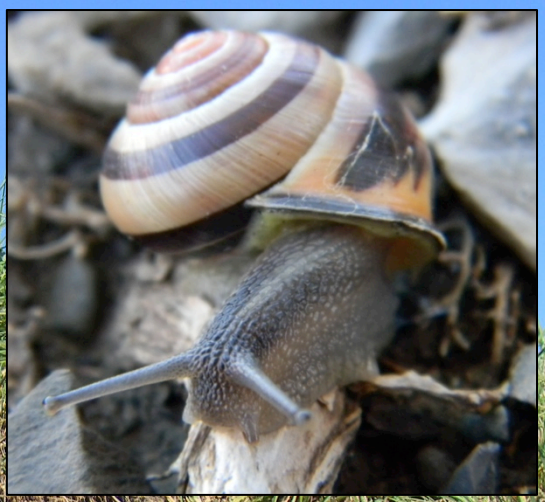
The Soil Animal Handbook



What is soil?

Soil has many definitions. Soil is the base of almost all terrestrial ecosystems, and almost all humans throughout history and in the modern era derive at least part of their sustenance from soil. Soils provide support and nutrients for plants, help store, filter, and purify water for humans, and absorb greenhouse gases from the atmosphere. Soils are always changing over time from erosion and the movement of plant roots.

Soils can lie over the ground where they were formed, atop the eroding bedrock they formed from, or be deposited thousands of miles from their "birthplace" by the movement of wind, water, and glacial ice.

Soil is not dirt! Dirt is soil where you don't want it, like on your floor.

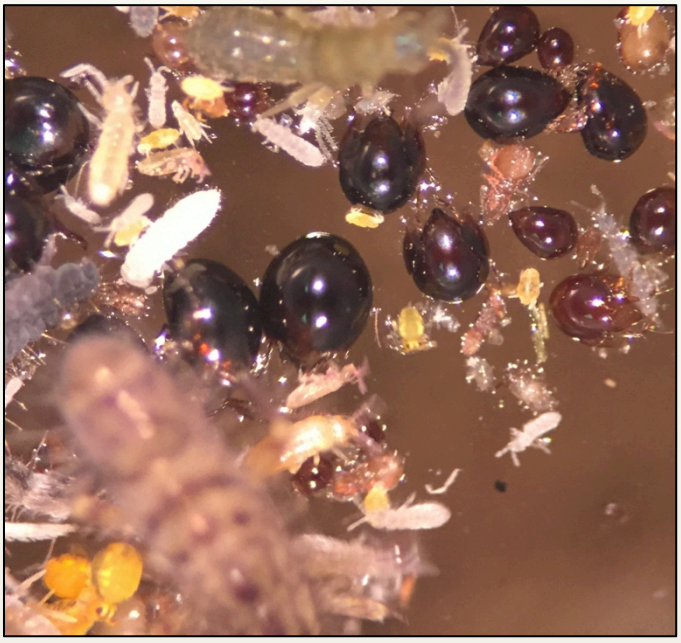
Soil is also one of humankind's most important natural resources, and needs to be conserved from threats such as erosion and pollution in order to continue sustaining human society.

And most importantly...

Soils are Alive!

From the deepest forests to the driest deserts to your own backyard, the Earth's soils are full of life! Millions of wriggling, skittering, crawling creatures call the soil home, and in their daily doings make possible all the benefits that soil gives us. A single gram of soil can contain 10^9 (1 billion) bacterial cells, and a square yard of forest soil can contain tens or even hundreds of thousands of tiny **microarthropods** (see below).

Many soil animals are too small to see without microscopes, but for many others, the naked eye or a simple magnifying glass is sufficient.



Benefits of Soil Animals

Soil animals provide numerous benefits to the environment and humankind. The four most important benefits are...

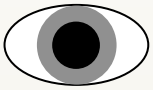
1) Aiding in breaking down organic matter to release nutrients back into the soil to be taken up by plants. Soil animals accomplish this both by feeding directly on organic matter and by stimulating populations of decomposer microbes. Without decomposition, the remains of old plants would remain forever and new plants could not grow.
2) Modifying soil structure through burrowing and tunneling. This promotes easier movement of air and water throughout the soil, which increases productivity and reduces water runoff and soil erosion.
3) Controlling populations of crop pests. Predatory and parasitic insects, arachnids, and nematodes feed on a wide variety of pests threatening our lawns, crops, and gardens.
4) Pollinating flowering plants, allowing fruits and seeds to develop. Not all pollinators live in soil, but some do, including many wild bees.

How to Use This Book

- To identify individual animals -> Use the key on page 10, then search each recommended section for the animal group bearing the closest resemblance.
- To learn more about the animals in your lawn or garden soil -> Read the soil animal entries starting on page 11.

In each entry, the following icons provide information on the size, habits, and benefits of the described organism or group.

Size



Animal is large enough to identify with the naked eye

Magnification is needed to accurately identify the animal

Habits

Animal dwells mostly in soil or leaf litter or on the soil surface throughout its life

Animal nests in soil, but spends a lot of time above the ground or develops into a flying adult stage

Benefits

Animal helps break down organic matter and cycle nutrients

Animal improves soil structure for movement of air and water

Animal helps control pests

Animal pollinates plants

In addition, the  icon indicates a species or group that can be a significant pest of crops or lawns. This guide is not intended to identify specific pest species. Resources for identifying and controlling pests can be found on page 42.

Glossary

Abdomen: The rearmost body section of an insect or other arthropod.

Antenna(e): Appendages present on the heads of many arthropods. They are packed with smell, taste, touch, and other sensory receptors and used to sense the environment around the insect.

Cerci: Appendages present on the tips of many arthropod abdomens. Their shapes can very from long filaments to stout pincers.

Decomposer/Detritivore: An animal that feeds on dead plant and/or animal material and aids in the process of decomposition.

Elytra: The hardened chitin plates (actually modified wings) covering the abdomens of most beetles.

Exoskeleton: The hard, external support and protection structure of an arthropod's body.

