KIRK'S ELEMENTARY GRICULTURE

THIRD EDITION

THOROUGHLY REVISED BY AN INSTRUCTOR IN AGRICULTURE

LIMITED

2/-

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WHITCOMBE AND TOMBS LIMITED
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PREFACE TO FIRST EDITION.

In this elementary book the author has dealt as simply as possible, without descending to puerility, with some of the principles of Agriculture, a knowledge of which is prescribed for the pupils of the public schools by the Syllabuses of Instruction in Australasia. In its preparation free use has been made of the information contained in various leading publications on the subject, amongst which may be mentioned Fream's "Elements of Agriculture," Webb's "Agriculture," Tanner's "First Principles of Agriculture," Wright's "Principles of Agriculture," Wrightson's "Farm Crops," Griffith's "Diseases of Crops and their Remedies," "The New Zealand Country Journal," "The New South Wales Handbook of Agriculture," and "The N.Z. Official Year Book."

PREFACE TO SECOND EDITION.

The book is arranged in two parts, and is intended for a two years' course. This edition has been revised and enlarged, and a number of new illustrations inserted. The following works have been consulted in addition to those mentioned in the preface to the first edition:—"Botany Primer," by Sir J. D. Hooker; "The N.S.W. Farmers' and Fruit-growers' Guide"; "Agricultural Botany," by Percival; "Agriculture," by R. Hedger Wallace; "Tropical Agriculture," by Nicholls; "Agriculture, Practical and Scientific," by Muir; The Reports and Leaflets of the New Zealand Department of Agriculture.

The illustrations have been culled from various publications, and the writer's indebtedness to the authors is gratefully acknowledged.

T. W. KIRK.

CONTENTS

PART I.

PART II.

NOTE ON PRACTICAL WORK.

THE conditions of rural schools are so varied that it is impossible to lay down a hard and fast rule; but in "all scientific study practical work is absolutely essential to a proper understanding of the subject." It is therefore desirable that the teacher should whenever possible conduct classes in "practical work." A great deal may be done with very simple apparatus. The various experiments suggested in this book should be actually performed. The pupils will then find the lessons not so much a matter of memory as of intelligence. The lessons will be "practical" and interesting, and the teaching will be "by the eye rather than the ear."

The pupils should be encouraged to make collections of (*a*) grasses and forage plants, (*b*) weeds, (*c*) injurious insects; and these should be exhibited in the school with notes attached, stating such particulars as the collector can supply, each ticket being signed by the collector.

If possible sufficient ground should be secured on which to test the requirements of various soils and plants by means of plots containing the same crops but different manures, or the same manure in varying quantities.

The children should be encouraged to keep Weather Calendars, showing the state of the weather each day, and Natural History Calendars, showing the observed habits of the birds, insects, and other animals, and the plants of the neighbourhood.

The officials of the Department of Agriculture are always pleased to assist by identifying specimens and giving advice concerning them, and by analysing soils and manures and advising as to their application.

Kirk's
Elementary Agriculture for Schools

PART I.

I.—WHAT IS AGRICULTURE.

The word "Agriculture" is made up of two Latin words (*ager*, a field, and *cultura*, cultivation) and means the cultivation of the soil.

Agriculture denotes the art of so cultivating the ground as to make it yield the greatest quantity and the best quality of vegetable produce (grain, grass, roots, etc.) for the least expenditure of money and labour.

From the earliest times, agriculture has been, and always will be, the most important occupation of man.

Baron von Liebig says: "There is no profession which can be compared in importance to that of agriculture, for to it belongs the production of food for man and animals; on it depends the welfare and development of the whole human race, the riches of States, and all industry, manufacturing and commercial. There is no profession in which the application of correct principles is productive of more beneficial results, or is of greater and more decided influence."

This is the opinion of a great authority. If the subject is so important, if so much depends on agriculture, surely a knowledge of its principles is a most useful possession.

Those countries that devote most attention to the teaching of agriculture, produce the best and heaviest crops, and consequently enjoy a greater amount of prosperity than those which pay less attention to the science and art of agriculture.

Now let us ascertain what a plant is, and what it requires.

A plant is a living thing, just as much as a horse, a cow, or a sheep, and just as plants constitute the food of animals, so plants in their turn require food.

II.—PARTS OF A PLANT.

Just as a boy or girl has a mouth, eyes, nose, legs, etc., so a plant has different parts that are required to perform some special work.

You will find that most flowering plants are made up of the following five parts:—

1. The **root,** or the portion underground, which supports the plant in the soil, and provides it with a portion of its food.
2. The **stem,** or the portion above ground, which forms the main body of the plant, and from which spring the leaves, etc.
3. The **leaves,** which, as we shall see, manufacture food materials, get rid of surplus water, and also play a part in the breathing of the plant.

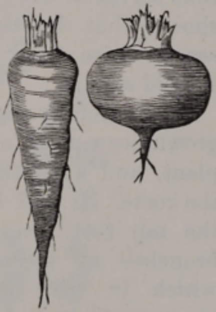
4. The **flowers,** which, after blossoming for a time die away, and leave behind
5. The **fruit** and the **seeds**, that afterwards sprout and grow into plants of the same kind.

Some plants have one or more of the parts wanting; but we need not talk about that at present.

Some plants are grown for the sake of their roots, such as carrots and turnips; others for their leaves and stems, such as grass, clover, parsley, cabbage, etc.; and others again for their fruit or seeds, such as oats, wheat, and barley. The first kind the farmer calls **root crops**; the second, **forage** or **fodder crops**; and the last kind he speaks of as **grain** or **cereal crops**.

A.—The Root.

The **root,** as we have seen, is the portion of the plant which grows down into the earth. Besides securely anchoring the plant and preventing the wind from blowing it down, the root absorbs dissolved plant food from the soil, which thus enables it to grow and flourish. Different forms of roots are met with in different plants. When a central root is found to grow thicker and more rapidly than the lateral ones, it is called a **tap root.** Examples of this kind are seen in the bean, dandelion, carrot, and turnip. If, however, the lateral roots keep pace with the central one, so that all are of much the same



Tap Root of Carrot and Turnip.

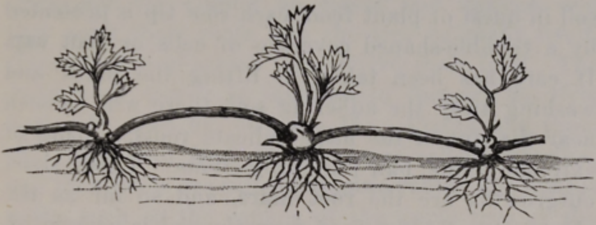
length and thickness, the plant has what is known as a **fibrous root** system. The roots of cereals and grasses are good examples of fibrous roots. Some roots, in addition to absorbing food for immediate needs, also store up a supply for future use, as in the case of biennial plants, such as carrots and turnips. It is the fleshy part of such roots that enables these plants to flower and seed during the second year. If you take up a carrot or a turnip when its seed is ripe, and cut the root, you will find it stringy and quite unfit to eat. The soft juicy part of the root has been used up in furnishing food for the plant while maturing its flowers and seed.

Fibrous Root.

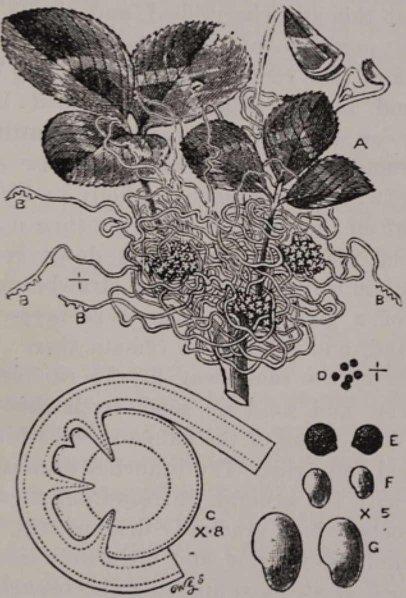
The dahlia also stores up food in its **tuberous** roots, which thus serves to nourish the new shoots that in the following season arise from the base of the old stem.

Tuberous Roots of Dahlia.

Now carefully dig up a well-grown bean plant or a cabbage plant, and wash the soil from the roots. It will be seen that the tap root gives off lateral branches or secondary roots, which in turn branch producing tertiary roots. Continued branching in this way gives rise to the extensive collection of roots, which leave very little of the neighbouring soil unexplored in their search for food. To guard against injury while pushing its way through the



Chance Roots of Strawberry Plant.



Clover Dodder, *Cuscuta Trifolii, Bab.*

A. clover plant infested with dodder.
B, suckers or haustoria of dodder.
C, section of clover stem, showing attachment of suckers of dodder.
D, dodder seed, natural side.
E, dodder seed
F, white clover seed } magnified five diameters.
G, red clover seed

soil in quest of plant food, each root tip is protected by a thimble-shaped covering of cells or **root cap.** If care has been taken in lifting the plant and washing away the adhering soil, there will be seen near the tips of the more delicate roots, a band of extremely fine hair-like projections. These short outgrowths are the **root hairs**, and so far as the absorption of plant food from the soil is concerned, are the most important parts of the root system.

Look at this strawberry bed, and notice how the stem-like portions of the plants run along the ground, and take root at intervals, sending up fresh stems and leaves. The roots formed by these runners, or suckers, are called **adventitious** or **chance roots.** Sometimes, as in the case of couch grass, or twitch, the runner is wholly under ground, instead of on the surface; but even then it is still a portion of the stem, and sends down roots, and sprouts up in leaves, just like the strawberry. If the branch of a gooseberry bush were pressed on to the ground, and allowed to remain there, it would take root in the same way as the runners of the strawberry, and send up some fresh shoots. You have probably read of the banyan tree, which grows in tropical countries. The branches do not come in contact with the ground, but send out these adventitious roots, which gradually descend, till, reaching the ground, they grow and ultimately assume the appearance of stems supporting the branches, until a single tree will often cover several acres of ground.

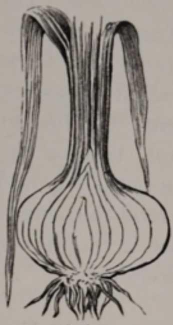
Besides these different kinds of roots, there are roots that do not grow in the ground at all. The mistletoe, for instance, grows on the oak and other trees, and the dodder on clover and lucerne, and they send their roots into the tree or plant itself, from the sap of which they derive their food. The dodder on clover is familiar to farmers in New Zealand. (See fig. on page 11). Plants like these that grow and feed on others are called parasites, and their roots are called **parasitic roots.** The fungus pests, such as the canker of the apple tree or the apple scab (see fig. on page 173), are parasites, and as they take away for themselves the food that ought to be nourishing the plant, they cause it to become sickly, and incapable of maturing properly.

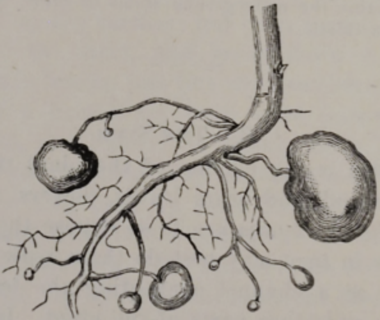
EXERCISES.

1. Dig up and examine the root systems of several garden plants, and of as many weeds as possible. Name the kind of root system of each.
2. Examine the underground stems of mint, couch grass, Californian thistle.

B.—The Stem.

The **stem** is the portion of the plant that grows above ground, and bears leaves, flowers, fruit, and seeds. Its chief uses are to so expose these organs that they in turn may best do their work; and also to serve as a channel connecting the leaves with the roots and other parts of the plant. In addition to these functions, the stem often enables a plant to propagate itself vegetatively, that is without the use of seeds. Instances of this we have already seen in the case of the strawberry and twitch, where the prostrate stems, by sending roots below and leaves above, produce new plants. In other cases the stem serves as a store place of reserve food. The bulb of the onion or lily, for example, is an underground stem in which nourishment is stored that will support the flowers and seeds in the second year of the plant's life. If you cut an onion in two, you will find that it is made up of a number of fleshy layers, which are continued upwards to form the stem and leaves of the plant, and that in the centre is a small bud. The potato tuber, too, is a swollen underground stem containing reserve food, which serves to nourish the buds or "eyes" when developing new plants in the second season.


Onion.


Potato plant, showing tubers, rootlets, and underground stem.

Trees and shrubs have hard woody erect stems, while the stems of herbs are soft and usually green.

In some plants the stem is not strong enough to support itself. **Twining plants**, like the scarlet-runner, the hop, the honeysuckle, and the convolvulus, could not grow upwards unless they had a stick, or tree, or some other upright substance to twine round. Others, like the grape vine, the green pea, and the melon are **climbers.** They do not twine round a stick like the hop; but they are furnished with little curling branches, or **tendrils**, which twist around branches, or strings, and thus support the plant as it grows. The ivy is a different kind of plant. It neither twines, nor has it tendrils to climb with, but from its stem grow numbers of adventitious roots, which penetrate the little cracks, or holes, in the surface of a tree or wall, and so keep the plant from falling.


Maize.

In other herbaceous plants, such as maize, wheat, oats, grass, etc., the stems, although green and comparatively soft, are strong enough to grow erect without support. If you look at this maize plant, you will notice that along the stem are a number of joints or swellings. These joints are called **nodes,** and the parts of stem between the joints are called **internodes.** It is from the nodes that the leaves spring. Maize, wheat, barley, oats, rye, and all other grasses grow but a single leaf from each node, and, as the plant continues to take in nourishment, joint after joint is added until it is full grown.

EXERCISE.

1. To show that the stem acts as a sap channel, cut a shoot from a geranium or other soft green plant, and place the cut end in water coloured with red ink. After a time make a cut across the stem, and note the path the liquid has taken.

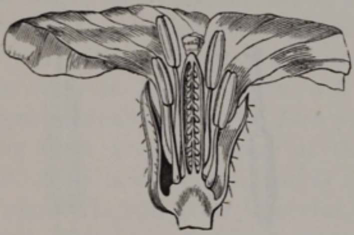
C.—The Leaves.

The **leaves** of plants grow from the nodes, or joints. At first a bud is formed, and this gradually expands into a leaf. In trees and shrubs, between the leaf and the stem you will notice another bud, and if you continue to watch it every day, you will find that it will gradually grow into a branch, from the nodes of which other leaves will be formed. The leaf itself consists of a number of layers of very tiny cells surrounding the ribs or veins that branch out from the stalk of the leaf. Both sides of the leaf are covered with a fine semi-transparent membrane full of little holes or pores. It is through these pores that the plant takes in air, and gives out the water and gases it has absorbed but which it does not need. The leaf is one of the breathing organs of the plant, and, as we shall see directly, it is also one of its feeding organs. The process of breathing in plants is not confined to the leaves, but is carried on continuously by all parts of the plant.

D.—Flowers and Fruit.

The roots, stem, and leaves of a plant are the parts that are engaged in its nourishment and growth. The **flower** has a different duty to perform. It is the organ engaged in producing the fruit, or seed, from which new plants spring. All plants grown by the farmer have flowers. Some are large and bright coloured, like those of the pea, bean, turnip, and potato. Others are small and dull-coloured, or green, like those of wheat, oats, barley, and beet. A grain of wheat is really a fruit, containing one seed: a pea-pod is a fruit containing several seeds.

Parts of a flower.—If you cannot get the flower of a turnip or cabbage, take the flower of a single wall-flower which is very much like the former, and examine it carefully. You will notice that the flower itself is produced at the end of a stalk arising from the stem, and that it consists of four distinct parts. At the base of the flower will be seen the calyx or flower cup, which consists of four leaves called sepals. The function of the calyx is to protect the internal delicate parts of the flower while in the bud. Inside

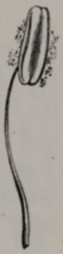


Vertical Section of wall-flower. (enlarged).

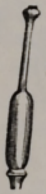
Stamens and pistil of wall-flower (enlarged).

the sepals are the coloured petals, collectively known as the corolla. It is the coloured corolla which attracts insects in search of nectar. Such visits of insects are encouraged by the plant and are, as we shall see presently, of great assistance in the production of fruit and seed.

If you now strip off the petals you will come to the parts of the flower that are directly concerned in the production of seeds. Notice these six upright stalks with oblong heads. These represent the male reproductive organ of the flower and are known as **stamens**. You will see that two of these stamens are shorter than the other four. The heads, which are called **anthers**, are little boxes filled with a yellow powder called **pollen,** the use of which we shall see directly. In the middle of the four longer stamens are the **carpels**, which collectively form the **pistil** or female reproductive organ of the flower. The carpels in the wallflower, as in the majority of flowers, are united, but in a number of flowers, as for example the buttercup, they are quite separate from each other. If you pull off the stamens you



Stamen of Lily showing pollen.



Pistil of Lily, rounded stigma at the top, slender stalk in the middle, swollen ovary at the bottom.

Section of ovary of Lily, showing seeds.

will notice that the pistil consists of a swollen portion at the base called the **ovary** or **seed box**. Surmounting this is a stalk-like portion, the **style**, terminating in a two-lobed head called the **stigma.** In the ovary are produced the **ovules**, which, under certain conditions to be referred to later, develop into seeds. It is important to remember that each carpel of a flower consists of the three portions, ovary, style, and stigma, but that when the pistil is composed of two or more carpels, these may be united to form a common ovary, style, and stigma.

In certain flowers the stigmas alone are not united, and in such cases the number of carpels composing the pistil may be determined by counting the number of divisions of the stigma. In the wall-flower we have seen a two-lobed stigma, indicating that the pistil is made up of two carpels. Where the stigma is not divided, the number of carpels can be ascertained by cutting across the ovary, and with the aid of a pocket lens, counting the number of chambers into which the ovary is divided, or in cases where the ovary consists of only one chamber, by noting the number of groups of ovules present.

If you look at an apple tree, or a gooseberry bush, when it is in blossom, you will notice that the flowers gradually die away, each one leaving behind it the little green swelling at the bottom of the pistil. This is the ovary, and is really the **fruit** of the plant. It will grow larger and more juicy day by day, and if you pluck the apple when it is ripe, and cut it in two you will find little black seeds at the centre, which will grow into apple trees if planted and looked after. The gooseberry and currant have a great many seeds scattered throughout the juicy part of the berry. In the plum, the peach, the apricot, and the cherry, on the other hand, the seed is enclosed in a hard woody shell, or **stone**. In such vegetables as the pea or bean the seed is contained in pods, as we have already seen.

EXERCISE.

Examine the flowers of gorse, broom, pea, marrow, turnip, potato, rye grass, and any others available. Note if any of the parts are absent.

III.—FERTILISATION OF FLOWERS AND FORMATION OF SEED.

Fertilisation.—If you watch a patch of clover in flower, or a bed of peas and beans, you will notice numbers of bees and other insects constantly circling about from flower to flower. They are in search of the nectar, or honey, that each flower contains; but they serve another useful purpose as well. When the bee enters the flower, it brushes against the pollen cases of the stamens. Look at this fellow; its legs and body are covered with a kind of fine yellow dust. This is the pollen. In the next flower the bee visits, some of this pollen will be brushed off on to the stigma, or top of the pistil, which is sticky, and will keep it there. In a short time the little pollen grains will send down tiny shoots, called **pollen tubes**, into the ovary; and through these tubes a fluid known as **protoplasmic** fluid, which is the source of all life, will flow on to the ovules, or eggs, contained in the ovary. This fluid **fertilises** the ovules, and enables them to grow into seeds, which will themselves grow into future plants. Unless the pollen from the stamens reaches the pistil, the seed will not be properly developed, and will not grow.

Perhaps you have heard that not so very long ago, in New Zealand, all the red clover seed had to be imported. The red clover grew and blossomed, but very little seed could be obtained from it. Why was this? Simply because there were few insects in the country with tongues long enough to reach the nectar, and thus the pollen was not carried away to other red clover flowers. So the humble bee (see fig. below) was introduced into Canterbury, and soon spread over the rest of New Zealand; and now the pollen carried by the humble bee fertilises the flowers it visits, and splendid crops of seed are obtained in different parts of the country; and instead of importing, we now export clover seed. Some of these humble bees have been exported from here to Victoria, New South Wales, and to other

HUMBLE BEES, *Bombus sp.* (Hymenoptera).

1, wood bee, *Bombus lucorum*.
2, 3, punctures in calyx of bean flower, though which nectar is withdrawn.
4, earth bee, *Bombus terrestris*.

parts of Australia at great cost, to confer a similar boon on that country.

Some birds, too, are useful in carrying pollen from flower to flower. In the spring, when the kowhai is in bloom, you will see the branches black with tuis, dipping their bills into the golden flowers for the honey they find there. If you were to catch one of these, you would find that its bill was yellow with pollen dust. Each flower it has visited has been fertilised with the pollen it has carried. Tuis, bell birds, and the other honey eaters, fertilise the flax flowers in a similar manner, so that you see that the birds, bees, and other insects are some of the means provided by Nature for carrying the pollen from flower to flower. In fact, naturalists tell us that many plants have highly-coloured flowers, a sweet smell, and stores of honey in order to attract insects to them. Thus, while the flowers are feeding the insects and birds, they, in turn, are fertilising the flowers, and so helping to secure a full harvest for the farmer.

Many plants, chiefly those that have small, dull-coloured flowers, such as wheat, oats, barley, and grass are fertilised by their own pollen, and do not require the visits of insects. The pollen drops from the long stamens on to the pistils, and fertilises the ovules in the ovaries. The wind, too, plays an important part in blowing the fine pollen dust about, until it settles on the stigma of other plants. In this way the flowers of many forest trees are fertilised.

Many plants, too, such as those that have brightly-coloured flowers, grow better seed when fertilised from other plants of the same kind by honey-gathering insects, than if they were merely fertilised by their own pollen. You can, therefore, see how useful bees and other similar insects are to the farmer.

Formation of Seed.—We have seen that after a plant has bloomed a certain time, the petals and stamens drop off and the ovary swells and becomes the fruit, which itself contains the seed. The fruit of the turnip is a kind of double pod containing two rows of seed. In the pea, bean, and other leguminous (pod-bearing) plants, the fruit is a single pod with one row of seeds. The fruit of wheat, oats, barley, and grass is generally called the *seed*, because the germ cannot be separated from the food that surrounds it without injuring or destroying it. The fruit of the potato is the potato apple, that grows on the stem when the flowers have disappeared. The seed it contains is made use of only when new varieties are desired. The production of a new variety of potato is an operation requiring several years. Ordinarily, crops of potatoes are raised by planting the tubers either whole or cut, provided each portion contains an eye.

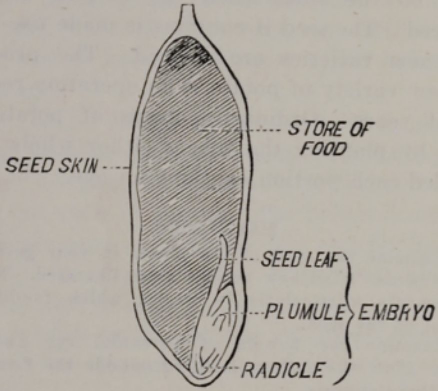
EXERCISES.

1. Examine the fruit of the plants in your garden, and also of weeds. Find how the seeds are liberated. Note any arrangements, particularly in weeds, which facilitate the dispersal of the seed.
2. Examine the flowers of perennial rye and other grasses. Note the anthers hanging outside the flower: also the feathery stigmas.

IV.—STORAGE OF FOOD IN SEEDS AND ROOTS.

The seed of wheat, oats, maize, and other plants of this kind is really the dried fruit of the plant. It contains the young plant, or **embryo,** and also a store of food to support the young plant until it is strong enough to obtain food for itself. If you split a grain of wheat in two, and put one of the parts under a lens, you will be able to see the embryo quite distinctly, as in the figure on the next page.

You will notice that surrounding the grain is a hard skin, and that the greater part of the seed is taken up with the supply of nourishment that has been stored up for the use of the young plant. The embryo itself takes up very little room, and consists of a single seed leaf or cotyledon, attached to which is the plumule and the radicle. On germination



the plumule grows up through the ground into the air, and the radicle pushes its way down into the soil.

In the French bean, the nourishment is stored up in two seed leaves or cotyledons, which, with the plumule, push themselves above ground, and support the plant until the nourishment contained in them is exhausted. The plant is then sufficiently strong to feed itself.

We have already seen that in such plants as the carrot, turnip, and parsnip, the root contains a store of nourishment that enables the plant to grow and ripen its seed in the second year of its growth.

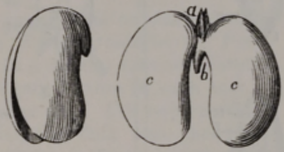
EXERCISES.

1. Soak some French bean seeds in water for several hours. Note any external markings. Remove the seed coat and observe that the seed inside can be separated into two halves. Open these out and examine with a lens the little structure you see attached to one of the halves.

2. Germinate some French bean and maize seeds in damp sawdust, and make drawings showing the different stages of germination. From one of the germinating bean seeds remove the cotyledons and note the result.

V.—GERMINATION.

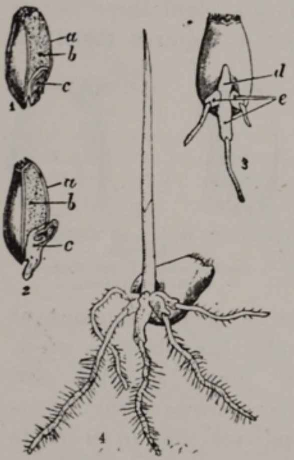
Before a seed can grow into a plant three things are necessary for it. First, it requires **moisture,** which soaks into the seed, and assists in turning the starch and albumen it contains into a sweet liquid food. The moisture softens the outer skin, and thus enables the plant to burst through it, and begin to grow. In the second place, a certain amount of **warmth** is necessary to enable the plant to grow. And thirdly, the young plant requires **air,** from which it may obtain the gases necessary to its growth. Further on we shall see that in order to reach maturity the young plant also needs **light.**



Beans with their seed leaves opening out.
a. the Plumule; *b.* the Radicle.
c. the Cotyledons.

If you soak some cress seeds in water, and place them in the sunshine on a piece of moist flannel, you will notice, that in a short time, if you keep the flannel moist, the little seeds will burst, and begin sending down little roots, and that little green leaves will be growing upwards. The plants will continue growing until they have exhausted all the nourishment that nature has provided for them in the seed. If you leave them longer than this, they will soon die, as of course there is no food in the flannel.

Now plant some peas in a garden where you have loosened the soil. If you watch the place every morning, you will find that in a short time little green sprouts are peeping above the ground. These are the first foliage leaves produced by the development of the plumule. As the stem of the plumule grows more leaves will be seen bursting out from the nodes. The cotyledons remain below the surface, and as the nourishment in them is exhausted, gradually shrivel up. If you take up some of the tiny plants you will find that the root, rootlets, and root hairs have also been growing.



Germination of wheat: 1 seed cut vertically, showing *a* the integument, *b* the albumen, *c* the embryo; 2 the same further advanced; 3 back view of grain, with *d* plumule, and *e* sheathed rootlets. 4 the same further advanced; all enlarged.

