FUNGAL ECOLOGY

(sometimes with special regard to macromycetes)

Fungi and their environment • Life strategies and interactions of fungi • Ecological groups of fungi, saprotrophs (terrestrial fungi, litter and plant debris, wood substrate, etc.) • Fungal symbioses (ectomycorrhiza, endomycorrhiza, endophytism, lichenism, bacteria, animal relationships) • Parasitism (parasites of animals and fungi, phytopathogenic fungi, types of parasitic relations) • Fungi in various habitats (coniferous forests, broadleaf forests, birch stands and non-forest habitats, fungal communities) • Fungal dispersal and distribution • Threat and protection of fungi

(the study material has not been corrected by native speaker)

PARASITISM, PATHOGENIC FUNGI

ZOOPATHOGENIC FUNGI

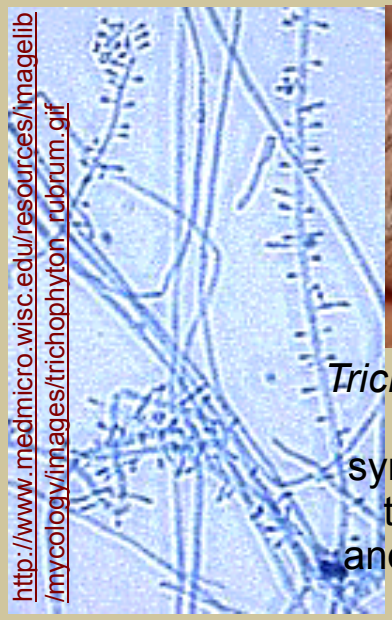
Fungal **parasites of animals** belong mainly to ascomycetes or imperfect fungi (however, two basidiomycetes have also been found in humans – *Schizophyllum commune* isolated from the nails, palate and respiratory tract, and mycelium of *Coprinus cinereus* in the heart membrane). They cause either superficial dermatomycoses on the skin or mucous membranes (most of them) or systemic mycoses affecting the internal organs. For successful attack of the host organism, it is usually necessary to pass through the epidermis or chitin cuticle and inside the host body to cope with response of the immune system, lack of oxygen, to buffer pH, ...

Recently, the number of cases of human mycoses in has been increasing – possible reasons are weaker human immunity, too frequent antibiotic treatment (it suppresses all bacterial biota => easier invasion of the fungal pathogen), or expansion of travel (transmission of fungi from other regions) – but it is difficult to determine one factor, it is always an interplay of several factors.

Dermatomycoses are usually more unpleasant than dangerous, but often they go into a chronic stage.

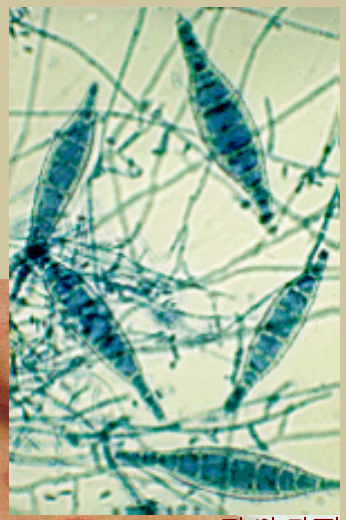
Skin parasites are most often species of the genera *Microsporum*, *Tricho-phyton*, *Epidermophyton* (ascomycete anamorphs), usually different species on different animals (however, it does not exclude that „animal“ species can be transmitted to humans).
They parasitise on keratin structures – skin and its derivatives, nails, hair, etc., and animal hairs, feathers, horns; some fungi are specialised only in this so-called „hard keratin“ (apparently they are eliminated by the presence of antifungal factor in living tissues).

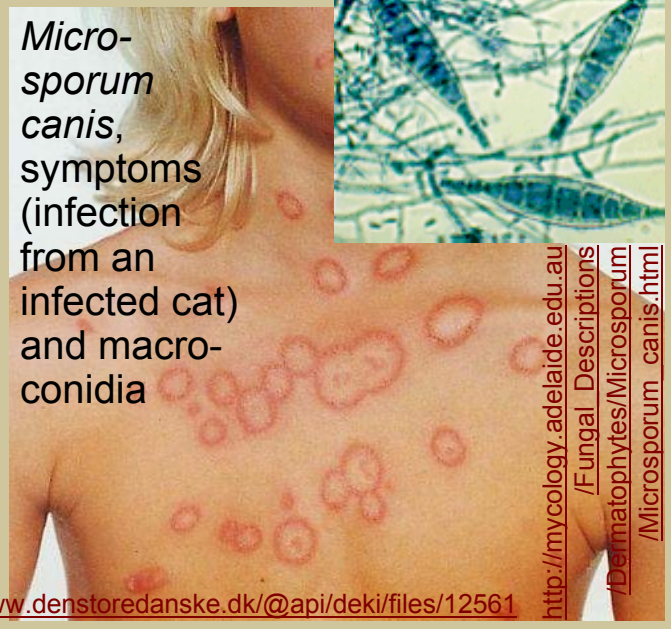
The mycelium grows along the dead cell layers and spreads by disintegration of the hyphae – by formation of arthrospores (in this vegetative state the fungi are indeterminable, they can be identi-fied by cultivation) => then they spread on skin fragments (in clothrooms, showers, etc.).


http://www.medmicro.wisc.edu/resources/imagelib/mycology/images/trichophyton_rubrum.gif


http://dermatology.cdlib.org/1411/case_presentations/tinea_barbae/xavier.html

Trichophyton rubrum, symptom in the beard and hyphae + conidia




http://mycology.adelaide.edu.au/Fungal_Descriptions/Dermatophytes/Microsporum/Microsporum_canis.html

Micro-sporum canis, symptoms (infection from an infected cat) and macro-conidia

http://www.denstoredanske.dk/@api/deki/files/12561

Under suitable conditions (for example, if the skin is wet for a long time; this typically occurs in wet and moist conditions between the fingers, where the skin is both thin and sensitive), certain species may switch to direct parasitism on living cells. Inflammatory reactions are caused by immune response of the body to fungal metabolites.

If cracks appear in the skin => exposure of living cells, it is an ideal „gate“ for secondary infections – e.g. species of the genus *Sporothrix*, dimorphic fungi that penetrate small wounds and cause sub-cuticular infections, but can change from hyphal to yeast-like form and be spread by the lymphatic system further in the body => invasion of internal organs. Secondary infections are usually a matter of facultative pathogens (these species are otherwise soil saprotrophs living on plant remnants with teleomorphs in the genus *Ophiostoma*).

Sometimes it can be confused with a more serious disease – „tinea nigra“ caused by *Hortaea werneckii* (anamorph of *Capnodiales*, *Dothideo-mycetes*) has a similar symptom as skin cancer.

