The

LIVING SOIL

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WHEN EIGHTY-FIVE PERCENT of the population of the United States is urban and only fifteen percent is rural, it is quite evident that our high standards of living are expectedly associated with business, with economics, and with industrial activities of which the assembly line of technological manipulations may well be highly symbolic. By means of power, complicated machinery, numerous appliances, gadgets, etc., we have reduced the human labors connected with technology to the push-button dimension. It is in this technological sphere that we find our major prograss. It is that prograss which has put our people into a gradual population shift from one mainly nature-made and rural about ten decades ago to one now so highly urban and man-made that the ratio of the latter to the former is more than five to one.

Nevertheless, when one sees the golf links near every city, and the parks within it, they suggest that the human being still yearns for the rural scene with its growing grass and all that the open country and its biological exhibitions of living, growing things can offer. Whether it be the backyard flower-gardening wife or the golf-playing husband of the city-dwelling couple, each is merely giving vent to the universal atavistic inclination to get back to the living soil. They exhibit their desires for contact with Nature's assembly line out of doors by which the creation of growing things in the open country is so commonly brought about. That is an assembly line which starts and stops itself with the turn of the seasons but without concern or control by man.

Careful observation of any industrial assembly line, however, points out that it doesn't run itself. It has some one at each of the depots along its line feeding it with the respective parts in correct order and amount, if the production is maintained. Even there where the materials are inert, dead, fixed in quality, and not perishable; and where the final product is only a machine, or gadget; yet the living human mind is in direction of it.

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AGRICULTURAL CREATION IS A CHALLENGE FOR CLOSER STUDY OF ITS STARTING POINT, VIZ. THE LIVING SOIL

The agricultural assembly line within the soil under Mother Nature's direction is no exception as to the many depots of it. The sand and the silt are the mineral reserve sections or depots. From them, by the weathering processes, the inactive nutrient elements of crystal structure are broken out to become ionicly active. Other elements, put into new combinations of different secondary minerals, form the clay. This is another and important depot along Nature's assembly line within the soil. This is the major, seasonally active one in that its store of adsorbed nutrient elements must supply quickly the high demands for these by invading, growing plant roots. When once highly depleted, and in turn stocked with the non-nutrient hydrogen, or acidity, which is taken in exchange from the carbonic acid of the respiring root for what nutrients were passed on to it, the acid clay becomes an active weathering agent. It breaks the silt and sand reserve minerals down and restocks itself while we commonly belive that "The soil is resting."

The clay is the assembly line's major section or depot holding the exchangeable stock of calcium, magnesium, potassium and other cations, or those ions with positive electrical charges. It may also be holding some anions, or those with negative charges, like the phosphate, sulfate, nitrate, bicarbonate, and others. These latter, however, are more often held and passed on to the assembly line of agricultural production from the organic matter depots within the soil.

Thus within the soil there is a flow of

fertility elements under their own activities from the rock to the clay and from there to the root, all in the presence of ample moisture by which as a medium these ionic activities are possible. This fertility is the control by the soil of creation to which the sunshine supplies the power; the soil contributes the stored water; and the air gives the carbon dioxide originating mainly in root and microbial respiration in the soil; and in which the carbon and the water are fabricated by plants into the carbohydrates, i.e. sugars, starches, cellulose etc., or the energy foods for the plants, the animals, and man. Thus the green chlorophyl of the leaves really creates what is truly food for the plants. It is from the digestion of these that the plant gets its biochemical energy when it burns within its cells the sugars, or the fats made from these sugars, just as we do in burning carbohydrates and fats in our bodies. It is from the burning of parts of these compounds in the plant tissue that energy is provided to make the nitrogen combine into some of the changed carbohydrates and thus to synthesize the life-carrying proteins.

The Inorganic or the Dead, Becomes the Organic, or the Living, via the Soil

Plants so growing and dying with their decaying roots left in, and tops returned to the soil are the organic matter from the digestion of which the microbial life within the soil must get its energy. It is thus that there results a living soil. Under virgin conditions then, or starting from the beginning of the mineral earth, the soil is first a rock that is making a temporary rest stop on its way to solution and to the sea. But soon it is no longer dead, inert, wholly inorganic, or of no more than plant-ash equivalent. It is changed from the inorganic and the dead mineral material to become the organic and the living soil. It contains carbon. It supports a microbial flora. It contains a micro- and macro-flora It has a micro- and macro-fauna. It is combustible. It takes in oxygen. It gives out respired carbon dioxide. It is truly living.

