Microbe-Animal Interaction
(Nematophagous Fungi)

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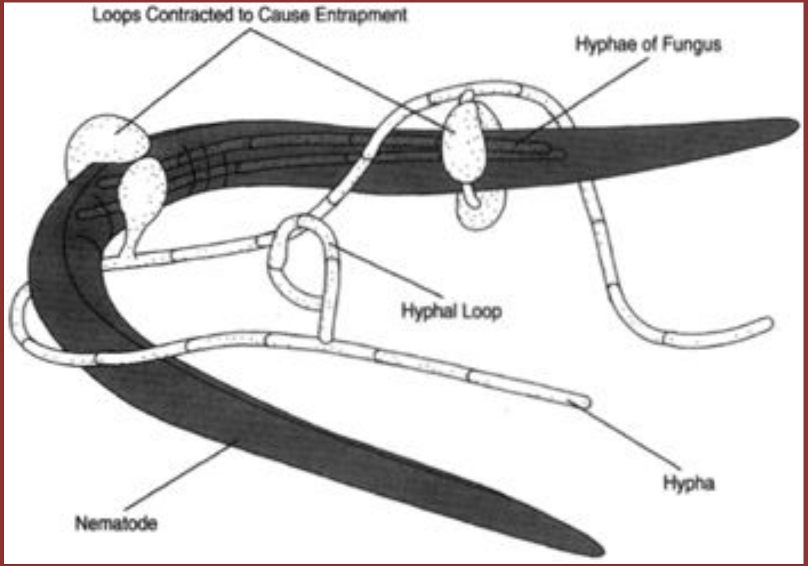

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- Fungi are **pathogenic, symbiotic (parasitic or mutualistic)** with a range of different animals.
- Fungi relationship with soil nematodes goes a step beyond parasitism and into predation.
- There are about 700 species of taxonomically diverse fungi that are be able to attack living nematodes (eelworms), which are active animals about 0.1 to 1.0 mm long.
- Among these nematophagous fungi, only a few species are obligate parasites of nematodes; the majority are facultative saprotrophs.

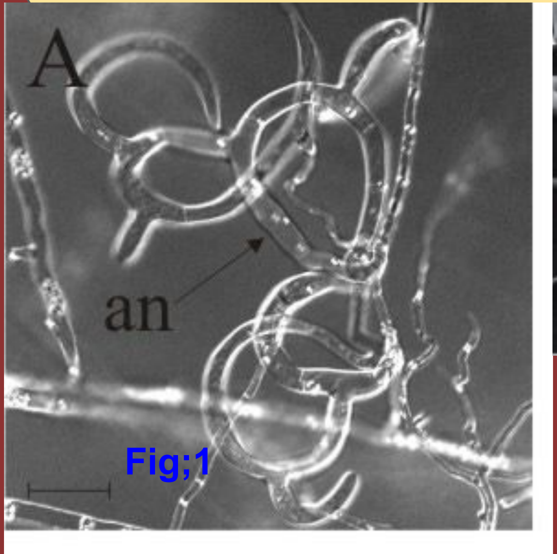
Nematophagous fungi (Predaceous fungi) fall into **four** general groups:

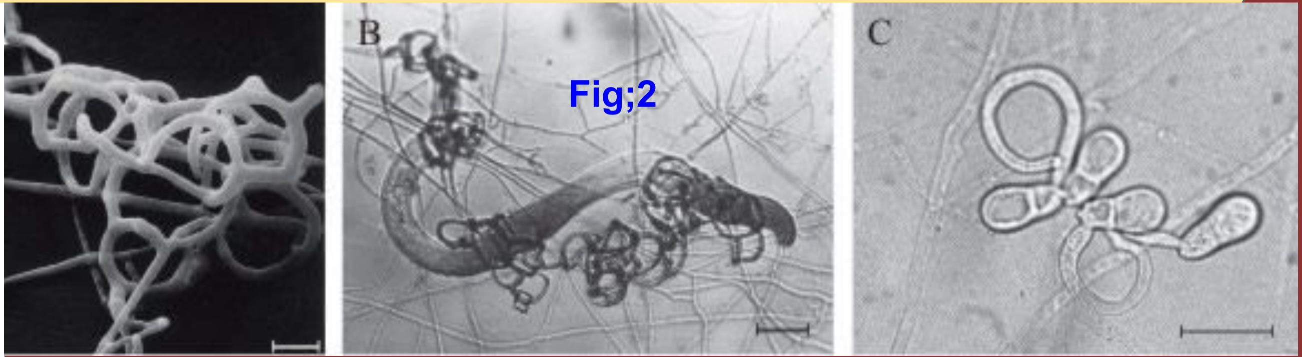
Nematophagous fungi are natural enemies of nematodes in soil ecosystems and **have potential as biocontrol agents against plant- and animal-parasitic nematodes** (Jiang et al., 2017).

