Zvyšování konkurenceschopnosti studentů oboru botanika a učitelství biologie

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PARASITIC SYMBIONTS

Fungi come into association with their host, but in parasitic symbiosis only fungus benefits and the host is harmed.

FUNGAL PARASITES OF HUMANS, OTHER VERTEBRATES, INSECTS AND NEMATODES
Fungal Diseases of Mammals

- The best studied on humans and other warm-blooded animals
- Subject of medical and veterinary mycology.

We can divide fungal attacks on humans into:

1. **Cutaneous Infections**, which involve the outer layers of the skin and cause an allergic or inflammatory response.

2. **Subcutaneous Infections** usually involving fungi of low inherent virulence which have been introduced to the tissues through a wound of some kind, and which remain localized or spread only by direct mycelial growth.

3. **Systemic Infections** which are caused, either by true pathogenic fungi which can establish themselves in normal hosts, or by opportunistic saprobic fungi which could not infect a healthy host, but can attack individuals whose immune system is not working. Both kinds of fungi sometimes become widely disseminated through the body of the host.

http://www.doctorfungus.org/mycoses/human/
(1) CUTANEOUS INFECTIONS

- Most cutaneous mycoses are caused by a specialized group of keratinolytic fungi called the dermatophytes.

- There are about 40 species of dermatophytic hyphomycetes, placed in 3 genera. *Epidermophyton* has 2 species, *Microsporum* has 17, and *Trichophyton* has 24 species and varieties.

- Eight species of *Trichophyton* have teleomorphs in *Arthroderma*, and nine species of *Microsporum* have teleomorphs in *Nannizzia*. These holomorphic genera are both members of the family *Arthrodermataceae* (*Onygenales, Ascomycetes*).

- Infections is confined to the outer layers of the epithelia – skin, hair, and nails, it means keratinized epithelic. Seldom invade living epithelium, but cause irritation.

- Increasing of occurrence with high humidity caused by tight closing, and mild abrasion.

- These are easily cured with nystatin, antifungal antibiotics.
The irritation caused by the presence of the fungus stimulates the epithelial cells of the host to divide more often than usual. This increases the amount of keratin available to the fungus.

*Trichophyton rubrum* destroying the toenails.

*Trichophyton* infections.

*Trichosporon beigeli* - black piedra - hair

*Epidermophyton*
(2) SUBCUTANEOUS INFECTIONS

- This category includes such diseases as chromoblastomycosis, mycetoma and sporotrichosis (species of *Phialophora, Sporothrix, Cladosporium, Acremonium*)

- Fungi manage to penetrate deeper through the epidermis and cause infections of the underlying subcutaneous tissues (by bites, wounds)

- These are caused by fungi that are normally saprobic, but which, when introduced to wounds, can adapt to growth in man, often changing their morphology or physiology in the process.
CHROMOBLASTOMYCOSIS

- Common throughout the tropics among people who go barefoot.
- The fungi most commonly observed to cause chromoblastomycosis are *Fonsecaea pedrosoi, Phialophora verrucosa, Cladosporium carrionii, and Fonsecaea compacta*.
- When the fungus starts to grow, the host cells respond by dividing rapidly, and produce unsightly, warty growths on the feet or legs.
- The fungus may spread through the lymphatic system.

*Chromoblastomycosis*
MYCOTIC MYCETOMA

- Disease of barefoot tropical peoples
- Again, the fungal agent enters the body through a wound
- The fungus attacks various tissues and stimulates the formation of a tumour, within which are many compact fungal colonies called grains.
- If the surface of the skin eventually ruptures, some of these colonies may be extruded.

- They have been found to belong to fungi such as *Madurella mycetomatis* (Hyphomycetes), *Exophiala jeanselmei* (Hyphomycetes), *Pseudallescheria boydii* (Ascomycetes) and *Leptosphaeria senegalensis* (Ascomycetes).