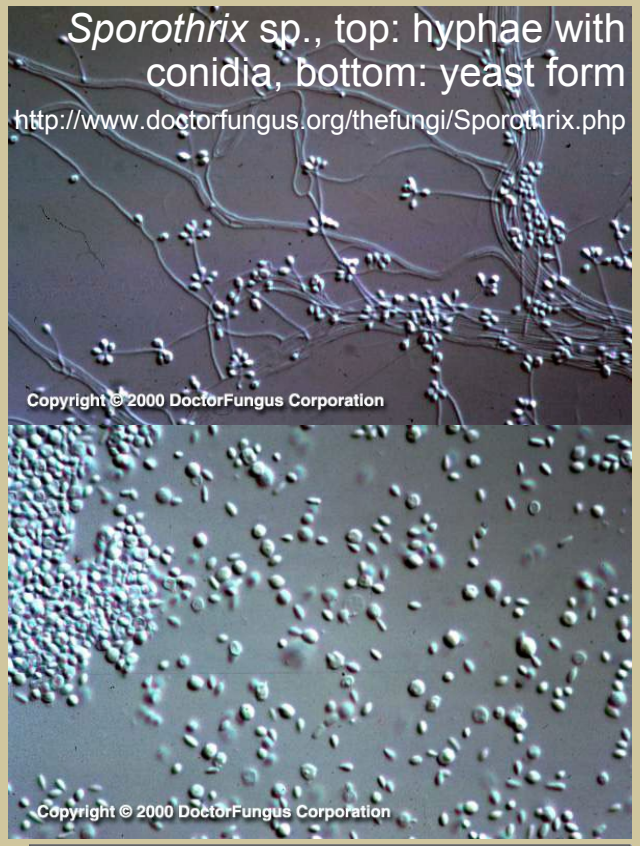
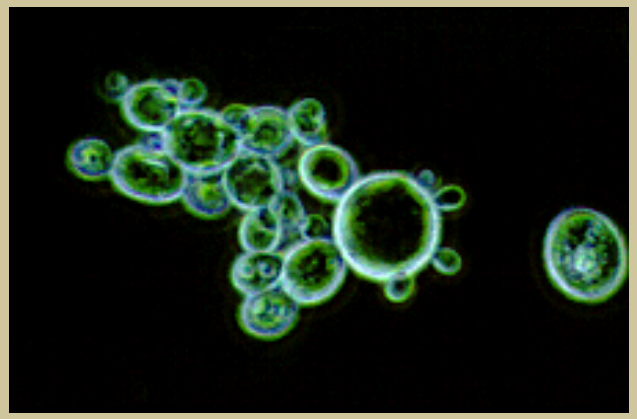
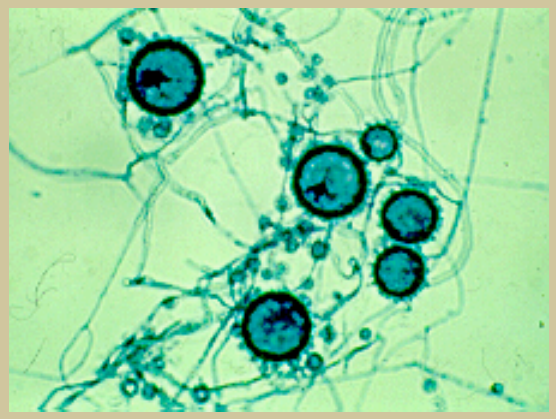


Figura 1: Mancha acastanhada, com 1,5cm de diâmetro, limites precisos, na palma da mão direita / *Figure 1: Brown stain, 1.5 cm in diameter, well-defined borders on the palm of the right hand*

Systemic mycoses are caused by both specialized and facultative (opportunistic) parasites.

The real specialized pathogens are anamorphs of fungi of the order *Onygenales*, causing skin and lung diseases – *Histoplasma*, *Blastomyces* (teleomorphs in the genera *Ajellomyces*, *Gymnoascus*), *Coccidioides* and *Paracoccidioides*.
The centers of their occurrence are in the American continents, but even after a short stay there it is possible to become infected, just inhale spores (the risk of infection is a problem mainly for people from areas where these fungi do not occur naturally, while „natives“ often have developed natural immunity).
Primarily, these fungi attack the lungs (these are also the main „gateway“ to infect the body), but in yeast form (they are also dimorphic fungi) they spread through the bloodstream to other organs.





Histoplasma capsulatum, macroconidia and microconidia

http://mycology.adelaide.edu.au/Fungal_Descriptions/Dimorphic_Pathogens/Histoplasma/

Paracoccidioides brasiliensis, budding yeast cells

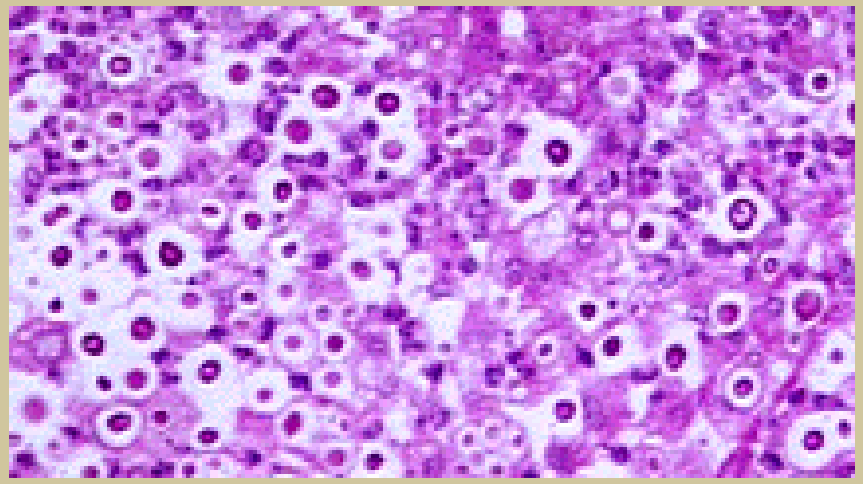
http://mycology.adelaide.edu.au/Fungal_Descriptions/Dimorphic_Pathogens/Paracoccidioides/

Opportunistic mycoses are caused by many normally saprotrophic fungi when they attack weakened or damaged tissues or organs.

Mucormycoses (species of the genera *Mucor*, *Rhizopus*, *Absidia*) or aspergilloses (species of the genus *Aspergillus*, for example *A. fumigatus*) of the digestive tract, lungs or parts of the head may be serious. Weakening of the organism is often a major cause – in 2021 there was a mass spread of mucormycosis among covid patients in India.

Cryptococcus neoformans (anamorph of the basidiomycete *Filobasidiella*) attacks the skin and mucous membranes, bones, lungs and nervous system; it often occurs in domestic animals (especially ungulates), and pigeons can act as vectors in cities (spreading spores in their excrements => then by wind).

Filobasidiella neoformans, basidiospores

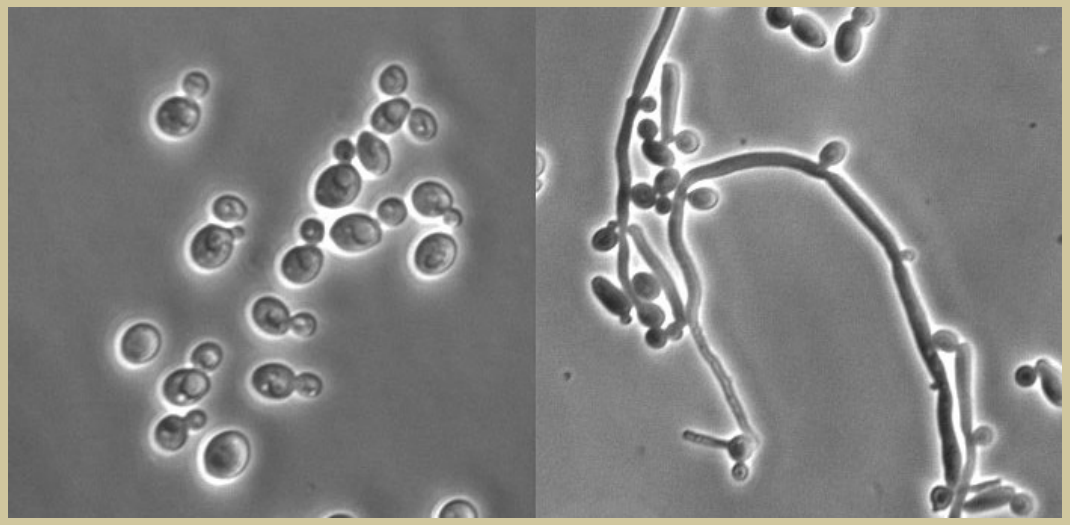


Cryptococcus neoformans, cells in brain tissue

http://www.mycology.adelaide.edu.au/Fungal_Descriptions/Yeasts/Cryptococcus/C_neoformans.html

http://www.medmicro.wisc.edu/resources/imagelib/mycology/images/HE_c_neoformans_brain.html

