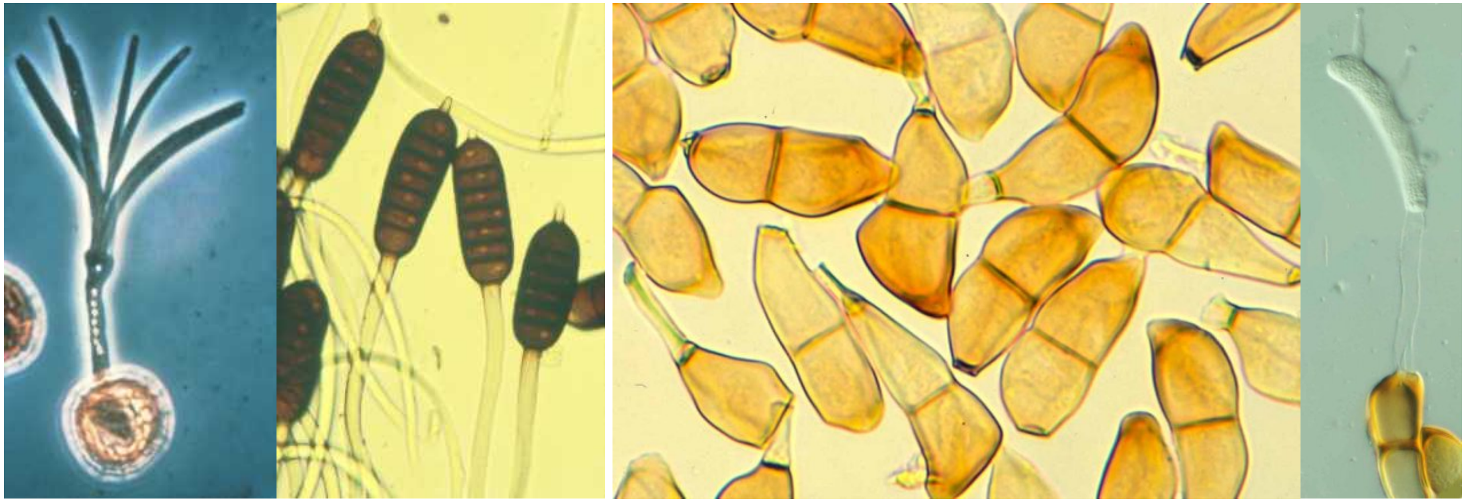
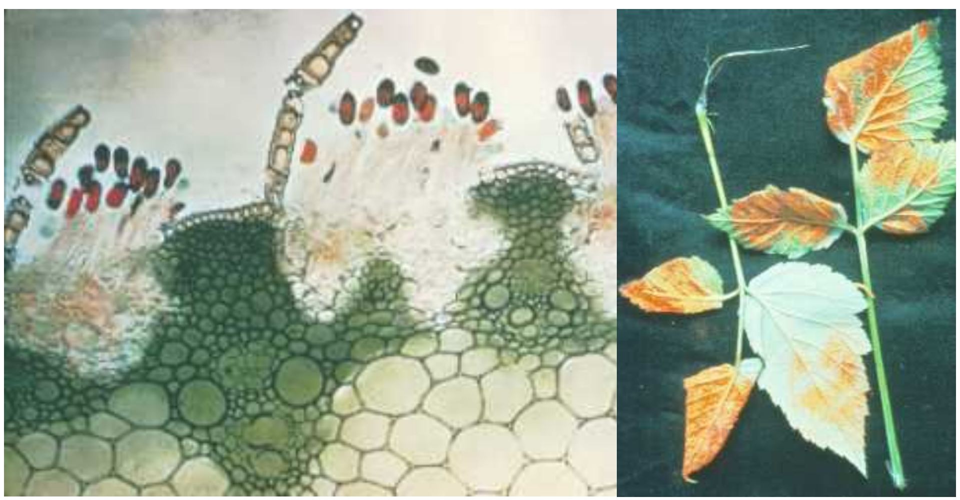
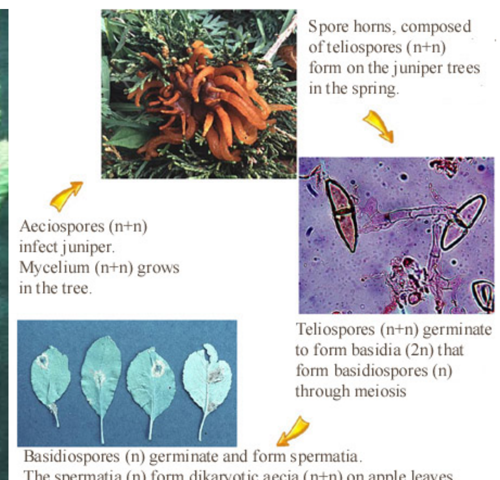
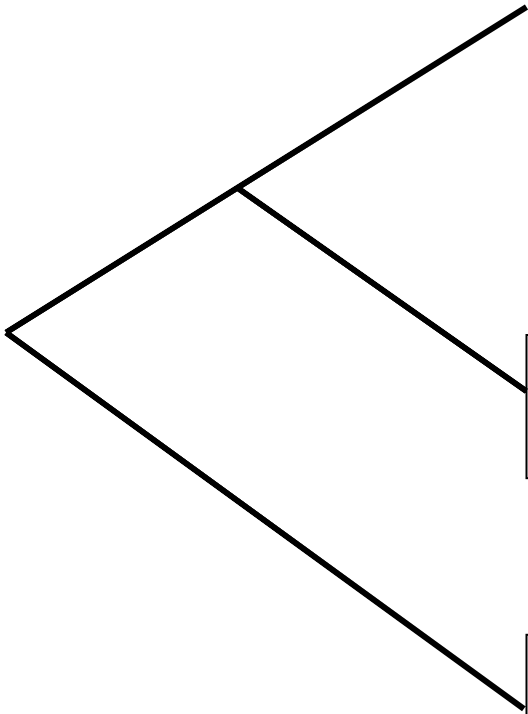
Rusts & Smuts: basidiomycete plant pathogens







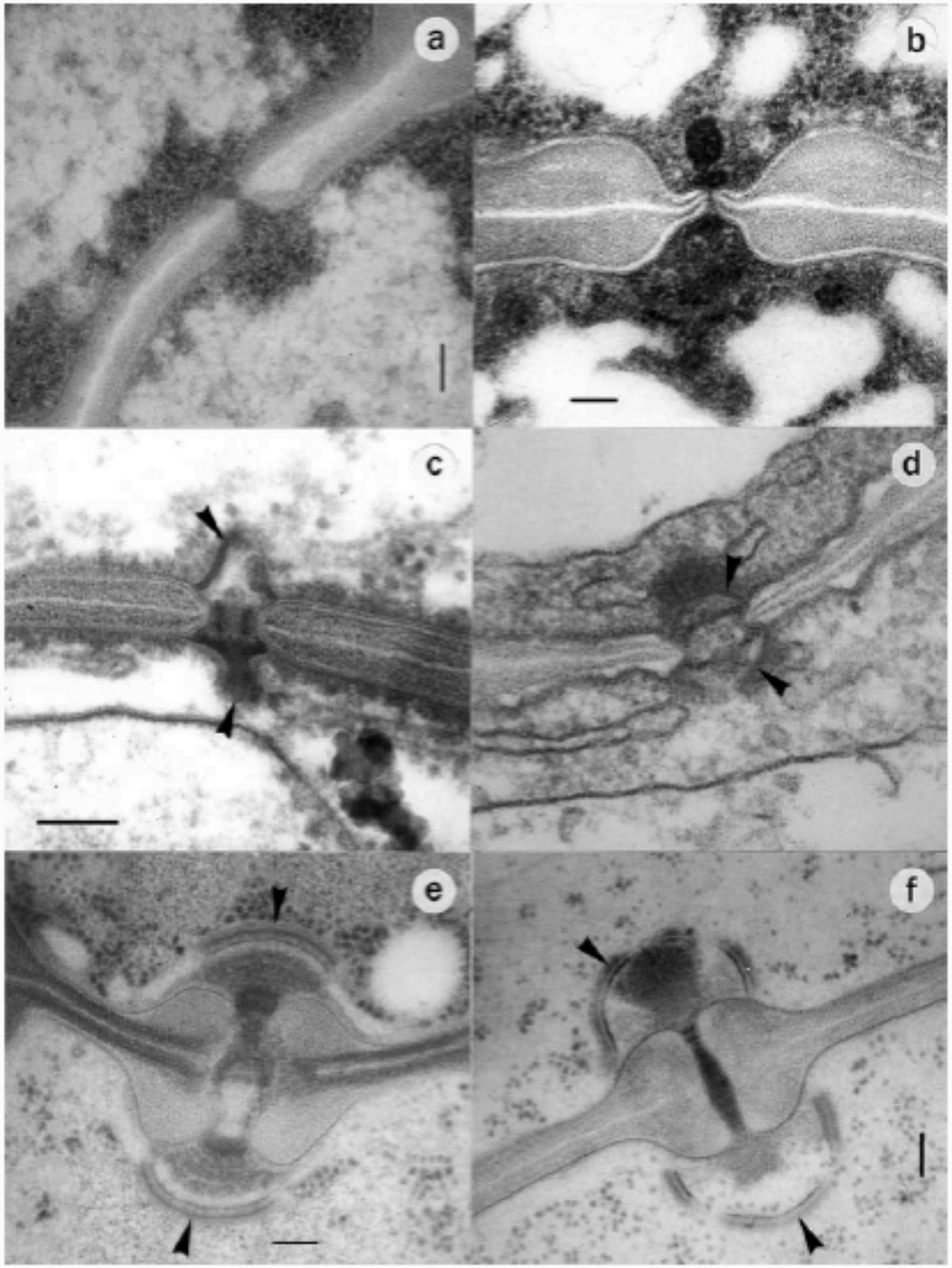
3 Major Clades - Subphyla - of the Basidiomycota



