Introduction -- What is Biodynamics?

Biodynamics is an approach to agriculture based on a concept of life forces. These forces work in nature to bring about balance and healing. Biodynamic agriculture uses a philosophical model articulated in eight lectures given in 1924 by Rudolf Steiner (1861-1925), an Austrian scientist and philosopher. Steiner delivered these "Agriculture Course" lectures in response to observations from farmers -- that soils were becoming depleted and that the health and quality of crops and livestock were diminishing following the introduction of chemical fertilizers. Thus, biodynamic agriculture was the first "organic" or ecological farming system to develop as an alternative to chemical agriculture.

Biodynamics combines "biological" agriculture with an understanding of "dynamic" ecological systems. If there is a "conventional" school of organic agriculture today, it practices "biological" farming. For example, it uses cover crops and manure to build the microbiology of the soil. The "dynamic" part of the practice takes a broader perspective to enhance metaphysical aspects (the life forces) and natural rhythms (such as planting seeds during certain lunar phases). As an analogy, consider an alternative form of medicine. Chinese acupuncture represents an intricately detailed philosophy and practice for which we have no equivalent in conventional medicine. Acupuncture recognizes a subtle energy -- chi or life force -- that pervades our bodies and influences our health. Acupuncture is able to mobilize those healing forces in ways that defy explanation by to Western medicine.

The test is not whether the concept of acupuncture is "true" according to Western medical standards, but whether it works. For certain conditions, acupuncture works better than anything in Western medicine. Similarly, biodynamics is concerned with chi or life force -- this time in the practice of using those forces beneficially in agriculture. In this sense, biodynamics has been described as a spiritual or mystical approach to agriculture. Steiner was very concerned that his system should be distinguished from mere superstition or dogmatic belief. To this end, Steiner advocated a scientific process of testing hypotheses as well as meditative insight. This makes biodynamics an on-going process in which the community of practitioners actively exchange ideas and refine their understanding.

Using a systems ecological approach, biodynamics sees each farm as an organism, a self-contained entity with its own individuality. Thinking about the farm as ecosystem leads to holistic management practices. These include integrating crops with livestock, recycling nutrients, maintaining soil, enhancing the health and wellbeing of crops and animals and even the farmer too. In this sense biodynamics shares concepts with permaculture -- humans have a role as the designer of the ecosystem.

However, in considering natural forces biodynamics introduces a different focus than other organic gardening schools of thought. Biodynamics parallels organic farming in many ways - especially with regard to cultural and biological farming practices - but it is set apart by its emphasis on chi or life energy. Biodynamic practices seek to balance the physical and non-physical realms, acknowledging cosmic and terrestrial forces that influence life energy. It is this complicated metaphysical terminology that makes biodynamics hard to grasp, yet these concepts are part of the biodynamic understanding of how living systems work.

The following table adopted from Steve Driver summarizes some organic farming practices.

Organic and Bio-Dynamic Farming Practices

Conventional Organic Practices	**Special Biodynamic Practices**
Green manures, cover cropping	Special compost preparations
Tillage and cultivation	Special sprays
Composting	Planting by calendar
Companion planting	Peppering for pest control
Integration of crops and livestock	Subtle forces - homeopathy, dowsing, radionics

Biodynamics includes the same practices as "conventional" organic farming but adds its own group of special practices. Sherry Wildfeuer describes some of the basic principles of biodynamics:

Broaden Our Perspective

Just as we need to look at the magnetic field of the whole earth to comprehend the compass, to understand plant life we must expand our view to include all that affects plant growth. No narrow microscopic view will suffice. Plants are utterly open to and formed by influences from the depths of the earth to the heights of the heavens. Therefore our considerations in agriculture must range more broadly than is generally assumed to be relevant.

Reading the Book of Nature

Everything in nature reveals something of its essential character in its form and gesture. Careful observations of nature -- in shade and full sun, in wet and dry areas, on different soils, will yield a more fluid grasp of the elements. So eventually one learns to read the language of nature. And then one can be creative, bringing new emphasis and balance through specific actions.

Cosmic Rhythms

The light of the sun, moon, planets and stars reaches the plants in regular rhythms. Each contributes to the life, growth and form of the plant. By understanding the gesture and effect of each rhythm, we can time our ground preparation, sowing, cultivating and harvesting to the advantage of the crops we are raising.

Plant Life Is Intimately Bound Up With the Life of the Soil

Biodynamics recognizes that soil itself can be alive, and this vitality supports and affects the quality and health of the plants that grow in it. Therefore, one of Biodynamics fundamental efforts is to build up stable humus in our soil through composting.

A New View of Nutrition

We gain our physical strength from the process of breaking down the food we eat. The more vital our food, the more it stimulates our own activity. Thus, Biodynamic farmers and gardeners aim for quality, and not only quantity. Biodynamics grows food with a strong connection to a healthy, living soil.

Medicine for the Earth: Biodynamic Preparations

Rudolf Steiner pointed out that a new science of cosmic influences would have to replace old, instinctive wisdom and superstition. Out of his own insight, he introduced what are known as Biodynamic Preparations. Naturally occurring plant and animal materials are combined in specific recipes in certain seasons of the year and then placed in compost piles. These preparations bear concentrated forces within them and are used to organize the chaotic elements within the compost piles. When the process is complete, the resulting Preparations are medicines for the Earth which draw new life forces from the cosmos. Two of the Preparations are used directly in the field, one on the earth before planting, to stimulate soil life, and one on the leaves of growing plants to enhance their capacity to receive the light.

The Farm as the Basic Unit of Agriculture

In his *Agriculture* course, Rudolf Steiner posed the ideal of the self-contained farm -- that there should be just the right number of animals to provide manure for fertility, and these animals should, in turn, be fed from the farm. We can seek the essential gesture of such a farm also under other circumstances. It has to do with the preservation and recycling of the life forces with which we are working. Vegetable waste, manure, leaves, food scraps, all contain precious vitality, which can be held and put to use for building up the soil if they are handled wisely. Thus, composting is a key activity in biodynamic work. The farm is also a teacher, and provides the educational opportunity to imitate natures wise self-sufficiency within a limited area.

Economics Based On Knowledge of the Job

Steiner emphasized the absurdity of agricultural economics determined by people who have never actually raised crops or managed a farm. A new approach to this situation has been developed which brings about the association of producers and consumers for their mutual benefit. The Community Supported Agriculture movement was born in the biodynamic movement and is spreading rapidly. Gardens or farms gather around them a circle of supporters who agree in advance to meet the financial needs of the enterprise and its workers, and these supporters each receive a share of the produce as the season progresses. Thus consumers become connected with the real needs of the Earth, the farm and the Community; they rejoice in rich harvests, and remain faithful under adverse circumstances.

Some personal observations help to explain the distinctions of biodynamics. Wolf Storl describes his own experiences in learning about biodynamics:

I enrolled at Ohio State University School of Agriculture to learn forestry. In the first year of general introduction into agriculture, I learned that the old family subsistence farm must come to an end, that the farm should be a production unit like a factory, the work processes must be specialized and technologized so that the farmer can go into his barn wearing a business suit and just push buttons... otherwise, humanity's exploding population would starve. More or less, that is what one was told.

While strolling through the experimental fields of the college and mentally comparing them to the other soils I had seen in the small Ohio farming community where I had grown up, I noticed their lack of a certain living quality. When I saw more of the research equipment and procedure, when a professor received an award for a starling-killing machine, when I heard of placing windows in the stomachs of experimental animals in order to watch the digestion, I became upset. I could not think of trees as renewable capital or mere, albeit complicated chemical processes. Though I had been part of a group of honor students, candidates for a technocratic elite that was meant to implement these concepts later, I gave up forestry and studied anthropology instead. I, for the most part, forgot about my early contact with agriculture until the research in the rural community in Switzerland where I found a better way of doing farming and gardening.

