(continued from page 21) often end up as a pollutant in our streams. In residential settings, our lack of understanding sometimes leads to over-irrigation and overuse of synthetic fertilizers. Most urban land uses deplete the soil of organic matter.

For gardeners and watershed residents, retaining organic matter and protecting soil biota is of primary concern. Though it is the least part of the soil, the organic component has the greatest importance. The health of soil biota is negatively influenced by common gardening practices such as removing plant debris and using quick-release fertilizers. Insecticides and herbicides, too, not only exterminate the pest, but kill beneficial soil organisms. Gardening organically and returning organic material to the soil both protect biota and restore soil fertility.

The Latin root for soil—*solum*—means seat. Every soil is in itself a habitat and provides the foundation for nearly every kind of plant. These plants, in turn, form the basis for countless food webs and natural relationships that sustain the majority of organisms on earth. The ground beneath our feet is in many ways the seat of life.

So, the next time you're sitting trailside on a log or wandering through your yard, listen for the hum above and below. You can almost hear the invisible industry of sow bugs, earthworms, fungi, and bacteria at work. You can almost hear the plants grow. With a little care and exploration, you can add your own voice to the chorus.

Funding for "Soil Matters" was provided by:

Bay-Friendly—a project of the **Alameda County Waste Management Authority** and **Source Reduction & Recycling Board**—is a holistic approach to gardening and landscaping that works in harmony with the natural conditions of the San Francisco Bay Watershed. Bay-Friendly practices foster healthy soil and conserve water and other valuable resources while reducing waste and preventing pollution. (www.bayfriendly.org)

East Bay Municipal Utility District (EBMUD) provides water to 1.3 million people in Alameda and Contra Costa Counties and wastewater treatment services to more than 640,000 people. Water conservation and recycling are key components of the District's integrated resource plan, designed to ensure a sustainable water supply for the future and to protect and enhance water quality and ecosystems in the Delta and San Francisco Bay. (www.ebmud.com)

Santa Clara County Integrated Waste Management Division strives to conserve and protect community resources through programs that "reduce, reuse and recycle." It also promotes sustainable practices that prevent pollution and excess waste throughout Santa Clara County. (www.reducewaste.org)

Santa Clara Valley Water District (SCVWD) manages Santa Clara County's wholesale drinking water resources; coordinates flood protection for its 1.7 million residents; and provides stewardship for the county's watersheds, including 10 reservoirs, more than 800 miles of streams, and groundwater basins. (www.valleywater.org)

The City of Antioch provides drinking water to all customers within the city limits. To ensure a safe and adequate supply of quality water, the City participates in various pollution prevention, composting, gardening, and water conservation programs. It also reduces runoff contamination in local creeks and rivers by educating residents on proper landscape and gardening practices. (www.ci.antioch.ca.us)

Contra Costa Water District (CCWD) provides reliable, high-quality water to residents of central and eastern Contra Costa County. To help assure a long-term sustainable supply of water, CCWD carries out a cost-effective water conservation program. Reducing demand enhances water quality and the environment of the Sacramento/San Joaquin Delta, benefiting both people and the environment. (www.ccwater.com)

The U.S. Fish and Wildlife Service (FWS) is the principal federal agency responsible for conserving, protecting, and enhancing fish, wildlife, plants, and their habitats for the continuing benefit of the American people. The Service manages the 93-million-acre National Wildlife Refuge System. (www.fws.gov)

The Alameda Countywide Clean Water Program is a consortium of public agencies working together to reduce stormwater pollution and protect our creeks and San Francisco Bay. (www.cleanwaterprogram.com)

The City of San Jose has established a national reputation for environmental leadership and innovation through the programs and services of its Environmental Services Department (ESD)—ensuring healthy streams, rivers, marshlands, and Bay waters; managing reliable water, garbage, and recycling services; developing clean and green air, land, and energy policies; and providing community education aimed at environmental sustainability. (www.sanjoseca.gov/esd/)

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FROM BACKYARD TO BACKCOUNTRY

SOIL MATTERS

SARAH ANNE BARDWELL

In a game of 20 Questions, soil could be animal, vegetable, *and* mineral. It is populated by multitudes of very small organisms, it holds the bodies of plants both dead and alive, and it contains remnants of the mother rock from which it originated. According to the textbooks, soil is minerals, organic matter, air, and water. According to the poets, it is the living edge where earth and sky meet.

Though it may be a more subtle feature of the land than the hills and valleys that surround San Francisco Bay, soil plays no less a role in defining the natural world around us. Soil is an essential, living element of the landscape and is the foundation for the health of entire ecosystems. Getting to know the soil is essential if we want to create habitats for wildlife at home or understand the processes that shape a landscape and allow wild species to flourish.

Our contemporary understanding of soil began around the close of the 19th century, when two scientists working independently in Russia and America took the first close look at it. They concluded that there are many different kinds of soils with distinct characteristics and discernible patterns of distribution. Our appreciation of soil has continued to gain breadth and depth ever since. The study of soil has become a separate science, and its practitioners have identified distinct orders of soils—there are 12 in the world—as well as suborders, great groups, families, and series. Nineteen thousand soil series have been described in the United States; there are at least 140 in the Bay Area.

Upon this diversity of native soils has grown almost as great a number of human uses for them. And with uses come impacts; your garden-variety soil may be considerably altered from the original material that once occurred where your home now stands. The quality of your soil depends upon the history of land use locally and the extent to which the soil has been manipulated by developers and homeowners. As with the protection of air and water, the individual actions that each of us takes—how we dig in the soil, what we put on or into it—can influence the quality and integrity of the life-giving soil.

As the concept of seeing our yards as habitat and haven for native wildlife has taken root, Bay Area gardeners have shown greater interest in growing native and climate-appropriate plants. But the choice to "go native" involves more than the plants we grow; it extends to the soil that nurtures those plants and a great variety of wildlife. *Bay Nature* invites you to explore this ground beneath our feet, to see it as a rich and complex habitat in its own right, and to understand the potential we have for degrading and nurturing it.

GETTING GROUNDED

A CLOSER LOOK AT BAY AREA SOILS

BY ANNE HAYES

Long, long ago, in a time before time, the place where we now live was a deep sea. Beneath the waters, however, the earth stirred. A coast range was lifted up. Rains fell upon the bare slopes. Rivers and streams formed, wearing away rock, transporting sediment.

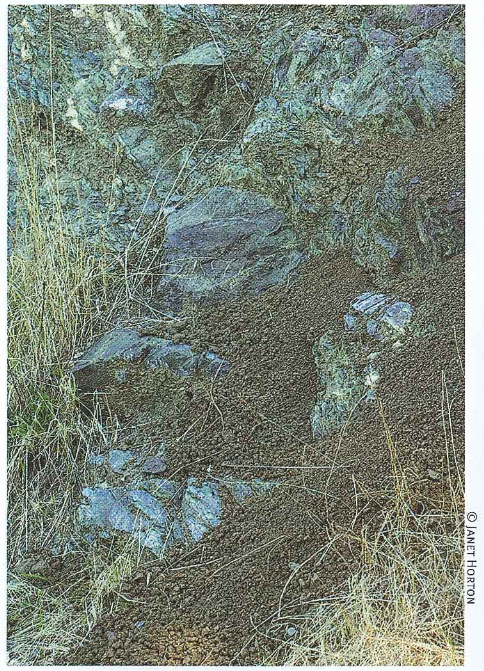
At a very stately pace, over the last two million years, land and water have assumed the outlines we see today. In just a few centuries, some of the same forces that gave form to the land have also given substance to the soil.

From Rock to Soil Soil begins with bare rock. Through the action of wind and rain and changing temperature, tiny particles wear off and gather, forming a loose matrix. This physical disintegration, combined with chemical decomposition, is known as weathering, and in it lies the beginnings of a soil.

The physical effects of weathering are easy to recognize. The pocketed sandstones along the San Mateo coast provide just one example of the scouring power of wind and water. With our mild Bay Area temperatures, examples of the changes wrought by the successive heating and cooling of stone aren't as easy to find. Over the course of time, however, these differentials eventually weaken and fracture stone, peeling, chipping, and cracking it, liberating particles to become soil.

You can also see the effects of chemical weathering—some soils are red because the iron in them has oxidized, for example—but understanding the processes at work requires some abstraction. Hydration, hydrolysis, and dissolution are common chemical processes that result in the breaking down or putting together of elemental components of soil.

