IMPERIAL DEPARTMENT OF AGRICULTURE FOR THE WEST INDIES.

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NATURE TEACHING.

ISSUED BY THE COMMISSIONER 1901

Imperial Department of Agriculture for the West Indies.

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BASED UPON THE GENERAL

PRINCIPLES OF AGRICULTURE.

FOR THE USE OF SCHOOLS

BY

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ISSUED UNDER THE AUTHORITY
OF THE
COMMISSIONER OF AGRICULTURE
FOR THE WEST INDIES.

London: DULAU & Co., 37, Soho Square, W.
Barbados: BOWEN & SONS, Bridgetown.

1901.

PREFACE.

One of the most hopeful features connected with the West Indies is the general movement now taking place in favour of Agricultural teaching.

The West Indian Colonies are wholly dependent on Agriculture, but hitherto no systematic attempts have been made to teach the Elements of Agriculture in such a manner as to win the intelligence and energies of the rising generation in favour of Agricultural pursuits.

The first step taken was to train the Teachers already in charge of Schools and qualify them to give the right kind of instruction, in the lower classes by means of object lessons, and in the upper, in close relation with experiments with plants grown in pots, boxes or school plots. The object aimed at, and clearly impressed on the minds of the teachers was not to load the memory with facts, but to train the powers of observation and give the children an intelligent interest in the every-day facts of rural life. It was understood that in Elementary schools no attempt was to be made to teach practical Agriculture or "farming." This was to be the business of later years assisted by the Agricultural schools and Experiment Stations.

Efforts were also made, by the offer of scholarships and provision for the services of Lecturers in Agricultural Science, to encourage the teaching of Agriculture in the High Schools and Colleges in the West Indies.

It is hoped by these means to educate, according to his station, the peasant and the planter, and give to each the particular training and knowledge necessary to equip him for the battle of life.

In the pages of *Nature Teaching* prepared by Mr. Francis Watts, F.I.C., F.C.S., and now issued as a Text book by the Imperial Department of Agriculture, an attempt is made to place in the hands of Teachers both in Elementary and Secondary schools a well selected, but co-ordinate body of information suitable to West Indian conditions, to be supplemented in each case by numerous illustrations and experiments in which the pupils themselves take an active part.

Nature Teaching is not a Reading Book, and it is not desirable that it should be placed in the hands of any except the older pupils who have already received oral instruction on the subjects dealt with.

The following suggestions, to those likely to use the book, are offered by Mr. Watts :—

"In work of this kind some skill and judgement 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.

"To this end it does not seem desirable to regard the text-book as offering a course to be gone through in exactly the order in which its chapters are arranged. It will, for instance, be found desirable, I believe, to deal with a considerable part of chapter V, treating of the nature and properties of soil, along with the chapters dealing with plant life and growth, thus filling in those gaps in time which will arise while the seeds and plants under observation are growing. Similarly the chapters dealing with weeds and with insects are intended to be suggestive of general work along these lines; work which may be continuously carried on at the same time as the instruction in other directions, and not merely be taken up towards the end as their position in the book may appear to indicate.

"By a judicious combination of work in boxes and pots, and work in the open garden, a teacher should succeed in keeping a class well in hand without confusion or loss of time. In the absence of a school garden a considerable amount of instruction may be given by means of boxes and pots alone."

I have only to add that I am greatly indebted to Mr. Francis Watts for the very clear and interesting way in which the book has been prepared and the readiness with which he has placed the results of his labour at the disposal of the Department. My thanks are also due to Mr. W. G. Freeman, B.Sc., F.L.S., for the very considerable service rendered by him in revising, editing, and seeing the work through the press, and to Mr. H Maxwell-Lefroy, B.A., F.E.S., for the chapter on the treatmemt of "Insect Pests."

D. MORRIS,
Commissioner of Agriculture
for the West Indies.

July 20, 1901.

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CHAPTER I.—THE SEED.

1. We are familiar with seeds as the means by which plants are propagated. Every seed contains a small plant, the *embryo*, together with a supply of *plant food* which is to nourish the little plant until it is able to obtain its own food from the air and soil. All this is wrapped round and protected by a covering known as the *seed-coat*.

2. When a seed is placed under proper conditions, the young plant, which it contains, begins to grow and the seed is said to *germinate*. Several things are necessary to enable seeds to germinate; they must have a supply of moisture and of air, and they must also be kept warm.

THE PARTS OF A SEED.

3. In order to distinguish the various parts of a seed it is well to examine one which has begun to germinate, for in that condition

the parts are more easily separated. One of the simplest and most easily understood seeds is that of any of the ordinary peas or beans. An examination of a very young bean plant, 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 pigeon-pea and some others, these leaves do not come above the surface of the soil) between which 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.

4. 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 that which is enclosed by the seed-coat is easily split 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, will become the stem with leaves upon it, while the remaining portion will develop into the root.

These portions are known respectively as *plumule* and *radicle.* 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.

1. 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 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 away. 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 cabbage, raddish, lettuce, pumpkin, squash, cucumber, lime, orange, cacao, nutmeg and many others.

2. But 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 plantlet which is in the seed, but exists as a separate store outside the

embryo. In these cases we have to distinguish the seed-coat, the young plant or embryo and the store of plant food. These may be made out in the seed of the *Canna* or *Tous-les-mois,* where the embryo will be seen lying in the midst of the store of plant food which makes up the greater portion of the seed.

3. In maize and corn the embryo will be found lying at one side of the seed, near the pointed end (base) and easily distinguishable as a white patch. In maize, 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.

4. This separate store of plant food is often spoken of as the *albumen,** hence seeds are described as *albuminous* or *exalbuminous* in accordance with the presence or absence of this albumen. The seeds of maize, guinea corn, all the cereals and grasses, coffee, beet, carrot, onion, cocoa-nut, date and other palms, afford examples of albuminous seeds.

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* 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.

5. 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 while the embryos of other seeds have only *one.* Maize may be taken as an example 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 associated with other constant characters of plant structure to which fuller reference will be made later. Seeds with embryos having one cotyledon are described as *mono-cotyledonous*, while those in which two cotyledons are present are known as *di-cotyledonous.*

GERMINATION.

1. When a gardener or planter 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 will produce 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.

2. If on alternate days a few seeds of

various kinds of beans are planted in moist soil and the process is continued until those first planted have developed into small plants four or five inches high, there will be provided an ample supply of material for purposes of study.

3. Now, 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 un-germinated 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.

4. 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.

5. Observation of the germinating beans will show 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.

6. The arch has then another duty to perform; the seed-coat still covers the cotyledons and the plumule, which 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.

7. 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 the seeds are provided with a seed-coat which becomes mucilaginous and sticky when wet, thus effecting the same purpose.

8. On looking over a plot where a number of beans are germinating, it will often be seen 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, but allowed them to be pulled up when the plant tried to draw out the cotyledons. It will be seen that these plants are often greatly hindered in their growth by the presence of these, no-longer-wanted, coats.

9. In the case of some beans and peas, as for example, the pigeon or Gungo pea (*Cajanus indicus*,) 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. Nearly every kind of seed will be found to present peculiarities in its method of germination well worth study.

10. The germination of the seed of the

cucumber, squash or pumpkin, has interesting peculiarities. 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 it 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, and that, the under one; and if, when germination has proceeded to a small extent, the seed be turned over so as to bring the upper side to the under side then the protuberance will form on the side which is finally downwards. This will happen even if a slight protuberance has begun to form before the turning took place.

11. In the instances of germination already referred to, the store of plant food is placed in the cotyledons from which position the food 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 conveyed into the young plant. It will be well to describe one or two examples showing how this is accomplished.

12. The onion has an albuminous seed. In germination the young rootlet 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.

13. A somewhat similar condition of things is to be found in the germination of the seeds of

many palms and may be studied in the date and the cocoa-nut. The case of the date palm is interesting owing to the manner in which the cotyledon performs its functions. It remains attached to the food supply and absorbs it, as in the case of the onion just described, but, owing to the manner in which it elongates, it carries with it, concealed in its free extremity, the rest of the embryo of the seed. By this means the young plant is thrust deep down into the soil on which the seed is germinating and carried to a considerable depth before there is any appearance of either roots or leaves. The whole of the work up to this stage is performed at the expense of the food supply contained in the seed; germination takes place very slowly and the germinating seed is independent of any supply of food from the soil, with the exception of a little moisture. The food supply in this instance consists of the hard horny albumen which is very slowly absorbed. It will be recognised how this method of germination is suited to a plant which usually lives in desert regions where the water supply is scanty. By making the young plant independent of food from the soil until it has been buried to a sufficient depth to obtain a supply of moisture for itself the chances of successful growth, under difficult conditions, are rendered much more certain.