The most common infection is caused by the yeast *Candida albicans*, normally living on the surface and inside the body (i.e. in both aerobic and anerobic conditions) – the saprotrophic stage is yeast-like, spreads via blastospores. If *Candida* has good conditions for multiplication (antibiotics, especially with a „wide range“, can have a negative effect when they reduce the bacterial biota => free niche for fungi, elimination of competition for nutrients), it turns into a parasitic pseudomycelial form => when it enters the blood, it is spread throughout the body and often causes lingering diseases of skin, lungs or digestive system.



Saprotrophic yeast stage, parasitic filamentous form.
http://www.digitalapoptosis.com/archives/science/Candida.jpg

http://www.candidablog.com/what-are-male-yeast-infections.php

Candida albicans on intestine walls and kidney surface (white spots).

In general, mycoses of the internal organs break out more easily when the immune system is weakened – due to a birth defect, another disease (the immediate cause of death in AIDS patients is often candidiasis, to a lesser extent aspergillosis or mucormycosis) or medication, typically after transplants (due to this reason the mycoses are a serious problem today, while not so much in the past).

Fungicide compounds that deactivate the plasma membrane of fungal cells are tested against fungal pathogens (polyenes produced by *Streptomyces* bind to ergosterol that is part of the membranes => they become permeable; synthetic azoles directly block the formation of sterols). In general, there are a number of fungicides, but only a very limited number of them can be applied in medicine (so as not to damage animal tissues); griseofulvin, for example, is used to treat mycoses. However, the fungal infection is often not completely cured and returns repeatedly.

The spores of some fungi act as **allergens** (similar to dust, pollen, etc.) – asthma can be a manifestation of such an allergy.

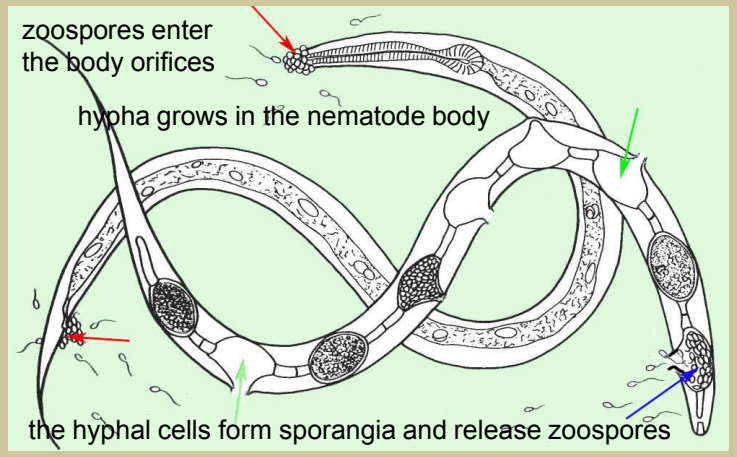
An example is aspergillosis (*Aspergillus flavus*, *A. niger* – common soil saprotrophs), which is rather an allergic manifestation when inhaling a large number of spores => hyphae grow in organs (especially the lungs), but aflatoxins are not produced here.

Aspergillus fumigatus belongs to the species involved at high temperatures in the process of composting *(see the chapter Saprotrophs)* => allergenic action of spores in larger quantities is a problem of people working with compost or silage.

Other common saprotrophs on plants are species of the genera *Cladosporium* (more in colder and wetter areas) and *Alternaria* (even in warm arid areas) – their spores are released in large quantities at harvest, which is a problem in agricultural regions.

Last but not least, we cannot forget the allergenic effect of a large number of spores in the process of mushroom growing (in growing halls of button mushrooms, oyster mushrooms, etc.).

The general principle that outbreak of the disease is easier with weakened immunity applies similarly to allergies, which even may not break out in a healthy person (a strong immune system makes it easier to eliminate the fungus).



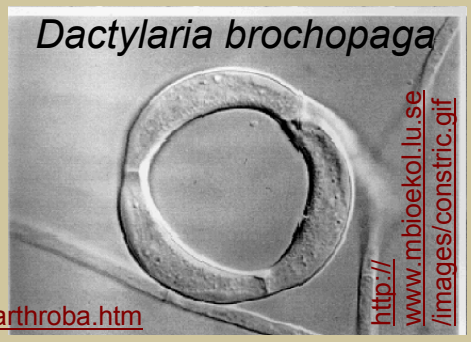
Fungi infesting nematodes are only rarely typical parasites, such as *Catenaria anguillulae* (*Blastocladiomycota*).

Source: George Barron, http://www.uoguelph.ca/~gbarron/2008/catenar0.htm

Most nematophagous fungi (especially imperfect) are in principle saprotrophs, which thus „supplement their diet“ with a source of nitrogen; gain from animal tissue also gives them a competitive advantage in its absence. On the other hand, they are not directly dependent on the animal source of nutrients – they can thus affect the abundance of nematode populations, but they are not limited by their deficiency.

From nematodes, which often form the most numerous and species-rich group of soil invertebrates in soil, litter and rotting wood, they obtain nutrients in two ways: The first is passive, the hypha sticks to the nematode => an appressorium is formed and then the digestive hyphae. Adhesion is due to touch of the nematode, which stimulates the secretion of a sticky drop containing lectins (surface proteins), which bind to the substances contained in the cuticle. (These proteins may be specific, for example *Arthrobotrys ellipsospora* produces mucopolysaccharide sensitive substances, while proteins of *Arthrobotrys oligospora* bind to N-acetylgalactosamine when the nematode cuticle contains galactose. In addition to them, however, non-specific adhesive substances are also formed, which bind to some carbohydrate chains – instead of nematodes, for example yeasts can be caught and trapping sites blocked.)

The second way is active „hunting“ – the fungi behave as predators (referred to as „predatory fungi“), applying various types of baits, snares, nets and trapping structures.



For example, species of the genera *Arthrobotrys* or *Dactylaria* form a mycelial loop (sometimes they also produce substances that attract the prey) => when the nematode enters the loop, the fungal cells „inflate“ and pinch the prey => then digestive hyphae absorb nutrients from its body. Another way of „hunting“ is applied by some *Pleurotaceae* (anamorphs of *Hohenbuehelia* or *Resupinatus* species), which do not form loops, but trap nematodes in wood by outgrowths with sticky matter => after gluing the nematode they excrete a substance that immobilises it => mycelium grows into the body cavity. (Also some other fungi can spontaneously „feed“ on nematodes immobilised by the excreted toxins or narcotics.)