The community, Argues Vertes, near Geneva, is interesting anthropologically because it is not a traditional Swiss village, but a newly founded community that dedicates itself to providing good homes and a sheltered environment for handicapped people, of which there were about fifty at the time I was there. The community's social structure consisted at the time of study of ten households, averaging about eight persons each, workshops (pottery, enameling, weaving, doll making, carpentry, repair shop, etc.), and a basis of biodynamic farming and gardening. The village was organized by committees, such as the housewives committee, produce committee, machine and equipment committee, and so forth. A weekly general village meeting was held where the committees reported problems and where projects were discussed and decided upon by unanimous agreement. Except for personal items, major means of production and resources were held in common. The village was one of several Camphill Villages, founded in the 1940's by, the Viennese child pedagogue and pioneer in curative education, Dr. Karl Konig. Konig conceptualized the villages as alternatives to the social arrangements that brought about the excesses of mass society, whether of capitalism, fascism or communism. He utilized the philosophies of the Bruderhof, of the Bohemian philosopher Comenius, of Robert Owen, and of the Three-fold Social Order of Rudolf Steiner. The handicapped villagers were happy and secure and I experienced this as one of the few communal efforts that seemed to be working successfully.

Agriculturally, the community had access to about 80 acres, of which only 32 acres (13 hectares) were in direct production, the rest being occupied by woodland and structures. The garden at the time of the study was a little more than two acres. From this amount of land all the food needed by the villagers was produced, along with some surplus to sell to city people who literally begged for fresh organic produce. The garden yielded a most varied assortment of vegetables the year-round. In the winter, the selection narrowed to carrots, leeks, witlof, endives, oysterplants, parsnips, turnips, beets and onions. If there was a good harvest, the cabbage, celeriac, squash and fennel could last well into spring. Five gardeners, three of them mentally handicapped, and occasional student helpers worked in the garden the year-round. In the summer, the work was intense from dawn to dusk; in the winter, the work was easier, consisting of cleaning vegetables, fixing tools, working on manure composts, picking up wheelbarrow loads of stones that kept growing like spuds in the moraine soil, planting witlof roots in warmer *indoor boxes for sprouting, watering the lamb's lettuce, endives and sugarloaf under the plastic foliage tunnels, and so on. In February, the hot beds were prepared from horse manure and liquid manure, the first sowings were put in, and the constant watering, airing and watching for frosts kept the gardeners on their toes.*

The farm was operated by two farmers and four or five handicapped who were skilled milkers and accustomed to a variety of work courses. Eight milk cows, a bull, some heifers, calves, a work horse sometimes with a foal, pigs, chickens, ducks, sheep and rabbits made up the animal helpers. The number of animals was carefully suited to the land and available pasture, so that the whole worked like a self-contained organism. The farm produced all the milk that was needed and all the grain that was baked into bread at the village bakery. Excess milk was turned into cheese, cottage cheese, etc. Eggs, butter, and cheese were sometimes in short supply. Red and black currants, gooseberries, strawberries, elderberries, roan berries and raspberries were produced in their season, requiring the workers from the workshops to help with the plentiful harvests. From the berries, plumbs, cherries, apricots, pears and apples, juices and preserves were made in the village, along with pickling and sauerkraut making. Similarly, during the haying season, potato harvesting or the beet-seedling-thinning, a large reserve labor force could be called upon to do the necessary tasks.

The farm and garden worked closely together. The farmers would supply the cow, horse, pig and chicken manure which the chief gardener and expert compost maker, 'Kompostmeister Hanfred Stauffer,' would biodynamically prepare with herbal essences and render into the finest humus substance possible. This composted manure provided the basis for a steadily increasing fertility of the land under cultivation. Originally, the land had not been so productive; the soil is composed of the gravelly moraine of an old Rhone glacier, and the area enjoys the least amount of annual rainfall in Switzerland. One family, prior to the establishment of the village, had failed to make a living on this land trying to raise pigs. The canton of Geneva acquired the land with tentative plans to make it part of an agricultural experiment station or school, but soil tests showed it to be unsuitable. Consequently, it was leased for a nominal sum to the Camphill people. Over the next 15 years, the population of the new community rose from 12 to nearly 100 people, all of whom were fed by the amount of land where before one family had not been able to survive. (It must be mentioned that a high *investment of starting capital was necessary to get this efficient system going, some of which was derived from donations by parents of the handicapped, or by insurance payments.) Of this population, only about 10% were actively and directly involved in agriculture, the rest were able to perform other tasks.*

The households ordered their daily vegetables and fruit needs each morning and the freshly harvested produce was delivered by handicapped villagers. The records kept of this and sales outside the village show that production nearly doubled each year for a period of five years, before leveling off to a steady peak. During that time, the expert handling of biodynamic practices had increased the humus content in the soil to a noticeable extent. Before, the soil had been compacted with few earthworms evident; now, the soil became darker, fluffier and more alive with a small fauna. Much of this was due to bringing in outside organic material, a practice that is generally avoided in biodynamics, but was initially necessary to raise the humus level on this gravelly soil to keep water from leaching out. For a few francs, city workers, driving truckloads of algae dredged from Lake Geneva, leaves from the parks and dirt from roadside ditches, were persuaded to dump their loads at Aigues Vertes instead of at the city landfill. Nonetheless, the greatest aid in soil-building was cover crops and manure of the livestock. Everything organic was composted, including garbage, old cloth, chicken feathers and leather scraps. Once a visitor accidentally left his coat on a rag pile only to return and find that it had been composted. Another time, a bookstore gave the village a truckload of books, mostly cheap French novels which could have been sold in town at a franc apiece. It was decided to compost these, too. After soaking them to loosen the bindings, it took two years to get a compost that was so full of earthworms (bookworms) that it looked like raw hamburger when disturbed, a fact that made it the favorite exhibit for the many international visitors to the garden. They did not use this compost on the vegetables after second thoughts about the lead contained in the printer's ink.

Experiments were made in the garden house to ascertain the quality of the various composts by seeing how well cress seeds (Lepidium sativum) sprouted, how quickly they developed mass, measuring the distance between internodes, etc.. Controls were run under identical conditions on various soils and composts. Other tests were done to check quality indications by placing plant saps into test-culture dishes to see when and which kind of bacteria or *fungus developed. The composts were applied in a directed way, depending on the preceding crops, the needs of the new crops and the condition of the soil. Eventually, outside sales brought enough money in to afford the building of a greenhouse and a pond to collect rainwater from the roofs of the village buildings. Rainwater was considered to be better water than well water.*

Despite ethnoscientific training, I had, at first, an excruciatingly hard time understanding the motives, postulates and world-view of the community. The results these people were getting in their 'treatment' of the mentally handicapped, in their agriculture, in nutrition and the general effectiveness of their lifestyle were impressive. But, they did not proceed from the scientific methodology that I considered the only basis of reality. Since I was there as an anthropologist doing research. I listened, observed and made notes of ideas about Invisible "etheric" forces at work, planetary and lunar influences, "beings" at work in the garden and village, etc.. My notebook was filled with observations of the following sort: Mountain crystals were pulverized and buried in a cow's horn in the ground for a year; of this, a pinch the size of a pea, was taken and stirred rhythmically clockwise alternating counterclockwise for one hour in a bucket of lukewarm water and then this was sprayed over the fields and gardens. One time, noticing a leaking gutter on the roof, I fixed it. The next rain, it was leaking again and I fixed it again. A third time, the master gardener mumbled disconcertedly something about someone always fixing the gutter. I found out that it was intended to drip on a certain spot where a sheep's skull was buried with oak bark in it. It was supposed to rot there in a certain way for a reason that I did not comprehend at the time. Another time, aphids appeared on the beans and I was ready to counter-attack with tobacco juice (figuring that was the organic way of destroying pests); but the gardener just sat there looking and thinking. "What is there to think about?" I demanded, "There is the problem and here is the solution." The gardener replied that it would be better instead to find out why the aphids were there in the first place. "Well, that is simple," I replied, drawing on my natural science studies, "They are most likely windborn or carried by another organism and we had better destroy them before they spread'." He then explained, "No, the reason they are here is more subtle than that; it has to do with how we fertilized the soil, what crop preceded it and what weather patterns exist which weakened the plants that they became susceptible."