Soil is not a technological assembly line where only collections of the non-living are built together, or merely assembled and managed by man. Instead, it starts with the inorganic determiners of the course of creation. When a microbial spore, a dormant seed, a rootlet, a cutting, all living parts from other life, give the opportunity, these determiners at the various depots integrate—not only add—their contributions. The inorganic materials in a limited or less limited list of elements set the degree of complexity of the creation. The organic matter adds its many items as elements in cycle, and in the form of compounds not fully recognized as yet or understood in plant nutrition for their hindrance or their help. It is then the living soil that truly creates, since the organic matter under decay contributes compounds actually taken by plants roots as we know sugars, vitamins, and other compounds are. Thus it is a living soil with its assembly line integrating its many items which in summation mean growth by living forms.

Because our daily experiences of our own living are so extensively and intimately geared to technology, and because so many of us are too far removed from what is truly biology, the growth not only of our agricultural crops but even of those non-agricultural is viewed as if it were a technological matter which we could readily manage. In the argument for that, there is often cited the hydroponic tank with no more than water and a collection of salts of the inorganic or the ash constiuents of the crops to be grown. But we have not demonstrated the hydroponics as means of growing very many kinds of crops, save for those which are mainly a vegetative, cellulosic mass carrying much water, sugar, and starch. Tomatoes, potatoes, spinach, flowers, and similar crops whose reproductive potential has not been tested for a series of generations of growth under hydroponics, have been the demonstrators of this procedure. As a challenge to the hydroponic technology using the flowing, very dilute, often replenished, inorganic solutions, let us ask the proponents of this method (who are probably opponents of the highly organic soil as a necessity for crops) to grow one crop of mushrooms in their hydroponic tank as a substitute for the rotted manure of the mushroom bed. The crop growth by hydroponics, claimed to be rapid, is no match for the speed with which the mushroom mycelia

literally "run" through the bed and grow the mushroom crop.

But, as a beginning and for a good start in our understanding of what makes things grow, the hydroponic idea is a very helpful demonstration. It uses water as a means to dilute the inorganic salts. It obviates the danger of too much salt. It permits renewal of the salt supply, since only by an enormous amount of water under such required dilution could enough salts be delivered to mature the crop. Water, however, is the medium for ionization of the salts to make their elements active for root entrance. Soil areas of crop production must contain both water and fertility compounds. Dry soils with salts in excess are the saline and alkaline areas with no crops. Hydroponic technology uses solutions so dilute that it duplicates the laws of gaseous behaviors and does not dulplicate the soil where within root-reach the nutrient supply dare not be in highly concentrated salt form but yet must be large enough in quantity and in active form to mature a significant crop.

Soil, as the assembly line, is then far different from hydroponics. So is the mushroom bed with its rotted manure. Decaying organic matter in the soil, similar to the clay there, is a colloid on which absorbed nutrient elements are held, and from which they are exchanged to the plant roots. Also for the nutrient release, by the decay of the organic matter in the soil, the increasing rate of this process is timed to be highest when the seasonal conditions suit the speediest growth of the crop. Nature has synchronized these two performances, i.e. the decay of the residues of past crops and the growth of a new crop, by making the increased rate of decay of the organic matter within the living soil provide the means of increased nutrition of the crop above the soil. Hence, the cause of the crop growth is a living soil under Nature's management. Crop growth is not the result so much then, of a technology under man's manipulation. Rather, it is an exhibition of the biology of Mother Nature.

Organic decay is an agency for the increased weathering of the dis-integrated rock. By it the living soil makes the dead rock elements become active to support more life. Our thinking has not pushed forward our understanding of what make things grow. Our comprehension of those processes has not gone much beyond the "solution' idea of hydroponics. We have not yet seen the soil as the handful of dust into which the moist breath is blown by the weather and can mean the creation of life. There is reason then why for so many folks there is as yet no concept of "A living soil." Hence, there can be no living soil in their vision when so commonly "We are down on what we are not up on."