While the forces of wind and water are at work, and while chemical interactions are taking place, plants and animals make their various ways in the world—and help create soil in the process. Plant roots and leaves add organic material and a host of organisms move in, each having an impact on the quality and composition of the developing soil. Over the course of centuries, a body of soil grows, eventually reaching depths of several inches to, in some cases, many feet.



© Janet Horton

Soil begins with small particles eroded from bare rock, such as the loose matrix of pebbles surrounding serpentine rocks on a hillside at Santa Teresa County Park near San Jose.

Soils in Profile Any given soil consists of distinct layers, or horizons. The organic material at the soil surface is known as the O horizon. Underneath it, in descending order, are the A, B, and C horizons. The color and composition of these layers differs sufficiently that soil scientists use them to identify different soils—hundreds of thousands of unique groupings of soils have been named around the globe.

In the parlance of the farmer and the gardener, the O and A horizons are topsoil. This is where the bulk of biological activity takes place, and it is, roughly, the depth to which soil is tilled. When talking about soils from a gardener's point of view, one is almost invariably talking about these uppermost layers of soil. And within that thin band of topsoil, gardeners and scientists move into a realm where definition can be had in two millimeters or less.

Charles Kennard

The erosive power of wind and water is evident in these five-foot-deep gullies at the base of Nicholl Knob near Richmond Inner Harbor.

Soils in Particular Soils are characterized predominantly by their textures—they are known, that is, by the combination of mineral particles, called sand, silt, and clay, that they contain. (All rocks, and hence the solid portion of soil, are made of minerals, which are either single elements or compounds of elements found on the periodic table.)

Sand, which is typically mineral quartz, can be from two to .05 millimeters in size. At two millimeters it is still smaller than the head of a pin, but that's as big as soil-sized mineral particles get. Silt is next, in the .05 to .002 mm. range. Anything smaller than that is clay—its particles are so small that they can't be seen without the assistance of an electron microscope.

Though most soil particles can't easily be seen with the naked eye, they can be felt—between the fingertips and in the lower back. Shovel soil all day and you'll know how heavy it is, especially when wet. Squeeze fine-textured, or clayey, soils between your fingers, and they feel sticky and slippery. You can shape them. Coarse-textured or sandy soils, on the other hand, are loose and porous and feel gritty to the touch. You can see sand particles with the naked eye. Silt, in-between both in terms of feel and appearance, is smooth and buttery on the fingertips.

The grittiness of sand and the stickiness of clay tell us a great deal about their properties as soils. The various amounts of sand, silt, and clay a soil contains influence how much water it can hold, how easily it releases nutrients, and how much air it contains.

Bay Area Soil Types Though many varieties of soil can be found in the Bay Area, the majority of them are medium- to fine-textured soils that have formed in place directly from the rocks beneath them. Such soils are called *residual*. They are distinguished from depositional soils, which have been transported by gravity, wind, rain, or rivers to the place they're found today.

Most of our residual, fine-textured soils formed from sedimentary rock that was once, eons ago, a depositional soil itself, before time and pressure turned it into rock. In many cases this rock has weathered to clay minerals and clayey soils that are nutrient rich, slow to absorb water, and slow to release it.

A few of the Bay Area's clayey soils are depositional. They occur in basin lands such as our bayshore wetlands, where very fine, clay-sized sediments, transported by streams that drain into the Bay, finally settle out, forming a heavy clay soil over time.

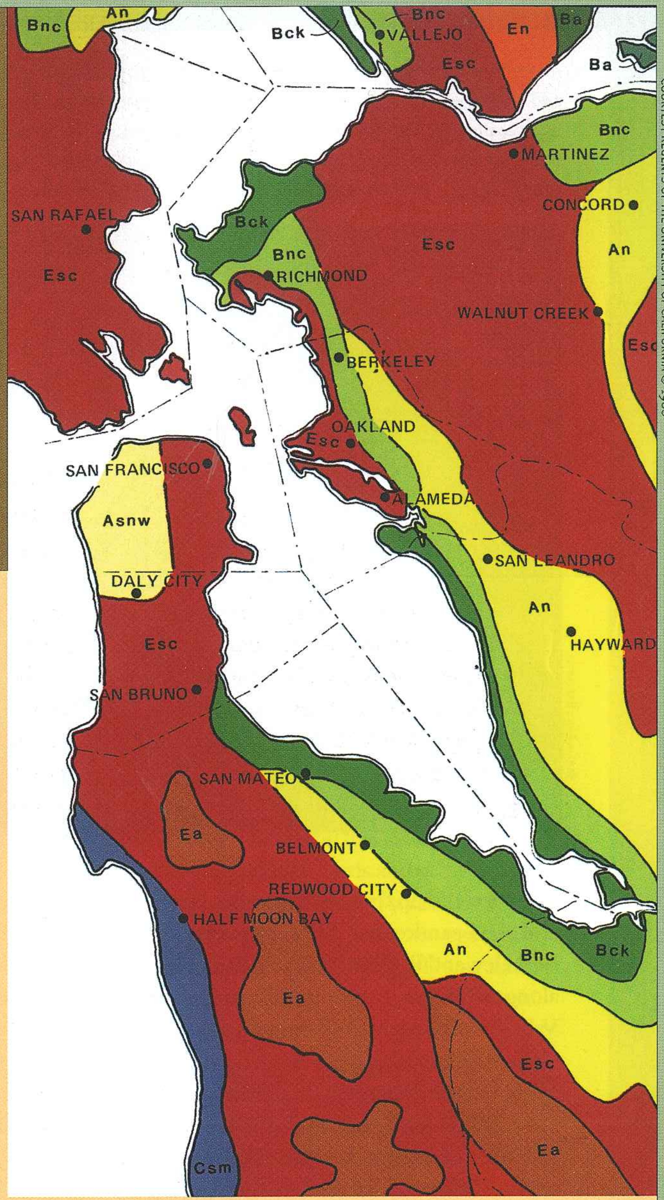
At the opposite end of the spectrum are the large-particle sandy soils. They are usually depositional, left along creek banks and beds by streams whose flow is slowing, or carried by wind, forming dunes in pockets along the coast. Onshore winds blowing across beaches outside the Golden Gate account for the sandy soils in western and central San Francisco, which, underneath the veneer of urban development, is essentially a great dune complex.

Loamy soils, which are the optimum blend of sand, silt, and clay, can be found in alluvial or depositional valleys and bay fronts around the Bay. The Santa Clara Valley, well known for its agricultural productivity in the first half of the 20th century, is a floodplain soil that has nutrient-holding clays and also the good drainage of silt and sand. These fertile

Mapping Soils

In 1951, R. Earl Storie and Walter W. Weir, soil scientists associated with the University of California, developed the *Generalized Soil Map of California* and a handbook of the same name to accompany it. The map, republished in 1988, includes a detail of the Bay Area, reproduced at right. (A poster of the map can be ordered at http://anrcatalog.ucdavis.edu).

The map identifies four land types—valley, basin, terrace, and upland—and 12 soil characteristics, including pH, texture, and depth, which are combined to describe California's many soils. This system, and the map itself, are simplifications of a much more complex reality on the ground. But precisely because Bay Area soils are so varied, this map provides a useful starting point.



Courtesy Regents of the University of California © 1988

An Deep alluvial fan and flood plain soils, usually neutral reaction (e.g., Yolo loam). Intermediate rainfall.

Asnw Sandy wind modified soils, neutral to slightly acid reaction (e.g., Oakley sand). Intermediate rainfall.

Ba Organic soils, generally acid reaction. Poorly drained (e.g., Peat Muck).

Bck Saline and alkali soils (e.g., Lahontan loam).

Bnc Imperfectly drained soils, reaction from neutral to calcareous (e.g., Sacramento clay).

Csm Dark colored slightly acid soils having moderately dense subsoils (e.g., Rohnerville clay loam). Medium high rainfall.

Ea Residual soils of good depth to bedrock. Acid reaction (e.g., Holland sandy loam). Aiken clay loam. Timbered areas. High rainfall.

En Residual soils of medium to fairly shallow depth, to bedrock, often stony. Brownish soils of neutral or basic reaction (e.g., Vista sandy loam, Vallecitos stony loam). Grass, woodland-grass, shrub-grass vegetation. Generally 10-20 inches rainfall.

