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TALKS ABOUT THE SOIL

IN ITS RELATION TO

PLANTS AND BUSINESS.

A BOOK OF OBSERVATIONS AND EXPERIMENTS FOR THE
USE OF SCHOOLS, STUDENTS, AND FARMERS.

BY

CHARLES BARNARD,

AUTHOR OF "TALKS ABOUT THE WEATHER," ETC.

The success or failure of our farmers affects the price of bread on all our tables, and we cannot say we do not care for these things. Whatever is good for the farmer to know is good for all to know.

BOSTON:

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1886.

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CONTENTS.

INTRODUCTION	PAGE ix
------------------------	------------

CHAPTER I.

THE EARTH'S CLOTHING.

I. The First Observations. II. The Bones of the World. III. Surface Indications	1-12
--	------

CHAPTER II.

THE HISTORY OF THE GROUND.

IV. The Soil-makers. V. Weathering. VI. The Soil Movers and Sorters. VII. Plants and Living Creatures as Soil- makers	13-35
---	-------

CHAPTER III.

THE SOIL THE HOME OF THE PLANTS.

VIII. Organic and Inorganic. IX. Experiments with Soils .	36-47
---	-------

CHAPTER IV.

KINDS OF SOILS.

X. Sand and Clay. XI. Experiments with Sand and Clay. XII. Sand Soils and Clay Soils	48-60
---	-------

CHAPTER V.

PAGE

THE ELEMENTS OF SOILS.

XIII. The Elements. XIV. Soil Analysis 61-71

CHAPTER VI.

*IMPROVEMENT OF SOILS.*XV. Taming the Land. XVI. Tillage. XVII. An Ancient
Tool. XVIII. Experiments in Tillage 72-95

CHAPTER VII.

*MANUS—A HAND.*XIX. An Old Fable. XX. Fertilizers. XXI. Plants as Fer-
tilizers. XXII. What to do 96-116

CHAPTER VIII.

ARTIFICIAL SOILS.

XXIII. Potting Soils. XXIV. Making New Soils 117-127

PREFATORY NOTE.

HEADQUARTERS OF THE C. T. C. C.,
HOUGHTON FARM, MOUNTAINVILLE, ORANGE COUNTY,
NEW YORK, 1886.

THE Chautauqua Town and Country Club is a branch of the Chautauqua University, and is devoted to the practical study of plants and animals, horticulture and agriculture. Its course of instruction extends over two years, and includes the reading of the four books forming this series, and the performance of a number of experiments and easy studies with plants and animals. This is the second book of the required course of reading, and is to be read by all members during the first winter of the class to which they belong. For full particulars concerning the course of instruction, address Miss Kate F. Kimball, secretary of the C. L. S. C., Plainfield, N. J.

This book was prepared at the Club Headquarters; and all the experiments here described have been made

the subject of study in the experimental department of the farm, under the immediate superintendence of Major Henry E. Alvord, manager of Houghton Farm.

THE AUTHOR.

TO THE MEMBERS OF THE CHAUTAUQUA
TOWN AND COUNTRY CLUB.

THIS book, entitled "Talks about the Soil," is the second of our required course of reading. We all join in reading this book at least once during the first winter we are members of the club. As in our first book, so in this, you will find a number of novel and instructive experiments and observations. You cannot fail to learn something from each, and you are all earnestly requested to try as many of the experiments as possible.

The examination papers that will be sent to you after reading this book will include a few questions that can be answered only by trying the experiments; and you will find it of advantage to try as many as possible in order that you may win our Chautauqua diploma when you graduate. Trusting you will find the book of interest and use to you, and that it will help you in taking one more step towards obtaining your diploma, I am

Sincerely your friend,

CHARLES BARNARD,

Superintendent of Instruction, C. T. C. C.

INTRODUCTION.

THE world is a great book, and he who walks or rides may read. We cannot get inside the earth ; and so it happens we do not know positively how it looks within the thin crust on which we live, nor can we, except in a very uncertain way, know of what the interior is made or in what condition it may be. This is not of much consequence ; because the outside of the world, the part we call the ground, and the things upon it, are quite enough to take all our attention. Upon the surface of the world are the great seas, the mountains, the plains and rivers ; and among these things we spend our lives. It is not very convenient to get off the ground, except for a few hours in a balloon : so it happens we must at all times remain on the surface of this great and wonderful book called the Earth or the World. We might board a steamer, and sail upon the sea, and soon lose sight of the land, and yet all the time we would be comparatively near the ground. Beneath the deepest seas is still the solid ground ; and the ship merely floats above the crust of the earth, upon the water. In a few places, men in

search of coals or metals have opened deep holes in the ground. We might go down into one of these mines, in the hope of finding out something concerning the inside of the world ; but we should find it so uncommonly dark that not a thing could be seen. We may carry a lamp ; but its feeble light only shows rough rocks or glistening coal, looking precisely like the rocks and coals we have seen on the hillsides. We stand still a while in the gloom of the mine, and listen, in the hope we may hear some sound from the interior of the earth that may tell us what is going on there : there is nothing, — nothing save intense blackness, awesome stillness, deep, profound, and terrifying. We may be glad to escape up the elevator to the sunshine, well content to spend our lives upon the solid ground. A trip in a balloon is quite as unsatisfactory. The sky seems just as high ; the stars, the sun, and the moon are no nearer ; and, if we look down, we find the ground extends in every direction till it is lost in the distance, — blue, indistinct, immense. The air is thin and cold, and we may be glad when the balloon voyage is safely over, and we are once more on the good, old-fashioned ground.

So, it appears, we have to spend our whole lives upon one of the planets ; and as we cannot get inside of it, and cannot get away from it, we are really prisoners on the outside or surface of the great star called Earth. The air is cold and thin, the caves and mines are dismal and dangerous. We do not care to stay either above or below the ground ; and, though we are

prisoners upon it, we may be very well satisfied. On the ground stand our homes ; out of the ground come our food and clothing, fruits, flowers, grain, wood, precious metals, coal, gas, iron, and all else that goes to make our lives worth living. Out of this same ground we stand upon, comes all wealth of every kind. Certainly it is well worth our time and labor to study this stony surface of the earth. If the ground is the source of so many good things, we ought to be well acquainted with it, that we may learn to win from it more food, more clothing, more wealth of every kind.

One of the first things we observe in looking at the ground is, that it is in almost every place covered with plants. These plants we see are good, some for food, some for useful woods, some for materials for clothing, and others are excellent foods for birds and animals. It is through these plants we gain wealth from the ground. We have already, in the first book of this series of Chautauqua Talks, made a number of observations and experiments, that we might learn something of the relations of the earth and the sun to living plants. We examined the effects of the movements of the earth upon plants ; we studied the effects of light and darkness, the changes of the seasons, the winds and rains, and learned much that is of value in caring for useful plants of all kinds. We have now to consider the home of plants, the soil in which they live and grow. We shall in this book, as in the other, make experiments with real things, and thus learn by direct

personal observations of nature. We shall learn why and how the soil in which plants grow was made, by observing the work still going on about us every day. We shall endeavor to find out for ourselves what the soil really is, by trying experiments with it to see how it behaves under certain circumstances. We shall also look at the different kinds of soils, to see which is best suited to our different plants ; and thus save ourselves from the mistake of planting cranberries on a rocky hillside, and watermelons in a peat-bog, or hunting for violets on a sand-bank, or pond-lilies on a mountain-side. We shall see that while there are trees in every State and Territory, these trees are different in different places, and that this difference depends in part upon the ground in which the trees stand. We shall see that it is not sufficient to learn from our observations of the sun, the wind, and rain, how plants are affected by the weather. We must know more. We must learn how plants feed, and where they get the food they need. It is not enough to learn from our first observations, where to place our garden, and how to arrange our plants in a sunny window. We must know how to select the right soil for the garden, and how to treat it, and how to prepare the soil in our flower-pots ; or all our studies and observations will be so many half-facts, — good as far as they go, yet not going far enough. It is to these new studies, experiments, and observations, we now advance, remembering all we learned before, and using our knowledge to explain much that may seem new and strange.

When we come to look at the ground closely, we soon learn that it rests upon masses of rocks and stone. Some of these stones are very hard; others are very beautiful, such as the rosy granites, the variegated marbles, and the blue slates. These, we see, are capital building-materials. Other stones are not so beautiful, and make good foundation-stones for our houses; others are soft, like soapstone; others split into thin slabs suitable for flagstones; others can be heated, and will melt, giving iron, copper, and other metals. In still other stones, gold and silver are found. Some stones will burn, some with a bright flame, others with much smoke; and we call these stones coals. All of these various stones form, with many others, the crust or outside of the earth; and they are often of great value. At the same time, we must observe here a distinction. The places where these granites, slates, soapstones, marbles, and other stones are blasted, cut, or dug out of the ground, are called quarries. The deep places where the ore-stones and crude metals are obtained are mines. These mines and quarries give us these valuable stones and metals, and so give us wealth. The work of getting them, or, as it is called, of winning them, is the art of mining and the art of quarrying. While we intend to study the ground, these lines of work would only lead us far astray. We are to study the top, or the immediate surface, of the ground; and the art of gathering wealth from this thin skin or outside of the ground, we call agriculture. We are to begin by studying the

rocks, not as quarrymen or miners, but as farmers and gardeners. From the rocks come all the soils. Thus it is true the world is a great stone picture-book, and he or she who has eyes to see can learn to read its wonderful pages. We cannot leave the book, as long as we live ; we walk over its pages every day, and this ought to make us eager to understand it. It is a book full of wonders, full of strange and curious things ; and, while men have been reading this book of the world for thousands of years, they have never found the end of the delightful story.

TALKS ABOUT THE SOIL.

CHAPTER I.

THE EARTH'S CLOTHING.

I. **THE FIRST OBSERVATIONS.** — We each of us live in a house. It may be a house in a city, and one of a block, or it may stand quite alone in the open country. Perhaps we have only one or two rooms in a hotel or apartment-house. It may be only a log house with one door and two windows. Whatever it is, we call it our home, the place where we live. We see that it is made of wood or stone, bricks, iron, marble, or other materials ; and we know that some one put these together to make our dwelling. We know it is an artificial structure. It was not found all finished like a smooth boulder in the fields, neither did it grow out of the ground like a tree. We look about the house, and very soon find it is resting on something. We can even go into the cellar, and find the very base of the whole thing. Under the house, whether it is in town or country, is the ground ; and this we recognize was not made by men.

We go outside the house, and find that the ground on which our home stands extends in every direction as far as we can see. To learn the truth concerning any natural object, we must study it, look at it from every side. Here is a natural object, immense in extent, of extraordinary variety in point of form, color, and quality. Let us leave our houses, which are only artificial affairs, and of less interest, and examine this great natural object, — the ground.

Perhaps we live in New York City, say in a cross town street below Central Park. We start out upon an exploring expedition, determined to take a good look at the world, and see what we can learn about it. Not very promising at first sight. Smooth flat stones on the walk, rough oblong stones in the street. We see at once that this is all artificial, and that the real earth is covered up out of sight. We walk on in either direction, and perhaps soon find a place where the street has been torn up for repairs, or where a cellar is being prepared for a house. Nothing but gray stones, glistening here and there with specks of silvery mica. Then the ground beneath the streets and houses is rock. That is one bit of truth. Is it the whole truth? Walk or ride down town as far as Astor Place, and then look about for a place where the roadway or a cellar is opened. Here is something very different. There are no stones to be seen; and in place of steam drills and blasting-powder to break open the hard rocks, the workmen here use shovels to dig up the loose yellow sand. If the cellar is deep,

we see the sand is laid in layers and curious streaks and lines, and that it appears to extend to an indefinite depth. We have learned another truth: The ground is rough rock that splits into irregular slabs, or is loose sand. We have not travelled a mile, and already we have learned two facts. We have also learned that one observation was not enough. The second observation showed that we should be entirely wrong if we concluded, from the first observation, that the entire world was made of splintery rock full of sparkling mica. It is clear we must go on, or make still another mistake. Already we have learned a good rule in observing nature: *The whole truth is found only after many observations.*

If you live in Chicago, or Portland, Me., or Portland, Ore., or in some other place, look about in the streets, — or if your home is in the country, around the house, — and make four observations, in four different directions, and find out whether the ground is rock or sand or something else. If we are in New York, we may extend our explorations a little farther. Walking west through the street, we come in time to the Hudson River. From the end of the docks we can look across the water, and see a steep wall of dark rock stretching along the bank of the river. There are trees and perhaps houses to be seen on top; and at the foot of the black cliffs, near the water, there appears to be a gentle slope covered with trees or grass. We know that this wall of rock is called the Palisades, and even at this distance we can see that

the great masses of rock must be of a very different kind from the whitish-gray rocks in New York. Another bit of truth : All rocks are not of the same kind and color. Another day we might go up the river above Yonkers, and cross over to the Palisades, and make a regular study of them, and find that there are many singular and interesting things to be learned from them. Just now we must go farther afield, and take a wider look over the ground.

We cross the river to Hoboken, and taking the Delaware, Lackawanna, and Western road, go towards the Orange Mountains. After passing the tunnel under the Palisades, we come out on an immense flat, covered with tall grass and crossed by winding rivers, and we recognize the great Hackensack meadows. Then, the ground is not all rock or sand. By the edge of the reedy banks we see the black oozy peat and river mud. Disagreeable ! Why, no ! nothing is disagreeable if we look at it in a scientific spirit. This great fiord is one of the most peculiar places in the world, and has much to tell us of the greatest interest, had we time to stop. See that hill off to the north, like an island in this green sea. That's a bit of the Palisades left out there by itself. That, too, could tell us a long story. We ride on through Newark, and come to pleasant villages. Observe the country roads and the ploughed fields. The ground is red, and the low places wet and muddy. Here is something new, — something very different from the meadows, or the rocks in the city.

Another day we may take the New-Haven road, and go out as far as Stamford in Connecticut. Here we find something wholly different. The land is hilly. There are very few level meadows, except along the shore of the sound. Through the grass in the fields appear many gray rocks covered with moss and lichens. The roads are gray and stony and the fields have none of that uniform red color we saw in New Jersey, but show every shade of brown and dark yellow. Another day we may take the Long-Island Railroad, and go out towards Far Rockaway. Here is quite another country, more level, with whiter fields and more sandy roads. Still another expedition may take us up the Hudson by boat, and in two or three hours we are sailing among steep mountains covered everywhere with forests.

These observations of different places about New York show us that the surface of the earth is full of variety in shape, in color, and character. The ground is composed in part of rocks, of sand and gravel, and many other things. If you are unable to make these journeys about New York, look around your home, wherever it may be, and you will discover that the ground varies in color, surface, and in materials, in every place. You may live upon a prairie, where all the ground seems, as far as you can see, to be everywhere the same ; yet even here there will be differences between one field and another. Examine the country about your home in four different directions, — north, south, east, and west, as far as you can conveniently

walk or ride, — and make notes of all you see concerning the surface of the ground. Note whether it be level or hilly, whether there are mountains near or in sight, or whether there be only low rounded hills and winding valleys. Note also the color of the roads and ploughed fields. Put the date, the names and distances of the places, and all these facts, on the report, and, having signed it, put it away in a safe place. The day may come when you will be glad to refer to it again.

We have learned that the surface of the world exhibits great variety in form and color. We must now take up a regular series of observations to find out the cause of this variety. The most important is the actual surface or form, — whether it be flat, or gently sloping, or steep and rough. The color of the ground is of use in helping us to study it ; but just now it is of less importance, and we will look at the surface only. In making these observations, it will be well also to observe the direction in which the ground slopes, — whether it be towards the sun at noon, or away from it in some other direction.

II. **THE BONES OF THE WORLD.** — We know that animals, fishes, and birds have bones. These bones united in various ways form the creature's skeleton, and upon the form of the skeleton depends the form or shape of the living creature. We might conclude that the surface of the ground was in like manner dependent upon some interior skeleton or bony structure. In one sense this is true, and in another

it is not exactly true. The hills and mountains have been called the "bones of the earth," because they are formed of rock over which is spread a thin layer of soil in which all plants grow. Here and there on the higher and steeper parts, as at the top of the Palisades on the Hudson and other hills or mountains, the rocks are bare; and people have said that the bare bones of the hills can at such places be seen. This is an interesting idea, and is good because it helps us to get at the real truth. All high hills and mountains are made of rock. The bare spots plainly show this, and every mine or oil-well sunk in the hills shows only solid rock, or the remains of rocks, as far down as men have ever been able to bore. The rocks are the bones of the hills. They are really much more.

A skeleton, as any visit to a museum will show us, is composed of bones arranged in a particular order, — the bones of a dog being arranged in one way, the bones of a pickerel in quite another way. There are spaces between the bones, and we recognize that every creature's skeleton is a framework held together by the creature's muscles and soft parts. It is quite different with a mountain. It is composed of rock, but the rock is in a mass. There is no framework; and, except in shape, the rocky mass of one hill may be just like another. Thus we see that the rocks do not form a true skeleton for the hills or mountains. They are simply masses of rock; and their shape or outside surface depends upon many different things, some of them quite independent of the rocks themselves.

This idea of the rocks being skeletons of the hills, we thus see, is a purely fanciful notion.

A mere fancy may suggest a truth. The hills and mountains are gigantic masses of rock. What of the meadows, the sandy wastes along the shore, the wide prairies where not a stone as big as a walnut can be found? Is there no rocky frame to these level parts of the world? Certainly. The whole exterior surface of the earth is rock. Under the prairie, under the seas, under the wide pine-barrens of the South, lie the deep rocks, the foundations that hold up all we can see of the world. A vast shell of rock really makes the skeleton of the earth. What is under the stony frame, we do not know; perhaps more rock to the very centre of the planet. Perhaps the rock is glowing white with heat. In the coal-mine we found it very warm. Volcanoes and hot springs plainly show there is heat and fire somewhere below the ground. Where, no one can tell. Perhaps no man will ever know. It does not matter. The rocky shell that completely covers all from sight, securely holds us up; and upon its surface we live and work. At times there are movements and earthquakes; yet the planet, as a whole, keeps quiet and secure. The rocks make the great bone-like frame of the earth, and it is these rocks we are first to study. Over a living skeleton is always flesh and skin, clothing it all from sight. So it is with the earth. The rocky frame of the globe is covered with an outside skin of the greatest beauty. This skin or outside part is called the soil. It covers nearly all

the rocky floor of the continents from sight, and upon it we live ; and from it come plants, each having a value and beauty of its own after its kind. This skin, or mask, that hides the rocks that cover all the planet is, compared with the whole thickness of the earth, infinitely thin. It is at best only a few feet deep, often only a few inches deep. It is as if we had placed a blanket of the thinnest cloth over the back of the largest elephant we could find. The rocky crust of the earth, from the top of the highest mountain to the bottom of the deepest mine, compared with the thickness of the earth from the surface to the centre, is as one is to four hundred. If the crust we are able to measure is only $\frac{1}{400}$ of the thickness to the centre, how thin is the soil compared with the mass of the earth? However, we are ourselves but specks and mites compared with the whole mass of the globe, so we need not trouble ourselves concerning the comparative thinness of the skin of our planet-home. We wish now to study the many-colored coat of the world, and to do this we must begin with the rocks. We wish to study the soil, because from it come plants, fruits, clothing, foods, flowers, and wealth ; and the soil is the child of the rocks.