Moles and gophers were, at times, a problem in the garden. Once in a while, the gardener's cat would catch one of these rodents. He would then take them, skin them and hang the hides to dry while his wife fried the carcasses for the cats to eat. At a certain time, when Venus was in a particular zodiac sign, he would burn the pelts and sprinkle the ashes over the fields, causing, he claimed the other gophers to reconsider where they had settled. I kept notes on all of this and had my own anthropological explanations. By placing the phenomena into categories of 'survivals of a primitive early European world-view' or into Sir James Frazer's 'homeopathic and contagious magic' I was doing less for anthropology than for my own cognitive dissonance.

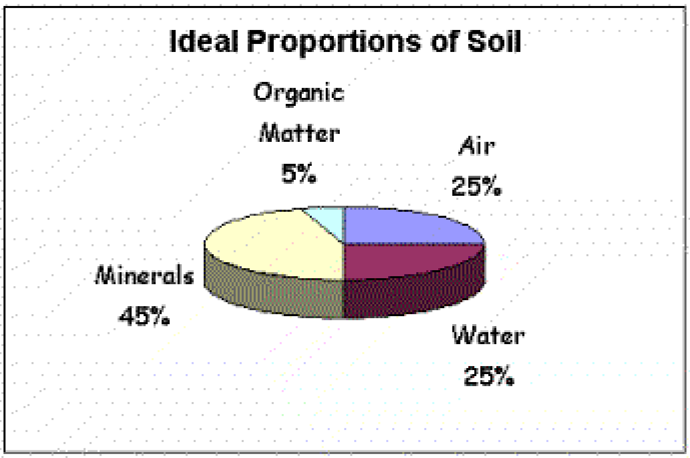
Other bio-dynamic gardeners and farmers that I met at this time engaged in strange practices, such as gathering water at the full moon or collecting and using herbs in unusual ways. One farmer boiled the shoots of the 'red pine' (Norway spruce-- Picea abies) for several hours, and, diluting the juice with rainwater, he poured it around his land to keep slugs out. He reasoned that the red pine belongs to Saturn and the slugs belong to the Moon. The characteristics of Saturn are, among others, warmth and dryness, while those of the Moon are wet and cold. The slugs will feel that they are leaving Moon territory and entering Saturn and recoil at the prospect. This explanation, and others like it, seem like the product of unbridled fantasy and it was hard for me to consider them to be real in the 'real' world.

Despite this, Aigues Vertes and other biodynamic places were shining examples of good husbandry, of healthy stock and plentiful produce. I stayed nearly three years instead of the one I had originally intended, and found the individuals working in biodynamics to be much more sophisticated than I had at first suspected. Rather than working with outmoded, hand-me-down superstitions, they were utilizing a meta-language, a complicated system of symbols to express and communicate fine and detailed observations about the workings of nature. I found out that many of the practitioners of this method were far from being uneducated; many had impressive academic and scientific credentials. In the meantime, my professor at the University of Bern with whom I was finishing my Ph. D. dissertation and exam, became worried that I had lost my scientific objectivity. He suspected me of the greatest heresy of anthropology; identification with the subjects under study. Besides, I had made none of my research public. I began to feel, however, that I had found a level of cognition superior to the one on which I was operating.

Fundamentals of Organic Gardening

Let's start with organic gardening -- what is it all about? The fundamental concept is that we should fertilize and treat plants, not with artificial chemicals, but with compost and natural methods. Why is that important? Because healthy plants start with healthy soil. So let's describe what soil is all about.

Components of Good Soil



Given the plant's reliance on its environment, the first step to healthy plants is soil with vitality. That means not just resolving soil chemistry but also providing the right kinds of vital forces. First, let's consider how the soil environment is constructed. The four important components are air, water, minerals and organic matter.

Air

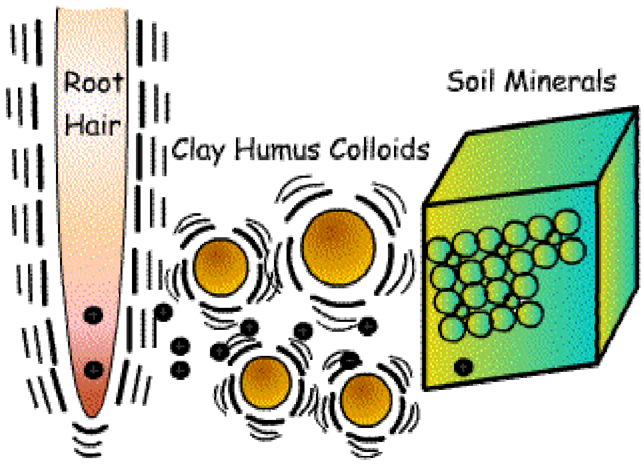
The microscopic air spaces between soil particles are tiny conduits for air and water. Air and associated energy influences need to penetrate the soil. Too little air, due to heavy soil and too much water, suffocates the soil life and reduces fertility -- a situation all too common in the Willamette Valley.

Water

Water is not only the medium of nutrient transport but also provides the protection plants need for drying influences of wind and air. But too much water can drown plants. Enough is needed to coat the soil particles so that their nutrients will be available to soil life and plants.

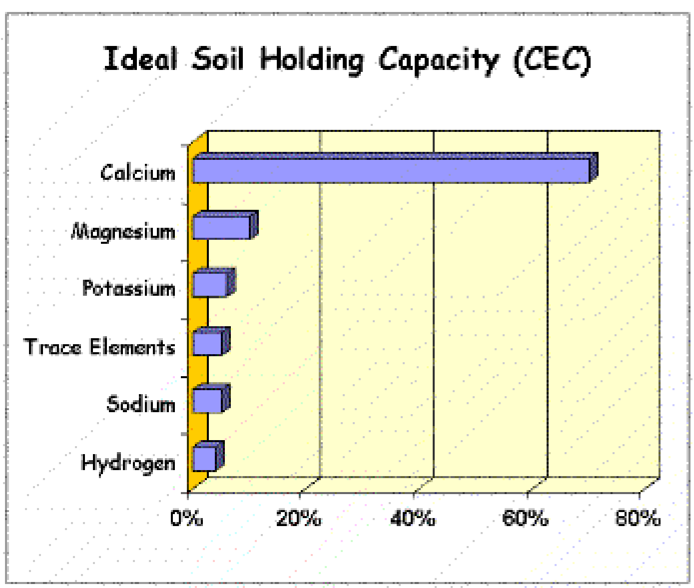
Mineral

The mineral component provides a storehouse of nutrients. Only a small percentage is ready for immediate use by the roots. Most of the reserve must first be altered by soil life and incorporated into living forms before it can be used by plants.



