NATURE TEACHING

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BASED UPON THE GENERAL PRINCIPLES OF AGRICULTURE

FOR THE USE OF SCHOOLS

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PREFACE

THIS little book was originally written for use in the West Indies, with the intention of shaping the courses of study both in secondary and primary schools; being employed as a text-book in the former, while in primary schools it is used by the teachers in preparing and formulating their teaching.

As it has been found useful in its original form in the West Indies, it has been suggested that an edition, rewritten and modified to meet the circumstances of British conditions, may prove acceptable in the mother country. I have, therefore, with the assistance of Mr W. G. Freeman, prepared the present revised edition.

Elementary nature teaching admits a wide range of subjects, and individuality plays an important part; but throughout, if good work is to be done, it must be impressed upon the teacher that the pupils must do things for themselves. Mere knowledge of how things *ought* to be done, and what they *ought* to look like if only they were found and seen, is of little value, and the absence of the true practical knowledge of things is soon revealed upon any attempt to ascertain the depth and reality of the pupil's information.

For this reason but few illustrations are used, lest both teacher and pupil, seeing how things appear in an illustration, may consider that "they know all about that," and may be tempted to shirk the effort of seeing the natural object for themselves.

In schools where the subject is taken up for the first time, it will probably be found prudent to do a considerable amount of work before attempting anything like a formal school garden. To this end a great deal of useful work can be done by growing plants in pots or boxes. Ideas for the school garden will soon evolve themselves from this work.

It must be clearly understood that the book is not arranged in such a manner as to afford a course of instruction to be taken in the precise order in which it is written. In work of this kind some skill and judgment are required to adjust matters, so that the teaching shall be so distributed as to proceed in an even manner from week to week, and also that there shall be no unnecessary delays, as may arise from waiting for some experiment or demonstration to mature.

In the appendix, attempts are made to indicate suitable courses of work according to the time of year at which the work is begun, but in this there is ample scope for the exercise of judgment on the part of the teacher. Nor are the exercises put forward as final; they are only indicative of a general course of study, and the intention is that the teacher shall extend and modify them as surrounding conditions demand.

In some instances a school garden cannot be provided, but in rural districts this may usually be obtained. It is not necessary to have a large piece of ground.

In connection with school gardening, difficulty is sometimes experienced in maintaining order, and preventing what should be serious, though interesting, teaching degenerating into a useless scramble. This may often be obviated by introducing the elements of a simple drill into the out-door work, as by marching the class to the tool-house, then passing out the tools to the class as it stands in rank, and marching to the plots where work is to be done, and so on.

In the working-plots themselves the work must be carried on in a manner similar to that of a laboratory; each pupil must have an idea of what he is aiming at, and proceed independently to the fulfilment of his object. In many cases it is well for the pupils to work in pairs.

In the garden itself, two kinds of work have to be distinguished, and it is well to keep them distinct in the minds of teacher and pupil. Some plants are to be grown with the object of studying their mode of growth: they are to be examined, and possibly destroyed in process of examination, in various stages. Other plants are to be grown for the sake of the crop they afford, whether the crop be ornamental, as in the case of flowers and decorative plants, or useful, as in the case of fruits and vegetables. The proper arrangement of both kinds of work requires care and thought on the part of the teacher.

In all the work, drawing, measuring, and weighing should be insisted on wherever circumstances permit.

F. W.

August 3, 1903.

Official duties having called me to Southern Nigeria for some months, it has been impossible for me to revise the final proofs.

My deepest thanks are due to my wife for kindly undertaking this laborious task, and compiling the index, in addition to the valuable assistance she has given throughout the progress of the work; and in particular, in preparing, especially for this book, the whole of the illustrations.

W. G. F.

February 28, 1904.

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CHAPTER I

THE SEED

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IN all agricultural and gardening work, seeds are so constantly employed for the purpose of raising new crops that every one is more or less familiar with them.

We know, as the result of experience, that if we sow seeds we shall in the course of time obtain young plants or seedlings, and that these, if properly looked after, will grow into large plants, and in due course flower and bear seeds themselves, from which a second crop of plants can be raised. This order of events is the same whether our experience has been gained by growing poppies, mignonette, hollyhocks, etc., in the garden, or wheat, turnips, and clover in the field, or whether we have been practically engaged in starting a new oak wood from acorns.

We have learnt also, as the result of our experience, that each seed has apparently hidden away in it the beginnings of a new plant of the same kind as that from which the seed was obtained, and that if we wish to grow bean plants we must sow bean seeds, and acorns if we wish to raise oaks.

We know, also, that although a dry seed is to all appearances a mere dead thing, it soon springs into life, or *germinates*, if we place it in a warm place and give it a supply of moisture.

Moreover, we are aware that even dry seeds cannot be stored for a very long time without gradually dying, for the farmer or gardener who is anxious to raise good, full crops is careful to secure good seed, obtained usually from the crop of the season before, and does not sow any old seed which may be to hand.

This general knowledge is most valuable, inasmuch as it is the outcome of the practical or experimental work of ourselves, and of those before us who have handed down their results. It is not, however, enough in itself, and we should endeavour to understand how, and as far as possible why, the events follow each other with such certainty.

A correct knowledge of the seed and of the conditions for its germination, and for the successful growth of the seedling and plant, touches the very foundation of that sound agricultural practice so essential to success at the present time.

The Parts of a Seed.

In order to distinguish the various parts of a seed, it is best to examine one which has begun to grow, or, as is more commonly said, to *germinate*, for in this condition the parts can be more easily separated and distinguished. Among the simplest and most easily understood seeds are any of the ordinary peas or beans. An examination of a very young plant of the French or kidney bean—one which has just made its appearance above the surface of the soil—will reveal the following parts: two thick leaves (in the case of the scarlet runner and some others, these leaves do not come above the surface of the soil); between these there is a very small leaf-bud with minute leaves, whilst below there is a stem which terminates in a root, the root itself being branched.

The parts of the young bean plant should now be compared with a bean seed which has not germinated, but which has been soaked for a few hours in water in order to soften it. The seed-coat will strip off without difficulty, and it will then be found that enclosed by the seed-coat is a structure which easily splits into two halves, and a little thought will show that these two halves correspond to the two thick leaves which have been spoken of already. These leaves are called the *cotyledons* or *seed-leaves*. Between the cotyledons there will be seen a small curved body, one portion of which, when the seed germinates, becomes the stem with leaves upon it, while the remaining portion develops into the root. These portions are known respectively as *plumule* and *radicle*. With the help of a pocket lens, the plumule is seen to consist of very small leaves folded together. There thus exists in the seed a minute plant with rudimentary root, stem, and leaves. When seeds are placed under suitable conditions these rudimentary organs grow, and the seed is said to germinate.

Plant Food in Seeds.

The first stages of germination take place at the expense of the store of plant food which exists in every seed. In the case of the bean, which has just been examined, the store of plant food is contained in the thickened seed-leaves. If some germinating kidney beans, growing in soil, are observed from day to day, it will be seen that the seed-leaves gradually become smaller and smaller, and finally shrivel up. In the scarlet runner a similar thing happens, although here the cotyledons never came above the surface of the ground. A great many plants with which we are familiar have their supply of plant food for germination stored away in the seed-leaves; this, for instance, is the case with all the peas and beans, with the seeds of oak, apricot, cabbage, radish, lettuce, cucumber, orange, and many others.

There are many seeds in which the store of plant food for germination is not contained in the seed-leaves, nor in any other part of the small plant in the seed, but exists as a separate store. In these seeds we find inside the seed-coat an embryo, as in the bean, but only small cotyledons, and, in addition, a separate store of plant food. These may be made out in the seed of buckwheat, marvel of Peru, etc., where the embryo is to be seen enveloping, but perfectly distinct from, the store of plant food which makes up the greater portion of the seed.

In wheat, barley, maize, etc., the embryo lies at one side of the seed, near the pointed end (base), and easily distinguishable as a white patch. In maize or barley which has been soaked for a few hours in water, the embryo may be readily separated from the rest of the seed, when it will be seen how large a part of the seed is occupied by the store of plant food.

This separate store of plant food is often spoken of as the *albumen*,* and seeds are described as *albuminous* or *exalbuminous* in accordance with the presence or absence of this albumen. The seeds of wheat, barley, maize, all the cereals and grasses, beet, carrot, buckwheat, marvel of Peru, onion, and date, afford examples of albuminous seeds.

If we now refer again to the seed-leaves or cotyledons which exist in every seed, we have to note that the embryos of some seeds have *two* cotyledons, as in the case of the bean and buckwheat, while the embryos of other seeds have only *one*. Barley, wheat, or maize may be taken as examples of the latter class. In some cases it is an easy matter to ascertain whether one or two cotyledons are present in the seed, while in others it is matter of some difficulty. It is found that the presence of either one cotyledon, or of two cotyledons, is usually associated with other constant characters of plant structure to which fuller reference is made later. Seeds with embryos having one cotyledon are described as *monocotyledonous*, while those in which two cotyledons are present are known as *dicotyledonous*.

* The term "albumen" is an unfortunate one, as the same term is commonly employed to denote a large class of chemical substances. There should be no difficulty, however, in understanding the limited sense in which it is employed here.

Germination.

When a gardener or farmer sows seeds, he takes care to proceed in such a manner in preparing the soil and placing the seeds in it as previous experience has shown him produces the best results. It is well, then, that we should learn what takes place during germination, in order that we may know what conditions are essential to success.

If on alternate days a few seeds of various kinds of beans are planted in moist soil, and this is continued until those first planted have developed into small plants some four or five inches high, an ample supply of material may be to hand for purposes of study.

Take a bean, which has been soaked in water but not planted, remove the seed-coat, separate the cotyledons, and bring into view the body lying between them. Next, dig up carefully one or two of each of the beans of different ages and compare them with the ungerminated seed. There will be no difficulty in recognising that germination produces changes whereby that portion of the embryo known as the radicle develops into the root, whilst the plumule becomes the stem with its leaves. The cotyledons become smaller and smaller as the development of the young plant proceeds, the stores of food which they contain being used by this young plant to build up its own structures.

This is one of the simplest methods of germination; but we should observe that the young and tender plant has certain definite objects to attain. The plantlet must get out of the seed-coat, and it must be able to force its way through the soil in which the seed is sown.

Observation of germinating kidney beans shows that the root, on its emergence from the seed, does not grow straight down into the soil, but bends in an arch near the seed and then grows straight downwards. This arch is generally the first thing which makes its appearance above the soil, and, from its form and structure, is well fitted to thrust aside the particles of earth. After the arch is formed, the young plant is firmly anchored in the soil by means of the root.

The arch has now another duty to perform; the seed-coat still covers the cotyledons and the plumule; these must be liberated. The seed-coat is held fast by the soil sticking to it; the arch continues to grow in an upward direction, and, as a result, the cotyledons are withdrawn from the seed-coat, much in the same manner as a hand is drawn out of a glove. When this is done, the arch straightens out and the plant grows into an upright position.

In order that the seed-coat may be held firmly by the soil and not be drawn out by the plant's movements during germination, seeds are frequently provided with projections, spines or hairs, which, becoming attached to the soil, afford the necessary firmness of hold. In some cases, for instance, linseed (flax) and cress, the seeds are provided with a seed-coat which becomes mucilaginous and sticky when wet, thus effecting the same purpose.

On looking over a plot where a number of beans are germinating, it may often be noted that some of the seeds have not been able to rid themselves of their seed-coats, owing to the fact that the soil did not hold down the coats sufficiently firmly, so that they were pulled up when the plant tried to draw out the cotyledons. Such plants are often greatly hindered in their growth by the presence of these no-longer-wanted coats. Cases such as this should be borne in mind in attempting to discover what are the uses of spiny or warty coats of many seeds.

In some seeds, for example, scarlet runners, peas, and acorns, the seed-leaves are not drawn out of the seed-coats in the manner described, but remain below the ground. The young stem makes its appearance above ground in an arched form, but, in this case, the arch is formed above the point of attachment of the cotyledons to the plumule. The growth of the arch now merely draws out the plumule with its tender leaves. The young plant lives for some time on the store of food in the cotyledons, which gradually become thin and shrivelled, exactly as in the case of the French bean, where, coming above ground, the changes in the cotyledons are more easily watched.

The seeds of the vegetable marrow and cucumber exhibit interesting peculiarities in their germination. The root makes its appearance first, and assumes the curved or arched form in a similar manner to that of the bean. The seed being flat, usually lies upon one side. On the other side of the arch, and quite close to the small hole through which the root makes its appearance, there is formed a protuberance. This protuberance catches the lower edge of the seed-coat and holds it firmly against the soil. The cotyledons, still within the seed-coat, are soon thrust upwards by the curved form of the growing root ; this leads to the splitting of the seed-coat into two halves, whereby the young plant is set free. It is worth observing that the protuberance is only formed on one side, the under one; and that if, when germination has proceeded to a slight extent, the seed be turned over so as to bring the upper side to the under side, then a protuberance will form on the side finally downwards. This will happen even if a slight protuberance has begun to form before the turning took place.

In the instances of germination already referred to, the supply of plant food is stored in the cotyledons, whence it readily passes to the growing parts of the young plant. In those cases, however, where there is a separate store of plant food, that is in albuminous seeds there must exist some means whereby this food can be made use of by the young plant. It will be well to describe one or two examples showing how this is accomplished.

The common buckwheat affords an interesting and readily observed case. If some buckwheat is sown in a pot of sawdust, seedlings can easily be obtained in various stages of development for us to see that as in the preceding cases the radicle first bursts through and grows downwards into the soil. Above ground appears the little stem, not as a mere arch as in the bean, but curled round in a complete loop, bearing at the free end the whole seed, with the cotyledons still inside. The cotyledons remain enclosed for some time in the seed, which fits them as a kind of cap. Slowly they throw off the husk, and open out as a pair of green leaves. The husk will then be found to be quite empty, all the food it contained having been absorbed by the cotyledons and passed on to the young plant. Whilst this is going on the stem has also straightened out.

The onion has an albuminous seed. In germination the young root first makes its appearance, and, immediately afterwards, there appears the lower portion of the cotyledon. This assumes the arched form as described in the case of other seeds; the tip of the cotyledon however is not withdrawn, but remains for some time within the seed-coat in contact with the supply of food stored up there. Upon the portion of the cotyledon in contact with this food there is formed what may be described as a *sucker*, an absorbing organ, which takes up the stored food and passes it on to the growing plant. When all the food store has been absorbed, the cotyledon is withdrawn from the seed-coat and the young seedling becomes erect, the cotyledon being now green, and acting as an ordinary leaf.

A somewhat similar condition of things occurs in the germination of the seeds of many palms, and may be studied in the date. The germination of the seeds of the date palm is of great interest, inasmuch as it supplies an excellent illustration of the way in which many plants overcome the difficulties of their surroundings. The date palm is well known as a plant which can thrive in sandy, desert regions, where the water supply is scanty. Most ordinary seedlings are delicate, and easily killed if kept without water. How then does the young date palm manage to survive? As the seed germinates, it puts out a structure which bores down into the soil like a root. As we shall see later, this is much more than a root, and really consists of the root, cotyledon, leaf-bud, and, in fact, the whole of the young plant. The upper portion remains inside the seed and gradually absorbs all the food contained in the seed, passing it down to the young plant, which gradually is thrust quite deep down in the soil. Here it forms its roots, so that when, later on, the first green leaves appear above the surface, the little seedling date palm has well-grown roots, and can get water for itself from the deeper layers of the soil, and is thoroughly able to exist even through very dry weather, when many seedlings would die. In this manner the seedling date grows at the expense of the hard food-supply stored up in the seed as the hard, horny substance which makes up a date "stone."

The seeds of the castor-oil plant are albuminous; when germination takes place the albumen is withdrawn from the seed-coat, together with the cotyledons, the albumen remaining attached to the back of the cotyledons. The plant food is then absorbed during the first few days after germination.

The seeds of all the ordinary grasses and cereals are albuminous. The manner in which the store of plant food is absorbed during germination can be studied in the case of barley and maize. Some grains of each should be planted on three or four successive days, in moist sand or sawdust, so as to furnish a number of specimens in different stages of germination. These should then be compared with grains in an ungerminated condition, and with some which have merely been soaked for a few hours in water to soften them.

On examining the grains, the embryo or "germ" may be seen as a white patch lying on one side of the grain near the pointed end; in the case of those grains which have been soaked, the embryo can be readily detached from the rest of the seed. The seed is monocotyledonous, and careful examination of the detached embryo shows that the single cotyledon does not grow or extend through the seed-coat, but forms the means of communication through which the reserve of plant food passes into the young growing plant. The cotyledon, here known as the *scutellum*, lies upon the surface of the albumen, which in these seeds consists almost entirely of starch. As soon as germination begins, the scutellum secretes a digestive fluid which converts the insoluble starch into soluble substances, which are readily absorbed by the scutellum and passed on to the growing plantlet, lying on, and attached to, the other side of the scutellum. As the starch is dissolved and used up, the scutellum presses forward into the vacant space, finally taking up all the starch and leaving the seed-coat empty. While this is going on, the young plant is growing in size, thrusting its roots into the soil and its leaves into the air, so that by the time the supply of starch within the seed is exhausted it is able to obtain its own food.

Practical Work

The following exercises are suggested in illustration of the principles already discussed; they may be performed by the pupils themselves or by the teacher, and used by him as demonstrations in his object-lessons. They admit of considerable modification and variation, and, in their present form, are merely intended to be suggestive. The precise manner in which they are conducted must necessarily depend on the circumstances surrounding each class of students, but too much stress cannot be laid on the advantage of the pupils actually performing all the experiments for themselves whenever there are no reasons rendering this quite impossible.

The Conditions of Germination.

Moisture, air, and warmth are necessary for the germination and continued growth of seeds. In order to demonstrate this, take four rather small but wide-mouthed bottles, two of which are furnished with good corks. Label these bottles A, B, C, and D respectively. In A, having first taken care that it is perfectly dry, place some dry seeds (wheat, barley, peas, or beans), cork the bottle, and seal with sealing-wax or beeswax. In B, place two or three layers of wet blotting-paper at the bottom, then put in the seeds, and cork and seal as before. Treat C exactly as B, but leave the bottle uncorked.

Place seeds in bottle D, and then fill the bottle completely with water, which has been boiled and allowed to cool, to drive out the air it contains. By this means the air originally in the bottle is displaced with water, and now closing the bottle with a cork, we have the seeds wet but with practically no air.

Put A, B, C, and D away side by side, preferably in a dark place, and examine daily. It should be found that in A the seeds do not germinate at all; they have no water at all, and very little air. In B the seeds have water but again very little air; they will probably germinate and grow for a short time, and then, having exhausted the air, die. The seeds in C have water, and, the bottle being open, air also. (The blotting-paper in C should be kept moist by the addition of water from time to time.) They should germinate and grow well. Those in D, although provided with water, have no air. They should grow but slightly, if at all. The experiment has so far shown the necessity of water and air. Keep careful notes of this experiment, recording the number of seeds which germinate at all in each bottle and the heights the seedlings attain.

In order to show the influence of temperature, take two pots filled with soil, properly prepared for the reception of seeds (see p. 15). In each pot place two or three seeds of several different kinds, for example, beans, peas, barley, radish, etc. Label the pots, and place one out of doors and keep the other indoors in a warm place, such as in the kitchen, or warm school-room. Keep the soil in both pots suitably moist. Note in your note-book the date when the seeds were sown and the dates on which the various seedlings first appear above the surface of the soil. Measure the heights of the young plants at regular intervals. Compare the rate of germination and early growth of the plants in the pot kept warm and in that exposed to cold, and draw conclusions as to the effect of temperature upon plant life.

Note.—This experiment should be made between the months of October and March.

Raising Seedlings.

Observations are readily made on seeds sown in boxes. For this purpose it is necessary to provide suitable boxes and material. The boxes should be shallow, from 4 to 6 inches in depth, with sides securely fastened so that they may bear the weight of the moist soil. A number of holes, about half an inch in diameter, should be bored in the bottom of each box in order to secure free drainage. In addition to wooden boxes, useful seed boxes may be made from large biscuit-tins.

The soil for filling the boxes should be prepared by sifting, first, through a sieve having holes of about an inch in diameter; this removes the large stones: the sifted soil should next be passed through a second sieve having holes of about a quarter of an inch in diameter; this separates the gravel from the fine soil. A small quantity of soil should be passed through a still finer sieve. It is advisable to prepare a good supply of soil and to store it in a dry place, so that, whenever required, stones, gravel, or fine soil may be available.

A tool is useful for levelling and lightly pressing down the soil as it is placed in the boxes. This is simply supplied by a piece of smooth board, half an inch in thickness and about 8 by 4 inches in area, with a suitable knob or handle fixed on the back.

A supply of dry, finely-chopped grass (for instance, lawn mowings) or preferably coco-nut fibre refuse, is also required.

To prepare a box for sowing seeds, place at the bottom a layer about 1 to 2 inches deep of the stones separated from the soil by means of the coarsest sieve. Over the stones place a layer of about the same depth, of coco-nut fibre or of the dry chopped grass, to prevent the finer material choking up the spaces between the stones. Over the fibre or grass put a layer of the gravel, and fill up the box with sifted earth. Level this last layer by means of the tool, at the same time compressing the earth *slightly*. If the soil is very dry it is advisable to water it now, as less damage is likely to be done than by heavy watering after the seeds have been sown.

The seeds may now be sown, the method of procedure depending on the size and kind of seed. If small seeds, like lettuce, are being sown, all that is necessary is to scatter them evenly and thinly over the surface, and then to distribute a layer of the very fine soil over the seeds, sifting the soil lightly on and adding only so much as is required to cover the seeds without burying them at all deeply. If larger seeds, such as peas or beans, are being sown, place them in shallow furrows, lightly marked out with a piece of stick or with the finger, and cover with very fine earth as in the previous case. Very large seeds, such as horse chestnuts or acorns, may be placed in position, buried by pressure about half their own depth in the soil, and then covered with moderately fine earth.

Everything being completed, press the soil gently down with the tool. This pressing down has the effect of producing a firm seed bed which is necessary, in certain instances, to enable the young plants to free themselves from their seed-coats. It also serves to keep the top layers of soil moist, for, if left loose and dusty, they would become dry, and the seeds would suffer from lack of moisture.

After the seeds have been sown the box must be watered. This requires care, or delicate seeds will be washed out of the ground. A watering-can having a rose with very fine holes, should be used, and the water only allowed to fall very gently.

The boxes should be placed in a shady place where they are screened from heavy rain and excessive sunshine. It is often of advantage to cover the box with a sheet of glass. In this way the air is kept moist, and germination usually hastened. The glass also prevents damage by rain if the boxes cannot be placed under a roof.

In order to observe the effect of a firm seed bed sow onion seeds in two boxes or pots. Compress the soil of one *firmly* after sowing the seeds. In the other cover the seeds lightly with sifted soil, avoiding carefully any compression. Tend the boxes or pots carefully, and note the difference in the manner the two sets of seeds germinate and the seedling grow, recording your observations in your note-book and making drawings and diagrams of the seedlings as they grow. Similar experiments may be made with seeds other than onion. These experiments should also be tried in garden beds which are left to receive no watering beyond the natural rainfall.

Seed Beds.

Seeds are generally sown in garden beds, or, young seedlings raised in boxes, are transplanted to beds. The preparation of a seed bed requires some care. Select a spot, sheltered as much as possible from the sun and wind, and near the water supply; remove all the weeds and fork the ground to a good depth. Mark out, by means of a line (see below), the paths which shall separate the beds; these paths should be about 2 feet wide, while the beds themselves should be from 3 to 5 feet wide. Having marked out the position of the paths, and while the line is still stretched in place, remove with a spade the soil from the paths and distribute it evenly over the beds. If this is properly done the paths should now be about 6 or 8 inches below the level of the beds. Remove all stones with a rake, and so make up the beds that the centre of each is slightly higher than the sides. This is of great importance, as it allows water to drain off freely, for nothing is more detrimental to good gardening than to have water lying in pools on the beds.

When working on a garden bed avoid walking upon it. When weeding or planting, it is often necessary to place the foot upon a bed in order to reach a particular spot; in this case use a foot-board, which is simply a narrow piece of board which can be laid across the bed, and upon this only should any one be permitted to place his foot when working. Another appliance in frequent use is a line for marking. A line consists of a length of moderately stout cord having a pointed stake about 18 inches long attached to each end. It is well to have two lines—a long one for laying out beds, paths, etc., and a short one for working across beds. After use, lines should always be neatly wrapped around their stakes, and carefully put away in the tool-house.

When seeds are to be planted in a garden bed proceed as follows:—Stretch a line across the bed, and, with the hand, open a furrow in the soil along the line, making the furrow of a depth suitable to the kind of seed to be sown, 2 inches deep for large seeds, an inch or less for small ones. Having made one furrow, move the line the required distance, fix it in position, mark out another furrow, and so on. In regulating the distance between the rows it is convenient to have a piece of stick of the same length as the distance the rows are to be apart, and to use this as a measure to mark the new position of the line every time it requires to be moved; this secures regularity and neatness of work. The furrows being opened, scatter the seeds by the hand along the bottom of each, care being taken to scatter them evenly and not too thickly. When the seeds are in position, gently draw the soil over them, and after they are covered apply a little pressure to render the soil around them firm.

Pots are sometimes used for sowing seeds in, particularly large seeds. They are also of use when the young plants are to be transferred subsequently to another spot, as, for instance, cucumbers. Pots are prepared for seed sowing in the same manner as boxes. In the tropics, pots made of bamboo are frequently used, and are indeed invaluable. They are made from large bamboos by cutting them across with a saw just below each node or joint; the division or partition found at each joint thus forms the bottom of the pot, and when a hole has been made in this to permit of drainage the pot is ready for use.

Observations on Seedlings.

The pupils should sow all, or at any rate the greater number, of the seeds in the list below, the teacher deciding according to circumstances whether they are to be sown in boxes, pots, or beds. All the various stages in their germination must be watched, and the observations recorded in suitable note-books, drawings, even if only roughly diagrammatic, being insisted on. As germination proceeds a few of the seeds should be removed at intervals for purposes of study and observation. At this stage of the pupils' work the object is not to raise crops, but to understand how crops grow. The observations recorded should determine the method of emergence of the young plant, the curves assumed by the young root and stem, the manner in which the cotyledons are disposed, whether the seed is albuminous or exalbuminous, and, if the latter, how the reserve of food material is absorbed by the growing plant. Careful attention should be given to any special contrivances to enable the young plant to escape from the seed-coat, and the existence of any special means whereby the seed-coat is held down by the soil while the young plant is being withdrawn.

Upon examining seed beds containing germinating seeds, it may often be noticed that a few of the young plants do not germinate properly. They may fail to rid themselves of their seed-coats or meet with other untoward experiences. These cases, in particular, should be observed, as they often throw considerable light on the methods of germination and impress the mind with the importance of what may, at first sight, seem trivial and unimportant details.

After some of the better known kinds of seeds have been studied, much instructive information may be gained by collecting seeds of wild plants and studying their methods of germination. In addition, observations serving to develop the pupils' powers of perception and reasoning may be made upon germinating seeds and seedlings found in a state of nature.

The following list of seeds for study is merely suggestive; examples should be selected from different parts of the list, and the seeds should not be studied in the order in which they are arranged:—

Peas and Beans
- Scarlet Runner
- Haricot or Lima Bean
- Broad Bean
- Garden Pea
- Sweet Pea
- Vetches

Cabbage
Radish
Cress
Cucumber or Marrow
Horse Chestnut
Oak (Acorn)
Ash
Buckwheat
Sycamore or Maple
Marigold
Tomato
Barley
Wheat
Maize
Onion
Castor-oil
Date Palm

Seeds of all these plants can be easily obtained. In the case of dates the seeds from the fruit as sold for eating purposes are quite good; it must be remembered, however, that they take several months to germinate, preferably in a pot in a greenhouse or warm room.

Testing Vitality of Seeds.

The following method of testing the germinating power or vitality of seeds is easily carried out, and affords results of practical value. Pupils should test the vitality of half a dozen or more of the common kinds of garden seeds purchased locally. (These experiments should be reserved for senior pupils and advanced classes.)