H & E stain of mycetoma caused by *Madurella grisea*
SPOROTRICHOSIS

- Caused by *Sporothrix schenckii*, a cosmopolitan hyphomycete which may be an anamorph of *Ophiostoma*.
- The fungus enters the host through a wound made, for example, by a contaminated thorn.
- Once inside the host, the normally mycelial fungus becomes yeast-like (it is therefore dimorphic),
- The initial, localized infection may ulcerate, drain and heal. But all is not well.
- The infection spreads through the lymphatic system, and many secondary lesions may form. Eventually, the disease may become systemic, spreading first to the joints, then the bones, and finally the internal organs, through the bloodstream.
These diseases are of two very different types: those produced by specialized pathogens, and those caused by opportunistic saprobes.

SPECIALIZED PATHOGENS

There are several examples of fungi that are primary pathogens and that can cause symptoms of disease in individuals who are apparently otherwise healthy. These are all dimorphic fungi able to grow either as unicellular yeasts or as mycelial filaments. They all infect via inhaled spores, infecting the lungs at first but later spreading to other organs of the body.

Histoplasmosis

Coccidioidomycosis

Paracoccidioidomycosis

Blastomycosis
HISTOPLASMOSIS

- **Caused by** the *Histoplasma capsulatum*, anamorph of *Ajellomyces capsulatus* (Ascomycetes). Endemic in tropical areas in the world – naturally found in the soil.
- This anamorph grows well in high-nitrogen substrates like wild bird droppings.
- Conidia of the fungus are inhaled and cause primary infections in the lungs.
- About 95% of all cases produce no obvious clinical symptoms, and heal spontaneously, leaving the subject with only a small calcified lesion in the lung, and resistance to reinfection.

In the other 5%, various clinical symptoms develop. At first ‘flu-like, the disease may go on to produce a progressive lung disease that mimics tuberculosis. If untreated, it may even develop into a generalized, systemic infection which can attack all internal organs, ultimately with fatal results.
Coccidioidomycosis

- The disease caused by *Coccidioides immitis*
- This fungus thrives in dry, saline soils, and is endemic in desert areas of the Southwestern U.S., and Mexico
- The process of infection, progress of the disease, and clinical symptoms, are very similar to those of histoplasmosis.
- Fortunately, as in histoplasmosis, most cases are benign, and healing is spontaneous.
- 5% of cases the disease can disseminate and progress to become a more serious disease - causing lesions on bones, the subcutaneous tissues, the meninges, and the major organs.

[Images of patients and fungal spores]
PARACOCCIDIOIDOMYCOSIS

- The disease exclusive to Central and South America
- It is caused by *Paracoccidioides brasiliensis*
- Inhalation of conidia causes a primary infection in the lungs.
- When secondary infections do occur, they tend to provoke ulceration of the mucosa of mouth and nose, often causing loss of teeth.
- Less commonly, the pulmonary infection progresses, mimicking tuberculosis, and sometimes eventually involves other internal organs.

Skin lesions of patient with paracoccidioidomycosis
BLASTOMYCOSIS

- Caused by *Blastomyces dermatitidis*, a fungus rarely isolated in culture from soil or other natural substrates.
- Endemic in large areas of North America
- Again, the primary infection is in the lungs, forming large granulomas that contain many tiny abscesses.
- These lesions may heal, but the organism then crops up in another area, frequently the exposed parts of the face and neck.

North American blastomycosis - *Blastomyces dermatitidis.*
OPPORTUNISTIC PATHOGENS

- Opportunistic infections are caused by diverse fungi -- a few species of *Aspergillus*, *Candida*, *Cryptococcus*, and some members of the *Mucorales*.

- All grow well at body temperature, but do not otherwise seem particularly different from closely related non-pathogenic species.

- None of them can usually cause an infection in a normal, healthy individual.