Wheat and other cereal plants develop their roots somewhat sooner than leguminous plants. In the former the embryo depends for a time almost entirely on the albumen stored up in the seed-shell. The moisture soaks into the seeds in the ground, and turns the solid floury substance into a kind of sugar sap which feeds the upward and downward shoots. Clusters of fibrous roots are at once found growing into the ground, and soon provide the plant with the food it requires. When the plumule rises above ground, it is, therefore, ready immediately to put out its leaves, and the plant is then able to support itself. The solid matter in the soil must be turned into a liquid state before it can be used by the plant. The root hairs suck up this liquid food, and when the leaves grow, they take in certain gases from the air, which the plant also requires for its subsistence.

EXERCISES.

1. In winter time place some bean seeds on damp flannel on a plate and set aside in a warm atmosphere. Place another plate of seeds, arranged in a similar manner, outside in a cold place. Note the rate of germination in each case.
2. Take three bottles of the same size. Fill one one-third full with damp sand, the second half-full, and the third three-quarters full. Now place about a dozen wheat seeds in each bottle and make it air-tight. Set aside in a warm room and record the result.
3. Study the germination of broad bean, wheat, oats, and onion seeds. Make drawings of the different stages in each case.

VI.—OUTLINES OF CHEMISTRY OF AIR AND WATER.

Air.—Here is a clear glass bottle, the bottom of which I have cut off. I remove the cork and place the bottle over an egg cup standing in a basin of water. In the egg cup is a very small piece of dry phosphorus. I now mark the level of the water in the jar with a piece of gummed paper, ignite the phosphorus, and insert the cork. The phosphorus at first burns brightly, producing dense white fumes, but the flame is soon extinguished although the phosphorus is not all burnt. The white fumes, being soluble in water, soon disappear, and you will notice that there cannot be as much air in the bottle as formerly, for the water has risen some distance up the sides. We find by measurement that the space above the gummed label now occupied by water, is approximately equal to one-fifth of the original air space in the bottle. Lower this lighted match into the bottle, and you will notice that it is also speedily extinguished. I take the match out of the bottle, and light it again, and it burns quite freely in the room. Why would it not burn in the bottle? Simply because that part of the air which enables substances to burn was used up by the burning phosphorus; or, rather, it united with the phosphorus to form the white fumes you saw. This portion of the air, forming approximately one-fifth of its bulk, is called **oxygen gas**, and the part that remains, and in which the match will not burn is called **nitrogen gas**.

Oxygen and nitrogen are the two principal gases of which the air is composed. In much smaller quantities there is another gas called **carbonic acid gas,** which helps to make up the air we breathe. Put some clear lime water into a glass, and blow the air from your lungs through it with a piece of straw, or glass tubing, and you will notice that the water soon becomes of a milky appearance. This shows that chalk has been formed. The carbonic acid breathed out from your lungs has combined with the lime in the water to form chalk. If you were to leave the clear lime water for a short time in the glass, and shake it occasionally, you would soon notice a thin white film on the top of the water. This is formed by the union of the carbonic acid gas of the air with the lime in the water, and shows that carbonic acid gas is present in atmospheric air.

Besides these three substances we have just mentioned, air also contains small quantities of **ammonia** and **nitric acid,** as well as one or two other substances.

Now let us see how **air affects the growth of plants**. We have already seen how cress seeds germinate on a piece of warm moist flannel. They use up the food stored in the seed, but when their leaves begin to grow they do something more than this. If you were to weigh the little stalk, leaves, and roots of one of the plants, you would find that they weighed a little more than the original seed. Where does the additional matter that makes up this extra weight come from? It comes from the air. As soon as the leaves are grown, they begin to take in small quantities of air through their pores. The leaves and other organs of the plant separate the carbon from the oxygen in the carbonic acid gas thus absorbed, and the carbon is used in helping to build up the stems, leaves, and other portions of the plant.

If the plant uses the carbon in building up its different parts, what becomes of the oxygen that it has also absorbed? Take some fresh green shoots of a healthy water plant and place some of them in a large clear bottle filled with spring water, so that no air is left in the bottle. Turn the mouth of the bottle downwards into a basin full of water, and leave it in the bright sunshine. Put the remainder in another bottle and treat it exactly like the first, but instead of placing in the sunlight, shut it in a cool dark cupboard. In a few hours' time you will notice that the leaves in the first bottle are covered with tiny bubbles, and that at the top of the bottle there are a great number of these bubbles. The bubbles consist simply of oxygen gas, which the plant has set free from the carbonic acid gas it had previously absorbed. If you add some lime water to the water in the bottle, you will find that it becomes slightly milky, showing that chalk has been formed from the carbonic acid gas dissolved in the water.

Plants, then, in the presence of sunlight, have the power of decomposing the carbonic acid gas of the air, and of using the carbon to build up their stems, etc., while the oxygen thus set free is returned to the air. Now open the cupboard and examine the second bottle. There are no bubbles of oxygen gas. This proves that plants must have sunlight to enable them to decompose carbonic acid, and this is necessary for their growth.

The giving off of carbonic acid gas by the green parts of plants can be observed only in the dark, because the chlorophyll, or leaf-green, decomposes carbonic acid. That plants do give off this gas may, however, readily be shown by using portions that are not green. Take a large bottle holding two quarts or more, and partly fill with the flower heads of common daisy, or, if these are not available, with peas that have previously been soaked in water.

Tightly cork, and put aside for three or four hours. Then carefully open and plunge a lighted taper within. It will be extinguished owing to the presence of carbonic acid gas.

Water.—If you leave a basin of water outside on a cold winter's night, in the morning you will probably find the top of the water covered with a thick coating of ice. Break a piece off, and hold it in your hand for a time, and the ice soon begins to melt, and to turn into water again. You know that when the kettle boils steam comes out of the spout; but if you were to boil water in a glass kettle, you would see no steam inside the kettle. When water is heated, or boiled, a portion of it is turned into an invisible gas called vapour of water; and it is this vapour of water, changed back into tiny drops of liquid, which you see coming out of the spout of the kettle, and which you call steam. Thus you see that water, at different temperatures, may have three separate appearances. When frozen it is solid, as in ice or snow; at an ordinary temperature it is liquid, as in water itself; and when heated to a certain degree it changes into an invisible gas, called vapour of water. All these, however, are merely different forms of water.

If instead of applying heat to the water we were to send a stream of electricity through it by means of two platinum wires, the water would be gradually split up into two very different gases—**oxygen** and **hydrogen**, and you would find that there would be just twice as much hydrogen as oxygen. No matter what we do, we can never get anything else except oxygen and hydrogen when we decompose water, and chemists have therefore come to the conclusion that water is composed of oxygen and hydrogen, in the proportion of one part of oxygen to two parts of hydrogen.

Elements and Compounds.—Now these gases, oxygen and hydrogen, are totally different substances. Vapour of water, although an invisible gas, was only water heated, or another form of water. Oxygen and hydrogen, on the other hand, are not water, but it is only when they are combined in the proportions already mentioned that they rush together, and form this totally different substance, water. Such a substance as water, which is totally different from its component parts, is called a **compound**. Substances like oxygen, hydrogen, or nitrogen, which cannot be reduced to any simpler form, are called **elements.** All the metals are elements, because they consist of only one kind of thing.

In atmospheric air, the oxygen, nitrogen, carbonic acid gas, etc., are simply mixed together, and do not combine to form a new substance as in the case of water, and we therefore call air a mixture. **Carbonic acid gas**, as we have seen, is composed of carbon and oxygen, and it is therefore a compound.

Now, water possesses a very important property that is extremely useful to plants, and that is, it has the power of dissolving a great many substances. We have seen that it can hold carbonic acid and oxygen in solution. You know that when lumps of sugar or salt are dropped into it they speedily disappear; but they are still in the water, as you can find out by tasting it. In the same way many solid substances that the plant requires for food are dissolved in the moisture surrounding the roots of the plant, and are absorbed by its root hairs. This is the only way in which the plant can receive food from the soil, as its tiny cells are incapable of absorbing anything solid.

VII.—COMPOSITION OF PLANTS.

Organic substances.—If any portion of the leaves, or fruit, or soft green stem of a plant be carefully examined under a microscope, it will be found to consist of a great number of closely-packed little cases, or **cells**, filled with some liquid substance. The liquid contains in solution the mineral and other food taken in by the roots of the plant from the soil, which easily passes through the thin walls of the cells, and thus it becomes **diffused** throughout the different parts of the plant.

Water is found to be the most abundant substance in fresh green plants. If you were to weigh 100 lbs. of freshly cut green meadow grass, and allow it to become thoroughly dried in the sun, you would find that the hay thus made would not weigh more than about 30 lbs. The other 70 lbs. consisted of water that has been turned into vapour in the process of drying. In the growing plant this large quantity of water passes from cell to cell until it reaches the leaves, which, being spread out to the air and sunshine, allow it to evaporate through their pores. About 90 per cent. of the root of the turnip consists of water, while a single cabbage plant has been found to evaporate more than half a pint of water in the course of a few hours.

Protoplasm is the most important substance found in all living cells of plants. It is a jelly-like material, composed of carbon, oxygen, hydrogen, nitrogen, and sulphur, and forms the life substance of the plant. It is a restless fluid, always at work forming new substances out of the liquid solutions sucked up by the roots, and passing from cell to cell building up different portions of the plant.

Cellulose is the paper-like substance which forms the outer coating of the walls of the cells. About one-half of wheat straw consists of cellulose; while paper, cotton, and linen fibre are almost wholly made up of this substance. When the plant is young and tender, the cellulose is soft and easily broken, and is readily eaten by animals; but it hardens into a strong and unpalatable fibre as the plant grows older. Cellulose is composed of carbon, oxygen, and hydrogen.

Chlorophyll.—If you carefully examine under a microscope a portion of a growing leaf, or of the green part of the stalk of a plant, you would find that floating about in the protoplasm of the cells were a number of tiny green bodies. The cell itself, as well as the protoplasm, is almost colourless, but in the green parts of plants this fluid in the sunlight undergoes a peculiar change, and part of it is broken up and becomes granular, and these granules contain the green colouring matter, chlorophyll or leaf green. Chlorophyll, aided by sunlight, brings about changes in the leaf-cells that cause the formation and distribution of starch through the plant as it is needed.

Other substances found in the cells of plants besides protoplasm and colouring matter, are starch, sugar, oils, and fats, gum, albuminoids, and some mineral matters.

Starch, a compound of carbon, hydrogen, and oxygen, is largely stored up in the cells of wheat, barley, oats, maize, rice, and other grain plants; and in those of the potato, sago, tapioca, etc. It is insoluble in cold water, but in hot water it can be readily dissolved. Starch can be very easily converted into **sugar,** which is soluble in cold water, and before the plant, therefore, can make use of the starch granules contained in its cells, the starch has first to be turned into sugar. When barley is turned into malt, the starch it contains is converted into sugar, and this is what gives malt its sweet taste. Sugar is contained in the cells of ripe fruit, in the sugar cane and maple, and in the parsnip, beet, and other plants. **Dextrine** is of the same chemical composition as starch, but it is soluble in cold water. Starch, when boiled with water for some time, forms a solution of dextrine. Dextrine forms the glazed crust of bakers' bread.

Oils and **fat** help to form the seeds of a number of plants, as in the case of linseed oil (obtained from the seeds of the flax plant), castor oil, olive oil, almond oil, colza oil, etc. Under this heading may be included the **waxes, resins,** and **turpentines,** which are obtained from a number of plants. Resins and turpentines are procured, for the most part, from trees of the pine family. Wax appears on the "bloom" of fruit, and also on the leaves and flowers of certain plants. **Gum**, also, is another substance found in plants. In some it oozes from the tree like the resin in kauri pine. It is found, also, dissolved in the cell-sap, and sometimes forms a portion of cellulose tissue.

The substances we have been mentioning are all compounds, consisting mainly of the three elements of carbon, oxygen, and hydrogen; and, as they contain no nitrogen, they are called **non-nitrogenous** substances. The **albuminoids**, however, in addition to the three elements already named, contain sulphur and a considerable proportion of nitrogen, and are known as **nitrogenous** substances. They also contain a little mineral matter. **Albumen, gluten,** and **legumin** are the most important albuminoids.

Albumen is the substance that forms the white of an egg. It is found dissolved in the juices of all plants, and forms an important part of the blood of animals. **Gluten,** the most common albuminoid, is found in the outer cells of grain, and is the sticky substance that remains in the mouth when new wheat is chewed. **Legumin** occurs in the seeds of peas, beans, and lentils, and is the vegetable form of the casein that is so important a constituent of milk and cheese.

All the substances we have just been dealing with are called **organic** substances, as they form the principal parts of living things—that is, of plants and animals that have organs for performing special work. Organic substances are made up of a combination of two or more of the following substances: —carbon, oxygen, nitrogen, and hydrogen.

Inorganic substances.—If we burn a dry plant, we shall find that all the organic or volatile substances have disappeared. About 95 per cent. goes off in the form of steam, and the other substances are changed chiefly into carbonic acid gas (carbon and oxygen), and ammonia (nitrogen and hydrogen), and are diffused through the surrounding atmosphere from which they were principally obtained. What is left behind is a small quantity, about 5 per cent. of ash, which will be found to contain substances that are found not only in plants and animals, but in minerals as well. For this reason these substances are called mineral, or **inorganic** substances. The following are the principal inorganic substances found in plants:—

Potash	Phosphoric Acid
Soda	Sulphuric Acid
Magnesia	Silica
Lime	Chlorine
Iron	

Although carbonic acid is an organic compound, it is also found in the ash of the burnt plant, combined with some of the minerals. Sometimes there is more or less than 5 per cent. of ash, the quantities varying from one to eleven, but five is considered the average.

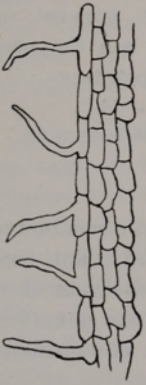
Some time ago, two tons of clover hay, obtained from an acre of land, were burnt, and the ashes obtained therefrom were examined by a chemist, who separated from each other the different substances of which the ashes were composed, and then weighed them. The following list shows the names and weights of the inorganic substances he found in the ash:—

Potash ..	87 lbs.	Sulphur ...	9 lbs.
Soda	4 „	Silica	7 „
Magnesia ..	31 „	Iron	3 „
Lime	86 „	Chlorine ..	9 „
Phosphoric Acid	25 „		

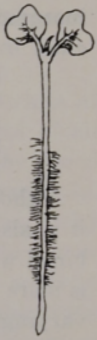
We shall have more to say about these inorganic substances later on.

VIII.—HOW PLANTS OBTAIN THEIR FOOD.

Absorption of food by the roots.—In an earlier lesson we spoke of the roots of plants being furnished with root hairs, which played a most important part in the absorption of nutrient solutions from the soil. These root hairs are only produced a short distance behind the root tip. They are short lived, lasting on an average for about five days, for as the root lengthens by growth at its tip, the older root hairs die and new ones are produced behind the growing section. Each root hair is a tube-like projection from the surface of young roots. Its walls consist of a very thin skin or membrane through which water with dissolved



Diagram, much enlarged, showing that root hairs are projections from the surface cells.

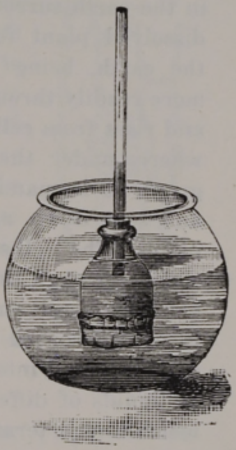


From Neve's "Botany"

Mustard seedling, showing root hairs.

plant food can readily pass from the soil to the plant.

By watching the following experiment you will see, that under certain conditions liquids can penetrate a membrane in which there are no visible openings. This pickle bottle has had the bottom cut off it. Round the lower open part I fasten this piece of bladder so as to make it quite water-tight and air-tight, and through the cork in the neck I pass this piece of glass tubing. This blue liquid which I pour into the bottle through the tube until it rises in the tube some distance above the cork, contains a solution of sulphate of copper, or blue stone, and is therefore somewhat heavier than water.

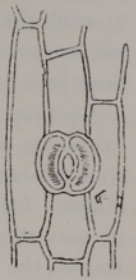


Notice that, as long as I hold the bottle of blue liquid in the air, the outside of the bladder is quite dry, none of the liquid having come through. But now when I plunge the bottle into this glass bowl, containing clear water, see what happens; the clear water in the glass becomes gradually tinged with blue, showing that the bluestone solution in the bottle is percolating through the bladder into the clear water of the bowl. The liquid is also rising in the glass tubing, showing that the water from the bowl is also passing through the bladder into the bottle, and that at a quicker rate than the bluestone solution passes into the bowl. The solution being heavier or denser than water, takes a longer time to pass through the bladder than the water does, and the latter therefore rises to the top of the bottle.

Now this is exactly what happens in the case of the sap contained in the root cells, and the moisture in the earth surrounding them. The water with its dissolved plant food, which it has obtained from the earth, being lighter than the cell-sap, passes more readily through the cell walls of the root hairs, and rises from cell to cell until it reaches the leaves, where, under the influence of sunlight and leaf-green, it is manufactured into proper plant food, and sent down again to nourish all parts of the plant. The cell-sap, being heavier, passes more slowly through the cell-walls into the soil, where it helps to dissolve more plant food, which in its turn is also absorbed by the root-hairs, and similarly manufactured into proper plant food. This passage of liquids of different density through a permeable membrane is termed **osmosis**.

Function of the leaf.—We have already seen that one function of the leaf is to turn the raw plant food, that has been absorbed by the roots and has risen from cell to cell, into proper plant food.

If you look at a portion of a leaf through a microscope, in addition to the cells we have already seen, you will notice a great number of little holes or **pores**, especially on the under side. An ordinary sized apple leaf will show more than 100,000. Each of these pores is termed a **stomate**, and is protected by thick lips or guard cells, by whose movements the size of the stomate is regulated. There are more of these pores on the under side of the leaf than on the upper, and it is through them that the plant takes in from the air some of the oxygen necessary for its breathing, and the carbon dioxide it requires to build up its food substances. During the day time, when the carbon dioxide, or carbonic acid gas, has been absorbed by the leaves, the warmth and light of the sun soon cause it to be decomposed, that is split up into its separate elements—carbon and oxygen. The oxygen thus set free is given out by the leaves, but the carbon is used by them and manufactured into plant food. The solid parts of the plant are principally composed of the carbon it has thus derived from the air. Carbon dioxide is absorbed by all the green portions exposed to the light, but chiefly by the leaves.


Fragment of epidermis with a stomate.

Now **chlorophyll**, or **leaf-green,** plays an important part in helping to change the carbon and the cell-sap that was originally taken in by the roots, into proper plant food. Chlorophyll as we have seen, forms the green colouring parts of plants, and cannot exist unless the plant is allowed to grow in the sunlight. Without it the plant cannot assimilate (make similar to itself), or digest, the plant food it has absorbed. From this you will see why light is so necessary to plants.

The plants return to the air the oxygen they have obtained from the carbon dioxide. In spite of this, however, they are continually breathing in oxygen from the air that surrounds them. This process goes on day and night, for plants can no more live without oxygen than animals can. They are also continually exhaling carbon dioxide, some of which during the daytime is absorbed again. Thus it will be seen that carbonic acid is used much more in sunlight than in dark; that at night plants still use oxygen but give off carbon dioxide, and should therefore not be kept in sleeping rooms.

Another important function of the leaf is that of excreting surplus water. We have seen that the root hairs absorb water with dissolved food substances from the soil. Some of this water is used in manufacturing plant food, but on reaching the leaves, the bulk of it is given off through the stomata in the form of water vapour. This process is known as **transpiration**. Enormous quantities of water are transpired through the stomata of the leaves of plants. It has been estimated that an acre of cabbages would transpire about three tons of water per day. It will, therefore, be seen that land carrying a crop will lose more water than bare fallowed land. If you cover the soil in a pot containing a growing plant with cardboard to prevent evaporation of soil water, and then place a glass vessel over the plant, you will see that after a time drops of water collect on the inside of the glass. This has been transpired by the leaves and condensed on the cool surface of the glass.

To sum up what we have just learned:—

Plants obtain from the air almost the whole of the carbon that forms the solid part of their stems, branches, etc., as well as most of the oxygen they require, together with a very small quantity of nitrogen. Nearly all the nitrogen required by them they obtain from the soil.

Plants obtain from water some of the oxygen and hydrogen required by the cells to manufacture starch and other organic plant food. Water also enters the root cells of the plants, carrying with it in solution the mineral or inorganic substances, which are afterwards also turned into plant food.

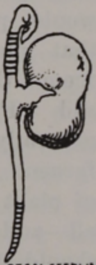
Plants derive from the soil the inorganic substances which, dissolved in water, enter the roots of the plants. It is from these inorganic substances they obtain most of the nitrogen to make the albumen, gluten, and legumin they require as plant food. These inorganic substances are *potash, soda, lime, iron oxide, magnesia, phosphoric acid, etc.,* and can be obtained only from the soil. Unless the plant can receive from the soil the mineral matter it requires, it ceases to be healthy, or to grow properly, and it may even die; and it is therefore necessary for us to learn not only what different mineral foods different plants require, but also which of these mineral foods are chiefly contained in different kinds of soil.

EXERCISES.

1. Germinate some radish seeds on damp blotting paper and examine the root hairs with a lens. Note where they are produced.

2. Find what portion of (*a*) the root, (*b*) the stem, grows most rapidly, by marking the root and stem of a bean seedling, as shown in the diagram.

3. Chip the shell from the broad end of an egg without breaking the thin membrane beneath. Also chip off a small piece of shell from the opposite end and pierce


BEAN-SEEDLING MARKED WITH INDIAN-INK

From Nave's "Botany."

the membrane. Place the egg in a bottle of water so that the unbroken membrane just dips below the surface of the water. In a few hours, the water which passes through the skin by osmosis, will force the contents of the egg out through the hole at the top.

4. Place the end of a shoot bearing several leaves in a small bottle. Place a similar shoot from which all the leaves have been removed in another bottle of the same size and containing the same amount of water. Pour a little oil on the surface of the water in each to prevent evaporation. Set both bottles in the sunlight, and after a few hours note the result.

5. Take two pots and fill with moist soil. After sowing some radish seeds in each, place one pot in the light, and the other in a dark cupboard. Several days later compare the seedlings in each.

IX.—THE SOIL.

The Soil is the name given to the fine, earthy matter found on the surface of the land, and which is often called mould, dirt, or earth. It is usually of a dark colour, and is nowhere very deep. If, in most places, you were to dig a foot or two down into the earth, you would find that the darker soil was resting on a lighter coloured substance. This would probably be clay. Now we have seen that plants derive all the food they require from the air, from water, and from the soil. Fresh air and rain water they can generally obtain without much assistance from the farmer; but different soils contain different kinds of plant food—some, indeed, contain very little at all—and it is, therefore, necessary that the farmer should study the nature of soils, and find out what they contain, if he wishes to grow good crops.

How soils are formed.—Nearly all soils have been originally formed by the gradual breaking up and wearing away of rocks. Air, water in various forms, changes of temperature, animals, and plants, are the instruments that help to turn hard rocks into soil. If you leave your open pocket knife out all night in the rain, in the morning you will find the blades covered with a multitude of red spots, or blotches. You then say that the blades have become rusty, or are covered with rust. Now, what is rust? See, when it is dry it can be rubbed off quite easily into a soft red powder. This new substance is called iron oxide or rust, and has been formed by the oxygen of the air combining with the iron. Air, however, must be moist before it will cause iron to rust.

Decay of Rocks.—Just in the same way the gases in the air, and in water, combine with portions of rocks, and eat their way into them. Take **granite**, for instance, which is made up of little **grains** of three minerals—quartz, felspar, and mica. Quartz consists almost wholly of pure silica; but the felspar and mica are made up of these substances—*potash, soda, lime, silica, magnesia, iron oxide, phosphoric acid, sulphur,* and *alumina*—and we have already seen that all these substances, except alumina, form the inorganic food of plants. Soil, therefore, formed from granite will contain all these kinds of food. When granite is exposed to the air, and to the action of water, the oxygen and carbon dioxide of the air combine with the iron oxide and potash of the felspar and mica, and change them into a soft powder, and this is easily washed out by the rain and running water, leaving little holes behind similar to those we noticed in the blades of the rusty knife. Into these little holes more oxygen and carbonic acid penetrate, forming more dust, which, with the help of the rain, causes the hard granite to crumble away more and more.

Action of frost, etc.—But this is not all. The unequal expansion and contraction of rocks produced by the changes of temperature of day and night, result in the formation of tiny cracks in the rocks. These crevices and the little tunnels formed by the oxygen and carbonic acid become filled with water. On a cold frosty night this water will freeze. Now, when water freezes, it expands with great force. If you fill a cast iron bottle, an inch thick, with water, securely fasten it, and then allow the water to freeze, the bottle will burst violently as the water is changed into ice, because the ice takes up more room than the water formerly did. In the same way the ice-covered water jug is sometimes found broken in the morning. So that when the water in the little tunnels of the granite becomes frozen, it expands with great force, and bursts the granite in many directions.

Running water, too, is constantly helping to wear away the surface of the rocks. Look at the caves on the sea-shore, and see how they have been hollowed out by the action of the waves. The same thing goes on wherever rivers are flowing, rain is falling, or tricklets are running down the mountain sides. Streams and rivers are constantly wearing away the rocks they flow over, and are continually carrying down the particles of soil and other matter they hold in suspension. Some of this soil is being continually deposited along their banks, or, when they are in flood, over the surrounding country. In this way broad and fertile valleys have been formed, covered with rich soil. In mountainous countries, too, the snow on the high slopes becomes crushed into ice by the pressure of that behind, and forms **glaciers,** or ice-rivers. These hard, solid glaciers gradually force themselves down the mountains, cutting out valleys in their course, and bearing away with them many of the rocks, and much of the soil over which they have passed. When the glacier reaches lower and warmer regions it begins to melt, and the stones, rocks, sand, and soil become thus distributed over the country far from the places from which they were brought. Soil formed in this way is called **transported** soil. When the soil has been formed from rocks in the immediate neighbourhood it is called **local** or **sedentary** soil.

Plants, too, often **help to form soil.** Place a layer of clean sand on a piece of perfectly smooth marble, and then scatter in the sand a few mustard and cress seeds. If you place the marble in a warm, moist atmosphere the seeds will soon germinate, and the plants begin to grow. In a few days' time carefully sweep the sand and the young plants away, and you will notice tiny furrows or grooves on the marble slab. These grooves have been made by the roots of the plants. Marble itself is insoluble in water, but it consists of carbonate of lime, which is made up of carbon, oxygen, and lime. The acid from the cell-sap has penetrated the walls of the root-cells, and has dissolved some of the material of the marble in order to seize upon the carbon, oxygen, and lime they require for food.

The great roots, too, of giant forest trees often penetrate the rocks in this way, or grow down through their clefts; and as they grow they force the rocks asunder, and thus render them more sensitive to the action of air, water, and frost. Even heavy paving-stones have been known to be broken or lifted by the growth of mushrooms, toadstools, and other fungi, growing under them.