Agaricomycotina
mushrooms, polypores, jelly fungi, corals, chanterelles, crusts, puffballs, stinkhorns

Ustilaginomycotina
smuts, *Exobasidium*, *Malassezia*

Pucciniomycotina
rusts, *Septobasidium*



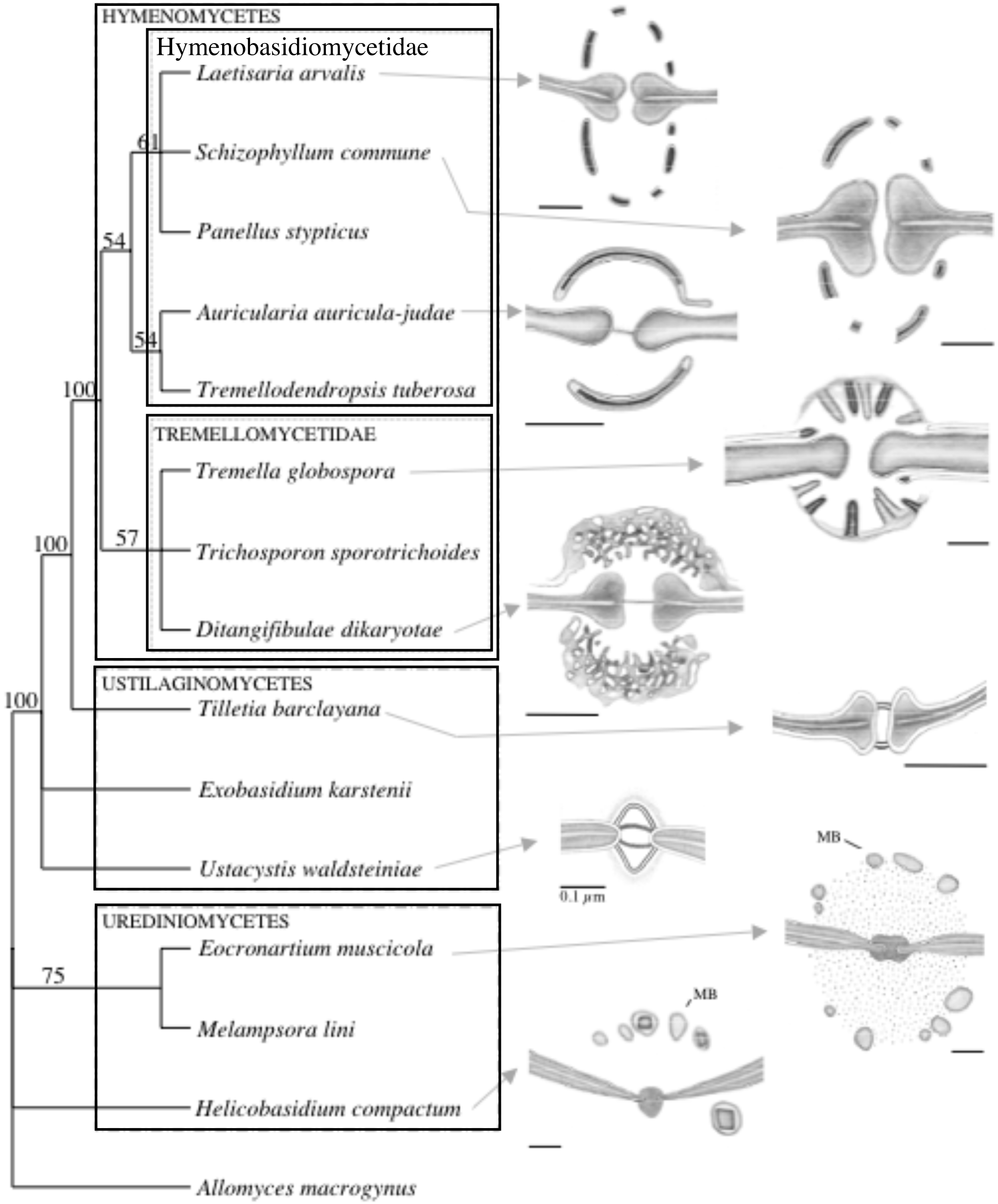
Septal pore structures in Basidiomycota

simple septa without membrane caps, Pucciniomycotina

simple septa with membrane caps, Ustilaginomycotina

dolipore septa with imperforate or perforate parenthosomes, Agaricomycotina

from: Bauer, Bergerow, Sampaio, Weiβ,Oberwinkler. 2006. Mycological Progress 5:41-66



Hymenomycetes

-dolipore septa
-perforated and nonperforated septal pore cap

-dolipore septa
-nonperforated septal pore cap or may be absent

Ustaliginomycotina

-"smut" septa
-no septal pore cap

Pucciniomycotina

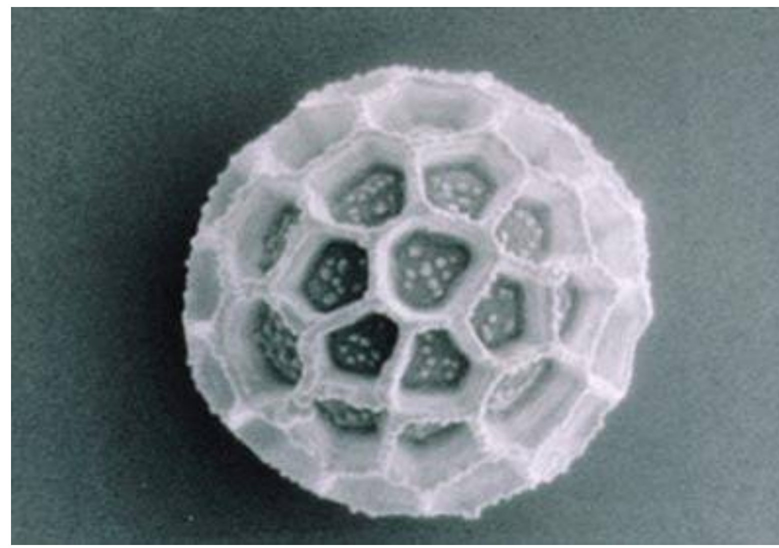
-simple septa, not dolipore
-no septal pore cap
-septal pore occlusions

Pucciniomycotina (Urediniomycetes) rust fungi

Formerly Class Teliomycetes (e.g. Kendrick) included both rust and smut fungi, now separate subphyla

Based on the teliospore stage
Karyogamy (dikaryon N + N → 2N) occurs in the **teliospore** of both rusts and smuts

Rust teliospores



Smut teliospores

Now subphyla Pucciniomycotina (Urediniomycetes, rusts) and Ustilaginomycotina (smuts)

Pucciniomycotina About 7,000 spp. 160 genera

Urediniomycetes (=Pucciniomycetes)

- **Uredinales (= Pucciniales)--rusts**
- **Platygloeales, moss parasites**
- **Septobasidiales, insect parasites**
- **Helicobasidiales, alternate plant parasites-rust parasites**

Cystobasidiomycetes, red yeasts, mycoparasites

Atractiellomycetes, "auricularioid with simple septa"

Mixiomycetes, one species a fern parasite

Cryptomycoccolacomycetes, one genus, mycoparasite

Classiculomycetes, freshwater aquatic specie

Microbotryomycetes

- **Microbotryales, smut-like plant parasites, teliospores**
- **Sporidiobolales, yeasts**
- **Heterogastridiales, mycoparasites**

Ustilaginomycotina

Ustilaginomycetes

- **Ustilaginales -** the Smuts; about 1200 species 50 genera

Exobasidiomycetes, plant parasites (exc Malasezzia)

Entorhizomycetes, parasites of Juncaceae, Cyperaceae

Hereafter: "Rusts, smuts & related fungi"

- Host range, host specificity
- Specialized structures: haustoria, appressoria
- Life cycles
- Tuberculina - Helicobasidium rust parasites
- Host tissue modification: floral mimicry, galls
- Evolution in rusts, Transzchel's law

Host specificity, host range

Specialized plant parasites often have limited ability to infect particular plant species.

