CHAPTER 3

Biology and Ecology of Earthworm Species Used for Vermicomposting

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CONTENTS

I INTRODUCTION

Earthworms are macroscopic clitellate oligochaete annelids that live in soil. They are segmented worms, bilaterally symmetrical, with an external gland (clitellum) for producing the egg case (cocoon), a sensory lobe in front of the mouth (prostomium), and an anus at the end of the animal body, with a small number of bristles (setae) on each segment. They are hermaphrodite animals, and reproduction normally occurs through copulation and cross-fertilization, following which each of the mated individuals produces cocoons containing 1–20 fertilized ova. The resistant cocoons, which are tiny and roughly lemon-shaped, with shape differing between species, are usually deposited near the soil surface, except in dry weather when they are laid at deeper layers. Cocoons hatch after an incubation period that varies according to the earthworm species and environmental conditions. Hatchling earthworms, unpigmented and only a few millimeters in length on emerging from the cocoons, gain their adult pigmentation within a few days. Assuming favorable conditions, they reach sexual maturity within several weeks after emergence. Mature individuals of most vermicomposting species can be distinguished easily by the presence of the clitellum, the pale- or dark-colored swollen band located behind the genital pores. The clitellum secretes the fibrous cocoon, and the clitellar gland cells produce a nutritive albuminous fluid that fills the cocoon. Earthworms display indeterminate growth and can continue to grow in size after completing their sexual development although they do not add segments.

According to Reynolds and Wetzel (2004), there are more than 8300 species in the Oligochaeta, of which about half are terrestrial earthworms. The most common earthworms in Europe, North America, western Asia, and many other parts of the world belong to the family Lumbricidae, whereas in West Africa, many of the common earthworms belong to the family Eudrilidae. In South Africa there is the Microchaetidae, in Australia and other parts of eastern Asia, the Megascolecidae, and the family Glossoscolecidae predominate in Central and South America.

Different species of earthworms have different life histories, occupy different ecological niches, and have been classified, on the basis of their feeding and burrowing strategies, into three ecological categories: epigeic, anecic, and endogeic (Bouché 1977). Endogeic (soil feeders) and anecic species (burrowers) live in the soil and consume a mixture of soil and organic matter, and thus excrete organomineral feces. Epigeic species of earthworms are litter dwellers and litter transformers; they live in organic soil horizons, in or near the surface litter, and feed primarily on coarse particulate organic matter. They ingest large amounts of undecomposed litter and excrete holorganic fecal pellets. These species are small in body size and uniformly pigmented with high metabolic and reproductive rates, which represent adaptations to the highly variable environmental conditions at the soil surface. In tropical regions, epigeic earthworms can also be found in the axils of Bromeliaceae plants.

II EARTHWORM SPECIES SUITABLE FOR VERMICOMPOSTING

Epigeic species of earthworms, with their natural ability to colonize organic wastes; high rates of consumption, digestion, and assimilation of organic matter; tolerance to a wide range of environmental factors; short life cycles; high-reproductive rates; and endurance and tolerance of handling, show good potential for vermicomposting. Few earthworm species display all these characteristics, and in fact only five have been used extensively in vermicomposting *Eisenia andrei* (Savigny), *Eisenia fetida* (Bouché), *Dendrobaena veneta* (Savigny), and, to a lesser extent, *Perionyx excavatus* (Perrier), and *Eudrilus eugeniae* (Kinberg). Characteristics and life history aspects of eight common species of earthworms are summarized in Table 3.1.

A Temperate Species

1 Eisenia fetida (*Savigny 1826*) *and* Eisenia andrei (*Bouché 1972*)

These lumbricid earthworm species are those most commonly used in vermicomposting and vermiculture mainly because they are ubiquitous with a worldwide distribution and colonize organic substrates naturally, their life cycles are short, they have a wide temperature- and moisture-tolerance range, and they are resilient earthworms that can be readily handled.