Subsoil.—The earth that lies **under** the surface soil, and which you can find in most places by digging down a foot or so, is called the **subsoil.** It is usually of a lighter colour than the soil on the surface, and is heavier, denser, and harder to dig. When the surface soil has been transported from other places, as in the case of alluvial soil formed by rivers and glaciers, the subsoil is often quite different from it, both in colour and in quality. In general it is the surface soil that is turned over by the plough, and stirred by the ordinary tillage of the farm; but in some cases special kinds of ploughs are used to turn over the subsoil as well, and expose it to the action of the air. This is more particularly the case where the surface soil forms only a thin layer, and where the treading of cattle and horses, and the pressure of the plough in the furrows has hardened the subsoil into a hard, firm cake, which farmers call a **pan.** Pans thus formed do not allow the surface water to pass through them, and tend to render the surface soil marshy or boggy.

Humus is the part of the soil formed by the decay of plants and animals that have lived and died upon its surface. Consisting of organic matter, it is found in all fertile soils, and is of so dark a colour as to be sometimes almost black in appearance. When plants or animals decay on the soil, they give off ammonia, carbon dioxide, and various other gases which help to enrich the soil. In fact, the plant food, of whatever nature, that the plant has stored up during its life, returns to the soil again, and serves as food for the new plants that grow there. For instance, the rich wheat-growing soil of Manitoba is very rich in humus formed from the growth and decay of the prairie grasses for centuries and centuries. The soil of the "Black Lands" of Russia, which is often from three to twenty feet deep, and frequently produces two crops in a year, consists of decayed vegetable matter. **Boggy,** or **peaty** soil, too, contains much organic matter or humus, and is the only kind of soil not formed by the decay of rocks.

Chemical Constituents of Soil.—The soil, then, consists of a mixture of organic and inorganic substances. The vegetable matter in the organic soils is chiefly composed of carbon, oxygen, nitrogen, and hydrogen. The inorganic matter is a mixture of sand, clay, and lime, and a few other important chemical substances which exist only in small quantities. This inorganic matter has been derived by the decomposition of the rocks which form the crust of the earth.

Silica forms by far the largest constituent of all **sandy** or clay soils. It is found in the soil in the form of sand, and, when mixed with water and alumina, it forms clay. It is the substance of which flint and quartz crystals are composed, and forms the hard flinty coating upon grass and straw.

Alumina, as we have said, is also a constituent of clay. It is not itself a plant food, and is not found in the ashes of plants, but it possesses the valuable quality of combining chemically with such important plant foods as lime, potash, iron, magnesia, soda, etc., and thus prevents these substances from being easily washed out of the soil by heavy rains, or running water.

Lime is generally found in the soil in combination with carbon dioxide, and is then known as carbonate of lime. Carbonate of lime exists in many forms, such as chalk, marble, oyster shells, and limestone, all of which are composed of it. When carbonate of lime is burnt, carbon dioxide is driven off, and **quicklime** is formed. If this is mixed with water, and exposed to the air, carbon dioxide is again absorbed, and carbonate of lime formed as before.

Potash is generally found in clay soils, and is derived chiefly from the decomposition of felspar. It is called "potash" because it was first obtained by washing the ashes of plants that had been burnt in a "pot" or stove. In America and other countries large quantities are still got by burning in shallow pans the branches and waste when cutting timber, by then soaking the ashes, and evaporating the solution in shallow pans. Great quantities of potash are allowed to go to waste in clearing land in New Zealand.

Soda and **Magnesia** are found in small quantities in fertile soils. The former is found in larger quantities in soils near the sea, or in the neighbourhood of salt lakes.

Iron Oxide, which, as we have seen, is a compound of iron and oxygen, and is sometimes called rust, is found in all soils, especially in clays.

Phosphoric Acid, which contains phosphorus, hydrogen, and oxygen, is also found in all fertile soils. The form in which it is usually met with is phosphate of lime, but it is also found in combination with alumina, iron, and magnesia.

Sulphuric Acid, which is a compound of hydrogen, sulphur, and oxygen, is usually found in the soil in combination with lime or iron.

Carbonic Acid is found in the soil chiefly in combination with lime, but it also occurs combined with magnesia, potash, soda, and iron. A very small quantity is absorbed by the roots, nearly the whole of the carbon that forms the solid part of the plant being derived from the atmosphere by means of the leaves.

Nitric Acid, consisting of hydrogen, nitrogen, and oxygen, occurs in small quantities in the air, and is washed into the soil, particularly during rain. It is produced in the soil by the decay of organic matter.

Chlorine, by itself, is a greenish-yellow, choking gas. It is chiefly found in the soil in combination with soda, when it forms chloride of sodium or common salt. It also occurs combined with potash.

Organic matter, or humus, as we have seen, consists of decayed, or decaying, vegetable matter.

X.—OUTLINE OF THE CHEMISTRY OF THE ELEMENTS ESSENTIAL TO THE GROWTH OF PLANTS.

Chemical Elements.—As far as we at present know, the whole earth is composed of about eighty elements—that is, of substances that consist of only one kind of thing that cannot be reduced to a simpler form. Some of these elements can exist in a free state, so that they can be seen or handled separately, while others are found only in combination with other substances. About sixty of these simple substances are metals, such as gold, silver, copper, iron, lead, tin, etc.; while the remainder, about twenty in number, are not metals, although they are far more actively engaged in building up the earth, and the plants and animals on it, than are the metals. The following list contains the names of the eight non-metallic elements, and the six metallic elements which are of importance in agriculture:—

Non-metals.	Metals.
Oxygen	Potassium
Nitrogen	Sodium
Hydrogen	Calcium
Carbon	Magnesium
Sulphur	Aluminium
Phosphorus	Iron
Silicon	
Chlorine	

We have already seen that oxygen, nitrogen, hydrogen, and carbon are called **organic elements,** because the principal parts of the organs of plants and animals are composed of these elements or their compounds. All the others in the list are called **inorganic elements**, and although of the greatest importance in agriculture, they form only a small portion of the structure of plants and animals.

Non-metallic Elements.—**Oxygen,** when by itself, is a colourless gas essential to the life of plants and animals. More than half the weight of the earth consists of oxygen. It forms one-fifth of the total bulk of the atmosphere, and when combined with **hydrogen** forms water, about eight-ninths of water in weight being composed of oxygen. (It is important to distinguish between weight and volume, for water consists of two volumes of hydrogen to one of oxygen). Hydrogen, when free, is the lightest of all the gases. It does not, however, exist in a free state in the air. One-ninth of water in weight is composed of hydrogen. It can be combined with nitrogen to form **ammonia**, and with nitrogen and oxygen to form nitric acid. **Nitrogen** forms nearly four-fifths of the bulk of the atmosphere. Although necessary to plant life, it is not usually obtained by the plant from the air, but in combination with other elements chiefly in the form of **nitrates,** it is absorbed from the soil by the roots of the plant.

Carbon we know in its free state as charcoal, coke, or coal; it is more abundant in plants than is any of the other elements, the woody fibre of the roots, stem, etc., being principally composed of it. When wood is burned in a vessel, closed so that no oxygen can enter, the carbon is seen in the form of a solid black substance known as charcoal; but if wood, or a plant, is burned in the open air, the carbon combines with the oxygen of the atmosphere, and disappears as carbon dioxide. The weight of carbon annually removed from the atmosphere by plants is enormous. Ingle states that an acre of forest increasing at the rate of 300 cubic feet of timber per annum absorbs about 4,500 pounds of carbon each year. This equals 12,375 pounds of carbon dioxide occupying about 93,000 cubic feet, and would be contained in 310,300,000 cubic feet of air, equal to a column of air two miles high, with a base of an acre. **Sulphur** and **phosphorus** are the most important of the inorganic elements useful to plants, as they help to form the albuminous substances mentioned before, and they also, in the form of **sulphates** and **phosphates**, enter into the composition of other inorganic substances necessary to plant growth. **Silicon** combines with oxygen to form **silica**, a compound which is very abundant in all soils. Fine white sand consists of almost pure silica. Chlorine is a yellowish-green gas, possessing a very strong smell. It is not found in a free state in nature, but is obtained from salt. It is present in all plants, but especially in those that grow near the sea or salt marshes. Beet, mangel, saltbush, etc., benefit greatly by salt. Many cereals, however, cannot stand more than one or one and a half per cent. of salt in the soil.

Of the **metallic elements** given in the above list, you will notice that **iron** is the best known metal that is mentioned. It is only of use to plants when it is combined with oxygen, forming the compound, oxide of iron. The remaining metals given in the list are generally found only in combination with other substances.

Potassium is the metal found in potash. It combines readily with oxygen. If you drop a small piece of potassium into a saucer of water, it will instantly begin combining with the oxygen in the water to form caustic potash, and this with such force, that the hydrogen thus set free will take fire upon the water from the heat caused by the union of the potassium with the oxygen. In the same way, if you buy from a chemist a small piece of **magnesium** wire, and hold one end of it in the hot flame of a lamp, the metal magnesium will burn with a brilliant light. It is combining with the oxygen of the air, and is being thrown down in the form of a fine white powder called **magnesia,** which is a compound of magnesium and oxygen, and is the same substance that you buy from the chemist as a medicine. Magnesia, you know, easily dissolves in water, and can, therefore, be dissolved by the roots of the plant. **Calcium** is a silvery white metal contained in lime. Ordinary clay and alum contain the lustrous metal **aluminium,** a substance that looks something like silver; while the metal **sodium** is found in soda, and in common salt (chloride of sodium), which is a compound of the metal sodium and the gas chlorine.

We shall have something more to learn further on about the compounds from these elements which form carbonates, sulphates, nitrates, and phosphates. The chemistry of air and water has already been dealt with.*

* Pages 27-33.

XI.—BACTERIA AS THE CAUSE OF DECAY AND FERMENTATION.

If you leave a piece of meat exposed to the air, it will soon begin to decay, and emit a disagreeable smell. The decay is caused by very minute organisms, which, in feeding themselves, are breaking up the organic masses into gases and other simpler forms. The disagreeable smell is caused by the escape of these gases. When plants or animals die they soon decay, owing to the action of these tiny organisms, to which the name **bacteria** has been given. These organisms are so very small that their presence can be detected only by the highest powers of the microscope, but they are very useful to the farmer in breaking up the organic substances (which you will remember are compounds of oxygen, nitrogen, hydrogen, and carbon) into simpler chemical forms, such as water (oxygen and hydrogen), carbon dioxide (carbon and oxygen), and ammonia (nitrogen and hydrogen). If the decaying plants or animals are lying on the surface of the soil the gases formed will escape; but if they are covered over with earth, the surrounding soil will absorb these gases, or hold them in combination with it so as to form plant food. The mineral or inorganic substances of the decayed plants or animals are left in the soil in the form of carbonates, phosphates, sulphates, etc., and are available as food for future plants.

The soil itself, too, is full of life that is continually turning the organic matter it contains into plant food. Worms live on the organic matter of the soil, and, in order to absorb from it the food they require, they have to swallow large quantities of earth. Some of the food thus swallowed is left behind in the earth in the form of water, carbonic acid, ammonia, and inorganic matter, and is, therefore, available as food for the plants growing there. Besides worms and grubs, the soil also swarms with bacteria and other microscopic ferments, which help to prepare the food of plants by converting the nitrogen compounds in the soil into **nitrates**. Nitric acid is formed by the union of nitrogen, hydrogen, and oxygen. In order to serve as food for the plant, the nitric acid must combine with some soluble substance in the soil, such as lime, potash, or soda, to form a nitrate, and the chemical change thus brought about is known as **nitrification**. Nitrification is caused by certain tiny organisms or bacteria already referred to. Bacteria are so small that it frequently requires 25,000 of them to make a row one inch long. The process of nitrification is constantly going on in the soil, and although the plant is able to obtain nitrogen from either nitric acid or ammonia, it acquires far more nitrogen from nitrates than from any other source.

XII.—INFLUENCE OF LIGHT, WARMTH AND MOISTURE ON PLANT GROWTH.

In order that the nitrifying ferments, as they are called, in the soil should become sufficiently active in the preparation of plant food, it is necessary that the oxygen of the air should be able to enter the ground freely. The soil must be well tilled so that the particles of earth should not press too closely together and thus exclude the oxygen. A moderate quantity of **moisture** and **warmth** is also necessary, and the land should therefore be well drained, especially in a moist climate; as stagnant water makes the land cold, and prevents the oxygen of the atmosphere from penetrating the soil. Nitrification goes on more rapidly in the summer than in the winter months, and ceases when the freezing point is approached. A fourth necessity is that there must be some substance in the soil capable of uniting with the nitric acid to form nitrates. This substance, or **base,** is usually furnished by the lime of carbonate of lime, so that much of the nitrogen absorbed by plants is obtained from nitrate of lime (nitrate of calcium) in solution.

Air, warmth, and moisture are also essential to the growth of the plant itself, as is also **light**. We have already seen how mustard and cress seeds will germinate when placed on a piece of moist flannel in a warm room. The moisture softens the shells of the seeds and causes the starch in them to swell and turn into sugar, which is soluble in water, and forms the food of the infant plant. The radicle and the plumule are thus fed, and enabled to push their way through the burst shell. When the leaves grow, we have already learned that they inhale oxygen and carbon dioxide from the air, and change them into proper food; and that they also manufacture into proper plant food the raw cell sap charged with the inorganic and other substances that the roots have procured from the soil. For this purpose it is necessary that the leaf cells should contain leaf green, and this is present only when the plant has free access to sunlight.

XIII.—MECHANICAL ANALYSIS OF SOILS.

If you wished to find out roughly what the soil of any particular paddock was composed of, you might proceed as follows:—Take five or six shovelfuls of soil from different parts of the paddock, and mix them well together. Weigh the whole, and sift this mixture through a wire sieve so as to get rid of all the stone and rocky fragments; weigh these. Having well crushed the soil thus obtained, place, say, a pound of it in a bucket of water, and allow it to soak for some hours, or boil it until the soil is thoroughly softened. Now stir it up vigorously, and pour off the muddy discoloured water into another vessel, leaving the sand, which will sink to the bottom of the bucket. Repeat this operation until the sand is washed quite clean, and no more discoloured water can be obtained from it. In both vessels leave the water standing for some hours to settle, when the sand in the bucket, and the clay in the other vessel, will gradually sink to the bottom. Now carefully pour out the clear water from each vessel, and you will have sand in one of them and clay in the other. Weigh each separately, and you will find out how much sand and how much clay there is in every pound of soil. This is called making a **mechanical analysis** of the soil, and if carefully done will result in a table showing the mechanical composition of the soil. If a clay soil it might be as follows:—

Stones	11
Gravel	8
Coarse sand	14
Fine sand	18
Clay	49
	100

A skilful farmer can generally tell by the appearance of the soil whether it consists principally of sand or of clay.

All soils are chiefly mixtures in various proportions of **sand, clay, lime, humus,** and **stones** or rocky fragments.

Sand is composed of little grains of quartz or flint. It is pure silica, and under another form is known as rock-crystal. We have seen that quartz is one of the constituents of granite. It is so hard that it will scratch glass, and, although it can be broken up and rounded down into little glassy grains by the action of water, it cannot be reduced to a fine powder like clay can. Quartz, rock-crystal, silica, and clean sand, are really only different forms of the same substance.

Clay is a chemical compound of silica and alumina, and is that portion of the soil which, when dry, can be pounded down into a fine powder. When wet, its particles cling together so closely as to form a soft sticky substance. When there is very little sand mixed with it, it can be moulded and burnt into bricks. Fine white clay is also used for making china and other pottery.

Humus and **lime** have been described on pages 48 and 50.

XIV.—CLASSIFICATION OF SOILS.

Soils are classified according to the proportions in which they contain sand and clay. What is called a **sandy soil** consists of more than three-quarters sand. If more than three-quarters of a soil is composed of clay it is called a **clay soil**. A mixture of about half sand and half clay is known as a **loam**. If there is rather more sand than clay in it, it is called a **sandy loam**; while if rather more than half of it consists of clay, it is called a **clay loam**. In addition to sand and clay, rich soils also contain lime and vegetable matter. If a soil contains nearly a quarter of its weight of lime, it is called a **marl soil**. If the remainder is mostly sand, the soil is known as a **sandy marl**; if it is mostly clay it is called a **clay marl**. Soils which contain more than a quarter of their weight of lime are known as **calcareous soils** (L. *calc-* = chalk). **Peaty soils** are those that contain twenty-five per cent., or more, of vegetable matter, or humus.

The following table shows roughly the constituents of each kind of soil, although it must be remembered that the proportions vary considerably in different soils, and that the figures given only show the average amount of each :—

SANDY SOILS.	LOAM SOILS.	CLAY SOILS.
Sand : $\frac{3}{4}$ to all sand	**Sandy loam** : $\frac{2}{3}$ sand, $\frac{1}{3}$ clay.	**Clay** : $\frac{3}{4}$ to all clay
	Loam : $\frac{1}{2}$ sand, $\frac{1}{2}$ clay	
Sandy marl : $\frac{3}{4}$ sand, $\frac{1}{4}$ lime	**Clay loam** : $\frac{2}{3}$ clay, $\frac{1}{3}$ sand	**Clay marl** : $\frac{3}{4}$ clay, $\frac{1}{4}$ lime

Calcareous soil: One-quarter to all lime.
Peaty soils: One-quarter to all humus.
Gravelly soils contain a large number of small stones.
Stony soils contain a large number of somewhat large stones.

XV.—INFLUENCE OF MECHANICAL CONDITIONS OF SOIL ON THEIR FERTILITY.

Light and heavy soils.—Soils are also called **light** or **heavy,** according to whether they are easy or hard to work. As regards weight, a sandy soil is much heavier than a clay soil, but it is called a light soil by the farmer because it is so much easier to prepare it for cultivation than a clay soil. Water causes the particles of clay to stick together closely, while it passes easily through sand. You can easily take up a handful of sand from the sea beach, but it is not nearly so easy to take a handful of clay from a clay bank. A clay soil is therefore called a heavy soil.

Take three flower pots and fill one with stones, the second with sand, and the third with fine clay. Now pour the same quantity of water into each and note the result. It will run through No. 1 at once, No. 2 not so quickly, and No. 3 more slowly still. It will be seen that the finer the particles of the substance, the longer will it hold water. The explanation is that the small particles of the clay lie so much closer than the stones, that the spaces between them are too small for the water to run through quickly. Thus, though the number of spaces is greater, their size is much less, consequently the clay is able to hold water better than any other soil, but the particles may become so closely pressed together that no water can escape. This means the accumulation of stale water, which is death to most plants.

Absorption of moisture from the atmosphere.—You have, perhaps, noticed that, if common salt be thoroughly dried in the oven, and then be left in the salt cellar untouched for some days, it becomes quite moist. In a school in South Canterbury some of the bricks were made with sea water. The consequence is that before it rains one of the walls frequently becomes of a whitish colour, the salt in the bricks making each of them a kind of weather glass. In the same way different soils have the power of absorbing some of the moisture that is constantly floating about in the atmosphere. The different kinds of soil have been tested, and it has been clearly shown that sandy soils will absorb very little moisture from the atmosphere in fine weather; that clay soils will absorb a great deal; but that humus will absorb more than twice as much as clay will. Sandy soils, then, we have again seen, are dry, and should be mixed with clay and vegetable matter to make them more fertile. The tendency of a pure clay soil, on the other hand, is to be too moist, and therefore to be cold for the plants, and they, as we know, require warmth; the soil should therefore be mixed with sand, lime, etc. Soils which can retain little water will evaporate water most, and those which can retain it best will evaporate least.

Capillarity.—We have seen that the weight of water causes it to sink, but it will also under certain conditions "spread upwards by a power called capillary attraction, which means the drawing power of hair-like tubes.''* If you dip the bottom of a stick of chalk into ink, you will notice that the black ink will rise some distance up the chalk above the surface of the ink. If a lump of sugar be dipped into your tea, the tea will rise between the particles of the sugar. Again, if you place two glass tubes of different sizes upright in a vessel of water, the water will rise higher in the narrower tube than in the broader one. This power, possessed by small hollow, or hair-like bodies, is called **capillarity** (L. *capillus* = a hair). All porous bodies possess it. As the pores of clay soils are smaller, but more numerous, than those of sandy soils, underground water will rise much higher, but more slowly in the former than in the latter.

Absorption of heat from the sun.—If you place your hand on a stone in the middle of a hot summer's day, you will find, perhaps that it is hot enough to burn you. The dry sand on a sunny beach, too, will sometimes feel very hot when you are running on it barefoot, and it will be quite a treat to walk for a change on the cool turf.

Experiments have shown that† :—

1. The more sand a soil contains the more rapidly will it absorb heat, and the longer will it retain its heat. Hence sandy and gravelly soils are the warmest.
2. Dark coloured soils absorb more heat than light ones. Hence peat soils are warmer than chalky ones.

* Wallace. † "Webb's Agriculture."

3. The more water a soil contains, the more slowly will it rise in temperature, and the more rapidly will it part with its heat (owing to heat being absorbed during evaporation).

4. The amount of heat received by the soil will be affected by its inclination or aspect.

In New Zealand the sun is always to the north of us, and therefore land facing the north, that is, having a northerly aspect, will receive more of the sun's rays than will other land.

Subsoil.—It is of importance that land should have a suitable sub-soil. In alluvial land (soils formed from the deposits of rivers) the sub-soil is frequently of the same nature as the soil. A stony or gravelly sub-soil is not generally considered a good one, as it is so porous that the water it should retain readily escapes, and sufficient moisture is not provided for the deeper roots. A sandy soil resting on a clay sub-soil is reckoned a good arrangement, as the clay prevents the rapid escape of the water and the plant food it holds in solution, and admits of more capillarity.

EXERCISES.

1. Take three lamp chimneys, or vinegar bottles with the ends cut off, and tie a piece of cloth round the narrow end of each. Fill one with coarse dry sand, the second with dry clay, and the third with dry soil. Place the apparatus in a stand and allow the cloth covered ends to dip into water contained in a vessel beneath them. Notice the height to which water rises in each.

2. Arrange apparatus as in Exercise 1. Fill each vessel to within three inches of the top with the material to be tested. No. 1 with coarse sand, No. 2 with fine clay, No. 3

with well-rotted vegetable matter. Now pour the same quantity of water on the top of the soil in each vessel, and collect the water which drains through in bottles placed below. As the water ceases to drip from each soil material, measure the amount which has drained through and estimate the amount that the soil has held. By comparing these measurements find which material holds most water.

3. Place a little benzine on your hand and allow it to evaporate. You will notice that your hand feels colder. This is because some of the warmth of your hand has been withdrawn to evaporate the benzine. In the same way evaporation of water cools the soil.

XVI.—PLANT FOOD IN THE SOIL, AVAILABLE AND DORMANT.

We have already seen that the plant food in the soil must be capable of being dissolved in water before it can be absorbed by the roots of the plant, and be manufactured by it into proper plant food. Those parts of the soil which can be dissolved in rain water, and which are, therefore, at once available as plant food, are known as the **available,** or **active** constituents of the soil; whilst those which are not immediately ready for use, but which require to undergo a chemical change before they are soluble in water, are called the **dormant** (sleeping, L. *dormio* = I sleep), or **unavailable** constituents.

If some soil be soaked for a time in a vessel of water, a chemist would be able to show that some of the substances it contained had been dissolved into the water. These substances would be at once available as plant food; and they form the active constituents of the soil in the vessel. If the water be poured off, and the soil be now thoroughly dried, and again soaked in fresh water, it will be found that no new substances have soaked out. Let the same soil be now thoroughly stirred up, and be exposed to the action of the sun, rain, wind, and frost for some considerable time. If it then be soaked in water again, a chemist would find that the water contained some new substances. These new substances would represent the plant food that had been **dormant** in the soil, but which had been made **available** for use by the action of the weather. The oxygen and carbonic acid of the air, and the crumbling of the soil, caused by the frost, have made the dormant constituents active, and available as plant food. This shows how necessary it is that the soil should be thoroughly cultivated. The farmer, by ploughing up the soil, and leaving it exposed during the winter, enables the action of the weather to have full force. The frost and rain crumble away the clods, so that the air can freely penetrate the soil, and the rain water flow freely through it. The frost tends to kill the weeds and other plant roots, and their decayed substances go to enrich the soil. The oxygen and carbonic acid, too, of the air, acting chemically on the dormant constituents, change them into plant food, available for the next crop.

XVII.—TILLAGE.

Objects to be gained by Tillage.—Tillage means the cultivation of the soil by such processes as **ploughing**, **stirring**, **crushing**, **harrowing**, and **draining** it. These processes are undertaken for the following reasons:—

1. The soil is broken up so as to enable the oxygen and carbon dioxide of the air to turn the dormant plant food it contains, into plant food soluble in water, thus making it available for the plant's use.
2. When the soil has been loosened, the air and water have freer access to the roots of the plants, and the roots themselves are able more easily to penetrate into the earth in search of plant food.
3. When the ground is turned up by the plough, and left to the action of the weather for some time, the frost tends to pulverise the soil, thus producing a good tilth for the germination of seeds.
4. During the cultivation of the soil any organic matter on the surface is buried, and weeds and many insect pests are destroyed.

Mechanical and Chemical Changes.—When a piece of land is dug up, or ploughed, the soil is turned over, and thus a fresh part of it is exposed to the atmosphere. The soil becomes looser in texture, and the air, rain, and frost entering it break up the clods into smaller fragments still. If the piece of land is small, such as a vegetable or flower garden, a **spade** or **fork** may be employed. If the garden be properly dug, the land will be likely to produce better flowers and vegetables than if it had been merely ploughed and harrowed.

For large pieces of land, however, this process is too slow and costly, and therefore **ploughing** is resorted to. The plough turns over the soil in ridges, thus exposing long furrows to the action of the atmosphere. In this country the ploughs are generally drawn by horses, and are usually either **two** or **three furrow ploughs**. When land has been regularly ploughed for years, however, the continual tramping of the horses, tends to harden the subsoil into a **pan**. It is, therefore, often found necessary to use a **subsoil plough**, which goes deeper than the ordinary plough, breaking up the hard bottom soil. This kind of plough, however, requires so much more force to work it that steam is sometimes employed to draw it, instead of horses.

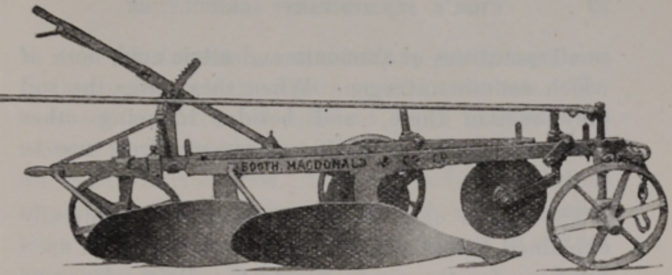
Harrows are used for breaking up the ridges formed by the plough, and the larger clods. They also collect the weeds, and cover the seed over when it is sown. The **roller** is used for crushing the clods, and also after harrowing, for pressing the soil round the seeds or young plants, so as to keep them moist, and enable their tiny roots to penetrate the soil. This operation should not be performed during the winter months. A special kind of roller, called a **clod crusher**, is also in frequent use. The **grubber** and the **horse hoe** are used for the purpose of clearing the land of weeds, and stirring the earth round the roots of the growing plants.

