# Seed-borne pathogens

Fungi

# Oomycota

- Fungus-like organisms
- Were classified as fungi – now in Kingdom Protista
- Algae in Kingdom Protista
- Cell wall – cellulose
- Fungus cell wall mostly chitin
- Nuclear status = 2N (diploid)
- Fungi nuclear status = 1N (haploid)

# 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

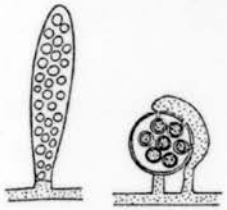
Secondary Zoospore

**Classification**

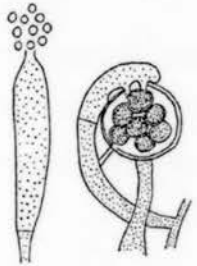
- Placed in Kingdom Stramenopila
- ~ 65 Genera; ~ 500-800 Species
- Placement...
  - Based on ultrastructure of flagella
  - Strongly supported by molecular data
- Other closely-related fungal-like phyla:
  - Labyrinthulomycota
  - Hyphochytriomycota
- Not closely related to Kingdom Fungi
- Within lineage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

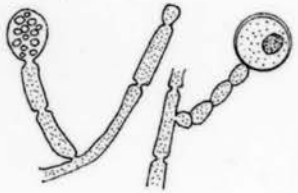






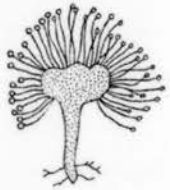
## Leptomitales

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



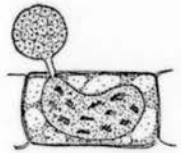
## Rhipidiales

- 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*

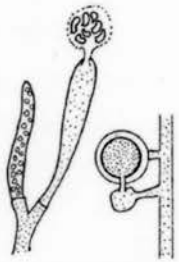


## Peronosporales

- 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

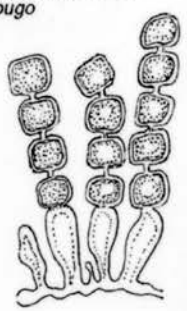


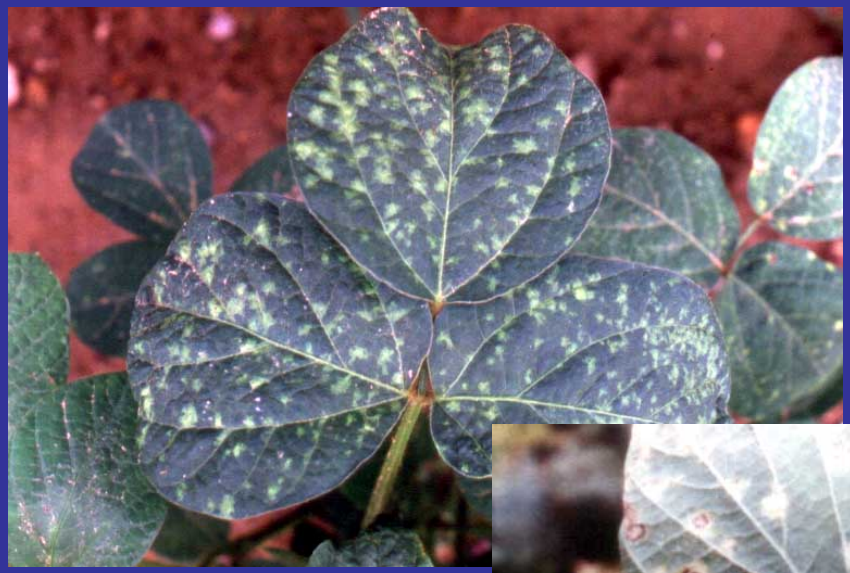
### Peronosporaceae

- 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*





Downy mildew of soybean
*Peronospora manshurica*

# 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

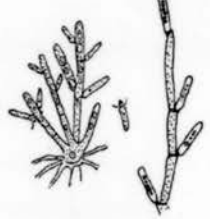
- Common saprobes of soil, dung, litter
- Asexual spores
  - Sporangiospores (Ss) borne in sporangia on sporangiophores
  - Conidia

## 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

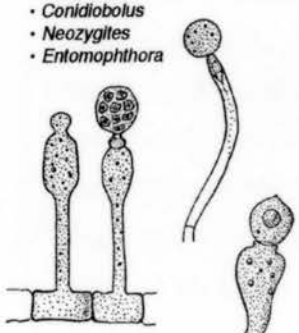
- Thallus coenocytic
  - Unbranched at base
- Ss prod. basipetally
- *Enterobryus*

### Amoebidales

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

## Entomophthorales

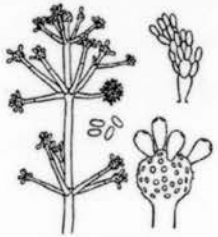
- Insect pathogens
- Saprobes - soil, dung
- Parasites of algae, ferns, invertebrates, mammals
- Mycelium not extensive
- Asexual structures
  - Undifferentiated
  - Spores = conidia
- Forcible spore discharge
- Distinguished by cell charac.
  - Nuclei size
  - Condensed chromatin
- *Ballocephala*
-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





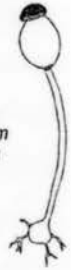
## Dimargaritales

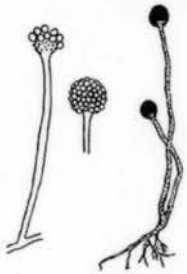
- Haustorial mycoparasites
- 2-spored merosporangia
- Septate hyphae - perforate
- *Spinalia*
- *Dimargaris*



## 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

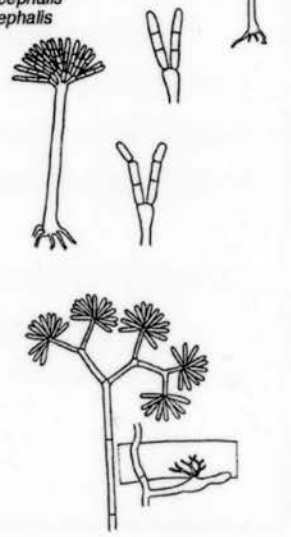
- Arbuscular mycorrhizae
- Form arbuscules
- Some form vesicles (VAM)
- Asexual spores only
- *Glomus*
- *Sclerocystis*
- *Acaulospora*
- *Entrophospora*
- *Gigaspora*
- *Scutellospora*