E. fetida corresponds to the striped or banded morph, with the area around the intersegmental groove having no pigmentation and appearing pale or yellow; hence, its common names of ''brandling'' or ''tiger'' earthworm; whereas *E. andrei*, the common ''red'' worm, corresponds to the uniformly reddish morph. Aside from the differences in pigmentation, the two species are morphologically similar and their overall requirements the same. Their reproductive performances and life cycles do not differ significantly, although growth rates and cocoon production are slightly higher in *E. andrei*. The problem of their taxonomic status remained unresolved for a long time, and moreover in much of the current literature both species are termed indiscriminately as *E. fetida* or *E. foetida*, the latter an illegal or inaccurate emendation of the former name, and it is often not clear which of the two species is being referred to. We have confirmed that they are two different biological species, reproductively isolated, and that they are also two different phylogenetic species. The reproductive isolation was confirmed after studying the offspring viability from inter- and intraspecific crosses of both species (Domínguez et al. 2005). Additionally, fully resolved and well-supported phylogenetic trees based on mitochondrial (COI) and nuclear DNA sequences (28S) confirmed that they are different phylogenetic species (Pérez-Losada et al. 2005). This evidence implies important considerations; thus in vermiculture or vermicomposting *E. andrei* is more often recommended since its growth and reproduction rates are higher. Moreover, the two species are syntopic, commonly living in mixed colonies in dung and vermicompost heaps, and therefore hybridization is possible. The existence of postcopula but not precopula isolation in sympatric populations clearly affects the population dynamics

Table 3.1a Comparison of Some Aspects of the Biology of the Vermicomposting Species

	Eisenia fetida	***Eisenia andrei***	***Dendrobaena rubida***	***Dendrobaena veneta***
Color	Brown and buff bands	Red	Reddish purple	Reddish and purple bands
Size of adult earthworms	4–8 mm × 50–100 mm (0.016–0.03 in × 1.9 × 3.0 in)	4–8 mm × 50–100 mm (0.016–0.03 in × 1.9 × 3.0 in)	3–4 mm × 35–60 mm (0.11–0.16 in × 1.3–2.4 in)	5–7 mm × 50–80 mm (0.2–0.27 in × 2–3.15 in)
Mean weight of adults	0.55 g (0.01 oz)	0.55 g (0.01 oz)	0.25 g (0.008 oz)	0.92 g (0.032 oz)
Time to maturity (days)	28–30	21–28	54	65
Number of cocoons day^{-1}	0.35–0.5	0.35–0.5	0.20	0.28
Mean size of cocoons	4.85 mm × 2.82 mm (0.03 × 0.11 in)	4.8 mm × 2.82 mm (0.03 × 0.11 in)	3.19 mm × 1.97 mm (0.12 × 0.07 in)	3.14 mm × 1.93 mm (0.12 × 0.075 in)
Incubation time (days)	18–26	18–26	15–40	42.1
Hatching viability (%)	73–80	72	85	20
Number of worms $cocoon^{-1}$	2.5–3.8	2.5–3.8	1.67	1.10
Self-fertilization	+	+	+	—
Life cycle (days)	45–51	45–51	75	100–150
Limits and optimal T^{a}	25°C (0°C–35°C) (77°F)(32°F–95°F)	25°C (0°C–35°C) (77°F)(32°F–95°F)	—	25°C (15°C–25°C) (77°F)(59°F–77°F)
Limits and optimal moisture	80%–85% (70%–90%)	80%–85% (70%–90%)	—	75% (65%–85%)

Table 3.1b Comparison of Some Aspects of the Biology of the Vermicomposting Species

	Drawida nepalensis	*Eudrilus eugeniae*	*Perionyx excavatus*	*Lumbricus rubellus*
Color	—	Reddish brown	Reddish brown	Reddish brown
Size of adult earthworms	—	5–7 mm × 80–190 mm	4–5 mm × 45–70 mm	4 mm × 70–150 mm
Mean weight of adults	0.82 g (0.02 oz)	2.7–3.5 g (0.09–0.12 oz)	0.5–0.6 g (0.01–0.02 oz)	0.80 g (0.02 oz)
	Drawida nepalensis	***Eudrilus eugeniae***	***Perionyx excavatus***	***Lumbricus rubellus***
Time to maturity (days)	34–42	40–49	28–42	74–91
Number of cocoons day^{-1}	0.15	0.42–0.51	1.1–1.4	0.07–0.25 mm (0.003–0.01 in)
Mean size of cocoons	—	—	—	3.50 mm × 2.46 mm (0.13 × 0.10 in)
Incubation time (days)	24	12–16	18	35–40
Hatching viability (%)	75–88	75–84	90	60–70
Number of worms $cocoon^{-1}$	1.93	2–2.7	1–1.1	1
Self-fertilization	+	—	—	—
Life cycle (days)	100–120	50–70	40–50	120–170
Limits and optimal temperature	—	25°C (16°C–30°C) 77°F(61°F–86°F)	25°C–37°C (77°F–99°F)	—
Limits and optimal moisture	—	80% (70%–85%)	—	—

by reducing the fitness of the individuals. For this reason, in applied aspects it is important to keep the two species separated (Domínguez et al. 2005) although they often occur in cultures together.