Hemolymph: A liquid comparable to human blood that circulates throughout the arthropod body

Larva(e)/Nymph: The juvenile stage of many arthropods.

Mandible: One of an arthropod's many mouthparts, designed for cutting, biting, or holding food.

Modified: An anatomical feature altered by evolution to suit a new purpose.

Omnivore: An animal that consumes a wide variety of plant and animal foods.

Organic Matter: Dead remains of plants and animals. It serves as food for many soil organisms.

Parasite/Parasitic: Any organism that lives on or within another organism (host) and feeds on it, causing harm to the host.

Pest: An organism that competes with humans for resources, typically by damaging crops or structures.

Predator: An animal which feeds on other animals.

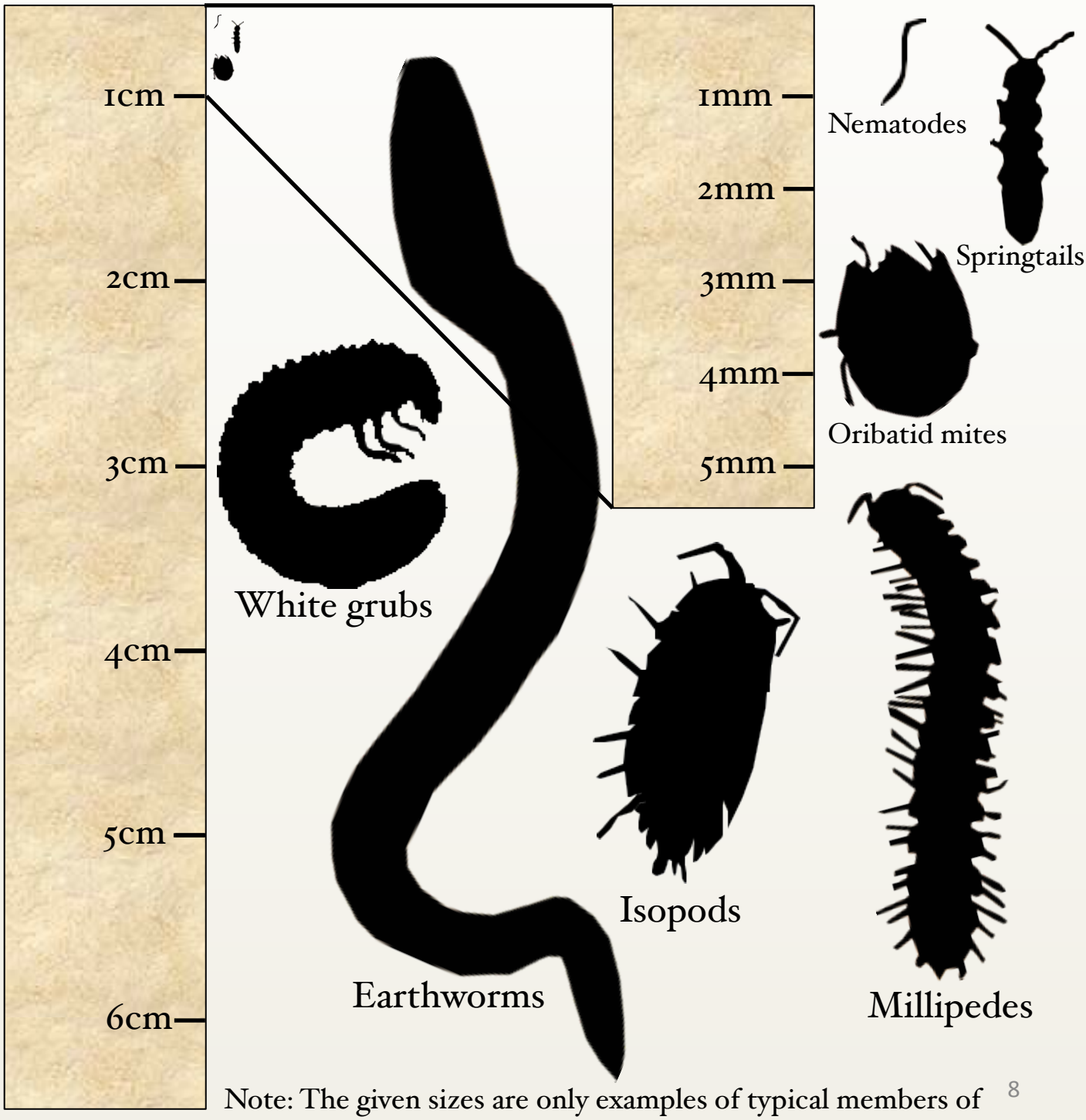
Thorax: The middle body section of an insect, behind the head and in front of the abdomen.

Guide to Taxonomic Terms

All organisms on Earth are classified based on their evolutionary relationship to other organisms. The science of defining and naming these classifications is called **taxonomy**. Taxonomists use eight increasingly specific levels of classification to distinguish between different organisms. At the broadest level, three **domains** of life are recognized; Bacteria, Archaea (single-celled organisms distinct from bacteria), and Eukarya (protozoa, plants, fungi, and animals). At the other extreme, individual species are given a **binomial** or **scientific name**, which always consists of a **genus** name followed by a **species** name (see table below).

Taxonomic Level	Gray wolf	Honey bee	Portobello mushroom	Plague bacterium
Domain	Eukarya	Eukarya	Eukarya	Bacteria
Kingdom	Animalia	Animalia	Fungi	Eubacteria
Phylum	Chordata	Arthropoda	Basidiomycota	Proteobacteria
Class	Mammalia	Insecta	Agaricomycetes	Gammaproteobacteria
Order	Carnivora	Hymenoptera	Agaricales	Enterobacteriales
Family	Canidae	Apidae	Agaricaceae	Yersiniaceae
Genus	*Canis*	*Apis*	*Agaricus*	*Yersinia*
Species	*Canis lupus*	*Apis mellifera*	*Agaricus bisporus*	*Yersinia pestis*

Soil Animal Size Chart



Note: The given sizes are only examples of typical members of each group. Many soil organisms vary tremendously in size.