Esc Residual soils of moderate depth to bedrock. Variable reaction. Dark colored grassland soils (e.g., Cayucos clay, Diablo clay). Generally 15-40 inches rainfall.

Ex Residual soils of very shallow depth, to bedrock, usually stony. Variable in color and reaction (e.g., Maymen stony loam). Usually brush cover.

(below) The decomposition of organic matter caused by soil organisms—from bacteria and fungi to worms and insects—is essential to the formation of healthy soil. Here, a sow bug and a small mushroom (identified by a mycologist as a VLBM, or "very little brown mushroom") help enrich the soil in a Lafayette backyard. (right) Soil samples from the City of San Ramon's Crow Canyon Community Gardens. On the right, unamended clayey soil; on the left, the same soil after it has been enriched with compost and other organic matter.


SARAH ANNE BARDWELL


CHARLES KENNARD

loams extend up through Fremont, Hayward, and San Leandro into parts of Oakland, Berkeley, and Richmond. They also occur along the Bay on the Peninsula, in the Tri-Valley area of Alameda County, and in eastern Contra Costa.

Along the coast from Half Moon Bay to Monterey Bay is a thin strip of fertile loam that has been likened to the rich prairie soils of the Midwest. Like the heartland prairies, our coastal terrace prairie is high in organic matter—decomposing leaves, stems, roots, snail shells, earwig carcasses, and so on. Soils found along the California coast have about 4 percent organic material, while inland soils have 1 to 2 percent. In general, the mineral fraction of soil—the particles—usually accounts for about 45 percent of the total volume of a soil and organic matter for about 5 percent. The remaining 50 percent is pore space, or the openings between soil particles. Those pores are filled with varying amounts of air and water, depending upon precipitation, drainage, evaporation, and transpiration by plants.

In parts of the Delta, there are soils that consist almost entirely of organic matter. Similar to the peat one can buy at nurseries, this deep soil was formed from the slow breakdown of tule reeds, cattails, and other wetland vegetation. Scientists classify them as *muck,* but, despite the name, these soils have been farmed for decades. The decomposed vegetation that makes up Delta muck is high in carbon, which, when exposed to the air, reacts with oxygen and breaks down, losing volume and gradually subsiding. Today, much of the Delta's farmland is below sea level and remains arable only because of the levees that surround it.

Soil Biota The decomposition of organic matter, which is essential to the formation of soil, is brought about through chemical reactions such as that of oxygen and carbon, but it is more often facilitated by living organisms. Soil is inhabited by a huge number of creatures, each of which contributes to a soil's character and overall health.

Soil organisms range from single-celled animals such as bacteria and fungi to soft, sinuous worms and hard-bodied insects. The creatures we see stalking the soil's surface, such as sow bugs and beetles, are the macrofauna; the smaller folk are truly small, but their impact is mighty. A single pinch of healthy soil harbors more than 10 million bacteria, for example, and they are just one of the many types of microorganisms that, in the course of living and dying, move materials, capture and recycle nutrients, transfer energy, and give the soil structure and integrity.

Different organisms play different roles. One of the functional roles of soil bacteria is that of decomposer: Bacteria consume organic matter, breaking it down into forms that can be used by other soil organisms. The protozoa—a group of larger single-celled animals that includes the well-known amoeba—are grazers. They feast on bacteria and release to the soil some of the nutrients captured by the decomposers.

Soil organisms also interact in ways that go beyond the etiquette of eat and be eaten. Some organisms depend upon one another or have an association that is beneficial to both. The rhizobium bacteria and mycorrhizal fungi provide examples of these mutualist relationships.

Like several other bacteria, rhizobium are capable of collecting, or fixing, nitrogen from the air and incorporating it into their bodies. When these bacteria die, the nitrogen they have captured remains in the soil, eventually becoming available for uptake by plant roots. The rhizobia go a step further, though, by taking up residence under the surface of pea-family plant roots and passing their nitrogen directly to these plants. Nitrogen is an essential nutrient for plants, but the mineral fraction of soil contains none. So, while there may now be nitrogen in any given soil thanks to organic matter, that nitrogen, initially, had to be plucked from thin air. Nitrogen-fixing bacteria, it could be argued, are responsible for life as we know it.

Of equal importance to the life of the majority of plants (and thus most animals) is an association of plant and fungi called mycorrhizae (the word means "fungus root"). Like the rhizobium bacteria, certain fungi can move into a plant's roots, in this case either by forming a sheath around the roots or by growing directly into and through them. In this mutually beneficial arrangement, the fungi obtain sugars from the plant, while the plant gets an extension of its roots and root surface area. Mycorrhizal fungi substantially increase a plant's ability to take nutrients and water from the soil.

A Structure for Life Other fungi, chiefly the decomposers, play a very important role in building and maintaining the structure of the soil. Fungi bind soil particles, forming units called aggregates. In a soil with good structure, these joined particles are like the stones in a wall—but without mortar. Good soil structure also includes adequate pore spaces. Ideally, soil aggregates form an irregular framework through which air and water can flow easily and in which plant roots can move freely.

The ideal is not always reality, however. Texture does influence structure. Supersmall, chemically active clay particles, for example, can stack up and stick together, creating a massed structure and tiny pore spaces that allow little passage of air, water, or plant roots. A loose, sandy soil, on the other hand, has large particles, loads of pore spaces, and almost no structure at all. As a result, water and nutrients pass right through. The soil dries out quickly. Plants not adapted to such conditions soon wilt and die.

That's why soil biota are so important. Fungi and bacteria bind particles together, create open spaces, and generate humus, which also improves soil structure. Humus (pronounced like *hu*man) is a more-or-less stable form of digested organic material that can remain in the soil for centuries. It can loosen up a clay soil or hold together a sandy one. To return to the image of the stone wall, humus is the mortar—acting as a gelatinous lattice, one that helps soil particles cohere but also makes space between them.

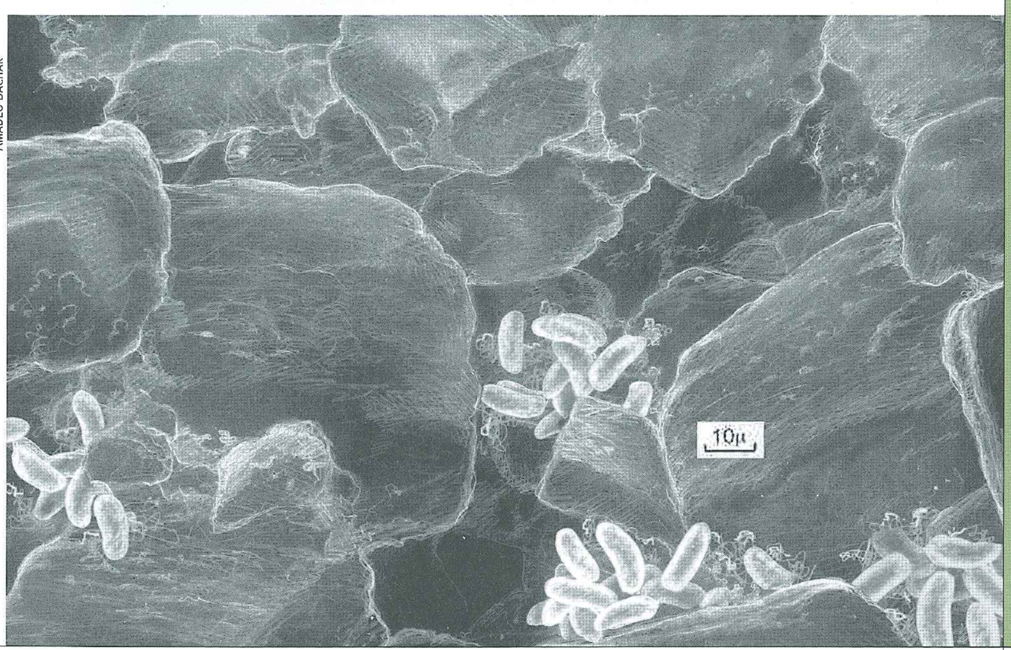
A Body Alive From bare outcroppings, soil begins as fallen bits and pieces of rock. Through the interactions of physical and chemical processes, and through the ceaseless activity of microorganisms, invertebrates, and insects, these random particles are augmented and ordered into a coherent body that influences and is responsive to its surroundings.