"A cheap and convenient form of apparatus for testing the vitality of seeds at home is the following:—Choose two earthenware plates of the same size. Cut out two circular layers of flannel somewhat smaller than the plates. Between the two layers place 100 seeds of the variety to be tested. Moisten the flannel with all the water it will absorb. The two layers of flannel are placed in one plate and covered with the other and set in a warm place. If the flannel is thin, several pieces should be used in order to absorb sufficient water. Other kinds of absorbent cloth or blotting-paper can be used, but thick flannel is rather more satisfactory. At the Kansas Experiment Station we have used damp sand for a seed bed with good success. . . . The flannel should be kept moist by the addition of more water when necessary. Some seeds will commence to germinate on the third day. Each day an examination should be made, and those seeds which have germinated should be recorded and removed. For practical purposes, two weeks is a sufficient time for the test. The results obtained may be considered as representing the percentage of vitality under favourable conditions."

"Grass seeds require as much as three weeks, and seeds of some trees a still longer time. Beet balls contain from three to seven seeds. With very small seeds it may be necessary to provide for the circulation of air by placing small pieces of wood between the layers of cloth among the seeds. With most varieties of garden plants the majority of seeds should germinate within a few days after the first sprout appears. If the period of germination extends over a longer time it shows that the vitality of the seed is low. Seeds of the carrot family and some melon seeds may not show as high results in the germinating dishes as they do in the ground."

In good sound seeds the following numbers per cent. should germinate[a]:—

[a] From Year-Book, U.S. Department of Agriculture, 1896.

Barley . . .	90 to 95	Oats . . .	90 to 95
Beans . .	90 „ 95	Onion . .	80 „ 85
Beet * . .	150	Parsley . .	70 „ 75
Cabbage . .	90 to 95	Parsnip . .	70 „ 75
Carrot . .	80 „ 85	Peas . . .	93 „ 98
Clover . .	85 „ 90	Radish . .	90 „ 95
Cucumber . .	85 „ 90	Tomato . .	85 „ 90
Lettuce . .	85 „ 90	Turnip . .	90 „ 95
Mustard . .	90 „ 95	Wheat . .	90 „ 95

* Each beet fruit or "ball" is likely to contain from three to seven seeds. One hundred balls should give at least 150 sprouts.

CHAPTER II

THE ROOT

We have already seen that the first thing to make its appearance when a seed germinates is the root. This is at first usually white and tender, but as it grows older often becomes hard and woody, and covered with a brown bark. The root may also increase in thickness to a very considerable size.

If very young roots are examined they will be found to be clothed with fine down or hairs near their extremities. Owing however to the very delicate character of these fine hairs it is not always easy to see them, for they are injured if the root is at all roughly dealt with. These hairs may be seen to great advantage on the roots of seedlings of barley, Indian corn, etc., which have been grown in a moist atmosphere. On examining such a root it will be noticed that the tip and the portion immediately behind it is quite bare and smooth; this, as we shall see later, is the growing region. Then follows a downy-looking portion, the character of which is due to the presence of large numbers of minute *root-hairs;* this is the absorbing region. The older portions of the root, like the youngest part, are completely free from root-hairs. When a very young seedling is pulled up from out of sandy soil it frequently happens that a considerable quantity of sand remains attached to the root, owing to the root-hairs adhering firmly to the grains of sand with which they were in contact.

The end or tip of a root is soft and tender, making one wonder how so delicate a structure is able to thrust itself through the hard, rough soil. Careful examination will show that the tip of every root is covered with a little cap or shield which serves to protect the point from injury. This *root-cap* is, in many plants, not very easy to see without the use of a lens, but may often be observed in roots growing in water, for instance, those of the frog's-bit, duck-weed, etc. The screw-pine (*Pandanus*), to be seen at many florists and in almost every botanic garden, throws out a number of roots from its stem. These roots grow downwards towards the ground, and, if their tips are examined, they will be found to be covered with well marked root-caps. These illustrate remarkably well the nature of the appendage to be found at the extremity of most roots, including even their finest and most minute branches.

Roots usually grow down into the soil, throwing out numerous branches, and permeating the soil with a network of fine rootlets, each provided with root-hairs and terminating in a root-cap. The main root exhibits a strong tendency to grow vertically downwards, in response to the pull of gravity. This can easily be proved by placing a growing seedling so that the main root lies horizontally. If this is done it is found that within a few hours the end of the root bends so that once again the tip is directed vertically downwards. A simple experiment such as this is sufficient to show that plants are not mere passive living things, but can control the movements of their parts almost as if they possessed senses similar to those of animals.

Roots increase in length by the addition of new material at their ends; the older parts may grow in thickness, but they do not increase in length. Indeed, a moment's consideration will show that this must necessarily be the case, for if roots were to grow in length anywhere but at their ends they would tear off their branches, which are firmly embedded in the soil.

Uses of Roots.

Roots have several uses: they fix the plant firmly in the soil, they absorb water together with the nutriment which plants derive from the soil dissolved in it. This absorption of water is only effected by the younger portions of the roots being practically confined to the root-hairs. The region, therefore, which bears the root-hairs is the absorbing region, and this fact explains the importance of the young roots and why plants suffer if these are unduly disturbed or injured. The older parts of the root have no power of themselves to take up water and plant food. They are of use as mechanical supports, and also as the means whereby the water taken up by the absorbing region is passed on to the stem and leaves above ground.

Roots frequently act as storehouses of plant food, particularly in the case of biennial plants. *Biennials* are plants which require two years to complete the cycle of their lives. They usually produce during the first year an abundance of leaves but no flowers. These leaves manufacture plant food, in the form of starch or sugar, in excess of the plant's immediate needs, and this surplus food is stored away in the roots which usually become very much enlarged. On the approach of winter the leaves die down, but the roots remain in the ground in a dormant condition. In the spring of the succeeding year the plants put forth new leaves and finally flower and produce seed, and, in carrying on these processes, the store of food in the roots is drawn upon so that by the time the seeds are ripe the roots are practically exhausted. After the seeds have been dispersed the plants die. This condition of things may be well seen in such plants as beet, carrot, and turnip. In agriculture man takes advantage of these plants storing up food, and, collecting the roots at the end of the first year, devotes their hoarded-up food to his own uses.

The observations made on seedlings have shown that the roots of a plant usually arise from the radicle of the little plant in the seed. In many plants, however, roots arise not only in this manner but also from stems. A good example is the ground ivy, which puts down little bunches of roots from its stem as it trails over the ground. It is obvious that these roots carry on the ordinary work of absorption of water, because if the main root dies or is cut away the plant is unaffected.

In some plants the roots formed above ground are also of use as supports; thus in the Indian corn a number of roots arise from the stem, at some distance above the soil, grow downwards and anchor the plant firmly. In the screw-pine such roots are still more obvious, and form curious, stilt-like supporting structures. The ivy furnishes another excellent example of adventitious roots borne on the stem. In this case they are of assistance to the plant, supporting it when climbing up trees, walls, etc.

In the case of many plants, a portion of the stem, separated from the parent plant, so that it no longer receives supplies of water and food, shows a tendency to attempt to save its life by producing roots of its own. In this effort it will usually be successful if it happens to be placed in a moist position. A piece of watercress placed in a bottle of water quickly develops a number of adventitious roots. Full advantage is taken of this tendency by gardeners and agriculturists. Many ornamental plants are propagated in this way. Pieces of the stem are cut off and placed in moist earth, when new roots soon make their appearance, usually from near the cut end of the stem, and a new plant is obtained. Roses, geraniums, chrysanthemums, and a number of other garden plants are regularly propagated in this manner. In tropical countries this method of propagation is used for many important food crops, for example, sugar-cane, sweet potato, and cassava (the source of tapioca).

Nor is it only from stems that roots may be developed. Some leaves, when plucked from their parent plant and laid on moist soil, will throw out roots and leaf-buds, so that, in a little time, a number of young plants may be raised from a single leaf. The leaves of "fibrous-rooted" begonias readily form roots when placed under suitable conditions, and are commonly propagated in this way.

Some plants grow as *parasites* upon other kinds of plants; they thrust their roots into the stems of their *hosts*, and live by robbing them of sap, thus weakening and often killing the plants on which they grow. Examples of parasitic plants are the strange, thread-like yellow dodders (*Cuscuta*), often found injuring clover and flax, and the mistletoe common in many parts of Britain on apple and other trees. The method by which this plant spreads from tree to tree is interesting (see chapter on Fruits).

The roots of these parasitic plants have no root-caps and no root-hairs, these structures being unnecessary under the peculiar conditions in which these roots grow. The dodder is at times a troublesome pest on clover, but, as a rule, parasitic plants are not serious enemies to the farmer in temperate climates, although they often are so to the tropical cultivator of cocoa, oranges, etc.

Practical Work

Dig up several germinating seeds and young seedlings, and examine their roots. Good examples may be obtained by sowing beans, peas, barley, wheat, etc., at intervals of a day in a box of moist sawdust or sand. Water the seeds as required. In warm weather they will be ready in about a week. In the winter a few days longer will be required. Observe that plants with two seed-leaves put out a main, or primary root, which soon forms numerous branches; on the other hand, plants with only one seed-leaf show no main root, but a number of fine roots more or less equal in size. A comparison of the root systems of young beans or peas and barley and wheat will make this difference clear. Make sketches of all the seedlings examined.

Root-Hairs.

Take a small wooden box, place at the bottom two or three layers of wet blotting-paper, and then some barley grains which have been soaked in water for about twelve hours. Cover the box with a sheet of glass, and put it on one side; examine the box from time to time, and add more water if the blotting-paper should become at all dry. At the end of two to four days, according to the season of the year, root-hairs should be present in abundance, and there should be no difficulty in making out the characters which have been previously described. Make sketches of two or three seedlings of different ages, showing exactly the position of the root-hairs in each case.

Pull up, very carefully, seedlings which have been grown in sandy soil; grains of sand are generally found adhering in great numbers to the region on which we now know the root-hairs occur. Wash off this sand very carefully by gently moving the roots about in a tumbler full of water. Whilst the roots are suspended in the water, examine them also for root-hairs. Draw a seedling before and after washing the sand off.

Root-Caps.

Examine, if an opportunity occurs, the aërial roots of the screw-pine, and observe their root-caps. Then look for similar, but much smaller and more delicate, structures on the roots of other plants, such as pea and bean seedlings. These may often be more easily seen when the roots are held up against the light, and a magnifying glass will be found very useful. Examine also roots growing in water; some water-plants have no root-caps, but the frog's-bit (*Hydrocharis*), if obtainable, furnishes good examples, as also do the duck-weeds (*Lemna*), so common on ponds. These roots should be examined whilst still in water. Grow seedlings and cuttings in water, and examine their roots for root-caps.

Make simple outline drawings of all the plants examined.

Growth in Thickness.

The youngest part of a root is usually the thinnest; this is readily seen by observing any of the seedlings already obtained. In most of the plants which have only one cotyledon the roots soon stop growing in thickness, and accordingly all the older roots are of a uniform size: see plants of barley, wheat, maize, grasses, etc.

In dicotyledonous plants, on the other hand, increase in thickness may go on for a very long time, and the roots in consequence become very thick. Take any opportunity of observing the roots of trees, for instance, elm, oak, beech, apple, etc. Good examples may often be seen in lanes with steep banks, where the roots are frequently left exposed, owing to the soil being washed away. The main roots are often as thick as the main branches of the stem. Interesting cases showing an enormous increase in the thickness of roots can readily be seen in plants of radish, turnip, carrot, and beet. These plants are biennials (see page 26).

Sow a few seeds of radish, turnip, or beet in a garden bed, or in a box, between the months of April and June. Towards winter the leaves die down, and it can be seen that by that time long roots have been formed underground. The roots may be allowed to remain in the ground, or, if more convenient, they may be dug up, labelled and stored for the winter in a moderately warm dry place, where they run no risk of being frozen. In April or May weigh the roots and plant them in the ground or box again, and water as required. In time new leaves should be formed, to be followed later by flowers and seed. When the seed is ripe, collect it for future use, then dig up the roots, dry them as before, and then weigh and compare their weight with their original weight when planted in the spring. The roots should, of course, be marked throughout the experiment with distinctive numbers. Careful notes should be made of the facts observed, also of the character of the roots when planted out, and after the plants have flowered. Drawings are very important to show the changes which go on in the roots.

Growth in Length.

Germinate some beans in moist sand or sawdust, and allow them to grow until their roots are about two inches long; wash carefully a number of the seedlings, and select one which has a straight, well-formed root, perfectly free from injury.

Lay the seedling on a piece of damp blotting-paper, and, alongside it, a piece of cardboard, so arranged that the surfaces of root and cardboard are on the same level. With a fine camel's hair brush and Indian ink make a number of fine lines on the root, and a corresponding set on the cardboard, commencing as close to the tip of the root as possible, and continuing them backward for about one inch. These lines should not be more than $\frac{1}{8}$th inch

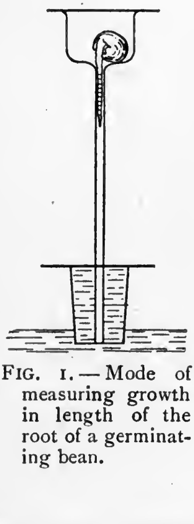

FIG. 1.—Mode of measuring growth in length of the root of a germinating bean.

FIG. 2.—Germinating bean fixed in a glass jar by means of a pin passing through the cork. The root is marked into equal transverse divisions at the beginning of the experiment. After a period of about twenty-four hours the region of most active growth may be ascertained.

apart, and in marking them great care must be taken not to injure the root. Place each bean in a thistle-funnel standing upright in a tumbler or bottle of water, and cover the top of the funnel with a watch glass, or small piece of wood (see Fig. 1).

As an alternative method, pin the seedling, with the root hanging vertically, on the inside of a box or bottle, the atmosphere in which is kept moist, as in the experiment with germinating barley. The best method of fastening the seedlings is to pass an ordinary pin through the two cotyledons, taking care not to injure the young stem or root (see Fig. 2).

Examine after twenty-four hours, comparing the marks on the root with those on the card.

It should be found that the first one or two divisions, near the tip, have not altered in length; that the next ones have grown a great deal; while those still further back have remained stationary like those at the tip. Make a drawing of a root as first set up, with the marks at equal distances, and after one, two, and three days, showing exactly the position of the marks at each of these times.

From this simple experiment we learn that in a root the greatest amount of growth is not at the apex, but some little way behind it, so that the root-tip protected by its root-cap is, as it were, driven down through the soil by the rapid growth of the portion just behind it.

Absorption by Roots.

Take two small bottles having short, narrow necks, and fill both with water. To one add a few drops of eosin solution or a little red ink, just enough in either case to colour the water distinctly red. To the second bottle add a little carmine which has been previously rubbed to a thin paste with water. Take two seedlings, such as those previously examined for root-hairs (p. 30), and fix one in each bottle so that its roots are immersed in the liquid. This may be done by wedging them in position with some cotton-wool. After a day or so remove the seedlings, and gently wash them in some clean water to remove any colouring matter on their outside. Then cut them lengthwise and across. Note that the one placed in the weak eosin or red ink has become red inside, whilst the one from the carmine has not. The explanation of this difference is to be found in the fact that eosin and red ink are soluble in water, whilst carmine is not, but remains in the water as very fine, solid particles. The red solution can pass into the roots, but it is not possible for any solid particles, however small, to make an entry.

This experiment has a very important bearing on the question of the relative value of manures and other forms of plant food.

Roots and Gravitation.

Take a wide-mouthed square bottle of clear glass (for instance, a sweet-bottle) and pour in it a small quantity of water. Obtain a good cork to fit the bottle, and pass through it a fine knitting-needle. Take a bean which has been allowed to germinate in damp sand or sawdust, and has a root about one inch long, and fix it on the end of the knitting-needle so that its root points downwards. Place the cork with the bean in the bottle, and allow it to remain for twelve hours. The root continues to grow straight downwards. Now lay the bottle on its side, when the root will lie horizontally. Examine at frequent intervals (for instance, of two hours), and note that the direction of the root changes, the tip soon curving round until it comes to point vertically downwards. The position of the bottle may now be changed again, and once more the root will be found to bend round into the vertical position.

A round bottle will serve almost as well, but care must then be taken to prevent it rolling.

Another simple and equally serviceable method is to use a box with a movable front. The atmosphere

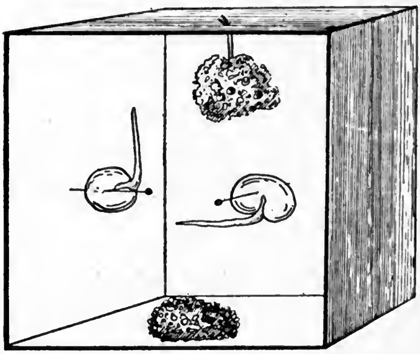

FIG. 3.—Germinating beans fixed on the sides of a box with a removable glass front. The beans are fixed with their roots pointing in different directions, but at the end of a few hours the tips of both roots will be seen to have curved round until they come to point vertically downwards.

in the box should be kept damp by means of wet sponges. Pin the seedling bean to the back of the box, and turn the box into various positions, as in the case of the bottle (see Fig. 3).

Careful drawings should be made showing the position of the root at first, and at intervals after the bottle or box has been turned round.

Roots and Water.

Sow some peas in an ordinary sieve filled with damp sawdust, and hang the sieve up. The roots of the seedlings grow down in the ordinary way, and at length project through the meshes of the sieve. Then, however, they usually change their course, and turning horizontally, they creep along the underneath surface of the sieve, or even grow vertically upwards into the damp sawdust. The attraction of the roots for water here overcomes their tendency to grow downwards.

Make careful drawings of the apparatus, and of the results noticed.

Propagation by Cuttings.

It is convenient to grow small cuttings in boxes and to transplant them afterwards into garden beds. Boxes for this purpose are prepared in the same manner as boxes for seed planting, but it is desirable to use either sand or very sandy soil.

Having prepared a box, proceed to plant cuttings of such plants as roses, geranium, willow, lilac, or coleus. Ascertain from a gardener what cuttings "strike" easily. Select a branch which is fairly firm and woody, but not too young and soft. Cut it into pieces of 4 to 6 inches in length, making the cut at the lower end close below a node or joint, as it is from the nodes that roots arise in the largest numbers. Cut off most of the foliage in order to reduce the loss of water which takes place from leaf surfaces (see chapter on leaves), and place the cuttings in the soil, embedding them to a depth of from two to three inches. Compress the soil firmly around the cuttings, for if the soil remains loose the cutting will suffer from lack of moisture. The work of planting cuttings is much facilitated by using a piece of wood about six inches long and about the thickness of one's little finger for making the hole in the soil to receive the cutting, and for compressing the soil around its base. Water and tend the boxes, as in the case of seeds.

Plant a number of cuttings so as to provide material for examination. At short intervals remove one or more cuttings from the soil, and note carefully the changes which have taken place; these examinations should continue until the relationship of the resulting new plant to the cutting is clearly established. Sketches or diagrams should accompany all the notes.

Place cuttings of watercress and coleus in bottles of water. After a time, roots will develop, and their growth and character may be observed. It is convenient to use a clear bottle wrapped round with paper or cloth to exclude the light.

Branches of shrubs will frequently take root if they are fastened down on moist soil. By means of suitable pegs, secure two or three branches of a rose, or other tree, firmly upon the ground, covering them with a little soil where they touch the ground; water and tend carefully. The branch will after a time be found to have rooted, and may then be severed from the parent tree and planted in another spot. Rooting may be encouraged in this operation by removing a narrow ring of bark at the place where the branch touches the ground.

When valuable trees are to be propagated, and it is important that no risk be run of the cutting dying, the last plan may be modified as follows. On the rose, gooseberry, lilac, or other shrub which it is desired to propagate, select a branch which is easily accessible, and from it remove a ring of bark, right round the stem, about half an inch in width. Have ready a flower-pot, sawn lengthways into halves, or a small wooden box with one side removed and a slot in the bottom to admit the branch, as shown in Fig. 4. Place the pot in position round the stem where it has been prepared, bringing that part of the stem from which the bark has been removed, to about the middle of the pot. Tie the two halves of the pot together, and secure it firmly in its place by fastening it to a stake driven in the ground. Everything being now in position, put a little dried grass or coco-nut refuse at the bottom of the pot and fill up with soil; keep the pot watered. After the branch has been for some time in the pot, begin the process of severing it from the parent plant by cutting a small notch in it a few inches below the bottom of the pot; after three or four days deepen this notch and repeat the process at intervals until complete severance is effected. The branch should now have rooted and become an independent plant which may be planted in a suitable place.

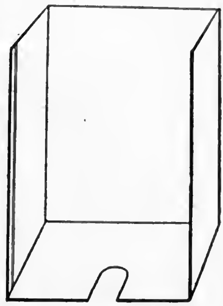

FIG. 4.—Box with top and one side removed, and slot cut in bottom to admit branch. When the branch is in position and the box filled with soil the front should be slid in along grooves in the sides.

Peg down on moist sand some leaves of "fibrous-rooted" begonias, the veins of which have first been nicked on the lower side with a penknife. The pot or box should be covered with a sheet of glass, and lightly watered occasionally as found necessary. In the course of a week or two roots will begin to be formed at the cut places, and rough wart-like outgrowths to appear on the upper side. From these small leaves are later formed, and develop into little plants. This method is employed for the propagation of these plants, and is of especial interest in showing that in some plants, at any rate, roots and even complete plants are formed by leaves.

CHAPTER III

THE STEM

In the previous chapter, although attention has mainly been directed to the root, it can scarcely have escaped notice that most of the plants examined are made up of two well-marked and very distinct portions—(1) the underground root, and (2) the aboveground stem bearing leaves and flowers, and often for convenience spoken of as the "shoot."

It is true that in some plants—for example, the houseleek and primrose—the stem is exceedingly short, so that the leaves appear to spring almost directly from the ground. In other cases, for instance, in climbing plants such as the hop, scarlet runner, etc., the stems are very long and thin, and the same holds good for many creeping plants like the couch grass.

Stems also vary greatly in another respect. Whilst young they are almost all soft and green; some remain permanently in this condition, but others become hard and woody with age. The comparison of young and old shoots of elder, and young and old garden balsams illustrate this point very well. Putting aside for the moment all these differences, we may say that plants in general are made up of the underground root, and the above-ground shoot bearing leaves, flowers, and fruit. Root and shoot are distinct even whilst the young plant is still contained in the seed, being represented there, as we have learnt, by radicle and plumule respectively.

The leaves are usually arranged on the stem in a definite manner; the places on the stem from which the leaves spring are known as the *joints* or *nodes*, and the interval between any two nodes is an *internode*. Nodes and internodes may be very clearly distinguished on most growing shoots, *e.g.*, roses, elder, privet, etc.

On examining any leaf-bearing stem it will be noticed that the oldest leaves are at the base, and that as we approach the summit of the stem the leaves get younger and younger. At the apex itself we find the youngest leaves, often more or less closely packed together to form a *leaf-bud*. Similar but smaller leaf-buds are usually to be found lower down the stem, situated just above the place where a leaf joins the stem; it is very general to find one to each leaf.

In the majority of plants the stem is the above-ground portion, the root only being below ground. This, however, is not always the case, and a few of the more important exceptions will be considered later.

Uses of Stems.

One of the most important functions of the stem of a plant is to support the leaves and display them to the air and light in the best possible manner for the work they have to do. Careful observations should be made of the arrangement of the leaves on—(1) upright growing plants; (2) climbers against walls, trees, etc.; (3) plants which trail along the ground; (4) plants in which some of the branches are upright whilst others lie more or less horizontally. The privet may be taken as a good example of the last class. On the upright growing shoots the leaves are arranged all round the stem, so that we cannot say which is the upper and which the lower side of the shoot. If, however, we examine a shoot growing horizontally, we at once notice that all the leaves are twisted round to one side, so that on looking from above we see only the upper sides of leaves, whilst from beneath only the under sides. Here, then, we have apparently a distinct upper and lower side to the branch. Still more careful examination, however, particularly of the tip of the same branch, will show that the leaves arise exactly as on the upright-growing shoots, and twist later into their final positions. Many creeping plants—*e.g.*, ground ivy, creeping jenny, etc.—also show very nice arrangements to prevent the leaves shading one another, and in the practical work great attention should be paid to them.

Stems, like roots, often serve as storehouses of food. The majority of the stems which serve as storehouses grow partially or entirely beneath the surface of the soil, probably to protect the valuable stores of food they contain from injury and cold. In general appearance these underground stems resemble roots, indeed in some cases it is difficult to distinguish them from roots. It may, however, be taken as a general rule that a stem—whatever use it may serve—always bears leaves. The examination of the examples given below will show us that we do not find green leaves in every case, as in underground stems the leaves are more commonly reduced to dry, scale-like bodies.

The iris or flag, and Solomon's seal afford good examples of stems of this kind, running horizontally in the ground, bearing scale leaves, leaf-buds, and roots. Stems of this nature are usually spoken of as *rhizomes.* Those leaf-buds which grow above the surface of the soil form green leaves, but the underground portion of the stem bears nothing but dry scales.

A potato is an enlarged and swollen stem, and not a root. Leaves are almost absent, being represented only by the "*eyes*," which are in reality leaf-buds, as is easily seen by keeping some potatoes in a damp place for a time, when the "*eyes*" will grow, developing finally into well-marked stems bearing leaves. Stems of the nature of the potato are known as *tubers.* The Jerusalem artichoke is interesting, as its underground stem, with its very well-marked scale leaves, serves to connect up the type of stem met with in the iris and Solomon's seal, and true tubers, such as the underground potato stems.

Rhizomes and tubers are examples of stems which are adapted to a special purpose, namely, to hold stores of food for the future use of the plant.

In the iris the underground stem keeps on growing, year after year, and by its branching serves also to propagate the plant, for, as the older portions die away, the branches become separated and form independent plants. In the potato this is still more marked, each potato plant forming each year a large number of tubers, every one of which can the next year form one or more new potato plants. As is the case of roots, so with stems, man puts some to his own use, and accordingly cultivates potato plants and allows them to form their tubers, or stores of food, which he utilises.

Stems also serve as the means whereby plants climb. In some cases—for instance, convolvulus and beans—the ordinary stem *twines* about any convenient support; in others—for example, the white bryony, passion flower, grape vine, etc.—portions of the stem are modified to form special climbing organs, known as *tendrils.*

The crocus affords another example of a stem acting as a storehouse of food. The stem is here even more specialised than the potato, and, as we shall see later, contains not only a store of food, and leaf-buds, but even the flowers which will come up in the spring after it is formed, the whole being packed up in, and protected by, special, tough, scale leaves.

It is of great interest to trace how what appear at first sight very different and distinct plant structures are really very much alike, and gradually pass into one another.

In the creeping jenny and many other plants we find stems which trail over the surface of the ground but bear leaves all along their length. In the strawberry these ordinary creeping stems bearing leaves are replaced by runners, with only small scale leaves. This type is the best for the special work they perform of spreading the plant from place to place. In the iris and Solomon's seal, underground stems loaded with food-reserve take the place of the strawberry runners. The artichoke supplies the connecting link between the rhizome and the potato tuber; and finally we get the crocus corm, a very compact, stem structure containing food-leaf and flower-buds, with a protective covering.

Structure of Stems.

A piece of the stem of a horse chestnut, elm, oak, ash, hawthorn, rose, or other tree, when cut across and examined, is seen to be composed of various parts arranged in a definite manner. In the middle there is a soft portion, the *pith*, small in some cases, large in others; this is surrounded by hard *wood*, which, in the case of old trees, makes up the greater portion of the stem, whilst in young branches it only forms a thin ring; outside of all is the *bark*, sharply marked off and easily separable from the wood. The bark itself is made up of three layers (easily recognised in the horse chestnut or ash)—an inner, fibrous layer; a middle, green portion; and an outer, thin brown layer, not at all fibrous, but which readily breaks in pieces if any attempt is made to detach it.