- Fungi that use specialised structures, to trap then invade eelworms;
- Fungi releases toxins for immobilising to eelworms before invade them
- Obligate endoparasitic fungi that invade eelworms following spore germination;
- Opportunistic saprotrophic fungi that colonise nematode eggs, females, or cysts.

- Over 200 species of fungi (zygomycetes, Basidiomycota, and Ascomycota) catch free-living nematodes in the soil **using traps produced by the fungal mycelium** that adhere to the worm, then penetrate, kill, and digest the tissue of the nematode.
- The most widespread predatory fungi are in the family of **Orbiliaceae (Ascomycota)**.
- **Five kinds of trapping device** have been recognised; the first four of those listed below capture nematodes using an adhesive layer covering part or the entire surface of the hyphal structure (Yang et al. 2007; Su et al., 2017).
- Phylogenetic analysis suggests that the trapping structures fall into two lineages: one **based on constricting rings** and the other **using adhesive traps.**

★ **Adhesive network (AN)**, the most widely distributed trap, is formed by lateral branches from a vegetative hyphae, looping around to fuse with the parent hypha, developing a network of loops with an aperture diameter of about 20 μm (Fig.1); this is a three-dimensional network (Fig. 2A) which entangles the prey (Fig. 2B) and can be formed by germinating conidia (Fig. 2C).

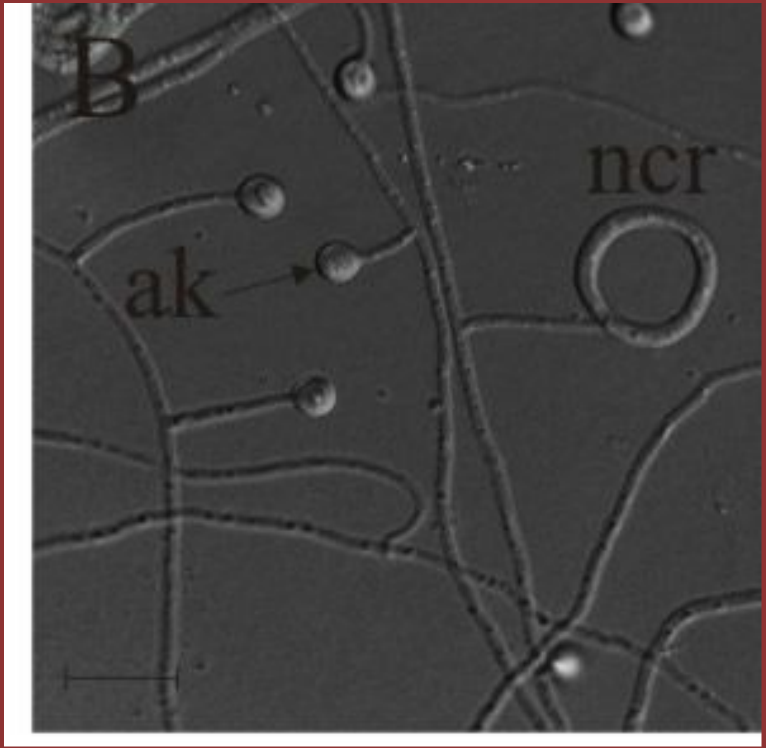




A. Scanning electron micrograph of typical adhesive network trap of ***Arthrobotrys oligospora***, bar = 10 μm. B. Light micrograph of a nematode captured in an adhesive network trap of *A. oligospora*, bar = 20 μm. C. Light micrograph of conidial traps of *A. oligospora,* induced by the inclusion of peptides in the agar used to germinate the spores, bar = 20 μm.
(From Nordbring-Hertz, 2004)

