I am proud to present our third NRCS planner, which is designed as an educational tool and as a means to provide a year-long agenda of important natural resource-related meetings and events. The previous planners emphasized the diversity of the nation's soil.

In this planner we introduce an aspect of soil that too often is overlooked—soil biology. The delicate balance of soil biology can be seriously impacted by our choices of soil amendments, grazing patterns, tillage systems, crop rotations, and other practices. We know that many conservation practices are beneficial, in part because they improve the function of the soil biological community. We have far to go, however, before we really comprehend the biological processes that are happening beneath our feet. By introducing the soil food web in this planner, we hope to give you a brief insight into the exciting interactions of a few of those fascinating processes.

Maintaining a healthy and diverse soil biology is vital to achieving our conservation objectives. We must understand and appreciate soil biology in order to optimally manage and conserve our natural resources.

To learn more about soil, contact your local Natural Resources Conservation Service Office, which is listed in the telephone book under U.S. Government, Department of Agriculture, or visit the following Web sites:

Natural Resources Conservation Service: http://www.nrcs.usda.gov
Soil Quality Institute: http://www.statlab.iastate.edu/survey/SQI/

Pearlie S. Reed
Chief
National Resources Conservation Service
The Soil Science Society of America is delighted to share in the publication of this 2001 NRCS planning guide. In this Planner we are greeted from time to time by NRCS's S.K. Worm; we see amazing images of life in soil; and we learn many startling facts about soil ecosystems in diverse habitats. There is exciting educational value in this Planner.

Please enjoy using the 2001 planner; we trust that you will find it helpful throughout the year. Also, please share the images and information with others. Many of our colleagues, family and friends will enjoy seeing and learning about the wonderful life in soil presented to us. In particular, we need to capture the imagination of the up-and-coming generation with the rich diversity of life in soil that contributes so abundantly to our lives. Perhaps this planner will lead some young persons into soils-related careers. Our lives will be enriched, as we all gain understanding and respect for soil and its life-sustaining marvels.

The Soil Science Society of America is a member-run organization that promotes research and education on all aspects of soils. We sponsor an informative Internet Web site at http://www.soils.org, and we encourage you to explore the broad range of our scientific and professional activities.

With all good wishes for a bountiful 2001,

Robert J. Luxmoore
President, Soil Science Society of America

Meet S.K. Worm, the official earthworm of the Natural Resources Conservation Service (NRCS). S.K. Worm is the host of a children's soil page on the NRCS Web site (www.nrcs.usda.gov) and will share some important soil biology facts in this planner.
Our lives depend on the minuscule creatures living in the soil beneath our feet. These creatures help to purify air and water, decompose plant residues and pollutants, cycle nutrients so crops and other plants can grow, prevent outbreaks of disease caused by pests, and help to create soil structure so water can be absorbed, pass through, and flow over the soil. In the coming months you will meet some of the organisms responsible for these functions. The world underground is an intriguing frontier of bizarre organisms and complex interactions. How well these organisms perform important functions is affected by how we manage the land.

A “food web” is not just the above-ground linkages among plants, animals that eat plants, animals that eat plant-eaters, and so on. In fact, animals do not eat most of the plant matter in the world. Decomposers in the soil consume most plant matter. The diagram of a “soil food web” represents this underground portion of a food web. The arrows represent the flow of energy and nutrients as one organism consumes another. Many important functions of the soil food web, such as nutrient cycling, pesticide decomposition, enhancement of soil structure, and pest control, are not the result of individual species but of the interaction of many species in the food web.

**Carbon in the Soil**

The carbon cycle illustrates the role the soil food web plays in cycling nutrients through the environment. Through photosynthesis, plants convert atmospheric carbon dioxide (CO₂) into plant matter made of organic carbon compounds, such as carbohydrates, proteins, oils, and fibers. The organic compounds enter the soil system when plants and animals die and leave their residue in or on the soil. Immediately, soil organisms begin consuming the organic matter, extracting energy and nutrients and releasing water, heat, and CO₂ back to the atmosphere. (See the account in August about decomposition.) Thus, some of the principal components of organic matter are changed into volatile compounds and are removed from the soil. A natural consequence of decay is a gradual disappearance of soil organic matter if it is not replenished with frequent additions of fresh residue. If residue is added to the soil at a faster rate than soil organisms can convert it to CO₂, carbon will gradually be removed from the atmosphere and stored (sequestered) in the soil. Cultivation aerates the soil, triggering increased biological activity, rapid decomposition, loss of soil organic matter, and the release of CO₂ into the atmosphere. Most soil carbon losses occur in the first several years after cultivation begins, as took place in many U.S. soils in the 1800’s. Farmers and other conservationists are interested in reversing that effect and increasing the amount of carbon stored in the soil. In general, reducing tillage can increase the extent of carbon sequestration and the amount of organic matter retained in the soil. Soil organisms can play a central role in this effort to adjust the balance of global carbon cycles.

