Microfauna – Nematoda

Morphology

Nematodes are aquatic transparent roundworms (0.1 - 5 mm in length in soil species) and are dependent on water films surrounding soil particles for their activity and gas exchange. The ability of nematodes to have many food sources and to live in numerous habitats (marine and freshwater sediments, as parasites of plants, invertebrates and vertebrates) is due largely to their morphological adaptations and survival strategies. Nematodes survive the harshest conditions (desiccation, heat, freezing, osmotic and oxygen stress), by shutting down their metabolism, altering their biochemical pathways and body shape and entering a dormancy state (cryptobiosis – see pages 44 and 86), which is reversible when favourable environmental conditions return. While in cryptobiosis, they can be dispersed by wind. Nematodes generally have an elongated body shape tapering at both ends, but they also can be spherical or pear shaped. They have a non-segmented flexible cuticle and their body organs (excretory, nervous, digestive and reproductive systems) are in a fluid-filled cavity, called coelom, and present in many other animals (e.g. earthworms – see page 58). Their movement is undulatory, contracting certain muscles against internal pressure. Most soil nematodes have separate sexes but some can be parthenogenic or hermaphroditic. Nematodes generally lay eggs that develop through four moulting juvenile stages to adults. [47, 48]

Nematodes generally have an elongated body shape, but they also can be spherical or pear shaped. (**a**) The plant parasitic nematode, *Belonolaimus longicaudatus*, feeding on a plant root shows the typical lengthened shape. (**b**) Spherical females (white) of *Heterodera schactii* feeding on a plant root. The eggs are laid inside the female body. (OB, JGB)

Taxonomy

The phylum Nematoda contains multicellular animals that are related to other moulting animals (the Ecdysozoa) such as Nematophora. Terrestrial nematodes predominate in the large orders of Panagrolaimida, Rhabditida, Mononchida and Dorylaimida.

Microhabitat

Global studies of the distribution of soil nematode species show that most are endemic to a site or region, and only a small fraction are cosmopolitan. Climate, vegetation, as well as soil physical and chemical characteristics all contribute to determining the habitat suitability of each community of nematode species. Nematodes are a key group for regulating biogeochemical cycling and ecosystem processes. These processes include mineralisation and decomposition in the soil system. Nematodes are also indicators of environmental quality. For these studies, nematodes can be differentiated into feeding groups based on their morphology and, in particular, the shape and size of their mouthparts. There are five main feeding types: bacterivores, fungivores, omnivores, plant parasites and predators. Ecological characteristics or life history traits of nematodes can also be indicators of environmental quality. For example, species that reproduce quickly in response to a nutrient-rich addition to the soil, are 'colonisers', while species with long life cycles and low reproduction rates are 'persisters'. Soil nematodes carry bacteria on their cuticle and can excrete viable bacteria, thus serving as a vehicle for translocation of bacteria throughout the soil, and as a potential food source.

