Know Your Urban Soil

Soil is alive and (hopefully) well in our cities! Although we generally think of soil in 'natural' fields and forests, it also exists beneath and between all the cracks of our paved and built environments. Some of our city soils have been formed by naturally occurring parent materials, while the rest of have developed on human-altered or transported materials.

Did you know? Approximately 9% of NYC is covered by soils formed in natural materials and approximately 28% is covered by soils formed in human-altered or human-transported materials.[1]

Urban Soil Issues

Why should we care about our city soils? Urban soil is capable of performing all of the essential life-supporting functions that its suburban and rural counterparts provide, such as cleaning water, supporting plant growth, and storing carbon and other greenhouse gases. But our urban soils are often highly disturbed by human activities and land use.

While it may take hundreds or thousands of years for fertile topsoil to form naturally, it can be eroded away almost instantly. Building on top of soils and walking or driving over them can cause soils to compact, which also limits their functions. We are constantly mixing or removing our city soils, cutting into them, or filling them with new materials, waste products, or construction debris. These actions make urban soils different from soils in non-urban areas in some important ways:

→ **Display greater variability**
→ **May have little or no organic matter**
→ **Have altered soil temperatures**
→ **Are likely to contain human artifacts**
→ **Have high probabilities of compaction**
→ **Display more contamination**

While overall quality is an important concern for urban soils, an evaluation of soil quality wouldn't be complete without assessing soil contamination.[2] The concept of **contamination** refers to a particularly high concentration of naturally occurring elements or human-made compounds that have the potential to negatively impact health. Humans can contaminate soils in any area, but our particularly high population density and industrial activities in cities have left a legacy of contamination that we still contribute to in the present day.[2]

Learn more about urban soils:
Cornell Waste Management Institute, *Sources and Impacts of Contaminants in Soils*
http://cwmi.css.cornell.edu/sourcesandimpacts.pdf

U.S. EPA, *Evaluation of Urban Soils: Suitability for Green or Urban Agriculture Infrastructure*
http://nacto.org/docs/usdg/evaluation_of_urban_soils_epa.pdf

Where do we find soil in the city?

→ **Gardens**
→ **Front and back yards**
→ **Athletic fields**
→ **Playgrounds**
→ **Parks**
→ **Woods**
→ **Tree pits**
→ **Traffic islands**
→ **School yards**
→ **Rooftops**
→ **Vacant lots**
→ **Planting pots**
→ **Air particulates (e.g. dust)**
→ **Beneath buildings and roads**

What about Phytoremediation?

Some plants may potentially remove or break down certain chemical and biological contaminants in soil through a process known as phytoremediation. However, this method of urban soil treatment is **not recommended** for heavy metals such as lead. Lead does not readily enter plants when the soil's pH level is neutral or near neutral (pH of 6.5 - 7.5), as is usually the case with urban garden soils. Though some heavy metals are *very slowly* absorbed by plants, they do not break down into less toxic components. Plants with accumulated contaminants would need proper disposal, and interaction with or accidental consumption of these plants could put people at risk.

Note: *Although some plants are capable of breaking down select biological and chemical contaminants, it is important to understand that not all plants are capable of this. In addition, not all chemical and biological contaminants can be broken down through phytoremediation, and even successful phytoremediation can take decades to affect significant change.*

Learn more about phytoremediation:
U.S. EPA, *Phytotechnologies For Site Cleanup*
https://clu-in.org/download/remed/phytotechnologies-factsheet.pdf

Newtown Creek Alliance's **Greenpoint Bioremediation Project** (gBP), in partnership with the NYC Urban Soils Institute (USI) at Brooklyn College's Environmental Sciences Analytical Center (ESAC), seeks to increase public knowledge and local practice of popular established bioremediation techniques, including mycoremediation strategies and compost tea amendments. As part of our outreach and education we have run a series of hands-on workshops covering the following topics:

1. *Know Your Urban Soils*, by USI instructors Sara Perl Egendorf and Tatiana Morin
2. *Beneficial Microbes and Compost Tea* by Elaine Ingham
3. *Mycoremediation* by Tradd Cotter and Daniel Reyes

In addition, a community compost tea brewer by Steve Storch of Vortex Brewer was installed at the Java Street Community Garden and the bioremediation books listed in this publication were donated to the Brooklyn Public Library (Greenpoint Branch).

Find out more about Bioremediation at www.newtowncreekalliance.org/bioremediation

A brief history of Newtown Creek by Mitch Waxman, NCA Historian

Prior to 1898, the Brooklyn side of Newtown Creek was its own city, and the Queens side of the Creek was part of two separate municipalities. Back then, when you said NYC you meant just Manhattan and a bit of the Bronx. In 1898, when the City of Greater New York was consolidated into one municipal entity, a process which modernity would call gentrification began in industrial Manhattan. Factories and mills were closed, and businesses were relocated to the Creek in Brooklyn and Queens. The factories and tenements of Manhattan were replaced by apartment blocks, and the labor pool of tenement row house dwellers followed their jobs east.

Industry found a comfortable home along Newtown Creek, and its shorelines were soon lined by maritime bulkheads and railroad tracks. Communities of laborers grew along the Creek, in Long Island City and Greenpoint, Maspeth, Williamsburg, and Bushwick. There was no Clean Water Act, or EPA, or even a Newtown Creek Alliance, and industrial waste was dumped directly into the water and air. In the middle 20th century came the highways, which brought in armies of trucks and automobiles. By the late 1960's, manufacturing began to decline in the Northeastern United States, and Newtown Creek was no exception. The oil refineries, rendering mills, and acid factories began to shut their doors, and were soon replaced by waste transfer stations and warehouses. A century of breakneck industrial expansion, however, left behind a toxic legacy in the ground and water.

The **Newtown Creek Alliance** is a community-based organization dedicated to restoring, revealing and revitalizing Newtown Creek. Since 2002, the Alliance has served as a catalyst for effective community action to restore community health, water quality, habitat, access, and vibrant commerce along Newtown Creek.
Find out more about Bioremediation **www.newtowncreekalliance.org/bioremediation**

The mission of the **NYC Urban Soils Institute** (USI) at Brooklyn College's Environmental Sciences Analytical Center, is to advance the scientific understandings and promote the conservation and sustainable use of urban soils.

The New York State Office of the Attorney General (OAG) and (DEC) Department of Environmental Conservation, through the **Greenpoint Community Environmental Fund** (GCEF), provided funding for the Greenpoint Bioremediation Project. The views and opinions expressed in this report are those of the authors, and do not necessarily reflect the views of the OAG, DEC, or GCEF. No official endorsement should be inferred.

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Restoring Urban Soils: How Can Bioremediation Help?

Our actions are not only a cause of urban soil degradation, but are also capable of helping to restore urban soil quality, particularly within the context of environmental movements and greening cities. We have tremendous opportunities to promote the sustainability of our urban areas by focusing on the health of our soils.

