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Unique facts about the nematodes

[1*]Berliner, J., [2]Manimaran, B., [3]Mhatre, P.H. and [4]Sankari Meena

[1]ICAR-IARI, RS, Wellington, Tamil Nadu; [2]ICAR-IARI, New Delhi; [3]ICAR-CPRS, RC, Muthorai; [4]ICAR-IIOR, Hyderabad

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The nematodes are the minuscule organisms known to humans for a very long time. However, is still poorly understood that a common man considers the nematodes as dangerous parasites of humans and other animals, a farmer looks them as pest causing severe yield loss whereas a researcher use the nematodes as biological model and biological indicators to decipher unknown nuance of the genomes and environmental changes. But, for an organism sharing the same subterranean habitat, the nematodes are either predators or prey in the food chain. One might wonder what its (nematodes) uniqueness is and why it is more special. In this article we discuss about the uniqueness of nematodes generally unknown to common people.

Are they microscopic?

All hear about the nematodes but not many have seen it. The soil nematodes are generally transparent and less than a millimetre in length and hence impossible for a human eye to observe them without the aid of the magnifying instruments (lens/microscopes). The smallest nematode known to human is 0.082 mm long *Greeffiella minutum*. However, the animal parasitic nematodes are bigger in size and may reach the length of about 8 meters as in the case of sperm whale nematode, *Placentonema gigantissima* (Shah and Mahamood, 2017). Despite the larger size of the animal parasitic nematodes, they are still uncommon to be seen by people as they live deep inside (cryptic habitat) the host animals.

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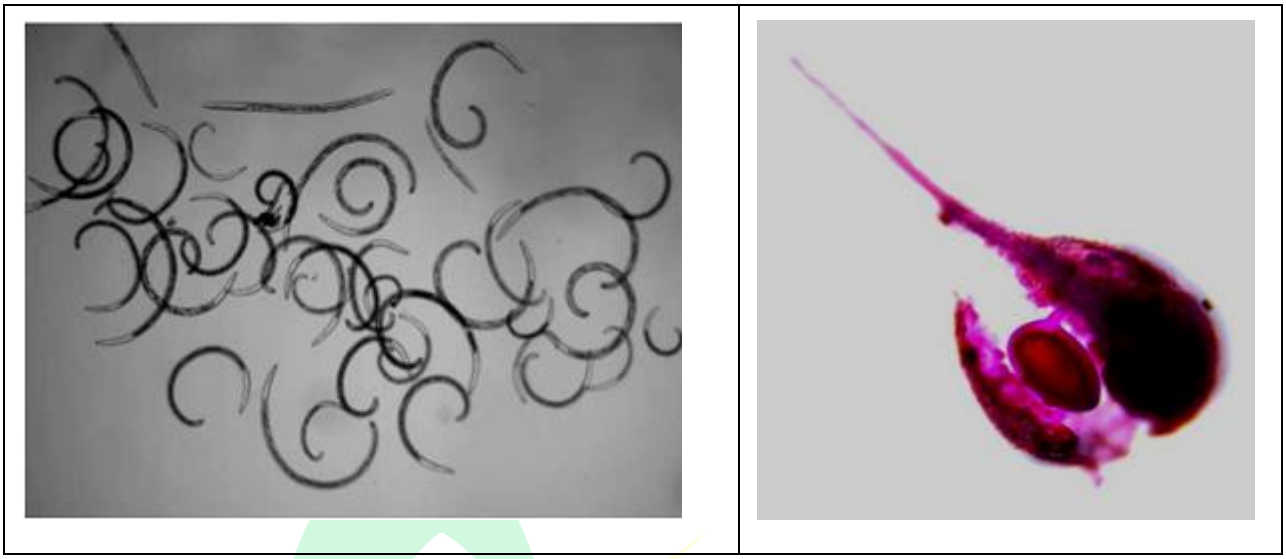

Figure 1: Consortium of Nematodes extracted from soil (left), female of Meloidogyne *sp. within dissected root tip*

Ecological uniqueness:

Nematodes are the most abundant animal on earth and are estimated to be around 4.4×10^{20} nematodes in earth's top soil and numerically accounting for 80% of all the individuals on terrestrial ecosystem (Hoogen et al., 2019) and more than 90% of individuals on ocean floor (Lambshead, 2004). Further, nematodes are the second most speciose invertebrate phylum after the arthropods and the Mollusc and it was estimated to be over a million (Lambshead, 1993). However many researchers refused to accept this numbers as baseless and later estimates put this number close to 40000 (Anderson, 2000). Nematodes are universally distributed all over the world including the extreme environments (Table 1) and their population is relatively stable to moisture and temperature changes compared to bacteria. Hence, they used as one of the indicators of environmental studies. In the same time, high sensitivity of predatory nematodes to wide range of disturbances should not be ignored.