III. **SURFACE INDICATIONS.** — The miner prospecting through the country in search of valuable metals is guided in part by what he calls the "surface indications." If the water in the brooks is deep red, there may be iron in the hills. If bits of worn and weathered coal lie half hid in the grass at the foot of

a cliff, then the edge of the coal-seam may crop out somewhere far up the mountain-side, from whence these stray bits of coal rolled down. If the man is looking for potters' clay, he studies the low places to see where the water has collected in muddy pools; after the rain-water has dried from the pools and shallows, he sees the ground has cracked into irregular fissures. The man looking for fine white sand for making glass examines the road-sides, and exposed places along the railroad-cuttings, for traces of sand-heaps. All these are marks or indications on the surface, giving hints of what may be found beneath the ground. We, in like manner, are prospecting for good soils; and we must first of all look out for surface indications.

Let us understand the matter clearly. Everywhere beneath the ground is solid rock continuous around the entire world. If the ground were everywhere level, as in some of our Western States, we might never know this till we came to dig down through the soil in search of coal or metals. Very likely, if the whole world were level, we might never have heard of these things. Fortunately the ground is not everywhere level. In many places the surface is crumpled up into ridges and knobs, so that the rocks with all their metals, coal, and mineral wealth, are in sight and often in easy reach. These raised places are the hills and mountains, and they form our first surface indications.

What is the character of the country about your

home? Is it level like a prairie for many miles in all directions? Is it a valley between hills? Is it directly among the hills or mountains, or are there many low hills with small valleys? Walk or ride about in different directions, and get at the facts in your case; and put it all down in your note-book, with the date and place of the observation.

Another indication may be found in the plants. Is the country about your home covered with forests, or are there cultivated fields and grassy pastures, with occasional groves of trees? Are there bare places where no plants grow? Do the wild plants and grasses grow rapidly in the summer, or are the wild plants small and stunted, and of feeble growth? Examine the plants and trees, both in fields and gardens, and put down in your note-book every thing you observe.

If there are streams near by, look at the water. Is it clear or muddy, and what is its usual color? If you live near the sea or the great lakes, note this also. Observe the ploughed fields and gardens. Is the land wet and sticky after a rain, or does all the water quickly disappear from the surface as soon as the storm has passed? What is the color of the ground about your home? All these things are surface indications, and should be noted, and the records kept for future reference. By their aid we shall be able, in due time, to decide upon the value of any soil we may see, with a certain degree of confidence. If we understand the surface indications of the soil, we shall be able to tell pretty closely whether any field or farm is valuable or

worthless ; whether it will give us good crops, or only poor and unprofitable returns for our labor. To make these surface indications of value, we must first study the past history of the world, and endeavor to find out how the various soils that cover the rocky frame of our planet were made. The soil is the child of the rocks. The rocks appear through the surface of the ground, among the hills and mountains. It is, therefore, to the hills we must look for information concerning this varied and beautiful garment of the world, we call the soil.

CHAPTER II.

THE HISTORY OF THE GROUND.

IV. **THE SOIL-MAKERS.**—There are two ways of looking at the history of things. One is to imagine that things were first made as they are now. The other is to think that things are as they now appear, because of many past events that gradually shaped them to their present form. It has been thought by many wise men, in the past, that the world was made, from the very beginning, just as we now see it; that when Adam went forth from the Garden of Eden, he found the world but freshly made, and precisely as we see it to-day. It has been thought by other wise men, that the years of the world are past counting; that our planet passed through many long stages of growth; that its present appearance is the result of infinite changes, every change being a step upward, a step toward improvement. In the opinion of these men, the world, under God's guidance, grew to its present form through various stages of growth, and in each stage subject to natural laws that have neither change nor turning. These are opinions, and there have been good men who have firmly held to one or the other of these two opinions.

The moment we come to study the rocks, we find many things that lead us to think that this last opinion must be the truth. The geologist is the student of rocks; and his history of the world, as he reads it in the rocks themselves, is the geological history of the world. This history, he tells us, is still going on now. The rocks make their own history every day. Day by day, year by year, the face of the rocks changes. From these changes, the geologist has reasoned backward to the time when the rocks began. He has put many observations together, and formed what seems to be a truthful story. We must glance at this story before we can rightly understand why and how the soil under our feet was made.

In the beginning God created the universe, "and the earth was without form, and void." There is nothing we can know beyond this. We see, far beyond the little group of planets we call the solar system, vaporous clouds of light without definite form, vast, void of life, perhaps only clouds of flaming gas. Are these the beginnings of a world? No man can say; yet they seem to suggest the beginnings of a star, and a star is a world. In like manner, our star, now clad with a cold skin of stone, may have been a cloud of fiery gases that through countless ages condensed into a vast ball, swinging round the sun. In time it became more solid, and spent a part of its heat; for the laws of nature, the laws of light, of sound, electricity, magnetism, attraction, and chemical action and re-action, were at work then as now. These laws would tend to

produce, in time, a globe nearly round, with a thin crust on the outside, that, as the cooling and condensation went on, would shrink and shrivel up into wrinkles and ridges. No man can say how slowly or how rapidly these changes took place. God is in no haste. A million years are as the swing of a pendulum in the clock of his time. All the years, up to the time when the first rocks appeared, are as the dust in the air, — past counting. Men have tried to roughly estimate them, but it is like measuring a mountain with a yard-stick. We have to be content to call it ages, and without knowing exactly what ages mean.

It is enough now to imagine that there came a time in the history of our planet when the surface of the earth became hard enough and cool enough to hold water. The clouds, driven off perhaps by the heat, condensed; and scalding rain fell on the first rocks. What these rocks were, or how they looked, we can only vaguely guess. They may have been precisely like our granites or like the lavas we see to-day thrown out of volcanoes. This does not matter at present. We have only to note that at the time the first rocks appeared, there were winds and storms, lightning, clouds, rains, and eventually hail, snow, and ice. The surface was probably very irregular; and the water gathered in certain places, and the dry land appeared. We have observed in our studies of the weather certain laws governing the temperature, the clouds and rain. There is no reason to think these laws did not prevail then. There is every reason to think that the laws we

see in operation to-day were in operation then. "He giveth snow like wool. He scattereth the hoar-frost like ashes. He casteth forth his ice like morsels : who can stand before his cold? He sendeth out his word, and melteth them : he causeth the wind to blow, and the waters flow." God reigns in this planet, though it be only a mass of flaming gas, a ball of liquid fire cased in a shell of glowing rocks, or the world beautiful where men live.

What effect would these laws have upon the first rocks? What influence would the weather have on them? The geologist tells us that the first rocks began to "*weather*." They were exposed to the weather, and remarkable changes at once began. This process he calls "*weathering*." The result of this weathering is at last to make soils. Naturally we might ask him how he knows that. His answer is very simple : because this process of weathering is going on now upon all rocks, and there is no reason to think it did not go on then. The geologist has also another word, "*denudation*." When the first rocks appeared, they were doubtless soon thrown or crumpled up by the shrinking of the crust, into heaps and ridges. These primeval hills began at once to be weathered, — to be torn down and denuded by stormy winds, frost, ice, rain, torrents, and floods. The moment there began to be a rocky crust to the world, destruction, wreck, change, and alteration began. The weather crumbled and broke down the rocks. Denudation set in ; and the crooked began to be made straight, the rough places plain, and

all the mountains were brought low. The sea brought its sledge-hammer waves to smash and destroy the rocks. Frightful storms and cyclones tore away the crests of the hills. Glaciers ploughed gigantic furrows through the hills, and icebergs scratched the very face of the hard rocks. No man was there to see. Perhaps no living creature, perhaps not even the lowest form of plant, was yet alive. We guess at these things, because they are still going on to-day. We see the record of past ages in the rocks under our feet. These things that tend to alter and change the rocks, the frost, rain, the air, storms, ice, and floods, were the first soil-makers.

v. **WEATHERING.**—Schunemunk Mountain forms the western side of the valley that opens through the rear of the Highlands back of West Point on the Hudson. The valley forms the gateway through the mountains from Newburgh to the valley of the Ramapo, and offers a road for the old Albany Turnpike, and the present Short Cut Railroad connecting Newburgh with the New York, Lake Erie, and Western. From Houghton Farm the whole eastern face of the mountain, extending north-east and south-west for several miles, can be plainly seen. At intervals through the trees can be seen frowning cliffs of dark rock deeply stained by the weather. About half a mile south of the station, one of these cliffs is quite near the railroad, and can be easily examined. This cliff admirably illustrates weathering, as the work is going on very rapidly.

On climbing over the fence by the railroad, and en-

tering the woods, the ground is found to be very rough. Through the thin grass can be seen irregular fragments of hard stone. On advancing up the hill, these rocks become more plentiful, till at last the ground is completely covered with sharp rough stones of every shape. Presently we see among these ragged rocks great numbers of smooth round pebbles. As we go on, these become more common, and we find many lumps or masses of pebbles bound together, and looking much like plums in a pudding. We recognize these as pieces of "pudding-stone." The first rock broken into irregular pieces is quite different in color and texture, and is a trap-rock. The particular names of these rocks are not now important. The thing to observe is that something has smashed and broken these rocks in pieces. These rocks were evidently once solid masses. Now they are only ruins, the shattered remains of some mountain. We climb upward in search of an answer. At every step the hill grows steeper, the fragments of rocks larger and more irregular. At last we reach a scene of the wildest ruin and confusion. Huge fragments of the pudding-stone lie piled one over the other, as if hurled down from the mountain-top. Here a mass weighing tons has ploughed deep into the ground, raising a mass of rough gravel before it as it slid down the mountain. Here a great lump has shot half-way through a tree, and is barely supported at one end as if ready to fall with a crash down the hill. A fallen tree with every leaf withered and yellow has a splintered trunk, and when

we reach it we find a mass of rusty rock has plunged completely through it. Climbing as best we can over the wild confusion of smashed and broken rocks and shattered trees, we reach the base of the gray cliff. It is split and splintered in every direction, and many pieces seem ready to fall and crush us. It is evident this cliff is being torn down, for here are the fragments at our feet. The work is going on now, for the fallen tree was cut down this very summer. The leaves have only withered recently, and the splintered wood is still fresh. The cliff is fast weathering away.

What are the causes of this destruction? Is it best that this great Schunemunk Mountain be thus torn down? and what good will come of all this ruinous change? We pick up a mass of pudding-stone, and throw it down upon the rocks below, and it bursts into a thousand pieces, and a shower of pebbles rattles over the rocks. Observe the color of the stone, — a dull red. The plums of the pudding-stone are bound together with iron. It has rusted on exposure to the air, and falls apart easily. Here is our first clew. The air is at work on the cliff. The oxygen of the air is combining with the iron to form the red dust called oxide of iron, and the pebbles being bound only with dust easily fall apart. Here we see the air is an agent in breaking down the rocks. The gases in the air act chemically upon all rocks, to disintegrate and break them up into dust and powder. — So it has been since the first rocks appeared. The moment they were exposed to the air, they began to be destroyed.

Rub your hand over the face of the cliff. It is dusty. The air attacks every part of the surface, and it slowly decays and turns to dust. In the case of the pudding-stone, the process is comparatively rapid, because the iron cement that binds the pebbles together rusts away and lets them free, just as beads are let loose when the string breaks. The fallen tree and the vast heap of shattered rocks at the base of the cliff plainly show that the destruction must be comparatively rapid. Could the air alone do this? From the appearance of the cliff, there must be other causes at work.

We notice that the cliff is full of cracks. When it rains, the water must flow down through all these cracks, and lodge in countless minute fissures in the face of the rock. After a heavy rain, when the rock is filled with water, it may clear away, and a sharp, cold wind come out of the north-west. Every drop of water freezes and expands, and bursts open the rock, splitting off minute specks and scales, or throwing down great lumps that crash through the trees, and destroy every thing before them. Here is another and more powerful cause at work breaking down the rock.

In the summer there is no frost; and yet the rain may be at work washing moss and dust into cracks already opened, and forming a sponge ready to hold water that freezing next winter will act with still greater force. The dry dust sifted into the cracks and openings formed in the rock will also expand when wet, and push off small pieces, or start a great mass that last

winter's ice left just ready to fall. Perhaps in this way the great lump that cut down the tree not many weeks ago was toppled over. The wind may also in storms brush off small bits already loosened and ready to fall, and occasionally the lightning splits off a fragment. Every rain that falls brings down acids from the air to slowly eat away the rock. The sun warms the face of the rock, and helps to destroy it by expanding its surface, and opening minute channels for the sudden summer rain, that with thin fingers seeks out every crack to pull the rock to pieces. Even the mosses and lichens growing here and there, and the roots of trees and plants, assist in the work ; and thus the noble cliff reared so high in the air, even the mountain itself, is visibly falling in ruins before our eyes. Slowly, infinitely slowly, but without pause, the work goes on, and has gone on since that wild day when with frightful sounds and awful earthquakes, old Schunemunk was upraised. As we go down the mountain-side, we find again the fragments of trap-rock. There, too, are the ruins of some higher cliff. It is a harder rock, and the pieces are sharp and jagged. The weather must have worked very slowly, for the edges and corners are hardly dulled. The trees that spring up among the stones show they have lain here for at least fifty years, and the stones are almost unchanged in that time. The years that passed while they were slowly broken down from their old cliff may be numbered by hundreds. No man can tell. We can only observe that while the work now going on at the pudding-stone

cliff is very rapid, this other and probably much older work was very slow.

This weathering of the rocks has been going on ever since the world began. Heat, cold, water, air, ice, the wind, expansion and contraction, storms, all the phenomena we have been studying in our observations of the weather, unite to break down and destroy the rocks. The work is still going on every day. It can be seen easily all along the Palisades on the Hudson, and on every rocky hill and mountain. Look about among the hills in your neighborhood, and make careful explorations and observations of the effects of the weathering upon the rocks. Put down full notes of the work, whether it seems to be going on slowly or rapidly; and note particularly what seems to be the chief influence, — the rain, or the frost. In some places you will find the rocks breaking down into sand, dust, and powder, during every rain. In others you will find it hard to tell whether the work is going on or not. In all it is going on, and good observation will soon enable you to find out its cause.

From the railroad that creeps along under the shadow of Schunemunk, looking south, can be seen the profile of the mountain. The slope is peculiar. At the top it is abrupt and steep; then it softens, and with a lovely curve the graceful outline melts gently away into the level meadows of the beautiful valley. The mountain is wasting away; and its ruins are slipping, slipping ever, down into the fertile valley. The soil-makers are at work here, as everywhere,

since the rocks began. The weathering of the rocks degrades and denudes the mountains, and this very destruction is for the benefit of the valley. These broken and shattered stones are melting away into sand and dust, and this sand and dust helps to make the soil out of which spring flowers and fruits and crops of every kind. - Faster or slower, forever and forever, the work will go on till the mountains are brought low, and the rough places are made plain. Out of ruin and destruction come ever life and beauty. Even the outline of this rubbish and wreck, swept down from the mountain, makes a beautiful curve against the sky. They call such a sloping mass of waste and broken material at the foot of a mountain or cliff, a *talus*. We see the talus about the base of nearly every rocky hill, and we recognize its outline by its wonderful beauty.

VI. **THE SOIL MOVERS AND SORTERS.** — In our excursion to the pudding-stone on Schunemunk, we observed the influence of the weather upon the rocks. We saw that heat and cold, water, air, rain, and storms, tended to tear down and degrade the mountain. If near our homes we found other examples of this weathering of the rocks, it was only to find illustrations of the same thing, showing that the work is universal, and not confined to this single mountain in the Highlands of the Hudson. All who live in the level portions of the country, and are unable to find near their homes examples of this work, will simply note the fact that this work does go on in all hills,

that the tendency of the rocks is to crumble and fall down under the influence of weathering, and that this weathering has undoubtedly been going on without interruption since the first rocks appeared. We will all, whether living near the hills or on the most level prairie, now join in still further observations out of doors, in the neighborhood of our homes.

If the mountains crumble and fall into loose heaps of broken stone, why do we not find the heaps just where they fall? Why is there a long, sloping talus at every denuded cliff? We might expect, from all we have learned, that there would be masses of loose stones about every ruined mountain, and that the broad plains, like the great valley between the Alleghanies and the Rocky Mountains, would be bare rock, just as at the beginning. We know that this is not so, and that our prairie States, far from any mountains, often have deep soils, rich in the remains of long-vanished hills. We must find the answer to these questions by observing what is going on about us every day.

Go to the nearest brook or river after a heavy rain. Observe the color of the water. It is perhaps yellow or brown, with mud and floating sediment. If you cannot do this, observe the little streams of water in the road or in the street-gutter at the beginning of a smart shower. The water is muddy and discolored. It is evident the water is carrying along many fine particles of earth and soil. If the stream is in a hilly country, we may observe, that, beside the fine mud

carried along by the water, there is sand sweeping onward over the bed of the stream. If the stream is a mere rivulet that quickly dries up after the rain has ceased, we can examine its bed when it is dry, and plainly see that the water carried along sand, small stones, and fine mud. At low stages of the water, our Western rivers show this very plainly wherever shoals and sand-bars appear. Make full and careful notes of all that is seen in such a dry bed, for there are two great facts to be learned from these observations. For those who live by the sea, the same observations can be made all along the shore, at the mouth of every bay or inlet on the coast.

We have here the great soil-mover, — water. The rain, falling on the wasting rocks, sweeps away the minute specks and grains chipped off by the weather, and carries them down to the nearest streamlet and brook. These fine bits of rock do not float, but are suspended in the water or roll along the bed of the stream. The ragged flakes and scales of stone crash and grind against each other. Every rough corner is knocked off, and all the pieces become rolled into smooth round particles. The brook is a mill. It is making, from the chips brought down by the rain, sand. A flood comes with more water, and larger pieces of broken rock are pushed into the rapidly moving water; and these, knocking, tumbling, and grinding over each other, are soon ground into smooth round pebbles and gravel. Onward rolls the confused mass of gravel, sand, and finer bits of rocks, grinding and polishing

each piece as it goes. In time the stream comes to more level ground, and runs slower and slower. The current, not being able to push the larger stones any farther, leaves them all by themselves. As it goes slower and slower, it is still weaker, and drops the coarser sand, and then the finer sand. Lastly, the finest dust suspended in the water must be dropped in smooth beds of mud ; and the water flows away to the sea quite clear, having left its loads behind in the lowlands, and all correctly sorted out, — the gravel by itself in one place, the sand in another, the fine mud in another. Running water is the great soil-mover. It takes the broken fragments of rocks from the hills, and transports the material to distant plains, perhaps hundreds of miles away. The bits of rock broken off by the cold in the White Mountains may be transported by the Connecticut River, and left as rich soft mud on the meadows about Hartford. The yellow mud of the Mississippi may drift a thousand miles across the continent, and lay the dust of Pennsylvania hills among the sugar-plantations of Louisiana. The first rains that fell on the oldest primeval rocks became the first soil-movers ; and the work has gone on for countless centuries on centuries, precisely as we see it going on to-day. Floods and storms may have hastened the work. Mountains of volcanic dust may have been swept away by a single storm, and scattered over the plains for a hundred miles in every direction. There is every reason to think, that, in the geological past, the streams and rivers wore down and carried

away whole mountain ranges in a very short time. In the West we find that this work of carrying away the ruins of degraded hills is going on now upon the most gigantic scale, and from this we can form an idea of what may have happened long ago. Currents and tides along the shore are also movers of sand and gravel, moving beaches and sand-bars from place to place, and often changing the whole character of the coast for miles.