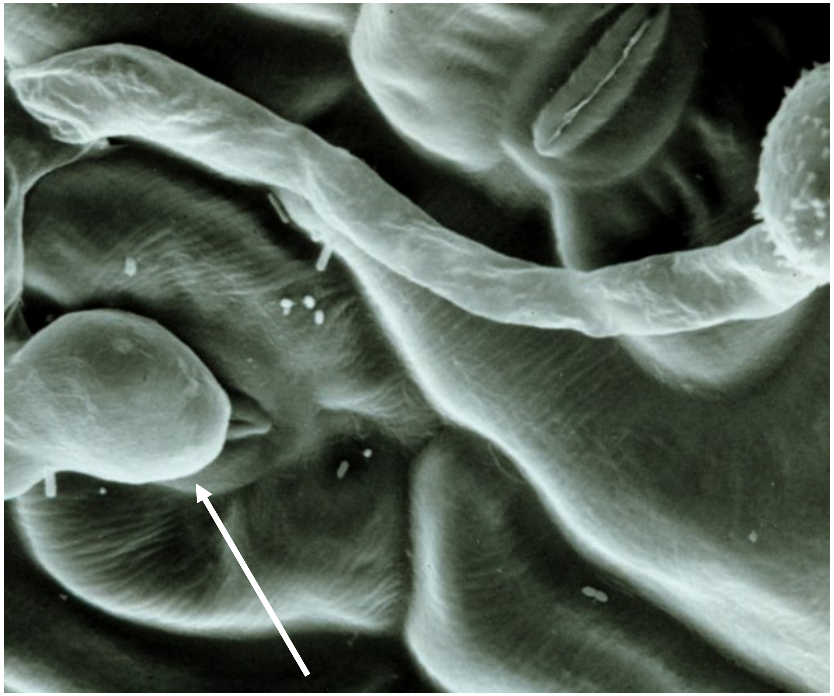
Host specificity refers to whether a particular fungus is restricted to a certain host or closely related group of hosts

Host range refers to the different plant species a particular fungus species is capable of establishing a parasitic relationship.

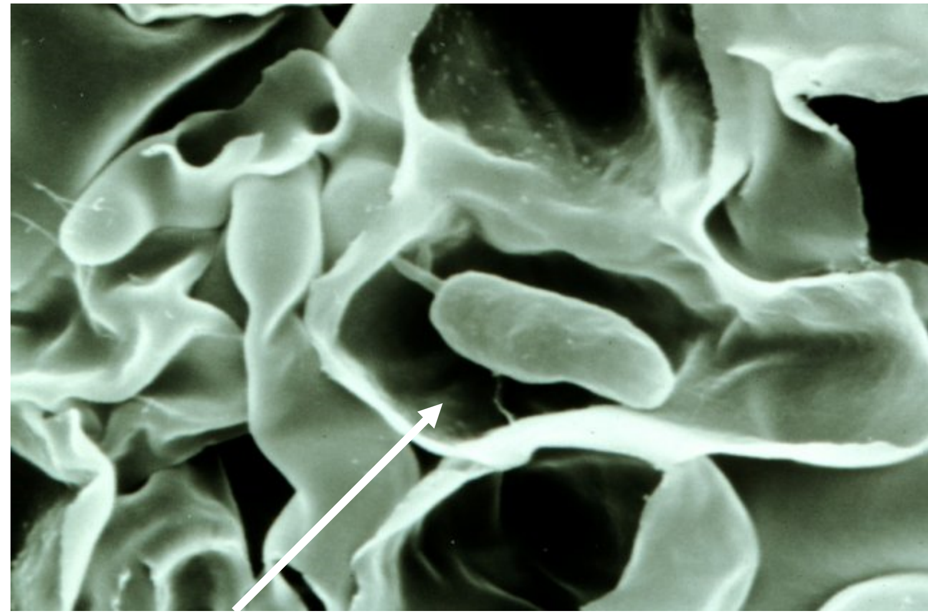
In general, the more specialized the parasitism, the more limited the host range. Rusts and smuts tend to be highly host specific, have narrow host ranges. Host range may be species, genus, or family level.

Pathogenic races of rusts can only infect certain susceptible cultivars of their hosts.

Specialized structures: appressoria and haustoria adaptations to parasitism



Appressorium:
functions in adhesion and initial host penetration by germinating basidiospore, aeciospore, or urediniospore

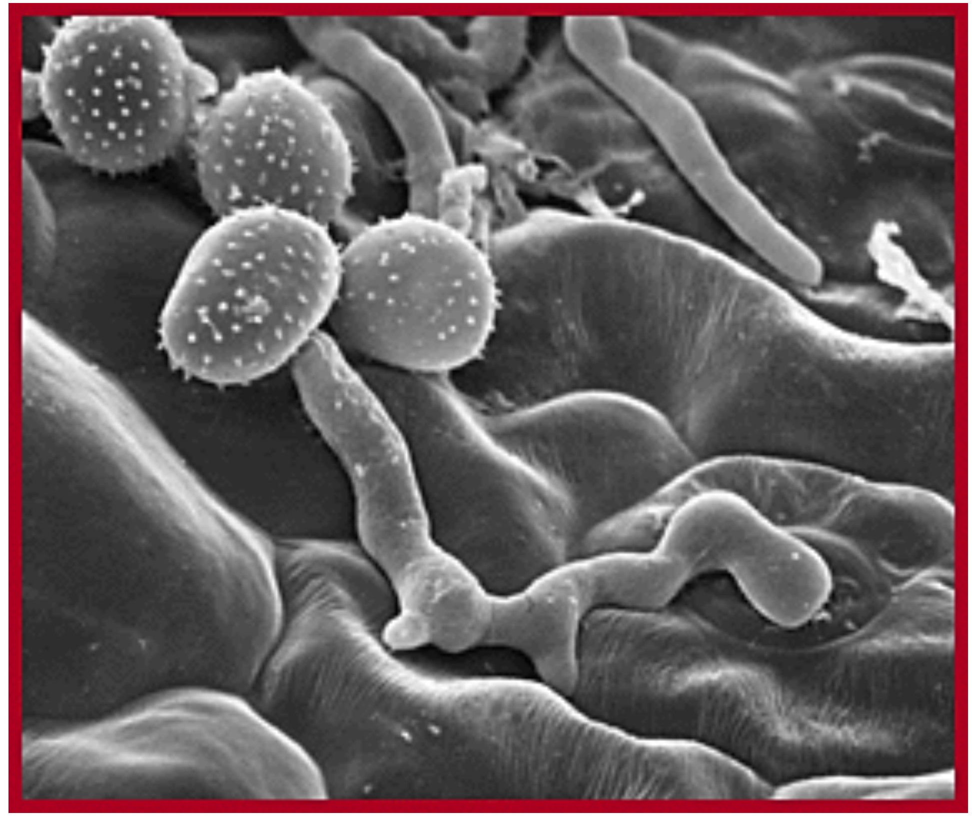


Haustorium:
functions in nutrient absorption, host cell is not killed, fungal cell wall is very thin, closely appressed to host cell membrane

Bean Rust – *Uromyces appendiculatus*

Appressoria only form directly above stomata. What is the mechanism for sensing position?