Soil acts, in the words of one expert, "as our earth's primary cleansing and recycling medium." We have seen how soil biota return nutrients to the soil; some soil bacteria and fungi also break down pesticides and pollutants. Soil's detox capabilities have also been put to service in the field of medicine—penicillin was first derived from a soil bacterium, and dozens of subsequent antibiotics have also come from a single soil-dwelling genus, *Streptomyces.*

Soil is also inseparably linked to water supply and water quality. The amount of water in our aquifers, rivers, and lakes depends partly on the health of the soil. A topsoil that has good structure and is covered by vegetation will absorb almost all the water that falls upon it. Once absorbed, the entire soil body acts like a sponge, first holding large volumes of water, then slowly releasing it to aquifers and surface water bodies. The living soil also cleanses the water passing through it, filtering out particulate matter and absorbing pollutants.

Life Above Ground Besides the tiny creatures who live at or near the surface of the soil, there are many larger animals—the moles and gophers who live underground and the deer, rabbits, birds and other vertebrates—that burrow into it, scratch it with their hooves and talons, graze its vegetation, and leave their droppings on it. These activities enhance nutrient cycling, soil structure, water infiltration, and aeration.

There is one above-ground vertebrate, in particular, that has mulitple impacts on the life of the soil. Human beings have cleared the ground, built upon it, farmed it, grazed it, and gardened it. In some cases our influence has been positive or benign; in many cases it has led to degradation. As a result of human activities, topsoils are blown or washed off our agricultural fields and *(continued on page 32)*



AMADEO BACHAR

Mineral particles generally make up approximately 45 percent of the soil. The pores and pockets between the particles are filled with air, water, and organic matter such as bacteria, as depicted in this artist's rendering of an electron micrograph. The size of the particles indicates a sandy soil (the scale is 10 microns, or one hundredth of a millimeter).

GARDEN STORIES

TAKING SOIL PERSONALLY

BY ANNE HAYES

The old saw about weather in San Francisco—if you don't like it, walk a block—could also be applied to Bay Area soils. Nonconformity in Bay Area rocks, along with varied topography, climate, and vegetation, has resulted in a great variety of native soils.

In addition to natural processes, human factors also greatly influence the composition of a soil. The soils of our residential landscapes have often been graded, reshaped, cut, or filled, resulting in melanges that confound even soil scientists. Given this variety, it is safe to say that there is no one correct way to approach the soil in your own yard. However, gardeners and soil scientists agree that all soils can benefit from nurture, and that getting to know your local soil is rewarding in itself and can yield big payoffs in the garden. This series of profiles of gardeners begins with two caretakers who helped bring degraded soils back to life.

Tackling Compaction and Degradation

When **Ben Weil** and his family moved into a flat on Telegraph Avenue in Oakland, the 15- by 20-foot backyard was overgrown with weeds and featured a moldering synthetic carpet. When Weil began to work the soil, he found a lot of debris. "We dug out scraps of wood and shingles; we were filling the garbage can each week." A year later, Weil says the earthworms are now digging up old nails, bits of glass, and other remnants of the land's past uses: "They keep bringing stuff to the surface, from way down below."

SCOTT BRALEY

BEN WEIL

The dirt in Ben Weil's small Oakland backyard wasn't always so easy to turn. Weil amended the compacted clayey soil with organic matter and dug in cover crops before it was ready to nurture an array of springtime wildflowers, native plants, and vegetables.

Despite excellent qualifications—Weil has an undergraduate degree in soil science and his father coauthored a well-known textbook on soils—this garden is the first where Weil has had full play. "Things didn't work well the first season," he says. "It was so compacted, there was no aeration, and the soil had lost aggregate strength entirely. It was really pretty dead."

To get a shovel into the ground, Weil had to jump on it with both feet. He dug to the depth of the shovel and then used a three-pronged hoe to work in amendments—worm castings and aged chicken manure. Weil also experimented with planting a seed mix that helped open the soil and return nutrients to it.

"My dad was doing some cover crop research. He had a mix of daikon radish, crimson clover, and rape. The radish," Weil explains, "was to aerate the soil, the clover was to fix nitrogen, and the rape was to hold the nitrogen and return it to the soil when it was turned under."

Weil planted in November and, in March, when the plants had just begun to flower, he cut them back to ground level and composted the leaves and stems. Where he planned to put in flowers or vegetables, he dug the cover crop into the ground and then planted. This time around, the soil—which Weil characterizes as clayey loam—was much easier to turn. "Those big daikon radishes loosened the soil," he says, "and the worms found the place. They really turned the soil for me."

Sharon McCray, certified as a Master Gardener through UC Cooperative Extension, is a big proponent of cover crops as well. When she worked with the City of Campbell to start the Edith Morley Park Community Garden in late 2000, she recommended planting green manures—another name for cover crops—over the winter.

Located in the floodplain of Stevens Creek, the sandy soil of Edith Morley Park was in dire need of some loving attention. For 50 years, it had been the site of a drive-in theater, buried beneath a six-inch layer of asphalt. When a business park across the street was completed, the City of Campbell began to develop the park.

McCray and her fellow gardeners faced some challenges with the low-nutrient, severely compacted soil. McCray recommended seeding clovers and other legumes as cover crops. "Between flower and fruit set is the best time to cut down the plants and let them rest on top of the soil," McCray explains. "This adds organic material to the soil. And the nitrogen-producing nodules in the roots will break down naturally to increase the nitrogen in the soil."

Adding commercially produced nitrogen is avoided at the garden. When it comes to fertilizers, McCray says, "more is not better." Nancy Garrison, former program coordinator for the UC Cooperative Extension Master Gardeners in Santa Clara County, seconds this point of view. Master Gardeners "promote the responsible use of organic fertilizers where needed," she says, and "discourage overuse of nitrogen because it gets into groundwater and can become a contaminant in our creeks and the Bay." Stormwater runoff also carries garden fertilizers and pesticides into our waterways.

Nitrogen impacts aquatic systems by overloading them with nutrients, which cause some water plants to bloom profusely. This overgrowth can clog the waterways, blocking sunlight and destroying habitat for many aquatic organisms. As it dies off, this plant growth also uses up oxygen in the water, depriving fish, insects, and other plants that need it to live. "The number one polluter to San Francisco Bay is the home gardener,"

PHIL ROBERTSON

Walt Davis and Master Gardener Sharon McCray inspect the robust cabbages they are growing without chemical fertilizers or pesticides at the Edith Morley Community Garden in Campbell.

McCray claims. "If you have to fertilize, use half as much twice as often. Corn and grass are heavy nitrogen feeders; otherwise nothing needs it."

McCray suggests that gardeners sometimes overfertilize because the plants they buy at the nursery have been raised on plant foods in artificial environments. "Nursery plants," she says, "can suffer shock when they're put in the ground." Asking how nursery plants are cared for, and choosing plants—especially natives—that can make do without chemical inputs, is a good way to reduce the temptation to fertilize at home.

Instead of feeding plants, feed the soil. Add organic materials, in the form of mulch or compost. McCray and Garrison agree that homemade compost is the one soil amendment you can never have too much of. The plants at Edith Morley are clearly not starved of nutrients: Tidy rows of garden plots—filled with fruit, vegetables, and flowers—greet the visitor. "This is what can be done when you reclaim a place," says McCray, with satisfaction. "You *can* take it back."

Working with Clay

Many Bay Area residents are familiar with clay soils. They dominate central Contra Costa and parts of Alameda County. They can be found in lowlands all around the Bay and in some uplands of Santa Clara County; they are also common in Marin.

"Clays are unique," says Lisa Hokholt of the U.S. Department of Agriculture's Natural Resources Conservation Service in Contra Costa County. "In general, they contain charged particles. Sand and silt don't." This makes clay chemically reactive, which means, among other things, that clay particles hold on to plant nutrients and have an affinity for water. And because clay particles are so very, very small, they have a tremendous amount of surface area to which nutrients and water molecules can adhere—a pound of clay has a particulate surface area of more than 90 acres.

"Clay can be very productive," Hokholt adds. "Unless you live in an area with a high water table, you're going to be able to garden in clay soils. You're dealing with hard digging conditions," she acknowledges, but not impossible ones. To every gardener, she offers this advice: "Work with what Mother Nature has dealt you."

SCOTT BRALEY

Master Gardener Bethallyn Black collects all the organic matter she can get her hands on—including cuttings and leaf litter from her neighbors' gardens—to add to the clayey soil in her own Walnut Creek yard.