Diversity, abundance and biomass

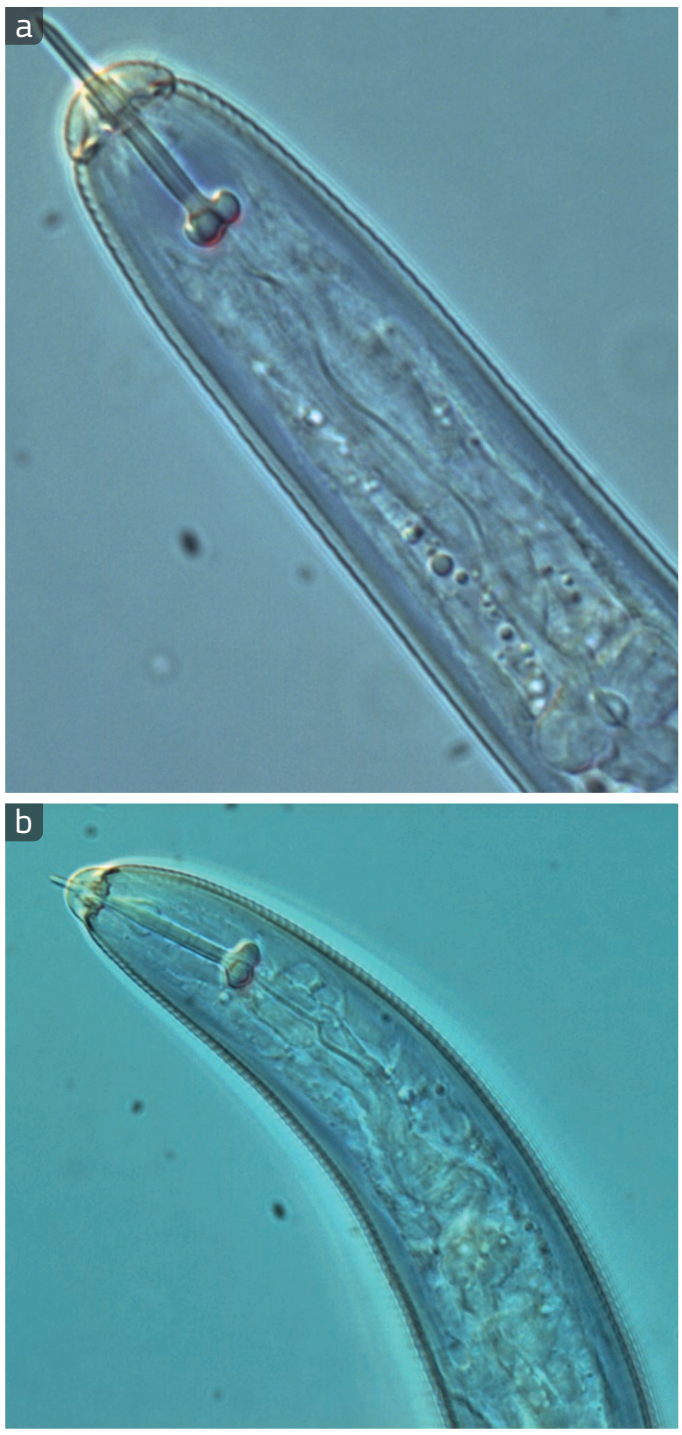
Nematodes are among the most diverse and abundant animals on Earth: one in five animals on Earth is estimated to be a nematode. Terrestrial nematodes make up a substantial portion of the more than 25 000 described species of the group. Nematodes are found in soils, marine and freshwater sediments, and as parasites of plants and animals, such as insects, humans and birds. Many nematode infections cause serious human diseases in the developing world (e.g. Guinea worm and elephantiasis).

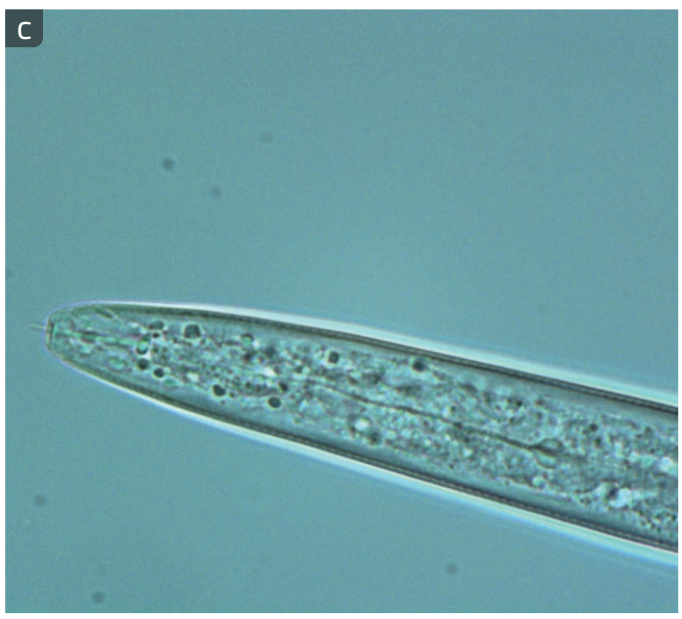
Nematodes, everywhere!