The region where wood and bark join is of great importance, for there is present, between these two conspicuous tissues, a soft, somewhat slimy, thin layer, best seen in young, vigorously-growing shoots. This layer is the *cambium*, or growing layer, and consists of young growing tissue similar to that which is present at the apices of stems and roots. The cambium has the power of producing new tissue in either direction; that is to say, situated as it is between wood and bark, it can add both to the wood and to the inner bark. The increase in thickness of the wood is generally very much more than that of the bark. This is well seen by examining the cut end of a felled tree, for instance, an elm or oak; the enormous difference in thickness between such an old tree and a seedling elm or oak being due almost entirely to the additions made to the wood by the activity of the cambium layer. The presence of a cambium is practically restricted to dicotyledonous plants.

Certain changes take place in the wood of many trees as it increases in age. From what has already been said, it will be recognised that the oldest wood is near the centre, the new wood being formed always on the outside. It is not uncommon to find the wood near the centre of the trunk darker in colour. This is particularly well seen in the laburnum, where the centre part is deep brown and the outer portion light yellow. The elm, oak, etc., show the same, although to a less striking degree. This central dark wood is the *heart-wood*, and the outer softer and lighter-coloured wood the *sapwood*.

The rate of formation and the character of the new wood formed from the cambium varies at different seasons of the year. Thus, when a cross-section of a stem is looked at, rings or layers in the wood are visible. Trees grown in countries having well-marked seasons of winter and summer, usually show a definite ring for each year's growth, and by counting the rings the age of the tree can be told. In tropical countries the seasons are often not sharply marked off, and the rings of growth are accordingly often wanting or indistinct.

Close examination of a cross-section of a stem reveals the presence of fine lines—well seen in a rose stem—running through the wood, joining up pith and cambium. They are also well indicated by radiating cracks, often formed in posts or felled timber which has been exposed to the weather for some time. These are the *medullary rays* which serve to connect up and maintain communication between the various parts.

If now a stem of maize, cane, or almost any other monocotyledonous plant is examined, the parts will be seen to be arranged in a very different manner from those of the stems already studied. In the stems of this second set we can distinguish no pith, no ring or column of wood, no separable bark, and no cambium. They exhibit in cross-section a groundwork of soft tissue, in which harder portions are irregularly scattered; and whilst the outer portion forms a kind of rind, it is not essentially different from the rest, but merely contains a much greater proportion of the hard portions, and very little of the soft ground-tissue. On cutting such a stem lengthwise, it is readily seen that the hard portions are in reality fibrous strands which run through the stem.

For a full description of the various tissues composing these two types of stems, the reader is referred to botanical text-books.

Grafting and Budding.

The existence of the cambium in the stems of dicotyledonous plants renders possible the carrying out of certain operations known as *grafting* and *budding*. This depends upon the fact that the cambium, being a region of active growth where new tissue is being regularly formed, can repair injuries to the bark or to the surface of the wood, and, moreover, when the cambiums of two stems are brought together by suitable operations, they both form new tissues so intermingled that the two stems unite and grow together.

To carry out grafting in its simplest form, select two branches, of equal thickness, of different trees of the same species, and without separating either from its parent, cut away a portion of the bark and a little of the wood below it, thus exposing the cambium as a narrow line surrounding the cut; take care to make the cuts on both branches of about the same size and shape. Bring the cut surfaces together with their respective cambiums in close contact as far as possible, and securely bind the branches together in this position. Each cambium now makes efforts to repair the injuries to the surrounding tissues, and, all being well, the new growth thus resulting unites the two branches. One of the branches may now be severed from its parent tree at a place between the root and the point of grafting. The upper part of the branch so severed will have to depend on the root of the other tree for its support, and thus becomes a part of that tree, or, as it is usually expressed, is grafted on to it. This method of grafting is known as "*grafting by approach*," because the two plants, each on its own roots, are brought together.

In other forms of grafting, separate pieces, called *scions*, of the tree which it is desired to propagate, are fixed, with proper precautions, to another tree of the same species, known as the *stock*, properly prepared to receive them.

In all the methods the essential point is that the cambium of the scion shall be brought into contact with the cambium of the stock; any mode of cutting or shaping the cut surfaces of the stock and scion which enables this contact of the cambiums to be secured may be adopted as a method of grafting, and the methods are often named according to the manner in which the scion and stock are cut or shaped. The branch or stem which is to serve as the stock is cut off at the place where it is desired to insert the scion, and shaped according to the method to be adopted. In the simplest case the stock is cut across obliquely, and a scion of the same thickness is cut in a similarly oblique manner, so that the two cut surfaces will fit together. Stock and scion being thus prepared, fit them together, so that their cambiums are in close contact, and fasten them securely in position by means of suitable binding material. There is a tendency for scions thus shaped to slip out of position; notches or tongues are therefore often cut in both stock and scion to diminish this danger of slipping, but care must be taken to cut the two surfaces in such a manner that they may fit together accurately.

In some cases it is desired to fix a small scion on a large stock. The stock is then cut off at the place where the scion is to be inserted, the end of the scion trimmed to a thin, pointed, wedge-like form, and thrust in between the wood and the bark of the stock—into the cambium in fact. In another method a long narrow V-shaped incision is made in the bark and down into the wood of the stock, the base of the scion is cut to a corresponding shape, fitted to the stock and secured in position by binding.

In all these methods of grafting it is necessary to cover the junction between scion and stock in order to prevent the tissues drying, for the cambium would then die and no union take place. In order to preserve the tissues in a moist condition it is sometimes the custom to fix a mass of clay over the place where stock and scion meet; this, however, is liable to become dry and to crack, so that it is preferable to employ soft wax in a similar manner. More commonly, strips of cloth or tape are covered with the wax, and these strips are bound round the joint, thus holding the scion in place, and, at the same time, forming a waterproof covering which effectually keeps the tissues from drying.

One particular method of grafting, known as *budding*, deserves special mention. It consists in the removal of a bud together with a little of the wood and bark, and consequently a portion of the cambium, from one plant, and its insertion under the bark, that is in the cambium region, of another plant. The inserted bud unites with the plant in which it is inserted, and, growing quickly, forms a new branch.

When plants are grown from seed they often differ very markedly from the parent-plant which produced the seed. This variation, whilst a useful feature when the grower is seeking for new forms of plants or striving to obtain improved varieties, is one which is not welcome to the cultivator who sows seed and wishes to raise a crop on the character of which he can rely. It is still more important in connection with fruit or other trees which take some years in coming to maturity, for it is naturally very disappointing to the grower to find that the tree he has raised does not produce fruit of such good quality as the tree from which he obtained the seed, or that the ornamental plant obtained has not the character which made the parent of value. It is therefore important to know of methods by which plants can be propagated and retain the characters of the plants from which they are derived. This is secured by planting cuttings and by budding and grafting: the plants raised by these methods retaining perfectly the characters of the original plants. It thus follows that when a new and desirable variety of plant has been secured from amongst the varying characters exhibited by seedlings, the cultivator can produce a large number of plants possessing the desirable characteristics of the selected variety by propagating it by means of cuttings or by grafting or budding.

It will be readily understood that budding and grafting can only be successfully practised with plants possessing a cambium, the absence of a cambium zone making these operations impossible in other plants. Budding and grafting are successful only when the two plants operated upon are nearly related, thus the various varieties of apples may be grafted on one another, and the different kinds of roses grafted on other roses, but an apple cannot be grafted on a rose, or a rose on a cherry.

Plants possess the power of healing up wounds, such as are made when a branch is sawn or broken off, gashes made in the stem, etc. The cambium plays an important part in this process also, and under favourable circumstances the whole wound may become covered over by the new growths which are formed. Interesting cases may often be seen in wayside trees.

Practical Work

Obtain complete specimens (*i.e.* with roots, and if possible flowers) of any ordinary non-woody plants—*e.g.*, marigolds, grasses, balsams, primroses, house-leeks, dead-nettle, etc.; climbing plants, such as convolvulus, beans; creeping plants, such as creeping jenny, couch grass, strawberry, etc. Notice how in spite of all their differences they all have an above-ground "shoot," made up of a stem (sometimes very short) with leaves and flowers, and a below-ground root, bearing no leaves or flowers. Make sketches to illustrate diagrammatically the characteristic points of at least one example of each group —*e.g.*, a balsam, a primrose, a bean, and couch grass.

Examine a leafy shoot of privet, elder, dead-nettle, or of almost any other plant available, and notice that it is made up of a stem, bearing leaves. Distinguish the nodes and internodes, and observe that the internodes get shorter as you approach the top of the stem, the leaves accordingly becoming more crowded. At the very summit the internodes are extremely short, and the young leaves are packed together to form the terminal leaf-bud. Observe the smaller leaf-buds which occur just above the place where a leaf joins the stem.

Examine a privet bush, and notice that whilst some shoots grow upright, others lie almost horizontally, and that whilst in the upright shoots the leaves are arranged equally on all sides of the stem, they are on the horizontal shoots twisted to one side. Examine closely the youngest leaves in both cases, and observe how this apparent great difference in the arrangement of the leaves is brought about.

Fasten one of the horizontal shoots, without damaging it in any way, so that it is upside down, and see how the young leaves arrange themselves.

Examine also shoots of hazel nut, ivy, horse chestnut, maple, creeping jenny, and learn that in all these cases leaves are arranged on the stems so that they may be well exposed to the light, and do not shade one another. Make drawings of these leaf arrangements.

Uses of Stems.

Dig up a growing plant of iris or flag, wash it free from soil, and notice the underground stem with its well-marked rings. Examine the youngest part, and notice the sheathing bases of the green leaves. Pull a leaf off and see the scar it leaves. What have these scars to do with the rings seen all along the stem? Look for leaf-buds along the stem, and ascertain how the stem branches, and how new plants may be formed. Make sketches showing all the parts seen, including the growing portion, the leaf-scars, the buds, and the roots.

Examine "Jerusalem" artichokes, noting the large number of slightly projecting scale leaves with which they are covered. If possible, obtain a whole plant as dug up, carefully wash away the soil, and see that the artichokes are borne on very short underground stems which are quite distinct from the roots of the plant.

Make drawings of the whole clump, and of one separate artichoke.

Place a ripe artichoke to germinate. Notice where the new shoots come from. Notice carefully how, on the new shoots, there is a gradual transition between the scale leaves of the tuber and the ordinary green leaves of the plant. Draw some of the best instances to show this.

Dig up carefully a potato plant, when the potatoes are about half-grown, and wash it clean from soil under a tap. Examine the underground stems on which the potatoes are borne, looking especially for any small leaves distinguishing them from the roots. Make drawings. Notice the "eyes" in the potatoes. Get some seed potatoes and place them in damp sand until they begin to sprout, and ascertain whether the new shoots arise anywhere on the potato, or from the eyes only. Make a drawing of a potato before it has started sprouting, showing the eyes; and after it has sprouted, showing the young shoots.

Obtain some crocus corms. Gladioli are still better, being larger, but they are more expensive. Notice the dry scale leaves forming a protective covering, and the white pointed buds at the top. Pull off the scale leaves one by one, and compare the scars they leave with those already seen in the iris. Cut the corm through lengthwise; it is solid. It is thus a stem structure, bearing leaves (the brown scales) at definite places (nodes), and is in reality a very much swollen stem. With the help of a lens, it is possible to see the young leaves and the flower, packed away in the central bud, when it is cut through. Dig up crocus plants (1) when in flower, and (2) after the flowers have died. Make out where the roots spring from; that the corm is gradually used up and withers as the plant flowers and that a new corm, which will flower next year, is formed on top of the old one. Make careful drawings of—(1) a corm ready to plant, with its leaves on; (2) the same cut through lengthwise; (3) the same with the leaves stripped off; (4) a plant in flower showing roots, etc.; (5) a plant after flowering, showing where the new corm arises.

If the new corm is always formed on top of the old one, why do not the corms after a few years appear above the surface of the ground?

Examine plants of hop, bind-weed, and scarlet runner, thin flexible stems about any convenient support. Make out the direction in which the stem twines, and how the free end of the stem moves in a circle until it meets with some object to twine around. Make similar observations on any other twining plants which can be obtained.

Examine the cucumber, white bryony and grape vine, and notice the special, delicate side branches—tendrils—by which the plant clings to a support. Those of the white bryony and cucumber usually twist up in a beautiful manner, forming a spring, after they have caught hold of an object, whilst before this they stick straight out. Two examples only are mentioned here, but many others will readily be found.

Structure of Stems.

Examine young and old pieces of the stems of any of the following plants obtainable: elm, horse chestnut, ash, oak, rose, hawthorn, and note, making careful drawings, all the parts previously described (p. 46). Cut stems both across and lengthways. Examine the cut ends of any old trees, and compare with young plants of the same kind, noting particularly the enormous difference in thickness of the wood.

Examine a thick branch or stem of a tree which has been cut lengthways, and observe how the branches can be traced downwards through the wood of the main branch or stem, giving rise to knots. Make drawings of these as seen in both longitudinal and cross sections. The trees mentioned above, or almost any timber trees, afford good examples.

Examine, in cross and longitudinal section, stems of any monocotyledonous plants—for example, maize, any large grasses, any palm (for instance, in museums). Note the hard, outer rind, and the inner, soft, ground-tissue with the hard, fibrous strands running in it. Compare the parts in these stems very carefully with those of the dicotyledonous stems of the preceding paragraphs.

Grafting and Budding.

To perform these operations, good, sharp and strong knives are necessary. Much may be done with an ordinary penknife, but proper grafting and budding knives greatly facilitate the work. They are inexpensive, and procurable from any dealer in gardening tools; a small number should form part of every school's equipment.

Before beginning work it is necessary to prepare supplies of grafting-wax and budding-tape. The following recipe should be followed for preparing grafting-wax:—Melt together four parts by weight of resin, one part of beeswax, and one part of tallow. When thoroughly melted, pour into cold water, and when cool enough, take out and work by moulding and pulling until it becomes quite stiff. It is necessary to have the hands well greased with tallow while handling this wax.

Budding-tape is prepared by dipping strips of cloth into melted wax. The wax used is beeswax mixed with a sufficient quantity of kerosene to render it soft and pliable, the mixing being aided by the *cautious* application of heat; a mixture of two parts of beeswax with one of resin is often used, the two substances being carefully melted together. Various kinds of cloth are employed; some workers using linen or calico, whilst others prefer thin flannel. The cloth is torn into strips —about $\frac{1}{2}$ to $\frac{3}{4}$ inch wide, and of convenient length— which are dipped into the melted wax, then lifted out, and all the superfluous wax allowed to drain off; when cool the strips are ready for use. A sufficient supply of budding-tape to last for some time should be prepared.

Some of the forms of adhesive plaster, as used by surgeons, which can be purchased from druggists in narrow widths ($\frac{1}{2}$ to $\frac{3}{4}$ inch) on reels, may be usefully and conveniently substituted for budding-tape.

Grafting by approach:—Select two trees of the same kind but presenting some points of difference, as two apples, two roses, or two currants; one or both of the selected trees should be growing in a pot or tub, so that the two trees may be brought together. Now decide which tree is to form the stock and which is to provide the scion. Select a branch of each—conveniently situated, so that the two branches can be brought into close contact—taking care that the selected branches are of nearly the same thickness at the points where they are to be operated upon. Devise some means whereby the two plants, or at least the two selected branches, may be firmly secured, so that the scion may be kept in position on the stock. The method of doing this will depend on the size and character of the two plants; merely binding the two branches together will be sufficient in many cases, or, if the stock is a large tree and the plant providing the scion is contained in a pot, the latter can be secured to the trunk or to a branch of the stock. Having made these preparations, cut away a piece of the stock at the selected point, removing from two to four inches of the bark with a little of the wood below it, taking care that the cut is smooth and even. Make a similar cut on the scion, in such a position that the two cut surfaces may be brought into close contact and will fit together fairly well. Bring the two surfaces together, secure them in position by means of strong, soft twine tied both above and below the place operated upon, and, finally, wrap a strip of budding-tape firmly around the united branches covering the junction completely; the edges of the tape should overlap, so as to prevent the evaporation of moisture from the cut surfaces, or the access of rain-water to the joint. It is not necessary to *tie* the budding-tape, for the end will remain in place if pressed down on the surface of the tape bandage, the wax holding it securely. Everything being properly and securely fixed, leave the plants for a sufficient time for union to take place and then cut off the scion below the place of grafting, and trim the cut end neatly with a sharp knife.

Grafting stems of equal size:—In this method we employ as before a rooted plant as the stock, but only a detached portion of the plant we desire to graft on to it as the scion. Cut back the stock to a place where its stem is of about the same thickness as the scion. Shape the cut ends of stock and scion, so that

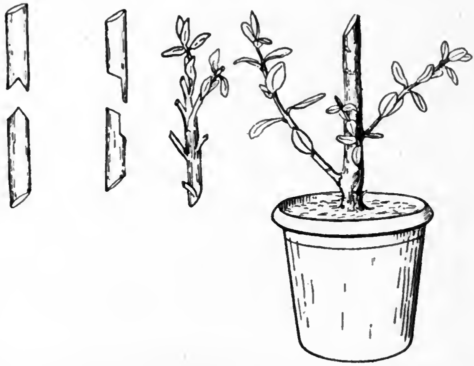

FIG. 5.—Showing modes of shaping the cut ends of stock and scion when grafting stems of equal size.

they may fit together accurately, with their cambial regions in contact. As soon as scion and stock are thus fitted together, secure them in position by firmly binding with binding-tape, taking great care that they are so securely fixed that no displacement can take place, and that the joint is so well covered that the cut surfaces will not dry.

This method admits of several variations in the manner of shaping the cut ends of stock and scion (see Fig. 5). In the simplest case, cut the two ends obliquely and merely place them in position ; the disadvantage of this method is that they are very liable to slip. Means must be taken, therefore, to prevent this, and it is usual to cut a notch in the end of the stock and a corresponding tongue or projection at the end of the scion ; or the end of the stock may be trimmed to a wedge, and in the scion a V-shaped incision made to fit accurately over the wedge. The form of the joint adopted may be varied indefinitely, but the great object to be kept steadily in view is the bringing of the cambial regions of the two cut surfaces into close contact and retaining them there.

Grafting a small scion on to a large stock :—In this case, as the cambium only forms a narrow ring near the outer margin of the stock, it is essential that the scion be placed here also. The simplest method of working is as follows :—Trim the end of the scion to a long wedge and thrust this wedge into the cambium of the stock, that is, between its wood and bark. Another method is to cut a V-shaped piece of bark from the stock, carrying the incision deep enough to remove a portion of the wood also (see Fig. 6). Then cut the end of the scion to a corresponding shape and fit it into the stock, and, having taken care to leave the bark undisturbed on one side of the scion, bring it into posi-

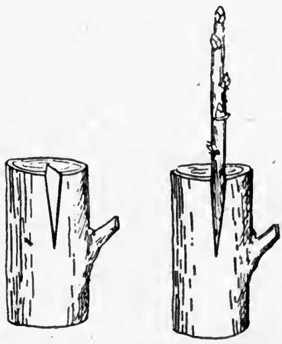

FIG. 6.—Showing a method of grafting a small scion on to a large stock.

tion so that it fits on to the bark of the stock. Fix the scion in place by means of grafting-wax, so moulding and pressing it around the joints and cut surfaces as to fulfil the double purpose of holding the scion in position and protecting it from drying up. This mode of grafting is adopted when it is desired to graft on to a thick branch or the stem of a tree which has had all its branches removed; several scions may be put on one stock.

Apple, pear, apricot, or other fruit trees available, are suggested for grafting experiments.

Budding:—For practice the pupil should work upon rose plants. Examine the tree which is to furnish the bud-wood, cut off two or three vigorous branches with well-developed side leaf-buds, and carry these to the tree which is to be the stock. Select a place on a young but fairly woody branch of the stock, and make a T-shaped incision in the bark, with the downward cut about an inch and the cross cut about three-quarters of an inch in length (see Fig. 7). Raise the bark gently from the wood, taking care not to tear it from the branch—the flattened end of the budding knife should be used for this purpose. The stock being now prepared, choose a good bud on the branches already selected, and cut off the leaf which accompanies it, leaving only a very short piece of the leaf-stalk; then with a firm clean cut remove the bud, together with a thin slice of the wood beneath. The whole piece so removed, including bud, bark, and wood, should be about three-quarters of an inch long and one quarter wide. Insert the bud thus prepared under the bark of the stock, proceeding carefully so as not to tear or unnecessarily injure the bark. All these operations should be performed as quickly as possible, to avoid the drying up of the cut surfaces. As soon as the bud is in position fix it by one or two turns of thin, soft twine or other material, then take a strip of budding-tape and wrap round the stock with the inserted bud, beginning slightly below the place of operation and allowing the edges of the tape to overlap at each turn. The bud may be covered over completely, or, if very prominent, it may be left exposed; the budding-tape should not be tied, the free end being held safely in position by pressing it down on the wrapped portion.

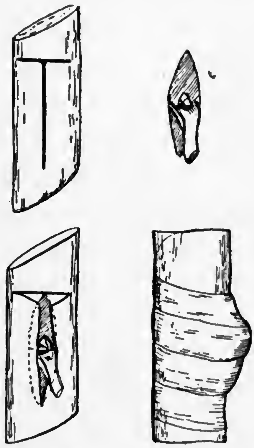

FIG. 7.—*Budding.*—The upper right-hand figure shows the bud ready for insertion under the cut bark of the stock (upper left-hand). The lower left-hand figure shows the bud in position, aud the remaining figure illustrates it bound up in the budding tape.

Budding is frequently resorted to in tropical countries, with oranges, lemons and other citrus fruits, when it is desired to grow some selected, choice kind upon a stock of a hardy variety. For this purpose seedlings of the kind to be used for the stocks—in practice often sour oranges or "rough" lemons—should be raised in nursery beds. When the stems are of about the thickness of one's finger, insert buds of the selected variety in the stem of the stock, three or four inches above the level of the ground. In about ten to fourteen days the buds should be found to be securely united to the stocks, when the wrappings of budding-tape may be removed. Four or five days after this, cut part-way through the stem of the stock, about an inch or two above the inserted bud, and bend down the top of the stem from the cut point, so as to lie along the surface of the ground. The flow of sap to the upper part of the stock is thus checked, and increased growth of the bud results. When each bud has developed into a good strong branch, cut off the now prostrate stem, and trim down the stump close to the point where the branch arising from the bud grows out, so that the scar may heal neatly, and the new branch may grow straight as a continuation of the stem, and thus form a shapely tree. Should any bud develop at any point below the place where budding took place, it must be rubbed or pinched off.

To ensure success in budding, the work must be done when the stock is in such a condition that the bark can be easily raised, this occurring when the cambium is in a state of active growth. Skill is also necessary in selecting good bud-wood from which to cut the buds. The work should be practised regularly, until each pupil can work rapidly, neatly, and with a small percentage of failures. This branch of work should not be dismissed in a lesson or two, but real practical skill should be acquired by repeated exercise.

Healing of Wounds.

Examine these places on trees where branches have been cut off or broken off, and notice how, after a time, new growths have formed whereby the wounds are healed. This healing of wounds is of great importance to the plant, as, just as in animals, an open wound is often the cause of the plant developing some disease. All cases seen should be examined carefully, and accurate drawings made.

CHAPTER IV

THE LEAF

DURING the previous practical work we have had occasion to observe the structures, known as leaves, which are borne on the stems of plants. It is a matter of common knowledge that the leaves of different plants vary greatly in size, character and shape, and we commonly distinguish plants, when not in flower, by the shape of their leaves. Apart from these minor differences many leaves agree in having a more or less thin, flattened, green portion, known as the *blade* of the leaf, which may be "simple" in shape, as a privet, elm, or nasturtium leaf, or much divided, as an ash, rose, or vetch leaf. In many plants—for example, the sow-thistle or honeysuckle—this leaf-blade joins directly on to the stem, but in others it has a thinner, generally rounded, lower portion, the *leaf-stalk*, easily seen in a maple, horse chestnut or nasturtium. In addition to these two parts many, but by no means all, leaves show, at the point where they join the stem, a pair of bodies which are known as *stipules*. These may be small, as in the garden geranium, or comparatively large, as in the pea, pansy and hawthorn.

The blade of the leaf has been spoken of hitherto as a thin expansion. This is true in by far the greater number of plants, but many plants, especially those which live in very dry places or near the sea, have leaves which are either thick and fleshy, as in the house-leek, or very small, as in the heather and furze. We have also seen already, when examining iris, artichoke and crocus stems, that leaves are not always green. Other examples of the various characters which leaves can assume will be met with later.

Uses of Leaves.

Leaves are necessary for the health and growth of most plants, as in them are carried on the processes of breathing and the manufacture of food-material. The consideration of these processes is, however, best deferred until we have made ourselves acquainted with the structure of leaves. We will therefore first deal with their other less important uses.

The young leaves of most plants are very delicate and easily damaged by exposure to the sun, wind, and frost. It is common to find these young leaves protected by being enclosed by the older ones, as may be seen in the leaf-buds of the lilac and privet, and very strikingly in cabbages and lettuces. In the docks the young leaves are rolled up within the next older leaf, and specially protected from drying up by being bathed in a sticky liquid. The school garden will readily furnish numerous other interesting cases. In the common red clover the stipules protect the young leaves. In many plants—for instance, the pear, apple, and beech—the stipules are small, and look at first sight mere useless structures. Examination of the buds of these plants shows that this is the time when the stipules are of use, as then they are large in comparison with the young leaves and serve to cover and protect them.

We have so far confined our attention to the buds found during the warm season of the year, when the plants are actively growing, and all that is necessary is to protect the delicate young leaves from the wind and sun, and possibly from cold during the night. In some parts of the world it is "always summer," the plants there are almost continually growing, and we find buds of this nature the whole year through. In Great Britain and other temperate countries, the conditions are very different, and summer and winter follow each other regularly. We are all familiar with the sight of trees and other plants growing through the summer, ceasing to grow in the autumn, and as soon as the weather begins to turn cold dropping their leaves and becoming quite bare. In this condition they remain during the winter, to all appearance dead, but they are only resting, and as soon as the weather turns warm again young leaves reappear and the plants once more enter on their growing stage. The bursting into leaf of trees and shrubs is one of the most constant features of the spring in temperate climates.

If we examine trees—for instance, a horse chestnut—during the winter we find no leaves, but a number of large brown bodies—the buds—covered with more or less sticky scales. One of these buds carefully pulled to pieces will be found to be covered on the outside by a series of overlapping brown scales, and to contain inside a number of small green leaves well wrapped up in what looks almost like cotton-wool. It is in fact an ideal arrangement for protecting the young leaves from the cold and wet. The cotton-wool-like material keeps the leaves warm, and the overlapping scales, fastened together by the sticky liquid, make a waterproof covering.

On a warm day in early spring the sticky material melts, and the buds glisten in the sunshine. If the warm weather continues, the scales are thrust apart and the tender green leaves come out and give the well-known green flush of spring to the whole tree.

How real the protection the buds afford to the young leaves and flowers is well shown by the great damage done, if a spell of warm weather sufficient to make some of the buds open is followed by frosts. It is the opened buds then which suffer; those which remained closed being quite uninjured by the frost.

We have already seen in the iris and crocus the dry scale leaves wrapping over the underground buds, and that when these buds grow into leafy shoots these scale leaves wither away. In other plants underground leaves are found, which act as storehouses of food. The common garden lilies, such as the tiger and white lilies, or an onion, serve as good examples; and on digging up one of their *bulbs* with the above-ground leaves still attached, it will be readily seen that the thick, fleshy structures which make up the greater part of the bulb, are really only the thickened bases of leaves, and are of use to contain starch and other food-reserves. That is to say, we find leaves in these plants performing exactly the same duties which the stem does in the iris, crocus, and potato, and the root in the radish, turnip and beet.

Leaves often act as the climbing organs of the plant, and all gradations can readily be found between an ordinary green leaf which has the power to hold on to, or even twist round supports and the special structures of other plants, often so much altered to make them more suitable for this particular use that they have almost lost their leafy character. Thus in the wild clematis (traveller's-joy or old man's beard) so common on chalk and limestone districts, the leaf-stalk twists round objects and holds the plant up; similarly in the garden nasturtium the leaf-stalks of the ordinary green leaves do the same. In the garden pea only a special part of the leaf—the long thin end—is of use as a climbing organ, and similarly in many of the vetches. Examples like these are of special interest, as they show us how adaptable the parts of plants are, and how the same part can serve very different purposes.