The life cycle and population biology of *E. fetida* and *E. andrei* in different organic wastes have been investigated by several authors (Watanabe and Tsukamoto 1976; Hartenstein et al. 1979; Edwards 1988; Reinecke and Viljoen 1990; Domínguez et al. 1997; Domínguez and Edwards 1997; Domínguez et al. 2000; Monroy et al. 2006). The optimum temperature for growth of both species is 25°C(68°F), and although they can tolerate a wide range of moisture conditions, the optimum moisture content for these species is 85%. In optimum conditions the length of their life cycles (from newly-laid cocoon through clitellate adult earthworm) ranges from 45 to 51 days. The time for hatchlings to reach sexual maturity varies from 21 to 30 days. Copulation in these species, which takes place beneath the soil or waste surface, has been mentioned by various authors since 1845 and has been observed more often than in any other megadrile species. Cocoon laying starts 48 hours after copulation, and the rate of cocoon production is 0.35–0.5 day^{-1}. The hatching viability is 72%–82%, and the incubation period ranges from 18 to 26 days. The number of young earthworms hatching from viable cocoons varies from 2.5 to 3.8 depending on the temperature. In controlled conditions, the average life span is 594 days at 18°C(64.4°F) and 589 days at 28°C(82.4°F) with a maximum life expectancy between 4.5 and 5 years, although under natural conditions it may be considerably shorter.

2 Dendrodrilus rubidus (*Savigny 1826*)

Dendrodrilus rubidus is a holarctic earthworm species belonging to the family Lumbricidae with a relatively cosmopolitan distribution. It is an epigeic earthworm with a clear preference for highly organic soils, and it has also been found in organic substrates such as rotting wood and straw, pine litter, compost, peat, and nearby sewage tanks and manure. Although some specific aspects of their biology have been investigated (Gates 1972; Sims and Gerard 1985; Bengtsson et al. 1986; Cluzeau and Fayolle 1989; Elvira et al. 1996), it is not an earthworm usually used in vermicomposting or vermiculture. The mean time for hatchlings of *D. rubidus* to reach sexual maturity is 51 days, and the mean rate of cocoon production is 0.2–0.4 cocoons $earthworm^{-1}$ day^{-1} (Bengtsson et al. 1986; Cluzeau and Fayolle 1989; Elvira et al. 1996). Hatching success for cocoons is 85%, with a mean incubation time of 22 days and an average of 1.7 hatchlings (between 1 and 3) emerging from each cocoon (Elvira et al. 1996). *Dendrodrilus rubidus* can complete its life cycle within 75 days, and according to Cluzeau and Fayolle (1989), one of the factors that contribute to the high reproduction rate of this species is that its reproduction may be biparental, amphimitic, or uniparental, either by parthenogenesis or by self-fertilization.

3 Dendrobaena veneta (*Rosa 1886*)

This species is a large earthworm that can also survive in soil with potential for use in vermiculture; although it is not very prolific, it grows very rapidly (Edwards

1988; Viljoen et al. 1991). A number of commercial vermicomposting companies use this species, and it may have particular potential for protein-production systems and for breeding for use in field soil improvement.

Dendrobaena veneta (also sometimes called *Eisenia hortensis*) is a robust earthworm that can tolerate much wider moisture ranges than many other species and has a preference for mild temperatures 15°C–25°C (59°F–68°F). Its life cycle can be completed in 100–150 days, and 65 days is the average time to reach sexual maturity. Mean cocoon production has been reported as 0.28 day^{-1}, but the hatching viability seemed low (20%), and the mean period of cocoon incubation period is 42 days. The mean number of earthworms hatching from each viable cocoon is about 1.1 (Lofs-Holmin 1986; Viljoen et al. 1991, 1992; Muyima et al. 1994).

4 Lumbricus rubellus (*Hoffmeister 1843*)

Lumbricus rubellus is usually found in moist soils, particularly those to which animal manures or sewage solids have been applied (Cotton and Curry 1980). In surveys of commercial earthworm farms in the United States, Europe, and Australia, earthworms sold under the name *L. rubellus* were usually always *E. fetida* or *E. andrei*.

