NEMATODES AND ARTHROPODS*

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Based on Superphylum Ecdysozoa by
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Abstract

By the end of this section, you will be able to:

• Describe the structural organization of nematodes
• Understand the importance of Caenorhabditis elegans in research
• Compare the internal systems and appendage specializations of phylum Arthropoda
• Discuss the environmental importance of arthropods
• Discuss the reasons for arthropod success and abundance

1 Roundworms and Arthropods

The nematodes and the arthropods belong to a clade with a common ancestor, called Ecdysozoa. The name comes from the word *ecdysis*, which refers to the periodic shedding, or molting, of the exoskeleton. The ecdysozoan phyla have a hard cuticle covering their bodies that must be periodically shed and replaced for them to increase in size. The cuticle provides a tough, but flexible exoskeleton that protects these animals from water loss, predators and other aspects of the external environment. After molting, they secrete a new cuticle that will last until their next growth phase. The presence of an exoskeleton suggests, surprisingly, that phylum Nematoda (the roundworms) is more closely related to the Phylum Arthropoda (the arthropods) than to the other worm phyla.

2 Phylum Nematoda

The phylum Nematoda, or roundworms, includes more than 28,000 species with an estimated 16,000 parasitic species. The name Nematoda is derived from the Greek word “nemos,” which means “thread.” Nematodes are present in all habitats and are extremely common, although they are usually not visible (Figure 1). Nematodes, like most other animal phyla, have three tissue layers, are also bilaterally symmetrical, and consist of both free-living and parasitic forms. It has been said that were all the non-nematode matter of the biosphere removed, there would remain a shadow of the former world in the form of nematodes.

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2.1 Morphology

Most nematodes look similar to each other: slender tubes, tapered at each end (Figure 1). Nematodes are pseudocoelomates and have a complete digestive system with a distinct mouth and anus.

The overall morphology of these worms is cylindrical, as seen in Figure 1. The head is radially symmetrical. A mouth opening is present at the anterior end with three or six lips as well as teeth in some species in the form of cuticle extensions. Some nematodes may present other external modifications like rings, head shields, or warts. Rings, however, do not reflect true internal body segmentation. The mouth leads to a muscular pharynx and intestine, which leads to a rectum and anal opening at the posterior end. The muscles of nematodes differ from those of most animals: They have a longitudinal layer only, which accounts for the whip-like motion of their movement.
Figure 1: Scanning electron micrograph shows (a) the soybean cyst nematode (*Heterodera glycines*) and a nematode egg. (b) A schematic representation shows the anatomy of a typical nematode. (credit a: modification of work by USDA ARS; scale-bar data from Matt Russell)
The nematode body is encased in a cuticle, a flexible but tough exoskeleton, or external skeleton, which offers protection and support. The cuticle contains a carbohydrate-protein polymer called chitin. The cuticle also lines the pharynx and rectum. Although the exoskeleton provides protection, it restricts growth, and therefore must be continually shed and replaced as the animal increases in size.

2.2 Excretory System

In nematodes, the excretory system is not specialized. Nitrogenous wastes are removed by diffusion. In marine nematodes, regulation of water and salt is achieved by specialized glands that remove unwanted ions while maintaining internal body fluid concentrations.

2.3 Nervous System

Most nematodes have four nerve cords that run along the length of the body on the top, bottom, and sides. The nerve cords fuse in a ring around the pharynx, to form a head ganglion or “brain” of the worm, as well as at the posterior end to form the tail ganglion. Beneath the epidermis lies a layer of longitudinal muscles that permits only side-to-side, wave-like undulation of the body.

2.4 Life Cycles

Nematodes employ a diversity of sexual reproductive strategies depending on the species; they may be hermaphroditic, dioecious (separate sexes), or may reproduce asexually by parthenogenesis. Caenorhabditis elegans is nearly unique among animals in having both self-fertilizing hermaphrodites and a male sex that can mate with the hermaphrodite.