Bethallyn Black has been working with clay soils almost all her life. She is a lifelong Contra Costa resident who, for the last eight years, has managed the UC Cooperative Extension Master Gardener program in the county.

Clay soils are incredibly rich, says Black, but air and water are slow to move through them. Plant roots, Black adds, can also have a hard time spreading through clay soils. The best remedy, she says, is organic material. "In our Mediterranean climate, we don't have organic matter falling all the time," she explains. "So you should be adding as much organic matter as you can get your hands on. Get free, chopped up organic matter any way you can."

For annual plantings, Black recommends working organic material into the soil—amending it—every fall. For perennial beds and other permanent plantings, she suggests piling mulch three to four inches thick and renewing as needed. Coffee grounds are a good amendment for clay because they're high in nitrogen and they lower pH. (According to Black, most clays have a high pH; a neutral soil is optimum for most plants.) For mulching, she recommends shredded pine needles because they're slightly acidic.

For success in clay, Black also stresses the importance of plant choice. "We live in an area where there's an explosive plant palette. It's possible to grow so many different plants here, but those possibilities have to be coupled with an understanding of the site."

Black believes that the bones of a garden—the permanent plantings—should be locally appropriate. Contra Costa County, for example, "was formerly a dry grassland," says Black, "not an urban forestry corridor. Until Sierra water was brought in, it was impossible to garden here. Gardens here are as out of place as bougainvillea and palm trees in the desert."

Black's home garden lies in a floodplain below Mount Diablo where, after a series of winter rains, groundwater reaches the surface of the clay soil. She says she's had less success with the native chaparral shrubs, such as manzanita and fremonto- (*continued on page 28*)

SERENGETI IN THE SOIL

PILL BUG · YELLOW-SPOTTED MILLIPEDE · RED MILLIPEDE · NATIVE SNAIL · WORM CASTING · GARDEN CENTIPEDE · WOLF SPIDER
SMALL EARTHWORM · EARTHWORM · PILL BUG · BEETLE LARVA
RHIZOBIUM NODULE · MITE · SPRINGTAIL · NEMATODE · SOIL CENTIPEDE

SNAILEATER BEETLE · LEAFCUTTER BEE · HARVESTER ANTS · MONARCH CATERPILLAR
SMALL EARTHWORM · LEAFCUTTER BEE BURROW · EARTHWORM
EARTHWORM · ANT NEST · FUNGUS · BACTERIA · RHIZOBIUM · PROTOZOA

ILLUSTRATION BY AMADEO BACHAR

NOTES FROM UNDERGROUND

WILDLIFE BENEATH OUR FEET

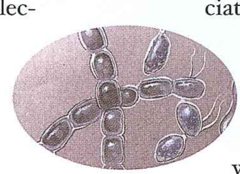
BY MIKE KOSLOSKY

It is often the smallest things that get overlooked, and life in the soil is probably the most neglected habitat of all. Tilling the soil or weeding the garden puts us in touch with a few members of the soil environment, and we might notice a spider, snail, beetle, or worm now and again. But underneath the surface there is a dynamic interplay between predators, prey, producers, consumers, and decomposers that we rarely witness. And their interactions are as complex and diverse as those found in the African plains, the tropical forest, or the rocky intertidal.

However, their habitat is measured in millimeters, not acres. The interactions between these organisms are frequently on the microscopic tips of root hairs, or in the thinnest layer of water film encasing a particle of soil, or in the miniscule air space between roots and organic debris. All this activity takes place within the top three inches of soil, but its diversity and productivity supports the rest of life on Earth.

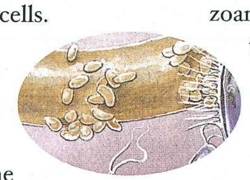
Earthworms, of course, are the mighty tillers of the soil, and great lengths have been taken to promote them, nurture them, and train people to raise them. They are the champions of soil excavation. They burrow through the soil, feeding on dead and decaying organic material and dragging dead leaves and grasses down from the surface. The extensive network of tunnels they create helps water penetrate into the soil, allows air to circulate through it, and improves soil "texture" by binding it into aggregates. Their wastes are deposited as nutrient-packed, ammonium-laden "castings" that serve as a prime plant fertilizer. These tiny heaps of droppings can often be seen littering the ground after a rain, dotting the landscape like hundreds of miniature volcanic eruptions.

Earthworms are extremely valuable, and they have a great marketing department, but there are many other species that collectively interact to make soil what it is.



Mites, nematodes, fungi, bacteria, and protozoans are the workhorses of the subsurface world, but due to their microscopic size they go mostly unnoticed. Their work frees up the components in complex molecules that plants can use directly. For example, earthworm castings are valuable packets of nutrients—including ammonium, or NH_4^+, a vital molecule for plant growth—but plants are able to access those nutrients only when they are released by the bacteria and fungi that feed on the castings.

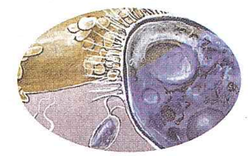
As Earth's atmosphere surrounds our planet in a protective, life-sustaining envelope, so the rhizosphere surrounds plant roots with a film of water and soil particles. Bathed in this lubricating sheath, root hairs grow through the soil seeking nutrients, oxygen, and more water. As the root hair makes its way, old damaged cells are sloughed off like dandruff to be replaced with new cells. **Bacteria** congregate just below the tips of the root hairs to feed on these dead plant cells.



Bacteria also feed on the wastes of other animals, degrade and neutralize pollutants, and improve the soil texture, or tilth, allowing air and water to reach the root zones of plants. Some bacteria are known to inhibit the hatching of parasitic nematode eggs, thus acting as a subterranean natural pesticide.

Certain **fungi** form a symbiotic relationship with plant roots called mycorrhizal associations. The fungus body is made up of many strands of filaments called hyphae. Grab a handful of leaf litter and you can see the expansive network of fine, white, hairlike threads of hyphae coating the underside. Fungi cannot photosynthesize, so they have to get their sugars and starches another way: The hyphae penetrate the outer wall of the plant root and transfer nutrients, especially phosphorous, from the soil to the plant while receiving carbohydrates from the plant in exchange. The long, trailing hyphal strands also serve as extensions of the plants roots, providing more surface area for nutrient and water uptake. Plants can extract phosphorus from the soil on their own, but it is a slow process. Mycorrhizal associations speed up this process because hyphae are more efficient at transporting phosphorus.

Several species of **protozoans** live in the soil, feeding on bacteria, fungal strands, and other organic wastes.



These single-celled organisms also inhabit the air spaces between soil particles and the rhizosphere surrounding roots. They move along by beating cilia or long filaments called flagella. Some are the amoeba familiar from our freshman biology class. Sliding along on extensible pods, they engulf bacteria, absorb them, and digest them. Protozoans excrete more ammonium than they use, benefiting plants that take up this natural fertilizer.

Cruising through this damp and dark habitat are the **nematodes**,

microscopic nonsegmented worms with voracious appetites. Some specialize in feeding on bacteria, while others seek fungal hyphae to bore into them and suck out the contents of their cells. There are also predatory nematodes that target protozoans and other nematodes. Once again, their need for ammonium is less than what they ingest, so the excess is excreted as waste, giving plants quick access to it.

Root nematodes have been the subject of much research because they damage plant roots and transmit soil diseases. However, like insects, most nematodes are beneficial; they are more numerous than their disease-causing kin and are an integral component of healthy soil.

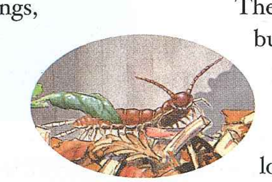
Soil arthropods are fewer in number than the protozoans and nematodes, but we at least have a chance of seeing them without a microscope. Characterized by articulating joints and a hard outer exoskeleton made of chitin, arthropods comprise more than 75 percent of life on the planet. Soil arthropods such as mites, millipedes, springtails, ants, termites and centipedes play a vital role in building complex, diverse, and healthy soils.

Mites are one of the more numerous of the soil macroinvertebrates. They are arachnids, eight-legged members of the arthropod group that includes spiders and scorpions. Measuring a robust millimeter or so in diameter, mites perform many functions in the soil. Some are involved in skeletonizing leaf material; others prey on nematodes or scavenge fungal spores and bacteria. Several hundred species of mites, and more than 15,000 individuals, can be found in a single shovelful of soil.