/More about various types of trapping structures see in General mycology, chapter Vegetative thallus of fungi, section Specialised cells and hyphal structures./

Trapping structures are in some cases produced spontaneously (we can also find them in pure culture), while in other cases they are formed only if the prey is present (i.e. after chemical induction).

Some species of fungi are completely „indiscriminate“ (in terms of prey, e.g. *Zoophagus pectosporus*), while others specifically hunt, for example, members of a specific family of nematodes (*Monacrosporium ellipsosporum*).
It should be added that the „hunter-prey“ relationship is not only one-way between fungi and nematodes – many soil nematodes can suck hyphae and thus negatively affect, for example, communities of ectomycorrhizal fungi.

Source: Cooke & Whipps 1993; taken from http://botany.natur.cuni.cz/koukol/ekologiehub/EkoHub_6.ppt

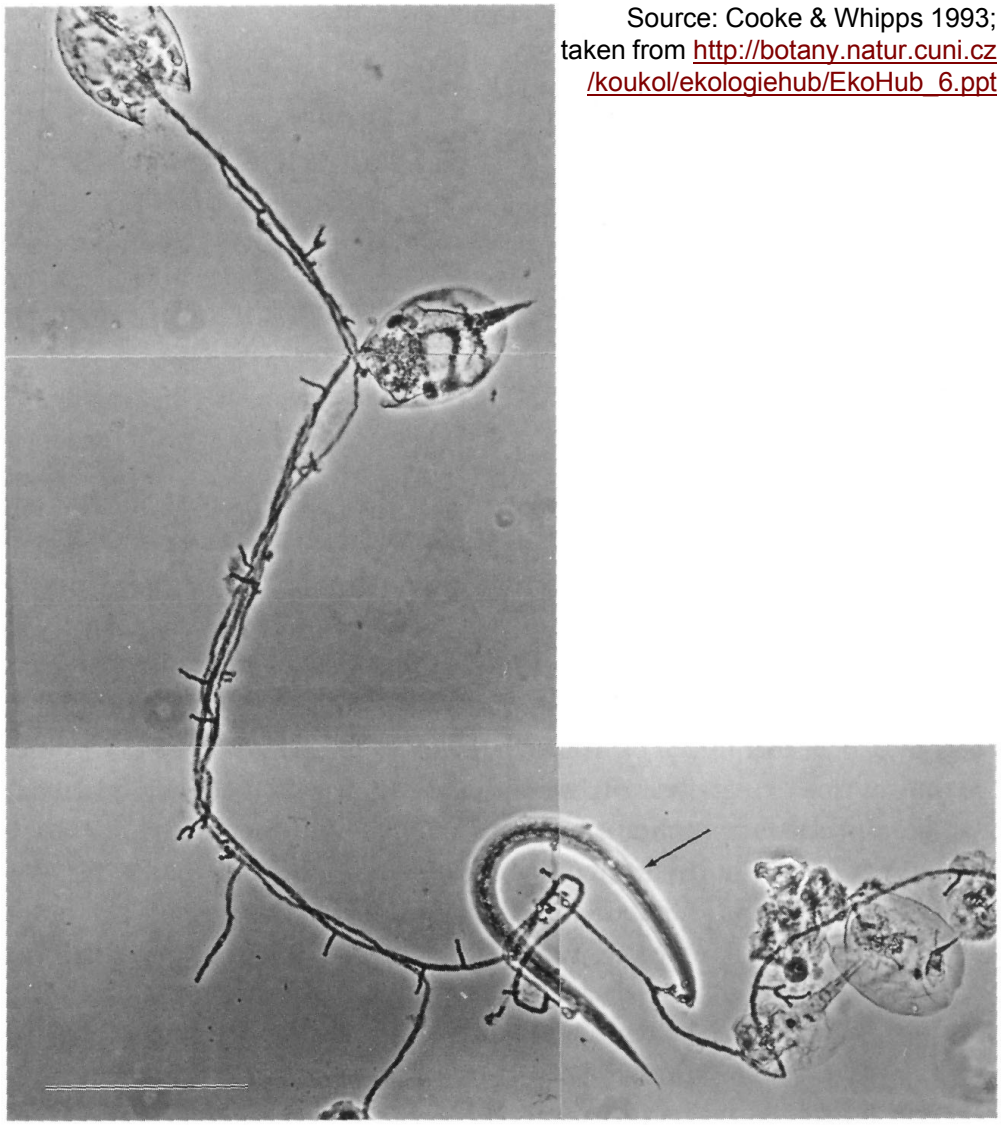
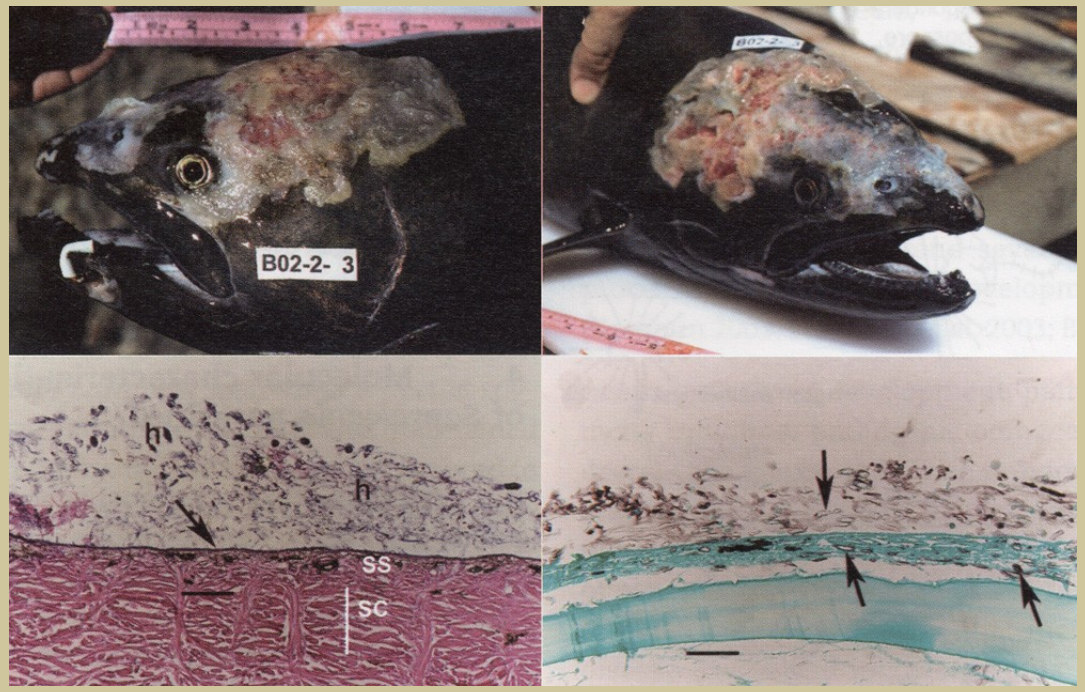


Fig. 10.5 Capture of rotifers by *Zoophagus pectosporus*. Several rotifers caught on the same hyphal system as a single nematode (arrowed). Bar = 100 µm (from Saikawa *et al.*, 1988, *Mycologia*, **80**, © 1988 New York Botanical Garden).