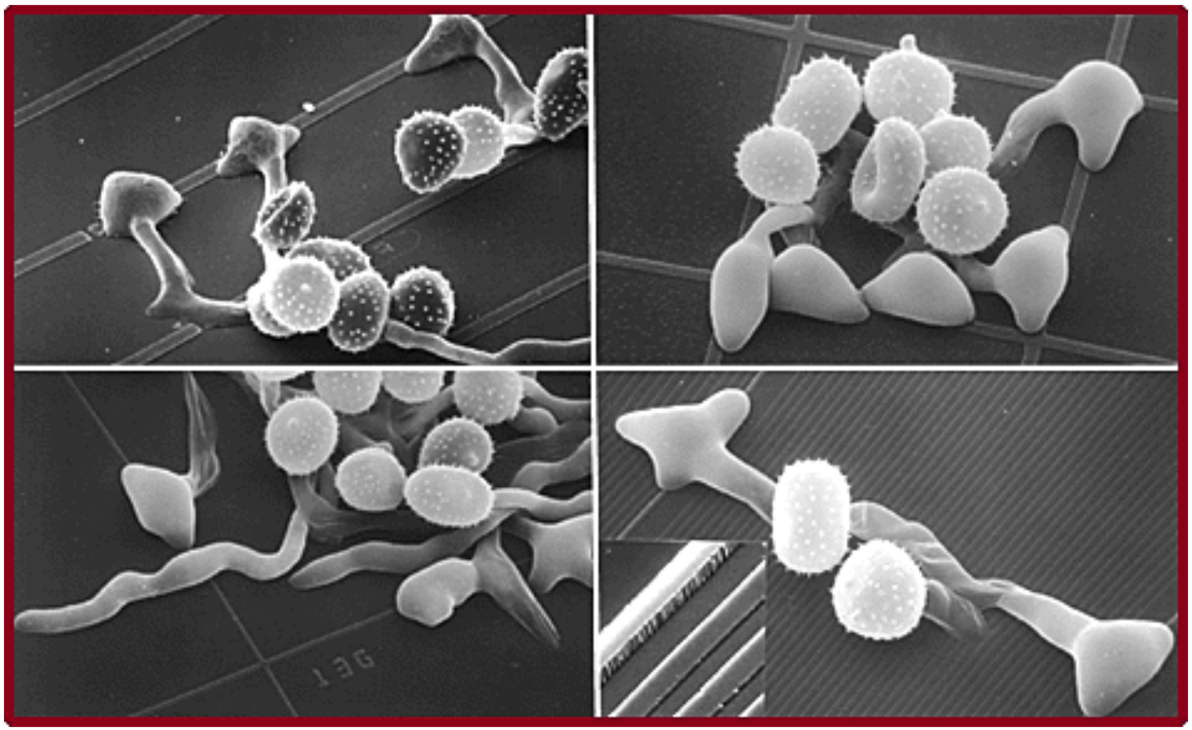
Growth of germ hyphae and induction of appressoria studied on plastic leaf impressions.



http://www.nysaes.cornell.edu/pp/faculty/hoch/bean_rust.html

Bean Rust – *Uromyces appendiculatus*

Thigmotropism and differentiation of appressoria

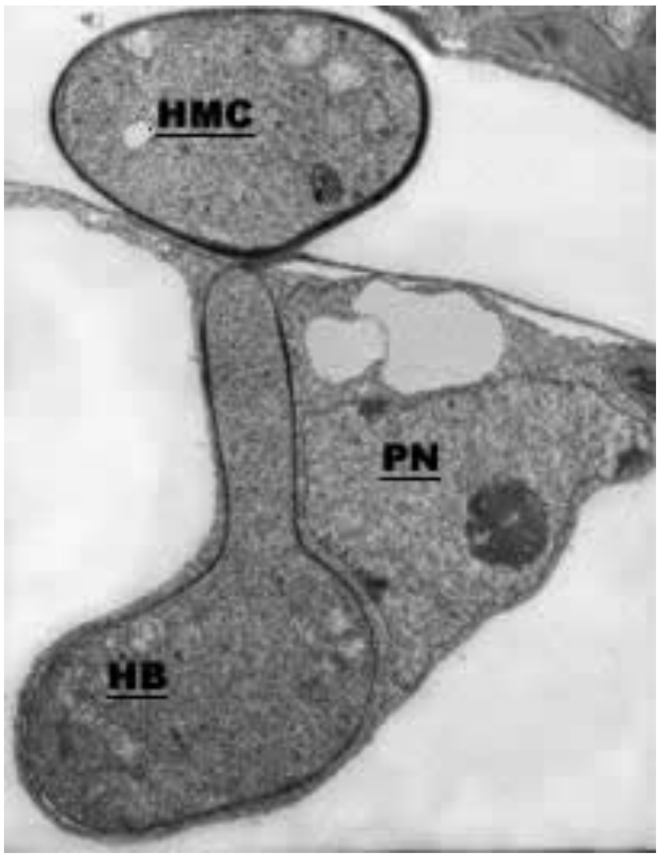


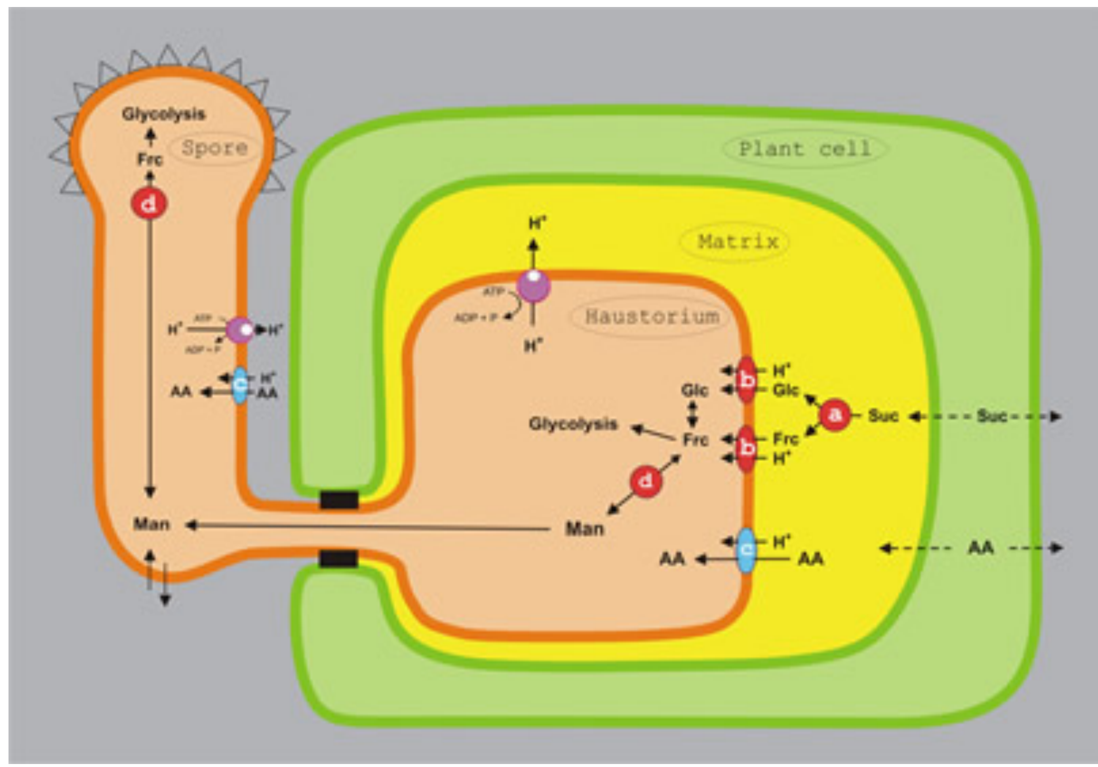
http://www.nysaes.cornell.edu/pp/faculty/hoch/bean_rust.html

Differentiation of appressoria is induced by topological features of the leaf. Appressoria induced in germinating urediniopores on a etched silcon surface, only respond to ridges of a certain size, 0.5 micron.

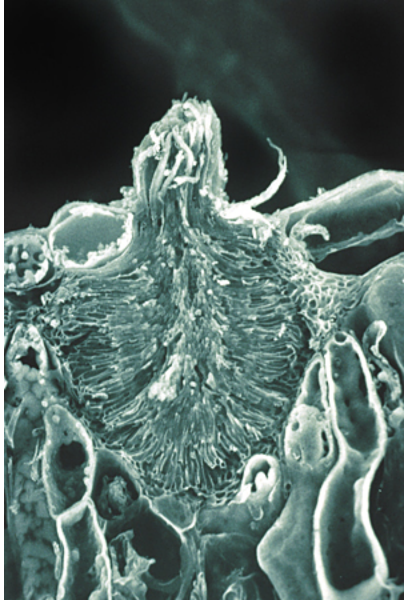
Rusts, haustoria

Hasutoria (sing. haustorium) are the hallmark of biotrophic parasites
A general term for an absorptive structure in a living cell





sucrose and amino acids are taken up, glucose & fructose converted to mannitol

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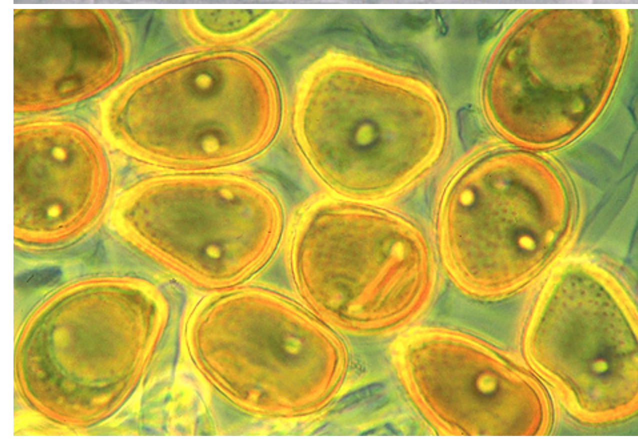
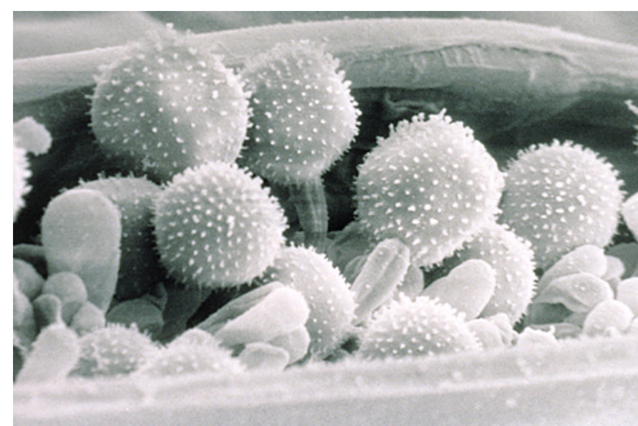