Another form of carbon sequestration. Fungal filaments (cf) encased in calcite crystals (CaCO₃) are common in arid and semiarid soils. This important repository of atmospheric CO₂ stores carbon released through root respiration. Calcite forms in soil as a result of both chemical processes and biological processes driven by fungi. Scientists are just beginning to learn about the fungal-driven processes.
**ARTHROPODS**
Invertebrate animals with jointed legs. They include insects, crustaceans, sowbugs, arachnids (spiders), and others.

**BACTERIA**
Microscopic, single-celled organisms that are mostly non-photosynthetic. They include the photosynthetic cyanobacteria (formerly called blue-green algae), and actinomycetes (filamentous bacteria that give healthy soil its characteristic smell).

**FUNGI**
Multi-celled, non-photosynthetic organisms that are neither plants nor animals. Fungal cells form long chains called hyphae and may form fruiting bodies such as mold or mushrooms to disperse spores. Some fungi, such as yeast, are single-celled. Saprophytic fungi decompose dead organic matter. Mycorrhizal fungi form associations with plant roots. These fungi get energy from the plant and help supply nutrients to the plant.

**GRAZERS**
Organisms such as protozoa, nematodes, and microarthropods that feed on bacteria and fungi.

**MICROBES**
An imprecise term referring to any microscopic organism. Generally, "microbes" includes bacteria, fungi, and sometimes protozoa.

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**MUTUALISTS**
Two organisms living in an association that is beneficial to both, such as the association of roots with mycorrhizal fungi or with nitrogen-fixing bacteria.

**NEMATODES**
Tiny, usually microscopic, unsegmented worms. Most live free in the soil. Some are parasites of animals or plants.

**PROTOZOA**
Tiny, single-celled animals, including amoebas, ciliates, and flagellates.
Bacteria are among the tiniest and most numerous living organisms of the soil community. Together with fungi they decompose dead organic matter and convert it to nutrients that plants can use, a process called mineralization. The metabolic diversity of bacteria as a group, however, far outstrips that of any other organism on the planet. Bacteria can be found eking out a living on exposed rock surfaces, hundreds of feet below the ground, in desert varnish, in Antarctic snow, and in other harsh environments. Bacterial activity explodes when rain falls in dry regions or when a farmer tills the soil. Tillage stimulates bacterial activity by aerating the soil and bringing plant residue in contact with the soil and bacteria. Organic matter decomposes rapidly after tillage, releasing nutrients into the soil and CO₂ into the atmosphere. This release of nutrients explains why newly broken-out sod was so productive for early settlers and why reducing tillage is one of the quickest ways to build up soil organic matter.

1. Compare the size of microorganisms to the root hair rising up in the middle of this photo. The thin strands are fungi dotted with bacteria.

2. Bacteria congregate in the rhizosphere—the space near roots where bacteria feed on the large amounts of dead root cells and exudates. Some plants release substances that attract specific bacteria. The bacteria release substances that improve plant growth or protect the plant from pests. This photo shows dead cells and exudates released from a corn root.

3a-3b. On this Georgia farm a no-tillage rotation of wheat, cotton, and corn reduces the spurts of bacterial activity that break down organic matter. Organic matter levels have visibly built up in just a few years.

4. Like bacteria, actinomycetes have simple cells made up of the same general components, but, like many fungi, actinomycetes grow in thin hyphal strands. Actinomycetes may account for as much living biomass in the soil as other bacteria. They are important in decomposition—especially in alkaline soils. They give soil its characteristic "earthy" smell most noticeable after rainfall.
### Events

**3-5**
21st International Soil Erosion Research Conference
Honolulu, HI
http://asae.org

**3-5**
2nd International Preferential Flow Symposium
Honolulu, HI
http://asae.org

**5-18**
Conference on Tailings and Mine Waste
Fort Collins, CO
lhinshaw@engr.colostate.edu

### Soil Facts

- One cup of soil may hold as many bacteria as there are people on Earth.
- Actinomycin, neomycin, and streptomycin are examples of familiar antibiotic drugs produced by soil actinomycetes when grown in laboratory cultures.
- Bacteria help protect environmental quality by degrading compounds that would otherwise become pollutants.