A number of common parasitic nematodes serve as prime examples of parasitism. These animals exhibit complex lifecycles that involve multiple hosts, and they can have significant medical and veterinary impacts. Humans may become infected by Dracunculus medinensis, known as guinea worms, when they drink unfiltered water containing copepods (Figure 2). Hookworms, such as Ancyclostoma and Necator, infest the intestines and feed on the blood of mammals, especially in dogs, cats, and humans. Trichina worms (Trichinella) are the causal organism of trichinosis in humans, often resulting from the consumption of undercooked pork; Trichinella can infect other mammalian hosts as well. Ascaris, a large intestinal round-worm, steals nutrition from its human host and may create physical blockage of the intestines. The filarial worms, such as Dirofilaria and Wuchereria, are commonly vectorized by mosquitoes, which pass the infective agents among mammals through their blood-sucking activity. Dirofilaria immitis, a blood-infective parasite, is the notorious dog heartworm species. Wuchereria bancrofti infects the lymph nodes of humans, resulting in the non-lethal but deforming condition called elephantiasis, in which parts of the body become swelled to gigantic proportions due to obstruction of lymphatic drainage and inflammation of lymphatic tissues.
Figure 2: The guinea worm *Dracunculus medinensis* infects about 3.5 million people annually, mostly in Africa. (a) Here, the worm is wrapped around a stick so it can be extracted. (b) Infection occurs when people consume water contaminated by infected copepods, but this can easily be prevented by simple filtration systems. (credit: modification of work by CDC)
3 Phylum Arthropoda

The name “arthropoda” means “jointed legs” (in the Greek, “arthros” means “joint” and “podos” means “leg”); it aptly describes the enormous number of invertebrates included in this phylum. Arthropoda dominate the animal kingdom with an estimated 85 percent of known species included in this phylum and many arthropods yet undocumented. The principal characteristics of all the animals in this phylum are functional segmentation of the body and presence of jointed appendages. Arthropods also show the presence of an exoskeleton made principally of chitin, which is a waterproof, tough polysaccharide. Phylum Arthropoda is the largest phylum in the animal world, and insects form the single largest class within this phylum. Arthropods are eucordomate, protostomic organisms.

Phylum Arthropoda includes animals that have been successful in colonizing terrestrial, aquatic, and aerial habitats. This phylum is further classified into five subphyla: Trilobitomorpha (trilobites, all extinct), Hexapoda (insects and relatives), Myriapoda (millipedes, centipedes, and relatives), Crustaceans (crabs, lobsters, crayfish, isopods, barnacles, and some zooplankton), and Chelicerata (horseshoe crabs, arachnids, scorpions, and daddy longlegs). Trilobites are an extinct group of arthropods found chiefly in the pre-Cambrian Era that are probably most closely related to the Chelicerata. These are identified based on fossil records (Figure 3).

Figure 3: Trilobites, like the one in this fossil, are an extinct group of arthropods. (credit: Kevin Walsh)
3.1 Morphology

A unique feature of arthropods is the presence of a segmented body with fusion of certain sets of segments to give rise to functional segments. Fused segments may form a head, thorax, and abdomen, or a cephalothorax and abdomen, or a head and trunk. The coelom takes the form of a hemocoel (or blood cavity). The open circulatory system, in which blood bathes the internal organs rather than circulating in vessels, is regulated by a two-chambered heart. Respiratory systems vary depending on the group of arthropod: insects and myriapods use a series of tubes (tracheae) that branch through the body, open to the outside through openings called spiracles, and perform gas exchange directly between the cells and air in the tracheae, whereas aquatic crustaceans utilize gills, terrestrial chelicerates employ book lungs, and aquatic chelicerates use book gills (Figure 4). The book lungs of arachnids (scorpions, spiders, ticks and mites) contain a vertical stack of hemocoel wall tissue that somewhat resembles the pages of a book. Between each of the "pages" of tissue is an air space. This allows both sides of the tissue to be in contact with the air at all times, greatly increasing the efficiency of gas exchange. The gills of crustaceans are filamentous structures that exchange gases with the surrounding water. Groups of arthropods also differ in the organs used for excretion. In order to grow, the arthropod must shed the exoskeleton; this is a cumbersome method of growth, and during this time, the animal is vulnerable to predation.