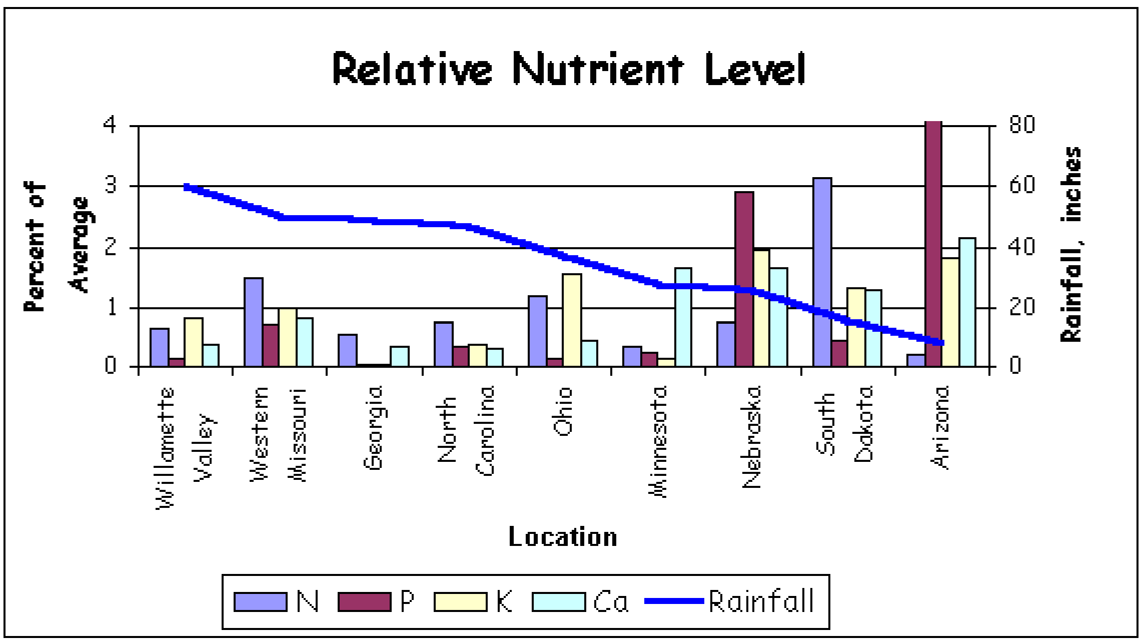
Colloids help to exchange hydrogen ions for mineral ions, thus transferring nutrients.

Clay and humus form colloids that act like a sponge for water and nutrients. Clay particles consist of flat plates -- their surfaces are "sticky" to water molecules. Chemically, clay consists of aluminum silicate compounds with varying amounts of potassium. This potassium can be available to plants but only after chemical decomposition of the clay -- another vital role played by soil bacteria. The chemical composition of the clay influences its "sponginess" or ability to store and release nutrients. Kaolin-type clays are relatively poor at storing nutrients, while bentonite, a montmorillite type clay, is very absorbent. Our area has both types of clay -- the kaolin types formed from very old basalt flows that have been well leached by our high rainfall. Volcanic ash that fell into the drier climate of Eastern Washington weathered into sticky bentonite clay that was brought here by glacial floods. All the lower elevation areas in the Willamette Valley were covered by these floods, resulting in the heavy, soggy soils we have during winter. The clay has the potential to be a nutrient



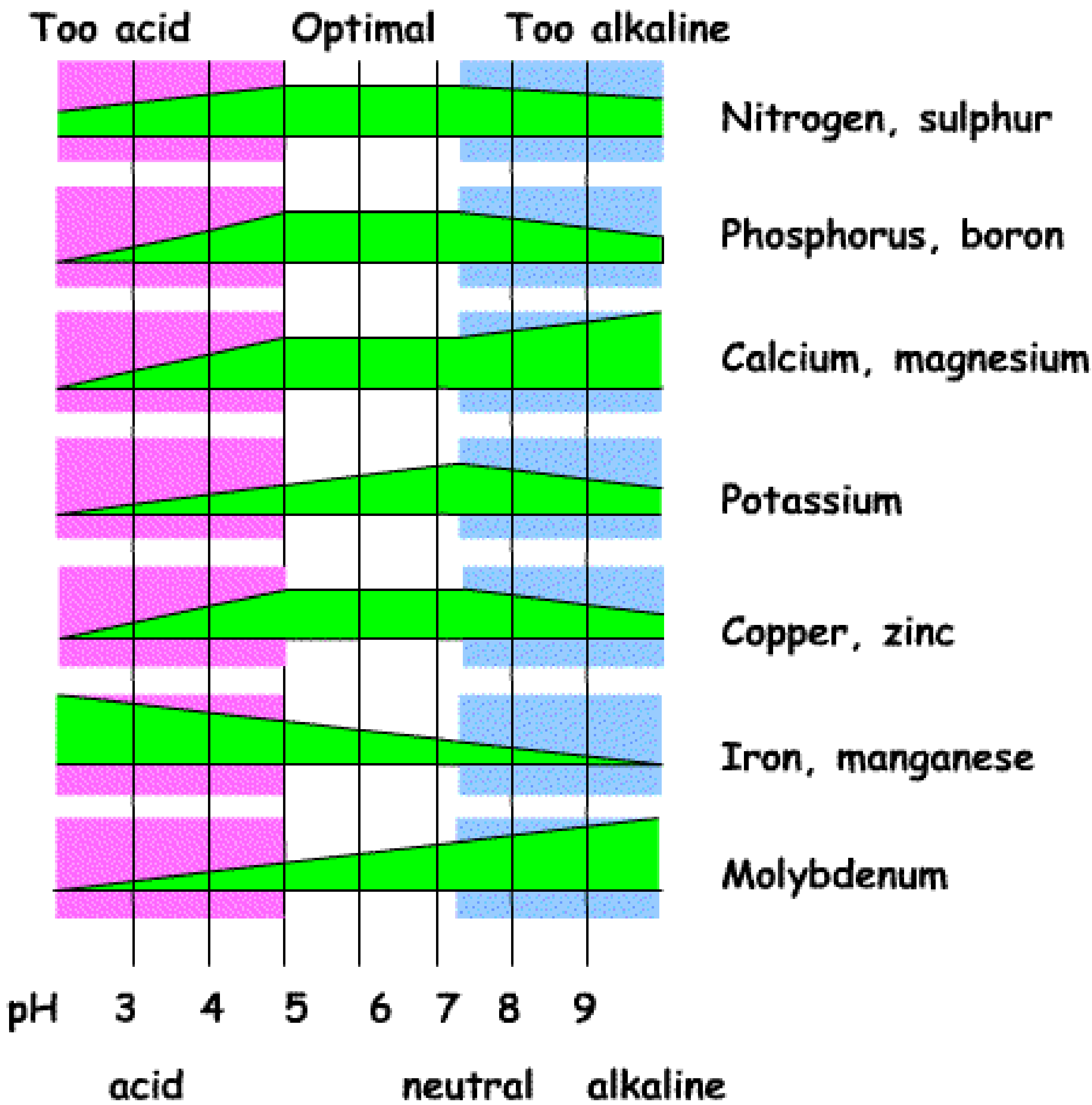
powerhouse but only if it can be opened up with organic matter.

The clay sponge holds on to a wealth of different chemical ions that can be used by plants. The holding ability is referred to as the Cation Exchange Capacity (CEC) and can be tested by soil laboratories. An ideally balanced soil CEC is calcium 60-75%, magnesium 6-12% (these two totaling 80%), 3-5% for potassium, trace elements and hydrogen. Calcium and magnesium are nutrients that act in opposition to each other, yet the plant needs both. The ideal ratio is about 7 parts calcium to one part magnesium. Our soils tend to be low in both nutrients, so adding dolomitic limestone with both calcium and magnesium is usually a good idea. Even better than amending the soil is adding minerals to the compost pile. That way soil life organisms have a chance to start breaking down the minerals.