Pull up a plant and carefully shake the soil off the roots. See how much soil is still attached? That is the rhizosphere - the narrow region of soil right next to roots. A large portion of microbes live here.

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### January 2001 Calendar

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The Mycorrhizal Bargain

Certain fungi and most of the higher plants have evolved together to form a symbiotic association called mycorrhizae. Here's how it works: Fungi easily extract nutrients from the soil. On the other hand, photosynthesizing plants easily get energy from the sun and carbon from CO₂. Fungi and the higher plants combine their advantages when mycorrhizal fungi invade roots and grow into the soil. This process can be thought of as expanding the root network of the plant. The fungi transfer nutrients and water back to the plant and, in return, receive carbon and energy from the plant.

Many trees, agricultural crops, shrubs, and grasses need mycorrhizal fungi to take up the phosphorus and other nutrients for vigorous growth. Practices that enhance mycorrhizal fungi populations include minimizing tillage; ensuring that applications of phosphorus fertilizers are not excessive; minimizing fallow periods, when there are no plants to host the fungi; and planting cover crops.
### EVENTS

**Black History Month**

4-8

National Association of Conservation Districts Annual Meeting
Ft. Worth, TX
www.nacdnet.org

15-20

American Association for the Advancement of Science
www.aaas.org

17-23

Society for Range Management Annual Meeting
Kailua-Kona, HI
www.casrm.org/Hawaii.shtml

### SOIL FACTS

- A teaspoon of farm soil may contain tens of yards of fungi. The same amount of soil from a coniferous forest may hold tens of miles of fungi.

- It was from a soil fungus, a *Penicillium* species, that the first modern antibiotic drug, penicillin, was obtained.

- Many antibiotics now on the market for the treatment of human and animal diseases are produced by organisms found in soil.

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**Did you ever notice a lot of mushrooms growing on a lawn where a tree once stood? Many fungi, including those that make mushrooms, thrive by decomposing wood.**
Protozoa are a group of one-celled creatures with a cell physiology similar to that of animals. Many protozoa eat bacteria, so they are common near roots and other places where bacteria congregate. Typically, when bacterial populations increase, such as right after tillage or rainfall, protozoa populations also increase.

Protozoa have lower nitrogen requirements than most bacteria. After consuming bacteria, protozoa excrete much of the excess nitrogen as inorganic nitrogen (ammonium). All soil organisms mineralize nutrients, especially bacteria and fungi, but protozoa and nematodes are important in enhancing mineralization in soil by releasing the nitrogen taken up by microorganisms.

1. Ciliates, the largest type of protozoa, eat smaller protozoa. They move by waving the hairlike cilia covering their surface.

2. Flagellates use a few whiplike flagella to move. They are the smallest of the soil protozoa. The third group of protozoa are the amoebas, which move and engulf prey by extending part of their cells and then following with the rest of the cell contents.

3. Forests and coarse-textured soils generally contain more of the large protozoa, such as ciliates, whereas agricultural land and fine-textured soil generally contain more of the small protozoa, such as flagellates. (Photo shows contour plantings of cabbage and “apio” root celery in Corozal, Puerto Rico.)
EVENTS

Women's History Month

11-14
9th National Symposium on Individual and Small Community Sewage Systems
Fort Worth, TX
WWW.asae.org

12-15
Riparian Habitat and Floodplains Conference
Sacramento, CA
WWW.tws-west.org/riparian/

22-25
National Science Teachers Association
St. Louis, MO
WWW.nsta.org

25-29
7th Federal Interagency Sedimentation Conference
Reno, NV
WWW.water.usgs.gov/wicp/Sedimentation_ann.html

SOIL FACTS

- The weight of all the bacteria in one acre of soil can equal the weight of a cow or two.
- Bacteria and actinomycetes make up half the mass of living organisms in some soils.
- Some bacteria can use very complex organic materials, such as lignin and pollutants, to support their growth, and they are important in degrading pollutants and improving environmental quality.
- Many bacteria eat organic (carbon-containing) matter. Some species get their energy from nitrogen, sulfur, iron, manganese, or hydrogen.
Nematodes are incredibly diverse. Twenty thousand species have been described, but half a million may exist. Those few species that attack roots and cause plant diseases have been studied extensively. Most soil nematodes are beneficial. Soil nematodes eat bacteria, fungi, protozoa, and other nematodes. A few predatory species can be purchased and applied to soil to control some crop diseases. Like protozoa, nematodes are an important part of the food web because they release plant-available nutrients into the soil. Soil compaction generally reduces the populations of nematodes, which need adequate space between soil aggregates to move around. The larger predatory nematodes are most sensitive to compaction. Root-feeding nematodes seem least affected by compaction—perhaps because they do not need to move around to feed.
**SOIL FACT**

Nematodes may be useful indicators of soil health because they are diverse and perform many functions. Soil health might be assessed by comparing the proportion of nematodes in different functional groups.