All these operations of digging, ploughing, harrowing, etc., do not of themselves produce any **chemical changes** in the soil. They merely prepare the soil in a way that enables chemical changes to take place. As we have seen, when the soil is loosened or turned over, more of the under surface is exposed to the action of the gases of the air than was formerly the case. When fresh soil is exposed to the air, portions of it combine with the **oxygen** of the atmosphere to form other compounds which are readily soluble in water, and, as a consequence, when they are formed, the soil tends to crumble into finer particles. Some poisonous matter, too, under the influence of oxygen, undergoes a change and forms a valuable portion of plant food. For instance, in some clays there is an oxide of iron known as **ferrous oxide,** which contains only a small proportion of oxygen, and is itself injurious to plants. If exposed to the air, this ferrous oxide absorbs more oxygen, and becomes changed into the common red oxide of iron which chemists call **ferric oxide**. This, as we have seen, is a very valuable food for plants.

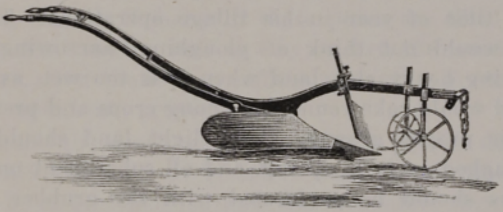
The **carbonic acid gas** of the atmosphere, too, acts in various ways on the newly turned soil. Like oxygen, it has the power of combining with various substances—such as quicklime, soda, potash, etc.—when it forms carbonates of these substances. These, being easily soluble in water, are readily absorbed as food by the delicate rootlets and root hairs of the plants.

Nitrification* in the soil, too, is increased by its exposure to the air. We have already seen that nitrogen is necessary to the plant, but that it can be absorbed only by the roots, and cannot be obtained directly from the air (except in the case of the leguminous plants). The atmosphere contains

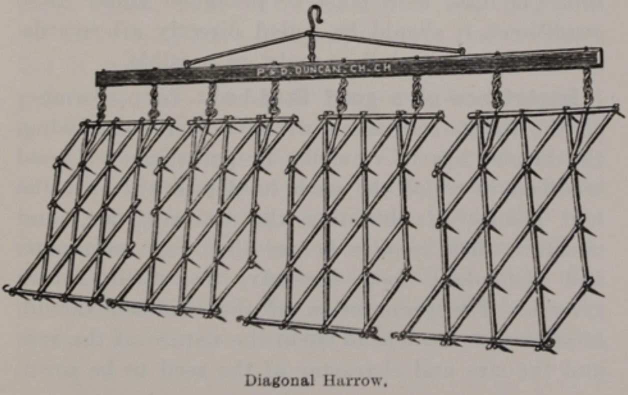
*For the action of bacteria, etc., in the soil, and their influence in the formation of nitrates see pages 56 and 57.



Double Furrow Plough.



Single Furrow Plough.



Diagonal Harrow.

small quantities of **ammonia** and **nitric acid,** both of which contain nitrogen. When they enter the soil they remain there, and besides inducing other chemical changes, are themselves of direct use to the plant.

The action of frost and rain has been already explained. Both tend to crumble the soil, and open passages for the air to penetrate. Rain, also, acts chemically as well as mechanically, helping to form hydrates with many minerals in the soil. The farmer must pay attention both to the weather and the time of year in his tillage operations. Thus, he would not think of ploughing, harrowing, or sowing heavy clay land when it is too wet, as the land would cake round the young crops and prevent their proper growth. Very light land should be ploughed early in spring, and all subsequent operations should be performed with the grubber and harrow. If turned over again in dry, warm weather it would lose too much of its moisture by evaporation. If light land must be ploughed under these conditions, it should be rolled directly afterwards, so as to keep the soil as moist as possible.

Importance of a good Seed-bed.—In performing all the tillage operations we have been considering, the farmer has in view the preparation of a good seed-bed, in which the seeds he plants will have the best chance of obtaining the warmth, air, and moisture they require before they can germinate, and the plant food necessary for their future growth. The preparation of the seed-bed should, to some extent, depend upon the nature of the soil, and the size and character of the seed to be sown.

In any soil, however, and with any seed, there are certain points which require special attention. The loose soil should be of sufficient depth to enable the roots of the growing plant to penetrate readily downwards in search of food. It should be firm enough to retain as much moisture and warmth as will enable the seed to germinate properly, but it must be neither too porous nor too firm.

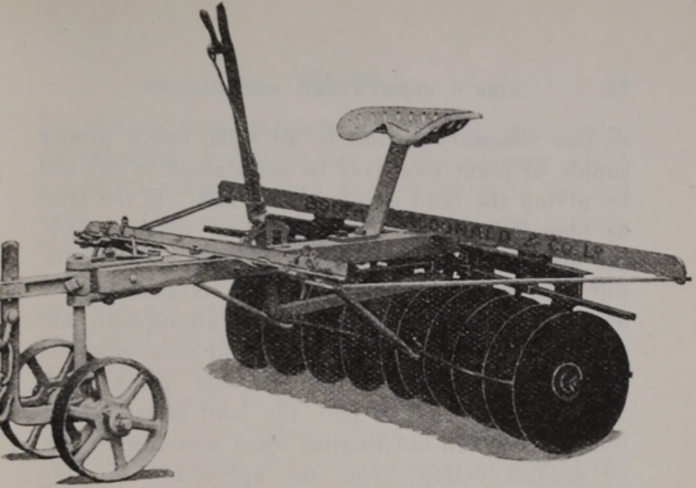
As to the seed itself, it must be **clean.** The seed of a plant is full of little pores through which the moisture of the soil penetrates. If the seed is not clean, that is, if many of these pores are filled up with other matter, such as clay or dirt, the moisture cannot enter the seed in sufficient quantity to enable it to germinate properly.

Again, the seed must be sown at a proper **depth** beneath the soil. If it is too near the surface, it will be at one time too wet, and at another time too dry, according to the weather, and consequently will not have that steady growth which a healthy plant should have. If it is buried too deeply in the soil, it may have sufficient warmth and moisture, but it will not be able to obtain enough air to supply it with the oxygen it requires. Even if it is planted at a proper depth, the soil around it may be either too loose or too close. It is a good practice to roll and then harrow the autumn sown wheat crops early in spring, provided always that the surface is dry. By this means the moisture will be retained in the soil. As a rule it will be found that the smaller the seed, the nearer it should be to the surface, and the finer should be the soil surrounding it.

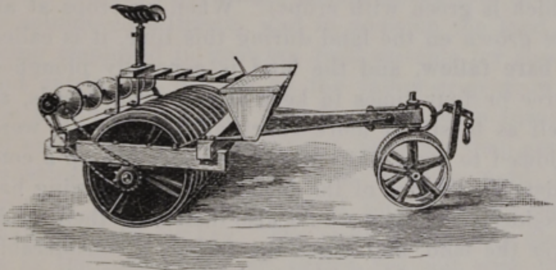
The nature of a seed-bed, too, sometimes depends upon the nature of the preceding crop. The roots of clover, for instance, penetrate to a considerable distance through the sub-soil, and tend to loosen it. They are also stored with considerable quantities of valuable food which they have obtained from the sub-soil, so that when the land is ploughed, and these roots decay, they leave behind them in the soil much valuable plant food for the next crop. Besides loosening the sub-soil, the roots of clover tend to bind together and render firmer the surface soil. A clover paddock, therefore, when ploughed and prepared, forms an excellent seed-bed for wheat. Wheat requires a firm support around its young roots, and the sub-soil should be sufficiently loose to enable them to penetrate it freely. This preparation has been already made by the previous clover crop, the decayed roots of which have also enriched the soil with valuable plant food, especially with the important element nitrogen, which is particularly beneficial to wheat.

XVIII.—TILLAGE—(*Continued*).

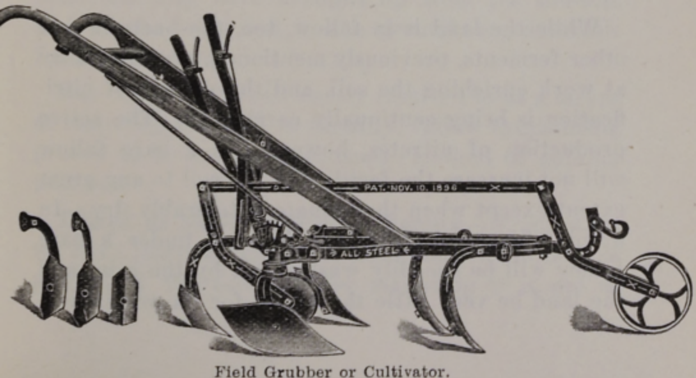
Fallows.—Plants gradually use up the plant food that is in the soil, and unless a fresh supply is furnished, the land will soon cease to produce flourishing crops. There are two principal ways in which a proper supply of plant food may be kept up. One is to place upon the land, and to work into it, such **manures** as contain those ingredients which are deficient in the soil, and which the crops require. This process is at some time or other more



Disc Harrow.



Swivel Wheel Roller.



Field Grubber or Cultivator.

or less necessary to nearly all soils, but a proper supply of plant food may be maintained in the soil by giving the land an occasional **rest**. If the land be ploughed up and left for a year without crop, the air, rain, and frost break up and crumble the soil into finer particles, and the oxygen, carbon dioxide, and other gases of the atmosphere are constantly at work enriching it and converting its dormant constituents into available plant food. During this period of rest, the land is said to be lying **fallow** (an old English word meaning yellow, or reddish yellow, from the appearance of the ground that is left bare, as distinguished from that which is green with crops). When no crops at all are grown on the land during this time, it is called a **bare fallow**, and the land is generally ploughed three or four times to keep it free from weeds, as well as to stir it more effectually. If weeds were allowed to grow, they would not only use up a considerable amount of the food that the fallowing has produced, but they would also distribute their seeds over the land, and cause the farmer a considerable amount of trouble in the future to destroy them.

While the land is in fallow, too, the bacteria and other ferments, previously mentioned, are constantly at work enriching the soil, and the process of nitrification is being continually carried on. The active production of nitrates, however, in a bare fallow will not increase the fertility of the soil to any great extent except when the climate is tolerably dry. In a wet climate the nitrogen in land under a bare fallow will be speedily washed out by the rain, and the land be very little the better for its production.

To remedy this, farmers grow what are called **fallow crops**, and these use up the nitrogen which would be otherwise lost, and return it to the soil again. The principal fallow crops are turnips, mangel-wurzels, and potatoes, as well as beet-root, cabbages, kohl-rabi. In some soils, carrots and parsnips are grown as fallow crops. Any of these vegetables can be planted in rows wide apart, so as to allow room for the grubber, the horse-hoe, and even the plough to stir the land in the intervals, and free it from weeds. Thus, all the time these crops are growing, the land is being exposed to the atmosphere; the dormant or insoluble constituents of the soil are increasingly being turned into active or soluble constituents, and in addition the land is being employed in growing food suitable for sheep and cattle. If turnips be the fallow-crop grown, the manuring the land gets from the sheep turned on to it to fatten on the turnips, far more than compensates it for the plant food already used in growing the crop, especially if the sheep get oat-chaff, oil cake, or hay. The roots of the crop also, as in the case of clover, enrich the soil with the materials they have brought up from the sub-soil, and which, being left in the ground, are available for a future crop.

Bare fallows are now rarely resorted to as a means of restoring the land to fertility, fallow crops being proved to be a more economical method of gaining that end.

Tillage as partly replacing manure.—From what we have learned, then, it is clear that, when land is well tilled, the necessity for manuring it is not so great. If properly ploughed and harrowed, land will continue in a state of fertility for a considerable time, if a suitable system of rotation of crops is pursued, thus avoiding the necessity for a naked fallow. Suitable cultivation enables the natural agents, oxygen, carbonic acid, rain, frost, etc., as well as the bacteria, ferments, and earthworms in the soil, to be constantly furnishing it with fresh supplies of plant food. Accordingly, the better the land is cultivated, the less manure will it require; the more it is ploughed, harrowed, and grubbed, the more it will preserve its fertility. Land cannot, however, be continually cropped without being manured if the crops are to be healthy and abundant; and in a great many soils tillage of itself is not sufficient, as too long a time and too much expense would be required in providing plant food sufficient for succeeding crops. Light sandy soils, especially, soon become exhausted unless provided with a certain amount of manure.

XIX.—WATER IN THE SOIL.

Water is constantly flowing under ground in all directions. The rain that falls from the clouds enters the soil and flows through it until it joins a river, lake, or sea. The water of a river, too, penetrates each bank, and moistens the soil on either side for a considerable distance. You have noticed, perhaps, on some of our shingle rivers a perfectly dry river-bed for a mile or two. Go some distance up the river-bed, and the river will be flowing. Go some distance towards the mouth, and the river will be again flowing. What has become of the water in the meantime that this long intervening stretch of river-bed has been left dry? The river has simply sunk into the shingle, and for a mile or two has flowed underground by various channels.

Now, this underground flowing of water is very useful to plants. We have already seen that soils are porous, and that porous bodies possess the property of **capillarity,** that is, the power of sucking up to a certain height the liquids with which they come in contact. It is by capillarity that a sufficiency of moisture is kept in the surface soil. Proper tillage, entailing as it does an occasional stirring of the soil, increases its capillarity. We can see how necessary such a process is when we consider that growing plants are continually draining the surface soil of its moisture. This drainage is of course greater in dry weather than at any other time. Cropped land gives up more moisture than it would if left under bare fallow, the moisture being transpired rapidly through the leaves of the plant as pure vapour of water. The substances that were dissolved in the water when it entered the roots of the plant remain behind to help to nourish it. Sometimes the moisture is transpired through the leaves more rapidly than the roots take up fresh supplies from the soil. If you look at a paddock of turnips on a hot sunny afternoon after a long spell of dry weather, you will, perhaps, notice that the leaves appear limp and drooping. This means that the leaves have been exuding watery vapour faster than the roots have been absorbing moisture from the soil. In the evening, when the sun has gone down, the leaves are not so active in transpiring water, and they will again become crisp.

The rain water that falls upon the soil sinks gradually down through it and forms a store, that by the action of capillarity will tend to rise through the soil again and keep the surface moist. The rising of water through the soil has also the effect of keeping the soluble plant food around the roots of the plants, and in a form in which it can be used by them. If the surface of the soil be occasionally stirred, so that its pores are disturbed for a little distance, the evaporation from the soil itself is not so rapid, and the surface tends to remain moist. This is what gardeners call an earth mulch. The operations of hoeing and raking, therefore, can be of great benefit to the plants especially in hot weather, by keeping the surface soil moist, as well as by enabling the air to penetrate more freely to the roots. This is what the American farmer calls surface irrigation.

XX.—DRAINAGE.

When land contains too much moisture it requires to be drained. Stagnant water on land prevents the air from penetrating it, and the oxygen and carbon dioxide of the atmosphere cannot, therefore, change the dormant plant food into a soluble state. Standing water also makes the land cold by preventing warm air from entering the soil. The soil when wet takes longer to heat than when it is dry. All the time water is exposed to the air it is evaporating. In doing so it is using up some of the heat in the soil and in the surrounding air, and thus both are made colder. You know that when the kettle once boils, the water it contains does not get any hotter, but the heat of the fire is employed in turning the water into vapour. The sun's rays, and the warmth of the soil, are used in the same way in turning the water in or on the soil into vapour. If you put some water on the palm of your hand, it will soon disappear. It has been turned into vapour, and you will have a feeling of coldness in your hand, as some of its heat has been used in turning the water into vapour. Stagnant water, too, helps to produce poisonous organic acids in the soil, and is, therefore, very unwholesome to plants. To be of service to plants, water should move freely through the soil. When this is the case, it makes passages through which the air enters, and besides allowing the gases of the atmosphere to form oxides, carbonates, and nitrates, flowing water itself bears along to the roots the plant food it has dissolved during its journey.

Some soils, owing to their position, others owing to their nature, become too moist unless a proper system of drainage is employed. The surface water from the slopes of a range of hills or mountains flows on to the adjacent lands, and, if the land is a stiff clay, or the rainfall is excessive, the soil often becomes soaked from top to bottom. A common plan is to have an open drain running between the hills and the land to be cultivated; this will receive and cut off the surface water from the higher slopes, and thus tend to keep the soil comparatively dry. In clay soils it is often fond necessary to have parallel drains running through the land and emptying themselves into a main drain, which carries off the water so collected, and conveys it into a river or some other natural watercourse. In this system of **artificial drainage** the drains may be either open ones, or drain pipes may be used to carry off the surplus water. In the latter case, the drain pipes are placed end to end, with a gentle inclination in the direction of the natural slope of the land, and then covered over with soil to admit of the land being ploughed. Sometimes, instead of pipes, three logs are placed thus, o
oo or loose stones are placed in the trenches, which should be covered with sods with the grass side down, or faggots, to prevent the soil from being washed between the stones, and thus prevent the water from flowing freely through them. An implement called a drain plough, drawn by six or eight horses, is frequently used in Otago and Southland. It has a strong blade made of steel, with a plug of metal attached to the bottom resembling a rifle bullet. This is drawn through the subsoil leaving a drain behind it through which the surplus water finds its way to the outfall drain. This system of draining costs very little money in comparison with the methods already described, and is found to be very effective in soils with clay sub-soils. Surface drainage is often effected by making ordinary plough furrows at certain intervals, these leading to a drain.

We have seen, then, that **land is drained** for the purpose of allowing the free passage through it of water and air.

Some land has a **natural drainage.** Such are sandy soils, land with a good slope, or land where the sub-soil is sufficiently porous to carry off the surplus surface water.

In some lands there is a danger of **over-drainage.** When water passes too freely through a soil in a district where the climate is moist, much of the plant food may be washed out of the soil, and thus cause great injury to the crops grown on it. This is especially the case with the nitrates—nitrate of soda and nitrate of lime—which form so valuable a portion of plant food, but which the soil has no power of retaining. These are readily soluble in water, and, consequently, are readily carried in an invisible form through a too open soil, or an over-drained piece of land, and are thus lost to the plants. In summer, nitrates are more abundantly produced in the soil than at any other period; but, as there is not much drainage during that season, they accumulate in the surface soil. As the winter advances, however, more drainage takes place, and the washing out of the nitrates **begins,** the process increasing as the rainfall becomes greater. "Shallow soils are most quickly washed out, whilst deep soils, possessing a larger mass for the diffusion of the nitrates, part with them more slowly and uniformly." In clay soils this washing out of the plant food they contain does not take place to nearly the same extent; as the clay, being closer in texture, retains greater quantities of both the nitrates and **phosphates.**

Advantages of Draining.—The general advantages of draining may then be summarised as follows:—

1. Drainage makes the land warmer, and therefore the harvest will be earlier, more abundant, and of a better quality, as a cold unwholesome soil tends to produce blights, mildews, rusts, and many other diseases amongst plants.
2. A greater variety of crops can be grown; as turnips, mangels, and other root crops will not come to perfection in wet land.
3. Dry land is easier and less expensive to work than wet land.
4. Manure is more beneficial on properly drained land, as it is not so readily washed out of the soil, and the plant food it contains is brought to the roots of the plants by the flowing water.
5. In dry land the health of the live stock is maintained, as wet land tends to produce footrot, liver fluke, and other diseases in sheep.
6. The condition of the soil is improved by drainage, the water flowing through it makes passages through which the air can follow. The oxygen and carbon dioxide of the atmosphere can therefore operate on the ingredients of the soil to form oxides and carbonates, thus changing dormant food into available plant food. Nitric acid and ammonia also thus get washed into the soil,

and percolating through it form nitrates. When air cannot penetrate freely, the land becomes sour by the formation of organic acids poisonous to plants.

7. The alternate moistening and drying of the land, caused by drainage, improves its mechanical condition by making it crumble more easily, and thus become more easily workable, and more readily susceptible to the beneficial influences of the weather.
8. Land that is properly drained retains a certain amount of moisture to a greater depth than undrained land, and gives it up gradually, thus feeding the growing plants more regularly.

Irrigation.—Some soils instead of requiring drainage require at times more water than they naturally receive. This occurs when the soil is light, the climate is dry, and the summer is warm. In much of the land on the Canterbury Plains, for instance, during a dry season the grass speedily gets burnt up, the ears of the grain crops do not fill out properly, and various blights attack the green crops. The land is light, and in some seasons there is not sufficient rainfall to keep the surface soil moist, in spite of the many large shingle rivers that flow over the Plains. In some districts, therefore, water-races have been constructed to bring the water on to the land. This artificial system of watering land is called **irrigation**. But even where irrigation is employed drainage is also necessary; for it must be remembered that the principal object is to make water **flow through** the soil, that is, to convert stagnant water (which contains no oxygen) into flowing water, as the latter not only contains oxygen, but also opens up the pores of the land, and thus enables the air to penetrate it.

When water is brought on to land by means of water-races, the surface of the land is sometimes allowed to be flooded, and the flood water then flows away, either by natural or by artificial drainage. In this way a sufficiency of flowing water is obtained, and the crops are benefited by the increased moisture, as well as by the fresh plant food manufactured by the gases of the air and carried to their roots by the flowing water.

XXI.—CULTIVATION OF LIGHT AND OF HEAVY SOILS.

We have seen that soils that are easily worked, such as sandy soils, are called **light** soils; but those that are not so easily worked, such as clay soils, are known as **heavy** soils.

In cultivating light soils the farmer's object is to make the particles cohere more closely, and thus increase the capillarity of the soil. He therefore endeavours to consolidate the soil and make it firmer by rolling it, by placing sheep on it, and sometimes by manuring it with well-rotted farm manure. Turnips, especially, are an excellent root crop for light lands. They use up organic matter from the sub-soil and from the air, much of which is returned to the soil. Their cultivation, during which the land is thoroughly hoed, grubbed, and stirred, tends to clean the land, and to store up in it additional plant food; while the sheep put on it to eat the crops help to manure it, as well as to trample it down and make it firmer. Besides this, fallow crops are less expensive and more beneficial to the soil than bare fallows.

Fresh farmyard manure should not be applied to light lands, because such would make the land more open. Besides this, much of the plant food it contains would be washed away and rendered useless by the rains. On the other hand, well-rotted farmyard manure helps to bind the particles of the soil more closely together. If light land is worked too much it tends to become too dry. It should not be ploughed too often, but should be well rolled and harrowed. The grubber is a very suitable implement to assist in the cultivation of light lands, as it thoroughly pulverizes the soil without bringing the lower portions to the surface. In this way the surface is kept moist.

Heavy lands need to undergo a process of lightening. They require more working than light lands, and therefore should be oftener ploughed and harrowed. This should usually take place in autumn, as the frosts of winter help to crumble the soil, which is often too wet in early spring to be properly worked. Heavy soils, such as clays, should never be worked when wet, as the clods when dried form hard unbreakable masses. Farmyard manure in a fresh state if ploughed into the soil helps to keep it open, as the long straws of the undecomposed manure leave hollow places in it which the rain and air can easily enter.

The ordinary fallow crops are not usually suitable to heavy soils, as the trampling of the sheep put on to fatten on them, or the carting away of the produce when ready, tends to harden the land and make it heavier still. If stiff clay soils be left occasionally under bare fallow, and be kept free from weeds, the action of rain, frost, and the gases of the atmosphere will considerably improve them, and there is not so much chance of the nitrates being washed out as in light soils; but, as already stated, bare fallows are now rarely resorted to.

Instead of turnips, cabbages and rape may be sown in spring with advantage on heavy soils, and the produce carted away or eaten off in autumn. In this way the land will not be injured by the trampling of stock, or by the pressure of horses and carts in winter.

XXII.—EXHAUSTION OF THE SOIL AND ITS REMEDIES.

Good and poor land.—By a good soil we mean one that is capable of producing large crops. In order to do this, it must contain a complete supply of plant food in a form capable of being used by plants. It must also be in good physical condition and situated in a climate favourable to the growth of the crops. If any of these conditions be absent, the soil must be considered a poor one, as it will be unproductive.

Plant food in the soil.—You will remember that plant food consists of certain organic and of certain inorganic matters. The organic matters form the softer parts of plants, and are those substances which disappear in gas and smoke when the plant is burned. They are carbon, oxygen, hydrogen, nitrogen, and sulphur. The inorganic substances are found in the ashes left behind when the plant is burned. They are potash, soda, magnesia, lime, iron; and phosphoric acid, sulphuric acid, silica, and chlorine. We have also seen that plants obtain carbon, oxygen, and hydrogen from the air and water, and that the bulk of the nitrogen is obtained from the soil in the form of nitrates. All the other substances contained in the ashes of plants, except carbonic acid, can only be obtained by them from the soil. If any of these substances which form the inorganic food of plants be absent from the soil, or be present in quantities too small to be of any use to them, the crops will not thrive. The productiveness of the soil depends upon that element of plant food which the soil contains in **least** abundance.* You cannot pay too much attention to this principle, and must always bear it carefully in mind. The plants derive eight or nine different kinds of food from the soil. In order to be productive, the soil must contain **each one** of these kinds of food in sufficient abundance. If one of them is not present in sufficiently large quantities, no matter how abundant the others may be, the plants will not thrive. For instance, all the farm crops use a very small quantity of the iron they obtain from the oxide of iron. This substance is useful in helping to form chlorophyll, or the green colouring matter of plants; and

*In order to assist farmers, the Department of Agriculture will analyse soils without charge. If intending to send samples, write to the Chemist, Department of Agriculture, Wellington, for instructions how to select, and forward them.

if it be not present in the soil, the plants soon present a sickly hue, as though they had been grown in the dark, and soon droop and die.

Exhaustion of the soil.—When the soil ceases to contain some one or more of the substances used by plants as food, it is said to be **exhausted**. Exhaustion may be caused by crops being continuously grown on the soil, without steps being taken for supplying it with a sufficiency of those substances that the plants have been using as food. We have seen, when dealing with fallows, that an exhausted soil may recover itself by giving it a period of rest, thus enabling it to convert its dormant supplies of food into available food. In some parts of America and Australia, for instance, when land was cheap, and there was plenty of new land always available for cultivation, the farmers continued year after year raising immense crops of wheat or maize, until the land became thoroughly exhausted and ceased to produce crops that would pay for their production. The farmers would then move further off, take up new land, and crop it with the same result, when the same process would be repeated. When the population increased, however, (and also in countries where land is limited in quantity) this could not be done, and a proper system of cultivation had to be introduced.

The land does not become exhausted in a natural forest or prairie; as when the trees, grasses, or other plants die, their leaves, stems, and branches return to the soil the same substances they have obtained from it while growing, as well as the carbon which they have received from the atmosphere. Their decayed roots, too, restore to the soil the plant food they have brought up from the subsoil, and make the surface even richer than before. But when grain is grown, it is cut and carted away to some other place, and does not enrich the soil by its decay. The inorganic substances contained in the stems, leaves, and grain, are permanently removed from the soil; and unless these are supplied to it in some other way, the land soon becomes exhausted.