Guide to Magnifiers

Many different tools and devices can provide the needed magnification to observe and identify small soil organisms.

Tool	Cost	Magnification	Portable?	Good for:
Magnifying glass 	Low	Low	Yes	Personal/ classroom use
Hand lens 	Low-Med	Low-Med	Yes	Personal/ classroom use
Desktop magnifier 	Low-Med	Low	No	Group viewing
Pocket microscope 	Low-Med	Med-High	Yes	Personal/ classroom use
Digital microscope 	Med-High	Med-High	No	Group viewing, presentation
Dissecting microscope 	High	Med-High	No	Personal/ classroom use

Quick Key to Major Soil Animal Groups

- Does it have legs?
  - No -> Worms (p32), some insects (p12), Mollusks (p37)
  - Yes, 6 -> Most insects (p12)
  - Yes, 8 -> Arachnids (p24)
  - Yes, more than 8 -> Myriapods (p29) or Woodlice (p31)
  - Too small to tell or count -> Likely non-insect arthropod (p22)
  - Yes, 4 -> Vertebrate, not in this guide!

Arthropods

Arthropods (phylum Arthropoda) are the most diverse group of animals on Earth, with over 1 million described species and 5-10 million species estimated to exist. They comprise 80% of all known animal species and inhabit all but the most inhospitable environments on Earth.

Groups of animals within Arthropoda include:

- **Hexopoda**: Insects and relatives
- **Chelicerata**: Arachnids (spiders, mites, etc.) and relatives
- **Myriapoda**: Millipedes, centipedes, and more
- **Crustacea**: Lobsters, crabs, woodlice, and more

Many arthropods, including many agricultural pests, spend at least part of their lives in soil. This guide will focus specifically on arthropods that live all or most of their lives in soil or on the soil surface.

Beetles
(Coleoptera)

The most diverse group of arthropods, beetles make up an estimated 20% of all plant and animal species on Earth!

- Rove beetles (Staphylinidae)

Size: Usually under 1.5cm long, though some species can be up to one inch.
Description: Rove beetles are slim, elongated, and dark-colored beetles. Their defining feature is that their **elytra**, instead of covering the entire **abdomen**, instead cover only a small part of the abdomen, leaving many segments visible. They cannot fly.
Ecology: Rove beetles are primarily **predators**, actively foraging for prey. They will eat any arthropod or invertebrate smaller than themselves, and will scavenge on carrion.

- Click beetles (Elateridae)

Size: Depending on species, adults can be less than an inch long or longer than two inches. Larvae have a similar size range.
Description: Click beetles are dark with an elliptical shape. Their name comes from the clicking sound they make when righting themselves from a fall onto their back. The yellow and orange click beetle **larvae** are also called wireworms.
Ecology: Adults eat plants. Larvae eat decaying vegetation and plant roots, occasionally becoming serious **pests** of cereals and vegetable crops.

Beetles
(Coleoptera)

Many beetles do not fly. The ones that do have to lift their hardened elytra out of the way of the functional wings beneath.

- Ground beetles (Carabidae)

Size: Varies by species, but generally 1-4 centimeters long.
Description: Ground beetles, as the name implies, are ground-dwelling beetles. They are most commonly shiny black in color, though some brightly colored and even iridescent species exist. A subfamily of ground beetles, known as tiger beetles, have a smoother and daintier appearance than other ground beetles, with long, spindly legs that allow them to run very fast. Tiger beetles in particular are often brightly colored and patterned. They are often found on beach sands and other bare, sunlit soils. **Larvae** are elongated with well-defined segments and large **mandibles**.
Ecology: Ground beetle adults and larvae are primarily **predators**, consuming springtails, mites, and other small invertebrates. Some species also feed occasionally on seeds.

Beetles
(Coleoptera)

Around the world, beetles are the most common insects prepared for human consumption.

- White grubs (Scarabaeidae)

Size: Varies by species and growth stage, but generally ranges from half a centimeter to over three centimeters in length.
Description: White grubs are the **larval** stages of scarab beetles. They are pale in color with a tan head and legs. When held in the hand, they will curl into a 'C' shape.
Ecology: White grubs eat a variety of plant-based foods, from rotting wood, leaf litter, and other **organic matter** to the roots of living plants. Some species can be serious **pests** of home lawns, golf courses, and other turfgrass areas. Adults are variable in appearance and feed on aboveground foliage, with some being pests of fruit trees, grapevines, and ornamental plants.

Hymenopterans

The order Hymenoptera includes ants, bees, wasps, and sawflies.

- Ants (Formicidae)

Size: Varies by species, but generally under one inch long. Some species are very small, only a couple of millimeters in length.

Description: Ants are some of the most recognizable soil animals. Despite considerable diversity in size and color, their general body form is constant. Key distinguishing features of ants include their elbowed **antennae** and thin "waist" between the **thorax** and **abdomen**. Ant larvae are small, white, and oval in shape.

Ecology: Ants display a wide array of habits and behaviors, though some generalities exist. Most ant species live in underground colonies of thousands or even millions of individuals, with sterile worker ants foraging for food and defending the colony while a queen produces eggs. They are rarely **pests** of crops, though they can be a nuisance either indoors through their presence and in turfgrass areas through making soil mounds. In addition, some species can deliver painful stings.

[1]Adult ants tending a mass of larvae.
[2]A small ant mound on a golf course putting green.

Hymenopterans

Hymenopterans' famous stingers are adapted from the females' egg-laying organ (ovipositor), which is why only female hymenopterans can sting.

- Ground-nesting bees

Size: Varies by species, but generally one inch long or less.
Description: Ground-nesting bees encompass a large number of familiar bee types. In fact, 70% of bee species nest in soil. These include bumble bees, sweat bees, miner bees, and numerous other social and solitary bee species. Their appearances are variable, but bees are generally recognizable by their triangular faces and often hairy bodies.
Ecology: Bee diets consist of pollen and nectar. While feeding, bees' hairy bodies become dusted with pollen, which allows them to transport pollen to other flowers of the same species and perform pollination. Many ground-nesting bees bring stores of pollen into their burrows to provide their **larvae** with food.