Nematodes are often called roundworms. Physiologically, they are much simpler than earthworms and do not have segments.
Arthropods are a diverse group of bizarrely shaped mites, millipedes, beetles, spiders, and other creatures. Many arthropods prey on disease-causing pests. Others help to shape soil structure and thus can improve root development, water intake, drainage, and aeration. Some arthropods are the front line in decomposition and facilitate microbial activity. They shred plant residue, mix it with microbes and soil, and stimulate decomposition within their intestines.

Arthropods are important everywhere, but they are especially numerous in forests, in pastures, in no-till cropland, and in other areas where the soil is minimally disturbed and covered all year. They cannot easily withstand soil compaction.

1. This oribatid mite feeds on fungi and algae and helps to decompose organic matter. Its fancy bristles usually lie flat but become erect (as in the photo) when touched.

2. The dozens of species of mites and other arthropods in this microscopic view were extracted from one square meter of forest litter and soil in Alabama.

3. Complex landscapes with a variety of vegetation support a wide variety of arthropods.

4. The eyes of this 1/8-inch-long predatory spider are on the tip of the projection above the spider’s head.

5. Normally, the tail of a springtail is tucked under its belly. When threatened, the springtail slams its tail on the ground, springs in the air, and lands as much as a yard away. Springtails are the most abundant arthropods in many agricultural and range soils.
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<td>Every time you take a step in a mature Oregon forest, your foot is being supported on the backs of 16,000 invertebrates held up by an average total of 120,000 legs. Even in agricultural soils, a thousand arthropod legs may support your every step.</td>
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See what lives in your soil! Sink a pint-sized cup into the soil so the rim is level with the soil surface. Check it once or twice every day for a week to see what falls in.
Earthworms are the original tillers of soil and the most charismatic of the soil organisms. Like many burrowing arthropods, they can improve the rooting environment for plants and increase the amount of water that soaks into the soil and is held there. Earthworms create burrows that speed the movement of water into and through the soil and provide channels for root growth. They mix soil and organic matter, leave casts in and on the soil to become aggregates, and encourage decomposition by micro-organisms.

Earthworms are native to the United States, but many species have been introduced from other countries. Most prefer well-aerated, moist soil and are uncommon in the arid West. They are more common where surface residue provides protection from desiccation and predation and provide food.

1. Earthworm in burrow.
2. A night crawler pulled a corn leaf into its burrow.
3. Cross sections of an Eisenia fetida cocoon.
4. Earthworm cocoons.
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To learn more about earthworms:
http://res.agr.ca/lond/pmrc/faq/earthworm.html
http://solum.soils.umn.edu/research/ars/mn_worm.htm

Charles Darwin first made my predecessors famous in 1881 when he published “The formation of vegetable mould [top soil] through the action of worms with observations on their habits.”
In ecosystems throughout the world, soil organisms create living crusts on the soil surface by binding soil particles with organic materials. These “microbiotic crusts” have been studied particularly in arid and semiarid regions. Most are a mixture of cyanobacteria, algae, lichens, mosses, liverworts, and fungi. Some, however, are primarily just cyanobacteria and algae or lichens and mosses. From region to region, the general appearance of crusts varies in color, surface topography, and the amount of the soil surface covered. Microbiotic crusts help to stabilize the soil, protect the soil from erosion, affect runoff and water infiltration, and increase the amount of nitrogen and phosphorus available to plants. Cyanobacteria and green algae swell when wet, migrate out of their sheaths, and exude new sheath material.
EVENTS
8–13
3rd International Conference on Mycorrhizas
Adelaide, South Australia
www.waite.adelaide.edu.au/Soil_Science/3icom

15–21
International Turfgrass Research Conference
Toronto, Ontario
www.uoguelph.ca/GTI/ITRC2001

23–Aug 1
National Boy Scout Jamboree
Ft. A.P. Hill, VA
www.bsa.scouting.org

24–29
Envirothon
Raymond, MS
www.envirothon.org/2001comp.htm

29–August 2
International Conference on the Biogeochemistry of Trace Elements
Guelph, Ontario
icobte.crle.uoguelph.ca

SOIL FACT
- Biological crusts function differently from chemical and physical crusts, such as salt crusts and platy surface crusts.