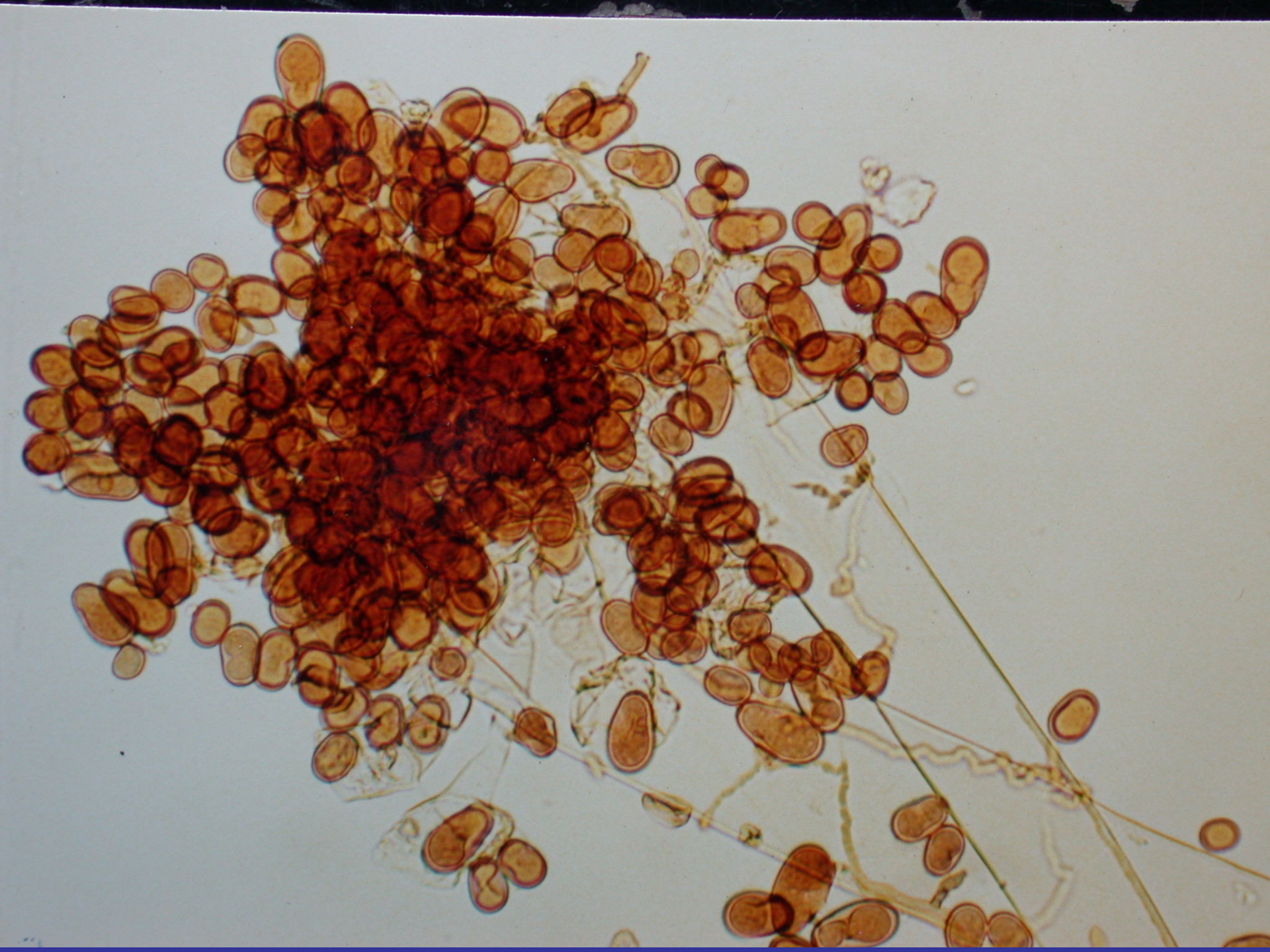
## Kickxellales

- 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*





# Ascomycota

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

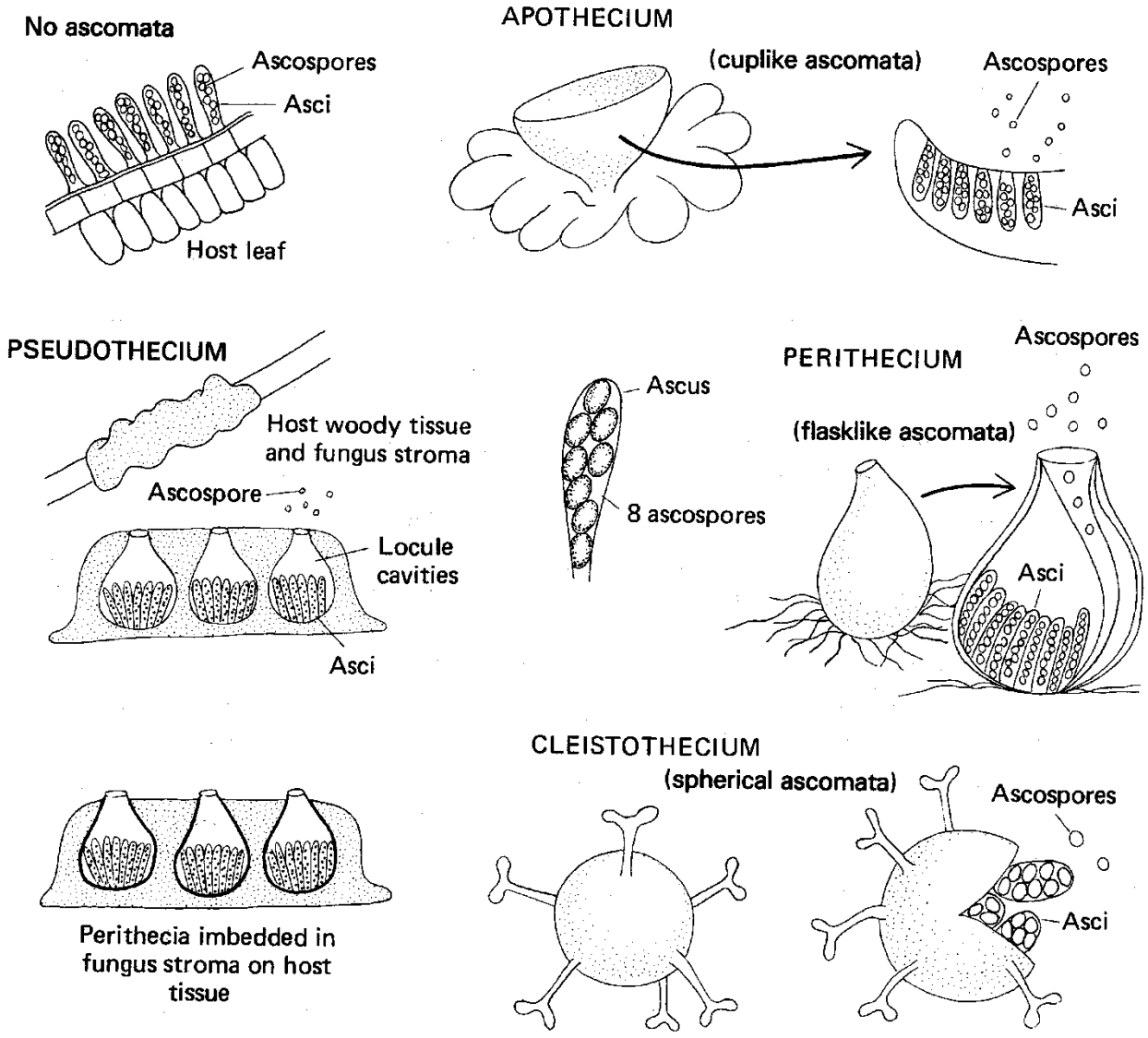



**Figure 8–9** Ascomycotina reproductive structures.

# Ascomycota

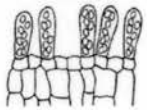
- Sexual spores borne in an ascus
- Single-celled, mycelial, or dimorphic
- Septate hyphae
- Simple septal pores
- Cell walls mostly chitin
- Heterothallic mating system - unifactorial