- Soil nematodes feeding on bacteria occur more than 3.6 km below the surface of the Earth – deeper than any known animal, and at a temperature of 48 °C.
- The smallest nematode, belonging to the genus *Micronema*, is 0.3 mm in size and lives between sediment particles.
- Nematodes were the first animal genome ever sequenced, and are thought to be the most genetically diverse of all animals.
- Based on DNA sequences, two nematode species can be as different as a tiger and a mouse.
- Nematodes can survive in space and are known to have survived the U.S. Columbia Space Shuttle crash.
- A nematode released to control the invasive species of Sirex woodwasp (*Sirex noctilio*) has saved the Australian forest industry an estimated US$80 M (approx. €75 M) per year.
- In 2013, groundsmen at Scotland's national rubgy stadium sprayed a solution of garlic on to the field in a bid to cure a nematode infestation that was destroying the playing surface.

Plant-feeding nematodes

Nematodes puncture the cell walls of plant roots with large hollow needle-like spears in their mouths and suck out plant nutrients. Their spears are called stylets and vary in shape. Enzymes, (e.g. cellulase and chitinase) are injected through the stylets of some plant parasitic species to help break down cell walls. Other species, such as *Xiphenema* spp., can carry plant viruses in their stylets and vector the viruses from plant to plant. Plant-feeding nematode species can be migratory or sedentary, feeding either inside the host plant root (endoparasites) or outside the plant root (ectoparasites) and can cause serious economic damage to agricultural crops, including citrus, rice, maize, soybean and numerous vegetable crops. The plant parasitic nematodes *Meloidogyne* and *Pratylenchus* spp. infect wide ranges of host plants, while *Globodera* and *Heterodera* spp. have more restricted plant host ranges. Crop rotations help avoid damage by the latter two nematode species.