The Roman god of rust, Robigus

The Robigalia, a ceremony held at the end of April in which a red dog (presumably red because of the color of rust, and a dog because the ripening of the wheat coincided with the appearance of the dog star, Sirius) and sheep were sacrificed to conciliate Robigus.

From the account by Ovid, the presiding priest prayed to Robigo: "Harsh Robigo, spare the sprouting grain… Grip not the tender crops but rather grip the hard iron… Better that you should gnaw at swords and baneful weapons."

Rust life cycles

Rust fungi can have complex life cycles with multiple spore forms

Specialized structures for mating: pycnia

Some require two different hosts to complete life cycle called alternate hosts

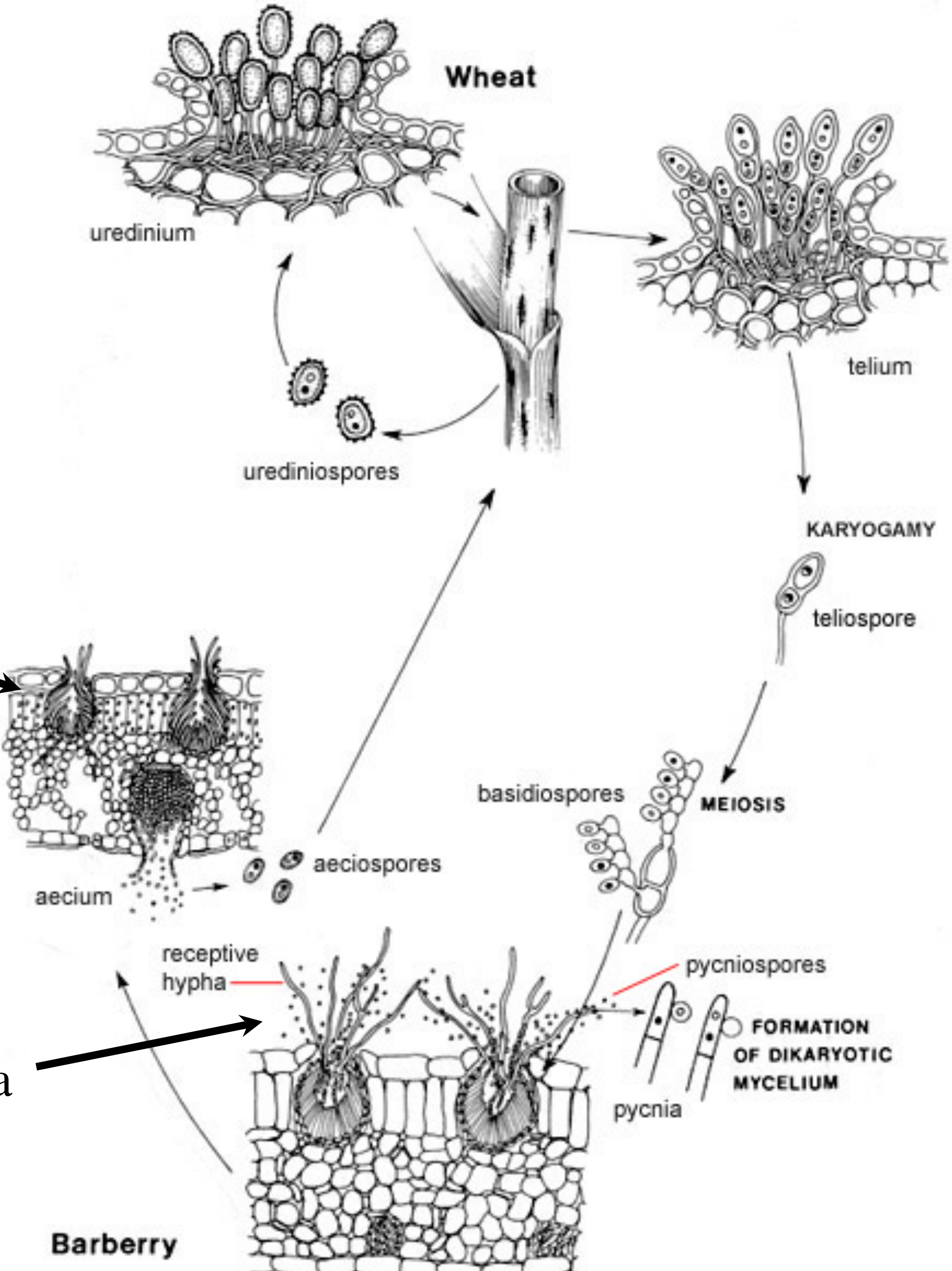
single host—autoecious: complete life cycle on one host

alternate hosts—heteroecious: both hosts required for complete life cycle

Rusts are important as agricultural pathogens and in forest trees affect stems, foliage and cones

Rust life cycles
macrocyclic
heteroecious

wheat rust



Rust life cycles

Stages in the rust life cycle designated 0-IV

0 Spermogonia and spermatia (pycnia) (monokaryon, n)
  often insect vectored, some are flower mimics
I Aecia and aeciospores (dikaryon, n + n binucleate spores)
II Uredinia urediniospores (n + n binucleate spores)
III Telia and teliospores (diploid stage, 2n)
  Teliospores usually a resistant resting stage
IV Basidia and basidiospores (Meiosis → haploid basidiospores)
  Basidiospores (monokaryon, n)

macrocyclic rusts– all spore stages present
microcyclic rusts—lack spore stages I-II,
  (so all must also be autoecious)
demicyclic rusts—lack spores stage II urediniospores,
  may be heteroecious or autoecious

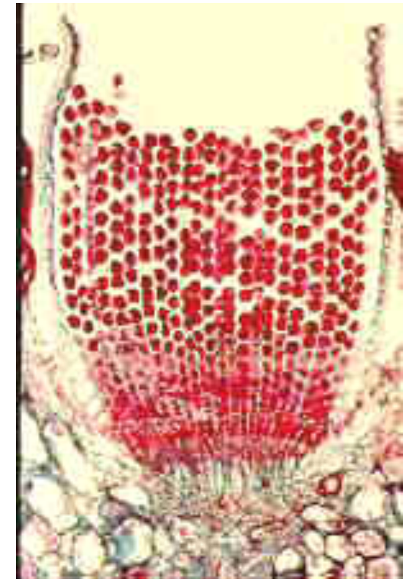
Life cycle patterns of the Pucciniales:

1. macrocylic forms- all five reproductive stages
2. demicyclic forms- the uredinial stage is absent
3. microcyclic forms- both aeciospores and urediniospores are absent; teliospore is the only binucleate spore produced

Heteroecious- two unrelated host plants required to complete their life cycles.