Representatives of „**water moulds**" of the order *Saprolegniales* (*Peronosporomycota*) are important parasites of aquatic animals, especially fish; *Saprolegnia parasitica* (photo on the left) is a natural inhabitant of our waters, but increased occurrence in fish farms (in ponds or in aquariums) is a serious problem. Other species of this group parasitise invertebrates; *Aphanomyces astaci* (introduced from the USA to Europe; photo on the right) destroys the local populations of crayfish.



West 2006; taken from http://botany.natur.cuni.cz/koukol/ekologiehub/EkoHub_6.ppt

Photo: Andrzej Martin Kasiński, http://www.nurkomania.pl/fauna_raki.htm, resp. http://www.nurkomania.pl/atlas/n285.jpg

Currently the most dangerous fungus, spreading in the aquatic environment, is probably *Batrachochytrium dendrobatidis* (*Chytridiomycota*).
It is not known where it comes from (human transport has a great influence on its spread, warming may have a certain effect too), but it is responsible for the global problem of the decline of amphibians.

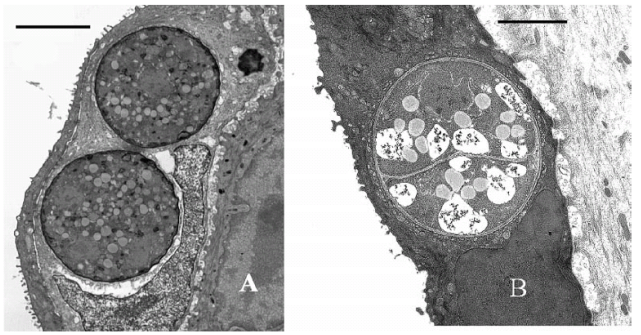


Fig. 2. Developing monocentric (A) and colonial (B) thalli in the keratinized skin layer of *Ambystoma tigrinum*. Electron micrographs. Bar = 4 μm.

Source: Davidson et al. 2003; taken from http://botany.natur.cuni.cz/koukol/ekologiehub/EkoHub_3.ppt

Figure 3. *X. tropicalis* illustrating hyperpigmentation, dysecdysis, loss of slime layer, and excessive buoyancy.

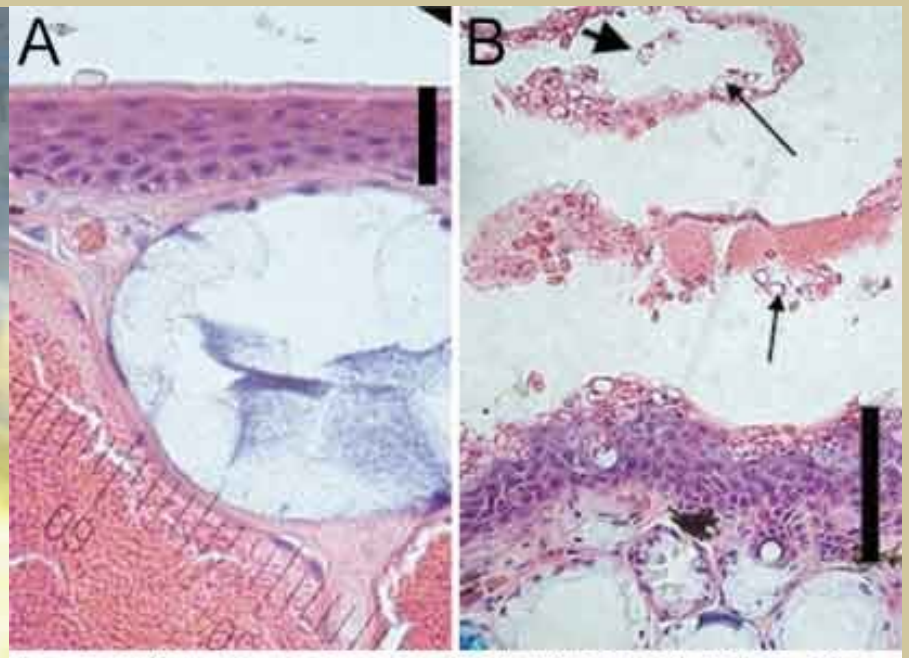


Figure 4. (A) Photomicrograph of a section of healthy *X. tropicalis* skin. Notice a uniform epidermal layer (vertical bar). (B) Photomicrograph of a section of skin from a *X. tropicalis* with chytridiomycosis. Notice thalli of B. dendrobatidis in the sloughing layers of epidermis (thin arrows) and the zoospores present in one thallus (thick arrow). Notice the irregularity of the epidermis (vertical bar).

The most frequent are **insect parasites** (they are also probably best known for their use in biological control, although bacteria or viruses are used more effectively – the success of fungal infection is more dependent on environmental conditions that allow spores to germinate). They are usually specialised in a certain stage of insect development – larvae and pupae are attacked mainly by soil species, while parasites of imagines spread through the air.

Fungi of the genus Entomophthora infect the insects by mucous conidia => they germinate, forming mycelium with apressorium => the hyphae penetrate the body (the skeleton is enzymatically disrupted) => inside they break down into hyphal bodies (single- or multicellular fragments) => they are spread by hemolymph throughout the body => further division => conidiophores and conidia are formed from hyphae growing on the body surface => they are thrown away and can spread to other individuals. *Entomophthora muscae* (see photo) parasitizes on flies, related species *Entomophthora grylli* attacks locusts and can decimate entire populations in wet weather. *Entomophthorales* (in addition to obligate parasites, recent subdivision *Entomophthoromycotina* of the zygomycete lineage *Zoopagomycota* includes also saprotrophs) are mainly temperate fungi; some species kill insects quickly (within a few days), others are „gentle“, the infested insect survives and is a carrier that spreads the released spores.

http://www.uoguelph.ca/~gbarron/MISCELLANEOUS/ento2.htm

Species of the genus *Cordyceps* sensu lato (order Hypocreales) commonly parasitize on larvae, pupae and adults of various insects, especially in the tropics (but many species grow in our country, for example *Cordyceps militaris* can be important in regulating populations of some parasitic insect species).
The affected body is grown through and „mummified“ => a pseudosclerotium is formed (often in the soil, a persistent stage), from which stromata subsequently grow. *Cordyceps* species are favourite food of some animals (e.g. deer eat them with mummified insects) and humans (a delicacy in China or Australia).

From left to right: *Cordyceps militaris*, two photos of *C. entomorhiza* growing from the pupa, top right *C. dipterigena* on the fly, bottom *C. lloydii* on the ant of the genus *Camponotus*.

Do you want to be like Sam Pakonen?

Let's eat *Ophiocordyceps sinensis*!

Many entomopathogenic species (at least hundreds) belong to imperfect fungi (*Beauveria*, *Metarhizium*; some are facultatively parasitic): the spores germinate on the body surface and the fungus penetrates inwards (similarly to *Entomophthora*), spreading through hemolymph like yeast cells (some producing toxins) => after death of the insect it goes back to the hyphal form and grows through the body.