Remedies for exhaustion.—We have already noticed that if land be **fallowed**, that is if it be ploughed and harrowed and given a rest, it will to some extent recover itself, and, by means of natural agencies, again become productive. But this is not sufficient. Unless the mineral substances taken from it by the crops that have been removed from its surface, be actually restored to the soil, there is no power in either land, air, or water to place them there again. Of course each crop does not take away these inorganic substances in the same proportions. Turnips, for instance, take more potash, soda, phosphoric acid, and sulphur than the others; clover takes more lime and magnesia; while wheat takes more silica. Again the quantities of these substances used by each crop varies according to the amount of crop yielded, to the nature of the soil, and to other circumstances. In a favourable season a piece of land may yield twice the crop that it did in the preceding year, or the land may be better cultivated during one year than during another, and both sets of circumstances will affect the quantities of the inorganic substances used by the crops; but the proportions of each will not vary much. The following table shows the number of pounds weight of nitrogen, etc., and of the most important mineral substances of plant food removed from an acre of English land by moderate crops of various kinds:—

Lbs. per Acre	Turnips	Barley	Clover	Wheat
Nitrogen	120	47	102	45
Potash	149	31	87	28
Soda	25	5	4	3
Lime	74	10	86	10
Magnesia	10	7	31	8
Phosphoric acid ...	33	21	25	23
Sulphur	21	6	9	8
Silica	8	64	7	100
Iron oxide	2	2	1	1
Chlorine	22	4	9	3
Totals	344	150	259	186

You are not expected to remember these figures, but merely to note such facts as:—wheat uses more silica than other plants, and so on.

Besides fallowing, then, the soil may be improved, and the mineral substances used by plants restored to it, either wholly or in part in two other ways. These are (1) by the application of manures, and (2) by adopting what is known as the principle of the rotation of crops.

Application of Manures.—Further on we shall deal at greater length with the subject of manures, and in the meantime we shall merely discuss how farm-yard manure may be applied.

Manures are of various kinds, and are applied to land for the purpose of supplying it with additional plant food. Farmyard manure, which consists of the refuse of the animals fed on the farm, mixed with hay, straw, or other litter, is suitable for all kinds of soil, and under nearly all conditions. We have already seen that fresh manure is suitable for heavy lands, as the long straws it contains tend to keep the soil open and make it lighter. Well-rotted manure, on the other hand, should be applied to light lands, as its decomposed matter tends to make the soil firmer by causing its particles to stick together more closely.

A farm does not usually produce sufficient manure for all its crops. The little that can be made owing to the conditions under which farming is carried on in this comparatively mild climate, is generally applied to top-dressing grass lands. In heavy lands it should be applied in autumn and ploughed in, as the soluble matter it contains is not so likely to be washed out, as in the case of light lands. On light lands it should be applied directly before it is needed, provided it is thoroughly well decomposed. Liquid manure is suitable for pasture lands.

Rotation of Crops.—It has been found that if the same kind of crop be grown year after year on a piece of land, it soon ceases to be healthy, or to produce an abundant return. The reason of this we have already seen. The crop is continually taking the same kind of food out of the soil; this food is not being returned to the soil at an equal rate, and consequently the land becomes exhausted, and is said to be "**sick**" of that crop. If, for instance, clover, which requires a considerable quantity of potash and lime for its sustenance, be grown for successive years, the potash and lime (unless re-supplied by manures containing these substances in sufficient quantities) become exhausted, and the land is said to be "**clover sick.**"

Although, however, the land may be exhausted as far as clover is concerned, it may yet be quite capable of producing another crop, such as wheat, in abundance. Wheat requires less than one-third of the amount of potash, and less than one-eighth of the lime that is necessary for clover, and there may be still enough of these left in the soil to produce a good crop of wheat. Similarly it may be found that another crop which uses more of other kinds of food than wheat requires, may be successfully grown after a crop of wheat has been taken off the land. Thus it has been noticed that different kinds of crops can be grown from time to time on the land, without much manuring or fallowing, for a far longer period than can the same kind of crop, because they do not all need the same food and some of them actually assist to restore to the soil constituents extracted by previous crops. This change of crops from year to year, or from period to period, is called a rotation, or round of crops; and the term "**rotation of crops**" may be taken to mean the order of succession in which different kinds of crops can be grown. The order in which different kinds of crops may be grown from year to year on the same piece of land of course varies according to the country, climate, and nature of the soil. A favourite rotation, especially in England, is what is known as the Norfolk, or four years' course. It consists of the following course of crops:—

First Year ...	Turnips	Third Year ...	Clover
Second Year ...	Barley	Fourth Year ...	Wheat

If you refer to the table on page 92 you will see why such a rotation as this is likely to be beneficial. The turnips take out of the soil large quantities of potash, soda, phosphoric acid, sulphuric acid, chlorine, and nitrogen. If turnips were planted the following year more of these substances would be used up, and there would be a danger not only of the land becoming turnip sick, but even of an insufficiency of potash, etc., to sustain a crop of a different kind. Barley, therefore, which uses less potash, soda, etc., is sown in the second year. In the third year it will be of advantage to sow clover, which requires a large supply of lime and magnesia, very little silica and soda, and only a moderate quantity of potash, phosphoric acid, and nitrogen. In the fourth year wheat can be sown, as it requires a very large amount of silica and nitrogen, but smaller or more moderate quantities of other more important, but less plentiful substances.

By this time turnips, or some other root crop may be again planted with advantage, as the substances they require have in the interval been rendered soluble, and therefore available as plant food, by the oxygen and carbonic acid of the atmosphere. In practice, however, it is found that to ensure a good crop of turnips, artificial manures must be resorted to, such as superphosphate, fine bone meal, or guano, or a mixture of these.*

There are, of course, many other systems of rotation followed in different countries, and in different parts of the same country. Farmers judge from the

*Most instructive accounts of experiments with manures are given from time to time in the Journal of Agriculture, which is published monthly by the Department of Agriculture.

nature of the soil, the climate, or the abundance and quality of the last yield as to what crop they will put in during any succeeding year. Some soils are so rich that year after year they will produce an abundance of the same kind of crop, particularly if they are well cultivated. On a fairly good soil, wheat, especially, can often be grown for two or three years in succession with satisfactory results, but the practice is not considered a good one.

The rotation of crops is also of great **mechanical value** to the soil. Before turnips can be planted, for instance, the land has to be deeply ploughed, the weeds to be drawn out by the harrow and grubber, and sometimes manure to be ploughed in. The seed is sown in rows at sufficiently great distances apart to allow of the land being stirred and the weeds grubbed out while the crop is growing. If barley is sown next, its roots do not penetrate far into the soil, but the plant derives its food from near the surface. The clover, on the other hand, planted in the third year, sends its roots deep down into the sub-soil, and stores up quantities of nitrogenous food, which on the decay of the roots will be of service to the crop that follows. The clover-roots, too, improve the texture of the soil. If it is too loose, they help to bind its particles together; but, if it is stiff and clayey, they tend to open it and enable the rain and air to penetrate it more freely.

Rotation of Crops in New Zealand.—It is only by carrying on a proper rotation of crops, by systematic farming, and by the judicious application of fertilizers, that the farmers of this country will be able to keep up their heavy export of first-class sheep and dairy produce, and yet maintain the fertility of their land.

The following system of rotation is frequently adopted in the best portions of the North and South Islands:—Land which has been five or six years under pasture, and on which the cultivated grasses have been pretty well eaten off, or have died out, is broken up. After lying fallow for perhaps three months, it is cross-ploughed, harrowed with disc and ordinary harrow, and then sown with wheat, oats, or barley.

When this crop has been reaped and threshed, and the straw stacked on the ground, to be afterwards eaten with the turnips by the sheep, the land is ploughed and thoroughly prepared for the turnip crop to be sown in November or December.

In order to give the turnips a good start and ensure a high yield, the soil should be supplied with from 1 to 1½ cwt. of superphosphate, or with a mixture of 1 to 1½ cwt. of superphosphate and ½ cwt. of bonedust. On land deficient in lime, however, basic slag, or basic superphosphate, should be used in place of superphosphate. At the end of the autumn or during the winter, the turnips are eaten off by sheep. While eating off the turnip crop, the sheep should be supplied with oaten stray, hay, or chaff, which they require to counterbalance the coldness of the watery turnip feed. The sheep are thus fattened, and the land at the same time is benefited by their droppings, and by the remains of the turnips and straw left unconsumed.

After the turnips are eaten off, the land is ploughed, harrowed, etc., and a good seed-bed formed. Oats, barley, or wheat are then sown, and at the same time, or afterwards, a proper mixture of cultivated grasses and clovers is sown in order to form a permanent pasture. If the land is light the second grain crop should be omitted, and grass seed, mixed with rape or turnip seed, sown.

When the land has thus been laid down in grass, it is allowed to remain in permanent pasture until the cultivated grasses again become too thin and require to be renewed, when the same course is repeated.

PART II.

I.—MANURES.

Object of Manuring.—Manure is matter added to a soil to increase its general store of plant food, or to supply it with any one or more ingredients in which it may be deficient. Thus, a crop of turnips takes from the soil considerable quantities of potash, soda, lime, phosphoric acid, and sulphur. Before another profitable root crop can be immediately raised from the same soil, it will probably be found advisable to apply to the soil a manure which contained those substances of which the soil's available supplies may be below crop requirements. Of the constituents essential to its growth which the plant draws from the soil, only three, namely phosphoric acid, potash, and nitrogen, ordinarily fall below the current requirements of the crop. This does not necessarily mean that the soil does not contain these ingredients, but that they are not present in the soil in an available form, nor are they likely to be rendered available in sufficient quantity during the growth of the crop. Manures may, therefore, be regarded as compounds supplying deficiencies in the soil's supplies of one or other or all three of the ingredients, phosphoric acid, potash, and nitrogen. Further, they may be applied to act **mechanically** on the soil. Such are manures containing straw or other litter. When applied to clay soils they help to open them, and thus render them lighter and more porous. When ploughed in to sandy soils they help to bind the particles together, and make them closer and heavier.

Manures may also act **chemically** on the soil, and help to convert the dormant plant food in it into soluble food that the crops can make immediate use of. Lime, for instance, helps to decompose the decaying organic matter and the silicates in the soil.

Other substances classed as manures are frequently applied, but it is rather for their indirect beneficial action on the soil, as in the case of lime, mentioned above, than for the purpose of supplying the particular plant food which they contain.

General and **Special Manures.**—Manures may be classified in various ways. Those containing lime are generally called **natural manures.** All other manures are either **general manures** or **special manures.** Special manures are sometimes called

artificial manures, as they have to be prepared by the manufacturer before they are fit for use.

General manures contain all those substances that are required to promote the healthy growth of plants. As they furnish different crops with all kinds of food they are of general use to them. Farmyard manure is the best example of a general manure. Other general manures are—green crop manures; certain guanos; seaweed.

Special manures are those that contain one or more of the ingredients that plants require for food. They are applied when the soil is deficient in these special ingredients, although it may contain an abundance of other plant food. Nitrate of soda forms a good example of a special manure. Other examples are superphosphate of lime, slaked lime, sulphate of potash, common salt, sulphate of iron, sulphate of ammonia, dissolved bones, etc.

Certain special manures are now prepared for manuring particular crops. Such for example are "mangel manure," "grain manure," "turnip manure," etc. These are compounded by the manufacturers on the basis of average crop requirements, and generally contain a mixture of each of the necessary food ingredients, phosphoric acid, potash, and nitrogen, in proportions which are considered sufficient to meet the crop's demands.

II.—GENERAL MANURES.

Composition of Farmyard Manure.—Farmyard manure contains a greater variety of plant food, and is more generally useful in making the soil fertile, than any other kind of manure. It consists of the straw and litter that has been used for the bedding of the farm animals in the stables, milking-sheds, and farmyards, mixed with their excrements (Latin *ex* = out of, *cretum* = separated), that is, their urine and dung. As the animals receive their food from the crops grown on the farm, and the crops themselves derive their sustenance from the air and from the soil, it follows that farmyard manure contains those substances that are most necessary to the growth of plant life; and that, when it is applied to the land in proper quantity, those substances of which the soil has been deprived are returned to it again. To prepare it for use, the manure is taken from the stables and farmyard and spread out in a suitable place, beneath which there should be a tank, or excavation, for the collection of the liquid manure that would otherwise be lost.

A ton (2240 lbs.) of fresh farmyard manure contains about 1600 lbs. of water and about 640 lbs. of solid matter. Nearly one-sixth of the solid matter will probably be soluble, and will, therefore, be very useful to the crops, as it consists of such fertilising substances as, *ammonia, silica, phosphate of lime, magnesia, potash, soda, sulphuric acid,* and *carbonic acid.* From a ton of this manure there may generally be obtained from nine to fifteen pounds of nitrogen, nine to fifteen pounds of potash, and from four to nine pounds of phosphoric acid (a compound of phosphorus and oxygen); and we have seen that these three substances are of special value in manures, and can be obtained by the crop only from the soil.

Value.—Farmyard manure, then, is of special value to the soil, as it contains all those substances which plants require for food. When applied in a fresh state to clay soils, it acts mechanically in making them more open, and therefore more susceptible to the action of air and water and the gases they contain. If applied in a well-rotted state to light lands, it has the effect of making them firmer, and therefore more able to preserve their warmth and moisture. In supplying a considerable quantity of organic matter to the soil, farm manure helps to form humus, and humus tends to absorb from the atmosphere its moisture and gases, and to retain them. Farmyard manure, too, itself contains carbonic acid, and other acids and gases in small amounts; and these help to make soluble the mineral matter in the soil that has hitherto lain dormant and unfit for immediate use by the plants. It also promotes the growth of bacteria in the soil; and the nitrification carried on in consequence, increases the stock of available plant food. Farmyard manure has also a lasting effect on the soil, and renders it more fertile for years afterwards. In this respect it is of more value than many other kinds of manure, the benefits of which often become exhausted in a single year. Being close at hand, farm manures are more easily obtained, and are generally cheaper than other manures.

A special kind of farm manure is not mixed with straw when applied to the land. When sheep and other stock are fed on root crops growing on the farm, their excrement returns to the soil those portions of their food which were not required in fattening them or in keeping them warm. Turnips and other root crops, as we know, deprive the soil of considerable quantities of *potash, soda, phosphoric acid, sulphur,* and *chlorine*; and the manure left behind by the sheep while they are eating off the turnip crop, returns part of these substances directly to the soil, and tends to prevent it from becoming exhausted.

Liability to ferment.—When farmyard manure is collected in heaps and left for some time, it begins to rot and ferment. The fermentation is caused by the growth of innumerable microscopic organisms or ferments, known as bacteria. The germs of these organisms are constantly floating about in the atmosphere; and when they fall upon a manure heap, they find there large supplies of the food they require; and they accordingly grow and multiply with astonishing rapidity. It is the organic portions of the manure that they use for food; and in its preparation they break up these organic substances into simpler forms, such as water, ammonia, carbonic acid, etc. While this change is taking place, the manure becomes hot, owing to the oxygen of the air combining with other substances to form carbon dioxide, etc. The mass also becomes lighter, and consists chiefly of the carbonaceous matter of the litter. The proportion of nitrogen in it is increased, as is also the other valuable soluble matters it contains.

It is necessary that the farmer should take care that none of these valuable substances are **lost,** and at the same time he should see that the manure heap is kept in a condition favourable to their production. If it is allowed to get too hot, carbonic acid is rapidly formed, and combines with ammonia to form strong-smelling carbonate of ammonia. This substance is very **volatile** (Latin, *volare* = to fly away), and in the form of a gas readily flies off into the air, and ceases to be available as plant food. If, on the other hand, the heap is kept moist, and is not allowed to become too hot, some of the organic acids it contains combine with the ammonia, thus retaining it in a solid form. An outer covering of earth also tends to absorb any ammonia evolved, and so helps to reduce its loss to a minimum.

It does not do to let the heap get too moist, as then a great deal of the soluble matter drains away in black streams; and unless collected in a tank or other receptacle, it becomes permanently lost, and the value of the manure that is left is considerably decreased. The drainage from the manure should be collected and poured over the heap again.

If a strong pungent odour, like that from smelling salts, comes from the manure heap, it shows that ammonia is coming from it and being wasted. The heap is then too dry, and should be moistened with its own drainage, if possible, or with water. If black streams are trickling from under the heap, the manure is too moist, and the organic acids and ammonia are being wasted in the drain unless collected in a tank.

If the farmer desires the fermentation to go on rapidly he should frequently turn the manure over in order to expose it to the air. The oxygen of the atmosphere has thus freer access to all parts of the manure, and combining more readily with the various substances it contains, greatly assists the process of decomposition. If, however, ammonia is being wasted through excessive fermentation, the manure heap should be trodden down and pressed, so that the air may be excluded as far as possible. If the manure be carefully attended to, the valuable plant food it contains will be preserved; but if it be neglected, it may be of so little value as to be unfit for use. The liquid manure from the tank is most valuable for pastures.

Animal and Vegetable Refuse.—The waste animal and vegetable products of the farm may be used to form a valuable manure if a **compost heap** be formed with them. To do this the waste straw, stubble, weeds (not containing seeds), ferns, leaves, ditch scourings, etc., should be collected in a heap and occasionally watered with liquid farmyard manure. Chemical changes then take place; the heap begins to decompose and ferment; and if it be turned over from time to time, the oxygen and carbon dioxide of the air having freer access to all parts of it cause the fermentation to go on more rapidly. If lime be added to the heap, and properly mixed with it, nitrate of potash will be produced from the nitrogenous matters and the potash contained in the refuse. Nitrate of potash, being easily soluble in water, is of peculiar value to plants, as from it they can obtain both nitrogen and potash. Care should be taken that turnips, cabbages, or other plants attacked by fungus diseases, especially by club-root, are never thrown on the compost heap; as the germs would survive and be distributed over the fields where the manure was used. Always burn such plants.

Fish and **sea-weed** are also in some places used as manures, as are the waste matters of certain industries, such as **blood** from the slaughter houses, **bran** and **brewers' grains, skin** and **hoof-cuttings** from tanneries and glue-works. **Wool**, in the form of woollen rags, is also used as a manure when dissolved in sulphuric acid. **Shoddy**, or the waste matter from the woollen mills, contains from nine to fifteen per cent. of ammonia, and, although rather insoluble, is used to assist other manures. In England and other places, **horn** shavings from the comb factories are used as manure. All this animal and vegetable refuse is valuable as manure for the nitrogen it contains, which in the form of ammonia is returned to the soil. The ammonia you buy from the chemist as smelling salts was formerly made from the horns of deer, hence it was called "hartshorn."

Green Manures.—Sometimes such crops as rye, lucerne, vetches, clover, rape, etc., are ploughed into the land when green, to act as manure. The best time to do this is when the crops are in flower, as they then contain more organic matter than at any other time; and this is in a condition to decay rapidly when covered with the soil. The organic matter has been derived principally from the air, and, as the plants still contain the mineral or inorganic matter they have taken up from the soil, the plant food they return to it, when they decay, will be of the greatest use to the next crop.

Their roots, too, when ploughed into the land, will furnish much valuable plant food. We have already seen that the long clover roots bring up nitrogenous matter from the subsoil, and as their broad leaves have stored up a quantity of plant food from the atmosphere, the ploughing in of a clover crop furnishes the soil with an abundance of plant food that will be of special benefit to the crop that follows.

Green manuring also benefits the soil **mechanically,** helping to break up stiff **clays**, and make them more open and easier to work; while the process helps to enrich **sandy** soils, binding their particles together, and enabling them more easily to retain moisture and soluble plant food.

Green manuring, however, is usually too expensive a process to be made much use of. It pays better, as a rule, first to feed sheep and cattle on the green crops. The farmer thus gets a price for his stock, the land is enriched by the animal manure left behind; the roots and other uneaten portions of the crop are then ploughed into the land; and, if necessary, a little artificial manure is applied to it to supply it with any ingredients that are thought deficient.

III.—SPECIAL MANURES.

We have already seen that **nitrogen, phosphoric acid,** and **potash** are the ingredients that are of the greatest value in manures. Of these, nitrogen and phosphoric acid are principally wanting in the different soils. Special manures, containing a sufficiency of one or two of these ingredients, are, therefore, applied to the soil to make up this deficiency, in order to supply the particular kinds of plant food that may be wanting. Manures that principally supply nitrogen to the soil, whether in the form of ammonia or not, are known as **nitrogenous manures.** Phosphoric acid is the chief ingredient of **phosphatic manures,** while those that contain a considerable quantity of potash are called **potassic manures.**

Guano, although generally classed among the general manures, may be regarded as a special manure, inasmuch as it especially furnishes the soil with considerable quantities of nitrogen and phosphoric acid. It is composed of the dried dung of fish-eating sea-birds, together with their feathers and bodies, pressed together into a hard solid mass, and is obtained principally from the rainless rocky coasts and islands of Peru, and other parts of South America. Owing to the absence of rain in these places, the guano deposits have accumulated until they are sometimes as much as 200 feet thick, and the soluble substances in them have not been washed out by running water. This kind of guano is the proper or nitrogenous guano. The guano found in rainy districts has had most of the ammonia and other nitrogenous matter washed out of it. It is known as phosphatic guano, and is not so useful as the former. Nitrogenous guano is especially useful as a manure for such crops as grain, grass, and potatoes, as it is capable of acting very rapidly, and of being of immediate use to the plants. It should never be mixed with lime, as lime has a tendency to drive off the ammonia it contains. Phosphatic guano is suitable as a manure for turnips and other root crops. To make its action more rapid it is sometimes dissolved in sulphuric acid to form a soluble manure, and it is then known as superphosphate.

Nitrogenous guano should not be sown with, nor allowed to touch the seed, as its strong pungent nature tends to destroy the embryo.

Nitrate of Soda is a purely nitrogenous manure, containing about 15 per cent. of nitrogen. It does not contain ammonia, the nitrogen being present in the form of nitric acid combined with soda. Large deposits of it are found in Peru, Chili, and other parts of South America. It is said to be derived from sea-weed, on the decomposition of which nitric acid is formed by a process of nitrification. The nitric acid by combination is changed into nitrate of calcium, and when this is decomposed in the presence of sodium salts, nitrate of soda is formed.

This substance acts more quickly than any of the other nitrogenous manures, and as it requires little moisture to dissolve it, it is especially suitable for dry seasons. It is supposed that nitrate of soda readily sinks into the soil, and has therefore a tendency to draw after it the roots of the crops which are thus enabled to find moisture and plant food in the lower layers of the soil. As it supplies only nitrogen, and its effects last for only one year, it should be used in conjunction with other manures, as otherwise the stock of phosphates, potash, etc., would soon be used up by the crops, and the land become exhausted.

This manure encourages a luxuriant growth of the leaves and stems of the plants, and is therefore of great value to grass lands. If it be mixed with common salt, and applied to grain and root crops, this luxuriant growth of foliage is somewhat checked, thus enabling the plants to devote more of their food supply to the growth of the grain-seed, or of the turnip tubers, etc. Sown broad-cast, or drilled over the land, after the crop is up, it forms a valuable top-dressing for such crops as, straw-growing plants, fodder crops, sugar-beet, and meadow grass.

Sulphate of Ammonia is another valuable nitrogenous manure. It is prepared from the ammoniacal liquor of gasworks, and often contains as much as twenty per cent. of nitrogen. As a fertiliser it is fully equal to Peruvian guano. When applied to the soil the sulphate of ammonia is changed into nitric acid and sulphuric acid, and these readily combine with any base such as lime. Nitrate and sulphate of lime are thus formed, and these being more or less soluble may be lost if the drainage is excessive. Sulphate of ammonia does not act so quickly as nitrate of soda, and is, therefore, less readily exhausted. As it is not so soluble as the latter substance, it is better fitted for use as a manure in rainy seasons, or on wet land.

Another means of supplying the soil with nitrogen is, as we have seen, by the application of **woollen waste, shoddy, dried flesh** and **blood, fish refuse, soot, seaweed,** etc. All of these substances contain considerable quantities of nitrogen, and as they are decomposed in the soil ammonia is gradually formed, and ultimately nitrates. This gradual formation of nitrates supplies nitrogen to the crops during their several successive stages of growth, and is therefore often of more benefit to plants than are those manures, such as sulphate of ammonia, which contain nitrogen in a more soluble form.

Nitrate of Potash (nitre or saltpetre) supplies both nitrogen and potash to the soil, but as this substance is greatly used in the manufacture of gunpowder, it usually is too expensive for general use as a manure. It contains from twelve to thirteen per cent. of nitrogen. When lime is added to farmyard manure, or acts upon the inorganic matter of the soil the production of nitrate of potash is promoted.

Two new nitrogenous manures that have given satisfactory results within recent years are **nitrolim** (calcium cyanamide) and **calcium nitrate.** The nitrogen each contains is obtained originally from the atmosphere. In the manufacture of the former, nitrogen is passed over calcium carbide (used in the production of acetylene gas) which has been heated until it is white hot. At this high temperature the nitrogen and calcium carbide combine to form a dark grey powder called nitrolim, a substance containing up to 20 per cent. of nitrogen.

Calcium nitrate is manufactured in Norway by an electric process, in which the oxygen and nitrogen of the atmosphere are made to unite to form nitric acid. This in turn is combined with lime, producing the substance known as calcium nitrate, which contains about 13 per cent. of nitrogen. These manures will no doubt be more extensively used in the future, but owing to their high cost of production, they cannot at present compete with nitrate of soda and sulphate of ammonia.

Potash forms an important constituent of most heavy soils and clays. It is also one of the principal ingredients in farmyard manure, and when that kind of manure is applied to soils no further application of potash is necessary. In light soils, however, it is usually present in insufficient quantities, and where farmyard manure is scarce, artificial manures containing potash will benefit the soil. **Wood ashes,** especially those obtained from burning young twigs and cuttings, contain a large amount of potash, as do **seaweed** and the **ashes of seaweed.** By the application to the soil of such green manures as beans, clover, and other leguminous plants, considerable quantities of potash are returned to it. A mixed salt, called **kainit**, which is obtained from certain mines in Germany, forms a useful potash manure. It contains about 12 per cent. of potash, 30 per cent. of common salt, and about 13 or 14 per cent. each of the sulphates and chlorides of magnesium. It is used either as a manure by itself, or mixed with farmyard manure, and is suitable for application to grain crops and pastures. **Sulphate of potash** and **muriate of**

potash are both used as manures and contain four times as much potash as can be obtained from the same weight of kainit. **Nitrate of potash** is the best of the potassic manures, but, as we have seen, it is too expensive for general application.

Potash manures tend to improve the growth of pastures, and should be applied to land where the hay and straw grown on it have been removed, in order to restore the potash they have taken from the soil. They also greatly benefit a potato crop, increasing both the yield and the size and quality of the tubers.

Common Salt (chloride of sodium, a compound of chlorine and sodium), is often used as a manure. It is not of much direct value to plants, but it produces chemical changes in the soil which have the effect of somewhat increasing its store of plant food. When applied to fallows it has a tendency to destroy insects, slugs, and weeds. If added to farmyard manure it helps to prevent the ammonia from escaping, and also to destroy the seeds of any weeds it may contain. Too much salt when applied directly to plants will have the effect of destroying them. When mixed with farmyard manure or nitrate of soda, it tends to **check the growth** of plants, and may therefore be of great benefit to certain crops. Grain crops, for instance, if grown on highly manured or very fertile soil, have a tendency to produce straw rather than grain. If common salt be applied to the land, the growth of the straw will be impeded, and the plants will therefore have more opportunity of devoting their food supply to the production of grain. The straw will be shortened and strengthened, and the grain will fill out to the satisfaction of the farmer. Mangels, which originally grew along the sea-shore, are benefited by a direct application of salt; and beans, cabbages, onions, and buckwheat, also appear to flourish under its influence.