We observed, in studying the empty bed of the rivulet, that the sand after the water had subsided is left in one place, the fine mud in another. This is often shown on a small scale in every street-gutter; and, to the young man or young woman with eyes, the street may be an open lesson in the first principles of geology. Running water is thus the great rock-sorter, as well as rock-mover. The ruins of the hills are not left in hopeless confusion on the plains. The whole of the material is completely sorted: the larger stones and pebbles are left in one place; the sand is carried farther away, and is left by itself; and the lighter stuff, the mere specks and scales of rock, are carried farthest, and left also by themselves. We saw in our studies of the weather, that the sun brought the water from the seas, and that the invisible vapor in the air condensed as clouds about the cold mountain-tops, to fall in rain. We now see that this same rain assists to break down the rocky hills, and to carry the ruins far and wide, and leave the sand and fine silt or mud on the lowlands to cover the naked rocks, and form a

home for plants and grasses. The sun, we learned, is the great rain-mover; and thus it is indirectly the great soil-mover.

Added to the moving water we have the wind, that may blow loose dust and sand long distances. Ice in streams may push loose gravel before it along a river-bottom, or even carry it floating on the water. These agencies—water, ice, and wind—have been sufficient to transport whole mountain ranges from one place to another. All that was required was time, and in the history of the ground a million years may be as one day in our lives.

There is also one other circumstance to be observed in the slow formation of the soil that now nearly everywhere covers the rocky shell of the world. The surface rock itself, even where there are no hills, slowly breaks up into fine bits, scraps and dust; and, the surface being level, this broken material left after the weathering of the ground-rock may remain where it is, and thus slowly form a covering of soil over the rock itself. This process is going on all the time, and slowly deepens the soil all over the world. This fact we must enter in our note-books also, because it is of the utmost importance to every man, woman, or child who sows a field of wheat, or plants a flower-seed.

While we have observed the effects of weathering upon the rocks, and noticed how running water tends to move and sort the loose material broken off from the rocks, we must not forget that there have been in

the history of the earth wonderful changes that have also had a great influence in giving the surface of the earth its present appearance. Earthquakes have raised mountains in the air. Volcanoes have lifted enormous heaps of lava, dust, and ashes into the clouds, or scattered vast quantities of cinders over whole tracts of country. The sea has rolled in upon the land. The lands have even sunk in the water, or been raised up; and this many times over, so that what were once shallow bays and lagoons became at last mountain-tops. Vast tracts of gravel scattered by streams from old dead mountains have been hardened into stone. Deep black pools of mud have been sunk and crushed in earthquakes, and turned to coal. Whole beaches have been solidified to red sandstones by water charged with iron filtering through the sand.

Moreover, climates have changed. Where now we have each season snow and ice in winter, and growing plants and hot sunshine in summer, there was at one time almost continual winter. It is now thought, that for a very long time all of New England, New York, and several other States, were buried out of sight under deep ice. This ice, like the glaciers we see to-day in high mountains, drifted slowly southward over the country, ploughing up the loose earth, grinding the hard faces of the rocks till they were polished like mirrors, cutting deep grooves in the rocks, and pushing enormous quantities of mud, stones, and gravel through all the valleys. Schunemunk Mountain bears upon its smooth rounded top hundreds of traces where

the ice ploughed over the rocks. Some of the stones at the top are to-day brilliant with the polish left by the slowly grinding ice. The very ruins of the mountain were carried far away to the south-east, and scattered over the State of New Jersey. Wherever we find—as in New England, on Long Island, through New York, New Jersey, and even farther west—rounded hills of gravel, we know the great glaciers once covered all the land deep in ice. When at last the seasons grew warmer, year by year the ice disappeared, till now there is not a trace of it except in the terrible ruin it wrought. Wherever you see a rounded hill of gravel, you may be sure that once the ice was at work making new soils. This Schunemunk Mountain thus contributed to the soils of New Jersey, and other mountains and hills far to the north sent down their remains on the ice to make the surface soil of the valleys all about old Schunemunk. So great was the movement of soils caused by the ice of the glacial period, that in this part of the country we cannot be sure that the soil near any hills all came from the hills themselves: it may have come from hills a hundred miles away.

These changes, with others of equal magnitude, form what is called the geological history of the soil; and, if you have time, it will be well worth the while to study it still more. In brief it is this: The rocks were first formed, and then torn down by the weather; sorted, moved about, and re-arranged into new soils and new rocks; and again all was overturned, ground

up, transported, and sorted out again,—till it is impossible to tell just how old any particular soil may be. Plants and living creatures also helped to form new soil. Shell-fish and countless millions of tiny creatures swarmed the old seas, only to die, and leave their shells and skeletons to make new stones that were afterwards lifted into hills, only to be torn down again, and scattered far and wide to form new soils.

VII. PLANTS AND LIVING CREATURES AS SOIL-MAKERS.—On the rocks everywhere to-day we find lichens and mosses ; dull, slow-growing plants, that live low, strange lives on the bare face of rocks where no other plants could grow. With your knife, scrape off these close-clinging lichens and mosses, and under them the rock is dusty. The plants are slowly destroying the surface of the rocks, and forming a thin dust in which they can find a foot-hold and live. These plants perish in time ; and their dusty, powdery remains slip into cracks and fissures of the rocks. Seeds blown by the wind lodge in these cracks, and spring up and try to live in the scanty soil. It is a soil, because the mosses powdered the rocks, and made a fine stony dust. Their own remains also added more material, and the seeds found what they wanted, — food and a place to grow. The plants from the seeds perished, and their remains were added to the soil. In this way all plants since the world began have helped to form the soil. The plants perished in the changes that came over the world. No doubt many times soils were formed, and trees grew for

thousands of years, only to be destroyed and overturned. Earthquakes, sinkings in the seas, showers of dust from volcanoes, floods and fires, swept away all traces of old soils and old forests, till only the rocks remained; yet in all there was progress, and the last new soil formed of dead plants and the remains of more ancient rocks now covers all the land. Every plant that has ever lived helped in some degree to make a soil for other plants. Every leaf that falls, every plant dying of old age or destroyed by frost or fire, leaves its gift for the plants that are to come after it. We have only to observe the thick carpet of fallen leaves under the trees in the woods, to see that each year the trees add to the soil in which they live. We walk along the edge of swamps and bogs, and see the thick moss and rank grass slowly moulding away beneath the water, and forming a black, soft soil, on which other generations of plants live, and, perishing in turn, add more and more to the ever-increasing mass of dead vegetable matter. In the past, long ages ago, plants and trees, giant ferns and quick-growing mosses, grew more rapidly than we ever see them growing now. These plants, many of them water-loving plants, grew apace in the hot, steamy climates, and in dying left their remains in the black swamps and muddy meadows, and contributed vast quantities of materials to our soils. Some of these old soils, made almost wholly of dead plants, afterwards became our coal-beds; others, no doubt, helped to form the deep black soils of our prairies. Earthquakes destroyed

and buried whole forests ; and their remains, squeezed between the rocks, turned to stone. Plants undoubtedly grew in great abundance everywhere they could find a foot-hold, from the time the first wild storms tore down the oldest rocks, and made the first scanty soils and in turn helped to form still other soils. We see how the rocks have contributed to make the soils, but we must also remember the plants. They have worked more slowly, and the proportion they give is smaller ; yet it is an important part, as we shall presently see. Plants have flourished every summer, in every portion of the earth not covered with ice and snow, for countless thousands upon thousands of years. We cannot even guess how long they have been growing. And each plant, tree, and vine has at last laid down its life, and left its remains as a contribution to the soil that hides the bare and naked rocks from sight. It is the remains of plants that give the black color to our soils, and give us the deep, soft, rich soils of the West where our great crops grow. No land, except perhaps parts of Russia, has such deep soils as we possess in some of our Western States and Territories ; and these soils have been largely formed from the remains of long dead and forgotten plants.

Every living creature has also helped to form the soils. Every fish and bird and beast that has ever lived since the world began has left its remains in the soil. Sometimes we find their skeletons turned to stone ; and only by these stony pictures — these fossils

photographs of ancient life — can we tell how and where they lived. We know they did live, — that every single creature, from the shellfish as big as a pin-head to gigantic mastodons, has left its remains in the earth to be turned to stone and to soils. The sweet earth quickly melted the dead thing away, and turned it into soft soil where flowers and fruits might grow. Some of these remains were turned at last to stone, only to be weathered away by storms and again turned to soils. Even at this day, there are whole islands covered deep with yellow soil left by millions of sea-birds that made their homes on the rocks. We call it guano, and send ships to gather it that we may use this pungent yellow soil to enrich our gardens. Even the earth-worms we have thought so useless and disagreeable are soil-makers. We find in the garden-walk in the morning, tiny heaps of black soil left over night by some creature. Only within a few years was it discovered that this is the work of the earth-worms. They burrow deep in the soil in search of food, eating the poor soil below, and then leaving the undigested portions on the surface as rich contributions to the soil. And these humble creatures have no doubt performed this work for millions of years, and we never knew it until just now. Little did they care. The Creator gave them this good work to do; and they went on attending to business, quite regardless of the opinion of men who wondered, ever since the world began, why such creatures were made.

So it appears that our soils are composed of these

three things, — the remains of old rocks, the remains of dead plants, and the remains of living creatures of every kind. Out of ruin come always new forms and new beauty, and out of death comes the food for more life.

CHAPTER III.

THE SOIL THE HOME OF THE PLANTS.

VIII. **ORGANIC AND INORGANIC.** — We go out in the garden, or upon the cultivated land of the farm. If it is winter, the ground is hard and rough, or is covered with snow. In the Southern States, or in all the States in summer, we find the ground is soft and loose. Unless covered with grass or other plants, it is easy to dig a hole in the ground with a spade. Get a spade or other tool, and try this. Dig directly down into the ground. Observe what you find. At the very top the loose earth is dark-colored. As we dig deeper, the color, whether it be red, brown, yellow, black, or gray, becomes of a lighter shade. The first part or top, that is almost always of a darker color, may be from six to ten inches deep. In some places, as on the prairies and along river-bottoms, it may be very much deeper. The lighter-colored part below may be only a few inches deep, or several feet deep, this varying greatly in different places. If we dig still deeper, we come to sand, gravel, clay, or even rock. Whatever we find within a few feet of the top, we shall certainly find, somewhere below, the bed-rock that forms the crust of the earth. This loose material

at the very top or surface of the ground is called the soil. For convenience it is divided into two parts: the upper and usually shallow part is called the *soil*, and the deeper part is called the *subsoil*. These two words, the *soil* and the *subsoil*, are used in all agricultural science; and as we are considering this science, we will remember them and use them in their exact meaning, though it is often quite proper on some occasions to give the name *soil* to both soil and subsoil. In some of our States and Territories, can be found wild lands where no man has ever cultivated the ground. In such places we call the soil *virgin soil*, because it is untouched, and just as it was formed from the remains of rocks, plants, and living creatures. It might be interesting to examine this wild soil, but for our present purposes we will examine only the cultivated soils. We shall therefore understand the word "soil" to generally mean the soil and subsoil of our farms and gardens. It is in this soil that all our useful plants live and make their home.

One of the first difficulties we meet in any study of nature is the infinite variety of things to be seen. It is bewildering to think that there are so many kinds of plants. A walk through the country, among the farms, shows us the greatest variety in soils also. Our exploring expeditions show endless variations in the surface and character of the ground. This apparent confusion and perplexing multitude of different things disappear at once when we bring to our observations the right scientific spirit. We must learn to classify

things. We must arrange things in groups and classes. All the infinite variety in nature can be easily brought into order by grouping every thing in two great classes. Every thing we can see or touch, even those things we can only smell or feel, as the air or a perfume, can be grouped into one of the two classes. It is either an *organic* substance, or thing; or it is an *inorganic* substance, or material. An *organic* substance is something that has been organized, or formed into organs or parts, and has life, or has had life at some time. Any creature, dead or alive, or any part of such creature, be it a minute bit of bone or part of a wing or feather; any plant, or remains of a plant, though it be only black dust where some plant has died, — any thing that shows organized structure, belongs to the organic class. All else, minerals, metals, water, gases, every thing that fails to show an organized structure, and that has no life, and never had life, belongs to the inorganic class. Look about carefully, and make a list of twenty organic and twenty inorganic things you may find in the house or out of doors.

The soil and subsoil are composed of both organic and inorganic materials. If you find in any place loose materials composed wholly of inorganic substances, or composed only of organic materials, you cannot properly call it a soil. A soil must have both, though in very different proportions. The soil will commonly contain more inorganic material than organic material. The subsoil will be the same, except that it will generally contain a greater portion of

inorganic materials than the soil immediately over it. For instance, if any soil contains ninety per cent of inorganic matter, and ten per cent of organic matter, the subsoil under it may not have more than three per cent of organic matter and ninety-seven per cent of inorganic matter. The reason for this is plain. Plants and animals that supply the organic materials live on the surface of the ground. Rocks that by weathering supply inorganic materials are below, and form the foundation of all soils. Besides this, organic materials are usually lighter than inorganic matter found in the soil, and naturally the heavier material is beneath the lighter material. There may be places, however, where this is quite different; as where a meadow, having a soil that is almost wholly composed of the remains of plants, may be covered with fine sands swept over it by a flood from the hills. The two are, however, in all cultivated soils, mixed together, and often so completely mingled that it is very difficult to separate them. Both organic and inorganic matters are necessary to the existence of all plants growing in a soil.

On the Hartford and New-Haven Railroad, a few miles north of New Haven, there is, on both sides of the track for a mile or more, a level bit of country where not a tree or shrub or blade of grass can be seen. The ground is covered with loose yellow sand, that in dry weather drifts hither and thither in the wind. Before the road was ballasted with stone, it was a terrible place to pass, on account of the dread-

ful clouds of dust that blew in the car-windows. Here is a soil probably almost wholly inorganic. It contains only sand, and it is so loose that no plants can find a footing in it. If by chance seeds fall there, as no doubt they do every year, they cannot grow; because the first dry wind pulls them up by the roots, and carries them away to perish, or the drifting sand overwhelms them, and they are suffocated. Besides this, the rains that fall there soak quickly away through the sand, and the plants die for the want of water. If you never chance to pass this curious place in Connecticut, look about your own home, examine the sloping sides of railroad-cuttings through sandy or gravelly hills, and see if you cannot find examples of a soil composed almost wholly of inorganic material like sand. Make notes of the color and general character of such soils.

In Orange County, N.Y., there is a great boggy tract called the Chester Meadows. Perhaps long ago it was a lake, and in time it was completely filled up by mosses and water-plants. These in dying left here a curious soft dark soil. Perhaps we should not call it a true soil; for it is composed of only organic matter, with a very small portion of sand or inorganic matter. It is a famous place for growing onions, yet it has its disadvantages; for, being very light and loose, the plants do not get a firm hold in the ground, and it has happened that in a gale of wind a whole crop of onions has been torn up, and blown away out of sight. The plants, finding no sand or heavy material in the soil,

could not anchor themselves, and were blown away by the wind.

Look about your home, and see if there are any soils near that are composed largely of remains of plants, or organic matter. Make full notes of the place, its color and general character. Observe it just after a rain, and see if it is wet like a sponge. Nearly all our useful plants object to wet feet, and refuse to live in these organic soils because they are so full of water.

On Cape Cod in Massachusetts, there are many bogs and low places, filled with a mass of dead vegetable-matter that forms a black soil almost wholly organic in character. In such places the cranberry-vine will grow finely, provided the soil is artificially prepared for it. To do this, the farmers cart clear sand into the bogs, and spread it over the damp, peaty mass of dead plants. On this mixture of organic and inorganic materials, the cranberry flourishes wonderfully. It is not blown away by the wind, nor does it wilt for want of water, or perish from too much water. Such artificial soils show just how the mixture of organic and inorganic matter in certain proportions must be found in all good soils.

Suppose, when you are walking about making your notes upon the soils near your home, you found a field composed almost wholly of an inorganic sand. Suppose in another place you found a black, boggy meadow, with only organic peat for a soil. Neither of these places is fit for useful plants, and yet each contains just what the plants need: each place has

the materials of a good soil. What would you do with such a place? How could the sandy field be improved, and made to bear good crops? Clearly, the thing to do here is to bring that black organic peat and muck from the bog, and put it on the sandy field. Here our observations are beginning to be of value. We are coming to see the value of agricultural science. Perhaps the sandy field does not produce enough to pay the taxes. Perhaps the bog is a dead waste, producing nothing of value. Bring the result of your observations to bear on the subject. Get cart and horse, and carry the organic material from the bog to the inorganic material in the sandy field, or take the sand to the bog. Bring the two together, and make a new artificial soil where useful plants will grow, to give us food, or supply food for cows that may give us milk, cheese, and butter.

IX. EXPERIMENTS WITH SOILS. — Our observations have shown us that a soil composed wholly of inorganic materials, or wholly of organic materials, does not make a good home for plants. A few plants may manage to live in a field of sand made from inorganic rocks; but their lives are very uncertain, and, even if they manage to live, they are not plants of any value. We do not call them useful plants. They are neither wheat, roses, nor good red cabbage. The useful plants that give us wealth from the ground will not thrive in such a soil. A large number of wild plants will grow in bogs and peaty meadows, but for a first-rate garden such a place is not of any value. The

soil composed almost wholly of organic materials is wet, spongy, and loose, and makes a poor home for vegetables or flowers. Either place may be admirable for a garden if properly treated by mixing the organic and inorganic materials together. At once it becomes plain that we must have some means of deciding whether any particular soil has too much or too little of either of these two classes of material.

First we may look at the surface indications. These are the color of the soil, and the position it occupies, the plants growing upon it, and the amount of water to be seen on the surface just after a rain. Soils composed almost wholly of inorganic materials are full of sand ; and such sands are gray, white, and light shades of yellow or red, the most common colors being gray and white. Organic soils are composed usually of the remains of plants, and these are black or dark brown.

The position of the soil — whether it be at the top of a hill, or on the side of a hill near the top, or near the bottom, or in a level place — is another indication. Organic materials are always lighter than inorganic matter, and in running water will travel the farthest, and be the last to sink. In a fall of rain, the water running over the surface of a gentle slope may sweep away all the organic matter, and leave the inorganic behind. This makes it plain, that of two fields, one on a hill-top and one in a valley, the hill field will have more inorganic matter than the lower field in the valley ; in like manner, the lower field will have more organic than inorganic. In a field occupying a hill-

side, the lower part of the field will be richer in the remains of plants and animals than the upper part.