There are little data about its moisture and temperature requirements and preferences, although it is known that it clearly prefers moist conditions and can survive cold temperatures well. The optimal temperature for growth is 18°C (64.4°F), and suboptimal temperatures are less harmful than supraoptimal ones. *L. rubellus* has a relatively long life cycle (120–170 days) with a slow growth rate and a long maturation time (74–91 days). The mean cocoon production rate varies from 0.07 to 0.25 cocoons $earthworm^{-1}$ day^{-1}, and hatching viability is 60%–70%. After an incubation period of 35–40 days, one single earthworm emerges from each cocoon (Cluzeau and Fayolle 1989; Elvira et al. 1996). The low maturation and reproductive rate indicate that it is not ideal for use in vermicomposting, although its size and vigor could make it of potential interest as fish bait or for land-improvement purposes.

5 Drawida nepalensis (*Michaelsen 1907*)

This is a temperate earthworm species not widely utilized in vermicomposting although it has affinity for organic matter and shows some suitable characteristics for vermiculture. Although this species has a lower growth rate and produces fewer cocoons and hatchlings per cocoon than most of the other vermicomposting species, it has a relatively short life cycle (100–120 days) and can reproduce, like *E. fetida*, without mating. The mean time to sexual maturity is 34–42 days, and the cocoon production is 0.15 cocoons $worm^{-1}$ day^{-1}. Its hatching viability is 75%–88%, and the mean incubation time is 23.6 days. The mean number of young earthworms hatching from viable cocoons is 1.93 (Kaushal and Bisht 1992, 1995).

B Tropical Species

1 Eudrilus eugeniae (*Kinberg 1867*)

This earthworm species is native to Africa, but it has been bred extensively in the United States, Canada, and elsewhere for the fish bait market where it is commonly called the "African night crawler." It is a large earthworm that grows extremely rapidly, is reasonably prolific, and under optimum conditions can be considered as ideal for production of animal feed protein. Its main disadvantages are its narrow temperature tolerance and sensitivity to handling. *E. eugeniae* has high-reproduction rates (Bano and Kale 1988; Edwards 1988) and is capable of decomposing large quantities of organic wastes quickly and incorporating them into the topsoil (Neuhauser et al. 1979, 1988; Edwards 1988).

It shows preference for high temperatures, with maximum biomass production occurring at 25°C–30°C (77°F–86°F), while the growth rates were very low at 15°C (59°F) (Loehr et al., 1985; Viljoen and Reinecke 1992; Domínguez et al. 2001). Its use in outdoor vermiculture may therefore be limited to tropical and subtropical regions, unless winter temperatures are controlled. It can tolerate moisture contents between 70% and 85%, the optimum being 80%–82%. Domínguez et al. (2001) reported that individuals continued to increase in weight with virtually no mortality for 22 weeks. Reinecke et al. (1992) reported continuous growth and maximum weight up to 21 weeks at 25°C (77°F). The life cycle of *E. eugeniae* ranges from 50 to 70 days, and its life span can be 1–3 years. Sexual maturity is attained within 40–49 days, and a week after this period the individuals start to lay cocoons, between 0.42 and 0.51 cocoons day^{-1} (Viljoen and Reinecke 1989; Reinecke et al. 1992; Reinecke and Viljoen 1993; Domínguez et al. 2001). This is, together with *E. fetida* and *E. andrei*, a more rapid rate of development than for any other species of earthworm that has been reported to date and makes a very fast rate of population multiplication possible. The cocoon incubation period ranges from 12 to 16 days, and hatching success from 75% to 84%, with the mean number of earthworms per cocoon between 2 and 2.7 (Viljoen and Reinecke 1989; Reinecke et al. 1992; Reinecke and Viljoen 1993; Domínguez et al. 2001).

2 Perionyx excavatus (*Perrier 1872*)

Perionyx excavatus is an earthworm commonly found over a large area of tropical South Asia (Stephenson 1930; Gates 1972) although it has also been transported to Europe and North America. This is an epigeic species that lives solely in organic wastes, and high-moisture contents and adequate amounts of suitable organic material are required for populations to become fully established and to process organic wastes efficiently.