Table 1: Nematodes in extreme environments

S. No.	Scientific name	Remarks	Reference
1	*Greenia orientals*, *Plectus chengmohiangi*,	Survives in hot springs	Hoeppli and Chu, 1932

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	Alicrolaintoides lingi, *Cyazhalaimus chitngsani*, *Monhystrella ginlingensis* and *Monhystrella filiformis*		
2	*Tylenchus polyhypnus*	Ability to revive after 39 years	Steiner & Albin (1946)
3	*Metachromadora onyxoldes*, *Terschellingia longicaudata*, *Eubostrichus parasitiferus and Gomphionema typica*	Survival in Sulphide system i.e. oxidized layers of the ocean floors	Fenchel & Riedl, 1970
4	*Anguina triticii*	Ability to revive after 32 years from wheat seeds stored in a refrigerator	Limber, 1973
6	*Panagrolaimus davidi*	Survives subzero level in Antartica (Cold desert)	Wharton et al., 2003
7	*Caenorhabditis elegans*	Survivor of Columbia disaster in 2003	Szewczyk, et al., 2005
8	*Halicephalobus mephisto*	Found in 0.9-3.6-kilometre deep African mines	Borgonie et al., 2011
9	*Paracanthonchus olgae*, *Prochromadora helenae*, *Prochaetosoma ventriverruca*, *Leptolaimus hydrothermalis*, *Oncholaimus scanicus*, *Desmodora marci* and *Halomonhystera vandoverae*	hydrothermal vents in Mid-Atlantic ridge	Tchesunov, 2015
10	*Steinernema feltiae*	Tested in space for	Kaplan et al., 2020

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infesting ability on insect host

Historical uniqueness:

The nematodes are soft bodied organisms and the hardest part of their body is the outer body cover called cuticle which can withstand brief exposure of 45000psi hydrostatic pressure. However, the toughness of the cuticle is not sufficient enough to provide us enough fossil evidences of their origin. Despite that, researchers succeeded in discovering some of the oldest known nematomorphs such as *Cricocosmia jinningensis*, *Maotianshania cylindrical* and *Paleoscolex sinensis*, which lived about 525 million years ago, from the fossil site of Chengjiang Maotianshan shales, Yunan Province, China. Humans were well aware of the animal parasitic nematodes which is evident from the Krimn or Krimis in vedic records (6000-4000 BC), Ascaris in Huang Ti Nei ching, Yellow Emperor's classic of internal medicine (2700 BC), Egyptian medical papyri, the Ebers papyrus (1553 BC), Biblical reference (1250 BC) about the extraction of 'Guinea worm' and the works of the Greeks, particularly Hippocrates (460 to 375 BC) (Jones and Whithington, 1948-1953). The Egyptians record was later confirmed by the discovery of calcified nematode eggs in mummies dating from 1200 BC. The oldest record of nematode eggs (*Ascariasis lumbricoides*) from the New World (Peru) discovered from fossilized faecal materials (coprolites) dates back to 2277 BC (Horne, 1985; Patrucco et al., 1983). Though the nematodes were known to humans for long time the first detailed anatomical study was done only in the 17th century (Tyson, 1683).

Evolutionary uniqueness:

The nematode body is basically a tube (alimentary canal) inside another tube (cuticle and muscles) which were connected in anterior side by mouth and in the posterior side by the anus and between the two tubes lays the reproductive system. The scientists argued that the simplicity in body architecture is evolved through secondary simplication from complex structures and hence nematodes may not be primitive in origin. Current studies indicate that nematodes are actually related to the arthropods and priapulids in a newly recognized group, the Ecdysozoa (Aguinaldo et al. 1997).

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Morphological and Physiological uniqueness

Nematodes are the only invertebrates with tail otherwise it is a general feature of vertebrates. Some invertebrates including scorpions, springtails, snails and slugs, have tail-like appendages and sometimes non-scientifically referred as tails. Another sole characteristic of the phylum is the lack of cilia or flagella and even their sperms are amoeboid. Nematodes exhibit extraordinary cuticular ornamentations like spines, setae, papillae, tubercles, warts, bands, plates, rugae and pores (Decraemer and Hunt, 2012) and these variations have commendable taxonomic importance (Fig 2).