A restoration technique called **bioremediation** has been gaining interest in recent years. Bioremediation is the use of natural processes involving microorganisms, plants, and fungi, or their enzymes to clean and restore polluted sites. Remediation, whether by biological means, chemical means or a combination of both, is of particular interest because it both addresses problems of pollution and paves the way for a more ecologically sustainable future. It presents humans with an opportunity to interact with nature in a way that is *proactive* and promotes ecological health in sites which are most in need of attention.

There are numerous methods for bioremediation, and each one has strengths and limitations. Soil remediation techniques can be either *in situ* or *ex situ*. *Ex situ* methods involve removing soil from the site or excavating soil for treatment while *in situ* methods involve direct treatment, keeping soil in place and essentially enhancing natural remediation processes.

In situ treatments have many benefits, including minimal costs and disruption to the site, and minimal human and environmental exposure to contaminated soil. The suitability of each bioremediation technology is determined by several factors, which may include site conditions, indigenous populations of microorganisms, and the types, quantities and potential toxicities of specific pollutants in the soil. Here, we will offer brief summaries of various bioremediation techniques which can be performed *in situ*.[3]

Bioremediation Methods

Compost & Compost Tea
The application of compost and compost tea to soil can help remediate sites polluted with certain types of contaminants through *bioaugmentation* of soil to increase its capacity to *biodegrade* contaminants. Compost is a mixture of living soil organisms and decomposing organic matter which can be made at home with substances like leaves, grass clippings, wood shavings and paper, among others. Compost tea is essentially liquid fertilizer that is rich in beneficial microbes. The tea helps build soil structure by supplying vital nutrients, microorganisms and organic matter to soil. It can also increase soil porosity and water retention, encourage biodiversity, and prevent plant diseases.

Mycoremediation
Mycoremediation is the use of fungi such as mushrooms and mycelia to treat polluted soil. Fungi break down, or encourage *biodegradation*, of certain chemical contaminants and discourage the spread of bacterial contaminants. This helps to rid the soil of some harmful components which may be transferred to edible plants or may otherwise be an exposure risk to humans and animals.

Some mushrooms are *hyperaccumulators* of heavy metals, meaning that they pull heavy metals from the soil and concentrate them within their own tissues at a very high rate. The potential for heavy metal mycoremediation is currently being studied, but is **not recommended** for use in your garden if heavy metals are present. The metals accumulated by mushrooms may stay in soils and accidentally consuming these mushrooms can cause potential health problems.

Bioremediation terms to know

Biodegradation: Breakdown of materials by bacteria, fungi, or other biological means.

Biostimulation: Modification of the environment to stimulate existing bacteria capable of bioremediation. This can be done by addition of phosphorus, nitrogen, oxygen, or carbon.

Bioaugmentation: Adding cultured microorganisms to assist in the breakdown of contaminants.

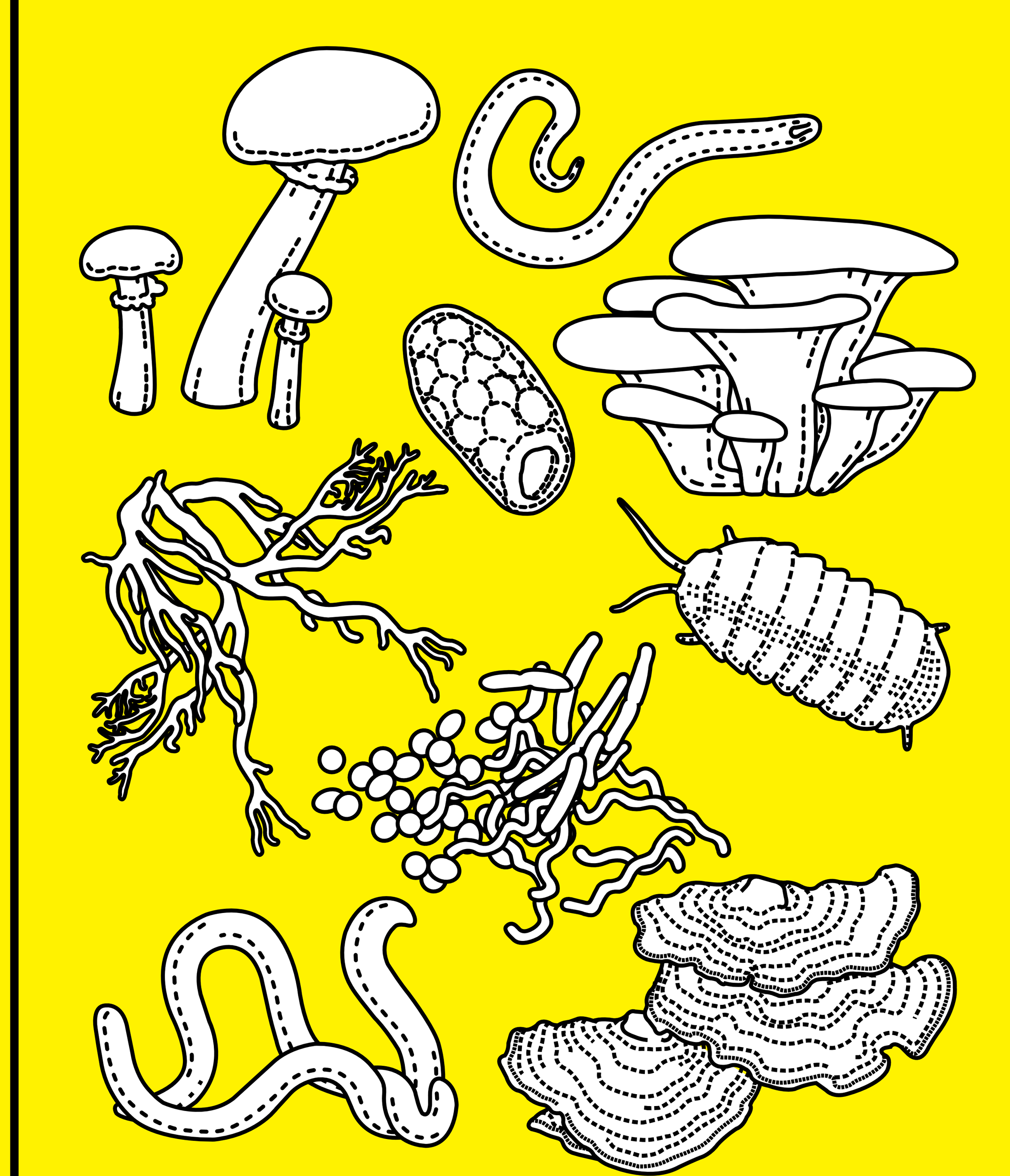
Bioavailability: The amount of an element or compound that is accessible to an organism for uptake or absorption across its cellular membrane.