The mineral-holding ability of the soil (CEC) is what keeps water from dissolving away the nutrients. Mineral nutrients tend to increase with low rainfall, but nitrogen (a proxy for Organic Matter) is low under desert conditions. The best soil lies in the Midwest, with high nutrients and also high organic matter. The Willamette Valley, with high rainfall, does well for organic matter but is low for all the mineral nutrients. That's why we need to consider adding soil minerals.

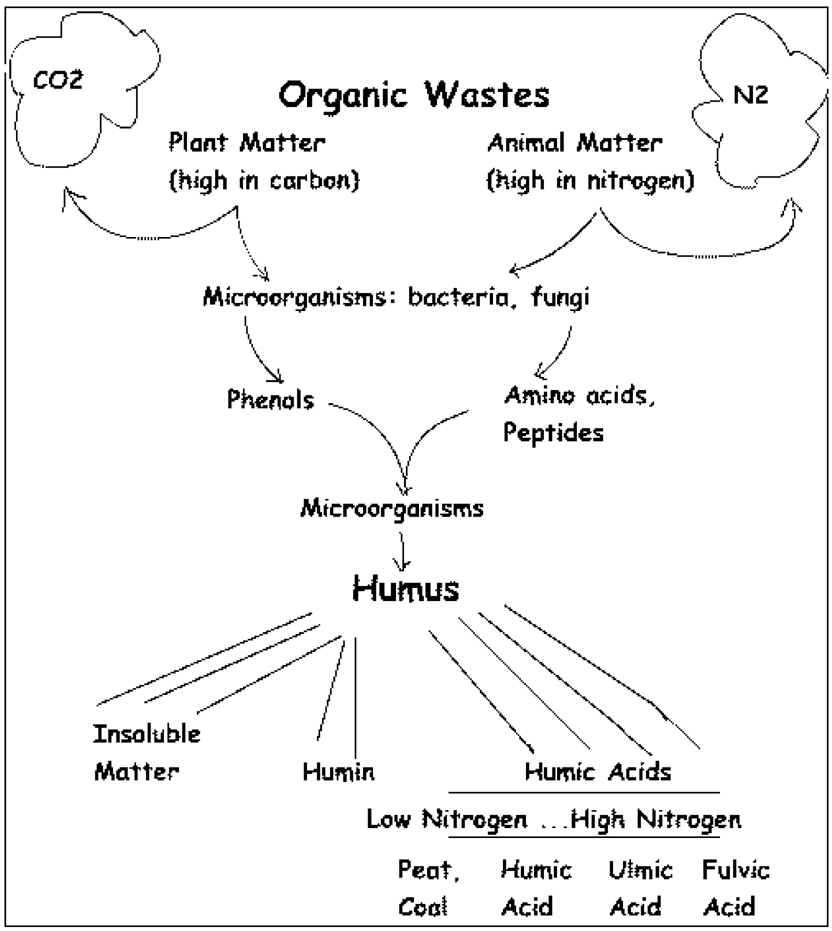
The amount of hydrogen in clay sponge is a statement of the soil acidity. Minerals are most available if the soil is slightly acid -- at extremes, the minerals can be locked up and unavailable to plants.



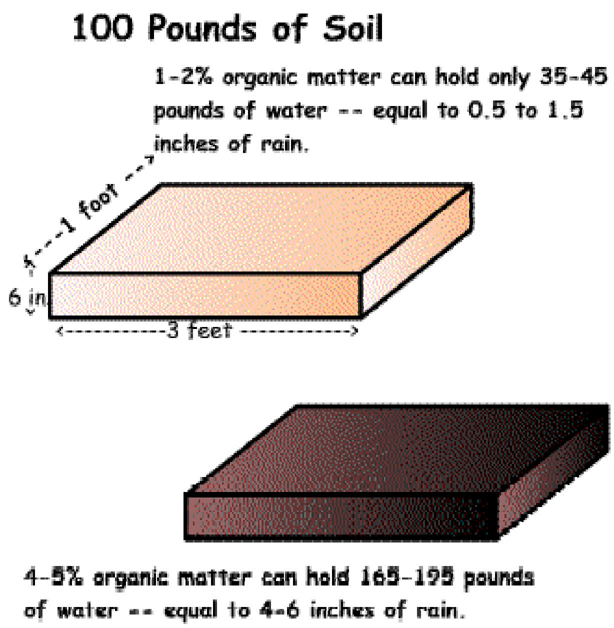
Mineral availability depends on pH

Organic Matter

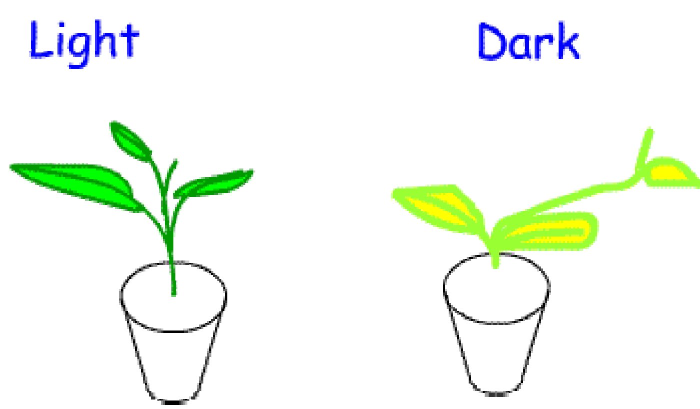
Even though the ideal amount of the percentage of organic matter is small (5% of the soil), its role is important. Fiber is as important for soil heath as it is for our health and for similar reasons. The bodies of plants and animals decompose in order to recycle nutrients back to life, Organic matter is the reservoir on which soil bacteria and fungi are working. Eventually, the organic matter will go back to plants. In the meantime, it holds the soil loose and spongy and saves nutrients that would otherwise leach away. As organic matter decomposes, bacteria eat the easiest molecules first. What is left are long-chain carbon compounds referred to as humus. Humus is a collection of the relatively stable long molecules and colloids, but it still decays slowly over time. This is why we have to consider constant replenishment of organic material.



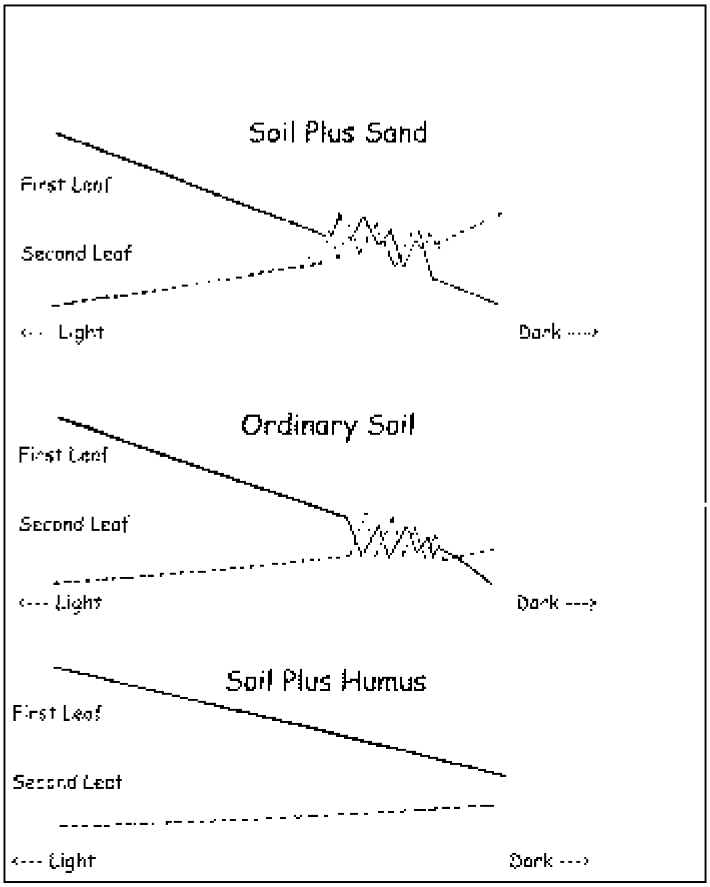
Humus has to go through a process of digestion by microorganisms in order to remove phenols and other decay products that can be harmful to plants. This is why we provide stable humus by composting wastes first, rather than applying them raw to the soil. Dr. E. Pfeiffer once estimated that 5% of the organic matter is present as nitrogen. So if the soil has 2% organic matter, that is 40,000 pounds of nitrogen to the acre. At any time, bacteria in the soil are slowly transforming the stored compounds into useful plant nutrients. If we feed those organisms and otherwise maintain a balance, organisms will release 80 to 120 pounds of nitrogen per acre per year. Thus, we really do not have to worry about supplying nitrogen from artificial sources.