14. The seeds of the castor-oil plant and the physic-nut 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.

15. The seeds of the grasses and cereals are all albuminous, the manner in which the store of plant food is absorbed during germination can be studied in the case of corn (maize). Some grains of corn should be planted on three or four successive days, in moist sand or sawdust, so as to furnish a number of grains in which the process of germination has progressed to several successive stages ; 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.

16. On examining the grains, the embryo or germ will 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 it will be found that 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 this case 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, which lies 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 intended to be merely suggestive. The precise manner in which they are conducted must necessarily depend on the circumstances surrounding each class of students.

THE CONDITIONS FOR GERMINATION.

1. 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, (corn, peas or beans) cork the bottle and seal with sealing wax or bees-wax. 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 and D exactly as B but leave the bottles uncorked.

2. Put A, B and C away side by side, preferably in a dark place, examine day by day and it should be found that in A the seeds do not germinate at all; they have no water 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. They should germinate and grow well. The experiment has so far shown the necessity of water and air.

3. In the tropics it is not easy to show the influence of cold; this may be attempted, however, by putting the bottle D, the seeds in which have both water and air, in an ice-chest, when it will probably be found that germination is either completely arrested or greatly delayed.

RAISING SEEDLINGS.

1. 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 will 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 the bottoms of kerosine tins.

2. The soil for filling the boxes should be prepared by sifting, first, through a sieve having holes of about an inch in diameter; this will remove 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 will separate 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.

3. A tool for levelling the soil, as it is placed in the boxes, is wanted. 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.

4. A supply of dry, finely chopped grass, such as is obtained by mowing lawns, or preferably of cocoa-nut fibre refuse, is required.

5. To prepare a box for sowing seeds, place on the bottom a layer of the stones which have been separated from the soil by means of the coarsest sieve. Over the stones place a layer of the cocoa-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 finally a layer of the sifted earth. Level this last layer by means of the tool, at the same time compressing the earth slightly.

6. The seed may now be sown, the method of procedure depending on the size and kind of seed. If a small seed, like lettuce, is being sown, all that is necessary is to scatter the seed 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 will cover the seeds without burying them at all deeply. If larger seeds are being sown place them in rows on the surface of the levelled soil and cover with very fine earth as in the previous case. Very large seeds, such as nutmegs, may be placed in position, buried by pressure about half their own depth in the soil, and then covered with moderately fine earth.

7. 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 rid themselves of 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.

8. 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.

SEED BEDS.

1. 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, the paths which shall separate the beds; these paths should be about 18 inches or two 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, proceed with a spade to remove the soil from the paths and to 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 very 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.

2. 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 anyone 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 and the like, and a

short one for working across beds. After use, lines should always be neatly wrapped around their stakes.

3. 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, two 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.

4. Pots are sometimes used for sowing seeds in, particularly large seeds. They are

also of use when the young plant is to be subsequently transferred to another spot, as in the case of cacao. 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.

1. 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.

2. Upon examining seed beds containing germinating seeds it will 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.

3. After some of the better known kinds of seeds have been studied much instructive information may be gained by collecting seeds of wild native plants and studying their methods of germination. In addition, obser-

vations serving to develop the pupils' powers of perception and reasoning may be made upon germinating seeds and seedlings found in a state of nature.

4. 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	Corn (Maize)
Bonavis	Guinea corn
Lima Bean	Onion
Pigeon Pea	Coffee
Black-eye Pea	Tous-les-mois (*Canna*)
Cabbage	Date palm*
Raddish	Cocoa-nut*
Squash or Pumpkin	Castor-oil (*Ricinus*)
Lime or Orange	Physic-nut
Cacao	
Nutmeg	

TESTING VITALITY OF SEEDS.

1. Seeds lose their germinating power on being kept for a long time. It is desirable therefore that we should be able to test their quality in this respect. The following method,

* The germination occupies a very long time.

recommended by the Kansas State Experiment Station, will enable the pupil to carry out investigations on his own account. He 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.)

2. "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 per cent. of vitality under favourable conditions."

3. "Grass seeds require as much as three weeks, and seeds of some trees a still longer time. Beet balls contain from 3 to 7 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."

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

Beans	90 to 95	Melon	80 to 90
Beet*	150	Mustard	90 ,, 95

(a) From Year Book, U. S. Department of Agriculture 1896.

*Each beet fruit or "ball" is likely to contain from 3 to 7 seeds. One hundred balls should give at least 150 sprouts.

Cabbage	90	to	95	Okra	80	to	85
Carrot	80	,,	85	Onion	80	,,	85
Corn (Maize)	90	,,	95	Peas	93	,,	98
Cotton	85	,,	90	Pumpkin	85	,,	90
Cow-pea	85	,,	90	Radish	90	,,	95
Cucumber	85	,,	90	Tomato	85	,,	90
Egg-plant	75	,,	80	Turnip	90	,,	95
Guinea corn	85	,,	90	Tobacco	75	,,	80
Lettuce	85	,,	90				

CHAPTER II.—THE ROOT.

1. The first thing to make its appearance when a seed germinates is the young 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. It may also increase in thickness to a very considerable size.

2. 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 young root is at all roughly dealt with. They may be seen to great advantage on the roots of seedlings, preferably of maize, which have been grown in a moist atmosphere. On examining such a root it will be noticed that the apex 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.

3. 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 find without the use of a lens, but may often be seen in roots growing in water, for instance those of the water-hyacinth. The screw-pine *(Pandanus)* throws out a number of roots from its stem; they are to be seen hanging, and growing downwards towards the ground, and, if the tips of these roots are examined, they will be found to be covered with well marked root-caps. These serve to illustrate the nature of the appendage to be found at the extremity of most roots including even their finest and most minute ramifications.

4. 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. Roots increase in length by the addition of new material at their ends; the older parts may increase 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.

1. 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.

2. Roots frequently act as storehouses of plant food, particularly in the case of biennial plants. *Biennials* are plants which, in temperate climates, require two years to complete the cycle of their lives, producing 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.

3. 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 common pumpkin, which puts down thick, white roots 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.

4. In some plants the roots formed above ground are also of use as supports, thus in maize and Guinea corn a number of roots arise from the stem, at some distance above the soil, grow downwards and anchor the plant firmly. In the mangrove and screw-pine such roots are still more obvious and form the curious, stilt-like supporting structures. Stem-borne roots may, moreover, be of assistance to a plant in climbing upon walls, trees, etc. as may be seen in the vanilla and the wax-plant *(Hoya)*.

5. 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 spot. Full advantage is taken of this tendency by gardeners and agriculturists ; indeed, we can have no better

example of the importance and the success of this method than that continuously afforded by fields of sugar-cane, the plants of which are derived from pieces of cane stem, which, planted in moist soil, throw out roots and form new plants. Many food-plants and 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. Sugar-cane, sweet-potato, cassava, roses, crotons, geraniums and a number of other field and garden plants are regularly propagated in this manner.

6. Nor is it only from stems that roots may be developed. Many 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. This is well seen in many begonias. A weed, very commonly found on the road-side, known as the leaf-of-life, thick-leaf and a variety of other names (*Bryophyllum calycinum,*) exhibits this habit in even a more striking manner, for a leaf plucked from the plant, and laid aside without any particular

preparation, will throw out roots and leaf-buds; the thick, fleshy leaf containing sufficient water to permit of considerable growth taking place.

7. Some plants grow as *parasites* upon other kinds of plants; they thrust their roots into the tissues of their *hosts* and live by robbing them of sap, thus weakening and often killing the plants on which they grow. Examples of such plants are the bright yellow dodder (*Cuscuta*) which is often found injuring lime and other trees; and mistletoe (*Loranthus*,) which is, in some places, common on cacao. 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. Parasitic plants often constitute troublesome pests in the cultivation of cacao, limes, oranges and other fruit trees.

Practical Work.

Dig up several germinating seeds, and young seedlings, and examine their roots. 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 and maize will make this difference clear.

ROOT-HAIRS.