Hyperaccumulation: Extremely high concentrations of trace metals absorbed into the roots and tissues of plants and fungi.

Learn more about bioremediation:
U.S. EPA Contaminated Site Clean-Up Information
https://clu-in.org/techfocus/default.focus/sec/Bioremediation/cat/Overview/

Books on bioremediation:
> *Earth Repair: A Grassroots Guide to Healing Toxic and Damaged Landscapes*, by Leila Darwish
> *Mycelium Running: How Mushrooms Can Help Save the World*, by Paul Stamets

AN INTRODUCTION TO URBAN (SOIL) BIOREMEDIATION



What is Soil?

The skin of the Earth. Soil exists as the exterior surface layer of our planet. The first living organisms may have originated in Earth's oceans billions of years ago, but for at least 500 million years life has been evolving on land. Soil provides the substrate for all five kingdoms of life to thrive on land, to take up nutrients, to grow in place and move through the world.

Soil allows for new forms of life to come into being, as they incorporate the nutrients left there by organisms of the past. It supplies the space for nutrients locked in living organisms to break down, while microbes like bacteria and fungi facilitate the decomposition of life. In soil, nutrients are released, stored in the Earth, and made available for new forms of life to continue to emerge.

Soil functions to protect the Earth and keep its many processes going, almost like organs in the body. As the Earth's surface it protects the land like skin and as gases move through soil it breathes like lungs. Water circulates materials through the soil system and like a digestive tract, soil releases nutrients and supplies energy to the organisms of our planet.

Soil may appear to be a uniform dirty mass, but it is truly dynamic and complex. It is a constantly changing mix of minerals, living organisms, decaying organic matter, air and water. Soil is bursting with life and can be vastly different from one inch to the next.

Only *half* of soil is solid material. Healthy soils contain about 50% solid matter (45% mineral, 5% organic matter) and about 50% pore space (with changing levels of air and water content).

Contained within just a few feet of this fragile surface, rocks, air, and water all meet and mix to support life on earth.

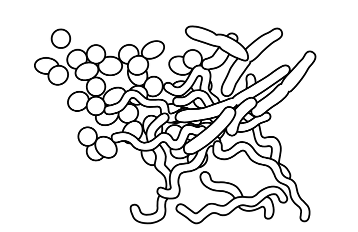
Soil Biology

Billions of organisms and thousands of different species can be found in a handful of healthy soil. The presence of these organisms is what sets soil apart from the nonliving rocks, minerals, and dust around us. It is the activities of these creatures that enable soil to perform its vital functions, and each organism provides its own essential role in soil ecosystems.
An incredible diversity of organisms make up the soil food web. They range in size from the tiniest one-celled bacteria, algae, fungi, archaea and protozoa, to the more complex nematodes and micro-arthropods, to the visible earthworms, insects, small vertebrates, and plants.

As these organisms eat, grow, and move through the soil, they make it possible to have clean water, clean air, healthy plants, and moderated water flow.

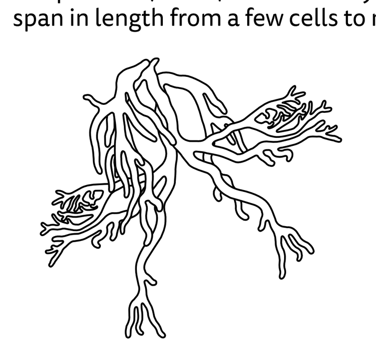
Soil organisms decompose organic compounds, including manure, plant residue, and pesticides, preventing them from entering water and becoming pollutants. They sequester nitrogen and other nutrients that might otherwise enter groundwater, and they fix nitrogen from the atmosphere, making it available to plants. Many organisms enhance soil aggregation and porosity, thus increasing infiltration and reducing runoff. Soil organisms prey on crop pests and are food for above-ground animals.

Bacteria are tiny, one-celled organisms – generally 4/100,000 of an inch wide and somewhat longer in length. A teaspoon of productive soil generally contains between 100 million and 1 billion bacteria.



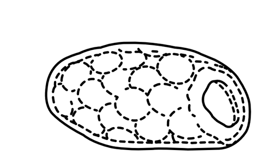
How **Bacteria** Enhance Soil Quality
-Feed other members of the food web
-Decompose organic matter
-Help keep nutrients in the rooting zone and out of the surface and groundwater
-Improve soil structure, improving the flow of water and reducing erosion
-Compete with disease-causing organisms
-Filter and degrade pollutants as water flows through the soil

Fungi are microscopic cells that usually grow as long threads or strands called hyphae, which push their way between soil particles, roots, and rocks. Hyphae are usually only several thousandths of an inch in diameter. A single hyphae can span in length from a few cells to many yards. A few fungi, such as yeast, are single cells.



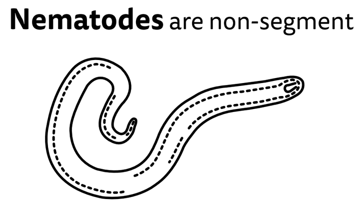
How **Fungi** Enhance Soil Quality
-Decompose complex carbon compounds
-Improve accumulation of organic matter
-Retain nutrients in fungal biomass, reducing leaching of nutrients out of the root zone
-Physically bind soil particles in aggregates
-Are an important food source for other organisms in the food web
-Improve plant growth when mycorrhizal fungi become associated with the roots of some plants
-Compete with plant pathogens
-Decompose certain types of pollutants

Protozoa are single-celled animals that feed primarily on bacteria, but also eat other protozoa, soluble organic matter, and sometimes fungi. They are several times larger than bacteria - ranging from 1/5000 to 1/50 of an inch in diameter. As they eat bacteria, protozoa release excess nitrogen that can then be used by plants and other members of the food web.



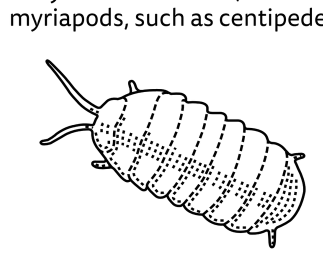
How **Protozoa** Enhance Soil Quality
-Release nutrients stored in microbial biomass for plant use
-Increase decomposition rates and soil aggregation by simulating bacterial activity
-Prevent some pathogens from infecting plants
-Provide prey for larger soil organisms, such as nematodes

Nematodes are non-segmented worms typically 1/500 of an inch in diameter and 1/20 of an inch in length.