No ascocarps/ Lack ascogenous hyphae

## Archiascomycetes

### Taphrinales

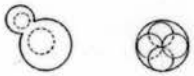
- Ascus arises from ascogenous cell
- Obligate plant parasites
- Dimorphic
- Saprobic haploid yeast
- Parasitic mycelium w/simple septal pores
- *Taphrina* - Peach leaf curl
- *Protomyces*



## 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*



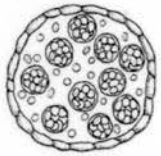
Filamentous
Ascocarps & Ascogenous hyphae

## 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

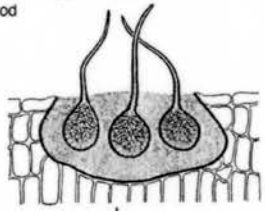
- Lack stroma
- Perithecia/cleistothecia leathery/membranous
- Periphysate
- Ascospores 1-2 celled w/apical ring
- *Sordaria, Neurospora Podospora*

### 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

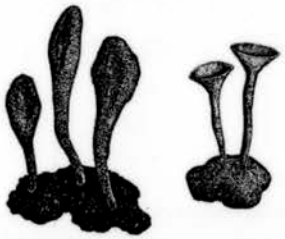
- Apothecia open
- Spherical Woronin bodies
- *Morchella, Sarcoscypha*
- *Ascobolus, Pyronema*
- *Helvella, Gyromitra*
- Hypogeous forms
- *Tuber, Elaphomyces*

### 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

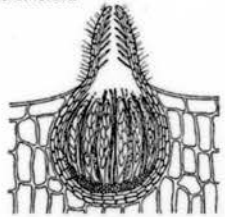
- Lack stroma
- Perithecia -long-necked
- Pseudoparenchyma
- Paraphyses absent
- Periphyses present
- Ascospores w/pores
- *Melanospora*

### 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*



*Septoria nodorum*

# Non sexual spore forming Ascomycetes

- 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

# Non sexual forming Ascomycetes

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

- 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

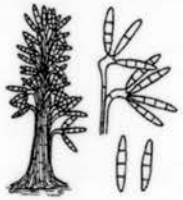
### Mycelia Sterilia
- No conidia produced
- Sclerotia may be formed
- Root rot, crown rot diseases
- *Rhizoctonia* (Basidiomycota anamorph)
- *Sclerotium*

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

Conidiophores:
- mostly single
- separate/loose clusters

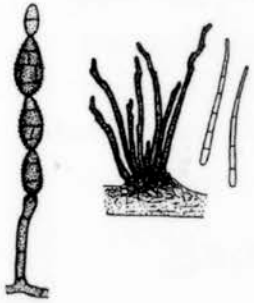
Conidiophores grouped/clustered

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

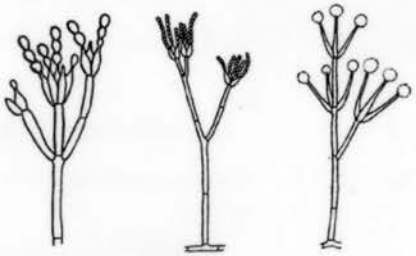


#### Tuberculariaceae
- Conidiophores = Sporodochia
- Canker, wilt diseases
- *Strumella*
- *Fusarium*

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

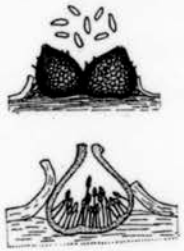


#### Moniliaceae
- Conidia - hyaline
- Gray mold, wilt, root rot, blight rot of stored seed, canker diseases
- *Aspergillus*
- *Penicillium*
- *Botrytis*
- *Candida*
- *Fusarium*
- *Verticillium*
- *Paecilomyces*
- *Trichoderma*
- *Cylindrocladium*
- *Sporobolomyces*