- All rely on some breakdown in the mechanisms of resistance. This kind of systemic fungal infection is often a complication of diabetes, AIDS, advanced cancer, using of corticosteroids, using of broad spectrum antibiotics.
CANDIDIASIS (CANDIDOSIS)

- The candida species most frequently associated with human infection is *Candida albicans*.
- It is very common comensal being found on the mucosal membranes of mouth, gut or vagina of more than 50% healthy individuals. And at most cases no harm.
- However can cause a significant problem in some debilitating conditions: diabetes, AIDS, steroid or antibiotic therapy, cancer, blood disease, endocrine deficiencies.
- Then it proliferates, and invades the mucosa causing the local irritation and in extreme cases it can grow systemically in the body with fatal consequences. In leukemic patients, candidiasis may become truly systemic (infect a wide variety of organs including kidney, liver and brain), or may produce a form of septicaemia.
- Common forms of candidosis:
  - Oral candidosis
  - Vulvovaginal candidosis
  - Systemic candidosis
ASPERGILLOSIS

- Approximately 20 Aspergillus species have been associated with human infections – vast majority are caused by *A. fumigatus*, *A. niger*, *A. terreus*, *A. flavus*.

- These fungi are saprophytic and ubiquitous in the environment and are particularly associated with soil and decaying vegetable matter.

- Due to small and numerous conidia they are routinely inhaled by humans and their size allows them to penetrate deep into the lower respiratory tract.
COMMON FORMS OF ASPERGILLOSIONS

(1) Bronchopulmonary aspergillosis is usually caused by Aspergillus fumigatus, which colonizes mucus within the bronchi, evoking a severe allergic reaction.

(2) In Aspergilloma, the fungus forms a mycelial ball in a lung cavity produced by an earlier attack of tuberculosis. The wall of the cavity may erode, causing the patient to spit blood, and necessitating surgical intervention.

(3) Invasive aspergillosis is found only in patients who are severely debilitated, or are immunosuppressed, as in AIDS. The fungus grows outward from the lung, invading blood vessels and spreading to other organs through the bloodstream (usually fatal).

(4) Metabolites of species of Aspergillus cause other health problems, such as acute and chronic aflatoxin poisoning.
CRYPTOCOCCOSIS

- Caused by an encapsulated, budding, basidiomycetous yeast, *Cryptococcus neoformans* var. *neoformans*, the anamorph of *Filobasidiella neoformans* (Aphyllophorales).
- The yeast anamorph commonly grows on pigeon droppings.
- Many people contract sub-clinical or asymptomatic cryptococcosis which resolves spontaneously.
- An unfortunate minority, often already suffering from leukemia or lymphoma, or on immunosuppressive therapy following organ transplants, develop lung disease which may then become systemic.
- This phase involves bones, or organs such as heart, testicle, prostate or eye, and is often fatal. A second form of the disease is cryptococcal meningitis.

*Cryptococcus neoformans* (anam.), *Filobasidiella neoformans* (teleom.)
PNEUMOCYSTIS PNEUMONIA

- **Caused by** *Pneumocystis jiroveci*

- One of the most commonly encountered opportunistic infections associated with AIDS.

- In large proportion of human population is in latent form in lungs, during AIDS infection becomes activated resulting in pneumonia-like symptoms, which if untreated can lead to death due to hypoxia. Worldwide distribution very common as the cause of a virulent pneumonia in AIDS patients.

- It can not be grown in culture.
ZYGOMYCOSIS

- Caused by several opportunistic members of the Mucorales (Zygomycotina).
- *Rhizopus arrhizus* and *Rhizopus oryzae* are most commonly involved, but species of *Mucor, Rhizomucor* and *Absidia* have also been reported.
- Four kinds of systemic disease occur:
  - Rhinocerebral (outward to the eyes and inward to the brain)
  - Pulmonary (bronchitis and pneumonia)
  - Gastro-intestinal (the walls of the stomach and intestine, blocking the arteries. The resulting necrosis and perforations are fatal).
  - Cutaneous (It has been reported with minor trauma, insect bites, no sterile dressing, wounds, and burns).
Some fungi that cause mycoses of humans and other vertebrates.