ACTIVITY
In an arid environment, look for biological crusts. When the soil is wet, crusts are rubbery and flexible. When dry, they are often brittle. Lift up an inch-thick layer of soil and look for many fine filaments that dangle in the wind. These are cyanobacterial sheaths.
Decomposition by soil organisms is at the center of the transformation and cycling of nutrients through the environment. Decomposition liberates carbon and nutrients from the complex material making up life forms—putting them back into biological circulation so they are available to plants and other organisms. Decomposition also degrades compounds in soil that would be pollutants if they entered ground or surface water. Decomposition is a stepwise process involving virtually all soil organisms. Arthropods and earthworms chew the material and mix it with soil. A few fungi may break apart one complex chemical compound into its simpler components, then bacteria can attack and transform the newly created compounds, and so on. Each organism gets energy or nutrients from the process. Usually, but not always, compounds become simpler after each step. The portion of plant and animal residue that is not broken down plays a crucial role in soil. It is transformed into the highly complex organic compounds called humic substances that can persist in soil for centuries and are essential for soil structure and good drainage.
SOIL FACTS

- Modern farming practices that reduce the amount of tillage and return plant residues to the soil are slowly rebuilding the nation's stock of soil organic matter.

- Of the carbon returned to the soil as plant residue, about 5 to 15 percent becomes tied up in the bodies of organisms, and 60-75 percent is respired as CO₂ back to the atmosphere. Only 10 to 25 percent is converted to humus in the soil.
Soil is a maze of pores and channels formed within and among aggregates of soil particles. The intricate pore structure creates habitat for soil organisms, storage chambers for the air and water plants need, and channels for draining and filtering water. Stable structure at the soil surface improves water movement into the soil and protects the soil from erosion.

Soil organisms help to build and stabilize soil structure. Earthworms and burrowing arthropods create large pores and channels that allow water to flow effectively into and through the soil. Arthropods excrete fecal pellets that become aggregates. The hyphae of fungi and actinomycetes hold together small soil particles in aggregates. Bacteria and fungi excrete sticky substances that help to stabilize soil aggregates.

One way to improve soil structure is to maintain plant residue at the soil surface. The residue helps to prevent erosion, in part because it supports the life of the soil organisms that stabilize the soil.

1 and 2 Fungal hyphae grow around soil aggregates and help to hold them together.

3. A laboratory procedure reveals glomalin as the green material on soil aggregates. Glomalin is an important soil "glue" produced in large quantities by a common group of fungi called "arbuscular mycorrhizal fungi." Higher glomalin concentrations in soil are associated with greater aggregate stability, greater water infiltration, better root development, and resistance to surface crust formation and erosion. Soil glomalin levels can be increased by practices that support mycorrhizal fungi. (See February.)

4a, 4b, 4c. Fecal pellets from (4a) Oribatid mites, (4b) Collembola, and (4c) Diptera larvae, Enchytraeids, and Collembola.
EVENTS
Hispanic Heritage Month
(Sept 15 - Oct 15)
23-28
7th International Meeting of Soils
with Mediterranean Type of Climate
Valenzano, Bari, Italy
imsmtc@iamb.it

SOIL FACT
- Under the proper conditions,
earthworms can create 800,000
small channels per acre that pipe
water throughout the soil after a
downpour.

ACTIVITIES
- Select a few aggregates from a
shovelful of soil. Place them in the
bottom of a cup. Gently add
enough water to halfway cover the
aggregates. Let them soak for a
minute. Did they break up as soon
as they got wet, or did they hold
together even when you gently
swirled the water? Repeat with soil
from different places (e.g., from
under a lawn versus a bare spot).
Which soil demonstrates the most
stability?

- Next time there's a downpour,
watch how water flows. Notice
where it ponds and where it is
absorbed.

SEPTMBER

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17x571
Plants extract more nitrogen than any other mineral from the soil. Soil organic matter contains plenty of nitrogen, but it is not available to plants until microbes degrade the organic matter and excrete excess inorganic nitrogen. Plants need microbes to continually recharge the supply of available nitrogen by degrading organic matter. Even when fertilizer is added, inorganic nitrogen (ammonium and nitrate) does not build up in the soil. It may be transformed into gas and lost to the atmosphere, taken up by soil organisms and plants and turned into new tissue to be recycled later, or leached deeper into the soil, to perhaps contaminate ground water.