Structure of Leaves.

In most leaves the blade has running through it a number of *veins*, often conspicuous, especially on the lower side, as ridges. The leaves of the maple, blackberry, and indeed almost any ordinary thin leaves, show them very plainly, and, on holding such leaves to the light, it is seen that there is a perfect network of these veins, the small veins being branches of the larger ones. These veins are really the continuations of the woody tissue which we have already seen in the stem, and are of use as a supporting framework to the soft tissue of the leaf, spreading it out to the light and air, and preventing the leaf from being readily torn. They are also the means whereby the water taken up by the roots is brought to the leaf, and the substances manufactured in the leaf are carried away to the other parts of the plant.

The veins of leaves are arranged in two main ways: *netted*, as in the examples above; *parallel*, as in the lily, wheat, barley, and all grasses where the veins run side by side and do not form an interlacing network. These two types of vein arrangement—netted and parallel—are, on the whole, characteristic of the leaves of dicotyledons and monocotyledons respectively, and with certain exceptions—for instance, the black bryony—may be taken as indicating to which of these two groups a plant belongs.

It is impossible, without the use of a microscope, to obtain very much information concerning the internal structure of leaves. If, however, we select some thick-leaved plant, such as the iris, we find that both upper and lower surfaces of a leaf are covered with a colourless skin, which, with a little care, can be stripped off. The main mass of the leaf is seen to be made up of comparatively soft tissue, through which harder, fibrous strands (the veins) run. The thin skin makes a kind of waterproof coating to the leaves, but has an enormous number of minute openings, called *stomata* (too small to be seen without a magnifying glass), through which the gases of the atmosphere can pass in and out, and so reach the spongy tissue of the inside of the leaf. This is most important, for it is in this inner part that the real work of the leaf, the breathing and building up of new matter, goes on, and for these processes a free interchange of gases with the outside air is absolutely necessary.

Transpiration.

Everyday experience shows us that if a leafy shoot is picked it soon becomes limp and then withers, but that if we place it in water it remains fresh and stiff for a longer time. Further, we know that a shoot which has commenced to wither can often be made fresh again by placing the cut end of its stalk in water. Similarly, plants growing in the ground droop and may die if they are deprived of water for a long time. They soon revive if water is poured on the soil so as to penetrate down to their roots. From these various facts it is clear that the withering and limpness of the leaves is due to the fact that they give off water, and that more can be supplied to them either by putting the cut end of the stalk in water, or, as happens in nature, by water being taken up by the roots and passed on through the stem to the leaves.

This loss of water by the leaves is known as *transpiration*, and is of great importance to the plant, because as water is given off from the leaves more is steadily drawn up through the stem to take its place. When a plant is growing and has plenty of water at its roots, water is taken up almost as quickly as it is given off, and the whole plant remains fresh; but if there is none or only very little water to be obtained, as in the cut shoot or the plant in dry ground, the roots cannot take up enough to make up for what the leaves give off, and first the leaves and afterwards other parts of the plant droop and wither.

In transpiration, the green spongy tissue of the leaf gives off moisture which escapes into the outside air through the minute openings in the surfaces of the leaf. These openings are able to open and close according to conditions, and so regulate the rate at which water can be given off. When the air is dry they become smaller, and so hinder the escape of water. We shall see, too, from our practical work that light has an important effect, and that plants give off more water when exposed to the light than when in the shade. When cuttings of plants are being taken the shoots are separated from their roots and cannot obtain much water. It will be clear now why, under such circumstances, some of the leaves should be cut off and the cuttings placed in the shade.

We can easily measure how much water a single leaf or a whole plant gives out during a certain time, and experiments for doing so are described in the practical work on this chapter.

Another point of interest is to find out whether this water is given off equally from the upper and lower surfaces of the leaf, or more from one surface than the other. An experiment to enable this to be ascertained is also described.

In a long drought there is often insufficient water to counterbalance that given off by the leaves, and, although the pores may be closed, there is danger of injury to the plant from excessive loss of water. To prevent this, some leaves—for instance, of many grasses, and particularly those which grow in dry, sandy places—have the power of curling themselves up so as to cover the pores (stomata) with the over-arched leaf-blade, thus further reducing evaporation. Many leaves have their pores so placed that when the leaf is curled up during dry weather they are all under cover, none being present on the exposed outer side. Thus it will be seen that order prevails even under such disturbing conditions as those which lead to the withering of leaves by drought, when all appears confusion. There are many other contrivances for protecting plants from excessive loss of water. Amongst the most common are the thickening of the outer skin, well seen in houseleek, laurels, box, etc., the provision of a coating of hair, for instance, in the mullein, and by the reduction in size of the leaves, as, for example, in the pines, heaths, furze, and other plants which can live in situations where they get but little moisture.

It is important that the pores in the leaf should be enabled to perform their functions under all the conditions to which the plant may be exposed. We have already seen how in some plants they are covered and protected during drought. It is also often essential that they should not be readily filled by drops of water during rain or dew, and the surfaces of leaves often have slightly waxy or hairy coatings, so arranged that those parts of the leaf which are abundantly provided with pores are extremely difficult to wet, while surfaces with few pores are wetted easily. Good instances of this are seen in leaves which are easily wetted on the upper surface where there are no pores, but which throw off water from their under surfaces in a wonderful manner. The leaves of water-lilies, duck-weed, frog-bit, etc., cannot be wetted on their upper surfaces, but the under surfaces live in constant contact with water.

It is interesting to observe how the leaves of plants, by their position and arrangement, throw in different directions the water which falls on them as rain. In many plants, as, for example, beet, violet, dandelion, the leaves are so arranged that much of the water which falls on them is directed towards the centre of the plant, moistening the ground near its base, where the main roots are to be found. As the plant grows, the leaves often bend downwards at the tops while still inclined inwards at the base. There is thus a division of the rain, a portion flowing towards the stem, and a portion towards the outer boundary of the plant, a greater area of soil being thus moistened. This may be observed in the sunflower. In many large trees, amongst other plants, practically all the water is thrown away from the trunk, so that there is a dry space beneath the leaves and branches; water is not wanted there, for there are no young roots to absorb it near the trunks of such plants. Close observation has revealed a relationship between the direction and spread of the rootlets and the drainage system of the leaves of a plant. In those plants with widely-spreading roots the water is conducted towards the margin of the plant system (oak and many other trees). In those with bulbous roots, or with closely-tufted rootlets, or with deep, penetrating taproots, the water is commonly conducted towards the centre (violets, beet, lilies).

A plant breathes, just as animals do, and also obtains a large proportion of its food from the air through the agency of its leaves. In order, however, to understand the various processes which go on in the leaf, it is necessary to know something concerning the composition of the atmosphere.

The Atmosphere.

The atmosphere consists almost entirely of two gases, *oxygen* and *nitrogen*, which relatively compose one-fifth and four-fifths of its volume. Oxygen is the substance by whose agency all burning or combustion takes place, and which, in the breathing of animals, removes the waste products from the blood by a process of slow combustion. Nitrogen, on the other hand, is an inactive gas which serves to dilute the oxygen and modify the rapidity and vigour of its action. In addition to these two gases there are present very small quantities of water-vapour and carbonic acid gas or *carbon dioxide* —so called because it is formed by the union of the two substances carbon and oxygen.

Carbon exists in various forms, the commonest being ordinary charcoal, which is very nearly pure carbon. All *organic* substances—that is, all substances which are the product of life, become blackened or charred when strongly heated. This charring may be taken as proof of the presence in them of carbon. We thus recognise the truth of the assertion that all organic matter contains carbon. If, however, the heating is continued still further, the oxygen of the air unites with the carbon, forming the gas carbon dioxide, and the substance has then, we usually say, " burnt away."

The presence of carbon dioxide can readily be made visible by taking advantage of the property which it possesses of combining with lime to form chalk. If a solution of lime in water—that is, clear lime-water—is brought into contact with carbon dioxide, chalk is formed, and, being insoluble in water, becomes at once apparent by the milky or turbid appearance it gives to the water.

Plants and the Atmosphere.

On breathing into lime-water it soon becomes cloudy, owing to the carbon dioxide present in our breath. Plants can easily be shown to produce a similar effect. We see, therefore, that both animals and plants breathe out carbon dioxide, and, as it is also formed in the burning of wood, coal, and all other substances containing carbon, it follows that carbon dioxide is continually being added to the air in large quantities. But carbon dioxide, when present to a certain degree, is injurious to life, and yet for countless ages the actual amount of carbon dioxide in the atmosphere has not increased. It follows, therefore, that there must be some agency at work whereby its accumulation in the air is prevented, or all life would become impossible. Plants are the means whereby this accumulation is hindered. When carbon dioxide comes in contact with the living substance of the plant, under certain conditions, it is split up into its constituent parts, carbon and oxygen. The carbon is kept by the plant and built up into its tissues, and the oxygen set free. The conditions referred to above are the presence of (1) the green colouring matter (*leaf-green* or *chlorophyll*) which gives the characteristic colour to the leaves,* and in some cases the stems of plants, and (2) sunlight.

The process which goes on in the leaf whereby the carbon dioxide is broken up in this way and the carbon used by the plant is known as *assimilation.* Assimilation must be very carefully distinguished from the *respiration* or breathing of plants, in which, exactly as in that of all animals, oxygen is taken in and carbon dioxide given out. A plant is always breathing, but can only carry on the process of assimilation under the special conditions mentioned above. Whilst a plant is in the sunlight the oxygen given out masks the breathing process, and it is only when plants are in darkness, either artificial or that ordinarily occurring at night, that the fact that a plant does really breathe out carbon dioxide like an animal can be detected. When later we try experiments on the breathing of plants, it is essential to remember that the plants must be kept in the dark.

The Food of Plants.

As the result of the building-up processes which go on in the leaf, we find that *starch* is formed. In the practical work at the end of this chapter, experiments are described which enable us to prove (1) that starch is actually formed in leaves; (2) that for this formation of starch, by the living substance of the plant, leaf-green and sunlight and the presence of carbon dioxide are necessary conditions.

* In some plants—for instance, copper beech, coleus—the colour of the leaf-green is hidden by other colours. But the leaf-green is always there nevertheless.

Starch is a very common substance in plant tissues. It is one of the chief forms in which plants store up reserves of food to be used on some future occasion, when greater demands are made for food than can be supplied by the assimilation of the moment. In the production of fresh shoots from potatoes, and in the germination of seeds, a large amount of growth goes on, entirely at the expense of the food-reserves stored away in the tuber or seed. It is only later, when the new shoot has formed its own green leaves, that it can do anything at all towards making fresh supplies of food for itself.

It has already been stated, and will later be experimentally proved, that assimilation, resulting in the formation of starch, can only go on in the green parts of plants, and only there when they are exposed to sunlight. The question naturally arises then: how do we find starch in tubers, seeds, or other non-green and even underground parts of plants? The answer to this, too, will be supplied by means of simple experiments. If a growing plant is left exposed to a good light from early morning to afternoon and its leaves tested then, they will be found to be loaded with starch. But, place this same plant in darkness for twelve hours or more, and its leaves will be found to be almost emptied of starch. As a matter of fact, the starch formed in them in the sunlight has been changed into sugar, and in this form carried away from the leaves in which it was made, and either used up in growth or often changed back again into starch and stored up in some other part as a reserve of food.

It may seem at first sight wasteful on the part of the plant to make starch, then change it into sugar, and often change this sugar back again into starch in some other part of the plant. We shall, however, see that there is a reason for this, inasmuch as only substances actually dissolved can be carried about from one part of a plant to another; and that, as starch is insoluble, it has to be changed into a soluble substance (sugar) to enable it to be moved from the leaves where it is formed to other parts of the plant where it is needed.

A plant requires for its complete nourishment other food-substances besides carbon dioxide and water. These foods are mainly nitrogen and mineral matters. They are usually obtained from the soil, being taken up, dissolved in water by the roots. This watery fluid which permeates the plant is known as the *sap*, and is in constant circulation owing to the evaporation which we now know goes on from the leaves. As the result of this circulation the mineral bodies taken up in the sap by the root are carried all over the plant, and, combining with the substances formed in the leaves, are enabled to play their proper part in the nourishment and growth of the plant.

Thus we see the leaf is one of the most important organs of the plant. By their leaves plants breathe, and also obtain a large amount of their food. The transpiration from the leaves maintains the circulation of the sap, thereby ensuring fresh absorption of mineral matters by the root.

Practical Work

Examine leafy shoots of, for instance, privet, lilac, nasturtium, oak, ash, vetch, maple, horse chestnut, sow-thistle, honeysuckle, and any grasses, paying special attention to the leaves. Observe that all these leaves have a thin *blade*, which is quite simple in shape in the privet, lilac, nasturtium and grasses, lobed in the sow-thistle, oak, and horse chestnut, and divided up, so as to look almost like a number of separate leaves, in the ash and vetch. Notice which of the leaves have *leaf-stalks*. Make sketches of all examined.

Examine the leaves of house-leek, and, if you live near the sea, such plants as the sea-rocket, sea-kale, sea-purslane, or any other thick-leaved plants, often to be found growing by the seashore or in very dry places. Compare their leaves with those above, noting their succulent or fleshy character.

Examine also shoots of furze, heather, broom, or pine. Notice that these plants live in dry situations, usually on sandy soils, where only little water is to be obtained.

Uses of Leaves.

Examine the available plants (privet, cabbage, lettuce, are very good examples to take), and observe the delicate young leaves forming the leaf-bud. Notice how they are protected from the sun, wind and rain, by being more or less covered over by the older leaves. Then observe the more elaborate methods in the common docks, where the young leaves are rolled up inside a special protecting sheath, and covered with a sticky liquid which prevents them from drying up. Continue these observations on the other plants to hand. Carefully sketch all the buds examined.

Examine shoots of the common red clover. At the end of each will be found a bud completely enclosed at first by a pair of greenish-white structures, the stipules of the next older leaf, inside which all the young parts are packed away. Notice how the bud gradually opens, and how in the older leaves the stipules gradually dry up and look mere useless bodies. Compare this arrangement with the pansy, where the stipules persist as green, leaf-like bodies. Examine also the buds of the garden geranium, and note in particular how the stipules, which look so small compared with an old leaf, are really able to help protect the leaves whilst these are young and small. Make sketches to show all these arrangements, drawing young leaves protected by the stipules, and older leaves with their comparatively small and useless looking stipules for comparison.

Collect, in the autumn, twigs of the horse chestnut, and notice the large buds. Make a sketch of a twig, showing the buds and the scars left by the fallen leaves. Examine a bud more closely, and notice how it is covered by a series of overlapping brown scales. Commencing at the base of the bud, pull off the scales one by one, and see how they are stuck together by a sticky resinous material. When all the outer scales have been removed, examine carefully the inner portion of the bud, and see that it consists of young leaves, beautifully folded up and .packed together and covered with white hairs, so that they appear to be wrapped up in cotton-wool.

Watch the buds through the winter and in early spring. Notice how on sunny days they glisten owing to the warmth melting the resinous coating. When spring sets in, trace the gradual swelling of the buds and how finally the scales are burst open, and the young tender leaves emerge from their long rest.

Make similar observations on the sycamore, apple, and any other trees near to hand. Sketch carefully buds in the resting conditions, when half opened, and again after the young leaves have expanded.

Examine again the underground stems of artichoke and iris, and observe the thin, dry scale leaves. In some kinds of potatoes similar scale leaves are well shown, but in most ordinary potatoes they are almost entirely absent. Note how they enwrap the delicate, young, growing points—the buds.

Make similar observations on crocus or gladiolus corms, cutting them through lengthways and across, and noting how the dry scale leaves wrap over and protect the delicate white buds containing the ordinary leaves and flowers. Make sketches to illustrate your observations.

Examine a plant of onion whilst it still has green leaves. Note how it is wrapped round by a number of dry scales. Look at the fresh leaves, notice what their lower portions are like, and see that in reality the whole onion bulb is composed of the thickened bases of leaves, some of which are already above ground and green, whilst the younger ones are contained in the centra bud. These points can be readily made out by cutting onions both across and lengthwise. Make similar observations on a hyacinth bulb, and compare the two carefully.

Examine, in the hedges, shoots of traveller's-joy (common only on chalk and limestone districts), and see how it climbs by twisting its long leaf stalks around twigs of other plants. In addition or in place of the traveller's-joy, look at garden nasturtiums, and see how these support themselves in much the same way. Make a sketch of a nasturtium holding on to a stick or other support. Examine the garden pea, sweet pea, or wild vetches. In all these plants the end of the leaf is prolonged into a special climbing organ, a tendril, which can wrap round a stick or string, and so hold the plant up. Compare young leaves which have not as yet caught hold of a support and older ones which have. Sketch one of each.

Structure of Leaves.

Observe the veins of the leaves under examination. See how much firmer they are than the rest of the leaf; how they support the softer tissue. Hunt among decaying leaves in wet places under trees, and try to find some "skeleton" leaves in which the soft parts having rotted, the hard and more resistent veins remain as a skeleton of the leaf.

Take some box leaves and boil them for fifteen minutes in water to which caustic potash has been added, in about the proportion of $\frac{1}{20}$ oz. of the potash to 1 oz. of water. After boiling, pour away the potash and put the leaves in a large dish of water. Gently brush the leaves with a stiff camel's hair brush, and if the leaves have been boiled enough the soft parts can be removed and the veins left forming a skeleton leaf.

With care it will be found possible, on other leaves boiled in the same way, to strip off a thin colourless skin from the upper and lower sides, leaving a middle portion consisting of the veins and the soft tissue. Examine the upper and lower skins with a hand lens, and see if any of the minute pores or stomata can be made out.

Compare all the leaves which can be obtained, and note the arrangement of their veins, whether *netted* or *parallel*. Examine the stems of the same plants and see whether, as a general rule, you find stems with dicotyledonous structure bearing leaves with netted veins, and monocotyledonous stems parallel-veined leaves.

Take leaves of the iris, and pull off a portion of the outside layer of the leaf (this layer is very thin and care is required, but if the operation is properly done no green tissue will come away). Note that the outer skin is colourless, that the underlying tissue is dark green and soft, and has a number of hard fibrous structures, the *veins* running through it. The point of a knife can easily be got under one of these, and the vein pulled up like a thread of cotton.

Transpiration.

Pick a number of shoots of any ordinary thin-leaved plants, such as dead-nettle, lilac, groundsel. Place some in water and leave others lying on the table. The latter soon droop and become limp. Now place some of these in water, first cutting a little off the end of the stem to make a fresh surface, and notice that, after a time, they become stiff and fresh again, whilst those left on the table steadily become more limp and at length wither and dry up. Treat in the same way, for comparison, some thick leaves, such as house-leek, sea-rocket, sea-purslane, etc., and small-leaved plants such as heather, furze, broom, etc., and notice that these take a very long time before they show any signs of drying up, indicating of what use to these plants, which can grow in places where they get very little water, their thick or small leaves are.

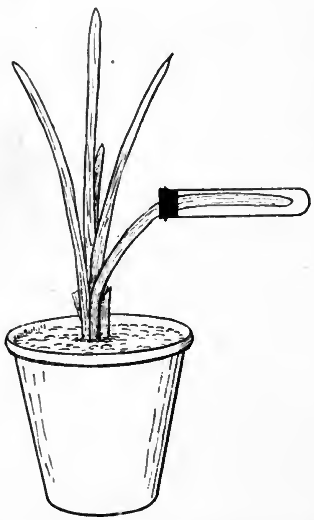

FIG. 8.—Experiment to prove that leaves give off water.

To prove more directly that it is the leaves which actually give off water, take a test-tube provided with a well-fitting cork. Split the cork lengthwise, and fit the pieces on either side of a straight leaf, such as wheat or daffodil (without cutting off the leaf or injuring it in any way), and put the cork back so that the leaf is inside the tube as shown in Fig. 8. Let the leaf remain on the plant, and notice that the glass inside the test-tube first becomes dimmed, and that later drops of water trickle down and collect at the bottom of the tube. It is not essential to use the leaves mentioned above, any leaf with a fairly long leaf-stalk will do equally well, the cork being split as before and clipped around the leaf-stalk, fitted into a slight groove made in one of the half corks if necessary.

Take a plant growing in a pot, and do not water it for a day or two. The leaves droop exactly as those of the cuttings left lying on the table. Soak the pot with water, and the plant revives. These experiments teach us that the leaves are continually losing water, but that if we supply sufficient water, either through the stem directly, or indirectly through the roots, the plant will keep fresh.

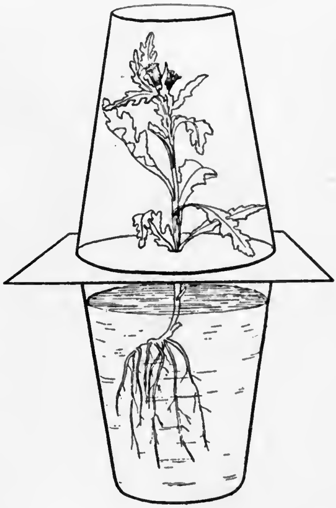

FIG. 9.—Second experiment to show that water is given off by leaves.

Take two tumblers partly filled with water, and cover each with a piece of cardboard with a small hole in the centre (see Fig. 9). Put through this hole the end of a leafy shoot —for instance, of dead-nettle or groundsel—and arrange matters so that the cut end of the stem dips under the water. Block the hole with wax or other material. Cover each of the shoots with a second tumbler, turned upside down and resting on the cardboard covering the first. Place one set in the light in a window, and the other at the back of the room where the light is dull. The inside of the upper glass standing in the window soon becomes dull with water settling on it, and after a time actual drops of water will trickle down. The one in the dull light remains bright much longer. The water which settles on the inside of the glass must come from the plant, for the card prevents the water in the lower tumbler being evaporated. We learn, then, as in our earlier experiments, that the leaves give off water, and in addition we have found out that they give off more water when in the light than when in the dark. Repeat this experiment with a shoot from which the leaves have been cut off, and compare results. Make sketches of the apparatus fitted up, and record all the observations made.

The last experiment can easily be modified to allow us to find out how much water a plant actually gives off in a given time. One method of doing this is as follows. Take a *glazed* pot without a hole in the bottom—for instance, an ordinary jam-pot—and plant in it a young sunflower or cabbage, in soil. After two or three days, when the plant has become established, water the plant, and cover up the earth with some thick tin-foil, wrapping it round the stem of the plant so that no water can escape except by transpiration through the leaves. Weigh pot and plant together, and record the weight and the time in your note-book. Place the pot in bright sunlight in a window, or out of doors if the weather is fine, until the next day, and then weigh again. The difference in the two weights gives the amount of water transpired in this time. Now lift up one corner of the tin-foil and water the plant; weigh again, and once more record the weight. Then by weighing after another interval you can obtain once more the amount of water transpired in this time. Vary the experiment by placing the plant in dull light, or cool places, and see what difference this makes in the weight of water given off in a certain time.

There is one point we have not yet determined, namely, is the water transpired by the leaves given off equally from both surfaces of the leaf, or does one surface transpire more than the other? A simple way of testing this is to place some leaves flat, between two pieces of glass, and notice whether one piece of glass becomes bedewed quicker than the other, or whether both become moist at equal rates. In making these experiments, place the leaves between the glasses, and fasten the glasses together with a string or elastic bands, and then stand them upright so that both sides are equally lighted. Unless this is done you would not be certain that any differences noted were not due to one side getting more light than the other, and as our earlier experiments have taught us, transpiring quicker.

Having found in the previous experiment some leaves which transpire from one surface and not from the other, plunge them into boiling water, and watch carefully for small bubbles of air coming from them. These should appear on the side from which the water is given off, the bubbles coming out through the little pores or stomata, owing to the air inside the leaf getting hot and expanding. In many leaves the bubbles come only from the lower side.

Examine these same leaves with a lens, looking carefully for the very small pores. As the above experiment has shown, these are often present only on the lower surface of the leaf.

Take a tumbler, fill it half-full of water coloured with a little red ink or eosin. Place some leafy shoots (balsams or lime twigs do admirably) with the cut ends of their stems dipping in the water, and leave them for a day in a light place in a warm room. The stems become marked with red lines, and finally the leaves also. This coloration is due to the water which passes up the bundles of the stem and their continuation in the leaves (the veins), and, being red, colours them, thus indicating the path in the stem along which water travels.

Note the manner in which the leaves of many grasses roll up during very dry weather. This may also be observed by bringing the grasses into the room and noting the change as the leaves become dry. Observe the positions assumed by the leaves of other plants during dry weather, or at the middle of the day when the sun is very hot, noting whether they roll up or droop. The leaves of house-leeks, laurel, holly, and other thick-leaved plants do not roll up. They are sufficiently protected by their thick skin.

Observe during rain, or while watering with a watering-can with a very fine rose, the direction in which the water is conducted by the leaves of the plants growing in the garden. Compare this with the distribution of the roots, and particularly of the young rootlets by which water is absorbed. Note the course of the water and the arrangement and character of the roots, in—beet-root, dandelion, violets, lettuce, hyacinth, and in trees such as the apple, pear, oak, etc.

Plants and the Atmosphere.

Put about an ounce of slaked lime (building lime) into a wine-bottle full of water; shake well and allow to settle. The clear liquid is *lime-water*, and should be carefully poured off and kept ready for use in another bottle.

Take a dry wide-mouthed bottle, such as a jam-bottle; pour into it a little lime-water and shake gently. The lime-water remains clear, showing that in ordinary air very little, if any, carbon dioxide is present.

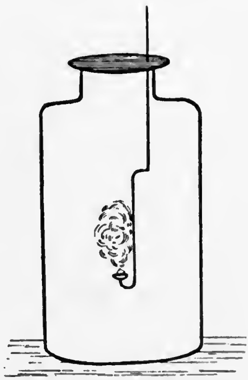

Fig. 10.—Charcoal burning in glass jar.

Fasten a small piece of charcoal to a thin wire, ignite the charcoal, and, using the wire as a handle, hold it in a dry wide-mouthed bottle similar to that used in the previous experiment (see Fig. 10). It is well to pass the wire through a cork or piece of cardboard, so as to close the mouth of the bottle while the burning charcoal is in it. After the charcoal has been burning for a few minutes the flame will go out, all the oxygen in the bottle having been used up. Remove it, pour in some lime-water, and shake gently: the lime-water will become cloudy owing to the formation of carbonate of lime (chalk) by the union of the lime with the carbon dioxide produced by the charcoal burning in the oxygen of the air.

Pour a little lime-water into a tumbler or small glass, and by means of a tube (of glass, bamboo or a straw) pass the breath from the lungs through the lime-water, which will soon become cloudy from the formation of carbonate of lime as in the last experiment (see Fig. 11). If the breathing is continued for a long time the lime-water will become clear again, owing to the chalk being dissolved in the excess of carbon dioxide.

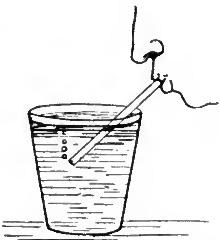

FIG. 11.—Breathing into lime-water to show that the breath contains carbon dioxide.

FIG. 12.—Experiment to show that plants breathe out carbon dioxide.

Into a similar bottle, corked or covered with a piece of glass, place about a handful of the young tips of leafy shoots, or opening flower-buds—for instance, marigolds (see Fig. 12). Add a very little water to keep them moist, and put away *in the dark* for about six hours. Test as before with lime-water, when it should be found that once again we have had carbon dioxide produced in considerable amount. Repeat the experiment with similar leafy shoots, but, instead of placing them in the dark, keep them in strong sunlight out-of-doors. No carbon dioxide should now be found, for, as fast as it is formed by the breathing of the plant, it is used up in the process of assimilation.

These three experiments teach us that the processes of burning and the breathing of animals and plants agree in resulting in the formation of carbon dioxide.

FIG. 13. — Experiment to show the bubbles of gas given off from leaves in sunlight.

Place some leaves in a wide-mouthed bottle, fill with water, and place it in the sunlight (see Fig. 13). Observe that in a short time small bubbles of gas appear on the leaves which are in reality bubbles of oxygen, formed in the process of assimilation and given off by the plant. On repeating this experiment, but placing the bottle in the dark, no bubbles will be given off, for, under these conditions, no assimilation can go on.