Manures containing Phosphorus.—These are principally artificial manures. **Phosphoric acid** (a compound of phosphorus and oxygen) is one of the inorganic substances required for plant food that occurs only in small quantities in the soil. Much of it, too, is carried away from the farm when the crops are removed, and is thus not restored to the land again. The grains of wheat and barley, for instance, which contain a large supply of phosphoric acid, are taken away from the land and made into flour, malt, etc.; while the straw is burnt on the farm, or is used for farmyard manure, and thus returns to the soil the silica and potash it contains. Cows' milk also contains a proportion of phosphoric acid which the animals have obtained from their pastures; while the young animals of the farm require considerable quantities of this substance in building up their bones, which are principally composed of phosphate of lime. There will often be as much as 58 lbs. of phosphate of lime produced from 100 lbs. of bones.

Unless manures containing phosphorus, therefore, are applied to the land, the soil will soon become exhausted.

Bone Manures.—Bones are principally composed of phosphate of lime, and they are applied to the soil in such a form that the phosphorus they contain is made available for plant food. It was first discovered in Cheshire, England, that crushed bones applied to the soil nearly doubled the value of pastures that were becoming exhausted; and since then bone manures have been applied to all kinds of crops and soils. At first the bones were merely broken up into fragments that would pass through a sieve having a mesh of half an inch, and were (and still are) known as "half-inch bone." When these fragments were applied to pasture lands, it was found that after a time the land produced more abundant crops of grass and clover. The reason of this can be easily understood. Cows require phosphate of lime for the formation of their milk, and the calves require the same substance for building up their bones; and very little of the phosphate of lime they have obtained from the herbage they have eaten will be returned to the soil in their manure. If the land is to remain fertile, therefore, manure containing phosphoric acid must be added to it, and bone manures are thus of great value.

Besides being beneficial to pasture lands, it was found that the use of bones improved the soil for other crops. Grain crops require considerable quantities of phosphoric acid for the formation of the grain, and sheep and other animals use up the greater part to the supply obtained by root crops from the soil. Unless, therefore, this supply is replenished the land will become poor.

It was found, however, that it was often a considerable time before "half-inch bone" was of much use in promoting the fertility of the soil, and the bones were accordingly broken into smaller fragments, or ground into powder, and sold as **bone dust**. This had the effect of making the manure act more quickly on the crops. If the bones were allowed to ferment, they were found to act more rapidly still. When placed in a heap, moistened with water, and covered over with clay, or fine earth, they soon become very warm and begin to decompose. In a few weeks' time they become very much softened, and, when applied to the soil, they quickly break up and mingle with it. Hence they are very soon able to supply the phosphate of lime that the plants require.

When bones are steamed they are easily reduced to a fine powder. This product, known as **steamed bone flour,** is much more readily available than bone dust.

Before bones can become a useful manure they have to undergo some **chemical changes.** The phosphate of lime they contain is a special form known as **tricalcic phosphate** (*tri* = three, *calc-* = lime), or three-lime phosphate, that is, phosphoric acid combined with three parts of the base lime. This is quite insoluble in water, and, therefore, before it can be available as food for plants, it has to be changed into a soluble form. This change takes place slowly in the soil, and a little more quickly when the bones are fermented, as the carbonic acid in the water changes one part of the lime into carbonate of lime, and thus reduces the three-lime phosphate into a **bicalcic** (*bi* = two), or two-lime phosphate. Two-lime phosphate is capable of dissolving slowly in soil water.

Carbonic acid, however, is a weak acid, and takes a considerable time to change tricalcic phosphate into a quickly soluble form. Even when by its action two-lime phosphate is formed, the fertility of the soil is but slowly increased, as the bicalcic phosphate takes a long time to dissolve and become available as plant food. It was accordingly found that if strong sulphuric acid were applied to the bones, **two** portions of the lime underwent a rapid chemical change, and that the tricalcic phosphate was at once converted into **monocalcic** (*mono* = one), or one-lime phosphate. The two portions of lime combined with the sulphuric acid to form **sulphate of lime,** or gypsum, which is itself a valuable manure supplying sulphur and lime to plants.

Sulphuric acid added to bones changes tricalcic phosphate into monocalcic phosphate and gypsum. The manure produced in this manner is known as **dissolved bones,** or **bone superphosphate,** because in proportion to the lime, it contains a supply of phosphoric acid greater than, or **beyond,** that of the other phosphates. By this simple chemical process the phosphate of lime, which formerly took months to change into a form suitable for plant food, can be made of immediate advantage to the soil and to the crops.

Mineral Superphosphate.—The term "superphosphate" is often restricted to manures made from mineral phosphates, and not from bones. Some rocks and other mineral deposits, contain tricalcic phosphate of lime, and, as the supply of bones is insufficient to produce the quantities of manure required, these minerals have been used instead.

Certain kinds of stone, called coprolites, found in various parts of England, are used for this purpose, and other mineral phosphates are imported into England from Canada, France, Spain, Norway, the West Indies, and other places, for the manufacture of phosphatic manures. The raw material is ground down into a powder, and then mixed with sulphuric acid as in the case of bonedust. The manure thus formed is known as **mineral superphosphate.**

Bone-ash Superphosphate.—Bone-ash, obtained by burning the bones of cattle, is exported to England from South America in large quantities. It contains very little nitrogen, and hence is different from bones in the ordinary state. The tricalcic phosphate, which forms the principal constituent of bone-ash, is reduced to monocalcic phosphate by the addition of sulphuric acid, and the superphosphate thus produced forms a valuable manure. Mineral superphosphates are not so readily soluble as bone superphosphates, and have, therefore, a more lasting effect on the soil. Mineral phosphates, like bones, can be used as manures without being dissolved in sulphuric acid. When ground down into a fine dust they form valuable manures for turnips and other root crops. **Phosphatic guano,** too, that is, guano that contains more phosphate of lime than it does ammonia, is often dissolved in sulphuric acid, and sold as **superphosphate of lime.**

Reduced Superphosphates.—Monocalcic phosphate, usually called "soluble" phosphate by farmers, has sometimes a tendency to return to the bicalcic form. It is then known as **reduced**, or **reverted** phosphate. This change may be brought about in various ways. If the superphosphate be mixed with bone-ash, which, as we have seen, contains insoluble, or tricalcic phosphate, the two manures will act upon each other in such a manner that a portion of the superphosphate will be changed into bicalcic or two-lime phosphate. This two-lime phosphate, we know, is more soluble in the soil water than three-lime phosphate, but is less soluble than one-lime, or monocalcic phosphate. The latter, being readily soluble in water, is washed into the soil and distributed through it by rain and running water. Bicalcic phosphate takes a longer time to dissolve, so that after the more soluble portion of the superphosphate has been used up by the crops, this two-lime phosphate will still be decomposing in the soil, and becoming available as food for future crops. Reduced superphosphates, therefore, are more lasting in their effects than superphosphates proper, and will in some cases prove a more suitable manure. For this reason a mixture of superphosphate and bone dust, or phosphatic guano, is often used.

Superphosphates form excellent manures for turnips and other crops that grow rapidly. They are also suitable for potatoes, barley, oats, clover, and all other crops that require much phosphorus. They are adapted to all soils containing sufficient lime, and act more quickly than any other phosphatic manures. The different kinds of superphosphate, however, are acid manures, and in the absence of sufficient lime in the soil to neutralise this acidity, should be replaced by non-acid phosphatic manures. In addition to bone dust, steamed bone flour, and phosphatic guano already mentioned, basic superphosphate and basic slag are useful manures of this latter class, and are better suited to soils with a tendency to sourness than is superphosphate.

Basic superphosphate is prepared by mixing with superphosphate, sufficient freshly slaked lime to neutralise the acidity of the superphosphate, and revert the one lime (mono-calcic) phosphate which it contains to the two-lime (bi-calcic) form. As we have seen this bi-calcic phosphate is less soluble than superphosphate, but the finely divided state of basic superphosphate makes it readily soluble in the soil water, and thus available for plant food.

Basic Slag consists of the residue left over after the manufacture of steel by the Bessemer process. To form the manure the slag is ground down into a fine powder, which contains a considerable quantity of phosphate of lime together with a varying amount of free lime. On heavy soils, and such as are deficient in lime, basic slag has proved a very effective phosphatic manure. Its availability, however, depends on its fineness of division. In a good sample about 90 per cent. will pass through a sieve with 10,000 meshes to the square inch.

IV.—ACTION OF LIME ON THE SOIL.

Lime, which is sometimes called a **natural manure,** has been used as a manure from the earliest times. In the form of **carbonate of lime**, which is composed of carbon dioxide, oxygen, and lime, it is found abundantly in limestone and chalk formations. Combined with sulphuric acid, it forms a component of many rocks, such as **sulphate of lime,** or gypsum. It also occurs in many places, as we have seen, in the form of **phosphate of lime**, which is a compound of phosphoric acid and lime. The last two compounds are used as manures rather for the sulphur and phosphorus they contain, than for the lime itself. Lime for manuring purposes is principally obtained from the carbonate, which is found in great abundance, and is easier of application than the other two.

Limestone, chalk, and oyster shells are chiefly composed of carbonate of lime. In this state, however they are not suitable for manures, as the hard lumps and shells of which they are composed take too long to break up, or to produce the important chemical changes necessary to benefit the soil. If they are placed in a limekiln, and exposed to the action of heat, the carbonic acid they contain is driven off in the form of gas, and the oxide of calcium is left behind. This is called **burnt lime**, or **quick lime**, from the quick or active manner in which it acts on the soil, or **caustic** lime (L. *causticus* = burning), from the hot, burning properties it possesses.

You can readily see that quick lime is a very different substance from carbonate of lime. If you pour some water on a piece of limestone, or chalk, no chemical change takes place, and the fragments simply become wet. But if you pour water on quick lime, a violent action takes place; the lime becomes very hot, and speedily breaks up into a fine powder. The water has combined with the lime to form **hydrate of lime**, or, as it is generally called, **slaked lime**, and the process is known as **slaking the lime**.

If the slaked lime be now exposed to the air, the carbon dioxide of the atmosphere will combine with it, and it will soon be again changed into carbonate of lime. It has lost all its caustic properties, and its appearance has been changed. Instead of the hard rocky fragments, or hard shells, it is now seen in the form of a fine powder, which can be easily applied to the land with beneficial effect. Without the direct application of water at all, quick lime when exposed to the atmosphere, will absorb some of the moisture and carbon dioxide it contains, and be slowly changed into carbonate of lime in the form of a fine powder as before, which can be thoroughly mixed with the soil.

Lime is a direct plant food.—If you refer to the table on page 92, you will see that it is one of the four most valuable forms of plant food, and is used in considerable quantities by some plants. A moderate crop of turnips, for instance, will absorb from the soil as much as 74 lbs. of lime per acre, while a similar crop of clover will use as much as 86 lbs. If the soil is deficient in lime, the application of lime manures will therefore be of great benefit to the crops. If quick lime be applied and harrowed in, it will speedily be changed into the carbonate; or the carbonate itself, or slaked lime, may be used.

Chemical Changes.—The chief use of lime in the soil is to set free food supplies that are more beneficial to the crops than lime itself is. Burnt lime, especially, acts very quickly upon the organic matter of the soil, helping to decompose it. Slaked lime also assists in the decomposition of organic matter, but it acts more slowly than quick lime, which by its combination with the carbonic acid and moisture in the soil to form carbonate of lime, produces more rapid chemical changes. When organic matter is decomposed in the soil, various acids are produced, some of which are injurious to plants. When these acids are present in any quantity, only the coarser kinds of herbage (such as weeds) will grow, and the land is then called "**sour**." Lime, however, combines with these organic acids and neutralises their effect, so that its application to the land will **sweeten** the soil, and cause it to grow richer, healthier, and better crops. We have already referred to the useful work carried on by the nitrifying bacteria in the soil. These organisms cannot live in a sour soil, so that the sweetening action of lime is of particular value in promoting their development. When there is an insufficient supply of organic matter in the soil, burnt lime should not be applied, as its rapid action tends to destroy this source of plant food. If liming be necessary it should be applied in the form of the milder carbonate. Nor should lime be applied continuously to soils, unless farmyard manure, or some other organic substance is applied to them after the lime has been added. There is an old rhyme that says—

> The use of lime without manure
> Will make both farm and farmer poor.

Some soils, however, such as peats and mosses, contain so much organic matter, that the application of lime to them cannot but be beneficial, and there is little fear of any considerable diminution of plant food resulting from its use.

Burnt lime also acts upon the **inorganic** substances in the soil, and tends to set free phosphoric acid, potash, and soda from the **dormant** constituents of the soil, and make them **available** for the growth of crops. In soils deficient in lime, phosphoric acid will usually be found in insoluble combinations as iron phosphate and aluminium phosphate. When, however, lime is applied in sufficient quantity, owing to the greater liking or affinity which phosphoric acid has for it than for either iron or alumina, a new compound, phosphate of lime, is formed, which is readily utilised by plants. In combination with acids in the soil, potash and soda form nitrates and carbonates, which, being soluble in water, are readily absorbed by the roots of the plants. Caustic lime also helps to produce **nitrate of potash** (nitre and saltpetre) in the soil. This change takes place either in compost heaps, or in the soil itself. Nitric acid, produced by the decay of animal or vegetable matter, combines with the lime to form **nitrate of lime,** and when this meets with potash in the soil, some of the lime is exchanged for the potash, and **nitrate of potash** is formed. In this way the farmer, with the help of lime, is able to supply his land with a valuable manure, which, as we have already seen, is generally too expensive to be applied directly to the land.

Lime has also a **mechanical effect** upon the land. Caustic lime helps to open up and lighten heavy clay soils, thus allowing water and air to penetrate and fertilise the soil, and making it easier of cultivation. On the other hand, it consolidates or makes firmer light lands, and therefore assists them in retaining their warmth and moisture. As lime has a tendency to **sink** deep into the soil, and as it is of more benefit to plants when near the surface, it is better to harrow it into the soil than to plough it in.

The soils that are principally benefited by the application of lime are stiff clays, and such soils as peats and mosses that contain a superabundance of organic matter. All kinds of turnips seem to thrive well under the influence of lime manures, and to produce healthier and more abundant crops. In a turnip crop grown on limed land there is an absence of that destructive disease known as finger-and-toe. Clover, beans, peas, and other leguminous plants seem also to be greatly benefited by the presence of lime, and grow most abundantly when that substance is plentiful in the soil.

EXERCISES.

1. Place a little pulverised clay in each of two bottles. To one add a little freshly slaked lime. Now almost fill the bottles with water and shake thoroughly until all the particles are in suspension. Set aside and observe in which bottle the water clears first.

2. Mix a little lime with some pulverised clay. Moisten with water and roll into a ball. Make another clay ball but without adding any lime. Set both aside, and when dry find by pressing with the fingers which is the more friable.

3. Prepare two balls as in Exercise 2, using sand instead of clay. When dry find in which ball the grains are held together more strongly.

4. Place a little ground limestone in a test tube, and add to it some dilute hydrochloric acid. Notice the vigorous effervescence due to the liberation of carbon dioxide from the limestone.

5. Place a small sample of dry soil in a test tube and cover it with dilute hydrochloric acid. Visible effervescence shows the presence of lime, while no effervescence indicates the lack of it.

V.—COMMON FARM CROPS.

We have seen that farm crops may be classified as (1) **root** or **fallow** crops, which are grown principally to supply stock with juicy roots in the winter time when other feed is scarce; (2) **fodder** crops, grown for their leaves and stems in order to provide green or dried food for stock; and (3) **grain** or **cereal** crops, grown chiefly for their grain or seed.

A.—ROOT OR FALLOW CROPS.

Turnips and **Swedes** are two varieties of the same kind of plant, and are grown specially for their roots, although the leaves are also eaten by sheep and cattle. Turnips are likewise grown as a garden crop, their "tops" being sometimes boiled for table use. The Swedish turnip, or Swede, is hardier and more nourishing than the commoner kinds of turnips and is distinguished from them by having leaves of a smooth, bluish colour. The leaves, too, spring from a "neck" or "collar" which is absent from the other kinds of turnips.

The turnip crop grows best on a light, loamy soil, but if the land is cultivated properly, it can also be grown successfully on many clay soils. In these, deep autumn ploughing is necessary. The seed-bed must be carefully prepared, as the success of the crop depends to a great extent upon how the seed is placed in the ground. The soil should lie close and moist around the small seeds, yet without shutting out the air from them. The sooner the seed is sown after ploughing, the more likely is the crop to succeed.

Turnips require a good supply of farmyard manure, if procurable. Some stimulating manure, such as guano or superphosphate, should always be supplied for the purpose of forcing on the young plants beyond the reach of the turnip fly, a very important consideration in turnip culture. The seed may be sown either broadcast or in drills. The latter method is now the usual one, and is far preferable to the other, as the seeds are then sown in rows ten or twelve inches apart. The intervening land can therefore be kept free from weeds, and be further stirred by the horse hoe and cultivator.

Turnips obtain most of their principal food from the surface of the soil, and absorb more nitrogen than the grain crops do. Their principal constituent is water, only about ten per cent. of dry matter being present, and when given to sheep or cattle they should be accompanied by some drier kind of food, such as oat-chaff, straw, hay, bran, etc. They make better feed when they are perfectly ripe, the medium-sized ones being preferable to the larger ones as they contain less water and more solid matter.

Kohl-rabi, or cabbage-turnip, is a kind of cabbage, the stem of which is swelled into the shape of a turnip. The leaves spring out of this tuberous stem, as they usually do from the stalk of a cabbage, and when they fall off they leave scars on its surface. The flavour of the tuber resembles that of a cabbage-stalk, and the plant forms an excellent food for sheep and cattle, whether eaten off the land where it grows, or whether stored and pulped. Kohl-rabi is a very hardy plant, resisting both drought and frost, and may be grown on land that has become "turnip sick." It is grown best on strong rich soils with plenty of manure, and is sown and cultivated in a similar manner to turnips. Its culture has, however, fallen into disuse for the reason that heavier crops of turnips can be grown per acre with the same treatment. It is also objected to on account of its excessively hard rind.

Mangel-wurzels (commonly called **mangels**), **sugar beet**, and **garden beet**, are all varieties of the same wild plant that grew originally near the sea shore. Sugar beet is grown principally in Germany, Austria, and France, sugar being extracted from the juice of the roots, and the refuse pulp furnishing an excellent cattle food. Garden beet **is grown as a salad plant**, its dark claret colour rendering it a welcome addition to red cabbage in the pickle jar.

Mangels are liable to fewer diseases than turnips, and usually produce a larger crop; but they will not grow on nearly so many descriptions of soil. They prefer a somewhat strong loamy soil, and thrive only on good land. They are not so much influenced by phosphatic manures as turnips are, as they are more able to absorb phosphoric acid from the soil itself. They are greatly benefited, however, by the use of nitrogenous manures, and, on account of their sea-side origin, they require a considerable supply of common salt. The salt attracts moisture, and helps to dissolve other plant food. Nitrate of soda, too, will stimulate the growth of the crop, and improve its quality. A mangel crop will thrive best in a hot and rather dry summer, while turnips seem to grow better when the summer is cool and moist.

The first sowing of mangels may be made in September, and continued during the following month, if the soil has had deep and careful tilling. The seed is drilled in rows far enough apart to admit of the use of the horse-hoe and cultivator, and the young plants are thinned out so that the remaining ones may have room to grow. The crop is not so suitable as turnips for feeding off purposes, as the roots will not stand severe frost. They are, therefore, generally taken up and stored in covered heaps before the frost comes, and given to the stock as they are required. Their feeding value increases by being kept a couple of months before using. They afford more suitable feed for dairy cows than turnips do, as they do not give the butter that peculiar flavour which is noticeable in the butter of turnip-fed cows.

Carrots and Parsnips are grown for the sake of their roots. They belong to the same order as celery, parsley, and some other garden plants. Parsnips are not much grown as a farm crop, but carrots form a useful winter food for horses and cattle. In the case of dairy cows, carrots are not so suitable as mangels for feed, as they make the butter hard and granular.

Carrots are best grown upon deep sandy soils or upon rich loamy clays free from stones. They may be sown in August and September, and the seed bed should be well pulverised, and stirred to a greater depth than for any other crop except parsnips. The manure should be well ploughed into the soil in autumn or during the winter, or be applied in a thoroughly decomposed state. The plants grow best on land that has been manured for another crop, as, if sown on newly-manured land, they are apt to become "forked." Carrot crops of from 27 to 30 tons per acre have been grown in Canterbury. Before planting, the seeds should be well rubbed, and mixed with dry sand or ashes. This prevents them from sticking together, and causes them to germinate more quickly and thus get a start of the weeds. Seed, already prepared for sowing, can, however, be had from any seedsman.

Potatoes are grown for the sake of their underground stems or tubers. In some places, as in the Channel Islands, they are grown under glass so as to be ready for the early market when prices are high. In New Zealand they are extensively grown as field crops. They grow best on a sandy loam, and on hill farms where the soil is suitable; but they do not seem to thrive so well on stiff clays. They are the only farm crop not usually grown from seed. For planting purposes some of the tubers, which are then called "seed" potatoes, are planted either whole, or cut in slices. The slices to be planted should contain not less than two "eyes," these being the buds from one of which a new stem and root will grow. For the earlier kinds of crop, "seed" potatoes, which have been previously sprouted in shallow boxes, may be planted in October, while the later kinds may be planted as late as the middle of December. The seed should be placed in the ground from 9 to 12 inches apart, and in rows from 27 to 30 inches between the drills. If the ground be harrowed just before the potatoes appear, a large quantity of weeds will be got rid of, and the crop will thus have a better chance of success. On ordinary land from 12 to 15 cwt. of "seed" potatoes per acre is required to ensure a good crop. As potatoes are principally used for human food, and are sometimes used to feed cattle, horses, and pigs, or for the manufacture of starch, they are generally removed from the farm, and therefore form an exhausting crop. They thrive admirably on soil supplied with well-rotted farm-yard manure, as well as manure containing a good supply of potash. Heavy crops are frequently produced on new soils, or on swamp land out of grass, without the aid of any manure whatever. Their shaws are frequently burnt on the ground where they were grown, or are ploughed into the soil, and thus return to it the food they had previously extracted, as well as the carbon they have obtained from the atmosphere.

The fruit of the potato, known as the potato "apple" or "berry," which contains the true seed, is sometimes sown for the purpose of producing new varieties. As long as seed potatoes only are planted, new varieties cannot be produced, and the longer they are grown in succession the more does the crop deteriorate both in quantity and quality. They are much improved, however, by a change of locality and soil. To keep up a healthy supply of potatoes, therefore, it is necessary that new varieties should be produced. This can only be brought about by cross-fertilisation in the flower, and the planting of the true seed thus formed.

The potato belongs to the same order of plants as the bitter sweet, and the deadly nightshade, both natives of Britain; the tobacco plant is of the same order.

B.—FODDER CROPS.

Fodder crops are grown entirely for their leaves and stems. They include the common forage grasses, clover, vetches, sainfoin and lucerne; and rape, mustard, cabbage, thousand-headed kale, etc.

The Grasses most commonly grown in this country are cocksfoot, ryegrass, meadow fescue, dog's-tail, and timothy.

Cocksfoot is a grass you will be easily able to recognise. It is a large, coarse-growing plant, harsh and rough to the touch. The leaves are broad, thick, juicy, and bluish-green, while the sheaths are white and flattened near the ground. It is a tall, quick-growing grass; and when grown in deep rich soil, its leaves are luxuriant and abundant. Cocksfoot is a very useful grass to the farmer. When young it affords excellent grazing, and when not too old, it is very suitable for hay-making purposes. On account of its coarse, vigorous leaves and stems, however, it is apt to become hard and woody, unless it is cut in good time. Its roots are fibrous, and descend deep into the earth, so

Cocksfoot, *Dactylis glomerata*, L.

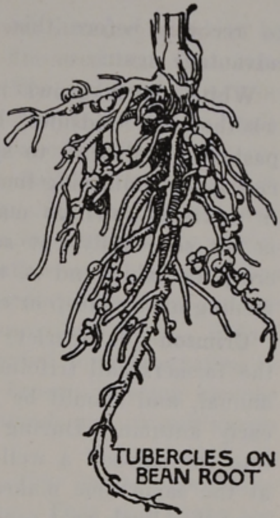
that, even in dry weather, it can usually supply itself with moisture from the soil. It grows well in damp and heavy soils, and in shady situations, but is not suitable for dry, sandy land.

The Ryegrasses are especially suitable for pastures. **Perennial ryegrass** is found wherever the land is rich enough to grow it. You will readily notice its dark-green polished leaves amongst the herbage on roadsides, where the soil has been enriched from the scrapings of the road and drains. It grows abundantly and luxuriantly on good land, and is benefited by the treading and grazing of cattle. Unlike cocksfoot, which grows in tufts, it forms a thick close sward, and therefore is more useful as a pasture than as a hayfield plant. **Italian ryegrass** is a larger and stronger plant than perennial ryegrass, and can be cut earlier. It should form part of every mixture used for laying land down in pasture, as it grows more quickly than any other grass, but it does not last long in the ground. It forms good feed for dairy cows while it lasts, increasing the yield of milk, and improving the flavour of the butter or cheese.

Perennial Rye Grass, *Lolium perenne*, L.

Timothy grass, or meadow cat's tail (commonly called timothy from the name of the farmer who first cultivated it), is much relished by all kinds of farm stock. It grows best on a cool damp soil, and yields a smaller produce when the land is dry. It is hardier than several other cultivated grasses, and suffers less from the frosts of winter. Although it succeeds best on cold clays, timothy will yield a fair return on light sandy soils if proper manures, such as sulphate of potash, have been applied. Like cocksfoot it is more useful as a green forage than when made into hay, and should be cut before flowering, as otherwise its fibres become woody, and its hay heavier and harder.

Some of the **Leguminous**, or pod-bearing **crops,** also make excellent forage. The most common and most useful of these are the **clovers,** of which there are various kinds, such as the common **red clover,** the **white** or **Dutch clover**, the **Swedish** or **Alsike clover,** and the **Italian** or **crimson clover.** Another variety, called **cowgrass** or **perennial red clover**, is also used for permanent pastures. We have already seen that clover is one of the crops used in a proper rotation, and forms an excellent preparation for wheat. Its roots go deep into the subsoil, and bring up from that source stores of nourishment, which are of the greatest use to the next crop when they are ploughed into the soil. Besides this, they exercise a good mechanical effect upon the land, helping to bind its particles together when too loose, and separating them for the admission of air, etc., when they are too closely packed together. The soil is thus rendered sufficiently firm without



From Neve's "Botany."

being made too hard—a condition very necessary to enable the roots of wheat to grow properly. Leguminous plants, too, are the only ones that draw their nitrogen directly from the air. This they are enabled to do by the help of certain bacteria which live in the little nodules to be seen on the roots of all leguminous plants. Little or no nitrogen is taken up by their roots, and therefore the soil, so far from being drained of its supply of nitrogen, has its supplies added to when the roots and stems decay.