In a low field where water collects, we shall find water-plants, — cat's-tails, ferns, and cardinal-flowers ; on the sandy hillsides, the blueberry and wild aster and mullein-stalks. A bare and sandy plain, where no plants can be found, will have a soil almost wholly inorganic. A level meadow overrun with sphagnum moss will have a pure organic soil. On the sandy place we shall find the water disappear through the soil the moment the rain ceases to fall : on a dark soil, composed of organic remains, the water may remain for weeks after a storm.

For those who live on farms or near farm-lands, the best plan in making these surface observations is to select from different spots, in different directions from the house, and to make notes of each place, — the position and color of the soil, and the amount of water to be seen after a rain, — and to make a sketch-map of the places, and to decide from the observations which soil is chiefly organic and which chiefly inorganic, and to put all the data on the map. For those who cannot do this, the best plan is to observe different fields seen on walks and rides or from a car-window, and to learn to decide on the character of a soil from its surface indications by making repeated practice observations.

Having decided from these indications what is the probable character of the soil of any particular field, we can next take up some of the actual soil, and ex-

periment with it to find out how far the surface indications are correct. We begin by selecting a pleasant day when the ground is dry, and with a spade and basket dig up about a peck of the soil from the surface of the nearest garden or flower-bed. Place the peck of soil on a board or on a newspaper in a round heap, and with the hand or a trowel stir it about till completely and thoroughly mixed. Then pile in a heap, and carefully divide it into four equal parts. Take one of these quarter-parts, and, placing it by itself, stir and mix it again. The object of all this work is to get a fair sample of the soil. Next weigh out of this last lot half a pound of the soil, and spread it on a board or table in some sheltered place to dry. If near an open window or in a warm room, it should be completely dry in twelve hours or in one night. To hasten the drying, it should be stirred or turned over occasionally with a trowel. When quite dry, weigh it carefully again. It will be found much lighter than when first taken from the ground. This loss of weight comes from the water it held; and we must here make a record of the actual loss by drying in the air, or, as it is called, in "air-drying." Next, place the soil in a pan or flat dish, and place it in a hot oven or other warm place for at least three hours or even longer. This is "kiln-drying," or fire-drying it; and in weighing it again, it will be found to be still lighter. It is now dry soil, and we can begin to estimate the proportion of inorganic matter it contains. Place a flat iron shovel (a fire-shovel will do) over a hot fire, and

put the dry soil on it, and let it burn, stirring it occasionally as it burns. It will smoke, and slowly smoulder away to dust and ashes. When it ceases to smoke, and is quite burned up, carefully weigh the ashes. This ash represents the inorganic and sandy parts of the soil. All the organic portions disappeared as smoke. We record the whole experiment in this way: —

8 ounces of fresh soil.
2 ounces lost in air-drying.
<u>6</u>
2 ounces lost in kiln-drying.
<u>4</u>
3 ounces lost in burning.
<u>1</u>
1 ounce of ash, or inorganic matter.

We can get at the percentages of water and organic and inorganic matter in this way: —

8	
<u>2</u>	$2 \div 8 = 0.25$
6	
<u>2</u>	$2 \div 8 = 0.25$
4	
<u>3</u>	$3 \div 8 = 0.37\frac{1}{2}$
1	$1 \div 8 = 0.12\frac{1}{2}$
	<u>1.00</u>

Counting out the water, or fifty per cent of the whole, we find that in four ounces of dry soil, three ounces were organic and one ounce inorganic; or,

seventy-five per cent of one, and twenty-five per cent of the other. Another soil might show a very different proportion, and only in the richest garden-soils in low lands will so large a proportion of organic matter be found. Select soils from different fields, and from different parts of the same field, and repeat this experiment. Try also subsoils obtained by digging down below the soil. Make careful notes of every experiment, and compare them with the notes already made of the same fields or gardens. If the amount of ash is very large, it is probably a very poor, sandy soil. If the amount of ash is very small, it is probably a peaty or boggy soil. In all things, test carefully. Leave nothing to guess-work ; and, above all, make accurate records of every thing done, and at the time it is done. Never leave the records to be made the next day. Have pencil and note-book always in the pocket, and record every thing in detail, and add the date, and sign with your full name. This is the true scientific spirit and method of work.

CHAPTER IV.

KINDS OF SOILS.

X. SAND AND CLAY.—In making our studies of the rocks as giving some of the materials of soils, we paid no attention to the many different kinds of rocks. Our observations have shown us that soils are largely composed of inorganic matter ; and this matter, we have seen, comes from the rocks. It is important, then, to get from the geologist some general idea of how the rocks are classified. It is not necessary to know the name of every variety of rock, provided we are able to classify them in a general way whenever we see them.

Get a piece of sandstone, a piece of granite, and a bit of chalk. The sandstone, if not in the fields or hills near your home, can be found at any stone-yard, as it is one of the most common building-stones in this country. Granite is used in all our large cities and towns, for paving-blocks. Do not, however, take the black trap-rocks formerly used so much for paving-stones. Granite used in our streets is usually white in color. If possible, use a microscope, or at least a strong magnifying-glass, in examining these three stones. The granite appears to be formed of crystals

or parts of crystals, thin scales, broken bits, and ragged scraps of different materials, thrown together in a confused mass. Look next at the sandstone. It appears to be formed of small grains, each one rounded and worn as if rolled in the water. It is made of sand arranged in layers and lines and cemented together. Under the glass, the grains of sand can be plainly seen. By rubbing, the sand can be rubbed out of the stone. Hold the piece of chalk over a tumbler of water, and brush or rub it till the dust falls and makes the water white and muddy. Let this settle; and then, after pouring the water off, spread some of the soft sediment in the tumbler on a piece of glass, and examine it under the microscope. The white powder appears to be composed in part of minute shells, and bits of broken shells. These three samples of rock represent the three great classes into which all rocks have been divided: the granite belongs to the *igneous* or fire-formed rocks; the sandstone represents the *sedimentary* or water-formed rocks; and the chalk came from the *organic* rocks, or rocks formed from the remains of shellfish laid down as sediment on the bottom of some old sea. The sedimentary rocks are the most abundant in the world, because they are composed of the remains of all kinds of rocks. They are divided, in turn, into three classes or groups,—the *conglomerates*, or *pudding-stones*, composed of gravel bound together into solid rock; the *sandstones*, composed of sand cemented together; and the *shales*, made from fine silt or mud hardened into stone.

Among the igneous rocks are the *granites*, *sienites*, *basalt*, *trap-rocks*, *porphyry*, *lavas*, and volcanic stones. Among the organic rocks are *chalk*, *coal* or stone formed from the remains of plants, and limestones formed from the remains of minute creatures from the sea. The sedimentary rocks may include materials from every one of these. The shales and sandstones come from the remains of weathered rocks worn down into mud and sand, and re-formed into rock.

Rock itself, whatever its character, is not a soil. Even when broken up and sorted out into gravel, it is not a true soil. Only the sands and fine silts make the real soils of our fields and gardens. It is plain, that this process of weathering, sorting, and forming into sands and silt, has been going on a long time, and that vast quantities of the material have been turned to sandstones and shales: the original materials of the soils must by this time be therefore completely mixed together. This is true, and from this comes in part the great variety in all our soils. All this weathering, tearing down, transporting and sorting in streams and rivers, has been going on for countless ages upon ages. The land has sunk in the seas, only to rise again and be cast up as mountains. The very floor of the sea has been bent and doubled up to form lofty hills. Ice, floods, glaciers, earthquakes, and terrible storms have mixed the rocks, sand, and silt in hopeless confusion. It is quite useless to think we can tell much about any particular soil in our fields, from the rocks in the hills near by, or deep under the soil itself. All we can do

is to take the two materials from the rocks of every kind,—the *sand*, and the fine dust or silt which we will now call *clay*. The sandstones represent sand turned to stone, the shales represent clay turned to stone. These two in turn also become sand and clay, and these two form the larger part of all our soils.

XI. EXPERIMENTS WITH SAND AND CLAY.

— Procure from a sand-bank, — or, if you are in town, from the nearest stonemason's yard or from the dealer in building-materials — a quart of clear sand. Spread it out in the sun to dry ; and when perfectly dry, place a small quantity on an iron spoon, and hold it over a hot fire. The heat has no effect upon it ; and even if thrown in the fire, it remains unaltered except perhaps in color. Remove the spoonful of sand from the fire, and it will be found that the sand keeps its heat for a long time. Place a small quantity of the sand in a fine sieve, and pour water over it. The water at first flows away more or less discolored, and presently runs quickly through the sand pure and clean. While wet, the sand sticks together slightly. Place it in the air, and it soon dries, and the grains are as loose as before. Place a little of this washed sand from the sieve in a bottle filled with water. Cork the bottle, and shake it up. The sand will be moved about as long as the water is in motion ; but the instant the bottle is at rest, it falls to the bottom, and forms a layer under the clear water. Place some of the sand in the sun or in an oven till perfectly dry. Place three tablespoonfuls

of water in a saucer, and then pour carefully into the saucer about a cupful of the dry sand. It becomes wet round the bottom of the little heap while still dry at the top; soon the water appears to creep up the sand, and in a short time it is all wet, and it remains wet as long as there is water in the saucer.

These experiments show us that sand is not affected by heat, and that it keeps heat for some time; that water passes through it readily, and, if clean, the water passes through the sand pure and clean. When wet it is very slightly sticky, when dry this stickiness disappears completely. In water it sinks the moment the water is at rest. Water will rise through it easily by capillary attraction.

Another experiment, taking more time, is to place some clean sand in a flower-pot or saucer, wet it, and then sprinkle over it fine grass-seeds, water-cress, spinach, or other small seeds. Place in a warm room, and the seeds will soon sprout, and send small roots down into the wet sand.

These simple experiments also show some of the characteristics of all soils composed largely of sand. We observed that sand when heated retained its heat for some time. Any soil having a large proportion of sand, when warmed by the sun, will keep the heat after the sun has set or is hid by clouds. It is therefore a warm soil for plants, and favorable to their growth. The watermelon and other heat-loving plants grow well in a sandy soil. We proved that water will flow quickly through it. A sandy soil is therefore a

dry soil, and for this reason favorable to nearly all our useful plants. Water-cress seems to enjoy plenty of water, and a sandy soil is therefore unsuited to it. Our common garden and field plants object to wet feet, and prefer more or less sand in the soil where they live. We saw that water will rise through sand by capillary attraction: this is useful in any soil, because in dry weather, if the subsoil is damp, water will rise through the sand to feed the roots of the plants growing in the soil.

However, there are also objections. Sand, we saw, is loose, and easily moved about by water. A sandy soil is therefore easily washed away by rains, and, if too sandy, may suffer great injury by washing in heavy storms. Water, we observed, flows quickly through sand; and, if any soil contains too much sand, every rain that falls upon it washes down the light organic parts of the soil, that are needed to supply the plants with food, into the subsoil out of the reach of the plants. This washing away, or *leaching-out* as it is called, may be so injurious that the plants can find nothing on which to feed, and so perish. A very sandy soil may be so light that it is also injured by being blown about by the wind.

We observed that sand, whether wet or dry, is easily moved in the hand. This is important in another respect. All soils where plants are growing must be frequently stirred, to let the air come to the soil, and to destroy the weeds. A sandy soil is easy to hoe or plough, because the sand is loose. This saves labor,

time, and money, on work in caring for plants, and is a commercial or business advantage.

If you carry out the experiment with seeds planted on sand, you will observe that the roots of the young plants easily find their way into the sand in search of food and water. This shows us that a soil containing sand is favorable to the growth of plants, because in it their roots easily spread in every direction.

Procure a small lump of pure clay from some clay-bank or brick-yard, or purchase a piece of moulding-clay from the dealer in art-materials. Place it in a warm place to dry, and in a day or two it becomes like a soft, impalpable powder. Pinch a little of it between the fingers, and it appears to stick together slightly. Place some in a bottle of water, cork it tight, and shake the bottle. The gray powder floats in the water in clouds, till the water appears completely filled with it. Let the bottle stand, and it will be many hours before it settles and the water becomes clear. Wet some of the dry clay, and it forms a sticky, pasty mass, that has a soft, greasy feeling in the fingers. Spread some of the soft, paste-like mass over a sieve, and pour water upon it, and the water will hardly pass through the sieve at all. Spread some of the wet clay over a rough board, and pour water over it, and the clay will cling to the board for a long time before it is swept away. Place a lump of the wet clay in the sun, and it will be many hours before it dries. Spread some of the wet clay on a dish, and place it in the sun, and when it slowly dries it will be found full of

cracks. Place a lump of wet clay in the oven, and it will dry quite hard like stone. Put it directly in the fire, and it will turn to a red, brick-like lump.

Place some of the wet clay in a saucer or flower-pot, and scatter fine seeds upon it, as in our other experiment. The seeds may sprout, and try to grow; but they will probably soon perish, as their tender roots are unable to push their way into the sticky clay.

After all these experiments have been performed with the clay and sand, another interesting experiment can be made by drying both the sand and clay, and then mixing them together in equal parts. When well mixed, place in a flower-pot, and scatter seeds upon the mixture. Water well, and place in a sunny window; and the plants will sprout, and grow longer and better than in either the clear sand or pure clay.

These experiments with the lump of clay show us that if a soil consists wholly of clay, it must be a poor place for plants. In every rain the water, instead of sinking in the soil to supply the plants, would run away over the surface and be wasted. After the shower had passed, the soil would remain wet for a long time. The sun would dry the soil very slowly, and when dry the soil would split and crack, and tear the tender roots of plants growing in it. The sticky, paste-like soil would cling to our spades and ploughs, and we should find it hard, slow work to cultivate the ground. It would be a wet soil, and, as a result, a cold soil. This was proved in every experiment with the wet clay, for it felt at all times cold in the hands. A clear

clay soil would appear, from all these experiments, a poor soil for any plants. We must not, however, be led astray by our own experiments. It is not easy to find a soil composed wholly of clay. It is usually mixed with other things, and then forms a valuable part of any soil. Sand alone would be a poor soil. Clay alone would be even poorer still. Mixed together, and mixed with other things, they make a part of the best soils.

XII. SAND SOILS AND CLAY SOILS.— The fact that clay and sand are found in nearly all soils has made it easy to classify soils into six classes or groups. These are as follows :—

1. **A Light Sand.**— This is a soil containing ninety per cent of sand. If it had more sand, and less of clay or other matter, particularly organic matter, it would hardly produce any useful plants, and could not fairly be called a soil.

2. **A Pure Clay.**— This would be a soil in which no sand could be found. A pure clay soil would be wet and cold, and it would not be a good soil for our common plants. Such soils are rare ; and what is commonly called a pure clay soil is one containing a great excess of clay, and only a little sand and organic matter.

3. **A Loam.**— This is one of the best of all soils. Such a soil may contain both sand and clay, as well as organic matter. There may be from twenty to sixty per cent of sand, or from forty to sixty per cent of clay and organic matter. A mixture of pure sand and

pure clay would not, however, make a loam. There must, in all good soils, be some organic matter.

4. **A Sandy Loam.**—This is a mixture of sand and clay, but with more sand than clay.

5. **A Clay Loam.**—This is a mixture in which there is more clay than sand.

6. **A Strong Clay.**—This is a clay soil containing from five to twenty per cent of sand and organic matter.

The strong clay and the loamy soils, with more or less of sand or clay, are all good soils, and each will make a good home for our useful plants. Some are better for certain plants than others, yet nearly every plant will thrive in both. The loamy soils are regarded as the best, and a sandy loam is generally regarded as the best of all.

It is plain, we must next have some guide to enable us to decide whether any particular field or garden has a soil belonging to either one of these classes. Our only guides must be observation and experiment.

First, of the surface indications. What is the color? Sand is usually gray, or of some light shade of yellow or red. Clay is often of many colors, blue, black, red, and yellow; and is commonly in dark shades of these colors. There are, however, clays to be found that are gray and even white. This makes the color a rather unsafe guide in deciding upon the character of any soil. We can therefore only use the color as a help in making other observations.

The position of the soil is a good indication ; low lands, intervalles, and meadows being more likely to contain clay than sand. Higher land, the tops of hills, and mountain-sides would be likely to have more sand than clay. This, like the color, is only a partial test or indication, and must not be taken alone as a guide.

The best surface indication of any soil is its appearance after a rain. If the water sinks into the ground quickly, and the soil becomes dry soon after the rain has ceased, it probably contains more sand than clay. If after a rain the soil remains wet for some time, or in drying cracks or forms hard lumps, it contains more clay than sand. If the soil when wet sticks to the spade, plough, or other tool we are using to stir the soil, it is a strong clay soil, or clay loam. Another indication is the character of the lumps and clods of soil on the surface after it has been ploughed. If they keep their shape, and do not crumble and break up into loose earth, there is more clay than sand. If the plough turns the soil over freely in a loose mass, it is a sand soil or sandy loam.

To be more accurate in our investigations, we must try a few experiments. Take, as before, about a peck of the surface soil from the field to be examined ; mix it well, measure off a quarter-part of it, mix it, and place it in a paper bag for safe keeping. Take small samples of this, say one or two ounces, and repeat with the samples every one of our former experiments. Refer to the notes made before, and compare them with the notes made now, and see how near this soil

compares with the results we obtained with pure sand and with pure clay. For instance, wet some of the soil, and roll it up into a lump, and roast it in the fire, directly on the coals. Does it turn hard like a stone, or break up into black ashes? Put some in a bottle of water, and shake it, and see if it settles quickly, or whether the water remains muddy a long time after the bottle is at rest. Notice, when the sediment has settled, if there is more than one layer of sand or mud at the bottom of the water. Try every experiment carefully, and note the results. Afterwards try a sample of the subsoil from the same place. Begin each series of experiments by burning some of the soil over the fire, to find out the proportion of organic matter, and then use the ashes to repeat the experiments with the bottle of water.

Besides these classes of soils, — the sandy soils and clay soils, loams, sandy loams and clay loams, — there are other classes into which soils are sometimes divided. These other classes have reference to the amount of organic matter in the soil. A soil containing a large proportion of peat or decayed vegetable-matter left under water, as in bogs and marshes, is called a *peaty soil*. It is easily recognized by its black and dark-brown color and by burning. A dry peaty soil placed on a red-hot shovel gives off much smoke, and burns slowly away, leaving a small proportion of ashes behind. The dark, soft soil found under trees in old woods, or on the surface of old kitchen-gardens, is likewise largely composed of organic matter, and is

called a *vegetable mould*, or *leaf mould*. Its color is a good test, and burning another test. There are also smaller classes of soils ; as, a *lime soil*, meaning one composed largely of weathered limestone. The red soils of New Jersey, made from weathered sandstones, are sometimes called *iron soils*, because containing great quantities of iron-rust that gives the sand its red color.