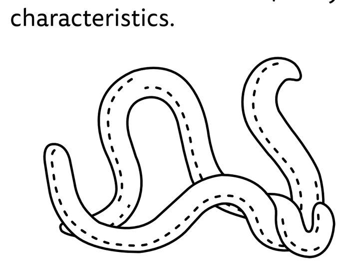
How **Nematodes** Enhance Soil Quality
-Regulate the populations of other soil organisms
-Mineralize nutrients into plant-available forms
-Provide a food source for other soil organisms that influence soil structure
-Consume disease-causing organisms

Arthropods known as bugs, make their home in the soil and range in size from microscopic to several inches in length. Arthropods are invertebrates, they have no backbone, and rely instead on an external covering called an exoskeleton. They include insects, such as beetles, and ants; crustaceans such as sowbugs; arachnids such as spiders and mites; myriapods, such as centipedes and millipedes; and scorpions.



How **Arthropods** Enhance Soil Quality
-Improve soil structure through burrowing and the creation of fecal pellets
-Control disease-causing organisms
-Stimulate microbial activity
-Enhance decomposition through shredding of large plant litter and mixing of the soil
-Regulate healthy soil food web populations

Earthworms are soft, slimy invertebrates that are hermaphrodites, meaning that they exhibit both male and female characteristics.



How **Earthworms** Enhance Soil Quality
-Shred and increase the surface area of organic matter, thus stimulating microbial decomposition and nutrient release
-Improve soil stability, porosity, and moisture-holding capacity by burrowing and aggregating soil
-Turn soil over, prevent disease and enhance decomposition by bringing deeper soil to the surface and burying organic matter
-Improve water infiltration by forming deep channels and improving soil aggregation
-Improve root growth by creating channels lined with nutrients

[source: NRCS, Soil Biology Primer]

Soil performs a number of essential life-supporting functions:

→ **Habitat for soil organisms:** Sustaining biological activity, diversity, and productivity
→ **Water supply and purification:** Regulating and partitioning water and solute flow
→ **Recycling nutrients and organic wastes:** Filtering, buffering, degrading, immobilizing and detoxifying organic and inorganic materials
→ **Medium for plant growth:** Storing and cycling nutrients and other elements
→ **Engineering Medium:** Providing support for our built environment

Soil Formation

Soil is constantly forming and reforming from a number of local and regional materials and processes. It can take thousands of years for a few inches of soil to form naturally.

Soil Forming **Factors**:

Parent Materials: Rocks, minerals, decaying organic matter

Climate: Sunlight, temperature, rain, wind

Organisms: Bacteria, archaea, fungi, nematodes, protozoa, insects, worms, mammals

Topography: Steep slopes, shallow valleys

Time: Years to millennia

***Humans** are also being recognized as a sixth soil forming factor. Our actions can significantly affect what is added to soil, what is lost from soil, and reactions within soil on very short time scales and with extremely large volumes. Human materials can also be the source of soil parent materials both intentionally and unconsciously.

Soil Forming **Processes**:

Additions: Materials added to soil such as decaying leaves and materials given off by plant roots

Losses: Materials removed from soil by water draining through or eroded from the surface

Translocations: Materials moved within the soil by plants and burrowing organisms

Transformations: Materials altered by biological and chemical reactions like decomposition and oxidation

Soil Properties

How do we understand and describe our highly diverse and complex soils? Each soil has a range of easily observable (and less easily observable) properties that allow us to categorize them and identify their forms and functions. The materials in soil and the ways soil forms largely shape these properties. These properties, in turn, enable the soil to perform its invaluable life-supporting functions. Identifying soil properties allows us to determine soil quality.

Color: Helps us understand soil mineral and organic matter content

Texture: Indicates the percentage of sand, silt, and clay in soil, which impacts pore space and the ability of air and water to move through soil

Structure: Pertains to how mineral and organic matter come together to form stable aggregates, which also determines how well air, water and roots can move through soil

Consistency: Refers to the stability of the soil structure

pH: A 'master variable' that tells us how acidic or basic a soil is, and regulates organism activity, nutrient supply, and plant growth

Salinity: Indicate ionic concentration in a soil solution. Ions affect plant growth and nutrient supply

Nutrient Supply: Refers to concentrations of the 18 essential plant nutrients needed for optimum growth, which include Nitrogen (N), Phosphorus (P), and Potassium (K)

Organic Matter (OM) Content: Refers to the percentage of organic matter in soil, which is important for structure, essential nutrients, and biological activity

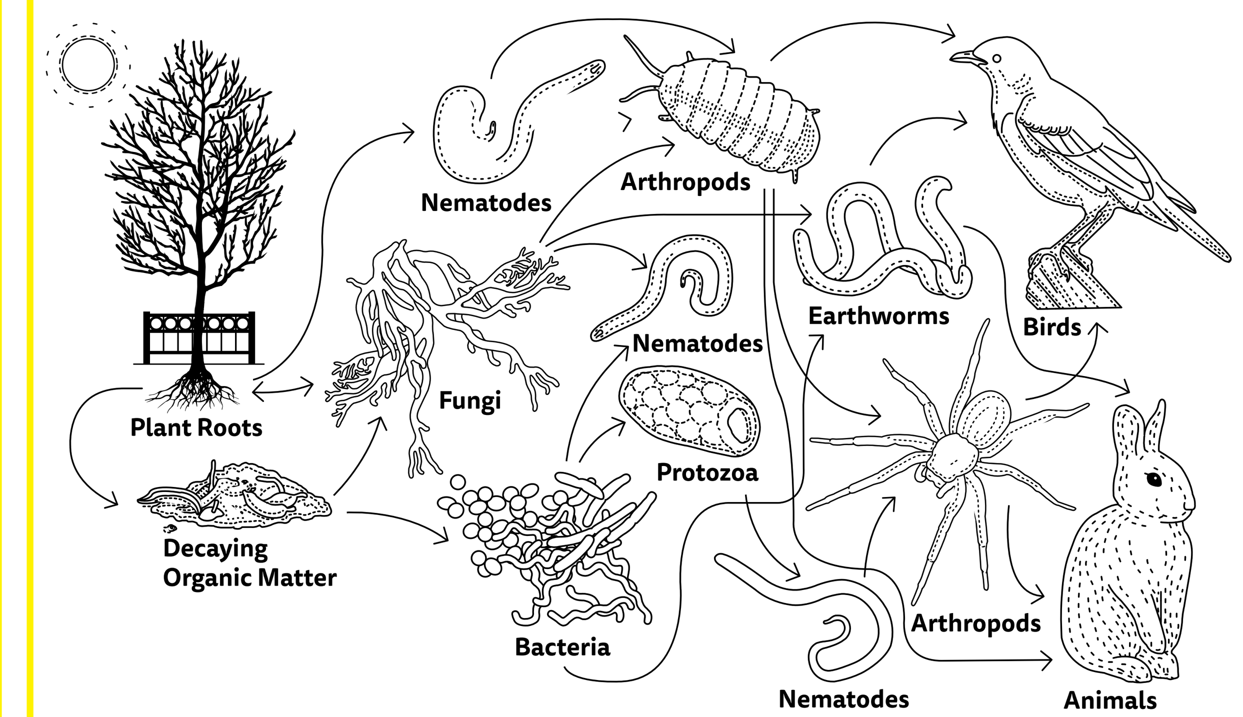
Cation Exchange Capacity (CEC): Refers to the soil's ability to hold onto cations (positively charged ions), which can be nutrients, salts, or positively charged metal contaminants

The Soil Food Web

The soil food web is the community of organisms living all or part of their lives in the soil. A food web diagram shows a series of conversions (represented by arrows) of energy and nutrients as one organism eats another.