The colloidal nature of humus is responsible for much of the soil's ability to hold nutrients and water, to keep the soil light and aerated and to release the nutrients when needed. These colloids are like a sticky glue holding the soil particles together, particularly the clay particles. Humus is the key to soil texture because it is so effective as a sponge for water and chemicals.

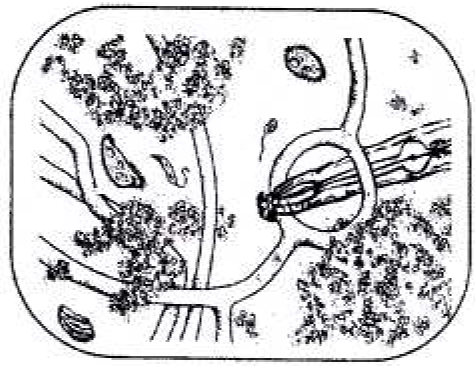


But there is another effect also. Steiner believed that it was light, through silica, also contributed to the soil's vitality. And too much humus can block this effect. The following graph shows a series of experiments conducted by E. and L. Kolisko. They raised a set of potted seedlings arranged in a row inside a tunnel. There was light only at the left end of the tunnel. So those plants had sufficient light. But plants to the right suffered from less and less light. The plants with good light exhibited a typical growth pattern -- the first leaf grew on a strong stem and then the plant used the incoming energy to grow a second set of leaves. The plants in the dark had another pattern -- they were starved for light, so grew the first leaf quickly. But then there was no more light, so they used up food reserves to stretch the second leaf, seeking desperately for light.



So the general trend is for the first leaf to dominate in the light; the second leaf dominates in the dark; and somewhere in between there is a region of chaos where the plant can't decide which leaf should dominate. Ordinary soil is used in the middle set; soil plus sand in the upper and soil plus humus in the lower set. We see that sand has some ability to shift the second leaf's line higher -- it acts like there were slightly more light. For humus the effect is quite opposite and very much stronger. Humus destroys the second leaf's ability to reach for the light -- humus has a large impact on removing light's influence from the soil. From this experiment, we see that soil benefits from light using silica and that excessive amounts of humus will remove that benefit.

Soil Organisms



All the previous discussion about soil chemistry is based on agricultural science that has been well known since the 1930's. What we have learned since then is that it is really the soil biology that makes this chemistry happen. Soil is actually a complex ecology or food web, with many symbiotic life forms contributing to its structure and fertility. Soil organisms include:

Actinomycetes (Ak-ti-no-my-CETS): These organisms seem to be an intermediate form between a bacterium and a fungi. Their specialty is breaking down resistant materials such as cellulose, chitin and phospholipids. Some studies have shown the production of antibiotic substances that cleanse the soil. They are drought resistant but like a high pH. One species causes potato scab, so potatoes are not usually limed to keep the pH low. A good 'earthy' smell in the soil indicates their presence.

Algae: These organisms live close to the soil surface and do best in moist conditions. They feed on simple organic materials and sunlight. Some forms are able to fix atmospheric nitrogen.

Molds: Molds are multi-cellular fungi with thread like hyphae or feeding structures. They feed on organic matter in moist conditions. They can develop vigorously and they can tolerate wide variations in soil pH. They are particularly adept at breaking down organic residues in highly acidic forest soils.

Mycorrhizal fungi: Certain fungi form symbiotic relations with the roots of plants. The roots get supplemental moisture and nutrients from the mycorrhizal fungi, while the fungi get plant sugars from the roots. The mycorrhizal fungi take very little from the root in comparison to what the root gets so the relationship is highly beneficial. There are ectomycorrhizal fungi that live on the surface of the root and there are endomycorrhizal fungi whose hyphae actually penetrate into the root's interior. Together these make for an extremely effective network delivering nutrients back and forth to each other. They supply growth hormones (auxins) that encourage the growth of root hairs. Some produce antibiotics, such as the well know penicillin and streptomyacin.

Soil bacteria: Bacteria are single-celled organisms, one of the simplest and smallest forms of life known. There are more numerous in the soil than any of the other microorganisms. They exist as mats, filaments, or clumps called, "colonies". They rival or exceed all of the other soil microorganisms in their ability to breakdown organic compounds, to form humus, to stabilize soil structure, and to re-cycle nutrients.

Soil fungi: Fungi are present in the soil in huge numbers. Fungi include yeasts, molds, and mushrooms. The yeasts are single-celled. The molds and mushrooms are multi-celled and have thread like hyphae. Their principal function is to breakdown organic residues, to aid in the production of humus and to absorb volatile nutrients such as ammonia. They breakdown cellulose, starch, sugars, gums, lignin and some protein. The immense network of hair-like hyphae gather together at times to make fruiting bodies that we recognize as mushrooms.

Yeasts: Yeasts are single celled fungi that live primarily in waterlogged, anaerobic soils. Their specialty is fermentation -- breaking down simple organic materials when conditions are anaerobic.

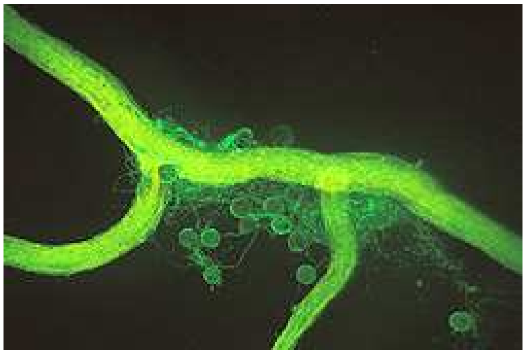
Nematodes: Nematodes or "ellworms" are found in almost all soils. They are tiny, unsegmented round-worms that feed mostly on decaying organic matter, soil microorganisms, and insect larvae. Most nematodes are beneficial to the garden but some do feed on plant roots and are considered as "pests". Root knot nematode occurs when there is not enough organic matter in the soil, the plants are weakened and there are not enough predatory nematodes. Rotation of crops, compost applications and planting French marigolds are management practices to control parasitic nematodes.

Protozoa: Protozoa are mobile, single-celled creatures that capture and engulf their food. They feed mostly on bacteria and decaying organic material. They do best in well-drained soils but there usually aren't enough of them to make a significant difference in the decay of organic matter or nutrient release. They are held in check by the antibodies produced by other soil organisms.

Earthworms: Earthworms are probably the most important macro-organism. They literally eat their way through the soil consuming huge quantities of organic matter, but not living plants or their roots. Worms grab leaves from the surface and draw them down into their tunnels to be munched into clay-humus complexes. Worm tunnels open up the structure of the soil aiding aeration and drainage. In their gizzard, worms grind up soil particles, pulverizing bits of rock into digestible pieces. Worm casts or wastes are particularly rich in calcium and other nutrients. Under normal conditions, worms produce up to 12 tons of castings per acre, containing 11 times the potassium, 7 times the phosphorous, 5 times the nitrogen and twice the calcium and magnesium of ordinary soil. The two most important earthworm species are Lumbricus terrestris, commonly called "Nightcrawlers" and Eisensia foetida, commonly called "Red Wigglers". The nightcrawlers are deep boring, even tunneling through hard pan. Red wigglers live close to the surface, eat copious amount of organic matter and are the preferred species for vermicomposting.