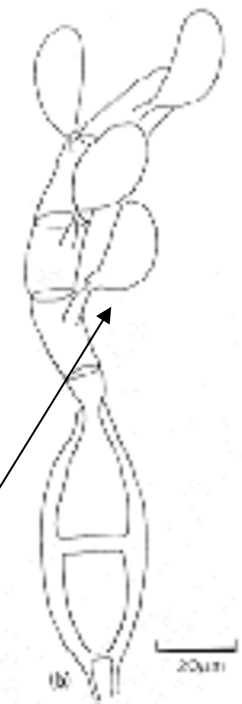
Autoecious- completes its entire life cycle on a single host species

pycnia



aecia, aeciospores

Urediniospores and teliospores

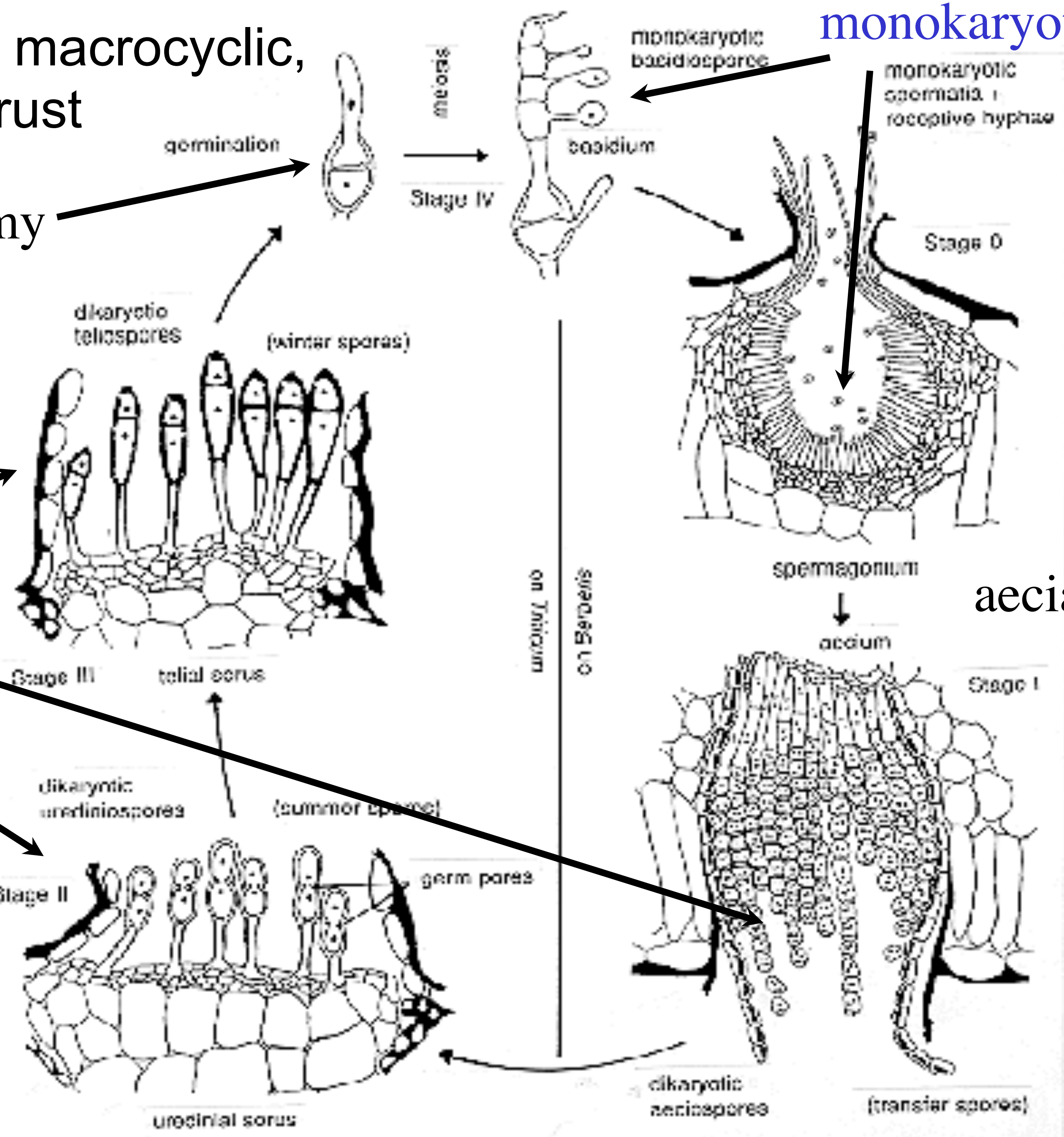


basidiospores

Life cycle of a macrocyclic, heteroecious rust

monokaryotic

karyogamy

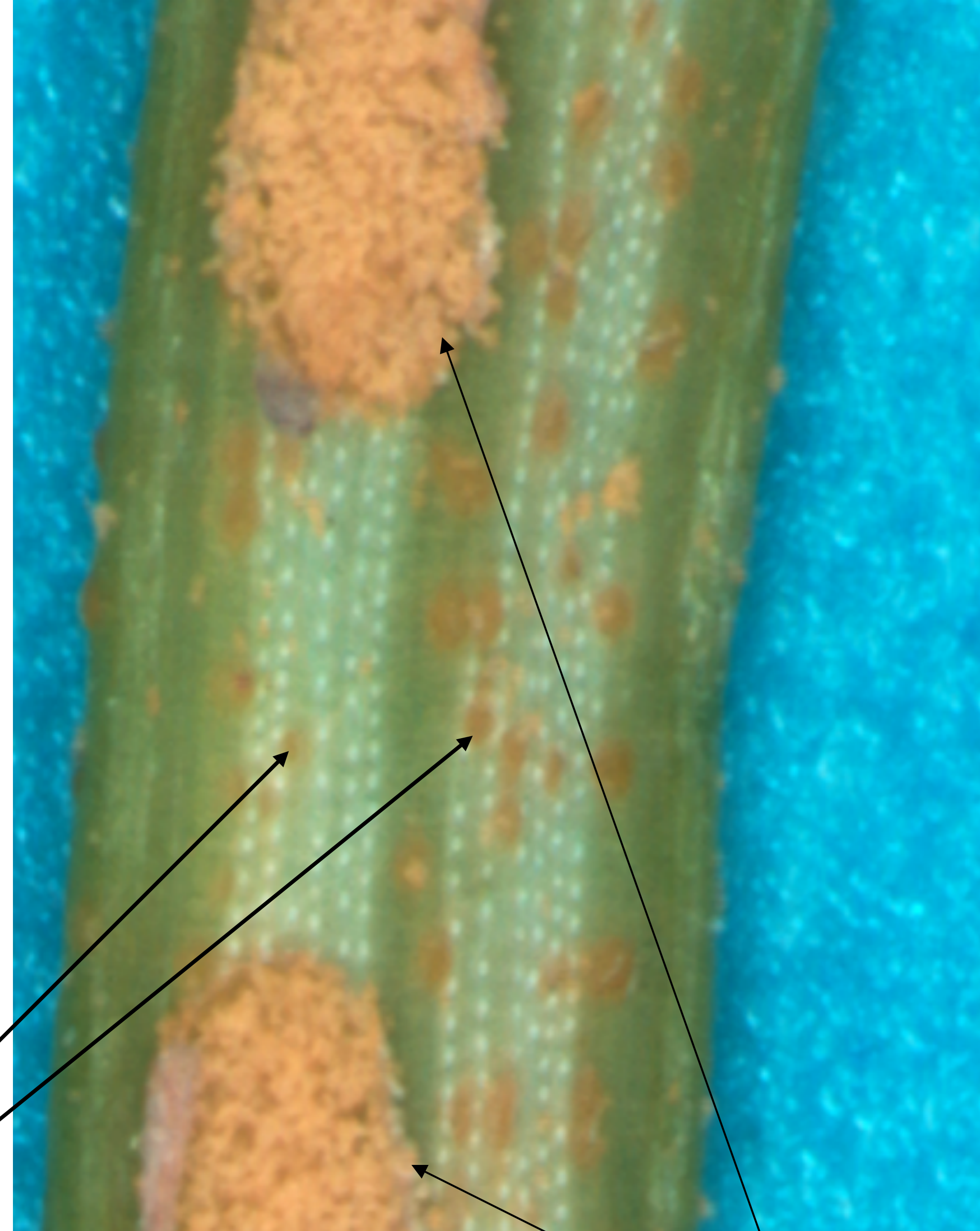


binucleate, dikaryotic

aecial host

telial host

Stage 0 pycnia



pycnia on
Douglas-fir needle

Stage I Aecia

Aecia

Pycnial stage is mating structure, the equivalent of pollination in plants

Heterothallic fungi require unlike mating types for reproduction-obligate outcrossing

Pycnia are attractive to insects, serve as vectors of pycniospores which function as spermatia

"Pseudoflowers" are modified host tissues in rust infected plants that mimic flowers for attracting potential "pollinators"

Modification of host tissues
pseudoflowers

Polygonia zephyrus
visiting
Puccinia monoica,
which is infecting
Arabis holboellii

