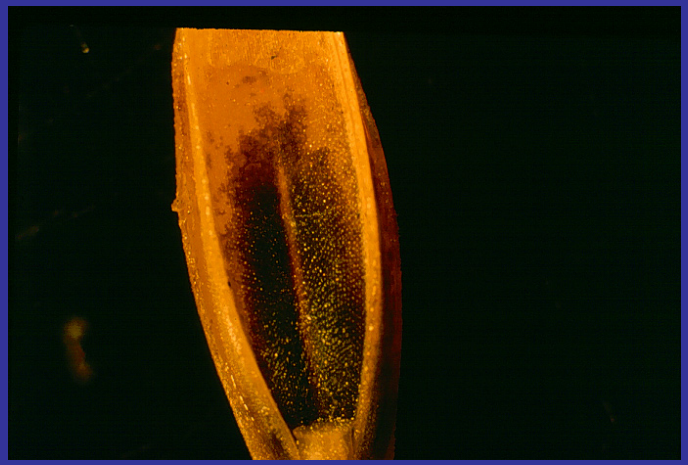
- Based on location of sorus in host:
  - Inflorescence smuts
  - Leaf smuts
  - Stem smuts
  - Root smuts

Infection Types

- Seedling infection
  - Systemic, initiated at seedling stage, mostly intercellular hyphae and sporulation in host ovary
- Embryo infection
  - Systemic, initiated through developing embryo; intercellular mycelium remains dormant in seed until infected seed germinates
- Shoot infection
  - Systemic, infection through shoots or young buds. May result in lack of floral development or aborted inflorescence.
- Local infection
  - Mycelium and sporulation restricted to region of infection, fungus is not systemic

Common types of smut diseases

- Bunt
  - Ovary-infecting species of *Tilletia* that infect cereals
- Stinking Bunt
  - Diseases caused by *Tilletia* species that produce foetid (fishy) odor
- Partial Bunt
  - Only a portion of seed or inflorescences are bunted, only part of seed is replaced by sorus.
- Covered smut
  - Well-developed, persistent peridium surrounding sorus
- Loose smut
  - Thin, delicate peridium that ruptures easily to expose teliospores

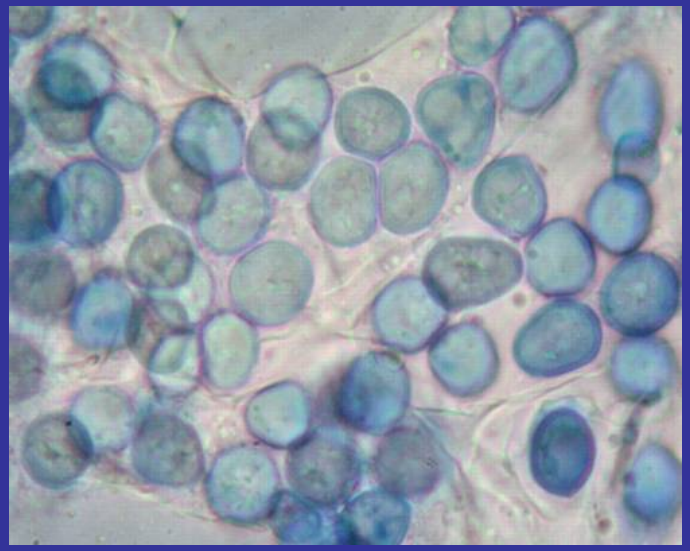


Tilletia

- Sori usually in reproductive organs of host
- Teliospores formed singly, usually pigmented with ornamented walls
- Sterile cells present in sorus
- Teliospores with foetid odor due to production of trimethylamine
- Tilletia-type germination (also see Fig. 14)

Entyloma

- Sori in vegetative organs of host
- Teliospores formed singly, permanently embedded in host tissue
- Teliospores with pale, smooth walls
- Tilletia-type germination (see Fig. 13)



Urocystis

- Sori mostly in leaves, stems, forming streaks, swellings or galls
- Spore balls with pigmented teliospores surrounded by hyaline sterile cells
- Tilletia-type germination (see Fig. 18)

Ustilago

- Sori in reproductive organs or vegetative tissues of host
- Teliospores formed singly, usually pigmented with sculptured walls
- Sterile cells absent
- Ustilago-type germination (see Fig. 9)