1. Bacteria convert, or "fix," large amounts of atmospheric nitrogen into plant-available forms. In fig. 1, nitrogen-fixing bacteria gather on the tip of a white clover root hair.
2. Nitrogen-fixing bacteria generate cellulose microfibrils as they attach to the root hair.
3. This newly emerged white clover root nodule will soon begin fixing nitrogen.
4. and 5. Soybean nodules are spherical (fig. 4). Alfalfa nodules may grow multiple lobes (fig. 5). This one may be 3 millimeters long. It is cut open to illustrate the pink color where there is active nitrogen fixation in contrast to the greener color at the base.
6. Denitrification occurs when specialized bacteria convert nitrate into gases that are lost from the soil. These bacteria live under anaerobic conditions, such as those in saturated, compacted soils, or inside soil aggregates.
**EVENTS**

- **Disabilities Month**
  - 7-13
  - Earth Science Week
    - www.earthscienceworld.org

- **North American Association for Environmental Education**
  - 11-15
  - Little Rock, AR
    - www.naaee.org

- **Water Environment Federation**
  - 13-17
  - Atlanta, GA
    - www.wef.org

- **Soil Science Society of America Annual Meeting**
  - 21-25
  - Charlotte, NC
    - www.soils.org

- **National FFA Convention**
  - 24-27
  - Louisville, KY
    - www.ffa.org

- **National Indian Education Association Convention**
  - 27-31
  - www.niea.org

**ACTIVITY**

Study the roots of a legume (e.g., beans, clover, or alfalfa) to see if you can find root nodules. Nodules that are actively fixing nitrogen are pink inside.

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**Columbus Day**

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Some species of soil bacteria, fungi, nematodes, and insects are harmful to plants and cause significant crop loss. However, these make up a small minority of the species living in the soil. Researchers continue to discover soil organisms that help to protect plants from harmful organisms and improve plant growth. Scientists have noticed that plant roots exude compounds that attract very specific kinds of bacteria. These bacteria give off compounds that enhance plant growth. Other organisms attracted to plant roots help to protect the plants from disease by competing with pests, preying on pests, or releasing chemicals that are toxic to pests.

1. Arthrobotrys fungi form rings that constrict when a nematode swims through. The fungi then digest the trapped nematode.

2. The disease-free potatoes in this picture were grown in soil inoculated with Streptomyces bacteria before planting. Potatoes grown in a control plot developed scab disease (caused by a fungus). Researchers are beginning to identify green manure crops (plants that are grown to be turned into the soil) that promote growth of this Streptomyces species and other actinomycetes that can help to control disease.

3. Pergamasus mites are raised commercially to feed on symphylans. Symphylans eat the fine roots of strawberries, corn, beans, and other vegetables. They are difficult to control with pesticides.

4. The "noose" of a nematode-trapping fungus.
S O I L  F A C T

"Biological pest control" is the manipulation of natural pest enemies or their habitat.

For more information on biological pest control, see:

National Biological Control Institute (USDA-APHIS),
www.aphis.usda.gov/nbcii/

Biological Control: A Guide to Natural Enemies in North America (from Cornell University)
www.nysaes.cornell.edu/ent/biocontrol/

The Association of Natural Bio-Control Producers,
www.anbp.org
Organisms do not just live in the soil; they are a component of soil. They alter the appearance of soil as a result of their biochemical and physical processes and help to make soil one of nature's most fascinating displays. Throughout the history of soil science, living organisms have been an essential aspect of the concept of soil.

1. "Although it [soil] is the realm of mediations between the inorganic and organic kingdom, it is by the variety of its functions more nearly akin to the vital than to the lifeless part of the earth." (N.S. Shaler, U.S. Geological Survey, 1891).

2. Soil is "a natural body having a definite genesis and a distinct nature of its own, and occupying an independent position in the formations constituting the surface of the earth." It is a "great formation in which the organic and inorganic kingdoms meet and derives its distinctive character from this union." G.N. Coffey, Bureau of Soils, 1912.

3. \( s = f(cl, o, r, p, t, ...) \) Soil is a function of climate, organisms, relief, parent material, and time. "...we shall designate [this] as the fundamental equation of soil forming factors." H. Jenny, 1941.

4. "...soil is alive and is composed of living and nonliving components, having many interactions. It is as a part of the larger unit, the terrestrial ecosystem, that soil must be studied and conserved....we must remember that the biota have been involved in [the soil system's] creation, as well as adapting to life within it." D.C. Coleman, D.A. Crossley, Jr., 1996.
SOIL FACTS

• The concept of earth or soil as one of four basic components of all matter was put forward by Empedocles about 400 B.C. (O. Neuss, 1914.) He thought that all matter consisted of fire, water, earth and air.