Farmers also say of soils, that they are *light*, *warm*, *dry*, *heavy*, or *cold*. These terms refer only to the character of the soil ; as, a *light* or *dry* or *warm* soil means a sandy soil or sandy loam. A *heavy* or *cold* soil means a clay soil or clay loam. The sandy soils and sandy loams are also called *leachy* soils, because water *leaches* or soaks through them readily. Soils are also classified according to the character of the sand they contain : as, a *gravelly* soil, or one in which the sand is mixed with small stones or gravel ; a *coarse sandy* soil, meaning a soil containing more or less coarse sand ; and a *fine sandy* soil, meaning one having sand that is very fine or more like silt and clay. Soils are also spoken of as being *lean* and *hungry*, or *rich* and *generous*. What these very odd terms may mean, we must learn by further observation and study.

CHAPTER V.

THE ELEMENTS OF SOILS.

XIII. **THE ELEMENTS.** — We have observed that the soils are composed of organic and inorganic materials. Our experiments have shown us that the larger part of every farm or garden soil fit for useful plants is composed of rocks in the form of sands and clays. Naturally we might wonder if the different rocks do not make different soils. Is not the soil made from the granite hills of Eastern Massachusetts very different from the soil formed from red sandstone in New Jersey, or the yellow drifting mud of the Mississippi? This is quite true. These soils are different, but the differences are not so great as between a soil with much sand and one with much clay. Besides this, we have observed that the rocks have been weathered and made into sandstone and shales, and these again into sand and clay, so many times, that soils as we find them to-day contain every kind of rock. The changes in the surface of the earth have been so great; the upheavals of mountains, the action of floods and ice, earthquakes, and the slow denudation of hills, have been continued so long, — that the stony remains of old rocks are mixed together in hopeless confusion;

and it would be difficult to decide where the sand or clay ever came from, or from what rocks it was originally formed. We must go to work in quite a different way, and look at soils from still another side.

When we begin to observe things about us, we see an endless variety of objects in nature. The variety of artificial things made from these natural objects is equally bewildering. We have already seen that every thing in the world is either organic or inorganic ; and we know that there are many different classifications of things, as plants, animals, wooden things, and cloth, paper, or metal things. There is still another classification, and that is the classification by *elements*. An *element* is a single thing that stands alone, and is not made of any two or more things. Glass is not an element, because it is composed of several things. Pure iron is an element ; that is, we are not able to divide it into two different things. Sulphur is an element : it is one thing only. Water is not an element, because it is composed of two elements. Salt is not an element, neither is the air we breathe. Many thousands of experiments have been made with all the myriad things in the world ; and it is now known that there are only about sixty-five separate single things in the world, and these things are called *elements*.

The soil and subsoil of our fields and gardens are composed of a great number of different things. Chemists have examined these things, and tell us that among them all they can find only fourteen of the

sixty-five elements. Occasionally three more are found, but the quantities to be met with are very small. We shall not be able to find more than one or two of these elements anywhere in a pure state, unless we visit the chemist's laboratory where they may be kept in small quantities for various uses in the arts. We shall not be able to find these fourteen elements in a pure state in the soil. Some of them we cannot see, touch, taste, or smell. Some of them are very common, others are comparatively rare. If we wish to know about the soil and its materials, we must here be introduced to these fourteen elements, in order to understand how they behave, and how they are related to each other.

1. **Oxygen.**— This is a gas that we can neither see, taste, nor smell. It is the most abundant element in the world. It forms one-half of all the rocks and soils, eight-ninths of all the water, and one-fifth of the atmosphere. It is sometimes sold in iron tanks, as a gas, for making the lime-light. In soils it combines with many elements to make compounds that appear to be very different. It combines with iron to make oxide of iron, that gives the red color to so many soils. It combines with another element to make white sand, that forms the larger part of all sandy soils. It is a greedy element, and is ready to unite with any element that comes near it. So greedy is it, that heat and light appear when it unites with some other elements, and we call this eager combination flame or fire. Animals cannot live without oxygen,

and plants must have it in abundance, or they cannot exist.

The chemist tells these few facts, and we now discover the meaning and value of many of the observations we have already made. If plants must have oxygen, we see the value of the rain and the atmosphere; for these are composed in large part of oxygen. If oxygen is greedy to combine with other elements to form new compounds, and these compounds, as we shall learn presently, are useful to all plants, we begin to see the value of a light sandy soil that permits air and water to pass through it and reach these elements. We also begin to see why we must open the top of the window or top of our greenhouse where plants are growing, that the fresh air may reach them, and supply them with oxygen.

2. Hydrogen. — This is another gas without taste or smell. It will combine with oxygen, and burns furiously with a pale blue flame and much heat. When pure it is used in balloons, and in tanks it is often sold for use in lime-lights. It forms a part of street-gas, as the blue flame of a gas-stove plainly shows. It unites with other elements to form some of the most important materials in all soils and in all plants. It unites with oxygen to form water, and in this shape spreads through the soil, dissolving other elements and compounds of elements, and making them fit for plant-food. It also combines with other compounds, to make still other compounds useful to plants.

3. **Nitrogen.** — This is another gas that forms a part of all plants and animals. It is colorless, tasteless, and without smell. It is not a poison alone, and yet animals will instantly die in it. No fire can burn in it; neither will it burn, like hydrogen, when mixed with oxygen. In the soil it appears as valuable compounds of nitrogen and other elements that form the principal foods of plants. It forms the larger part of the atmosphere; and if we wish our plants to be well fed, and to grow large and luxuriant, we must have nitrogen in the soil. To do this we must freely admit the air to the soil, that, by enabling the nitrogen to mingle with decaying vegetable-matter, it may make new compounds on which plants may feed.

4. **Carbon.** — This element forms a part of every plant. If we burn a plant, we shall find carbon in the ashes left behind. It is very common. Coke, charcoal, coal, black-lead, lampblack, and sugar are largely composed of carbon. The diamond is pure crystallized carbon. When carbon burns, it unites with oxygen to form a heavy, suffocating gas, in which no animal can live. At the same time, it is of the greatest value in all soils, and forms a food for all plants.

5. **Silicon.** — This element, combined with others, forms common sand, and makes a quarter-part of all the solid crust of our world. As sand it is of the utmost value in making the soil a fit home for plants.

6. **Sulphur.** — This element we often meet in sulphur matches. It combines with other elements to make some of the most important plant-foods in our

soils. It is yellow in color, and burns with a blue flame and suffocating smell.

7. **Phosphorus.** — This is a pale-yellow matter, that burns so easily that it has to be kept under water. It unites with other elements to form valuable plant-foods. Without these compounds in the soil, it is difficult to make any plants grow. It is essential in every soil, and it forms a part of every plant.

8. **Chlorine.** — This element is a gas of yellow-green color, and is quite poisonous. Combined with sodium it forms chloride of sodium, or common salt. Combined with other elements it is found in all plants and soils.

These elements are called the non-metallic elements. The remainder of the fourteen elements found in soils are metals. They are as follows: *potassium, sodium, calcium, magnesium, aluminium,* and *iron*. The potassium and sodium form, with other elements, important parts of all soils. Calcium, with oxygen, forms lime; and in the rocks it forms a part of marble, limestone, and chalk; and as these rocks are weathered, it appears in many soils. In one form this element makes an important compound called *gypsum*, which forms an important part of our soils. Magnesium is found in certain limestones; and aluminium is in all clay, and thus forms a large part of many of our soils. Iron we all know. It is the most common of the metals, and in various compounds is abundant everywhere in the earth. In our soils it is usually combined with oxygen, as iron-rust, and gives the red and brown

color to the fields and roads. Besides these fourteen elements, there are at times to be met in soils small quantities of *manganese*, *iodine*, and *fluorine*.

XIV. **SOIL-ANALYSIS.**—While these fourteen or seventeen elements may be found in nearly all soils, we must not think they can be found in a pure state. All are mingled together in various compounds. The chemist can take a quantity of soil from a field, and tell us just which of these compounds are in that little mass of loam or earth. Such an examination he calls an *analysis*. The following is an analysis of a good soil, as reported by Professor Lupton of Nashville, Tenn. :—

	Percentage.
Potassium oxide	0.2
Sodium oxide	0.4
Calcium oxide, or lime	5.9
Magnesium oxide, or magnesia	0.8½
Iron oxide	6.1
Aluminium oxide, or alumina	5.7
Manganese oxide	0.1
Silicon oxide, or silica	64.8
Sulphuric acid, or sulphur tri-oxide	0.2
Phosphoric acid, or phosphorus pentoxide	0.4½
Carbonic acid, or carbon di-oxide	4.0
Chlorine	0.2
Organic matter	9.7
Loss	1.4
	100.0

This analysis is very interesting as showing the combinations of the elements. Observe how very largely oxygen appears mixed with the other elements. The

soil is a sandy loam, because there are sixty-four parts of the silicon oxide, forming sand. The clay, or aluminium oxide, forms only five parts in one hundred; and the calcium oxide, another five parts. The organic matter was probably the remains of dead plants left in the soil from old crops. Twelve of the fourteen elements were in the soil, and one of the rare elements — the manganese — was represented by a small percentage.

The chemists have also analyzed plants; and it is found, that, of the fourteen elements in soils, ten are to be found in plants. These are carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, calcium, magnesium, and iron. These the plant obtains either from the soil or from the air. It does not find any element, in either the air or soil, in a pure state; neither does the plant show them in a pure state in itself. Naturally we might wonder if it is worth while to remember these fourteen elements. If they cannot be found in a pure state, why try to remember them? Plants contain phosphorus. They obtain it from the phosphorus in the soil. Suppose, now, we wish to plant a crop in a certain field. The plants need phosphorus. Will they find it ready for use in the soil? Perhaps they will, and perhaps they will not. Very likely the plants that grew in this field last year, or the year before, have taken up all the phosphorus that is fit to use. There may be plenty there, but not in shape for food. Our new plants, not finding it ready, refuse to grow, and the crop will be a failure. If we

think there is not enough phosphorus in the soil, we must put some in it. Where shall we get it? We can buy pure phosphorus by paying a very high price for it, but it would all burn away long before the plants could find it. We look about to see if there is any thing that contains phosphorus. The chemist tells us this element is in bones. Bones can be used; and we get a quantity, grind them up fine so that the plants can find them easily, and sow the white dust over the field. The plants find the phosphorus in the bone-dust, and attack it greedily, and produce a bountiful harvest. Thus, by knowing the elements, we are able to find them in various things, and can place these things in the soil, and thus supply the plants with the very elements they need. Thus we see it is well to make the acquaintance of our friends the elements, though we may never be able to find them alone or in a pure state.

We might ask now why we may not continue our observations and experiments, and find out by analysis just what elements are in any particular soil. Our experiments have shown us that soils vary greatly in the amount of organic and inorganic matter, sand, or clay they may contain. May there not be an equal variety in the amount of the different elements in different soils? There is the greatest variety; and analysis will tell us what elements are abundant, and what elements are scarce, in any particular sample of soil. Observe, that in our experiments we have been using only small samples of soils. Even a whole peck

of soil is a very small part of an acre. As far as the sand and clay and the organic parts are concerned, our examination of a few ounces of soil may be fair, because these things form the whole of the soil. When we come to the elements, it is quite different ; and instead of three parts we have seventeen parts, and the proportions of each are very small. There may not be in a whole acre of soil, weighing hundreds of tons, more than fifty pounds of one of the elements ; and thus the proportion in one pound would be so small, we might not be able to find it. Moreover, the work of analyzing soils is troublesome and expensive, and can only be done by a chemist. Even the chemist tells us the work is unsatisfactory, because of the strange way things are mixed together in every soil. In one place there may be a good deal of phosphorus, and in places not twelve inches away on either side not a trace of it to be found. Plainly, if he happened to dig in the wrong place, he would tell us quite a wrong story about the field. So, while it seems a capital plan to have a field examined by a chemist, it is really very misleading. The chemist will tell us the truth about a little handful of soil ; but the field contains a million handfuls, and not one may be exactly like another. Our best plan is to try experiments, and, if we fear any single element is missing from a soil, to add them all, and thus be on the safe side.

It is all much like the man who declared he must have soup, fish, meat, potatoes, beans, lettuce, pease, bread, salt, pepper, vinegar, sugar, oil, and coffee for

dinner every day. If a single thing was left out, he declared he would certainly starve, and would not touch his dinner. For some reason he would never tell which particular dish he preferred ; so the house-keeper, like a wise woman, said nothing, but took pains every day to see that all the fourteen things were on the table. It is the same with plants. They are distressed, and sometimes die, if one of the elements is missing from the soil. They want something, and, being disappointed in not finding it, refuse to grow, and perhaps die, which is a very unsatisfactory business for all concerned. Plainly, our only plan is to follow the sensible housekeeper, and see that the dinner-table spread for our plants contains at all times every thing they want. In actual practice, we shall not be obliged to put in the soil every one of these elements. Many will take care of themselves, the air and the rain and snow will provide others in abundance ; and we shall really be obliged to provide only three or four. This makes the whole matter far more simple and easy than we might at first imagine ; and we can now go on, feeling sure that nothing is as difficult as it appears, if we have the courage to try experiments, and the patience to learn. We will next see what we can do to improve those soils whose history and nature we have learned. We must see what can be done to make our soils give us more fruits, more flowers, more food, and more wealth.

CHAPTER VI.

IMPROVEMENT OF SOILS.

XV. **TAMING THE LAND.** — When the first settlers landed in the old colonies along the Atlantic coast, they found a wild, virgin soil, covered everywhere with forests. They cut down the trees, and, ploughing up the dark vegetable mould between the stumps, planted their first crops of wheat, corn, oats, and vegetables. The Indians had planted corn in a few places here and there, in openings in the forest; but their planting was a poor, rude work, that made very little impression on the soil. For the settlers in Massachusetts Bay, along the Connecticut Valley, about Providence, around the Dutch settlement of New Amsterdam, and in Pennsylvania and Virginia, the land was practically a fresh, native soil, in which the useful plants were strangers. This new soil proved to be very fertile. It contained all the elements the plants needed, in abundance, and they flourished amazingly. It was indeed a new world, and the people discovered that wonderful new wealth could be obtained everywhere as soon as the primeval forests were cut down. The people went to work with great energy, and cleared away the forests, and extended their fields and crops in every direction.

This went on for some time, and the crops appeared to be as abundant as ever. Then, after a number of years, the people began to find that the crops in the older fields, that had first been cleared, were not so abundant as formerly. If a certain field near the first settlements gave a hundred bushels of wheat when the land was first used, it would now give only seventy-five. That was still a good crop, and more wheat was planted year by year. But the crops steadily grew less and less, till finally there was not enough wheat produced in that field to pay for the seed and the labor of cultivating it. There was more land a little farther back in the woods; and the settlers left the old fields, and went deeper into the forest, cut down the trees, and cleared more land. Again the virgin soil returned bountiful harvests, and the farmers won more wealth from the new ground. In a few years the new fields refused to give these great harvests, and the settler or his sons pushed on again farther west. This, in time, became the agricultural history of our country. The land was abundant and cheap; and when the virgin soils refused to give large crops, the farmers moved on and on towards the west, in the search of fresh new land. Whoever wanted large crops took new land; and, as there was plenty of it, the American people grew rich at a wonderful pace.

Here was certainly a curious matter. Why did not the old soils keep on producing abundant crops? The plants did not consume the soil, and leave nothing but the bare rocks behind. The soil remained apparently

unchanged ; and yet the wheat, corn, rye, and other plants dwindled away to poor, starved things producing nothing. If it is true, as we might think from the behavior of our farmers, that when a soil refuses to give good crops we must find more virgin soil in another place, then we must be pretty near the end of the world. There is no virgin soil in Europe or Asia, and we have not much left in this country. There may be some in Africa or Australia, or perhaps in South America. Must we move to these places when we come to the end of all our new land? If plants, like the man with the fourteen dishes, are disappointed if one be gone from their table, what are we to do? We look about, and find people have been living in Europe for many hundreds of years ; in fact, a very long time before this great piece of virgin soil we call America was discovered. Clearly, they did not starve, neither did they follow the plan of our foolish farmers, and go off to find new virgin soil, every time a field refused to give good crops. This plan of going out West for new land was all very well while this country was new : it was cheaper, and there was plenty of room. Now we must do something else, for we are rapidly coming to the end of our new soils. We must look at the European farmer, the Frenchman, the Englishman, and German. What did he do with his soils? He repaired them. He learned, in some rude way, that something was wrong. He found the plants did not grow in certain soils, and he worked over the soils till he made them as good as new. He found some

of the elements were missing, and he put them back in the soil ; and then the plants grew just as well as ever. They found the fourteen elements in reach, and were satisfied, and grew big and fat on the old, old soils.

Here is a most important matter. Soils can be improved, and can be made to bear good crops year after year, apparently without end. We read that seedtime and harvest will not fail : this means, that the time for sowing seed and the time for gathering harvests will not fail. But if we fail to do our part, the harvests will fail also every year. There is another thing we must notice. A good soil kept in repair is better than a gold-mine. The mine gives great wealth for a short time, and then there is an end. The miner gathers all the ore, and the mine is then only a worthless hole in the ground. The fields can, with care and skill, be improved from year to year, and give the farmer food (which is wealth just as much as gold) for his children and grandchildren and great-grandchildren, and all their children, till there shall be neither times nor seasons, seed-sowing nor harvests, forever, world without end.

As there is still some virgin soil left in this country, we may stop just a moment to see what must be done to it to make it ready for our useful plants. Our observations have already shown us that plants will not grow in the shade. If, therefore, there are trees growing in the soil, they must be removed. There are two ways in which this has been done. One way is to cut

a ring round the tree, through the bark, and let it slowly die. This would let the light in between the trees, because the leaves would shrivel and fall off; and in time the wind would blow the dead tree down. Another and a better way is to cut the tree down, and drag it away. The limbs and bark can be burned, and the logs sold to the lumberman. That leaves only the stumps in the ground; and these can be pulled up and burned, or dragged out of the field. This hard, rough work is called "clearing the land," and has been done by our fathers ever since they landed on this continent. In many of our States and Territories, the work is still going on. It is even done in the old States like New York, by men who still think it cheaper to clear off the trees, and find the wild land, and thus slowly tame it, than to buy old fields that were cleared off a hundred years ago. In some places the virgin soil will be good, and the work will pay; but we must remember that our fathers and grandfathers were wise men in their day, and they found out all the best land, and cleared it up, long before we were born. Nearly all the land that is now being cleared in the older States is poor land, and the virgin soils to be found will not compare with the virgin soils our grandfathers found way back before the Revolution.