Red Clover, *Trifolium pretense*, L.

Red clover, sometimes called broad clover, is usually grown as a hay crop, but is also used for sheep-feeding and for other purposes. On good soil it will last for two or three years, but the land on which it is grown soon becomes "clover sick," and has to be allowed a considerable time to recover, before this crop can be grown with advantage again.

White clover grows readily almost everywhere, whether on roadsides, lawns, downs, or ordinary pastures. It seems to spring up spontaneously on rich lands containing lime, and is generally included in mixtures sown to make permanent pasture. It is not so readily cut as red clover, owing to its creeping habit, and is, therefore, more suitable for feeding off by sheep or cattle.

Crimson (or Scarlet) **clover** is the plant which the farmers call trifolium. It is a winter-growing annual, and should be planted in late summer or early autumn. During the winter it sends down into the sub-soil a well-branched fibrous root, and at the same time makes a fair amount of surface growth. Each root sends up from twenty to forty stalks, terminating in a beautiful crimson or scarlet flower. The time of planting is from January to March, and if planted early a nice crop can be grazed off in the winter.

Lucerne, or purple Medick, is a leguminous plant grown extensively in Europe and America. It is very largely grown in Australia for grazing purposes and for hay. It grows luxuriantly even in hot, dry summers; its long roots, which penetrate the soil to a depth of many feet, supplying it with an abundance of moisture and plant food. It grows best on a calcareous soil, but it thrives well on a great many varieties of soil, and may be relied on to last for at least seven years. One of the chief factors determining success in lucerne culture is the treatment of the soil preparatory to sowing. In the early stages of its growth lucerne is apt to be choked by weeds, hence a fine seed bed, free from weed seeds, is essential. The cultivation of the young crop is risky, as the young plants are likely to be pulled out, but when once established lucerne is materially benefited by cultivation after each cutting. It makes into hay of a fine quality, and also forms excellent pasture for horses, cows, sheep, lambs and pigs. When weather or other conditions are unfavourable to its conservation as hay, lucerne can be converted into most nutritious silage. Indeed it is one of the crops best suited for conservation in this manner. The value of lucerne is being increasingly recognised in New Zealand, and its cultivation is consequently extending.

Sainfoin and **Vetches** are other leguminous plants which form excellent fodder. **Peas** and **beans** are also leguminous plants, but are grown rather for their seeds than for their foliage, and are, therefore, usually classified as grain crops.

Some of the **cruciferous** (or cross flower) family of plants, such as the turnip, swede, and kohl-rabi, are, as we have seen, grown for their roots. Other members of the same family are specially cultivated for their leaves and stems, and form useful fodder crops. Amongst these may be mentioned **rape**, **mustard**, **cabbage**, **thousand-headed kale**, and **chou moellier.**

C.—CEREAL OR GRAIN CROPS.

The cereals, or members of the grass family, that are principally cultivated for their seeds, are **wheat, oats, barley, maize**, and **rye**.

Wheat, when ground into flour, forms one of the principal articles of human food in English-speaking countries, and is, therefore, the most valuable of all the cereals. It grows readily in most parts of New Zealand, particularly in Canterbury and Otago. The Canterbury Plains produce more wheat than all the rest of the colony put together, nearly two-thirds of the total annual crop being grown there, while Otago supplies the bulk of the remainder. The different kinds of wheat sown vary according to the soil and the climate. The red wheats are stronger and coarser than the white varieties, and are, therefore, better adapted to a soil that is rather poor and a climate somewhat severe. The white wheats flourish on a fertile soil, and under a mild climate, and, as they produce a superior kind of flour, when grown they are likely to be more remunerative to the farmer than the coarser red wheat.

The varieties of wheat known as winter wheat, red and white chaffed, and velvet wheat, may be sown in May, June, and July, but this entirely depends on the season, and the fitness of the soil. Spring wheat, which includes the Tuscan varieties, is sown in September, and sometimes in October. Great care should be taken in the selection of the seed to be sown. Experiments have repeatedly proved that the best results are obtained by using nothing but large plump grain. The smaller grains should therefore be screened out. Wheat is subject amongst other diseases, to one known to farmers as smut. An effectual method of preventing an attack of smut is to pickle the seed before sowing it either in a solution of sulphate of copper (bluestone), a dilute preparation of Formalin or by the use of hot water. A rotation of crops, too, and a proper system of drainage is said to lessen the probabilities of the crop being attacked by smut.

When the wheat grain has germinated, it sends up several stalks. This is called "tillering," or frequently "stooling," and as many as fifty stalks have been known to shoot up from a single seed where the climate and the soil have been favourable. When the wheat has tillered, the young crop should be rolled in dry weather to consolidate the soil about the roots and stem, so that the warmth and moisture may be conserved for the benefit of the plants. The rolling is sometimes followed by harrowing, to prevent the surface from caking, and thus to enable the air and rain water to penetrate freely into the soil. Sheep are also sometimes put on the land to eat down the young shoots, and by their tramping make the soil firmer. This process causes the crop to grow more vigorously. Wheat should be cut before it is quite ripe, unless it is required for seed purposes. If this is not done much of the grain will be shaken out of the ear and be lost during the harvesting. The plants take little nourishment from the soil for two or three weeks before the seed is ripe, the ripening of the grain being due to the starch and other substances formed in the leaves moving up the stem and into the ear. As this process goes on after the wheat is cut, the seed is not prevented from then becoming quite ripe.

The average yield of wheat in New Zealand is about twenty-five bushels per acre, but crops of from seventy to eighty bushels per acre are often grown in particular localities. The largest crops are of course the most valuable.

Oats are grown more abundantly on the hill farms of Otago than in any other part of the Dominion, nearly two-thirds of the total annual crop being grown in that district. Large crops are also grown in Canterbury, Auckland, Wellington, Nelson, and other parts. The oat is a hardier plant than the wheat, and will thrive in a poorer soil, and under a colder climate; although, of course, the better the soil and the more suitable the climate, the more productive will be the yield. Careful cultivation and deep drainage are just as necessary in the production of a good crop of oats, as in the case of wheat. The cultivation required is much the same as for wheat. In Otago and Canterbury the seed is sown in August, or even in September, but in the more northerly districts it may be planted during the earlier months of May, June, and July. The seed may be sown more thickly than is necessary for wheat, as the young plants do not "tiller" or "stool," so much, or grow so many shoots from one seed. The crop should be cut before it is dead ripe, to prevent the grain from being scattered and lost during harvest, unless it is required for seed purposes.

Oats are chiefly grown for food for horses and cattle; but they are also grown for human food. Oatmeal contains more nitrogenous matter than wheat, and in the form of oatcakes or porridge is one of the most useful foods we possess, particularly for people accustomed to outdoor exercise in a cold climate. Oat straw cut into chaff forms a better fodder for horses and cattle than either wheat or barley straw, and often contains almost as much nourishment as hay. This is particularly the case when the crop has been cut before the grain is quite ripe.

Barley is not grown in this country to nearly the same extent as wheat or oats. It grows best on a friable loam, particularly on land where the previous crop was turnips or rape that have been eaten off by sheep. To produce good crops the land must be deeply tilled, and the surface soil pulverised. The seed may be sown in September, or even as late as the middle of October. The roots of barley do not penetrate the soil to any depth, as the plant obtains most of its inorganic food from near the surface. A barley crop may, therefore, precede a clover or a wheat crop, the roots of either of which go deep into the subsoil in search of nourishment.

Barley is used for feeding horses and cattle, and when made into pearl barley it becomes an article of human food. Its principal use, however, is for making malt, which is chiefly employed for brewing beer. For this purpose the barley is soaked in water, and then thrown into heaps, where it begins to germinate. When the radicles have sprouted to about the length of the grain, the barley is dried in a kiln, and the radicles rubbed off. The process of germination has partly changed the starch of the seed into sugar, and when the malt has been powdered and stirred in warm water the whole of the starch turns into sugar. If this be now allowed to stand for some time it will begin to ferment, during which process the sugar will be changed into alcohol. For malting purposes the barley must be quite ripe.

Maize requires a warm summer to enable its grain to ripen. It is not grown to any extent in this colony except in Auckland, which grows more than 90 per cent. of the total annual crop. In the warmer parts of America it forms the principal corn crop, and in New South Wales and Queensland it is also extensively grown, but in New Zealand its principal use is as a forage crop. It forms excellent feed for dairy cows, and should be sown in the early part of November on good land. The proper time to cut it for fodder is just before it begins to bloom. Maize is one of the most valuable crops for converting into silage.

Rye is also very little grown in New Zealand. When grown here it is used only as a forage crop. It is a hardier plant than oats, and will grow on poorer soil and under more unfavourable conditions. The peasantry of Germany and other parts of the Continent still use rye as their principal article of food.

VI.—ADAPTATION OF MANURES TO CROPS.

Manure for root and forage crops.—Neither turnips, swedes, mangels, nor, indeed, any root crops can be successfully grown unless they are suitably manured; except on tussock land broken up for the first time, or on land reclaimed from swamps or forests. The same principle applies to the other members of the cross flower family, such as rape, kale, and cabbage. The manures suitable for particular crops have already in part been mentioned.

Root crops are said to be "greedy and needy." They occupy the ground for a shorter time than the cereals, and have proportionately a far larger growth. They consequently impoverish the soil to a greater extent, and reduce its power of yielding. An acre of turnips will take from the soil five times as much potash, eight times as much soda, seven times as much lime and chlorine, and more phosphoric acid and sulphur than will an acre of wheat.

In order to restore this loss to the land, therefore, manuring is highly necessary, and as farmyard manure contains the greatest abundance of each of these substances, that kind of manure will be found the most useful. Farmyard manure is a general fertiliser, and contains nitrogen as well as the other ingredients necessary for plant growth. The nitrogen supplied by it is in a form which is more readily used by turnips than when nitrate of soda or sulphate of ammonia is applied.

The substance above all others that **turnips** require is phosphoric acid, and this as we have seen often occurs in least abundance in the soil. A seventeen-ton crop of turnips will contain in its roots and leaves about thirty-three pounds of phosphoric acid, while thirty bushels of wheat and its straw require only about twenty-two pounds. If the soil then is deficient in phosphoric acid, the application of superphosphate to it will have a marked effect on the growth of the root crops. If potash or lime be wanting, manures containing these substances should be applied. The farmer can, to some extent, judge from the nature and growth of his previous crops what artificial manures should be applied to the land. A dressing of superphosphate generally encourages the growth of turnips at their earliest stage, and puts the young plant beyond the reach of the turnip fly.

For **mangels,** superphosphate does not generally seem to exercise the same beneficial effect as upon the turnip crop. A mangel crop, on the other hand, is often greatly benefited by a top-dressing of nitrate of soda, or of sulphate of ammonia. Common salt, too, as we have already seen, when mixed with nitrate of soda, is a useful manure for mangels, especially upon dry soils and in dry summers. If the soil is deficient in potash, kainit may be applied with advantage.

Carrots and **parsnips** are usually manured with superphosphate or bone dust, as in the case of turnips. Top-dressings are not so effective in their case, as, being deep rooted, they depend more upon the richness of the soil and subsoil for their food supply. Superphosphate, mixed with a nitrogenous manure, is also an excellent manure for **rape, kale,** and **cabbages.** Being leafy in their nature they are strongly affected by the action of nitrate of soda, which always stimulates the growth of the leafy parts of plants. Guanos are also excellent manures for all these crops.

When growing **potatoes** market gardeners in the Old Country often supply to the soil as much as 20 or 30 loads of rich farmyard manure per acre. To this they sometimes add bone-meal and potash manures, or soot and sulphate of ammonia. In dry seasons farm manure is especially valuable, as it helps the soil to retain its moisture, and to prevent that stoppage of growth which, on unmanured land, causes the quality of the tubers to deteriorate.

Clover and the other leguminous plants derive most of their nitrogen directly from the air, and, therefore, do not require nitrogenous manures; but they stand in great need of phosphoric and potassic manures, and are specially benefited by the addition of lime.

Manures for Cereal Crops.—As wheat occupies the land nearly twice as long as oats or barley it removes more of the soil's constituents. With a proper rotation, nitrogen will generally be available in sufficient quantity in our soils. The crop, too, is generally able to obtain sufficient potash from the soil. The supply of available phosphoric acid, however, is likely to fall below requirements, and the manuring of wheat usually resolves itself into the use of some form of phosphatic manure according to the nature of the soil.

VII.—IMPORTANCE OF GOOD SEED.

Unless the farmer sows good seed he cannot expect that his crop will be either of the kind or quality that he desires. The first essential is that the seed should be capable of germinating. In some portions of it, owing to age or other causes, the embryo may be dead. Some clover seeds are unable to germinate on account of the thickness of their skins. The seed may have been gathered before it was ripe; and although such seed will often germinate, it will only produce sickly plants incapable of coming to proper maturity. The seeds, too, may have been injured by insects or fungus; or they may be so mingled with the seeds of weeds, or other objectionable plants, as to be unfit for sowing.

The germinating power of seeds may be **tested** in a very simple manner. Place the bottom of an unglazed flower pot in a shallow dish, having first scored ten parallel lines on the upper surface, and ten other lines at right angles to these and intersecting them. A hundred little squares will thus be formed, on each of which place a single seed from the sample intended to be sown. Now, pour some water gently into the dish until it rises to about half the thickness of the tile. The water will soon by capillarity rise through the pores of the tile and moisten the seeds. In a day or two the seeds will begin to swell, after which the skin or coat will burst, and a small whitish structure will push its way out. The seeds have sprouted or germinated. If you allow a sufficient time to give all of them a chance of sprouting, and then count the number that have actually germinated, you will know the germinating capacity of the sample per cent. If more convenient, place a piece of damp flannel in a saucer, and arrange 100 seeds in 10 lines. The Royal Agricultural Society has laid down the rule that in satisfactory samples the germination of cereals, green crops, clovers, and timothy grass should be not less than 90 per cent.; of foxtail, not less than 60 per cent.; and of other grasses, not less than 70 per cent.

This, of course, is merely a test of the germinating capacity of the seed, but gives no indication of any injurious impurities it may possess. The seeds of many plants resemble each other so closely that it is often almost impossible to tell whether the sample under inspection is what it professes to be or not. There is no excuse for sowing impure seeds; seed cleaning machines are now so perfectly constructed that with a little care the seeds can be made perfectly free from the seeds of weeds. It is false economy to choose badly cleaned seeds because they happen to be cheap.

Careful farmers are generally very cautious in the purchase of seeds, and bear in mind the saying that "bad seed is dear at any price." Grass seeds, especially, are very liable to adulteration with seed of an inferior kind, and also with old seed that will not germinate. Samples of seed should be bought with a guarantee of their **purity** and **germinating power**, these being the two essential qualities they must possess in order to produce satisfactory results.

EXERCISE.

1. Test the vitality of various seeds by placing 100 of each on damp blotting paper or flannel in a saucer. Examine each day and remove any seeds that have germinated. Tabulate the result in your notebook.

Variety Tested	Percentage germinated after									Total
	1 day	2 days	3 days	4 days	5 days	6 days	7 days	8 days	9 days	

VIII.—PROPAGATION OF PLANTS BY CUTTINGS, TUBERS, BULBS, ETC.

We have seen that plants produce seed in order to perpetuate their kind. Other methods of propagation, both natural and artificial, are, however, commonly met with in plants. In all such cases a detached portion of the parent plant is induced to develop into a new and complete plant.

Natural examples of reproduction by division of the parent, or vegetative reproduction, as it is called, are seen in the potato, crocus, and narcissus, which are ordinarily propagated by means of tubers, corms, and bulbs respectively. Of the various artificial methods of propagation by division which are practised the commonest are by means of cuttings and layers, and by budding and grafting.

Propagation by one or other of these methods ensures the production of a number of plants exactly resembling the parent, a result desired in the propagation of fruit trees, roses, etc., but which is not attainable with certainty in reproduction by seeds. Further, these methods effect a great saving of time in producing the desired plants, and also afford a means of propagating plants that rarely or never produce seed, *e.g.*, banana, sugar cane, certain kinds or oranges, etc.

Cuttings.—Hard wood cuttings are made in the autumn from well-matured shoots of the current season's growth. These shoots are cut straight across just below a node at the base, and above a bud at the top, making a length of ten or twelve inches. They are inserted in the soil for about two-thirds of their length, the buds on this portion having previously been removed. This latter precaution is necessary only in cases where a clean stemmed bush is desired. On black currant cuttings the lower buds are frequently left. During the winter months the cut surface heals over or forms callus tissue, and adventitious roots are developed during the next growing season. Currants, gooseberries, and many other plants may be readily propagated in this way.

Layering.—In propagation by layering, a branch is bent down, and after an oblique upward slit is made almost through the stem at a node, it is pegged down and covered with soil. Instead of tongueing as above, a ring of bark about half an inch wide is sometimes removed before pegging down the branch. In either case the object is to interrupt the flow of sap backward from the leaves, thus causing an accumulation of plant food above the cut, which thus favours the development of adventitious roots. When these are sufficiently developed the new plant may be severed from the parent.

Budding.—In budding, a bud is cut from the stem of the plant desired to be perpetuated and inserted under the bark of another called the stock, where it develops. The operation is performed in January or February, and the method most commonly practised is that known as T budding. The first step in the operation is to make a vertical cut through the bark $1\frac{1}{4}$ inches in length and then a horizontal cut across the top of it. (Fig. 1, p. 150). The bark is then slightly raised. A well-developed leaf bud is next selected from the middle of a shoot of the current season's growth. In removing this bud the blade of a budding knife is inserted about half an inch below it and an upward cut is made through the bark passing behind the bud and coming out about half an inch above it. (Fig. 2). After this operation a thin slice of wood will be found adhering to the bark (Fig. 3). This should be removed, care

Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5

being taken not to tear out the core of the bud in so doing. Using a portion of the leaf stalk which has been left to serve as a handle, the bud with its shield of bark is now inserted in the T incision and pressed well down (Fig. 4). This done, the whole is bound firmly in position with moistened raffia, the bud itself being allowed to protrude between the binding (Fig. 5). As the bud shows signs of developing, usually in from three to six weeks, the raffia should be loosened by cutting on the side of the stock opposite the bud. The stock is cut back to within six inches of the bud in late autumn or winter, and all other growths than that from the bud inserted should be rubbed off.

Fruit trees are usually budded about four inches above the ground in order to prevent the growth from the bud striking roots into the soil.

Grafting.—In this process a portion of the stem of the desired variety is induced to unite with the stock of another. Several methods are practised, the commonest being the whip or tongue graft, the crown or bark graft, and the wedge graft.

Whip grafting is practised in working small stocks. In this method a sloping cut $1\frac{1}{2}$ to 2 inches in length is made upwards on the stock a few inches above the ground. A cleft is made in this surface by cutting downward for a short distance, commencing at a point halfway between the centre and its upper point. The graft or scion is cut to correspond, the cleft, however, in this case being made between the centre of the cut surface and its lower point. In joining the two portions, the tongue of the scion is fitted into the cleft of the stock and pressed firmly into position, care being taken to bring the bark of the scion in contact with that of the stock at least on one side. This latter precaution ensures that the growing cambium layer of each beneath the bark will be in contact, and by the growth of new tissues, will effect a complete union. The junction should be bound with raffia and covered with grafting wax, or simply bound with waxed cloth. Two or three buds on the scion above the binding are sufficient.

Crown and Wedge Grafting are practised chiefly in re-working old trees. Some few weeks before

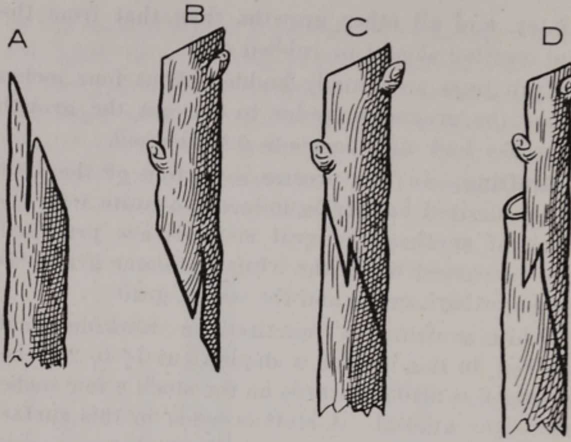


Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 1, Whip graft: A, stock; B, scion; C, stock and scion joined together; D, whip graft on stock thicker than the scion. Fig. 2, Wedge graft. Fig. 3, Crown graft. Figs. 4 and 5, Scions cut for crown grafting.

either of these operations, the branches are cut back to within a short distance of the main stem, and immediately before inserting the scions a few inches more are cut off, thus giving a fresh surface to work upon. In crown grafting the scions are cut as for whip grafting, but without the cleft. One or more of these are inserted in slits two inches long made in the bark of the stock and firmly bound, after which the wounded parts are completely covered with grafting wax.

In wedge grafting, scions cut wedge shape are inserted into a cleft made in the stock, the bark of the scion meeting that of the stock at least on one side. The whole should then be bound and waxed as in crown grafting.

The scions should be cut during the winter from healthy wood of the previous season's growth, and buried in moist soil in order to retard the development of the buds until required. If the scions are in a more forward condition than the stock the developing buds exhaust the reserve of food in the scion before a union is effected.

Grafting is usually performed in September or October.

Fruit Tree Stocks.—We have referred to the tree to which a bud or scion is united as the stock. In fruit tree culture, the stock on which the desired varieties are budded or grafted largely determines their future growth and fruitfulness. As failure may result from trees worked on stocks unsuited to the variety and the soil, the selection of varieties for stock purposes is a matter of considerable importance. For apples the stock most largely used in New Zealand and Australia is the Northern Spy. It is a vigorous grower, resistant to the attack of woolly aphis on its roots, and suited to all varieties of apples. Apricots, peaches, and pears are largely worked on their own seedlings, but for certain classes of soils other stocks are used.

IX.—OBJECTS OF PRUNING.

The branches of fruit trees are pruned in order to make the tree assume a desired shape; to improve the quality, and regulate the supply of fruit; or to encourage the growth of new wood.

Pruning is especially important in the case of such trees as peaches and apricots, which produce fruit only upon the younger branches. When some fruit trees make too much growth without bearing fruit, it is often found desirable to have their **roots** pruned. When this is the case with pears, and similar fruit trees, a trench is dug some two or three feet from the stem, the coarse or wood-producing roots are then cut away, but the small roots and fibres near the surface are left uninjured. When the tap root is cut, fresh soil should be added to encourage the growth of new roots near the surface.

X.—INSECT FRIENDS AND FOES.

True insects (Lat. *inseco*, I cut into) play a very important part on the farm, and usually their work is harmful. In number they comprise about four-fifths of the Animal Kingdom. There are over

200,000 species known. Their bodies have three great divisions—the head, thorax, and abdomen: in the full grown stage, these divisions may always be readily distinguished. There are never more than three pair of legs, and these are attached to the three rings of the thorax: in most insects the two hinder rings also carry the wings. The abdomen of a mature insect never carries any legs.

The life history of the New Zealand "army worm" or grass caterpillar (see fig.) may be taken as typical of most insects. The female lays her eggs on the grass or other vegetation. Directly the young caterpillars, or **larvae,** frequently called "grubs," and in America often known as "worms," come out of the eggs, they begin to eat the grass, young oats, or garden vegetables. They are always hungry, eat greedily, and grow rapidly. At certain periods they moult or throw off their old skin. When full grown, they cease to eat, become sluggish, and look about for a safe sheltered spot, such as a crevice in the bark of a tree, a tuft of grass, or a sod of earth; and there, after spinning soft silken nests, they go to sleep. During this sleep, the caterpillars gradually contract and become covered by a hard skin or case, pointed at one end. This is known as the **chrysalis,** or **pupa** stage (Lat. *pupa,* a doll). Gradually the bodies inside these cases undergo remarkable changes: and at the proper time the cases are burst, the complete moths gradually crawl out, and spread their wings to dry. Then they fly off, lay their eggs, and the whole process is repeated. The moth is known as the "**imago**" (Lat. *imago*, an apparition).

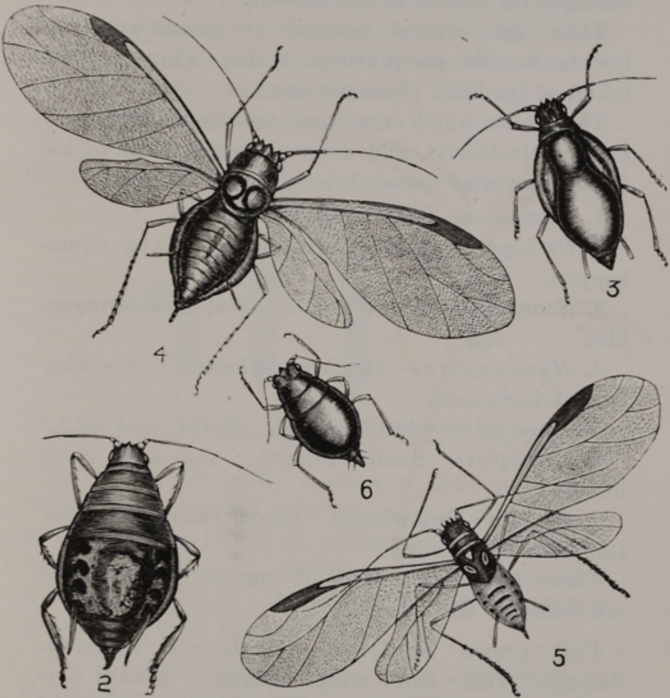
Young twig with "black aphis" on stem, reduced.

In some of the lower orders of insects, the young when they leave the egg resemble the adult in everything except size. They undergo no changes, except that they grow larger. The species in which this occurs are small, and frequently destitute of wings when fully grown. Hence they are called *Aptera* (Greek, *a*, without; *pteron*, a wing). In other insects, with a few exceptions, the adult has wings: and the young pass through the changes described above, and known scientifically as the Metamorphoses.

The plant lice, one species of which is familiar to you as the "blue blight" of cabbages, the black aphis which attacks the fruit trees (see fig.), and the phylloxera which frequently ruins vineyards by sucking all the nourishment from the roots, are

Aphides; they are amongst the greatest pests the gardener has to deal with.

Centipedes and Millepedes (false wireworms) are destructive to vegetation, but are not insects. They



Black Aphis. Fig. 2. Apterous viviparous female. 3. Pupa. 4. Winged viviparous female. 5. Winged male. 6. Oviparous female. All magnified.

belong to the class called *Myriapoda* (Greek, *muria*, ten thousand, *pous*, foot). They do not undergo the metamorphoses or changes which characterise true insects.

Spiders are not insects: they have eight legs instead of six. They belong to the class *Arachnida*, which also includes the ticks and scorpions. They are more nearly related to the Crustacea—crabs, shrimps, etc.—than to the Insecta.