All food webs are fueled by the primary producers: the plants, lichens, moss, photosynthetic bacteria, and algae that use the sun's energy to capture carbon dioxide from the atmosphere. Most other soil organisms get energy and carbon by consuming the organic compounds found in the primary producers and waste by-products.

As organisms decompose complex materials, or consume other organisms, nutrients are converted from one form to another, and are made available to plants and to other soil organisms. All plants - grass, trees, shrubs, agricultural crops - depend on the food web for their nutrition.[4]



Learn more about soil health and soil biology:
Natural Resources Conservation Service, United States Department of Agriculture (NRCS)
http://soils.usda.gov/

NRCS *Soil Health*
www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/

Cornell *Soil Health Assessment Training Manual*
http://soilhealth.cals.cornell.edu/training-manual/

Books on soil and soil biology:
> *Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web*, by Jeff Lowenfels & Wayne Lewis
> *Soil Biology Primer*, by Natural Resources Conservation Service and Soil and Water Conservation Society
> *The Hidden Half of Nature: The Microbial Roots of Life and Health*, by David R. Montgomery and Anne Biklé
> *Dirt: The Erosion of Civilizations*, by David R. Montgomery

Compost

*"There is no substance on this planet that some microorganism will not be able to chew up. The problem is finding the right organisms to chew up the right nasties and giving them the right food to do their job. If we just make really good **aerobic compost**, we are going to get the full set of organisms that we need to get into that soil, like protozoa, mycorrhizal fungi, nematodes and micro-arthropods."* Elaine Ingham

Compost is living soil organisms and decomposing organic matter recycled into a rich a soil amendment. When plant matter falls to the ground or organisms die, they slowly decay materials into **humus** under the activity of the many soil organisms present. This process takes the minerals and nutrients locked in the formerly living tissue and makes them available for new forms of life. While this process, facilitated by the soil food web, occurs naturally in soil, making compost is how humans create and enhance this cycle.

Compost may help remediate contaminated soils by increasing microbial communities to immobilize, dilute, degrade, and remove toxins that might be present in urban soils. Compost can also help by moderating pH, binding soil particles together, and eliminating the need for synthetic fertilizers, pesticides, and herbicides. Although compost can breakdown some organic contaminants, the remediation process can take decades to be effective depending on the level, type, and/or source of contamination, and may not be able to rid soil completely of toxins. However, an additional benefit to reduce public exposure to toxins exists when gardeners, farmers, and landscapers use compost to manage nutrients, weeds and pests, instead of using synthetic chemicals.

High heat (Thermophilic Compost)

The most commonly known type of compost is made in **thermophilic compost** piles. These produce the largest number of beneficial microorganisms and create the ideal environment for their rapid growth. Attention is placed on the ratios of carbon to nitrogen rich materials, temperature, and good aeration in the pile.
TWO parts Browns - Carbon-rich materials (brown leaves, wood shavings, paper), are mixed with **ONE part Greens** - Nitrogen-rich materials (green grass clippings, fruit and vegetable waste, coffee grounds), and placed in piles. **Avoid** meats, oils and grease, cheese and dairy products, cat droppings, and pressure treated lumber and plywood. A small amount of finished compost or garden soil is often added to provide the range of soil organisms. Compost piles that are at least 1 square meter and a meter high are generally large enough to provide enough heat.
Kept moist and well-aerated, the compost pile will begin to heat up. After a week or two, temperatures will reach 120 F to 170 F. During this stage frequent mixing is important to maintain oxygen levels and heat all the material evenly. The easily decomposed compounds are used up by the soil organisms first, leaving a curing stage that follows with lower temperatures that may last weeks to months. Longer curing times often tends to increase the fungus population in composts. Finished compost can be applied directly into soil or used to make Compost Tea.

Benefits of Actively Aerated Compost Tea

Compost tea is a liquid extract brewed from finished compost. When quality compost is in limited supply, brewing compost tea allows you to get more out of the initial compost as it increases the population of microorganisms, and is able to cover more ground than the original compost would. The technique increases the population of beneficial microorganisms by aerating the water with a pump and adding a food source such as humic acid, kelp power, or fish hydrolysate to encourage specific beneficial microorganisms to reproduce. Dissolved oxygen is maintained at high levels of airflow (above 6 parts-per million) to maintain **aerobic** conditions. Low levels can cause **anaerobic** conditions that encourage pathogen growth, loss of nutrients, and toxins to be released. Bacteria, fungi, protozoa and nematodes are fed while brewing to increase numbers and activity of the beneficial species to outcompete any non-beneficial organisms. When compost tea is applied to the soil it increases the biological activity in soil, which enhances overall soil structure, moisture content and nutrient retention. Spraying compost tea directly on plant surfaces can also help prevent pests, fungal and bacterial disease by causing the beneficial organisms to outnumber the disease-causing ones.[5]

To learn more about compost, compost tea and soil biology go to the Soil Foodweb Inc website headed by pioneering soil microbiologist Dr. Elaine R. Ingham.
www.soilfoodweb.com

Benefits of Compost

-Stable nutrient supply for plants (instead of chemical fertilizers)
-High yield for crops
-Restoration and habitat revitalization
-Reduced need for water and pesticides
-Reduced methane in landfills
-Reduced waste transportation
-Extended use of landfill

Important Composting Factors

Nutrient balance
"Green" organic materials (such as grass clippings, manure, food scraps) contain high quantities of nitrogen. These must be balanced with "brown" organic materials (such as dry leaves, branches, and wood chips), that contain high quantities of carbon.

Particle size
Smaller particles have more surface area, which provide microorganisms with more space to feed. Shredding materials ahead of time can facilitate this process. Using smaller materials can also help make a homogenous compost, but the particles should not be too small to prevent air from flowing.

Moisture content
Water is essential for microorganisms and making nutrients available for them. Compost should be moist but not too wet such that they become water logged and oxygen cannot flow through.

Oxygen content
Aerobic microorganisms need sufficient oxygen, which also speeds up the decomposition process. Turning the pile, or placing it on pipes can aerate the pile. This must also be balanced so that the pile is not dried out, which would impede the composting process.