Larvae of dipterans are attacked by *Coelomomyces* (*Blastocladiales*) – it is applied against mosquitoes in the tropics.

http://www.dropdata.org/cocoa/cocoa_biological.htm

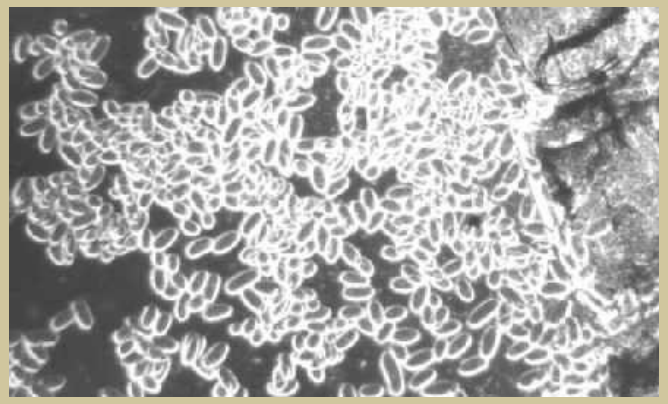


Photo J. Robert Harkrider, http://empidid.com/NatEm/coelomom.html

Left: *Beauveria bassiana* growing out between body segments of *Pantorhytes plutus*.

Right: *Coelomomyces* sp., hyphal bodies in hemolymph of *Dicrotendipes californicus*.

The same fungal species can be a symbiont for one organism and a pathogen for another – an example is the yeast *Rhodotorula glutinis*, which probably lives symbiotically in the frog intestines => if excrement with this yeast is released into the water (likely even release of its metabolites is sufficient), it has decimating effect on the larvae of female mosquitoes (higher mortality, some do not pupate, hatched imaga are smaller – why it affects only females remains a question).

http://classes.plantpath.wsu.edu/plp521/

Apparently **commensals** (not very harmful to their hosts, at most a slight parasitism is supposed) are *Laboulbeniales*, which form very specific associations (one species of this fungal group grows only on a very limited range of related insect species). They grow on the surface of the insect body and their haustoria penetrate surface cells of the cuticle, from where they probably take all the nutrients – we can regard it as obligatory commensalism.

Perhaps parasites and perhaps also commensals are also fungi formerly classified in the class *Trichomycetes* (orders *Harpellales* and *Asellariales*, zygomycetes now also belonging to *Zoopagomycota*, subdivision *Kickxellomycotina*), growing in the intestines of arthropods. It is also a matter of concept – whether a parasite is, in principle, any organism that removes nutrients from its host, or whether it is commensalism if the host is not visibly damaged; in the case of *Trichomycetes*, it has not been proven to what extent these fungi diminish the nutrition of their host.

PARASITES OF PROTOZOA, ALGAE AND FUNGI

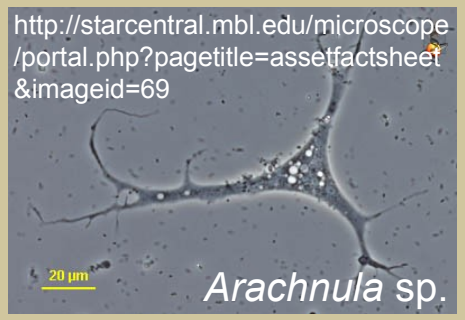
Many fungi parasitise on protozoa and other **single-celled organisms**. Species of the order *Zoopagales* (*Zoopagomycota*) attack amoebae: a hypha or sticky conidia sticks to the cell (the reaction of the cell is a "dead beetle", it stops moving) => the fungus grows inside and creates digestive hyphae in the cell. Similarly, species of the genus *Zoophagus* (also *Zoopagales*) attach to the rotifers.

http://www.masozravky.com/rody/drave_houby/zoophagi.htm

Hyphal peg of *Zoophagus insidans* growing into the rotifer body.

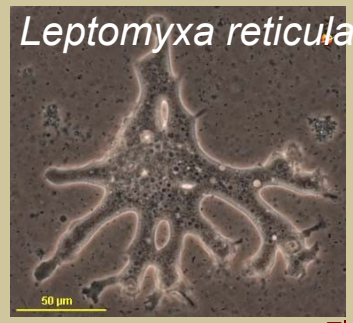
On the other hand, we also encounter cases where fungi are victims – predatory rhizopods of the group *Vampyrellidae* (divis. *Cercozoa*) suck the content of hyphae (*Leptomyxa reticulata*) or hyphae and spores (*Arachnula*).

http://starcentral.mbl.edu/microscope/portal.php?pagetitle=assetfactsheet&imageid=69



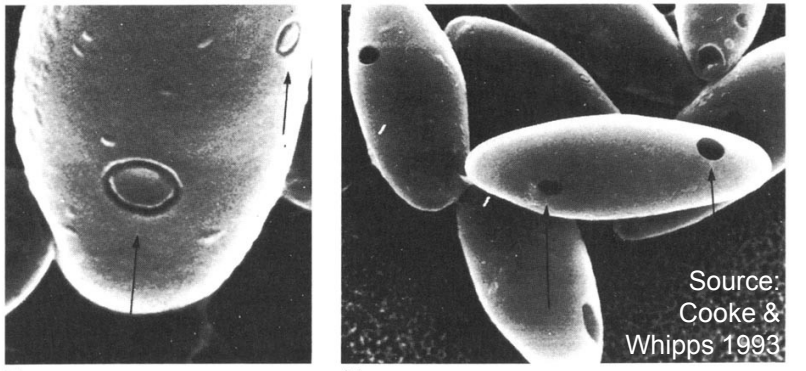
Arachnula sp.

Leptomyxa reticulata



http://microscope.mbl.edu/baypaul/microscope/lucidkeys/Xamoebae/html/LMEB_branchbodies.htm

Slime mould plasmodia secrete chitinases, they can „consume“ mycelium, conidia and decompose fruitbodies of macroscopic fungi.



taken from http://botany.natur.cuni.cz/koukol/ekologiehub/EkoHub_6.ppt

Fig. 6.3 Destruction of spores by soil amoebae. (a) Conidium of *Cochliobolus sativus* with annulations caused by contact with mycophagous amoebae; (b) conidia with large perforations resulting from removal of discs produced via annulation (from Anderson & Patrick, 1978, © American Phytopathological Society).

Parasites of algae are mainly from the division *Chytridiomycota* – they are usually difficult-to-identify organisms, mostly with eucarpic monocentric thalli and uniform zoospores. They play an important role in the regulation of phytoplankton populations, in freshwater lakes they can be at some stages the richest component of aquatic biocenosis.

Species of the genus *Rhizophydium* parasitise on diatoms, euglenids, green algae (but also on nematodes or pollen grains), *Polyphagus* (both *Chytridiales*) also on euglenids.

Left: sporangia of *Rhizophydium* sp. on diatom frustule.

Right: *Polyphagus euglenae* – zoospore, rhizomycelium connecting infected cells, course of the sexual process and formation of zoosporangia.