• Virgil (70-19 B.C.) commented on how necessary it is "...that we learn the temper and quality of our ground, the depth and substance of our soil and the color too, and then consult carefully what plants are natural to such a soil and which plants will grow the most freely upon it."
Acknowledgements/Photo Credits

ACKNOWLEDGEMENTS:
In appreciation for their assistance in developing and reviewing the materials contained in this Planning Guide:

Dr. Kate M. Scow, Professor, Dept. of Land, Air, and Water Resources, University of California, Davis

William G. Ypsilantis, Soil Scientist, Bureau of Land Management, Coeur d'Alene, Idaho

PHOTO CREDITS:

INTRODUCTION
Figure 1: Curtis Monger, New Mexico State University
Figure 2: NRCS Soil Quality Institute. 1999. Soil Biology Primer

JANUARY
Figure 1: R. Campbell, In R. Campbell. 1985. Plant Microbiology. Edward Arnold, London, p. 149.
Figure 2: Deborah Allan, University of Minnesota
Figure 3a, 3b: James Dean, NRCS
Figure 4: No. 14 from Soil Microbiology and Biochemistry Slide Set. 1976 J.P. Martin, et al., eds., SSSA, Madison, WI

FEBRUARY
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MARCH
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Figure 3: Becky Fraticelli, NRCS

APRIL
Figure 1: Sven Boström, Department of Invertebrate Zoology, Swedish Museum of Natural History
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MAY
Figure 1: Gozmaryna majestus (Acari: Oribatida), Val Behan-Pelliter, Agriculture and Agri-Food Canada; and Roy Norton, College of Environmental Science & Forestry, State University of New York
Figure 2: Val Behan-Pelliter, Agriculture and Agri-Food Canada
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JUNE
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Figure 3: Michael Sadowsky, University of Minnesota
Figure 4: Clive A. Edwards, The Ohio State University, Columbus

JULY
Figure 1: Utah, Arlene J. Tugel, NRCS
Figure 2: New Mexico, Giora J. Kidron, Institute of Earth Sciences, The Hebrew University of Jerusalem, Givat Ram Campus, Jerusalem 91904, Israel.
Figure 3: New Mexico, Giora J. Kidron, Institute of Earth Sciences, The Hebrew University of Jerusalem, Givat Ram Campus, Jerusalem 91904, Israel.
Figure 4: Arlene J. Tugel, NRCS

AUGUST
Figure 1: Collokhmannia sp, Roy A. Norton, College of Environmental Science & Forestry, State University of New York
Figure 2: Julie Jastrow, Argonne National Laboratory
Figure 3: Julie Jastrow, Argonne National Laboratory
Figure 4: Phillip Sollins, Forest Science Laboratory, Oregon State University
Figure 5: Michael Russelle, USDA-ARS, St. Paul, MN

SEPTEMBER
Figure 1: R. Michael Miller, Argonne National Laboratory
Figure 2: Phillip Sollins, Forest Science Laboratory, Oregon State University

Figure 3: Sara Wright, USDA-Agricultural Research Service, Soil Microbial Systems Laboratory
Figure 4a, 4b, 4c: Nos. BF26, BF28, BF34 from A Reference Slide Collection for Soil Micromorphy. 1993. Reference Slide Subcommittee, Soil Micromorphy Committee, SSSA, Madison, WI

OCTOBER
Figure 1: Rhizobium leguminosarum bv. trifolii. Frank Dazzo, Center for Microbial Ecology, Michigan State University
Figure 2: Rhizobium leguminosarum bv. trifolii. Frank Dazzo, Center for Microbial Ecology, Michigan State University
Figure 3: Rhizobium leguminosarum bv. trifolii. Frank Dazzo, Center for Microbial Ecology, Michigan State University
Figure 4: Stephen Temple, University of Minnesota, St. Paul
Figure 5: Michael Russelle, USDA-Agricultural Research Service, St. Paul, MN

NOVEMBER
Figure 1: Institute of the Scientific Film, Gottingen, Germany
Figure 2: Neil Anderson, University of Minnesota.
Figure 3: Eric Groth, Oregon State University
Figure 4: Kate Scow, University of California, Davis

DECEMBER
Figure 1: California, Arlene J. Tugel, NRCS
Figure 2: California, Arlene J. Tugel, NRCS
Figure 3: Soil profile of Cecil Series, State Soil of North Carolina, John Kelley, NRCS
Figure 4: Arlene J. Tugel, NRCS