1. Take a small wooden box, place at the bottom two or three layers of wet blotting paper, and then some maize seeds which have been soaked in water for about twelve hours. Cover the box with a sheet of glass and put it on one side for four or five days; examine it from time to time and add more water if the blotting paper should become at all dry. At the end of this time root-hairs should be present in abundance, and there should be no difficulty in making out the characters which have been previously described.

2. Pull up, very carefully, seedlings which

have been grown in sandy soil; grains of sand will generally be found adhering in great numbers to the region on which we now know the root-hairs occur. Wash off this sand very carefully, and, whilst the roots are suspended in a tumbler of water, examine them also for root-hairs.

ROOT-CAPS.

Examine the aerial roots of the screw-pine and observe their root-caps; then look for similar, but much smaller and more delicate structures on other roots. Examine also roots growing in water; some water-plants have no root-caps, but if the water-hyacinth (*Eichornia*) can be obtained, its roots will be found to show root-caps to perfection. These roots should be examined whilst still in water. Grow seedlings and cuttings in water and examine their roots for root-caps.

GROWTH IN THICKNESS.

1. The youngest part of a root is always 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 maize, grasses, palms, etc.

2. 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 example, bread-fruit, mango and others in which the main roots are often as thick as the branches of the stem. Interesting cases showing an enormous increase in the thickness of roots will readily be seen in plants of radish, turnip, beet and cassava.

GROWTH IN LENGTH.

1 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.

2. 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 apart, and in marking them great care must be taken not to injure the root.

3. Pin the seedling, with the root hanging vertically, on the inside of a box, the atmosphere in which is kept moist, as in the experiment with germinating maize. 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. Examine after twenty-four hours, comparing the marks on the root with those on the card.

4. 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.

5. Thus we see 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.

6. Make a similar series of measurements on the aerial roots of corn, Guinea corn, or of the screw-pine; in these roots growth will be found to extend over a greater region and to be more uniform in its amount than in the case of roots growing in soil.

PROPAGATION BY CUTTINGS.

1. 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.

2. Having prepared a box proceed to plant cuttings of such plants as roses, crotons, hibiscus or coleus. 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 6 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.

3. 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.

4. Plant a similar series of cuttings of larger plants in garden beds, using for this purpose such plants as sugar-cane, cassava, sweet potato, ginger and arrowroot. At short intervals note the changes taking place.

5. Place cuttings of croton 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 white bottle wrapped round with paper or cloth to exclude the light.

6. 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 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.

7. 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, hibiscus, 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 bamboo pot, split into halves, 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 cocoa-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.

8. Peg down on moist soil some leaves of the weed known as "thick-leaf;" in the course of a few days roots and buds will appear at the margins and finally a number of young plants will be produced. Repeat this with other fleshy leaved plants such as begonias and peperomias; place these in different positions, some pegged down on the soil's surface others partly embedded in the soil. It is found that roots are more readily formed if the veins are cut across, therefore in some of the leaves cut across the principal veins with a penknife, taking care to leave the cut places in contact with the soil.

CHAPTER III.—THE STEM.

1. The stem, as opposed to the root, is that portion of the plant which bears the leaves and flowers. Stem and root are, as we have seen, distinct even whilst the young plant is still contained in the seed, being represented there by plumule and radicle respectively.

2. 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 a piece of sugar-cane stem.

3. 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.

4. 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.

1. 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 horizontally. The lime tree 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 speak of an upper and lower side to the branch. 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, but still more careful examination, particularly of the

tip of the same branch, will show that the leaves arise exactly as on the upright growing shoot and merely twist later into their final position. From a careful examination of these various cases it will be apparent that the parts of a plant are not rigidly fixed in any particular way but that each can adapt itself to special circumstances.

2. Stems, like roots, often serve as storehouses of food, for instance, the sugar-cane stores up a large amount of sugar in its stem, and similarly the sago-palm stores starch. The majority of the stems which serve as storehouses do not stand erect in the air as in the examples already given, but grow partially or entirely beneath the surface of the soil. 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.

3. Ginger affords a good example of a stem of this kind, running horizontally in the

ground, bearing scale-leaves, leaf-buds and roots. 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. In the arrowroot, somewhat similar stems run beneath the surface bearing dry, scaly leaves, and roots.

4. The yam and English potato (but not the sweet potato) are also enlarged stems and not roots. Leaves on them are almost absent being represented only by the '*eyes*' which are in reality leaf-buds, as is easily seen by keeping some potatos or yams 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 and yam are known as *tubers*. The 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 ginger and arrowroot and the true tubers.

5. 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 other cases, for example, passion-flower, grape vine, portions of the stem are modified to form special climbing organs, known as *tendrils*.

STRUCTURE OF STEMS.

1. A piece of the stem of a cacao, mango hibiscus, 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 firm *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 hibiscus), an inner fibrous layer, a middle, thick, 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.

2. 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, a mango ; the enormous difference in thickness between such an old tree and a seedling mango 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.

3. 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. In the West Indies—as in other tropical countries—the trees generally show only irregular rings, being determined by less regular changes such as the alternation of wet and dry periods.

4. 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. These

are the *medullary rays*, which serve to maintain communication between the various parts. By their means the water brought up by the wood can be supplied to the cambium.

5. If now a stem of sugar-cane, maize, any palm, or indeed almost any other monocotyledonous plant is examined, the parts will be seen to be arranged in a very different manner to 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 ground work 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.

6. 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.

1. 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.

2. 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.

3. 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 often cut therefore 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.

4. 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.

5. 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.

6. 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. Budding is much more commonly employed than any other form of grafting in the West Indies, being very successful with such trees as oranges amongst economic plants, and roses amongst decorative ones.

7. 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.

8. 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 oranges, limes, and lemons may be mutually grafted on each other, but a mango cannot be grafted on an orange nor a rose on a croton.

Practical Work.

Examine a leafy-shoot of sugar-cane, coleus 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.

USES OF STEMS.

1. Dig up a growing plant of ginger, wash it free from soil and notice the underground stem (the ginger of commerce) irregularly lobed and bearing a large number of buds. The younger buds, are still covered over by scale-leaves. The older buds have grown above the soil and formed green leaves ; notice, particularly at the base of the leafy stem, the gradual change from scale-leaves to ordinary green leaves. On the old portions of the underground stem the scale-leaves will have fallen off but their former positions are indicated by the scars which form characteristic ridges. The thick roots which arise from the lower portion of the stem are, by their form and the absence of scale-leaves, easily distinguished from the stem.

2. Examine plants of English potato, yams and eddoes. These all show enlarged underground stems of the kind known as tubers. Wash free from earth and notice the 'eyes.' Place some for a few days in a moist place (burying in damp sand answers well) and see how from the 'eyes' leafy stems arise.

3. Examine plants of bean and convolvulus, and notice how they climb by twining their

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.

4. Examine the passion-flower and grape vine and notice the special, delicate side-branches—tendrils—by which the plant clings to a support. Those of the passion-flower generally 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.

1. Examine young and old pieces of the stems of any of the following plants obtainable: hibiscus, rose, mango, saman, cacao, 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.

2. Examine, in cross and longitudinal

section, stems of any monocotyledonous plants, for example, sugar-cane, cocoa-nut or any other palm, maize, Guinea corn. 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 paragraph.

GRAFTING AND BUDDING.

1. 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.

2. Before beginning work it is necessary to prepare supplies of grafting wax and budding tape. The Year-book of the U.S. Department of Agriculture gives the following recipe 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.

3. Budding tape is prepared by dipping strips of cloth into melted wax. The wax used is bees-wax 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 bees-wax 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 $\frac{3}{4}$ 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.

4. One of the simplest, and at the same time economically useful, instances of grafting is that of the cultivated egg-plant (*Solanum Melongena*) on the common allied form (*Solanum torvum*) found as a weed in every West Indian island, and known locally as sushumber (Jamaica), shushumber (Leeward Islands), melongène (Dominica.) To perform the operation select a convenient wild plant as a stock

and have ready some branches of a good kind of egg-plant. Cut off a piece of the stem of the stock, and; with a sharp knife, cut longitudinally into the stump and remove a thin wedge. Take a small piece of the cultivated plant as a scion, trim off most of the leaves and taper the end of the stem to fit the cut made in the stock. Insert the scion in the stock, taking care that the cambiums of stock and scion are in contact in at least one place, and secure in position by means of soft twine or other suitable material. Now take a large leaf from one of the plants and tie it, like a cap, over the scion and the top of the stock so as to shield the joint from the rays of the sun In the case of this soft, quick-growing plant there is no need for the use of grafting wax or tape, the plant remaining moist until union has taken place.