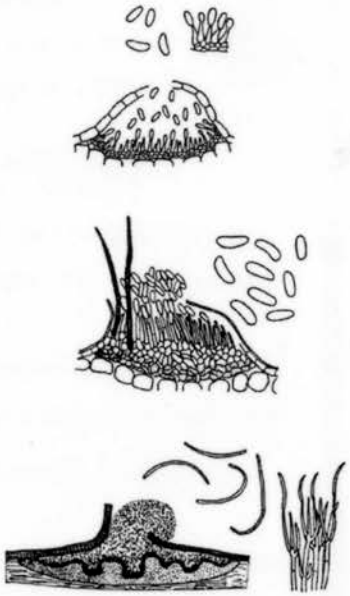


## Coelomycetes

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



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




Cercospora leaf spot

Anthracnose sweet pepper

# Chilli anthracnose


Chilli anthracnose

Anthracnose of Vegetable soybean


*Colletotrichum capsici*

Alternaria leaf spot


Alternaria leaf spot

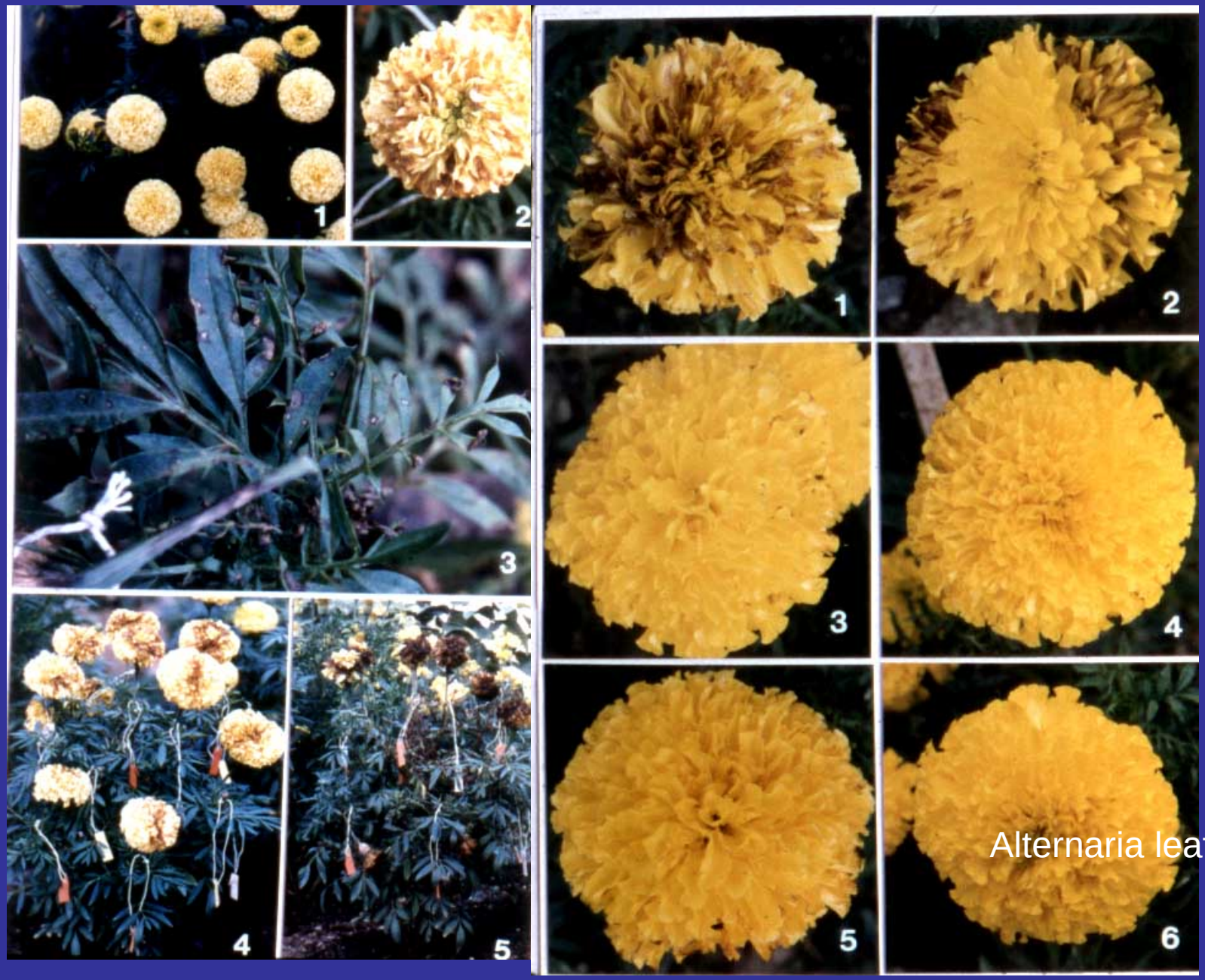
*Alternaria brassicicola*


Alternaria leaf spot


Alternaria leaf spot


Alternaria leaf spot


Alternaria leaf spot




Alternaria leaf spot

# Basidiomycota

- 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