In our Western States and Territories, there are virgin soils without trees. On such soils, all this labor of clearing away the trees is saved, and we have nothing to do but to prepare the ground at once for our plants. In the old forests there were very few small

plants under the trees, and when the trees were removed the ground was almost bare. On the open prairie-lands there is a thick mat or sod of grass. This we know consists of wild plants, weeds, and grasses, growing so close together that the roots have become twisted together to form a mass like a thick carpet, and called a sod. If the settler sows his wheat, oats, or corn on this grass, the seeds will fall down between the wild plants, and be lost ; or, if it succeeds in growing, will be starved and smothered by the wild plants. There will be a fierce fight to see which shall live ; but the wild things will be sure to win, and the wheat and other good plants will surely perish. The settler knows this, and gets out his great "breaking-up" plough, and with a strong team of horses cuts the sod into strips, and turns each strip completely upside down, one slice or strip resting beside the next. This is the first step in the improvement of the soil. We call the work *ploughing*, and it forms a part of the science of *tillage*. Whether it is wiser to clear up forest-land or break up prairie-land, in preference to buying land already cleared and that is starved and all out of repair, must depend on a great many circumstances. No doubt, to raise large crops of wheat, it is best to take the new lands. To raise vegetables, and fine fruits and flowers, we must take the old lands near the cities. Which we should do, depends entirely on our taste, education, and capital. Even though we may never use old soils, or break up virgin soils, it is well we know and understand these things ; for they

affect us all, whether we live in town or country. The success or failure of our farmers affects the price of bread on all our tables, and we cannot say we do not care for these things. Whatever is good for the farmer to know, is good for all to know. Many people think we have too much land, and that we should not cut down any more trees, but use the fields already cleared. This is a most important and interesting question; and before we have finished our observations and studies of the soil, we may be able to understand it better than we can just now.

XVI. TILLAGE.—The settler in the Far West ploughs up the wild soil, turning it neatly over in long furrows. Before, it was long grass: now it is brown soft earth. What will happen next? Let us look at the matter, for the observations we have already made will in various ways help us to an answer. First, we notice that before the plough passed, the grass and other plants hid the ground from sight. Now the plants are turned completely upside down, and are buried out of sight. Secondly, a part of the soil was below and out of the reach of the air and sunlight: it is now on top, and fully exposed to sun, wind, and rain. Lastly, in place of a thick mat of tangled roots we have the loose soil. What will be the effect of all this?

Plants are living things. They require air and light, or they cannot live. These plants are torn up and buried, and will quickly perish. The moment they are dead, decay begins. This means that they will turn back to their original elements. The com-

pounds of which they are composed will separate, and form new combinations with the elements already in the soil, the air, or the rain. There will be new combinations in every direction, and nothing will remain that bears any resemblance to the original plants. Some of the elements of the plants will float away as invisible gases on the air, or sink deep into the soil with the water that falls in the next rain. Not a thing will utterly perish, not an atom will be lost. The greedy soil will take up all that is not carried away by the air or the water, and will hold it fast till other plants seeking for food find it and use it once more as part of a living thing. All this happens whenever any living thing dies. If it is left on the ground, the larger part floats away on the air unseen. Another part soaks away into the soil in the ground. If it is buried under the soil, the most valuable parts unite with the elements in the soil, and make new combinations ready for future plants; and the rest escapes in the air and water. Disagreeable, do you think? Not at all. This is nature's sweet, sure way of restoring every living thing to its native elements in the soil and air from whence it sprang. Thus we see that the first step in improving the soil is to return to it the wild plants that occupy the virgin ground, that in dying they may make room for better plants,—the potato, the yellow corn, and sweet grasses, fit food for men and animals,—and that they leave their remains to become food for the plants that come after them. We see now that the soil is not merely a storehouse of

wealth left by Nature for our use, but that it can be improved by the wise use of knowledge, and that the study of these things is well worth all our time and labor. It is more like a bank than a storehouse, because we can add to it as well as take away from it.

Secondly, we observe that in turning over the sod with a plough, a part of the soil that was below is now on top. We have seen that the soil is composed, in large part, of the remains of old rocks. There is in every soil more or less sand. This old granulated rock can be affected by the frost, the sun, the rain, to-day, precisely as in the old past when it was broken from some ancient cliffs. The work we saw going on at Schunemunk is going on everywhere in the soil. The plough turns up the soil, and brings the particles of rock we call sand to the surface, and it is again broken up finer still. The elements are released by the frost and rain, and made ready to enter into new combinations. The greedy oxygen attacks it, and forms new compounds ready to be used by new plants. Thus the mere turning-over of the soil is a benefit by bringing new particles of rock to the influence of the weather.

Finally, observe how loose and broken the plough has left the soil. In this soft mould, the roots of the new plants can push their way in eager search of the new food just formed from the dead plants, or set free from the decaying sands and clays.

This is the first great step in the improvement of a soil, and it is given the general name of *tillage*. At

first it may seem doubtful if there is any immediate effect on a sod-land by turning the sod over and exposing a part of the soil to the air. We can prove that there is an improvement in the course of a few hours, by means of a simple experiment. Find a plant in a greenhouse or the window, — say a small verbena, or other quick-growing plant, — that has been neglected for some time. A green mould has grown over the top of the soil in the pot; and with a small stick we dig this up, stirring and breaking up the soil for an inch or two deep. Keep the plant in the same place as before, and give it no more light or warmth, and it will show in a single day a decided change. It will be greener and brighter, and be materially improved in appearance. If not too much injured by neglect, it will begin to grow rapidly within twenty-four hours. Observe, we give no more water than usual: in fact, the plant will need less water. We give it no more heat or sunshine; and yet it looks better, and soon begins to grow afresh. We are obliged to think that the breaking-up of the mat of moss on the top of the soil, and the exposure of the soil to the air, does in some way improve the plant. The plant itself may be untouched, and yet it plainly shows that the work upon the soil, or the tillage, has affected its life and health. One effect is to remove the crust or mat of moss on top of the soil, and to expose the surface to the air. Another effect is, that, the soil being loosened, the air can penetrate the soil through countless little cracks and holes. The water also easily finds its way

through the loose soil; and both air and water bring elements that combine with elements in the soil, dissolving some, and forming others into new combinations. Even the hard sand in the soil is affected and disintegrated, and made finer and softer. Thus by tillage we assist the air, water, heat, and cold, to continue their ancient work of making new soil out of old materials. We can see no change in the soil; but the plant is aware that the soil has been improved by tillage, and by its improved health and vigor tells us what has happened. This work of stirring up the soil in flower-pots is one of the surest ways of keeping house-plants in good health, and should be done at least twice every month.

XVII. **AN ANCIENT TOOL.** — The oldest tool for improving the soil was probably a forked limb from a tree. With this rude tool, which was the first suggestion of a hoe, the ancient cave-man scratched up the soil in such bare spots as he could find in pre-historic woods, and made a place for his poor, small seeds. No man can tell where or when this work began. It is utterly lost and forgotten. Perhaps the limb of the tree was broken or cut off with stone hatchets, and looked like *a* in Fig. I.

Then some more ingenious fellow suggested finding a longer limb, and making the shorter arm sharp. By this change the crooked stick could be dragged along the ground by the long handle, while the sharpened branch made a rough furrow in the soil. (See *b* in Fig. I.) By dragging such a sharpened stick over



Fig. I.



Fig. II.

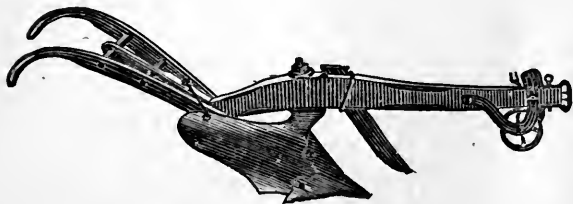


Fig. III.

the ground many times, the soil might be readily broken up, and made loose and soft for a few inches deep. When and where this change began, we can never know. We can only guess that this must be the true history, because we find, even in modern times, wooden ploughs that suggest this idea. Fig. II. is a sketch of a Kooloo plough used in India in this century; and it is very like a forked stick sharpened at the end of one branch, and fitted with a third piece that serves as a handle. Pins are also added to hold the harness of the horse or cow used to drag the plough. Fig. II. also shows how the plough was rudely shaped out of three pieces of wood, and how it was fastened together with a wedge. Old Egyptian monuments show ploughs used in that country before the Christian era, that were very much like this Kooloo plough. It was not till quite modern times, that the plough was any thing more than a scratching-machine, that merely made a shallow furrow by throwing out the soil on both sides.

In Fig. III. we have a modern American plough. Let us look at it a moment. It consists of several parts. First is the long *beam* (that corresponds to the longer branch of the forked limb of the original plough), the steel *share*, the *mould-board*, and *handles*. There are also other details, — as the *coulter*, that acts as a knife to cut and separate that part of the soil that is to be turned over, from the part left undisturbed; the *wheel* on the beam, that causes the plough to run at a certain depth in the soil; and the *clevis* at

the end of the beam, for adjusting the draught or pull of the horses. Let us see how it works. When the horses start, the ploughman lifts the handles, and the point of the share sinks into the ground. Then the ploughman's work is simply to guide the horses, and, by means of the handles, to keep the plough straight and level. The coulter cuts off the weeds and divides the sod ; and the share, as it is dragged forward, slides through the soil, and turns the part cut loose by the coulter upon the mould-board. Here the soil, or the sod if there is one, is turned completely over, and falls upon the last furrow upside down. If there is no sod, the soil loosened and broken falls in a cascade from the end of the mould-board.

A good plough turns the sod completely upside down ; it buries the grass or other plants out of sight, and leaves the soil loose and broken on top ; it should also run straight and smooth, and be easy to pull through the ground. Ploughs made and used in this country are among the best in the world, and in some respects are the very best made anywhere. There are many shapes and styles used for different soils and for different purposes. Some are for one horse, some for two or more. Some are on wheels, and the driver rides on top, as in the *sulky-plough* and *gang-plough*. There are ploughs for turning over wild prairie-lands, and for moving light garden-soils ; ploughs for deeply stirring the subsoil, and for making ditches. In England, ploughs are often drawn through the ground by

means of steel ropes drawn to and fro across the fields by steam-engines.

The plough is the most ancient horse-power tool in the world, and it is the first and most important tool used in tillage. For this reason it has become the symbol of agriculture, and it stands as a mark on the letter-heads used in all the correspondence of The Chautauqua Town and Country Club. With a good magnifying-glass you can look at the handsome plough at the top of our Club letters, and you will see on the beam of the plough the Club motto, — "RESULTS." Tens of thousands of ploughs in the United States are at work every year, winning wealth from our soil. The results are food and crops and wealth, vast beyond counting, and the like of which the world never saw before. The plough is indeed the symbol of our nation's wealth; and the men who guide our tens of thousands of ploughs are the best ploughmen who have ever lived, because they think and read, study, observe, and learn. So we too, though we may many of us never use a plough, must learn to respect the men who do, and, like them, seek for RESULTS in work, in reading, study, observation, and knowledge.

The crooked branch from a tree, that the cave-man used to stir the soil, in time became the modern plough. At the same time, it appears to have still survived in another form. Did you ever think that the common hoe is only the cave-man's crooked stick slightly improved? Here is the long branch now

smooth and straight, and the crotch of the tree turned into a flat blade of steel. This is another tillage-tool, as old as and perhaps older than the plough, come down to us from pre-historic men and times. No doubt, for centuries and in many countries it was used before the first modern plough was made. It can be used by hand, and for this reason it is useful in many places where horses cannot be used. It is a stirring and breaking tool for opening the soil, and making it light and loose. It is also used to cut down and destroy small plants that are so impolite as to spring up where they have not been asked to appear. Some plants are very rude at times; and the hoe is used to remonstrate with them, and show them that the way of the transgressor is hard. There are several different kinds of hoes; but all are essentially alike, and are used to stir and break up the soil, and expose it to the air. A kind of plough with many small shares under the beam has been used as a hoe: that is, it is used to break up, stir, and pulverize the soil after ploughing; and, as it is used somewhat like a hoe, it has been called a *horse-hoe*. Still other forms are called *cultivators*.

When the land has been broken up by the plough, and the sod turned over, it is still rough, and in clay soils is often full of hard lumps. The tender roots of plants find it difficult to push through these lumps in search of food and water; and consequently they grow slowly, and produce poor crops. The finer and softer the soil can be made, the better the plants like

it, the better will they grow. This was learned long ago ; and various things have been used to scratch the soil, break up the lumps, and make it fine and soft. No doubt the first thing used was a branch of a tree dragged over the ploughed land. Such things are still used ; as when a farmer, wishing to smooth over a rough field, cuts down half a dozen small birch-trees, and fastens them by the ends to a wooden cross-bar dragged over the ground by a horse. From some such tool came the modern *harrow*. This horse-tool is now made in many shapes, the most common being a wooden triangle armed with iron teeth. In place of teeth, metal disks and shares of various shapes, and even chains, are sometimes used ; and, when dragged over a ploughed field, soon make the soil smooth, soft, and loose, ready for the tender roots of young plants. On heavy clay lands, where the plough is apt to leave the soil in hard lumps, another tool called a *clod-crusher* is used in place of a harrow.

Beside these various forms of ploughs, harrows, cultivators, and hoes, there are also the *spade* and the *garden-rake*. The spade is a tillage tool for inverting and breaking up the soil, and the iron rake is for stirring the top of the soil about young plants. For small work, there are also trowels and small hand-rakes.

XVIII. **EXPERIMENTS IN TILLAGE.** — Not many years ago the farmers in a certain part of Ohio found, as many American farmers had found before, that their fields produced less and less wheat year after year. It

is true, they ploughed their land, and put in good seed ; and yet the wheat-crops grew smaller and smaller, till they began to despair of raising any more wheat. The crop did not pay for the labor spent on it. It seems their fathers or their grandfathers, or some other stupid persons, had told them that when they had ploughed their land they must leave the lumps and clods of soil just as they fell from the plough. The idea was, that, after the wheat-seed was planted, these lumps of soil would slowly break and crumble to pieces, and protect the roots of the young plants. At last, just as every one seemed utterly discouraged about growing wheat, a young man thought he would try a little experiment. He ploughed up two acres of land, which was only a very poor little field for wheat. He ploughed early, and he ploughed well. Then he harrowed and re-harrowed ; and got out his brush-scraper, and went over the land again and again, breaking up every lump, till the soil was as soft and fine as the soil in a gardener's flower-pot. He made the field like a velvet carpet, and then he put in his seed. The result surprised all who saw it ; for the very soil that before would hardly produce any thing gave a crop of fifty-eight bushels of good wheat on two acres of land, which was regarded as a great and profitable crop for that kind of land. This is a true account of a real experiment ; and, should you have any doubt of it, you can on any good land repeat the experiment in many different ways. The following experiments are easily performed ; and all who can do so are recom-

mended to select one or more of them, and carry them out, and make a complete record of the work and the results.

1. Plant a row of Early Mohawk beans, twenty feet long, and divide it into two equal parts, and mark and number each half by stakes in the ground. Call one half No. 1, and the other No. 2. As soon as the plants appear, note carefully if there are about as many plants in No. 1 as in No. 2; and, if there are gaps or failures in either, enough plants must be pulled up in the other to make them equal. This, of course, applies to all these experiments. They must be as nearly alike as possible. As the plants come up, rake the soil for two feet on each side of No. 1, and leave No. 2 untouched. When weeds appear, hoe No. 1 about two inches deep, but do not disturb No. 2 except to pull up the larger weeds by hand. After that, hoe No. 1 after every rain, and rake the ground on each side once a week on pleasant days. Leave No. 2 untouched except to pull up weeds. When the beans are ready to pick, pick each lot separately, and weigh each lot. Do this every time; and at the last picking, gather all the pods, large and small, and weigh every lot. Keep a record of these pickings from No. 1 and from No. 2, and see if there is any difference in the total crops of No. 1 and No. 2. There will probably be a difference in favor of No. 1, and this will show the effect of tillage.

2. Plant twenty hills Crosby's Early sugar-corn. Mark ten of the hills No. 1, and ten of them No. 2.

Hoe and rake the soil after every rain, or at least once a week, about hills No. 1, and let hills No. 2 take care of themselves except to pull up the larger weeds by hand. After the tassels appear, measure the height of all the stalks in No. 1, and find their average height by dividing the number of hills by the sum of all their heights. Do the same with the stalks of No. 2, and compare and record the results. Count and compare the number of good ears on each.

3. Plant ten hills of Early Rose potatoes. When they come up, give five of them two good hoeings during the summer, to keep down the weeds. Hoe or rake the other five every pleasant day through the growth of the plants (Sundays excepted). This will take but a moment, and, if the plants are near the house, will not be a difficult thing to do. Record the number of times the plant is hoed or raked; and when the potatoes are dug, carefully weigh the whole crop, large and small, of each hill, and record the difference in weight.

4. To make a variety in this last experiment, and to see if tillage has any money value, plant two lots of potatoes, say half or quarter of an acre each; or, of the same number of hills, one hundred hills being a good number. Mark each lot; and plough, hoe, or use the cultivator on one lot three times, and the other lot ten times, during the growing-season. Make a careful estimate of the cost of this extra culture. Weigh each crop; and if there is a gain in the crop cultivated ten times, over the one cultivated three

times, see if this gain at the usual market-rates will cover or exceed the cost of the extra tillage, and how much.

5. Procure two bean-poles, and set them up in the ground about six feet apart. Plant at the foot of each a few seeds of *convolvulus minor tricolor*. When the plants appear, number one pole No. 1, and the other No. 2; and rake or hoe the soil lightly for a space of three feet round No. 1. Leave No. 2 untouched. After that, rake the soil about No. 1 twice every week, on pleasant days, and leave No. 2 untouched except to pull up the larger weeds. Measure the height of each vine once a week, for eight weeks from the day the seeds are planted. Record these measurements, and compare the results.

In these experiments, the effect is more striking if the soil is untouched since the previous season. Plough or spade up for lot No. 1, but only scratch the surface with the hoe sufficiently to get the seeds into the ground. These experiments are easy, and the results interesting. It is quite possible they will not always show any difference between the cultivated plants and those that are neglected, but in the majority of instances there will be a difference in favor of the plants that are tilled. In some experiments, the difference will be very small; still, it is advisable to try the work, because it will be pretty sure to teach something. Whichever experiment you perform, take the utmost pains with every thing. See that the two lots are as nearly alike as possible at the beginning. If a

plant is killed during growth in any one lot, a plant must be removed in the other lot to keep the balance even. Be particularly careful to note all the facts of the work ; because there may be some apparently trifling circumstance, such as the neighborhood of a manure-heap, that may quite upset all calculations, and render the results quite misleading.