Millipedes are like the professional tree trimmers of the underground neighborhood.

They are able to eat and digest the bigger, bulkier leaf material and reduce it in size for smaller soil organisms to work on. They, too, leave tunnels and burrows near the surface where they have been grazing, enhancing aeration and water penetration. Since they do not have a waxy waterproof coating on their exoskeleton, we encounter them during the cool, wet seasons of the year. Their cylindrical bodies have two legs per segment; as grazers they are slow-moving creatures that amble through the garden as if they had all the time in the world and no place special to go. When threatened or disturbed they will coil into a protective spiral and exude noxious chemicals from pores lining both sides of the body. Bitter and acrid, these chemicals are powerful enough to kill some insects and discourage other animals from trying to eat them.

Centipedes might look something like a millipede but they have much longer legs—one pair per body segment—and are fast runners. The first pair of legs has been modified into a pair of poison-injecting fangs,



allowing centipedes to be active predators that hunt for larger soil arthropods such as beetles, crickets, or spiders. Most range in size from one to three inches. One of our local natives is brown and another is a vivid orange-red. Their bodies are flattened from top to bottom, allowing them to be at home scrambling through loose soil or mats of leaf litter. As with millipedes, their burrows serve to aerate the soil. And, as predators, centipedes help keep other organisms in check.

Sow bugs and **pill bugs** are familiar soil-dwelling crustaceans that are also important for breaking down larger elements of organic debris. Armed with chopping mouthparts,

they make quick work of heavy fibrous plant material, rendering it more easily digested by the smaller denizens of the decomposition food web. Since they evolved from marine crustacean ancestors, their respiratory organs are better suited to a wet environment. Unlike their gill-breathing aquatic relatives, they can breathe atmospheric oxygen, but they don't have insects' more efficient tracheal systems. Given their preference for humid habitats, they are well equipped for their role of recycling detritus in damp, cool leaf litter. The body is covered with overlapping plates, a protection against predation and desiccation.

Females carry eggs in a pouch under the body called a marsupium where they are kept cool and moist until hatching. Pill bugs can keep themselves from drying out by rolling into a ball.

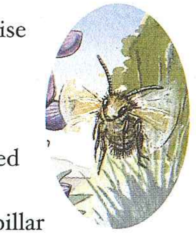
Although they are detritivores and valuable as decomposers, both species can be troublesome to gardeners due to their fondness for seedlings.

Ants are significant insects of the soil.

Harvester species collect the seeds of grasses, annuals, and perennials, ferrying them underground to be stored and eaten when needed. Other species feed on fruits, nectar, or animals and in so doing recycle this organic material into the ground. Underground colonies house thousands of workers that regularly excavate mineral particles to the surface during expansion of their homes. The exchange of mineral soil for organic humus improves soil quality, while extensive networks of galleries and tunnels provide passageways for both water and air.

The **Jerusalem cricket**, or potato bug, is a huge burrowing invertebrate that, while infrequently encountered, causes great surprise when unearthed. These formidable-looking animals, easily identified by their striped, bulbous abdomen, shiny head, and spine-covered legs, can be as large as your big toe. Armed with a set of powerful jaws and the ability to run quickly, they appear intimidating but bite only if grabbed. They feed on roots, bulbs, tubers, soft-bodied insects, and occasionally, dead organisms. Although their habitat is primarily underground, they will come to the surface at night to forage. They are solitary and territorial, coming together only during the breeding season. They communicate by stridulating: scraping spines on the rear legs against roughened bristles on the side of the abdomen. Females lay their eggs in a small, excavated chamber and provide maternal care for them. Like earthworms, Jerusalem crickets are beneficial organisms, loosening the soil, and recycling organic debris.

Some animals use the soil as a temporary nesting site. **Bumblebees** frequently adopt abandoned mouse nests or gopher holes in which to raise their young.



Many native **solitary bees** are ground nesters and deposit eggs in an excavated chamber stored with a bolus of pollen and nectar or a paralyzed caterpillar as food for the soon-to-hatch larvae. These legless grubs remain in the burrow dining on the provisioned meal until they metamorphose into the adult winged form, usually emerging the following spring. As pollinators they split their time between flowers growing aboveground and the nest site underground. They depend on healthy soil for both their feeding and nesting activities.

Also inhabiting this interface of subterranean and aboveground worlds is a variety of opportunistic hunters. **Wolf spiders** actively pursue their prey—crickets, earwigs, beetles, ants and sow bugs—by chasing them down and overpowering them,

relying on keen eyesight and swiftness instead of aerial webs. Predaceous **beetles** are common in this leaf litter and topsoil zone; one local species in the genus *Scaphinotus* specializes in feeding on native snails. Its head, mouth and thorax are extremely

narrow, allowing it to enter the small opening of the fingernail-sized snail. The snail itself is not a significant pest since it occurs in small numbers and feeds on organic debris rather than garden plants. The introduced European snail, however—a behemoth by comparison—is the source of many a gardeners' frustration, owing to its preference for leafy green vegetation and flowers. Unfortunately, it is much too large for the *Scaphinotus* beetle to control.

All these organisms are not just present in soil; they are active agents in making the soil productive, and even become essential components of the soil when they die. By contributing and breaking down organic debris, they make carbon and nutrients available to the plants, which then transport those components aboveground, where they become available for humans and other wildlife. So when you tread on the soil, do so lightly, and in appreciation of all the work that is going on below.

SCOTT BRALEY

Pat Bacchetti realized that planting natives such as hazelnut and toyon was the way to go in the hard clayey soil of her hillside garden in the Rockridge area of Oakland.

(continued from page 23) dendron, which require good drainage, but miscanthus, or deer grass, has done well in her yard.

Chris Dundon, a landscape architect with the Contra Costa Water District who also lives in central Contra Costa, says perennial bunchgrasses are one of the best plants to start with, because they're what's native to the area. He's also had success with many native buckwheats and California coffeeberry.

PAT BACCHETTI has been a gardener all her life, growing vegetables with her family at their farm in Tracy and then focusing on flowers as an adult. Bacchetti chose what was pretty, and she had a passion for orchids—and then she moved into her current home near Rockridge in Oakland.

Most of her lot is taken up by a steep, north-facing slope that was planted with acacia and stunted fruit trees. According to Bacchetti, "I took a year to ask myself, 'What is it I have here? What can I do with this space?'" She also took a class—and began her own transformation as a gardener.

"I took a shrub class taught by Glenn Keator at the Academy of Sciences," Bacchetti explains, "and it opened my eyes up—to the *world.*" She learned to recognize California hazelnut and other native shrubs that grow wild on our hillsides. "That got me into restoration," Bachetti says. She realized she had stumbled upon a way to garden on her steep slope "and give it back to nature."

"The slope is clay," Bacchetti says, "It's really hard!" With the help of two people and three shovels, Bacchetti put in 80 mostly native shrubs, both small and large. Before planting, she applied a thin layer of compost, which she bought from American Soil Products, on the surface. She waited until after two good soaking rains, so the nutrients from the compost would have a chance to sink in and the clay became saturated. Then she planted. Afterwards, Bacchetti put down a mulch of shredded bark to prevent erosion.

During this winter's rainy season, Bacchetti plans to replant two terraces at the bottom of the garden, which the previous owners had laid with sod. She will be putting in a meadow of native bulbs and grasses. Work on that project began last summer, when Bacchetti killed the lawn by not watering it. In the fall, she sheet mulched—that is, she put down a biodegradable barrier, a layer of cardboard—and then planted directly into the cardboard. After that she spread a layer of wood chips over the top of the cardboard.

She's looking forward to seeing what the spring will bring.

Minimizing Soil Disturbance

It is widely recognized that tilling the soil too often can destroy it. A growing number of gardeners are choosing to do less with their soil, in order to help it live more. Such gardeners avoid digging in the soil, aside from what's necessary to put plants in the ground; many grow local native plants that are adapted to their soil, and they leave organic material in place.

ARVIND KUMAR has a three-year-old native garden in San Jose. He characterizes his soil as "good old Santa Clara Valley clay" and says that it was probably graded and leveled by bulldozers.

Kumar's approach to his site and soil has been to plant what is locally native and appropriate. He is one of the organizers of the Going Native Garden Tour that takes place each spring in the South Bay and an eloquent spokesperson for the advantages of gardening with native plants.