http://protist.i.hosei.ac.jp/pdb/images/Eumycota/Rhizophydium/index.html

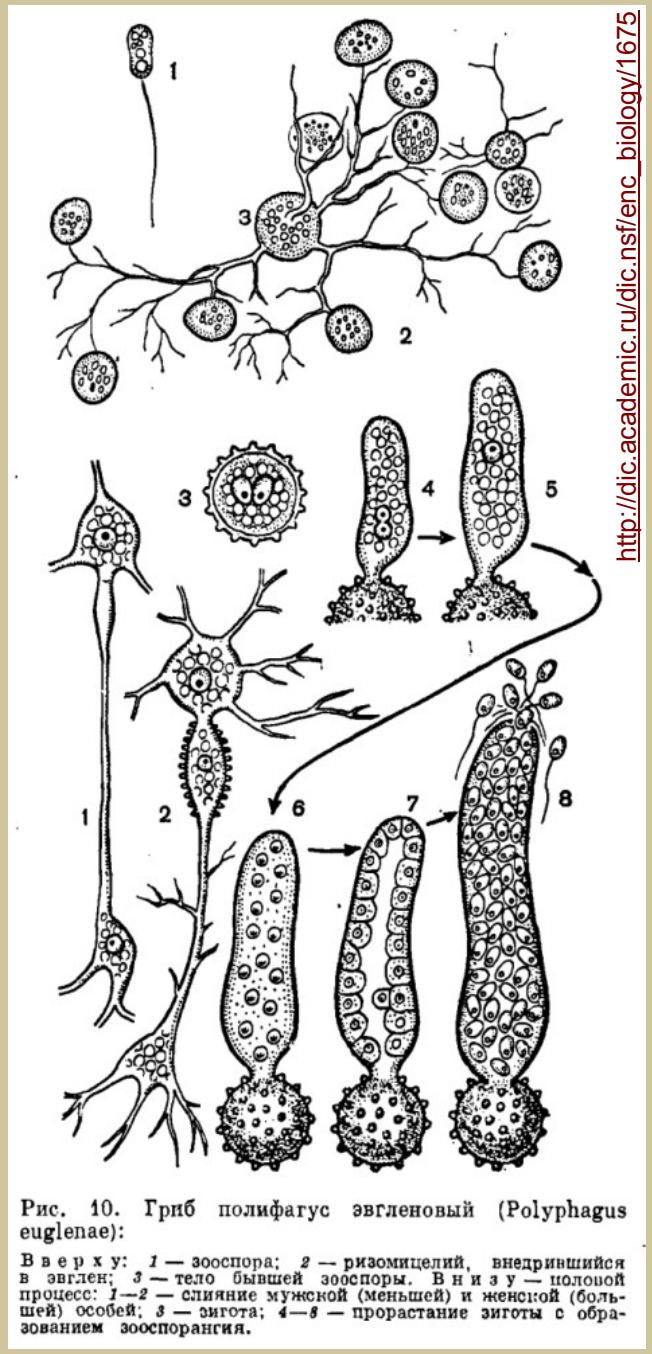


Рис. 10. Гриб полифагус эвгленовый (Polyphagus euglenae):

В в е р х у: *1* — зооспора; *2* — ризомицелий, внедрившийся в эвглен; *3* — тело бывшей зооспоры. В н и з у — половой процесс: *1—2* — слияние мужской (меньшей) и женской (большей) особей; *3* — зигота; *4—8* — прорастание зиготы с образованием зооспорангия.

http://dic.academic.ru/dic.nsf/enc_biology/1675

Mycoparasitism is proving to be common in nature (up to 3,000 species parasitising on other fungi have been reported). There is always contact between the mycelia of the parasitic and the host fungus based on the recognition of the host mycelium by surface lectin reactions, followed by adherence or penetration of the host cell and biotrophic or necrotrophic nutrition. *(Types of parasitism see later.)*

Biotrophic parasites usually attach their hyphae close to the infested ones, penetrate the cell wall (they have only chitinolytic enzymes, but not enzymes that would kill the cell) and create haustoria inside the cell.


Spinellus fusiger

Most biotrophic mycoparasites belong to zygomycetes:
– *Spinellus* (order *Mucorales*) parasitise fruitbodies of various basidiomycetes;
– many species of the order *Dimargaritales* parasitise biotrophically on *Mucorales* (they are difficult to grow in culture and do not sporulate if they do not have a host), applying positive chemotropism to the host hyphae;
– *Piptocephalis* (order *Zoopagales*) grows on coprophilic saprotrophs; although these fungi are found on faeces, they are not coprophilous species but their parasites.


Piptocephalis sp.
http://www.mycolog.com/CHAP3b.htm

Once more *Piptocephalis* ... Source: Cooke & Whipps 1993; taken from http://botany.natur.cuni.cz/koukol/ekologiehub/EkoHub_6.ppt

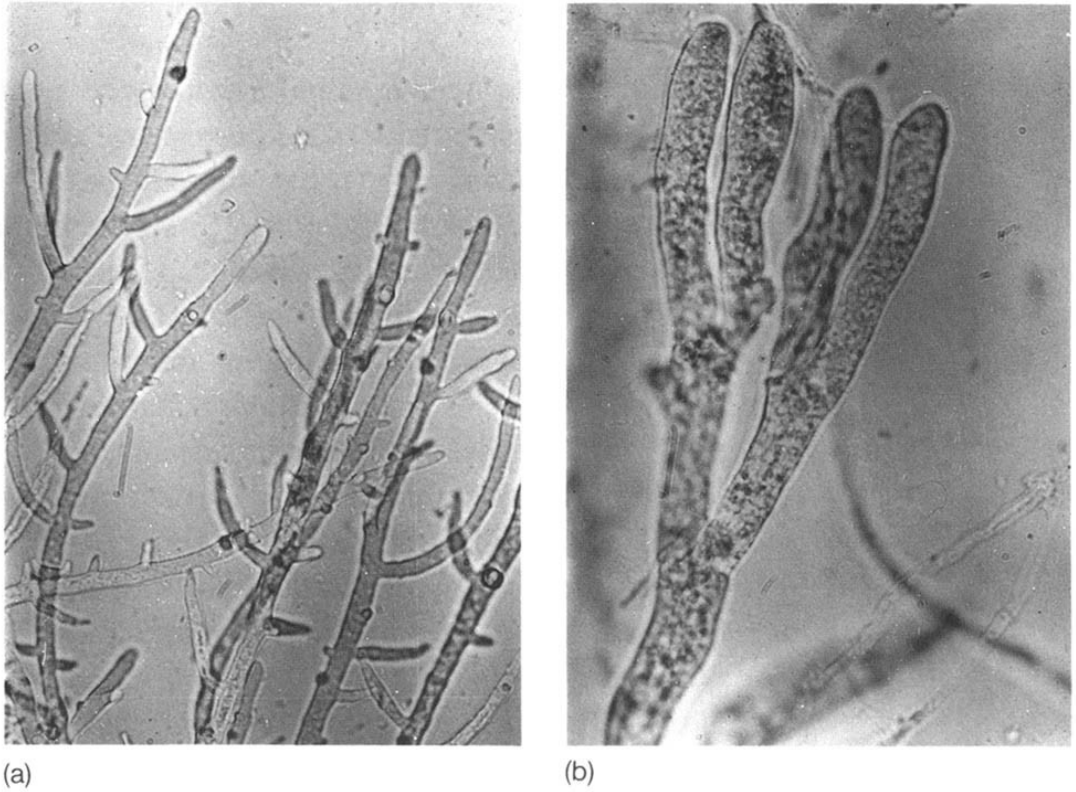


Fig. 10.8 *Piptocephalis fimbriata* attacking a mature colony of *Mycotypha microspora*. (a) Marginal hyphae of an uninfected host colony; (b) swollen and abnormally branched marginal hyphae of an infected colony (from Curtis *et al.*, 1978, © *New Phytologist*).

Another group where biotrophic mycoparasites occur are *Blastocladiomycota – Catenaria allomycis* grows endobiotically in fungal cells of the genus *Allomyces* (of the same division).