The plant does not exist as an isolated individual -- rather it is part of a complex eco-system under the soil. Here is an example. Hugh Lovel's corn plants were growing without irrigation during a drought. Yet the plants were green and healthy. When you looked at the roots around each one, you would see that the soil was black and moist. How could that be? Because the corn plant is actually exuding sugar sap to feed the soil micro-life. In return, the soil life, particularly mycorrhizal fungi, are digesting nutrients and passing them back to the corn.

This is a microscopic view of an arbuscular mycorrhizal fungus growing on a corn root. The round bodies are spores, and the threadlike filaments are hyphae. The substance coating them is glomalin, revealed by a green dye. As a glycoprotein, glomalin stores carbon in both its protein and carbohydrate (glucose or sugar) subunits and serves as "super-glue" to bind soil particles together. Photo by Sara Wright.



Soil organisms perform a variety of important tasks that include:

(1) Breakdown and bio-degradation. Just about any organic, mineral, or synthetic material can be degraded into a form that plants use. Many plants exude alleopaths or growth inhibitors to discourage completion from other plants. Walnuts and cedar trees, for example, stunt other plants. Soil organisms break down alleopathic compounds into harmless substances.

(2) "Fixing" chemical elements. Nitrogen fixing bacteria, for example, take nitrogen from the air and organic mater in the soil to form organic nitrites, then turn those organic nitrites into organic nitrates that are usable by the plants.

(3) Humus production. Humus benefits the nutrient transfer and removal of waste products from the root, making minerals contained in insoluble rock particles available to the plants. Humus provides a rich diet for the soil organisms, serving as a buffer to resist changes in soil pH and helping soil aggregates.

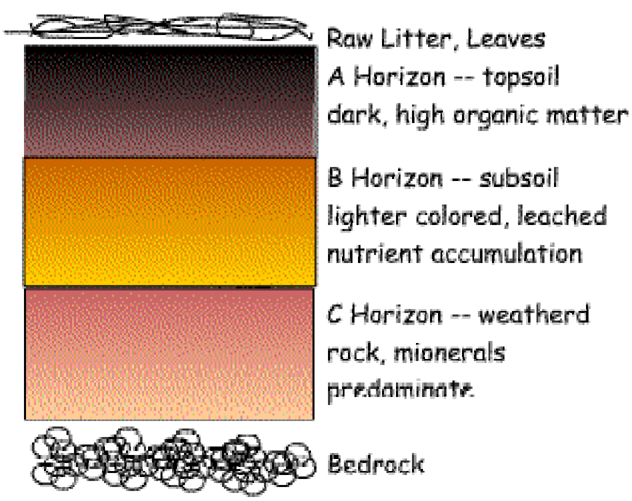
(4) Producing carbon dioxide: Soil carbon dioxide helps to breakdown insoluble rock particles and may also be available to plant roots as a feed stock for photosynthesis.

(5) Feed for the plants and other soil organisms. The life span of the various soil microorganisms is relatively short. After they die, their bodies are a major source of nutrients.

(6) Defeating soil pathogens: Most of the soil microorganisms are beneficial and promote the health of the garden. Some cause problems and disease if plants are unbalanced. Generally, the beneficial populations serve to control the undesirable species.

It should also be mentioned that plant roots themselves are a major component of the soil community. The foliage above ground gives no indication of the size of the plant underground. R. Koepf reports that 60% of a plant's biomass is actually located out of sight, in the soil. Studies of ryegrass have shown that a single plant grows three MILES of root hairs per day and up to 5,000 miles in a season. That's why when we grow a "green manure" crop, we are adding a lot of organic matter to the soil.

Soil Structure And Chemistry



Soil can be described as occurring in strata. The topsoil or A -Horizon is important for plants because it provides the nutrient-rich seedbed. But minerals and nutrients are also located in the lower strata and the plants will extend roots to reach those areas. When cultivating the soil, we try to preserve the stratification. Topsoil organisms want to stay on top. If the surface soil is tilled under, the surface-loving bacteria will die. Merely mixing the two strata together will not make the deeper levels more biologically active -- the soil life will just disappear.

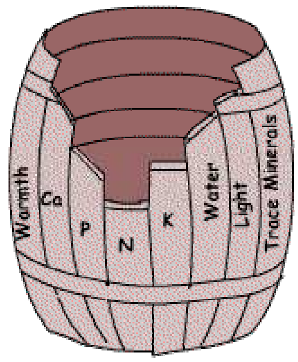
Soil depth (inches)	Bacteria	Actinomycetes	Fungi	Algae
1-3	9,750	2,080	119	25
8-10	2,175	245	50	5
14-16	570	44	14	0.5
26-30	11	5	6	0
53-57	1	0	3	0

The table shows the relative abundance of soil organisms at varying depths. Topsoil is obviously the most biologically active. Its open structure encourages respiration and the escape of any harmful gases. Alan Chadwick, an early proponent of biodynamics, stated, "We are actually cultivating the air -- a distance of approximately two inches above the soil surface -- and reaching perhaps one-half inch below it. We are, by proper cultivation, inducing the soil to breathe." The aerobic metabolism of soil life gives the energy to extract and make available soil minerals.

Organisms decline rapidly in the subsoil, which is typically clay. The color of the clay tells us something about the amount of aeration it has received. Red-orange color means that there has been enough air to oxidize iron. A yellow color indicates less oxidation. Blue clays are without oxygen, usually because they are water-logged and won't support plant roots. Nutrients wash down from the topsoil and are absorbed by the clays, so this layer still feeds plants. What is important is that the clay should not be packed down. Too much pressure, especially on water-logged clay, may create a hard-pan layer that will prevent water drainage and not allow roots to penetrate deeply. This is a reason to be cautious of a rototiller. The tiller smears clay particles together at the bottom of its tillage. On a heavy clay soil this can be a mess. If soil is sufficiently dried out, mechanical tilling can be considered.

Nutrients

Liebig's Law of the Minimum stated that crops fail because a single key nutrient is lacking. The analogy is that of a barrel with staves broken at different lengths; the barrel will only hold water up to the shortest stave.



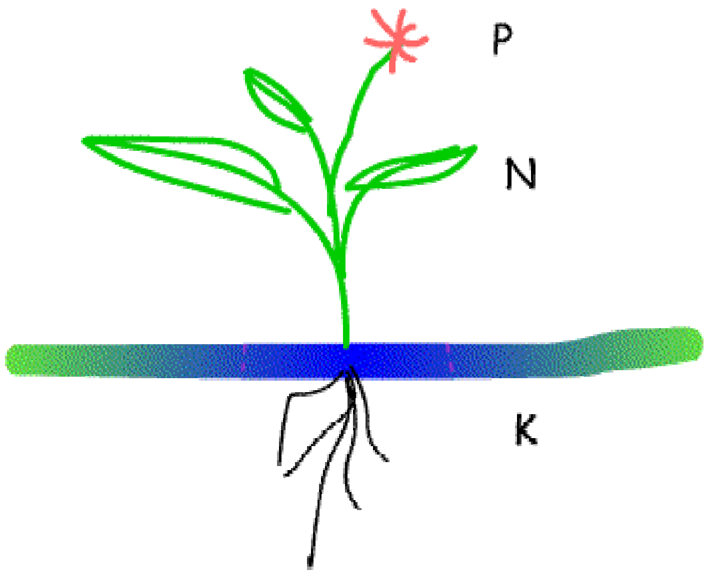
Liebig's Barrel Analogy

Adding, say potash, would not help if the deficiency were in nitrogen. For the first time, plant nutrients could be reduced down to small enough quantities that adding artificial chemicals to fields was feasible. Thus was born the age of chemical agriculture. The drawback is that scientists begin to think that only these chemical elements matter.