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7th Federal Sedimentation Conference
Theme: "Sediment: Monitoring, Modeling, and Managing"
ATTN: Jerry Bernard
Natural Resources Conservation Service, USDA
P.O. Box 2890
Washington, DC 20013
jerry.bernard@usda.gov

Ag in the Classroom,
U.S. Department of Agriculture
1400 Independence Avenue, S.W. Stop 225
Washington, DC 20250-2251
www.agclassroom.org
Phone: 202-720-7926

American Association for the Advancement of Science
1200 New York Avenue, S.W.
Washington, DC 20005
www.aaas.org
Phone: 202-326-6400

American Geological Institute, Earth Science Week
4220 King Street
Alexandria, VA 22302-1502
www.agiweb.org
Phone: 703-379-2680

Arbor Day Foundation
100 Arbor Avenue
Nebraska City, NE 68410
www.arborday.org
Phone: 402-474-5655

Boy Scouts of America
1325 Walnut Hill Lane
Irving, TX 75015
www.bsa.scouting.org
Phone: 972-580-2000

Canon Envirothon
P.O. Box 855
League City, TX 77574
www.envirothon.org
Phone: 800-825-5547 ext. 15

Environmental Alliance for Senior Involvement
8733 Old Dumfries Road
Catlett, VA 22019
www.easi.org
Phone: 540-788-3274

General Federation of Women's Clubs
1734 N Street, N.W.
Washington, DC 20036-2990
www.gfwc.org
Phone: 800-443-GFWC

Geological Society of America,
P.O. Box 9140
Boulder, CO 80301-9140
www.geosociety.org
888-443-4472

Girl Scouts of the USA
420 Fifth Avenue
New York, NY 10018-2798
1-800 GSUSA 4 U
www.gusa.org
Hugh Hammond Bennett 120th Birthday Celebration
Natural Resources Conservation Service
Conservation Communications Staff
P.O. Box 2890
Washington, DC 20013

National Association for Agricultural Education
1410 King St.
Suite 400
Alexandria, VA 22314
www.naae.org
Phone: 703-838-5885

National Association of Biology Teachers,
12030 Sunrise Valley Drive, #110
Reston, VA 20191
www.nabte.org
800-406-0775

National Association of Conservation Districts,
Service Center
P.O. Box 855
League City, TX 77574
www.nacdnr.org
1-800-825-5547

National Council for Geographic Education
Indiana University of Pennsylvania
16A Leonard Hall
Indiana, PA 15705
www.ncge.org
Phone: 724-357-6290

National Council for Social Studies
3501 Newark Street,
Washington, DC 20016
Phone: 202-966-7840
www.ncss.org

National FFA Organization
6060 FFA Drive
P.O. Box 68960
Indianapolis, IN 46268
www.ffa.org
Phone: 317-802-6060

National 4-H Organization
Cooperative State Research, Education, Extension Service
USDA
1400 Independence Avenue, S.W. Stop 2225
Washington, DC 20250
www.usda.gov
Phone: 202-720-2908

National 4-H Council
7100 Connecticut Ave
Chevy Chase, MD 20885
www.fourthcouncil.edu
1-800-368-7432

National Indian Education Association
700. N. Fairfax St. Suite 210
Alexandria, VA 22314
www.niea.org
Phone: 703-838-2870

National Science Teacher Association
1840 Wilson Blvd.
Arlington, VA 22201
www.nsta.org
Phone: 703-243-7100

North American Association for Environmental Education
1825 Connecticut Avenue NW 8th Floor
Washington, DC 20009-5708
www.naeee.org
Phone: 202-884-8788

Project Food, Land and People
Presidio of San Francisco
P.O. Box 29474
San Francisco, CA 94129
www.foodlandpeople.org
Phone: 415-561-4445

Project Learning Tree
American Forest Foundation
1111 19th St. NW, Suite 780
Washington, DC 20036
www.plt.org
Phone: 202-463-2462

Soil and Water Conservation Society
7515 N.E. Ankeny Road.
Ankeny, IA 50021
www.swcs.org
Phone: 515-289-2331

United Nations Environment Programme - Mexico City
Environmental Training Network for Latin America and the Caribbean
Blvd. De los Virreyes
Col. De los Virreyes
11000 Mexico, D.F. Mexico
www.educamb.rolac.unep.mx

Water Environment Federation
601 Wythe Street,
Alexandria, VA 22314-1994
www.wef.org
800-666-0260