It is not difficult to see why tillage improves the plants growing in any soil. After every rain the surface of the soil appears to be hard, as if a crust had formed on top. In sandy soils this is slight, but still it is to be seen ; and on clay soils it is often quite thick and hard. Every drop that falls seems to beat the soil down ; and when the sun and winds dry up the soil, after the rain has passed, the top of the earth is like the top of a well-baked loaf. Through this crust very little air can pass, and the roots of the plants are sealed up as if in a close box. With a rake we easily break up this crust, and open the soil to the air. The oxygen of the air can then enter the soil through millions of minute holes and passage-ways, combining with elements brought down by the rain or already existing in the soil ; and the plant, finding fresh food prepared for it, greedily stretches out its roots to get it. No doubt the fresh air thus allowed to penetrate the soil also ventilates and purifies it, and makes it a sweeter and more healthful home for the plants. The loose, broken surface, left after the crust formed by rain has been removed, also offers millions of fine points on which the dew may condense, and thus more

water is obtained in times of drought. A hard soil, with the surface beaten down by rain and baked by the sun, resists the next rainfall; and the water runs off over the surface, tearing up and carrying away the light parts of the soil, and leaving the soil below untouched. Rain falling on land freshly raked, or tilled by any tool, quickly sinks into the soil, carrying down food from the air to the thirsty plants. This is the philosophy of tillage. It improves the soil by letting in the air, the rain, frost, and sunlight, to work on the sand and broken rock in the soil, and continuing the work of soil-making; it enables the elements to meet, and form new combinations suitable for the food of plants; and it makes it easy for the roots of all plants to push their way through the soil in search of food. The roots do not appear to actually push through the soil, but to creep between the small grains and lumps, and to feed on their surfaces. Thus we can easily see, that in a barrel of nuts there is much more surface on the nuts than in a barrel filled with squashes. It is the same with a fine soil and a lumpy soil.

Of course we see that tillage costs money. If a field of corn is planted, and cultivated once, it will cost more to cultivate it again or three or four times more. How can we find out this? how tell how often it will pay to hoe any crop? Mark off a portion of the field, — say an eighth of an acre, — and give this twice as much or even three times as much cultivation as another piece near it that gets no more care than the rest of the field. Gather the crop from each eighth

of an acre, and see if there is any difference, and how much. There must be a right way and a wrong way ; but the wrong way is probably on the side of little tillage, the right way on the side of much tillage. Experiment will alone settle the matter.

CHAPTER VII.

MANUS—A HAND.

XIX. **AN OLD FABLE.**— Ever since men gave up living in caves and trees, and hunting wild animals for food, they have tried to win more food by planting seeds and tilling the ground. The ancients, anxious to explain every thing, used to say that certain fanciful creatures they called gods and goddesses came down out of some imaginary place in the clouds, and politely informed certain men just what to do to make grain, fruits, and other crops grow. Of course it was very kind in the gods; and the men and women who were foolish enough to believe it all very properly built temples, and wrote poetry, and did many other amiable things, to show their gratitude. The temples and the statues and poetry are very fine, and yet we know now that nothing of the kind ever took place. Not a solitary idea in regard to the plants or the soil, or the sun or rain or frost, was ever sent down from any imaginary Olympus in the clouds. All that men know of the soil, the weather, the plants, or of the universe, they learned from observation and experiment. Some savage creature, half starved in the forests, saw the fruit of a plant, and ate it, and threw away the seeds

before the entrance of his cave. Months after, he noticed young plants springing from the ground, and in time he ate fruit from these new plants. It was this that suggested to him to try gathering fruits, and saving the seeds for the purpose of experiment. He was the first man of science. He performed an experiment in agriculture. He planted seeds, and raised a crop. Others saw it, and repeated the experiment; and in time the news slowly spread from man to man, through the great forests. Thousands of years may have passed before some other savage genius tried a more daring experiment. He tried scratching the ground about the poor little plants. He began to till the soil—perhaps at first with only his hands. Afterwards, perhaps long, long afterwards, some other bold experimenter tried a broken limb from a tree for a hoe. This too slowly spread, and it was found that hand-labor or hand-tillage greatly improved all crops. Then came a more wonderful experiment than all. Some hard-working tiller found that if he took the waste matter from the bodies of animals, and buried it in the soil, it had the same effect as tillage,—it acted as a hand. It made the plants grow faster and larger, and bear larger crops; and, as this was the same as the effect produced by hand-labor, he called this animal waste *manure*. In the language of his time, *manus* meant a hand: so we easily see why he invented the word *manure*.

We cannot tell who made this discovery of the value of manure. Very likely it was discovered in many

lands, and perhaps in some countries hundreds of years before it was given this name. The fact that manure can be used to improve soils, and thus improve crops, has probably been known in China for thousands of years. There is no record of the time or place where the discovery was really made. It is not important to know dates and names in such a matter. It was one of those great discoveries that first taught men how to win wealth from the ground ; and it probably did more to help men to become civilized than any other single discovery ever made. No fanciful goddess whispered the secret to priests in ancient temples : it was discovered by experiment. While this great fact — that manure placed in the soil improves it, and benefits all plants growing in it — has been known for a long time, it was only within a short time that men learned by experiments why and how it works.

We go out in the fields, and see grass or oats growing in the soil. We know these plants take from the ground more or less of the fourteen elements in the soil. We know, if the grass and oats are cut down and carried away to the barn, the soil is robbed of a portion of each of these elements. We know — for our worn-out farms in New England prove it — that if we go on year after year carrying away all the plants that will grow in the fields, the time will come when one, two, or three of these fourteen elements will be used up, and the plants will grow less and less, year by year, and refuse to produce enough to pay for planting the seed. In the barn we find a horse eating this

grass and oats, and consuming these very elements the plants took from the ground. After each meal the horse digests his food ; using a part to keep himself warm, and enable him to live, grow, and work, and rejecting all the rest. Beneath the barn we know there lies in the cellar a quantity of matter, — unfit for any purpose except to be buried in the ground out of sight. Chemists tell us that in this matter are portions of the fourteen elements carried away from the soil by the plants that were eaten by the horse. This is nature's grand circle : that which the plants take from the ground, the animals return. Thus it is true that seedtime and harvest shall not fail. The soil will never fail to give bountiful harvests, while plants grow, and animals live. The only thing that stands in the way is the selfishness and greediness of men, who by the means of plants rob the soil, taking all its elements away, and bringing none back again. We gather wheat and corn in vast and wonderful harvests, and send it away to Europe. We carry off thousands of tons from our land every year in tobacco-plants ; and then with stupendous folly burn it up, and wonder why our soils grow poorer and poorer year by year. We may think the farmer's manure-heap very vulgar, and refuse to think or speak about it ; yet so God has arranged the law of his beautiful world : that which the plant needs, the animal returns. Let no man call any thing unclean. "Dirt is matter out of place ;" and half the science of agriculture consists in knowing how to put the right thing in the right place.

xx. **FERTILIZERS.**—When all the fourteen or seventeen elements are present in abundance in any soil, we say it is *fertile*. It must be noticed, however, that in nearly all poor or unfertile soils we shall find it is only three of these elements that are usually missing, the others being everywhere abundant. When one or more of these elements are missing, and we add any thing containing the missing elements, we call the material, whatever it may be, a *fertilizer*. Fertilizers include plants, seeds and parts of plants, waste matter from animals, the remains of creatures of every kind, fish, bones, hair, shells, etc., rocks containing remains of animals or particular elements, and waste materials from shops and works of every kind. For convenience, fertilizers are divided into three classes: first, living plants or *green manure*; second, waste matter from animals, or *manure*; and, third, all those various materials,—ground bones, crushed rock, prepared chemicals, blood and slaughter-house waste, saltpetre, potash salts, and phosphatic rock and waste matter from some kinds of manufactories,—all of these receiving the general name of *commercial fertilizers*.

Let us return a moment, and recall the elements needed by plants, and that are to be found in greater or less quantities in any rich and fertile soil. These elements are oxygen, hydrogen, nitrogen, carbon, silicon, sulphur, phosphorus, chlorine, potassium, sodium, calcium, magnesium, aluminium, and iron. There are also three more,—manganese, iodine, and fluorine; but the first fourteen are the most important, and of

the whole seventeen only three will require our careful attention. Let us examine them again, and endeavor to understand this matter. It is not half so difficult as it appears at first sight; and when we once get at the facts, experiment will easily show us what to do with every kind of soil.

Oxygen, we remember, is a gas. It is abundant in the air and in the water, and, combined with other elements, forms the larger part of every soil, however rich, however poor. As it is in water and in air, and as it is ever eager to unite with other elements in the soil, all we have to do is to give the air and water a chance. Tillage settles that. The plough, the hoe, the harrow, the spade, and the rake invite the oxygen to come in and be at home in the soil. So we have not to think about the oxygen. There will always be oxygen in every soil, even without tillage; and with tillage there will be more than enough for every crop. It is the same with carbon and hydrogen. They are abundant in the air; and though these three, oxygen, carbon, and hydrogen, form the larger part of every plant, we need not concern ourselves about them, because every plant in a well-tilled soil, if well supplied with water, will find more than it wants of each. Of course we must keep in mind, all the time, that none of the fourteen elements are used by the plants in a pure state. All are combined in some way with others in every soil.

The silicon, sulphur, chlorine, sodium, magnesium, aluminium, iron, manganese, iodine, and fluorine can

be found in nearly every soil ; and, as the plants need only very small portions of each, we need have no fear that they will not find enough everywhere. Tillage will help to supply these also ; because the elements exist in many rocks, and tillage brings air and water into the soil to release the elements from the sand and clay. This leaves us four elements, — nitrogen, phosphorus, potassium, and calcium ; and these we shall also find in any fertile soil. In wild virgin soil they are abundant ; and plants in such soils grow wonderfully, and produce bountiful crops. Wild plants, like trees, growing in a virgin soil, shed their leaves every year, and in time die, and decay upon the ground. In this way they return to the soil all the elements they took from it, and the soil remains fertile. When we clear away the trees, and plant corn, cotton, or potatoes, and then carry off the crop, the whole thing is changed. In the crops carried away, are all the elements taken from the soil ; and the soil is robbed of just so much. If we go on planting crops, even with the best of tillage, the time will come when these four elements will dwindle away. The plants will live and grow, perhaps for many years, perhaps as long as we choose to plant the seeds ; but the crops will be smaller and smaller till at last they are not worth the gathering. We must understand that a plant in growing must have all the elements in reach, if it is to be vigorous and thrifty, and bear good crops. If one be wanting, it will bear less and less every year. The plant cannot speak ; the soil refuses to tell us, except

by costly and troublesome analysis, which element is missing: but we may be very sure it is one of these four. If the soil is poor and the crops are light, and the business of raising crops is unprofitable, some one or more elements are missing, or have been eaten up by previous crops; and these elements will be these same four. We need not trouble ourselves about the oxygen, the silicon, the iron, and others. They will look after themselves; and we have only to consider the nitrogen, phosphorus, potassium, and calcium. The last, calcium or *lime*, is abundant in many soils, and on such soils need not be considered. Where it is not found naturally in the soil, it may be added. How to tell whether it is needed in any soil, is purely a matter of experiment, as we shall presently see. This leaves only three elements, and makes the whole matter very simple.

XXI. PLANTS AS FERTILIZERS.—If we pull a living plant, like a pea-vine or clover, out of the ground, we shall find in the stem, roots, branches, flowers, or fruit, all the various elements it has obtained from the soil, the water, and the air. Taken from its home in the ground, the plant soon dies. It begins to wither, it shrinks and shrivels up, and loses nearly all its weight. If we go on drying it by placing it in an oven, it loses more and more weight, and finally becomes merely a mass of brittle material that readily breaks up into dust. Such a green, soft plant will give, when perfectly dry, only a small part of its original weight or bulk. If we take this light, brittle matter,

and burn it, we shall have a little smoke, and last of all a pinch of soft ashes. In this drying and burning, the dead plant parts with a portion of the elements it contained, by permitting them to float away unseen on the air. The rest it leaves in its ashes. We can gather up the ashes, and put them back in the soil, and they will be ready for some new plant growing on the spot occupied by the dead pea-vine or clover-plant. All the elements burned up in the plants, that were lost in drying, and that disappeared as gas and smoke, remain in the air, or fall to the ground, and thus go to feed other plants. All the elements left in the ashes are also ready, when put back in the soil, to be used by other plants. A thin, poor soil can thus be made more fertile by sowing clover, and, when the plants are about one-third grown, ploughing the live plants under, and burying them out of sight. The green plants will decay, and restore to the soil the elements they took from the air and water, and leave all their elements in a condition fit for food for another and a better crop that is to follow. Besides this, the dead clover causes the soil to be light, loose, and ready for the roots of new plants. The next plants will find more organic matter in the soil than before, and will take up the elements left by the clover, and grow larger, and bear better crops, than if the clover had not lived and died for their benefit.

This plan of burying live green plants in the ground is called *green-manuring*. The best plants for this purpose are pease and clover, and when used in this

way they are fertilizers. Of course the pease and clover ploughed under are lost as far as crops of pease and clover are concerned ; yet so great is the gain to the next crop, that in many places the farmer can well afford to lose the clover and pea-plants for the sake of the next crop that follows them. The pease and clover are rich in the element called nitrogen ; and this, too, makes them useful for green manure. By the use of green manure, poor and barren soils may be made fertile, and even good soils greatly improved. Plants thus make the cheapest of all fertilizers, and can be used when other manure cannot be obtained. This use of plants also shows us one thing more. If a plant buried in the soil restores to it the elements it obtained from the soil and the air, then all the useless plants in our fields and gardens should be at once returned to the ground. Suppose we have a kitchen or flower garden. We plant pease, and, when the peas are ripe, gather them for the table. There are the vines standing in the garden, and there are the pea-pods. Many people throw both away : the pods go to the waste-barrel ; and the vines are left where they stand, to go on robbing the soil, or they are pulled up, and left to wilt and die in a corner. The true way is to pull up every vine the very day the last pease are gathered, and to bury them with the pods in the ground. We have already learned in our studies of climate, that, when a crop is gathered, the ground should be planted again with some other crop. By using the vines as a fertilizer, we clear the ground and

get rid of the old plants, stop the waste of more elements from the soil, and return those already taken out, and make them ready for the next crop. It is the same with all plants. When the mignonnette ceases to bloom, dig it into the ground, and plant more. When the tomatoes, the strawberries, the beans, and other things are gathered, bury the plants at once. When the frost cuts down the flowering plants in the fall, pull every thing up at once, and bury it in the soil. Gather all leaves, trimmings, and waste parts of every green thing, and bury it. A convenient way to do this is to make a compost-heap. Throw the old plants in a heap, and cover them over with fresh soil thrown on top. Let nothing green go to waste, and slowly and surely your garden will bear better crops and fairer and more abundant flowers year by year. The soil will become darker and richer, and lighter to move with the spade or hoe. In kitchen-gardens, nothing should be taken from the garden, except the things actually used on the table. If beets, turnips, or carrots are pulled, bury the tops; if cabbages are gathered, save the larger leaves for fertilizers. Save every thing, gather up every green thing, every weed and waste leaf, and bury in a compost-heap or in the ground. If, in the fall, rubbish and brush are left, burn it all, and scatter the ashes on the ground, and at once cover it over with soil. Pursue the other and more common plan, — waste every thing, take all you can get out of the soil, and return nothing, — and year by year the soil will take a sharper revenge for

the wrong you have done. Good Fortune will leave your home, and hungry Poverty will come unbidden, and sit at your dinner-table. The cotton-plant is valuable to us for its lint, but the lint is a very small part of the plant. On many a cotton-plantation, in the past, the plants were left to wither away in the ground, and the seeds, rich in precious elements, were thrown away and lost ; and then the planter wondered why his poor, starved fields refused to grow more cotton. Planters are wiser now, and the seeds, even when crushed to extract the oil, are carefully returned to the ground as a fertilizer ; and the plants are buried, or burned and the ashes returned to the land, that the future crops may not perish of starvation. It may be thought just here, that, if animals produce manure, it would be better to give them the waste plants to eat. This is true, and we shall consider it in future studies. But in gardens where no cows or pigs are kept, all useless plants and weeds should be buried in the ground or compost-heap just as soon as possible ; for, the greener and fresher they are, the more they will enrich the soil.

XXII. WHAT TO DO.—When men first began to use manure to improve the soil, they knew nothing of the elements of the soil. They only knew that a field that is manured bears larger crops than one that is not manured. Their experiments proved that when manure is applied year after year, the soil remains continually fertile, and thus an old field becomes just as good as a new one. There they stopped ; and

why and how the manure affected the soil, they did not know. We know now that a plant living in the soil requires all the seventeen elements, and dies or grows slowly if one be absent. The three most likely to be absent are nitrogen, potassium, and phosphorus; and these three are present in greater or less quantities in all fresh manure. It is for this reason manure is the best fertilizer for all crops. It brings back to the soil nitrogen, phosphorus, and potassium; and these are the very three most likely to be needed. The oxygen, the carbon, and all the other elements are plentiful; and by adding these three we restore to the soil all the plants are ever likely to want. There will be other elements in the manure; but as these are not wanted, no harm, but only good, is done. One of the most curious things about this matter is, that the manure from different animals differs greatly, and consequently has more or less of the three elements. This is a matter we must examine, but we must leave it till we come to our Chautauqua Talks about Animals. All we have to do now is to observe that the farm-manure commonly made on our farms contains the three elements,—nitrogen, phosphorus, and potassium; and it is therefore a good fertilizer for every variety of soil and every kind of crop.

Beside this green manure from living plants, and this barn and stable manure, there are many other materials—guano, marl, phosphatic rocks, waste matter from factories and shops, bones and other remains of fish and animals—that contain more or less of these

three elements ; and if these things are placed in the soil, they act as fertilizers. Such fertilizers are called *commercial fertilizers*, and they are very largely used in place of manures. There seems to be, at first glance, a great variety ; and we may wonder which we had better use for our plants. If we read the advertisements of the people who sell these fertilizers, we might fancy all we had to do would be to buy a few bags of these wonderful things, and have potatoes as big as watermelons and corn as tall as a two-story house. These commercial fertilizers are good, some of them are very good indeed ; and if we wish to raise good crops in our old fields, we shall do well to purchase some of them. Which shall we buy ? One man says his fertilizer will make our Lima beans try to climb a steeple ; and another man shows us beautiful pictures of wheat as tall as a horse, and other wonderful crops, growing on soils made rich with his special and truly remarkable chemicals. How shall we find out whether our fields require nitrogen, phosphorus, or potassium ? How can we tell whether the land would produce more if calcium were put upon it ? If we look at these commercial fertilizers, we shall be more bewildered than ever. Not one of them gives the slightest sign of these elements as they appear in a pure state. The fertilizers look like mere dust and ashes, having a strong and disagreeable smell ; and we have to trust to the dealer in these things. If he says nitrogen is locked up in his bags of chemicals, we must take his word for it. This is

what we must do in nearly all business ; and no doubt the dealer is a good and honest man, and knows what he tells us. Dishonesty never pays in the long-run, in any business ; and the real question before us is, which of all these various kinds of fertilizers we shall buy for our particular piece of land.

Experiment is our only guide. We have a field or garden in which crops have been growing for many years, and the soil is worn out. It wants something, but what it wants we do not know. Our first step must be to find out which element is missing. Perhaps the hills about our land are full of limestone. It is a limestone country, and there may be enough lime or calcium already in the soil. However, we may not be sure of this, and we must find this out by experiment. If, after we have tried it once, we find it is not needed, we can omit it after that.