Since then, we have learned that trace amounts of many chemical elements are needed by plants. Usually, this is not a problem because any soil has at least minor amounts of all the elements. However, under intensive crop pressure, trace deficiencies turn up. Adding trace elements as artificial fertilizers is tricky because they may be toxic in excessive amounts. The organic gardener does not have to worry. Applying compost and natural materials from a variety of sources will ensure that there are trace amounts of every needed substance. Steiner also suggested that small amounts of these substances are distributed everywhere, supplied by the wind and rain. We just have to make sure that the plant has the vital force to absorb these finely distributed elements. Steiner also suggested that, when a substance is lacking, natural organisms have some ability to transmute other elements into the needed nutrient. The same phenomenon has been described by Kervan.

Applying Liebig's methods, conventional farming adds fertilizer materials that are salts of strong nutrients. These materials create other sorts of problems. Most NPK salts leave the soil acid, requiring lime. But the lime interferes with trace element absorption. Chemical nitrogen used excessively stunts root development because the compounds are not in the natural form absorbed by mycorrhizal fungi and root hairs. Salts kill earthworms and microorganisms, interfering with humus formation and fertility.

So what are the necessary nutrients? Carbon is the fundamental scaffold on which the plant hangs its structure. We rarely think of carbon as a nutrient because it is never scarce. Plants absorb carbon out of the air, but the atmospheric concentration is quite low. Plants also can absorb carbon compounds through their roots. Carbon dioxide concentration is much higher in the soil due to the soil life so this represents an important source for plants. Silica is barely considered in conventional farming because we consider it insoluble. We know that sand or glass do not dissolve. Therefore, how can a plant mobilize silica? Yet silica is found in all plants -- somehow the plant has a way to absorb and transport silica as organic compounds. Silica important where tissue need to be strong.



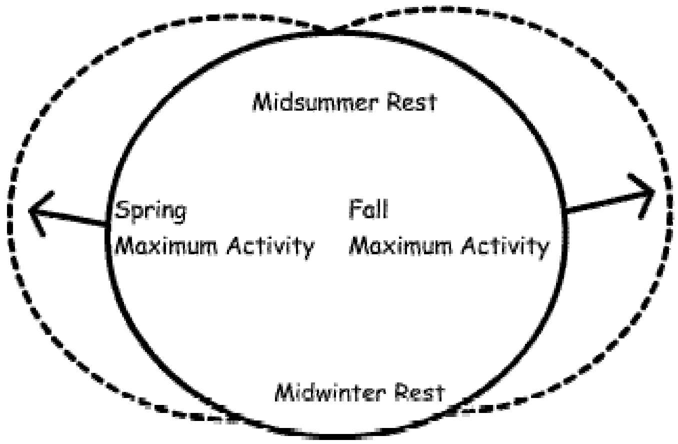
Nitrogen is considered the major plant food by conventional agriculture. Nitrogen deficiency is indicated by plants that are tough, spindly and with yellowing leaves. Excessive nitrogen shows up as overly lush, watery growth, usually too much leaf and stem while roots and flower parts are retarded. These conditions are ripe for pests and disease, so aphids and fungus soon appear. It is best to apply nitrogen from organic materials. These materials release nitrogen slowly due to bacterial decomposition, so they avoid the problems of ionization and rapid leaching from overly soluble salts. In our climate, we have extensive winter rains, leaving a cold, leached soil in spring. Under such conditions, nitrogen is difficult for the soil life to mobilize, at least early in the year. Useful nitrogen supplements include feather, blood and fish meal form animals. Alfalfa meal is a good nitrogen source form plants and brings along other growth simulating auxins. We will discuss cover crops and legumes later as another way to add nitrogen to the soil. Be cautious of bagged steer and chicken manure -- they often contain a high salt content. Plus they are coming from unhappy animals in confinement. The best source for nitrogen is well-done compost. More on that subject later.

Phosphorous is needed for flower and seed development. It is also important in sugar metabolism and thus for fruit development. Lack of phosphorus shows plants that don't mature, reddish discolored leaf veins and defective seeds. In tomatoes, the undersides of leaves turn purple. The best phosphorus source is finely powered rock phosphate or colloidal phosphate clay. These release phosphate slowly so they should be applied well in advance, preferably added to the compost pile to initial biological activity. Chicken and bird manure are good natural sources. Some legumes, such as lupine and vetch, accumulate phosphorus. Bone meal is widely used as an organic source of phosphate. However, lately there have been concerns raised about "mad cow" disease. Little is known about how this disease is transmitted, but a cautious approach would be to avoid bone meal. Demeter, the official Biodynamics certifying agency, requires farmers to avoid bone meal.

Potash or potassium is important for nutrient transport. For that reason, it is related to good root development and root crops are sensitive to deficiency. Insufficient potassium shows up when edges and tips of leaves look dried and scorched and plants look stunted. Nubbin corn, unevenly ripening fruits, curled up carrot leaves, tapered beet roots are all symptoms of insufficiency. One natural source is greensand (glauconite) which also contains other mineral nutrients. However, the deposits of greensand are at the other end of the country so it is not a local material for us. Potash is found in wood ashes, but remember that these are salty and caustic. They have to be applied carefully to avoid damaging soil life. Hog manure, seaweed and alfalfa are good sources. Vetch and bracken fern accumulate potassium.

A number of trace minerals are needed in small amounts to serve as catalysts. These include boron and zinc (frequently low in rain-leached soils), copper, cobalt and other minerals.

Biodynamics pays special attention to two minerals that are not normally noticed because they are not usually deficient. Silica helps grain and straw stem to stand up stiffly; it is found in the sheaf and aumn of the grain; it toughens plant stems to resist aphids and fungi. Silica counters the effect of excessive nitrogen fertilizer. It reduces the amount of rank growth and develops maturity and ripening. Calcium works with the earth forces. Unlike silica, it is highly reactive in the metabolism of soil and plants. Since it dissolves, it can leach out of soil when there is too much water. Calcium aids soil structure and nutrient availability, working closely with magnesium and promotes vegetative growth.



Bacteria Yearly Cycle

Remember the key task is to make the soil as alive as possible, using compost, manure and cover crops if possible. Rock minerals and animal products can be added to correct known deficiencies. But it's best to add these materials to the compost pile and let them enter into the soil food web before adding to the garden soil. Agriculturists use a soil test to identify nutrient levels. However, the results are very dependent on the amount of bacterial activity. As the chart shows, that varies according to season and even according to time of day. For a garden area, a chemical soil test is probably not necessary since we already know that we want to add a goodly amount of compost. To get an idea of the underlying soil capability, one can assess the types of weeds and plants already growing there. The appenidx chart shows weeds as indicators of soil nutrient problems.

References:

Wolf Storl, Culture and Horticulture: A Philosophy of Gardening, 1978.

Dr Ingham's articles on the soil food web are online at http://www.soilfoodweb.com/phpweb/. Her Soil Biology Primer is a great introduction at http://soils.usda.gov/sqi/SoilBiology/soil_biology_primer.htm.

John and Helen Philbrick, Gardening for Health and Nutrition, Rudolf Steiner Publications, 1971.

Glomalin: Hiding Place for a Third of the World's Stored Soil Carbon, Agricultural Research magazine, http://www.ars.usda.gov/is/AR/archive/sep02/soil0902.htm