<table>
<thead>
<tr>
<th>Fungus</th>
<th>Disease</th>
<th>Primary route of entry</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Trichophyton Microsporum</em></td>
<td>Rongworm, tinea, dermatomycosis</td>
<td>skin</td>
</tr>
<tr>
<td><em>Epidermophyton</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phialophora Cladosporium</em></td>
<td>Subcutaneous mycosis, chromomycosis, sporotrichosis</td>
<td>Wounds</td>
</tr>
<tr>
<td><em>Sporothrix</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Candida albicans</em></td>
<td>Candidosis, vulvovaginitis, thrush</td>
<td>Mucosa</td>
</tr>
<tr>
<td><em>Aspergillus fumigatus</em></td>
<td>Aspergillosis, lungs or invasive</td>
<td>Lungs</td>
</tr>
<tr>
<td><em>Blastomyces dermatitidis</em></td>
<td>blastomycosis, lungs, skin bones, brain</td>
<td>Lungs</td>
</tr>
<tr>
<td><em>Coccidioides immitis</em></td>
<td>Coccidiomycosis, lungs, systemic</td>
<td>Lungs</td>
</tr>
<tr>
<td><em>Cryptococcus neoformans</em></td>
<td>Cryptococciosis, lungs, brain, meninges</td>
<td>Lungs</td>
</tr>
<tr>
<td><em>Histoplasma capsulatum</em></td>
<td>Histoplasmosis, lung, rarely systemic</td>
<td>lungs</td>
</tr>
<tr>
<td><em>Paracoccidioides brasiliensis</em></td>
<td>Paracoccidiomycosis, lung, cutaneous, lymph nodes</td>
<td>lungs</td>
</tr>
<tr>
<td><em>Pneumocystis carinii</em></td>
<td>Pneumonia</td>
<td>Lungs</td>
</tr>
</tbody>
</table>
OTHER FUNGI PARASITIC ON VERTEBRATES

*Batrachochytrium dendrobatidis*

- Responsible for decline of amphibian populations, particularly frogs, in six continents (Africa, South, Central and North America, Europe, Australia and Oceania)
- Only member of Chytridiomycota to parasitize vertebrates
- Sporangia restricted to keratinized skin of adult frogs and keratinized mouth parts of tadpoles
- Superficial layer of skin is thickened, this layer often sloughs off

- Causes widespread, fatal epidermal infection only in adults
- Epidermal hyperplasia that results may seriously impair cutaneous respiration and osmoregulation
- Toxin production has not been demonstrated
Skin may slough in some species

*Myxophes fasciolatus* with chytridiomycosis showing sloughing of epidermis

Two zoosporangia of *Batrachochytrium dendrobatidis* with discharge tubes
**Saprolegnia parasitica** (Saprolegniales, Oomycota)

- Is ubiquitous in freshwater ecosystems; responsible for significant fungal infections of freshwater fish and eggs.
- On fish, *Saprolegnia* invades epidermal tissues, generally beginning on the head or fins and can spread over the entire surface of the body visible as white or gray patches of filamentous mycelium.
- The genus *Saprolegnia* is considered an opportunistic facultative parasite which is saprotrophic and necrotrophic; generally invades fish that have been stressed or otherwise have a weakened immune systems.
- Also infects moribund eggs by adhesion to and penetration of the egg membrane.