1

2

1. A ground-nesting bee larva with its store of pollen.
2. The entrance of a bee nest. Nests are typically dug in sandy soils.
All photos courtesy of Kristen Brochu.

Hymenopterans

In stinging hymenopterans, eggs are laid from the base of the ovipositor while venom exudes from the tip.

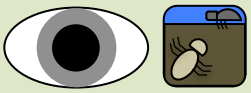
- Ground-nesting wasps

Size: Varies by species, but generally one and half inches long or less. Some species reach lengths of up to three inches.
Description: A wide variety of wasps make their nests in soil. Though they are highly variable in size, body shape, and color, wasps are generally recognizable and distinguishable from bees by their relative hairlessness.
Ecology: Wasps have diverse and varied diets. Adults are often **predators** of other arthropods, though many species also drink nectar and can end up performing some pollination. Wasp **larvae** dwelling in their underground burrows enjoy arthropod prey paralyzed and taken underground by their parents. Wasps are not crop **pests**, but their burrows can be a nuisance the wasps can be a safety hazard in parks, lawns, and sports fields due to their painful stings.

Orthopterans

The order Orthoptera includes familiar organisms such as grasshoppers and locusts.

- Camel crickets (Rhaphidophoridae)



Size: Generally between two and three inches long, with antennae included.
Description: Camel crickets are wingless, brown crickets often found in leaf litter or under rocks and logs. They have long **antennae** and a distinct "hump-backed" appearance.
Ecology: Camel crickets are **omnivores** that will eat a wide variety of foods, including smaller animals.

- Mole crickets (Gryllotalpidae)

Size: Generally between two and four inches long.
Description: Mole crickets are large and stocky crickets possessing thick forelegs adapted for digging.
Ecology: Mole crickets tunnel under the soil surface and eat a wide variety of foods, including dead **organic matter**, living plant roots, and live animal prey. They can be **pests** of turfgrass lawns and other crops.

Other

Some groups of insects have only limited representation in soil, or are less commonly encountered.

- Crane fly larvae (Diptera: Tipulidae)

Size: Varies by species and growth stage, but generally ranges from one centimeter to two inches in length.
Description: Crane fly **larvae** are gray-brown, leathery, legless insects. Adults resemble large mosquitos (but do not bite and are harmless to humans) with long, delicate legs and paddle-shaped wings.
Ecology: Most crane fly larvae feed on decaying **organic matter**, and are found in moist places such as under rotting logs or exposed stones in stream beds. Some species feed on living plant roots and can be **pests** of turfgrass lawns. Adults may feed on small amounts of nectar or else not feed at all before mating and dying.

1. A crane fly pupal case pokes up from the soil of a turfgrass lawn.

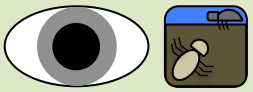
Other

Insects have been on Earth for almost 500 million years, though many major groups were not present until 150-300 million years ago.

- Termites (Isoptera)

Size: Varies by species and social caste. Commonly-encountered workers are generally close to one centimeter long.
Description: Commonly-found worker termites are small, pale insects with short **antennae** and large **mandibles**.
Ecology: Termites are **detritivores**, feeding on dead wood and other kinds of **organic matter**. Termites live in large colonies similar in social organization (though not identical) to those of ants.

- Earwigs (Dermaptera)



Size: Generally between half an inch and two inches in length.
Description: Earwigs are small insects similar to rove beetles (p10) except for the pair of pincer-like **cerci** at the tip of their abdomens.
Ecology: Earwigs are **omnivores**, consuming dead plant and animal matter, smaller invertebrates, and occasional live plant roots and leaves.

Other

Insects are arguably the most successful animal group on Earth, in terms of ubiquity and diversity.

- Root aphids (Hemiptera: Aphididae)

Size: One to three millimeters long.
Description: Root aphids look the same as their aboveground relatives, with small, plump, oval-shaped bodies and thin legs.
Ecology: Root aphids suck fluids from the roots of plants, and can be minor **pests** of many garden crops. Root aphids are sometimes herded and tended by ants, offered protection in exchange for sweet honeydew excreted from their abdomens.

- Bristletails (Archeognatha)

Size: Generally close to one inch long.
Description: Bristletails are small, elongated, wingless insects that live in leaf litter. They have long **antennae** and three filamentous **cerci** protruding from their abdomens. They are ancient insects, appearing almost without change from the way they looked 400 million years ago.
Ecology: Bristletails feed on decaying plant matter, mosses, and lichens.

Non-Insect Hexapods

Not all six-legged arthropods are insects.

- Diplurans (Diplura)

Size: Generally between five millimeters and one centimeter in length.
Description: Diplurans are elongated arthropods with long **antennae** for sensing the soil environment around them. Though they have six legs, they are not true insects. Some species have pincer-like **cerci** on the tips of their abdomens, similar in appearance to those of earwigs, which they can use to grab prey. More commonly encountered species have long, filamentous cerci instead (see images).
Ecology: Diplurans are primarily **predators** of mites, springtails, and other small arthropods, though some species also consume fungus and dead **organic matter**.

Non-Insect Hexapods

Non-insect hexapods lack the external mouthparts required for classification as insects.

- Springtails (Collembola)

Size: Generally between one and six millimeters long.
Description: Springtails are tiny, six-legged arthropods that live in soil and leaf litter. Their name comes from the lever-like appendage on their abdomen that springtails can extend against the ground to jump up to 6 inches into the air. Beyond these basics, their appearances are diverse, with great variation in body shape and color. In general, species that live on the soil surface or in leaf litter are more brightly colored and can jump higher compared to those living deep in the soil, which are paler and often cannot jump.
Ecology: Springtails are **omnivores**, eating fungus, dead plant material, and animals such as nematodes and even other springtails. Springtails sometimes feed on roots or leaves of crops, though damage is very rare. Conversely, some springtails prefer feeding on plant pathogenic fungi to feeding on other fungi, and thus may reduce infection of crops.