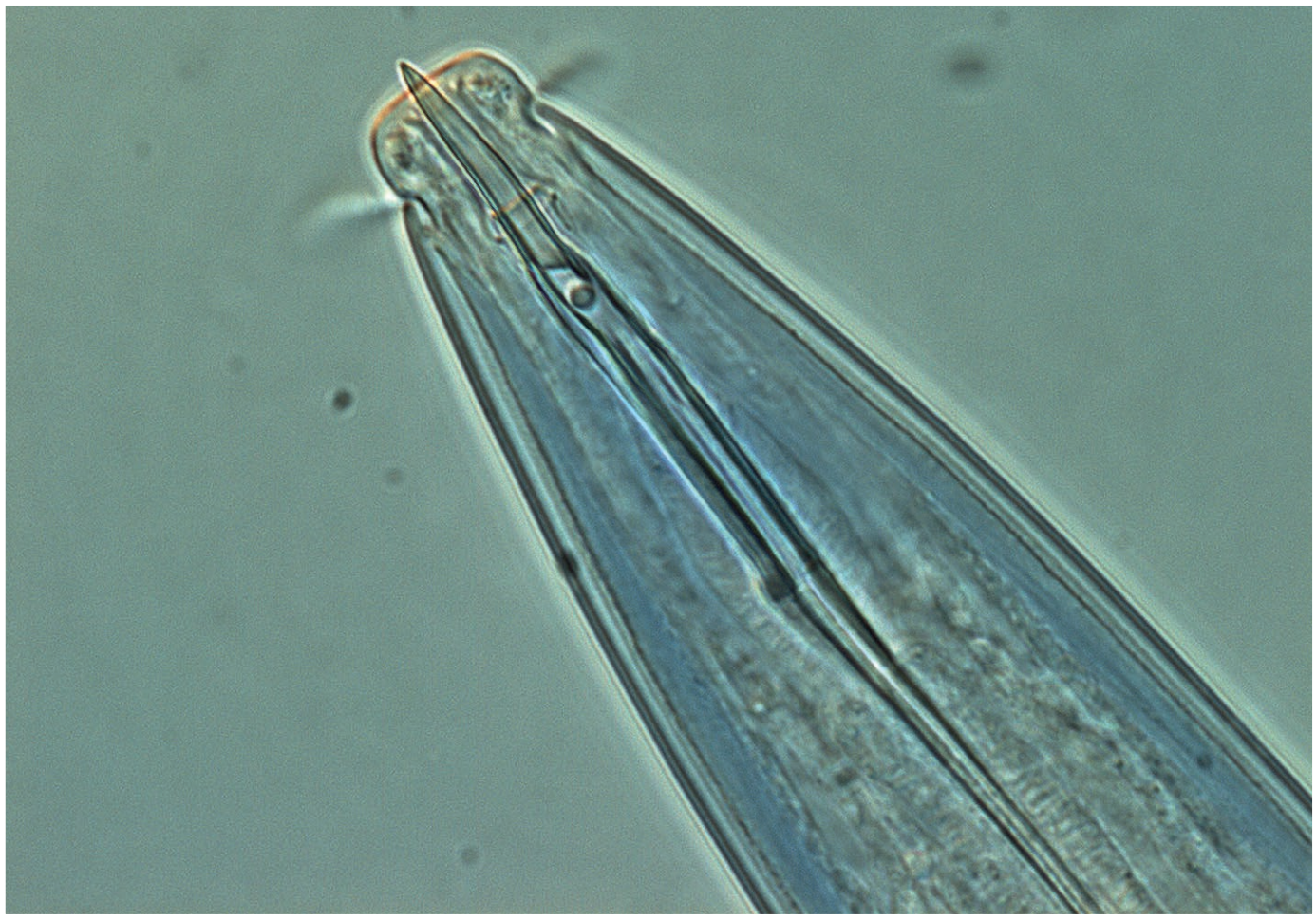




Plant-feeding nematodes. (**a**) Head of *Globodera pallida* with an extendable spear used to penetrate roots of host plant species, such as potatoes (*Solanum tuberosum*). Note the knobs on the base of the spear that anchor muscles extending forward to the head. When these muscles contract, the spear juts forward. (**b**) The plant hosts of the nematode *Helicotylenchus pseudorobustus* include: fruit crops, vegetables, agronomic crops, ornamental plants, forages, turfgrasses, weeds. (**c**) Grasses [e.g. *Elymus farctus* (Viv.)] are a host to this plant parasitic nematode species, *Meloidogyne duytsi*. (HM, HH, JGB)

Omnivorous nematodes

These are large free-living soil nematodes (up to 5 mm in length), and are omnivorous, using a variety of food sources. They have a hollow tooth that can pierce other organisms and suck out nutrients. Depending on environmental conditions and food availability, they can feed on algal filaments, protists, other nematodes and then, when their primary food sources are unavailable, switch to feeding on fungal hyphae and bacteria. They often have low reproduction rates and generally occur in stable habitats, rather than in newly established or disturbed habitats.



The omnivorous nematode *Prodorylaimus filarum* has a spear without knobs. Omnivorous species can feed on algae, protists, other nematodes and then, when these primary food sources are unavailable, switch to feeding on fungi and bacteria. (HM, HH, JGB)

Predaceous nematodes

Predaceous nematodes have one or more large teeth or a pointed spear that are used to attack and ingest nematodes and other small animals, such as enchytraeids, tardigrades, rotifers and protists (see pages 36-37, 44-45, 48). Predatory nematodes make up approximately 5 % of the overall soil nematode community, and decline in abundance when soils are disturbed. *Mononchoides* spp. can also feed on bacterial cells and can be cultured in the laboratory as biocontrol agents against plant parasitic and other nematodes.