![Figure 4: The book lungs of (a) arachnids are made up of alternating air pockets and hemocoel tissue shaped like a stack of books. The book gills of (b) crustaceans are similar to book lungs but are external so that gas exchange can occur with the surrounding water. (credit a: modification of work by Ryan Wilson based on original work by John Henry Comstock; credit b: modification of work by Angel Schatz)](http://cnx.org/content/m48097/1.1/)

3.2 Insects

The name Hexapoda denotes the presence of six legs (three pairs) in these animals as differentiated from the number of pairs present in other arthropods. Hexapods are characterized by the presence of a head, thorax, and abdomen, constituting three tagma. The thorax bears the wings as well as six legs in three pairs. Many of the common insects we encounter on a daily basis—including ants, cockroaches, butterflies, and flies—are examples of Hexapoda.
Amongst the arthropods, the insects (Figure 5) are the largest class in terms of species diversity as well as biomass in terrestrial habitats. Insects have six legs (three pairs) three body segments: the head, thorax, and abdomen. The thorax bears the wings as well as six legs. Typically, the head bears one pair of sensory antennae, mandibles as mouthparts, a pair of compound eyes, and some ocelli (simple eyes) along with numerous sensory hairs.

![Figure 5: In this basic anatomy of a hexapod insect, note that insects have a developed digestive system (yellow), a respiratory system (blue), a circulatory system (red), and a nervous system (red).](http://cnx.org/content/m48097/1.1/)

Which of the following statements about insects is false?

a. Insects have both dorsal and ventral blood vessels.
b. Insects have spiracles, openings that allow air to enter.
c. The trachea is part of the digestive system.
d. Insects have a developed digestive system with a mouth, crop, and intestine.

### 3.3 Myriapods

Myriapods include arthropods with legs that may vary in number from 10 to 750. This subphylum includes 13,000 species; the most commonly found examples are millipedes and centipedes. All myriapods are terrestrial animals and prefer a humid environment.

Myriapods are typically found in moist soils, decaying biological material, and leaf litter. Subphylum Myriapoda is divided into four classes: Chilopoda, Symphyla, Diplopoda, and Pauropod. Centipedes like *Scutigera coleoptrata* (Figure 6) are classified as chilopods. These animals bear one pair of legs per segment, mandibles as mouthparts, and are somewhat dorsoventrally flattened. The legs in the first segment are modified to form forcipules (poison claws) that deliver poison to prey like spiders and cockroaches, as these animals are all predatory. Millipedes bear two pairs of legs per segment and are herbivores or detritivores. (Figure 7).
Figure 6: (a) The *Scutigera coleoptrata* centipede has up to 15 pairs of legs. (b) This North American millipede (*Narceus americanus*) bears many legs, although not a thousand, as its name might suggest. (credit a: modification of work by Bruce Marlin; credit b: modification of work by Cory Zanker)

### 3.4 Crustaceans

Crustaceans are the most dominant aquatic arthropods, since the total number of marine crustacean species stands at 67,000, but there are also freshwater and terrestrial crustacean species. Krill, shrimp, lobsters, crabs, and crayfish are examples of crustaceans (Figure 7). Terrestrial species like the wood lice (*Armadillidium* spp.) (also called pill bugs, roly pollies, potato bugs, or isopods) are also crustaceans, although the number of non-aquatic species in this subphylum is relatively low.