The Food of Plants.

Take enough starch just to cover a threepenny-bit, drop it into about half a pint of boiling water, and, when cold, add a little iodine solution. The liquid becomes a deep blue. (If you have too much starch present the colour will be almost black, and water should be added). This is a convenient test whereby to recognise the presence of starch.

Take a few leaves which have been exposed to bright sunlight for several hours (fuchsias answer admirably), plunge them into boiling water for about two minutes, and then place in strong methylated spirits. When the liquid has become of a deep green colour—owing to the leaf-green being extracted—pour it off and add fresh spirit, repeating this until the leaves are free from colour. Put one or two of these leaves in water containing a small quantity of iodine solution; they will turn blue. The colour will not be a pure bright blue, but, owing to the brown stain communicated to the tissues by the iodine, of a somewhat greenish hue.

Take a plant with smooth leaves—for instance, a fuchsia—growing in a pot, and leave it exposed to the sunlight from morning to afternoon. Then cut off one-half only of two or three leaves, leaving the other halves attached to the plant. Test the cut-off halves for starch as described above. If they have plenty, place the whole plant in the dark until the next day, either in a cupboard or covered up by a box or tin, taking care that no light at all gets in. Now cut off the remaining halves of the leaves tested previously, and test these in exactly the same way. If they have been in the dark long enough (fuchsias usually require only twelve hours, but some other plants take twenty-four hours or even longer to get rid of all their starch) they will be found to show no blue colour, indicating that all the starch they contained has been used up during the time they have been in the dark.

Using the plant which we now know to have no starch in its leaves, we can prove that starch is only formed in the parts actually exposed to the light. Take some tinfoil or lead-paper (such as is used for tea packages), cut out a cross or other pattern, and wrap the foil round a leaf (attached to the plant) so that the only portion of the leaf which can be seen is that which shows through the cut-out pattern (see Fig. 14). Press the tinfoil tightly down on the leaf, to prevent light getting under the edge of the cut portion, and expose the plant to sunlight. If this is done in the morning the plant may be tested in the afternoon, and it should then be found on

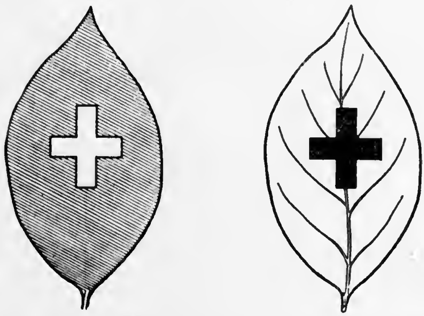

FIG. 14.—Experiment to show that starch is only formed in the portions of leaves exposed to sunlight. The left-hand figure shows the leaf wrapped in tinfoil, from which a cross has been cut. The right-hand figure shows the leaf after exposure to sunlight and tested for starch.

boiling the leaf and decolorising it in spirit, and putting it in iodine solution, that we obtain a pattern, in blue, on the leaf exactly similar to the portion exposed to the light. That is to say, the part of the leaf exposed to the light, and that part only, has been able to form starch, or, in other words, assimilation only goes on in the light.

The coloration due to the iodine soon fades away, but the leaves may be preserved for any length of time in methylated spirit, and the colour obtained again on once more putting them into iodine solution. Leaves can thus be prepared in the summer and kept for use as required during the winter.

Take a leaf of a variegated geranium or other plant with green and white leaves, which has been in a good light for a day. Make a sketch of the leaf, shading in the green parts. Decolorise the leaf by immersing in boiling water and methylated spirit, and then place in iodine solution. A pattern should be obtained similar to the one drawn, showing that starch is formed only in the green parts of the leaf, and that the white parts contain no starch. Draw the leaf after treatment with iodine, shading the blue parts, and compare it with your previous sketch.

The following experiment will serve to show that unless a plant is provided with air no starch can be formed in its leaves, even though it is placed in the light. Germinate some peas and beans, and after the first leaves have expanded, place the young plants in the dark for a day. Test some for starch: if they contain none, they are ready for use; but if they still show the presence of starch, replace them in the dark until they are starch-free. Place some of the seedlings in bright light in a window, giving water to their roots so that they do not dry up. Put others in a thin glass vessel full of water which has been boiled and allowed to cool (this precaution is necessary to get rid of the air dissolved in the water), and put these alongside the others in the window. The plants should be weighted with small stones to keep them well beneath the surface of the water. Leave them there for several hours, and then test leaves from both for starch. It should be found that those exposed to the air have formed starch, whilst those under the water and consequently deprived of air have formed none.

Another way of carrying out the above experiment is to take a plant the leaves of which have been found to have the pores only on the underneath surface. Place it in the dark until free from starch. Then smear the under sides of some leaves with vaseline. This fills up the pores and prevents air entering the leaf. Expose the plant to sunlight, and after some hours test for starch both coated and uncoated leaves. The latter should be found to contain starch, but the former to contain none.

We can now pursue our inquiry one step further, and endeavour to ascertain what constituent of the air is actually necessary for the formation of starch. There are two chemical substances, soda lime and caustic potash, which have the power of absorbing carbon dioxide, and by using these we can obtain an atmosphere in which oxygen and nitrogen are both present, but carbon dioxide is not. Let us do so, and see if under these circumstances a plant can form starch. This experiment can be arranged as follows:—

Take two bottles of clear glass (not tinted) with wide mouths; in each put a tightly-fitting cork with a bent glass tube, about half an inch in diameter, passing through it. In one of the tubes put some lumps of soda lime, but leave the other empty. In the bottom of the bottle fitted with the tube containing soda lime, place a little dish with some pieces of caustic potash in it. This caustic potash will absorb what carbon dioxide there is in the bottle, and the soda lime will prevent any more entering.

Have ready two fuchsia shoots, which have been in the dark for a day and have been tested, and are known to be free from starch. Put the ends of their stalks in little bottles of water, and place one in each bottle. Replace the corks. It is best to paint the corks over with a coating of paraffin wax to make sure that no air gets through them. Put the bottles thus fitted up, side by side, in the sunlight, and after say six hours' exposure, test a leaf from each for starch in the ordinary way. If there is no appreciable difference leave them for another day, and test again in the late afternoon. By this time it should be found that the leaves in the bottle containing carbon dioxide have formed starch, whilst the others have not. The success of this experiment depends on having well-fitted, good corks, and on the glass tubes fitting tightly in the corks. Any leakage will allow air containing carbon dioxide to enter, and so spoil the experiment.

In the course of our experiments we have repeatedly found that if a plant with its leaves loaded with starch is put away in the dark and left there for twelve hours or longer (according to the kind of plant employed), the starch will have disappeared. What has become of this starch? An answer to this question can also be obtained by experiment, but it is necessary that we should first make some preliminary experiments so that we may understand what is taking place.

Place a piece of starch in cold water and let it remain there some hours. The starch does not disappear. In other words it is insoluble in the water. Put a lump of sugar in water. It quickly disappears, being soluble in water. Starch, then, is insoluble in water, whilst sugar is soluble. Soluble substances can readily pass from one part of a plant to another. If now we can show that starch is changed in the leaf to sugar, we can easily understand how it may be that a leaf containing starch in the afternoon may have none in the morning. It may, in fact, have been altered into sugar and carried away to other parts of the plant. A convenient method of testing sugar is by adding some to a solution known as Fehling's solution, and boiling for a minute in a test-tube. When this is done a red deposit or precipitate collects in the bottom of the tube, whilst with starch no red precipitate is formed.

Take two test-tubes, and fill each about one-quarter full of Fehling's solution. To one add a very little starch, and to the second add a few drops of honey. Boil both. In the second a red precipitate collects, whilst no red precipitate is formed in the first.

Take a little starch on the end of a penknife, mix it up with some cold water, and drop it into about half a pint of boiling water, and boil for two minutes. When cool, add iodine to a small portion. It turns blue, showing the presence of starch. To a second small portion add Fehling's solution, and boil for not more than a minute. No red precipitate forms, showing that no sugar is present.

Place in two fresh test-tubes some more of the starch in water, and add to each some saliva, and put the two tubes in a glass of warm, not boiling, water. After half an hour test one for starch and the other for sugar. It should be found that the starch has disappeared, and that sugar has been formed.

To two other portions of starch in water add a little malt (obtained from a brewery). Keep warm in the same way, and afterwards test for starch and sugar. It should again be found that the starch has disappeared and that sugar has been formed.

Repeat the above experiment, but instead of using malt from a brewery, take a good number (50 to 100) of just-sprouted barley grains. Break off the young shoots, and grind them up with a very little water. Add some of this paste to the two tubes containing starch, and keep just warm for an hour or two. Test the tubes now for starch and sugar. As in the previous experiments, it will probably be found that the starch has gone, and sugar has been formed in its place. Germinating barley, therefore, contains something which can change starch into sugar.

Gather during the night twenty or thirty leaves of the garden pea, or garden nasturtium. Rub them to a paste with a little water, and add this liquid to two more samples of starch in water. Keep warm, and test after a few hours for starch and sugar. The same process will be found to have gone on, showing that these green leaves, like the germinating barley, contain a substance able to change starch into sugar.

CHAPTER V

THE SOIL

If we dig a hole in the ground we usually notice certain changes in the appearance of the earth which we remove as we go deeper and deeper. That near the surface is often dark in colour and loose or friable; below this we come in succession upon material of a lighter colour, then probably a rather compact layer with stones, and finally hard rock. If we look at a place where a deep trench has been dug, as, for example, in a road-cutting, quarry, or excavation for the foundation of a house, or where a heavy rush of water has cut away the soil, we see that there is a gradual change in appearance from the upper to the lower layers. The stones of the lower layers are probably of a similar material to the rock at the bottom; similarly the small stones and even the finest particles which can be picked out are often recognisable as fragments of the rock which lies beneath. In other words, we see that soil largely consists of rock broken up into small particles.

This breaking-up results from the action of various agencies, but is very largely due to water, containing carbon dioxide in solution, which dissolves carbonate of lime (chalk), and which also attacks the mineral known as felspar, dissolving a portion of it and leaving a residue which is clay. A little search amongst the stones in a garden is almost sure to reveal that while some of the stones are quite hard, others are relatively soft; some being found which may be crushed in the hand, or crushed or broken by the spade. In these soft stones the felspar has been attacked and partly converted into clay. If the stones are of flint or chert (quartz), these, being practically indestructible, never become soft.

Frost is, in temperate climates, an important agent in breaking up rocks and stones to form soil. Many rocks and stones are somewhat porous, absorbing appreciable quantities of water. Now, water expands in changing from the liquid to the solid state; in other words, a certain quantity of water increases in bulk when it is frozen and changed into ice. This may easily be shown by filling a bottle with water, tightly corking it, and exposing it out-of-doors on a cold winter night, when the bottle breaks, unless the glass is very strong, in which case we usually find the cork forced out. The ice must get extra room somehow, and it is merely a question whether less force is required to break the bottle or to force out the cork. The bursting of water-pipes in winter is due to the same cause.

To return to the consideration of a porous rock; it absorbs water, and if this water is subsequently frozen it expands, and in doing so often exerts sufficient force to crack the rock. The cracking due to any one freezing may be very small, but when repeated over and over again, even large blocks of stone are in the course of time reduced to small fragments.

It requires little observation to see that the particles of which the soil is composed vary greatly in size. This variation is of great importance, agriculturally, for the nature of the soil is greatly influenced by the preponderance of large or small particles. By stirring up a small quantity of soil with water and pouring it away, repeating the operation until the water comes away clear, the fine and coarse particles may be separated from one another; and by stirring up the water containing the finer particles, and pouring away again, a further separation may be made into fine and very fine particles. It will be noticed that the water remains muddy for a long time, indicating the presence of particles of an extreme degree of fineness; these very fine particles are clay. This method, carried out with certain precautions, is largely employed in ascertaining the proportions of particles of various sizes existing in soils, and yields information of considerable value to the farmer.

The particles are classed as gravel, sand, silt and clay.

Soils are classed as gravelly, sandy, or clayey, according to which of these constituents predominates. Gravelly or sandy soils are often spoken of as "light," not because they weigh relatively less than other soils, but because they offer little resistance to implements of tillage (such as ploughs, spades, and forks); that is to say, they are light or easy to work. Clay soils, on the other hand, are often called "heavy," because of the difficulty with which the implements pass through them.

Water in Soils.

Sandy or light soils differ in a marked degree from clayey or heavy soils as regards their relation to water. Water drains through sand with ease, while it passes through clay soils with difficulty. When water falls, or is poured upon soil, which is then allowed to drain, a certain quantity of the water is retained by the soil, and does not drain out. Sandy soils retain only a small amount of water, and clayey soils a great deal. Thus sandy soils, while permitting drainage to take place more freely, retain less water than clayey soils, and therefore require rain more frequently than clays, or the crops growing on them would suffer from drought. Illustrations of these differences, drawn from his own neighbourhood, will probably occur to the reader.

The explanation of this retention of water by soil is to be found in its physical structure. There are spaces between the small particles of soil through which the water passes. Usually these spaces are filled with air, but when heavy rain comes the air is largely replaced by water, returning when the water drains away. The better the tilth of the soil the larger will be the number of these fine air-spaces, which are necessary for the maintenance of vigorous plant growth (roots needing air as well as moisture). As we shall have occasion to see later, important changes, requiring free access of air, are going on in every fertile soil. When water drains away, the draining is never complete, for soil, after it has been wetted, always retains some moisture, however thoroughly it is drained.

This water is retained by "*capillary attraction*," which is the power that causes water to flow into any very small cavities, and is commonly well exhibited in sugar, blotting-paper, and similar porous substances. If one of these is gently brought into contact with a drop of water, the water enters the small pores or cavities and spreads over a large area, where it is retained, and from which it will not drain away again. By means of this power, soils retain a sufficiency of water for the use of plants, the small spaces being filled with water while the larger spaces contain air. The soil is thus provided with both of these requisites for plant growth.

Clay.

It has already been said that clay is formed from felspar by the action of water and carbon dioxide. Pure clay consists of extremely minute particles, but soils are never pure clay, there being always a certain amount of sand present. The fine particles of clay have a tendency to collect together in groups or masses. If this were not the case all the small openings and passages in the soil would be choked, and drainage rendered impossible. Clay also has the power of absorbing water and becoming *plastic;* that is to say, it can be kneaded and moulded by the hand, a property which is taken advantage of in making bricks and pottery. When strongly heated, clay loses this property.

The operations of tillage are partly directed toward breaking up the masses of clay, admitting air into the soil, and increasing the size of the capillary spaces. They also increase the tendency which the fine particles possess to gather into masses, thus permitting a freer circulation of water. Lime has a similar effect in causing the particles to collect or *flocculate*, and is therefore often used as a dressing for stiff, clay lands, in order to make them lighter, and more easy to till. Kneading and trampling have the opposite effect; breaking up the little collections, groups or floccules of clay, and thus closing the small openings. Hence it is that brickmakers and potters, who require firm, compact masses, thoroughly knead the clay they use before working it into shape. The cultivator, on the other hand, desires to bring his clay into a flocculent condition, so as to permit the circulation of air and water; he thus, at intervals, digs, forks, or ploughs the soil, admitting the air and causing the clay to become flocculent, while he is careful to prevent, as far as possible, any trampling or walking over the soil which he has tilled.

Vegetable Matter in Soils.

In digging down through the soil, it was seen that the upper layers (*surface-soil*) were darker than the lower (*subsoil*). This is due to the presence of decaying leaves, roots, and other vegetable matter derived from plants previously growing on the spot, or brought there as manure. Some soils are almost entirely made of decayed vegetable matter—for instance, in woods of beech, oak, etc., where every year enormous quantities of dead leaves are added at the approach of winter. In swampy lands, covered with bog moss, enormous accumulations of vegetable matter are formed, resulting frequently in the formation of peat, which is almost pure vegetable matter. If a little of the surface-soil is burned, by placing it on a sheet of iron over a fire, it will be seen that it first becomes dark, owing to the charring of the vegetable matter; then, as the vegetable matter burns slowly away, it becomes lighter in colour, and more like the subsoil. If the heat be great and long-continued, the soil undergoes still further changes of colour, often finally becoming red, like bricks.

This decaying vegetable matter is known as *humus*, and is essential to the production of true soil. Mere crushed, powdered, or disintegrated rock does not constitute true soil, but requires the admixture of humus. Humus plays several important parts. It increases the amount of water which sandy soils can retain; it tends to preserve the porous nature of stiff clays, facilitating drainage and admitting more air; it assists in maintaining the friable condition known as *tilth;* and, moreover, soils rich in humus do not become hard and compact. It is worth noting that the common expressions "poor land" and "rich land" usually refer respectively to soils with little humus and soils with much humus in them.

Earth-worms are very active agents in distributing humus through the soil. They carry leaves down into their burrows and bring to the surface, and deposit there, large quantities of earth in the form of castings. Darwin estimated that in an English meadow the earth-worms brought to the surface upwards of 15 tons of earth per acre per year. Owing to this action of the earth-worms, objects lying on the surface are slowly buried or appear to sink into the ground. In 1842 Darwin spread a quantity of chalk over a field in order to observe at a future date to what depth it had been buried. At the end of twenty-nine years a trench was dug across the field, when a line of white nodules was traced on both sides of it at a depth of seven inches below the surface. The mould, therefore (excluding turf), had been thrown up at an average rate of ·22 (or about $\frac{1}{5}$) inch per annum through the agency of earth-worms. It was estimated that the soil so brought up in this meadow weighed about 73,000 lb. From these and similar facts it has of late years been recognised that earth-worms exercise a very considerable influence in keeping soils in a fertile condition.

Natural processes of decay lead to the steady disappearance of humus; so that if land is cultivated and the crop steadily removed, there is a tendency for the soil to become poorer and poorer as the humus, originally present, rots away and nothing is added to replace it. When this happens we hear complaints about the soil being "worn out." "Wasted" would be a better expression. In places where no crop is removed, as in woods and forests, there may be a steady increase of humus owing to the annual addition of vegetable matter from the fallen leaves being greater than the amount used up in a year. The soil of such places, commonly called leaf-mould, is thus usually very rich in humus, and much sought after for purposes of cultivation, on account of its fertility. Unfortunately this fertility is often rapidly wasted because the cultivator takes no pains to keep up the supply of humus.

In the cultivation of all soils it is necessary to add supplies of vegetable matter from time to time, so that it may decay and become mingled with the soil as humus. Good agriculturists take care to save and dig into their fields and gardens all the available refuse vegetable matter, such as manure and stable refuse, dead leaves, twigs and grass. We shall have to refer to these later when dealing with the question of manures.

The very wasteful habit is often adopted of burning a great deal of refuse vegetable matter instead of burying it in the soil to form humus. It is not uncommon to find a man busily engaged in burning leaves, and other vegetable refuse, and at the same time lamenting that this soil is becoming worn out. Instead of being burnt these things should be dug into the soil, or, if that is inconvenient or impracticable, they should be thrown into heaps and allowed to decay partially. Loss of valuable plant food may be prevented by covering the heap with layers of soil, which also prevents the production of any offensive smell or other unpleasantness. Such heaps are known as *compost-heaps*, and if adopted in every garden the laments about worn-out soil would cease. It is often urged that by burning the leaves, twigs, etc., plant ashes are obtained which are of value when added to the soil. This is true. The important fact, however, is usually overlooked that the leaves before burning are made up, speaking generally, of ash and organic matter, and that when burnt the most valuable portion, the organic matter, burns away and is lost. The ash is thus added in either case, but by not burning the matter, we add the most valuable portion, the organic matter, in addition.

Chalk in Soils.

Carbonate of lime, or chalk, is present in some soils in such quantities, that they are distinguished as chalky or *calcareous.* Other soils contain very small quantities of carbonate of lime, and are known as *non-calcareous.* A large portion of the soils in Great Britain are non-calcareous, but there are extensive areas where the principal rocks are chalk and limestone, and as these are almost pure carbonate of lime, the soils formed from them are often very rich in this same substance. Examples of calcareous soils occur in Kent, Surrey, Yorkshire, Norfolk, Cambridgeshire, Bedfordshire, the Isle of Wight, in all of which chalky rocks are found. A band of limestone extends right across England from Dorsetshire to Yorkshire, and on this calcareous soils are found.

Calcareous soils are formed by the breaking down of the chalk and limestone rocks of these districts.

Carbonate of lime may be recognised by the manner in which it effervesces when an acid is poured upon it. This test may be used to distinguish calcareous from non-calcareous soils, the former effervescing, the latter not. According to the proportion of fine and coarse particles entering into their composition, calcareous soils may be either light or heavy.

Carbonate of lime is an important constituent of soils, because it takes part in many changes which go on in them, as will be understood later. Carbonate of lime is necessary for the production of nitrates from nitrogenous manures; it reacts with most of the substances employed as artificial manures, so that their application uses up a certain quantity of the carbonate of lime. There is thus a steady, though small, drain on the carbonate of lime present. This requires but little thought when an appreciable amount is present in the soil, but some soils contain so little that the addition of dressings of carbonate of lime, in the form of chalk or limestone, at long intervals, may be expected to add to their fertility.

PRACTICAL WORK

Dig a hole or trench in the garden, and note the character of the soil from the surface downwards (see Fig. 15). This trench may perhaps be designed to fulfil some useful purpose, or the observations may be made when occasion arises for digging thus deeply. Sketch what you see.

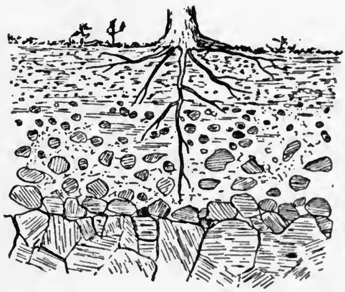

FIG. 15.—Diagrammatic section illustrating gradual passage from the soil to the subsoil, and, finally, the underlying rock.

Ascertain, if possible, the character of the rock lying beneath the garden either by digging down to it or by observing it at some place in the immediate neighbourhood where it comes to the surface, or is exposed, as in a road-cutting.

Collect the different kinds of stones to be found in the garden soil, and note whether they are of a similar character to the underlying rock. If other kinds of stones are found, endeavour to explain whence they are probably derived. (A selection of these stones should be kept in the school.)

In frosty weather select one or two pieces of sandstone, and of brick, of very porous character. Wash off all dust and loose pieces, place them in a vessel of water so that they are about half covered, and leave them to soak for two or three hours. Put them out of doors where they can become thoroughly frozen, and allow them to remain exposed to two or three nights' frosts. Then bring them into a warm room, and when they have thawed completely, examine carefully to see whether any small fragments have been split off. The stones or bricks should be placed on clean plates or saucers when put out in the cold, in order that any small pieces broken off can be more easily seen.

Mechanical Analysis of Soil.

Separation of soil particles by means of water:—This operation may be conducted so as to give quantitative results of interest and value, if a small amount of apparatus is procurable. For this work it is necessary to have three sieves with holes of known sizes; brass sieves with circular perforations are preferable to those of wire. A suitable set consists of three sieves with holes of 2, 1, and ½ millimetre respectively. (1 mm. = $\frac{1}{25}$ inch.) A small scale or balance for weighing the separated gravel, sand, etc., is also required.

With these proceed as follows:—From a well mixed sample of soil weigh out 50 grammes (1¾ oz.), stir this well with water in a glass or cup, and pour the water through the sieve with 2 mm. holes; the sieve resting on a dish or basin. With successive quantities of water, transfer all the weighed portion of soil to the sieve. Gently wash the particles of gravel by moving them about in the sieve with a wooden rod or stirrer (or a glass rod tipped with rubber), using fresh supplies of water until the small stones are quite clean. Pour the water and soil which has passed through the first sieve through the second, similarly supported on a basin, and the water and material from the second through the third. Wash the residues in each of the sieves with gentle stirring, until the water coming away ceases to be muddy. Put aside the sieves, with their contents, to dry. Collect the washing-waters together, and stir well. After standing two or three minutes pour away the muddy water from the sandy sediment, wash the sand into a beaker or tumbler, and again wash with gentle stirring and rubbing with the wooden or rubber-tipped rod. After standing a short time once more pour the water from the sandy sediment. Repeat this process until the water ceases to become turbid.

Dry the various portions separately and weigh them; the different grades may be designated as follows:—From the first sieve, *coarse gravel;* from the second sieve, *gravel;* from the third sieve, *coarse sand;* the residue from washing, *sand.* The amount carried away in the water may be found by adding together the weights of the various grades obtained and deducting this from the total weight taken to be operated on. The difference may be called *silt* and *clay.* The quantities should be calculated in percentages. Samples of the separated grades should be put into tubes or small bottles, and kept as a record and for future reference.

This method gives interesting, and approximately accurate, results, and is within the capacity of the older pupils of a school class. For the method of procedure where great accuracy is required, see such books as Wiley's *Agricultural Analysis*, Vol. I. For junior classes it is sufficient to omit the weighing and to make approximate separations by washing.

Water in Soils.

Place in separate glass funnels, supported over cups or tumblers, equal weights of sand, clay and garden mould; these should be dry and coarsely powdered. From 50 to 100 grammes is a convenient quantity. Place a small piece of blotting-paper (or filter-paper) at the bottom of the funnel to prevent the soil from getting into the neck. Shake and tap the funnel gently to cause the contents to settle down closely. Now pour equal measures of water on the contents of each funnel, using enough water to soak the soil thoroughly and to allow water to drain through into the vessels placed beneath. Observe that the water flows away with different rapidity in the three cases, and that when all the water which will drain away has been collected, the three different kinds of soil retain different amounts of water.

The funnels with their contents may be weighed before the water is added, and again after it has drained away. The difference between the two weighings gives the weight of water retained in each case, and the results should be recorded for the different kinds of soil, calculated for convenience of comparison to 100 parts of soil.

Fit a cork, with a hole in it, into a glass tube, about ¾ inch in diameter, and arrange a small piece of linen or blotting-paper over the cork, inside the tube; now pour shot into the tube (see Fig. 16). The shot may be taken to represent particles of soil with their air-spaces. Close the opening in the cork with the finger, and pour water on the shot, fully covering them. This condition may be taken to represent soil from which all the air has been displaced by water. Remove the finger; most of the water will now drain away, but some will be retained, by capillary attraction, between the grains of shot. From this experiment draw inferences as to the relation of water to small soil-particles.

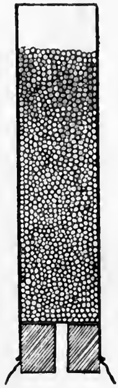

FIG. 16.—Experiment to illustrate the retention of water between small particles by capillary attraction.

Place in a saucer a little water, to which a few drops of red or black ink has been added (merely to colour it), and dip one corner of a piece of blotting-paper into the water: notice how the liquid rapidly spreads through the whole piece. This is an example of the action of capillary force.

Take two small pieces of glass (about 3 or 4 inches square); stand them upright in a saucer of water (which may be coloured if desired); bring their edges together on one side so that the pieces stand like a partly-opened book standing on its edge (see Fig. 17). Gradually bring the open edges together, as if closing the book, and notice that the water rises between the glasses, being highest where the space between the glasses is narrowest, and lowest where the space is widest. This is another example of capillary attraction, and shows that the effect is greater in small spaces and cavities than in large ones. Make diagrams showing the position of the water when

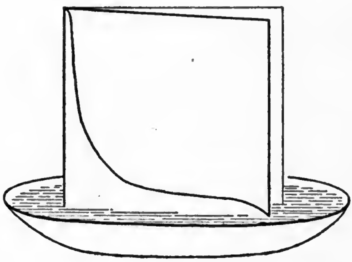

FIG. 17.—Experiment to show that water rises, by capillary attraction, higher in narrow than in wide cavities.

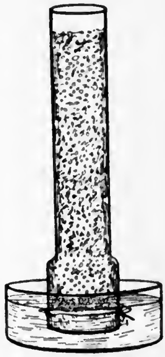

FIG. 18.—Experiment to demonstrate the rise of water in soils by capillary attraction.

the glasses are somewhat widely separated and when close together.