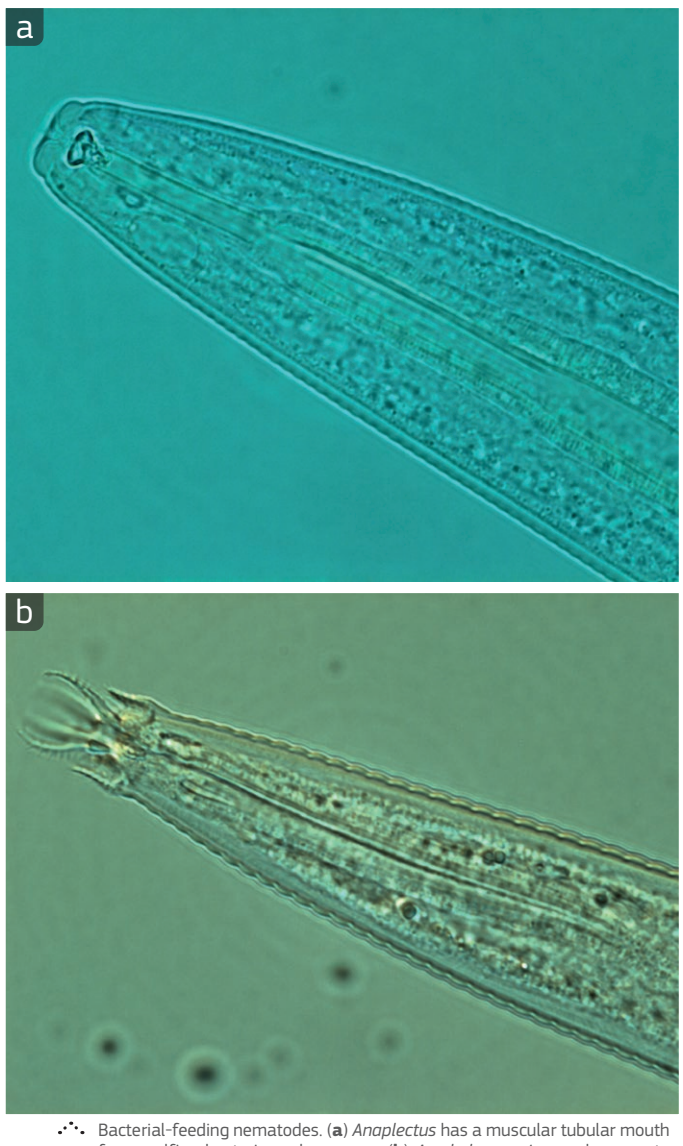
(**a**) This predator with a large dorsal tooth (*Mylonchulus sigmaturus*) eats other nematodes. (**b**) This predaceous nematode has a hollow spear to kill enchytraeids and other small animals. (HM, HH, JGB)