We now proceed to lay off a level place in the field where the soil is to be tested, and mark out ten squares, each measuring one rod on each side. We place these in two rows, leaving spaces three feet wide between the squares. These empty spaces or walks are to be kept clear and free from weeds as long as the experiment continues. Each square should be marked by stakes at the corners, and properly numbered as in the accompanying diagram.

These squares are to be planted with the same crop, and cultivated through one season ; and each square is to be a testing-place for fertilizers. Two of these squares — Nos. 2 and 9 — are to have no fertilizers.

This is to serve as a check or guide in testing the other squares. Square No. 1 is to have a fertilizer

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Nitrogen and Potassium.	No fertilizer.	Nitrogen.	Potassium and Phosphorus.	Potassium.
No. 6.	No. 7.	No. 8.	No. 9.	No. 10.
Nitrogen and Phosphorus.	Phosphorus.	Nitrogen, Phosphorus, Potassium.	No fertilizer.	Calcium.

containing nitrogen and potassium ; No. 3 is to have a fertilizer containing nitrogen only ; No. 4, potassium and phosphorus combined ; No. 5, potassium alone ; No. 6, nitrogen and phosphorus ; No. 7, phosphorus alone ; No. 8, all three elements combined ; and No. 10 is to have calcium only.

To perform the experiment, fertilizers containing these elements are to be placed on each of the squares, and carefully worked into the soil, about two or three inches deep, before the crop is planted. No rule can be laid down for the amounts to be used, but two bushels on each square will be about a fair quantity. After this each of the ten squares is to be planted with the same seed, at the same time, and carefully cultivated through the entire season, treating all the squares exactly alike.

We will suppose that potatoes have been used. During the growing-season, carefully observe the different plats, and see if any one or more appears to be more or less thrifty than the others. Notice which plat appears to mature first, and which blooms first, and keep a record of the observations. At the end of the season, carefully dig the crop on each square, gathering all the tubers large and small, and weigh each lot. First weigh the crops on squares 2 and 9. This will serve as a standard of comparison, as it will show the natural condition of the soil. If there is any difference between them, get the average. Record the weights in each lot; and, just for illustration, we may say it is something like this: Average of 2 and 9, 80 lbs.; No. 1, 380 lbs.; No. 3, 250 lbs.; No. 4, 360 lbs.; No. 5, 350 lbs.; No. 6, 300 lbs.; No. 7, 220 lbs.; No. 8, 400 lbs.; No. 10, 100 lbs. This is a purely imaginary crop. It might vary greatly in different soils, and this variation is the point we want to notice. On the particular soil we are supposed to be testing, we clearly see that the land is benefited in some degree by the addition of every element. Calcium helps, and this means that it should be used on that soil in addition to any and all of the others. Potassium and phosphorus helped the most alone, and still more when put together. All three elements naturally produced the best results of all. It is plain that this soil needs all four, — calcium, nitrogen, phosphorus, and potassium. Squares Nos. 10, 3, 7, and 5 show us the proportions in which these elements should

be used, and they will stand in this order: calcium, nitrogen, phosphorus, and potassium; the last being most important.

Another and a more simple way to repeat this experiment is to select in the spring a level space of grass-land, and to set up ten stakes in the grass in two rows two rods apart, and two rods apart in the row. Number and mark the stakes as in the squares. Then scatter on the grass, for ten feet about each stake, the fertilizers containing these elements, in the same order as in the squares; leaving the space about stakes Nos. 2 and 9 untouched. As the grass grows, carefully observe from week to week the grass about each stake, and see if it grows any faster or taller and thicker, or shows a darker color, about one more than another. These surface indications will tell a good deal in regard to the wants of the land, though the results will not be so accurate as in the first experiment. In the Eastern States nearly every experiment will show that any fertilizer containing potassium will produce the best results with all crops.

Where shall we find these four elements? Calcium is found in the form of *lime*, *land-plaster*, and *gypsum*. We require less of this than of the other three; and, if our experiments prove that it does not help greatly, we can omit it. If it does appear to help, one good dressing of forty or fifty bushels per acre will be good for fifteen years.

The nitrogen we shall find in *manure*, in *sulphate of ammonia*, *nitrate of soda*, *guano*, *fish-guano* or *scraps*,

castor pomace, dried blood, and tankage or slaughter-house waste.

We shall find phosphorus in *bones of animals, bone-meal, etc., mineral phosphates* and the so-called *phosphoric fertilizers, superphosphates, etc.,* and in *farm-manure.*

We shall find potassium in *wood-ashes, potash salts,* and in *manure.*

These are some of the names given to the commercial fertilizers now for sale everywhere, and advertised in all the agricultural papers; and each element can be found singly or combined with the others, and in any proportion that you may need, in some of these fertilizers. Observe this most important fact: Manure contains all three, and for this reason is called a *complete fertilizer.* Many of the commercial fertilizers are also called *complete fertilizers;* and this means that they contain potassium, phosphorus, and nitrogen in different proportions.

This is the sum of this whole matter. The soil becomes exhausted of certain elements. We do not know which; but by applying all three to any particular piece of land, we can tell very nearly which is wanted. If any application produces a small effect, or only increases the crop slightly, it is already abundant in the soil, and we need apply only a little more. If the effect upon the crops is marked and very plain, the soil needs that particular element. Manure, we shall find, always improves the soil, because it is a complete fertilizer, containing all three elements, and

because it makes it lighter, and adds organic matter to the soil. The supply of the commercial fertilizers increases every year, as men of science find out how to make and use them. Every waste matter is now searched for these precious three; and where before many things were thrown away as useless, or buried in the ground or the sea, now all is saved and prepared for the use of the farmer, that his fields no longer grow lean, and his crops perish for hunger. The cost of these fertilizers has been much reduced in the last few years, and it may be the cost will be still further reduced as science finds new sources of supply. The supply is never likely to give out, and each year the people see that the old law of nature is right: *That which comes from the soil must be returned to the soil.* In this way the land will be a bank that will pay good dividends long after every gold-mine in the world is exhausted. In this way the soil will supply food for countless millions of people, and farms will cover all the earth, so that no man can number the bountiful crops that will spring up to feed and clothe the people.

What is our duty in the matter? We must learn of these things. Observe, study, and experiment. If you own land, remember it is a trust. You have no right to rob the soil. You dare not rob a bank, or your father, lest you come to poverty or the jail. How much more, then, are you bound in honor not to rob the soil made by the Creator for the use of all his children. If you receive the land from your fathers, you are bound to leave it to your children in better

condition than you found it. You cannot rob the soil, and hope to escape all punishment. Your children's children will resent your theft in their poverty, and, when they learn the truth of all these things we have been considering, will remember you only with shame. There is no excuse in this matter. A simple experiment, well planned and faithfully carried out, will tell you what to do. It is not a deep science fit only for the schoolmen. It means only experiment, experiment, and experiment. Try things, and learn, and, having learned, do what is right by your soil ; and it will return all your labor in full measure, running over, and your children will inherit the land as a well-kept trust and blessing.

CHAPTER VIII.

ARTIFICIAL SOILS.

XXIII. **POTTING SOILS.** — In our talks about the soil, we have so far considered the natural loam, or earth as we find it in our gardens. Now, we know that thousands of plants live in pots through the whole or a part of their lives, and these plants must have a soil of their own. We have already studied artificial climates in cold-frames, hotbeds, greenhouses, grape-ries, and plant-houses of all kinds; and we learn that there are also artificial soils for plants growing in these artificial climates. The florist and the greenhouse-man call these soils "*potting soils*," because they are used in flower-pots. Some of the men who have written books about plants in greenhouses have said that nearly every kind of plant, particularly flowering plants, must have a particular kind of soil. The books written about plants twenty-five years ago, and nearly every book on the subject in England at this day, contain minute and special directions for making soils for different plants. They say, for geraniums you must have one kind of soil, for mignonnette another, for the Chinese primrose still another, and so on; whereas, for nearly all plants it does not make the slightest

difference whatever. If you have two different kinds of soil, you can raise in these every variety of plant to be found in any common greenhouse or in any window in a dwelling-house.

Suppose we take a geranium. We wish to have it grow and bloom in the house. We might take the flower-pot to the garden, and fill it with soil, and in this plant our geranium. It might live and even grow, but it would grow far better if we prepared a special soil for it. The soil of a garden is usually too heavy, has too much clay, and is comparatively poor and exhausted. If we pull up a geranium in the garden, we shall find it has extended its roots in every direction, perhaps a foot or eighteen inches on each side of the stem. If this same plant is to live in a pot, it is plain the roots must be very much cramped and crowded. Consequently we must do something to make up for this, and we make the soil placed in the pot very rich. Take a plant that has been growing for some time in a pot, and, holding it upside down in the hand, gently tap the edge of the pot on a bench or table. The plant easily slips out of the pot, and we see its roots have twisted themselves round and round in the pot in their search for food in the soil. If the plant has been growing in the pot for a long time, the soil will seem to have greatly changed. We may shake all the loose soil out of the matted roots, and find only a small part of the original soil—perhaps not enough to half fill the empty flower-pot. If we take this old soil out of a pot where a plant has

been growing for a long time, and, putting it in another pot, attempt to make another plant grow in it, we shall fail. The second plant refuses to grow in that old soil, for it is completely worn out. The first plant has taken all it could find, and there is nothing left but barren sand and waste matter.

If our geranium is to thrive and grow, we must have a light and a rich soil. It must be light, sandy, and porous, because we cannot till the soil in a pot. The best we can do is to occasionally stir the surface to let in the air. It must be sandy, to permit water to flow through it easily, and the roots of the soil to find their way without difficulty. It must be rich, because we have only a very small space in which the plant can grow. Its roots cannot extend freely in every direction in search of food, and all that it requires must be abundant and in easy reach.

Three materials are needed to make potting soils for all the common, quick-growing greenhouse plants, fruits, and vegetables; and with one more we can make soils suitable for every plant that grows under glass. We will begin with the soil for the quick-growing or soft-wooded plants, as they are the most numerous, — the geraniums, fuchsias, primroses, roses, begonias, chrysanthemums, etc. For the organic matter we can take sods cut from a pasture or grass-land. These must be cut when green, and piled up in a heap in some dry spot out of doors, — that is, away from swampy or wet soil. In about three months the grass, plants, and roots will completely decay, and

we shall have a light, loose soil, almost wholly composed of organic matter ; and this we store in a shed, or in barrels under cover. If we cannot get sods, dig up the loose top soil under the trees in the woods. This too will be almost wholly organic, because composed of the remains of the dead leaves fallen in the course of years beneath the trees. If we cannot obtain either of these, get the fine top soil from a field where farm-crops have been cultivated ; choosing, if possible, a field that has only recently been ploughed up from grass. For the inorganic part, use clean sharp river-sand. If it cannot be found along the river-bank or by the shore of fresh-water ponds, take it from any sandbank ; but test it before using, to see if it contains clay. To test the sand, burn it as described in our experiments. Common mason's sand can also be bought at the mason's yard, and may be used if no other can be found. Sea-sand can be used, but it must be freely washed in fresh water to get rid of the salt. It is also best to wash the mason's sand to prevent any danger from salt. The fine gravel found at the side of a road or paved street can also be used if carefully sifted. For fertilizers the very best material is stable-manure. It should be piled in a heap under cover for three months, and occasionally turned over with a fork. It will be then completely decayed, and will be dry and clean. If this cannot be obtained, a good fertilizer can be made by mixing equal parts of guano and ground bones. A small proportion of wood-ashes may also be added with benefit.

These three — the organic matter (old sods or leaf-mould or soil), the sand, and the fertilizer (whether it is from the stable, or is a mixture of commercial fertilizers) — should be mixed in equal proportions. The materials should be well sifted to free them from lumps and from worms or grubs, and completely and thoroughly mixed together when dry. The best plan is to store them in a dry place, free from hard frost, and to mix them as wanted for potting. The mixing should be done on a broad table; and, if the materials are dry and dusty, only enough water should be used to merely lay the dust. A wet and muddy potting soil should never be used.

For the hard-wood plants, the orange, the camellia, heaths, azalias, rubber-trees, capé-jessamine, etc., we use the same materials with the addition of old peat. This peat, or meadow-muck, is a black soil composed almost wholly of organic matter, and is found in bogs and swamps. It must be dug up and piled in a heap for a whole winter before it can be used. It must be placed in a pile out of doors, in some well-drained place, — and for this reason it is best to take it away from the swamp, — and left to freeze all winter. After being exposed to frost, it breaks up into a fine black, powdery soil, that should be stored in barrels in a shed or cellar. To prepare a soil for these slow-growing, hard-wood plants, make a mixture of the leaf-mould and the peat, using one-third of the leaf-mould (old sods or soil) and two-thirds of peat. Next mix this with an equal proportion of sand. This must form

the larger part of the soil, and only a small proportion of manure is needed. Measure the mixture, and to each four quarts or four pecks add one quart or one peck of the manure, using with it a little wood-ashes and ground bones.

For lettuce, cabbage, and other small plants in a hot-bed or in a plant and forcing house where the plants are cultivated in boxes or on benches, and for rose-houses, cucumber and melon houses, a mixture of equal parts of good soil from a field, coarse sand, and old manure or some good complete commercial fertilizer, should be used. The soil need not be sifted except for small plants; and, if common manure is used, it need not be broken up so fine as for potting soils. For roses the proportion of fertilizer should be larger than for any of the common flowering plants. In regard to the actual work of potting plants, we will consider that in detail in the next book of the Chautauqua Series.

XXIV. MAKING NEW SOILS. — It will often happen, that in building a house a bare or barren spot is selected for the site; and when the house is finished, it is surrounded by barren, dusty gravel or sand, sometimes adorned with pieces of brick and other waste materials left by the contractors. We must, of course, furnish the place, and, if we do nothing more, have a rug of grass put before the windows, and perhaps a few ornaments in the way of shrubs or trees. Neither plants, shrubs, nor grass will grow on such a spot; and a special soil must be prepared for them. First of all,

see that the place is dry. See that the water runs away quickly after a rain; and then from some old pasture dig up a quantity of sods, and place them upside down two and three deep all over the spot where the grass is to grow. They will in time decay, and help form a good soil. In place of sods, cart on the top soil from some field, and spread it not less than one foot deep over the place. Add about one cart-load of sand to every three loads of soil (unless it is very sandy), and add one load of manure to every four loads of soil. If old muck can be procured, use one load of muck to every two of loam, and use more sand. In this way, even out of poor materials, a fair soil can be made, and every year it will be improved by culture and additional fertilizers. A good plan will be to sow it first with clover, and when well grown to dig it into the soil as green manure.

The site selected for a house may be a garden with good soil. In this case all the top soil should be carefully dug up, and piled in heaps in a safe corner till the last mechanic has left the place. Contractors often have a habit of digging a cellar for a new house without the slightest regard to the soil; throwing out the stones, gravel, and useless material under the subsoil right on top of the natural soil, and burying it out of sight forever. Such a waste of good soil is simply wicked. Nature may have been at work a thousand years to make that little bit of good soil, that sweet grasses, the wild rose and aster might bloom in it, or the amiable potato and cheerful squash find a home

there ; and the blundering cellar-digger destroys it all in a day, and thinks he has done no harm. People who pass the house years after it is built, and see the dusty yard, the half-starved grass, the sickly plants, know better, and may justly think him a fool and a dunce.

It often happens that a field has a soil containing too much sand. It would produce more if richer in organic remains. Green-manuring will help ; but if a soil rich in organic matter is near, it may be worth while to bring some of this soil to the sandy field. The best material for making an artificial soil in this way is to get peat from a bog or meadow, pile it up one winter that it may be broken up by the frost, and then scatter it over the sandy field, and plough it in. This use of muck for improving soils is quite common in some parts of the country, and one or more good books have already been written showing how it should be done. Purely artificial soils are also to be found in New England and New Jersey, wherever cranberries are cultivated. The peaty soil of the meadows is covered with sand, and on this compound soil the cranberry flourishes wonderfully.

Finally, we can change the character of some soils by artificial means, without adding any thing to them. In many parts of the country, there are meadows, particularly near small streams, where none of our useful plants seem to flourish. The soil is rich, deep, and black, and to all appearance it is very good soil. It is good soil, for it is covered with many kinds of

plants that seem to flourish wonderfully. Unfortunately, these plants are aquatic or semi-aquatic plants, and seem to enjoy a wet soil. They plainly point to all the trouble. The soil is wet. These flags, mosses, and reeds, these rapid-growing water plants, plainly tell us just why our farm-crops will not grow there. The water lingers after every rain, and in the spring it is wet and soppy there. In the winter there are little patches of ice, and in long rains the water seeps through the grasses and moss in sluggish rivulets. These wet places vary from actual bogs and swamps, to meadows that have pools and puddles lingering after every rain. All are unfit for good crops, and must be improved by draining.

Drainage, or treating any soil so that its surplus water will run away, is a great science by itself. We cannot now take it up, yet we must learn to recognize any soil that needs it. Wherever the common sphagnum moss grows under the grass, wherever aquatic plants appear, wherever water lingers in pools after a rain, the soil needs draining. If we find such a place, and wish to cultivate it and make it produce good paying crops, we must get rid of this surplus water that clings to the soil like water in a sponge. There are many ways of doing this; some cheap and easy but not very permanent, others more costly but very efficient and durable. The soil must be cleared of water by finding or making some opening where the water can escape to a lower level, and thus leave the soil dry. A ditch dug through the field will drain

the soil on each side for many feet. A drain made of stones, or porous earthenware pipes called *tiles*, may be made under the soil; and through this drain the water will run away as fast as it falls. Whether it is best to drain any particular soil, how it is best to do it, are questions that would require a long time to answer. First, decide whether your land needs draining. Next, see if better land, that does not need draining, cannot be bought for less money than the cost of draining. If you decide it is best to drain, do it well and thoroughly; for it is a permanent investment that will last long years after your children have ceased to cultivate the land, or have sold it for house-lots. In any case it will always be a benefit, as it makes the soil dryer, and consequently warmer and lighter and more easily worked, and makes the neighborhood more healthful. Great sums of money have been spent in this and other countries, in drainage-works; and there can be no doubt such works have added millions of dollars to the value of farm-lands, and driven away malaria and kindred diseases, greatly to the benefit of the people who so wisely improved the soil given to them by the Creator.

We have now finished our studies of this singular and beautiful carpet that covers the rocky skeleton of our earth. We have seen much that is curious and interesting, and have gone just far enough to see how much there is yet beyond equally curious and interesting, had we time to study it. We have been look-

ing at the soil as the home of the plants, because plants give us food, clothing, and wealth from the ground. We have, in our first book of this series, seen how the air, the wind, the sun, and the rain affect the lives of plants ; and in this book seen something of the way in which plants are affected by the soil in which they grow. Plants live in the soil, and are affected by the weather ; and for these two reasons we have now examined both weather and soil. We can next turn to the plants themselves, living things full of beauty, governed by curious and beneficent laws, and opening to us a wonderful range of the most singular and fascinating study. To this new and delightful work we will go on in the next book of this series, feeling sure that all we have already learned will be of the greatest value in helping us to understand the ways and habits of our friends the plants.





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