![Eggs infected with Saprolegnia](image)
FUNGI PARASITIC ON INSECT

- Most insect pathogens are from groups Entomophthorales (Zygomycotina), or from Ascomycotina and Deuteromycotina, but also from Chytridiomycota
- Insect can be attacked during larval or pupal stages which often live in soil or within substrates, or in the adult, often aerial form. Some of them can be used in biocontrol of insect populations
- The infection cycle (Ascomycotina and Deuteromycotina):
  - Penetration by appressorium and penetration peg (proteases, chitinases) –
  - Grow into insect tissue and produce blastospores or hyphal bodies that proliferate into haemolymph (insect blood) – which leads to death by depletion of blood sugars or by production of toxins.
  - Than fungus reverts to saprophytic phase and extensively colonize the body tissues
  - After death of insect the conidiophores are forcibly discharged from the surface of the mummified dead body.
  - A few entomophthorales has a different strategy – do not cause rapid death but colonize only limited part of the insect body discharging spores through a small hole in the exoskeleton over a longer period.
ENTOMOPHTHORALES (ZYGOMYCOTINA)

- Species of *Entomophthora, Erynia* attack aphids, houseflies, caterpillars, and grasshoppers,
- They invade mature insects by hyphal growth through joints between plates of exoskeleton.
- Most types of entomophthorales are highly invasive and destroy the host's tissue within a matter of days.
- Some of these species are specialized:
  - *Entomophthora grylli* – parasite of many grasshoppers
  - *Entomophthora musci* – widespread and common on many insects.

Sporangia *Entomophthora musci*
LIFE CYCLE OF *ERYNIA RADICANS*:

- **DISEASED LEAFHOPPER**
- **CAPILLOCONIDIUM**
- **RESTING SPORES**
- **GERM CONIDIA**
- **2° CONIDIA**
- **3° CONIDIA**
- **HEALTHY LEAFHOPPER**

3-4 DAYS
ASCOMYCETE FUNGI

- The best known is insect parasite *Cordyceps*, with several hundred species. [http://ocid.nacse.org/research/cordyceps/](http://ocid.nacse.org/research/cordyceps/)
- It commonly infects larvae or pupae, producing yeast-like cells in the haemocoel, and usually killing its host some weeks after initial infection.
- Continued hyphal growth within the body produces a kind of sclerotium which acts as a survival stage for the fungus.
- Finally, when conditions are favourable, a phototrophic aerial fruit body emerges from the sclerotium, and bears perithecia and conidia.

*Cordyceps militaris*

*Cordyceps sinclairii*
The life cycle of *Cordyceps militaris*
DEUTEROMYCETE FUNGI

- Include a number of genera with ability to colonize living insects.
- *Beauveria* and *Metarhizium* are the most studied of fungal insect parasites.
- Some species of *Verticillium, Aspergillus, Paecilomyces* and *Hirsutella* are facultative insect pathogens.
- The fungi are dimorphic and inside the host’s blood grow as single yeast-like cells. Later, as the host’s tissues are killed, the fungus reverts to the hyphal form and grows throughout the body.
- Species of *Metarhizium* and *Beauveria*, have been investigated as possible agents of biological control of insect pests.
**Beauveria bassiana** (Hyphomycetes) conidia
And infected insect

*A weevil killed by* *Metarhizium* *which is now sporulating.*

*Metarhizium anisopliae* var. *acridum* is also now used for biocontrol of locusts and grasshoppers in Australia.
**VERTICILLIUM LECANII** (HYPHOMYCETES)

- Causes natural epidemics in two groups of plant-sucking pests: aphids (*Aphidoidea, Homoptera*) which cause malformation and transmit viruses, and scale insects (*Coccoidea, Homoptera*) in the tropics and in greenhouses.
- Most successful commercial biocontrol agents of insect – used for control of whitefly and aphids, scale insect (mainly in chrysanthemums).
- It can be used also against rust fungi (parasitize fungal spores in experimental conditions) – can give dual control. Similar feature – presence of chitin.
COELOMOMYCES

- Member of order Blastocladiales, Chytridiomycota
- Parasitized mosquito larvae but zoospores produced from these larvae can only infect a copepod (Cyclops). The fused gametes released from Cyclops will only infect mosquito larvae – obligate alternation of host in the haploid and diploid phases.