Arachnids

There are over 100,000 described arachnid species, with a total estimated diversity of 600,000 species.

- Spiders (Araneae)

Size: Highly variable between species. Many soil-dwelling species are less than five millimeters long, though others have legspans of up to three inches or even larger.

Description: Spiders are instantly recognizable to most people, unlike many other soil animals. They all possess similar two-sectioned bodies and eight long legs, though beyond that, color, size, hairiness, and many other details are highly variable between species.

Ecology: Spiders are **predators** with a wide variety of strategies for catching prey. Some, like wolf spiders, actively roam the soil or litter surface in search of prey, which others sit within a web or burrow and wait in ambush for prey. They consume a wide variety of small arthropods, and are thought to contribute to natural **pest** control in agricultural fields.

Arachnids

Many arachnids are venomous, but only a few are dangerous to humans.

- Pseudoscorpions (Pseudoscorpiones)

Size: Generally between two and eight millimeters long.
Description: Psuedoscorpions are small arachnids that live in soil and leaf litter, particularly soils rich in **organic matter**. Their name (literally "false scorpion") comes from their long, scorpion-like pincers, though they lack a stinging tail. Their bodies are usually reddish-brown or gray in color.
Ecology: Pseudoscorpions are **predators**, consuming a wide variety of small soil animals such as mites, springtails, and potworms. They grab prey with their pincers, which contain a venomous sting. They then suck the fluids from their prey. Pseudoscorpions can also inhabit libraries and archives, where they prey on barklice and other insects feeding on the binding of old books.

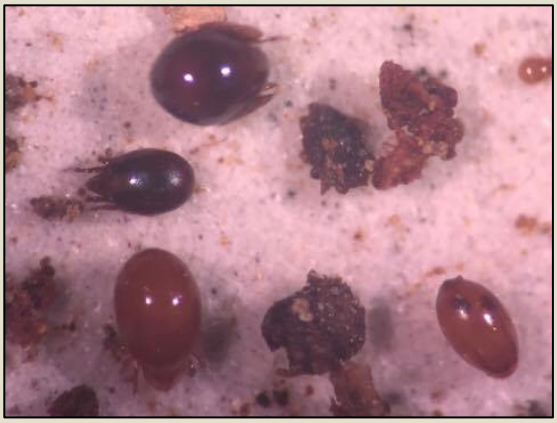
[1]Pseudoscorpion consuming a springtail (pale blob).

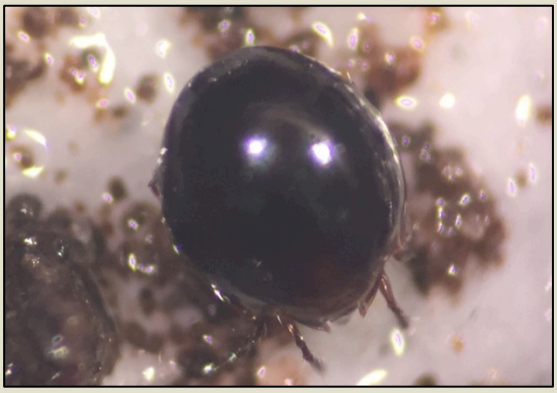
Mites

The most important soil arachnids are mites, not spiders.

- Oribatid mites (Oribatida)

Size: Varies by species, and ranges from microscopic in size up to one or two millimeters in length.
Description: Oribatid mites are characterized by a rounded, shiny **exoskeleton** that makes them resemble tiny, slow-moving beads. This exoskeleton acts as a hard, armored "shell" to defend against **predators**.
Ecology: Oribatid mites feed mainly on fungi and dead plant material, with some species preferring one or the other. However, many species will also feed on nematodes and occasionally on springtails when they can catch such prey. Oribatid mites live for a surprisingly long time; some species can take more than a year to develop from egg to adult.





Mites

Mites are actually composed of two distinct arachnid lineages bearing only distant relation to one another.

- Predatory mites (Mesostigmata and Prostigmata)

Size: Varies by species, and ranges from microscopic in size up to one or two millimeters in length.
Description: Predatory mites often resemble very small spiders, having eight long, skittering legs that are often visible from above (in contrast to oribatid mites, see previous page). Beyond that, color, body shape, and even leg length varies between different species.
Ecology: Predatory mites feed on a wide variety of arthropods and other invertebrates, including small insects, juvenile earthworms, nematodes, springtails, and other mites. Smaller species are primarily nematode feeders, while larger species are more generalist. Predatory mites impale their prey with a sharp, snout-like set of chelicerae and bathe it in saliva, liquefying the prey so that its tissues can be sucked up like a milkshake.

Mites

Newly hatched mites (larvae) have only six legs, obtaining another pair when the develop into the later-juvenile (nymph) stage.

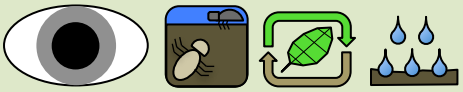
- Red velvet mites (Prostigmata: Trombidiidae)

Size: Most species range from one to three millimeters in length, though some tropical species can be up to half an inch long.
Description: Red velvet mites are particularly visible members of the mite community, often found in leaf litter and on bare surfaces such as rocks as well as manmade objects like grate covers, propane tanks, and concrete sidewalks. As the name suggests, they are bright red in color, with a tongue-shaped body and a noticeably fuzzy appearance.
Ecology: Red velvet mites' feeding habits differ based on life stage. Juvenile mites are **parasites** of larger arthropods such as grasshoppers, sucking the blood-like **hemolymph**. Adults are **predators** of insect eggs and other small arthropods. Their red color warns their own predators of their toxic nature and foul taste.