The Living Soil Keeps Itself Living First and Our Crops Second

That the soil is living may well be illustrated in trying to bring about a loose soil structure in a flower pot or in the putting green of a golf course by mixing peat, saw-dust, or other cellulosic matters with the soil, and then discovering that the potted plant or the grass crop does not grow well as a consequence. Very often the plant or crop turns yellow. The grass appears to be "burning out" and fails inspite of good rain or applied water. The farmer experiences the same with the damage to a fall-seeded wheat crop after turning under much straw of a preceding wheat or oat crop, or the stubbles of a matured soybean crop. The wheat crop following the turning under of such cellulosic organic matter, supposedly to enliven the soil, is said to be "burned out." On the contrary, it is apt to be "starved out" for the nitrogen taken away from it by the living soil's crop of living microbes. These are in competition with the grass sod crop of the golf green or with the wheat crop of the farmer or with the plant in the pot, not so much for water as for nutrients.

The living soil must, first of all, be balanced nutrition for the microbes, the major life of the soil. This life in the soil is the soil's primary crop that must be properly fed. It eats at the first table set in the soil. The grass crop, or any other supra-soil growth, eats at the second table. The high carbohydrate contents of the sawdust, the peat, or the straw, are not carbohydrates of energy value to the plants. Plants use sunshine energy and chlorophyl to make their own energy foods by photosynthesis. But

plowed under and buried into the soil, those highly carbohydrate substances are energy food for the microbes with too little nitrogen or protein added along with it or stored in the soil to balance this large allotment of carbon. They draw that nitrogen supply in the soil down far below the level required for nourishing the competing crop with nitrogen. Thus the living soil given too much of only energy supply in the organic matter and too little growth-promoting nitrogen or protein with it, feeds even the microbes with a poor diet. As a consequence, their competition with the crop means just that much too poor a diet for the latter. The agricultural crop is thus "burned out" and must be a poor one because it was on a truly living soil. But that living soil was one not fertile enough to feed two families, namely, first the microbes under Mother Nature's management, and second, the crop plants under human nature's management.*

Nutrition from the soil for microbes and for the plants may be under not only a shortage of any element, but also under imbalances in regard to combinations of many of the nutrient elements when we manage the soil as only a technological procedure that dumps on fertilizers, whether organic or inorganic, in the belief that "If a little is good more is better." This policy of generous applications of even the supposedly insoluble limestone rock as a soil treatment has now shown itself a case of poor biology though it might be considered good economics and excellent technology. Fortunately, the microbial life of the soil tolerates any shocks of imbalance in soil treatments better than they are tolerated by our crops. The living soil can stand up under shock better than the crop can. Hence, the naturally higher levels of organic matter in our virgin soil and the accompanying much larger numbers of highly active microbes, have been what might well be called the "constitution" of the soil. This term implies about the same as the doctor indicates when in speaking of his patient he says, "He has a good constitution." By that statement the doctor merely designates the biological capacity of his patient to survive in spite of, rather than because of, the doctor's technological treatments. Our soils of high organic matter contents have thereby had "good constitutions" through the protection of which the commercial fertilizer prescriptions have been successful rather than because of the knowledge of their biological function and behaviors in the soil exhibited by those prescribing them. If then we are to grow good crops of nutritious food, a good grass agriculture feeding our livestock, a fine lawn, or an excellent putting green, which can continue to grow while we cut it back often, it is well to build up the soil in organic matter as well as in the inorganic chemicals. That means a good soil constitution to grow the grass in spite of, if not because of, the able superintendent and all he tries in hoping to make the grass grow continually.

*For fertilizing values from a green manure crop turned under ahead of vegetable crops, the dry matter of the crop plowed under should contain nitrogen, 1.5 percent; phosphorus, 0.3 percent; and potassium, 3.0 percent, according to Frank App, Director of Research, Seabrook Farms, in National Fertilizer Review, XXIX:3-6. 1954.