Coelomomyces resting spore
Life Cycle of Coelomomyces

**Conjugation of gametes**

Gametophytic thallus lacking cell wall forms in copepod

**Zoospores (meiospores) infect copepod**

**Germination of resting spore**

**Motile zygote encysts, infects mosquito larvae**

**Sporothallus develops in host, resting sporangia formed**

**Resting sporangia**
<table>
<thead>
<tr>
<th>Fungus</th>
<th>Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Metarhizium anisopliae</em></td>
<td>Lepidoptera, Coleoptera, Hemiptera, Hymenoptera</td>
</tr>
<tr>
<td><em>Beauveria bassiana</em></td>
<td>All</td>
</tr>
<tr>
<td><em>Cordyceps militaris</em></td>
<td>Many larvae and pupae of Lepidoptera, some Coleoptera and Hymenoptera</td>
</tr>
<tr>
<td><em>Paecilomyces farinosus</em></td>
<td>Many Lepidoptera, Diptera, Homoptera, Coleoptera, Hymenoptera, Arachnida</td>
</tr>
<tr>
<td><em>Verticillium lecanii</em></td>
<td>Several, especially aphids, scale insects</td>
</tr>
<tr>
<td><em>Entomophthora, Erynia</em> and similar fungi (Zygomycotina)</td>
<td>Various, often host-specific, entomophthora muscae on housefly, Erynia neoaphidis on aphids</td>
</tr>
<tr>
<td><em>Coelomomyces</em> (Chytridiomycotina)</td>
<td>Mosquitoes and midges; often host-specific</td>
</tr>
</tbody>
</table>
NEMATOFAGOUS FUNGI

- Nematophagous fungi are common in organic rich environment and they include representatives of all major fungal groups.
- Belong mainly to the families Deuteromycotina, but some to the Zoopagales, a Zygomycotinae order, some to Oomycota and Chytridiomycota.
- Here we consider the three major types with different adaptations for feeding on nematodes:

1. THE PREDATORY NEMATODE-TRAPPING FUNGI
2. ENDOPARASITIC FUNGI
3. PARASITES OF NEMATODE CYCTS OR EGGS
NEMATODE TRAPPING FUNGI

- All these fungi are considered to be essentially saprophytic, but to exploit nematodes as an additional source of nutrients.
- Involved representative of Deuteromycotina: *Arthrobotrys, Monacrosporium, Harposporium, Dactylella, Dactylaria*, and *Zygomycotina* (*Stylopage, Cystopage*)
- They have very similar mode of parasitism: The nematode is captured by an adhesive then the fungus penetrates rapidly by means of narrow penetration peg, swells to form an infection bulb in the host, and hyphae grow from this infection bulb to fill the nematode body and absorb its contents. Usually this phase is completed within 1-3 days then the hyphae grow out of death nematode to produce further capture organs or to sporulate.
- They capture their prey by specialized devices:
  - Adhesive hyphae
  - Adhesive nets
  - Short adhesive branches
  - Adhesive knobs
  - Non-constricting rings
  - Constricting rings
A few species of *Arthrobotrys* (Hyphomycetes) have specialized adhesive-coated side branches on their otherwise non-sticky assimilative hyphae.
Adhesive knobs are specialized, swollen cells, coated with 'nematode glue', and often situated at the ends of short side-branches. They are found in nearly twenty species of *Arthrobotrys*, *Dactylella* and *Nematoctonus*. 