5. Grafting by approach: Select two trees of the same kind but presenting some points of difference, as two crotons, two roses, or two mangoes; 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. This method of grafting is the one usually employed for mangoes.

6. 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 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.

7. This method admits of several varia-

tions in the manner of shaping the cut ends of stock and scion. 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.

8. 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. 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 position 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.

9. Budding : For practice the pupil should work upon orange, rose and hibiscus. 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. 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.

10. Budding is frequently resorted to 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.

11. 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 pupils should make trials in budding on young limes or oranges which they have raised from seed, using selected oranges or other citrus fruits as the source of the buds. Roses, crotons, hibiscus and other garden shrubs may also be employed. 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.

12. The wild and cultivated kinds of egg-plants, previously alluded to in connection with grafting (p 58) afford excellent material also for lessons in budding. The buds are prepared and inserted in the usual way, but need not be protected with budding tape, a piece of leaf tied over the budded region being quite sufficient.

For other information and for figures illustrating the various methods of budding and grafting see NICHOLLS' *Tropical Agriculture*, p. 82.

Chapter IV.—THE LEAF.

1. 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. But almost all 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 mango leaf or much divided as a tamarind leaf. In many plants, for example the screw-pine, 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 hibiscus or croton. 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 very large as in the bread-fruit tree, or very small as in the hibiscus.

2. The blade of the leaf has been spoken of so far 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 thick and fleshy and sometimes very difficult to distinguish in appearance from stems. We have also seen already, when examining ginger and arrowroot 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.

1. 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.

2. The young leaves of most plants are very delicate and easily damaged by exposure to the sun. It is common to find these young leaves protected by the older ones, as may be seen in the leaf-buds of the coleus and many other plants. In bananas and tannias the young leaves are rolled up in the hollowed leaf-stalk of an older leaf. The school garden will readily furnish numerous other interesting

cases. In the bread-fruit the stipules will easily be seen to protect the young leaves, and when this work is done they fall, being of no further use. In many plants, for instance the hibiscus, the stipules are very small and look, at first sight, mere useless structures. Examination of the bud often shows that their real use is here, where they are large in comparison with the young leaves and serve to cover and protect them.

3. The examples of leaf-buds mentioned so far are all of plants which are almost continually growing. There are also numerous plants which grow for only a portion of the year and then lie dormant for a time—usually the dry season. The mahogany tree is an example of such a plant and during the dry season each of its shoots has at its apex a bud which is completely covered over by brown scales, which are in reality special leaves whose only function is to protect the young delicate parts beneath. When the wet weather comes these scale-leaves are burst aside, and the bud gives rise to a new shoot with ordinary green leaves. In climates where the trees have to withstand a winter these resting-buds are much more common and very elaborate and beautiful methods of packing up the young

leaves and protecting them from the cold are often met with.

4. We have already seen in the ginger 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 'lilies' of the West Indies or an onion serve as good examples, and on digging up one of their *bulbs*, it will be readily seen that the thick, fleshy structures which comprise it are really only the thickened bases of leaves which now serve 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 ginger and potato, and the root in the radish and cassava.

5. In the climbing lily (*Gloriosa superba*) the end of each leaf forms a whip-like *tendril*, which is sensitive and able to curl round a support and so enable the plant to climb. The 'cat's claw' (*Bignonia Unguis-cati*), not uncommon in West Indian gardens, is another very interesting example, each leaf having three stout claws which catch on to rough places, such as walls and tree-bark and support the plant.

STRUCTURE OF LEAVES.

1. In most leaves the blade has, running through it, a number of *veins*, often conspicuous, especially on the lower side, as ridges. The leaf of the hibiscus shows them very plainly, and, on holding such a leaf 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 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.

2. The veins of leaves are arranged in two main ways: *netted*, as in the hibiscus; *parallel*, as in the banana 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 yam,

may be taken as indicating to which of these two groups a plant belongs.

3. 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 Spanish 'needle' or the 'dagger,' 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 a rather soft, more or less spongy tissue through which 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.

USE OF WATER IN PLANTS.

1. Every-day 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 the 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.

2. 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.

3. In transpiration the green spongy tissue of the leaf gives off moisture which escapes into the outside air by 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.

4. In a long drought there is 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 many leaves 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 crotons and the various 'dagger' plants and the provision of a coating of hair, for instance in the geranium and 'cattle-tongue.'

5. 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 bamboo 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 cannot be wetted on their upper surfaces but the under surfaces live in constant contact with water.

6. 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 young plants, as for example tobacco, cabbage, or beet, the leaves are so arranged that all the water which falls on them is directed towards the centre of the plant, and flows down the stem moistening the ground near its base, where, at an early stage of growth, the young rootlets 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 sugar-cane and tobacco. 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 (cacao, mango). In those with bulbous roots, or with closely tufted rootlets, or with deep, penetrating taproots, the water is commonly conducted towards the centre (violets, canna, beet, lilies).

7. 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.

1. 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.

2. *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 recognize 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.'

3. 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.

1. 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; 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.

2. 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

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

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.

1. 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 are necessary conditions.

2. 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 yams or potatos or 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.

3. 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 carried away by the plant from the leaves in which it was made, and either used up in growth or stored up in some other part as a reserve of food.

4. 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.

5. 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.

1. Examine leafy shoots of, for instance, mango, hibiscus, croton, bread-fruit, tamarind 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 mango and grasses, lobed in the hibiscus and bread-fruit, and divided up, so much, as to look almost like a number of separate leaves, in the tamarind. Notice which of the leaves have *leaf-stalks*.

2. Examine the leaves of 'dagger' and 'needle' plants, and any other thick-leaved plants, often found growing by the sea-shore or in very dry places. Compare their leaves with those above, noting their succulent or fleshy character.

USES OF LEAVES.

1. Examine the available plants, (hibiscus, coleus, sweet potato are good) and observe the delicate young leaves forming the leaf-bud. Notice how they are protected from the sun, either by being more or less covered over by the older leaves, or by being themselves folded up (sweet potato). Then observe the more elaborate methods in bananas and tannias. Continue these observations on the other plants to hand.

2. Examine shoots of the bread-fruit tree. At the end of each will be found a bud completely enclosed at first by a pair of yellowish-green, rather leathery structures—the stipules

of the next older leaf to that which is enclosed in the bud--inside which all the young parts are packed away. Notice how the bud gradually opens, and how, as soon as their work of protecting the young leaves is done, the stipules drop off. Examine also the buds of the hibiscus, 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 young and small.

3. Examine shoots of mahogany (or other tree with a resting period in its growth) preferably just when coming into growth after the dry season. Some of the stems will already have new leaves, but all stages should be looked for, down to still unopened, terminal buds. A comparison of the various stages will show that the young leaves in the bud are protected by a number of dry, brown scales, which are burst aside when the bud opens. These scaly bodies are really special leaves which are very small, have no green blade, and whose sole use is to protect the young organs during the dry resting-season.

4. Examine again the underground stems of ginger, arrowroot, artichoke and potato, and observe the thin, dry scale-leaves. Note

how they enwrap the delicate, young, growing points—the buds.

5. 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 central bud. These points can be readily made out by cutting onions both across and lengthwise.

6. Examine plants of *Gloriosa* and the 'cat's-claw' and note how the leaves form in the one case tendrils, in the other case hooks. Compare the behaviour of these leaf-tendrils with the stem-tendrils already seen.

STRUCTURE OF LEAVES.

1. 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 under trees and try to find some 'skeleton' leaves in which, the soft parts having gone, the hard and more resistant veins remain as a skeleton of the leaf.

2. 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.

3. Take leaves of vanilla, 'needle' and 'dagger' plants, 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.

WATER IN PLANTS.

1. Pick a number of shoots of any ordinary thin-leaved plant, such as a coleus. 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

withered and at length die. Treat in the same way, for comparison, some thick leaves, such as 'dagger' and notice that these take a very long time before they show any signs of drying up, showing of what use to these plants, which can grow in places where they get very little water, their thick, fleshy leaves are.

2. 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.

3. To prove that leaves actually give off water, take two tumblers partly filled with water, and cover each with a piece of card-board with a hole in the centre. Put through this hole the end of a leafy shoot 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 therefore that the leaves give off water and that they give off more in the light than in the dark Repeat this experiment with a shoot from which the leaves have been cut off and compare results.