Myriapods

One of the largest terrestrial arthropods on Earth was the 300 million-year old millipede *Arthropleura*, which could grow up to 8 feet long!

- Millipedes (Diplopoda)



Size: Varies greatly by species. The smallest millipedes can be only a couple of millimeters long, while the largest is over a foot in length.

Description: Millipedes are long, thin arthropods with many (though not exactly 1000) legs. They are distinguished from centipedes by having two pairs of legs per body segment, whereas centipedes have one. Millipede legs are also held under the body and are not always easily visible from above.

Ecology: Millipedes are primarily **detritivores**, consuming dead plant matter. However, some species feed occasionally on living plants and even on other invertebrates. When threatened by **predators**, millipedes can coil up into a tight spiral, presenting only their armored plates to the predator. Many species also secrete foul-smelling or toxic chemicals. The secretions of some tropical species can cause burns and eye irritation in humans.

[1]Pincushion millipedes are very small, less than 2mm long. Their bristles can break off and entangle the limbs or mouthparts of attacking predators, immobilizing them.

Myriapods

The myriapod with the most legs is the inch-long Californian millipede *Illacme plenipes*, with one specimen possessing 750 legs.

- Centipedes (Chilopoda)

Size: Varies greatly between species. Most common species are between one and four centimeters long, though some can grow up to a foot in length.

Description: Centipedes are long, thin arthropods with many (though not exactly 100) legs. Centipedes have pincer-like "fangs" (actually **modified** legs with a venomous sting) growing from the first body segment behind the head. They are distinguished from millipedes by having one pair of legs per body segment, whereas millipedes have two. Centipede legs are also held out to the sides and are easily visible from above. Their bodies also tend to be more flattened than those of millipedes, though this is not always the case.

Ecology: Centipedes are voracious **predators**, actively pursuing and consuming smaller animals. However, they occasionally eat plant litter, and are also known to scavenge on carrion.

Isopods

Some deep-sea isopods can grow as long as 50cm. Like their terrestrial cousins, they are primarily decomposers, though of animal remains instead of plants.

- Woodlice (Oniscidea)

Size: Generally between one and two centimeters long.
Description: Woodlice are stout, flattened arthropods covered with dark brown and/or gray plates. They have seven pairs of legs. Some species, commonly called “pill bugs” or “roly-polys” can curl themselves up into a ball when threatened. They are often found under rocks and rotting logs.
Ecology: Woodlice are **detritivores**, with strong **mandibles** for cutting up plant litter, and are major influences on decomposition and nutrient cycling in soils where they are abundant. Although they also feed on roots and leaves of some plant seedlings, they are not considered **pests**.

Worms

'Worm' is a common name that refers to organisms from many groups, sometimes ones only distantly related to one another. In general, worms are long, thin, legless invertebrates inhabiting soil or water or parasitizing other organisms.

Of major animal groups referred to as worms, the phyla Annelida and Nematoda contain many soil animals. These two groups of soil-dwelling "worms" play an enormous variety of roles in soil ecosystems and are among the most important soil animals. A third phylum, the Platyhelminthes or flatworms, consists mainly of parasitic and aquatic worms, but some soil-dwelling groups exist.

Oligochaetes

Oligochaete worm species range from less than 0.5mm long to almost 10 feet.

- Earthworms (Megadrilacea)

Size: Highly variable by species. Commonly between one and six inches long, though can be smaller or far larger.

Description: Earthworms are among the most recognizable soil animals, with long, segmented bodies colored red, brown, or gray. Adult earthworms have a thickened ring near their head end, which contains their reproductive organs. Earthworm egg sacs (cocoons) resemble small, turgid sacs of fluid.

Ecology: Earthworms primarily feed on dead plant matter, but consume soil, microbes, and smaller animals in the process. Undigested material is sometimes deposited on the soil surface as globular castings. Earthworms are major **decomposers** and have large effects on nutrient availability and soil structure (through their burrowing and tunneling activities).

[1]Earthworm cocoon, roughly 3mm in diameter.
[2]Earthworm casts on the soil surface.

Oligochaetes

Oligochaete worm species range from less than 0.5mm long to almost 10 feet.

- Potworms (Enchytraeidae)

Size: Generally between one and two centimeters long.
Description: Potworms resemble earthworms, but are smaller and paler in color. Potworms are more tolerant of acidic soil conditions than earthworms are, and thus are more common in acidic soils such as those of coniferous forests and peat bogs. They are also found in compost bins alongside earthworms, and in many other soils.
Ecology: Potworms feed on decaying plant matter to get at the fungi and bacteria present on it, which are their primary source of nutrition. Some potworm species can reproduce by breaking into several pieces, each of which regrows into a new worm.

Nematodes

"If all the matter in the universe except the nematodes were swept away, our world would still be dimly recognizable... we would find its mountains, hills, valleys, rivers, lakes and oceans represented by a film of nematodes." – Nematologist Nathan Cobb, 1914

- Nematodes (Nematoda)

Size: Microscopic, usually less than one millimeter in length. A few species grow larger, up to roughly five millimeters long.
Description: Nematodes are minute, unpigmented roundworms that inhabit soils from the Amazon to the Antarctic. Nematodes are only rarely visible with the naked eye and even with a magnifying glass can be hard to distinguish from the soil. However, certain types (discussed below) leave visible signs of their presence.
Ecology: Nematodes are a diverse group with diverse lifestyles. Some graze on soil bacteria and fungi, some **parasitize** plant roots, some prey on other nematodes, and others are **omnivores**. Plant-parasitic nematodes are common **pests** of a wide variety of crops, leaving unnatural growths and deformations in the roots and reducing yield. Some species parasitize and kill insects, including pests. Insects infected with these nematodes become discolored as well as limp and squishy to the touch.

[1]Nematode under high magnification.
[2]Nematode-infected caterpillars. Note discoloration and limp, deflated appearance.
[3]Insect-pathogenic nematodes emerging from a host.

Flatworms

Flatworms are famous for their ability to regenerate their bodies after an injury. They can even grow whole new heads!