# 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*

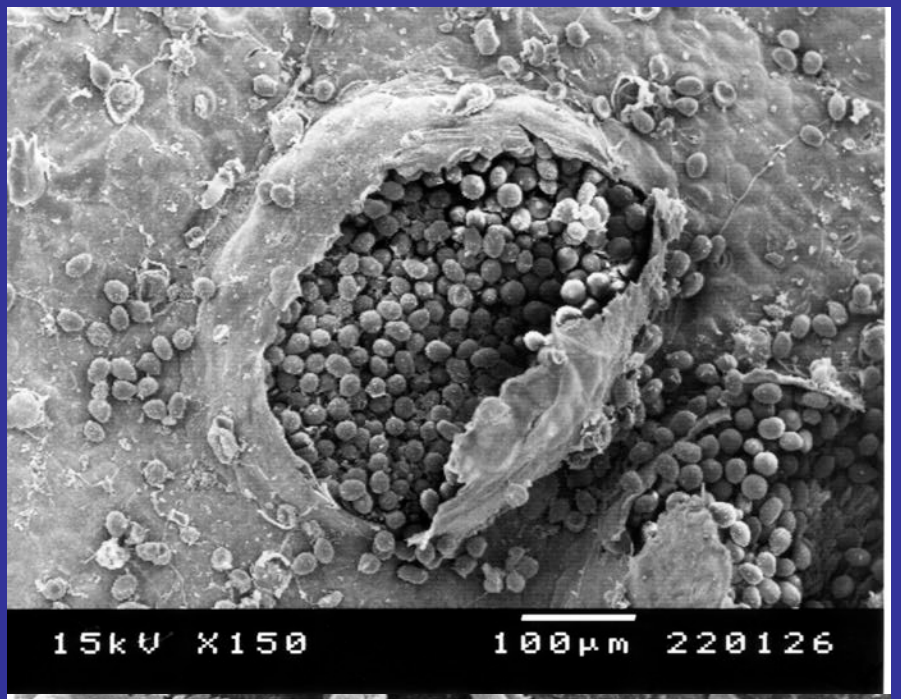
### Nidulariales

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

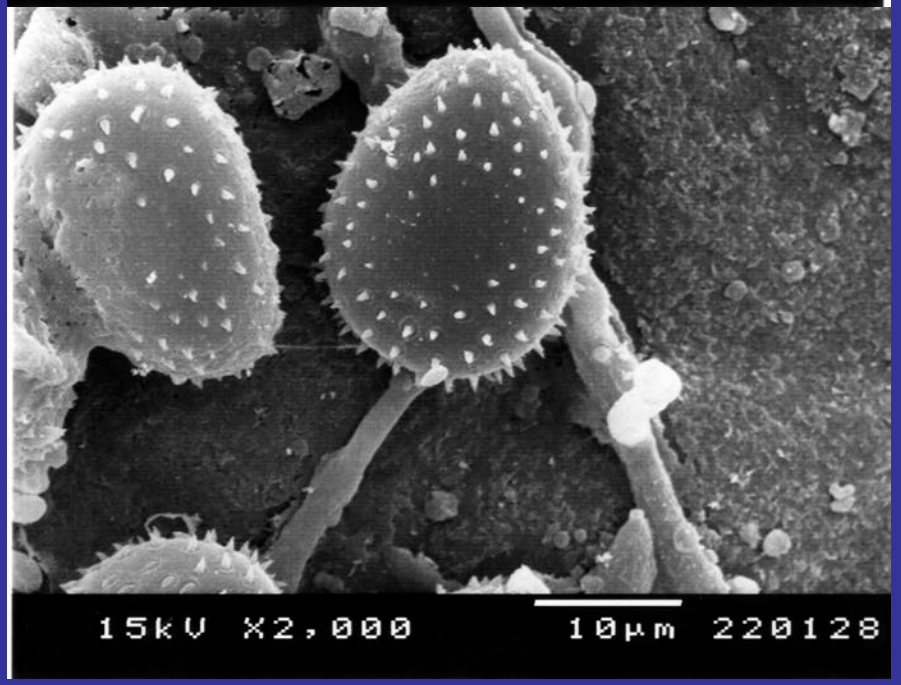
### Hymenogastrales

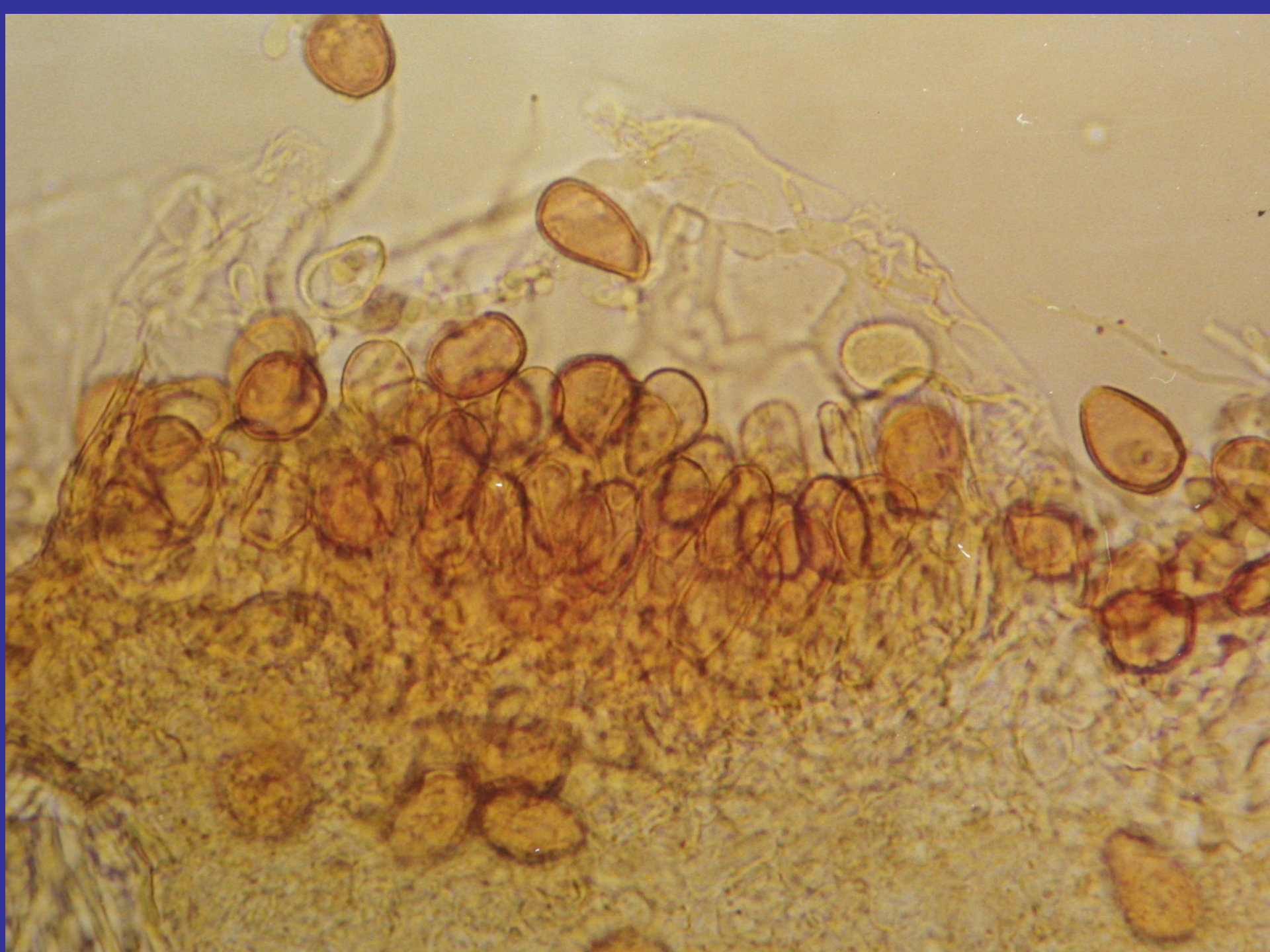
- False truffles
- Hypogeous/animal-dispersed
- Chambered hymenium
- *Rhizopogon* • *Hymenogaster*

Pastule of Uromyces sp..




Urediospore



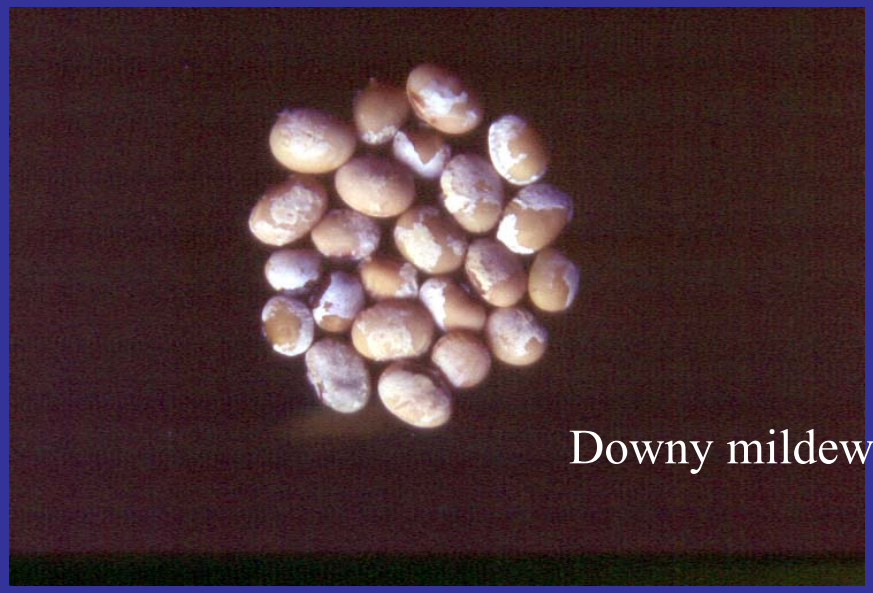



Covered smut

## Detection of seed borne fungi

- dry seed examination
- blotter method
- agar method
- seed symptom test & growing-on test
- embyo extract method