4. Take a tumbler, fill it half full of water coloured with a little red ink. Place some leafy shoots (balsams do admirably) with the cut ends of their stems dipping in the water and leave for a day. The stems become marked with red lines and finally the leaves also. This colouration 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.

5. Note the manner in which the leaves of a sugar-cane roll up during dry weather. This may also be observed by bringing a cane-

top, with the leaves attached, 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. 'Dagger plants,' *Agave*, etc., grow in dry places but their leaves do not roll up. They are sufficiently protected by their thick skin. Similarly crotons, vanilla, 'thick-leaf' and other plants whose leaves do not roll up during drought often have thick skins to their leaves, or they may be protected by a coating of hairs as in the case of geranium and eupatorium leaves.

6. Plunge freshly gathered leaves, such as bamboo, sugar-cane, water-lily, hibiscus, potato, into water; and notice, on withdrawing them, which portions are easily wetted and which throw off the water.

7. 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 :—Sugar-cane, dagger, *Agave*, eddoes, canna (Tous-les-mois), lettuce, mango, cabbage, violet, corn (maize), pine-apple, tobacco, cacao, beet and croton.

PLANTS AND THE ATMOSPHERE.

1. 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.

2. 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.

3. 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. 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.

4. Pour a little lime-water into a tumbler or small glass, and by means of a tube (of glass, bamboo or a grass stalk) 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. 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.

5. Into a similar bottle, corked or covered with a piece of glass, place about a hand-full of the young tips of leafy shoots, or opening flower-buds, for instance marigolds. 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 a strong light in a window. 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.

6. Place some leaves in a wide-mouthed bottle, fill with water, and place it in the sunlight. 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.

1. Take enough starch to just cover a three-penny 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.

2. Take a few leaves which have been

exposed to light for several hours (roses, amaranthus). Plunge them into boiling water for about two minutes and then place in alcohol (high wines, rum or other available spirit). When the liquid has become of a deep green colour—owing to the leaf-green being extracted—pour it off and add fresh alcohol, 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, owing to the brown stain communicated to the tissues by the iodine, the resulting colour is therefore of a somewhat greenish hue.

3. Take a plant, with smooth leaves, 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, and, if they have plenty, place the whole plant in the dark for several hours, either in a cupboard or covered up by a kerosene tin, taking care that no light at all gets to it. 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 (some plants

require twelve hours, others twenty-four or even more) 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.

4. 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. 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 boiling the leaf and putting it in iodine solution, that we obtain a pattern, in blue, on the leaf exactly similar to the portion exposed. 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.

Chapter V.—THE SOIL.

1. 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 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 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.

2. 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.

3. 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.

4. 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.

1. 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.

2. 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.

3. 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.

1. 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 the making of

bricks and pottery. When strongly heated clay loses this property.

2. 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 have 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 brick-makers 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.

1. In digging down through the soil it was seen that the upper layers (*surface-soil*) were darker than the lower (*sub-soil*). 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. 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 sub-soil. If the heat be great and long-continued the soil undergoes still further changes of colour, finally becoming red, like bricks.

2. 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.

3. 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 were 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 inches per annum through the agency of earth-worms. It is estimated that the soil so brought up in this meadow weighed about 73,000lbs. 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.

4. 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 leaves and other parts of the trees falling to the ground and accumulating there more rapidly than they are used up. The soils of such places are thus, usually, very rich in humus, and much sought after, for purposes of cultivation on account of their fertility. Unfortunately, this fertility is often rapidly wasted because the cultivator takes no pains to keep up the supply of humus.

5. 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 agricul-

turists take care to save and dig into their fields and gardens all the refuse vegetable matter they can, 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.

6. In the West Indies 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 bush, leaves, and refuse, and at the same time lamenting that his 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 partially decay. 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 or provision ground, the laments about worn-out soil would cease.

CHALK IN SOILS.

1. 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.* The majority of the soils of the British West Indies are non-calcareous, but soils containing large amounts of carbonate of lime are found in Barbados, Jamaica, and Antigua. Calcareous soils result from the breaking down of rocks composed of corals and shells, which are to be met with in the islands named.

2. Carbonate of lime may be recognized by the manner in which it effervesces when an acid is poured upon it. This test may be used to distinguished 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.

3. 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 ; it 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, as chalk or limestone, at long intervals, may be expected to add to their fertility.

Practical Work.

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

2. 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.

3. 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).

MECHANICAL ANALYSIS OF SOIL.

1. 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 apertures 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 $\frac{1}{2}$ millimetre respectively. (1 m.m. = $\frac{1}{25}$ inch) A small scale or balance for weighing the separated gravel, sand, etc. is also required.

2. With these proceed as follows:—From a well mixed sample of soil weigh out 50 grammes, ($1\frac{3}{4}$oz.), stir this well with water in a glass or cup and pour the water through the sieve with 2 m.m. 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 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.

3. 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.

4. 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. 1. For junior classes it will be sufficient to omit the weighing and to make approximate separations by washing.

WATER IN SOILS.

1. 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. 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.

2. Fit a cork, with a hole in it, into a glass

tube, about $\frac{3}{4}$ 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. The apparatus 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 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.

3. 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.

4. Now 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. 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 the glasses are somewhat widely separated and when close together.

5. 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, in a saucer of water and note the manner in which the water slowly rises through the soil. This experiment may be made quantitative if the tube is weighed, before and after filling with soil, to ascertain the weight of soil used, and again weighed 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. 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.

6. Take a small ball of clay—this may be obtained from the sub-soil 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.

VEGETABLE MATTER IN SOILS.

1. 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.

2. 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 arranged on the beds.

CHALK IN SOILS.

1. 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, lime juice, 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.

2. 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 island, or of the district, on a somewhat large scale, may be drawn on stout drawing-paper and hung up in the class-room. Observations on the character of the soil may be recorded, from time to time, by means of colours upon

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* 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.

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 will 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.

1. 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 pro-

vide 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 bodies 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.

2. All living things, animal and vegetable, contain nitrogen. When these 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 beneficient 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 temperate climates. 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.

3. As plants require their 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 bush 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.

4. 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.

1. 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 in-as-much as plants belonging to the pea and bean order (*Leguminoseæ*) are able to thrive even 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 kinds. 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.

2. 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 it is best to bury the crop while it is in a green, vigorous condition, instead of dressing the soil with dead or decaying material of the nature of pen manure, or with chemical substances.

3. 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.

4. 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.
Sugar-cane (30 tons)	70 lbs.	45 lbs.
Sweet potato (10 tons)	100 ,,	25 ,,
Irish potato ...	75 ,,	20 ,,
Corn (grain only, 30 bushels) ...	7 ,,	10 ,,

MANURING.

1. 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 then draw upon the supply of food material present in the soil, and thrive until this is no longer able to satisfy their wants. The object of manuring is to maintain this supply, or even to increase it.

2. 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.

3. 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 pen manure, and guano, which add *all* the requisite substances for an ordinary crop, are known as *general* manures. Pen 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.

1. Farm-yard manure, stable manure, and pen 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 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 the substances generally known as artificial manures.

2. 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 phosphate. 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.

3. Green dressings have already been described. They are a very valuable method 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.

1. 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.

2. 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 recognized 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.

3. 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 more lasting in its action.

PHOSPHATIC MANURES.

1. 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, are treated with strong sulphuric acid, which renders the phosphate of lime soluble. Thus prepared the manure is known as *super-phosphate.* Super-phosphate contains from 25 to 45 per cent. of phosphate of lime in a soluble condition.

2. 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 which should be as fine as flour. Unlike super-phosphate, 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 weeks later, the sulphate of ammonia should be added.

POTASSIC MANURES.

1. 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. On calcareous soils, such as those of Barbados, potash gives very good results.

2. 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 coal-pot. 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.

EXPERIMENTS WITH MANURES.

1. 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, vegetable matter (humus), or other plant food. 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.

2. 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 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.

3. 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.

4. 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 8lbs. of well rotted pen manure, 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 2oz. of finely powdered chalk or marl, scattering it evenly over the surface and stir in lightly with a fork. Then add ½oz. of sulphate of ammonia.

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

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

5. 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 follow :—

A. No manure.

B. Farmyard or pen manure ; at the rate of about 30 tons per acre.

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

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

6. Raise in each box, or on each plot, the same crop. Maize (corn), beet or cabbage are recommended. 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 trans-

planted 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. Compare the crops of the different boxes.