This tropical earthworm is extremely prolific, and it is almost as easy to handle as *E. fetida* and very easy to harvest. Its main drawback is its inability to withstand low-temperature conditions, but for tropical conditions it seems an ideal species. Although it has a shorter maturation and incubation time than *E. eugeniae*, its fecundity is higher. It is a very common species in Asia and is used in vermiculture in India, the Philippines, and Australia. The life cycle and the potential of this species for breaking down organic wastes have been documented by various authors under controlled conditions (Kale et al. 1982; Reinecke and Hallatt 1989; Hallatt et al. 1990; Reinecke et al. 1992; Hallat et al. 1992; Edwards et al. 1998). *P. excavatus* does not grow much at low temperatures although it can survive them 4°C (39.2°F), but it is less susceptible to high temperatures over 30°C (86°F) than *E. eugeniae*. Even in tropical areas, *P. excavatus* does not grow during low-winter temperatures but can survive the high-summer temperatures, whereas *E. eugeniae* has a much narrower tolerance range for temperature and cannot survive either the extreme low winter or the high summer temperatures. The life cycle of *P. excavatus* takes 40–50 days. Sexual maturity is attained within 20–28 days, and the mean cocoon production is 2.8 cocoons earthworm^{-1} day^{-1}, the mean incubation time of cocoons at 25°C (77°F) is 18 days, the hatching success is high (85%–90%), and usually only one hatchling emerges from each cocoon (Kale et al. 1982; Reinecke and Hallatt 1989; Hallatt et al. 1990, 1992; Reinecke et al. 1992; Edwards et al. 1998).

3 Polypheretima elongata (*Perrier 1872*)

This tropical earthworm species has been tested for the treatment of solid organic wastes, including municipal and slaughterhouse wastes; human, poultry, and dairy manures; and mushroom compost in India. A project in India using this species claimed to have a commercially viable facility for the "vermistabilization" of 8 tons (7.8 t) of solid wastes day^{-1}; they developed a "vermifilter" (packed with vermicompost and live earthworms) that produces reusable water from sewage sludge, manure slurries, and organic wastewater from food processing. *P. elongata* appears to be restricted to tropical regions and may not survive severe winters. There seem to be no detailed data about its life cycle available in the literature.

III INFLUENCE OF ENVIRONMENTAL FACTORS ON SURVIVAL AND GROWTH OF EARTHWORMS

Cocoon production, rates of development, and growth of earthworms are all critically affected by environmental conditions. Epigeic earthworms are relatively tolerant to the environmental conditions of the organic wastes, so quite simple low management windrow or bed systems have been used extensively to process these wastes. However, it has been demonstrated clearly that these earthworms have well-defined limits of tolerance to environmental parameters, such as moisture and temperature, and that the wastes are processed much more efficiently within a relatively narrow range of favorable chemical and environmental conditions. If these limits are greatly exceeded, earthworms may move to more suitable zones in the waste, leave it, or die, so that these wastes are processed very slowly.

A Temperature

Earthworms have fairly complex responses to changes in temperature. Neuhauser et al. (1988) studied the potential of several earthworm species to grow in sewage sludge, and they concluded that all these species have a range of preferred temperatures for growth, ranging between 15°C (59°F) and 25°C (77°F). In their studies, cocoon production was more restricted by temperature than growth, and most of the cocoons were laid at 25°C (77°F). Edwards (1988) studied the life cycle and optimal conditions for survival and growth of *E. fetida*, *D. veneta*, *E. eugeniae*, and *P. excavatus*. Each of these four species differed considerably in terms of response and tolerance to different temperatures. The optimum temperature for *E. fetida* was 25°C (77°F), and its temperature tolerance was between 0°C (32°F) and 35°C (95°F). *Dendrobaena veneta* had a rather low-temperature optimum and rather less tolerance to extreme temperatures. The optimum temperatures for *E. eugeniae* and *P. excavatus* were around 25°C (77°F), but they died at temperatures below 9°C (48.2°F) and above 30°C (86°F). Optimal temperatures for cocoon production were much lower than those more suitable for growth for these species.

Temperatures below 10°C (50°F) generally result in reduced or little feeding activity; and below 4°C (39.2°F), cocoon production and development of young earthworms ceases completely. In extreme temperature conditions earthworms tend to hibernate and migrate to deeper layers of the windrow for protection. Earthworms can also acclimate to temperature in autumn and survive the winter, but they cannot survive long periods under freezing conditions unless they are in protective cells. The unfavorable effect of high temperatures (above 30°C (86°F)) on most species of earthworms is not entirely a direct effect because these warm temperatures also promote chemical and microbial activities in the substrate, and the increased microbial activity tends to consume the available oxygen, with negative effects on the survival of earthworms.