Take a tube, such as a narrow lamp-chimney, tie a muslin or linen cap over the bottom end and fill with soil. Place the tube, thus filled, upright in a saucer of water, and note the manner in which the water slowly rises through the soil (see Fig 18). This experiment may be made quantitative if the tube is weighed, before and after filling with soil, to give the weight of soil used; and again after standing for some time, say for twenty-four or forty-eight hours, or until the water has risen to the top of the soil, to ascertain the weight of water absorbed. This should be calculated to 100 parts of soil. If necessary, water must be added to the saucer from time to time in order to ensure that the soil in the tube is always in contact with water. Comparisons should be made of the weight of water absorbed by sand, clay, and garden-mould; sand absorbs the least and clay the most water.

The following experiment will demonstrate the influence of capillarity in bringing water from the subsoil to the surface. Take two *large* pots, or two tubs or deep boxes, fill one with soil in the ordinary way for sowing seeds, as described on page 15. Fill the other in the same way, but in filling place a layer of fine wire-gauze horizontally across the box or tub, about 4 or 5 inches below the surface of the soil. This gauze will serve to interrupt the capillary connections between the subsoil and the surface. Sow seeds of barley, grass, or other shallow-rooted plants (more than one kind may be used) and place the boxes, pots, or tubs side by side out-of-doors. Give a little water until the plants are established, and then leave them dependent on the rainfall. Record the rate of growth and development of the two sets of seedlings, and determine the effect of restricting the capillary flow of water. In a very wet season the pots, etc., should be screened from excessive rainfall.

Take a small ball of clay—this may be obtained from the subsoil of the garden—let it dry in the air for a day or two, and then put it into the kitchen fire for some hours. When cold, compare it with a portion of fresh, unburned clay. Note that, although it is still able to absorb water by capillarity, it has lost its plastic character and can no longer be moulded into shape by the hand. Crush it to powder and moisten with water; the plasticity is not restored, it is permanently lost. Note also the change in colour.

Make small bricks of wet earth, sand and clay respectively. Measure and record their length, breadth and thickness. Place the bricks on a piece of board and put them on one side for a day or two until quite dry. Now measure them again, and note any changes in size. Note also the looseness or hardness of the dried bricks.

Take a small piece of clay, about the size of a hazel-nut, and rub it down with water to the consistency of thin cream. Pour this into a pint of rain water or distilled water and stir well. After standing a minute or two pour off the muddy water from any sand which has settled to the bottom. Now take two similar glass cylinders or large tumblers, and fill each with the clay water, which should again be stirred before being poured out. To one cylinder or tumbler add a tablespoonful or two of lime-water and stir. Set the two vessels aside for the clay to settle. Note the difference in the way subsidence takes place in each, and recognise that lime causes the fine particles of clay to collect together into larger masses or floccules which subside quickly.

Vegetable Matter in Soils.

A place should be set apart in the school garden for a compost heap. All available refuse should be collected and placed on this heap, and, at intervals, a layer of soil should be thrown over it to promote decay and prevent unpleasant smells. The heap should be kept damp throughout. Care should be taken to select the place for the compost heap where it will not be unsightly, and, if a low hedge is planted round the spot, it need not disfigure the neatest garden. It is convenient to have two heaps—one in process of formation, the other ready for use.

To illustrate the influence of vegetable matter on soil fertility, select in the school garden two beds, of equal size, with similar soil, and conveniently near together for purposes of comparison. Give one a good dressing of stable-manure (which is vegetable matter in a partially-decomposed condition), or a dressing from the compost heap, or of such material as grass-cuttings from a lawn or indeed of any available form of vegetable matter. (There is a great difference in the rates of rotting of various substances, some change so slowly as to be troublesome in a garden; stable-manure, owing to its being already partly decomposed, is the most effective, rotting and mingling with the soil rapidly.) Give the second plot no manure. Plant similar crops, at the same time, on the two beds; the nature of the crop adopted depending on time and local circumstances. Keep a record of the character and growth of the crops, noting the development and appearance of the plants, the effect of dry weather or other climatic conditions. Note the weight of the various parts yielded by each crop, and, from time to time, observe the character of the soil of each plot. These beds should be permanently established, and at intervals, perhaps once a year, the manured plot should receive a dressing of manure of a vegetable nature. In a school garden a succession of lettuce, beet, beans, and cabbage can readily be grown on the beds.

Chalk in Soils.

Carbonate of lime—chalk. Place a small piece of chalk in a saucer and pour upon it a little *acid*, which may be strong vinegar, or hydrochloric acid. Note how it bubbles up, due to its giving off carbon dioxide. Chalk always does this when acted on by an acid, and thus this is a useful test to find out whether a soil contains chalk or not. Repeat the experiment, using small quantities of soil from different places.* From the observations made classify the soils as calcareous and non-calcareous.

If the surrounding district contains examples of both calcareous and non-calcareous soils, mark their distribution on a map. For this purpose small samples should be collected, by the pupils, from a number of localities, and examined as a class exercise or as a demonstration by the teacher. A map of the district, on a somewhat large scale, may be drawn on stout drawing-paper and hung up in the class-room, or the appropriate map of the Ordnance Survey may be purchased. Observations on the character of the soil may be recorded, from

* The teacher should provide himself with a collection of soils from different places, taking care to have samples of both calcareous and non-calcareous soils. These samples are preferably kept in bottles.

time to time, by means of colours upon this map, which will ultimately become of considerable interest if the observations are made carefully. The pupils should prepare copies of this map, on a smaller scale, for their own use.

CHAPTER VI

PLANT FOOD AND MANURES

REFERENCE has already been made to water and carbon dioxide as two of the constituents of plant food. These two substances are obtained from the atmosphere, the former falling as rain and usually entering plants through their roots, the latter being absorbed and assimilated by the green leaves. In addition, certain constituents of the food of plants are derived from the soil. We may divide these into two classes: nitrogenous and mineral matters. This division is convenient, for the absorption of nitrogen is sufficiently interesting to make it desirable to devote separate attention to it. Moreover, when a plant or any other vegetable substance is burned, the nitrogen disappears in the gases or vapours, together with the carbon, hydrogen and oxygen, while the mineral matter remains behind in the form of ash.

Nitrogenous Matter.

As the air by which we are surrounded consists of four parts of nitrogen and one part of oxygen, it would seem reasonable to suppose that its nitrogen would amply provide for the needs of plants. Careful investigations, however, have shown that plants, as a rule, are unable to use this nitrogen (exceptions will be referred to later), but obtain their nitrogen from the soil in the form of complex substances known as *nitrates.* We are familiar with nitrates in the form of saltpetre which is nitrate of potash, and nitrate of soda largely used as a manure.

All living things, animal and vegetable, contain nitrogen. When they decay in the soil, their nitrogen is converted into nitrates, this change being brought about by the agency of microbes or *bacteria* which live in the soil in countless numbers. In consequence of the results they bring about, these bacteria are spoken of as *nitrifying bacteria.* In order that they may live and thrive and so carry on their useful work, it is necessary that the soil should present certain conditions. Moisture and air are needed, for in their absence the nitrifying bacteria cannot live. A certain amount of warmth is also necessary, the activity of the bacteria being suspended, although they themselves are not actually killed, by the cold of winter. In addition, it is essential that there should be some lime in the soil. It will be observed that these conditions are those which have been repeatedly referred to as the objects aimed at in good tillage and cultivation; that is to say, the presence of moisture, air, and lime, together with vegetable matter which contains the nitrogen to be acted upon. Speaking generally, therefore, we find that those operations and conditions which render the soil best suited for the life and growth of the nitrifying organisms are those which most conduce to its fertility. Practical agriculturists long ago discovered these facts, and scientific workers have now supplied the explanation.

As plants require their nitrogenous food to be in the condition of nitrates it will readily be understood that nitrate of soda is a valuable source of plant food, for it can be used at once without any change. Other substances containing nitrogen are slower in action in proportion to the time they require for the necessary changes to take place. Such bodies are converted into nitrates, or, as we say, *nitrified*, at very different rates. Sulphate of ammonia is very quickly changed, whilst horn and leather are very slowly altered and are of less immediate use as plant food on account of the slowness with which they are nitrified. Most vegetable substances change with moderate facility, hence stable-manure, decaying grass, weeds, and leaves are valuable sources of nitrogen. Certain animal substances are also useful, such as blood and refuse from slaughter-houses, the refuse from fish-curing establishments, as well as fish themselves, when caught in greater abundance than required for food.

One fact demands notice. Many substances, when mixed with soil, are so firmly held by it that they are not readily washed out by rain and carried away in the drainage water. This is the case with phosphates, potash and ammonium salts. With nitrates, however, it is different; over these, soil possesses little holding power, and they are easily washed out and lost. As all nitrogenous matters eventually pass into the form of nitrates, it follows that the supply of nitrogen in the soil is peculiarly liable to become diminished. This is found to occur in practice, for nitrogen is usually the first item of plant food which becomes deficient in the soil, and most of the efforts of the cultivator, in the way of keeping up the stock of plant food, are directed towards supplying nitrogen.

Leguminous Plants and Nitrogen.

It has just been said that plants are unable to use the nitrogen of the air; that they must have a supply of nitrogen-containing bodies in the soil; and that nitrification makes these useful to plants. There is, however, a remarkable exception inasmuch as plants belonging to the pea and bean order (*Leguminosæ*) are able to thrive in soils containing no nitrogen. It has been found that this interesting and important property is due to the presence of great numbers of bacteria (microbes or germs) which inhabit small *nodules* or swellings to be found on the roots of plants of this order. The bacteria living in these swellings are able to feed on the nitrogen of the air and pass on this nitrogen to the plants in connexion with which they live. They thus enable these plants to use the nitrogen of the air. Now, as nitrogen is the most expensive constituent of plant food, this property, possessed by leguminous plants, of using and building up into their own structures nitrogen from the air, is of great value to the cultivator. He is able to grow crops of beans and peas upon soils which are too poor in nitrogen to produce remunerative crops of other plants. When the bean crop is reaped the roots which remain in the ground, together with the leaves, stems, etc., may be returned to the soil to increase its nitrogenous store. The result is that the soil is richer in nitrogen after the crop has been removed than before. In this case it is assumed that a reasonable proportion of the growth, that is of roots, leaves and stems, is left upon the land.

Leguminous plants, accordingly, are frequently made use of to increase the fertility of soils. Crops of these plants are grown, and when the crop is well developed, the whole of it is buried in the soil. This method increases the store of nitrogen in the soil, that in the crop being largely derived from the air. At the same time, it adds greatly to the store of humus. This operation is usually referred to as "*green dressing*," from the fact that in this method of working, the crop is buried while it is in a green and fresh condition, instead of dressing the soil with dead or decaying material of the nature of farmyard manure, or with chemical substances.

It will be understood why it is more profitable to use leguminous plants for green dressings than plants belonging to other orders. The latter will, it is true, increase the store of humus, yet the nitrogen which they contain is nitrogen which was already present in the soil. With leguminous plants there is a gain of nitrogen—a constituent which it is costly to purchase.

The nitrogen question is of the first importance to the practical cultivator, a large part of his efforts being directed towards securing a sufficient supply of this important plant food. This question also demands especial care and thought owing to the fact that nitrogenous substances are capable of many changes, and that, if carelessly dealt with, there are many ways in which nitrogen may be wasted and lost.

Mineral Matter.

Of the mineral constituents of plant food, lime has already been mentioned; others are potash, magnesia, iron, phosphates, chlorides and sulphates. Of these, potash and phosphates are often present in the soil in such small proportions, and are so constantly needed by plants, that beneficial results follow their addition to the soil. It is estimated that about the following amounts of potash and phosphoric acid are removed by the crops mentioned :—

	Potash.	Phosphoric Acid.
Potato	75 lb.	20 lb.
Corn (grain only, 30 bushels) .	7 ,,	10 ,,

Manuring.

Every crop taken off the land represents so much actual weight of nitrogen, phosphates and potash removed from the soil. This fact is too often lost sight of in practice, and crops are removed, year after year, without any attempt being made to keep up the supply of food-stuffs in the soil. The plants draw upon the supply of food material present in the soil, and thrive until it is no longer able to satisfy their wants. The object of manuring is to maintain this supply, or even to increase it.

Any method by which the fertility of the soil can be increased may be included under the general term—

*manuring.** Thus thorough tillage of the soil, and the careful maintenance of the conditions necessary for the activity of the useful bacteria, are in themselves most important manurial operations. At the present day, however, the word manure is only applied to the actual substance added to the soil.

Manures may be classed according to the substances they contain. Thus we have *nitrogenous* manures, *potassic* manures, and *phosphatic* manures, which add, respectively, nitrogen, potash, and phosphates to the soil. Such substances as farmyard manure and guano, which add *all* the requisite substances for an ordinary crop, are known as *general* manures. Farmyard manure, guano, etc., are also *organic* manures, being the direct product of living beings, as opposed to such substances as nitrate of soda, basic slag, etc., which are spoken of as *artificial* or *chemical* manures.

General Manures.

Farmyard manure and stable-manure contain all the constituents of plant food in well-adjusted proportions. The actual amount of plant food contained in these manures is often comparatively small. Their great value is due to the fact that they add a large amount of organic matter to the soil. Light soils are thus enabled to retain more water, and the crops on them to withstand droughts better. Heavy soils are rendered more porous and easier to work. Such manures, therefore, are of great value to the cultivator, and are useful for almost all soils and crops. When

* See derivation of the word in the Glossary, page 181.

manuring has to be done on a large scale it is not always easy to procure sufficient quantities of these substances, and recourse must then be had to artificial manures.

Guano is the excretion of sea-birds, deposited in rainless, tropical regions. It contains all the essential constituents of plant food; that is to say, nitrates, phosphates, and potash in a condition in which they are most readily assimilated by crops. The nitrogen exists in various forms, part ready to be used at once by the plant, part requiring to be changed before use. Guano is thus both lasting and rapid in its effect. Rich nitrogenous guano is becoming a scarce commodity, and much of that now collected and sold contains comparatively little nitrogen, but a considerable quantity of phosphates. These phosphatic guanos are very inferior in value to the rich nitrogenous ones. In order to increase their usefulness and value, nitrogenous substances are frequently mixed with them by the dealers, but, even then, they are by no means equal to guanos naturally rich in nitrogen. Guano, when stored, must be carefully protected from the rain, as it readily spoils.

Green dressings have already been described. They are a very valuable means of adding organic matter, and the various constituents of plant food to the soil. In particular they supply that most costly and most easily wasted substance, nitrogen.

Nitrogenous Manures.

Sulphate of ammonia. This is obtained as a by-product in the manufacture of gas from coal, in the form of small white or grey crystals. When heated with lime or other alkali, it gives off ammonia gas, which is easily recognised by its pungent smell. Sulphate of ammonia contains about 20 per cent. of nitrogen (equal to about 24 per cent. of ammonia). It is a quick acting manure, although not nearly so rapid as nitrate of soda, and can be applied in comparatively large doses without risk of loss. It gives excellent results on clayey lands.

Nitrate of soda or Chili saltpetre. This is obtained from certain deposits in Chili. It occurs in commerce in larger crystals than sulphate of ammonia, and has a tendency to become damp by the absorption of moisture from the air. For this reason it should be stored in a perfectly dry place. It may be recognised by placing a fragment on a piece of burning charcoal, when it flares up and burns. Nitrate of soda contains upwards of 16 per cent. of nitrogen. It is very rapid in its action; the plant being able to use it at once. It is readily washed out of the soil, and should never be applied in large doses.

Dried blood occurs in the form of dark brown grains or powder containing from 10 to 14 per cent. of nitrogen. It also contains small amounts of potash and phosphate. Dried blood, being insoluble, cannot be used at once by the plant, but requires to be altered first. It is therefore lasting in its action.

Phosphatic Manures.

Phosphate of lime occurs in nature (as an insoluble substance), in bones and in certain mineral deposits.

These are sometimes finely ground and used as manure without any further treatment, but, as certain changes are necessary before this insoluble phosphate can be used by plants, their action is slow. More frequently, the phosphatic mineral, or the bones, is treated with strong sulphuric acid, which renders the phosphate of lime soluble. Thus prepared, the manure is known as *superphosphate.* Superphosphate contains from 25 to 45 per cent. of phosphate of lime in a soluble condition.

Basic phosphate, Thomas' phosphate, or basic slag, is a form of phosphate of lime obtained as a by-product in the manufacture of steel. It is a heavy, brownish or purplish-grey powder and should be as fine as flour. Unlike superphosphate, which is *acid,* basic phosphate is *alkaline,* hence, if mixed with sulphate of ammonia it will liberate the ammonia. For this reason it must not, when used as a manure, be put on with sulphate of ammonia, but if these two substances are to be applied to the same piece of ground the basic phosphate should be put on first and worked into the soil, and, some days later, the sulphate of ammonia should be added.

Potassic Manures.

Kainit. A mineral obtained from the Stassfurt mines in Germany. It consists of sulphate of potash, together with common salt and Epsom salts. The actual amount of potash contained is usually about 12 per cent.

Sulphate of potash. This is really a purer form of kainit, containing about 50 per cent. of potash.

Practical Work

Burn some vegetable matter—for instance, leaves or twigs—on a sheet of iron over a fire, or some wood in a grate or stove. Notice that a large amount of the material disappears, and that a comparatively small amount of *ash* remains. This ash is the mineral matter of the plant, the carbon and nitrogenous substances having burnt away.

Gently heat a fragment of wood, a little starch, a lump of sugar, and a leaf, on a sheet of iron over a lamp or fire. Notice that all of them blacken, thus indicating the presence of carbon. If sufficient heat is applied the carbon burns away, forming carbon dioxide and water (see p. 76).

The Food of Plants.

Take four ordinary flower-pots containing damp sawdust, and sow in them seeds of barley, buckwheat or other plants. Place all the pots in the dark until the seeds have germinated. Now leave two pots in the dark, and put the other two in a window where they obtain plenty of direct sunlight. Water all as required.

Make careful notes of the progress of the plants in each case, noting whether they become green or not, the growth each makes, and how long they live.

The experiment may be made quantitative as follows. Weigh out say a dozen seeds for each pot, before sowing, and record their total weights. Allow the plants to grow, and then when they have died pull them up carefully, wash off any sawdust, and dry them thoroughly in the sun. Weigh the twelve plants from each pot, and compare their total weight with that of the twelve seeds sown in the pot.

This experiment should teach us that plants cannot thrive very long if supplied with nothing else but water, for they are unable to make any use of sawdust as a food.

When plants are grown under these conditions, does it make any difference whether they are in the light or not? This experiment if carried out carefully should answer this question.

The above experiment can be usefully extended by growing some plants in sawdust with the addition of water only, others in sawdust watered with a solution containing all the essential things for plant growth, and others in ordinary good soil.

A useful plant food solution for this purpose is the following:—

Calcium nitrate .	4 grammes	or about	60	grains.
Potassium nitrate .	1 gramme	,,	15	,,
Magnesium nitrate .	,,	,,	15	,,
Potassium phosphate .	,,	,,	15	,,
Iron chloride . .	one or two drops.			
Water	3 litres or about 5 pints.			

Place as before some plants in the dark, and others in sunlight, and note carefully their growth and appearance in each case. Also dry and weigh a certain number of seedlings from each set of experiments, and compare their weights.

These two sets of experiments should teach us the importance of light and plant food to the life and growth of plants.

Experiments with Manures.

By cultivating plants in boxes or in isolated garden plots, experiments may be made as to the action of the various manures in common use. The soil of an ordinary garden is usually fairly well supplied with all the necessary constituents of plant food. In order therefore to obtain immediate and striking proof of the effects of manures, it is advisable to use poor soil. Sand is very convenient, and, if obtainable, should be employed. In most localities accumulations of sand suitable for the purpose can be found, for instance, on the sea-beach or in beds of streams. The sand used should be free from salt. Before using it, therefore, it is advisable to wash it thoroughly to remove the salt.* The manner of doing this will depend on the facilities at hand. A convenient method is to put the sand into a barrel, the bottom of which has a number of holes bored in it, and to pour water on it. The water will drain away through the holes, and carry the salt and other soluble matters with it.

Pure sand is a very unfavourable soil for plants, and a small amount of moss litter, not more than 1 per cent. should be added to it.

Take four boxes, about 2 feet long, 2 feet broad, and 9 to 12 inches deep. Bore a few holes in the bottom of each to allow of drainage. Place them, side by side in a hole dug in the garden, with not more than an inch of the box projecting above the surface of the soil. By so

* Washing is unnecessary if one is reasonably sure of the absence of salt; washing is more particularly referred to in case sea-sand is used.

placing the boxes, excessive evaporation from the soil in them is prevented. A well-drained spot should be selected for the boxes in order to guard against water accumulating under and around them. If the soil is very clayey this object may be secured by putting under each box a layer of small stones. It is also necessary to arrange the boxes so that the drainage-water from one will not run under the next. Mark the boxes A, B, C, and D.

In all such experiments too much care cannot be taken to secure uniform conditions for the boxes or plots to be experimented upon. For instance, if one box is shaded and another not, and they are treated differently as regards manuring, it is impossible to be certain afterwards whether any difference in their crops is due to the different manures used or to the difference of lighting.

Fill the boxes with the washed sand, and to this add the various substances whose effects we wish to try.

To the soil in A, add nothing. This is the control or standard.

To B, add about 8 lb. of well-rotted farmyard or stable manure. Carefully fork the manure into the sand, or remove the soil and mix the manure with it in a dry place, and then return to the box.

To C, add 2 oz. of finely-powdered chalk or marl, scattering it evenly over the surface, and stir in lightly with a fork. Then add ½ oz. of sulphate of ammonia.

To D, add about 2 oz. of finely-powdered chalk or marl; mix well, and then apply ½ oz. basic slag, ½ oz.

sulphate of potash and ½ oz. sulphate of ammonia.* Scatter these substances evenly over the surface, stirring each in before the next is added. Dig in the basic slag somewhat deeply.

Finally, spread an ounce of moist garden soil over each, in order to ensure the presence of the nitrifying organisms which would probably be absent from the washed sand.

If it is convenient to make plots, treat these in exactly the same way, taking similar precautions with regard to situation and drainage, as observed in the case of the boxes. The amounts given above are for boxes of the size mentioned, 2 feet long by 2 feet broad, that is with a surface of 4 square feet. Larger or smaller boxes would require correspondingly larger or smaller quantities of manure. Similarly, a bed 8 feet long by 3 feet broad, or 24 square feet in surface, would require six times the amounts given. The four boxes or plots now stand as follows :—

A. No manure.

B. Farmyard or stable manure, at the rate of about 30 tons per acre.

C. Nitrogen only, as sulphate of ammonia, about 2 cwt. per acre.

D. Nitrogen as sulphate of ammonia, about 2 cwt. per acre, together with potash and phosphate.

Raise in each box, or on each plot, a similar crop. Barley, wheat, oats, turnips, beet or cabbage, are recom-

* In accordance with what has been said before, it is advisable to add the sulphate of ammonia about a week after the lime or basic slag has been applied, to prevent the loss of the ammonia.

mended. The seeds may be sown in the boxes themselves, and when they have germinated an equal number of vigorous and well-placed seedlings kept in each box. Carefully pull up all the seedlings not wanted. If transplanted into the boxes, put in each the same number of seedlings, as far as possible equal in size and vigour. Care is just as necessary here as in arranging the boxes at first. The ideal to aim at is to have the boxes or plots exactly alike in everything except the actual manure added. Make and record observations during the growth of the crops, noting the general vigour and character of the plants in each box, their times of flowering, and any other points. When they are mature dig up and weigh the whole crops, recording the weight of seed and the weight of the whole plant. Compare the crops of the different boxes.

Leguminous Plants.

Sow in boxes or in plots, seeds of various plants of the leguminous order; for instance, various kinds of beans, peas, etc. (Those sown in the experiment described on page 21 will probably be at hand, and if so may well be examined now.) When the plants have become well developed, carefully dig them up, wash their roots, and examine for *nodules.* These appear as little swellings along the roots, varying from about the size of mustard seed. Also, dig up and examine for nodules any leguminous plants found growing wild. Many may be recognised by the great resemblance of their flowers to those of the garden peas and beans, and by their similarly divided leaves. Study therefore the look of the leaves and flowers of such garden leguminous plants as you have, and then dig up similar-looking plants found growing wild.

Make two or three plots in the garden, taking the precautions previously described. Weed and dig the plots carefully. Plant nothing at all on the first plot, but keep it free from weeds; that is, in the state known as *bare fallow*. On the others sow some leguminous crop (peas, field beans, lupines). Tend the plants carefully until they produce a good growth of foliage, and cover the ground well. Then pull up the plants by the roots, dig up the ground and bury the whole growth in the plot in which it grew. The crop should be buried whilst still green, and not allowed to remain until it becomes old or woody.

After the green dressing has been buried several weeks, plant all the plots, including the one which was kept bare and received no green dressing, with such a crop as wheat, barley, turnip, beet or cabbage, and observe the varying growth on, and the crop produced from, the various plots. If a poor piece of ground is chosen for this experiment the results will be the more striking.

CHAPTER VII

FLOWERS AND FRUITS

MOST plants—for example, those raised from the seeds sown during the work of Chapter I.—if kept under observation, are found to pass through well-marked stages in their life-history. For some time they grow, producing only new stems, leaves, and roots. Sooner or later they begin to form flowers, which appear first as flower-buds, later as open flowers. After the flowers have been open for some time, certain parts of them wither away, but some portions remain and, later, fruits containing seeds may be expected to be found. Clearly, fruits and seeds are dependent on and result from flowers. Everyday experience tells us that it is useless to look for beans on a bean plant before it has flowered. In the present chapter we shall try, first of all, to understand what a flower is, of what parts it is made, of what use these parts are, and how fruits and seeds are formed from flowers.

Parts of a Flower.

Flowers at first sight vary very much in appearance ; they are of different colours, sizes and shapes.

When, however, we examine them more closely, we find that a very large number are built up on a similar plan just as we found the various kinds of leaves to agree in essential parts. In selecting the first flowers for examination it is important to choose those whose parts are large, simple, and not too numerous. A tulip or any of the ordinary garden lilies affords an excellent example.

In a lily or tulip flower the following parts can be made out: Six large (white, yellow, or red) leaf-like bodies—the *petals* which make the outside, showy portion of the flower. They are obviously arranged in two rings, three being inside and three outside. Inside these come six bodies, each consisting of a stalk with a swollen portion at the free end. These are the *stamens*, the end portion of each of which is full of a yellow powder, the *pollen*, which, when the stamens are ripe and open, is exposed. In the midst of the stamens is another body, bearing no pollen-box at its upper end, but swollen out beneath into a green structure, which, if cut across, is found to be divided into three compartments, each containing a large number of small white bodies, the future *seeds*. This swollen portion is the *ovary* and the little white bodies it contains are the *ovules*.

Flowers of the common meadow buttercup or crowfoot may well be examined after we have made out the structure of such a large and simple flower as the lily or tulip. Buttercups have the advantage of being very common and obtainable practically all the year round. On the outside there is a ring of five greenish-yellow, hairy bodies, the sepals. Inside these is another ring, of five petals; these are much larger than the sepals, and of a bright shining yellow colour; within the petals are a large number of stamens, which, although much smaller than those of the lily, consist of the same parts—a thin stalk with a swollen portion, the pollen-box at the free end. In the centre of the flower, instead of the single large ovary of the lily, are a large number of little green bodies, slightly swollen below, and ending in a thinner, hooked portion. By examining an older flower, one from which the petals have dropped off, we shall find that these little green bodies have grown, and become hard and brown, and that with care we can open them and see that each contains one seed. These green bodies are in reality the ovaries containing each one ovule, and correspond to the large ovary of the lily flower. The thin curved portion of each little ovary is the style, and spreads out at the end into a wider body, the stigma. Overlooking thus for the time all the differences, we find that the buttercup agrees with the lily and tulip in possessing petals, stamens containing pollen, and ovaries enclosing the ovules which later develop into seeds.