# Dry seed examination



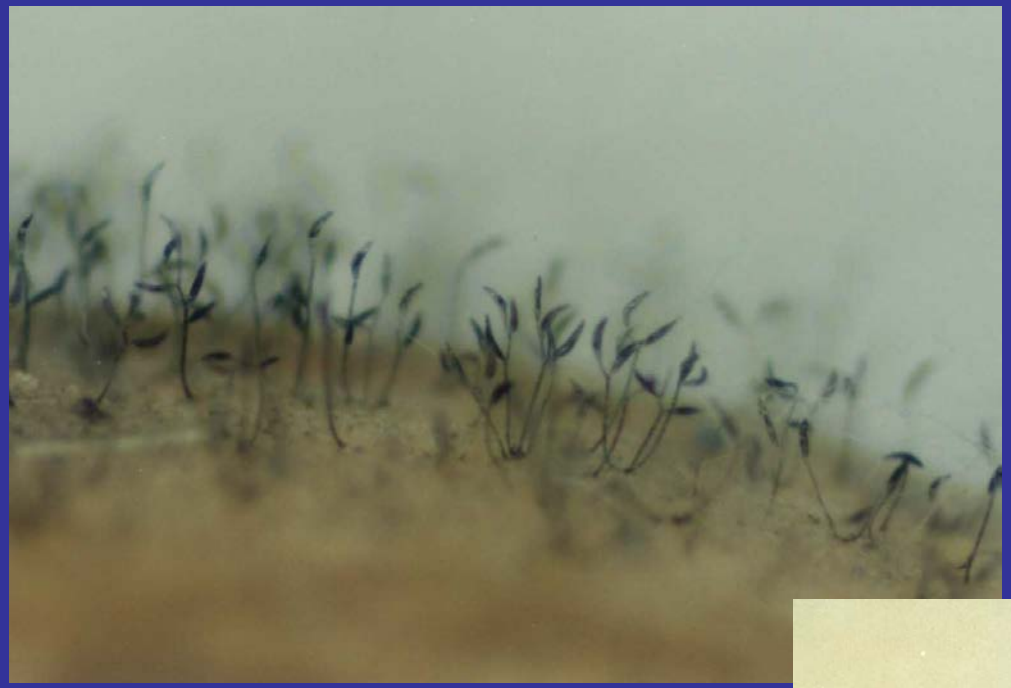
Downy mildew

## Seed discoloration

SMV

SMV and purple stain

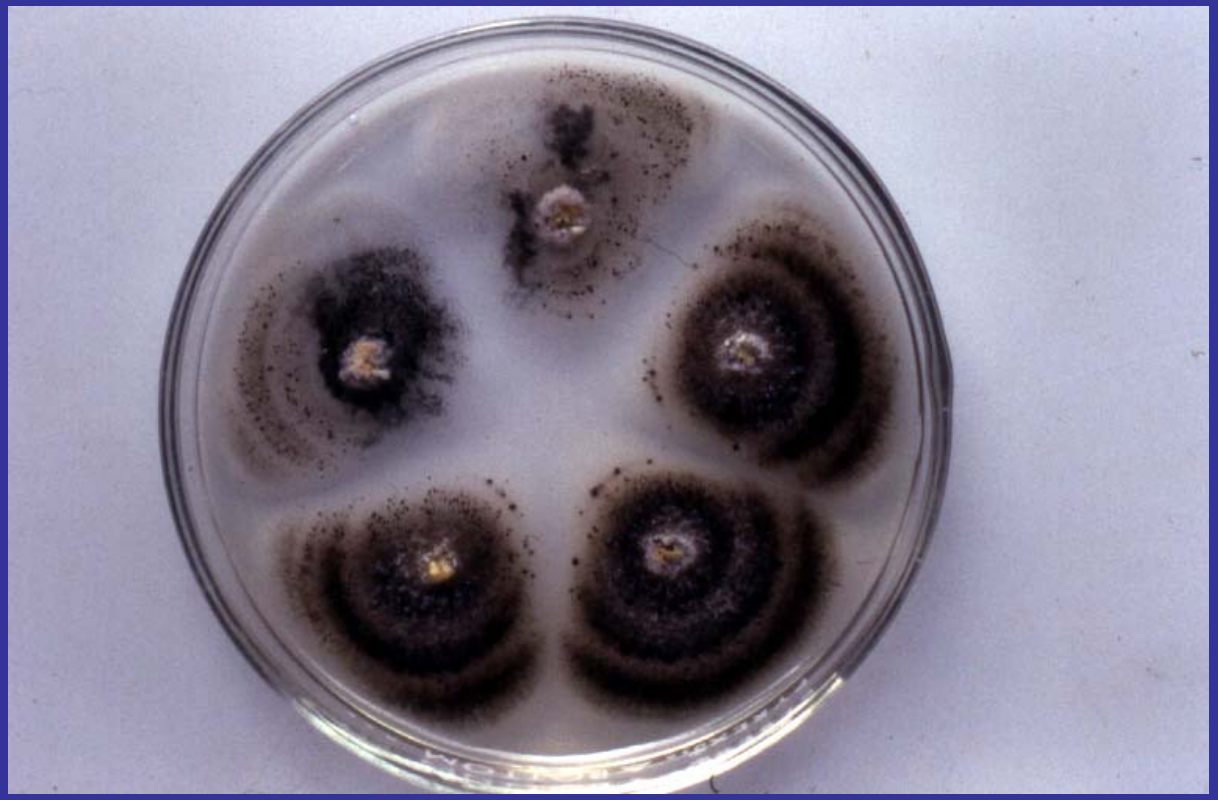
# Blotter method



*Bipolaris oryzae*

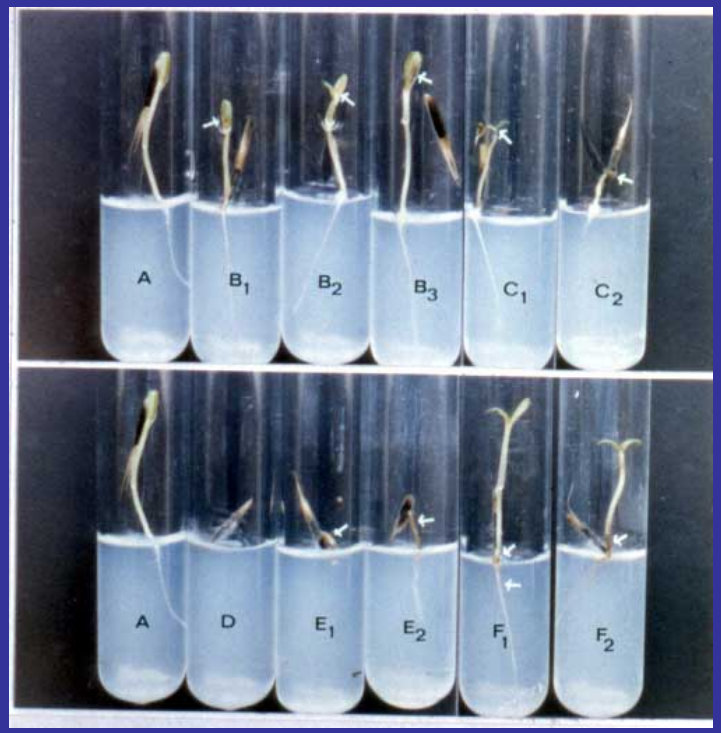