B Moisture Content

There are strong relationships between the moisture content of organic wastes and the growth rate of earthworms. In vermicomposting systems, the optimum range of moisture contents for most species has been reported to be between 50% and 90%. *Eisenia fetida* and *E. andrei* can survive in moisture ranges between 50% and 90%, but they grow more rapidly between 80% and 90% in organic wastes (Edwards 1988; Domínguez and Edwards 1997).

C PH

Most epigeic earthworms are relatively tolerant to pH and can tolerate pH levels of 5–9, but when given a choice in the pH gradient, they move toward the more acid material, with a pH preference of 5.0.

D Aeration

Earthworms lack specialized respiratory organs, and oxygen and carbon dioxide diffuse through their body wall. Thus, earthworms are very sensitive to anaerobic conditions. *E. fetida* have been reported to migrate in high numbers from a water-saturated substrate in which oxygen has been depleted, or in which carbon dioxide or hydrogen sulfide has accumulated.

E Ammonia and Salts

Earthworms are very sensitive to ammonia and cannot survive in organic wastes containing high levels of this cation (e.g., fresh poultry litter). They also die in wastes with large quantities of inorganic salts. Both ammonia and inorganic salts have very sharp cutoff points between toxic and nontoxic (<1 mg· g^{-1}(0.016.1b^{-1}) of ammonia and <0.5% salts) (Edwards 1988). However, organic wastes containing high levels of ammonia can become acceptable after the removal of ammonia by a period of precomposting or by leaching with water.

Outside the limits of these environmental parameters, both earthworm activity and the rates of processing of the organic wastes decrease dramatically; for maximum vermicomposting efficiency, wastes should be preconditioned to make them suitable for earthworms. The optimal conditions for breeding *E. fetida* and *E. andrei* are summarized in Table 3.2. These characteristics do not differ too much from those suitable for other species (Edwards 1988).

In addition of environmental conditions, earthworm population density affects rates of earthworm growth and reproduction. Even when the physical–chemical characteristics are ideal for vermicomposting, problems can develop due to overcrowding. Reinecke and Viljoen (1990) in studies with *E. fetida* reared in cow manure and Domínguez and Edwards (1997) studying the growth and reproduction of *E. andrei* in pig manure found that, when grown at different population densities, the earthworms in the crowded containers grew more slowly and with a lower final bodyweight, although the total weight of earthworm biomass produced per unit of waste was greater. Maturation rate was also affected by the stocking rate; thus, earthworms of the same age developed the clitellum at different times in the different stocking rates.

Table 3.2 Optimal Conditions for Breeding *E. fetida* and *E. andrei* in Organic Wastes

Condition	Requirements
Temperature	15°C–20°C (limits 4°C–30°C) (59–68°F) (limits 39–86°F)
Moisture content	80%–90% (limits 60%–90%)
Oxygen	Aerobicity
Ammonia content of the waste	Low: < 1 mg·g^{-1} (0.016 oz.1b^{-1})
Salt content	Low: < 0.5%
pH	5–9

IV PREDATORS, PARASITES, AND PATHOGENS OF EARTHWORMS

Earthworms can be the target for a wide range of vertebrate predators and are attacked by several parasites and pathogens. Earthworms are an important component of the diet of many vertebrate predators. They are preyed on by many species of birds and mammals. Centipedes, ants, carabid and staphylinid beetles, and their larvae also prey on earthworms.

Earthworms have many internal parasites, including Protozoa, Platyhelminthes, Rotatoria, nematodes (Nematoda), and fly larvae. Bacteria, such as *Spirochaeta* sp. and *Bacillus* sp., and fungal pathogens have been reported to parasitize earthworms, although little is known of their effects on their hosts. The most common protozoan parasites of earthworms belong to Gregarina. These protozoa have been found in many different parts of the body of earthworms, including the alimentary tract, coelom, blood system, testes, spermathecae, seminal vesicles, and even inside the cocoons. A number of ciliate protozoa and platyhelminth worms also infest the bodies of earthworms although few cause them any serious harm. There are several instances of platyhelminth worms being found in the bodies of earthworms. Many nematodes occur in the tissues of earthworms; few seem to cause serious damage, and often the earthworm is merely acting as an intermediate host for them. Some nematodes are carried passively by earthworms. Others develop within the earthworm, and some are true parasites, with the earthworm being the sole host. Some mites feed on and destroy the developing earthworm cocoon.

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