- Land planarians (Geoplanidae)

Size: Highly variable, ranging from a few millimeters to about three feet in length.
Description: Land planarians can be wide and flat or long and thin, brightly colored or drab. Some species can be confused for earthworms at first glance. However, they lack the segmented body of an earthworm. Their head is distinguishable by a flattened flange at one end.
Ecology: Land planarians are carnivores. Some species primarily scavenge on carrion, but most are active predators of arthropods, earthworms, gastropods, and other invertebrates. Despite the wide prey range of the group as a whole, individual species are sometimes specialists on particular types of prey. Planarians actively hunt for prey, following chemical signals or even mucus trails from snails and slugs to locate them. They will then subdue their prey by either immobilizing them in sticky mucus or entangling them in their body like a boa constrictor. The planarian then secretes digestive enzymes to dissolve the prey's tissues, which it sucks up as a grisly soup.

Mollusks

Mollusks (phylum Mollusca) are a large group of primarily marine invertebrates. They are highly diverse in body form and general appearance, as the phylum includes organisms from bivalves (mussels, clams, scallops, and others) to cephalopods (squids, octopi, cuttlefish, and others).

The class Gastropoda contains the only soil-dwelling mollusks, commonly known as slugs and land snails. Despite this, the majority of gastropods are still freshwater or marine animals, including such familiar organisms as conchs, abalone, and limpets.

Gastropods

Some slugs actually possess shells. However, these shells are both too small for the slug to retract into and are usually concealed within the flesh.

- Slugs

Size: Highly variable between species, ranging from less than one centimeter to several inches in length.
Description: Slugs are long, stout, fleshy animals that live in moist soil and litter. They are typically pale gray or brown in color, though some, such as the leopard slug (top right) are intricately patterned.
Ecology: A slug's diet includes plant matter (dead or alive), fungus, and carrion. A few species are **predators**. They can be **pests** of seedlings and leafy plants in gardens.

- Snails

Size: Variable between species, ranging from one centimeter to several inches in length.
Description: Snails resemble slugs with a coiled shell on their back (the shell contains internal organs and *is* attached to the body).
Ecology: Snail diets are similar to those of slugs, consisting of plant material and occasional carrion or other animals. Like slugs, they can be **pests** of garden plants.

How to Find Soil Animals

There are many ways to find out what soil animals are living near your home or school.

Pitfall trap
Materials needed: Plastic cups, dish soap
Instructions: Dig a hole the size and shape of a plastic cup and place the cup inside. Make sure the rim of the cup is even with the soil surface. Pour about an inch of soapy water into the cup and watch it periodically for animals that fall in. You can also place a folded piece of cardboard tent-like above each trap to keep the cups from flooding during rain.
Commonly found: Beetles, spiders, springtails, ants, isopods, crickets, slugs

Cardboard trap
Material needed: Large piece of cardboard
Instructions: Wet the cardboard and place it flat on the soil surface, ideally in a cool, shaded place such as in a stand of trees or in the shade of a building. Return 1-2 days later and lift the cardboard to see animals that have taken shelter under it and on its underside.
Commonly found: Woodlice, millipedes, centipedes, beetles, earthworms, slugs

How to Find Soil Animals

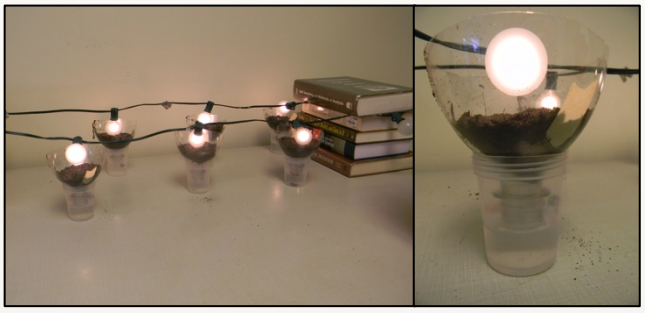
Tullgren funnel

Materials needed: Funnel, stand, desk/workshop lamp (ideally with an incandescent bulb), tape, 1-3mm mesh (e.g. window screen), small container (with mouth larger than the funnel opening).

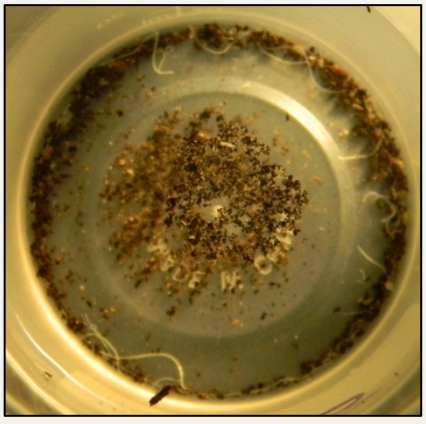
Instructions: Secure the mesh in the bottom of the funnel with tape and place the funnel in the stand (shown on the right as a one liter plastic cup) with the container below. Put about one cup of soil or litter into the funnel (or however much fits into the funnel) and suspend the light above it. Turn on the light. The heat from the bulb drives animals down into the collection container, which is filled with water to allow live viewing of the animals within using a magnifying glass or (better yet) microscope. Scientists fill the collection cups with ethyl alcohol to preserve the extracted specimens, but viewing them alive is much more fun!

Commonly found: Arthropods and non-nematode worms

Single Tullgren funnel.



Multi-funnel array made from cut-off tops of 2-liter soda bottles and string lights.



Tullgren funnel collection cup, with a raft of mites and springtails floating on the surface and several potworms visible below.

Keeping Soil Animals as Pets

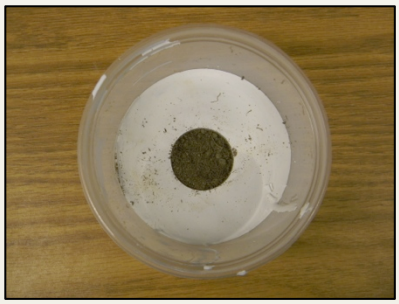
Many soil animals can be kept in captivity for personal enjoyment or as a teaching tool. Here are some general directions and care guidelines for keeping them healthy and happy in captivity. Bear in mind that more specific research should be conducted before bringing a soil animal inside, especially with larger animals that often require more specific and intensive care practices.