*Cercospora kikuchii*

# Agar method



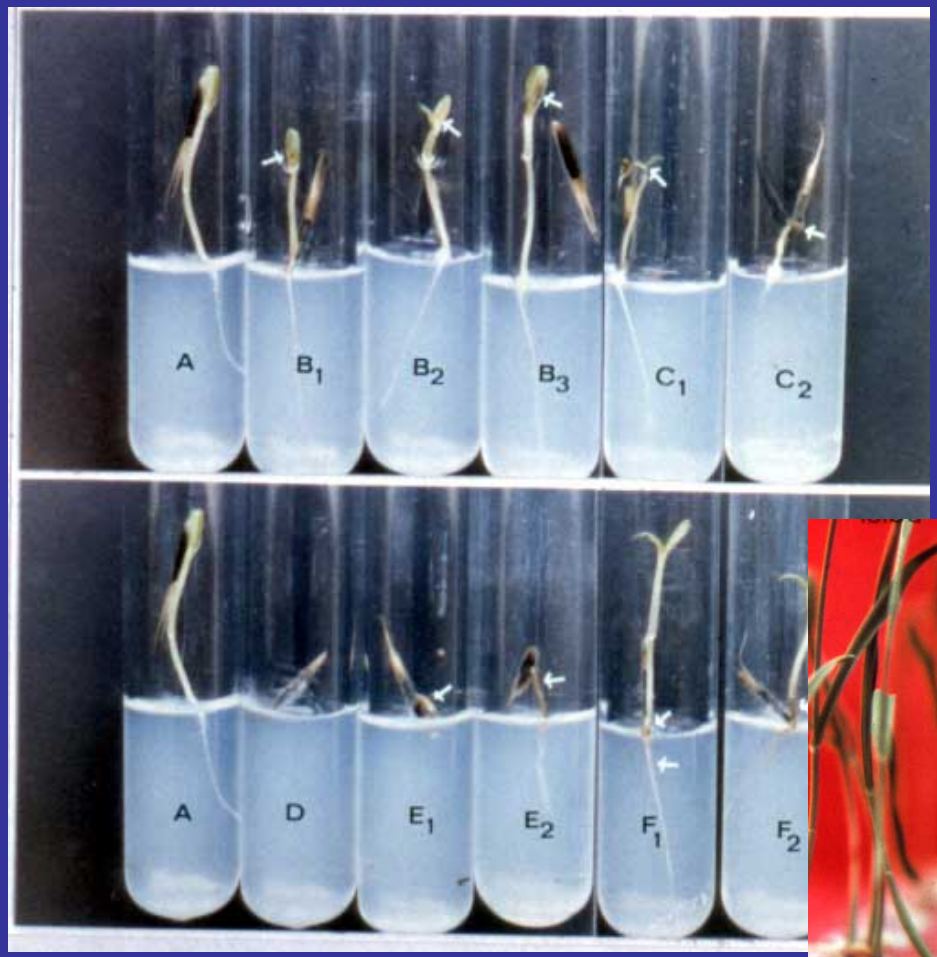
*Colletotrichum capsici*

# Seedling symptom test

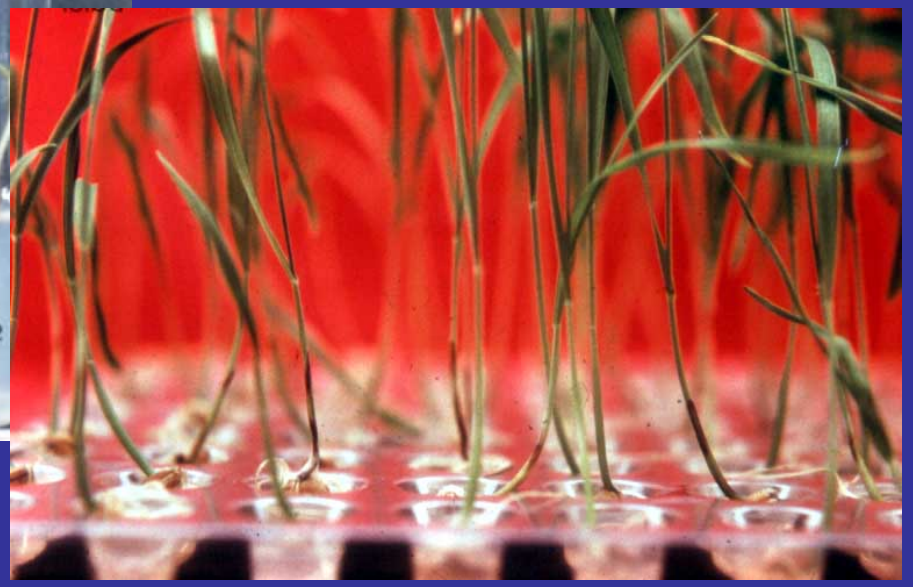



# Seedling symptom test

*Alternaria zinniae*




*Septoria tritici*

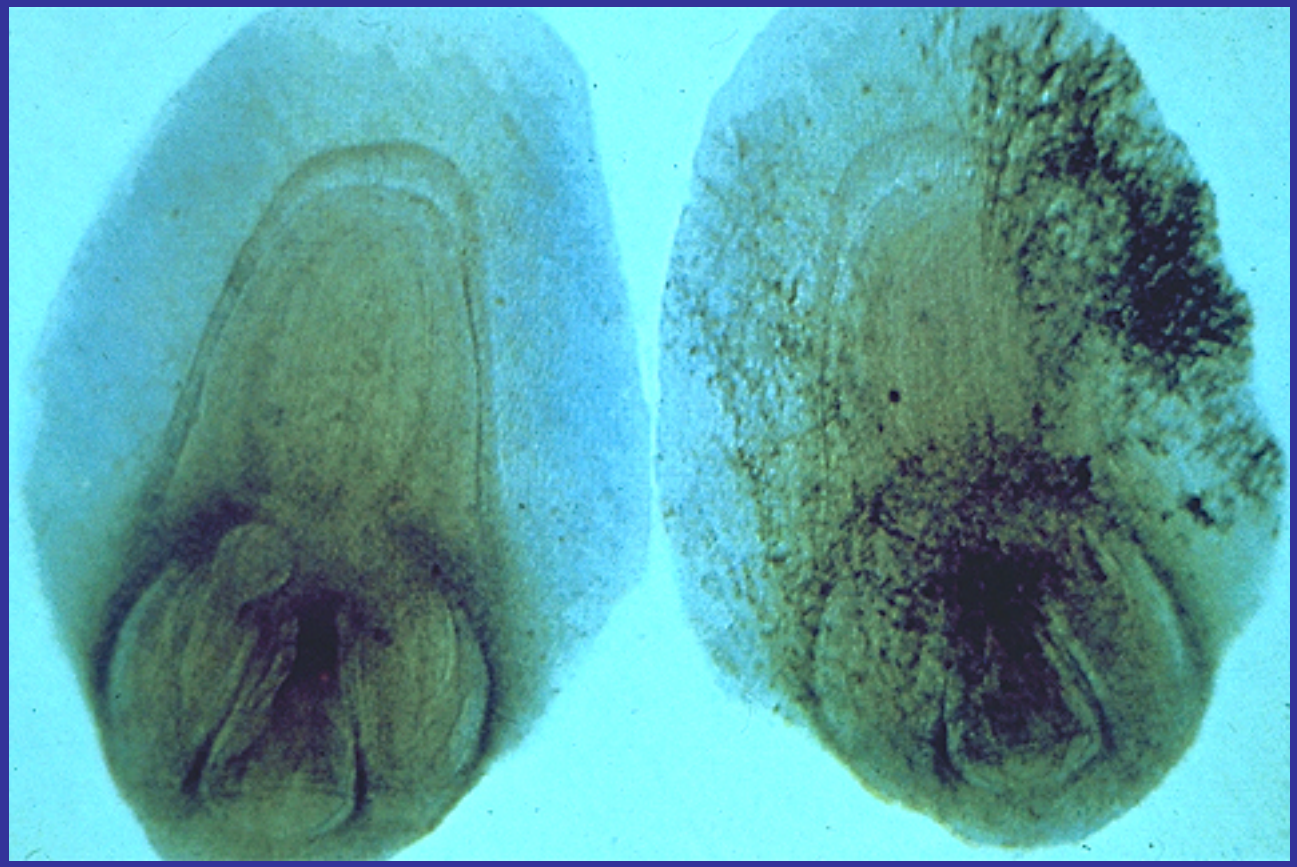