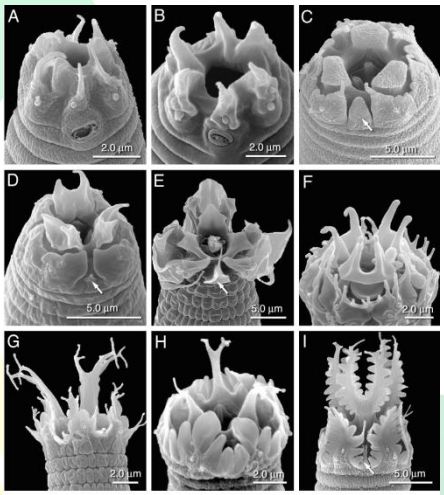

Fig 2: Scanning electron micrographs of the lip region of females of Cephalobidae (Courtesy, Nadler et al., 2006)

Anatomically the epidermis is generally cellular in nature, but in nematodes they are non-cellular. Nematodes only have longitudinal muscles so they can only bend or thrash back and forth. Unlike the other animals, in which, the nervous system branches into the muscles to form a network of neurons, in nematodes the muscles branched out into the nervous system. For the same the muscles are also specially called as myoneural arms in nematodes. The number of somatic cells will remain the same all through the life (Eutely). It is the only organism along with many arachnids, whose first moult occurs within egg. They are the only organism with post uterine sac. In general all animals move in a dorso-ventral plane but the nematodes have laterally creeping nature.

Physiologically nematodes do not have discrete circulatory or respiratory organs and have simple digestive ducts (tubes) without flame cells or nephridia. A fluid that occupies the

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body cavity facilitates nutrients circulation within nematode through muscular or locomotor movement. The nematodes have male, female and hermaphrodite sexes and adopt diverse reproductive methods (Table 2) which are one of the key reasons for their success. Sex reversal is observed in some species of nematodes, in which the nematodes destined to become female, will become male due to external stress. The nematodes group comprises some of the big mamas such as *Ascaris lumbricoides* which lays about 27 million eggs during her lifecycle @ 200,000 per day.

Table 2: Different reproductive strategies of Nematodes

Reproductive method	Explanation	Example
Amphimixis	Bisexual reproduction	General
Autotoky	Reproduction without males	
Parthenogenesis	Embryo formed without the fertilization by sperm i.e. without the need of the male and the mating process	*Meloidogyne* spp.
Hermaphroditism	Have both male and female reproductive system in the same body and either partner can act as male or female.	*Caenorhabditis* spp
Pseudogamy	Mating is required but no union of gametes takes place i.e. male does not contribute genetically to the offspring	*Aphelenchus avenae*
Heterogamy	With sexual and autotokous life cycles and switch from amphimixis to hermaphroditism during alternating life cycles	*Heterorhabditis* spp.
Male hermaphrodites	after mating with a female, the male produces eggs within its body,	*Heterogonema ovomascularis*

	fertilises them and then dies when the newborn break through his body to exit

Maggenti, 1982; Poinar, 2011; Decraemer and Hunt, 2012

Biological uniqueness:

Many basic concepts of biology were discovered using the nematodes as Model organisms. The Meiosis was discovered and described for the first time in sea urchin eggs in 1876 by the German biologist Oscar Hertwig and it was re-described (1883) at the chromosome level in Ascaris roundworm eggs by the Belgian zoologist Edouard Van Beneden. Since then it was used as biological model for embryogenesis study. *Caenorhabditis elegans* is the first eukaryote, whose complete Genome has been sequenced. Important discoveries about programmed cell death, RNA interference, gene silencing by double-stranded RNA were made using *C. elegans* as a model system (Hillary and Horvitz, 1986). Then, in 2008, American worm researcher Martin Chalfie shared in the Nobel Prize in Chemistry for his contribution to the development of green fluorescent protein as a tool for visualizing biological structures in living organisms. Recently in 2015 Campbell & Omura won the Nobel Prize in Pjysiology or Medicine for the discovery of Avermectins variant to treat round worm.

Conclusion:

Thus the nematode is unseen yet comprises several bewildering uniqueness in its morphology, anatomy and physiology as discussed above. Further many exciting phenomenas may be deciphered in near future. After reading this, it is not uncommon for a person to think, weather we are living in our world or their (Nematode and other microbes) world. Moreover, nematodes are also believed to be one of the important components of space agriculture (EPNs) for us during our future space travel programs.

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