Other flowers will show other variations in arrangement of parts. In the harebell or Canterbury bell the large blue portion obviously corresponds to the petals of the buttercup. It is, however, all in one piece, and only the lobing at the top reveals the fact that it really represents a number of separate petals. In some other plants—for instance, the primrose—the petals are joined up so as to form a narrow tube below, spreading out above, however, in five large lobes. Notwithstanding these differences, all these flowers have the same general plan :—

(1) Outer leafy bodies which may be all alike as in the lily and tulip, or divided into two more sets as in the buttercup. When the latter is the case we often find only the inner row, the *petals*, coloured; and the outer row, then called *sepals*, green. Petals and sepals may be separate, or joined up so as to form cup-like or tube-like flowers.

(2) *Stamens*, each consisting of a stalk, and a knob containing *pollen*.

(3) The *pistil*, consisting of a lower swollen portion, the ovary (containing the *ovules*), and an upper portion, the *style*, which may be long or short, and often ends in a more or less hairy or sticky *stigma*.

The lily, tulip, and buttercup have all these parts contained in one and the same flower. They are examples of *perfect* or *complete* flowers. The cucumber or vegetable-marrow flower, on the other hand, is different. If a flowering plant of either of these is carefully looked over, two kinds of flowers may be distinguished—even whilst in the bud stage. Both, when open, are large and have a yellow cup of petals. The centre of one is occupied by a yellow column which is covered with pollen. The other kind of flower has its centre taken up with a large, lobed body, the stigma, sticky and covered with short hair; and beneath the yellow petals is a swollen portion (obviously a very young cucumber or marrow), the ovary. We have, in fact, here stamens and pistil in separate flowers, which are respectively described as *staminate* and *pistillate*.

Uses of the Parts of a Flower.

Plants, such as the cucumber, in which the stamens and pistils are in separate flowers, are very convenient to employ in endeavouring to understand the uses of the various parts. Keeping a cucumber plant under observation, we find that cucumbers are never borne on the staminate flowers, but always on the pistillate flowers. Of what use, then, are the staminate flowers?

Experiments have often been made (and any one with care can repeat them), which clearly show that both staminate and pistillate flowers play a part in the production of seeds and fruit. A pistillate flower, tied up just before it opens, in a thin paper bag, and kept tied up, forms no fruit, but its ovary shrivels up and withers like the rest of the flower. A second pistillate flower, also tied up before it has opened, but which when open has had some pollen from a staminate flower put on its stigma, forms fruit. The petals of this flower wither up like the first, but its ovary does not, but commences to grow and finally forms a ripe fruit with seeds in it.

Thus we learn that for the production of fruit and seeds, it is necessary for the stigma of the flower to have some pollen of the same kind of plant placed upon it. When this has been done the flower is said to be *pollinated*. The actual events which take place as the results of pollination cannot be studied without more apparatus than is at our disposal. They will be found fully described and illustrated in most botanical text-books. The final result of pollination is the *fertilisation* of the flower, and only when this has happened are seeds formed. Pollination, the actual placing of the pollen on the stigma, and fertilisation resulting from this, are two perfectly separate processes, and should be clearly distinguished.

The other parts of a flower may be naturally absent, or artificially removed, without hindering the formation of fruit. They are not essential. *Stamens* and *pistil* are *essential*, for without them no seeds can be formed. Not only, too, must they be present, but unless the stigma receives upon it some pollen, no seeds will be formed.

Sepals and petals are of use in other ways. The sepals usually protect the more delicate and important parts when young. They cover the flower-buds and act in a very similar manner to the scale leaves which protect the leaf-buds in many plants. The petals usually make the showy part of the flower, and, as we shall see later, are of great use in helping to attract insects. They are aided in this by the sweet smell of so many flowers, and also by the presence of honey, which is well known to be very commonly present in flowers, and in most of those already discussed is to be found in fairly large amounts.

To sum up, we find that in flowers the stamens and pistil are essential to the production of seed. The sepals and petals are not essential; the former acting as a protective covering to the young flower, and the latter having other uses in relation to insects.

Insects and Flowers.

Still bearing in mind such a case as the cucumber, we have next to discover how the pollen finds its way from a staminate flower to the stigma of a pistillate flower, which, although on the same plant, may be several feet or yards away. Those who grow cucumbers know that it is not actually necessary to go to the trouble of putting pollen on the stigmas; yet fruits, containing good seeds, are regularly formed. There must be some way therefore in which pollen naturally gets from one flower to another.

Careful watching of a bed of cucumbers will often show that the open flowers have various visitors. Bees come to the flowers, go down to the bottom where the honey is, and if it is a staminate flower, have in so doing to push past the column in the middle which is covered with pollen. As a result they come out with a large amount of pollen on them. Such a bee, if watched, will probably be found to visit another cucumber flower. If the second one is also a staminate flower it simply gets more pollen on itself. If, however, it goes to a pistillate flower, that portion of itself which has become covered with pollen, now rubs against the stigma, to which, being sticky, some of the pollen adheres. Thus we see that insects play a very important part in the carrying of pollen from one flower to another. The importance of this work of bees and other insects to flowers cannot be overestimated, and it requires very little observation to see how general it is. Besides bees, butterflies and moths carry on the same work. An owner of an orchard of apples or cherries, for example, who keeps bees, may not only directly profit by the honey they yield, but also, perhaps to a much greater extent, by the increased amount of fruit he obtains from his trees, due to their visits.

It might at first be thought that whilst the visits of insects were absolutely necessary to plants in which the stamens and pistils were not in the same flower, that they were unnecessary to those plants (by far the greater number) in which both these essential organs are in the same flower. This, however, is not so. The stamens and pistils of such "complete" flowers commonly ripen at different times, so that when the stigmas are ready to receive pollen, the stamens of that particular flower have already shed their pollen. In other cases various arrangements are found whereby the pollen of a flower is prevented from reaching the stigma of the same flower. The result is that *cross-fertilisation*, the fertilisation of a flower by the pollen of another flower, is the general rule, and self-fertilisation—that is, by the pollen of the same flower—is comparatively rare even in plants which have both stamens and pistils in one flower.

Many flowers can be pollinated by almost any insect. Others have very complicated arrangements, and are specially adapted to particular insects. This is well illustrated by the flower of the vanilla plant (a climbing orchid, grown in many parts of the tropics), which is so elaborately made that it must be visited by certain insects before it can be pollinated naturally; and, as these particular insects are not found in most of the countries where vanilla is now grown, the cultivator of vanilla, in order to be certain of obtaining pods, has to place pollen upon the stigma of every flower by hand.

Wind-Pollinated Flowers.

As a general rule the flowers visited by insects are brightly coloured, sweet-scented, and secrete honey.

Some have all three of these characters; others only one or two of them. There are, however, a large number of flowers which are not brightly coloured, have no sweet scent, and secrete no honey. The flowers of cereals and grasses—for instance, wheat, barley, and ordinary grasses, hazels, many willows, pine trees, etc.—are good examples. Insects do not visit them much, and their pollen is carried from one flower to another by the wind.

In these wind-pollinated flowers attractions to make insects visit them are absent; but instead they have other special arrangements. They usually produce comparatively large amounts of pollen, which is very dry and powdery, and easily blown about by the wind. The stamens often hang out of the flower, so that their pollen is easily shaken out by the breeze. Their stigmas, too, project in a similar manner, and are often large and feathery, so that they present a large surface on which to catch the pollen. A comparison of such insect-pollinated flowers as the bean, lime, and wild rose, with such wind-pollinated flowers as those of grasses, cereals, some willows, alders, pines, etc., will make these differences clear.

Wind-pollinated flowers may, just as insect-pollinated flowers, have stamens and stigmas in the same or in separate flowers. Many of the ordinary meadow grasses, and barley, wheat, and other cereals are examples of the former group; maize, willows, hazel-nut and pines of the latter. In the maize the "tassel" at the top of the plant consists of a group of staminate flowers from which the pollen is readily shaken out and blown about by the least breeze. The beautiful "silk," which protrudes from the top of every young cob, is a bunch of stigmas, which, being widely spread out, readily catch the pollen grains as they float in the air.

Fruits and Seeds.

The production of seeds is the most important object in the life of most plants, because in their natural condition this is the chief method by which they multiply. When the flower has been pollinated and fertilised, the petals and other non-essential parts often fade and wither away, their use being over. The pistil develops into the fruit containing the seeds, each one of which, as we have already learnt, contains a young plant, the embryo. It is important to distinguish clearly between fruits and seeds. *Seeds* are formed from the *ovules.* During their ripening certain changes take place in the ovary which contains them, resulting in the formation of the fruit. The fruit, therefore, is the ripened ovary, and contains the seeds, the ripened *ovules.*

Fruits are very variable in character, and, according to their nature, they are often classified in various ways. Some of the different kinds of fruits are distinguished by the names in common use, for instance, berries, nuts, pods, etc.

When the plant has formed its seeds it is most important that these should be placed in such positions that they may germinate, and that the seedlings may have a good chance of success. Amongst other things it is of advantage that they should be scattered to some distance, for if they were merely dropped from the plant on to the ground beneath, the seedlings would be so crowded together that only a very few would live. Many of the plants which are troublesome weeds are so owing to their good methods of seed dispersal. In studying the dispersal of seeds the uses of the different kinds of seeds and fruits will be seen.

Dispersal of Fruits and Seeds.

There are four principal methods by which seeds are distributed:—(1) wind; (2) water; (3) animals; the seeds being carried either inside or outside the animal; (4) by some explosive apparatus.

Wind. Many seeds—for instance, those of the common grasses—are extremely small and light, so that they readily float in the air. Some large seeds are carried about in a similar manner, and these are often provided with thin appendages of various kinds known as "wings." Good examples of winged seeds are those of the pines, whilst in the ash, elm, and maples the whole fruit has a big wing and is blown about. Other wind-borne fruits and seeds are provided with downy or silky hairs which enable them to float; for instance, thistle, dandelions, lettuce, willow-herbs, etc.

The seeds of many plants lie at the bottom of dry seed-cases (often open only at the top) and out of which it looks extremely difficult for the seeds to get until the seed-case decays. On a still day this is so, and no seeds escape. When, however, there is a strong wind blowing, the plants are shaken about and the seeds often thrown or sprinkled to a considerable distance. It will be easily understood that this is preferable to having the openings at the bottom, for in the latter case the seeds would simply fall through and a dense growth of seedlings spring up immediately around the parent plant. The poppy, wild hyacinth or bluebell, and foxglove, afford good examples. The seeds in such seed-cases which are open above would be liable to be damaged by rain, and we often find that this is guarded against. Thus in some fruits the openings are very small, whilst other fruits only open in dry weather, closing again when it is wet.

Water-borne fruits. The fruit of the coco-nut, with its tough fibrous covering, is able to float long distances without damage. The coco-nut palm is now found on almost all tropical shores, and is one of the first plants to reach new coral islands, often many miles from the nearest land. The seeds or fruits of several South American and West Indian plants have been found on the shores of Scotland, Norway, etc., having travelled some 4000 miles, by the aid of the Gulf Stream. Those who live near streams and rivers should watch for seeds and fruits carried down by the water. Interesting examples may sometimes be seen; for instance, the floating portions of the fruits of the white water-lily enclosing the seeds, and the seeds of sedges and other similar plants which grow by the waterside.

Animals. Many fruits are provided with hooks and spines, whereby they become attached to the coats of passing animals. The greater number of the fruits which do this are commonly spoken of as "burrs." Amongst examples common in Great Britain are the fruits of butter-burr, cleavers, wood-avens, enchanter's nightshade, and the wood-sanicle. The sight of these fruits sticking to a person or an animal who has pushed his way through the plants must be familiar to every one. The fruits with the seeds inside them may be carried some considerable distance, but sooner or later they are sure to be brushed off, and some probably fall in places suitable for their growth, and thus spread the plant from place to place.

The fruits mentioned in the preceding paragraph are all small, dry and hard. Animals also play a large part in the distribution of quite another set of fruits, namely those which are commonly known as succulent or fleshy fruits. The fleshy portion is usually the wall of the fruit, the seeds—the important part to the plant—being generally small and hard. Animals eat these fruits for the sake of the fleshy portion, and the small, hard seeds pass uninjured through their bodies. Examples of such fruits are numerous; mention need only be made here of strawberries, raspberries, the various kinds of currants, grapes, and elderberries. Apples and pears are fleshy instead of being pulpy, but they are equally pleasant to animals, and their seeds are similarly small, smooth and hard. In plums, damsons, peaches and other "stone fruit," the seed is protected by the hard stone, and most animals eating the fruit leave the seed untouched. The fruits of such plants are often green, inconspicuous, and unpleasantly flavoured whilst the seeds are unripe, but after they are ripe the fruits are often brightly coloured, easily seen, and sweet to the taste. In all these cases the part of the fruit of importance to the plant—the seed—is carefully protected from injury, and the plant actually benefits from what seems at first sight a destructive proceeding, namely, an animal eating its fruit. Many of the fruits of this class have been greatly altered in character by cultivation and selection by man, who has increased the pleasant edible portion, even to the suppression of the seeds; for instance, bananas, pineapples, seedless oranges, seedless grapes, etc.

The mistletoe, which has a fleshy berry much eaten by birds, has an interesting method of seed dispersal. Its seeds are extremely sticky, and when a bird eats the fruit the seeds adhere to its bill. The bird, sooner or later, cleans its bill by rubbing it against the bark of the tree on which it has been feeding, or of some other tree to which it has since flown. The seeds stick, and after germination pierce the bark and so establish themselves. Mistletoe once introduced into an orchard may thus spread from tree to tree and become a troublesome pest.

Explosive fruits. There are some fruits which possess power of themselves to throw their seeds to some distance. Sitting on a hot August day by a furze bush we may often here a crackling sound, caused by the ripe pods bursting open, when the two halves twist up and throw out the seeds. The fruits of the violet when ripe "flip" out the seeds, owing to the sides of the seed-box pressing on the smooth seeds, so that they are shot out just as we can flip a wet apple-pip between thumb and finger.

The garden balsam and the wild oxalis have special kinds of fruits which, when ripe, throw out the seeds to some considerable distance.

Variation in Seedlings.

As a general rule the seeds produced by plants which have been fertilised by pollen from another flower of the same species, that is to say cross-fertilised, yield more vigorous plants than the seeds from self-fertilised flowers. When cross-fertilisation takes place between two plants of the same species, but possessing some different characters, the resulting plants usually possess some of the characters of each parent. Thus a plant which bears white flowers, crossed with one which bears red flowers, usually gives seedlings whose flowers are, in various ways, marked with red and white. These facts are made use of in the production of new varieties of plants, both economic and ornamental. A plant, possessing some one desirable character, is crossed with another plant of the same species, with some other desirable character, and the seedlings examined with care; those showing the required characters in the greatest degree are selected, and the others rejected. It must be remembered that only closely-allied plants (plants of the same species), are as a rule capable of being crossed with one another. Thus the various kinds of peas, evening primroses, orchids, etc., can be crossed with one another, but you cannot cross a pea with an orchid, or an orchid with an evening primrose.

These variations in plants are further made use of when it is desired to produce a plant with some special character, whether it be the shape or colour of the flower, the size of the seed, or some particular feature in the fruit. A large number of seedlings are raised from a plant which possesses the desired character to a certain degree. Those which show this desired character to the greatest degree are allowed to grow and their seed saved. The seedlings from these are again rigidly selected, and the process repeated, season after season, until plants are obtained, the seeds of which we can depend on to give a large number of seedlings with the particular character in question.

A desirable kind of plant, whether the desired character be in foliage, flower, seed or fruit, may be perpetuated by propagation by cuttings, budding or grafting. The variations presented by seedlings afford the means of producing new kinds of plants; propagation by cuttings or grafts enables us to reproduce these, otherwise variable, plants with the assurance that their characters will be permanently retained.

Practical Work

Examine any plants which can be obtained, and clearly make out the relation to each other of flower-bud, flower, fruit and seeds. Notice how the plant for some time forms no flowers, and that, later, first flower-buds appear, then open flowers, and finally fruits containing seeds.

Parts of a Flower.

Examine any of the following flowers obtainable:—tulip, lilies, buttercups, wild rose, evening primrose, pea, bean, wallflower, anemone, dead-nettle, primrose, geranium, cucumber, marrow, hazel, alder, willows, and pines. Some are in flower almost the whole year round. Others must be examined as occasion offers. In the text the tulip, lily, evening primrose, etc., were suggested because they are large and their parts are easily distinguishable, but many of the others will serve almost equally well.

In all cases endeavour to distinguish the sepals, petals, stamens and pistil. Make enlarged drawings of the stamens and pistils, and show the parts of which they are composed, and the stages in the progress of the young ovary into the ripe fruit.

Note carefully those plants which have stamens and pistil in the same flower, and those which have them in separate flowers. Examine the flowers for honey, and make a list of all the flowers found which contain honey.

Under cultivation the stamens of many plants have lost their original character, and have become converted into petal-like structures, thus giving rise to what are known as "*double flowers*." Many of these flowers form no seeds, owing to the fact that they have lost the pollen-bearing stamens, which, as we have already learnt, are necessary for the production of seed. Many varieties of roses, geranium, balsams, and hollyhocks furnish good examples for examination.

The flowers of grasses and cereals have no sepals and petals in the ordinary sense of the words. They have a number of scaly structures instead, but their stamens and pistils are, as a rule, easy to find. Examine some of the following :—wheat, barley, maize, and the common meadow grasses.

Examine the "flower" of the sunflower. The yellow structures around the edge are very different from the central portion, and at first suggest petals. Where, then, are the stamens, and the pistil? Cut the head through: the middle is seen to be made up of a number of separate tubular bodies, each of which possesses its own petals, stamens and pistil. The head is not a single flower, but a *collection of flowers*. This is true of all the plants in the large order to which the sunflower belongs, including the daisy, groundsel, pyrethrum, Michaelmas daisy, etc.

Experiments in Cross-fertilisation.

Examine the separate pistillate and staminate flowers of the cucumber or vegetable marrow, and learn how to distinguish them before the flower-buds are open. Watch them, and notice that the fruits are only formed from pistillate flowers. Staminate flowers die after shedding their pollen.

Tie up two pistillate flower-buds (which are almost ready to open) in separate bags made of tough paper (for instance, flat sugar-bags), with a string put through them as shown in Figs. 19 and 20. When one of these flowers is open, pluck a staminate flower and remove its petals; uncover the pistillate flower, and gently touch its stigma with the pollen-bearing portion of the staminate flower, so that some of the pollen sticks. Replace the bag. Leave the second pistillate flower tied up the whole time. The first should form a ripe fruit, the second not.

Select two plants of the same kind, but possessing well-marked differences; for instance, different-coloured polyanthus, or begonia. Carefully cut, or pull off, from one flower some of the stamens which are just shedding their pollen, and carry them to the flower of the other plant in which the stigma is mature (they are then somewhat sticky). Touch the stigma with the stamens, so that some of the pollen grains adhere. Tie a label or mark near the flower, that it may be recognised in future, and make a note in your note-book of the circumstances of the experiment. Repeat the operation with several flowers. When the fruit is ripe, gather it, sow the seed, and, later, plant out the young seedlings in the garden.

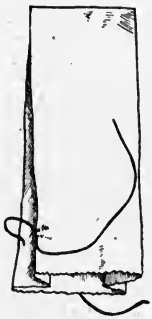

FIG. 19.—Bag for pollination experiments. (After Bailey.)

FIG. 20.—Bag for pollination experiments, tied over flower. (After Bailey.)

When the plants blossom examine their flowers, and notice how they differ from each other and from the parent plants. A similar series of experiments may be carried out with such plants as coleus, balsam, tomato, sweet peas, etc.

When it is desired to effect cross-fertilisation with great accuracy, precautions must be taken to prevent access to the stigma of pollen from any other flower than the one selected. Thus in the last experiment pollen might also have been naturally brought from another flower in addition to that from the one actually used. Choose the flower to receive the pollen while still in the bud-stage, before the anthers have ripened and any pollen has escaped. Gently open the bud and remove the stamens, either by cutting them out by means of fine-pointed scissors, or by pulling off their heads by means of forceps. Protect the flower, thus prepared, from insect visits by covering it with a muslin or paper bag, which may be conveniently fixed over a small branch having upon it several prepared flowers. After a few days the stigmas will be mature and ready to receive the pollen. Then, temporarily remove the bags and apply pollen from a selected flower to the stigmas. Replace the bags immediately, and leave them until the flower fades. When this has occurred, remove the bags; tie a label near to the ripening fruit in order that it may be identified. As before, raise plants from the seeds, and compare them with their parents, this time definitely known.

Dispersal of Seeds.

The practical work on this subject must in the main consist of observations made out-of-doors. Examine the weeds which come up in the garden, and endeavour to find out how they probably got there; that is to say, whether their seeds are likely to have been blown by the wind, carried by birds and other animals, or introduced in other ways.

In addition to the weeds of the garden, the plants growing on walls and in the hollows of trees—for instance, in the crowns of pollarded willows—should be noted, and their fruits and seeds examined in the hope of determining how they also reached these out-of-the-way places.

It is not, as a rule, difficult to suggest the possible means by which the plants have reached their present situations, if attention is paid to the previous notes on seed dispersal, and if a careful study is made of the examples given below.

Wind-Borne Seeds.

Examine the seeds of ordinary lawn grass and see how small and light they are, and that they are readily blown about in the wind. If any wild orchids are to be found in your neighbourhood examine the seeds of some of these. They are extremely small and also readily carried in the air.

Collect dandelion "flowers" in various stages, or better still keep one particular "flower" under observation, and notice the changes through which it passes. At first it appears as a bud; this opens into the dandelion "flower," or, as we know it really is, collection of flowers. After a time it fades, and then the head closes up, and might at first sight be mistaken for a bud. Open another head in a similar stage, and it will not be difficult to see that the lower parts of the old withered flowers are swelling and forming little seed-like bodies. In another few days the head once more opens, but instead of the flowers we find a large number of small, dark brown, seed-like bodies, each with a dainty white parachute attached to it. Blow these; they float away through the air carrying the seed-like bodies with them, and after travelling a longer or shorter distance, according to how windy it is, settle down on the ground.

Similar observations should be made on the thistle, lettuce, goat's-beard or salsify, willow-herbs, etc. The details will vary in each case, but all are alike in possessing some means of enabling their seeds to be readily blown about by the wind. Additional evidence can be obtained by going on a dry windy day in summer to a piece of waste ground which has a lot of thistles growing on it, and watching the thistle-down blowing about. Collect some pieces of thistle-down and note the small seeds attached to them. Then recollect that each little piece of thistle-down is probably carrying one seed, and you will understand how thistles are often such troublesome pests to farmers, and why it is so important that they should be cut down *before* and *not after* they have flowered.

Take a ripe pine-cone. Pick out the seeds from amongst the scales, and note that each is provided with a thin wing or sail.

Examine also the seeds of the white birch. These are very small, and each is provided with a delicate thin wing. In many localities near London and elsewhere, numerous instances will be seen of young birches coming up on waste lands, a result due very largely to their effective method of seed dispersal.

Examine ripe fruits of the maple and ash "keys." Both of these have wings by which they are blown about by the wind. Cut some open and see the seeds inside. In the pine and birch the seed itself had a wing, whilst in the maple and ash, it is the fruit which is winged, the seeds inside having no wings. The result is the same, the seeds in all being blown about. Make sketches of all the winged seeds or fruits examined.

Look at a ripe poppy fruit, whilst still attached to the plant. Around the top edge are a number of small holes, through which it is apparently impossible for the seeds to get out, until the fruit drops off or decays.

Place a sheet of newspaper under the plant, and then pull the head to one side and let it spring back with a jerk. Some of the seeds will probably be thrown out through the little holes, and will be found on the paper. On a windy day this process goes on naturally, and the holes being placed at the top ensures that seeds are only set free when the conditions are such that they will be scattered to some distance from the parent plant.

Similar observations can be made on the fruits of the wild hyacinth, bluebell, etc. Notice how in all of these plants the seed-cases are placed on the top of long, springy stalks.

Dispersal by Water.

Examine fruits of water-lilies, sedges, and other plants found naturally growing by the waterside, and see if any of them are able to float in water. Collect all seeds and fruits found floating on streams or ponds and endeavour to ascertain to what plants they belong.

Dispersal by Animals.

Collect in the hedge-row a spray of goose-grass or cleavers which has a number of the little round green or brown fruits on it. Pull the spray along your coat and notice how the fruits stick to the cloth. Make similar simple experiments with fruiting sprays of the hemp-agrimony, burdock, enchanter's nightshade, wood-sanicle or avens, if any of these are obtainable. Examine the little bodies which stick to your coat in each case, and satisfy yourself that they are really the fruits of the plant, and that they do contain the seeds.

Dogs which have been running through copses, or "grubbing about" in a hedge, will often be found to have a large number of various fruits sticking to them. If occasion offers, look these over and try and find out to what plants they belong.

Make careful drawings of all the fruits examined, showing the hooks on each.

Examine the following fruits:—strawberry, blackberry, raspberry, currants and grape. Notice that these all consist of a pulpy portion, pleasant to eat, and contain small, hard pips (seeds). Make drawings of all of these.

Cut an apple across and also lengthways, and make a drawing to show the position of the seeds.

Similarly make sketches to show the structure of a plum or other stone fruit. Crack the stone and observe the seed inside. Show on your drawing the great thickness of the stone.

Dispersal by Explosive Action.

Watch a furze bush on a hot day in late summer and try and detect some of the pods opening and scattering their seeds. Squeeze some ripe black pods at their ends, and notice how they split and twist up, throwing out the seeds. Try the same experiment with pods of vetches, lupines, and similar plants.

Get some plants of wood sorrel (oxalis), and balsams, with ripe fruits on them. Slightly squeeze the fruits and notice how they curl up, and shoot out the seeds. By placing a sheet of paper under the plant, find out how far the seeds are thrown.

Make similar observations on the violet. Sketch the fruits of all these plants before and after they have opened, and try and understand what really goes on in each case.

CHAPTER VIII

WEEDS

In all gardening and agricultural operations the careful cultivator makes it his constant care to destroy weeds. These are wild plants which invade the cultivated land and impede the growth of the crop. Weeds act injuriously in several ways. They crowd out cultivated crops by their leaves overshadowing and robbing the crop of the necessary sunlight, which as we have seen, plants make efforts to secure, being essential to their growth. The roots of the weeds rob the soil of moisture, thus retarding the crop's growth. At the same time the weeds use up some of the available plant food, thus leaving the crop insufficiently fed. This is particularly the case with the nitrogen, as when there are many weeds in the soil their roots compete with those of the crop in taking up the nitrates as fast as they are formed in the soil, and thus the crop may be unable to secure a sufficient supply for the purposes of vigorous growth.

When a piece of land is newly brought under cultivation much trouble is often experienced in removing the weeds, which grow from the seeds lying dormant in the soil, and from others brought there by the wind, or other agents in seed dispersal. Even after years of cultivation, weeds continue to make their appearance, owing to the great distances to which the seeds of many plants can travel. The seeds of weeds, moreover, are often introduced in stable and farmyard manures, and compost. For this reason, it is desirable that manures of this description should be well rotted before being used.

In getting rid of weeds it is very important to remove them before they have had an opportunity of ripening their seeds. If this precaution is not taken the cultivator will never have his land clean, and will be subject to unending trouble and expense. Many weeds propagate themselves by suckers and rooting branches; as, for example, couch grass or twitch, coltsfoot, dandelions. It is essential that these should be completely dug up and destroyed; merely chopping them with a hoe or spade only helps in spreading them, and thus to cause future trouble.

The kinds of weeds which make their appearance in any particular place often indicate very clearly the character of the soil. Such knowledge may be of considerable use to the cultivator, for he may often thus, at a glance, learn facts of great value concerning certain areas.

The traveller's joy or old man's beard (*Clematis*), fumitory, rock rose, and salad burnet are almost entirely confined to chalky or limestone soils, and the beech, yew, box and wild guelder rose are often characteristic. Sandy localities are often easily distinguishable by the presence of heaths, furze, broom, whortleberry, Spanish chestnut, and birch trees, and by such less conspicuous plants as the small lady's mantle, corn spurrey, etc. The presence of the lesser celandine or pilewort is almost certain proof of the presence of clay. Wheat and marigolds are characteristic crops, and oak trees thrive well on clayey soils. Wet lands are sufficiently indicated by the growth of rushes, sedges, and other moisture-loving plants.