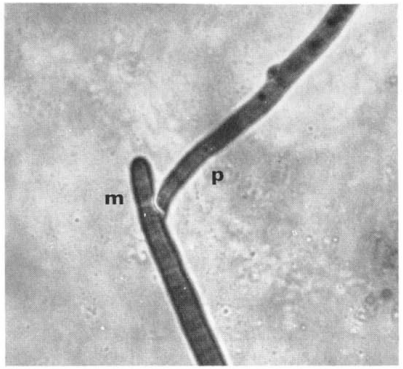
Among the biotrophic fungi we can find also hyperparasites (i.e. parasites of parasites), e.g. *Phoma glomerata* invades powdery mildews; in contrast, the yeast *Tilletiopsis* has enzymes that kill the mildews.

Necrotrophic parasites can be found, for example, among yeasts. *Pichia guilliermondii* (*Saccharomycetales*) is a necrotrophic parasite of hyphomycetes.

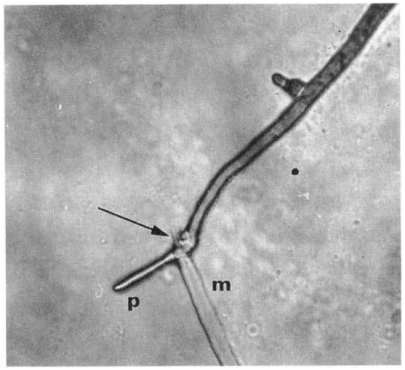
Famous necrotrophic parasites are species of the genus *Trichoderma*,

which penetrate the host hypha => toxins kill the cells => their contents are then decomposed. It is preceded by thigmotropic reaction of the mycelium – upon contact with potential hypha host (it appears to be a reaction to exudates of the host hypha, different parasites have different specificities), hyphae of the parasite begin to wrap around it. *Trichoderma* species are used in biocontrol of phytopathogenic fungi.

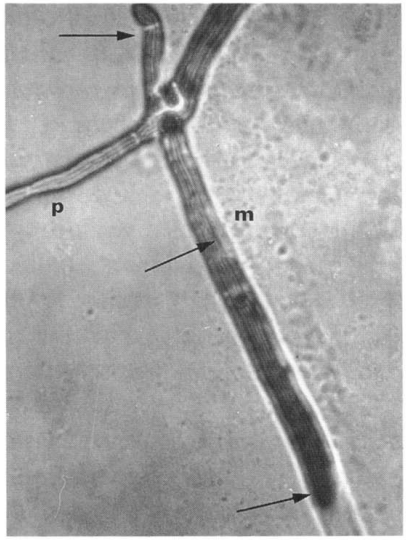
Important necrotrophic parasites are also among oomycetes: *Pythium oligandrum* attacks endomycorrhizal fungi of the genus *Glomus*, zygomycetes or hyphomycetes (the „attack“ is quite rapid, the host hypha is killed within tens of minutes and *Pythium* continues to grow).



(a) Source: Cooke & Whipps 1993



(b)



(c)

taken from http://botany.natur.cuni.cz/koukol/ekologiehub/EkoHub_6.ppt

Fig. 10.12 Rapid killing of a hypha of *Mycocentrospora acerina* (m) by *Pythium oligandrum* (p). (a) Contact between host and mycoparasite; (b) same hyphae 14 minutes later with loss of opacity of host hypha (transparent tip of host hypha arrowed), and continued growth of the mycoparasitic hypha; (c) appearance 70 minutes after contact with *Pythium oligandrum* producing side branches (arrowed) within the host hypha (from Lutchmeah & Cooke, 1984, © British Mycological Society).

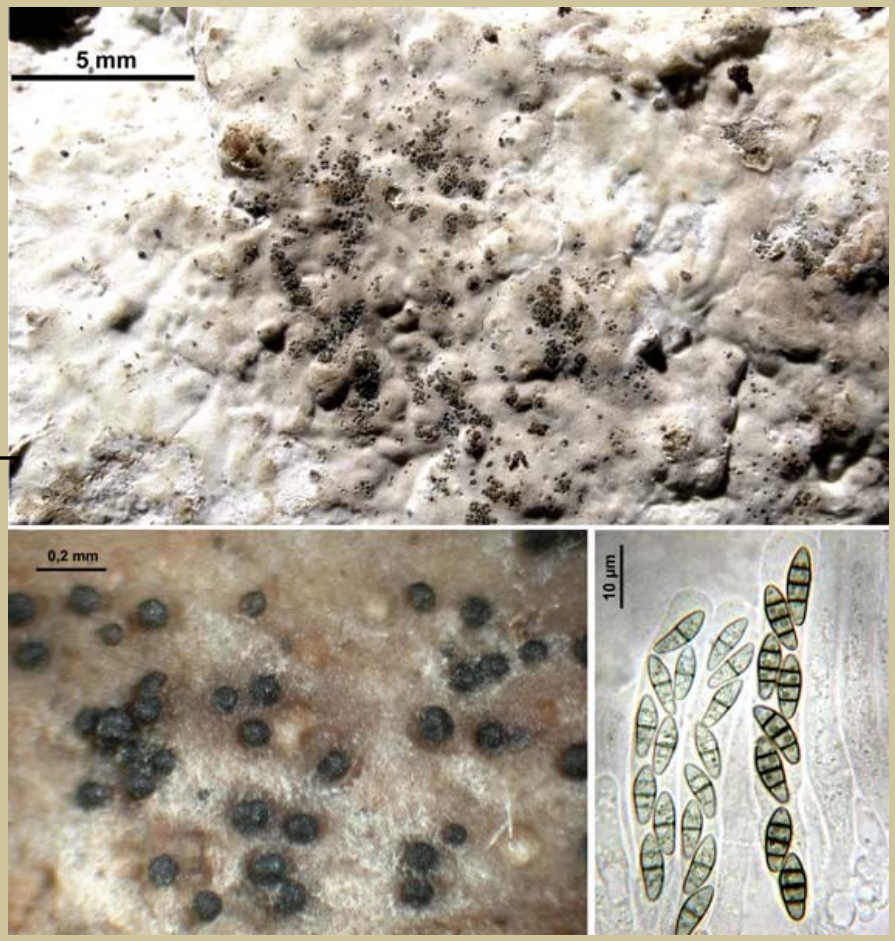
Macromycetes also have their parasites, such as *Pseudoboletus parasiticus* on *Scleroderma*, *Asterophora* species on *Russulaceae*, *Tremella* species on stereoid fungi or *Elaphocordyceps ophioglossoides* (*Hypocreales*) on *Elaphomyces*. In some cases (*Asterophora*) the fruitbodies of the parasitic fungi are found on dead fruitbodies of the host fungi – it is then difficult to distinguish whether they are saprotrophs or parasites (whether they have already parasitised in the form of mycelium during the host life).

Elaphocordyceps ophioglossoides

Pseudoboletus parasiticus, *Asterophora parasitica*

However, species that are probably not parasites also grow on the fruit-bodies of other fungi – examples can be found in *Herpotrichiellaceae* (*Chaetothyriales*): *Capronia porothelia* growing on *Laxitextum bicolor* is said to be a parasite, but is it really harmful to its „host“?

Capronia porothelia —



http://houby.humlak.cz/big_htlm/laxitextum_bicolor_1.htm

http://myco-cheype.chez-alice.fr/classification/ascomycetes/Ascomycetes.htm

Another case is the relationship between lignicolous fungi (it concerns only a few species, for example *Trametes gibbosa* versus *Bjerkandera* spp. or *Lenzites betulina* versus *Coriolus* spp.) – the „attacker“ looks like a „parasite“, but its main aim is to occupy the substrate which is already occupied by the „host“ fungus.