LEGUMINOUS PLANTS.

1. Sow in boxes or in plots, seeds of various plants of the leguminous order, for instance various kinds of beans, cow peas, etc. (Those sown in the experiment described on page 23, 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 swellings varying in size, some being perhaps as large as a pea. 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.

2. 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 (cow peas, or wooly pyrol). 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.

3. 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 maize or beet, 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 1, 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. Then, sooner or later, they begin to form flowers, which show 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 and seeds may be expected to be found. Clearly fruits and seeds are dependent on, and result from flowers. Every-day 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.

1. 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 of them 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. Such a flower is to be found in almost any of the common 'lilies' of West Indian gardens.

2. In a lily flower the following parts can be made out: Six large (white, red, or other colour) 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 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, which bears no pollen box at its end. In some lilies it is divided into three branches, in others it is not. By carefully pulling off the petals the stamens come away too, being joined to them, whilst this body remains and is found to be connected to the

swollen portion at the base of the flower. This swollen portion is the *ovary*, and when cut through lengthwise shows two rows of small white bodies, the future seeds. The ovary, together with the upper portion, are conveniently included in the single word *pistil.*

3. A hibiscus flower, compared with a lily, shows very similar parts arranged in a very similar manner. Thus, commencing in the centre of the flower, we find a pistil, branching into five red velvety arms at the top and leading down to the ovary; stamens consisting of stalks, and knobs full of pollen; then a ring of large red petals, and outside these two rings of green leafy bodies. Overlooking for the time all their differences, you find the two flowers agree in having a pistil, stamens containing pollen, and petals.

4. In the lily it will be noticed that the parts of the flower are arranged in threes or sixes. There are six petals, in two rings of three each; six stamens; the ovary if we cut it across is divided into three, and the stalk coming from it has three branches at its end. In the hibiscus the parts are in *fives*, (except the stamens which are very numerous). This number of the parts of a flower is an additional character which serves to distinguish

the two groups of flowering plants which have been spoken of before. The flowers in monocotyledons being usually arranged in threes and in dicotyledons in fives.

5. Other flowers will show other variations in arrangement of parts. In the pumpkin the large yellow portion obviously corresponds to the petals of the hibiscus. But it is all in one piece, and only the lobing at the top reveals the fact that it really represents a number of separate petals. In still other plants, for instance the periwinkle, the petals may join 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, or divided into two more sets as in the hibiscus. 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 which may be long or short and often ends in more or less hairy or sticky branches the *stigmas*.

6. The lily, hibiscus, periwinkle, have all these parts contained in one and the same flower. They are examples of *perfect* or *complete* flowers. The pumpkin flower, on the other hand, is different. If a pumpkin vine 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, brown body, the stigma, sticky and covered with short hair ; and beneath the yellow petals is a swollen portion (obviously a very young pumpkin), 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.

1. Plants, such as the pumpkin, 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 pumpkin vine under observation, we find that pumpkins are never borne on the staminate flowers, but always on the pistillate flowers. Of what use then are the staminate flowers ?

2. 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 in a thin paper bag, just before it opens, 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 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.

3. 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 with-

out 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 *fertilization* of the flower and only when this has happened are seeds formed. Pollination, the actual placing of the pollen on the stigma and fertilization resulting from this—are two perfectly separate processes and should be clearly distinguished.

4. 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.

5. 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.

6. To sum up then, we find that in flowers the stamens and pistil are essential to the production of seed. The sepals, 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.

1. Still bearing in mind such a case as the pumpkin 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 pumpkins 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.

2. Careful watching of a bed of pumpkins will often show that the open flowers have various visitors. In the flower are often a large number of ants, busily engaged in eating honey

Bees too 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 pumpkin 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 over estimated and it requires very little observation to see how universal it is. Besides bees, butter-flies, moths, and humming-birds carry on the same work. An owner of an orchard, of limes 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.

3. It might at first be thought that whilst the visits of insects were absolutely neces-

sary to plants in which the stamens and pistils were not in the same flower, that they were unnecessary to those plants (which are by far the greater number) in which these organs are in the same flower. This however is not so. The stamens and pistils of 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-fertilization*, the fertilization of a flower by the pollen of another flower, is the general rule and self-fertilization—that is, by the pollen of the same flower—is comparatively rare even in plants which have both stamens and pistils in one flower.

4 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 vanilla, 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 the West Indies, the cultivator of vanilla, in or-

der to be certain of obtaining any pods at all, has to place pollen upon the stigma of every flower by hand.

WIND-POLLINATED FLOWERS.

1. 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 is a large class of flowers which are not brightly coloured, have no sweet scent, and secrete no honey. The flowers of many grasses, Guinea grass for instance, are good examples. Insects do not visit them much, and their pollen is carried from one flower to another by the wind.

2. 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 lily and hibiscus, with such wind-pollinated flowers as those of grasses and palms, will make these differences clear.

3. Wind-pollinated flowers may, just as insect-pollinated flowers, have stamens and stigmas in the same or in separate flowers. Sour grass and Guinea grass are examples of the former class; maize, and many palms 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.

1. 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 fertilized the petals and other non-essential parts fade and wither away, their use being over. The pistil developes 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*, and 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.*

2. 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.

3. When the plant has formed its seeds it is most important that they 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 necessary 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 because of 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 SEEDS.

1. 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.

2. Wind. Many seeds, for instance those of most orchids, 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 usually provided with thin appendages of various kinds known as 'wings.' Good examples of winged seeds are those of the mahogany and 'cedars.' Other wind-borne seeds are provided with downy or silky hairs which enable them to float, for instance French cotton, cotton, silk cotton, wild ipecacuanha, lettuce and many grasses.

3. 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 'thistle' (*Argemone*) and tobacco 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.

4. Water-borne fruits. The fruit of the cocoa-nut with its tough fibrous covering, is able to float long distances without damage. The cocoa-nut palm is now found on almost all tropical shores and is one of the first plants to reach new coral islands, which may be many miles from the nearest land. The seeds or fruits of several South American plants are often found on the shores of the West Indian islands, and, through the agency of the Gulf Stream, not infrequently reach Europe.

5. 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 'burs.' Amongst examples common in the West Indies are the fruits of the 'bur-grass' and the 'broom-weed' which readily adhere to clothing, etc., by means of their short spines. Other fruits are sticky, being covered with glandular hairs, for instance 'hogweed' (*Boerhaavia*), a not uncommon weed in cane fields, and the 'lead-wort' (*Plumbago*) commonly grown in gardens.

6. 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 such 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 the guava, wild banana and all-spice. The formation of a new all-spice 'walk' is commonly due to seeds dropped by birds, after

feeding on the trees of a neighbouring 'walk.' 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. 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, pine apple, seedless oranges, etc.

7. 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 rapidly spread from tree to tree and become an extremely troublesome pest.

VARIATION IN SEEDLINGS.

1. As a general rule the seeds produced by plants which have been fertilized by pollen from another flower of the same species, that is to say cross-fertilized, yield more vigorous plants than the seeds from self-fertilized flowers. When cross-fertilization 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 orange, and lime, hibiscus, and croton, may be crossed with each

other, but a hibiscus cannot be crossed with a lime, nor a rose by a croton.

2. 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.

3. 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 sometime forms no flowers, and that later, first flower-buds appear, then open flowers, and finally fruits containing seeds.

PARTS OF A FLOWER.

1. Examine any of the following flowers obtainable. Some are in flower the whole year, others must be examined whenever occasion offers. The parts of some flowers are simpler than others, and the lily, and flamboyante are recommended for early examination. In the text, the hibiscus was described because it can be always obtained, but its flower is somewhat more complicated (owing to the stamens being joined up so as to form a tube, enclosing part of the pistil), than the flamboyante, and the latter should be examined first if obtainable. 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.

Flowers recommended for examination.

Hibiscus.	Pea & Bean.	Barbados Pride.
Mango.	Periwinkle.	Convolvulus.
Papaw.	Pumpkin.	Stephanotis.
Flamboyante.	Squash,	Croton.
Cleome.	Egg-plant.	Lily.

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.

2. 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, hibiscus, geranium, tube-roses, and balsam furnish good examples for examination.

3. 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:—Sugar-cane, Guinea grass, sour grass, maize.

4. Examine the 'flower' of the sunflower. The yellow structures around the edge are very different to 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.

EXPERIMENTS IN CROSS-FERTILIZATION.