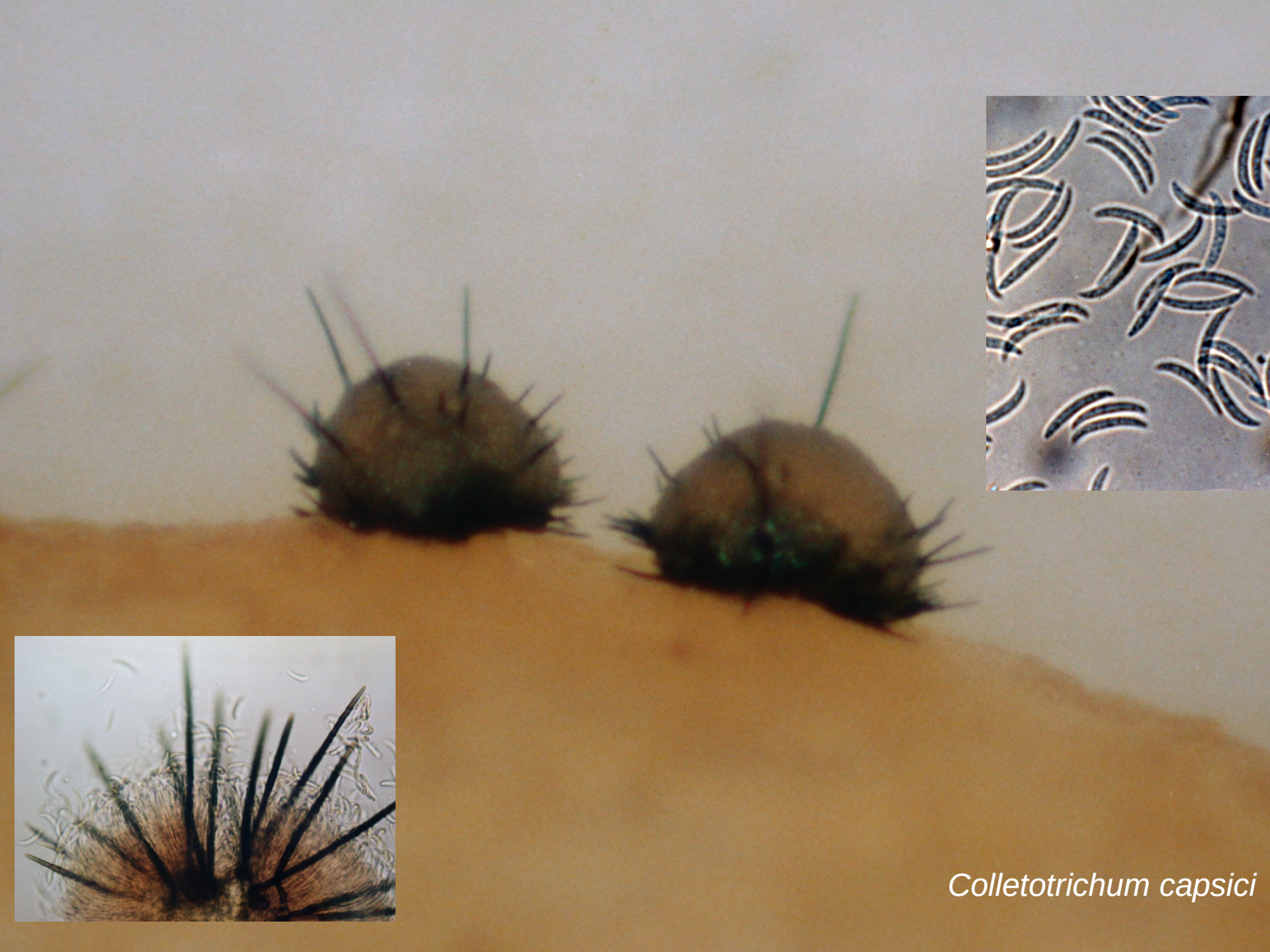
Seedling symptom test
*Ascochyta pinodes*

# Growing-on test

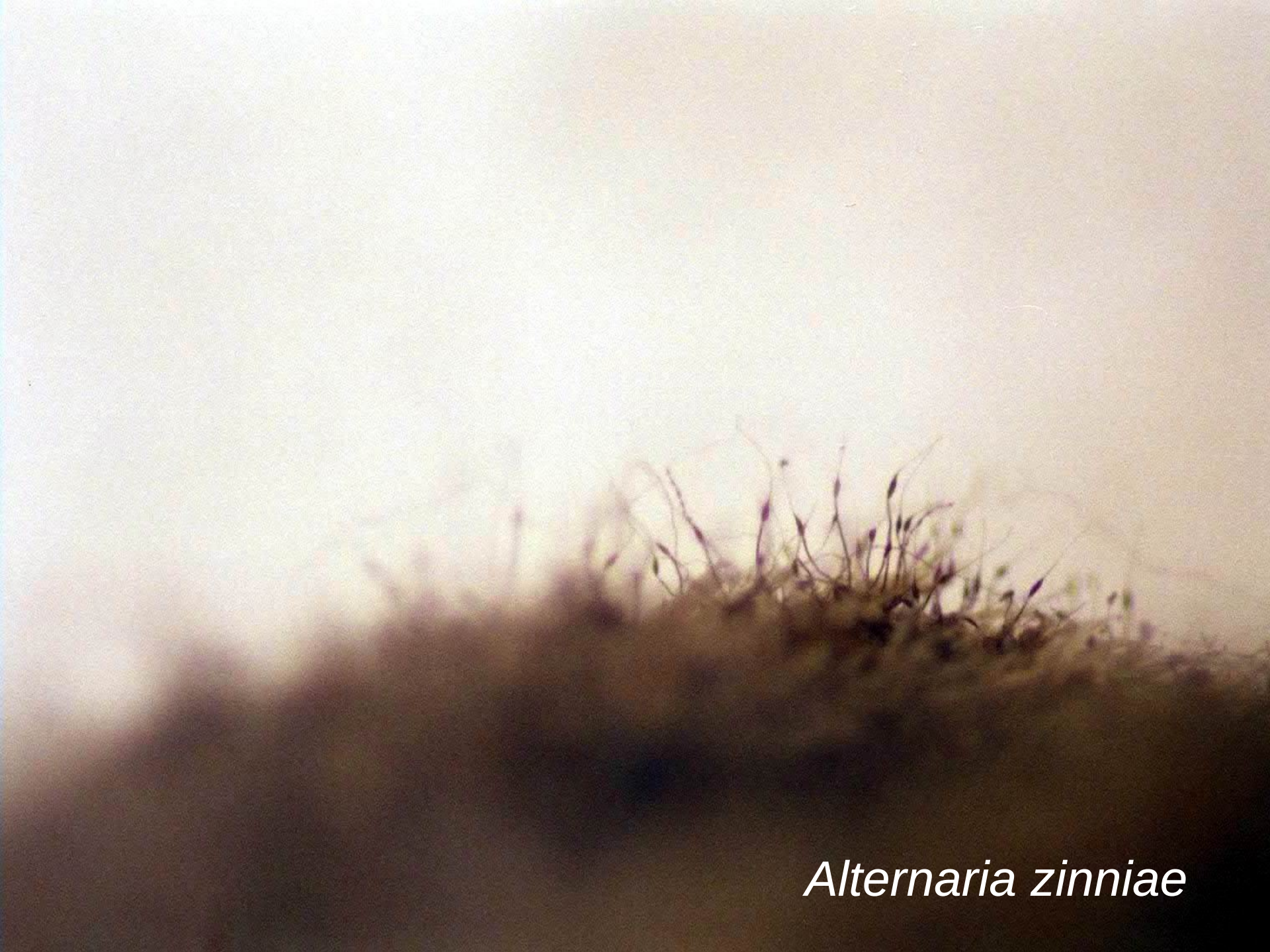
Loose smut of barley

# Embryo extract method





*Colletotrichum capsici*


*Alternaria zinniae*