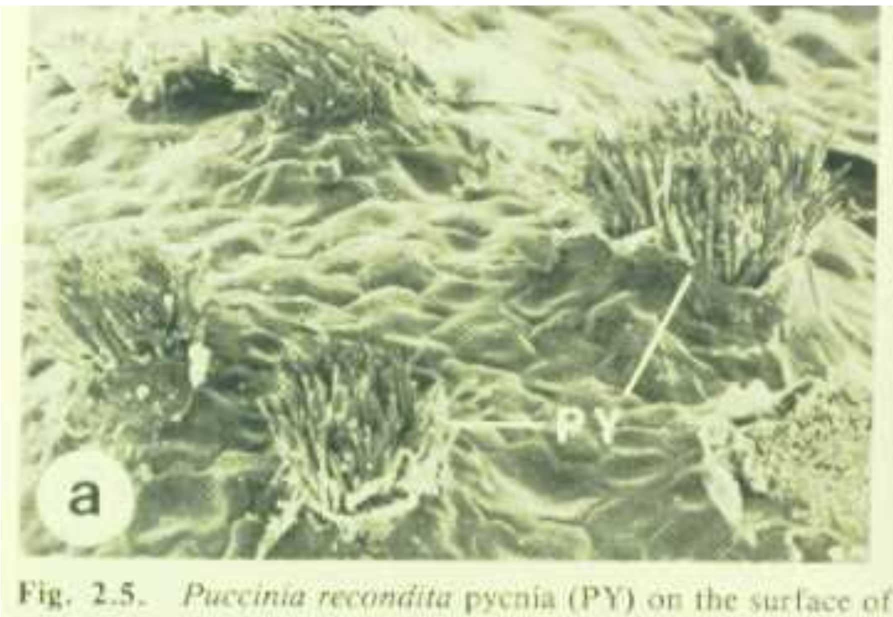
Bitty Roy

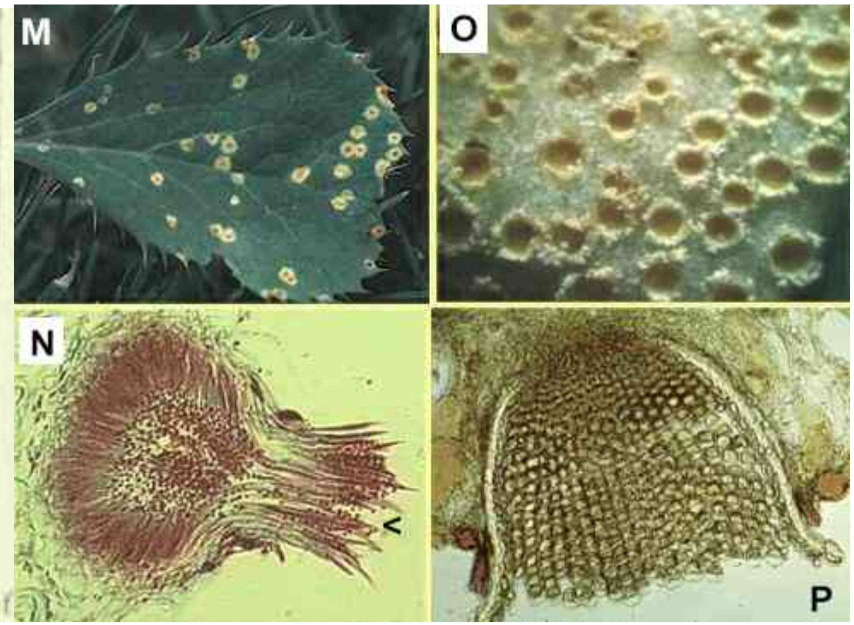
Modification of host tissues: Rust galls
abnormal plant growth caused by infection

Pucciniastrum goeppertianum telial galls

Stage 0 and I produced on <u>alternate (aecial) host</u>

Stage 0: Pycnia (spermogonia) bearing spermatia (n) and receptive hyphae (n)



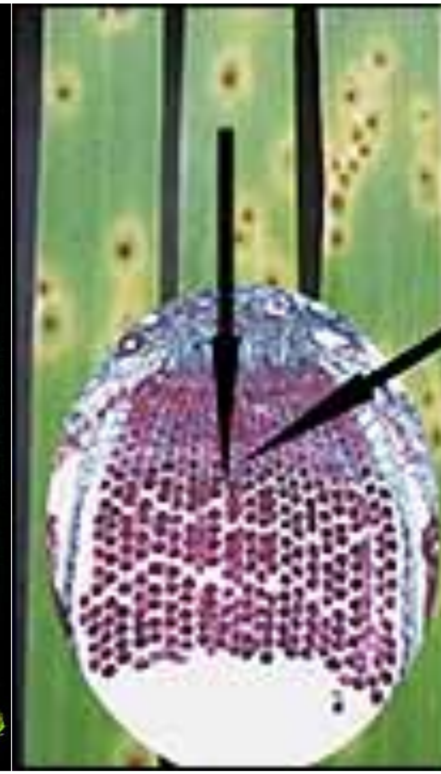


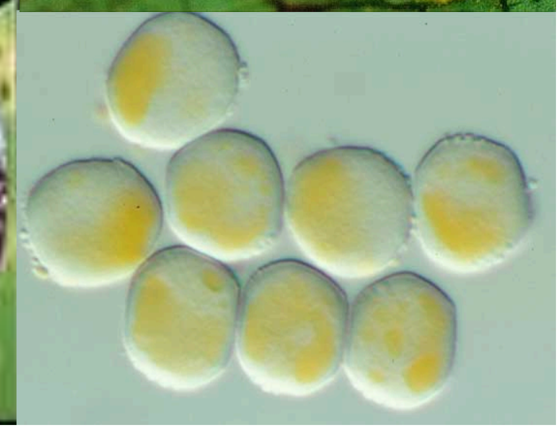
helios.bto.ed.ac.uk/bto/microbes/biotroph.htm

- **fertilization of the receptive hyphae by pycniospores initiates the dikaryon and the formation of aecia, aeciospores**

Pycnia on Amelanchier

Stage I: Aecia bearing aeciospores (n+n)

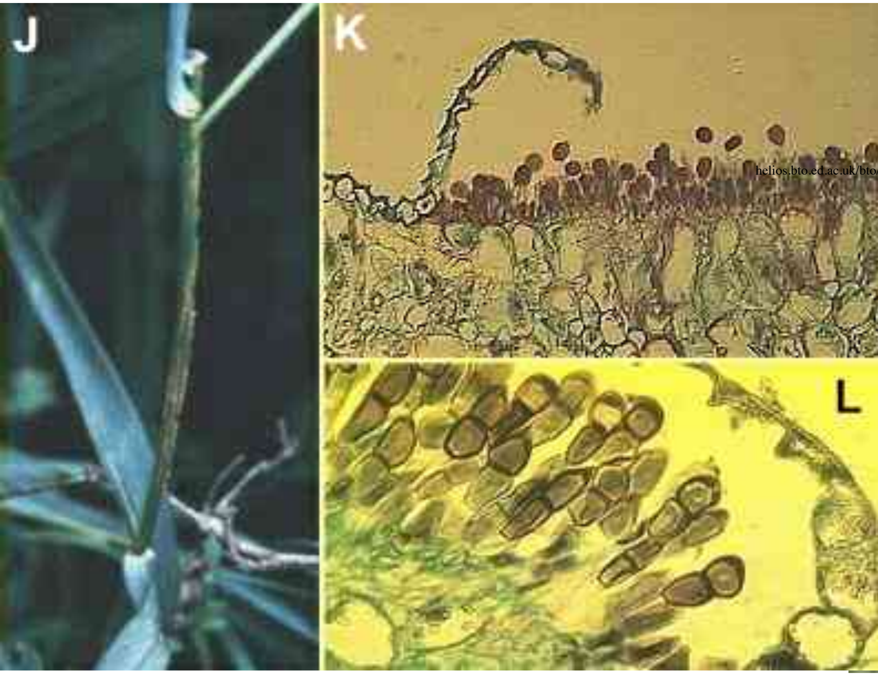


- **aeciospores infect <u>primary or telial host</u>**
- **e.g., aeciospores produced on alternate host (e.g., Barberry) infect primary host (e.g., grasses)**

Aecia on Pyrus

Stage II: Uredinia (j) bearing urediniospores (n+n)