There are several systems of classification of insects, but the peculiarities of their wings may be taken as the chief characteristic.

The insects which cause most trouble to the farmer and horticulturist, and amongst which most of his friends are also found, belong to the orders:—

1. *Coleoptera*—Sheath-winged. Beetles.
2. *Orthoptera*—Straight-winged. Crickets, Grasshoppers.
3. *Neuroptera*—Nerve-winged. May-flies, Dragonflies.
4. *Hymenoptera* — Membrane-winged. Saw-flies, Bees, Ichneumons.
5. *Lepidoptera*—Scale-winged. Moths (see fig.).
6. *Homoptera*—Similar-winged. Aphides, Scale insects.
7. *Diptera*—Two-winged. Gnats, Daddy-long legs, Bot flies, House flies.

There are other orders of insects; but we need not consider them here.

Full grown beetles frequently do enormous damage. Their front wings consist of a hard pair of wing sheaths, which cover and protect the folded hind wings. These insects have biting jaws, and they all pass through the complete series of changes we have noticed in the case of butterflies—egg, larva, pupa, full grown insect. The larvae are usually fleshy grubs, and are very destructive to plants. The New Zealand brown beetle, or grass grub, which in the larval stage destroys the roots of grass, and in the beetle stage eats the leaves of trees; and the wire-worms (the larvae of click beetles) live in the soil for years, and attack the roots of grasses, cereals, and various other crops. The turnip fly, or flea beetle, is another insect of the same order, and, as its name implies, is very destructive to turnip crops.

Grass Grub, White Grub, Chafer, Brown Beetle (*Odontria zealandica*).

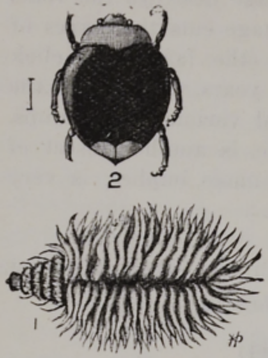
Fig. 1 Larva, side view. Fig. 2. The same from below. Fig. 3. The same from above. Fig. 4. Adult beetle. All natural size. From nature.

Ladybirds are useful beetles, as both adult and larvae feed upon the aphides, or plant lice, such as green fly, blue blight of cabbages, etc., which we have seen to be so destructive to the vegetable world. Ladybirds, therefore, should be rather encouraged than destroyed (see fig.).

Weevils also belong to this order: and some of them cause immense loss to the farmer and grain merchant by eating the grain, peas, beans, etc., in the stores (see fig.).

Grasshoppers—which cause such devastation in South Africa and Australia—belong to the Orthoptera or straight-winged order.

Ladybirds.



Red-headed Ladybird and larva—
eats mealy bug.

Another Ladybird (*Leis*)—
eats aphis.

Fig. 1. Cushion Scale (*Icerya*). Fig. 9. Ladybird beetle. Vedalia, which eats scale. Natural size. Fig. 8. Magnified.

GRAIN WEEVIL, CORN WEEVIL (*Calandra granaria*).

Fig. 1. Grain of wheat, showing weevil emerging. Fig. 2. Weevil. Fig. 3. Grain of wheat with two holes, the interior having been entirely eaten out. Figures all magnified. The line near Fig. 2 indicates the natural size of the beetle.

The Nerve-winged insects:—

To this order belong the lace-winged flies or golden eyes which devour large numbers of Aphides; also the dragon flies, which are the hawks of the insect world, and by killing injurious species assist the farmer.

The membrane-winged insects usually have four membranous wings, in which are but few veins. They are developed from eggs, and like the beetles pass through a complete series of changes. Wasps, bees, soldier-flies, and other true stinging insects, and most of the parasitic insects, such as the Hessian fly parasite, belong to this order (see fig.).

Amongst the species most destructive to plants are the saw-flies, such as the cherry slug (see fig.) the larvae of which have ten pairs of legs, and feed on the leaves or stems of plants.

HESSIAN FLY.

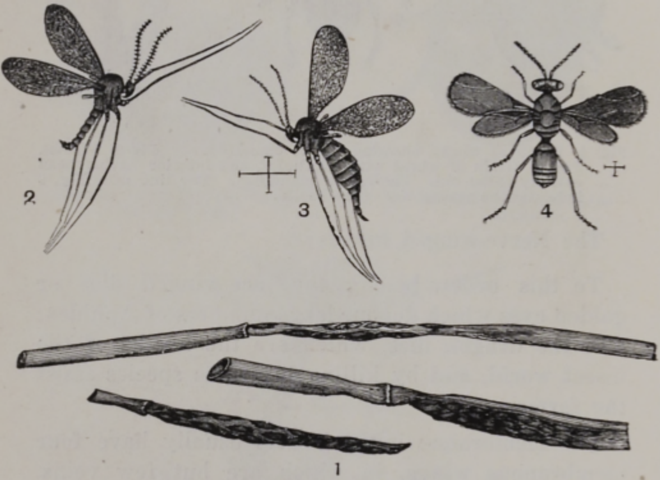


Fig. 1. Straw, with fly in chrysalis stage, showing damage to straw. This prevents the head from filling and causes the straw to fall. Figs. 2 and 3. Male and female flies. Fig. 4. Parasite, which lays eggs in chrysalis of the Hessian fly, and so helps the farmer to fight the pest.

PEAR AND CHERRY SLUG; LEECH; SLUG-WORM

(*Selandria cerasi*).

Fig. 1. Portion of pear-leaf with eggs. Fig. 2. Leaf with young larvæ. Fig. 3. Leaf showing surface partly destroyed: larvæ about natural size. Fig. 4. Larva, enlarged. Fig. 5. Fly, enlarged. Fig. 6, Fly, natural size.

Butterflies and moths belong to the scaly winged order of insects. Almost all of them are very destructive to vegetation, their larvae especially so. The green caterpillar of the diamond back turnip

SHOT-HOLE MOTH, DIAMOND-BACK MOTH, CABBAGE MOTH (*Plutella cruciferarum*).

Fig. 1. Leaf a cabbage, much reduced, showing caterpillars and cocoons, natural size. Fig. 2. Moth, natural size, flying. Fig. 3. The same at rest. Fig. 4. Caterpillars dropping to the ground when disturbed. Fig. 5. Moth magnified.

moth attacks the under surface of the leaves of the plants of the cabbage tribe, and by completely riddling them soon destroys the plant. Other caterpillars attack the roots of turnips, cabbages, mangels, and beet.

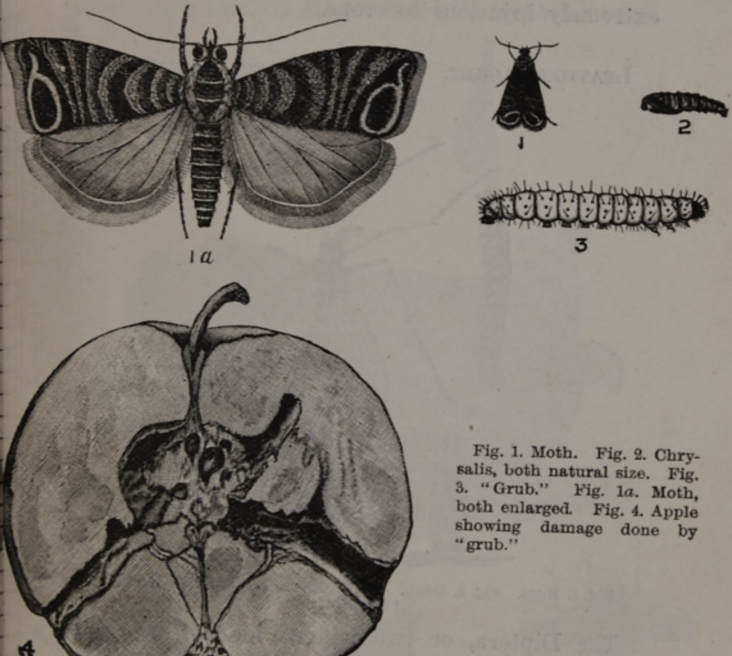


Fig. 1. Moth. Fig. 2. Chrysalis, both natural size. Fig. 3. "Grub." Fig. 1a. Moth, both enlarged. Fig. 4. Apple showing damage done by "grub."

Codlin Moth.

The larvae of the codlin moth are especially destructive to the apple crop.

Similar winged insects have wings of the same texture throughout, either wholly leathery or wholly membranous. The larva is much like the full grown insect and does not go through the chrysalis stage. The aphides, already noticed, of which there are many varieties, belong to this order. They are all extremely injurious to crops.

LEATHER-JACKET, DADDY LONGLEGS, CRANE-FLY
(*Tipula* sp.)

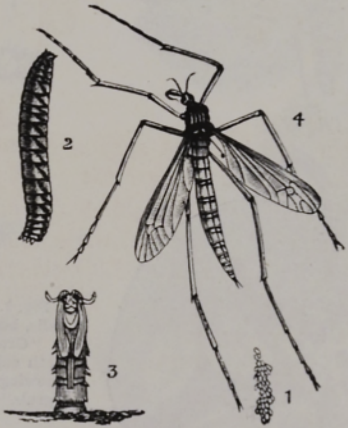


Fig. 1. Eggs. Fig. 2. Grub. Fig. 3. Chrysalis. Fig. 4. Perfect Fly.
(After Curtis)

The Diptera, or two winged insects, have only one pair of wings, and these possess but few veins. This is the order of the true flies, of which the house fly and the blow fly are the most familiar examples. The Hessian fly (see fig.) does great damage to wheat. The leather jacket, or larva of the daddy-long-legs is a very destructive crop pest belonging to this order (see fig.). It lives in the soil, and like the wireworm, does great damage to the roots of plants.

The sheep tick and the horse bot fly are other injurious dipterous insects.

HORSE BOT FLY, OR HORSE BEE (*Gastrophilus equi*).

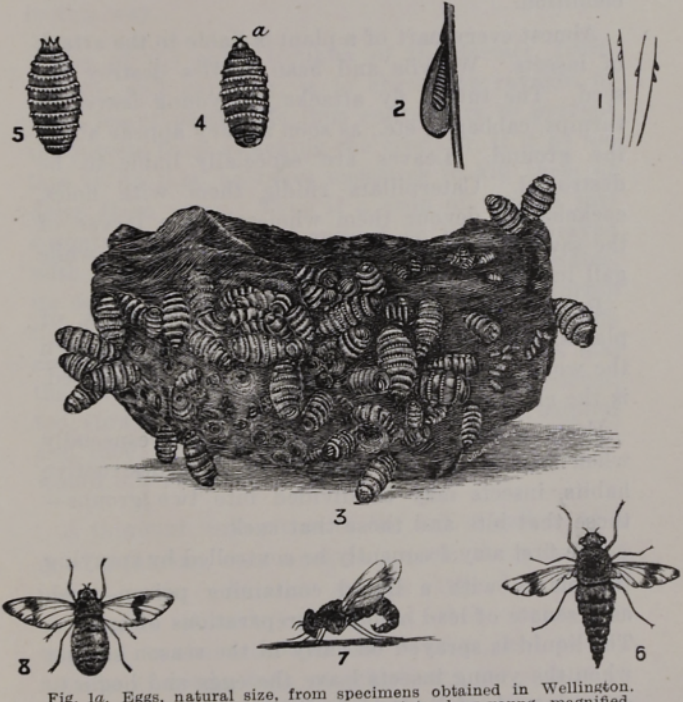


Fig. 1*a*. Eggs, natural size, from specimens obtained in Wellington. Fig. 2. The same, rendered transparent to show young, magnified. Fig. 3. Portion of stomach with larva attached, also showing "pits" from which larvæ have been removed, natural size. Fig. 4. Larva further developed. Fig. 5. Chrysalis. Fig. 6. Female fly. Fig. 7. Side view of female, showing the way in which the abdomen is turned under. Fig. 8. Male fly.

Some insects are more especially destructive when they are in the caterpillar or grub stage, as in the case of wire-worms, leather jackets, and surface caterpillars. Others, like the turnip fly, are more injurious when they are fully grown. Aphides and cockchafers, on the other hand, are almost equally destructive in both the larval and the perfect condition.

Almost every part of a plant is liable to the attack of insects. Weevils and bean beetles destroy the seed. The turnip fly attacks the young leaves of turnips, cabbages, etc., as soon as they appear above the ground. Leaves are especially liable to be destroyed. Caterpillars riddle them with holes, cockchafers devour them wholesale, the larvae of the saw-fly gives them a scorched appearance, while gall insects cover them with swellings.

Beetles and aphides destroy the blossoms of plants, while other insects attack the stems and even the woody trunks. The wireworm, already noticed, is the chief enemy to the roots of crops.

From a farmer's point of view, and especially when considering the question of their destructive habits, insects may be divided into two groups—those that bite and those that suck.

The first may frequently be controlled by spraying the plants with a liquid containing poison—such as arsenate of lead or other preparations of arsenic. The liquid is sprayed on early in the season so that when the young insects leave the eggs and begin to gnaw into the foliage or fruit, they may get a fatal dose of poison before they can do any serious damage.

Poison would be useless against the suckers because they do not bite, but they insert their probosces into the tissues of plants and suck up the juices. These are therefore killed by the contact of such sprays as red oil emulsion or kerosene emulsion, or by placing a tent over the trees and filling it with a poisonous gas—scale insects are often fought in this way.

One of the chief troubles of the farmer, fruit-grower, and gardener, is to check the ravages of these insect pests. He thus endeavours to prevent the insects from attacking the crop; or, if it be too late to do this, he takes measures to kill them or drive them away. Thus if a crop of turnips just sprouting through the ground be lightly sprayed with diluted kerosene emulsion or with tar water, its odour will in some measure prevent the turnip fly from attacking the plants until they are sufficiently grown; for it is the smooth seed leaves that the turnip fly is especially fond of. The gardener, too, sprays or paints his fruit trees with oil, sulphur and lime, or other substances, to kill insects that would otherwise work havoc.

A thorough cultivation of the soil, together with good manuring, does much to prevent the growth of insect pests. As the soil is turned up and thoroughly stirred, insects and their larvæ are exposed to the action of the weather, and to the attacks of birds, both of which are the means of destroying vast quantities. At the same time, everything that tends to make the plants healthy, vigorous, and quick growing, makes them more hardy as well as tides them over the youthful period when they are more liable to be attacked.

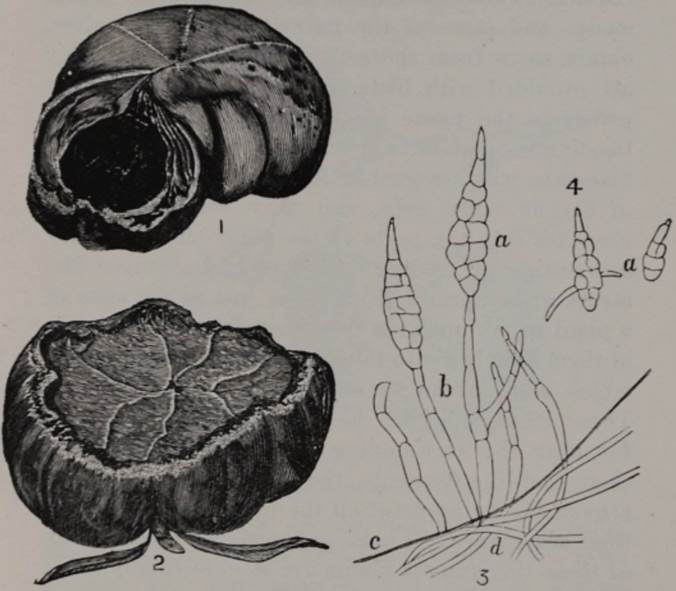
A proper system of rotation of crops, too, lessens their liability to insect attacks. If one crop is constantly grown on the same piece of land, the special kinds of insects which feed on it tend to increase in numbers, as their food is always ready for them. But if the crop be changed for one that does not afford such suitable sustenance for these particular insects, they speedily die off and disappear.

XII.—FUNGUS PESTS.

You have no doubt seen **mushrooms** and **toad stools** growing in the fields. These plants derive their food from the decaying organic matter in pasture lands. Mushrooms are used as human food, and form one of the most common forms of **fungus,** but toad stools are not eaten. There are plants of the same kind that cause diseases in orchards and crops; but, unlike the mushroom, these are so extremely small that they cannot be seen separately without the aid of a microscope.

You all know that if a piece of bread or cheese be kept for some time, it becomes covered with a kind of bluish mould. This mould consists of very tiny fungus plants that feed on the dead organic matter of the bread and cheese. Such plants are very useful in using up decaying organic matter that might otherwise pollute the atmosphere with poisonous germs, and cause disease to spread generally.

Another class of fungus plants, however, are not capable of feeding on decaying organic substances, but derive their food directly from living organic tissues. In this respect all fungi differ from



Figs. 1 and 2. Tomato fungus. Fig. 3. Drawing of fungus magnified 400 diameters, taken from the black mass shown on fig. 1. The dark line *c* is the sunken surface of the tomato; *d* are the roots (*mycelia*) of fungus penetrating the tissues of the fruit; *b* the stems of the fungus. Fig. 4. Spores, the larger one germinating.

ordinary plants. We have seen that most plants obtain the greater part of their solid substance from the air in the form of carbon dioxide, and that this, together with the food they have derived from other sources, is changed in the presence of sunlight by the aid of chlorophyll into proper plant food.

Now, as fungi have no chlorophyll, they are not able to assimilate the carbon from the carbon dioxide of the atmosphere, and therefore they cannot themselves manufacture the carbon compounds they require. These substances they must obtain ready-made; and some of the parasitic fungi, therefore, obtain them from the cells of living plants. They are provided with little threads, or filaments, that penetrate the tissue of the leaf, stem, or fruit of the living plant on which they are resting. These filaments, which resemble the roots of plants, consist of one or more cells, and they send out many branches into the parts of the plant on which they are resting or feeding. Thicker and stronger filaments grow upright from these, just as the stem of a plant grows upwards from the roots, and the ends of them soon begin to thicken into swellings or cases, which contain the spores or seeds of the fungus. These when ripe will be distributed by the wind far over the surrounding country. By means of their root-like filaments, the fungi obtain from the cells of the living plant all the food they require for their sustenance. It must be remembered that many of these tiny fungus plants are so exceedingly small that four or five thousand of them can be placed side by side on a line an inch long. So that if many of them have found resting places on any given plant—each one of which will be sending its branching filaments into the cells of the plant in search of its life food—you can readily understand that the plant that supports the parasites will soon become starved. Its living cells will be broken up and robbed of the food they contain; and the plant itself, unable to keep its nourishment for its own uses, will soon pine away and die.

Some of the most destructive diseases produced by parasitic fungi are known as **scab** (see fig.), **mould, rust, mildew,** and **smut.**

Apple, leaves and fruit attacked by scab.

Rust and **mildew** are diseases caused by fungi, that attack the leaves and stems of wheat and other cereals, and also meadow and pasture grasses. Orange-yellow lines and spots appear on the leaves, and rapidly increase in size and numbers. When the leaf is shaken a coloured powder is set free, which under the microscope is seen to consist of fungus spores or seeds. As the summer advances, the lines and blotches become almost black. As the fungus develops, it requires more and more nourishment, all of which is taken from the wheat or other plant. As the grain, therefore, does not obtain the sustenance it requires to perfect it, it will not ripen properly. In mildewed corn crops the grain is thin, shrivelled, and of inferior value. If the crop is severely attacked, the straw is so much discoloured as to be worthless, and should be burnt.

Mist, and dampness generally, seem to be favourable to the increase of rust and mildew. The pest is also more prevalent where the crops are surrounded by bushes and trees that prevent the free circulation of air. Open, wind-swept crops are not so liable to attack. Wet, warm weather is also favourable to the growth of the fungus.

Loose smut and **bunt,** or **stinking smut,** are other diseases caused by parasitic fungi that attack the cereal crops. The ravages of **bunt** are confined chiefly to wheat, of which it destroys the grain, which is converted into a dark greasy mass with a foul fish-like odour. The spores are so minute that a single grain of wheat may contain upwards of four millions of them. **Loose smut** is usually most destructive to oats, but it also attacks wheat and barley. The spores are either sown with the seed, or are blown on to the field from other diseased crops. The fungus grows up the plant and attacks and wholly destroys the ears. The spores form a very fine powder, the smell of which is not foul as in the case of bunt. Bunt or stinking smut can be prevented by pickling the seed in a 1½ per cent. solution of copper sulphate (bluestone) for three minutes, and after being allowed to drain, steeping in ½ per cent. solution of lime water for two or three minutes. This treatment is also effective for loose smut in oats, but for reducing the liability of wheat and barley to attack by this fungus, soaking in hot water is the more effective treatment. An accurate thermometer is necessary for this treatment.

Ergot is a fungus disease which most commonly occurs on the rye crop, and is, therefore, often called ergot of rye, but it also attacks the other cereals and grasses. The ears of infected plants show hard dark violet coloured protuberances in place of some of the grains. Ergots are poisonous, and produce very injurious effects on animals that eat the ergot-infested crop. As the ergots fail to germinate if well covered with soil, deep ploughing in order to bury any fallen ergots is beneficial.

Club-root is a widely distributed disease that attacks turnips, cabbages, rape, etc. Plants affected by this parasite show irregular swellings on the roots which, in cases of severe attack, become completely deformed. These malformations prevent the plant from obtaining its proper supply of water and nourishment from the soil, and therefore retard its growth. When badly attacked the plant dies before reaching maturity. The disease is caused by the attack of a very tiny fungus, which completely fills the cells which form the substance of the root. Liming the ground is the most effective method of controlling this fungus. All refuse from a diseased crop should be burnt, and the cultivation of a cruciferous crop on the infested area should be avoided for at least three years. Club root is very common in many parts of New Zealand. The small knob-like swellings frequently seen on the roots of turnips, etc., are not always due to the club-root fungus, but are comonly caused by the attack of eelworms. Such malformations are usually smaller than those due to the club-root fungus.

The Potato Disease (**Irish Blight**).—The potato is liable to many diseases which injure the crops more

Leaf of potato attacked by fungus (*Macrosporium solani* or *alternaria solani*)

or less; but one disease is so common and widespread that it is known as the potato disease. Half a century ago this disease attacked the crops in Ireland with such severity that almost the whole of them were destroyed, and the majority of the people were in consequence reduced to a state of semistarvation. From this attack originated the name Irish Blight, under which the disease is now generally known. Potatoes form such an important article of daily food, and are everywhere so generally cultivated, that any widely spread disease amongst them seriously reduces the yield and produces a great deal of suffering and misery, especially amongst the poor people. The disease is caused by the growth of a particular kind of fungus, the botanical name of which is *Phytophthora infestans* (Greek, *phuton,* a plant; and *pthora,* decay, or destruction). Spraying with Bordeaux mixture at regular intervals during the growing season has proved a complete preventive against the attacks of this fungus. Care should also be taken to secure Blight free "seed."

Farmers are, however, familiar with another form of fungus known as *Macrosporium,* or Early Blight. It attacks the leaves and causes them to become brittle and wither away.

The starch, which forms the principal constituent of the tubers, must be carried down to them from the leaves, where it is manufactured. The tubers are, therefore, stopped in their growth by the loss of the leaves: not being mature, they will not keep, and frequently become watery and rotten. This disease sometimes causes considerable loss to New Zealand farmers. Proper spraying with Bordeaux mixture (bluestone and lime) will prevent the disease.

Another disease which causes great loss to potato growers in New Zealand is **Scab**. This can be prevented by soaking the seed potatoes in preparations of corrosive sublimate, or formalin. The former is a powerful poison, and must be used with extreme care.

As in the case of other farm pests, a rotation of crops tends to check this disease. If potatoes are not planted in the same paddocks during the next and succeeding years, the diseased stalks and tubers of the old crop left to decay in the land are unable

Potato affected by Scab.

to supply sufficient sustenance for the fungus, and it consequently speedily dies out.

The diseased stalks and tubers should, however, where possible, be burnt. No seed from an infected crop should ever be used, nor should diseased potatoes be placed on the manure heap. Suitable manuring and good cultivation tend to make the crops vigorous in some cases to resist the disease. Seed from a different part of the country, and new varieties of potatoes, do not seem so liable to become affected by the disease as the same or older kinds formerly planted. Varieties of potatoes that have been cultivated for a number of years seem to degenerate. Their quality deteriorates, and their constitutional vigour becomes weakened, so that they fall an easy prey to the disease.

The **wet rot** of potatoes is caused by certain species of bacteria. These also cause the rot of onion bulbs, and the pink decay of wheat. As a rule, however, bacteria produce very few diseases of plants.

*Leaflets indicating the principal fungicides and insecticides that have proved effective, and their method of preparation and use are published by the Department of Agriculture.

XII.—WEEDS.

Californian Thistle.

Fig. 1. Flower- and seed-heads. Fig. 2. Leaf. Fig. 3. Underground stem, showing creeping habit, and the manner in which stems are developed at short intervals. All greatly reduced.

A weed is a plant which injuriously affects the interest of the farmer or gardener. Weeds in this

Dominion cause enormous loss to farmers—it has been estimated at over a million and a half sterling per annum.

The Ragweed or Ragwort
(*Senecio jacobæa*).

A Root Leaf.

Most of our weeds have been introduced from other countries, in grass and other seeds.

Weeds do almost incalculable harm to crops and pastures: for, not only do they take up space which should be occupied by more useful varieties of plants, but they absorb a very large proportion of the food and moisture which should go to stimulate the growth of the crop. Moreover, as the crop or grass is eaten down, the weeds, being very free

Ragweed—Portions of Stems, showing Flowers, Buds, and Stem Leaves.

seeders, seize on the bare spaces and so spread rapidly.

The chief cause of the spread of weeds is the use of improperly cleaned seed. The use of "cheap" (*i.e.*, dirty) seed should be looked on as an unpardonable crime: for, not only does it injure the land of the person who sows it, but before long the weed seeds are carried far and wide, causing great loss to his neighbours. The use of clean seed, followed by proper cultivation, goes far towards controlling weeds.

Amongst the worst weeds in New Zealand are the Californian thistle, the ragweed, fat-hen, and yarr.

Yarr—1. Foliage. 2. Flowers. 3 and 4. Seed, natural size and magnified.

The Californian thistle is known in England as the corn thistle, or green thistle. It spreads both by underground stem and seed; frequent cutting close by the ground will kill it; without leaves a plant must die. It is, however, a most difficult weed to eradicate.

Ragweed is closely related to the common groundsel. It is found chiefly in grass lands, and spreads both by seed and root. It causes disease in cattle and horses—sheep, however, eat the young plants greedily and may be used to exterminate the weed, but should not be left on too long at a time.

Yarr or spurrey is a weed of cultivated land. It is very common in Southland.

EXERCISE.

Make a collection of the weeds (showing root, stem, leaves, flowers, and fruit) in your district. When pressed and dried, label and mount on cardboard. Record in your notebook details of each weed collected, *e.g.*, name, where growing, kind of soil, habit of growth, whether annual or perennial, when in flower, means of seed dispersal, how eradicated.

[Samples of the principal New Zealand weed seeds, arranged in a glass case for the purposes of identification and comparison, may be obtained from the Department of Agriculture.]

INDEX.