Figure 7: The (a) crab and (b) shrimp krill are both crustaceans. (credit a: modification of work by William Warby; credit b: modification of work by Jon Sullivan)
The head and thorax of most crustaceans is fused to form a cephalothorax (Figure 8). Crustaceans have a chitinous exoskeleton that is shed by molting whenever the animal increases in size. The exoskeletons of many species are also infused with calcium carbonate, which makes them even stronger than in other arthropods. Crustaceans have an open circulatory system where blood is pumped into the hemocoel by the heart.

![Carapace and Heart](http://cnx.org/content/m48097/1.1/)

**Figure 8:** The crayfish is an example of a crustacean. It has a carapace around the cephalothorax and the heart in the dorsal thorax area. (credit: Jane Whitney)

Most crustaceans are dioecious, which means that the sexes are separate. Some species like barnacles may be hermaphrodites. Serial hermaphroditism, where the gonad can switch from producing sperm to ova, may also be seen in some species. Fertilized eggs may be held within the female of the species or may be released in the water. Terrestrial crustaceans seek out damp spaces in their habitats to lay eggs.

Most crustaceans are carnivorous, but herbivorous and detritivorous species are also known. Crustaceans may also be cannibalistic when extremely high populations of these organisms are present.

### 3.5 Chelicerates

This subphylum includes animals such as spiders, scorpions, horseshoe crabs, and sea spiders. This subphylum is predominantly terrestrial, although some marine species also exist. An estimated 77,000 species are included in subphylum Chelicerata. Chelicerates are found in almost all habitats.

The body of chelicerates may be divided into two parts: cephalothorax and abdomen. A “head” is not usually discernible. The phylum derives its name from the first pair of appendages: the chelicerae (Figure 9), which are specialized, claw-like or fang-like mouthparts. These animals do not possess antennae. The second pair of appendages is known as pedipalps. In some species, like sea spiders, an additional pair of appendages, called ovigers, is present between the chelicerae and pedipalps.
Chelicerae are mostly used for feeding, but in spiders, these are often modified into fangs that inject venom into their prey before feeding (Figure 10). Members of this subphylum have an open circulatory system with a heart that pumps blood into the hemocoel. Aquatic species have gills, whereas terrestrial species have either trachea or book lungs for gaseous exchange.
Most chelicerates ingest food using a preoral cavity formed by the chelicerae and pedipalps. Some chelicerates may secrete digestive enzymes to pre-digest food before ingesting it. Parasitic chelicerates like ticks and mites have evolved blood-sucking apparatuses.

The nervous system in chelicerates consists of a brain and two ventral nerve cords. These animals use external fertilization as well as internal fertilization strategies for reproduction, depending upon the species and its habitat. Parental care for the young ranges from absolutely none to relatively prolonged care.
Visit this site² to click through a lesson on arthropods, including interactive habitat maps, and more.

4 Section Summary

Nematodes are pseudocoeelome animals akin to flatworms, yet display more advanced neuronal development, a complete digestive system, and a body cavity. This phylum includes free-living as well as parasitic organisms like *Caenorhabditis elegans* and *Ascaris* spp., respectively. They include dioecious as well as hermaphroditic species. Nematodes also possess an excretory system that is not quite well developed. Embryonic development is external and proceeds via three larval stages. A peculiar feature of nematodes is the secretion of a collagenous/chitinous cuticle outside the body.

Arthropods represent the most successful phylum of animal on Earth, in terms of the number of species as well as the number of individuals. These animals are characterized by a segmented body as well as the presence of jointed appendages. In the basic body plan, a pair of appendages is present per body.

²http://openstaxcollege.org/l/arthropodstory
segment. Within the phylum, traditional classification is based on mouthparts, number of appendages, and modifications of appendages present. Arthropods bear a chitinous exoskeleton. Gills, trachea, and book lungs facilitate respiration. Sexual dimorphism is seen in this phylum, and embryonic development includes multiple larval stages.