Step 1A: The Container (large animals, e.g. slugs, woodlice, millipedes)

The ideal home is a plastic or glass terrarium, at least 8 inches in length or three times the body length of the largest animal within. Cover the bottom with a few centimeters of potting mix, topsoil, peat moss, or a similar substrate. Then place rocks, sticks, pieces of rotting wood, and other debris to add structure to the habitat.

Step 1B: The Container (small animals, e.g. springtails, mites, pseudoscorpions)

- Pour one to two centimeters of Plaster of Paris into the bottom of a small plastic container such as a deli cup or food storage container (the plaster retains moisture and prevents static electricity buildup).
- Place a smaller cup or other cylindrical object partway into the center of the wet plaster to make a depression, which you can fill with soil or potting mix when the plaster dries to create a small shelter for the animals.
- Containers should be escape-proof. Many small soil animals can climb walls and even walk upside-down on ceilings. Tight-fitting lids and fine fabric or mesh covering all air holes are a must.

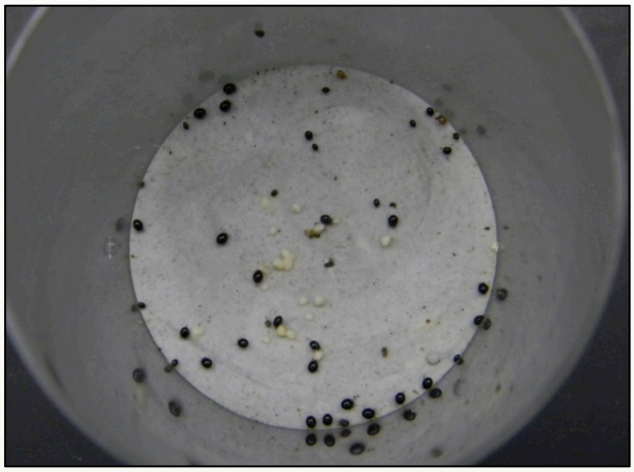


Keeping Soil Animals as Pets

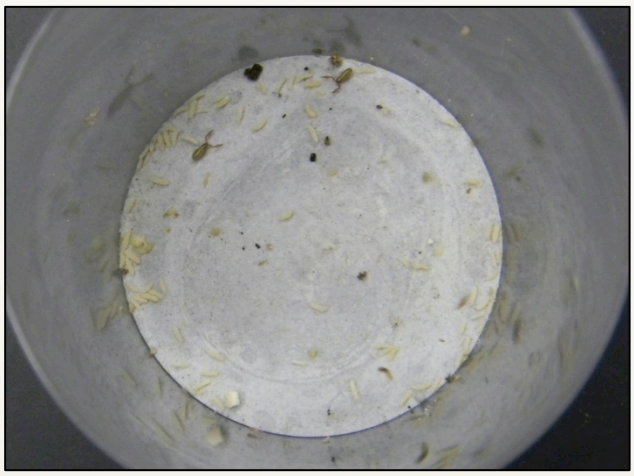
Step 2: The Food

Soil animals are generally not picky eaters. Being willing and able to eat anything they find helps them survive in an environment where specific foods can be hard to come by.

- Small fungus-eating or decomposer animals, such as springtails and mites, can be fed by sprinkling pellets of baker's yeast (5-25 pellets every other day, depending on population size) onto the plaster of their container.
- Larger plant eaters, such as slugs, millipedes, and woodlice, regardless of whether they normally consume live or dead plant material, can be fed fresh produce such as green leaf lettuce or apple slices. Feed them as needed, whenever the supply in their cage gets low.
- Predatory animals obviously require live animal prey, which makes them hardest to keep as pets. However, prey animals such as springtails can be raised in the same or a separate container as their predator.



Yeast feeding oribatid mites (black dots)



Yeast feeding springtails feeding pseudoscorpions

Keeping Soil Animals as Pets

Step 3: The Conditions

To keep soil animals healthy and happy, follow these guidelines.

- Keep the container moist but not wet. A spray bottle is ideal for providing a light mist every day or two. In a plaster container, a good trick is to squirt a few drops on the plaster and watch how quickly the water is absorbed. If it is absorbed quickly, add more until the rate of absorption slows down. Do not let standing water accumulate.
- Remove and dispose of any large pieces of organic matter (old food, structural objects, dead animals) that show signs of mold growth.
- Keep the containers in a shaded environment with a constant temperature.
- Be prepared to move animals to a new container if mold growth gets out of hand or animals start dying. If possible, make extra containers to keep handy at all times.

How to Conserve Soil Animals

Here are some ways to conserve soil animals around your home, to ensure they and their many benefits stick around.

1) Avoid excessive use of chemical insecticides to control lawn and garden pests. Use cultural, physical, or biological control methods when possible.
2) Don't bag and throw away all the dead leaves from your yard in the fall. If possible, leave some or all of them where they fall. Leaf litter provides both food and winter shelter for many soil animals.
3) Compost! The organic-matter-rich mulch produced by composting provides an excellent food source for many soil animals as well as nutrients for your lawn or garden.
4) Control soil compaction and erosion by planting grasses or shrubs over patches of bare soil. The plants will also provide food for soil animals.

Additional Resources

Diagnosing and Managing Soil Pests

Cornell Cooperative Extension (http://cce.cornell.edu/)

New York State IPM Program (http://nysipm.cornell.edu/)

General Arthropod ID

BugGuide (http://bugguide.net)

Overview of Insect Orders (http://bugguide.net/node/view/222292)

Educational Resources

Checklist of the Collembola (http://collembola.org)

Soil Arthropod Ecology Lab Educational Resources (http://blogs.cornell.edu/wickings/soil-ecology-resources-2/)

About this Book

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