Adhesive knobs of the nematode-trapping fungus *Monacrosporium ellipsosporum* on hyphae growing from a parasitised nematode.
Adhesive nets are probably the commonest trapping device. They may originally have evolved by anastomosis of adjacent adhesive branches. Others are more complex, to the contorted three-dimensional labyrinths of *Arthrobotrys oligospora*.
Non-constricting or detachable rings, are produced by four species of *Arthrobotrys* (Hyphomycetes). A single hypha grows around in a perfect circle. When a nematode crawls through the ring, this fits snugly around its body, and easily breaks away from the narrow stalk.
Constricting rings are the most sophisticated nematode traps of all. They are produced by at least twelve Hyphomycetes, especially species of *Arthrobotrys*. If a nematode passes through the loop, and touches the inside of one or more of the cells, after a delay of a few seconds all three cells simultaneously inflate inward. The three cells of each constricting ring trap have a high turgor pressure, generated by a high internal osmotic pressure.
ENDOPARASITES

- The endoparasitic fungi are quite different from the trapping fungi because they seem to depend on nematodes as their main or only food source in nature.
- *Catenaria anguillulae* (Chytridiomycota), *Haptoglossa* (Oomycota), *Hirsutella rhossiliensis* (Deuteromycotina) produce zoospore or adhesive conidia which seem to attract nematodes by chemotaxis.
- Then the adhered spores germinated rapidly and the hyphae fill the host killing it within a few days. Finally the hyphae grow out through the host wall and produce a further batch of spores.

*Hirsutella rhossiliensis*, an endoparasitic fungus on a nematode host. Infection occurred from a spore (S) that adhered near the nematode's mouth.
NEMOTOPHAGOUS FUNGI - CHYTRIDIOMYCOTA

Catenaria

The uniflagellate spores of *Catenaria* (*Chytridiomycota*) swim to a nematode by chemotaxis (below, left), and encyst near its mouth or anus before penetrating the cuticle and attacking its internal organs, which are eventually more or less replaced by the zoosporangia of the fungus (below, right).
Catenaria anguillulae

http://helios.bto.ed.ac.uk/bto/microbes/catenar.htm
The genus *Haptoglossa* (*Oomycota*) is unique among fungi. It expels from large sporangia in a nematode corpse (below) spores which germinate to produce secondary spores which are sophisticated 'harpoon cells'. A harpoon cell adheres to the substrate and internal tube with a harpoon-like tip is rapidly everted to penetrate the integument of the prey and inject sufficient material into the animal to form a tiny infection unit.
EGG PARASITES

*Verticillium chlamydosporum* – it is facultative parasite of nematode eggs, which it destroys after they have been released into the soil. *Nematophthora gynophila* (Oomycota) – infect the females presumably from zoospores and fills most of their body cavity with thick walled resting spores, so the nematode cyst if formed at all, contains relatively few eggs but a large number of fungal spores.

PARASITES OF OTHER INVERTEBRATES

There are also predacious fungi which feed on soil animals as amoebae, rotifers. Protozoans, crustaceans and mollusc have highly specialized fungal parasites

Zoophagus (OOMYCOTA) traps rotifers by means of 'lethal lollipops' -- sticky knobs which the animals unwisely try to eat (below). The knobs then expand and release an adhesive which clogs up the animal's mouth and makes escape impossible.
Six hyphomycetes trap amoebae, usually testaceous rhizopods. These fungi are drawn from four genera: Arthrobotrys (f-h), Pedilospora (a-c), Tridentaria and Triposporina (d, e).
**Aphanomyces astaci**

- Is commonly referred to as crayfish plague.
- Belongs to order Saprolegniales of the Oomycetes
- It is a specialized parasitic fungus that infects only crayfish species. This fungus is endemic of North America, but the parasitic fungus *A. astaci* was introduced into Europe.
- Native European crayfish populations are not resistant to this fungus. It has since devastated native crayfish stocks throughout the continent.
- Black melanized spots may be indicative of the presence of the crayfish plague fungus.
- Melanized black shell in chronically infected individuals.

Crayfish plague – segment with brown markings show signs of typical infection from fungus.

The sign of a crayfish plague may be the presence of crayfish at large during daylight hours, some of which may show evident loss of coordination in their movements, and easily fall over on their backs and are unable to right themselves.