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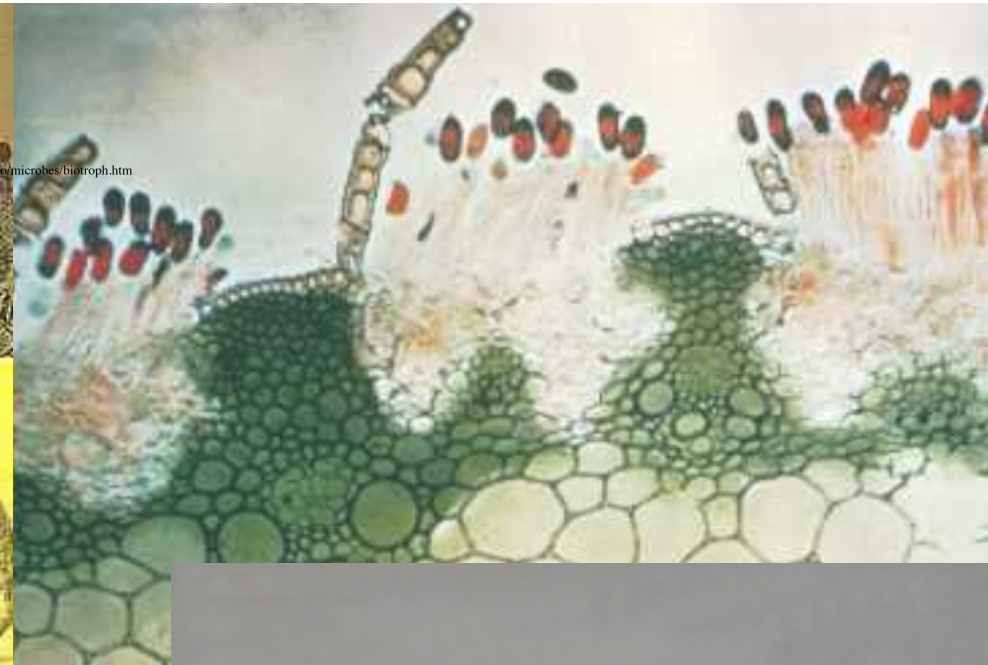
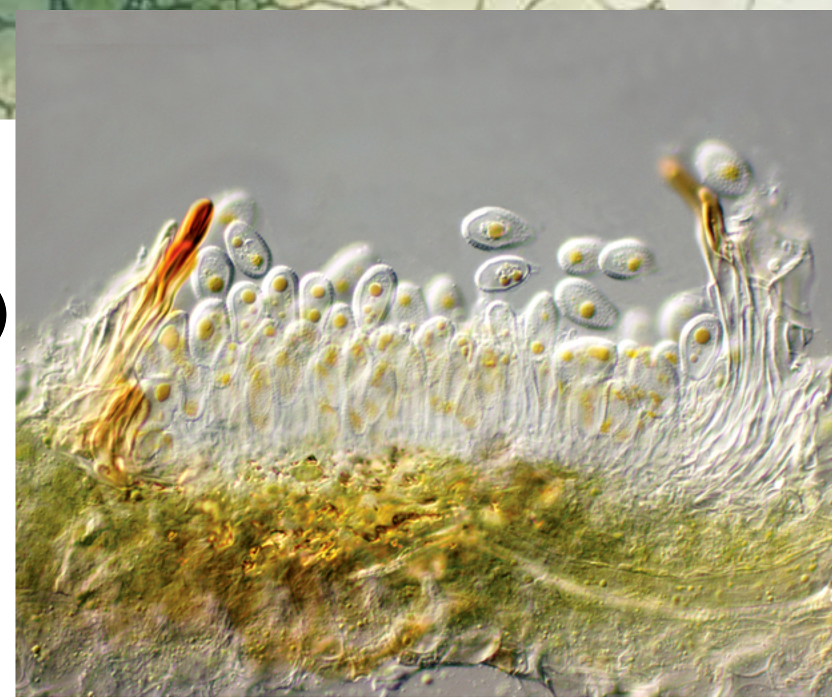
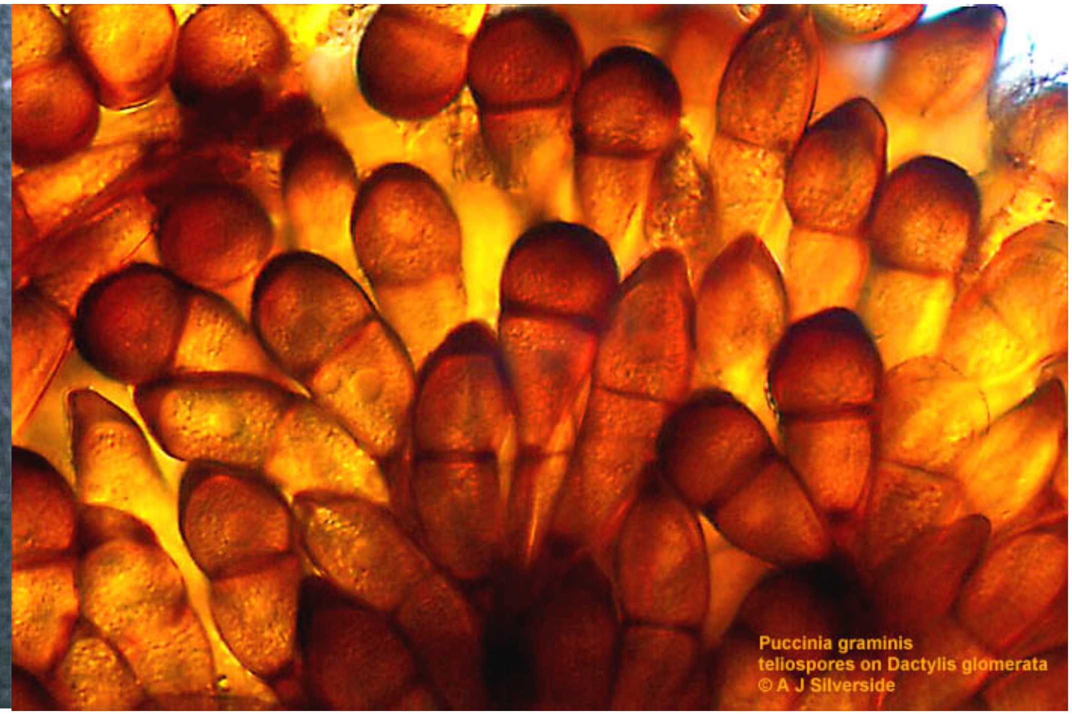




- develop on primary host
- reinfect primary host (epidemic phase)
- amplifies disease within primary host
- uredinia eventually develop into telia


Gymnosporangium uredinia on Amelanchier

Stage III: Telia bearing teliospores
site of karyogamy (n+n>2n)



- final stage on primary host
- overwinters as dikaryon
- karyogamy, meiosis occur in spring in many spp.

Following karyogamy teliospore germinates to form a promycelium

Germinating teliospore and promycelium which becomes a basidium

Stage IV Basidia bearing basidiospores (n)

- in the spring teliospore germinates a promycelium
- diploid nucleus migrates into the promycelium and undergoes meiosis
- four haploid nuclei migrate into developing sterigmata & are incorporated into basidiospores
- basidiospores infect alternate host

Examples of distantly related alternate hosts

Puccinia graminis **wheat rust**
0 and I on barberry bushes (*Berberis vulgaris:* dicot)
II and III on various grasses (monocot)

Cronartium ribicola **white pine blister rust**
0 and I on white pines (gymnosperms)
II and III on currants & gooseberries (angiosperms)

Uredinopsis osmundae
0 and I on the balsam fir (*Abies balsamea*: gymnosperm)
II and III on the cinnamon fern (*Osmunda cinnamomia*)

Tranzschel’s Law:

Microcyclic rusts telial stage adopt the habit of the parent macrocyclic species and occur only on the (ancestral) aecial host plant. Macrocyclic species are ancestral.

Microcyclic rusts are evolutionarily derived from macrocyclic rust species that have lost stages I and II, produce telia directly on the ancestral species’ aecial host.

Microcyclic species are derived from macrocyclic species but the ancestral uredinial and telial states (I, II) are lost, the life cycle is completed on the alternate (aecial) host. Aecia have become telia.

Teliospores of microcyclic rusts often are morphologically similar to aeciospores, but upon germination produce basidia and basidiospores, not germ hyphae.

Rust Diseases

Conifer Rusts

Stem Rusts - more economically damaging than foliage rusts
- primarily diseases of pines

  - Cronartium ribicola White Pine Blister Rust
  - Cronartium quercuum Fusiform rust
  - Endocronartium harknessii (Peridermium pini) Western gall rust
  - Cronartium comandrae Comandra blister rust

Stem rusts of other conifers
- Gymnosporangium species affect Junipers, Incense cedar

Damaging stage of pine stem rusts is usually the aecial stage
Infection by basidiospores in spring, usually on foliage

western gall rust on lodgepole pine

Hosts are 2- and 3-needle pines—lodgepole pine, ponderosa pine, knobcone pine

Endocronartium (Peridermium) pini

Life cycle is still not understood. May be microcyclic—aeciospores function as telia, or aeciospores able to reinfect pine

Cronartium comandrae affects lodgepole, ponderosa pine, native to NA

Comandra blister rust aecia

Uredinia on Comandra umbellata
“bastard toadflax”