Growth is the Regular and Balanced Integration of the Many Essential Factors, Not Merely the Occasional Addition of Them

Growth of any vegetation is always promoted by cell multiplication (except in some cases like the watermelon in which what seems to be growth occurs because the cells are only expanded by putting in more water.) Any cell multiplication calls not for carbohydrates, not for fats, but for proteins delivered regularly, and all else usually accompanying the proteins. Proteins are also required for protection against disease, and for reproduction of the species. If the growth of a grass in a pasture, on a lawn, or on a golf green is to be maintained, the soil's assembly line must be delivering fertility steadily with nitrogen and all other required helps for protein production coming both prominently and regularly. Any protein synthesis calls for many life processes supporting it. They need not be merely in gear or running. Instead they must all be doing so in complete integration, coordination, and inter-action with each other. It calls, therefore, also for many intra-soil conditions like aeration, rela-

tive moisture, limits of temperature, and others as well as certain supra-soil conditions for the processes to run the plant's assembly line of making carbohydrates, proteins, fats, vitamins, etc., from the elements and compounds to be truly growth. "Better" pasture grasses are not necessarily "better" as feed for the animals because they make more mass and more complexity of the protein. Better grasses must make more protein to protect themselves from diseases. They are also makers of protein in seed as their method of reproduction in place of multiplying by cuttings, rhizomes and other vegetative means of keeping the species surviving. We must see the plant struggling to grow itself, to protect itself and to multiply itself. We must help it in those objectives of its own survival first and its services to us second.

In this there is a basic principle, namely, that the grasses in their growth are a living body. There are many requirements to be satisfied if the physiological processes within the plant are to be maintained at a high level. Also, only as those functions are more numerous and more complex do we have vegetation that is apt to be called "better." It can be such only as the soil is "better" in its fertility supply, in the moisture, in the air, and in the biological dynamics which keep it living and active in all that a soil does when it grows plant. To keep on growing is the plant's struggle for which we give it all too little support via the soil.

First of all we like grasses best, whether pasture, lawn or golf green, that keep on growing regularly. But we clip grass back and give it little chance to grow tops by which to build reserve nutrients into the root system. That root system is therefore shallow. Regrowth after every clipping back calls for nutrient reserve in the roots and a high level of fertility for protein-making since only protein synthesized within the plant results in plant growth. Instead, we dodge that nutritional responsibility to any plant that can serve us. We start to search for another grass as if grasses could be found that will tolerate starvation coming via the soil. Only as the soils are living providers of the soil fertility and an environment which keeps grasses producing protein—not just vegetative bulk—can a crop be expected to be kept on living, especially if pruned back regularly by the cow or the lawn mower.

The imbalance of fertility for a shallow-rooted crop is common if we expect to grow it by a hydroponic procedure with a dead soil serving as only the site for the demonstration. Salts and water are too much of a shock treatment. That kind of treatment represents much of what is man's struggle to make grasses grow themselves. But after composting the fertilizer salts with the organic matter to let the microbes take the shock and bring about their own quick recovery, as is true in the compost pile, the composted and transformed salts combined with the decayed plant residues represent a new constitution for the soil. Such composted matter put into the soil represents better microbial liberation of fertility, more water retention, regular temperatures and a timing of the rate of decay by the season to keep grasses growing.

Naturally there are some climatic limitations for truly "living" soil. One must therefore appreciate man's possible error in his high hopes to grow certain grasses where he fails to observe that Nature never grew them. Bowling on the lawn is common in Great Britain. The game of golf rose to its height in one section of that country. Pastures are the idol, as it were, of the Herefords, the Aberdeen Angus, the Shropshire, the Clydesdale and other animals with British-sounding names, as real grazing. But when grasses are moved out of that setting as for example southward even within the north temperate zone into high temperatures and spasmodic distribution of rainfall, they are no longer "naturally" on what is truly "living" soil for them.

Soils Are Not Living Under Our Control, Rather We Are Living Under Theirs

While we may think technology so readily under control of human nature, we dare not forget that the soil as a creative manifestation by Mother Nature is biology and not technology. Industry may readily exercise control of what it does, since it deals only in technology. But agriculture cannot exercise much control since it deals mainly in biology. Managing the soil is not just technology. It is also biology since the soils that truly feed

us, that grow proteins, and that keep crops growing will do so only if they are truly living and not dead soils. They must be considered (a) in their climatic setting (b) in relation to the physiology of the crop they are to nourish, and (c) the biochemical as well as chemical services at all times in the growing season if their assembly lines are to put out the maximum for our pleasure and profit by the growing things.

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