1. On a squash, pumpkin or melon plant examine the separate pistillate and staminate flowers, and learn how to distinguish them before the flower-buds are open. Watch them and notice that the fruits, (squashes, pumpkins or melons, as the case may be) are only formed from pistillate flowers. Staminate flowers after shedding their pollen die.

2. Tie up two pistillate flower-buds (which are almost ready to open) in separate bags made of thin, tough paper. 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.

3. Select two plants of the same kind but possessing well marked differences. The hibiscus affords one of the best examples, as great differences in form and colour are readily found in the different varieties, and the flower being large, and the stamens and pistils prominent, manipulation is easy. 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 stigmas are mature (they are then somewhat sticky). Touch the stigmas 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. When the plants flower 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, various lilies, tomato, squash, melon, orange, lime, and cacao.

4. When it is desired to effect cross-fertilization with great accuracy, precautions must be taken to prevent the 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.

5. Select plants such as the following, which are bearing flowers and young fruit. Observe the form and position of the pistil in a flower and then trace the changes in position, form, and size which it undergoes during its development into the fruit. Make drawings or diagrams :—Balsam, beans and peas of various kinds, cacao, egg-plant, lilies, lime, maize, mango, nutmeg, orange, sunflower, tomato, zinnia. Gather and preserve, for future sowing, seeds of various kinds as they ripen.

DISPERSAL OF SEEDS.

1. 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; whether their seeds are carried by the wind or by animals.

2. Observe the ripe fruits of the following plants, and notice and sketch the wings or hairs of the seed or fruit in each case. Mahogany, cedars (white and red), 'redhead'

or wild ipecacuanha, white-wood, stephanotis, lettuce, cotton, French cotton (*Calotropis*), silk cotton.

3. Observe the ripe pods of the horse-nicker in dry and wet weather; make drawings or diagrams. Under the same conditions observe and draw ripe fruits of tobacco and 'thistle.' Shake a plant of either of the latter bearing ripe fruits and see how the seeds are sprinkled about.

4. Collect the various fruits and seeds which adhere to the clothing, or to the coats of animals. Note how they stick, that is to say, what part of the flower it is which is modified to serve as the clinging organ. Endeavour to find the plants from which they come, and, in the case of hooked and other fruits, study the changes which take place to bring the grappling apparatus into the position in which it will prove effective.

5. Examine the cocoa-nut, noticing its tough fibrous protective coat, and the nut with its hard shell. If living near the sea, collect any fruits found on the beach and try and make out whence they have come: whether they are the fruits of trees growing on the shore or have probably been brought from a distance.

6. Notice at what distance from the foot of a sand-box tree seeds may be found. Obtain, if possible, an unopened, nearly ripe fruit and place it in the sunshine. Measure, after the explosion, the distance to which the seeds have been thrown. Collect ripe fruiting spikes of the castor-oil plant, place them upright in the sun, and make similar observations. Similarly examine the methods of seed dispersal in the garden balsam, peas and beans.

CHAPTER VIII.—WEEDS.

1. 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, and which is 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.

2. When a piece of land is newly brought under cultivation much trouble is often expe-

rienced in removing the weeds, which grow from the seeds lying dormant in the soil. Even after years of cultivation, weeds are liable 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 pen-manures, and compost, when they may occasion much trouble. For this reason, it is desirable that manures of this description should be well rotted before being used.

3. 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 'French weed' (*Commelina*), purslane and devil's or Bahama grass. It is essential that these should be completely dug up and destroyed; merely chopping them with a hoe only tends to aid their spreading and to give rise to future trouble. Others, as the 'nut-grass' have underground tubers which make them extremely difficult to entirely remove.

4. 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 concérning certain areas. Thus on rich soils the 'trumpet tree' or *bois canon* (*Cecropia*); *balisier* (*Heliconia*); the wild egg-plant or sushumber. French weed or *Herbe grasse*, and nut-grass (*Cyperus*) are commonly met with. All-spice or *bois d'Inde*; logwood; gru-gru palm and the coco plum are especially characteristic of poor lands. Sedges are almost entirely confined to wet places and French cotton (*Calotropis*) to sandy localities.

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 recur 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.

PRESERVING PLANT SPECIMENS.

1. 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.

2. 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.

3. 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.

4. 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. With good absorbent paper, used perfectly dry, two changes are often sufficient, except for thick-leaved plants, which require more.

5. For future reference it is advisable to mount the dried plants on sheets of paper. The same size should be used throughout, (16 ins. by $10\frac{1}{2}$ ins. 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.

6. Write on each mounted sheet the name of the plant in the bottom left-hand corner; also 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 to the sheet on which it is mounted. Plants collected, dried and mounted without notes made at the time, giving some or all of the particulars above, lose much of their value.

7. 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.—INSECTS.

Constant disappointment and annoyance are caused to the cultivator by the ravages of insects 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 insects and their habits unpleasantly brought to his notice. Caterpillars will 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.

1. 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.*'

2. 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.

3. 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, some being covered with spines or bristles, others being coloured green or yellow. Many grow to a very large size, as may be seen in the caterpillar that eats the Frangipani tree. The pupal stage is often spent on the food-plant, sometimes in a cocoon, but many chrysalides are found in the earth.

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

LIFE-HISTORY OF A BEETLE.

1. Many destructive insects 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 larvae 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.

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

3. 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.

4. Beetles thus prove destructive both in the larval and in the mature stage; they feed upon a great variety of substances, some boring in the stem, as the weevil borer in sugar-cane or the cacao beetle in cacao trees, others in tubers, as the sweet potato weevil, others again in grain, stored foodstuffs, furniture and even cigars and cigarettes.

GRASSHOPPERS AND CRICKETS.

1. Another class of insects causing annoyance to the cultivator includes the grasshoppers, crickets, etc. These insects differ from those just referred to in that they do not pass through a caterpillar or grub stage. The larvae, when hatched from the eggs, are not unlike the mature insect except that they are smaller and do not possess wings; wings are formed gradually, and there is no resting pupal stage.

2. The perfect insect has four wings, the upper pair being leathery or parchment-like, the lower ones being membranous; the insects have strong biting jaws. These insects feed in all their stages, being active and voracious, throughout their lives. They thus differ from butterflies and beetles whose pupae are inactive and do not feed. Some of these insects are very destructive. Grasshoppers and crickets often

seriously damage young growing crops. The mole-cricket, which is not uncommon, and which may be recognised by its powerful, short, thick front legs by means of which it burrows in the earth, attacks the plant both at the roots and above ground and thus, at times, causes much injury. To this group of insects also belongs the cockroach, the damage and annoyance caused by which is a matter of common knowledge to all West Indians.

SUCKING INSECTS.

1. The foregoing insects cause injury to plants by biting them. There are many insects however, which do not bite, but which are provided with a '*beak*' or '*proboscis*' which they thrust into the tissues of the plants on which they live and thus suck out the juices. Some of these attack and feed upon other insects and animals.

2. The plant-bugs, which are very common on many crops, belong to this class. They have four wings; the upper ones are peculiar in that they are not uniform in texture, the part nearest the body being leathery, the remainder membranous; the under wings are entirely membranous. These insects do not pass through a caterpillar or grub stage. The

larvae and pupae resemble the perfect insect, but they have no wings in their early stages and only rudimentary ones later, the perfect insect being completely winged. Many of these plant-bugs emit very unpleasant odours when handled.

3. The scale-insects belong to the plant-sucking class of insects. They are usually so peculiar in appearance that it is difficult to recognise that they are insects. If the twigs and underside of the leaves of many plants such as the lime, orange, mango, guava and avocado pear be examined, there will often be found white or brown scale-like bodies, firmly attached to the plant. These vary much in shape, colour and general appearance, being often brown or white. Some are covered with a hard leathery shell, or cottony down, or again with a waxy secretion, while others have little covering. Under the scale or covering, the insect lives with its beak or proboscis fixed in the plant and sucking out its juices. The female insect has no wings, and when once fixed on any spot rarely moves from it; here the eggs are laid and are often to be seen in great numbers beside the body of the parent insect, underneath the scale which covers them both. The male insect becomes winged, and

flies about, being thus entirely different in habit and appearance from the full grown female; the male insects are very small and are not often seen unless specially looked for.

4. The scale-insects often cause a great amount of damage, as the plants attacked by them frequently die. In this way they are a source of much anxiety to West Indian fruit-growers, particularly to cultivators of oranges and limes which often suffer seriously from their ravages.