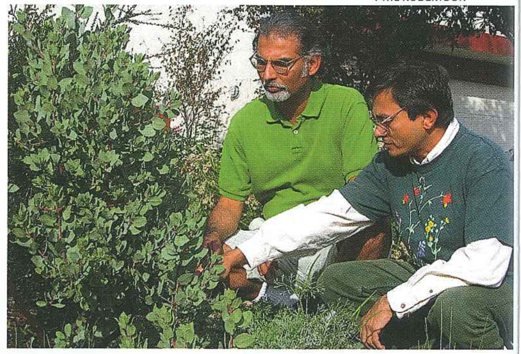
"As much as I love redwood forests and Sierra meadows," Kumar says, "I have no wish to replicate them in my San Jose yard. I want to try to reproduce, even if only on a small scale, what might have existed in the Santa Clara Valley before it was paved and urbanized. I look out for plants that do well in clay.

"My view," explains Kumar, "is that no garden or soil is difficult. For every type of soil, there is an appropriate type of plant. You just need to find it. It is much easier (not to mention environmentally sound) to change the plants to suit the site than the reverse. Azaleas are beautiful—in moist redwood forests. Trying to grow them in San Jose is not only hard work, but a colossal waste of water and other resources."

Though Kumar focuses on plant choice as a primary means to work with his soil, he does amend it with organic matter. He uses mulch to control weeds and he loosens the clay a little with homemade compost before planting. "But," Kumar says, "I don't try too hard to make my clay soil into something it isn't and will never be: the fast-draining, humus-rich soil that vegetable gardeners love.

"I belong to the native school of gardening," Kumar concludes, "which says disturb the soil as little as possible, and allow the mycorrhizae to build up and sustain the plants."

PHIL ROBERTSON



ARVIND KUMAR

(right) The native wildflowers growing profusely in Arvind Kumar's San Jose backyard include sticky monkeyflower (left foreground) and California poppy. (above) Kumar and his partner, Ashok Jethanandani, inspect a thriving three-year-old bigberry manzanita in the front yard.

RANDY ZEBELL is someone who understands mycorrhizae. He thrills to the sight of all manner of biota, be they insect, bird, or fungus. He characterizes himself as a home habitat gardener; he's also a professional gardener for the City of San Francisco. In addition, he is the president of the San Francisco chapter of the California Native Plant Society. Zebell has been gardening at his home in the Sunset District for eight years.

Historically, Zebell's garden was sand, like much of western San Francisco. When he digs down six or eight inches in his small backyard, that's still what Zebell finds. Sometime before he began gardening at the site, though, Zebell suspects a layer of topsoil was added. So he has what he says is an ideal arrangement for his plants—a top layer of loam with great drainage underneath.

To get to the soil, Zebell had to excavate a fair amount of plant material. When he first moved in, the entire lot was overgrown with coprosma, or mirror plant. He pulled it all out and built what he calls a "legitimate" compost pile with the wood. "I chipped a lot of material," Zebell says, "and layered my greens and browns. It really cooked—got up to 140 degrees." (Zebell has continued to compost, but he's now got a cold pile that's populated with earthworms and beetles.)

Sandy soil—a sign of the vast dunes that lie beneath the veneer of human structures in western San Francisco—is what Randy Zebell finds when he digs several inches down in his Sunset District backyard.

SCOTT BRALEY

Once the yard had been cleared, Zebell double-dug a main bed, which, in retrospect, he feels was unnecessary. "It was a lot of work," he says, and he now feels that, to keep the weeds down, he'd have been better off just laying cardboard on the surface. He began to plant natives chosen for their tolerance of sandy soils.

Zebell also developed a veggie bed along a south-facing wall. He grows lettuce, chard, and arugula, which are appropriate for his foggy, cool microclimate. He adds his homemade compost to this bed and mulches it with wood chips.

To increase the habitat value of his garden, Zebell tries to have a range of plants flowering throughout the year. He also leaves "all the dead stuff. It's amazing," he adds, "what comes to eat it." Old seed pods and dry flower stalks also offer perches for birds and places for butterflies to lay eggs—they offer, in other words, shelter and nesting places. Zebell points to the stalks of a California bee plant in one corner of the yard. "Some of those shoots are two years old," he explains, "and they provide a structure for spiderwebs."

Allowing stalks, stems, and leaves to stay in place also has benefits for the soil. They add organic material and provide habitat for soil organisms. "The less-woody herbs and grasses lay down pretty quickly," says Zebell, "and I'm guessing the worms—which I do seem to have in pretty good numbers—work this into the soil." Between the active worms and minimal soil disturbance, Zebell feels that his soil structure has improved.

While such a let-it-be approach may go against our it's-got-to-be-tidy sensibilities, the results are nonetheless quite beautiful. A habitat garden has the harmony and beauty of wild places—with a human touch. This is a place cultivated on behalf of all creatures, but it is cared for by a gardener who says, quietly, that the other crucial element of habitat gardening is taking the time to observe.

SOIL-FRIENDLY PRACTICES

Organic matter is the most important part of the soil because it is fodder for the many organisms that keep soil alive and elastic. And because it is consumed by these organisms, soil organic matter needs to be replenished.

The makings of soil organic matter are a constant part of all of our lives, from banana peels and apple cores to tree bark and fallen leaves. By collecting and recycling these materials back into the ground, each of us can care for the soils around us, regardless of where we live or what our livelihoods may be.

The following soil-friendly practices are just an introduction to the many ways that we can have a positive impact on the land around us.

COMPOSTING

There are many techniques for making compost. All of them involve combining compost's four main ingredients: *Browns, Greens, Air,* and *Water.*

Browns are dry, woody materials that are high in carbon, such as fallen leaves, dry grass, branch trimmings, and sawdust. *Greens* are moist materials high in nitrogen: food waste (such as fruit and vegetable trimmings), new grass clippings, and fresh weeds. To make compost:

- **Chop** materials to help them break down more quickly.
- **Mix** *Browns* and *Greens* in equal amounts.
- **Maintain** *Air* and *Water* balance by keeping compost as moist as a wrung-out sponge.

Air can be the forgotten element of compost; to make sure yours has enough, turn or poke your pile about once a week.

Do Compost

Fallen and trimmed leaves
Chopped, woody prunings
Pine needles
Most sawdust
Grass clippings
Plant trimmings
Weeds without seed heads
Fruit and vegetable trimmings
Coffee grounds and filters
Tea bags
Herbivore manures

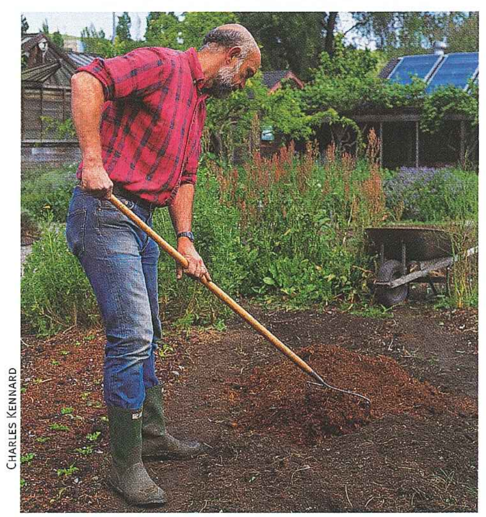
Don't Compost

Grains, beans, or breads
Sawdust from plywood/treated wood
Meat, bones, or fish
Dog, cat, or bird feces
Diseased plants
Dairy products or grease

MULCHING

An easy, low-maintenance way to build soil over time is to mulch with organic materials. Any material laid on top of the soil is a mulch; inorganic materials such as gravel and crushed rock can be used, but plant materials are better because they break down and enrich the soil.

In addition to building soil, mulch offers other benefits, such as retaining soil moisture, moderating soil temperature, suppressing weeds, preventing erosion and soil compaction, and conserving landfill space.



Joe Queirolo, former garden manager at Crow Canyon Community Gardens, spreads compost on a bed to be used for growing vegetables.

The best plant materials to use for mulch are those you can obtain locally. This doesn't mean commercial wood or bark chips from nurseries—they may have originated far, far away—but organics such as wood chips from a local tree service or leaves from your neighbor's trees. Such materials are called *green waste mulches,* and they include chipped or shredded wood from trees or even used pallets; pine needles; leaves; other plant trimmings; grass clippings; and compost.

The very best mulch of all is one you've made yourself. Soft clippings can be cut into smaller pieces by hand; if you have a rotary mower, run it over dry leaves to chop them up. Brush cutters and weed whackers can also be used to cut materials to mulch size.