Practical Work

Examine the plants which occur in the garden, and endeavour to determine where they come from, and how it is that some of them appear again and again after all attempts to get rid of them. In many, this will be found to be due to a good method of seed dispersal. Others, which are exceedingly difficult to get rid of, have underground stems, bulbs, and tubers, which remain in the ground.

Make lists of the plants found on some piece of waste ground, or which come up as weeds in the garden, and endeavour to understand how each spreads from place to place, whether by its seeds or by underground stems and roots.

Preserving Plant Specimens.

Collect specimens of every weed found in the school garden, and preserve them for future examination and reference. This may, with most plants, easily be done by carrying out the following simple directions. The first requisite is drying material, which is best of coarse, stout, and unsized paper. Ordinary blotting-paper is much too tender except for very delicate plants.

If nothing better is available, newspaper answers fairly well. Cut the paper into single sheets of convenient size (about 16 by 12 inches is recommended). Next obtain two boards, about half an inch thick, and slightly larger than the sheets of drying-paper. A few stones or bricks (best wrapped in stout brown paper) will complete the plant-drying outfit.

In gathering a plant, take care to get as complete a specimen as possible. A perfect botanical specimen should show root, stem, leaves, flowers, and fruit. Some plants are too large to allow of this, and in their case portions should be selected to make the dried specimen as fully representative of the plant as possible.

Take one of the boards, and put on it two or more sheets of the drying-paper. On the top sheet lay the plant, carefully arranging it so that its parts are as nearly as possible in their natural positions. On the plant place some more sheets of drying-paper, and then arrange another plant. (Two plants must never be placed on top of one another between the same two pieces of paper.) Go on in this way until all the plants are spread out, and finally put on the second board, and the weights.

By the next day the sheets of paper will probably have become damp, and must be changed for dry ones. Damp papers should be dried in the sun. When changing the plants, lift them carefully and take care that their leaves, etc., are in natural positions. The work of arranging the parts in position is often best accomplished after drying has gone on for a few hours. The plant is then limp, and the leaves, etc., will be found to remain in any position. When quite dry any attempt to move a part usually results in breaking it. With good absorbent paper, used perfectly dry, two changes are often sufficient, except for thick-leaved plants, which require more.

For future reference it is advisable to mount the dried plants on sheets of paper. The same size should be used throughout (16 inches by 10½ inches is a common and convenient size), and only one species of plant should be placed on any one sheet. Fix the plants to the sheets by small strips of gummed paper.

Write on each mounted sheet the name of the plant in the bottom left-hand corner, and add locality and date of collection, time of flowering, nature of soil in which it grows, whether it is a troublesome weed or not, and any other facts of interest. These observations should be made *at the time the plant is collected* and written on a slip of paper, which should be put with the plant when drying, and then neatly copied on the sheet on which the specimen is mounted. Plants collected, dried and mounted without notes made at the time of collection, giving some or all of the particulars above, lose much of their value.

A collection of this kind may be made by individual pupils, but it will usually be found advisable to make a general collection for the school. The work of drying and mounting can then be distributed amongst a number, and a collection formed which will steadily grow and become of permanent value and increasing interest.

CHAPTER IX

ANIMAL PESTS OF PLANTS

CONSTANT disappointment and annoyance are caused to the cultivator by the ravages of insects and other animals which devour or otherwise injure his crops, so that in his attempt to raise any crop the pupil is sure to have the presence of some animal pests and their habits unpleasantly brought to his notice. Caterpillars are certain to be amongst the first thus found, and, as an example of an insect's life-history, we may shortly summarise what can be observed in their case.

Life-History of a Caterpillar.

A caterpillar is produced direct from the egg laid by the parent. It will be found to be a soft-bodied insect, with a head, and a long body divided into "*segments.*" Behind the head, on each of the first three segments, is one pair of short-jointed legs. On some of the remaining segments and on the last will be found soft "*sucker-feet*" (or "*pro-legs*"), but never more than five pairs in all. The head is hard, and provided with very small eyes and strong hard jaws. The caterpillar lives for some time, eating voraciously and casting its skin periodically to allow for growth in size. When it is full grown and contains a large amount of fat, it again sheds its skin and appears as the "*chrysalis*" or "*pupa.*"

This stage is comparatively short and is a period of rest, when the body of the perfect insect is built up anew from the body of the caterpillar. At its close, the hard skin cracks, and the fully developed *moth* or *butterfly* comes out.

The perfect insect has two pairs of large wings clothed with scales, three pairs of long-jointed legs, large eyes, and, in place of the jaws of the caterpillar, a long tubular *proboscis* which serves to suck up the honey which may form its food. The female moth or butterfly then seeks the right food-plant and deposits a varying number of eggs, from which the caterpillars hatch. The eggs may be laid singly or in clusters, and are of very varied appearance. The caterpillars that hatch therefrom are also very varied in colour, being white, green, or marked with red, black and yellow; some are perfectly smooth, whilst others are covered with hairs, spines or bristles. Some caterpillars are very small—for instance, those found in "maggotty" peas—whilst others are as much as four inches long—for example, the caterpillars of the goat's-moth, and of the death's-head moth. The resting or pupal stage is often spent on the food-plant, sometimes in a cocoon; but many chrysalides are found in the earth.

Crops are destroyed only by the caterpillar. Neither the pupa nor the perfect insect injure plants, and, as has already been stated, moths and butterflies are important agents in the pollination of many flowers.

Life-History of a Beetle.

Many destructive agricultural pests belong to another order of insects, the beetles. These go through a similar series of changes: egg, larva (called "*grub*" in this order), chrysalis or pupa up to the perfect insect. The larvæ of beetles are often provided with three pairs of jointed legs, but have no sucker-feet. Sometimes they are entirely without legs, and are then usually white and fleshy. They have very strong biting jaws, and the segments of the body are not so well marked as in caterpillars.

The pupæ are inactive, often enclosed in a cocoon, and in them the form of the forthcoming beetle is easily recognised.

The perfect insect is usually hard, with two pairs of wings, of which the first pair are hard and long, forming a sheath for the second pair, which are thin and membranous. Their jaws are usually strong and well adapted to biting.

Beetles thus prove destructive both in the larval and in the mature stage; they feed upon a great variety of substances. Some, like the grubs of the flea-beetles, burrow in the leaves of plants; others eat the roots underground—for instance, wire-worms, the grubs of cockchafers, and of daddy longlegs or "leather jackets." The death-watch beetle bores into beams in houses, and several others eat their way into the stems of trees; and the ravages of a little beetle, the so-called "furniture worm," in furniture are well known. Biscuits, grain, and other stored food-stuffs, are very liable to the attack of small beetles called weevils, and others have a liking even for cigars and cigarettes.

Green Fly.

Every gardener is sure at some time or other to have his attention called to another group of insects, "green fly," or plant lice. These are often found on young shoots and buds, and if nothing is done to check them they increase enormously, and the leaves on which they are often curl up, wither, and die. Green fly are provided with a *beak* or *proboscis*, which they thrust into the plant and use to suck up its juices. Each green fly is very small, but they often occur in such countless numbers that together they do a great deal of harm to the plant. Although usually called green fly some are black; for instance, the plant lice often found on beans.

The presence of green fly is often indicated by a sticky deposit on the leaves of the plants, which sometime trickles down the stems or drops on the ground. This sticky liquid is called "honey dew," and is produced by the green fly. In London the lime trees are often attacked by green fly, and the honey dew dropped by them forms damp patches on the pavement, so that walking along and watching the pavement you can often tell that you are passing under a lime tree and that the tree is attacked by green fly.

Rose-growers are often troubled by finding the leaves of their plants disfigured by having pieces cut out of them as neatly as if done by a sharp knife. The offenders are certain biting bees which cut out these pieces and use them to build nests in holes in trees and similar places.

Flies.

Distinguished from the insects already mentioned, all of which have four wings (some green fly have no wings), are the flies which only possess two. The larvæ, usually called *maggots*, are footless grubs with an undefined head; they are thus distinguishable from the grubs of beetles. The pupæ are inactive and often resemble brown seeds. The adult insects have two membranous wings, and the mouth is formed for suction and not for biting.

The grubs of some flies burrow in leaves, and eat out tunnels in the soft tissue. Thus cineraria leaves are often disfigured by meandering trails made by the grubs of the leaf-miner, and the grubs of the celery-fly are responsible for the blister-like patches often seen on celery leaves; in these cases the green tissue of the leaf is eaten, leaving the colourless upper and lower skin. The grubs or maggots can often be seen in these blisters, and here they change into the pupal or resting condition, whence later the perfect winged fly emerges.

Slugs and Snails.

Slugs and snails also cause a great deal of damage in gardens. They are obviously very different from the pests already noticed, and belong to another class of animals altogether, the *Molluscs*, or Shellfish. In the ordinary garden snail the shell is easily seen, but in most slugs there is no visible shell, it being present only as a small, hard plate embedded in the flesh of the animal. Snails and slugs lay eggs in damp places, on leaves of plants, etc., and from these hatch directly young snails or slugs, there being in this group no stages corresponding to the larvæ or pupæ of insects.

Most snails and slugs feed on vegetable matter, and their ravages in gardens are familiar to every one. The garden snail and the ordinary grey slug are to be found in almost every garden, and in fields the large black slug is often met with.

Remedies.

In order to limit the damage done to crops by injurious insects, various steps may be taken; first of all the eggs of butterflies and moths when seen upon leaves should be destroyed, and the caterpillars should be picked off and killed. When these remedies are inapplicable various insecticides may be dusted or sprayed upon the plants attacked. Full directions concerning the use of many of these are to be found in the excellent leaflets of the Board of Agriculture, obtainable, free of charge, on application to the Secretary, 4 Whitehall Place, S.W.

Many caterpillars are kept in check by being attacked by other insects which lay their eggs in their bodies. The insects attacked are not immediately killed by this operation, which commonly takes place in the caterpillar stage, but the caterpillars often live and pass into the chrysalis stage. By this time the larvæ of the insect which has attacked them have hatched out and usually kill their host by feeding on it in this stage, so that instead of the expected moth or butterfly issuing from the chrysalis, a number of flying insects, the mature form of the attacking insect, make their appearance. Not only caterpillars, but all kinds of destructive insects may be thus destroyed by other insects, and many species that would otherwise become very injurious are thus kept in check.

Slugs and snails are best kept in check by hand picking, or by trapping them with cabbage leaves.

Practical Work

Collect a few caterpillars, together with portions of the plant on which they are feeding. Place these in a box, in the bottom of which is a little garden-mould, to the depth of about 1½ inches. Cover the box with muslin, perforated zinc, or glass, in such a manner that the caterpillars cannot escape. Supply them with food morning and evening. When the caterpillar changes into a chrysalis, note where the chrysalis places itself, whether it is buried in the soil or whether it attaches itself to the leaves of its food-plant, and note any other arrangement which it makes for its protection. Keep the box with the chrysalides in a safe place until the moths or butterflies appear. Make notes, with sketches of the size, colour, and appearance of the insect in the various stages. Keep an account of the time occupied by each stage. Record the plant on which the insect under observation is found feeding. As many insects as possible should be raised under observation.

Make a list, which may be added to from time to time, of the insects found upon particular crops, keeping specimens of the insects, drawings or descriptions, with notes of the parts of the plants attacked and of the injuries caused. Thus lists may be made of insects found upon cabbages, turnips, corn, lettuce, peas, beans, roses, celery, etc.; these lists may prove of considerable interest and value. In preparing these lists, efforts should be made to observe the habits of the insect and to obtain all the stages from the egg to the mature insect.

Collect specimens of the snails and slugs found in the garden. Observe the shell in snails, and note how the animals withdraw into it when touched or alarmed in any way. Compare with slugs in which the shell is apparently absent. Put snails and slugs to walk on a piece of glass, and looking at them from beneath observe the wave-like contraction of the muscles. Notice their eyes, their method of feeding. Keep some for a time in a box, and supply them with leaves; they may lay eggs, and if so watch the development of the young animals.

Insects required as specimens are best killed by putting them into a "killing-bottle." This is a wide-mouthed stoppered bottle in which some fragments of cyanide of potassium have been placed, and some plaster of Paris, mixed with water to the consistency of thick cream, poured over the cyanide so as to cover it completely. When the plaster has set, the bottle is ready for use, and any insect placed in it is quickly killed. Owing to the extremely poisonous nature of potassium cyanide, it is desirable that these killing-bottles should be purchased ready for use. When the bottles are old and exhausted, care should be taken in disposing of them, so as to avoid injury to persons or animals by any remaining cyanide. *It is impossible to be too careful in this respect.*

Remedies.

Two very generally useful mixtures for spraying plants with are:—

Kerosene or paraffin emulsion, made by dissolving half a pound of hard soap in one gallon of boiling water. When dissolved, add two gallons of kerosene (paraffin) to the hot liquid, and immediately churn up well with a syringe until the mixture becomes creamy. This is the stock solution, and, before using, water should be added to make it up to thirty-three gallons. Only rain-water or other soft water (that is without lime) must be used.

Whale-oil soap. Dissolve one pound of the soap in one or two gallons of warm water, and use when cold.

GLOSSARY

Acid (Latin, *acidus*, sour). The name given to a large series of substances, which possess, amongst other properties, (1) a sharp taste, (2) the power to turn moist blue litmus-paper red, and (3) to cause carbonates (such as lime or soda) to bubble up and give off carbon dioxide. Vinegar is an example of an acid.

Albumen (the Latin word for the white of an egg). Used botanically for a reserve of plant food contained in the seed. See footnote, page 5.

Alkaline (Arabic, *al*, the ; *kali*, ashes of a plant, "glass-wort"). The opposites of acids ; substances which turn moist red litmus-paper blue, and have as a rule a peculiar burning taste. Slaked lime and caustic potash are common examples.

Analysis (Greek, *analusis*, a loosing or breaking-up). The separation of a substance into the various parts of which it is composed.

Apex (the Latin for summit). The growing point of a stem or root and the free end of a leaf.

Assimilation (Latin, *assimulatio*, a making like). Used to denote the process by which the raw food of a plant is changed into plant substance. The term is often confined to the formation of starch and other substances from water and carbon dioxide in sunlight by plants containing chlorophyll.

Bacteria (Greek, *bakterion*, a small stick or staff). Minute forms of plant life, commonly spoken of as germs and microbes. The decay of animal and vegetable matters is largely brought about by bacteria.

Berry (Latin, *bacca*, a berry). A fruit consisting of a thin outer skin, and a pulpy interior in which the seeds are embedded ; *e.g.* a tomato.

Botany (Greek, *botané*, grass, or more generally any plant). The study of plants.

Bulb (Latin, *bulbus*, a bulb, or round root). Usually an underground leaf-bud, containing reserves of plant food stored up in thickened leaves, and protected on the outside by scale leaves.

Capillary (Latin, *capillus*, a hair). Hence any very fine threads, tubes or cavities.

Carbon (Latin, *carbo*, a cinder). The substance which forms a large proportion of all organic matter.

Cereals (Latin, *Ceres*, the goddess of corn). A general name for those grasses whose seeds are used as food, *e.g.*, maize, rice, and Guinea corn.

Chemical (Arabic, *Kimia*, the hidden art or science). The science which deals with the composition of matter.

Chlorophyll (Greek, *chloros*, pale green or grass-green; *phullon*, leaf). Leaf-green.

Chrysalis (Greek, *chryseios*, golden). The pupal stage (see Pupa) of butterflies. So called because some chrysalides are golden yellow in colour.

Cob—The spike of the Indian corn (maize) plant, made up of rows of pistillate flowers which, when ripe, form the corn grains.

Combustion (Latin, *combustum*, a burn). The phenomenon of burning, in which the majority of substances unite with oxygen.

Cotyledon (Greek, *kotuledon*, a cup-like hollow). Seed-leaves.

Cultivation (Latin, *cultus*, a tending or taking care of a thing). In agriculture the term denotes the operations of tillage whereby the soil is brought into a condition suitable for the economic production of crops.

Dicotyledons (Greek, *dis*, two; *kotuledon*, cup-like hollow). A large subdivision of flowering plants, the members of which have embryos with two seed-leaves. For other characters see text.

Dormant (Latin, *dormio*, I sleep). Used to denote the resting condition of parts of plants—for instance, seeds when kept dry, tubers before starting into growth, etc.

Effervesce (Latin, *effervesco*, I foam up). Applied to a bubbling action like that which takes place when an acid and a carbonate come in contact.

Embryo (Greek, *embruon*). Used botanically for the young plant present in a seed.

Fertility (Latin, *fertilitas*, fruitfulness). Used generally of soils. "Fertile" is usually applied to flowers.

Fertilisation (Latin, *fertilisatio*, the making fruitful). The process by which the contents of the pollen grain act on the ovules. After fertilisation the ovules develop into seeds.

Flower (Latin, *flos*, a flower or blossom). The reproductive organs, *i.e.* the stamens and pistil of a plant, usually together with one or more protective coverings. The simplest flowers consist of stamens and pistil only.

Fruit (Latin, *fructus*, profit or produce, especially of land or trees). The ripened ovary together with its seeds. Many things commonly called vegetables are botanically fruits ; for example, tomatoes, cucumbers, etc.

Germination (Latin, *germinatio*, a sprouting forth, a budding). The first stage of active growth of a seed.

Host—The plant which supplies "board and lodging" to a parasite.

Humus (Latin, *humus*, earth, soil). Leaf mould. The substance formed by the decay of vegetable matter.

Internode (Latin, *inter*, between ; *nodus*, a knot or joint). The portion of a stem between two joints.

Larva (Latin, *larva*, a mask). The first stage of active life of an insect. Insects in this stage are variously known as maggots, caterpillars or grubs. The name was originally given because the caterpillar was thought to hide or mask the future butterfly.

Leguminosæ. The Latin word *legumen* was originally applied to pulse. Hence, the pod which contained the peas from which the pulse was made, was called a *legume*, and the name *Leguminosæ* given to all the plants which belong to the pod-bearing order. In addition to the flower, the plants in this order are characterised generally by divided leaves and root nodules. It is the second largest order of flowering plants, and contains some 7000 species.

Manure (French, *manœuvre*, to till by hand). The word thus originally meant cultivation of the soil by hand. It is now restricted to the special substances added to supply plant food.

Mechanical (from the Latin, *machina*, a machine, a work artifically made). The mechanical analysis of soil denotes the separation of the constituents of the soil by some method which does not entail any change in composition of the constituents, *e.g.* by washing.

Medullary rays (Latin, *medulla*, the pith in plants, the marrow in bones). The bands of tissue which pass from the pith, through the wood, into the inner bark. The "grain" in oak wood is due to the medullary rays.

Monocotyledon (Greek, *monos*, one ; *kotuledon*, cup-like hollow). One seed-leaf. The name given to a division of flowering plants, the members of which have embryos with only one seed-leaf.

Nitrification (Latin, *nitrum*, nitre ; *facio*, I make). Applied to the bacteriological process in the soil by which various organic substances containing nitrogen are changed into nitrates. The bacteria bringing about the change are called nitrifying bacteria.

Node (Latin, *nodus*, a knot or joint). The joints on a stem, at which the leaves are generally attached.

Nodules (Latin, *nodulus*, a little knot). Small, rounded swellings ; for instance, those on the roots of leguminous plants.

Nut (Latin, *nux*, a nut, a fruit with a hard shell). Usually applied to hard fruits, which do not split open, and contain only one seed.

Organic (Greek, *organon*, an instrument or implement). Belonging to life. The name given to all substances which, although not alive themselves, are the results of living processes. For instance, wood, starch, hair, bones, etc.

Organism—Any living thing, whether animal or plant.

Ovary (Latin, *ovum*, an egg). That portion of the pistil of a plant which contains the ovules.

Ovule (Latin, *ovulum*, a little egg). The young seeds.

Parasite (Latin, *parasitus*, a fellow-boarder, a guest). An organism which lives on and obtains its nourishment from another—the host. Distinguished from epiphytes which live on but do not obtain nourishment from another organism.

Petal (Greek, *petalon*, a flower leaf). One of the leafy bodies, commonly brightly coloured, which usually form the showy portion of a flower.

Pistil (Latin, *pistillum*, a pestle). The ovary and stigma (which may or may not be stalked) of a flower. In some plants the pistil is pestle-shaped, hence the term pistil.

Plastic (Greek, *plastos*, moulded). Capable of being moulded or worked into various shapes. For instance, potters' clay is plastic.

Plumule (Latin, *plumula*, a little feather). The name given to the undeveloped shoot (that is, the stem bud) of the embryo. Its appearance in such seeds as the bean probably suggested the name.

Pod—A dry (not fleshy) fruit, containing several seeds. A pod usually splits open when ripe along both sides.

Pollen (Latin, *pollen*, anything as fine as dust ; hence, very fine flour). The powdery substance contained in the stamens, essential to the fertilisation of flowers.

Pollination—The act of placing pollen on the stigma of a flower, usually, but not necessarily, followed by the fertilisation of the flower. Insects can pollinate flowers, but they cannot fertilise them.

Propagate (Latin, *propago*, I propagate, I extend). To increase the numbers of a plant by means of cuttings, reproduction by seeds, or other methods.

Pungent (Latin, *pungo*, I sting). Used to describe the smell of such a substance as ammonia.

Pupa (Latin, *pupa*, a baby). The third stage in the life of many insects, usually inactive. The name was given from the resemblance of many pupæ to a baby bound up in clothes as is the custom in Southern Europe. Pupa and chrysalis refer to the same condition.

Radicle (Latin, *radix*, a root ; hence radicle, a little root). The young root of the embryo.

Respiration (Latin, *respiratio*, the act of drawing breath). Used to denote the breathing process in both plants and animals.

Rudimentary (Latin, *rudimentum*, a first attempt, a beginning). Often used to describe parts of plants which have not reached their full development.

Scutellum (Latin, *scutulum*, a little shield). A descriptive name for the body on the embryo of a grass, by means of which it dissolves and absorbs the food-reserve stored up in the seed.

Sections (Latin, *sectio*, a cutting). Thin slices cut from a plant. They may either be cut across the stem—cross-sections ; or cut lengthwise—longitudinal sections.

Segments (Latin, *segmentum*, a division or a portion). The divisions, or rings, which make up the body of an insect.

Sepal (from Greek, *skepas*, covering or shelter). One of the leafy bodies, commonly green, which form the outermost portion of the flower, and usually make a protective wrapping to the more delicate inner portions.

Species (Latin, *species*, a kind or sort). All those animals or plants are said to be of the same species which do not vary more from one another than might be expected in the produce of the same parents.

Stamen (Latin, *stamen*, a thread). One of the essential parts of a flower, consisting usually of a stalk, bearing a pollen-box containing the pollen grains.

Stigma (Greek, *stigma*, a spot). The portion of the pistil which receives the pollen. It is often hairy or sticky.

Stipules (Latin, *stipula*, straw, stubble). The bodies borne where a leaf joins on to a stem ; not present in all plants.

Stoma—(plural, stomata)—(Greek, *stoma*, a mouth). The small pores in the surfaces of leaves, and other green parts of plants.

Sucker. This is used botanically in two senses. (1) For a branch which starts underground, and then comes above. (2) For a special sucking apparatus by means of which some young plants empty their seeds of food.

Tendril—A thin structure, branched or not, by means of which a plant climbs. Stems and leaves are frequently modified to form tendrils.

Transpiration (Latin, *trans*, across ; *spiro*, I breathe). The giving off of water-vapour through the stomata of plants.

Tuber (Latin, *tuber*, a swelling). A thickened, usually underground structure, which may be a root or stem. Important as store-houses of plant food.

Variation (Latin, *variatio*, a difference). Used to express the tendency of living things to differ to some extent from the ordinary type. The differences which enable us to distinguish different persons from one another, afford an everyday illustration of variation in human beings.

Vitality (Latin, *vitalis*, of or belonging to life). Seeds, for instance, are said to retain their vitality so long as they are capable of growing when placed under suitable conditions.

APPENDIX I

SUGGESTED COURSES

In schools taking up this work in autumn, the following course is suggested :—

Chap. 1.—Parts of a seed.
Plant food in seeds.
Conditions of germination.
Chap. 2.—The general characters of roots.
Chap. 3.—The general characters of stems.
The life-history of a crocus or gladiolus.
The structure of stems.
Chap. 4.—Winter buds.
The structure of leaves.
Chap. 5.—Mechanical analysis of soil.
Water in soils.
Effect of frost on rocks.
Vegetable matter in soils.
Chalk in soils.

The ground in the school garden should be dug up, and if possible the beds and paths laid out before the frosts set in.

In the spring the remaining portions of Chap. I. can be undertaken, and the order in the book followed as far as found convenient, care being taken to start the manurial experiments, collection of weeds, and observations on insect pests at an early date.

When the work is commenced in the spring, the weather offers no obstacles. Care must be taken to examine the opening of leaf-buds, the life-history of the crocus, and to begin the experimental work on seedlings at an early date.

If not already done, the school garden should be at once put into order, beds and paths laid out, and seeds sown for transplanting into the plots for manurial experiments.

As in the previous case, an early beginning should be made in recording observations on flowers, weeds, insect pests, etc.

APPENDIX II

APPARATUS AND MATERIALS REQUIRED

6 wide-mouthed, corked bottles, *e.g.*, 1 lb. jam bottles.
3 small, narrow-necked bottles.
2 square, wide-mouthed bottles, *e.g.*, pickle bottles, and corks to fit.
12 test-tubes, about ½ in. diameter, and corks to fit.
1 thistle-funnel.
6 dinner plates.
4 tumblers.
2 glazed jam pots.
2 beakers (4 oz.).
3 glass funnels (3 in. diameter).
1 glass tube (1 ft. long, ¾ in. diameter).
6 glass plates (4 × 3 in.), *e.g.*, clean quarter-plate negative glasses.
1 straight lamp-chimney.
4 saucers.
2 doz. flower-pots (5 in.).
64 flower-pots (8 in.).

½ lb. starch.
½ lb. paraffin wax.
2 oz. iodine solution.
1 qt. methylated spirit.
4 oz. vaseline.
½ lb. soda lime.
½ lb. caustic potash.
¼ lb. paraffin wax.
2 oz. Fehling's solution.

1 lb. chalk. 1 lb. sulphate ammonia. 1 lb. basic slag. 1 lb. sulphate potash.	Larger quantities if manurial experiments are to be carried out in school garden.

1 oz. calcium nitrate.
1 oz. potassium nitrate.
1 oz. magnesium nitrate.
1 oz. potassium phosphate.
1 oz. iron chloride.

Nitrate of soda. Dried blood. Phosphate of lime. Basic slag. Kainit.	A small quantity of each as a specimen.

Soap.
Kerosene oil.
Whale-oil soap.
Cardboard.
Tinfoil.
Copper wire.
Camels' hair brushes.
1 lb. shot.
Muslin.
2 doz. sugar bags.
Fine wire-gauze (1 sq. foot).
Sealing-wax.
Beeswax.
Resin.
Coco-nut fibre refuse.
Indian ink.
Budding-knife.
Grafting-knife.
Budding-tape (see instructions in Chap. III.)
1 pr. fine forceps.
1 pr. sharp-pointed scissors.
$\frac{1}{2}$ ream botanical drying-paper (16 × 12).
$\frac{1}{2}$ ream botanical mounting-paper (16 × 10$\frac{1}{2}$).
1 pr. boards (17 × 13).
Gummed labels.
6 pieces of flannel (each size dinner plate).
Balance and weights, to weigh from 100 to $\frac{1}{10}$ gramme.

Ordinary scales and weights to weigh to 5 lb.
Box with removable glass or wooden front.
Box with one side removable and slot in bottom.
2 stakes and lines.
Levelling-tool.
Ordinary sieves, 1″, $\frac{1}{4}$″, $\frac{1}{8}$″ mesh.
Brass sieves, 2, 1, $\frac{1}{2}$ mm. mesh.
6 stout wooden seed-boxes, 4 to 6 ins. deep.
4 stout wooden boxes, 2′ × 2′ × 1′.
Box for rearing insects in.
Triplet pocket lens.

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