5. Mention should be made of bees and wasps. These insects have four membranous wings, their larvae are grub-like and their pupae inactive. Most of the insects of this class possess a sting, which either serves for defensive purposes, or is fashioned into an apparatus by means of which the eggs are placed in the animal or vegetable tissues in which the insect deposits them.

6. Distinguished from the insects already mentioned, all of which have four wings, are the flies, which only possess two. The larvae usually called *maggots* are footless grubs with an undefined head; they are thus distinguishable from the grubs of beetles. The pupae 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.

7. Reference is made here only to those classes of insects which are commonly met with in gardening operations. Ticks and spiders are not insects, but are placed in a class by themselves. They are distinguished from insects by the fact that when full grown they have eight jointed legs whereas insects never have more than six.

REMEDIES.

1. 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. An account of these is to be found in a pamphlet recently issued by the Commissioner of the Imperial Department of Agriculture for the West Indies entitled *General Treatment of Insect Pests.*

2. 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 on and pass into the chrysalis stage. By this time the larvae 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.

Practical Work.

1 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 $1\frac{1}{2}$ 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. Make a record of the plant on which the insect under observation is found feeding. As many insects as possible should be raised under observation.

2. In carrying on the above work instances where the caterpillar has been attacked by parasites are sure to come under observation. Careful note should be made of these, and specimens of the parasites should be reared, drawn and described.

3. 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 corn, sweet potatos, cacao, limes, or sugar-cane; 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.

4. 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 :—

(1.) Kerosene emulsion, made by dissolving half a pound of hard soap in one gallon of boiling water. When dissolved add two gallons of kerosene 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.

(2.) 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 foot note, page 4.

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 which consists of a thin outer skin, and a pulpy interior in which the seeds are imbedded, *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, *chryscios*, 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 sub-division 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, *efferresco*, 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.

Fertilization. (Latin, *fertilisatio*, the making fruitful). The process by which the contents of the pollen grain act on the ovules. After fertilization 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 tomatos, squashes, 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 a 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.

Leguminoseae. 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 *Leguminoseae* 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 7,000 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 artificially 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 which contain bacteria.

Nut. (Latin, *nux*, a nut, a fruit with a hard shell.) Usually applied to hard fruits, which do not split open, and which 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, which 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 fertilization of flowers.

Pollination. The act of placing pollen on the stigma of a flower. Usually, but not necessarily, followed by the fertilization of the flower. Insects can pollinate flowers, but they cannot fertilize 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 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*, a 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. For this purpose it is often hairy and 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 storehouses 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 are an every-day 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 1.

THE following table shows the number of plants to the acre at various distances, and the area in square feet available for each plant :—

Feet apart.	Square feet to each plant.	Number of plants to the acre.	Feet apart.	Square feet to each plant.	Number of plants to the acre.
1 × 1	1	43,560	8 × 8	64	681
2 × 1	2	21,780	9 × 9	81	538
2 × 2	4	10,190	10 × 10	100	435
2 × 3	6	7,260	11 × 11	121	360
3 × 3	9	4,840	12 × 12	144	302
3 × 4	12	3,630	13 × 13	169	258
4 × 4	16	2,722	14 × 14	196	222
4 × 5	20	2,178	15 × 15	225	193
5 × 4½	22½	1,936	16 × 16	256	170
5 × 5	25	1,742	17 × 17	289	151
5 × 6	30	1,452	18 × 18	324	134
6 × 6	36	1,210	19 × 19	361	120
6 × 7	42	1,037	20 × 20	400	109
7 × 7	49	889	25 × 25	625	69
7 × 8	56	778			

APPENDIX 2.

LIST OF BOOKS USEFUL TO ELEMENTARY STUDENTS.

Primer of Botany. By Sir J. D. HOOKER, F.R.S.
Macmillan & Co., London. 1*s.* 0*d.*

First Book of Indian Botany. By D. OLIVER, F.R.S.
Macmillan & Co., London. 6*s.* 6*d.*

A Practical Introduction to the Study of Botany. By J. B. FARMER, F.R.S.
Longman's Green & Co., London. 2*s.* 6*d.*

First Lessons with Plants. By L. H. BAILEY.
The Macmillan Co., New York, 1*s.* 8*d.*

Chemistry of the Garden. By H. H. COUSINS.
Macmillan & Co., London. 1*s.* 0*d.*

Elements of Agriculture. By W. FREAM.
John Murray & Co., London. 2*s.* 6*d.*

Tropical Agriculture. By H. A. ALFORD NICHOLLS,
Macmillan & Co., London. 6*s.* 0*d.*

Tropical Gardening. By JOHN F. WABY.
"Argosy" Office, Georgetown, British Guiana.

APPENDIX 3.

List of Tools and Appliances.

In the following list the whole of the tools and appliances which it would be advantageous to have, in order fully to carry out the experimental work of the book, are given. It should, however, be clearly understood that no school is recommended to obtain the complete set, at the commencement. Many of the articles would not be required, at any rate during the first year. The comparatively few essential items should therefore be obtained first, such as a fork, flower pots, wooden boxes, etc., and the others added as found necessary. Many of the articles are themselves in everyday use, and for many of the others ordinary household articles could be substituted, *e.g.* jam pots for the wide mouthed bottles, empty soap boxes and wine cases for the plant boxes, etc.

Garden Tools.

Spade, rake and fork. Syringe and watering pot. Measuring tape; levelling tool (p. 16); long and short lines, which may be made by pupil (p. 19); foot-board, 8 ins. wide and 4 ft. long (p. 19).

Two sieves about 18 ins. in diameter, one with $\frac{3}{4}$ to 1 in. mesh, and the other about $\frac{1}{4}$ in. mesh (p. 16).

Three wooden boxes, 14 × 10 ins. and 4 to 6 ins. deep (p. 15).

Four wooden boxes, 2 ft. × 2 ft. and 1 ft. deep (p. 131).

One wooden box, 6 ins. × 4 ins. and 1 to 2 ins. deep, with glass cover.

One dozen earthenware flower pots, of assorted sizes.

One dozen bamboo pots.

Grafting and Budding Appliances.

Budding knife.
Budding tape, which may be made by pupil (p. 57).
1lb. grafting wax which made be made by pupil, (p. 57).

Manures and Chemicals.

Whale oil soap, 2-7lbs. (p. 180). Chalk, 1lb.
Charcoal. Quicklime, 4oz. in bottle.
Starch, 1oz. (arrowroot). Iodine, ½oz. solution in alcohol (p. 93).
Hydrochloric acid 1oz., limejuice or vinegar (p. 115).
Alcohol, ½pint, (p. 93).
Basic phosphate 7lbs. Sulphate of potash, 2lbs.
Superphosphate of lime, 4lbs. Kainit, 1lb.
Sulphate of ammonia, 4lbs. Nitrate of soda, 2lbs.
Dried blood, 2lbs. Guano, 2lbs.

Chemical and other Apparatus.

Wide mouthed bottles 2oz. capacity, with corks, one doz. (p. 14).
Wide mouthed bottles, 4oz. capacity, with corks, one doz.; to preserve specimens and samples in.
One set small brass sieves for mechanical analysis of soils (p. 108).
3 glass funnels, 3½ in. diameter (p. 110).
One glass tube, 1–1½ in. diameter, and 8 or 9 ins. long. A cylindrical lamp chimney will serve (p. 112).
One killing bottle (p. 179).
Scales and weights, to weigh from 1oz. to about 7lb., for weighing manures and crops.

For Advanced Pupils only.

Four dinner plates, one yard of thick flannel, and one set of small scales and weights to weigh from 1 to 50 grammes.

Miscellaneous Items.

Strong pocket knife, strong pair of scissors, and a pair of small, fine pointed scissors.

Cardboard, Indian ink, fine brush, tin foil, twine, cord, bottle of gum or paste, 3ft. copper wire.

Three earthenware bowls, varying from 1 to 2 pints capacity.

Two pieces of glass, 3 or 4 ins. square.

Two dozen paper bags.

Kerosene ; yellow soap.

Two small boxes for raising caterpillars, with covers of muslin, perforated zinc or glass (p. 177).

Two quires botanical drying paper, or a stock of newspapers (p. 166).

Two pressing boards, 20 in. × 15 in. and ½ in. thick (p. 166).

Two to five quires stout cartridge paper, 16 × 10½ in. (p. 167).

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V. GALE,

Printer to the Government of Barbados.