Bacterial-feeding nematodes

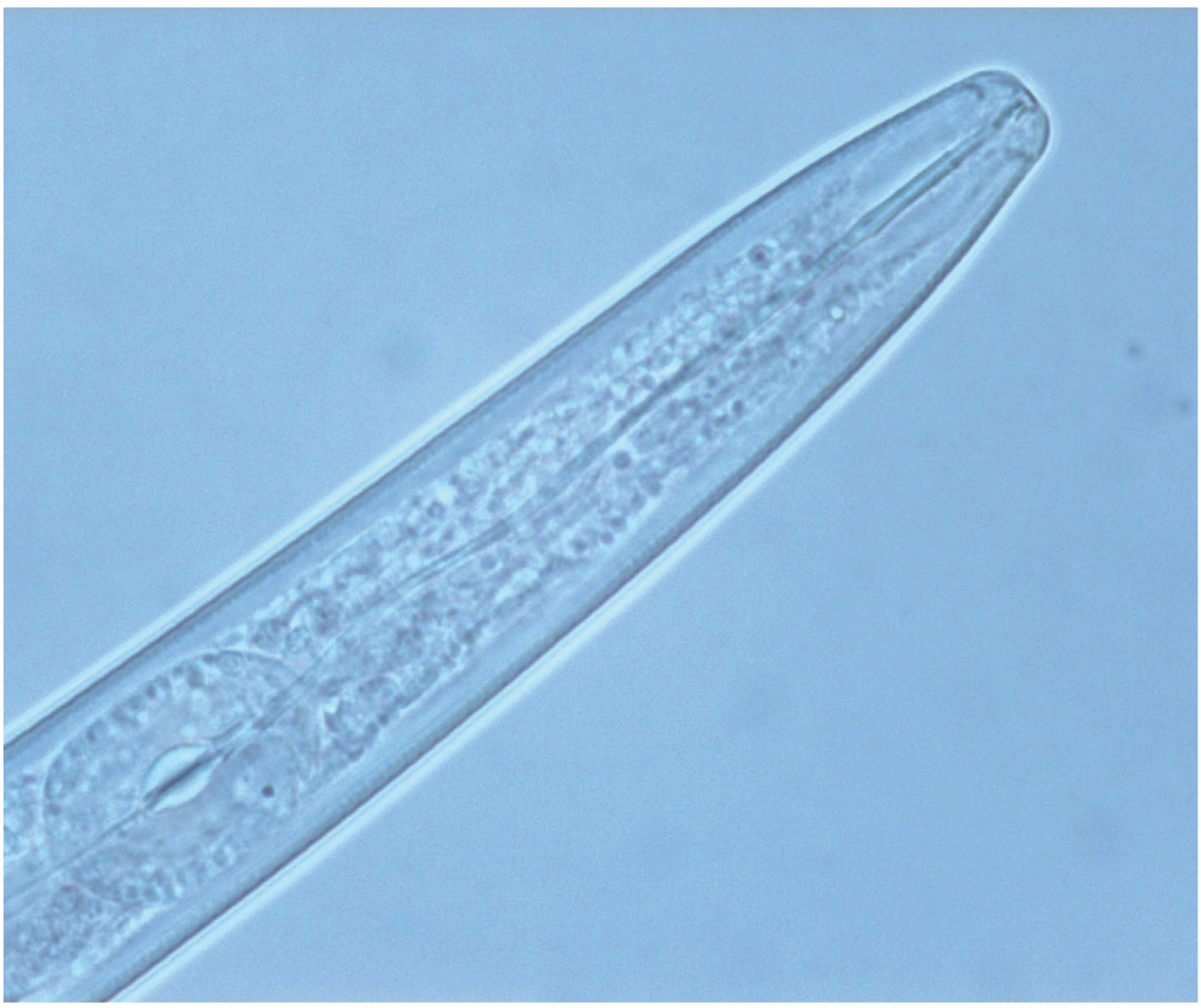
Bactivorous nematodes have tubular mouths and graze on bacteria by swallowing them or scraping them from soil substrates using structures on top of their head. Grazing of bacteria increases the rate of decomposition of the chemical compounds in organic matter (carbon and nitrogen mineralisation) in soil. There is also evidence that grazing on bacteria can positively affect the plant root growth. These animals have germination times ranging from a few days to a week, which is advantageous for colonising new habitats.

Fungal-feeding nematodes

Fungal-feeding nematodes have small, fine stylets optimally adapted for feeding on fungal hyphae (see box, page 39). Fungivorous nematodes can affect plant growth indirectly via the destruction of arbuscular mycorrhizal fungi (see page 40) or other beneficial fungi, leading to reduced nutrient availability for the plant. Other species are beneficial for pest control through the destruction of plant fungal pathogens (see box, page 39). Fungal-feeding nematodes are generally less abundant in highly disturbed soils (e.g. agriculture) than bacterial-feeding nematodes.



Bacterial-feeding nematodes. (**a**) *Anaplectus* has a muscular tubular mouth for engulfing bacteria and no spear. (**b**) *Acrobeles mariannae* has ornate head appendages (probolae). (HM, HH, JGB)



Fungal-feeding nematodes, such as *Aphelenchus* sp., have a tiny spear to pierce fungal hyphae. (HM, HH, JGB)