5 Art Connections

Exercise 1
(Solution on p. 16.)
Figure 5 Which of the following statements about insects is false?

a. Insects have both dorsal and ventral blood vessels.
b. Insects have spiracles, openings that allow air to enter.
c. The trachea is part of the digestive system.
d. Insects have a developed digestive system with a mouth, crop, and intestine.

6 Review Questions

Exercise 2
(Solution on p. 16.)
The embryonic development in nematodes can have up to _________ larval stages.

a. one
b. two
c. three
d. five

Exercise 3
(Solution on p. 16.)
The nematode cuticle contains ______.

a. glucose
b. skin cells
c. chitin
d. nerve cells

Exercise 4
(Solution on p. 16.)
Crustaceans are ______.

a. ecdysozoans
b. nematodes
c. arachnids
d. parazoaans

Exercise 5
(Solution on p. 16.)
Flies are ______.

a. chelicerates
b. hexapods
c. arachnids
d. crustaceans
7 Free Response

**Exercise 6**
Enumerate features of *Caenorhabditis elegans* that make it a valuable model system for biologists. *(Solution on p. 16.)*

**Exercise 7**
What are the different ways in which nematodes can reproduce? *(Solution on p. 16.)*

**Exercise 8**
Describe the various superclasses that phylum Arthropoda can be divided into. *(Solution on p. 16.)*

**Exercise 9**
Compare and contrast the segmentation seen in phylum Annelida with that seen in phylum Arthropoda.
Solutions to Exercises in this Module

to Exercise (p. 14)
Figure 5 C

to Exercise (p. 14)
D

to Exercise (p. 14)
C

to Exercise (p. 14)
A

to Exercise (p. 14)
B

to Exercise (p. 15)
It is a true animal with at least rudiments of the physiological systems—feeding, nervous, muscle, and reproductive—found in “higher animals” like mice and humans. It is so small that large numbers can be raised in Petri dishes. It reproduces rapidly. It is transparent so that every cell in the living animal can be seen under the microscope. Before it dies (after 2–3 weeks), it shows signs of aging and thus may provide general clues as to the aging process.

to Exercise (p. 15)
There are nematodes with separate sexes and hermaphrodites in addition to species that reproduce parthenogenetically. The nematode Caenorhabditis elegans has a self-fertilizing hermaphrodite sex and a pure male sex.

to Exercise (p. 15)
The Arthropoda include the Hexapoda, which are mandibulates with six legs, the Myriapoda, which are mandibulates with many legs and include the centipedes and millipedes, the Crustacea, which are mostly marine mandibulates, and the Chelicerata, which include the spiders and scorpions and their kin.

to Exercise (p. 15)
Arthropods have an exoskeleton, which is missing in annelids. Arthropod segmentation is more specialized with major organs concentrated in body tagma. Annelid segmentation is usually more uniform with the intestine extending through most segments.

Glossary

Definition 10: Arthropoda
phyllum of animals with jointed appendages

Definition 10: biramous
referring to two branches per appendage

Definition 10: cephalothorax
fused head and thorax in some species

Definition 10: chelicera
modified first pair of appendages in subphylum Chelicerata

Definition 10: cuticle (animal)
the tough, external layer possessed by members of the invertebrate class Ecdysozoa that is periodically molted and replaced

Definition 10: cypris
larval stage in the early development of crustaceans

Definition 10: hemocoel
internal body cavity seen in arthropods

Definition 10: hermaphrodite
referring to an animal where both male and female gonads are present in the same individual

http://cnx.org/content/m48097/1.1/
Definition 10: nauplius
larval stage in the early development of crustaceans

Definition 10: Nematoda
phylum of worm-like animals that are triploblastic, pseudocoelomates that can be free-living or parasitic

Definition 10: oviger
additional pair of appendages present on some arthropods between the chelicerae and pedipalps

Definition 10: pedipalp
second pair of appendages in Chelicerata

Definition 10: uniramous
referring to one branch per appendage

Definition 10: zoea
larval stage in the early development of crustaceans