Temperature
A high heat compost can reach up to 140 degrees F. If this temperature is not achieved, certain pathogens and weed seeds can persist in the compost, or anaerobic conditions can also occur. Monitoring temperature is important, and balancing the other factors can help achieve the optimal ranges.

Did You Know?

>Aerobic: Existing only in the **presence** of oxygen, encourages the growth of beneficial microorganisms

>Anaerobic: Existing in the **absence** of oxygen, encourages the growth of potentially harmful pathogens

Powerful addition to boost compost

Mycorrhizal fungi create a symbiotic relationship with plants. Mycorrhizal fungi produce **chelates**, compounds that break down the tight chemical bonds of inorganic chemicals that are usually unavailable to plants. The chelates absorb these inorganic nutrients - particularly nitrogen, phosphorus, and copper, but also potassium, calcium, magnesium, zinc, and iron - and then deliver them to the plant in return for the nourishing carbon made available to them through the plant's roots.

Microorganisms, particularly bacteria, associate with mycorrhizal fungi and stimulate the growth of the fungi, and thus the growth of the host plant. In addition to all these benefits, mycorrhizal fungi also produce vitamins, hormones, cytokinins, and increased protection against host plant pathogens.[6]

Learn more about compost:

NYC Compost Project
www.nyc.gov/compostproject

NYC Compost Project: Master Composter Course Manual
www1.nyc.gov/assets/dsny/docs/nyc-master-composter-manual-mcm.pdf

Soil Foodweb Inc by Dr. Elaine R. Ingham
www.soilfoodweb.com

Cornell Waste Management Institute
www.cwmi.css.cornell.edu/composting.htm

Brooklyn Botanical Garden's Guide to Composting
www.bbg.org/gardening/composting

Books on working with compost and compost tea:
> *Adding Biology - For Soil and Hydroponic Systems*, by Dr. Elaine R. Ingham and Carole Ann Rollins, Ph.D.
> *The Field Guide 1 For Actively Aerated Compost Tea*, by Dr. Elaine R. Ingham
> *The Field Guide 2 For Actively Aerated Compost Tea*, by Dr. Elaine R. Ingham
> *Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web*, by Jeff Lowenfels & Wayne Lewis
> *The Hidden Half of Nature: The Microbial Roots of Life and Health*, by David R. Montgomery and Anne Biklé

What Can We Do?

Are you at risk of exposure to contaminated soils?

A few considerations:
-Where are you may potentially be exposed contaminated soils?
-Do you know what types and concentration of contaminants in soil you may be exposed to?
-What is your frequency and duration of exposure?
-What is your general health and age?

Note: Children are the most at-risk populations due to their developing systems and likelihood for hand-to-mouth exposure.

In the city, be aware of *potentially* contaminated soil especially around:

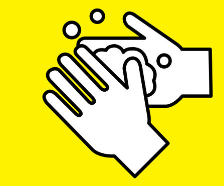
-Vacant lots
-Current and former industrial sites
-Near buildings with chipping lead paint
-Areas of heavy street traffic
-Underneath bridges, highways, train and subway overpasses

Learn more about soil safety at
The Johns Hopkins Center for a Livable Future
https://www.jhsph.edu/research/centers-and-institutes/-johns-hopkins-center-for-a-livable-future/_pdf/projects/urban-soil-safety/CLF Soil Safety Guide.pdf

Human Exposure Pathways:

-Inhalation: breathing soil particles
-Ingestion: eating soil particles
-Dermal contact: touching soil

General Best Practices:



-Wash hands
-Take off shoes when indoors
-Leave sports and garden equipment outside of home
-Keep an eye on children

Gardening Best Practices:

-Use clean soil and compost (contaminant free)
-Grow edible crops in raised beds
-Avoid using treated or painted wood in your garden
-Maintain soil nutrients and pH
-Wash and/or peel produce
-Cover soil and garden paths with mulch or cover plants
-Block wind so as not to disperse potentially contaminated particles
-Wear gloves

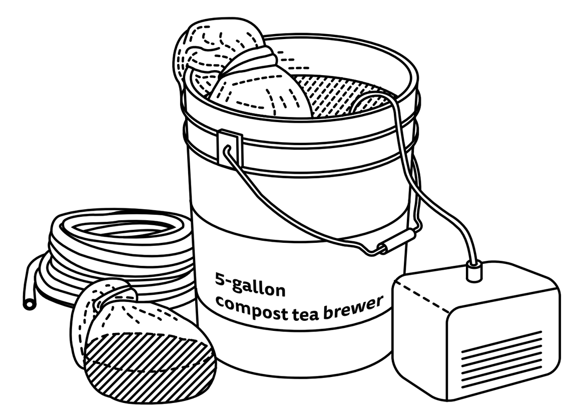
Note: If making compost, avoid using materials like yard waste that may have come into contact with contaminated surfaces (e.g. sidewalks, streets, exterior house paint)

Planning a vegetable garden?

You should have your soil and compost tested for contaminants, such as heavy metals, as well as pH and nutrient content.

Affordable soil testing is available at the NYC Urban Soil Institute, a partnership between Brooklyn College, USDA NRCS, and the NYC Soil Water Conservation District www.usi.nyc/soil-testing.html

Learn more about urban gardening safety practices on Cornell's Healthy Soils, Healthy Communities www.cwmi.css.cornell.edu/healthysoils.htm



Instructions:
Bucket Compost Tea Brewer

You can purchase a large community compost tea brewer or try making one yourself by following these instructions.

This brewing process takes 1 day and should be applied to plants and soil immediately after finishing.

Supplies:
•3 cups of good quality compost or vermicompost
•a 5-gallon bucket
•chlorine-free water
•an aquarium air pump
•several feet of tubing
•a gang valve
•bag for compost (stockings, paint strainer bag or burlap bag)
•1 ounce microbial food source (humic acid, kelp, and fish hydrolysate)
•a watering can or a clean fertilizer sprayer

1. **Attach tubing and gang valve to bucket.** Cut four lengths of tubing as tall as your five gallon bucket. Attach one length of tubing from your pump to the gang valve. Secure the tubing to the lip of the bucket and place the gang valve inside.

2. **Add water in bucket.** Fill bucket three quarters full with water and aerate for one hour, or let sit for 24 hours to allow the chlorine present in city water to dissipate.

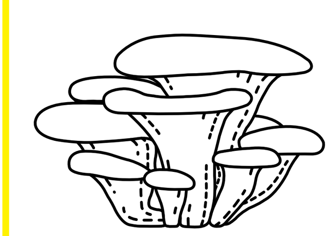
3. **Add compost bag.** Fill three cups of compost to your straining bag. Move compost bag into the center away from bucket walls and off floor. Arranging the air output tubing so they surround the bag will ensure maximum aeration.

4. **Feed microorganisms.** Add one ounce each of the amendments: humic acid, kelp, and fish hydrolosate to the bucket. Modify recipe as needed.