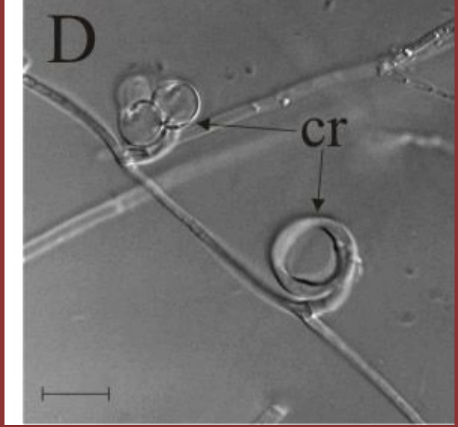
★ **Adhesive knob (AK)** is a morphologically distinct inflated cell that is either a short ('sessile') or long ('stalked') hyphal branch, which are usually closely spaced along the hypha.

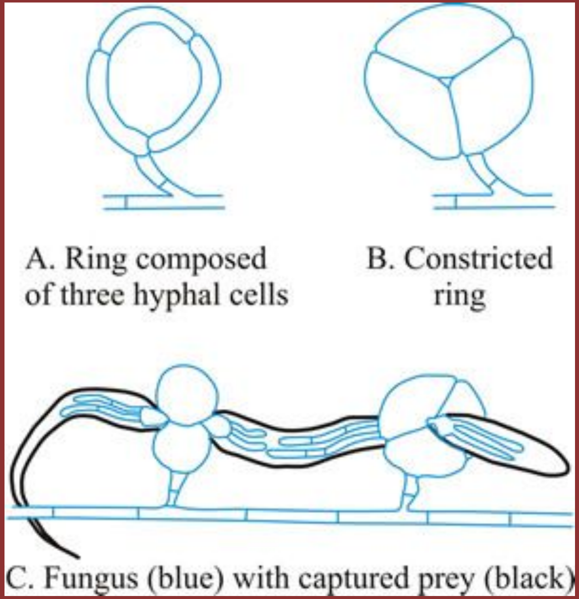
★ **Non-constricting rings (NCR)** always occur alongside AK, and are produced when lateral branches from a vegetative hyphae loop and inflate, forming a three-celled ring on a supporting stalk.



Adhesive knob (ak) with Non-constricting rings ncr.

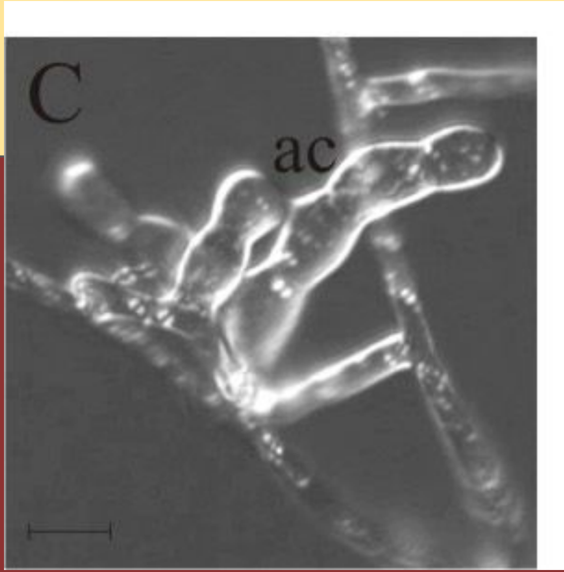
★ **Constricting ring (CR),** is also a looped hyphal branch of (usually) three cells, but it is the most sophisticated trapping device and captures prey actively.





Constricting rings of *Drechslerella*. When a nematode enters a constricting ring the three ring cells (A) are triggered to swell inwards within 1 to 2 seconds and firmly lasso the victim; the cells inflate to maximum size, which is an approximate threefold increase in cell volume, within 0.1 second, with the swelling of the ring cells being strictly inward (B). The constricted rings clamp the prey firmly (C).