As for how much mulch to use once you've made it, a two- to four-inch layer will work in most circumstances. For weed control, use a coarse mulch such as wood chips and spread a four- to six-inch layer. For moisture retention, use a finer mulch such as compost or shredded leaves, applying a layer no more than two inches thick.

GRASSCYCLING

An often overlooked but very simple way to support the soil is by leaving grass clippings on the lawn. Grasscycling quickly and easily returns nutrients to grass and soil.

To start grasscycling, take these few steps.

- **Mow often.** Mow often enough that no more than a third of the grass blade is cut. The shorter the clipping, the faster it decomposes.
- **Mow dry.** Mowing when the grass is dry prevents clippings from clumping.
- **Leave the clippings on the lawn!** You don't need special equipment for grasscycling. Simply remove the bag from your mower as you mow, or, better yet, use a push reel mower.

Another way to care for soil (and the larger environment) is to reduce or eliminate the lawn altogether. The tradition of landscaping with great swaths of grass orginated in climes much different from our own, where rainfall is frequent and occurs year-round. Here, where we experience six months or more of drought each year, watering the lawn can be a costly and wasteful proposition.

In addition, most lawns are nitrogen-greedy; over the course of time, they can deplete this important soil nutrient. What's more, in feeding the lawn (that is, in adding nitrogen) gardeners inadvertently pollute both land and water. Grasscycling can help return nitrogen to the soil, but a better solution is to replace the lawn with a drought-tolerant ground cover or mulch.

Anne Hayes

RESOURCES FOR HEALTHY SOIL

General Information Sources and Websites

BIO-INTEGRAL RESOURCE CENTER
www.birc.org
(510)524-2567
Extensive information resources for least-toxic pest management.

CALIFORNIA INTEGRATED WASTE MANAGEMENT BOARD
www.ciwmb.ca.gov/Organics/Gardening
Information and resources for organic materials management and home gardening, including grasscycling, home composting, and worm composting.

OUR WATER—OUR WORLD
www.Ourwaterourworld.org
Integrated Pest Management fact sheets; lists of less toxic products and participating stores.

USDA NATURAL RESOURCES CONSERVATION SERVICE (NRCS)
Soil biology information resources:
http://soils.usda.gov/sqi/soil_quality/soil_biology/index.html
Soil facts:
http://soils.usda.gov/education/facts/
County soil surveys:
http://offices.usda.gov/scripts/ndCGI.exe/oip_public/USA_map

UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION MASTER GARDENERS ONLINE
www.mastergardeners.org
University of California Extension program website has links to Master Gardener programs in most counties.

County Waste Management Programs

BAY-FRIENDLY LANDSCAPING AND GARDENING (ALAMEDA COUNTY)
www.BayFriendly.org
(510)444-SOIL composting information hotline;
(877)STOPWASTE recycling hotline
Public program of the Alameda County Waste Management Authority for residents and landscape professionals. Offers workshops, booklets, and more on building soil health and growing sustainable gardens. Offers discount compost bins to Alameda County residents.

CONTRA COSTA COUNTY WASTE REDUCTION AND RECYCLING
www.cccrecycle.org
(800)750-4096
Home composting, worm composting, and grasscycling

MARIN COUNTY STORMWATER POLLUTION PREVENTION PROGRAM
http://mcstoppp.org
(415)499-3202
Home composting, worm composting, less-toxic pest management.

SAN FRANCISCO DEPARTMENT OF THE ENVIRONMENT
http://temp.sfgov.org/sfenvironment/aboutus/recycling/compost.htm
Building healthy soil, home composting, worm composting, and grasscycling.

SAN MATEO COUNTY RECYCLEWORKS
http://www.recycleworks.org/compost
(650)599-1498
Home composting, worm composting, sustainable gardening, and grasscycling.

SANTA CLARA COUNTY HOME COMPOSTING EDUCATION PROGRAM
www.reducewaste.org
(408)918-4640
Home composting and worm composting.

SONOMA COUNTY WASTE MANAGEMENT AGENCY
www.recyclenow.org/r_composting.html
(707)565-3375
Home composting, worm composting, grasscycling, and less-toxic pest management.

Books

BAY-FRIENDLY GARDENING: FROM YOUR BACKYARD TO THE BAY
Alameda County Waste Management Authority and Recycling Board, 2004
Gardening tips, a design survey, profiles of East Bay gardens, and much more.
Printed guide is available free to Alameda County residents and to out-of-county residents for $10.61 ($7 plus tax and shipping) at (510)444-SOIL. Also available as a free download at www.stopwaste.org/bfg-download.html.

CALIFORNIA MASTER GARDENER HANDBOOK
UC Agriculture and Natural Resources Division, 2002
A comprehensive, science-based guide to all aspects of horticulture. Order online at http://anrcatalog.ucdavis.edu.

DIRT: THE ECSTATIC SKIN OF THE EARTH
by William Bryant Logan
Riverhead Books, 1995
Brings to life the many aspects of soil and the mystery of the world beneath our feet.

THE EARTH MOVED: ON THE REMARKABLE ACHIEVEMENTS OF EARTHWORMS
by Amy Stewart
Algonquin Books of Chapel Hill, 2004
Enjoyable and informative book about one of the most important inhabitants of the soil.

LET IT ROT: THE GARDENER'S GUIDE TO COMPOSTING
by Stu Campbell
Storey Publishing, 1998
Classic guide to home composting.

SOIL BIOLOGY PRIMER
Soil and Water Conservation Society in cooperation with USDA NRCS, 2000
Great introduction to soil organisms and their importance. Copies are available from the society at www.swcs.org or (800)THE-SOIL ext. 24.

THE SOUL OF SOIL: A GUIDE TO ECOLOGICAL SOIL MANAGEMENT
by Grace Gershuny and Joseph Smillie
agAccess, 1996
Good introductory book for learning how to think about and manage garden soil in the most sustainable way.

START WITH THE SOIL
by Grace Gershuny
Rodale Press, 1993
Good interpretation of basic information about soil. Part of the organic gardening canon.

WORMS EAT MY GARBAGE: HOW TO SET UP AND MAINTAIN A WORM COMPOSTING SYSTEM
by Mary Appelhof
Flower Press, 1997
The definitive guide to worm composting.

Classes and Workshops

COMMUNITY COLLEGES
Some local community colleges offer classes on soil fertility and composting.

COUNTY WASTE MANAGEMENT AGENCIES—see above
All offer classes on composting, etc.

CITY OF PALO ALTO
www.city.palo-alto.ca.us/recycle/homecompost.html
(650)496-5910
Home composting workshops and other classes on organic and sustainable gardening.

COMMON GROUND ORGANIC GARDEN SUPPLY AND EDUCATION CENTER (Palo Alto)
www.commongroundinpaloalto.org
(650)493-6072
Workshops on backyard composting, worm composting, and organic gardening.

ECOLOGY CENTER (Berkeley)
www.ecologycenter.org/erc/index.html
(510)548-2220
Classes on composting, worm composting, and other aspects of sustainable gardening.

GARDEN FOR THE ENVIRONMENT (San Francisco)
www.gardenfortheenvironment.org
Workshops include composting and soil fertility.

THE GARDENS AT HEATHER FARM (Walnut Creek)
www.gardenshf.org/AdultClass.html
(925)947-1678
Classes on soil and composting, and EBMUD's water conservation demonstration garden.

OCCIDENTAL ARTS AND ECOLOGY CENTER (Occidental)
www.oaec.org/OAEC_Courses.html
(707)874-1557 ext. 201
Classes on various aspects of permaculture including composting, soil fertility, mulch, and erosion control.

Compost Demonstrations

HOME COMPOST EDUCATION PROJECT—SONOMA COUNTY
Environmental Discovery Center of Sonoma County
Spring Lake Park, Santa Rosa
(707)539-2865
Composting information available for the public, hands on activities for children, demonstration worm-boxes, etc.

BAY-FRIENDLY AND COMPOST DEMONSTRATION GARDENS
• 666 Bellevue Ave. (in Lakeside Park at Lake Merritt), Oakland
• 3589 Pacific Ave, Livermore
www.BayFriendly.org for directions
Displays of composting, mulch, and materials' reuse and recycling.

For additional resources, visit www.baynature.org.

compiled by Sue Rosenthal