5. **Remove and apply compost tea.** After 24 hours, turn off the pump, remove all the contents except the compost tea brew from the bucket. Use the compost tea immediately (within a couple of hours, if possible), either as a soil drench or a plant spray. As a soil drench, empty the tea into a watering can and pour into the soil especially near the plants. For use as a plant spray, empty tea into a clean sprayer, and gently cover the leaf surfaces of the plants.

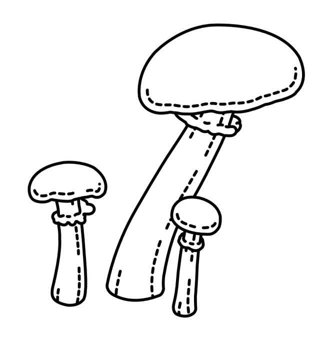
6. **Clean equipment well.** Using a soft brush, baking soda, and water, clean all surfaces of equipment and flush tubes repeatedly.

Mushrooms for Mycoremediation



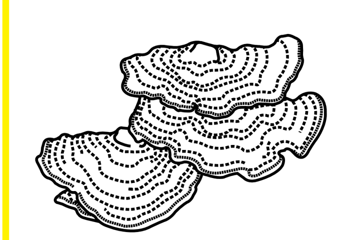
Oyster mushrooms (*Pleurotus ostreatus;* others of the *Pleurotus* genus)
Oyster mushrooms are powerful bioremediators that can be found all over the globe,[9] growing in a variety of even harsh and unique climates with ideal growing temperatures ranging from 35 to 90 degrees Fahrenheit. They can develop and feed on a variety of growing material (**substrates**), including straw, hardwood, and paper. Oysters generally have a trumpet-like appearance, with a smooth flattened cap growing off-center atop the mushroom stem. Gills, appearing as vertical ridges, descend from under caps often covering most of the stem. Some species of Oyster mushroom can survive in salt water.

→ In addition to being powerful bioremediators, **Oyster mushrooms** are some of the fastest growing fungi and are found all over the world. Different strains fruit in bright, beautiful colors, from salmon pink to neon yellow and silver-blue.[7]



King Stropharia (*Stropharia rugosoannulata*)
King Stropharia (also "Garden Giant") has been used to break down harmful bacteria such as fecal coliform[13] and generally supports excellent diversity in the soil ecosystem. The mushroom grows well on hardwood chips, cereal straw and other agricultural byproducts. King Stropharia is resilient in dry conditions, needing only minimal moisture as it develops into the mature form. In a mature mushroom, the cap is centered on the stem and appears in a tan or darker burgundy color, more rounded in shape than Oysters, for example. Smaller buttons exhibit deeper red, firm caps.

→ **King Stropharia** and **Oyster mushrooms** are widely recommended for use in urban sites, since they thrive in a variety of climatic conditions, and can be supported on growing mediums typically used in urban gardens, such as wood chips and composts.



Turkey Tail (*Trametes versicolor*)
Turkey Tails are found throughout the world and grow on many different types of wood, from pressure treated wood to decaying tree logs. Turkey Tails grow in flat "brackets" which may resemble dark wood chips when growing in their usual clusters. The tops of the brackets exhibit color-banding, often with dark grey-brown regions toward the center, giving way to bands of reddish brown and tan around the edges. The underside of brackets are covered with distinctive white pores. Turkey Tail is a moisture-loving wood decomposer and has been known to spread aggressively.

→ Polypores such as **Turkey Tails,** that intensely bind organic matter are valuable in remediation to provide structural support or when dealing with strong water flows.[7]

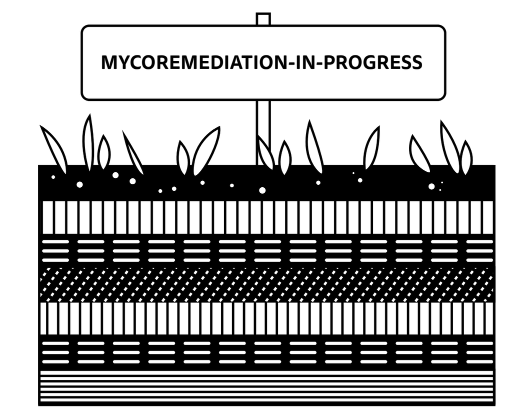
Note: While these mushrooms can act as powerful agents of remediation on some sites, they may not be effective in every site and against all contaminants. We recommend soil testing and consultation with an expert before considering mycoremediation for your site.

Is my site suitable for mycoremediation?

Chemical pollutants (e.g. petroleum-based contaminants) or **biological pollutants** (e.g. fecal bacteria)**:** If the presence of chemical or biological pollutants is detected or suspected, your site may benefit from soil remediation using mushroom mycelium. To begin the process, we recommend that you purchase a bag of sawdust-based mushroom spawn and consider the simple mycoremediation patch site instructions as a starting point while you read and learn more about mycoremediation.

Heavy metals: Some mushrooms and fungi are impressive *accumulators* of toxic heavy metals. Mushrooms and other fungi absorb heavy metals through a process termed "mycosorption."[11] This amazing technology is being researched by experts all over the world who hope to harness mushrooms' potential for large-scale industrial clean-up efforts, however, **we do not recommend mycoremediation of heavy metals in urban soils**. This is because mushrooms may easily be consumed when not under regulated conditions, leading to serious illness or death if ingested. Because of this risk, mycoremediation of heavy metals should only be performed by professionals.

As an alternative, consider installing **raised garden beds** above the ground soil. Be sure to line and protect the raised beds so that ground soil does not mix with the uncontaminated soil in which crops will be planted. Always wear protective gear such as garden gloves when handling contaminated soil.



Instructions:
Mycoremediation Patch

These instructions should serve as a basic outline. If you would like to learn more, to start, read *Organic Mushroom Farming and Mycoremediation*, by Tradd Cotter or *Mycelium Running* by Paul Stamets.

Note: We recommend that you **purchase a 5 lb bag of mushroom sawdust-based spawn** for your first urban soil clean-up project. Homegrown mushroom cultivation can be very tricky the first time around. With research and guidance, this can be a worthwhile endeavor once you've successfully worked with spawn.

Start layering! Starting with a layer of organic materials helps to both optimize the pH of your soil and speed up the breakdown of toxins.