★ **Adhesive column (AC)** is a short erect hyphal branch consisting of a few swollen cells



Traps, have adhesive layers, and thicker cell walls than vegetative hyphae and their cells contain electron dense bodies.

How do they recognize each other ?

carbohydrates (ascarosides) on the surface of the nematode.

These are *lipophilic glycosides of the dideoxy sugar ascarylose*, which serve essential functions in regulating nematode development and behaviour, so they are highly specific to the desired prey of the fungus.

lectins (sugar-binding proteins) in the cell wall of the fungus

Destruction of pray (nematode)

- Recognition of the prey results in reorganisation of the adhesive surface polymer on the fungus and adhesion of the nematode to the fungus.

- It also triggers the growth of hyphal branches into the nematode to initiate its digestion. Interaction between predator (e.g. *Arthrobotrys oligospora*) and prey (nematode) shows no species specificity.

- Hyphae penetrate the nematode within 1 hour of capture. These hyphae digest the nematode (Li et al., 2005; Yang et al. 2007; Su et al., 2017).

- Nematophagous fungi, natural predators of soil-dwelling nematodes, can detect and respond to their prey's own ascaroside pheromones (Hsueh et al., 2012).

- **An interesting addendum** to this story is that some bacteria can mobilise nematode-trapping fungi to kill nematodes.

- In their soil habitat, bacteria are consumed by bacterivorous nematodes; however, some of these bacteria release urea, which triggers a lifestyle switch in the fungus *Arthrobotrys oligospora* from saprotrophic to its nematode-predatory, nematode trapping, form; it seems to be ammonia that the fungus produces from the urea that functions as the signal to form traps. This bacterial defensive mechanism significantly promotes the elimination of nematodes by *A. oligospora* (Wang et al., 2014).

Examples of NF

Arthrobotrys is characterised by adhesive networks and unstalked adhesive knobs that grow out to form networks;

Dactylellina by stalked adhesive knobs and non-constricting rings, and unstalked adhesive knobs that grow out to form loops adhesive knobs; and

Drechslerella by constricting-rings.

Hohenbuehelia and ***Resupinatus*** (Basidiomycota) by adhesive knob

By Paralyzing prey

- The oyster mushroom (*Pleurotus ostreatus*) and related *Pleurotus* species, which is in the Basidiomycota, is a nematode-trapping fungus that does not form trap structure.
- Instead of trap structure they release some toxin, by which they rapidly paralyze the nematodes.
- Thus hyphae invade and digest the immobilized nematode.
- This fungi grow on decaying wood (a nitrogen poor substrate).
- Therefore, it is suggested that nematode act as nitrogen source for the fungi (Thorn and Barron 1984).

By special cyst

- Parasitic oomycete *Haptoglossa mirabilis* , zoospore of this fungus after a short swarming period, produce a special cyst that almost immediately germinate in the form of “gun” cell.
- It is resembles bowling pin in shape.

Importance of NF

Soil nematodes are very abundant in all soils (commonly millions per square metre) and species diverse (commonly more than 30 taxa). They feed on a wide range of soil organisms within the rhizosphere of agricultural crops and several eelworms are parasitic. Some are important pests of crop plants and farm animals and nematode-trapping fungi may have **use in biological control** (Yeates & Bongers, 1999; Moosavi & Zare, 2012; Moura & Franzener, 2017).

For example,

- The nematode-trapping fungus *Nematophthora gynophila* can be used to control the cereal nematode, *Heterodera avenae*, which feeds on the host roots damaging the roots and reducing water uptake.
- Nematodes that are gastrointestinal parasites of farm animals can be controlled with the nematode-trapping *Duddingtonia flagrans*. The resting spores (chlamydospores) can be included in animal feed and survive passage through the animal. Subsequently, the fungus grows in the animal dung where it traps and destroys the parasitic nematode, so reducing pasture infectivity and the worm burden of grazing animals, especially young cattle, sheep and goats. Three months treatment can reduce the worm burden by 90% (Graminha et al., 2005; Larsen, 2006).