1. **Compost** or **Compost Tea.** Lay down soil amendments.
2. **Woodchips** (Hardwoods or check mushroom for compatibility). Cover with a thin layer. Check local parks or tree cutting companies that provide a source of free woodchips. **Water** until completely saturated.
3. **Recycled cardboard boxes**, to protect the layer of compost underneath and allow it to break down contaminants. **Water** until completely saturated.
4. **Mushroom spawn.** Add a thick layer of the sawdust spawn.
5. More **woodchips,** to mix with the spawn. **Water** lightly.
6. Cover with more **cardboard**, to protect from moisture loss and sunlight, weigh down the cardboard with rocks or more woodchips.
7. **Water** periodically to keep the spawn and woodchips moist, especially the first few weeks while your mycelium gets established.
8. After mycelium growth is highly visible and is well-established, **add a final layer of new clean soil.**
9. **Add your sign.** As a final but ***important*** step, don't forget to add the "Do not eat Mushrooms!" sign found on this poster to prevent visitors to your site from ingesting harmful contaminants.

Note Disclaimer: *All fungi may not be benign (such as those possibly contaminated by growth in contaminated soils). Although some sites may respond well to mycoremediation, not all contaminants can be significantly broken down using this method. It is also important to understand that even successful mycoremediation can take decades to produce significant reduction in contamination levels. It is crucial to prevent the consumption of any fungus which may have accumulated heavy metals. You may need to consult professionals (including for liabilty purposes) before getting started.*

Recommended suppliers of spawn:
Fungi Perfecti, headed by mycologist Paul Stamets
Website: www.fungi.com

Mushroom Mountain, headed by mycologist Tradd Cotter
Website: www.mushroommountain.com

Mycoremediation

Note: *While the below may be enough to get you started, we recommend you look deeper into mycoremediation techniques as you approach your urban soil site. Please see the reading list at the end of this section for some wonderful and in-depth resources.*

Mycoremediation = **myco** [fungus] + **remediation** [to clean, resolve].
Mycoremediation is a technique that uses fungi to break down or immobilize industrial and environmental pollutants. It is a powerful technology based in the natural processes of the Earth's best decomposers, and its potential to heal contaminated environments has only just begun to be explored!

For over 2000 years, the benefits of medicinal mushrooms to human health have been studied and practiced. More recently, research has shown that fungi are effective at breaking down some dangerous contaminants, such as petroleum products leached from oil spills and industrial processes, and biological contaminants like fecal coliform bacteria which pose a health risk to humans and animals.[7]

Generally, mycoremediation is best at tackling two main types of pollution: microbial (biological) contamination and chemical contamination.

In **microbial mycoremediation**, fungi may work to prevent a microorganism from replicating, thereby "deactivating" it and stopping it in its tracks. Fungus can also simply claim the territory that microorganisms would otherwise occupy, effectively banishing them from an area. Alternatively, a fungus can make conditions inhospitable for pathogenic microorganisms by altering features of the soil like pH.[7] This type of fungus-based remediation is particularly useful when dealing with fecal coliform bacteria.[8]

Mycoremediation of **chemical pollutants** involves the breakdown of chemicals such as petroleum-based PAH's (polycyclic aromatic hydrocarbons) by fungal enzymes. The molecular structure of such chemicals resembles parts of wood and other growing mediums which mycelium digest, and they are able to break down these chemicals in the same way. The chemicals break down into nontoxic components as they become food for fungus.[9]

How does mushroom mycelium break down petroleum?

"A good fit: the magic of mycelial enzymes"

Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals naturally found in petroleum-based materials and products such as crude oil, coal and gasoline, and produced through the burning of coal, gas, oil, wood, garbage and tobacco, and high-temperature cooking of food. PAHs are considered harmful chemicals, and have been linked with cancer, poor fetal development and cardiovascular disease.[10]

Wood-decaying white rot fungi, such as Oyster and Turkey Tail mushroom **mycelium**, contain enzymes capable of breaking down the hydrogen-carbon bonds which hold plant material together (in wood, this is called *lignin*).[11, 12] This is what enables this type of fungus to both live on and digest its woody *substrates*, sometimes completely covering fallen logs or discarded pallets.

PAHs contain chemical bonds remarkably similar to those bonds found in *lignin*, and herein lies the key to mycoremediation as a powerful tool for cleaning up PAH-laden toxins: the very same mycelial enzymes can break down petroleum products.[13] As the petroleum-based contaminants are broken down by the fungus, metabolites that it does not digest are put to use and further broken down by other microorganisms. In addition, the nontoxic byproducts of water and carbon dioxide are left behind.[8] Through this process, the end products in their most simplified form are once again made available to the food chain.[6]

Did You Know?

Fungi = member of the kingdom of living things such as mushrooms, molds, and yeasts that have no chlorophyll, that live in or on plants, animals, or decaying material.

Mycelium = the vegetative part of a fungus or mushroom, and appears as a network of small "threads" that grow underground. In mushrooms, mycelia give rise to the recognizable fruiting body that we traditionally call a "**mushroom**."[7]

Spawn = any material which can host mycelium, such as cardboard, straw, sawdust, woodchips, logs. The spawn supports the growth and development of the mycelium and can also encourage its growth on other substrates.[14]

Mushrooms as Ecological Instigators

"In nature, mushrooms are decomposers and constructors, the agents of habitat renewal" - *Tradd Cotter*

"Fungi control the flow of nutrients, and as a consequence they are the primary governors of ecological equilibrium" - Paul Stamets

The concept of an **ecosystem** tells us that many different organisms *coexist* and are continuously cycling nutrients and energy through a living system, passing from one organism to the next.

Research with mushrooms and other fungi in toxic waste sites has revealed the power of these organisms to reintroduce life to areas where it has been almost completely extinguished. The introduction of certain species like Oyster mushrooms into a toxic environment soon attracts insects to the site. Next, vertebrates large and small are drawn to the mushrooms and insects as food sources, while bacteria use decomposing mushrooms for their own growth. Fungi instigating a cycle of life during which nutrients are repeatedly made available for all organisms within the ecosystem, and bacterial growth ushers in plant life once again. In this way, mushrooms set the stage for ecosystem overhaul in a wonderful chain of natural habitat restoration.[9]

Mycorrhizal fungi are fungi that form **symbiotic** relationships with the roots of plants.[7] The plant's root structures and the fungi live side by side, often in a relationship which benefits both. In these cases, plants bring food to the fungi, while the fungi allows nutrients and water to flow more easily to the plants.
→ *Learn more about the power of mycorrhizal fungi in the **Compost** section*

Books on cultivation and mycoremediation:
> *Organic Mushroom Farming and Mycoremediation: Simple to Advanced and Experimental Techniques for Indoor and Outdoor Cultivation*, by Tradd Cotter
> *Fungi in the Environment*, edited by Geoffrey Michael Gadd, Sarah C. Watkinson, Paul S. Dyer
> *Fungi in Bioremediation*, edited by Geoffrey Michael Gadd
> *Radical Mycology: A Treatise On Seeing & Working With Fungi*, by Peter McCoy
> *Growing Gourmet and Medicinal Mushrooms*, by Paul Stamets
> *Mycelium Running: How Mushrooms Can Help Save the World*, by Paul Stamets

Cut out and add this sign to mycoremeidation sites!